25. *Geological and Petrological Studies of Volcano, Fuji, V.**
5. *On the 1707 eruption of Volcano Fuji.***

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Introduction

Volcano Fuji (Fuji-san or Fuji-yama), situated near the shore of Suruga Bay, central Japan, was in a state of eruptive activity thirteen times, at least, in historic times. Its earliest recorded eruption occurred in 781 A.D., being followed by the eruptions of 800, 826, 864, 870, 937, 999, 1033, 1083, 1511, 1560, 1700 and 1707[1]. Of these, according to all the historical materials ever found, the eruptions in 800, 864, and in 1707 were more violent than the rest which have been mentioned only as being eruptions of the volcano.

The eruption of 800 (19th year of the Enryaku era) occurred at the summit crater of the volcano, the activity continuing for thirty five days from April 15 to May 19. Lava was poured out of the crater, flowing down on all sides. In the daytime the smoke covered the mountain under a pall of darkness, and at night the fire showed up against the sky. The noises that accompanied the eruption were like thunder, and the ashes fell like rain, causing the rivers at the base of the mountain to be of a reddish color.

The eruption of 864 (6th year of the Teikan era) occurred in June[2] at the parasitic cone Nagao-yama[3] on the northwest flank of the volcano. The eruption was quite violent with the fire covering the mountain for

* Parts I-IV of this paper have been published by the author in Japanese, respectively in the *Bull. Earthq. Res. Inst.*, **16** (1938), 452; *ibid.*, 638; *ibid.*, **18** (1940), 419; and *ibid.*, **21** (1943), 376.

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1) F. OMORI, "History of Volcanic Eruptions in Japan," *Report Earthq. Invest. Com.*, **86** (1918), 90 (in Japanese).

The Earthquake Investigation Council, *Historical Data on the Earthquakes in Japan*, **1** (1941); **2** (1943).

2) Definite date and duration of the eruption are not mentioned.

3) H. TSUYA, *Bull. Earthq. Res. Inst.*, **16** (1938), 639 (in Japanese).

a space of several kilometers square and the flame shooting up to a height of scores of meters. The land was shaken three times in succession with noises like thunder. During the eruption which lasted for more than ten days, red-hot stones broke loose from the mountain, and sand and stones fell like rain. Red-hot lava flowed down northwestwards falling into the two lakes, Motosu-ko and Seno-umi, which at that time stood side by side at the northwest foot of the volcano. Parts of the lakes were filled up with the lava, together with a number of farm-houses on the shores, and the lake water became so hot as to cause the death of many fish and tortoises. The lava field now called "Aokigahara marubi"[4] is the product of the eruption, and the two lakes, Shôji-ko and Sai-ko, situated 2 km and 8 km northeast of another lake

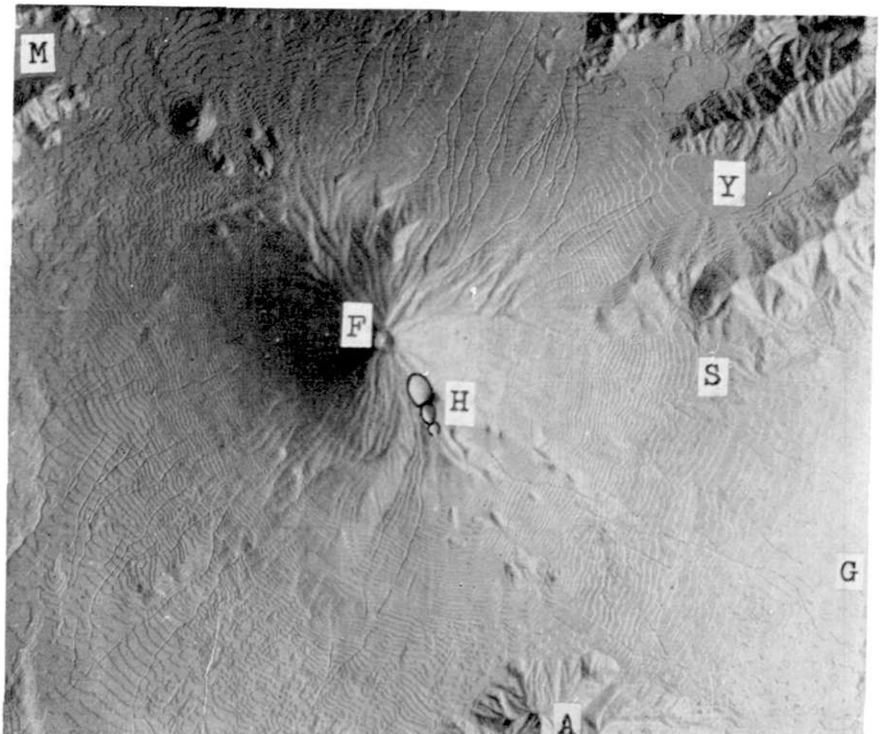

Fig. 1. Vertical photograph of a topographic model of Volcano Fuji, showing location of the 1707 flank eruption. F: top of the volcano. G: Gotemba (town). H: Hôei-san with three craters of the 1707 eruption. M: Lake Motosu. S: Subashiri (village). Y: Lake Yamanaka.

4) "Marubi" means recent bare *aa* flows (identical with the Mexican "malpais") on the lower slopes of the volcano.

Motosu-ko respectively, are evidently those parts of the historical lake Seno-umi left intact by the lava. At present the three lakes are separated from each other with broad belts of the Aokiga-hara marubi.

The eruption of 1707 (4th year of the Hôei era) occurred half way up the southeast flank of the volcano (Fig. 1). It was not only the most violent eruption ever recorded in the history of the activity of the volcano but a severe explosive eruption—quite unusual for basaltic volcanoes. Moreover, the eruption deserves special mention from the fact that prior to the ejection of a large volume of basaltic material (scoriae and bombs) ejection of acid andesite or dacitic material (pumice and obsidian) occurred for a few hours at the beginning of the activity. This material, though small in quantity compared with the basaltic ejecta, was juvenile in origin, and was new to the basaltic Fuji, its occurrence being absolutely unexampled in the history of the volcano. The fact that the 1707 eruption was a violent explosive activity attended by successive ejection of acidic and basic materials has been mentioned in some old writings on the eruption, and can be actually proved by investigating both the distribution and the mode of occurrence of the ejecta of that time. The purpose of this paper is to give an account of this eruption by referring to some authentic writings and at the same time studying the geological data obtained by field observations.

Volcanic and seismic activities in Japan within ten years before the 1707 eruption of Fuji

The volcanoes that erupted in Japan during the ten years from 1697 to 1707 are Fuji-yama, Asama-yama, Kirishima-yama and Sakura-jima[5]. The twelfth eruption of Fuji in historic times occurred in 1700, but it might have been of a small scale, seeing that the only historic record of the eruption to which reference can be made mentions nothing about the activity but the word "eruption". Neither ejecta nor craters which may be assigned to that eruption can be traced at the present time. Asama-yama, situated about 117 km north of Fuji, had a big eruption in 1704 lasting for several days, and another eruption in 1706; Kirishima-yama and Sakura-jima, both in southern Kyushu, had an eruption each in 1706. But further details of these eruptions are quite unknown. Asama, Kirishima aud Sakura-jima, together with Aso-zan in Kyushu and Ô-shima in Izu, all rank among the leading active

5) F. OMORI, *loc. cit.*

volcanoes in Japan, having records of many eruptions in historic times. Their activity culminate in eruptions repeatedly in recent years, although Kirishima alone has been quite without any eruptive activity since the beginning of the present century. It may be said therefore that volcanic activity in Japan had never become exceptionally violent in the ten years' period 1697–1707, at the end of which the 1707 eruption of Fuji occurred, and during which volcanic activity was about as normal as in recent years.

As to the seismic activity of Japan in the period 1697–1707, two big earthquakes may be specially mentioned, besides a number of smaller ones[6]. One of the big earthquakes occurred on Dec. 31, 1703, with its epicentre in Sagami Bay off the southern tip of the Bôsô Peninsula. Tokyo and the provinces on the shore of the bay suffered heavily from the shocks and associated fires, the damage including the loss of 5233 lives and 20,161 houses destroyed. The other occurred on Oct. 28, 1707, with its epicentre in the sea off the southern tip of the Kii Peninsula, causing serious damage to life and houses in the provinces on the shore of the Pacific in Southwest Japan[7]. Among the damage were included 4900 lives lost and 29,000 houses destroyed. In addition to these big earthquakes, a local but destructive one occurred in 1704 on the shore of the Japan Sea, in Noshiro district north of Akita City, Northeast Japan, with the loss of 58 lives, 435 houses destroyed and 759 houses burned. Taking into account another earthquake of the same district in 1694, together with some others[8], it may be said that the seismic activity of Japan got to a peak around the beginning of the 17th century in the fluctuation of its rise and fall, so far as earthquakes of destructive nature are concerned. But it could have had no positive correlations with the volcanic activity of Japan at that time, if the latter, as inferred above, was not deviating from the normal course of the intermittent volcanic activities through centuries.

6) Rika Nempyo (the Annual Science Table) compiled by the Tokyo Astronomical Observatory, 1954 (in Japanese).

7) The earthquake might well be compared with the Nankai earthquake of 1946 in various aspects, i.e., loci of the epicentres, extent of the stricken provinces, and nature and scope of the damage wrought.

8) An earthquake occurred in 1710 in the provinces to the west of Tottori City, another in 1711 in the same provinces, and the third one in 1714 at Omachi City and vicinity, all being local but destructive ones on or near the shore of the Japan Sea.

Course of the 1707 eruption[9)]

Although an eruption of Fuji occurred in 1700, the volcano must have recovered immediately from its effects and entered into a dormant state, thus keeping it from being noticed by those who lived nearly. Thus no smoke or other signs of activity of the volcano have been mentioned in any of the writings of the time. Nothing unusual of the volcano has been mentioned also on the occasion of the big 1707 (Oct. 28) earthquake in Southwest Japan, while considerable damage done by the shocks to the district adjacent to the south of the volcano has been reported. Only fifty days later, on Dec. 16, came the present eruption accompanied with great havoc wrought by a heavy ash-fall in the countries adjoining the east of the volcano.

Preliminary symptoms of the eruption. During the first half of December, 1707, light shocks were felt at times at Mito, a fishing village on Suruga Bay, near the southeast foot of the volcano[10)]. From Dec. 3, unusual rumblings as coming from the mountain became audible three or four times a day at Yoshida on the northeast foot of the volcano. These shocks and rumblings might be indications that, within about two weeks preceding the eruption, the volcanic activity beneath Fuji-yama was drawing nearer to the surface of the volcano where, however, no change was yet noticed in its surface features.

From the evening of Dec. 15 to the next morning, earth-shocks were felt more than thirty times at Yoshiwara on the south foot of the volcano, and more than fifty times at Yoshida, becoming almost countless by the same morning. Being followed soon by the eruption, these shocks must have occurred as premonitory symptoms warning that the volcanic activity was approaching the surface of the volcano. At Yoshiwara, some houses which narrowly escaped being destroyed by the big earthquake of Oct. 28, 1707, were destroyed by the present shocks. At Subashiri on the east side of the volcano, too, some of the precursory shocks were strong enough to demolish some houses.

9) Of many writings about the eruption, two may be mentioned as the most authentic descriptions: *Ito Shimanokami Nikki* (a diary written by Ito, the then Lord of Shima Province) and *Motokiko-ki* (a description by Prince Konoe Motoki, one of the five regent houses at the time, including several official and private reports of the eruption). The course of the eruption here outlined has been traced mainly through these descriptions, as well as by referring to some other writings.

10) Previous to that, earthquakes were felt at times, but they might have been aftershocks of the earthquake of Oct. 28, or otherwise shocks from sources other than the volcano Fuji.

In Tokyo and vicinity, the weather continued to be calm without rain for two weeks from Dec. 3 to the day of the eruption, although from Dec. 13 on it was cloudy and cold with occasional snow-falls.

Beginning of the eruption, Dec. 16, 1707. Subsequent to some rather strong earth's shocks at dawn on Dec. 16, 1707, rumblings like thunder were heard at about 8h at Subashiri and the neighbouring village Ômika, and at the same time black clouds were seen rising in the west and overcasting the entire sky. Everything in and about the villages was shrouded in the clouds so thickly that the people there could barely distinguish the difference between day and night. About 10h there came a heavy fall of volcanic sand and stones. They were white to yellow in color, more or less salty and ill-smelling, and looked like a pumice stone. On falling on the ground, the bigger stones, which were of the size of footballs, broke flamingly into pieces. Some houses and vegetation were burnt by heat from the hot stones with which they came in contact. A violent eruption of Fuji was seen taking place half way up the mountain and near the Subashiri-guchi trail[11], causing avalanches of the snow thereabout. The eruption continued throughout the day with heavy explosions, besides the thunder and lightning that occurred from time to time in different quarters of the sky overcast with the eruption clouds. By the evening of the day the country roundabout had been covered with the sand and stones ejected by the eruption.

The eruption was witnessed for the first time at about 10h of the same day by those who lived in Yoshiwara and Fujimiya, respectively situated on the south and southwest foot of the mountain. At that time they saw a rolling cloud rising from the southeast side of the mountain, at about eight tenth of its height and near the upper limit of the zone of vegetation, with rumblings resounding through the country roundabout. The vomiting clouds in a moment spread high in the sky to the south and southeast of the mountain, but a few hours later, about 14h, blown by the westerly wind, they spread over the provinces east of the mountain. In the evening, a great fire was seen on the mountain, with black smoke repeatedly drifting to the east. Fire balls shot up into the night air and broke to pieces on falling on the ground, and flashes of lightning crossed in all directions through the clouds of black smoke. Owing to the fire, the villages to the west

11) There are five old trails leading to the top of the mountain, the Subashiri-guchi trail being on its east side.

of the mountain were light as day in the night. Concussions accompanied with noises of rattling doors were felt almost continuously.

At Yoshida the eruption was seen first at 10h with gigantic clouds of black smoke rising from the south side of the mountain and fire-balls falling from the clouds, accompanied with rumblings and thundering noises. From that time on the eruption continued far into the night with shooting flames and fire-balls, and repeated thunders and lightnings.

At Mito on Suruga Bay, subsequent to several earthquakes in the early morning (6h–9h), houses were shaken by rumblings like thunder and the noises of the doors and windows rattling were loud enough to make conversation impossible. The clouds with which the sky had been overcast broke at 15h, and variegated clouds were seen drifting from Fuji to the east. The villagers were informed of the eruption of the mountain by a message from Numazu.

In Tokyo and vicinity, at about 10h on the same day, pale and dark clouds were seen spreading high in the air southwest, and shocks were felt shaking houses with noises of rattling doors and windows, but without accompanying any sensible earth-shocks. From that time on rumblings kept occurring frequently, forerun by house-shaking shocks, and at noon, accompanied with thunder, flashes of lightning were seen in the black clouds overcasting the southern sky. Shortly afterward, as the heavens suddenly became overcast with black clouds, it darkened outdoors as well as indoors like a moonless night, so that nothing could be seen clearly without lighting a candle. About 13h ashes of white to grayish color began to fall like snow, everything on the ground was coated with the ashes, and people found difficulty in walking outdoors because the ashes got into their eyes and noses. After 15h volcanic sand also fell and by 20h they accumulated to a depth of several centimeters. The sand-fall was heavy particularly during the evening hours, and late in the evening black sand began to fall instead of the whitish sand and ashes that fell during the preceding hours. About 22h the sky cleared a little, and at midnight the moon was seen in the star-strewn sky, but the southwest part of the sky continued to be overcast with black clouds. House-shaking shocks also kept occurring frequently through the night, together with distant thunders and lightnings.

The above-mentioned description of the first day of the eruption indicates that the mountain Fuji started an explosive eruption at about 8h (or 10h) on Dec. 16, 1707, with some forerunning earth's shocks, and that for the first several hours of the eruption it ejected whitish ashes, sand and stones, turning soon after into longer-continued and more violent ejection of black sand. That the eruption was taking place on Fuji naturally became known from the first to those who lived in the provinces near the mountain, while in Tokyo and vicinity it became known first by a courier's message which arrived from Yoshiwara two days later (Dec. 18). Till then many people in Tokyo, knowing nothing of the eruption, were very fearful of the ash-fall and shocks which were strange features they never met with before, and some hastily ascribed these phenomena to Asama-yama, which at that time was known as an active volcano causing occasional ash-fall in Tokyo and the neighbouring provinces, as it still does in recent years.

Continuous eruption, Dec. 16–20, 1707. The eruption which began on Fuji Dec. 16, 1707, displayed itself almost continuously for five days until Dec. 20, without any daylong or longer lull in the activity as shown by the fact that ash-fall, rumblings and shocks, all occurred frequently every day during that period. However, the eruption seems to have reached its most violent explosions on the first day and then to have declined day by day, seeing that the largest piece of the ejecta that fell in Subashiri and vicinity was of the size of a football on the first day, then decreasing into the size of a peach, a pea, and of fine dust, successively on the second, third, and fourth days. The main events relative to the eruption in these days are as follows:

Dec. 17. At Subashiri and Ômika ashes and stones were seen falling as on the preceding day, but the eruption clouds with which the sky was overcast became a little thinner, and through a rift in the clouds the sun shone at intervals in the daytime and the stars would be seen at night. Viewed from Subashiri, Fuji was found for the first time to have formed a new mound (Hôei-san)[12] halfway up the southeast side of the mountain. At Yoshida, about 20h, a rather strong earth-shock was felt, and more violent rumblings and flashes were still coming from the mountain.

At Tokyo, for the most part of the day, the northern sky was clear, while in the southwestern sky pale and black clouds were occasionally giving out thunders and lightnings. Shocks were felt at times, particularly at 3h and 16h, with a short lull between 10h and 16h. A rather strong earth's shock was felt at about 20h, and smaller ones at

12) Who named the new mound after the era Hôei (in which the eruption occurred) and when it was so named is quite unknown.

18h, 23h and 24h. Volcanic ashes rained off and on while it was blowing from the west, and they continued to fall during the evening hours after sunset when the wind had died down.

Dec. 18. At Subashiri and Ômika the weather continued to be gloomy with ash-fall, although the latter had abated somewhat and most of the ash grains had become smaller than the size of a pea. In the villages a number of animals, domestic and wild, were struck to death by the ash-fall, and the people without a drop of water to drink faced starvation; the wells in the neighbourhood had all dried up, and the rivers had become muddy with the ashes. Leaving their household effects, these people sought safety in the southwestern villages.

This day, in Tokyo, it was almost windless, the northern sky was clear, while there were black clouds in the southern sky. Rumblings like thunder kept occurring frequently in the south, as well as shocks which caused the houses to repeat rattling noises. At 14h it became so gloomy with the overhanging clouds that one could hardly recognize his neighbouring houses. At 16h black sand began to fall, and during the evening hours they continued falling heavily.

Dec. 19. This day, at Ômika, the sun shone a little, and the new mound (Hôei-san) could be viewed at intervals through a rift in the thin clouds of smoke emitted by the eruption which was still going on. The ashes that fell in the village on this day were for the most part of the size of fine dusts, although sandy pieces of pea size came down at times.

In Tokyo, though rumblings like thunder were heard, they were much slighter and of less frequent occurrence than those on the preceding day. Early in the morning black clouds hang in the southern sky, about 9h and afterward they were blown by the south wind and spread over Tokyo and vicinity, and black sand continued falling till late in the evening, making a noise like heavy showers. After falling on the ground the sand drifted here and there accumulating to a depth of 5 to 10 mm.

Dec. 20. This day, at Yoshida, the weather was fine, but black clouds of smoke were seen rising from the mountain. At Subashiri, ashes, sand and stone were found to have accumulated to a depth of 3-4 m within the last five days.

In Tokyo, volcanic sand stopped falling at 1h, and rumblings like distant thunder were heard only at long intervals all through the night but they died down towards morning. In the morning it was overcast with white clouds, but about noon black clouds were seen again rising to the southern sky and spreading to the north, and at the same time there came a fall of black sand, together with rumbling noises and shocks. The sand fell at intervals in the afternoon, rather heavily in the evening hours, but stopped falling at 23h. At midnight there were occasional shocks and noises like thunder.

Intermittent eruptions, Dec. 21–31, 1707. Subsequent to the daily eruption which continued for five days till Dec. 20, eruptions continued to occur intermittently and at intervals of a few days through the latter part of the month of December, although the intensity of the eruptions gradually diminished toward the end of the month[13].

Dec. 21. In Tokyo, rather strong shocks were felt at about 9h, black clouds were seen in the southern sky for the most part of the day, and noises like distant thunder were heard in the south several times at midnight. Viewed from Yoshida, both rumblings and flashes had greatly calmed down.

Dec. 22. At Yoshida nothing new was seen in the direction of the volcano. But in Tokyo, black clouds which were seen in the southern sky in the morning came to spread overhead in the afternoon, and volcanic sand began to fall at 23h.

Dec. 23. About 3h at Tokyo, shocks were felt at times, and noises like distant thunder were of frequent occurrence with flashes like lightning in the southern sky. The volcanic sand continued to fall through the night, but stopped falling at 4h in the morning. An hour later, when it was raining, both shocks and noises like thunder had stopped. The rain continued for hours in the morning, and after it stopped falling at noon, the sky cleared, but black clouds spread overhead in the evening and volcanic sand continued to fall for an hour from 22h to 23h. At Yoshida, about 20h, an earth-shock was felt, and at the same time Fuji was seen emitting a tremendous column of smoke in company with fire-balls.

Dec. 24. In Tokyo, the sky was overcast with black clouds and volcanic sand continued falling for four hours from 2h to 6h. The sand stopped falling afterwards, while in the sky were black clouds all day, hanging like a thick fog over Tokyo toward the evening.

Dec. 25. This day, in the daytime, the sky had cleared up in all

13) How and when eruptions occurred on and after Dec. 21 must be inferred from the course of events observed in Tokyo at that time, because in the writings found, only brief mention has been made about the eruptions as observed from a shorter distance.

directions, for the first time since the beginning of the present eruption, but after 16h, in Tokyo, a line of black clouds was seen running from the southwestern sky to the east, and volcanic sand continued to fall for six hours from 22h to 4h the next morning.

Dec. 26. After the volcanic sand stopped falling at 4h, in Tokyo, there was no fall of volcanic material throughout the rest of the day, while the sky was overcast with white clouds and in the southwestern sky was a black cloud of volcanic smoke rising all day. At Yoshiwara, by this day, it had become calm without any audible volcanic noise.

Dec. 27. At Yoshida, this day from 10h to midnight, earth-shocks were felt at times, and fire-balls were seen shooting up violently from the volcano. In Tokyo, there was a dense vapor in the early morning as during the preceding few days, a roaring sound like that caused by running water was heard from 10h to 19h, earth-shocks were felt for some time about 12h, and volcanic sand came down at 13h and at midnight.

Dec. 28. At Yoshida, from morning to evening (17h), rumblings were heard, and at the same time, Fuji was seen to emit a clouds of smoke. In Tokyo, earth-shocks were felt at about 4h, and black clouds were seen in the southern sky throughout the day.

Dec. 29, 30. Throughout these days, the weather was fine at Yoshida, while in Tokyo it was cloudy for the most of the time, the southern sky being dark with black clouds. There was no falling of volcanic ashes and stone in the least.

Dec. 31. This day, at midnight, heavy rumblings were heard at Yoshida, and Fuji was seen to emit both flames and fire-balls to the southern sky. According to a report from the province of Suruga on the south side of the mountain, a number of shocks were felt there at about 21h. In Tokyo black clouds were seen rising in the southern sky throughout the day, but there was no falling of volcanic ashes or sand.

The end of the present eruption was practically complete on the last day of the year; volcanic ashes stopped falling and rumblings like thunder became inaudible even at Ômika on the east foot of Mt. Fuji and the weather returned to its normal condition. Thus early in the morning of Jan. 1, 1708, the mountain as viewed from Yoshida was covered with fresh snow from its top to half way down. The same day, in Tokyo, the black clouds which continued to rise to the southern sky during the eruption became invisible, the sky was overcast with the snow clouds, and about 20 cm of snow fell in twelve hours ending at 10h the next day.

Judging from the events that have been followed thus far in their chronological sequence, the present eruption may be regarded as an activity of purely explosive type, occurring in two successive stages: (1) the activity of the first stage from Dec. 16 to Dec. 20, during which the eruption attained its culmination with continual explosions accompanied with ejections of incandescent material, and (2) the activity of the second stage from Dec. 21 to Dec. 31, representing a declining phase of the eruption, with intermittent explosions becoming less intense and of shorter duration towards the close of the activity.

Since this eruption which was the last of its activities in historic times, the volcano Fuji has kept dormant for 250 years. An eruption of the volcano on Feb. 24, 1708, is mentioned by Omori in his "History of Volcanic Eruptions in Japan", and another one on Jan. 16, 1709, together with that, are mentioned in the "Historical Data on the Earthquakes in Japan"[14]. But there remains the question whether the volcano really had these eruptions or not, because there is no reliable document describing the events. Even if these eruptions really occurred to the volcano, they might have been an aftermath of the big eruption of 1707.

Within ten years after the cessation of the present eruption of Fuji, some certain eruptions occurred to the volcanoes Miyaké-shima (1712–14), Asama-yama (1708–11), Iwaki-san (1709), Aso-zan (1708–09) and Kirishima-yama (1716–17). But these eruptions were of usual occurrence and do not suggest that volcanic activity in Japan had exceptionally increased at the time. Of the afore-mentioned volcanoes, Miyaké-shima is an active insular volcano in the Seven Islands of Izu and, together with Ôshima in the same island group, are members of the Fuji Volcanic Zone. Although the eruption of Miyaké-shima in 1712–14 was of the bigger ones of its twelve eruptions[15] in historic times since 1085 A.D.[16], there is no reliable basis for inferring that the Miyaké-shima eruption occurred in response to the foregoing Fuji eruption, much less is it likely that the latter occurred in response to

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14) *Loc. cit.*

15) H. TSUYA, "Geological Observation of the Miyaké-shima Eruption of 1940. (I)," *Bull. Earthq. Res. Inst.*, **19** (1941), 163.

16) In addition an eruption of Miyaké-shima on April 23, 1709, is mentioned in the "Historical Data on the Earthquakes in Japan".

the eruption of Ôshima in 1684–1690. Seeing that either Ôshima and Miyaké-shima had several eruptions during the last 250 years, the latest being the eruptions of 1950–54 and 1940 respectively, these volcanoes seem to have no correlation in activity with Fuji, which has kept dormant since 1707.

Damage caused by the 1707 eruption

Little is known definitely of the damage caused by the 1707 eruption of Fuji, because they are not given in detail in any of the writings ever found. But from a few fragmentary and unconnected references to the damage in the writings describing the eruption, together with the distribution and volume of the ejecta as stated below, it is conceivable that considerable damage must have been done in the provinces adjacent to the east of the volcano[17]. Thus the eastern foot of the volcano, together with the country adjoining the east, had been devastated, everything within 20 km of the scene of the eruption being buried in a pile of volcanic ashes and sand more than 1 m deep[18]. The villages of Subashiri and Ômika were totally destroyed; of 75 houses in Subashiri, 37 were burnt and the rest collapsed. Most of the rivers and wells in and around the town of Gotemba, which took their rise on the eastern foot of the volcano, were temporarily dried up. The river Sakawa also ran dry temporarily on its lower course near the town of Odawara where it flowed into Sagami Bay, as a result of the stoppage of its middle and upper courses owing to the ejecta accumulated deep in the area through which the river was running.

During the eruption, in Tokyo, the falling of volcanic ashes and sand was occasionally so heavy that the towns people were kept indoors, and not a few of them had sore throats. But it is not known for certain whether any epidemic or infectious desease spread on that occasion in the district stricken by the eruption or not.

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17) As the damage done to houses, cultivated land, roads and bridges in the stricken district was enormous, repairs were carried out with a very large sum of money raised by the then government (the Tokugawa Shogunate) from all the feudal lords in Japan.

18) The report that the towns of Yoshiwara, Hara and Numazu had been buried and Mishima burnt by the eruption, as told in one of the writings dealing with this, is incorrect and may be a miscopy from a report of the disasters caused by the big earthquake of Oct. 28, 1707.

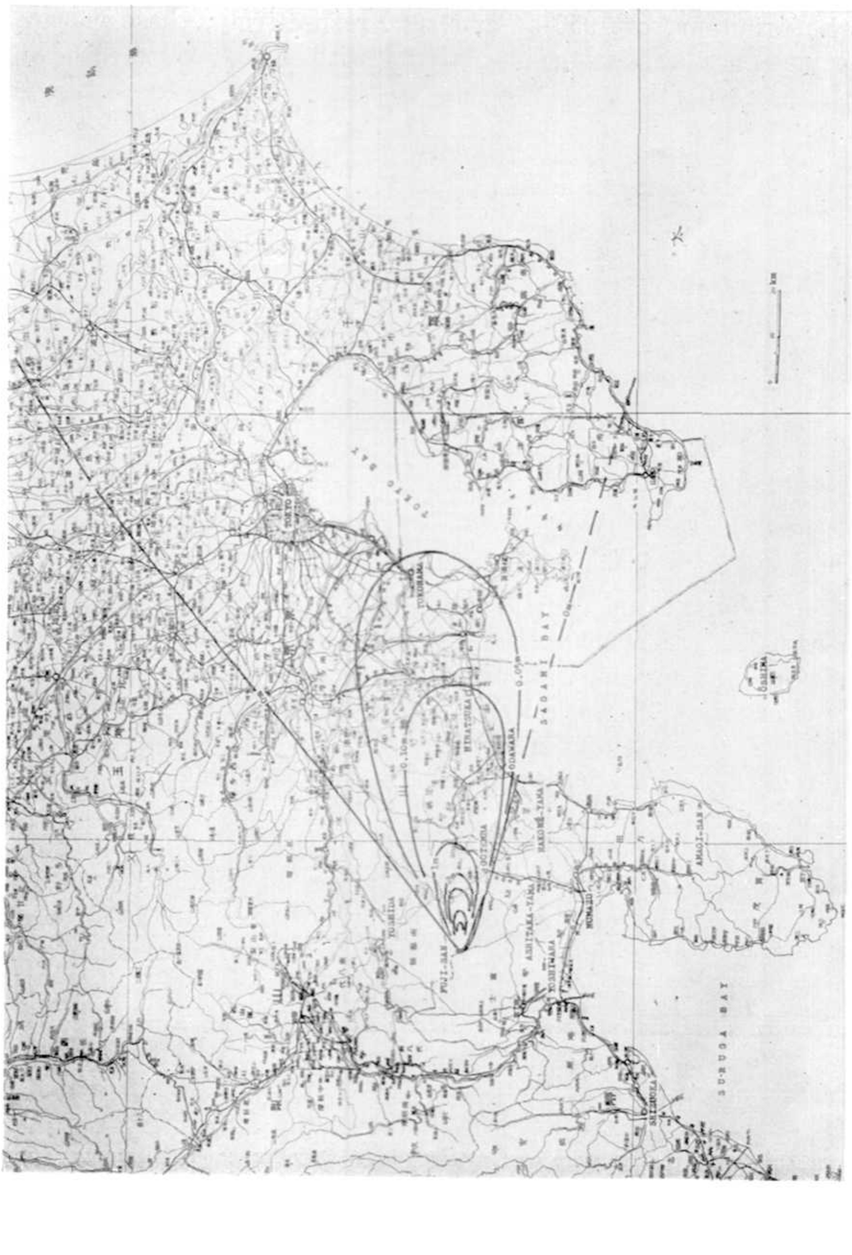

Fig. 2. Map of the southern Kantô, showing the distribution of the ejecta in the 1707 eruption.

The 1707 craters

That the present eruption took place in the vicinity of Hôei-san halfway down the southeast slope of the volcano is evident from the above-mentioned course of the eruption, and it can be proved by tracing the distribution of the material ejected at the time. Thus as mentioned below, the ashes and sand which, distributed on the eastern foot of the volcano and in the adjacent country, are regarded unmistakably as the material in question, cover a fan-shaped area becoming narrow westwards towards the vicinity of Hôei-san. Moreover, when an attempt is made in the field to follow the ejecta to their source, it is easily accomplished by finding out the actual connection of the ejecta with craters lying close to the side of Hôei-san.

There are three craters, namely the first, second and third craters, which have survived from the eruption of 1707. Although these craters must have been greatly deformed through the unceasing erosion after the eruption, their crateriform features are quite evident even now, as shown in the topographic map (Fig. 3). They are situated on the mountain slope with an inclination of about 25°, between the heights of 3100 m and 2100 m above the sea, and form a crater chain running straight as a line in the direction of the summit of the volcano (Fig. 6). Thus the second crater, lying at the middle of the chain, is linked with the first and third craters on its upper (northwest) and lower (southeast) sides respectively. The first crater, which is by far the largest of the three, is popularly known as the one which was opened by the eruption of 1707; hence the name "Hôei Crater" (Fig. 6). It is really the main crater which must have played leading roles in 1707 in repeating heavy explosions with the ejection of a large quantity of basaltic materials. The other two craters, though small in dimension and liable to escape notice of casual observers, are worth noticing too, particularly in that

Table I. Dimensions of the 1707 craters.

Crater	Major axis (m)	Minor axis (m)	Depth* (m)	Height of the floor** (m)	Volume (m^3)
The first	1400	750	650	2400	77,742,000
The second	550	400	235	2265	12,141,000
The third	500	400	195	2155	5,273,000

* From the highest point of the crater rim.
** Above the sea.

they are the source of the pumice and obsidian which, prior to the *ejection of basaltic materials from the first crater, had been ejected* for a few hours at the beginning of the eruption of 1707 (Fig. 8). The dimensions of the three craters as measured in the topographic map (1 : 25,000) are shown in Table I.

The *first crater*, which is recognizable at a glance as the largest of the scars that break the regularity of the conical outline of the volcano,

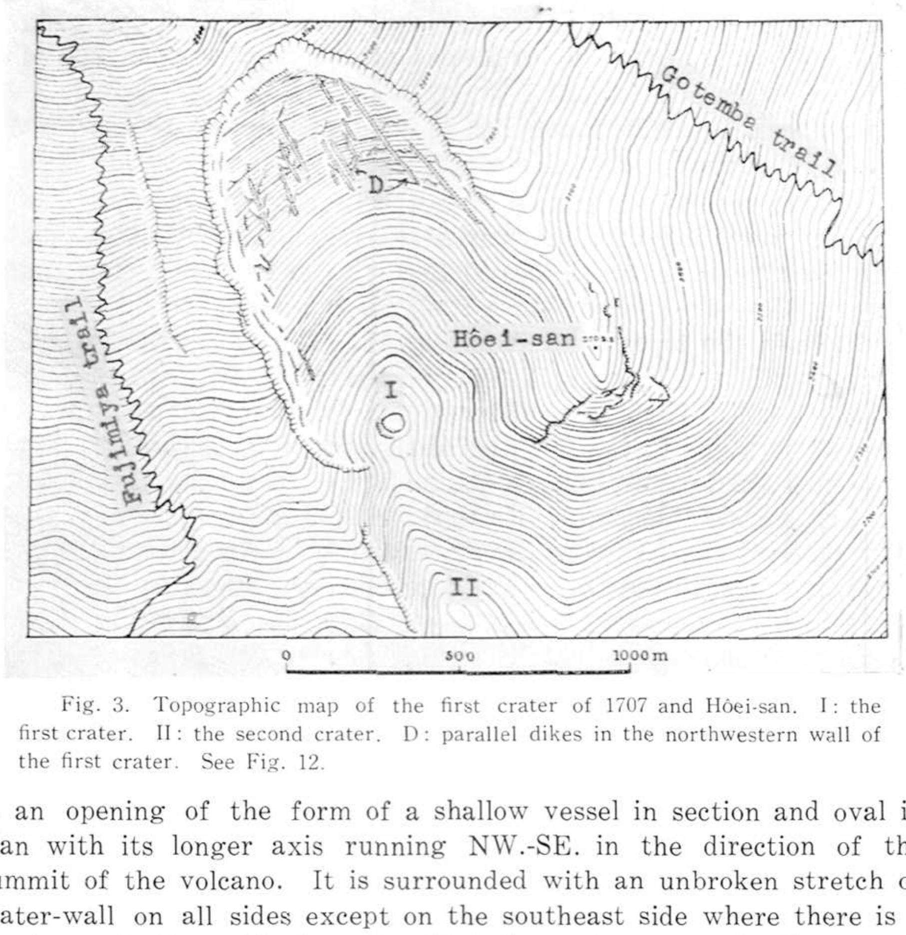

Fig. 3. Topographic map of the first crater of 1707 and Hôei-san. I : the first crater. II : the second crater. D : parallel dikes in the northwestern wall of the first crater. See Fig. 12.

is an opening of the form of a shallow vessel in section and oval in plan with its longer axis running NW.-SE. in the direction of the summit of the volcano. It is surrounded with an unbroken stretch of crater-wall on all sides except on the southeast side where there is a great gap in the wall, through which the crater opens to the second crater (Fig. 9). The crater-wall is highest on the northwest side, lowering gradually towards the southeast and southwest sides, in accordance with the slope outside the crater. In the upper half of the wall are exposed alternating layers of basaltic lava flows and fragmentary ejecta, besides a number of lava dikes (Fig. 12). These dikes run nearly parallel to each other and in the same direction with the longer axis of the crater, showing that the volcano is cut with a number of nearly vertical fissures radiating from its central conduit and through which the dikes have intruded into its flank. So far as have been observed, the dikes are exclusively of basaltic composition, though there are some petrographic varieties among them, and each stands like a partition-wall, a few meters or less in thickness, protruding from the general slope of the crater wall. Some of the dikes each merge upward into their contemporaneous lava sheets, showing that the former are the feeders through which the latter erupted to the surface. Thus, for example, the youngest of the dikes, which is exposed at the northwest wall of the crater, merges at its upper end into the uppermost lava sheet which forms a bluff several meters high at the northwest brim of the crater. However, all the dikes and flows exposed in and around the crater are older than the products of the 1707 eruption, and they have no direct relation with the latter.

The eastern half of the southeast side of the first crater is walled with the back slope of the knob of Hôei-san, the top of which is 2700 m above the sea but only 300 m above the floor of the crater. This part of the crater wall is covered thickly with the ejecta of 1707, neither lava dikes nor sheets nor anything else being exposed in the part. As to Hôei-san, particular mention will be made presently.

The lower half of the wall of the first crater is covered everywhere with a gently sloping talus of the detritus that fell from the cliffs above. Originally, the crater floor must have been wider and deeper than it is now, seeing that the talus extends from the surrounding wall down to near the centre of the floor. Thus the floor is nearly flat only within a radius of a few scores of meters in its lowest part lying about 650 m below the upper edge of the crater wall on the northwest side and 2400 m above the sea[19]. This part of the floor is surrounded on its south side with a crescentic heap of basaltic ejecta (scoriaceous lapilli, bombs, and lava blocks), remnant of a cinder cone formed within the crater during the later stage of the 1707 eruption (Fig. 13). The northern side of the heap is a cliff about 10 m higher than the adjoining crater floor and suggestive of the demolished wall of a small

19) The diary written by Ito already referred to, mentions that some people went to see the crater immediately after the 1707 eruption and that they failed in their attempt to measure the whole depth of the still rumbling crater with a rope about 550 m long.

crater on the cinder cone, while the back of the same heap descends with an almost imperceptible slope to the flat ground[20] on the boundary between the first and second craters.

The *second crater* is rather oblong in plan with its longer axis running northwest and southeast and in the direction of the summit of the volcano, and shows a V-shaped outline in transversal section. On the west the crater is bordered with a steep wall running nearly straight from northwest to southeast for a distance of about 700 m, while on the east it is hemmed in with the southwestern slope of the knob of Hôei-san (Fig. 10). The western wall exposes in its upper half a number of basaltic lava sheets, which are concordant with each other and parallel to the upper rim of the wall. These lava sheets, like those exposed in the walls of the first crater, are not of the 1707 eruption, but belong to older eruptions either at the summit or on the flank of the volcano. The eastern wall is covered everywhere with the ejecta (basaltic lapilli and bombs) of 1707, besides being studded with blocks of basaltic tuffs that have tumbled down from a high bluff near the top of Hôei-san; lava sheets like those of the opposite wall are exposed nowhere in the wall.

Although the second crater opens out of the first crater, there is a difference of about 135 m in level between their floors. Thus the second crater is walled on its northwest side with a gentle slope ascending from its bottom to the floor of the first crater (Fig. 9). This slope is covered with the ejecta of 1707 and other detritus.

On the southeast side of the crater there is a wall separating it from the third crater. The lowest part of the wall is probably not more than 30 m in height above the bottom of the second crater, and forms a saddle between the adjoining higher walls. This part of the crater wall also is covered with the ejecta of 1707 and other detritus.

The *third crater* ranks in size with the second crater, although its longer axis from northwest to southeast is a little shorter than that of the latter. It is surrounded with a wall on all sides except the southeast side where it opens into the head of a large valley (Fig. 11). As the bottom of the crater lies about 110 m below that of the second crater, it naturally follows that the northwest side of the former rises

20) The flat ground, together with the deep part of the crater floor, are studded with a number of huge lava blocks that fell from the surrounding walls, besides the ejecta of 1707, and are popularly known as "Botanbatake" (peony-garden). Large bombs lie broken on the ground, showing a feature suggestive of the flowers of peony, hence the name, according to a common view.

as a high but gently sloping wall up to the crest of the southeast wall of the latter. The west and east walls of the crater become higher as they approach the corresponding walls of the second crater; the west wall exposes in its upper part a number of lava sheets probably continuing from those on the west side of the second crater[21]; while the opposite wall is covered with the ejecta of 1707, besides being studded with various detritus.

The second and third craters are evidently of the 1707 eruption, to say nothing of the first crater, seeing that the ejecta thrown out by the eruption are distributed in a fan-shaped area widening out eastwards from these craters, as will be mentioned presently. Besides, there is a horseshoe-shaped, crater-like hollow on the slope adjacent to the east of the third crater. It can hardly be supposed, however, that the hollow is the fourth crater of the 1707 eruption; it may be the ruin of an older crater instead.

Each of the above-mentioned three craters is nothing but an opening bored in the flank of the volcano by the 1707 eruption. Although these craters may be regarded morphologically as explosion craters, they are not merely of phreatic origin, but are magmatic in the sense that their explosions have been accompanied by ejections of juvenile incandescent materials. The volumes of the crater bowls are as shown in the last column of Table I, being calculated on the assumption that before the eruption the site of the craters was a smooth slope representing that part of the conical surface of the volcano. Although the crater bowls must have been shallowed to some extent with detritus accumulated by weathering, their present volumes all told may represent the minimum amount of the old materials which occupied the bowls before being blown away by the eruption.

Distribution and volume of the solid ejecta of 1707

The solid ejecta thrown out by the 1707 eruption are exclusively of fragmentary materials, consisting of volcanic ash, sand, lapilli, bombs and lava blocks. They as a whole are distributed in a fan-shaped area widening out eastward from the crater region, their deposit decreasing in thickness as well as in grain size with the increase of distance from their source. Thus they are actually traceable as a mantle deposit

21) The west and south sides of the crater are grown with alpine flora, representing the upper limit of the vegetation zone on the southeast flank of the volcano.

more than 1 m thick within about 25 km east of the point of outbreak on the volcano, and beyond this distance their thinner deposit is identified only locally as it was. The northern limit of the ejecta-covered area is represented by a nearly straight line running from the northeast margin of the first crater northeastwards in the direction of the village of Hirano on the east shore of Lake Yamanaka, while the southern limit is represented by two different lines according to the kind of the ejecta distributed thereabout. One of these lines represents the southern limit of the area covered with basaltic ejecta, running from the southern margin of the first crater southeastwards in the direction of the south of Gotemba, a town in the intervale between Fuji and Hakone, and the other represents the southern limit of the area covered exclusively with acidic ejecta (pumice and obsidian), running from the southern margin of the third crater southeastwards in the direction of the same town. Beyond this town, however, no definite demarcation can be made out in the areal distribution of the two different kinds of ejecta. There is also no remarkable discrepancy between the northern limits of distribution of the two. Thus in the area covered with the basaltic ejecta, even very close to its northern limit, their deposit is seen accumulated always on a whitish bed of the acidic ejecta, the former being over ten times as thick as the latter. Their stratigraphic relation, together with the thickness of their deposits, may be seen almost everywhere where a thick bed of the basaltic ejecta is exposed in a vertical section either natural or of artificial cuttings (Fig. 18).

The thickness of deposition of the ejecta was measured by the writer at a number of places both near the craters and on the eastern foot of the volcano, with the results shown in Table II in which it is compared with that measured by some people just after the eruption. So far as data are available, the writer's measurements are approximately comparable with the old ones, which proves that the latter are reliable, although they all include both the basaltic ejecta and the underlying acidic ejecta, in the thickness of the deposit. As to the ejecta that fell in the area far distant from the volcano, the thickness of their deposit at several places is shown in the table, as deduced from some old writings of the eruption. But in the area where the ejecta might have lay less than 1 m deep, the thickness of their deposit can hardly be confirmed by actual measurement, because they are not found as such at present. Thus the volcanic ash and sand which must have fallen fairly deep at the time of the eruption in

Fig. 4. Map of a portion of Volcano Fuji and the country adjoining the eastern foot of the volcano, showing the distribution of the ejecta in the 1707 eruption. Cf. Table I.

Table II. Thickness of the deposit of the 1707 ejecta.

Locality*		Thickness** (cm)	Diameter of one of large-sized ejecta (cm)
(1)	Hôei-san	**1000**	**100**
(2)	West side of the second and third craters	100	30
(3)	Shishiga-hana	**800** / 10	10
(4)		**500** / x	30
(5)		**700** / x	
(6)		***y*** / 100	
(7)		**200** / x	
(8)		**400** / x	
(9)	Dainichidô	***y*** / x	5>
(10)	Subashiri	**250** / 6 (400)	
(11)		**300** / 10	
(12)		**300** / x	
(13)		**0** / 2	
(14)		**200** / 5 (210)	
(15)		**100** / 5	
(16)	Ômika	**200** / x (150)	
(17)	Kagosaka	**200** / x	**10>**
(18)	South shore of L. Yamanaka	**50** / x?	
(19)		**150** / x	
(20)		**100** / 3 (100)	3
(21)		(136)	
(22)		(130)	
(23)		(136)	
(24)		**100** / x (106)	

(to be continued.)

Table II. (continued.)

Locality	Thickness (cm)	Diameter of one of large-sized ejecta (cm)
(25)	**150** / 10	0.5
(26) Suruga-Koyama	**100** / x (110)	
(27)	**100** / 5 (110)	**2**>
(28)	**70** / x	
(29)	(40)	
(30) Ôiso	(6–12)	(coarse sand)
(31) Fujisawa	(9–12)	(coarse sand)
(32) Kawasaki	(5)	(fine sand)
(33) Tokyo	(3?)	(fine sand and ash)

* See Fig. 2.

** Thickness of the deposit of the basaltic ejecta is shown by Gothic letters, that of the acidic ejecta by Roman; the deposit whose thickness was not measured is shown by x for the acidic ejecta and by y for the basaltic ejecta; the figures in brackets in the column of thickness give the thickness of the deposit of the ejecta, as deduced from old writings of the eruption.

southern Kantô including Tokyo and the neighbouring prefectures Kanagawa, Chiba, Saitama and Ibaragi, have been washed away, or otherwise have been decomposed into soil in the course of two and a half centuries after the eruption.

The thickness data are plotted in Figs. 2, 4, together with several contour lines, each of which passes through the places where the deposit of the ejecta has a certain equal thickness. Thus seven contour lines are shown representing their respective grades of the thickness of the deposit, namely, 5 cm, 10 cm, 100 cm, 200 cm, 300 cm, 400 cm, and 500 cm. Of these, the 5 cm and 10 cm lines may be rather uncertain for lack of reliable data, while the rest are considered to be nearly accurate, being based on a number of reliable data checked by actual measurements in the field. Table III shows the areas enclosed with the two successive contour lines and the volumes of the ejecta distributed in the respective areas.

The calculated total volume of the ejecta comes approximately to 847×10^6 m^3, which is nearly comparable with that of the 1914 eruption of Sakura-jima (918×10^6 m^3)[22], but is far larger than that of the

22) B. KOTO, "The Great Eruption of Sakura-jima in 1914," *Jour. Coll. Sci., Tokyo Imp. Univ., Japan.*, **38** (1916), Art. 3, 103.

1950–51 eruption of Ôshima (26×10^6 m^3)[23].

Table III. Areas covered with the ejecta and volumes of the ejecta.

Division	Mean thickness (m)	Area (m^2) $\times 10^3$	Volume (m^3) $\times 10^3$
I	7	11,830	82,810
II	4.5	8,738	39,321
III	3.5	42,668	149,338
IV	2.5	28,505	71,262
V	1.5	76,450	114,675
VI	0.3	601,250	180,375
VII	0.07	1,129,250	79,047
VIII*	0.03	4,345,060	130,352
Total			
I–V		168,191	457,406
VI–VIII		6,075,560	389,774
I–VIII		6,243,751	847,180

* Division VIII represents the area outside the 0.05 m line, limited on the east by the meridian of Tokyo.

In the volume calculation, no distinction has been made between the basaltic ejecta and the underlying acidic ejecta. But the acidic ejecta are expected to occupy only a small part of the above-mentioned total volume, since the thickness of their deposit is far smaller than that of the basaltic ejecta throughout the area covered with them. Thus the deposit of the acidic ejecta, which reaches to about 1 m in thickness at the western margin of the second and third craters, thins out rapidly southeastwards, becoming less than 20 cm thick within a distance of about 5 km and near the southern boundary of its distribution. In the area covered with the basaltic ejecta, so far as the observed exposures are concerned, the underlying acidic ejecta are about 10 cm or less in the thickness of their deposit everywhere but one place (locality No. 6, Table III, Fig. 2) where they lie about 100 cm deep. Assuming that the acidic ejecta lie 10 cm deep all over the area enclosed with the 100 cm line shown in Fig. 4, their volume in all amounts to $7{,}645 \times 10^3$ m^3, occupying only a little more than 6% of the total volume of both the basaltic and acidic ejecta in the same area. Even

23) H. TSUYA, R. MORIMOTO, and J. OSSAKA, "The 1950–51 Eruptions of Mt. Mihara, Oshima Volcano, Seven Izu Islands, Japan. Part III," *Bull. Earthq. Res. Inst.*, **33** (1955), 99.

if the acidic ejecta distributed outside that area are taken into account, the whole amount of the ejecta of this kind is not likely to run much over ten millions in cubic meters. The acidic ejecta of this amount at the most were thrown out from the second and third craters in a few hours at the beginning of the 1707 eruption.

The basaltic ejecta, which occupy more than 90% in volume of the 1707 ejecta, are of the main eruption which, immediately after the preceding short eruption of the acidic ejecta, took place at the first crater with repeated explosions for about two weeks ending on Dec. 31, 1707. The basaltic ejecta are mostly scoriaceous and of the size of lapilli, but as a matter of course there is, in general, a gradual increase in the size of the ejecta with decrease in distance from the crater, and larger lava blocks and bombs are met with, besides the lapilli, particularly in and about the crater. Thus a large number of well-formed volcanic bombs[24], together with something like lava spatters, are distributed within a few hundred meters from the crater bottom, suggesting, as has been noticed on some other volcanoes, that the ejection of the volcanic bombs took place mainly at a later stage of the eruption[25].

Formation of the knob of Hôei-san

The first crater of 1707 is walled on its east side with a knob called Hôei-san, the top of which rises about 300 m above the bottom of the crater and 2702.3 m above the sea (Fig. 14). As already mentioned, some old writings of the 1707 eruption give the knob this name as it was formed by the eruption occurring in the fourth year of Hôei era. However, granting that the knob was a new appendix to the volcano at the time, it is neither a usual parasitic cone nor a simple pile of the ejecta thrown out of any of the three 1707 craters. An inquiry into the morphological and structural features of the knob suggests how it was formed by the eruption.

Morphologically, Hôei-san is a ledge on the steep slope of the main volcano; its summit reach forms a flat ridge about 500 m long from NNW. to SSE. and about 100 m wide; its west side is a steep slope looking on the bottom of the first crater, its back side decends eastwards with a little gentler slope merging downwards into a far gentler

24) H. TSUYA, "On the Form and Structure of Volcanic Bombs, with Special Reference to the Origin of the Basaltic Bombs from Volcano Fuji," *Bull. Earthq. Res. Inst.*, **17** (1939), 809.

25) H. TSUYA, The Eruption of Miyaké-shima in 1940. *Loc. cit.*

part of the eastern flank of the main volcano; the ridge ends on the south abruptly with a bluff up to 100 m high and about 500 m long from NE. to SW., and from the foot of the bluff a rather steep slope extends southwards and southeastwards until it merges into the adjoining gentler slopes of the main volcano (Fig. 15). Supposing that Hôei-san is a knob formed by the 1707 eruption on the proper slope which the main volcano might have had in that place before the eruption, the volume of the knob above the supposed slope amounts to about 68×10^6 m^3, which is a little less than the total volume of the adjoining three craters (95×10^6 m^3, cf. Table I).

Although Hôei-san is covered for the most part with the deposit more than 10 m thick of the 1707 ejecta, a small part of its summit reach is entirely devoid of that deposit, being occupied by confusedly dislocated strata of older ejecta (Figs. 16, 17). Thus, well-bedded volcanic breccia and tuffs, which *en masse* may be termed Hôei-san tuffs, are exposed in the bluffs at the southern end of the summit ridge of Hôei-san and also in patches adjacent to the top and bottom edges of the bluffs, being unconformably surrounded by the deposit of the 1707 ejecta. They are cut by numerous faults and fissures running in various directions, resulting in fault-blocks large and small (Fig. 5); the bluffs in which the tuffs are best exposed, are simply ruins of certain major fault scarps along which the eastern hanging side has slid down. The strata of the tuffs show different dips and strikes in different fault-blocks, their dips being often as large as 90°. Their disposition suggests nothing of a usual volcanic cone whose ejecta are formed in layers showing a quaquaversal dip, or of a deposit of the ejecta thrown out either from the summit crater of the main volcano or one of the 1707 craters.

The Hôei-san tuffs are certainly basaltic in composition, but they are quite different in petrographic features from the basaltic ejecta of 1707. Thus the latter, which are for the most part black scoriaceous lapilli, form a loose deposit without any remarkable stratification, while the former consist of well-bedded tuff-breccia and fine tuffs, both of which have become hard enough to be easily trimmed with a hammer. The tuff-breccia, which stratigraphically lie on the fine tuffs, are composed of angular rock-fragments, mostly smaller than 10 cm in diameter, and interstitial sandy materials. The rock-fragments are various in petrographic characters, and as far as have been examined, they differ very much from the younger lavas that form the upper part of the volcano, that is, a few of them are of the foreign rocks which seem to underlie the volcano. The fine tuffs are pale brown or gray in color, bearing a resemblance to the Pleistocene volcanic tuffs which, distributed extensively in the Kantô region, are collectively called the Kantô loam. They consist exclusively of angular pieces less than 5 mm in diameter of basaltic lavas containing microphenocrysts of lath-shaped plagioclase and irregularly shaped olivine, besides a few grains of augite, in a groundmass composed either almost wholly of brown glass or of aggregate of minute mineral grains (plagioclase, pyroxene, and magnetite) and interstitial glass; while the material with which the tuffs are cemented hard is a colorless, scaly mineral, isotropic with the refractive index lower than Canada balsam and probably of a kind of clay minerals (Fig. 30). Besides, only a few basaltic bombs are found imbedded in the tuffs, together with fragments of some foreign rocks.

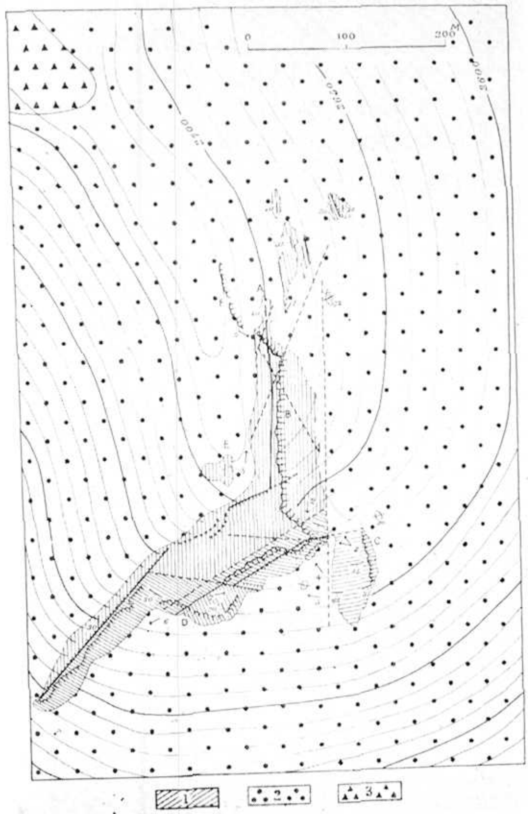

Fig. 5. Geologic sketch-map of the top of Hôei-san. 1. Hôei-san tuffs. 2. 1707 ejecta (basaltic bombs and lapilli). 3. Detritus.

The Hôei-san tuffs have their equivalents nowhere in the inner walls of the 1707 craters nor on the upper slopes of the volcano; on the contrary, they resemble in many respects the tuffs and tuff-breccia which, distributed on the eastern and southwestern skirts of the volcano, are regarded as products of the old Fuji volcano[26]. It is inferred

26) According to the writer's geological study, Volcano Fuji is a composite volcano consisting of three parts, andesitic Komitake, basaltic Ko-Fuji (old Fuji), and basaltic Fuji proper, which began their activities in lower Pleistocene, upper Pleistocene, and in the uppermost Pleistocene or the lowest Recent, respectively. The products of the old Fuji are older than the oldest visible lava flows from the Fuji volcano proper, the former being unconformably covered with the latter (H. Tsuya, *Bull. Earthq. Res. Inst.*, **16** (1938), 452; **18** (1940), 419).

consequently that the Hôei-san tuffs may have their origin in the activity of this volcano. If this inference may be provisionally accepted, it follows that the tuffs must be geologically older than any of the oldest lava flows erupted from the Recent Fuji volcano proper. Although no outcrops have been found where the tuffs are seen either covered with or cut by one of the lavas from the Recent Fuji, a number of lava flows are distributed about Hôei-san in such a way that the former might run dodging an obstacle (a mass of the tuffs) at the site where the latter stands now. Supposing that this obstacle existed already before the 1707 eruption, it might not have been so prominent as the present knob of Hôei-san. Then it is inferred that the 1707 eruption might have caused a upthrust of the Hôei-san tuffs which had already existed as the said obstacle, bringing the latter to its present position. As a possible cause of the upthrust, we may mention an intrusion of acidic magma which must have introduced the ejection of pumice and obsidian at the beginning of the present eruption. Thus it may be that the Hôei-san tuffs, which had stood as a "kipuka"[27] for a great many years, were upheaved to their present position and were broken into fault-blocks by the underground intrusion of acidic magma at the time of the eruption[28].

Mineral and chemical compositions of the ejecta of 1707

Ejecta from the first crater. There are three kinds of the ejecta thrown out of the first crater, viz., juvenile, accessory, and accidental ones. Of these, the juvenile ejecta occupy by far the greater part of the total mass of the three. The accessory ejecta, which must exceed the first crater in volume, do not occur by themselves, but are found embedded scatteringly in the deposit of the juvenile ejecta, together with the accidental ejecta.

The juvenile ejecta, which occur as volcanic sand, lapilli, bombs and blocks, are all basalt of one and the same composition. Thus the rock has been identified as an augite-bearing olivine basalt containing microphenocrysts of plagioclase (anorthite and bytownite), olivine and augite, in a groundmass composed of plagioclase laths and dark-brown

27) "Kipuka" is an Hawaiian term meaning an "island" of older rock in a sea of younger lava flows.

28) Shallow-seated intrusion of a stiff, acidic magma might cause a dome-shaped swelling of the ground above it, as has been actually observed on Showa-Shinzan, a new volcano born in 1944 at the north-eastern foot of Volcano Usu in Hokkaido.

glass packed with dust materials (Fig. 24)[29]. It does not differ much in chemical composition from basalt lavas of the volcano, as shown in Table IV.

Table IV. Chemical analyses of basalts from Fuji*.

	1	2	3	4	5	6
SiO_2	51.09	51.30	50.80	50.25	50.12	50.80
Al_2O_3	17.62	18.74	17.59	16.96	16.26	16.92
Fe_2O_3	2.64	1.83	3.48	2.81	3.05	2.92
FeO	8.42	8.34	7.26	9.64	10.10	8.36
MgO	5.09	4.80	5.34	5.34	4.67	5.12
CaO	9.68	9.76	9.75	9.25	8.60	9.78
Na_2O	2.80	2.55	2.67	2.46	2.78	2.65
K_2O	0.76	0.71	0.67	0.76	0.96	0.76
H_2O+	0.28	0.22	0.40	0.36	0.44	0.21
−	0.06	0.06	0.12	0.07	0.20	0.16
TiO_2	1.38	1.43	1.26	1.59	1.91	1.37
P_2O_5	0.26	0.29	0.18	0.21	0.29	0.29
MnO	0.21	0.28	0.24	0.22	0.23	0.24
Total	100.29	100.31	99.76	99.92	99.61	99.58

* By S. Tanaka, the late analyst of the Earthquake Research Institute. For further analyses of Fuji rocks, see the papers in the footnote (29).

1. Augite-bearing olivine basalt. Scoriaceous lava-block, one of the ejecta of 1707.
2. Two-pyroxene-olivine basalt. Aokiga-hara lava of 864 eruption on the northwestern foot of the volcano.
3. Olivine basalt. Lava from Ômuro-yama, the largest parasitic cone, situated on the northwestern foot of the volcano.
4. Aphyric basalt carrying a few microphenocrysts of bytownite. Lava on the south-west side near the top of the volcano.
5. Aphyric basalt consisting of bytownite, olivine, monoclinic pyroxene, iron ores, and a little interstitial glass. One of the oldest lava flows from the volcano, in the valley of Kise-gawa, about 6 km south of the town of Gotemba.
6. Olivine basalt. One of the bombs embedded in the Hôei-san tuffs.

The accessory ejecta, representing rock-fragments torn off and ejected from the crater bottom and surrounding walls at the time of the eruption, are mostly olivine basalt with or without augite and/or hypersthene. Besides, numbers of blocks up to about 20 cm across of coarse-grained, crystalline rocks are found among the ejecta, especially

29) H. TSUYA, "On some lavas of Volcano Huzi (Fuji), *Bull. Earthq. Res. Inst.*, **13** (1935), 645; On the Volcanism of the Huzi Volcanic Zone," ibid., **15** (1936), 216.

around the top of Hôei-san[30]. They occur not only as isolated blocks embedded in the deposit of the ejecta but occasionally as cores of the juvenile basaltic bombs. Of the specimens examined under the microscope, the following types of crystalline ejecta are distinguishable according to their mineral composition, the constituent minerals of each type being mentioned in order of increasing amount.

1. Magnetite-plagioclase-hypersthene-augite-olivine-rock.
2. Magnetite-augite-olivine-plagioclase-rock (Fig. 27).
3. Magnetite-hypersthene-augite-olivine-plagioclase-rock (Fig. 26).
4. Magnetite-olivine-hypersthene-augite-plagioclase-rock (Fig. 28).
5. Hornblende-magnetite-olivine-augite-hypersthene-plagioclase-rock (Figs. 25, 29).
6. Magnetite-augite-bearing plagioclase-rock.

Of these, the rock type (3) is more frequently met with than the rest, including some varieties which differ from each other in granularity and other textural characters. A little brown glass is present in every one of the rocks either in the form of small drops occluded in the constituent minerals or as interstitial filling of the mineral grains. Hypidiomorphic granular texture is common in all the rock types but the type (3) in which there is a variety showing an ophitic texture (Fig. 32).

As shown in the above-mentioned list, plagioclase predominates over the rest of the constituent minerals in all the rock types but (1), and in the type (6) it forms more than 95% of the rock. The plagioclase, usually devoid of any remarkable zoning, has a composition of bytownite, as the plagioclase phenocrysts in many of the lavas of the volcano have. The bulk analysis of plagioclase pieces collected from a crystalline block belonging to the type (3) is shown in column 1, Table V, in which it is compared with the analyses of anorthite from Volcano Miyaké-shima, Izu[31].

The analyses (1) and (2) contain several oxides which may be regarded as impurities derived mostly from minute, inseparable inclusions of mafic minerals in the analyzed plagioclase crystals. Because of the notable amount of the impurities, particularly iron oxides and magnesia, the actual molecular composition of the analyzed plagioclase

30) T. HIRABAYASHI has mentioned some of these crystalline ejecta under the name of "phanerocrystalline bombs". "Geology of Volcanoes Fuji and Ashitaka", *Report Earthq. Invest. Com.*, **24** (1899), 1-74 (in Japanese).

31) Anorthite, together with olivine, are found as crystal bombs among the ejecta of the eruption in 1940 and 1874, besides occurring as phenocrysts in some lava flows.

cannot be computed with accuracy from either of the analyses. However, the analysis (1) gives a bytownite approximately of the composition $Ab_{15}An_{85}$, and the analysis (2) an anorthite of the composition Ab_3An_{97} which is comparable with the anorthite Ab_5An_{95} analyzed by H. S. Washington[32].

Table V. Chemical analyses of plagioclase crystals from Fuji and Miyaké-shima.

	1	2	3
SiO_2	45.65	42.98	44.49
Al_2O_3	33.46	35.31	36.00
CaO	17.29	19.46	19.49
Na_2O	1.88	0.35	0.59
K_2O	0.31	0.04	0.03
Fe_2O_3	0.60	0.96	0.08
FeO	0.36	0.57	
MgO	0.79	0.35	0.04
H_2O+	0.24	0.01	
−	0.16	0.02	
TiO_2			
P_2O_5	tr.	0.02	
MnO	tr.	tr.	
Total	100.74	100.07	100.72

1. Bytownite from a phanerocrystalline block (magnetite-hypersthene-augite-olivine-plagioclase-rock) ejected from the first Hôei crater, Volcano Fuji, in 1707. S. Nakajima, analyst.
2. Anorthite bomb ejected from Hyôtan-yama, the 1940 parasitic cone, Miyaké-shima. S. Nakajima, analyst.
3. Anorthite bomb ejected in 1874, Miyaké-shima.[32] H. S. Washington, analyst.

Olivine leads all other minerals in the rock type (1), and is next to plagioclase in (2) and (3) in abundance, thus it can be collected easily from specimens of these types. An analysis of the olivine which, together with the analyzed plagioclase (column 1, Table V), was made on a specimen of the type (3), is shown in column 1, Table VI , besides two analyses of olivine from Miyaké-shima.

The analyses show that the Fuji olivine is a little more ferric than the Miyaké-shima olivine, the former being approximately of the com-

32) S. Kozu, "Optical, chemical and thermal properties of anorthite from three localities in Japan," *Sci. Rep. Tohoku Univ.*, **2** (1914), second series (geology).

position $Fo_{76}Fa_{21}$ as against $Fo_{85}Fa_{15}$ (analysis 2) or $Fo_{83}Fa_{17}$ (analysis 3) of the latter.

Table VI. Chemical analyses of olivine crystals from Fuji and Miyaké-shima.

	1	2	3
SiO_2	37.53	38.48	38.82
MgO	37.50	44.37	42.51
FeO	21.53	14.65	14.93
MnO	0.83	0.12	0.23
Fe_2O_3	2.66	1.76	1.65
TiO_2	tr.	tr.	—
P_2O_5	tr.	tr.	
Al_2O_3	tr.	0.43	0.20
CaO	tr.	tr.	0.40
Na_2O	tr.	tr.	
K_2O	tr.	tr.	
H_2O+	0.03	0.14	0.90*
−	0.07	0.36	
Total	100.15	100.31	99.64

* Ignition loss.
1. Olivine from a crystalline block ejected in 1707, Fuji. S. Nakajima, analyst.
2. Olivine from an allivalite block ejected in 1940, Miyaké-shima. S. Nakajima, analyst.
3. Olivine ejected in 1874, Miyaké-shima.[33] K. Seto, analyst.

Pyroxenes (augite and hypersthene) are next to plagioclase in abundance in the two rock types (4) and (5), and are common in (1), (2) and (3), while a little augite is the only pyroxene met with in (6). The pyroxenes show neither zoning nor twinning; the augite is pale brown in color, and the hypersthene is greenish brown with distinct pleochroism. Crystallization of the pyroxenes around olivine is seen to have advanced further in the rock types (4) and (5) than in (1), (2) and (3). Furthermore, a greenish brown hornblende is present in the rock type (5) in which hypersthene surpasses augite in quantity; the hornblende develops around the periphery of the pyroxenes and along their cleavages, besides occurring as small rods scattered in the rock.

Full account of their petrographic characters being set aside for

33) S. Kozu, "Studies on Ejecta from Volcano Miyaké-shima," *The Globe (Chikyu)*, **9** (1928), 246 (in Japanese).

the present, the above-mentioned phanerocrystalline ejecta may be all regarded as being genetically related to each other and to the magma which underlies Mt. Fuji as the source of basaltic lavas of the volcano. It is likely that some of them, especially those having ophitic texture, are immediate products of crystallization of the basaltic magma either at the periphery of its reservoir or in its offshoots (dikes) which intruded into the surrounding rocks. But some others, especially those of the rock type (6), seem to have been derived either from a composite mass or separate masses of different mineral assemblages formed by local accumulation of the minerals that were crystallizing out of the magma under deep-seated conditions[34].

A few fragments of pumice and obsidian are found among the 1707 ejecta at the top of Hôei-san. Petrographically, they are similar to those ejected from the second and third craters, so that it is quite uncertain whether they are juvenile ejecta thrown out from one of these craters or accessory ejecta from the first crater.

Besides the juvenile and accessory ejecta, there are rock fragments which, being quite unfamiliar to the volcano, may be regarded as accidental ejecta from the first crater. Altered tuffs are most frequently met with among them, especially at the top of Hôei-san, being not only scattered as ejected blocks but also enclosed as xenoliths in the juvenile basaltic ejecta. They are usually light gray to white in color, consist of granular aggregate of quartz and feldspar (albite) with an amorphous matrix, either colorless or clouded with dust materials, and some of them show a vesicular structure like that of pumice (Fig. 35). Their original character is obscured by secondary changes, so that they can not be traced back to any particular kind of unaltered rocks; some of them are silicified tuffs, but some others may be highly altered igneous rocks, originally of the composition of acidic andesite or allied rocks. One of these rocks is hornblende andesite, the only specimen of which was found among the accidental ejecta collected at the top of Hôei-san. The rock is partly altered, but its original structure is clearly seen under the microscope. Thus the rock contains phenocrysts of labradorite and brown hornblende in a groundmass consisting of lath-shaped crystals of plagioclase, minute grains of monoclinic pyroxene and magnetite, with a little interstitial glass. The hornblende is usually

34) Hirabayashi has mentioned two kinds of phanerocrystalline blocks (two-pyroxene diabase and olivine-pyroxene diabase) from the Hôei crater, considering them as fragments torn by the eruption from a deep-seated dike. *Loc. cit.*

bordered with minute granular aggregate of pyroxene and iron ores (Fig. 33).

The altered tuffs and andesites mentioned have their equivalents among the Miocene volcanics distributed in the Izu region adjacent to the southeast of the volcano. Therefore, it is inferred that they have come from a basal formation which, underlying the volcano at some depth below the first Hôei crater, may be correlated with one of the Tertiary volcanic formations of Izu[35].

Ejecta from the second and third craters. The most important of the ejecta from these craters are fragments of pumice and obsidian. As already stated, the pumice occurs in a thin bed at the bottom of the deposit of the 1707 ejecta (Fig. 18), while the obsidian is found locally accumulated in the vicinity of the craters (Fig. 19). Thus angular blocks less than 1 m across of obsidian, together with grayish pumice and other rock fragments, are found on the ground close to and outside of the western rims of the second and third craters. They are also exposed forming a bed of volcanic breccia in the walls of the valley through which the third crater opens to the south. Whitish pumice is of rare occurrence in the vicinity of the craters, but it becomes predominant instead of the obsidian within a distance of several hundred meters to the southeast.

The pumice is commonly light gray to white in color, but it is sometimes yellowish brown or dark gray. There are also varieties in which variously colored bands are mixed with each other, revealing a flow structure (Figs. 20, 21). Vesiculation of the pumice is exhibited in various degrees in different specimens; alternation of highly vesiculated parts with denser layers, exhibiting flow bands, is met with in some specimens. The pumice is sometimes so extremely vesiculated as to resemble a mass of "soap-bubbles", and in other cases it is fibrous with silky luster, possessing a structure like "thread-lace scoria". Regardless of its various structures, the pumice consists essentially of glass; in the whitish pumice the glass is colorless, while in the dark grayish one it is clouded with very minute microlites and dust materials. Microscopic phenocrysts of plagioclase (andesine Ab_{55}) and small prismatic crystals of monoclinic pyroxene are found very sparingly in the pumice,

35) According to the core-boring carried out at Obuchi (700 m above the sea) on the southern flank of the volcano, there is a mass of altered andesite (propylite) at the depth from 620 m down to more than 1000 m below the surface. This rock is also similar to one of the representatives of the Miocene volcanics distributed around the volcano. H. TSUYA, *Bull. Earthq. Res. Inst.*, **18** (1940), 417.

besides a few larger crystals of more calcic plagioclase and augitic pyroxene. These larger crystals are regarded as xenocrysts, seeing that the pumice often carries basaltic xenoliths, from which they might have come. Among the xenoliths is a phanerocrystalline rock consisting of plagioclase, augite, hypersthene, magnetite and olivine, with a little interstitial glass. Some xenoliths occur as nucli in the vesicular cavities of the pumice (Fig. 26), being either attached to the walls of the cavities, or entwined with glass thread spinned out of the enclosing pumice material. None of the xenoliths show such thermal alteration as might have been caused by the host material.

The obsidian is dull-black in color with a pitchy luster and has a perfect conchoidal fracture (Figs. 22, 23). It contains only a few microscopic phenocrysts of lath-shaped plagioclase and small prismatic crystals of monoclinic pyroxene in a groundmass packed with plagioclase and pyroxene microlites, although, like the pumice mentioned, it often carries xenocrysts and xenoliths. The xenocrysts are of plagioclase, olivine, augite, hypersthene and green hornblende. Pyroxene-bearing biotite-hornblende dacite and olivine-two-pyroxene andesite are present among the xenoliths, besides various basalts and phanerocrystalline rocks like those mentioned above in regard to the accessory ejecta from the first crater. The dacite xenolith is white in color and pumiceous with abundant vesicular cavities, but differs from the pumice ejected in quantity together with the obsidian, in that it contains phenocrysts of strongly zoned plagioclase (andesine—oligoclase Ab_{65-80}), bipyramidal quartz, dark-brown biotite, deep-green hornblende, hypersthene, augite and magnetite in a colorless glassy groundmass (Fig. 34). The olivine-two-pyroxene-andesite xenolith resembles petrographically certain lavas from Volcano Komitaké underlying the northeastern flank of Fuji or from Volcano Ashitaka-yama abutted upon by the southeastern flank of Fuji.

The pumice, together with the obsidian, are undoubtedly of juvenile origin, occupying the greater part of the ejecta from the second and third craters. Among the rest of the ejecta are found rock fragments similar to the xenoliths contained in either the pumice or the obsidian. Thus, for example, the pyroxene-bearing biotite-hornblende dacite occurs not only as xenoliths in the obsidian but also as isolated fragments among the ejecta, suggesting the existence of a mass of the rock at some depth beneath the volcano as a member of late Tertiary or early Pleistocene volcanic formations. Naturally there are also among the ejecta fragments of basalt lavas which, formerly occupying the site of the second and third craters, were blown away by the 1707 eruption. There are also ejected fragments of basaltic tuffs, and one of these (Fig. 31) is worthy of special mention in that it is petrographically quite similar to the Hôei-san tuffs (Fig. 30) already referred to. Compared with the latter, the former is harder and more colored, suggesting a baking effect possibly due to volcanic heat to which it might have been subject at the time of the eruption. Supposing that both are the same, it follows that the Hôei-san tuffs had been in exsistence as such already before 1707 and were fragmented partly by the eruption of the year.

Table VII. Chemical analyses of pumice and obsidian, juvenile ejecta from the second and third craters of 1707, Volcano Fuji.

	1	2	3	4
SiO_2	63.84	63.93	67.22	68.25
Al_2O_3	15.82	14.74	13.40	14.28
Fe_2O_3	0.95	1.44	2.71	2.43
FeO	5.02	5.32	2.30	1.74
MgO	1.67	1.82	1.18	1.41
CaO	4.88	5.10	4.57	3.15
Na_2O	3.88	3.15	3.62	3.68
K_2O	2.12	2.30	2.66	2.82
H_2O+	0.45	0.75	0.98	1.30
$-$	—	0.36	0.91	0.26
TiO_2	0.87	0.50	0.40	0.44
P_2O_5	0.22	0.36	0.19	0.16
MnO	0.17	0.16	0.12	0.09
Total	99.89	99.93	100.26	100.01

1. Obsidian.[36] An ejected block about 10 cm across collected at Nagamine on the west side of the second crater. S. Tanaka, analyst.
2. Obsidian. Locality, same as (1). S. Nakajima, analyst.
3. Pumice. An ejected piece about 5 cm across collected from the pumice bed underlying the basaltic scoria bed, about 4 km northeast of the second crater and 1800 m above the sea, on the eastern flank of the volcano. S. Nakajima, analyst.
4. Pumice. Locality, same as (3). J. Ossaka, analyst.

36) In an earlier paper dealing with the volcanism of the Fuji Zone, the writer used the name "pitchstone" for the rock. But, seeing that the rock is small in water content, it may be called obsidian rather than pitchstone whose water content is usually as high as 8–10%. H. TSUYA, *Bull. Earthq. Res. Inst.*, **15** (1937), 307.

Chemical analyses of the obsidian and pumice are shown in Table VII. The two analyses of the obsidian, one by S. Tanaka and the other by S. Nakajima, are very much alike, showing that the obsidian is an andesite of intermediate to acidic composition. Thus the norm of the analysis (1) contains 18% quartz, 65% feldspars ($Or_{20}Ab_{51}An_{29}$) and 13% pyroxenes ($Wo_{10}En_{33}Fs_{57}$), and that of the analysis (2) 21% quartz, 60% feldspars ($Or_{22}Ab_{45}An_{33}$) and 14% pyroxenes ($Wo_9En_{33}Fs_{58}$). But compared with the obsidian, the pumice is more acidic as shown in analysis (3), Table VII. Its norm contains 26% quartz, 58% feldspars ($Or_{27}Ab_{52}An_{21}$) and 8% pyroxenes ($Wo_{47}En_{34}Fs_{19}$). For comparison, another specimen of the pumice, collected at the same locality as the said pumice (3), was analyzed by J. Ossaka, with the result as shown in (4), Table VII; it is likewise higher in silica content than the obsidian, although its analysis slightly differs from the analysis (3). The norm of the pumice (4) consists of 27% quartz, 62% feldspars ($Or_{27}Ab_{50}An_{23}$) and 4% pyroxenes ($Wo_6En_{82}Fs_{12}$), besides a small amount of magnetite, ilmenite and apatite.

The pumice can not be regarded as a highly frothed equivalent of the obsidian, so far as their chemically analyzed specimens are concerned. But, among the ejecta scattered about the craters are fragments intermediate in appearance between pumice and obsidian, and also those in which pumiceous and obsidian-like parts are accompanied with each other, sometime showing a flow structure with their alternating layers. Therefore, it is inferred that both the pumice and the obsidian have come from one and the same underground mass, more or less heterogeneous in chemical composition and which was vesiculated in various degrees in its different parts.

As already stated, both the pumice and the obsidian contain not a few xenocrysts and xenoliths of basaltic composition, besides those of some other rocks. Petrographically, the basaltic xenoliths are quite similar to the proper basalts of the host volcano, Fuji. Therefore, supposing that both the pumice and the obsidian have come from one and the same magma mass, this latter must have been intruded into the basaltic body of the volcano as a fluid capable of capturing the basaltic xenoliths from the surrounding. It is inferred that, on the eve of the 1707 eruption, this magma of acid andesitic composition was located close to the basaltic magma at some depth below the south-eastern flank of the volcano, both having become so high in gaseous tension as to be explosively ejected in succession and in the form of acid andesitic pumice and obsidian on the one hand and of basaltic lapilli and bombs on the other.

It is possible that the acid andesitic magma represents a foreign mass accidentally intruded into the basaltic mass of the volcano, or that the former is a palingenetic magma originated from a rock of quartz-dioritic composition under the influence of heat from the basaltic magma of the volcano. But, under such circumstances as mentioned above, it may be more natural to consider that the acid andesitic magma is genetically related with the basaltic magma of the volcano, the former having been derived from the latter through a process of crystallization-differentiation. Assuming that the two magmas are represented respectively by (A) and (B) of Table VIII, the composition of the material to be subtracted from (B) to yield (A) is obtained graphically by means of the addition-and-subtraction diagram. It is shown in (C) of the same table, together with its norm, and represents the smallest amount (57%) removed without yielding nepheline in the norm.

Table VIII.

	A	B	C		
SiO_2	65.0	53.0	44.0	Norm:	
Al_2O_3	16.1	15.1	14.4	Or	1.6
Fe_2O_3	1.0	4.6	7.4	Ab	16.8
FeO	5.1	9.3	12.5	An	29.5
MgO	1.7	5.3	7.9	Wo	11.7
CaO	5.0	8.8	11.6	En	6.1
Na_2O	3.9	2.8	1.9	Fs	5.3
K_2O	2.2	1.1	0.3	Fo	9.5
				Fa	8.9
				Mt	10.6

A. Analysis ot the obsidian (Table VII, 1), calculated as free of water and other minor oxides.
B. Average of calculated groundmass compositions of four Fuji basalts. H. Tsuya, *Bull. Earthq. Res. Inst.*, 13 (1935), 655.
C. Composition of a material subtracted from (B) to yield (A).

The norm of the subtracted material (C) consists of feldspars ($Or_3Ab_{35}An_{62}$), pyroxenes ($Wo_{51}En_{26}Fs_{23}$), olivine ($Fo_{51}Fa_{49}$) and magnetite. This mineral assemblage is comparable with some of the phanerocrystalline rocks found among the 1707 ejecta.

Although Fuji proper is a young basaltic volcano born at a late date, probably later than the uppermost Pleistocene, it seems likely that part of the basalt magma underlying the volcano has been subjected to crystallization-differentiation so advanced as to bring about only a little residual liquid of acid andesitic composition, and that this residual liquid has been squeezed out of the parent body to make the only source of the acid andesitic pumice and obsidian of the volcano.

Table IX. Intensity of volcanic activity, classified according to the volume of solid ejecta.

Intensity scale		Volcano	Year of eruption	Ejecta	
Grade	Limit of volume of ejecta (km³)			Kind*	Volume (km³)
IX	>100	Tambora, Soembawa	1815	B	150
VIII	100~10	Krakatau, Sunda Str.	1883	B	18
VII	10~1	Kljutschewskaja Ssopka, Kamchatka Shtyubelya, Kamchatka Sakurajima, Japan Bandaisan, Japan	1829 1907 1914 1888	A B A B D	3.7 3.0 >1.5 1.2
VI	1~0.1	**Fujisan**, Japan Taal, Luzon Komagataké, Hokkaido, Japan Asamayama, Japan Sakurajima, Japan	1707 1911 1929 1783 1946	B D B A B A	0.8 0.5 0.1 0.2 0.1
V	0.1~0.01	Torishima, Japan Ôshima, Izu, Japan Miyakéshima, Izu, Japan Lemongan, Java	1939 1902 1950-51 1940 1877	A B B A A B A	0.09 0.03 0.03 0.02 0.01
IV	0.01~0.001	Goentoer, Java Adatarasan, Japan Keloet, Java	1843 1900 1901	B B B	0.008 0.004 0.002
III	0.001~0.0001	Azumasan, Japan	1893	B	0.0005
II	0.0001~0.00001	Ôshima, Izu, Japan Tokachidaké, Japan	1912 1926	A D	0.00002 0.00001
I	0.00001>	Yakéyama, Niigata, Japan Kusatsu-Shiranésan, Japan	1949 1932	D D	small small
0	0	Volcanoes displaying fumarolic activity only		0	0

* A: essentially lava-flows, B: fragmentary ejecta only, D: essentially ejected old detritus.

Summary and conclusions

The last eruption of Volcano Fuji began in the morning of Dec. 16, 1707, continued for four days with explosions coming in succession, and thenceforward was repeated with intermittent and smaller explosions until the last day of the year, when it virtually stopped, being followed by its long dormancy lasting up to the present. During the eruption, explosions were frequently heard in Tokyo and vicinity, where at the same time the sky was overcast with eruption-clouds blown by the westerly wind and volcanic ashes fell to lie several centimeters deep.

The eruption occurred halfway down the southeastern flank of the mountain, with ejection of incandescent fragmentary materials from three new craters. Of these craters, the first one, situated on the northwest side of a knob called Hôei-san, is by far the largest, forming the only bowl-shaped hollow which has fatally broken the regularity of symmetrically curved slopes of the volcano. The two other craters, the second and the third, are much smaller and, situated on the southwest side of Hôei-san, they are in a NW.-SE. line, together with the first crater. This crater line represents one of the radial fissures in the volcano, as a number of parallel dikes exposed in the walls of the first crater do.

Hôei-san is mentioned in some of the historic records of the 1707 eruption (Hôei era in the Japanese history) as having been formed for the first time by the eruption, hence the name. But, so far as the writer's geological observations are concerned, the knob is neither a new cinder cone having its own crater nor a pile of ejecta thrown out of either one of the new craters mentioned. Although the knob is really veneered with the ejecta of 1707, its main mass is composed of loosely-coherent beds of volcanic ashes and breccia, both of which altogether are called Hôei-san tuffs. These beds, which are well exposed in the steep cliffs on the southeast side near the top of the knob, are divided into numerous minor blocks with both minor faults and fissures mostly striking in the NE.-SW. direction and less so in the N.-S. direction. They are basaltic in composition, but differ petrographically as well as structurally from any that are exposed in and around the new craters. Admitting that Hôei-san was formed by the 1707 eruption, its formation was not due to accumulation of new ejecta, but probably resulted from the upthrust of the older mass (Hôei-san tuffs) yielding to a magmatic intrusion which was advancing from the heart of the volcano to break out into the eruption.

The solid materials thrown out by the eruption are exclusively fragmentary ejecta including juvenile bombs, lapilli, pumice and obsidian, besides some accessory and accidental ejecta. The juvenile pumice and obsidian were ejected from both the second and the third craters only in the first several hours of the eruption, causing the first falling of whitish ashes in the ash-covered area. Subsequent to the pumice and obsidian, the juvenile lapilli and bombs of basaltic composition began to be ejected from the first crater, and their ejection was repeated for the rest of the eruption.

The ejecta were accumulated in a fan-shaped area widening out eastward from the crater region, their deposit attaining a thickness of more than one meter within about 25 km of the craters and several centimeters even in Tokyo and vicinity, about 100 km distant. The total volumes of the ejecta which were accumulated within 25 km and 100 km of the craters, amounted respectively 0.5 km^3 and 0.8 km^3, both inclusive of small amounts of the pumice and obsidian. The volume of these ejecta puts the 1707 eruption at grade VI of the intensity scale of volcanic eruption (Table IX), which classifies the intensity of volcanic activity into ten grades, 0–IX, on the assumption that the intensity is proportional to the potentiality of volcanic gases to drive their container (lava), either fluent or fragmentary, hence proportional to the total volume of ejecta. Generally speaking, volcanic activity of grade VI is usually big explosive eruptions of the Vulcanian type; these are common in andesitic volcanoes, but quite unusual for such a young basaltic volcano as Fuji. The 1707 eruption, in this sense, may be specially worth noticing.

The basaltic ejecta of the 1707 eruption are augite-bearing olivine basalt, while the pumice and obsidian are andesite of intermediate to acid composition. The andesite is interpreted as having been derived through a process of crystallization-differentiation from the basaltic magma underlying the volcano. Be that as it may, it is almost an unheard-of occurrence in the world volcanoes that the juvenile ejecta of two rock types, wide apart in chemical composition, were thrown out in succession by one and the same eruption. In company with the juvenile ejecta were thrown out not a few fragments of foreign rocks, which must have come from the foundation of the volcano, suggesting that the 1707 eruption had its origin at a large depth, possibly more than 2 km below the 1707 craters. The highly explosive character of the eruption might have been an inevitable consequence of the large depth of its origin and also of the incorporation of basaltic magma with more viscous andesitic magma in the eruption. Exhaustion of an enormous mass of volcanic gases by the eruption may have brought forth the dormancy in which the volcano has lain for 248 years since 1707.

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25. 富士火山の地質学的並びに岩石学的研究 (V)
5. 富士山の宝永4年噴火について

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富士山の最新の噴火は 1707 年 12 月 16 日 (宝永4年 11 月 23 日) の朝に始まり, 4 日間にわたつて殆ど休みなく続き, その後も同月 31 日まで間歇的に爆発を行つたが, 同日に至つて事実上止んだものである. この2週間にわたる噴火中, その爆音は東京及びその附近においてしばしば聞かれ, また西風になびいた噴煙は黒雲となつて空をおおい, そのため東京では昼間に灯を用いるほど暗くなつた時があり, 火山灰は数センチメートルの厚さまで降り積つた.

この噴火は富士山の東南側中腹に起つたもので, 三つの新噴火口から白熱の抛出物を噴出した. その第一火口は宝永山という小山の北西側にでき, 富士山の規則正しい外形を損う唯一の大きい窪みとして残つているものである. 他の二つ, すなわち第二及び第三火口は宝永山の南西側にできたもので, 第一火口よりはるかに小さいが, 明かに噴火口の跡として現在も認められる. これらの3火口は北西–南東方向に相接して並び, 第一火口の火口壁に露出する多数の同方向の平行岩脈と共に, 同火山の頂上火口から出る放射状割目の一つを表わすものである.

宝永山はこの宝永4年噴火によつて初めてできたものと伝えられ, そのためこの名が与えられている. しかし, この小山は新しい噴火口をもつ噴石丘でなく, また上記の3火口からの噴出物が積つてできたものでもない. すなわち, この小山はこれらの火口からの噴出物で大部分がおおわれてはいるが, その主体は宝永山凝灰岩層とよぶ黄灰色の一見ロームに似る凝灰岩と灰色凝灰角礫層とからできている. そしてこの地層は宝永山東南側の断崖でよく見られるように, 割目や小断層によつて切断され, いくつかの小地塊の集まりになつており, 宝永4年噴出物には不整合的に接している. 岩質上, この地層はやはり玄武岩質であるが, よく固まつており附近の富士山腹を構成する火山灰や角礫層のどれにも対比できず, むしろ富士山麓の一部に見られる古い富士火山の噴出物に類似するものである. それ故, もし宝永山が宝永4年の噴火によつて現れたものとすれば, それは新噴出物の堆積によつて小山になつたのではなく, 以前からその附近の富士山腹の一部にかくれていた古い凝灰岩層が, 噴火を起そうとする岩漿の地下貫入によつて, 推し上げられて小山となり, 断層や割目で切断されたものと見ることができよう.

宝永4年の噴出物は熔岩流を伴わず, すべて抛出物で, 新しく生じた火山弾, 火山礫, 軽石, 黒曜石等の他に, 同火山を構成する古い火山岩の破片や火山基盤の岩石の破片などをふくむ. 軽石と黒曜石とは噴火の初めの数時間の間に第二及び第三火口から抛出されたもので, これらが白い火山灰となつて噴火の最初に降つたことが記録に残つており, また, これらが全噴出物の最下位に堆積していることは, 降石地域内の各地で現在も認められる. 次いで玄武岩質の火山礫や火山弾が第一火口から抛出されはじめ, その抛出が噴火の終るまでくり返された.

噴出物は噴火口附近から東方に次第に拡がる扇状地域内に堆積し, 駿河駅附近に至る 25 km 以内では厚さ 1 m 以上に達し, 現在でもよく追跡される. 古記録によると, それより遠くでは, 平塚附近で 10 cm 内外, 川崎附近で 5 cm 内外, 東京でも同程度の厚さの火山灰が堆積した. 噴火口から 25 km までの地域内に堆積した噴出物の全容積は約 0.5 km^3, 東京附近 (約 100 km) までのそれを加えると約 0.8 km^3 となる. この量は宝永4年噴火が噴火強度階の VI に相当することを示す. ここに噴火強度階というのは, 噴火の強さが噴出物の総量に比例するものと仮定して, 噴出物の多少を 10 階級, 0–IX, に区分したものである. 火山噴出物は, 熔岩流も抛出物も共に, それに伴うガスの圧

Fig. 6. Volcano Fuji as seen from the top of Volcano Hakoné, showing the 1707 craters (I, II, III) and Hôei-san (H). S: Subashiri. G: Gotemba. Part of the somma and caldera of Hakoné volcano in the foreground.

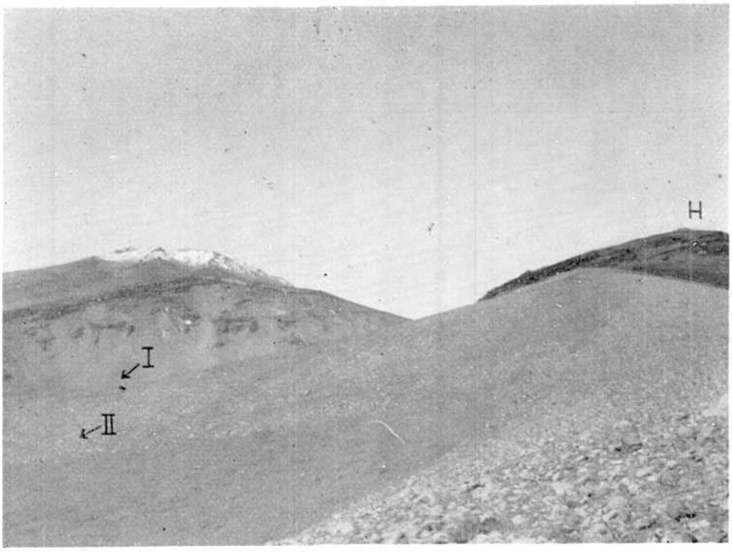

Fig. 7. The southeast flank of the mountain where the 1707 eruption occurred. Right, top of Hôei-san (H) showing cliffs of the Hôei-san tuffs. Left, the first crater (I) with the eastern wall of the second crater (II) in the foreground and the snow-covered top of the mountain in the background.

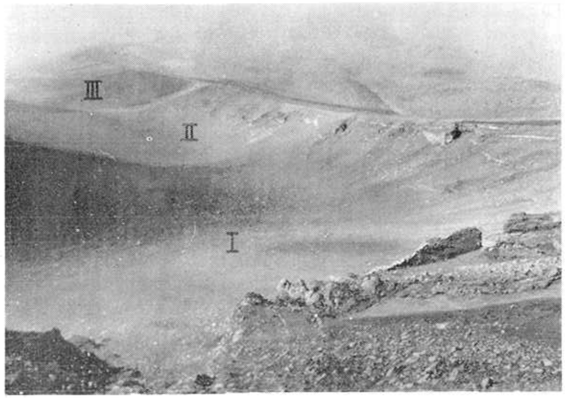

Fig. 8. All three 1707 craters (I, II, III), looking downward.

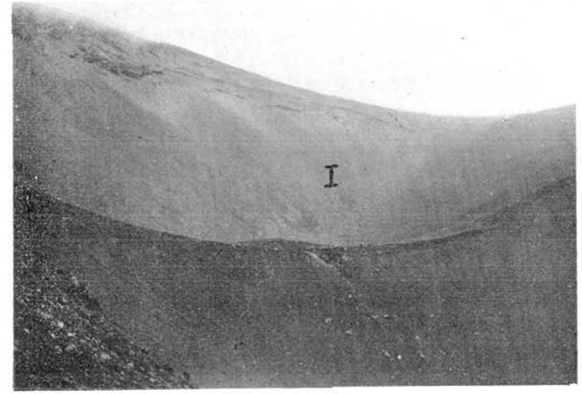

Fig. 9. The first crater with the northwestern wall of the second crater in the foreground.

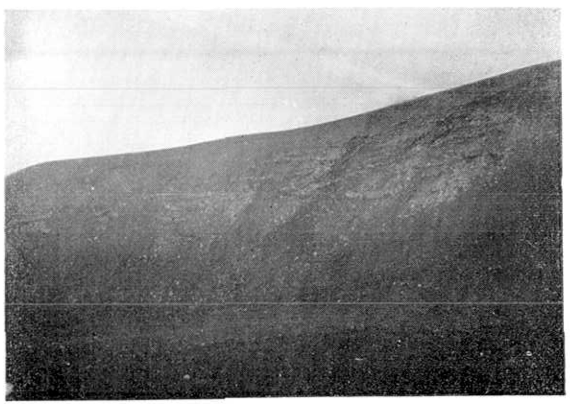

Fig. 10. The second crater and its western wall.

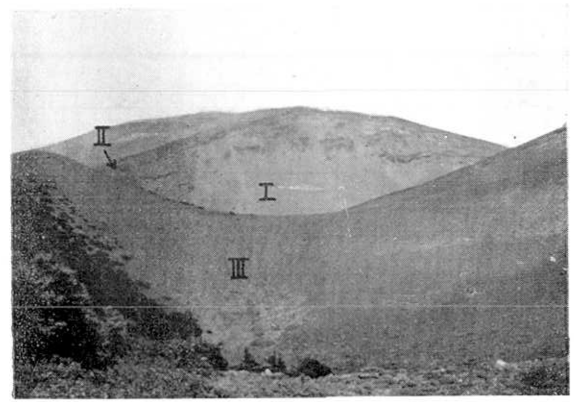

Fig. 11. The third crater with the northwestern wall of the first crater in the background.

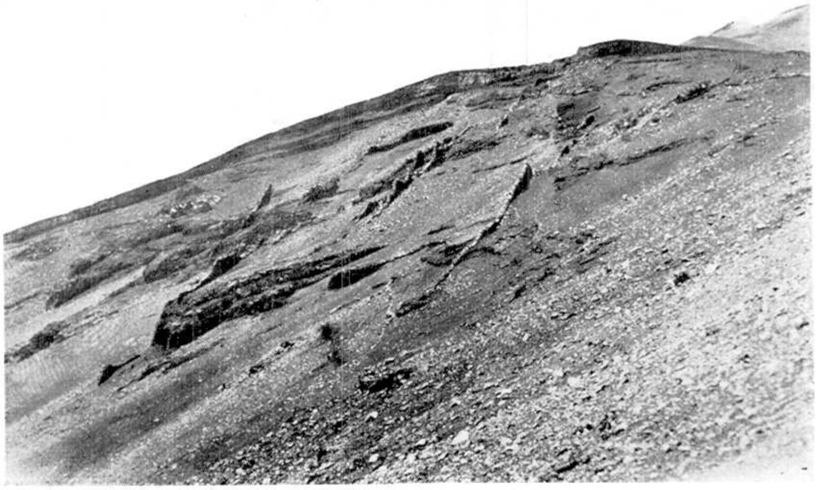

Fig. 12. The northwestern wall of the first crater, showing strata of lava flows and parallel dikes. Top of the mountain in upper right.

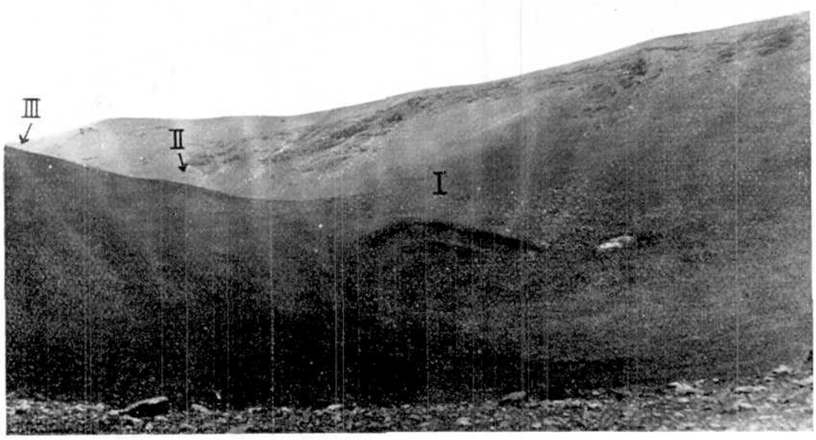

Fig. 13. Bottom of the first crater, showing a low half cone of 1707 ejecta. Upper left, the second (II) and third (III) craters.

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Fig. 14. Hôei-san, looking downward from near the eighth stage of Gotemba trail. I: the first crater.

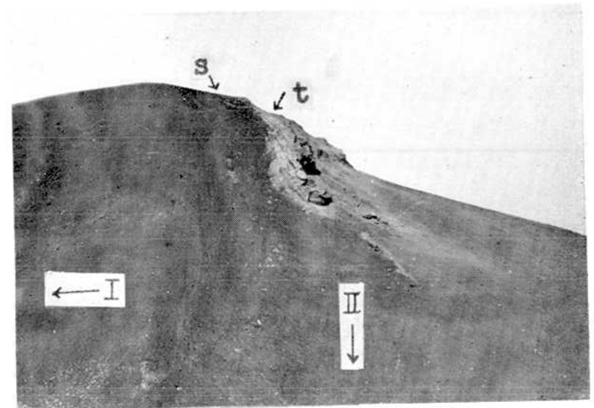

Fig. 15. Hôei-san seen from the west. I: the first crater. II: the second crater. S: 1707 ejecta. t: Hôei-san tuffs.

Fig. 16. Cliff of the Hôei-san tuffs. II: the second crater.

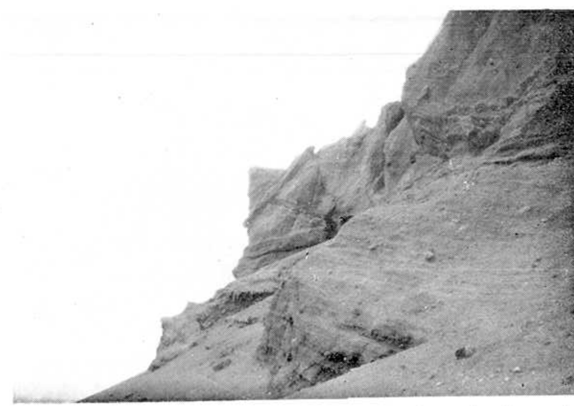

Fig. 17. Hôei-san tuffs showing minor faults and cracks.

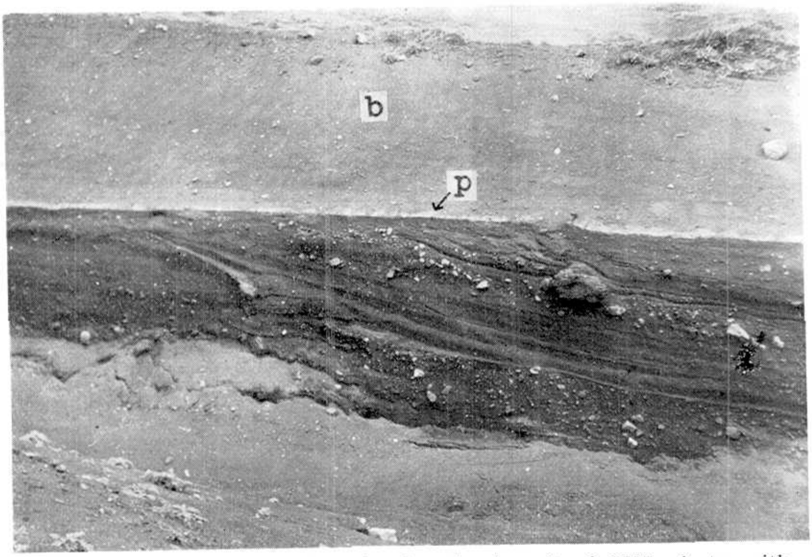

Fig. 18. Wall of a gully, showing the deposit of 1707 ejecta with underlying old ejecta. b: basaltic lapilli. p: acid andesite pumice. Locality: Shishiga-hana on the eastern flank of the volcano.

Fig. 19. Volcanic breccia composed essentially of fragments of acid andesite obsidian. Locality: Head of a gully in the gap of the southern wall of the third crater.

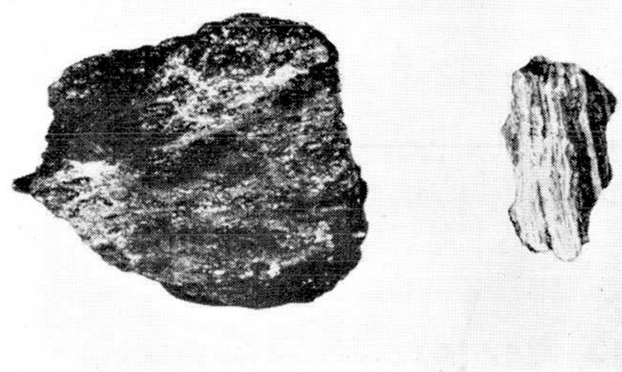

Fig. 20. Acid andesite pumice of 1707, from Shishigahana on the eastern flank of the mountain. 2/3 natural size. Right, a light-grayish specimen. Left, a specimen showing flow bands of whitish and grayish pumice.

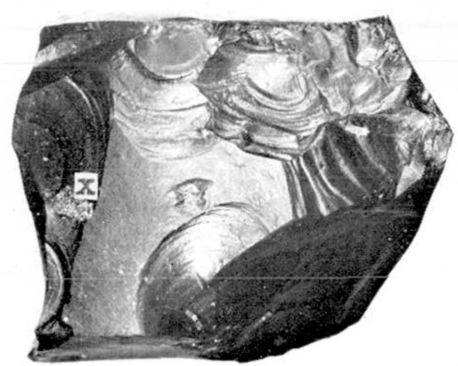

Fig. 22. Andesite obsidian of 1707, from the west side of the second crater (II, Fig. 2). 2/3 natural size. Showing conchoidal fracture. x : xenolith.

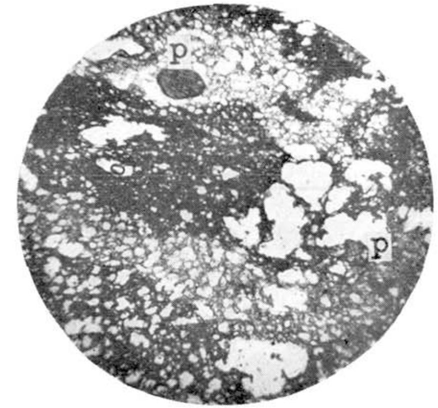

Fig. 21. Microphotograph of the pumice (Fig. 20, left). ×15. p : augite xenocryst.

Fig. 23. Microphotograph of the obsidian (Fig. 22). ×15. x : xenolith (augite-plagioclase-rock). x′: xenolith (olivine-basalt).

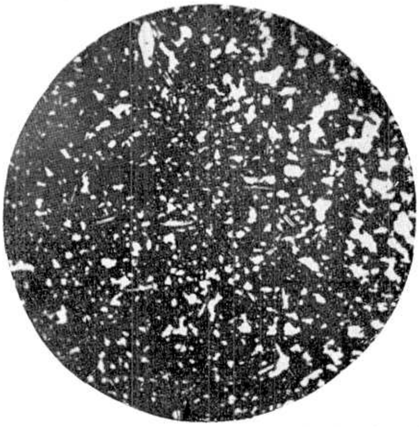

Fig. 24. Augite-bearing olivine basalt. 1707 ejecta (scoriaceous lapilli). ×15.

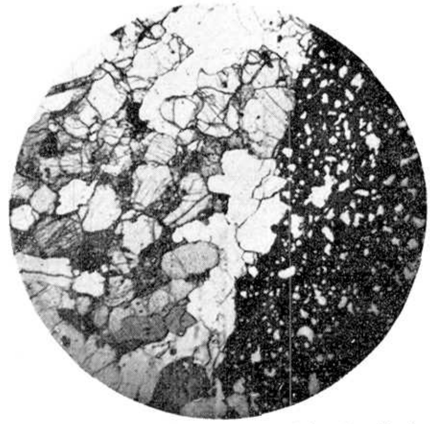

Fig. 25. Magnetite-hornblende-olivine-hypersthene-augite-plagioclase-rock (left) enclosed in the basalt (right). ×15.

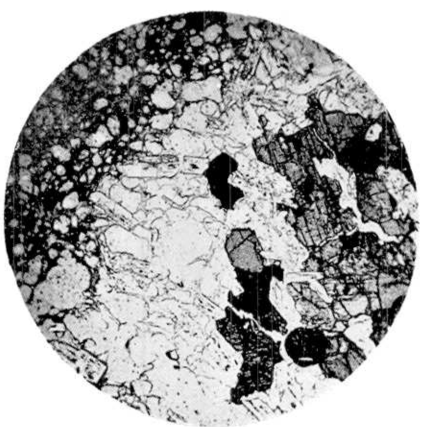

Fig. 26. Magnetite-hypersthene-augite-olivine-plagioclase-rock (right) enclosed in the andesite pumice (left). ×15.

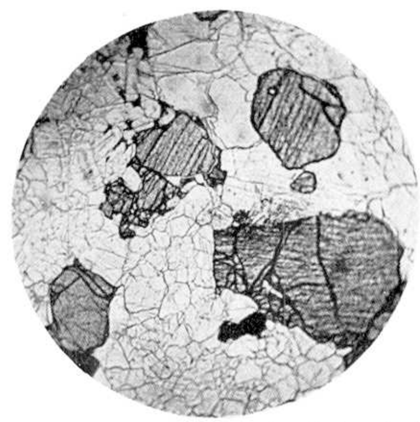

Fig. 27. Magnetite-augite-olivine-plagioclase-rock (isolated ejecta). ×15.

Fig. 28. Magnetite-olivine-hypersthene-augite-plagioclase-rock (isolated ejecta). ×15.

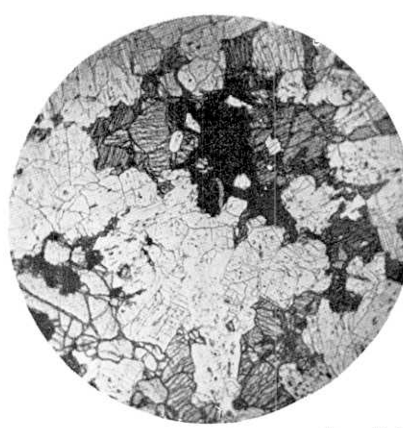

Fig. 29. Hornblende-magnetite-olivine-augite-hypersthene-plagioclase-rock (isolated ejecta). ×15.

Microphotographs of 1707 ejecta of Volcano Fuji.

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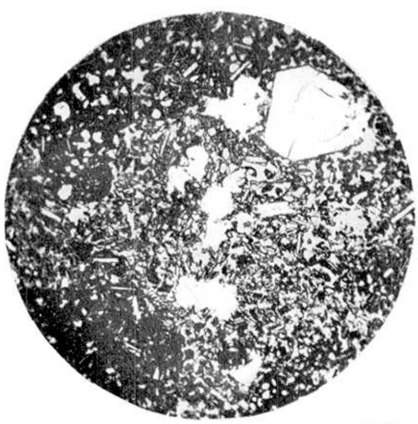

Fig. 30. Augite-olivine-basalt tuff (Hôei-san tuffs). ×15.

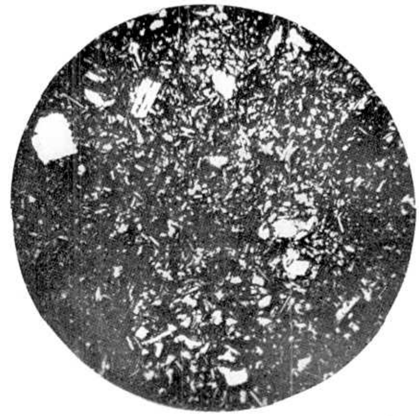

Fig. 31. Augite-olivine-basalt tuff (ejected block). ×15.

Fig. 32. Magnetite-olivine-hypersthene-augite-plagioclase-rock (isolated ejecta), showing an ophitic texture. ×15.

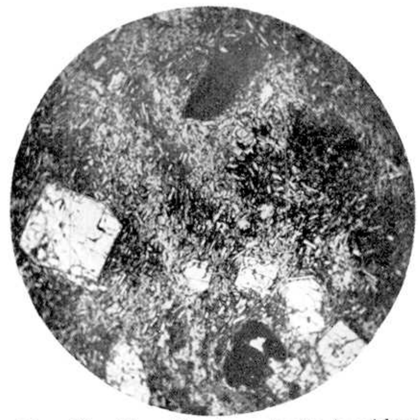

Fig. 33. Hornblende andesite (accidental ejecta). ×15.

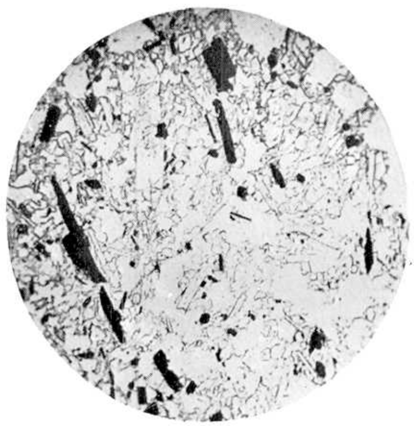

Fig. 34. Augite-biotite-hornblende-dacite pumice (accidental ejecta). ×15.

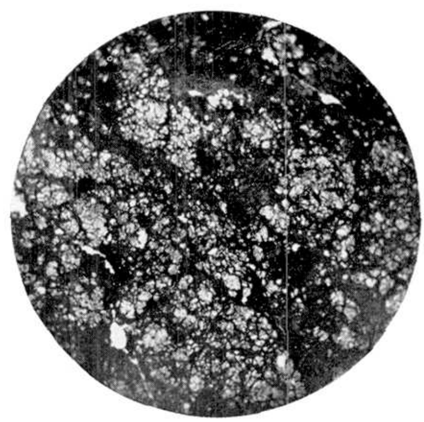

Fig. 35. Silicified tuff (accidental ejecta). ×15.

Microphotographs of 1707 ejecta of Volcano Fuji (Fig. 30 excepted).

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力によつて地表に噴出されるものであるとすれば，噴出物の量が多い事はその噴出に与つたガスの総圧力が大きく，したがつてその噴火の強さが大きいと考えられるだろう．強度 VI の噴火といえば，ヴルカノ式の大きい爆発的噴火の例が多く，安山岩或はこれより一層酸性火山岩を噴出する火山で普通に行われ，富士山のような玄武岩火山ではまれである．この意味で，宝永4年の噴火は，同火山はもちろん一般玄武岩火山の活動として，注目に値する稀有の爆発的噴火であつた．

この噴火で抛出された玄武岩質火山礫や火山弾は一様に含普通輝石橄欖石玄武岩である．それに反して，軽石及び黒曜石は僅少の斜長石斑晶のみを有するガラス質の中性乃至酸性安山岩である．軽石は標本によつては多少異なる化学成分を示し，黒曜石も軽石と多少異なる化学成分をもつ．しかし，軽石と黒曜石との中間的構造を示すもの，両者が流理構造をもつて混つているものなども，同時の抛出物として見出されるので，これらは全体として一つの多少不均質な岩漿から生じたものと考えられよう．そして，この岩漿は富士山本来の玄武岩々漿から結晶分化作用によつて生じたと解釈される．昭和 14 年の三宅島噴火の際の無斑晶玄武岩と灰長石の巨晶，橄欖石などを多くふくむ斑状玄武岩との例のように，同一噴火で多少異なる岩質のものが同時或は相次いで噴出されることは知られているが，玄武岩と酸性安山岩とのように著しく異なる岩石が相次いで噴出された例は他には知られていない．富士山自体においても宝永4年の噴火のみがその例で，同火山の他のどの部分にも軽石，黒曜石などのような噴出物は発見されない．これらの新抛出物の他に，愛鷹山火山の熔岩に類似する岩片，第三紀火山岩と考えられる岩片などが上記の3火口の何れからも抛出され，また火山弾や軽石，黒曜石などの中に捕獲岩として包まれている．したがつて，宝永4年の噴火は富士山基盤の岩石を通して，少くとも地下 2 km 以上の深さの所から起つたものと考えられる．この噴火が玄武岩火山の活動として稀有の大爆発であつた事は，その爆発源が地下深くにあつた事，粘性の大きい酸性安山岩々漿が玄武岩々漿と共に噴火に与かつた事などによる必然の結果であろう．また，この噴火によつて岩漿内のガスの大量が一時に失われ，岩漿温度の著しい低下を来たした事はその後現在に至る 248 年の永い休眠を富士火山にもたらしたものと考えられる．