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11. *The Eruptive Activity of Mt. Asama from 1958 to 1961 and the Associated Minor Pyroclastic Flows.*

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Abstract

Mt. Asama, one of the most frequently active volcanoes in Japan, began an eruptive activity in Oct., 1958, after a duration of quiescence of 40 months from July, 1955. The eruptive activity continued for the remainder of the year and the first half of the next year with an intermediate halt of two months. From the latter days of July, 1958, the fumarolic activity in the crater became gradually active, increasing in intensity through Aug. and Sept. The amount of vapor and gas issuing from the fumaroles at the bottom of the crater and the lower end of the crater-wall began to increase by degrees, being accompanied by a gradual increase of roaring and rumbling. The number of minor volcanic tremors which were felt by the seismographs set up around the volcano began to increase simultaneously. The ash-fall which might have been brought from the first eruption was observed on Oct. 3, 1958, on the eastern slope of the volcano. After that, the eruptive activity gradually increased in intensity with frequent occurrence of minor ash eruptions and puffings of smoke, being associated with a great increase of minor volcanic tremors. The activity culminated in an intense outburst on Nov. 11, which was considered to be one of the strongest explosions that had occurred for some decades. Moreover, the eruptive activity continued with some surges until the end of the year. There was a remarkable surge of explosive activity in the early days of Dec., when several intensive outbursts and major ash eruptions took place successively. From the latter days of Dec., 1958, to the end of Feb., 1959, no eruption was observed and the volcano seemed to rest in a fairly calm state. On March 10, 1959, however, the eruptive activity recurred with an intensive outburst. Afterwards, the eruptive activity continued with intermittent outbursts and minor ash eruptions. On April 14, there was a major outburst, the shooting out of a large amount of ejecta consisting almost entirety

of bread-crust bombs. About the end of June and the middle of July, there were noteworthy surges of explosive activity, when several outbursts took place with the ejection of pumiceous materials. The ejection of such porous materials at these outbursts showed a striking contrast with the mode of each explosion occurring in 1958 which ejected dense materials of consolidated rock fragments and subordinate bread-crust bombs. The eruptive activity lasted until the latter days of Aug., 1959, when it died down to the ordinary fumarolic activity. From Sept., 1959, to the middle of Aug., 1961, the volcano had been in quiescence, only emitting white vapors from the crater. On Aug. 18, 1961, the volcano erupted suddenly with an intense explosion, and the eruptive activity continued until about the middle of Nov., 1961. Following this the volcano has rested in a calm state without any eruption up to the present (Dec., 1963). The explosion on Nov. 10, 1958, was the biggest among all which occurred in the period of eruptive activity from 1958 to 1961. As to the volume of solid materials ejected by the eruption on Nov. 10, 1958, it is considered to be the largest among all the explosions covering recent years. The total volume was calculated to be $3.6\times 10^5\,m^3$, which puts the explosion in the grade III of Tsuya's intensity scale of volcanic activity. The explosion on Aug. 18, 1961, ranks next to the explosion on Nov. 10, 1958, among the explosions from 1958 to 1961 on the intensity of explosion. The volume of the ejected materials was estimated to be $7\times 10^4\,m^3$, which puts the explosion in the grade II of Tsuya's intensity scale. These two explosions were the principal ones in the period of eruptive activity from 1958 to 1961. The other explosions were by comparison unimportant, being in the grade I of Tsuya's intensity scale, about one hundredth of the explosion of Nov. 10, 1958. Moreover, the two major explosions are noteworthy in that they were accompanied by the discharge of minor pyroclastic flows. The discharge of pyroclastic flow on this volcano was eyewitnessed for the first time in the eruption of Nov. 10, 1958, although the occurrence of much larger pyroclastic flows in the 1783 eruption of the volcano had been geologically proved. About $2.7\times 10^5\,m^3$ of incandescent fragmental materials were deposited inside the crater-wall of Maekake-yama as well as on the upper slope of it, occupying the larger part of the bulk of ejected materials from the eruption of Nov. 10, 1958.

Introduction

Mt. Asama (Asama-yama) is one of the representative volcanoes which have been most frequently active during recent years in Japan. It is a compound volcano consisting of three overlapping bodies; the older strato-cone of Kurofu-yama, a shield volcano of Hotoke-iwa and the younger strato-cone of Maekake-yama and Kama-yama (Tsuya, 1934; Yagi, 1936 and Aramaki, 1963). Kurofu-yama is the older dissected strato-cone whose crater has been enlarged by erosion and cut down by a large radial valley of the Jabori River. The Highest part of it represents the western ridge of the semi-circular crater rim at the altitude of 2,000 to 2,400 m above sea level. The eastern part of the cone is completely missing, having been down-faulted and destroyed by a catastrophic explosion in ancient times. The deposits of large scale mud-flows which resulted from that destruction of the cone were distributed on the north and south bases of the volcano. The rocks constituting the cone of Kurofu-yama are olivine-augite-hypersthene andesite and augite-hypersthene andesite rich in phenocrystic minerals, belonging to the most basic varieties of the rocks of Asama Volcano. They are divided into three groups depending on their petrography as well as the geologic structure and relation. The volcanic body of Hotoke-iwa and the younger strato-cone overlie the collapsed part of the eastern half of Kurofu-yama. Hotoke-iwa is an independent volcanic unit comprising a group of thick lava flows of hornblende-augite-hypersthene dacite with glassy groundmass, which belong to the most silicic members of Asama Volcano. It represents the intermediate activity in the transitional period between the completion of the activity of Kurofu-yama and the beginning of the growth of Maekake-yama, together with the succeeding eruptions of ash flows of dacite magma. A tremendous mass of discharged materials from the ash flow eruptions, which was distributed on the lower skirts of the volcano, resulted in the formation of a depression on the area around the vent, where the birth of Maekake-yama began after a long period of quiescence. This younger cone has grown almost continuously up to the present time. It shows an almost symmetrical form with a very young smooth and naked surface covered with fragmental materials from recent eruptions. The summit of the cone was enlarged by a collapse, and then a central cone, Kama-yama, formed growing up higher with repeated eruptions. The rocks constituting Maekake-yama are augite-hypersthene andesite, being more silicic than the andesites of Kurofu-yama. The active crater-pit occupies the top of Kama-yama of 170 m height, being in the shape of a hollow cylinder about 300 m in diameter (Figs. 17 and 18). The highest point of Mt. Asama is situated at the eastern rim of the crater-pit, which may reach more than 2,560 m above sea level although being as 2,542 m in the topographic map published by the Geographical Survey Institute in 1911.

Maekake-yama and Kama-yama are composed of an alternation of lava flows and fragmental materials, among which several different units of pyroclastic flow deposits are recognized. It seems remarkable that the younger strato-cone of Asama Volcano has erupted with so many pyroclastic flows through its rather short period of growth, perhaps less than five thousand years. The latest eruption of major pyroclastic flow took place in 1783 (Yagi, 1963 and Aramaki, 1956 and 1957). After that all the recent eruptions of the volcano are of small-scale explosion type generally called the Vulcanian type. The eruptive activity usually consists of main outbursts and subordinate minor ash eruptions. The outburst is characterized by the instantaneous ejection of a mass of ash, rock fragments, bombs and sometimes pumice, rising up as a column of eruption cloud like a mushroom to a height of several thousand metres above the top of the volcano with the accompaniment of loud detonations, airshocks and rumblings. Large blocks and bombs are thrown out and fall to the ground in the area of a few killometre distance around the crater, digging large conical holes. The main phase of outburst lasts only a minute or less, and the mushroom cloud loses shape immediately, being carried away by the atmospheric currents. Then a heavy shower of lapili and ash attacks the adjacent areas on the leeward.

The previous eruptive activity of Mt. Asama which started in Dec., 1953, ceased in July, 1955. Afterwards the volcano was in a state of quiescence for 40 months up to Oct., 1958, when the eruptive activity recurred with a repetition of minor ash eruptions. On Nov. 10 of the same year the volcano broke out in an intensive outburst that was regarded as one of the strongest explosions during recent decades. This outburst was followed by other outbursts and minor eruptions through the remainder of the year. The eruptive activity came to a halt at the end of the year, but recurred again in March of the following year, continuing over the first half of that year. Finally it died down to an ordinary fumarolic activity in the latter days of Aug., 1959, followes by a long period of quiescence. On Aug. 18, 1961, the eruptive activity of the volcano revived suddenly with an intensive outburst. It continued until Nov. of the same year, and then came to a halt. Following this activity the volcano has rested in a quiescent state up to the present (Dec., 1963).

The general features of these eruptive activities of 1958, 1959 and 1961 were quite similar to those which occurred in the recent years. However, the major explosions on Nov. 10, 1958, and Aug. 18, 1961, are noteworthy in that they were accompanied by the occurrence of minor pyroclastic flows. This type of pyroclastic flow of a very small magnitude may be inferred to have been erupted many times during the prehistoric as well as historic eruptions without being recognized. Thus the minor pyroclastic flow of Nov. 10, 1958, was a definite one that was able to be witnessed for the first time, although the occurrence of major pyroclastic flows such as those in the 1783 eruption has been inferred from the geological consideration on the deposits.

The writers have been resident at the Komoro Geochemical Station situated on the south-western foot of the volcano, attending to the research of the mode of eruption and ejected materials. This paper presents an outline of the eruptive activities of the volcano from 1958 to 1961, including special remarks on the minor pyroclastic flows on Nov. 10, 1958, and Aug. 18, 1961, and the results of mechanical analyses of ash fall and pyroclastic flow deposits.

The writers wish to express their sincere thanks to Prof. Hiromichi Tsuya, University of Tokyo, who occasionally visited the volcano in order to carry out investigations with the writers, for constant guidance in the course of the work as well as for giving invaluable advice. They also wish to express their grateful appreciation of many courtesies rendered to them by the local authorities as well as individuals, among them must be specially mentioned Messrs. H. Sekiya, Chief of the Karuizawa Weather Station, M. Yanagisawa and T. Fujisawa, members of the Komoro City Office, K. Misaizu, E. Nakamura and Y. Yanagida. This work was supported in part by a Grant in Aid of Fundamental Scientific Research.

Outline of the Eruptive Activities from 1958 to 1961

Prior to the major explosion on Nov. 10, 1958. Since July, 1955, when the previous eruptive activity of Mt. Asama continuing from Dec., 1953, had died down to an ordinary fumarolic activity, there came a long period of quiescence of 40 months until Oct., 1958. The amount of vapor emitted from the crater-pit decreased to an extremely small amount. Through the period of quiescence the inside of the crater-pit showed no noticeable change. The bottom floor of the crater-pit was covered almost entirely by rock debris, showing features of a dry riverbed. About the center of the bottom floor there lay uncovered a large block of yellowish-gray color with a diameter of several metres, from which a faint bluish fume was discharged constantly. Small amounts of white vapor were issued without any hissing noises from the lower end of the crater-wall at several points of contact between the talus deposits and the rock debris on the bottom floor. The depth of the crater-pit seemed to show no change through the period of halt. It was reported to have been measured as being about 200 m by a observer of the Karuizawa Weather Station on April 10, 1958.

In July, 1958, the amonut of gas component, especially of sulphic gases, in the emitted fume from the crater bottom tended to increase, resulting in a deposition of sublimates at the center of the bottom floor. During the latter days of July minor volcanic earthquakes began to be felt by the seismographs set up on the mountain-slope of the volcano. The amount of discharged vapor and gas began increasing remerkably, rising as white vapor clouds up to several hundred metres in height above the crater, which promoted the growth of cumulo-nimbus in the summer season. Hissing noises and rumblings were reported to have been heard from the crater-bottom by some climbers. In Aug. minor tremors were registered frequently with an increase in number and magnitude. The amount of emitted vapor and gas continued to increase. In Sept. the frequent occurrence of volcanic tremors and vigorous emissions of vapor clouds still persisted with an increase in intensity. In the latter half of Sept. the intermittent rising of a large amount of white vapor clouds was observed, which immediately lost shape and exhaleted into the clear sky of the fall season leaving bluish-grey traces along the direction of air currents. All of these symptoms were considered to indicate the imminent commencement of eruptive activity. The local authorities in the area around the volcano began taking greater precautions against the possible occurrence of major explosions. On Oct. 3 the ash fall which might have been brought from the first eruption was recognized on the eastern mountain-slope of the volcano, and the eruptive activity of Mt. Asama ultimately started after a long duration of quiescence of 40 months from July, 1955, to Oct., 1958.

After the presumed first eruption on Oct. 3, minor eruptions of ash occurred in succession. Especially on Oct. 11 and during the latter days of Oct., minor ash eruptions took place one after another. The eruptive activity consisting of a frequent occurrence of minor ash eruptions and puffings of smoke and accompanied by a great increase of volcanic tremors lasted until the early days of Nov., and eventually culminated in an intensive explosion on Nov. 10, 1958.

The major explosion on Nov. 10, 1958. From Nov. 7 to Nov. 9 the cloudy weather continued, and the upper part of the volcano was almost hidden by thick clouds. On Nov. 10 the weather changed to fair, and at the moment of the outburst the sky was clear, affording a magnificent view of the explosion. According to the accounts of eye-witnesses, including those of the writers, the course of the outburst was as follows.

In the daytime of Nov. 10, the amount of effused vapor clouds was so small that any traces of smoke were could hardly be observed except for very small puffs of white vapor. The explosion began with the rapid rise of a black eruption cloud, being accompanied by the ascent of a red refrection column at 10 : 55 p. m. Then followed vigorous ejection of numerous incandescent bombs, which afforded a grand spectacle in the dark sky. The eruption cloud continued to rise into a mushroom, in which sparks caused by the collision of ejecta, lightnings and thunders occurred sporadically. After ten seconds or so from the initial rise of eruption clouds, belts of incandescent materials were discharged from the crater, descending down the slope of the central cone, Kama-yama, with a remarkably high speed. They seemed like lava flows at a glance, but flowed down considerably faster. The main parts of the incandescent belts descended on to the southern and south-western slopes of the central cone. The south-westward part was barred on its course by the high cliff of Maekake-yama of about 100 m height, the outer crater-wall, being deposited on the bottom of the hollow, Mugen-dani, inside the cliff of Maekake-yama (Figs. 13, 15, 16, and 18). The southward and south-eastward parts flooded over the low ridge of the crater-rim of Maekake-yama, almost buried by younger ejecta of the central cone, and descended the mountain-slope forming large red-hot tongues, whose fronts reached an altitude of about 1,850 m above sea level (Fig. 11). When these incandescent belts passed on the crater-rim of Maekake-yama, terrific detonations and airshocks were heard at the villages at the foot of the volcano, which lie in an area 8 to 18 km off the crater. Consequently, it may be inferred that the incandescent belts flowed down a distance of about 500 m in 15 to 20 seconds, and the speed of flowage may be estimated as being about 25 to 30 m per second. Judging from the mode of flowage and the nature of deposits, they were inferred to be pyroclastic flows of small scale.

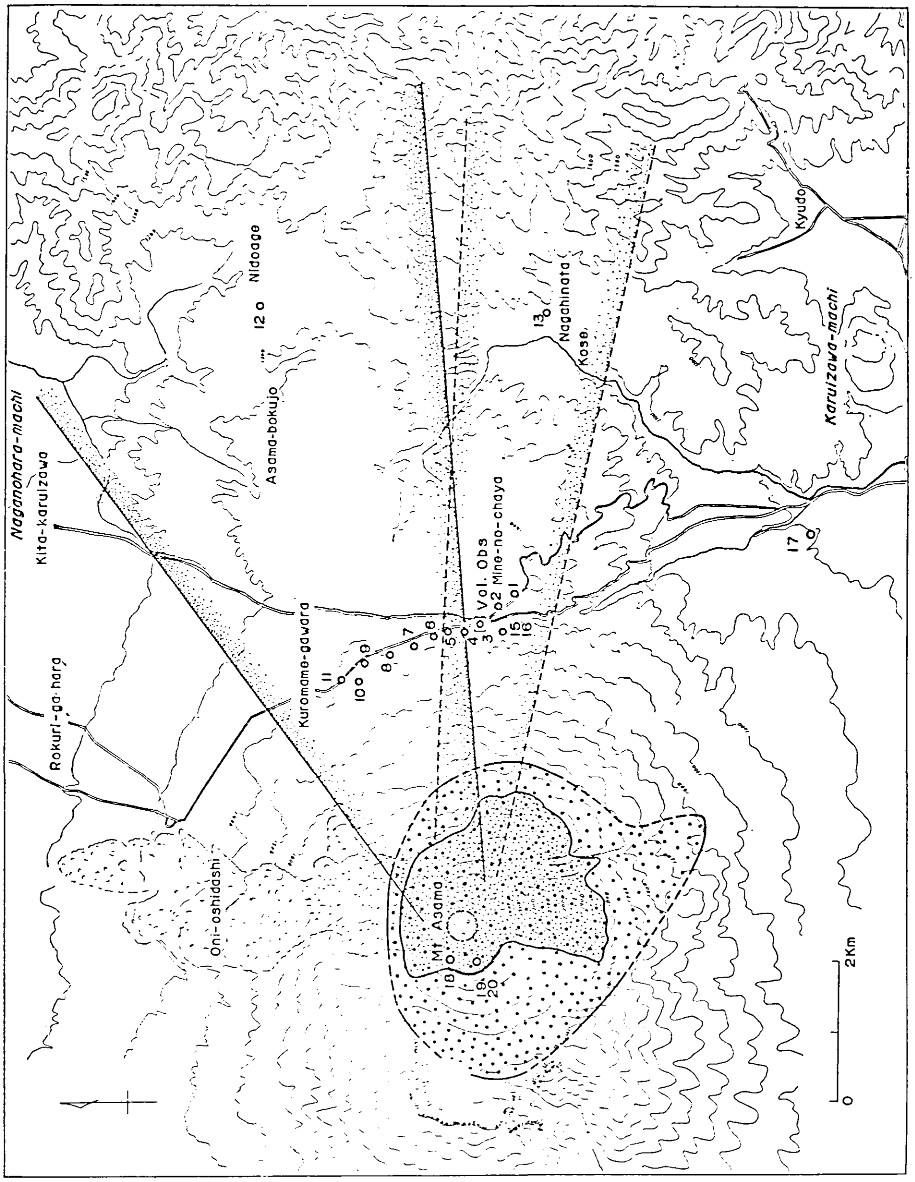


Fig. 1. Map showing the distribution of discharged materials from outbursts on Nov. 10 and 11, 1958. Open circles show the localities of collected specimens of ash falls and pyroclastic flows for mechanical analyses. The area spotted with large dots represents the range of falling of large ejecta. The area spotted with both large and small dots represents the distribution of pyroclastic flow deposits. The narrow fanshaped area bordered with solid lines represents the distribution of ash fall from the outburst on Nov. 10, and that with dotted lines represents the distribution of ash fall from the outburst on Nov. 11.

Forest fires broke out at several places on the upper slopes of the volcano caused by the heat of the falling ejecta, lasting for about one hour. The top of the mushroom of ash cloud continued to rise up to a height of about 7,000 m above the crater in about 2 minutes, then lost shape being transported eastward by atmospheric current. After that black ash clouds continued to rise for a while, and forcible rumblings went on for about ten minutes.

A heavy shower of lapili and ash fell over a wide area to the east of the volcano. At Asama-bokujô, Nidoage, etc. lapili and ash showered severely for ten minutes immediately after the outburst. Ash and dust were carried by winds into an eastern quadrant, resulting in ash falls on areas of Gumma, Saitama, Tochigi and Ibaragi Prefectures, across the north part of the Kantô District (Figs. 1~3). At Maebashi in Gumma Prefecture, 49 km distant from the volcano, the ash fall was reported to have begun from 0 : 45 a. m. and lasted till 6 : 00 a. m. on Nov. 11, and about 250 g/m^2 of ash deposits was measured. At Onahama in Ibaragi Prefecture, 224 km distant from the volcano, the ash fall was reported to have begun from 1 : 10 a. m. on Nov. 11. Ash falls were also observed at Shibukawa, Ashio, Nikkô, Ôtawara, Tanakura, Hitachi, etc. Explosion noises and airshocks were felt on the eastern area of the Chûbu District as well as almost the whole area of the Kantô District. Some noises were also heard at Sendai, Morioka, Gifu, Ôsaka, Kanazawa, Miyake-jima, Hachijô-jima, etc., about 150 to 400 km and 300 to 400 km away from the volcano, due to the refraction of sound waves by a layered atmosphere.

The damage to buildings and to persons was rather slight in spite of the violence of the explosion. Many panes of glass were broken by the explosion airshocks and seven persons were hurt by broken pieces. Prior to the commencement of the eruptive activity the local authorities had consulted one another on how to take proper countermeasures to prevent the damage which might be brought about by major explosions, and had decided to prohibit climbers climbing up to the area around the crater since Sept. 1. Actually there was no climber there at the moment of the outburst, and consequently no damage to human life by ejecta. Police offices reported that 2,305 houses in an area of 430 km^2 around the volcano suffered some damage by airshocks from the outbursts. The longest range of damage by the airshocks reached about 15 km from the crater. The villages to the south-southeast of the crater, i. e. Naka-karuizawa, Oiwake, etc., suffered larger damage than the villages in other directions. Shin-karuizawa, Minami-karuizawa, Kita-karuizawa, Miyota and Iwamurata suffered some damage, but Komoro suffered only very slight harm.

Large blocks and bombs were shot up at the initial moment of the explosion, falling within an area having the range of 1 to 4 km from the crater (Figs. 37 and 38). On the southside of the mountain-slope the amount and range of falling ejecta were by far larger than on the northside. Especially in the direction of south-southeast from the crater ejected blocks reached to the longest range of 4 km. The center of the outburst might have been situated at the northside in the crater-bottom. This was considered to have been attributable to such preferred direction of south-southeast in the distribution of thrown ejecta as well as that of damage by the explosion airchocks. A photograph taken several days after the explosion showed that the southern half of the crater-bottom were buried by fragmental materials, while on the northside there remained a large explosion hollow (Fig. 28). The northen rim of the crater-pit was partly destroyed by the explosion, where the largest block from the 1949 eruption was also partly destroyed and covered by ejecta. The largest block thrown out by this explosion had a dimension of $6\,m \times 6\,m \times 4\,m$. The total mass of thrown ejecta was estimated to be 27,250 tons by the Karuizawa Weather Station. The total mass of ash fall from the explosion settled on the eastern quadrant of the volcano was estimated as 1.2×10^5 tons and the volume as $7.5 \times 10^4\,m^3$ by the writers (as the density of ash fall is presumed 1.6). Besides these ejected materials, a large quantity of incandescent fragmental materials was discharged froming minor pyroclastic flows. It covered an area of about $5.3\,km^2$ on the upper part of the volcano. In the hollow inside the cliff of Maekake-yama it accumulated as chaotically mingling deposits of discharged materials of all sizes with several metres thickness, whose surface showed features like a sand-plain (Figs. 13, 15 and 16). The total mass of the deposits of the minor pyroclastic flows was calculated to be 4×10^5 tons and the total volume $2.7 \times 10^5\,m^3$. Further, the total mass of discharged materials from the explosion on Nov. 10 was estimated as 5.5×10^5 tons and the total volume as $3.6 \times 10^5\,m^3$. This value puts the explosion in the grade III of Tsuya's intensity scale of volcanic activity (Tsuya, 1955). The initial velocity of ejection was calculated as 166 m/sec and the initial pressure of gas as 340 atmospheres by the Karuizawa Weather Station. Thus the kinetic energy for the ejection at the initial moment of explosion may be calculated as 2×10^{19} erg, and that for the effusion during the following phases that resulted in the formation of pyroclastic flows may be of the same order if the initial velocity of effusion is presumed to be 100 m/sec or less. Then the total kinetic energy may reach about 4×10^{19} erg.

After the first major explosion. The first explosion on Nov. 10 was followed by continuous emissions of black ash clouds, which lasted for about 30 minutes with gradual diminution. At 3 : 25 a. m. on

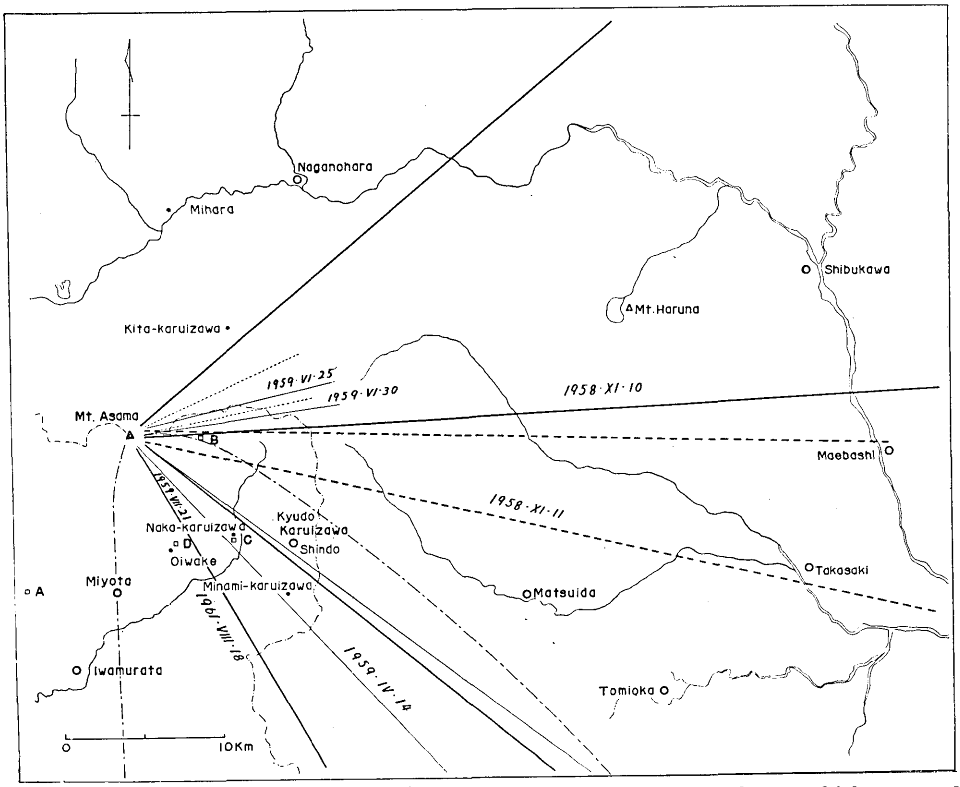


Fig. 2. Map showing the distribution of ash falls from the outburst which occurred during the period of eruptive activity from 1958 to 1961 in the surrounding area of Mt. Asama.

Nov. 11, the second, less intensive, outburst took place, rising as an eruption mushroom up to a height of 5,000 m above the crater. The ash cloud was transported eastwards by winds, from which lapili, pumice and ash descended to the ground. This outburst was noteworthy in that it ejected a small amount of pumiceous materials, unlike the other explosions which occurred in 1958 and which did not discharge any amount of pumice (Fig. 39). The total mass of ejected materials from this outburst was estimated as 3×10^3 tons and the total volume as $2\times10^3\,m^3$ by the writers, less than one hundredth of the first explosion. On Nov. 11 and 12, minor ash eruptions occurred very frequently with a successive rise of ash clouds up to heights of about 500 to 1,500 m above the crater. Ceaseless emission of white vapor clouds followed after these minor eruptions. From about the middle to the end of Nov. the same condition of eruptive activity continued with some surges.

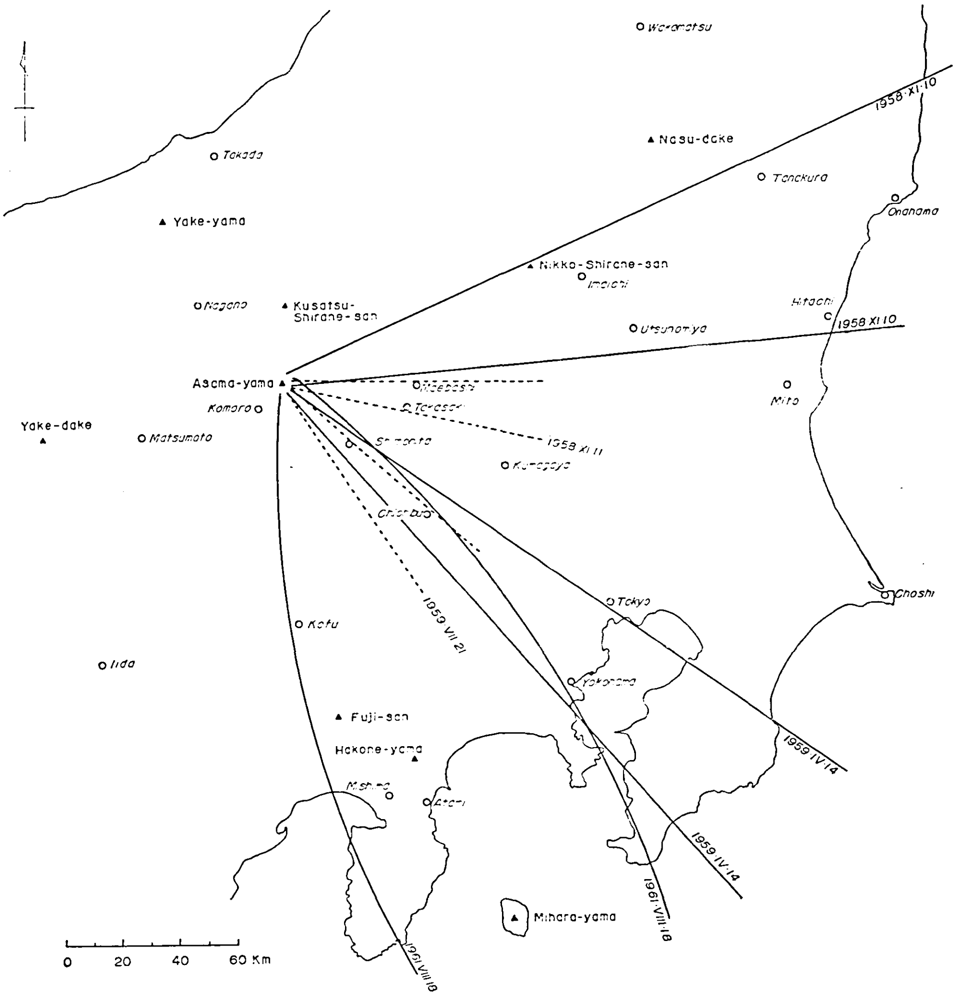


Fig. 3. Map showing the distribution of ash falls from major outbursts of Mt. Asama in the period from 1958 to 1961.

Especially from Nov. 21 to 24, minor eruptions took place one by one, which sometimes lifted ash clouds up to heights of 2,000 to 3,000 m above the crater. Copious amounts of grayish white clouds were emitted almost continuously in the intervals of each eruption.

From the end of Nov. the emission of white vapor clouds tended to become intermittent with a decrease in their amounts, although the eruptive activity continued without any diminution in intensity and minor ash eruptions still occurred repeatedly. There appeared a minor surge of eruptive activity on Dec. 2, when the number of minor ash eruptions increased and in turn the emission of vapor clouds in the intervals of the eruptions became rather sporadic with a decrease in amounts. On Dec. 4, the explosive activity recurred, and major explosions occurred at 7 : 02, 7 : 05 and 11 : 46 a. m., which were followed shortly by subordinate minor ash eruptions (Fig. 21). The tops of the explosion mushrooms reached heights of 4,000 to 5,000 m above the

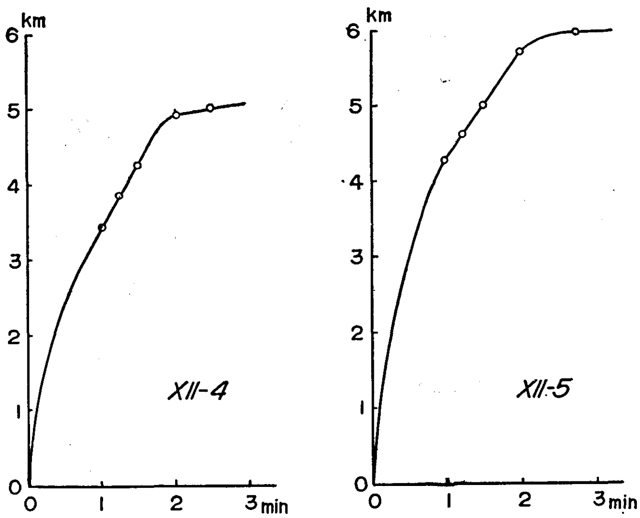


Fig. 4. Situation of the rising of explosion clouds at 11:46 a.m. on Dec. 4 and at 1:08 p.m. on Dec. 5, 1958. The abscissae represent the height of the rising cloud agains the time from the initiation of the outburst shown on the ordinates.

crater (Fig. 4). Airborn ash clouds were carried eastwards by winds, which brought slight ash falls to Maebashi, Kumagaya, Utsunomiya, etc. By midday of Dec. 5, the emission of ash and vapor had almost entirely ceased, but at 1 : 08 p. m. an intensive outburst took place again (Figs. 19 and 22). The top of the mushroom column reached to a height of 6,000 m above the crater (Fig. 4). Ash falls from this outburst were recognized at Kumagaya, etc. Several panes of glass were broken by the explosion airshocks at Naka-karuizawa. Minor ash eruptions also followed after the outburst. They took place in succession in the afternoon of Dec. 5 and in the morning of Dec. 6, producing ash clouds to heights of 1,000 to 3,000 m above the crater. Ash laid clouds were emitted with a tendency of some duration. Strong west winds prevailing in the winter season at this district around the volcano swept the ash clouds out of the upper air above the crater, drawing a very long tail of smoke toward the eastern sky.

At 11:23 a. m. on Dec. 6, a peculiar type of eruption took place (Fig. 23). At first, a black ash column rose up slowly and then a continuous discharge of copious amounts of ash clouds followed. Dark ash laid clouds failed to rise into the upper air but crept downward along the upper mountain-slope of the volcano, being carried by strong west winds. At an altitude of about 2,000 m above sea level, above the cliffs of Hotoke-iwa, the descending clouds turned their downward course to an upward one, rising up gradually into the eastern sky away from the mountain-slope. Such a mode of transportation of ash clouds might have resulted from the special condition of atmospheric currents. A vigorous emission of ash clouds lasted for over one hour and were transported in such a way as if they were on a large moving belt. At Kyû-karuizawa, the ash fall lasted for about 20 minutes. Ash falls from this eruption were also reported at Tôkyô, etc. The mode of this eruption was considered to be unusual compared with an ordinary eruption which consist of the sporadic emission of an ash cloud with a brief duration. The tendency of continuous emission of ash clouds was maintained throughout the whole day of Dec. 6. Since Dec. 7, the eruptive activity tended to decrease in intensity, the number of ash eruptions decreasing gradually except on Dec. 11 when there was a minor surge of eruptive activity with frequent occurrence of minor ash eruptions. All of the ash eruptions which have occurred since Dec. 7 showed the tendency of continuous emission of ash clouds to some extent. In the intervals of ash eruptions, large amounts of white vapour clouds rose up in succession.

During the whole day of Dec. 13 the amount of emitted white vapor became much less, and on the morning of Dec. 14 it almost entirely stopped. At 11:55 a. m. on Dec. 14, there was an intensive outburst (Figs. 20 and 24). At 1:02 p. m. on the same day another minor outburst took place. Minor ash eruptions followed after these outbursts, occurring repeatedly through Dec. 14 and 15. Black ash clouds were lifted up into the air in succession and immediately swept away eastward by strong winds. This was the last outburst which occurred during the period of eruptive activity in 1958. After that the eruptive activity of the volcano decreased in intensity, continuing with gradual diminution until Dec. 25, except on Dec. 17 and 19 when minor ash eruptions took place repeatedly. From the afternoon of Dec. 25 to Dec. 27, volcanic tremors were registered frequently and the amount of discharged vapor clouds increased remarkably, but no eruption was observed. From Dec. 26 Mt. Asama discontinued its eruptive activity.

The eruptive activity in 1959. In Jan. and Feb. 1959, no eruption of the volcano was reported, but a faint reddish glow was sometimes observed in the dark upper air above the crater during midnight, which indicated the exposure of a red heat surface of magma on the crater-bottom. After a short duration of quiescence, the eruptive activity of the volcano recurred with an outburst at 7 : 00 p. m. on March 10, 1959. The ash cloud was carried north-eastward by winds, resulting in the falling of lapili and ash at Rokuri-ga-hara, Kita-karuizawa, etc. At 8 : 30 p. m. on Apr. 14, another major outburst took place, rising up a black mushroom cloud to a height of 7,000 m above the crater. A large amount of red heat ejecta was thrown up into the dark sky. Dead grass and bush were burned by the heat of falling ejecta at many points on the upper mountain-slope. Violent roarings and rumblings continued for about 8 minutes. The ash cloud was carried south-eastward by winds, resulting in a shower of lapili and ash in an area to the volcano. At Naka-karuizawa, the amount of the ash fall was reported to have been about 300 g/m^2 by the Karuizawa Weather Station. Ash falls were also recognized at Chichibu, Tôkyô, Yokohama, etc. The initial velocity of the ejection was estimated to be 165 m/sec and the initial pressure of gas to be 202 atmospheres by the Karuizawa Weather Station. The total mass of ejected materials was calculated as 1×10^4 tons and the total volume as $7\times10^3 m^3$ by the writers, which puts the outburst in the grade I of Tsuya's intensity scale. The total kinetic energy may become 1×10^{18} erg. Pumiceous bread-crust bombs were predominant against dense blocks of consolidated rock fragments in the ejecta from the outburst (Figs. 33～35 and 40). This is a remarkable feature of this outburst compared with that of the ejecta from the former outbursts occurring in 1958 which consisted mainly of dense blocks of consolidated rock fragments and of less porous bread-crust bombs. It might be inferred that on the bottom of the crater the top of the new molten magma was exposed, from which the outburst took place.

After the outburst on Apr. 14, the eruptive activity consisting of minor repeated ash eruptions continued with some surges through the latter half of Apr., and in May and June. In the latter days of June the explosive activity revived with outbursts on June 25 and 30. Very porous ejecta of pumice were predominate in these two outbursts (Figs. 41 and 42). Repetition of minor ash eruptions continued with rather sporadic occurrence. Vigorous emission of white vapor also lasted in the intervals of each ash eruption. On July 16 and 21, outbursts occurred, and these two were the last ones which occurred during the period of eruptive activity in 1959. In these outbursts almost entirety of ejected materials consisted of very porous pumice and scoria (Figs. 43 and 44~46). The eruptive activity continued until the latter days of Aug., showing general diminution in intensity, and at last died down to the ordinary fumarolic activity. From Sept. there came a long halt in the volcano. Through this halt the volcano only emitted white vapor clouds from the crater. On the bottom floor of the crater-pit there remained a large explosion hollow, at the center of which the top of the conduit of magma was exposed (Fig. 31).

The eruptive activity in 1961. After a long duration of quiescence of about 23 months, from Sept., 1959, to Aug., 1961, Mt. Asama suddenly entered into an active state. The volcano seemed to show a faint symptom of eruptive activity with a little increase of volcanic tremors from the middle of July to the end of the same month. From Aug. 16 the number of volcanic tremors registered by the seismographs of the Asama Volcanic Observatory began to increase greatly. At 2:24 p.m. on Aug. 18, the volcano broke out in intensive explosion. The explosion began with an emission of white smoke, then followed by the rapid rise of a black ash cloud which immediately grew into a large mushroom. The top of the mushroom reached to a height of 7,000 m above the crater. Forcible detonation and airshocks were felt over a wide area around the volcano. Violent roarings and rumblings were heard from the crater for about 17 minutes after the initial outburst. A smaller part of the rising ash column began to descend and flowed laterally along the upper mountain-slope of the volcano, showing a state of flowage like minor pyroclastic flows (Fig. 25). A greater part, almost all, of the ash column was lifted into the air, and then carried southeastward by winds. A heavy shower of lapili and ash attacked the ground over the southern foot of the volcano. 1,370 g/m^2 of ash fall was measured at the Karuizawa Weather Station. Ejected large blooks and bombs fell on the ground in a circular area having radii of about 1.5 km from the crater. Ejected materials consisted of consolidated rock fragments and bread-crust bombs (Figs. 47 and 48). One man who might have been on the top at the moment of the outburst was lost, and two climbers on the upper mountain-slope were slightly injured by falling ejecta, but fortunately many other climbers had already descended because of bad weather, escaping unhurt. A heavy shower of lapili and ash caused some damage to crops. Ash falls from the outburst were recognized at Atami, Kôfu, Fuji-yoshida, etc. Emission of black ash clouds followed after the outburst and lasted until 3 : 40 p. m. of the same day. The total mass of ejected materials from this outburst was estimated as 1×10^5 tons and the total volume as 7×10^4 m^3 by the writers, which puts the outburst in the grade II of Tsuya's intensity scale.

Afterwards, the eruptive activity continued with intermittent occurence of minor ash eruptions with some surges. On Sep. 15 slight detonations were heard from the volcano. On Sept. 5, 9, 19 and 20, minor ash eruptions took place repeatedly, discharging large amounts of ash laid clouds. On the latter days of Sept. no eruption was observed, but during the early days of Oct. the eruptive activity of the volcano consisted of a surge. On Oct. 3, 6 and 7, minor explosion occurred (Fig. 27). Ejected materials from these explosions consisted of consolidated rock fragments and bread-crust bombs (Fig. 36). During remainder of Oct. no eruptive activity was observed except on Oct. 12, 13 and 24. During the early and middle days of Nov. there came the last surges of the eruptive activity in 1961. On Nov. 5 and 7 minor outbursts occurred. On Nov. 7, 15 and 16 minor ash eruptions took place very frequently, and in the afternoon of Oct. 16 the eruptive activity stopped suddenly, dying down to the ordinary fumarolic activity. After that Mt. Asama has been in a state of quiescence up to the present (Dec., 1963). At the latest stage of the eruptive activity of 1961, the top of the new molten magma might have ascended filling over the crater bottom, judging from the photographs of the crater-pit which were taken after the eruptive activity entirely ceased. Through the period of quiescence after the last eruption, white vapor and fume were emitted alomst ceaselessly from the outer edge as well as from the centers of consolidated new lava pool (Figs. 31 and 32).

Ash Falls

Every intensive outburst of Mt. Asama throws up a large amount of solid materials into a mushroom cloud to a height of several thousands of metres above the crater in two minutes or so. The violent ejection of solid materials usually lasts only a minute or less, and the mushroom loses shape immediately, being carried away by winds. Then falling materials from the explosion cloud cause a heavy shower of ash and lapili over the areas on the leeward. The wind in the higher levels of the region around the volcano, especially in the winter season, are prevailingly from the west, accounting for the narrow belt of the distribution pattern of ash fall. From almost all of the eruptions of Mt. Asama, from 1958 to 1961, ash blown to higher levels was usually transported eastward at a fairly high speed into an eastern quadrant across the Kantô District. During the explosion on Aug. 18, 1961, the atmospheric condition was somewhat different from the ordinary state, resulting in ash fall in a southern quadrant (Figs. 2 and 3).

The ash fall from the explosions on Nov. 10 and 11, 1958. The ash cloud blown up into the air by the explosion on Nov. 10, 1958, was transported to the east-northeast, settling a large amount of ash and lapili over a wide area in the northern part of the Kantô District. At the initial moment of the explosion, the direction of wind might have been east-northeast, causing a heavy ash fall of coarse grain in this direction. However, the direction of wind might have shifted gradully immediately after the initial outburst, from east-northeastward to north-eastward. The writers surveyed the situation of the ash fall along the the road running from the south to the north on the eastern slope of the volcano. They measured the amount of ash fall in a unit area, and collected samples in order to examine their size characteristics. They found that deposits of lapili were distributed on the southside of the whole distribution of ash and lapili fall, while finer deposits of ash were on the northside, overlying the deposits of lapili. According of such overlapping of coarse and fine deposits and the shift in the direction of distribution, the size characteristics of the deposits show remarkable variation from place to place. These facts may be considered to indicate that the explosion consisted of the initial instantaneous shooting of coarser materials with higher initial velocity and succeeding effusion of

Table 1. The results of mechanical analyses of ash fall deposits. The result of a given specimen is noted in the column beneath its specimen number with weight per cent of each fraction.

ϕ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
~−4.5																				
−4.5~−4									7.8											2.5
−4 ~−3.5		3.4		14.9	14.4	40.8	22.7	20.4	13.5			22.9					3.4			3.3
−3.5~−3	26.0	21.9		25.8	9.9	16.2	14.3	10.9	7.2	5.3	1.5	16.6					4.4		2.4	4.6
−3 ~−2.5	26.5	22.2	3.7	20.0	6.2	11.0	11.0	8.5	5.5	3.7	0.5	11.1			1.6		4.0		3.0	4.9
−2.5~−2	21.5	25.5	16.3	12.6	1.9	3.8	7.6	5.1	3.4	2.9	1.3	7.6			2.4		4.4	1.8	3.9	5.4
−2 ~−1.5	11.3	12.0	18.4	3.3	0.7	1.0	6.4	6.2	4.3	2.5	1.7	4.3			2.8	3.0	4.2	3.4	4.5	4.3
−1.5~−1	5.7	4.3	18.5	0.9	0.7	1.0	5.2	7.4	7.1	2.8	3.0	3.8		0.1	3.4	4.0	5.6	3.8	4.7	7.4
−1 ~−0.5	2.3	0.9	18.4	0.2	1.2	1.0	4.8	7.9	8.7	3.6	4.3	2.8		1.6	4.5	4.8	14.0	5.8	4.5	6.3
−0.5~ 0	1.2	2.9	13.2	0.1	2.4	2.5	5.5	7.9	11.0	4.2	4.0	2.7		5.3	5.9	5.9	27.9	5.0	5.0	6.8
0 ~ 0.5	5.5	3.6	3.5	0.2	5.6	8.9	7.8	6.3	9.9	7.7	3.0	3.5		21.3	8.1	8.1	26.3	7.0	7.3	8.8
0.5~ 1		1.1	1.5	0.3	5.7	2.9	5.7	4.6	6.0	11.9	6.5	4.6	3.0	32.4	13.6	6.7	3.7	11.3	8.7	8.8
1 ~1.5		0.8	0.5	1.2	5.6	1.9	3.1	4.0	4.9	11.6	13.4	6.3	5.7	18.8	19.9	5.5	0.5	9.7	9.3	8.9
1.5~ 2		0.5	1.0	3.5	5.7	1.3	2.4	3.0	3.5	12.1	19.3	5.6	15.5	2.8	17.5	10.0	0.4	9.4	9.7	7.0
2 ~2.5		0.4	2.2	6.0	5.7	1.3	1.1	2.5	2.6	11.1	13.0	3.6	30.8	3.7	9.8	11.5	0.4	9.8	9.0	5.8
2.5~ 3		0.2	1.3	4.2	5.6	1.2	0.6	1.7	1.7	5.6	6.8	1.7	21.8	8.0	3.2	9.5	0.4	8.0	7.6	4.2
3 ~ 4		0.2	1.1	4.1	10.6	1.7	0.7	1.6	1.2	5.3	6.5	1.1	14.4	2.9	2.3	14.0	0.4	11.7	9.9	5.2
4 ~ 5		0.1	0.3	2.0	10.1	1.8	0.6	0.5	0.5	3.2	5.2	0.8	4.5	1.3	1.1	7.5		7.2	5.0	2.3
5 ~ 6			0.1	0.7	6.0	1.7	0.5	1.5	1.2	6.5	8.3	1.0	4.3	0.8	1.1	5.3		4.1	1.8	1.2
6 ~ 7					2.0						1.6			0.4	1.5	2.7		0.7	1.4	0.8
7 ~ 8											0.1			0.6	1.3	1.5		0.7	1.1	0.7
8 ~ 9																		0.3	0.7	0.4
9 ~																		0.3	0.5	0.4

The figure in the lowest fraction of each column represents the rest weight per-cent in the finer fractions of each specimen.

copious amounts of finer materials with lower initial velocity. The first shooting may represent the initial phase of the outburst and the succeeding effusion may correspond to the later phases of discharge of pyroclastic flow and of subordinate ash eruption. The microbarometer at the Karuizawa Weather Station recorded a long micro-oscillation of atmospheric pressure continuing for about 1 minute, which indicated that the explosion on Nov. 10 consisted of not only one momental phase of outburst but also a duration of eruption.

The ash cloud blown up by the second outburst on Nov. 11 was carried eastward by winds. The distribution of the ash fall was shifted slightly to the south from the distribution of the ash fall from the first outburst on Nov. 10 (Fig. 1). During this outburst a small amount of pumiceous ejecta was discharged.

The writers collected 14 specimens of ash fall deposits from the outburst on Nov. 10 and 11, and carried out their mechanical analyses. The localities of the specimens collected are shown in Fig. 1. The results of the mechanical analyses are shown in Table 1, where figures

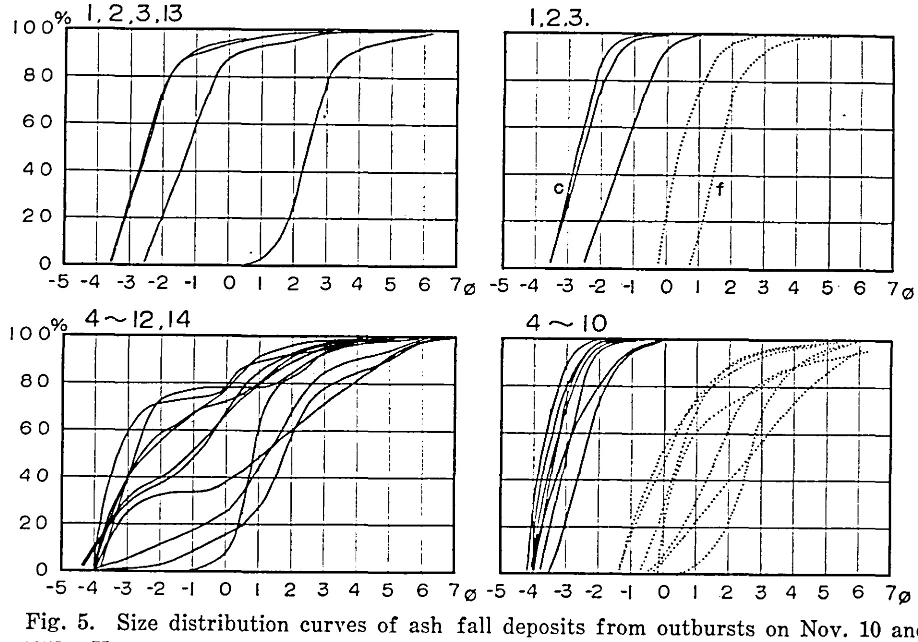


Fig. 5. Size distribution curves of ash fall deposits from outbursts on Nov. 10 and 11, 1958. Upper: the ash fall from the outburst on Nov. 11. Lower: the ash fall from the outburst on Nov. 10. The left diagrams show the whole curve of each specimen, and the right diagrams show the separate curves of two units with different coarseness in each specimen, i. e., c (solid curve) represents the coarser unit and f (dotted curve) represents the finer unit.

Table 2. Data on parameters of particle size distribution.

Sp. no.	$M\alpha\phi$	$M\phi$	Q'	Q''	$\sigma\phi$	$\alpha\phi$	$\alpha_2\phi$	$\beta\phi$	Remark
1	−2.55	−2.38	0.54	0.22	0.83	0.21	1.19	1.26	1958-XI-11-fa
2	−2.45	−2.43	0.54	−0.07	0.78	0.03	1.10	1.35	〃
3	−1.16	−1.16	1.20	−1.03	0.96	0.00	−0.08	1.33	〃
4	−2.78	−0.70	0.78	0.61	2.79	0.75	0.95	0.27	1958-XI-10-fa
5	1.12	0.37	3.16	−0.59	3.82	−0.20	−0.09	0.21	〃
6	−3.24	−1.73	1.66	1.40	2.10	0.72	1.25	0.69	〃
7	−2.37	−1.66	1.62	0.07	2.06	0.34	0.61	0.36	〃
8	−1.57	−1.38	1.69	−0.08	2.25	0.08	0.40	0.44	〃
9	−0.92	−1.39	1.79	−0.64	2.34	−0.20	0.03	0.38	〃
10	1.23	0.85	1.14	−0.16	2.05	−0.19	0.02	1.11	〃
11	1.70	1.90	0.89	1.84	1.93	0.10	0.15	0.84	〃
12	−2.53	−1.15	1.90	1.08	2.52	0.55	1.53	0.25	〃
13	2.42	2.58	0.47	0.28	0.73	0.21	0.79	1.43	1958-XI-11-fa
14	0.83	1.33	0.45	0.40	1.05	0.48	0.62	0.59	1958-XI-10-fa
15	1.22	0.89	0.77	0.74	1.29	0.26	0.10	1.26	
16	2.07	1.99	1.46	−0.24	2.12	−0.04	0.11	0.67	
17	−0.30	−0.88	5.85	−0.06	1.15	−0.50	−0.95	0.69	1959-IV-14-fa
18	1.63	1.72	1.34	0.04	2.02	0.04	0.11	0.68	1958-XI-10-fl
19	1.33	1.05	1.21	−0.20	2.33	−0.12	−0.01	0.66	〃
20	0.26	−0.01	1.66	−0.24	3.45	−0.08	0.02	0.14	〃
1c	−2.67	−2.66	0.43	0.00	0.60	0.06	0.26	0.53	
2c	−2.55	−2.50	0.46	0.55	0.74	0.07	0.27	0.53	
2f	0.42	0.70	0.53	0.40	0.78	0.35	1.01	0.77	
3c	−1.25	−1.28	0.62	−0.10	0.86	−0.03	0.08	0.50	
3f	1.53	1.70	0.44	0.25	0.69	0.24	0.66	0.82	
4c	−3.08	−2.90	0.40	0·25	0.61	0.30	0.34	0.45	
4f	2.62	2.91	0.52	0.19	0.93	0.31	0.31	0.92	
5c	−3.40	−3.28	0.39	0.23	0.56	0.23	0.48	0.46	
5f	2.90	2.70	1.48	−0.41	2.08	−0.58	−0.02	0.41	
6c	−3.08	−3.37	0.33	−2.46	0.50	−0.58	−0.17	0.57	
6f	0.60	1.71	1.14	1.16	1.70	0.06	1.17	0.73	
7c	−3.10	−2.80	0.70	0.43	0.98	0.31	0.63	0.47	
7f	0.44	0.71	0.59	0.44	0.96	0.28	0.94	1.02	
8c	−3.43	−0.33	0.41	0.44	0.59	0.27	0.66	0.30	
8f	−0.12	0.35	0.97	0.22	1.46	0.32	0.76	0.63	
9c	−3.57	−3.28	0.51	0.67	0.76	0.39	0.80	0.58	
9f	0.03	0.27	0.87	0.07	1.36	0.18	0.49	0·65	
10c	−2.47	−2.38	0.50	0.80	0.75	0.12	0.40	0.60	
10f	1.60	1.79	0.82	0.05	1.44	0.13	0.95	1.17	
11c	−0.85	−1.25	0.49	−0.65	0.91	−0.43	−1.10	1.05	
11f	2.02	2.86	0.83	0.65	1.66	0.51	0.70	0.48	
12c	−3.24	−2.92	0.55	0.61	0.81	0.40	0.89	0.73	
12f	1.36	1.82	0.69	−1.97	1.05	0.44	0.64	1.28	
14c	0.67	0.70	0.33	0.15	0.47	0.06	−1.15	0.74	
14f	2.81	2.98	0.32	0.25	0.60	0.28	0.90	1.13	

c: coarser unit, f: finer unit.

listed in the column represent the weight per cent of each fraction evaluated by the mechanical analyses. Fig. 5 shows the particle size distribution of the specimens by cumulative curves. The diameter of particles in millimetres ξ are replaced here by ϕ as expressed $\phi=-log_2\xi$. The values of parameters of size distribution curves are listed in Table 2. Here, Md_ϕ, Q' and Q'' are median, deviation or sorting coefficient and skewness respectively by the quartile methods, and M_ϕ, σ_ϕ, α_ϕ and $\alpha_{2\phi}$, and β_ϕ are mean, deviation, skewness and kurtosis of the Inman's phi measure system (Inman, 1952). No specimen of the ash fall from the explosion on Nov. 10 shows the usual size characteristics of ash fall deposits; i. e. well-sorted, uni-modal and positively skewed size characteristics. Each specimen tends to show irregular and changeable size distributions. As concerns to specimens nos. 1~11 which were collected from spots about 4 km off the crater, values of Md_ϕ show a very wide range of -3.2 to 1.7. Among them specimens nos. 1~4 and 6~7 are much coarser than the other specimens. The variation of Md_ϕ value from place to place is shown in Fig. 8. Values σ_ϕ are also in a wide range of 0.8 to 3.8. There was found a distinct variation of size distribution curves among these specimens.

Specimens nos. 1, 2 and 3 show well-sorted size characteristics of typical ash fall deposits (Fig. 5). They included a small amount of pumice, compared with the lack of pumice in specimens nos. 5~11, and were considered to be deposits from the outburst on Nov. 11. Each curve of particle size distribution of specimens nos. 1~3 shows a sharply cut end in the coarser part and a tailing end in the finer part, with a mode skewed towards the coarser fractions. There was found a slight irregularity in the finer tailing end of each curve, and the curve is able to be divided into two units on both sides of this irregularity (Fig. 6a and Table 2). The coarser main unit represents the ash fall from the main phase of the outburst and the finer subordinate unit represents the ash fall from the succeeding minor ash eruption. The former unit (Md_ϕ: $-2.7\sim-1.2$, σ_ϕ: $-0.60\sim0.86$, α_ϕ: $-0.03\sim0.07$, β_ϕ: $0.50\sim0.53$) is of course by far coarser and predominate than the latter unit (Md_ϕ: $0.4\sim1.5$, σ_ϕ: $0.69\sim0.78$, α_ϕ: $0.24\sim0.35$, β_ϕ: $0.77\sim0.82$), and consequently the irregularity on the size distribution curve which resulted from the mixing of two units of different coarseness is situated on the tailing end of the finer part with insignificant grade. In general, specimens of ash falls collected near the crater usually show such mixing of two or more units which correspond to the main phase of outburst and subord-

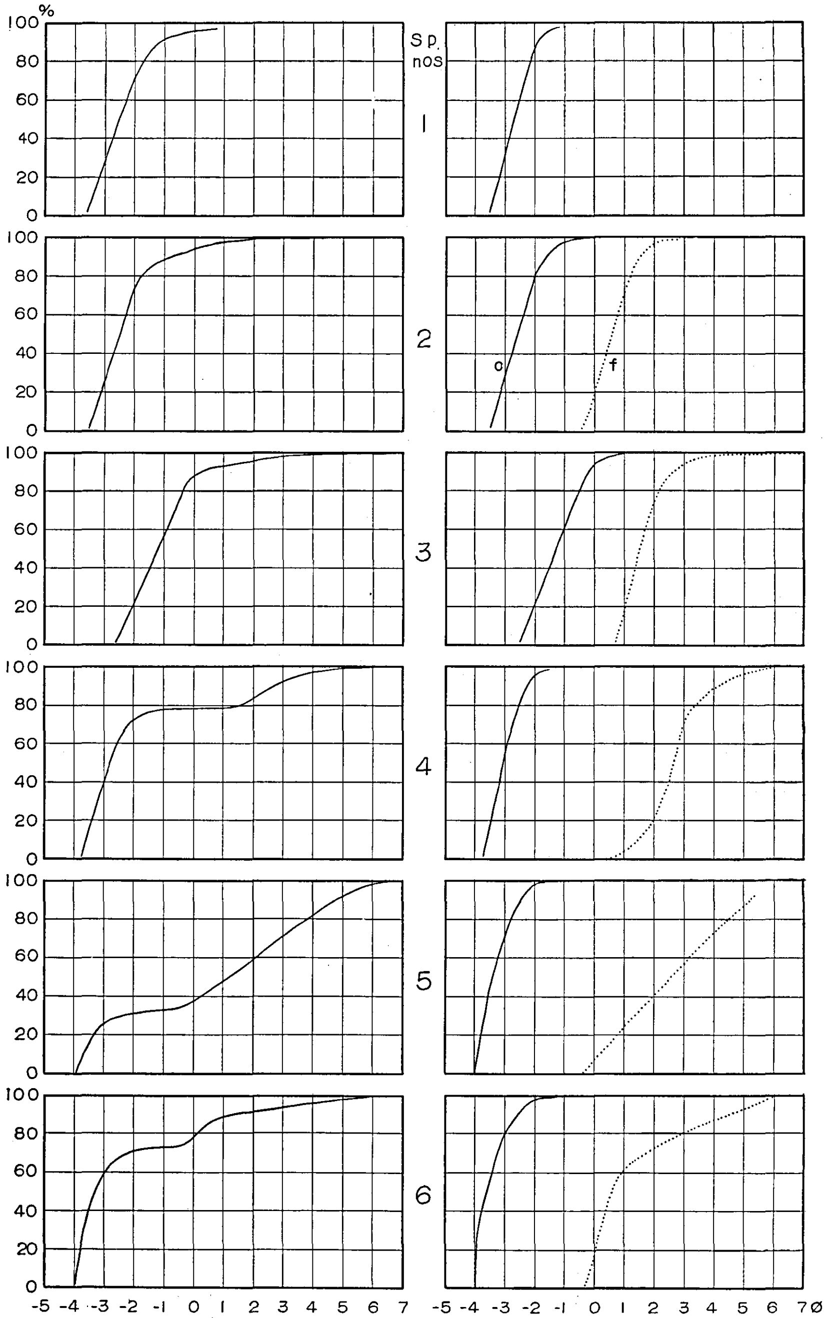
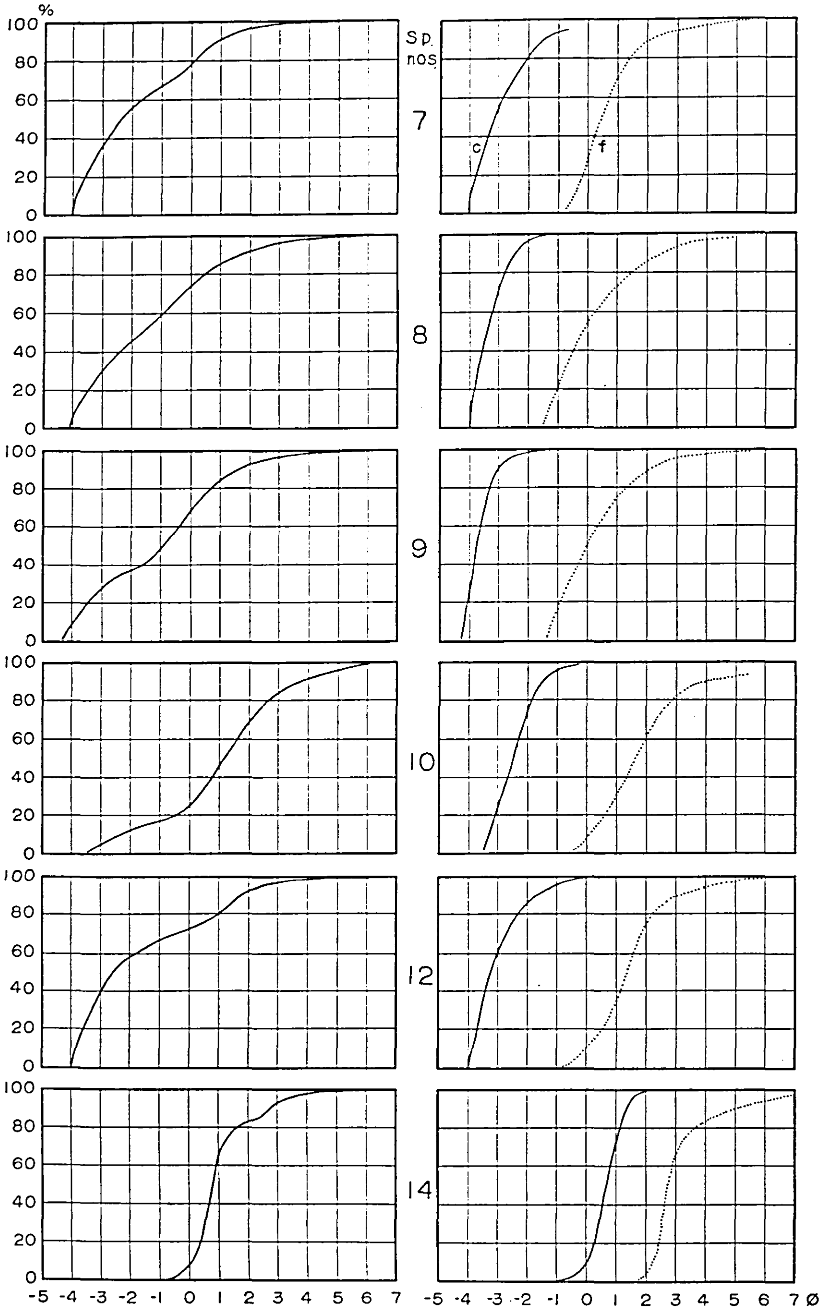


Fig. 6a. Size distribution curves of ash fall deposits from outbursts on Nov. 10 and 11, 1958, showing the curve of each specimen separately. The right diagrams show separate curves of two units with different coarseness in each specimen, as those in Fig. 5.


%
100
80
60
40
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0
Sp. nos.
7
8
9
10
12
14
c
f
-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 Ø

Fig. 6 b. Ditto.

inate phase or phases of succeeding minor eruptions of ash.

Specimens nos. 4~11 are considered to have been settled from the eruption cloud on Nov. 10. They show unusually irregular size distribution curves, having a tendency of bimodal to polymodal property. Both their coarseness and shape of curve exhibit remarkable variation from specimen to specimen. Md_ϕ values are larger than those of specimens nos. 1 and 2 except specimens nos. 4 and 6, which indicate finer grain-sizes of the deposits, in spite of the magnitude of the outburst on Nov. 10 being a hundred times larger than the outburst on Nov. 11. Each curve of particle size distribution is able to be divided into two curves

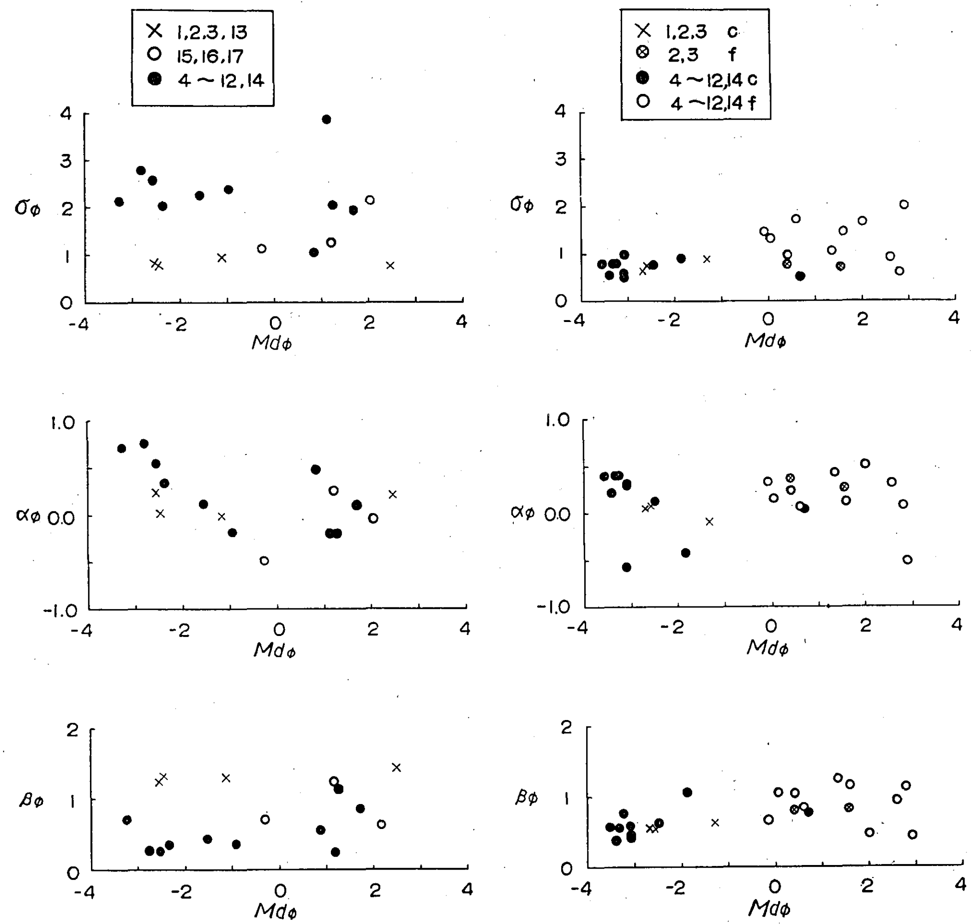

Fig. 7. Diagrams showing the relation of the values of $\sigma\phi$, $\alpha\phi$ and $\beta\phi$ to the values of $Md\phi$. Figures in the squares above the diagrams represent sp. nos., and c and f represent the coarser and finer units in each specimen respectively.

of coarser and finer units, parting two modes in the original curve from each other, as was done in the case of specimens nos. 1～3 (Fig. 6 and Table 2). The coarser unit of each specimen represents the lapilli fall from the eruption column ejected at the initial phase of the outburst, while the finer unit represents the ash fall from the ash cloud discharged during the succeeding phases. As already mentioned in the preceding chapter, the explosion on Nov. 10 is considered to have consisted of the initial phase, rising of explosion mushroom and shooting of blocks and bombs, and the succeeding phases, discharge of pyroclastic flow and subordinate emission of ash cloud. Thus the peculiarly changeable size characteristics of these specimens are considered as the results of mixing of some units of different coarseness. As a matter of fact, the finer ash deposits were overlaid on the coarser lapilli deposits on the spot. However, the writers could not separate these units of fall because of their thinness. The distribution curve of the coarser unit of each specimen shows the general features of well-sorted pyroclastic fall deposits. Md_ϕ values are in a range of $-3.57\sim-0.85$, σ_ϕ values are $0.50\sim0.98$, α_ϕ values are $-0.58\sim0.39$ and β_ϕ values are, $0.30\sim1.05$. The distribution curves of the finer unit of some specimens, however, show very bad-sorting, indicating the mixing of ash fall layers of different coarseness settled during the long duration of vigorous ash eruption (Fig. 7). Md_ϕ values are $-0.12\sim2.90$, σ_ϕ values are $0.93\sim2.08$, α_ϕ values are $-0.58\sim 0.51$, and β_ϕ values are $0.41\sim1.28$. As already mentioned, the direction of the atmospheric current might have shifted from east-northeastward to northeastward during the long duration of discharge of eruption cloud. The direction of the ash fall with coarser sizes in the initial phase might have been east-northeast, while the direction of the ash fall with finer sizes in the succeeding phases might have shifted gradually from east-northeast to northeast. Such a situation of the ash fall and the atmospheric condition may be considered to be responsible for the above-mentioned peculiar size characteristics of the ash fall deposits from the explosion on Nov. 10.

Md_ϕ values of size distribution curves of the coarser unit of specimens nos. 4～10, which represent the main part of the ash fall deposits from the outburst on Nov. 10, are smaller and so indicate coarser grain sizes than those of the coarser unit of specimens. nos. 1～3 of the Nov. 11 outburst. The density of the ash fall, i. e. the amount of ash fall on a unit area, was measured by the writers at the same time of collecting the specimens. The result is shown in Fig. 8. The density

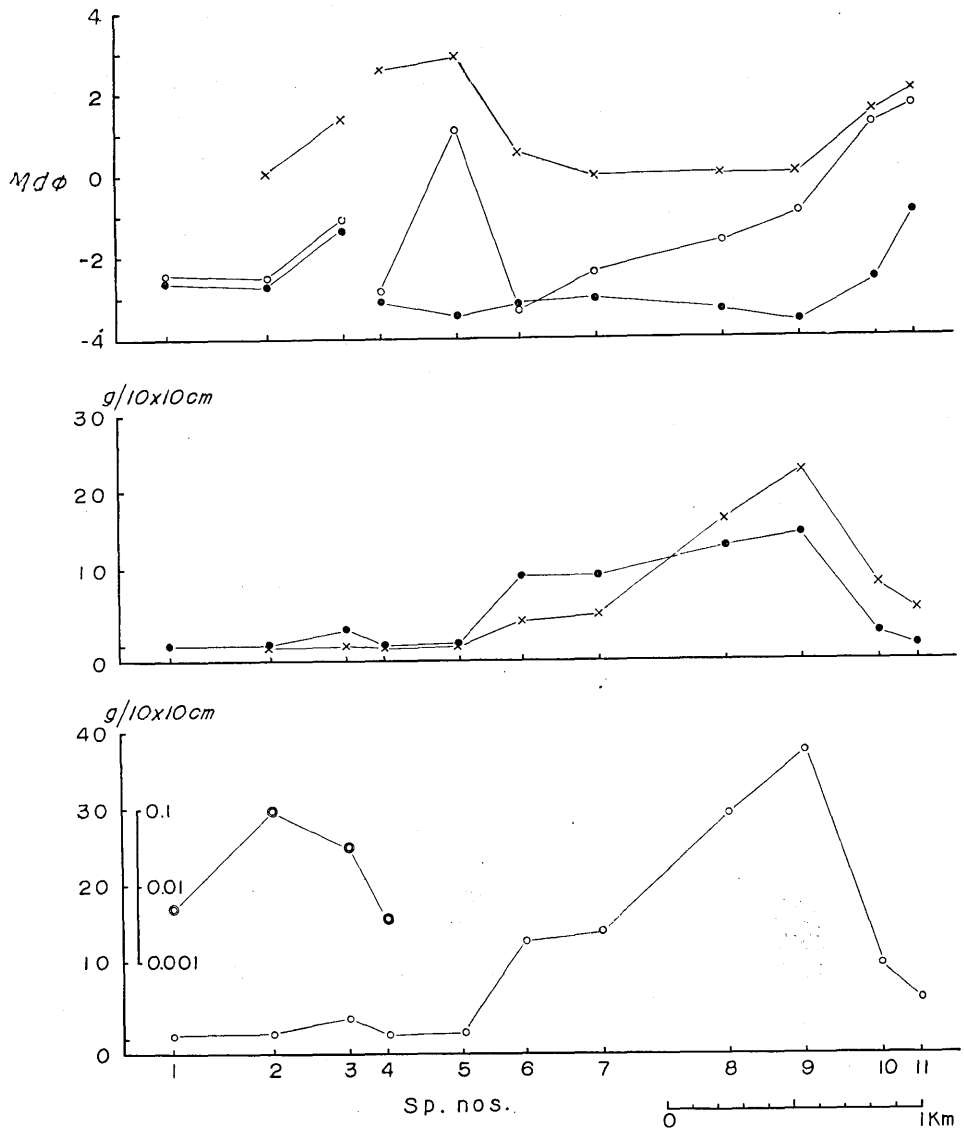

Fig. 8. Variation of coarseness ($Md\phi$ value) and density of ash fall deposits from outbursts on Nov. 10 and 11, 1958, along the road running from south to north on the eastern slope of Mt. Asama. The localities of specimens are shown in Fig. 1. Open circles represent the value of the whole specimen, solid circles represent the value of the coarser unit, crosses represent the value of the finer unit, and double circles represent the value of pumice.

of the ash fall of Nov. 10 was by far larger than that of Nov. 11. Thus both the grain size and the density of ash fall deposits are consistent with the superiority of that of Nov. 10 among the two outbursts. Judging from the density distribution of the ash fall deposits, the center of the ash fall from the Nov. 11 explosion followed the direction of S 81°E. The center of the ash fall from the Nov. 10 outburst followed the direction of N 78°E at the initial phase, then shifted to the direction of N 70°E at the following phase, which perhaps corresponds to the discharge of pyroclastic flow, and at the latter phase of succeeding ash eruption the center of the finer sah fall shifted to a more northward direction.

Specimen no. 12 was collected at Nidoage, 9.5 km off the crater, and specimen no. 13 was collected at Nagahinata, 9 km off the crater. The former is the specimen of the ash fall from the Nov. 10 outburst, showing a similar size characteristics with a poorly sorted and bimodal property. While the latter is a specimen of the ash fall from the Nov. 11 outburst, showing typical size characteristic of well-sorting and of much finer sizes. Specimen no. 14 is a specimen of the ash fall from the Nov. 10 outburst, collected at Shibukawa, 50 km distant from the volcano, also showing a similar irregular curve of size distribution with bimodal property as those of specimens nos. 1~12, although the degree of irregularity is by far smaller. Each curve of particle size distribution of specimens nos. 12 and 14 is also able to be divided into two curves of coarser and finer units as done in the case of specimens nos. 1~10 (Fig. 6).

The ash falls from later outbursts. Each explosion which occurred during the period of eruptive activity at Mt. Asama from 1958 to 1961 resulted in the deposition of ash fall mainly on the eastern mountain-slope of the volcano. Forcible rising of explosion cloud usually lasts only a minute or less, although being followed for some duration by minor ash eruption (Figs. 21, 22, 24 and 27). Size characteristics of ash fall deposits brought from the ash laid cloud from each outburst shows the general character of ash falls, the coarseness of which depends on the magnitude of the outburst responsible. All of the recent eruptions of Mt. Asama are of small magnitude and tend to occur in groups. The volumes of their discharged materials are rather small, and so ash fall deposits from them are usually very thin. Consequently it is very difficult to collect specimens of ash fall deposits from each eruption respectively at each occasion unless by some special means of

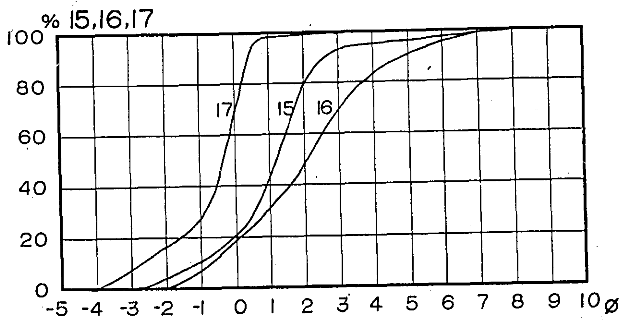

Fig. 9. Size distribution curves of ash fall deposits from outbursts which occurred in Dec., 1958, and on Apr. 14, 1959.

collection. The writers collected several specimens from the later outbursts and carried out mechanical analyses on them. The results are shown in Tables 1 and 2 and Fig. 9. Specimens nos. 15 and 16 are specimens of ash falls intercalated within the layers of new snow on the eastern mountain-slope of the volcano. The former may represent ash falls from the eruptions from Dec. 1 to 8, 1958, including the outbursts on Dec. 4 and 5, showing an irregular size distribution curve due to the mixing of several units of ash falls. The latter may represent ash falls from the eruptions from Dec. 8 to 15, 1958, including the outbursts on Dec. 14, also showing a rather ill-sorted size distribution curve. Specimen no, 17 is a specimen of the ash fall from the explosion on Apr. 18, 1959, showing a more well-sorted size distribution curve than specimens nos. 15 and 16.

Minor Pyroclastic Flows on Nov. 10, 1958, and on Aug. 18, 1961.

The outburst on Nov. 10, 1958, was one of the biggest explosions which have occurred during recent decades. It discharged about $3.6\times 10^5\,m^3$ of fragmental materials, with the grade III of Tsuya's intensity scale of volcanic activity. As concerns the discharged volume, this explosion is larger than the explosion on June 7, 1938, which was considered the strongest one during recent years with the volume of ejected materials calculated to be $2\times 10^5\,m^3$ by Minakami (Minakami, 1942). All of the other eruptions occurring during the period of eruptive activity from 1958 to 1961 belong to the grade I of Tsuya's intensity scale, except the explosion on Aug. 18, 1961, with the grade II. Consequently, it may be considered that the majority of the discharged materials from the volcano during this active period was occupied by the discharged materials from the explosion on Nov. 10, 1958. As mentioned in the preceding chapter, the discharge of a minor pyroclastic flow with the volume of about $2.7 \times 10^5 m^3$ followed after the initial rising of a explosion cloud. Thus, the pyroclastic flow on Nov. 10, 1958, is considered to have a great significance in respect to the volume of discharged materials as well as to its peculiar nature of eruption, among the eruptive activities occurring from 1958 to 1961. The deposits of the pyroclastic flow occupied a wide area on the upper part of the volcano. In the hollow inside the cliff of Maekake-yama, the deposits were accumulated with several metres thickness, the muximum thickness of which was estimated at about 8 metres by the Karuizawa Weather Station (Figs. 13 and 14). The surface of the deposits kept considerably high temperatures for ten or more days after the deposition. The snow falling on the surface of the pyroclastic flow deposits was seen to have thawed immediately (Fig. 15). The deposits consisted of the chaotic commingling of particles of all sizes (Fig. 16). The writers collected several specimens of these and carried out mechaical analyses of them. The result is shown in Fig. 10, although detailed data has already been published

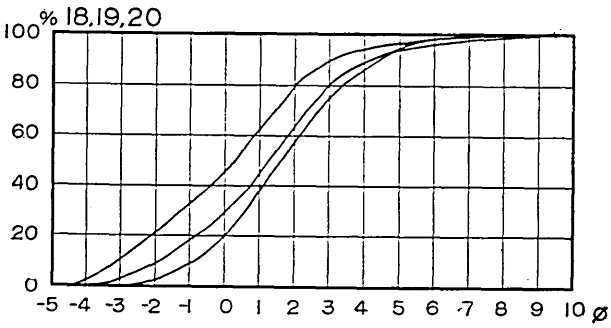

Fig. 10. Size distribution curves of ash fall deposits from the outburst on Nov. 10, 1958.

in the preceding paper by one of the writers (Murai, 1961). They show typical size characteristics of pyroclastic flow deposits. These specimens were collected from the uppermost layer of the deposits, perhaps containing a less amount of coarser fragments. Size characteristics of the whole deposits may be more coarse-grained than those represented by these specimens. The essential fragments of the deposits are not so vesiculated, having a bulk density of over 1.5 in general. The ash exhibited a characteristic reddish color due to the oxidation at the high temperature which might have occurred before the emplacement.

The explosion on Aug. 18, 1961, was also one of the major explosions which has occurred during recent years. It discharged about $7 \times 10^4 m^3$ of fragmental materials, with the grade II of Tsuya's intensity scale. During this explosion a phenonenon like minor pyroclastic flow was observed. A mass of ash cloud was seen to have descended from the outer part of the explosion ash column, flowing down over the upper mountain-slope on the northside of the volcano (Fig. 25). The front of the descending ash cloud reached a range of about 1.5 km off the crater. Ash deposits occupied hollows on the surface of the Onioshidashi lava flow. Leaves of plants died by the heat and gas of the descending ash cloud on the course of the flow. Coating of the wire of seismographs made of vinyl plastic was also burned by the heat of the descending ash cloud but only on one side that faced the crater, and that buried in the deposits from the cloud entirely melted. The total mass of discharged materials in a state of pyroclastic flow was considered to by far smaller than that of the pyroclastic flow on Nov. 10, 1958.

Concluding Remarks

Mt. Asama has experienced violent eruptions accompanied by major pyroclastic flows at several periods in ancient ages as well as historical times. All of these eruptions were of very large magnitude, the grade of which generally belong to VI or more of Tsuya's intensity scale. The last of the large-scale eruptions accompanied by major pyroclastic flows occurred in 1783, and afterwards the volcano has erupted out only as a small-scale explosion type. The mode of eruption is generally called the Vulcanian type, characterized by the sudden shooting of a mass of fragmental materials from the crater-pit (Fig. 49). The ejection of discharged materials is instantaneous, and the main phase of eruption lasts only a minute or less, although being followed by the emission of an ash cloud of less violence for a while. There has not been reported any occurrence of pyroclastic flows in recent eruptions of Mt. Asama. However, the writer recognized minor pyroclastic flows which occurred during the major explosions on Nov. 10, 1958, and Aug. 18, 1961. These explosions were not such violent ones, their grades being only III and II. It is not certain whether similar eruptions which were accompanied by minor pyroclastic flows might have occurred in recent decades. Some reports said that thick deposits of ash piled up near the crater after some outbursts. The hollow inside the crater-cliff of

Maekake-yama has been buried up considerably during recent years. The volume of buried materials seems to be too large to be interpreted as the accumulation of ordinary ejecta falls, although large amounts of materials might have been swept into the hollow from the slope of the central cone by rain-falls. Perhape similar eruptions of minor pyroclastic flows as those on Nov. 10, 1958, and Aug. 18, 1961, might have taken place in recent years. The writers examined a lot of photographs of outbursts which occurred during recent years. Almost entiretly of them showed no indication of the occurrence of minor pyroclastic flow but a few, for instance the photograph of the outburst on July 29, 1936, exhibited some features of descending clouds on the mountain-slope which might be inferred to suggest the occurrence of minor pyroclastic flow (Fig. 49). It may be possible to consider that such minor pyroclastic flow as those on Nov. 10, 1958 and Aug. 18, 1961, may take place again in the eruptions of Mt. Asama in near future.

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11. 昭和 33 年より昭和 36 年に至る間の浅間山の噴火活動と小規模火砕流

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浅間山は昭和30年 (1955 年) 7月以降静穏な状態を続けていたが，昭和33年 (1958 年) 10月より 40 カ月ぶりに噴火活動を開始した．同年7月下旬より火山性地震が増加し，噴煙量の増大，火口底の鳴動などが認められはじめた．このような状態は8月および9月を通じて続き，しだいにその烈しさを増していつた．10月3日には最初の降灰が認められ，その後は微小噴火が繰返して起つた．このような前駆的活動ののちに，11月10日午後10時50分大爆発が起つた．爆発は黒煙の烈しい上昇にはじまり，その下からすさまじい火柱が立ち，同時に赤熱した火山弾が無数に抛出された．黒煙の上昇にともない，その中に烈しい火花と電光雷鳴が起つた．爆発の開始後10秒ほどして，火口から真赤な火の帯が現われ，中央火口丘 (釜山) の斜面を流れ下るようにして噴出してきた．これは高温の火砕流であつたと考えられる．この火砕流の南西方へ流れ出した部分は前掛山の断崖に遮られ，その内側に数 m の厚さの堆積物を残した．この堆積物の表面は 10 日以上の間かなりの高温を保つていた．南方へ流れ出した部分は前掛山の断崖の南縁および東前掛山を越えて溢れだし，仏岩の断崖上に達して止つた．この火砕流の流下速度は 25～30 m/秒と推算された．噴き上げられた黒煙は山頂上7,000m の高度に達し，風によつて東方へ流され，関東地方の北部一帯に火山灰を降らせた．抛出された熔岩塊およびパン皮状火山弾の内最大のものは直径 6 m，高さ 4 m あり，最も遠方まで飛ばされたものは火口より約 3.5 km の地点に達した．烈しい爆風により山麓の町村では多数の窓ガラスが破壊され，その破片により7名の軽傷者を出したが，山頂への登山が禁止されていたため，火山弾の落下による人員の損傷はなかつた．抛出熔岩塊および火山弾の総量は 27,250 トン，降灰総量は 1.2×10^5 トン (7.5×10^4 m^3)，火砕流堆積物の総量は 4×10^4 トン (2.7×10^5 m^3) と計算された．したがつてこの爆発による噴出物の総量は 5.5×10^5 トン (3.6×10^5 m^3) となり，津屋 (1955) による噴火の強度のグレードは III となる．噴出物の総量の点では，この爆発は最近における最大の爆発と考えられている昭和13年 (1938年) 6月7日の爆発の場合 (3.8×10^5 トン，2×10^5 m^3) よりも大きい．この爆発の総エネルギーは 4×10^{19} エルグと推算された．

11月10日の大爆発は約30分ほどで全くおさまつたが，11日3時25分にも爆発が起つた．この際には少量の浮石を噴出したことが特徴的であつた．噴出物総量は 3×10^3 トン (2×10^3 m^3) と計算された．噴火活動はその後も続き，微小噴火を繰返した．12月上旬には，活動は再び活発化し，4日と5日に中程度の爆発が繰返された．6日には爆発を伴わぬかなり大規模な噴火が起り，多量の黒煙が1時間以上にわたつて連続的に噴出された．14日には再び中程度の爆発が起り，その後微小噴火を続けたが，活動の勢力はしだいに衰え，12月26日以降休止期に入つた．

昭和34年 (1959 年) は3月上旬まで噴火が認められなかつたが，火口上に火焔の上るのが認められたこともあり，火口底に赤熱熔岩が露出している状態が示唆された．3月10日の爆発を最初として，再び噴火活動が開始され，4月14日午後8時30分にはかなり烈しい爆発が起つた．この際抛出された物質は多孔質のパン皮状火山弾を主としていた．このことは昭和33年に起つた爆発では，11月11日の爆発を除けば，他の場合はすべて抛出物が熔岩破片とパン皮状火山弾とであつたこととと相異を示していた．噴出物の総量は 1×10^4 トン (7×10^3 m^3) と計算され，また爆発の総エネルギーは 1×10^{18} エルグと計算された．その後噴火活動は続き微小噴火が続けられたが，6月25日および30日には再び爆発が起つた．さらに7月16日および21日にも爆発が起つたが，これらの爆発を最後にして噴火活動は衰え，8月下旬にはついに平常の状態に戻つた．6月と7月に起つた爆発の際には主として非常に多孔質な岩滓および浮石を抛出し，火口底に露出した熔融熔岩から噴火が起つたことを物語つていた．

昭和34年9月より静穏な状態を続けた浅間山は，24カ月の休止期の後に急速に活動期に入つた．

昭和36年 (1961 年) 8月18日，午後2時24分大爆発が起り，死者1名のほか軽傷者2名の損害を出した．この爆発は昭和33年11月10日の大爆発についで大きなもので，噴出物総量は 1×10^5 トン ($7\times10^4\,m^3$) と計算された．この爆発の際，上昇する噴火雲の一部が側方に落ち山体の北斜面にそつて流れ，ごく小規模な火砕流の状態を示した．この爆発による抛出岩片は熔岩破片とパン皮状火山弾よりなつていた．噴火活動はその後も続き10月3日，6日，7日には小規模な爆発が繰返された．11月上旬および中旬に微小噴火が繰返されたが，11月16日午後より噴火活動は停止し，再び静穏な状態に戻つた．その後現在 (昭和38年12月) まで静穏な状態が続いている．

昭和33年11月10日および昭和36年8月18日の二つの大爆発は，昭和33年より36年にわたる浅間山の噴火活動の中での主要なものであつた．特に昭和33年11月10日の大爆発は噴出物の量の点で近年の爆発中最大のものと考えられる．この二つの爆発の際に小規模な火砕流の噴出が認められた．これらは浅間山の噴火において最初に目撃され確認された火砕流である．とくに昭和33年11月10日の爆発の場合は，噴出物総量の 2/3 以上が火砕流として噴出している．この爆発の際の降灰堆積物の粒度組成はかなり特徴的な様相を示し，爆発の最初の時期に射出された噴煙柱よりの粗粒の降下堆積物と，その後に続いた時期 (火砕流の噴出とさらにその後の噴煙の継続した時期) に吹き上げられた噴煙柱よりの細粒の降下堆積物との混合を示していた．浅間山は過去数度にわたり火砕流を伴つた烈しい噴火を行つてきたことが特徴であるが，そのような大規模な噴火は天明3年 (1783 年) を最後とし，それ以後は比較的小規模な単純な爆発 (ヴルカノ式活動) を繰返してきた．この間噴火活動において今回認められたような小規模な火砕流が起つていたかどうか明らかでないが，これまでの記録の中には，その可能性を示唆するものも認められる．おそらく，このような小規模火砕流は遠い過去においてもまた近年においても繰返して起つているのではないかと想像される．そしておそらく将来の噴火活動の際にも起こり得るであろう．

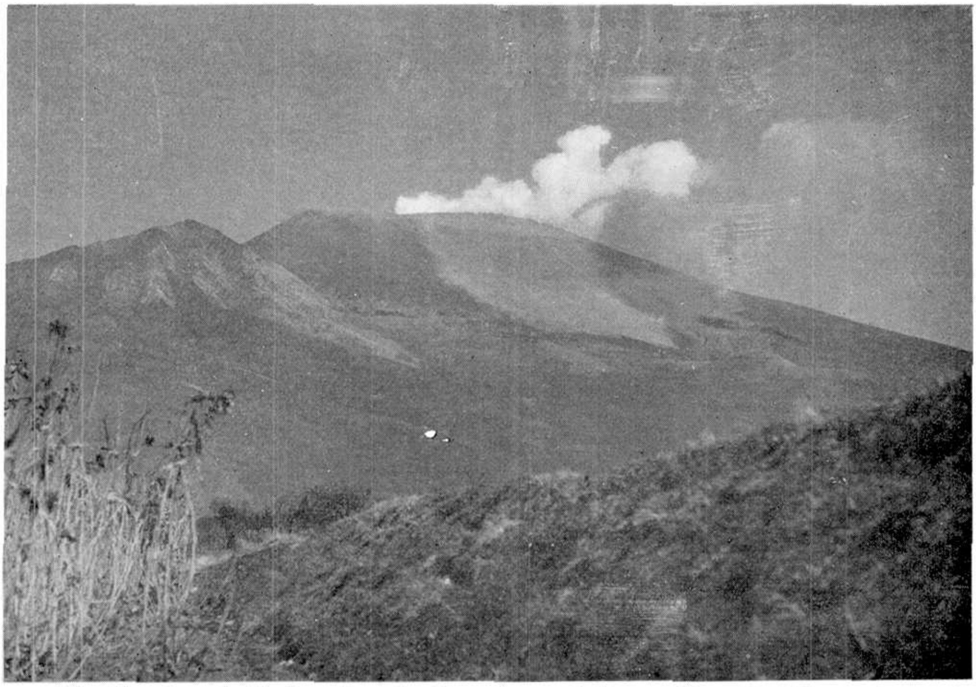

Fig. 11. Pyroclastic flow deposits from the explosion on Nov. 10, 1958, on the southern slope of Maekake-yama. (Photo. taken on Nov. 11 by Mr. Y. Yanagida.)

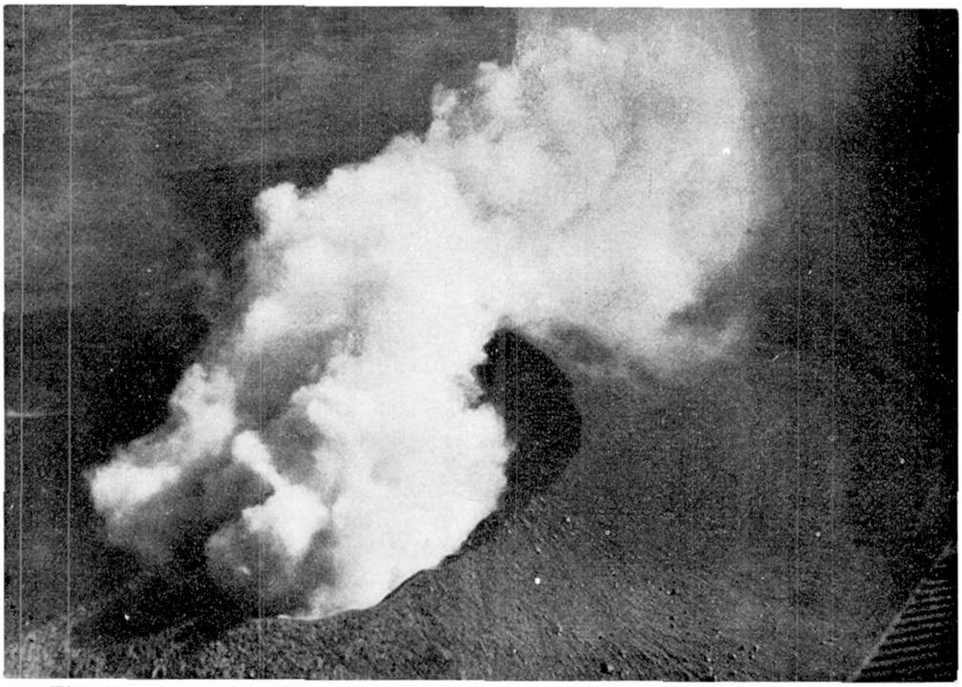

Fig. 12. An aerial view of the crater-pit of Mt. Asama. From the south-west. (Photo. taken on Nov. 11 by The Yomiuri.)

Fig. 13. Pyroclastic flow deposits from the explosion on Nov. 10, 1958, in the hollow called Mugen-dani inside the crater-cliff of Maekake-yama. (Photo, by the Karuizawa Weather Station.)

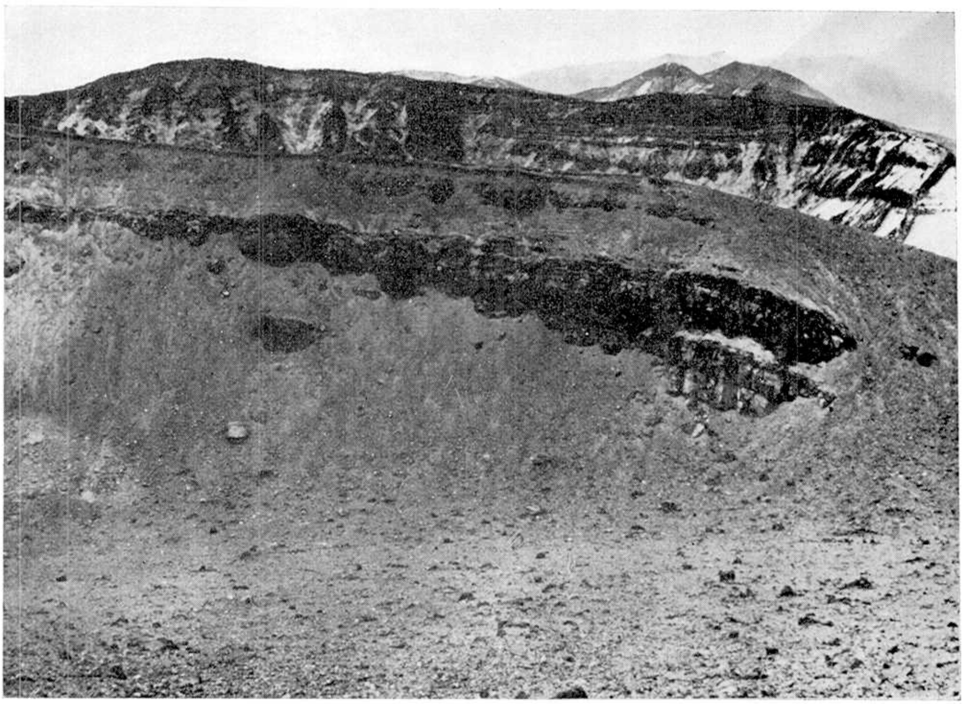

Fig. 14. A view of Mugen-dani prior to the eruptive activity of 1958. When compared with the photo. of Fig. 13, it is clear that the hollow was buried by pyroclastic flow deposits of several metres thickness. (Photo. by Mr. Y. Yanagida.)

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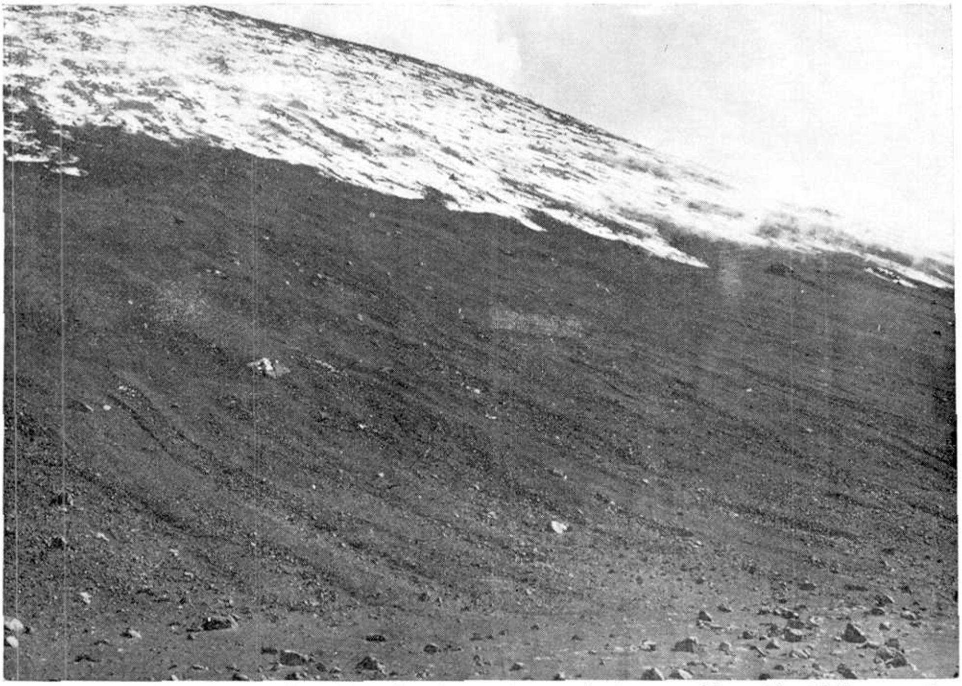

Fig. 15. Pyroclastic flow deposits from the explosion on Nov. 10, 1958, on the southern side of the central cone called Kama-yama. Snow was thawed immediately by the heat of the deposits. (Photo. by the Karuizawa Weather Station.)

Fig. 16. Dittio, at the eastern edge of the crater-cliff of Maekake-yama. (Photo. by the Karuizawa Weather Station.)

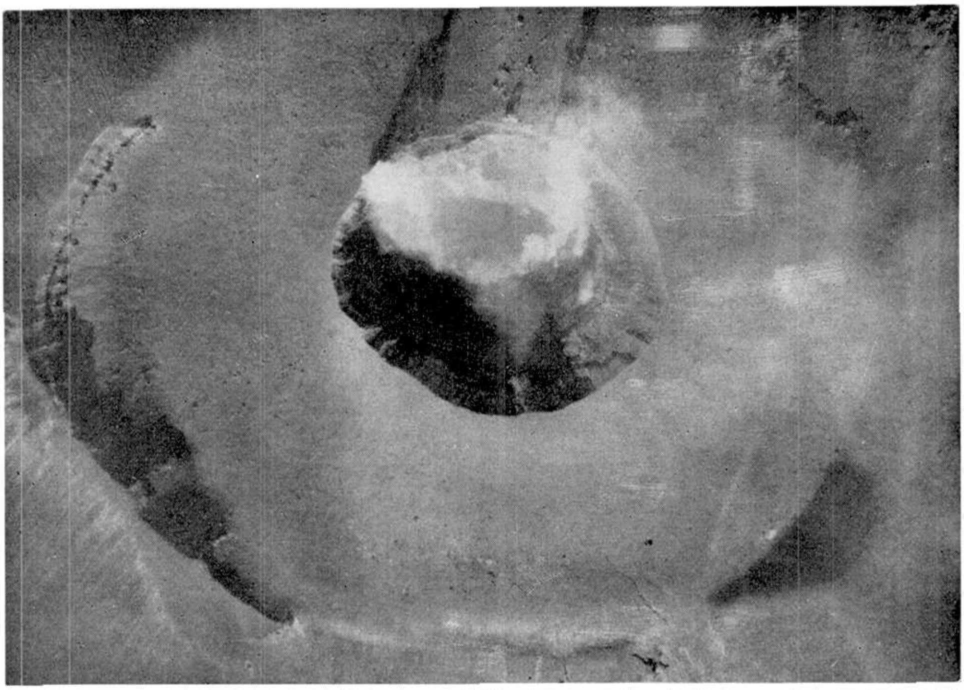

Fig. 17. An aerial view of the top of Mt. Asama prior to the eruptive activity of 1958.

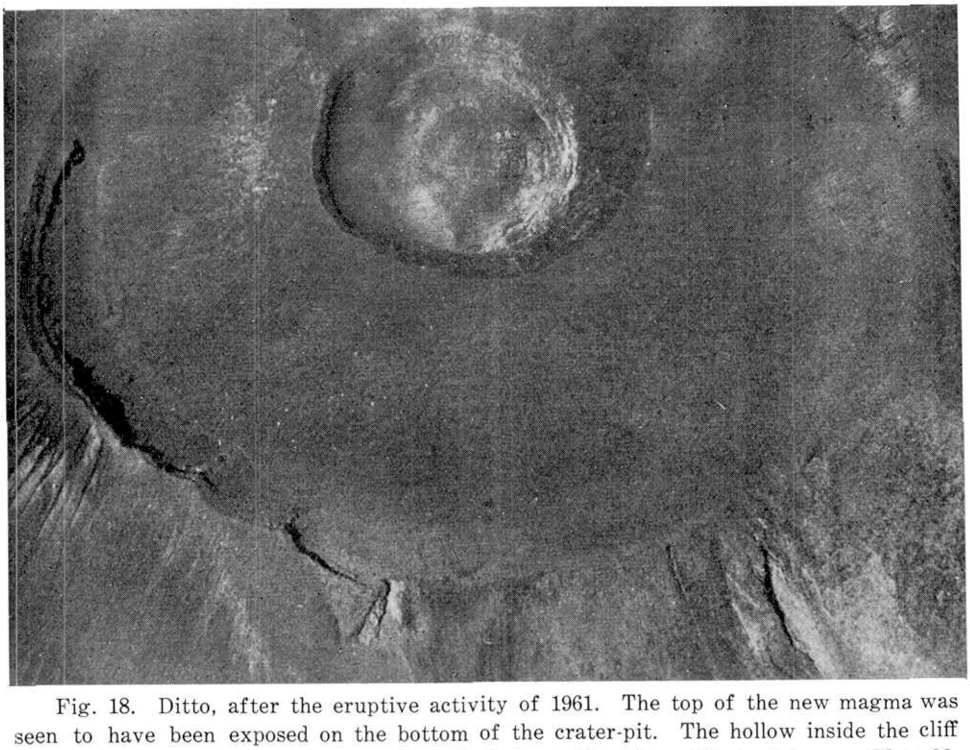

Fig. 18. Ditto, after the eruptive activity of 1961. The top of the new magma was seen to have been exposed on the bottom of the crater-pit. The hollow inside the cliff of Maekake-yama appeared to have been buried considerably. (Photo. taken on May 26, 1962, by the Forestry Agency.)

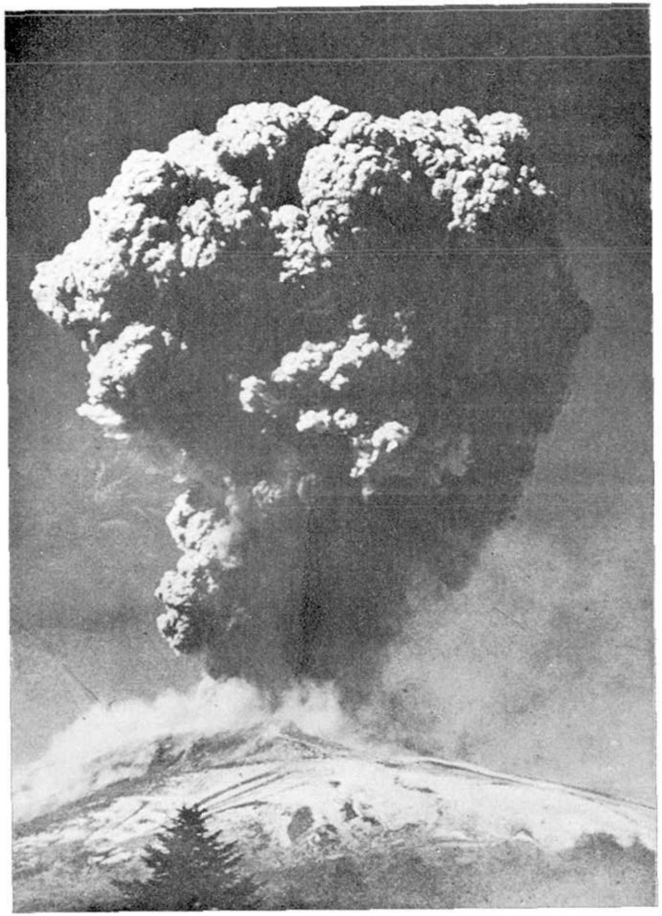

Fig. 19. The eruption cloud of the outburst at 1:08 p.m. on Dec. 5, 1958, viewed from Naka-karuizawa.

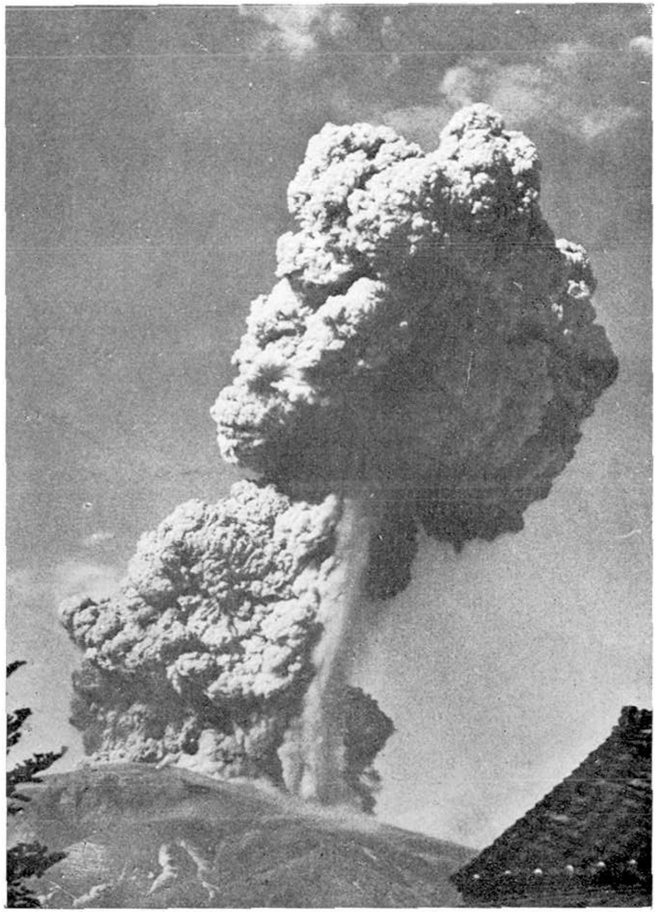

Fig. 20. The eruption cloud of the outburst at 11:55 a.m. on Dec. 14, 1958, viewed from Naka-karuizawa. (Photo. by the Karuizawa Weather Station.)

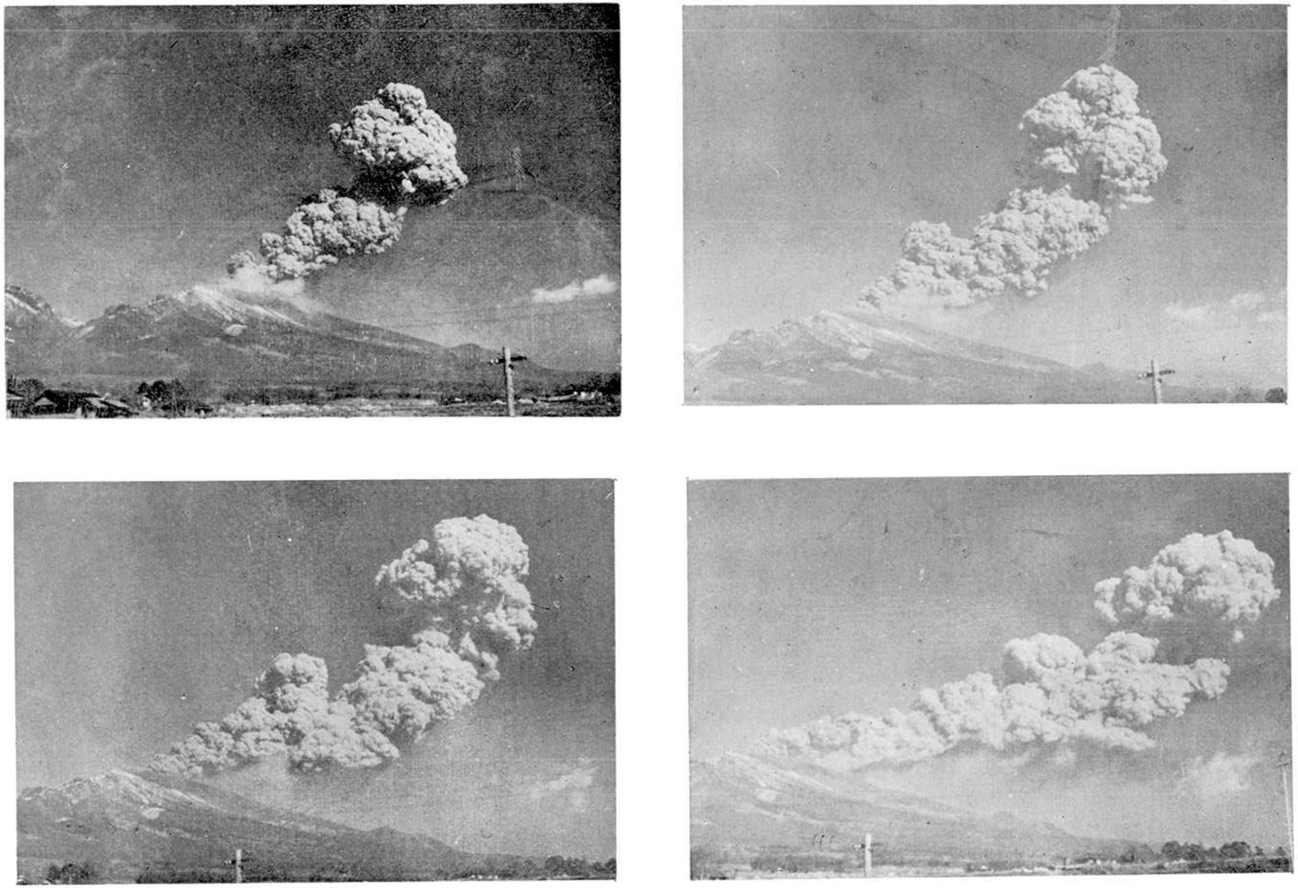

Fig. 21. Successive views of the outburst at 11:46 a.m. on Dec. 4, 1958, taken from the Komoro Geochemical Station.

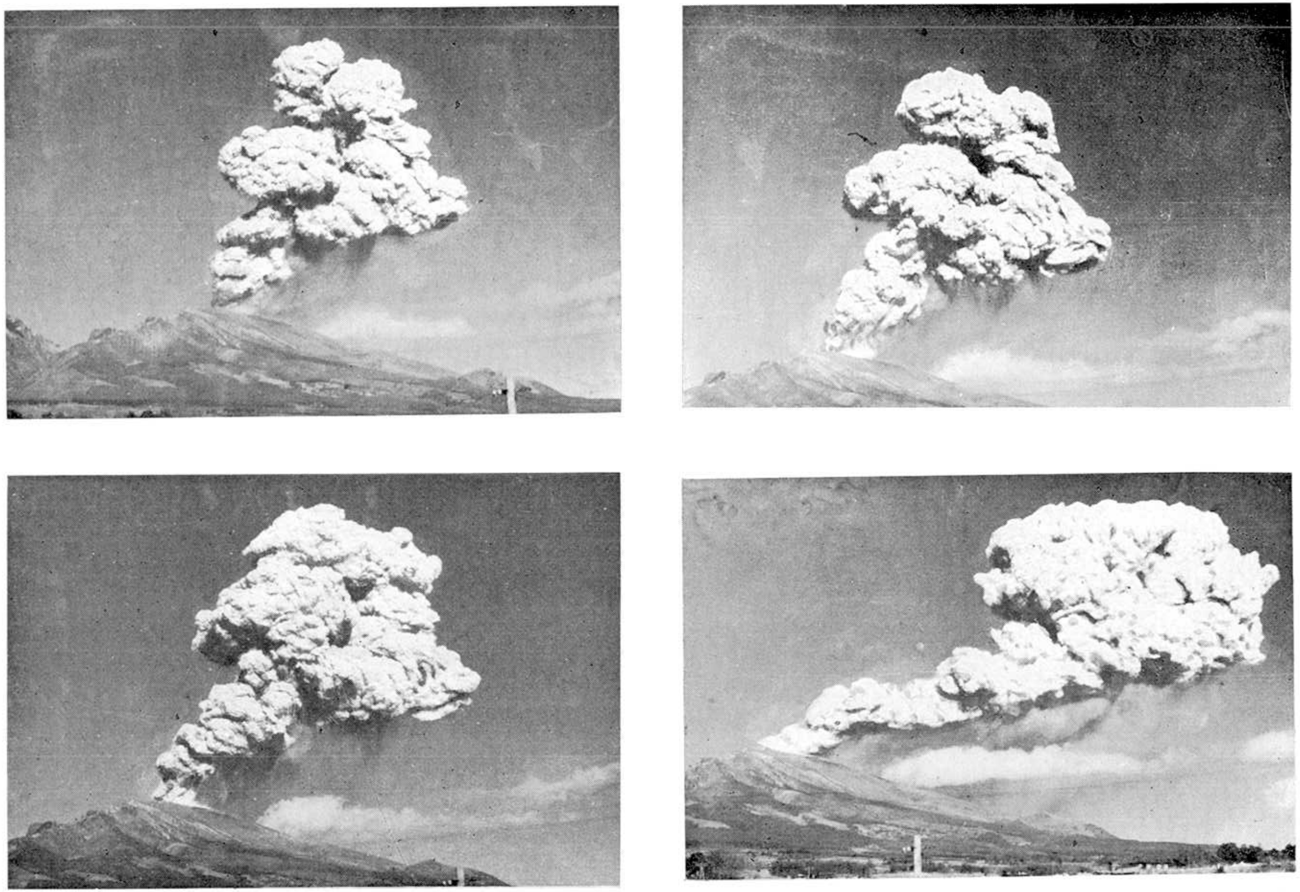

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Fig. 22. Successive views of the outburst at 1:08 p.m. on Dec. 5, 1958, taken from the Komoro Geochemical Station.

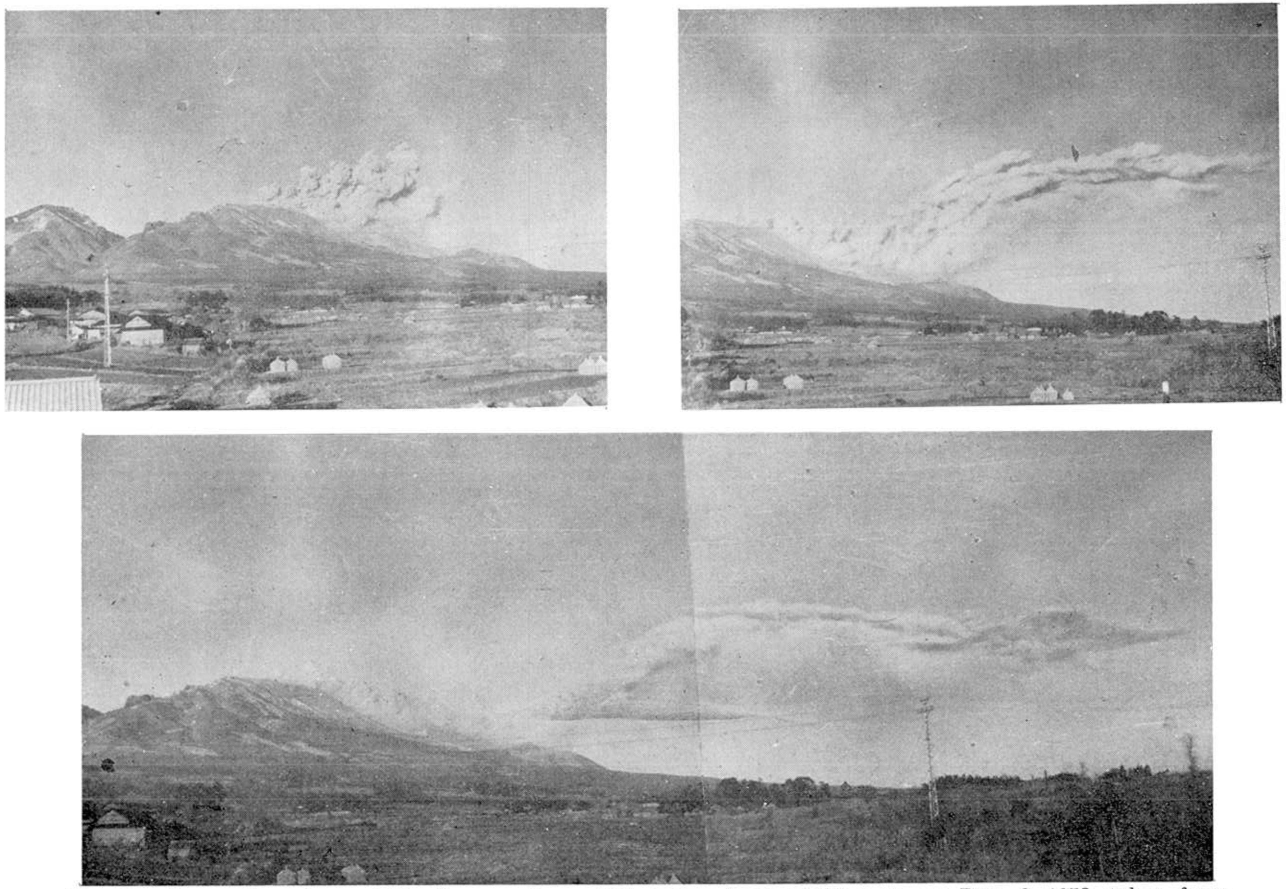

Fig. 23. Successive views of the the eruption which began from 11:23 a.m. on Dec. 6, 1958, taken from the Komoro Geochemical Station.

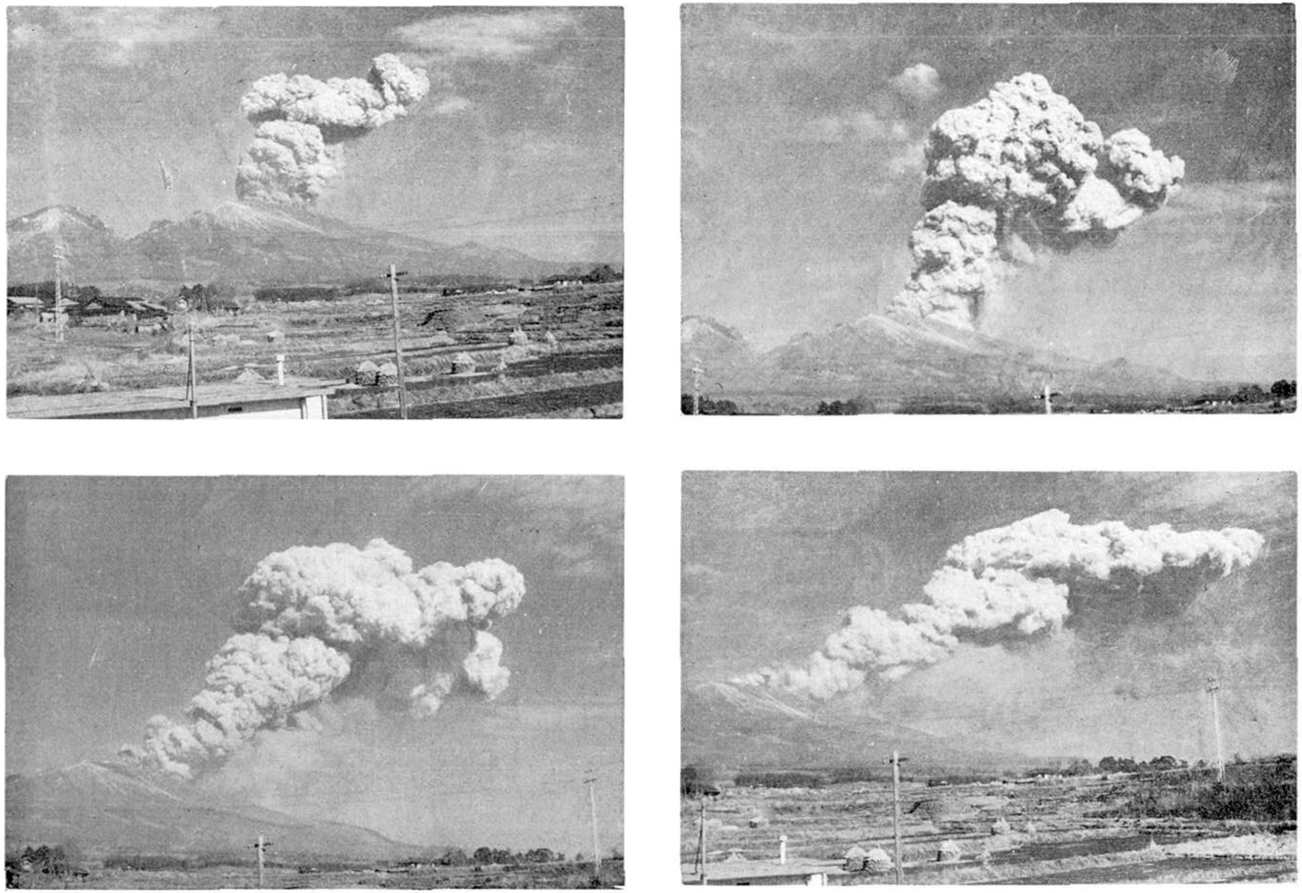

Fig. 24. Successive views of the outburst at 11:55 a.m. on Dec. 14, 1958, taken from the Komoro Geochemical Station.

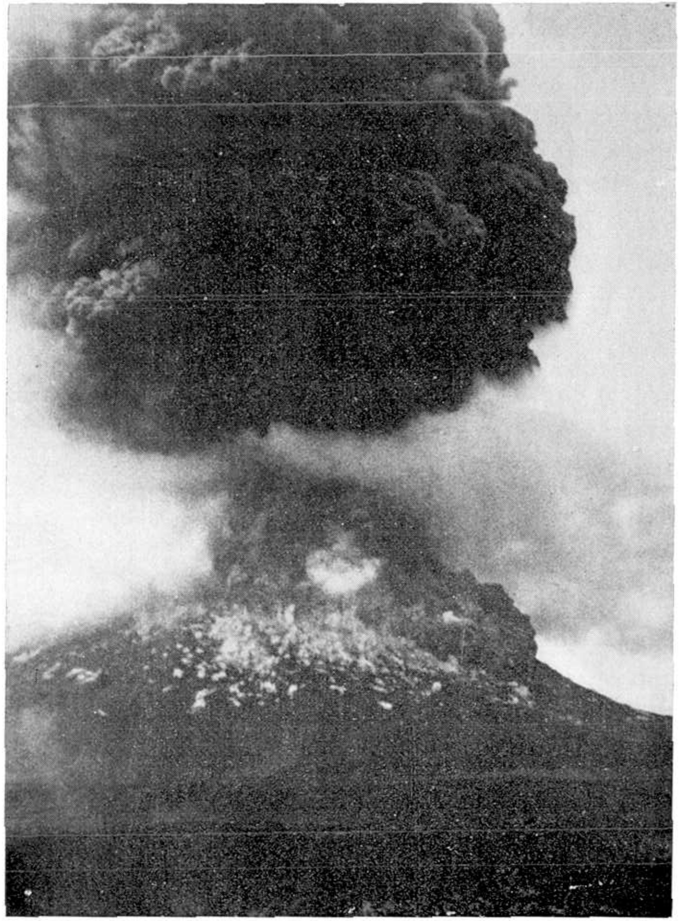

Fig. 25. The eruption cloud of the explosion at 2:24 p.m. on Aug. 18, 1961, viewed from Rokuri-ga-hara. A small part of the rising cloud is seen descending down the northern mountain-slope. (Photo. by The Shinano-mainichi.)

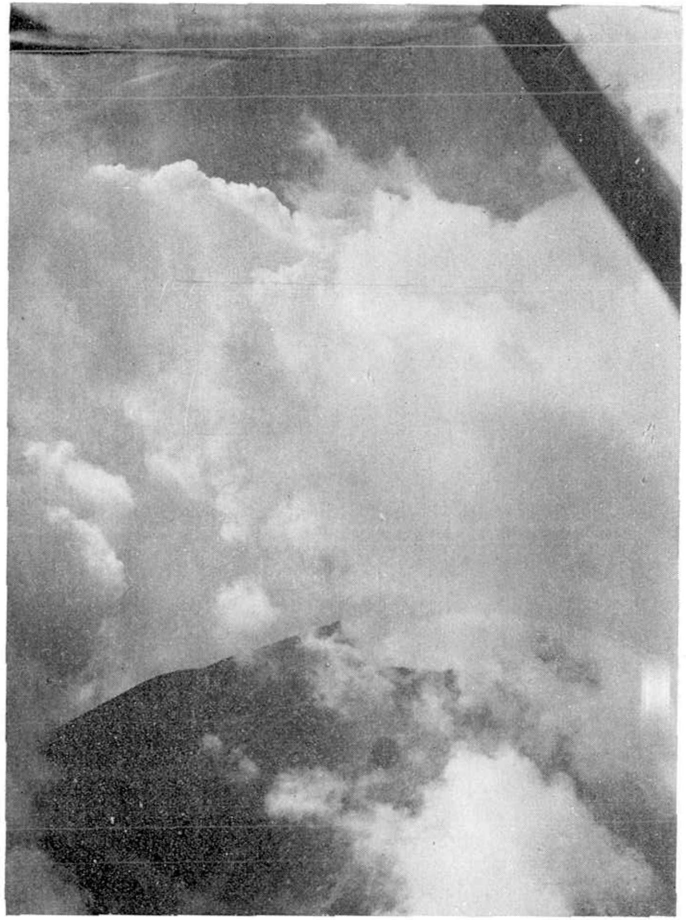

Fig. 26. An aerial view of the top of Mt. Asama on Aug. 18, 1961, after the explosion, taken from the north. (Photo. by The Shinano-mainichi.)

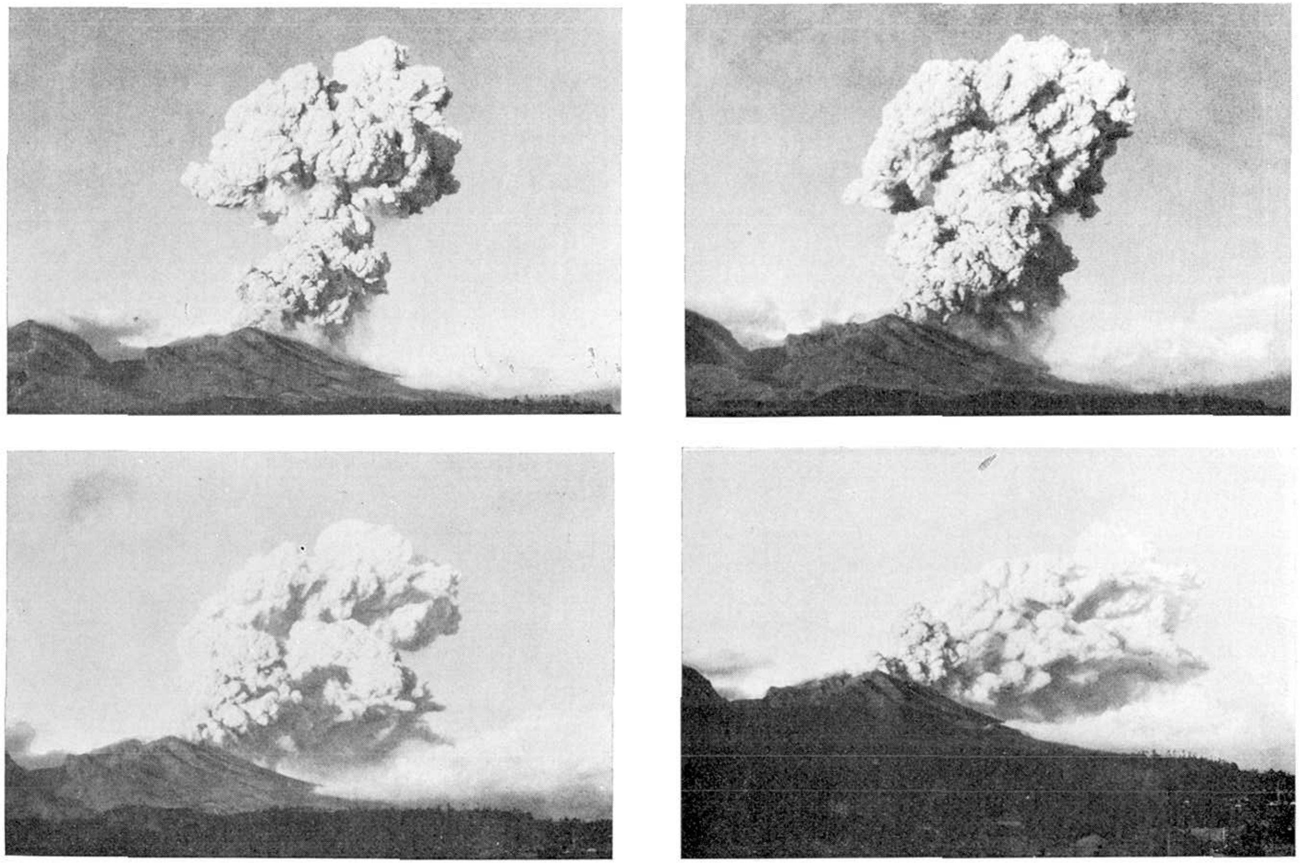

Fig. 27. Successive views of the outburst at 5:05 p.m. on Oct., 7, 1961, taken from Komoro. (Photo. by Mr. E. Nakamura.)

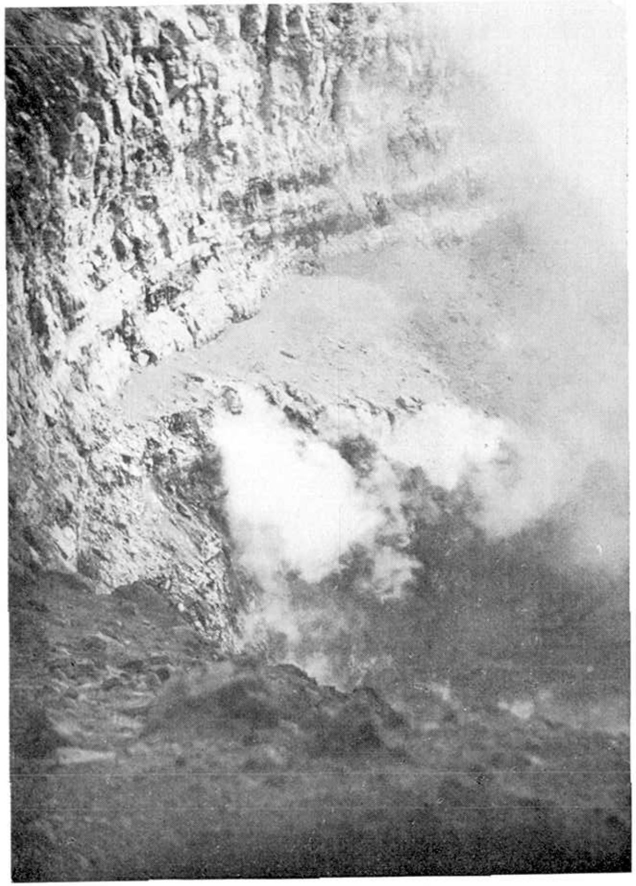

Fig. 28. The inside of the crater-pit immediately after the outburst on Nov. 10, 1958. From the north. (Photo. by the Karuizawa Weather Station.)

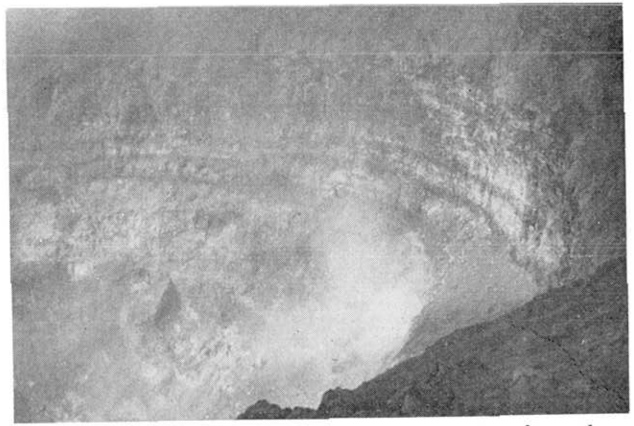

Fig. 29. The inside of the crater-pit after the eruptive activity of 1959, taken on July 21, 1960. From the north.

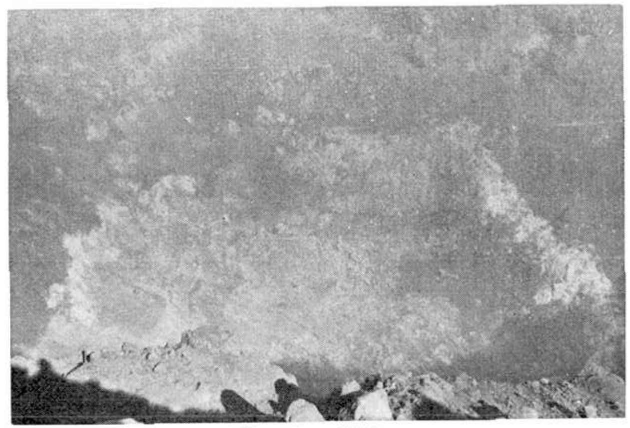

Fig. 30. Ditto.

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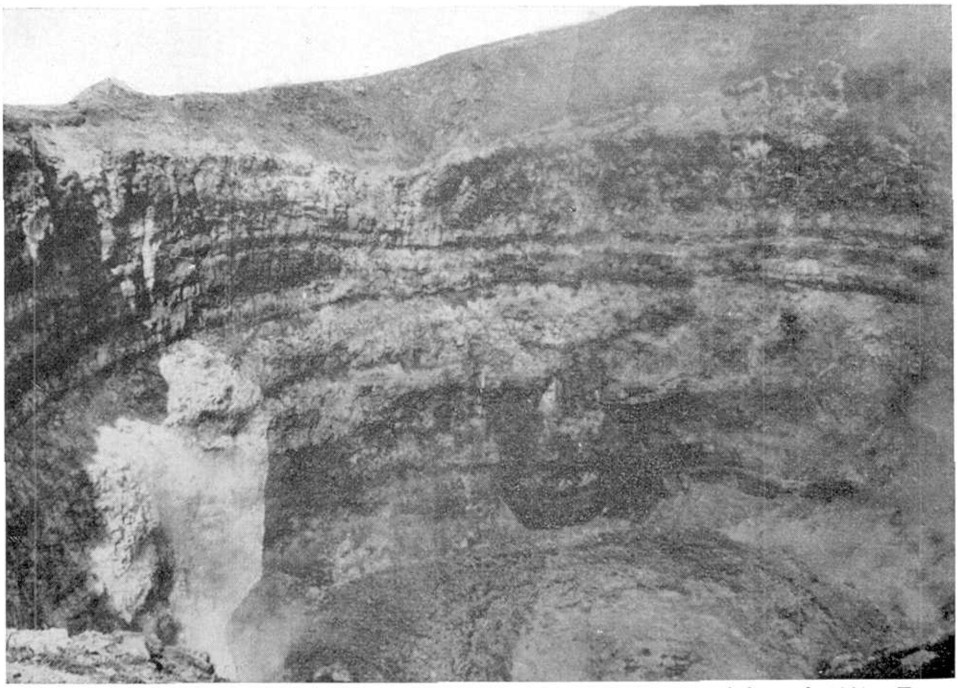

Fig. 31. The inside of the crater-pit after the eruptive activity of 1961. From the south. (Photo. taken on May 8, 1962, by The Asahi.)

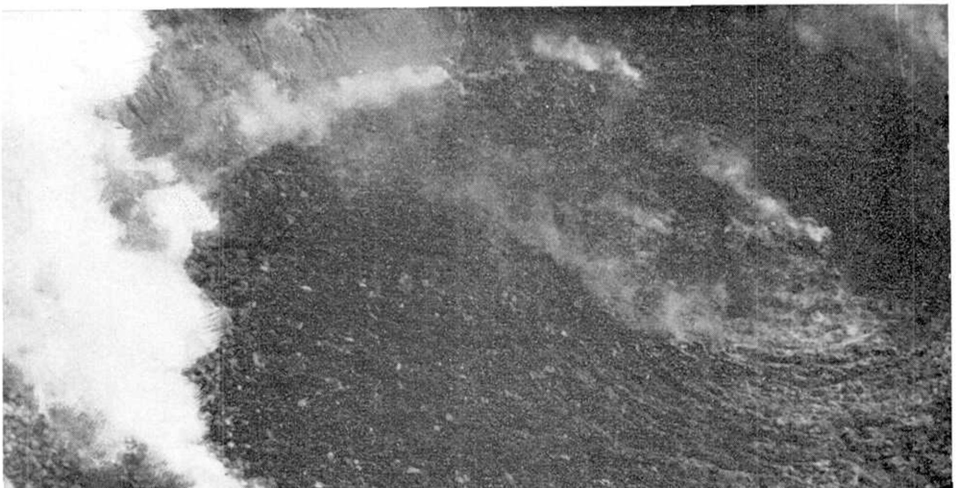

Fig. 32. Ditto. From the north. (Photo. taken on Sep. 7, 1963, by Mr. E. Nakamura.)

Fig. 33. A falling block on the ground ejected by the outburst on Apr. 14, 1959.

Fig. 34. A falling bomb on the ground ejected by the outburst on April. 14, 1959.

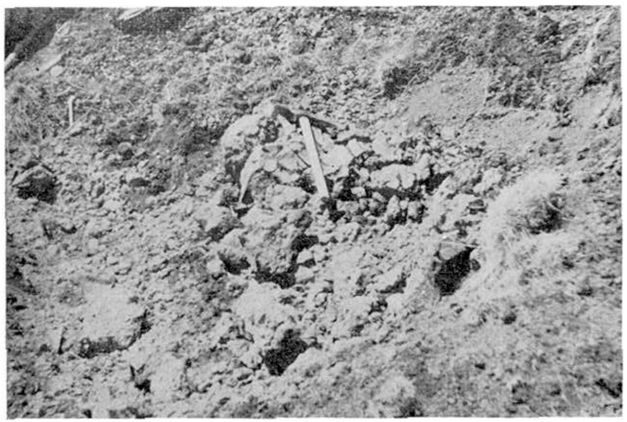

Fig. 35. Ditto.

Fig. 36. Falling blocks and bombs on the western slope of Maekake-yama ejected by the outbursts in 1961.

Fig. 37. A bread-crust bomb ejected by the outburst on Nov. 10, 1958.

Fig. 38. A block of rock fragment ejected by the outburst on Nov. 10, 1958.

Fig. 39. A pumiceous bomb ejected by the outburst on Nov. 11, 1958.

Fig. 40. A bread-crust bomb ejected by the outburst on Apr. 14, 1959.

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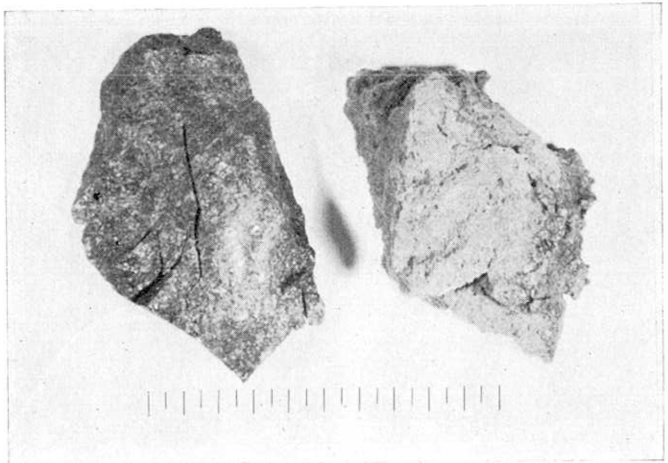


Fig. 41. Bombs ejected by the outburst on June, 25, 1959.

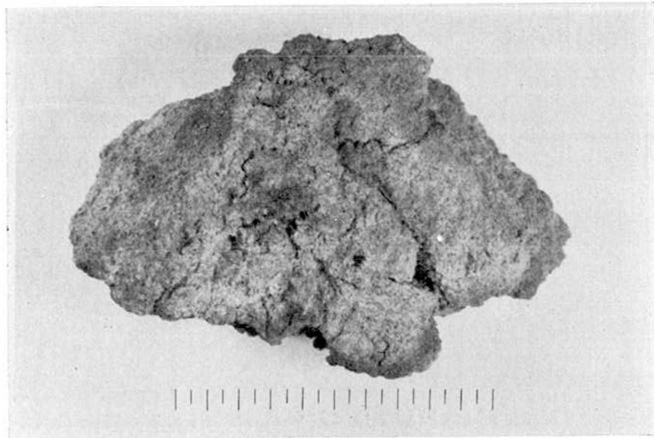


Fig. 42. A pumiceous bomb ejected by the outburst on June 30, 1959.

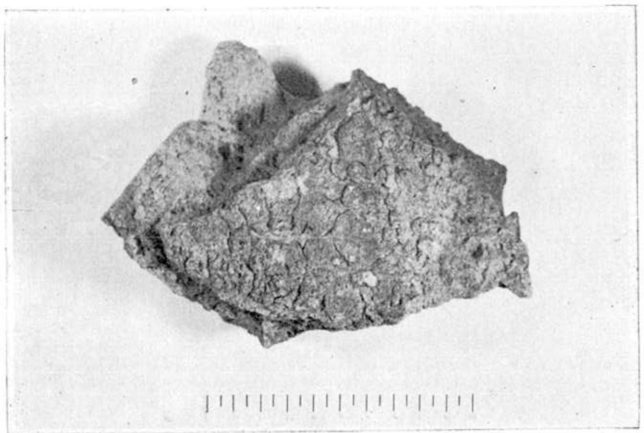


Fig. 43. A pumiceous bomb ejected by the outburst on July 16, 1959.

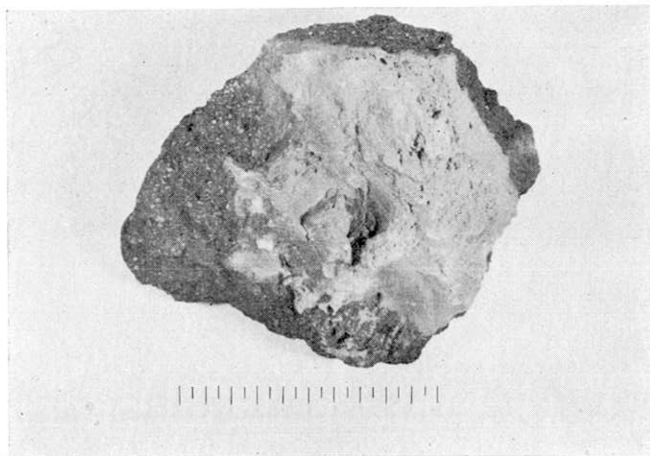


Fig. 44. A bomb including a xenolith ejected by the outburst on July 16, 1959.

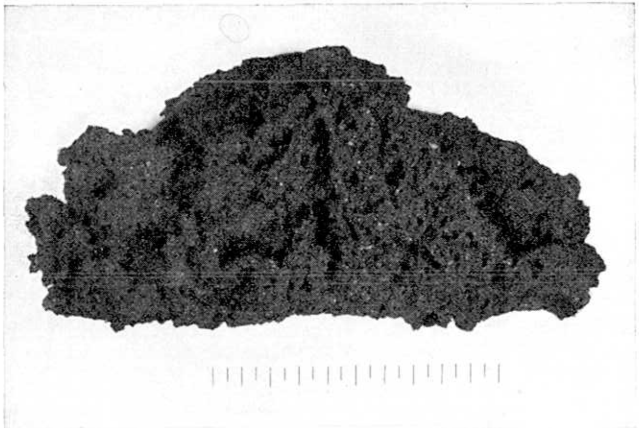
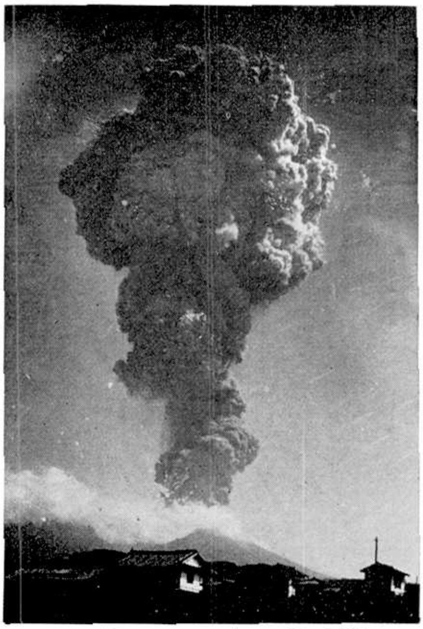


Fig. 45. A scoria fragment ejected by the outburst on July 21, 1959.

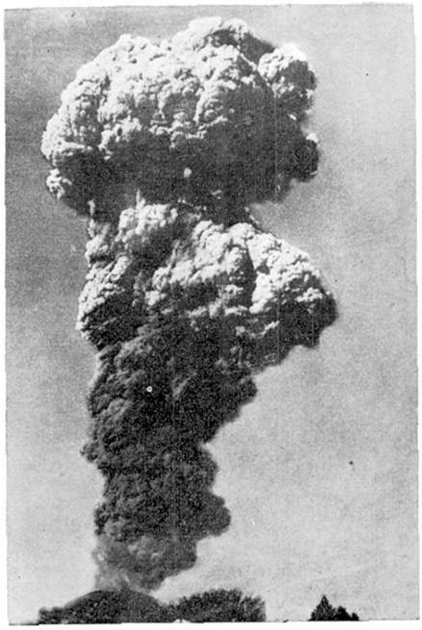
Fig. 46. A pumice fragment ejected by the outburst on July 21, 1959.

Fig. 47. A fragment of vent conglomerate ejected by the outburst on Aug. 18, 1961.

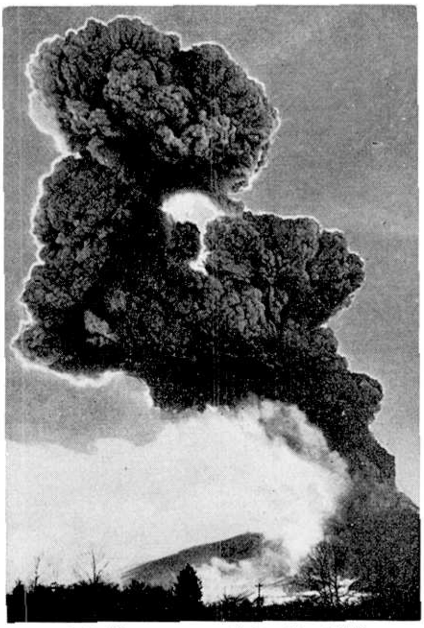
Fig. 48. A rock fragment ejected by the outburst on Aug. 18, 1961.



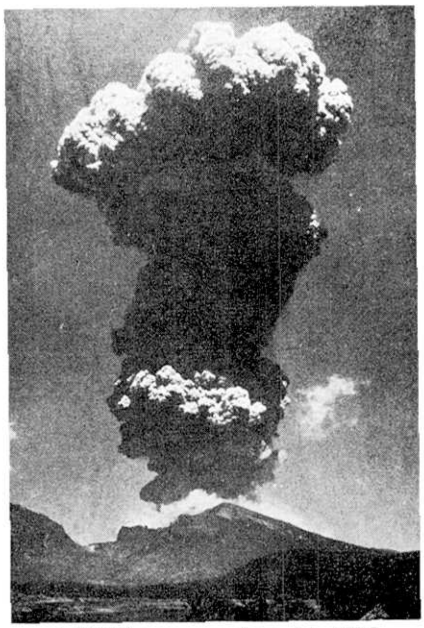
at 9:42 a. m. on Aug. 20, 1931.



at 4:23 p. m. on Apr. 20, 1935.



at 9:10 a. m. on July 29, 1936.



at 12:17 a. m. on Aug. 14, 1947.

Fig. 49. Views of some major outbursts in the recent years.