Jour. Fac. Sci., Hokkaido Univ., Ser. IV,
vol. 18, no. 3, Mar., 1978, pp. 385-408.

PRELIMINARY REPORT OF THE 1977 ERUPTION OF USU VOLCANO

by

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(with 4 tables, 15 text-figures and 2 plates)

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Abstract

On August 7 (09^h 12^m, local time), 1977, a major eruption of dacite pumice occurred from the summit of Usu Volcano (42°32'N, 140°50'E), Hokkaido, Japan, after 32 years of dormancy since the birth of Showa-Shinzan lava dome. Four notable explosive eruptions, two moderate and ten small ones have been recorded until the midnight of August 13–14, and then marked crustal movements and local earthquake swarms continue still at present. The sequence of the present eruption, the distribution and nature of the new ejecta, and the topographic deformation of the volcano, are briefly given in this report.

Introduction

Usu Volcano (42°32'N, 140°50'E), Hokkaido, which had been dormant for 32 years since the formation of Showa-Shinzan lava dome in 1943–1945, became active with local earthquakes on August 6, 1977. On August 7, 30 hours after the beginning of the preceding earthquake swarm, a major pumice eruption occurred from Usu Volcano, producing an eruption cloud 12 km high. There have been four notable explosive eruptions, and two moderate and ten small ones until the midnight of August 13–14. The pumice and ash showers caused destruction of cultivated fields and forests around the volcano. Since then, no explosive eruptions have been recorded, but crustal movements in the summit area and northeastern foot of the volcano are still in progress and local earthquake swarms continue at present (October 31, 1977).

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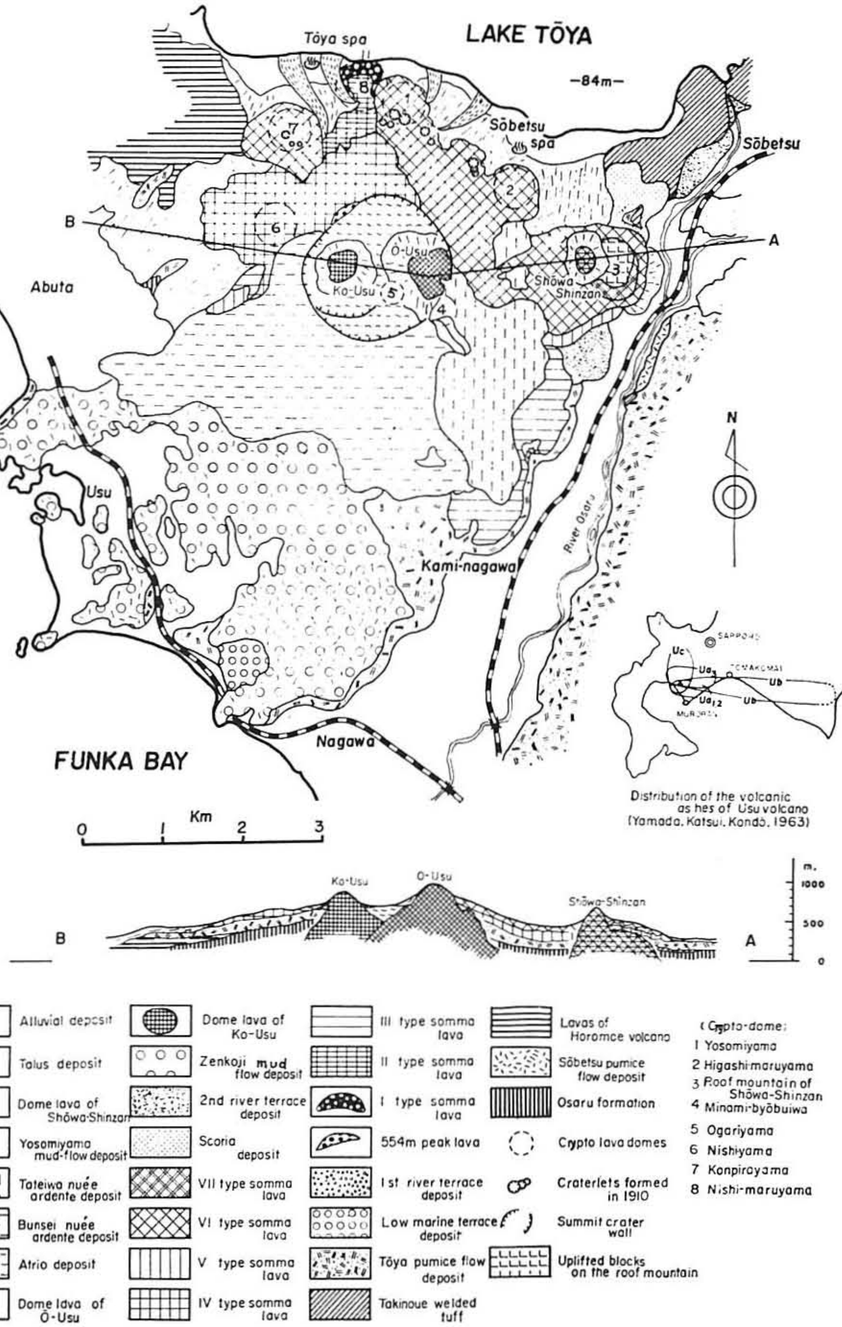


Fig. 1 Geologic map of the Usu Volcano (after Ōba, 1966, slightly modified).

Fortunately, no one was killed or injured seriously by the present activity, though some damage was caused not only to cultivated lands and forests by the ejecta, but also to some buildings, underground constructions and others by the subsequent crustal movements.

This paper is a preliminary report on the 1977 eruption of Usu, which summarizes our field and laboratory work on the sequence of eruption, distribution and nature of the ejecta, and topographic change of the volcano, though most of these studies are still under way. Seismological, geodetical, geothermal and other geophysical and geochemical studies on the present eruption have been also carried out by a number of staffs of universities and institutes. The results will be reported elsewhere.

Brief History of Usu Volcano

Usu Volcano is located on the southern rim of the Tōya Caldera which was formed as a result of large scale eruptions of pyroclastic flow in the late Pleistocene age. The volcanic edifice of Usu is composed of a somma volcano and a number of lava domes and cryptodomes, as shown in Fig. 1. The main body of Usu was formed by repeated eruptions of lava flows and scoria of tholeiitic basalt and mafic andesite in the early Holocene age. After the completion of a stratovolcano, its summit was broken by a violent explosion,

Table 1 Record of the eruptions of Usu Volcano.

age of eruption	interval (year)	duration of forerunning earthquake	main activity
1663		3 days	pumice and ash eruptions, and formation of Ko-Usu lava dome.
	–105–		
1769		? *)	ash eruptions.
	–52–		
1822		3 days	ash eruptions and nuée ardente.
	–30–		
1853		10 days	ash eruptions and nuée ardente, and formation of O-Usu lava dome.
	–56–		
1910		6 dats	steam explosions and formation of Meiji-Shinzan cryptodome.
	–30–		
1943–1945		ca. 6 months	steam explosions and formation of Showa-Shinzan lava dome.
	–32–		
1977–		30 hours	pumice and ash eruptions

*) Occurrence of forerunning felt shocks has been recorded, but its duration is unknown.

accompanied by a rock avalanche ("Zenkoji mudflow deposit"), which led to the formation of a somma (or small caldera), 1.8 km in diameter and about 500 m in elevation.

Recent tephrochronological studies revealed that the volcano had been in a dormant state for several thousand years since the formation of the somma. During this long period of quiescence, the nature of the magma changed into extremely felsic. Then, the historic activity during the past 300 years commenced with a strong Plinian eruption of rhyolitic pumice ("Us-b"), which was followed by the formation of dacite lave domes and cryptodomes, sometimes accompanying nuées ardentes (Table 1).

A full account of the geology, petrology, and record of historic eruptions of Usu Volcano is given by Minakami *et al.* (1951), Ota (1956), Ōba (1966), Yokoyama *et al.* (1973), and others.

A regular repetition of the eruptions of Usu at an interval of 30–50 years in later historic times, as shown in Table 1, attracts our attention in regard to the prediction of eruptions in the near future (Yokoyama *et al.*, 1973). The present eruption occurred after an interval of 32 years. The occurrence of locally felt shocks preceding each eruption in historic times is also one of the characteristic features of the activity of Usu, which may be interpreted as due to the high viscosity of magma (Minakami *et al.*, 1951; Yokoyama *et al.*, 1973). The duration of the preceding earthquakes was generally short, 3–10 days except for that of the 1943–1945 activity. In the present activity, the forerunning earthquakes started about 30 hours before the eruption.

Sequence of the Eruption

The sequence of the eruption of Usu in August, 1977, was compiled on the basis of data of our observations together with those of the Japan Meteorological Agency and others. The result is illustrated in a schematic diagram as shown in Fig. 2.

At about 03^h (local time = GMT + 9 hours) on August 6, 1977, local earthquake swarms occurred in the Usu district. Then the earthquakes increased in frequency and in intensity. They were strong enough to be felt in the whole area around the Usu Volcano, up to about 8 km from the volcano, but no damage was caused.

At $08^h 50^m$ on August 7, a normal fault which traversed a trail with a vertical displacement of about 40 cm was found at the eastern foot of the Ko-Usu lava dome. Then, 20 min. later, a white vapour rising from the southeastern foot of Ko-Usu was witnessed. At $09^h 12^m$, after 30 hours from the beginning of earthquake, an ash-laden gray cloud rose from the same point

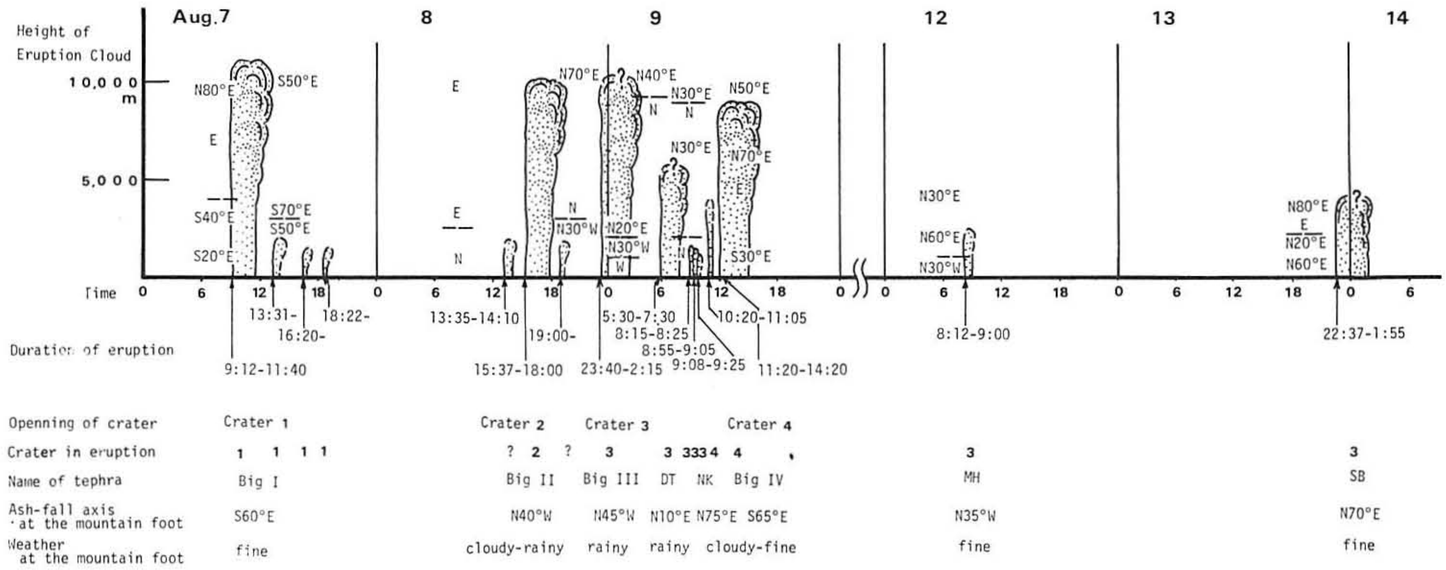


Fig. 2 Sequence of the eruption of Usu Volcano in August, 1977. Direction of wind expressed by leeward at the Sapporo Station of the Japan Meteorological Agency.

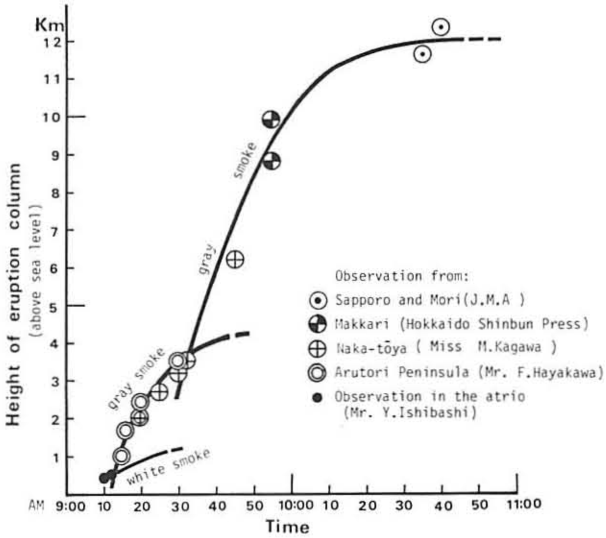


Fig. 3 Growth of the eruption column of the first eruption on August 7, 1977.

without notable explosion sounds. The eruption became increasingly intense, and lightning flashed in the eruption cloud. The eruption column grew rapidly, and rose up to a maximum height of 12 km in elevation at 10^h30^m (Fig. 3 and Plate 1). A large volume of pumice and ash were ejected and transported to the southeast of the volcano by the westerly wind.

The first eruption lasted about 2.5 hours and ceased at 11^h40^m, then three minor eruptions took place at the same point in the afternoon. On the next morning, August 8, it was confirmed from the air that a new crater (Crater 1), about 100 m across, was opened at the southeastern foot of the Ko-Usu lava dome. The fault on the eastern foot of Ko-Usu was extended for about 400 m to the southeast, approaching Ogari-yama, a small lava dome between Ko-Usu and O-Usu.

In the afternoon of August 8, 15^h37^m – 18^h00^m, the second major pumice eruption occurred. Then, in the midnight, 23^h40^m – 02^h15^m, the third major pumice eruption took place. Two craters, Craters 2 and 3 respectively, were opened by both major eruptions at the eastern foot of Ko-Usu. At that time, the direction of wind changed due to the approach of a low pressure. There was a notable difference in direction between the lower and upper winds, as shown in Fig. 2. Accordingly, the pumice and ash fell toward the southwest of the crater near the volcano, whereas in the regions far from the volcano they were scattered to the north and finally to the east of the volcano.

In the early morning of August 9, all of the inhabitants and tourists were evacuated from Tōya-ko Spa on the northwestern foot of the volcano. On this morning, the Crater 3 was active, ejecting intermittently pumice and ash, which were mostly transported to the north of the volcano.

From the late afternoon of August 8 to the next morning, it was rainy. Heavy rain-drops containing abundant ash which were called "cement mortar-like drops" by inhabitants fell together with pumice, devastating forests and cultivated lands. Accretionary lapilli were also a characteristic product in the rainy weather.

At $10^h 20^m$ on August 9, a small eruption began at the northern part of the atrio, and lasted 45 min. Then, this was succeeded by a major pumice eruption which lasted 3 hours from $11^h 20^m$ to $14^h 20^m$. Crater 4, about 100 m across, was opened by the fourth major eruption, and the pumice and ash were scattered to the east of the volcano.

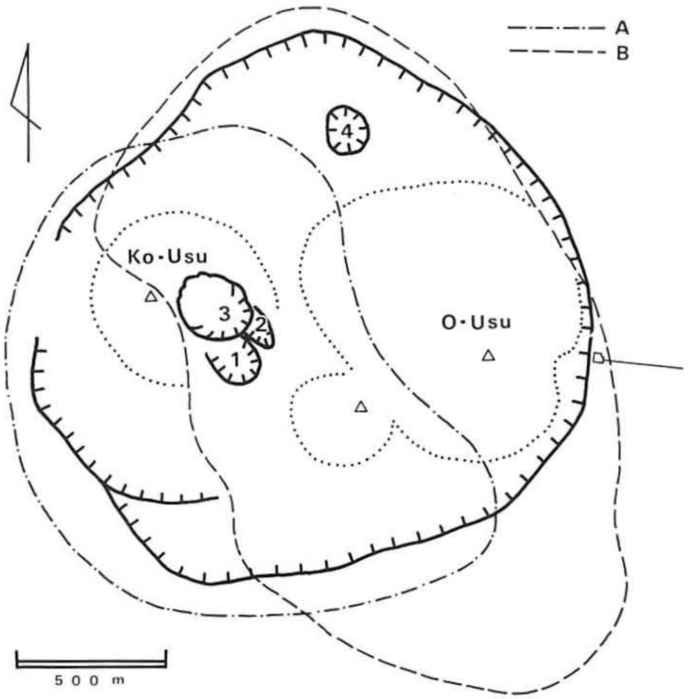


Fig. 4 Map showing the distribution of the new volcanic blocks and bombs larger than 30 cm in size.
A: distribution limit of those from the Craters 1, 2 and 3.
B: distribution limit of those from the Crater 4.

Then, a small explosion at $08^h 12^m$ on August 12, and a moderate explosion at midnight of August 13–14, took place.

Since the paroxysmal eruptions which occurred from August 7 to 14, no eruptions have been recorded. However, notable crustal movements have taken place with local earthquake swarms up to the present, causing a marked topographic change in the summit of the volcano.

Distribution of Ejecta

The volcanic blocks and bombs larger than 30 cm in diameter which were

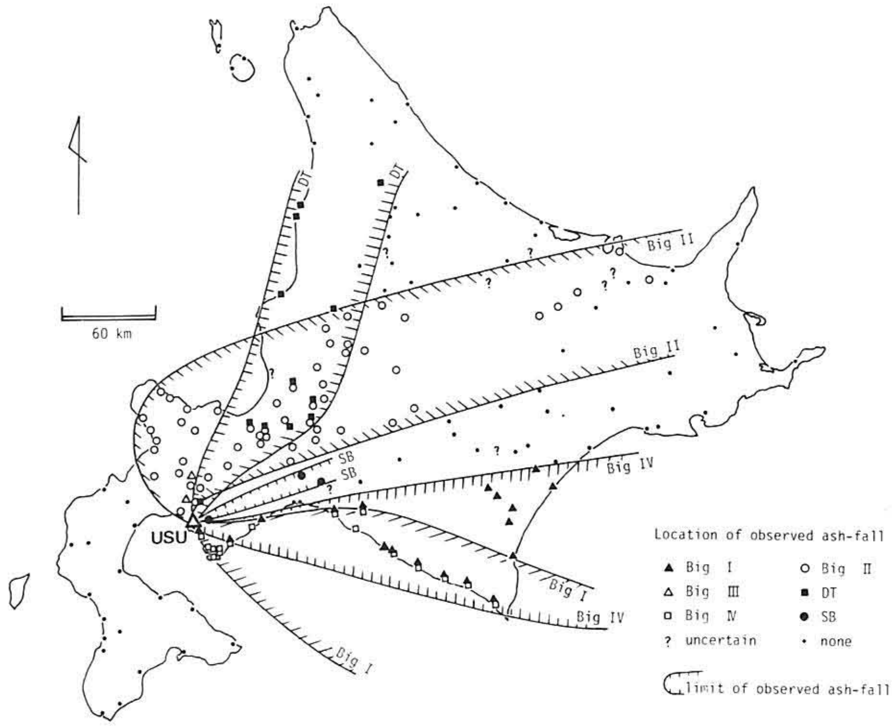


Fig. 5 Map showing the distribution of the ash-fall deposits from the eruption of the Usu Volcano in August, 1977. Data based on the report from town offices and fire-brigade stations in Hokkaido.

ejected by the present eruptions, were distributed up to 2 km from the source in horizontal distance. The limit of their distribution shows an area elongate in a certain direction from each crater, as well represented by the impact area from the Crater 4 (Fig. 4). This evidence may be interpreted as due to the form and structure of the crater. The distance and falling angle of many blocks from the

Crater 4 were measured. Assuming the coefficient of resistance of the air to be $0.6 \times 10^{-5}\,cm^{-1}$, the initial velocity of ejecta from the Crater 4 amounts to as much as 230 ± 10 m/sec.

The incandescent pumice and ash together with lithic fragments of lapilli-size were ejected high into the air forming eruption clouds, and they were transported and fell to the leeward of the wind direction (Fig. 2). The distribution of each ash-fall has been traced as shown in Fig. 5 which was compiled from various data supplyed to us from 180 town offices and fire-brigade stations in Hokkaido. The time of beginning of each ash-fall in the areas far from the source propagated at an average velocity of 50 – 60 km/h

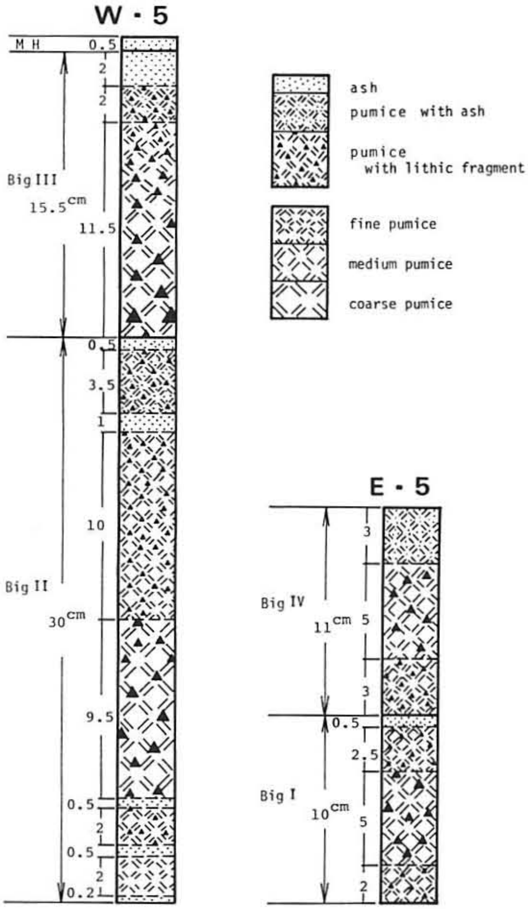


Fig. 6 Standard columnar sections of the 1977 pyroclastic fall deposits of the Usu Volcano. Loc. E-5: O-daira, 3.5 km SE of the crater. Loc. W-5: Konomi-danchi, 2.5 km NW of the crater.

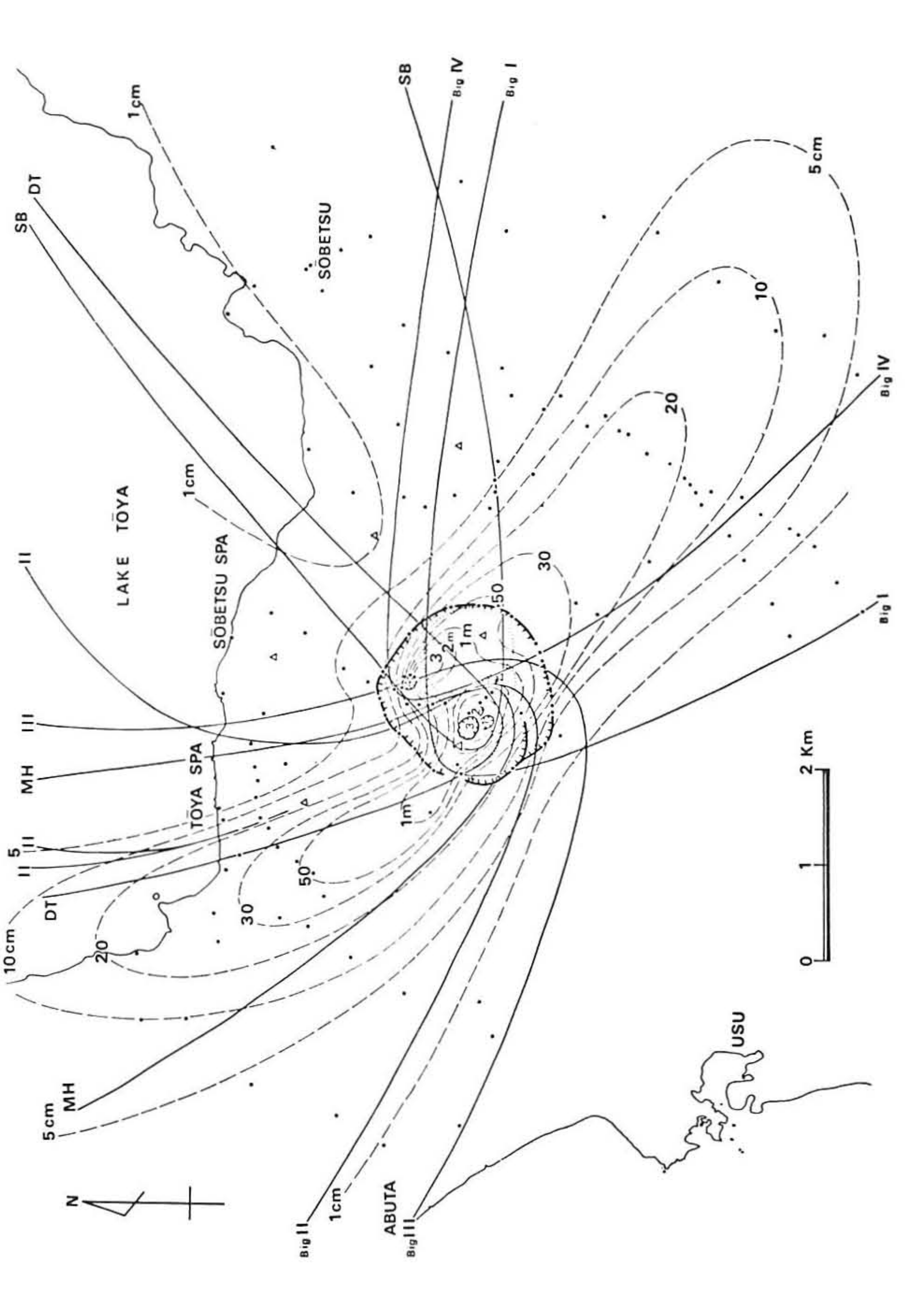


Fig. 7 Map showing the distribution of the 1977 pyroclastic fall deposits around the Usu Volcano. Dot: observed point, solid line: limit of each pyroclastic fall deposit, dashed line: cumulative thickness contour.

which corresponds roughly to that of the upper wind.

The stratigraphic sequence and distribution of each air-fall deposit were surveyed on and around the volcano as shown in Figs. 6 and 7. The total thickness of all deposits are represented by dashed lines in Fig. 6. The thickness contour lines are elongate toward the NW and SE of the volcano due to the distribution of the major tephras of Big II & III and Big I & IV, respectively. Secondary mudflows were intermittently caused by heavy rains on the NW and SE slopes of the volcano, where the pumice and ash were thickly piled up and the forests were completely destroyed.

In the summit area, the new deposits are generally thick, and show fairly complicated thickness contours because of the presence of the four new craters. However, it is noticed that the new deposits are not so thick, even at the crater rim, as in case of the Strombolian type of eruption. This may be a characteristic feature of the pumice eruption.

The total volume of the new ejecta was calculated on the basis of both thickness and distribution area of the deposit. The volume amounts to as much as 8.3×10^{13} cm^3.

Nature of The New Ejecta

Pumice

Pumice is the most predominant new essential ejecta of the present eruption. The pumice distributed in the area 3 km from the crater is usually less than 5 cm, and rarely up to 10 cm in size. In the summit area, the maximum size attains 52 cm. The pumice varies from white to gray in color. Sometimes, banded pumices consisting of white and gray bands were found. The white pumice is more vesiculated than the gray one. Apparent density is 0.35 – 0.80 in the white pumice, 0.8 – 1.1 in the light-gray and banded pumices, and 0.95 – 1.4 in the gray one. It is a characteristic feature that most of the pumice lumps are cracked due to rapid cooling, and have an angular form.

The pumice is hypersthene dacite. Phenocrystic minerals are small in amount, consisting of plagioclase, orthopyroxene, and magnetite. The plagioclase phenocrysts are usually fresh and euhedral to subhedral in form, up to 1.5 mm in length. Zonal structure is conspicuous. Polysynthetic twinning after Carlsbad and albite laws is common, and sometimes pericline twinning is also observed. The orthopyroxene phenocrysts are also euhedral to subhedral, up to 0.4 mm in length, and show a faint pleochroism.Chemical analysis reveals this mineral to be hypersthene in composition. Magnetite is granular, up to 0.4 mm in size.

The groundmass is hyalopilitic and consists of vesiculated glass, plagioclase,

Table 2 Selected microprobe analyses of the phenocrystic minerals from the 1977 pumice.

	Plagioclase				Orthopyroxene				Titanomagnetite	
	1	2	3		4	5	6	7		8
SiO_2	49.56	57.15	52.18	SiO_2	51.25	52.00	49.87	51.75	TiO_2	9.90
TiO_2	-	0.00	0.04	TiO_2	0.18	0.20	0.15	0.15	Al_2O_3	2.34
Al_2O_3	31.48	28.08	29.14	Al_2O_3	1.03	1.11	1.40	0.91	Cr_2O_3	0.02
FeO*	0.36	0.16	0.36	FeO*	25.54	22.81	28.06	24.94	FeO*	79.91
MgO	-	0.02	0.05	MnO	1.45	1.46	2.01	1.68	MnO	0.62
CaO	15.08	9.32	12.73	MgO	19.20	20.53	16.87	19.73	MgO	1.48
Na_2O	2.72	5.12	4.13	CaO	1.37	1.32	0.92	1.20		
K_2O	0.02	0.09	1.18	Na_2O	0.03	0.29	0.02	0.05		
Total	99.22	99.94	99.81	Total	100.05	99.72	99.30	100.41	Total	94.27
	O = 32				O = 6				Recalculated analysis	
Si	9.123	10.212	9.592	Si	1.955	1.964	1.946	1.961		
Al	6.826	5.912	6.312	Al^{VI}	0.045	0.036	0.054	0.039	Fe_2O_3	47.21
Ti	-	0.000	0.004	Al^{IV}	0.001	0.014	0.010	0.001	FeO	37.42
Fe	0.055	0.024	0.056	Ti	0.005	0.006	0.004	0.004		
Mg	-	0.004	0.012	Fe	0.815	0.720	0.915	0.790	Total	98.99
Ca	2.973	1.784	2.508	Mn	0.047	0.047	0.066	0.054		
Na	0.971	1.776	1.472	Mg	1.091	1.155	0.981	1.114		
K	0.004	0.020	0.028	Ca	0.056	0.053	0.038	0.049		
Total	19.952	19.732	19.984	Na	0.002	0.021	0.001	0.004		
				Total	4.017	4.016	4.015	4.016		
An	75.3	49.8	62.6	Ca	2.8	2.7	1.9	2.4		
Ab	24.6	49.6	36.7	Mg	54.3	58.5	49.0	55.5		
Or	0.1	0.6	0.7	Fe+Mn	42.9	38.8	49.1	42.1		

* Total Fe as FeO.

1. Plagioclase (core), Big I pumice, analyst T. Nagao.
2. Plagioclase (core), Big III pumice (80918), analyst M. Yamamoto, T. Watanabe and T. Uda.
3. Plagioclase (rim), Big III pumice (80918), analyst M. Yamamoto, T. Watanabe and T. Uda.
4. Orthopyroxene (core), Big I pumice, analyst T. Nagao.
5. Orthopyroxene (rim), Big I pumice, analyst T. Nagao.
6. Orthopyroxene (core), Big II pumice (Suimeiso), analyst T. Nagao.
7. Orthopyroxene (rim), Big II pumice (Suimeiso), analyst T. Nagao.
8. Titanomagnetite (core), Big I pumice, analyst T. Nagao.

and a small amount of orthopyroxene and opaque mineral. The groundmass of white pumice from the Big I consists mostly of glass which includes a small amount of plagioclase needles. On the other hand, the groundmass of other pumices is generally more crystalline. Apatite and cristobalite are seen as accessory minerals.

More than 50 chemical analyses of rock-forming minerals by EPMA were carried out. Selected chemical analyses of phenocrystic minerals such as plagioclase, orthopyroxene and magnetite are given in Table 2.

Compositions of plagioclase from the Big I, II and III pumices are plotted in Or-Ab-An diagrams (Fig. 8). Anorthite content of the plagioclase ranges from 63.4 to 56.5 mol.% in the Big I pumice, from 56.9 to 51.1% in the Big II, and from 65.0% to 56.0% in the Big III. Fig. 9 shows the zoning patterns of plagioclase. It is noticed that the core of the plagioclase is sometimes up to 75.3 and 79.0% An content in the Big I and Big III pumices, respectively. A calcic core of plagioclase attaining 90 – 100% An content was found in the Big II pumice (bottom of Fig. 9). It is also noticed that the anorthite content becomes higher in the margin, which may be interpreted as due to increasing vapor pressure before the eruption. The plagioclase from the Showa-Shinzan

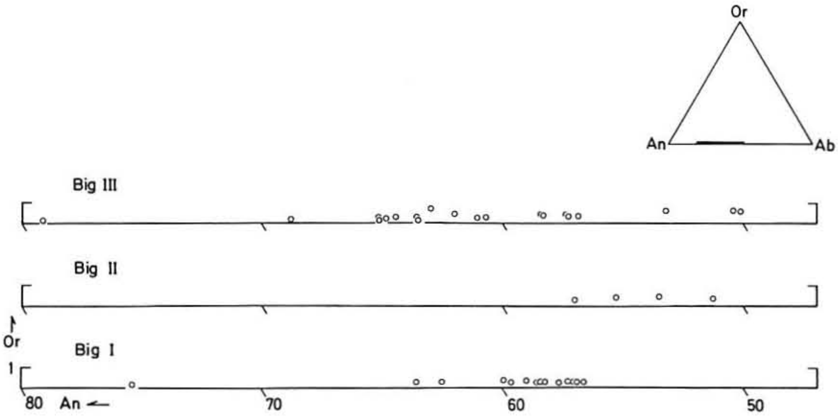


Fig. 8 Composition ranges of plagioclase phenocrysts.

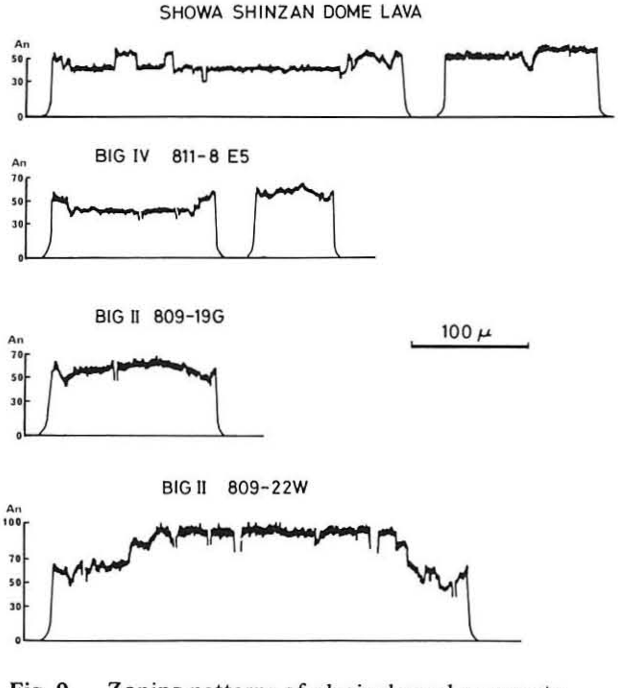


Fig. 9 Zoning patterns of plagioclase phenocrysts.

dome lava has a similar An content and zoning pattern.

Compositions of orthopyroxene from the Big I, II and III pumices are plotted in Ca-Mg-Fe diagrams (Fig. 10). The compositions vary from the core to the margin, as indicated by the arrows. The enstatite content of the

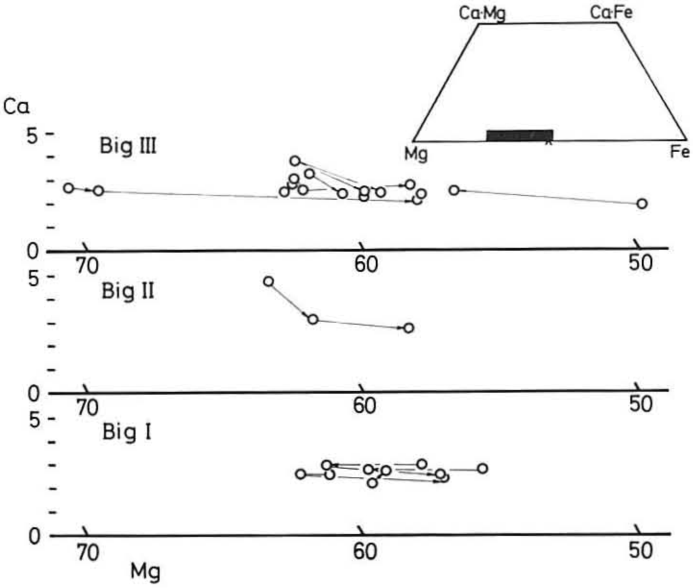


Fig. 10 Composition ranges of orthopyroxene phenocrysts.

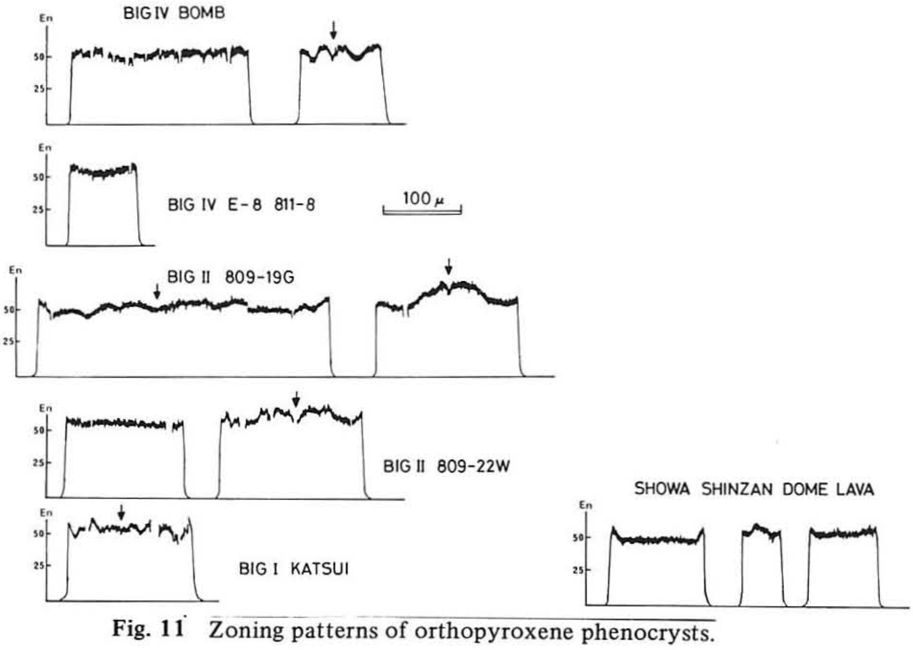


Fig. 11 Zoning patterns of orthopyroxene phenocrysts.

Table 3 Chemical compositions of the essential products of Usu Volcano in historic times.

Year	1663			1822	1853		1944			1977					
No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	73.13	73.04	71.25	70.83	70.60	68.26	69.74	69.17	68.89	68.05	68.74	69.34	68.77	68.43	68.57
TiO_2	0.18	0.26	0.43	0.33	0.36	0.36	0.45	0.41	0.47	0.44	0.45	0.46	0.48	0.44	0.50
Al_2O_3	14.19	12.95	13.21	14.86	15.00	15.77	15.59	15.68	14.92	15.13	15.52	15.34	14.87	15.14	15.58
Fe_2O_3	0.91	1.11	3.19	1.86	1.37	1.91	1.52	2.37	3.01	1.80	1.42	1.45	1.53	1.61	1.45
FeO	1.51	1.54	1.96	1.61	2.49	2.15	2.59	1.72	1.78	2.88	2.39	2.00	2.34	2.95	2.49
MnO	0.08	0.06	0.27	0.09	0.09	0.31	0.08	0.20	0.16	0.20	0.08	0.12	0.14	0.15	0.16
MgO	0.22	0.36	0.84	0.78	0.77	0.99	0.85	0.92	0.90	0.96	0.84	0.75	0.69	0.96	0.79
CaO	2.30	2.41	3.10	3.53	3.30	4.37	3.63	4.00	4.10	3.93	3.78	3.56	3.93	3.93	4.06
Na_2O	4.71	5.07	4.02	4.71	4.42	3.83	3.43	3.63	4.00	4.54	4.62	4.63	4.77	4.41	4.46
K_2O	1.32	1.14	1.15	0.93	0.98	1.29	1.36	1.32	1 03	1.13	1.10	1.02	1.07	0.92	1.13
P_2O_5	0.36	0.43	0.46	0.08	0.21	0 18	0.22	0 20	0 24	0.19	0.28	0.32	0.38	0.14	0.27
$H_2O(+)$	0.66	1.02	0.50	0.05	0.69	0.51	0.67	0.37	0.12	0.56	0.47	0.21	0.27	0.55	0.24
$H_2O(-)$	0.15	0.21	0.25	0.18	0.12		0.23		0.32	0.14	0.10	0.20	0.06	0.02	0.12
Total	99.72	99.60	100.63	99.84	100.40	99.93	100.36	99.99	99.94	99.95	99.79	99.40	99.30	99.65	99.82

1. Essential lithic fragment from the Us-b pumice-fall deposit. New analysis by Y. Oba.
2. Pumice from the Us-b pumice-fall deposit (Oba, 1966).
3. Dome lava of Ko-Usu (Minakami et al., 1951).
4. Pumice from the Bunsei nuée ardente deposit. New analysis by Y. Oba.
5. Dacite from the Tateiwa nuée ardente deposit (Minakami et al., 1951).
6. Dome lava of O-Usu (Minakami et al., 1951).
7. Dome lava of Showa-Shinzan (Minakami et al., 1951).
8. Dome lava of Showa-Shinzan (Minakami et al., 1951).
9. Dome lava of Showa-Shinzan (Oba, 1966).
10. Pumice from the lower part of the Big I pumice-fall deposit (Aug. 7). Loc. E-4, 3.2 km ESE of the Crater 1. New analysis by Y. Ikeda.
11. Pumice from the middle part of the Big I pumice-fall deposit (Aug. 7). Loc. E-62, 1.7 km SE of the Crater 1. New analysis by Y. Oba.
12. Pumice from the lower middle part of the Big II pumice-fall deposit (Aug. 8). Loc. W-5, Konomi-danchi, 2.5 km NW of the Crater 2. New analysis of Y. Oba.
13. Pumice from the middle part of the Big III pumice-fall deposit (Aug. 8-9). Loc. W-5, Konomi-danchi, 2.5 km NW of the Crater 3. New analysis by Y. Oba.
14. Pumice from the upper middle part of the Big III pumice-fall deposit (Aug. 9). Loc. W-1, Suimeiso, 2.5 km NW of the Crater 3. New analysis by Y. Ikeda.
15. Pumice from the middle part of the Big IV pumice-fall deposit (Aug. 14). Loc. E-54, Nishi-sekinai, 5.7 km SE of the Crater 4. New analysis by Y. Oba.

orthopyroxene ranges from 63.8 to 57.2 mol.% in the Big I pumice, and from 63.9 to 58.5% in the Big III pumice. Sometimes, orthopyroxene having an En-rich core (more than 70 mol.%), is found. This value is similar to that of orthopyroxene in the somma lava (Ōba, 1966). As shown in Fig. 11, it is noticed that the orthopyroxene is richer in Mg in the margin than the core.

An analysis of opaque mineral is listed in Table 2 which indicates that this mineral is titaniferous magnetite.

More than 20 chemical analyses of lavas, pumices and ashes by both wet and X-ray fluorescence methods were carried out. The results of wet chemical analyses of six pumices produced by the present eruptions are given in Table 3 together with those of the historic products. All of the pumices ejected by the present eruption are dacite in composition. The pumices do not show significant change in composition throughout the four major eruptions. Their SiO_2 content ranges from 68.57 to 69.34%, Al_2O_3 from 14.87 to 15.58%,

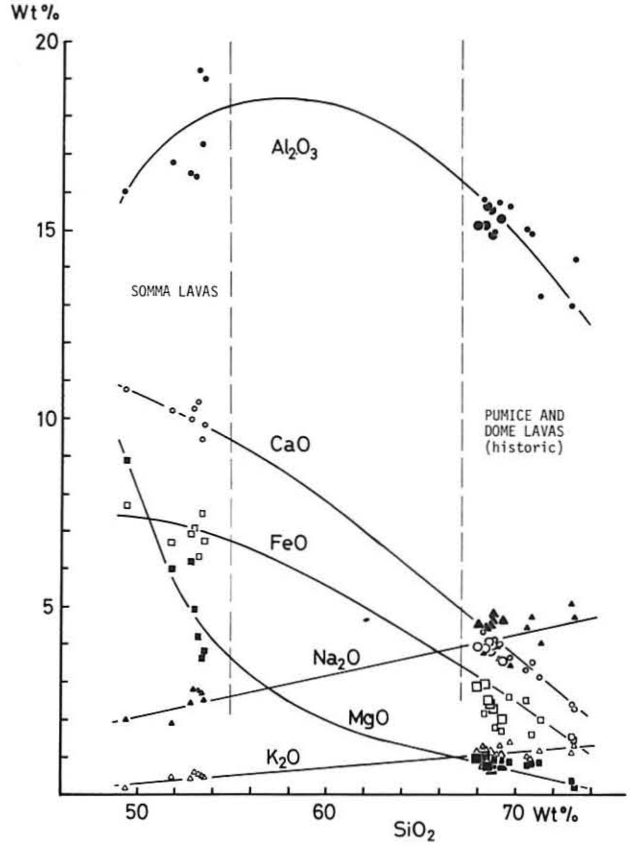


Fig. 12 Variation diagram of oxides for the somma lava and the historic pumice and dome lavas of the Usu Volcano. Large symbols: the 1977 pumice. (Data from Ōba, 1966, and Table 3 in the present paper).

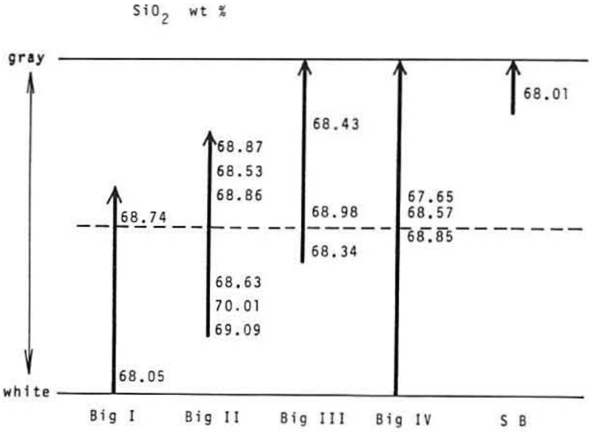


Fig. 13 Relation between sequence of the eruption and nature of the pumice. Silica contents of the pumice were analysed by X-ray fluorescence.

Na_2O from 4.41 to 4.77%, and K_2O from 0.92 to 1.13%. Chemical compositions of the pumices are plotted in a variation diagram in Fig. 12. They fall on the variation trend of the Usu volcano established by Ōba (1966) (solid lines in Fig. 12). It is noticed that the pumices of the present eruption are very similar in chemical composition to the dome lava of Showa-Shinzan which erupted in 1944. On the other hand, the 1663 pumices and lavas, which erupted after a long dormancy, are more felsic in composition than those erupted later. Such change in composition may be interpreted in terms of a compositionally zoned magma chamber.

An interesting relationship is found between the variation in color of the pumice and the sequence of the present eruption. As shown in Fig. 13, the pumice ejected at the early stage of each major eruption is generally white or light gray and well vesiculated, whereas with the progress of the eruption the darker and less vesiculated pumice becomes abundant. It is also observed that the color of the pumice ejected at the early stage in each major eruption, become darker from the Big I to the Big III. At the beginning of the Big IV eruption, which occurred at another site 800 m NE of the Craters 1 – 3, white and well vesiculated pumice was again ejected as in the Big I eruption. The difference of the color of the pumice does not depend on the chemical composition, but probably on the crystallinity of the groundmass.

Volcanic Blocks and Bombs

Near the new craters a large number of volcanic blocks and bread-crust bombs were ejected. They are classified into essential, accessory and accidental ejecta, as follows:

Essential blocks and bombs:
- Dacite blocks
- Bread-crust bombs

Accessory blocks:
- Dacite mostly derived from the Ko-Usu dome lava
- Olivine basalt and pigeonite andesite from the Usu somma lava

Accidental blocks:
- Welded tuff with obsidian patches
- Pyroxene andesite from Tertiary volcanics
- Propylite and tuff breccia from Tertiary volcanics
- Quartz diorite from the basement plutonics

Most of the essential blocks and bombs were thrown out at a later stage of the Big III, IV, and SB eruptions. They are light to dark gray in color and are up to 50 cm in size. The bombs have a glassy surface which is cracked due to vesiculation of the interior. The volcanic blocks are compact and usually

Table 4 General properties of the 1977 ash of the Usu Volcano.

Sample	Color	Md (mm)	So	2.0-0.2mm	0.2-0.02mm	0.02mm-2μ	2-0.2μ	<0.2μ	Liquid limit (%)
						(<2mm fraction, wt %)			
				%	%	%	%	%	
Big I ash	Dark grayish yellow (10Y 3/1)	0.42	3.54	30.90	42.97	20.08	1.72	4.33	—
SB ash	Dark grayish yellow (10Y 4/1)	1.18	3.27	53.82	23.30	18.63	2.15	2.10	17.0

Sample	SiO_2 (%)	pH(H_2O)	water soluble and exchangeable cations (mg/100g)					water soluble anions (mg/100g)		CEC* (me/100g)
			K^+	Na^+	Ca^{2+}	Mg^{2+}	Mn^{2+}	Cl^-	SO_4^{2-}	
Big I ash	58.15	8.17	21.4	80.7	259.3	16.2	11.0	10.3	28.2	10.71
SB ash	64 25	7.32	15.2	31.9	86.9	17.5	4.7	6.9	29.2	4.29

*CEC = cation exchange capacity

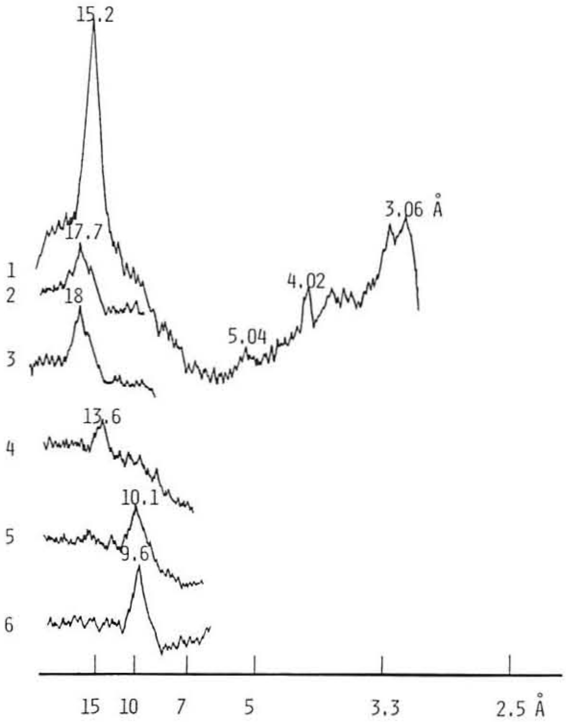


Fig. 14 X-ray diffraction patterns of a clay sample (< 0.2μ) from the Big I ash. 1: untreated, 2: solvated with glycerol, 3: water saturation, 4: K-saturation, 5: heated to 400°C, and 6: heated to 550°C.

higher in crystallinity than the bombs. A gradual change in vesiculation from the bread-crust bombs to volcanic blocks is observed.

Ash

Fine ash samples (< 2 mm) of the Big I and the SB were collected at points 4.5 and 3.0 km east of the source, respectively.

The ash samples are weakly alkaline (P_H = 8.2 – 7.3), and rich in water-soluble and exchangeable Ca and Na, but poor in water-soluble Cl and SO_4, as shown in Table 4. They contain 6% < 2μ clay and 4% < 0.2μ clay. The clay consists mainly of montmorillonite (Fig. 14). The ash has a high cation exchangeability, adsorptivity and viscosity, and also shows high dispersion in

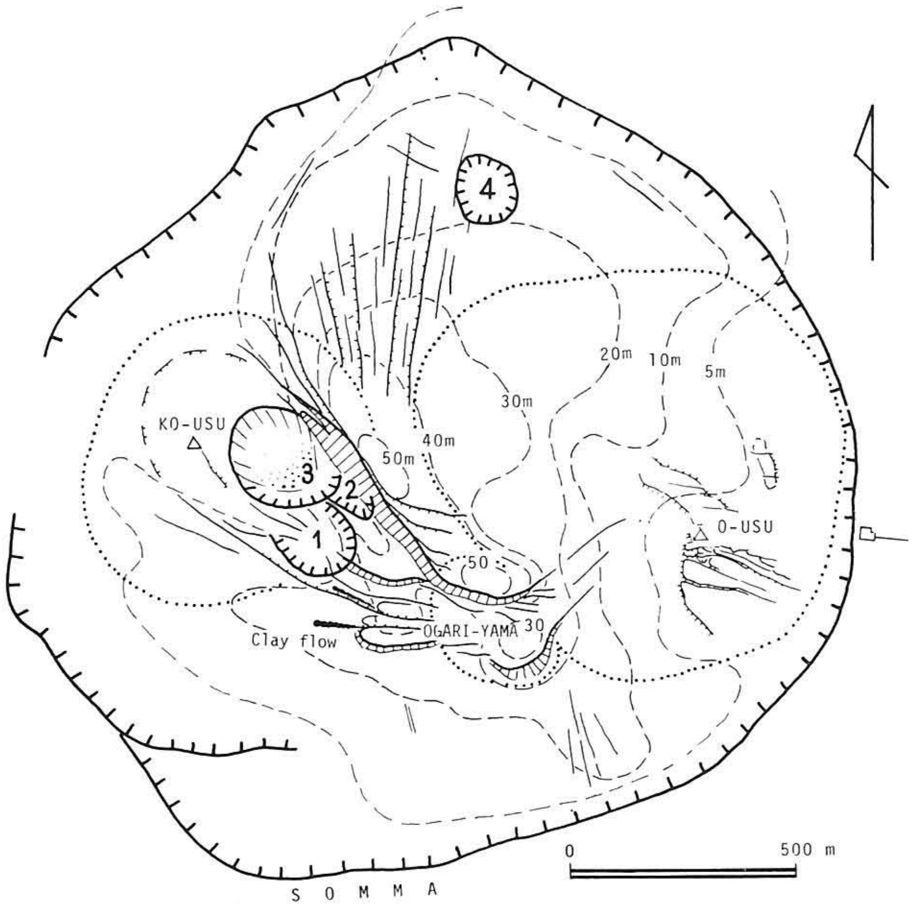


Fig. 15 Topographic change in the somma-atrio of Usu Volcano (August 23, 1977). Arabic figures (bold): name of the new craters, solid lines: faults and fractures, and dashed lines: amount of upheaval. Topography based on the maps of the Geographical Institute of Japan.

air and water. Such properties are probably due to the presence of the clay mineral in the ash.

The montmorillonite in the ash is not an essential material, but an accidental one which has possibly been derived from the lake deposit in the atrio on the summit of Usu. In this connection, late in August, it was confirmed that two clay flows consisting mainly of montmorillonite were squeezed out on the surface of the atrio due to crustal movement, as shown in Fig. 15. The presence of clay mineral in the ash gave rise to severe damage to the forests and agricultural lands near the volcano during the eruptions on rainy days, as mentioned earlier.

Topographic Deformation

Notable crustal movements accompanied by local earthquakes have occurred during the present activity. The topographic deformation caused by the upward movement of viscous magma, is a characteristic feature of the volcanic activities of Usu in recent years (Minakami *et al.*, 1951).

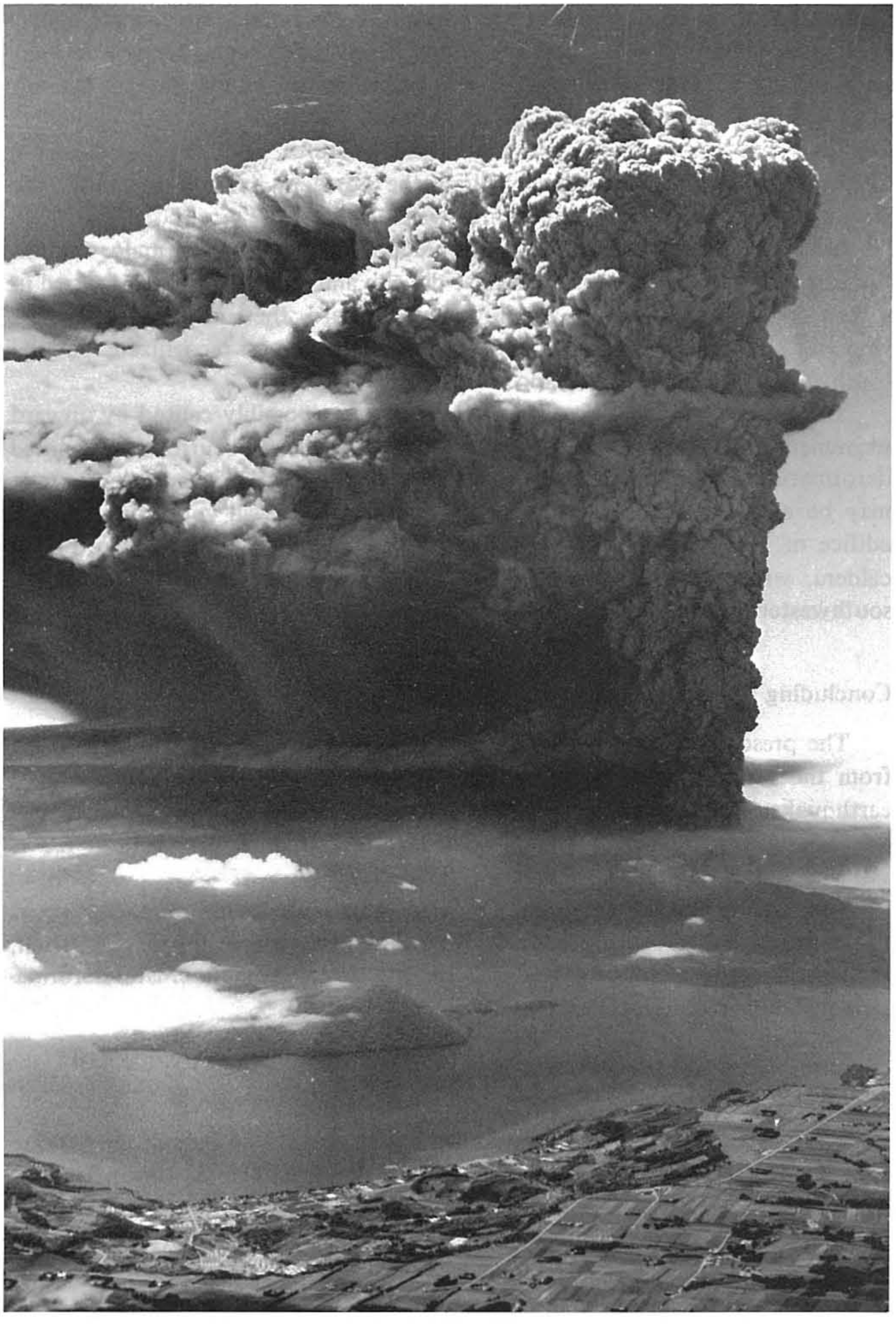
During the present activity, numerous faults and fractures were produced by uplift of the atrio, as illustrated in Fig. 15. The biggest one traverses the atrio from Ko-Usu to Ogari-yama in a NW – SE direction. The first sign of this major fault was found just 20 min. before the first eruption. Then, it developed into a big normal fault dipping to the south, and this fault cut the pre-existing lava domes. These lava domes were notably destroyed by invasion of the fault and frequent earthquake shocks. Many fractures with small grabens have developed radially from the center of the atrio toward the north since August 10.

Subsequent to the formation of the major fault, another notable fault, which runs also from NW to SE but dips to the north, has developed in the south. As the result of development of both faults, which are probably conjugate to each other, a graben formed between them. The summit of Ko-Usu, located in the graben, has sunk considerably.

The amount of upheaval until August 23 is shown by the dashed contour lines in Fig. 15. The maximum uplift was up to 50 m along the northern side of the major fault in the central part of the atrio. This place is still rising at the rate of several tens of centimeters per day.

Explanation of Plate 1

Ash-laden cloud from the first eruption of Usu Volcano, Hokkaido, on August 7. The photograph was taken from the northern sky at $09^{h}50^{m}$, 38 min. after the beginning of eruption. Photo by The Hokkaido Shinbun.



On the northeastern flank of the volcano, many houses, stone walls, stairs, paved roads, water pipes, and other constructions have been slightly damaged since August 15. Most of the damage was caused by crustal movements, though some was by earthquake shocks and land-sliding.

Since September 5, marked faults and fractures have developed in the northeastern part of the somma. Along the northern limit of the atrio, the sediments were thrust up to the somma wall.

It is evident that normal faults are predominant around the major fault in the summit. On the other hand, reverse dip-slip and strike-slip faults, formed in a compressive stress-field, are prevalent toward the northeastern flank. However, no marked crustal deformation has been recognized on the southwestern flank of the volcano.

The present topographic deformation has been possibly caused by upward movement of the viscous magma beneath the atrio. The occurrence of marked deformation exclusively on the summit and NE flank, attracts our attention. It may be ascribed to the presence of the Tōya Caldera wall under the volcanic edifice of Usu. The northeastern flank of Usu is situated on the inside of the caldera, where the Tertiary basement may be more fragile than that of the southwestern outside.

Concluding Remarks

The present eruption of Usu began with ejection of dacite pumice and ash from the summit, after 30 hours from the beginning of the forerunning local earthquakes. The explosive eruptions lasted intermittently from August 7 to 14. The total volume of the new ejecta amounted to as much as 8.3×10^{13} cm^3.

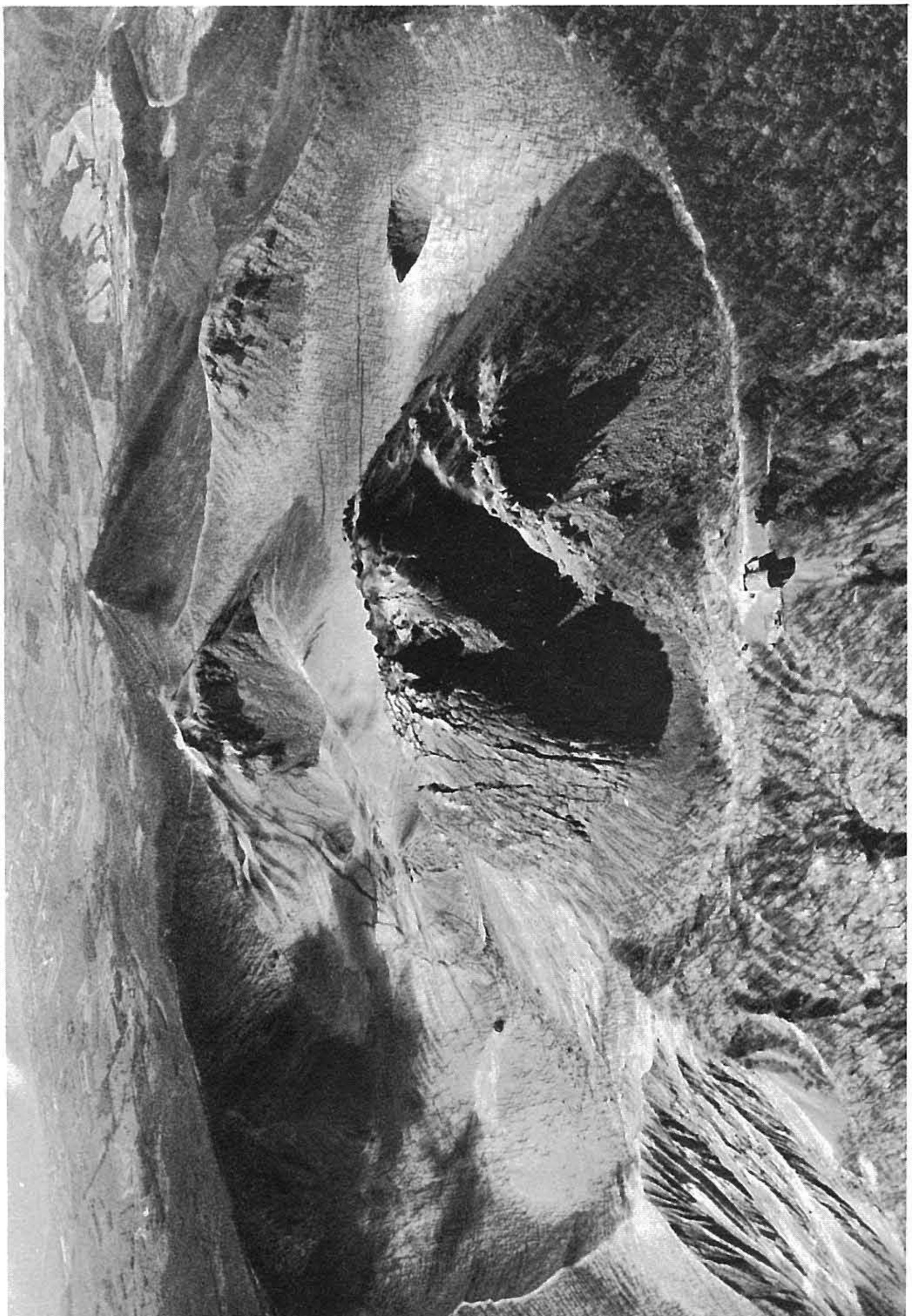
Toward the end of the paroxysmal eruptions, vesiculation of magma seems to have dimisnished probably due to depleting of water from the magma. Then, the upward movement of the viscous magma caused notable crustal deformation accompanied by local earthquakes.

Acknowledgement

This report is dedicated to Professor Kenzo Yagi, President of the Volcanological Society of Japan, at his retirement from Hokkaido University. We

Explanation of Plate 2

The summit of Usu Volcano seen from the eastern sky, on August 24. (cfr. Fig. 15) Photo by The Kyodo Press.



would like to thank him for drawing our attention to volcanology.

We are grateful to Emeritus Prof. T. Ishikawa and Prof. I. Yokoyama of Hokkaido University, Emeritus Prof. T. Minakami and Profs. D. Shimozuru and S. Aramaki of University of Tokyo, Prof. A. Takagi of Tohoku University, Mr. M. Seino of Japan Meteorological Agency, Dr. H. Satoh of Geological Survey of Japan, and Mr. T. Sasaki of Hokkaido National Agricultural Experiment Station, for their helpful suggestions and discussion. Thanks are due to Dr. N.C. Stevens of University of Queensland for a critical reading of the manuscript.

We are also indebted to the following organizations and laboratories for their help in the field and laboratory: Hokkaido Government, Sōbetsu Town Office, Date City Office, Abuta Town Office, Hokkaido Police Headquater, and Seventh Division of Ground Self-Defence Force, Thin-section Laboratory and EPMA Laboratory of Hokkaido University, Institute for Thermal Spring Research, Okayama University, and Hokkaido National Agricultural Experiment Station.

A part of the expense for this study was defrayed by the Grant for Scientific Research from the Ministry of Education of Japan.

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(Received on Oct. 31, 1977)