11. *The Eruption of Komagatake, Hokkaidô, in 1929.*

On June 17, 1929, there occurred an eruption of Komagatake in southern Hokkaidô. After the eruption, some members of our Institute visited the scene of activity to study the volcanic phenomena from geological, seismological, geodetic, gravitational and other sides. The papers presented by them embodying the results of their investigations are compiled here. They are:

The writers of the papers jointly take this occasion to express their sincere thanks to Professors B. Kotô, K. Suyehiro, T. Terada, S. Fujiwhara, M. Ishimoto and F. Tada of our University for their interest throughout the course of the present investigations. They are also indebted to Messrs. M. Ootuka, S. Kawasima and M. Iwasita for the assistance in the instrumental observations, to Mr. H. Nemoto and other members of the Hakodate Meteorological Station for giving facilities in many respects and to Mr. Z. Sato of Sahara for granting the use of his cottage for our instrumental observations. Thanks are also due to many other gentlemen, whose assistance in various ways is acknowledged in the following papers.

Part I. The Volcano Komagatake, Hokkaidô, its Geology, Activity, and Petrography.

By Hiromichi TSUYA,

Earthquake Research Institute.

(Received March 20, 1930.)

Contents.

I. Morphology and Structure.

General Topography.—The volcano Komagatake, Hokkaidô, is a *homate* truncated at its top with the ring-wall surrounding a horseshoe-shaped caldera. The sides of the volcano show generally the natural slope of a volcanic cone. They are steep, 30-40°, near the top, decreasing in slope downwards. The northern and western sides are steeper than the other sides. On the flanks there are several knobs, Kakaruma-Maruyama, Sahara-Maruyama, Akahageyama, etc., elevated 30-50 m. from the general slope. The north and west skirts are gentle as well as extensive; while the east and south skirts are undulated with numerous hills, less than 20 m. in height.

The volcano is not much dissected. The northern, western and southern flanks are dissected by numerous radial valleys, V-shaped in the upper courses, but U-shaped in the lower, finally disappearing at the skirts. These valleys are empty, for the rain-water that falls on the upper slope of the volcano is soaked into the deposits of clastic ejecta with which the entire slope is loosely covered. The eastern half of the northern flank is dissected by several valleys that open to the sea (Hunkwa Wan or Volcano Bay). Some of them have the permanent streams. The eastern flank is rather gentle up to the summit and is dissected by numerous gulches.

The river Oridogawa runs east through the southern skirt. This is the passage of the lakes Oonuma, Konuma, and Junsainuma, all of which are dammed with mud-flows of the volcano.

The northern skirt is subjected to marine-erosion, being cut into

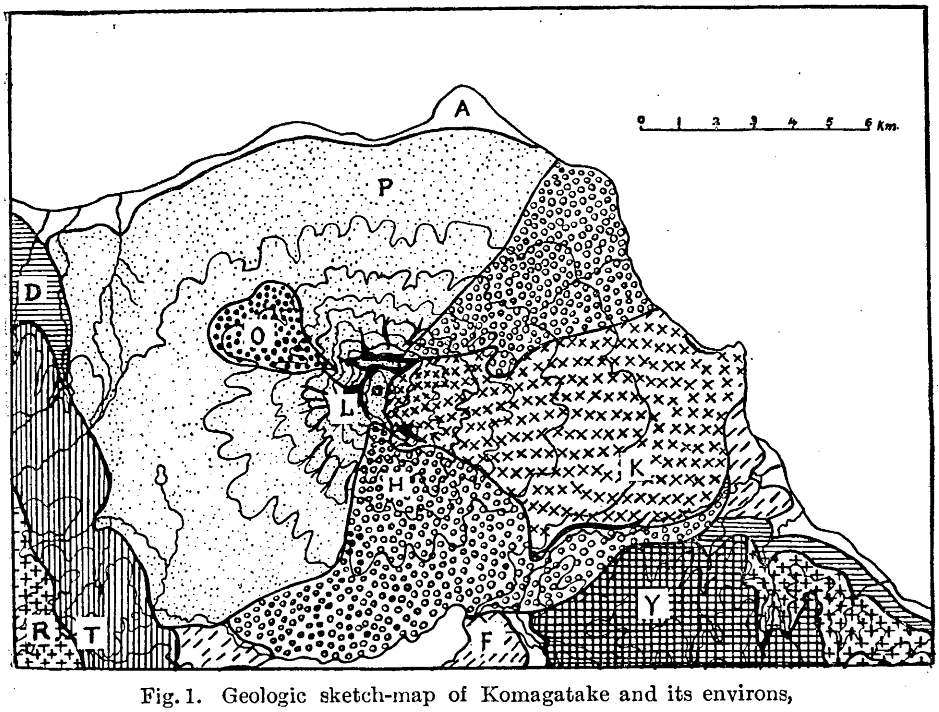


Fig. 1. Geologic sketch-map of Komagatake and its environs, based on Kato's geologic map.

A—Alluvium; O-Osidasizawa mud-flow; K—Kurumizaka mud-flow; H—Horseshoe-shaped crater mud-flow; F—Flowed mound region; P—Pumiceous ejecta; L—Lavas; D—Diluvial terrace-deposits; Y—Yokotudake volcanics; R—Rhyolitic rocks; T—Tertiary.

precipitous sea-cliffs. The elevation of the sea-cliff varies in different parts, generally increasing eastwards. It is especially high in the eastern half of the northern coast, where the thick deposits of mud-flows are subjected to the marine-erosion.

Foundation.—The immediate foundation, on which the volcano has been constructed, may be conjectured from the geology of the neighbouring districts (Fig. 1). The districts adjacent to the volcano are built up of younger volcanics such as rhyolite, andesite, basalt, and allied rocks, along with the Tertiary and Quaternary formations. The volcanics cover the wide areas, southeast as well as southwest of the volcano. The Tertiary formation develops in a narrow zone adjacent to the west, consisting of clayey rocks and tuffs. The Diluvial formation occurs as coastal terraces along the shore outside the area, in which the volcano is situated, and consists of gravel-and pumice-beds ; while they are entirely absent along the shore between Sikabe and Mori, where the northern skirt of the volcano faces directly on the sea. Accordingly, it is probable, as Tak. Kato considers[1], that the immediate foundation of the volcano is represented by the Diluvial formation which now is buried under the products of the volcano.

General Structure.—As the volcano is not merely young in dissection, but is entirely covered with the ejecta of later eruptions, the inner structure is not discovered in detail. As far as visible parts are concerned, the volcano is a stratified one built up of some lava-flows and much fragmentary materials.

The apical part of the volcano consists of a horseshoe-shaped caldera and a small central cone in the latter. The eastern side only of the central cone is developed ; while the other sides are absent, being occupied by the northern and western parts of the ring-wall. Thus, an oval crater in which active pit-craters are situated, is surrounded by the ring-wall and the crest of the central cone.

On the northwestern flank, there is a knob, Kakaruma-Maruyama, whose outer form suggests it to be a parasitic cone ; while nothing is known of its inner structure and building materials, as it is covered with later ejecta. The knobs, Sahara-Maruyama, Akahageyama, etc., on the southeastern flank and numerous hills at the east and south skirts are the mounds composed of lava-blocks and ash-materials, being resulted from accumulation of mud-flows.

1) Tak. Kato, "Geology of Komagatake Volcano (Hokkaidô)," *Report Earthq. Inv. Comm.*, 62 (1909), 1–64, (in Japanese).

Craters.—*Caldera.* The caldera is surrounded on its north, west, and south sides with the ring-wall represented by ridges, viz. Saharadake, Komanose, Komagatake proper, Umanose, and Sumidamori; while on its east side there is a great gap in the ring-wall (Fig. 2, p. 242).

The northern wall, Saharadake, has an unbroken stretch from E. to W. of one thousand meters. Its highest point is 1115·1 m.[2] above sea level. The northwestern wall forms a saddle, Komanose, between the northern and western walls, stretching from N.N.E. to S.S.W., with an uniform crest-line for a length of 500 m. This saddle is the result of a side explosion, by which the upper part of the northwestern wall has been blown away. The western wall culminates in a rocky pinnacle, Komagatake proper, attaining 1140 m. above sea level. The southern wall runs from N.W. to S.E., its highest point, Sumidamori, attaining 880 m. above sea level. There is a saddle, Umanose, between the highest points, Sumidamori and Komagatake proper, on the southern and western walls. The crest-line of this saddle is elevated gradually toward N.W. Thus, the ring-wall is lower on the south than on the north in altitude.

The ring-wall, except for the part of the southern saddle, Umanose, forms an almost perpendicular cliff toward the inside. On the cliff are exposed repeated layers of lava-flows and fragmentary materials.

The eastern gap in the ring-wall has a meridional width of 2 km. from the eastern end of the northern wall, Saharadake, to the eastern end of the southern wall, Sumidamori.

Oval crater. The northern and western parts of the ring-wall and the crest, Namakoyama, of the central cone surround an oval crater, the major and minor axes of which are 1 km. from N.N.E. to S.S.W. and 0.7 km. from W.N.W. to E.S.E. respectively. The configuration of the area within this oval crater has been changed from time to time. During half a century past, it was:

In 1872, when Captain Bridgford[3] visited the volcano, there were six small craters, one of which was then active.

In 1877, according to John Milne[4], there was a pit-crater, 100 m. across and 20 m. deep, from which steam was issuing. There were fissures running to the pit-crater.

In 1889, according to K. Jimbo[5], there were two pit-craters, one of

2) The heights of the ridges above sea level are those read on the topographic map 1:50000, sheet Komagatake, Land Survey Department, 1915.
3) Bridgford, R.M.A., *Transactions of the Asiatic Society*, Tokyo, 2 (1874), 80.
4) J. Milne, "The Volcanoes of Japan," *Transactions of the Seismological Society of Japan*, 9 (1886), 121–122.
5) K. Jimbo, Report on the Geology of Hokkaidô, 2 (Hokkaidô, 1892), 128–129.

which was formed by an eruption in 1856 and the other by an eruption in 1889. The former, 350 m. by 290 m. in size and 100 m. in depth, was situated at the center of the oval crater. The latter, 270 m. across, was situated on the northwest side of the former. Its inside was screened by dense vapor issuing vigorously.

In 1906, a year after an eruption took place, Tak. Kato[6] made a general geological survey of the volcano. Fig. 2 is a crater-map based on the geologic map he made. According to him, the configuration of the area within the oval crater was: A, the pit-crater of 1856, 200 m. across and 30 m. deep, with a central dome from which a little solfataric vapor was issuing. K, a rift-crater of 1905, 200 m. long and 20 m. wide, running northeast. In this rift-crater there were active solfataric vents steaming vigorously. F, a large carter-like depression, the southern part of which was studded with numerous solfataric vents. L, a pit-crater, extinct. Besides these, there were numerous rifts, on which steaming vents were arranged, running from east to west.

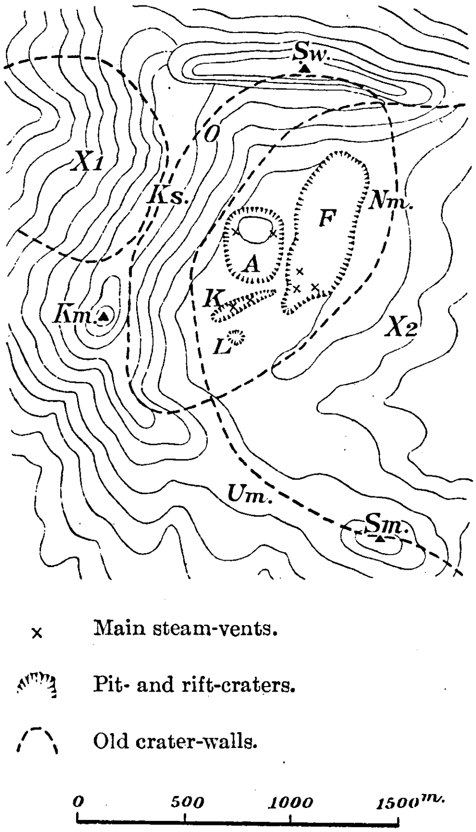


Fig. 2. Sketch-map showing the state of the inside of the caldera in 1906. (After Tak. Kato).

Ridges: Sw—Saharadake; Ks—Komanose; Km—Komagatake; Um—Umanose; Sm—Sumidamori; Nm—Namakoyama.

Craters: X_1—Osidasizawa explosion-crater; X_2—Horseshoe-shaped explosion-caldera; O—Oval crater; A—Crater of 1856; K—Crater of 1905; L—Crater extinct; F—Crater ?

In 1907, C. E. Bruce Mitford[7] visited the volcano. He considered

6) Tak. KATO, *loc. cit.*

7) C. E. B. MITFORD, "Notes on the Physiography of Certain Volcanoes in Northern Japan," *The Geographical Journal*, 31 (1908), 187–198.

the cone, Namakoyama (Nm. in Fig. 3), to be a new one thrown up near the eastern gap of the caldera, for no mention of this cone had been made either by Captain Bridgford or John Milne. K in Fig. 3 was then jointed further east by several longer rifts, which ran parallel to the former, to the flank of Namakoyama. A in Fig. 3 was then 40 m. across and 10–15 m. deep.

In 1909, when I. Friedländer[8] visited the volcano, the western wall, Komagatake proper, of the caldera was passed through by a fissure running toward A in Fig. 3, which was then 50 m. deep. Steam was issuing from this fissure.

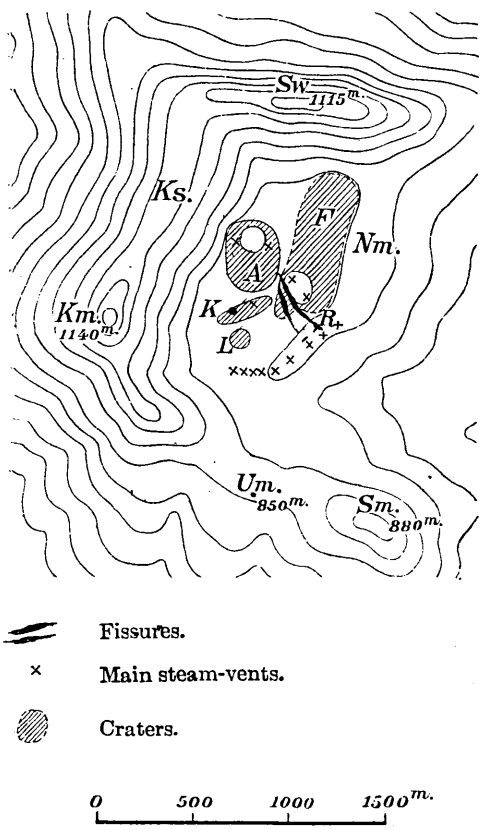


Fig. 3. Sketch-map showing the state of the inside of the caldera in 1918–20. (After A. Imamura).
Sw, Ks, Km, Um, Sm, Nm, A, K, L, and F correspond to those in Fig. 2. R: rift appeared in 1918.

In 1918–20, A. Imamura[9] observed thrice the state of the crater before and after a slight activity displayed in 1919. Fig. 3 is based on the crater-map he made. A, K, L, and F in the figure correspond to those in Fig. 2. According to him, A was then 350 m. by 270 m. in size and 60 m. in depth, with a central cone, somewhat to the north of the center of the crater-floor, from which steam was issuing. Of two vents in K, one at the east was discharging steam most vigorously till 1919 when a slight activity was displayed; while the other at the west was filled with water. There were several steam vents, somewhat to the south of L, on a line running east toward Namako-

8) I. Friedländer, "Über einige japanische Vulkane," *Mitteilungen der Deutschen Gesellschaft für Natur- und Völkerkunde Ostasiens*, **12** (1910), 144–148.

9) A. Imamura, *Report Earthq. Inv. Comm.*, **95** (1921), 92–99, (in Japanese).

yama. In the southern corner of F, there was a mound, 30 m. high and 15 m. across, with solfataric vents on its east, west, and south sides. A rift, R in Fig. 4, 280 m. long and 20–30 m. wide, ran southeast toward Namakoyama through the mound. The activity in 1919 was displayed in this rift.

The bottom of this oval crater was about 300 m. in depth from the top of Komagatake proper and about 130 m. from the crest of Komanose; while it was only 50 m. in depth from the crest of Namakoyama which was about 870 m. above sea level.

Geologic History.—The present structure of the volcano is the result of repeated eruptions and explosions which have taken place in two periods in the geologic history of the volcano, viz. period of construction and period of destruction.[10]

The former period is represented by the alternating layers of lava-flows and fragmentary materials, some of which are exposed on the ring-wall. The northern and western sides of the volcano are mostly composed of the materials of this period, although they are covered with later ejecta. All the materials of this period, except for the products of the parasitic knob, Kakaruma-Maruyama, are considered to have been ejected from the apical crater, for there is no flank opening from which they may have been discharged.

The latter period is represented by mud-flows. The apical part of the cone constructed in the former period was blown away by explosions to result in the formation of the horseshoe-shaped caldera, and the disrupted cone-materials caused mud-flows spreading down to the northeastern, eastern, and southern skirts. Again, the northwestern part of the ring-wall was blown away by a side explosion and the disrupted materials caused a mud-flow spreading down to the northwestern skirt. Osidasizawa explosion-crater is the result of this side explosion.

By subsequent eruptions a small central cone was constructed in the caldera. As its crater (oval crater) was situated by the inner side of the ring-wall, the eastern side only of the cone was developed and the products, agglomerate-lava and mud-flows, discharged from the crater descended the eastern side through the eastern gap of the ring-wall.

It is recognized that volcanic eruption often accompanies either upheaval or depression of the land on which the eruption has taken place. However its cause may be, relative depression of the land occupied by the volcano Komagatake is confirmed by evidences:

10) Tak. KATO, *loc. cit.*

Near sea level of the sea-cliff, 2·5 m. high, at Kakaruma, west of Sahara, is exposed a black soil-bed, 0·3 m. thick, overlain by an ash-bed, 0·2 m. thick, containing fossil plants (stalks and blades) that take roots in the underlying black soil-bed. The ash-bed is then overlain by a pumice-bed, 1 m. thick, which passes upwards into a bed, 1 m. thick, composed of volcanic ashes mingled with pumice-blocks. These succession of beds shows that an ancient land-surface represented by the black soil-bed has been buried under the products of subsequent eruptions of the volcano, and that the ancient land-surface has been brought to sea level by relative depression of the land.

In the lakes Oonuma and Konuma are found numerous submerged trees. It is probable that they are the result of depression of the land by the lakes.[11]

By comparing the result of precise levelling done after the eruption, June 17, 1929, with that previously done, it is confirmed that the land at the northwestern foot of the volcano has been depressed relatively from the land adjacent to the west (Part V, p. 298).

From what has been stated, it is suggested that a differential movement between the land occupied by the volcano and adjacent land may have taken place along the conjugate lines, probably tectonic, represented by the trend of low land extending, N.N.W.-S.S.E., from Mori to Oonuma and the river-course, S.S.W.-E.N.E., of the Oridogawa; and it may be answered by relative depression of the land occupied by the volcano, why the Diluvial terrace is seen nowhere on that land; while it develops on the land outside.

II. Recorded History of Eruption.

The volcano seems to have been active for untold ages, but nothing about its eruption has been recorded but the eruptions since 1640, A. D. The eruptions on record are:

1640 (*17th year of Kwan'ei era*). On June 13, 1640, a great eruption took place. It was accompanied by tunamis and earthquakes. At noon on the same day, the southern coast of the Volcano Bay was visited by tunamis. Ships more than one hundred were wrecked and people more than seven hundreds drowned. During the following three days, the ash fell in the districts, southwest of the volcano.

11) F. Omori, "Eruption of Komagatake and the Submerged Trees of Oonuma," *Journal of Geography*, 34 (1922), 133-136, (in Japanese).

1765 (*2nd year of Meiwa era*). A slight eruption took place in 1765.

1784 (*4th year of Temmei era*). On February 8, 1784, an eruption took place.

1856 (*3rd year of Ansei era*). At daybreak on August 26, 1856, earthquakes were felt at the southeastern foot of the volcano. At about 9 a.m., roarings were heard from the volcano and ash-clouds were seen ascending from the summit. Pumices were ejected and fell in the southeastern districts. A large number of houses were destructed by fire started from the hot ejecta. A new pit-crater, A in Fig. 4, was formed by this eruption.

1888 (*21st year of Meidi era*). A small eruption took place. A new pit-crater was formed on the northwest side of the crater of 1856.

1905 (*38th year of Meidi era*). Roarings were heard from the volcano on August 16–17, 1905. In the morning on August 19, the first eruption took place from a newly opened crater, K in Fig. 4. The activity culminated during the next four days. On August 22, a mud-flow caused by rain-fall ran northeast toward Osiranai.

1919 (*8th year of Taisyô era*). On June, 17, 1919, a small eruption took place. A new rift, R in Fig. 4, from which the activity was displayed, was formed. On June 24, another eruption occurred.

1922 and 1924 (*11th year and 13th year of Taisyô era*). In these years, slight activities were displayed.

III. The Eruption of 1929.

The Course of Eruption.—On June 17, 1929, a great eruption of the volcano took place. Taking the accounts by eyewitnesses and by people who live in the neighbourhood, the course of eruption was as follows:

It was about 0 : 30 a.m., June 17, when rumblings from the volcano were heard at Oonuma. About an hour later rumblings were also heard at Sikabe. Some people there found the volcanic ashes falling at about 3 a.m. Then, rumblings were of frequent occurrence.

During the early morning, the top of the volcano was hidden from view by a dense fog, and it was past 9 a.m., when the top was seen for the first time, discharging dark volutes of ash-cloud.

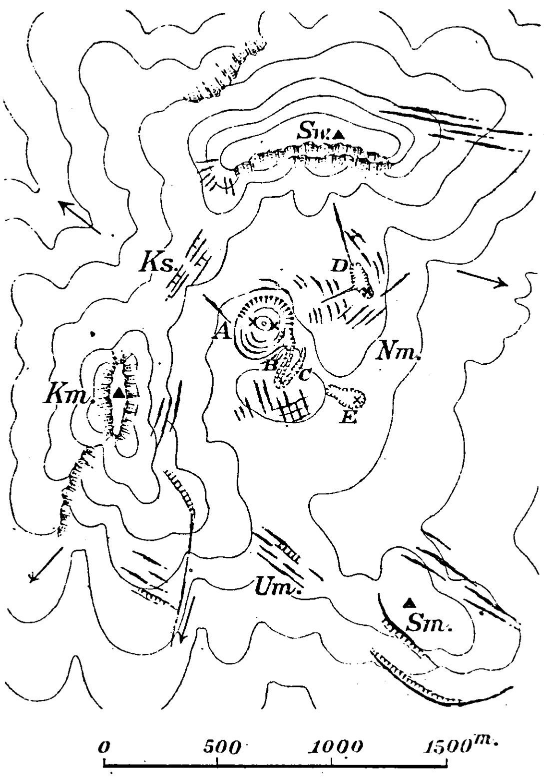
Simultaneously with heavy rumblings came great explosions at about 10 a.m. In the meantime, volcanic ashes and lapilli began to fall heavily in Sikabe district. Emission of dark ash-cloud increased in violence, with ejection of incandescent pumice-blocks. Following the violent emissions of dark ash-cloud, flashes of lightning appeared in the midst of the cloud, being accompanied by thunders (Part VII, p. 302). In Sikabe district, the rain of ejecta was steady.

It was past noon when a mass of pumice-blocks ran for the first time over the northwestern saddle, Komanose, in the ring-wall, flowing into the valley Osidasizawa.

At about 1 p.m. or a little later, the ejecta began to fall in Tomenoyu near the mouth of the lake Oonuma.

The ash-laden cloud was ejected to an enormous height (PL. I, Fig. 1). At 2 p.m., its height measured by a sextant at Hakodate Meteorological station attained about 13000 m. (Part III, p. 275). The cloud expanded outwardly in the cauliflower-shape against the surrounding air (PL. I, Fig. 2). Dispersion through the air of the ejecta was mainly controlled by the prevailing wind (PL. I, Fig. 3). Thus, ashes and sands were borne far into the Pacific in the direction of the upper atmospheric current (Fig. 5); while lapilli and bombs fell in showers from the ash-cloud on the ground within a short distance to the southeast.

After 3 p.m. on, great masses of pumice-blocks were not only projected through the air, but dis-



Fissures.

Main vents discharging vapors.

Craters.

Main directions of the flows of pumice-blocks.

Fig. 4. Sketch-map showing the state of the inside of the caldera after the eruption, June 17, 1929.

charged intermittently over Komanose, Umanose, and Namakoyama, toward northwest, southwest, and southeast and descended the mountain-slope (PL. I, Fig. 4). At about 5 p.m., they were also discharged northwards over Saharadake.

The eruption continued through the day into the evening hours. When the night fell, a red look near the crater of the ejecting materials was observed.

At about 7 p.m., the eruption culminated in discharging products, in lightning, and in thundering, and it was almost steady till about 11 : 30 p.m. on the same day.

Thenceforth, the eruption subsided and at about 1 : 30 in the next morning, Sikabe district entirely left off showers of the ejecta. At the same time, the ash-cloud decreased much in quantity as well as in height.

During the following several days, slight earthquakes were often felt (Part III, p. 275) and rumblings were heard, but again no eruption took place.

Craters.—By the eruption, the configuration of the area within the caldera has remarkably changed. Fig. 5 is a sketch-map showing the feature of the crateral part at the time when the writer visited.

The inside of the caldera is accumulated more thickly than 100 m., with the ejecta. Accordingly, the oval crater is shallower in depth of its floor than that before the eruption. The bottom of the oval crater is almost in the same level as the crest of Namakoyama, being about 200 m. in depth from the top of Komagatake proper; while before the eruption it was more than 300 m. from the latter. Compare Fig. 1 in Pl. II with Fig. 2 in the same plate.

The northwestern and southern saddles, viz. Komanose and Umanose, in the ring-wall are covered by thick accumulation of the ejecta; and the grounds of their crests are broader now than those before the eruption, sloping gently toward the inside. The crest of Namakoyama is also accumulated by the ejecta, being elevated to higher altitude than the top of Sumidamori; while before the eruption the former was lower in altitude than the latter.

The active pit-craters are situated on the ground in and around the oval crater. In the oval crater there is a circular pit-crater A, 150 m. across and 50 m. deep, which is successor to the crater formed by an eruption in 1856, A in Fig. 3. The southern wall of this pit-crater slopes gently toward the crater-bottom; while the northern wall is an almost

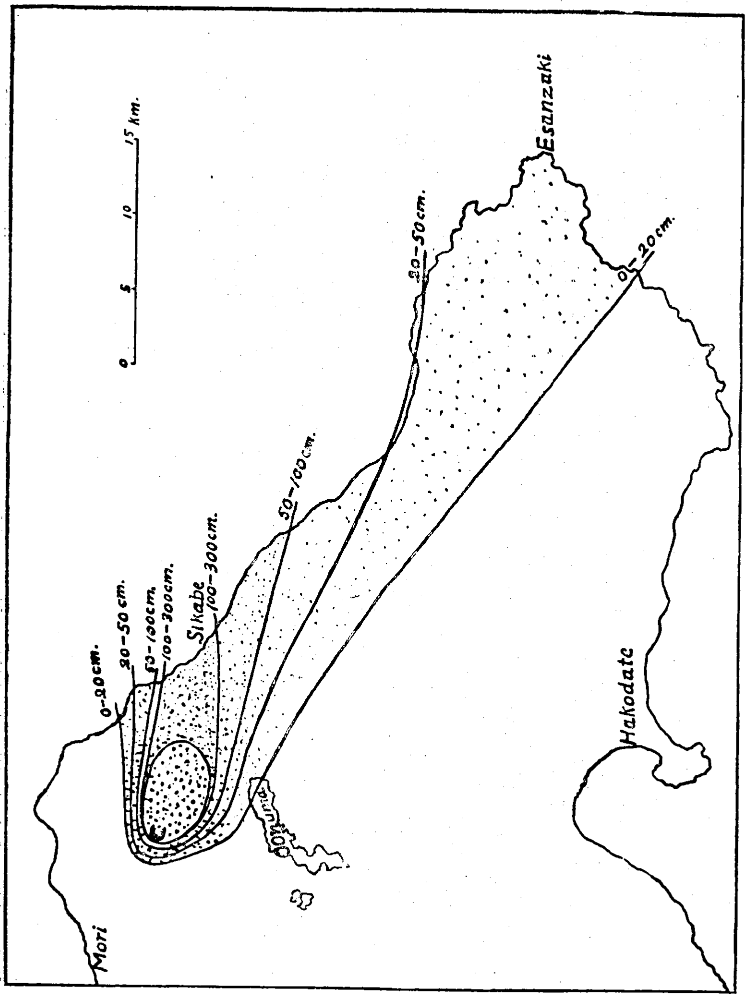


Fig. 5. Map showing the zones of equal thickness of ejecta distributed in the eastern Osima.

perpendicular cliff exposing numerous layers of the ejecta. The crater-bottom is occupied by an ash-covered cone, 20 m. across and 5 m. high, issuing much vapor charged with ashes from the crevices on its east and west sides.

The pit-crater A is breached on its east side and is communicated with a rift-crater B, 70 m. long, 30 m. wide, and 20 m. deep. The ground of the crest of the wall between A and B is narrow, sloping on both sides steeply toward the crater-bottoms.

Adjoining to the east of B, there is another rift-crater C of somewhat smaller dimensions, running northeast. The wall between B and C forms a sharp crest. These rift-craters may be in the extension of the rift-crater of 1905, K in Fig. 3, which is now buried in the ejecta.

At intervals of 20 m. to the northeast of A, there is a new crater D. It is crumped in the middle and is a trench-like stretch, 70 m. long and 20–25 m. wide, of small vents running N.N.W.-S.S.E. The rim of the precipitous crater-wall overhangs the crater-bottom, which is at least more than 30 m. below the average rim. From the southernmost crater-bottom, steam is issuing vigorously with a hissing noise.

On the west side of D, there is a ditch, 30 m. long, 15 m. wide, and 10 m. deep, running southeast toward A. It contains numerous vents discharging steam.

On the southeastern slope of Namakoyama and at intervals of 200 m. to the southeast of A, there is a crater E, 70 m. across and more than 50 m. deep in its southeast part, while about 30 m. across and 25 m. deep in its northwest part. The crater-wall forms an almost perpendicular cliff exposing numerous layers of the ejecta. From the southeastern crater-bottom, steam highly charged with ashes is issuing with a roaring sound. No mention of this crater has been made either by Tak. Kato or A. Imamura, who visited the volcano in 1906 and 1918–20 respectively. But the topographic map, 1 : 50 000, sheet Komagatake, Land Survey Department, 1915, shows two craters placed close together at the place where E is opened now. Accordingly, E may be successor to these shown in the topographic map.

Fissures.—Numerous fissures traverse the ground within the caldera (see Fig. 4). Among them prevail the radial and concentric fissures on the ground around the central pit-crater, A in Fig. 4. In this connection, it is noted that the crater D is situated at an intersecting point of fissures of these two systems and that the crater E consists of two vents arranged in a line running southeast radially from A.

There are also numerous fissures on the internal wall of the caldera. On the flat ground of the crests Komanose and Umanose, the fissures often form trench-like depression along the crests; while on the steep inner slopes of Saharadake, Komagatake proper, and Sumidamori, they form step-faults along which the hanging sides of the grounds slip down, causing occasional avalanches of the tali of ejecta.

Solid Ejecta.—During the paroxysmal phase of the activity, a large quantity of solid materials was projected. The map[12] in PL. VIII shows the distributions of these ejecta on the volcano.

Volcanic ashes, sands, lapilli, and bombs. These cover a large area, southeast of the volcano. Their deposit is the thickest in a zone running from the crater-bowl southeast toward Sikabe, where it attains about 1 m. in thickness, and thins rapidly on both sides of that zone; while there is no accumulation on the western foot of the volcano. Toward the crater, these ejecta naturally increase in thickness of their deposit as well as in individual size. A large quantity of these ejecta fell in the Volcano Bay (Hunkwa Wan) and was washed up by the waves, forming a new beach at about 50 m. off shore along the coast at Sikabe.

Flows of pumice-blocks. These occupy most of the lower slope of the volcano, running through the gaps, viz. Umanose, Komanose, and Namakoyama, in the ring-wall. Their distributions are as follows:

The pumice blocks, which descended the outer slope of Umanose, accumulate on the southwestern skirt between 200 m. and 400 m. in altitude above sea level, forming an extensive elevated ground. Their flows are counted by more than seven. The farthest front of these flows reaches Yakeyama, 6 km. off the crater. The pumice-blocks, which, running over the northwestern saddle, Komanose, flowed into the valley Osidasizawa, accumulate on the northwestern skirt between 100 m. and 400 m. in altitude above sea level. The farthest front of these flows reaches 6·5 km. off the crater. Several flows of pumice-blocks, which ran over Namakoyama, accumulate extensively on the eastern skirt, up to 500 m. in altitude above sea level. The front of one of these flows reaches the shore, north of the cape Dekimazaki. In this area, however, they are overlapped with the deposit of volcanic ashes, sands, lapilli, and bombs. Several flows, which are however less extensive, accumulate on the western and northern skirts.

When descended the steep slopes near the summit of the volcano,

12) For the preparation of the map, the writer is indebted to Mr. K. Yasumuro, the cartographer of this Institute.

the pumice-blocks eroded the surface of the ground to form frequent scars (see Fig. 1 in PL. IV). Accordingly, in the subterminal parts of the flows of pumice-blocks are found occasionally old materials swept by ths flows. At the skirts where the slopes are gentle, the flows stretched in the fan-shape, accumulating thickly upon one another (see Fig. 2 in PL. IV). Earlier flows were pushed aside by later ones, being thrown up like a lateral morain. At places where their courses turn sharply to either side, the flows branched off laterally, even over high ridges. Near the fronts of the flows, pumice-blocks formed numerous mounds elevated 5–30 m. from the general slope.

The pumice-blocks are of all grade of size, up to 1 m. in diameter, and are rounded due to the mutual friction on flowing. They are mingled with fine ash-materials resulted from smashing themselves on flowing. Flowing like a fluidal liquid, the ash-materials are often locally collected.

Temperatures of the solid ejecta. There are several evidences that the solid ejecta were fairly high in temperature when they were projected:

(1) In a large area, southeast of the volcano, where the ejecta fell in quantity, the foliage of trees was entirely scorched and the grasses pinned under the bombs were blackened. At Tomenoyu, about 6 km. from the crater, fire was started by heat from the ejecta, and all houses were burned down.

In the area where the flows of pumice-blocks accumulated, trees buried in the flows were burned, and for several weeks the fire was being smothered with them.

(2) Temperatures of the flows of pumice-blocks were measured by a thermometer and an electric pyrometer with the following results:

Table I.

	Temp. (C)	Date	Loc.
1	180	June 22, 1929	Yakeyama
2	335	June 22, 1929	Yakeyama
3	426	July 2, 1929	Osidasizawa

1. At 25 cm. below the surface of a flow of pumice-blocks.
2. At 51 cm. below the surface of a flow of ash-materials.
3. At 70 cm. below the surface of a flow of ash-materials.

(3) The pumice that flew through the air has a reddish zone inside. On the other hand, there is a reddish zone at a depth below the surface of the flows of pumice-blocks. These facts indicate that the outer crust of pumice-bomb and the surfacial part of the flow of pumice-blocks were rapidly cooled; while the zones inside retained for a sufficient length of time at a sufficiently high temperature to be oxidized by circulating air.

In order to ascertain the temperature at which oxidation took place, some laboratory study was made of the pumice. The results are discussed in the next paper (see p. 271).

(4) The temperature, at which the pumice had ever been, was ascertained from the microscopic study of the xenoliths found in the bread-crust bombs. A xenolith is of hornfels structure, and is similar in component minerals to some contact metamorphosed rocks, consisting of quartz, plagioclase, pyroxene, wollastonite, and accessory minerals (accidental xenolith, see p. 267). Among the component minerals of the xenolith, quartz occur in aggregates at the contact between the xenolith and the host rock (see Fig. 6). This fact indicates that the quartz was formed after the xenolith had been caught by the lava in which it occurs. Accordingly, the quartz is useful as a geologic thermometer in ascertaining the temperature, at which the lava might have been before it was ejected as the bread-crust bombs.

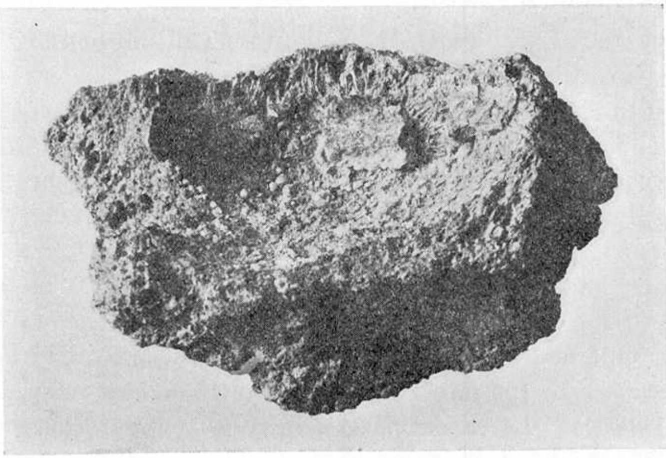


Fig. 6. An accidental xenolith in a piece of bread-crust bomb.

There are evidences that the quartz in the xenolith has suffered the high-low inversion. On the other hand, it is certain that the quartz is not that which has changed from tridymite. Therefore, it may be said that the quartz has ever been at a temperature above the high-low quartz inversion point (573°C. at one atmosphere pressure); but that it has not been retained for a sufficient length of time at a temperature above the quartz-tridymite inversion point (870°C. at one atmosphere pressure) to be transformed to tridymite. The high-low quartz inversion point is raised about 23°C for 1000 megabaryes of pressure, and the quartz-tridymite inversion point about 100°C. for 1000 megabaryes of pressure. But, practically, the influence of pressure on these inversion points may be negligible in near-surface conditions in which the quartz in the xenolith may have been formed.

From what has been stated, it may be concluded that the lava, in which the xenolith occurs, was at a temperature above 573°C., but it was not retained for a sufficient length of time at a sufficiently high temperature above 870°C. to transform the quartz in the xenolith to tridymite.

The same xenolith contains low-wollastonite. Accordingly, it may be said that the lava, in which the xenolith occur, did not heat the xenolith at a temperature above 1180°C. (high—low wollastonite inversion point) for a time sufficiently long for inversion of the wollastonite. But, unless its chemical composition is known, wollastonite is uninstructive as the geologic thermometer, for its inversion temperature is highly effected by the presence of $MgSiO_3$ which the wollastonite may take into solid solution.

Secondary mud-flows. Dark ashes that fell during the days after the activity cover the deposits of ejecta, June 17, 1929, on the east slope and the eastern half of the northern slope of the volcano. The temporary drainages caused by the rain-water furrowed the slopes covered with the ashes, and carried the materials down. In the lower courses they cut gulches through the deposits of ejecta. Thus, the ashes and pumice-fragments conmingled with rain-water formed the secondary mud-flows that devastated the areas along the valleys on the eastern half of the northern slope.

Solfataras.—There are two kinds of solfataras, viz. primary solfatara and secondary solfatara. The primary solfataras are those in which the water-vapor and gas may be directly fed from the main source of activity. The secondary solfataras are those which develop upon the flows of pumice-blocks (see Fig. 3 in PL. IV). Far more active and longer-lived are the primary solfataras formed upon a series of fissure on the ground around the active craters.

The secondary solfataras are relatively short-lived, for their sources are limited to the volatile substances occluded in the flows of pumice-blocks. They follow either cracks, with which the flows of pumice-blocks are traversed, or zone of contact of one flow of pumice-blocks with other. They apparently fluctuate in number according to the weather, for in fine weather heated gas is emitting without visible condensation of water-vapor. But, as time passes, they decrease in number and show declining activity in temperature as well as in emanation.

The gas from the solfataras may be uninstructive in its composition, for it is liable not only to contain extraneous matter derived from the terranes it traverses, but also to mix with air when it passes through crevices. According to incomplete analyses by S. Tanaka, the gases collected (air-displacement method) at solfataras on the ground near the active craters and on a flow of pumice-blocks consist, except for the water-vapor, mainly of sulphur dioxide, with carbon dioxide, oxygen, and much nitrogen. A larger amount of carbon dioxide was detected in the gas from a solfatara on the flow of pumice-blocks. It may be due to burning of trees buried under the flow of pumice-blocks, through which the gas traverses.

The solfataras are incrusted with sublimates, white, yellow, red, and brown in color. In accompany with ash-materials, the sublimates at a solfatara on the ground near the active crater A were collected in a flask, which after collection of the sublimates was sealed by fusing its mouth. The analyses by S. Tanaka[13] of the sample are as follows:

Composition of mixture

Insoluble matter	59·80
Soluble matter	14·50
S	3·70
H_2O	22·00

Composition of soluble matter

SO_4	29·38
Cl	44·52
Fe″	1·01
Fe‴	6·00
Al	8·38
Ca	7·52
Mg	1·63
Na	1·56
Total	100·00

13) For the chemical analyses published in this paper, the writer is indebted to Mr. S. Tanaka, the analyst of our Institute.

The soluble matter may be in the forms of salts as follows:

$FeSO_4$	2·75
$Fe_2(SO_4)_3$	21·48
$Al_2(SO_4)_3$	14·43
$AlCl_3$	30·16
$MgCl_2$	6·38
$CaCl_2$	20·83
NaCl	3·97
Total	100·00

Among the sublimates formed by the solfataras on the flows of pumice-blocks, ammonium chloride is also found. Sometimes, these sublimates are sooted by carbon probably derived from trees buried under the flows of pumice-blocks. In the ashes are detected metallic sulphides even at places where solfataras are absent. In accompany with the ash-materials, they might be ejected from the craters in which the primary solfataras were depositing them.

The temperatures of the solfataras, primary as well as secondary, are variable from time to time and from one to other. They also depend on the depths from the mouths of the solfataric vents, where they are measured. In Table 3 are shown some data as to the temperatures at various solfataras on the ring-wall.

Table II.

	Temp. (C)	Date	Loc.
1	73	July 1, 1929	Sumidamori
2	170	"	"
3	340	"	"
4	275	July 1, 1929	Saharadake
5	375	"	"

1, 2. On solfataric vents.
3. On fissure discharging solfataric gas.
4, 5. On fissures discharging solfataric gas.

IV. Petrography of the Ejecta of 1929.

There are three kinds of the ejecta of 1929, viz. juvenile ejecta, accessory, and accidental ones. Besides these, some of the juvenile ejecta have xenoliths. Petrographic descriptions of these ejecta and xenoliths will be given below.

A. Juvenile Ejecta.

Pumice (*Two-pyroxene-andesite*). (Figs. 1, 2, & 3, PL. VI).

Mode of Occurrence.—There are three different modes of occurrence of the pumice: (1) Pumice occurs as a thick deposit that covers a large area, southeast of the volcano; (2) It occurs as the bread-crust bombs scattering on the deposit in a limited area, southeast side of the volcano; (3) it occurs as numerous flows occupying most of the lower slope of the volcano.

Megascopic Characters.—The pumice of the first category is angular and is of three grades—sands, lapilli, and bombs—in size. The pumice of sands-and lapilli-grades are white; while the pumice of bomb-grade is white on its surface, with a reddish zone inside, representing probably the zone of oxidation on cooling (see p. 253)

The pumice of the second category has a denser bread-crusted surface surrounding the pumiceous interior. It is white inside and ash-gray outside. In this pumice, the effect of oxidation is generally absent.

The pumice of the third category is rounded due to the mutual friction on descending the slope, and is up to about 1 m. in diameter. Each piece of pumice that is exposed to the air is generally white; while its bottom-side is red, representing probably the zone of oxidation on cooling.

In hand-specimens of any pumice above mentioned, phenocrysts of plagioclase (1·5 mm. by 1·0 mm. in size) and pyroxene (1·5 mm. by 1·0 mm. in size) are scattered through the vitreous groundmass. Grouped phenocrysts of these minerals are often enclosed in vesicles.

Microscopic Characters.—Phenocrysts seen under the microscope are plagioclase, hypersthene, augite, in the decreasing order of amount.

Plagioclase phenocryst in the pumice of the first and third categories is euhedral and prismatic. Albite twin, often combined with the Carlsbad twin, is common, but the pericline twin is rare. Faint zoning of less and more calcic plagioclases is exhibited. Extinction angles on a zoned crystal are: $X\wedge(010)=43{\cdot}5°$, $X\wedge(010)=34{\cdot}5°$. $n_{1D}=1{\cdot}564(3)$. Optic character : positive. Accordingly, the plagioclase phenocryst was identified as a calcic labradorite Ab_{31} An_{69}. It contains numerous inclusions of brown glass and rare inclusions of pyroxene.

Plagioclase phenocryst in the pumice of the second category is euhedral, but occasionally is broken into pieces. It is not zonally built. Albite and Carlsbad twins are common. Extinction angles are: $Z\wedge(001)=42°$, $Y\wedge(001)=47°$. $n_{1D}=1{\cdot}561(8)$, $n_{2D}=1{\cdot}569(3)$. Optic character: positive. Thus, the plagioclase phenocryst was identified as a labradorite Ab_{38} An_{62}.

Pyroxene phenocrysts in the pumice of all categories are identical. Hypersthene is euhedral and prismatic parallel to c-axis. It is moderately pleochroic with the axial colors: Z—light green, Y—yellowish brown, X—light brown. Optic plane is parallel to c-axis. $n_{1D}=1{\cdot}700(5)$. The mineral contains, as inclusions, plagioclase and glass. Augite is euhedral and is in a short prismatic form with (100), (010), (110), and (111). Twinning after (100) is often developed. Extinction angle: $c\wedge Z=50°$. $n_{1D}=1{\cdot}693(5)$. The mineral contains inclusions of plagioclase, magnetite, and glass.

Groundmass is a colorless glass. It is very vesicular, flow-structure being well marked. $n_D=1{\cdot}493(5)$.

Chemical Compositions.—The chemical analyses of the pumices were made by S. Tanaka, the analyst of our Institute, with the following results.

Table III.

	Wt. %		Norms		
	1	2		1	2
SiO_2	59·15	59·35	Q	16·10	16·33
Al_2O_3	17·00	16·42	Or	5·56	5·00
Fe_2O_3	2·68	3·38	Ab	28·31	27·26
FeO	4·74	5·54	An	28·65	28·09
MgO	2·84	2·96	Di	2·97	5·51
CaO	7·21	7·17	Hy	11·37	11·33
Na_2O	3·34	3·25	Mt	3·94	4·86
			Il	1·22	1·21
			Ap	0·31	0·31

(*to bo continued.*)

Table III. (*continued.*)

	Wt. %		Ratios	1	2
K_2O	0·93	0·88			
H_2O+	0·72	0·28	$\frac{Sal}{Fem}$	3·9	3·3
H_2O-	0·09	0·02			
TiO_2	0·64	0·67	$\frac{Q}{F}$	0·25	0·27
P_2O_5	0·21	0·20	$\frac{K_2O'+Na_2O'}{CaO'}$	0·62	0·60
MnO	0·18	0·20			
Total	99·73	100·32	$\frac{K_2O'}{Na_2O'}$	0· 8	0·17

1. Pumice-block of 1929 flowing down the slope into Yakeyama.
2. Bread-crust bomb of 1929, from Sumidamori. Includes S 0.34.

According to the C. I. P. W. quantitative system of classification, the pumice-block from Yakeyama belongs to Tonalose (II. 4. 3(4). 4) and the bread-crust bomb from Sumidamori to Tonalose (II. 4. 3(4) 4(5)).

Comparison with the Old Rocks.—According to Tak. Kato,[14] the rocks of the volcano are of the types:

1. Two-pyroxene-andesite.
2. Olivine-bearing two-pyroxene-andesite.
3. Quartz-hypersthene-andesite.

Lavas and pyroclastic products of which the volcano is built are mostly two-pyroxene-andesite. Olivine-bearing two-pyroxene-andesite occurs locally among the rocks exposed at Saharadake. Quartz-hypersthene-andesite occurs as a dike (1 m. thick) at Kakaruma-Maruyama. Some of the phenocrysts contained in these rocks were examined optically by the writer. The results are shown in Table IV, with those of the pumice of 1929.

14) Tak. KATO, *loc. cit.*

Table IV.

	Plagioclase (n_{1D})	Hypersthene (n_{1D})	Augite (n_{1D})
1	1·562(3)	n. d.	1·6940
2	1·5630	n. d.	1·6940
3	1·565(1)	n. d.	1·693(5)
4	1·562(7)	n. d.	1·693(2)
5	1·563(3)	n. d.	1·6940
6	1·544(9)	1·699(3)	—
7	1·564(3)	1·700(5)	1·693(5)
8	1·561(8)	1·700(5)	1·693(3)

1. Olivine-bearing two-pyroxene-andesite···Komagatake lava.
2. Two-pyroxene-andesite···Basal lava.
3. Two-pyroxene-andesite···Komagatake lava.
4. Two-pyroxene-andesite···Umanose mud-flow.
5. Two-pyroxene-andesite···Kurumizaka mud-flow.
6. Quartz-hypersthene-andesite···Dike at Kakaruma-Maruyama.
7. Two-pyroxene-andesite···Pumice of 1929.
8. Two-pyroxene-andesite···Bread-crust bomb of 1929.

The above table shows that the rocks of Komagatake, except the rock occurring as dike, vary within a very limited range of composition of plagioclase. The phenocrysts in the pumices of 1929 do not differ much in composition from those in the rocks which build the visible parts of the volcano. From this fact, it is inferred that the volcanic history, from the ejection of the visible oldest products to the recent day, is limited to a relatively short interval in the cooling history of the magma.

2) *Ashes and Sands.* These are found abundantly in accompany with the lapilli and bombs. Ashes and sands are white in color, consisting under the microscope mainly of splinters of colorless glass and fragments of minerals (plagioclase, augite, and hypersthene) that occur as phenocrysts in the pumice, with a negligible amount of magnetite grains. Accordingly, it is probable that they were derived from subdivision due to explosions of the pumice.

Ash-materials also occur in the flows of pumice-blocks. They are white; but sometimes red, having been oxidized on cooling. The ash-materials are composed, under the microscope, of comminuted glass, with fragments of plagioclase, augite, and hypersthene. The glass fragments in the reddish ash-materials are stained under the microscope with reddish dusts, probably microcrypt particles of oxidized magnetite. The ash-materials may be considered to have been derived from smashing of the pumice-blocks on flowing.

B. Accessory Ejecta.

Accessory ejecta occur as fragments of two grades, lapilli and bombs. They are found on the southeast slope of the volcano, in accompany with the juvenile ejecta. Principal types of the accessory ejecta will be described in the order: 1) scoriaceous ejecta; 2) glassy ejecta; 3) porphyritic ejecta; and 4) crystalline ejecta.

1) *Scoriaceous Ejecta (Two-pyroxene-andesite).* (Fig. 4, PL. VI).

Megascopic Characters.—These are dark gray; sometimes banded with white pumiceous base. They are vesicular, porphyritic, and are crowded, especially in the vesicles, with megacrysts, 0·5 mm. in average diameter, of plagioclase and pyroxene. Occasionally, they enclose fragments of foreign materials.

Microscopic Characters.—Phenocrysts seen under the microscope are: plagioclase, augite, and hypersthene.

Plagioclase phenocryst is euhedral, and is twinned in simple and polysynthetic lamellae according to the Carlsbad and albite laws. Faint zoning of less and more calcic plagioclases is exhibited. $c \wedge Y'$ (on 010)= 24·5°. $n_{1D}=1{\cdot}5610$, $n_{2D}=1{\cdot}565(2)$. Optic character: positive. Accordingly, the plagioclase phenocryst was identified as labradorite $Ab_{38}An_{62}$. The mineral has numerous inclusions of brown glass.

Augite phenocryst is euhedral, of staut prism, 0·1—2 mm. in length, and is greenish brown in color. Lamellar twinning on (100) is often exhibited. $c \wedge Z$ (on 010)=50°. $n_{1D}=1{\cdot}692(7)$. Inclusions are: plagioclase and magnetite.

Hypersthene is euhedral, 0·5 mm. by 0·2 mm. in size, and pleochroic with the axial colors: Z—green, Y—yellowish brown, X—light brown. Optic plane is parallel to c-axis. $n_{1D}=1{\cdot}7010$.

Groundmass is hyalopilitic, with plagioclase laths, 0·1 mm. in length, augite and magnetite. The glass base is brown and vesicular.

Microscopic inclusions of foreign materials are often found. One of them is angular, 1 mm. across, porphyritic, and holocrystalline, consisting of plagioclase, augite, hypersthene and magnetite, with biotite developed around the pyroxene crystals.

Chemical Composition.—A specimen of the scoriaceous ejecta was chemically analysed by S. Tanaka, with the following result.

Table V.

	Wt. %		Norm		Ratios
SiO_2	58·03	Q	13·80	$\frac{Sal}{Fem}$	3·4
Al_2O_3	18·04	Or	4·45		
Fe_2O_3	2·63	Ab	25·15	$\frac{Q}{F}$	0·21
FeO	5·36	An	33·64		
MgO	3·17	Di	12·44	$\frac{K_2O'+Na_2O'}{CaO'}$	0·4
CaO	7·95	Hy	4·79		
Na_2O	2·99	Mt	3·71	$\frac{K_2O'}{Na_2O'}$	0·16
K_2O	0·65	Il	1·22		
H_2O^+	0·19	Ap	tr.		
H_2O^-	0·04				
TiO_2	0·61				
P_2O_5	0·18				
MnO	0·18				
Total	100·02				

According to the C. I. P. W. quantitative system of classification, it belongs to Bandose (II. 4'. 4. 4 (5)).

2) *Glassy Ejecta* (*Two-pyroxene-andesite*). (Fig. I, PL. VII).

Megascopic Characters.—These are angular, black or dark brown, and compact. Phenocrysts of plagioclase (1 mm. by 0·7 mm. in size) and pyroxene (2 mm. by 0·5 mm. in size) are scattered through the glass base.

Microscopic Characters.—Phenocrysts seen under the microscope are: plagioclase, augite, and hypersthene.

Plagioclase phenocryst is euhedral and is twinned according to the albite, Carlsbad, and rarely pericline laws. Faint zoning of less and more calcic plagioclases is exhibited. $n_{1D}=1{\cdot}564(3)$, $n_{2D}=1{\cdot}5720$. Optic character: positive. Accordingly, the plagioclase phenocryst was identified as a calcic labradorite $Ab_{31}An_{69}$. Inclusions are: plagioclase, pyroxene, and brown glass.

Augite is euhedral, of staut prism, and is greenish brown in color. Twinning on (100) is common in either simple or polysynthetic lamellae. $n_{1D}=1{\cdot}693(2)$.

Hypersthene is euhedral and pleochroic, with the axial colors: Z – green, Y – yellowish brown, and X – light brown. Optic plane is parallel to c–axis. $n_{1D}=1{\cdot}703(6)$.

Accessory minerals are magnetite and apatite. Magnetite occurs as subhedral or euhedral isometric crystals, about 0·2 mm. across. Apatite is 0·05 mm. long and occurs either as inclusions in the phenocrysts or isolated crystals.

Groundmass is a glass, colorless or brown. The brown part of the glass shows a sinuous flow-structure, with slender laths of plagioclase microlite. The colorless part of the glass is: $n_D=1{\cdot}494$. Vesicles are not common.

Chemical Composition.—A chemical analysis of the glassy ejecta was made by S. Tanaka, with the following result.

Table VI.

	Wt. %		Norm		Ratios
SiO_2	58·25	Q	13·19	Sal/Fem	3·23
Al_2O_3	17·50	Or	5·56	Q/F	0·22
Fe_2O_3	2·68	Ab	25·15	$(K_2O'+Na_2O')/CaO'$	0·50
FeO	5·45	An	31·69	K_2O'/Na_2O'	0·21
MgO	3·40	Di	12·61		
CaO	7·79	Hy	5·69		
Na_2O	3·04	Mt	3·94		
K_2O	0·77	Il	1·37		
H_2O^+	0·25				
H_2O^-	0·06				
TiO_2	0·71				
P_2O_5	0·16				
MnO	0·20				
Total	100·26				

According to the C. I. P. W. quantitative system of classification, it belongs to Bandose (II. 4′. ′4. 4′).

3) *Porphyritic Ejecta* (*Two-pyroxene-andesite*).

Megascopic Characters.—These are angular, compact, and dark gray. Phenocrysts of plagioclase (1 mm. by 2 mm. in size) and pyroxene (1 mm. by 0·5 mm. in size) are scattered through an aphanitic groundmass.

Microscopic Characters.—Microscopically these are dopatic in texture, with phenocrysts of plagioclase, augite, and hypersthene.

Plagioclase phenocryst is euhedral and is twinned according to the albite and Carlsbad laws. Faint zoning of less and more calcic plagioclases is exhibited. $n_{1D}=1{\cdot}564(5)$. Accordingly, the plagioclase phenocryst was identified as a calcic labradorite $Ab_{31}An_{69}$. Inclusions are: plagioclase, pyroxene, and brown glass.

Augite phenocryst is euhedral, prismatic, and light greenish. Simple and lamellar twinning on (100) are present. $c \wedge Z=48.°$ $n_{1D}=1{\cdot}693(4)$. Plagioclase inclusions are commonly observed.

Hypersthene is euhedral, prismatic, and pleochroic, with the axial colors: Z—clear green, Y—pale yellow, and X—light brown. Penetration twinning is rarely developed. Optic plane is parallel to c–axis. $n_{1D}=1{\cdot}702(2)$. Inclusions are: plagioclase, apatite, and glass.

Augite and hypersthene are usually altered to an uralitic hornblende. The alteration occurs along the borders or the cleavage planes of the pyroxenes. The hornblende is fibrous or is in the forms of the pyroxenes. It is green and weakly pleochroic. Optic character: negative. Elongation: positive. $n_{1D}=1{\cdot}640$.

4) *Crystalline Ejecta* (*Two-pyroxene-porphyrite*).

Megascopic Characters.—These are light gray, holocrystalline, and porphyritic. Phenocrysts (1–1·5 mm. in diameter) of plagioclase, pyroxene, and rarely of hornblende are seen with the naked eyes.

Microscopic Characters.—Microscopically, these are persemic or dosemic in texture, consisting of plagioclase, augite, hypersthene, and hornblende, with the groundmass composed of feldspar, biotite, quartz, magnetite, and apatite.

Plagioclase phenocryst is euhedral and is twinned according to the albite, Carlsbad, and pericline laws. Zoning of less and more calcic plagioclases is strongly exhibited. Extinction angles in a crystal cut normal to X are: $Y \wedge (010)=33°$ in the core part of the crystal, and $Y \wedge (010)=27°$ in the shell part. Accordingly, the plagioclase varies in composition from $Ab_{25}An_{75}$ in its core part to $Ab_{40}An_{60}$ in its shell part. Optic character: negative. A cleavage piece showed $n_{1D}=1{\cdot}5640$. Inclusions are: plagioclase, pyroxene, and glass.

Augite is euhedral and light brownish. Twinning is present in lamellae parallel to (100). $n_{1D}=1{\cdot}693(7)$.

Hypersthene is euhedral and moderately pleochroic, with the axial colors: Z—green, Y—light yellow, and X—brown. Contact and penetration twinnings are developed. Optic plane is parallel to c–axis. $n_{1D}=1{\cdot}700$.

Hornblende is euhedral and green. $c \wedge Z'=16°$. $n_{1D}=1{\cdot}662$, $n_{2D}=1{\cdot}673-1{\cdot}678(5)$.

Feldspars in the groundmass are both plagioclase (andesine) and orthoclase which is however negligible in amount.

Biotite occurs as isolated flakes (0·15 mm. in length) or as rims surrounding the pyroxene crystals.

Quartz is anhedral, filling the interstices of other minerals.

C. Accidental Ejecta.

The accidental ejecta are of two types:

1) *Accidental Ejecta—α–type.* These are gray, aphanitic, and show sometimes a perlitic luster on their surfaces. Microscopically, they are holocrystalline, millimeter-grained, and somewhat of hornfels structure, consisting of quartz, orthoclase, plagioclase, magnetite, rutile, together with vein-like swarms of quartz, magnetite, biotite, and rhombic pyroxene.

2) *Accidental Ejecta—β–type.* (Fig. 2, PL VII).

Megascopic Characters.—These are light gray in color, holocrystalline, and fine-grained. Minerals seen with the naked eyes are plagioclase and pyroxene.

Microscopic Characters.—Under the microscope these are decimillimeter-grained, of hornfels structure, but sometimes of poikilitic texture, consisting of plagioclase, orthoclase, hypersthene, quartz, magnetite, and apatite.

Plagioclase is subhedral or anhedral, and 0·05–0·7 mm. across. It is twinned according to the albite and Carlsbad laws. Zoning of less and more calcic plagioclases is absent. $n_{1D}=1{\cdot}550(3)$. Optic character: positive. Accordingly, the plagioclase was identified as a calcic andesine $Ab_{56}An_{44}$.

Orthoclase occurs as an interstitial matter or oikocryst for plagioclase and hypersthene. It also occurs as small anhedral crystals, often arranged in parallel extinction, in plagioclase.

Hypersthene is subhedral or anhedral, and 0·01–0·2 mm. long. It is moderately pleochroic, with the axial colors: Z – green, Y – yellowish green, X – brown. Optic plane is parallel to c–axis. $n_{1D}=1{\cdot}701(3)$. The hypersthene crystals are sometimes set in lines, exhibiting parallel extinction.

D. Xenoliths.

Xenoliths, accessory and accidental, are found almost always in the bread-crust bombs. They occur as nucli in voids within the bombs, there being either attached to the walls of the voids, or detached from the latter. Occasionally, they are coated with thin crust of the material of the bomb. These xenoliths are:

1) *Accessory Xenolith* (*Two-pyroxene-andesite*).

Megascopic Characters.—This is compact, angular or rounded, and is dark or light gray in color. Phenocrysts (2 mm. by 1 mm. in size) of plagioclase and pyroxene are scattered through an aphanitic groundmass.

Microscopic Characters.—This is markedly porphyritic and sempatic. Phenocrysts seen under the microscope are plagioclase, augite, and hypersthene.

Plagioclase phenocryst occurs as simple euhedral crystals or glomeroporphyritic groups. Albite and Carlsbad twins are common, and penetration twinning is rarely exhibited. Faint zoning of less and more calcic plagioclases is developed. $n_{1D}=1{\cdot}5650$, $n_{2D}=1{\cdot}568(4)$. Optic character: positive. Accordingly, the plagioclase phenocryst was identified as a calcic labradorite $Ab_{31}An_{69}$. Inclusions are: plagioclase, pyroxene, and brown glass.

Augite phenocryst is euhedral, of staut prismoid, and light greenish. Lamellar twinning on (100) is often developed. $c \wedge Z=48°$. $n_{1D}=1{\cdot}693(5)$. Inclusions are: plagioclase, hypersthene, and brown glass.

Hypersthene is euhedral and prismatic. It is moderately pleochroic, with the axial colors: Z—light green, Y—light yellow, X—light yellowish brown. Penetration twinning is often developed, there $c \wedge c$ being about 60°. Optic plane is parallel to c-axis. $n_{1D}=1{\cdot}701(5)$. Inclusions are: plagioclase and brown glass.

Groundmass is intersertal in texture and percrystalline or docrystalline, consisting of plagioclase laths (0·1 mm. long), augite grains (0·01 mm. across), magnetite, and glass.

2) *Accidental Xenolith.* (Fig. 3, PL. VII).

Megascopic Characters.—This is compact, angular, about 3 cm. across, and is light gray in color. It is microcrystalline and only mineral seen with the naked eyes is quartz. Quartz grains (1–0·3 mm. across,) occur in irregular pathes or are scattered through the mass. Besides these, quartz crystals occur in aggregates at the boundary between the xenolith and the host rock.

Microscopic Characters.—Microscopically, this is holocrystalline, seriate homoid but sometimes poikilitic in fabric, consisting of about 45 parts quartz, 20 parts plagioclase, 15 parts pyroxene, 10 parts wollastonite, and 10 parts magnetite, titanite, and zoisite.

Quartz is anhedral, and forms a mosaic in which the grains of quartz and plagioclase lie in contact with each other. Again, it occurs as oikocrysts for other minerals. It is very clear, and is traversed uniformly by irregular cracks, sometimes showing a distinct biaxiality. These facts indicate that the quartz underwent the high-low inversion (p. 253).

Plagioclase occurs either as chadacrysts for the quartz or a mosaic of subhedral crystal grains, less than 0·1 mm. in diameter. Albite twin is common. $n_{1D}=1{\cdot}5750$, $n_{2D}=1{\cdot}581(7)$. Accordingly, the plagioclase was identified as bytownite-anorthite $Ab_{10}An_{90}$.

Augite is subhedral or anhedral, 0·05 mm. across, and is greenish brown in color. Lamellar twinning is often developed. n_{1D} and n_{2D} are larger than 1·701.

Wollastonite occurs as anhedral crystal grains (0·05–0·1 mm. across) arranged in parallel extinction, or as long-continued crystals filling the interstices of other minerals. Lamellar twinning is developed. Optic character: positive. Optic plane is perpendicular to b-axis, that is, elongation: positive or negative. In sections perpendicular either to X or Y are developed two systems of cleavage cracks, one parallel and the other normal to the optic plane. Optic angle is small. Double refraction (γ-α) is fairly high, green color of the second order being exhibited on a section, about $20\mu\mu$ thick.

Among the accessory minerals, magnetite is isometric and 0·05–0·1 mm. across. Titanite is euhedral, 0·05 mm. across, and light yellowish, exhibiting distinct pleochroism. Zoisite, which is however rare, is 0·1 mm. across. Its optic character is positive and elongation negative.

V. Summary and Conclusions.

Komagatake is a homate composed of repeated layers of lava-flows and fragmentary materials of two-pyroxene-andesite. As far as the visible parts are concerned, lavas are quite inferior in amount to fragmentary materials. This fact suggests probably the explosive nature of the activity which has been displayed at the volcano. The apical part of the volcano has been blown away by explosions to result in the formation of a caldera, from which mud-flows spread down eastwards through the eastern gap in the ring-wall. The products of later eruptions build up a cone occupying the inside of the caldera. This cone, together with the northern and western parts of the ring-wall, embrace an oval crater in which several pit-craters are opened.

In historic times the activity has been frequently displayed in the oval crater. Accordingly, the configuration of the area within the oval crater has changed from time to time, probably in the courses of eruptions that took place in the years: 1640, 1765, 1784, 1856, 1888, 1905, and 1919.

In recent years the volcano had continued its activity in discharging solfataric gas, but no surface manifestation of the activity, which might be a preliminary symptom of coming of the eruption on June 17, 1929, was observed at the volcano.

The activity began with an earthquake and rumbling noises at about 0 : 30 a.m., June 17, 1929. Thenceforth, the activity had gradually increased in discharging volcanic ashes and in rumblings till about 10 a.m., when a great explosion came in accompany with an earthquake. Since then, emission of ash-laden cloud, ejection of pumice, and earth-tremor had been done almost without interruption. In the afternoon of the same day, a large amount of pumice-blocks was projected over the ring-wall, still retaining hot gas, and spreaded down to the skirts of the volcano. The eruption continued through the day into the evening hours. At about 11 : 30 p.m. on the same day, it subsided; while violent emission of ash-laden cloud continued for the following several days.

The configuration of the area within the oval crater was remarkably changed by the eruption. The inside of the oval crater was filled with the deposit of the newly ejected materials; and three groups of pit-craters, two of which are successor to those before the eruption, are formed on the deposit.

A large quantity of fragmentary materials of all grades—volcanic ashes, sands, lapilli, and bombs—covers not only the ground around the crater but also the wide area, southeast of the volcano. Numerous flows of pumice-blocks occupy most of the lower slope of the volcano.

Numerous solfataras, primary and secondary, develop on the ground around the pit-craters and on the flows of pumice-blocks. Among the sublimates, metallic sulphates, metallic chlorides and free sulphur are predominant.

The ejecta were so high in temperature at the time when they were ejected that fires were started on trees and houses at places where they deposited. On July 2, 1929, with an electric pyrometer, the writer observed the temperatures, as high as 415°C. in a flow of pumice-blocks. From the effect of oxidation which the juvenile pumice underwent by air circulating through its deposit, it was confirmed that the juvenile pumice had probably been at a temperature above 700°C. On the other hand, the bread-crust bomb of juvenile pumice was certainly at such a temperature for such a length of time as an accidental xenolith within it might be thermally metamorphosed to result in the formation of high-quartz and α-wollastonite, which under one atmosphere pressure are stable at temperatures between 573° and 870°C., and below 1180°C. respectively.

Accordingly, the temperature of the lava, in which the xenolith occurred, was certainly higher than 573°C. But it might not be higher than 1180°C., or probably it might not approach to that temperature, at least just before the ejection of the lava in the form of bread-crust bomb. By all means, it was not sufficiently higher than 870°C. for a sufficient length of time to allow the high-quartz in the xenolith to be transformed into tridymite.

The ejecta are, except for a small quantity of the accessory and accidental ones, fairly uniform (pumice) in characters, megascopical as well as microscopical, petrographically belonging to two-pyroxene-andesite. Accordingly, they might be derived from a subcrateral magma-reservoir.

The volcano has probably been born in late Diluvium. Since the time when the visible oldest products were ejected, however, the subcrateral magma appears to have been maintained within a narrow range of temperature, as may be inferred from the petrological evidences. Consequently, evolution and accumulation of gases, which are occluded in the magma, have constantly been done, leading to occasional outbursts without prolonged period of quietude. In this way, the gas-content in the subcrateral magma-conduit had increased till it was released with the violent explosions, June 17, 1929. The course of the eruption, June 17, 1929, may be analysed as follows.

Several hours in the early morning were passed in ejecting the materials of the old crater-floor, in rumblings, and in earthquakes. When the load of the conduit had been removed to some extent by blowing-away of the materials of the old crater-floor, the gas-content began to be released with violent explosions, along with ejection of juvenile lava from the magma-conduit highly charged with free gas.

The early explosions were so powerful that the lava was subdivided into pumice-fragments of all grades—volcanic ashes, sands, lapilli, and bombs. These fragments were projected in the air and landed on the ground not only around the crater, but also in a distance, southeast of the volcano.

When the gas-content had been partially spended on the early powerful explosions, less powerful explosions were set in. In this case the lava might not be subdivided into fragments and might not be projected highly in the air, as in the former. Accordingly, a large quantity of pumice-blocks was projected over the ring-wall still retaining hot gases, and descended the slope of the volcano. At a later phase, a small quantity of bread-crust bombs was projected. Such mode of activity as has been stated may be one of the Vulcanian type of eruption.

The results of precise levelling show that the land occupied by the northwestern half of the volcano has been relatively depressed from the land outside. There are also geological evidences that the land occupied by the volcano has relatively sunk. Thus, depression of the land, on which volcanic activity has been displayed, may have a causal relationship to the volcanic activity.

The Eruption of Komagatake.

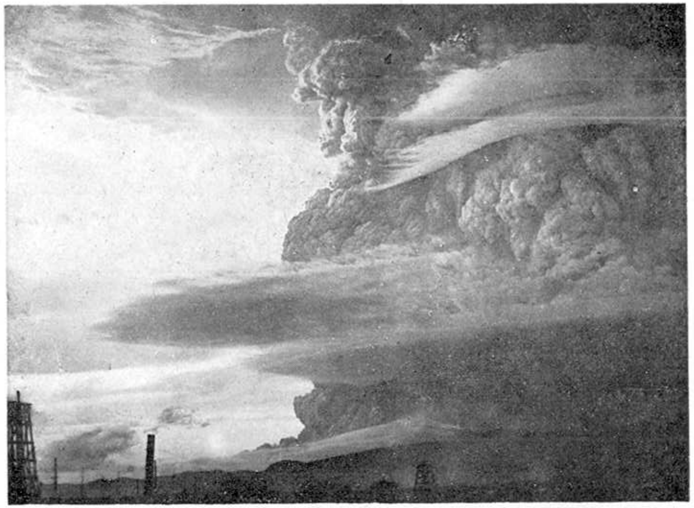


Fig. 1. Komagatake at a paroxysmal phase of eruption, as seen from Hakodate. About 5:30 p.m., June 17, 1929. (Hakodate Meteor. St.)

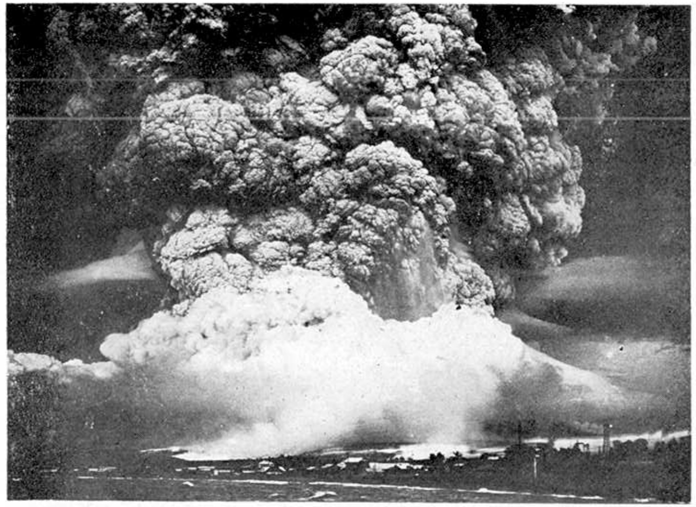


Fig. 2. Komagatake at a paroxysmal phase of eruption, as seen from Mori. About 7 p.m, June 17, 1929. (Photo Kagaya)

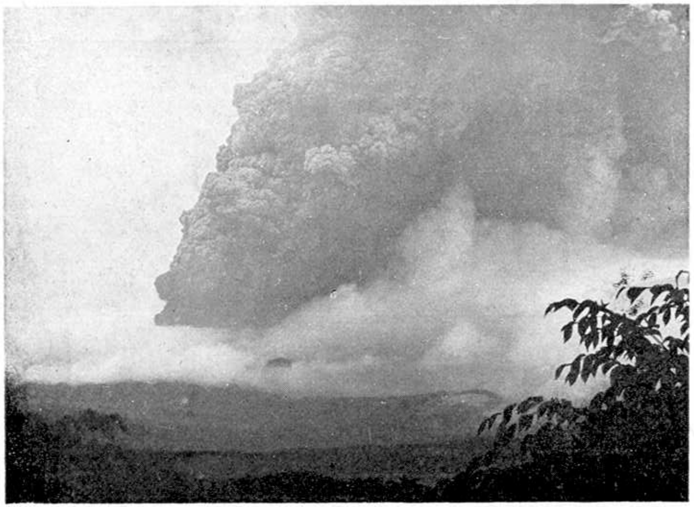


Fig. 3. Ash-cloud veering toward southeast, as seen from Oonuma. About 5 p.m., June 17. 1929. (Photo Sasako)

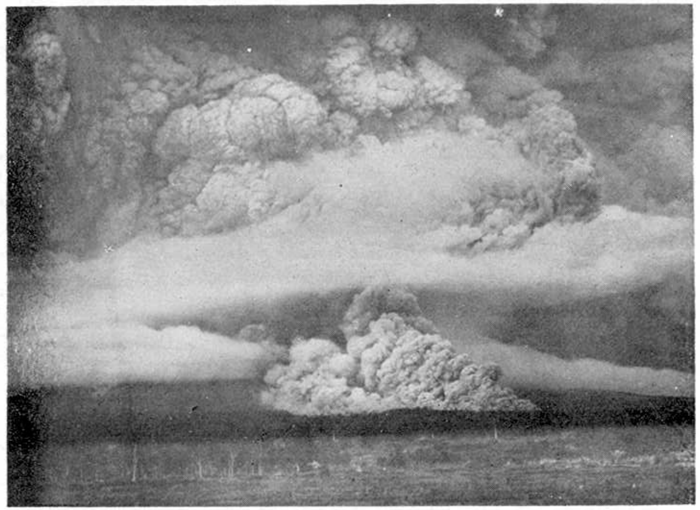


Fig. 4. A flow of pumice-blocks descending the southwestern slope of the volcano. About 5:30 p.m., June 17, 1929. (Photo Tomoe)

The Eruption of Komagatake.

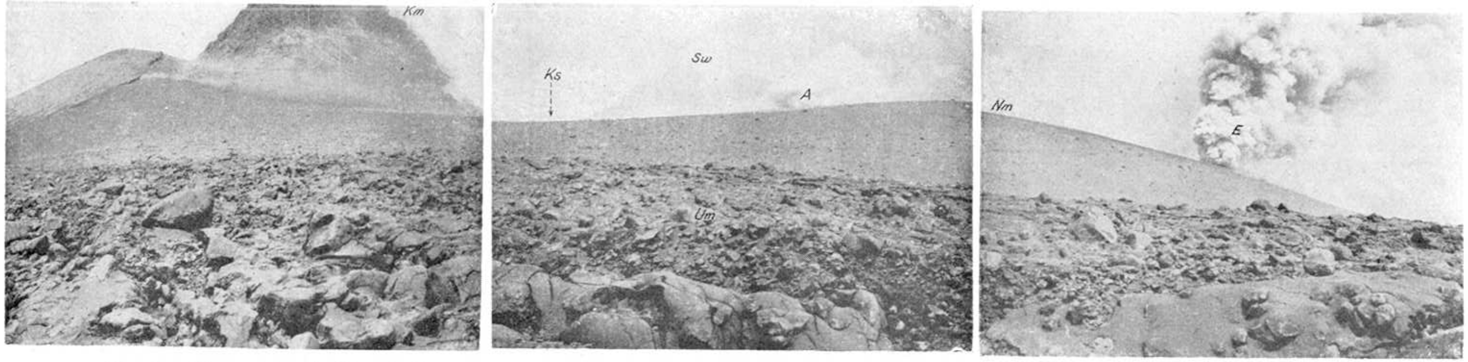


Fig. 1. View of the inside of the caldera after the eruption in 1929, as seen northwards from Umanose. Km-Komagatake; Sw-Saharadake; Nm-Namakoyama; Ks-Komanose; Um-Umanose. A and E—Vapor-clouds issuing from the respective pit-craters. See Fig. 4, p. 247.

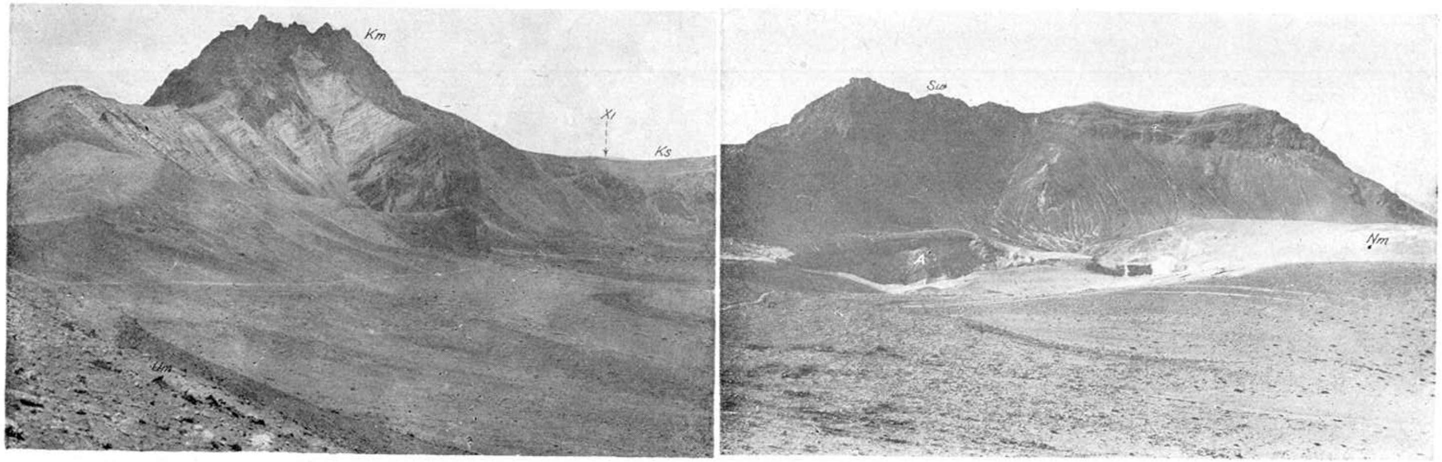


Fig. 2. View of the inside of the caldera before the eruption in 1929, as seen northwards from Umanose. Km-Komagatake; Sw-Saharadake; Nm-Namakoyama; Ks-Komanose; Um-Umanose; A—Crater in 1856.

The Eruption of Komagatake.

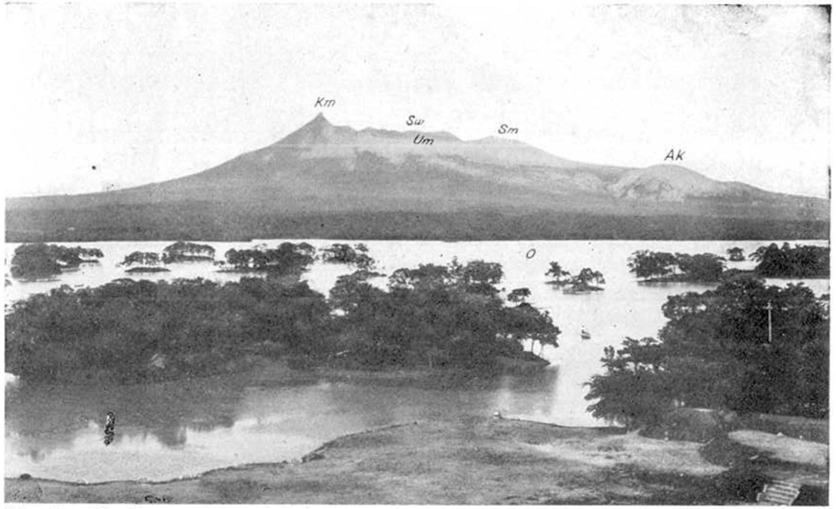


Fig. 1. Northern view of the volcano prior to the eruption in 1929, as seen from Oonuma Km-Komagatake; Sw-Saharadake; Um-Umanose; Sm-Smida-mori; Ak-Akahageyama; O-Oonuma

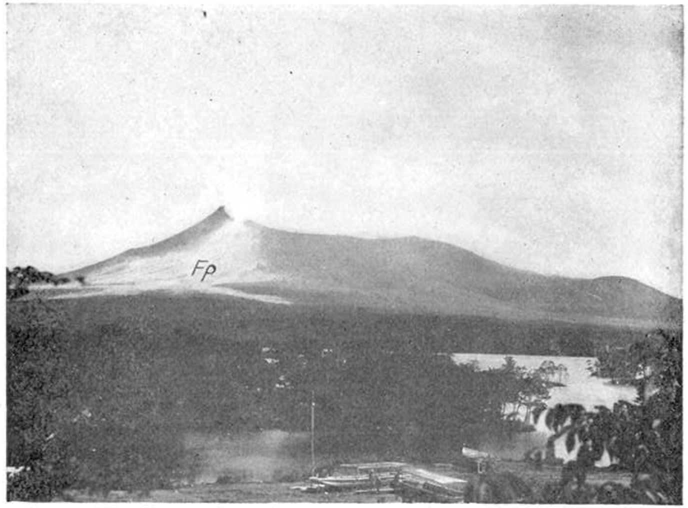


Fig. 2. Northern view of the volcano after the eruption in 1929, as seen from Oonuma. Fp-Flows of pumice-blocks. The crest of Saharadake can slightly be seen above that of Umanose. Compare with the le t figure.

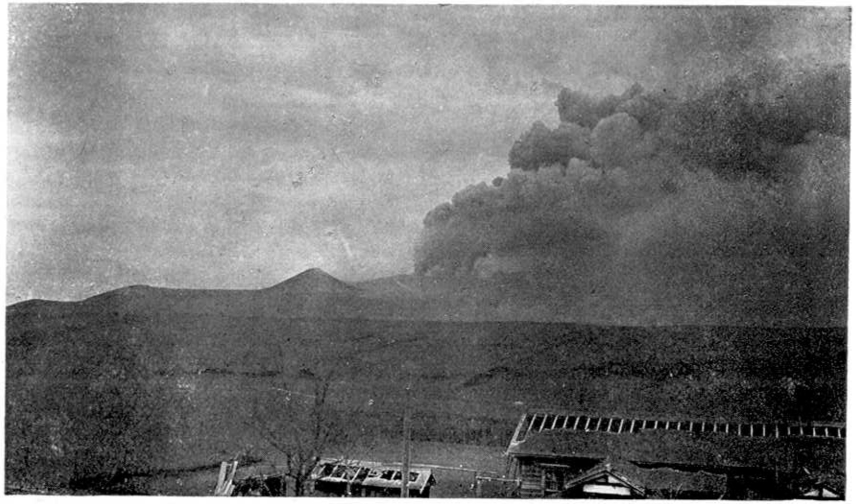


Fig. 3. Northwestern view of the volcano after the eruption in 1929, as seen from Orido near Sikabe. Sm-Sumidamori; Nm-Namakoyama; Sw-Saharadake; E-crater on the east-side of Namakoyama.

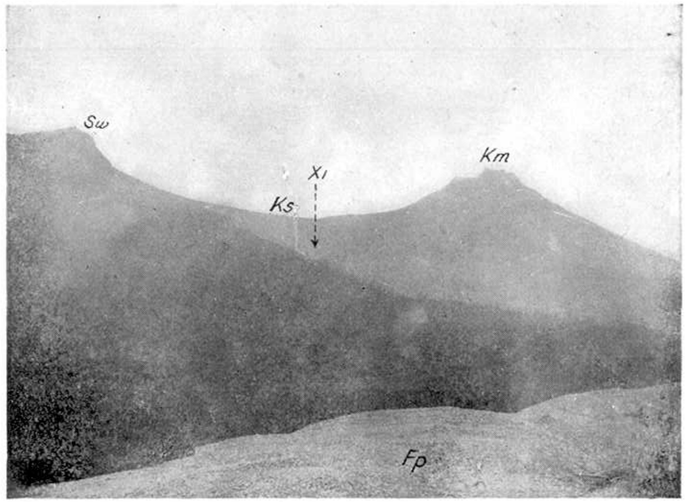


Fig. 4. Southern view of the apical part of the volcano after the eruption in 1929, as seen from the Tentozawa, a northern tributary of the Osidasizawa. Km-Komagatake; Sw-Saharadake; Ks-Komanose; X_1-Osidasizawa explosion-crater; Fp-Flows of pumice-blocks.

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The Eruption of Komagatake.

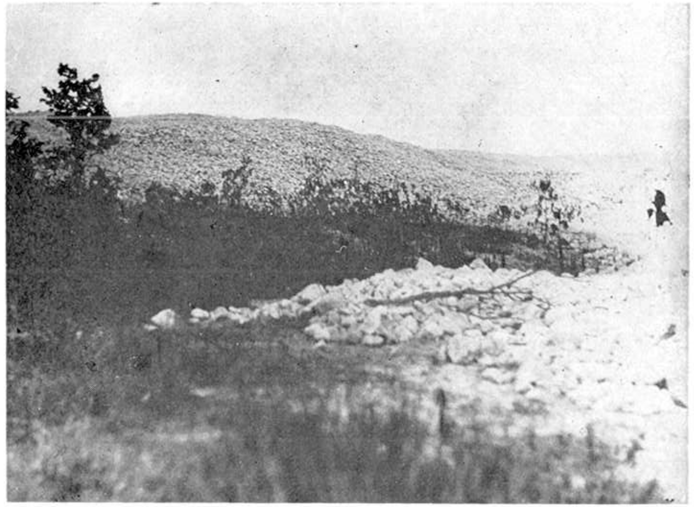


Fig. 1. Flows of pumice-blocks on the northwestern skirt of the volcano. See p. 251.

Fig. 2. A scar produced by the flows of pumice-blocks on the northwestern side of Saharadake. See p. 252.

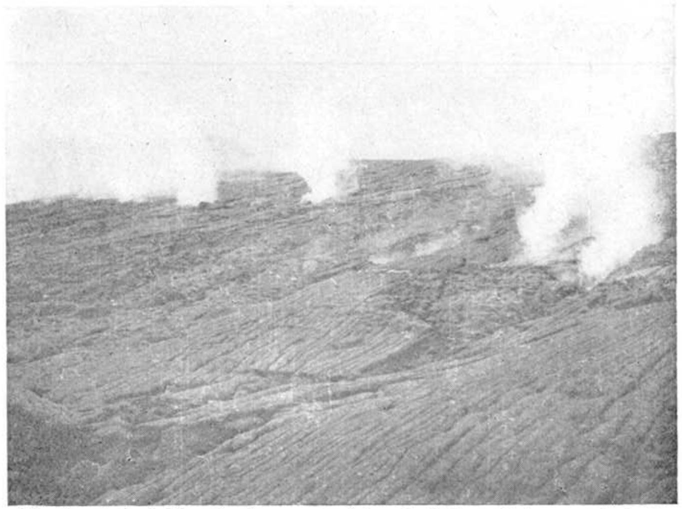


Fig. 3. Ash-field of the east side of Saharadake, eroded by drainages of rain-water. Solfataric vapors are issuing from the underlying deposit of pumice ejected by the eruption in 1929. See p. 253.

The Eruption of Komagatake.

Fig. 1. Houses in Orido near Sikabe buried in the deposit of volcanic ashes, sands, and lapilli.

Fig. 2. Houses in Sikabe damaged by the ejecta.

（震研彙報第八號、圖版、津屋）

[Bull. Earthq. Res. Inst., Vol. VIII, Pl. VI.]

(震研彙報第八號、圖版、津屋)

Microphotographs of the Ejecta of Komagatake.

Fig. 1. Two-pyroxene-andesite. Pumice (lapilli) of 1929, from Saharadake. See p. 257. ×28

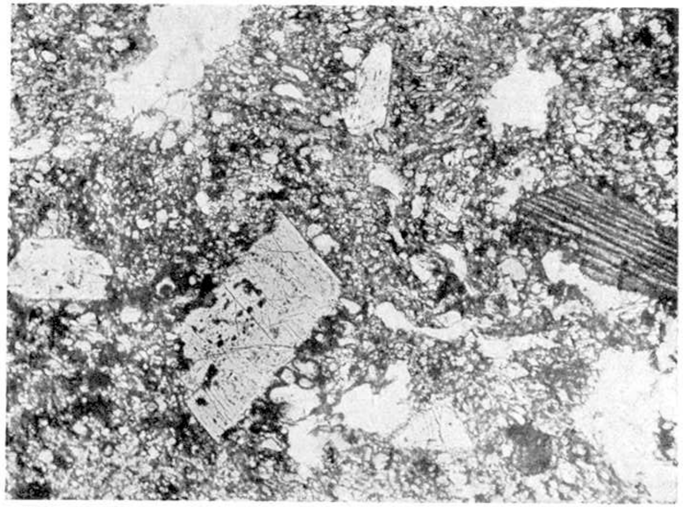


Fig. 2. Two-pyroxene-andesite. Pumice-blocks of 1929, flowing down the mountain-slope. See p. 257. ×28.

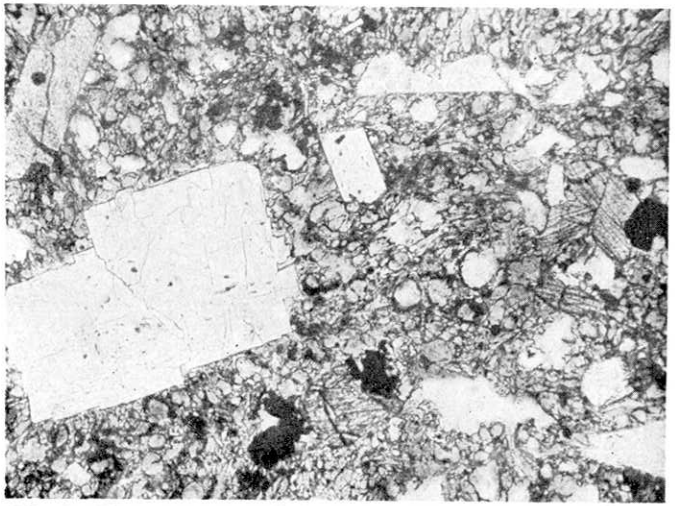


Fig. 3. Two-pyroxene-andesite. Bread-crust bombs of 1929. See p. 257. ×28

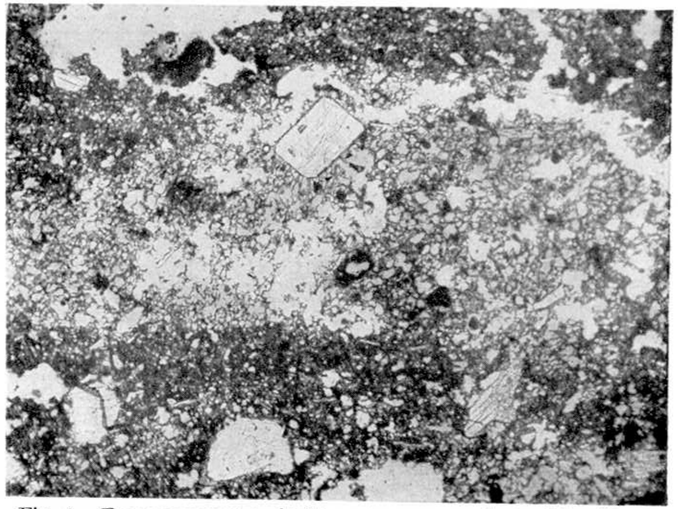


Fig. 4. Two-pyroxene-andesite. Accessory ejecta (1). See p. 261. ×28

Microphotographs of the Ejecta of Komagatake.

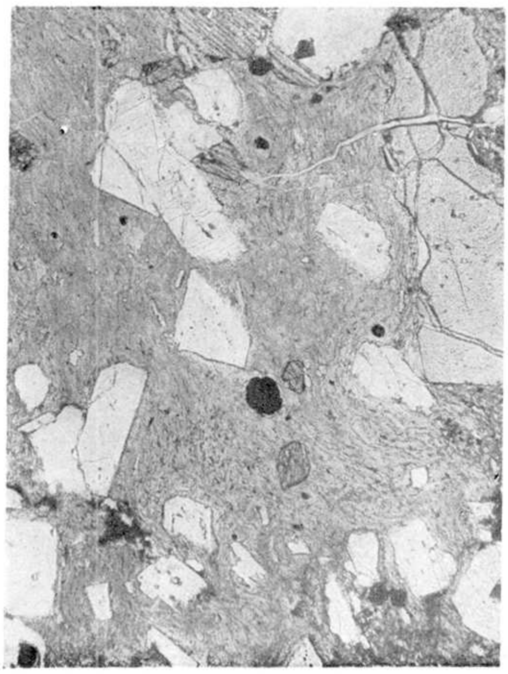


Fig. 1. Two-pyroxene-andesite. Accessory ejecta (2). See p. 261. × 28

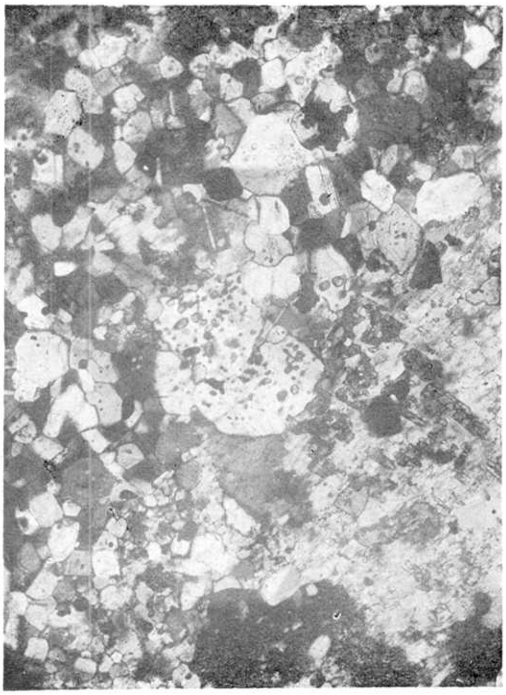


Fig. 2. Hypersthene-orthoclase-plagioclase-rock. Accidental ejecta (β-type). See p. 265. Crossed nicols. × 60

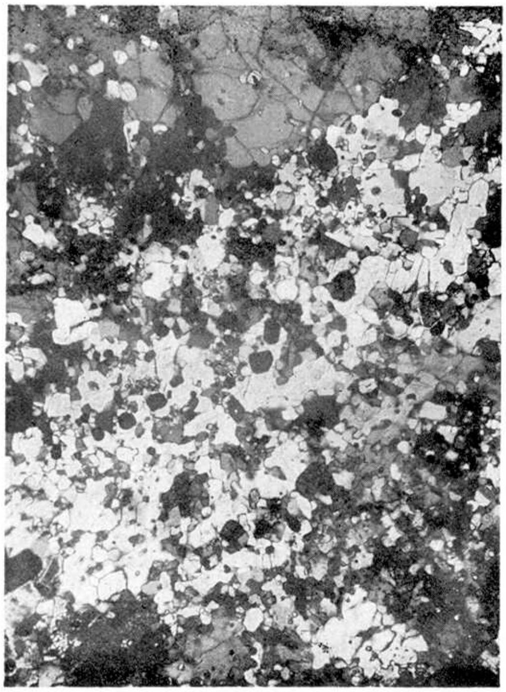
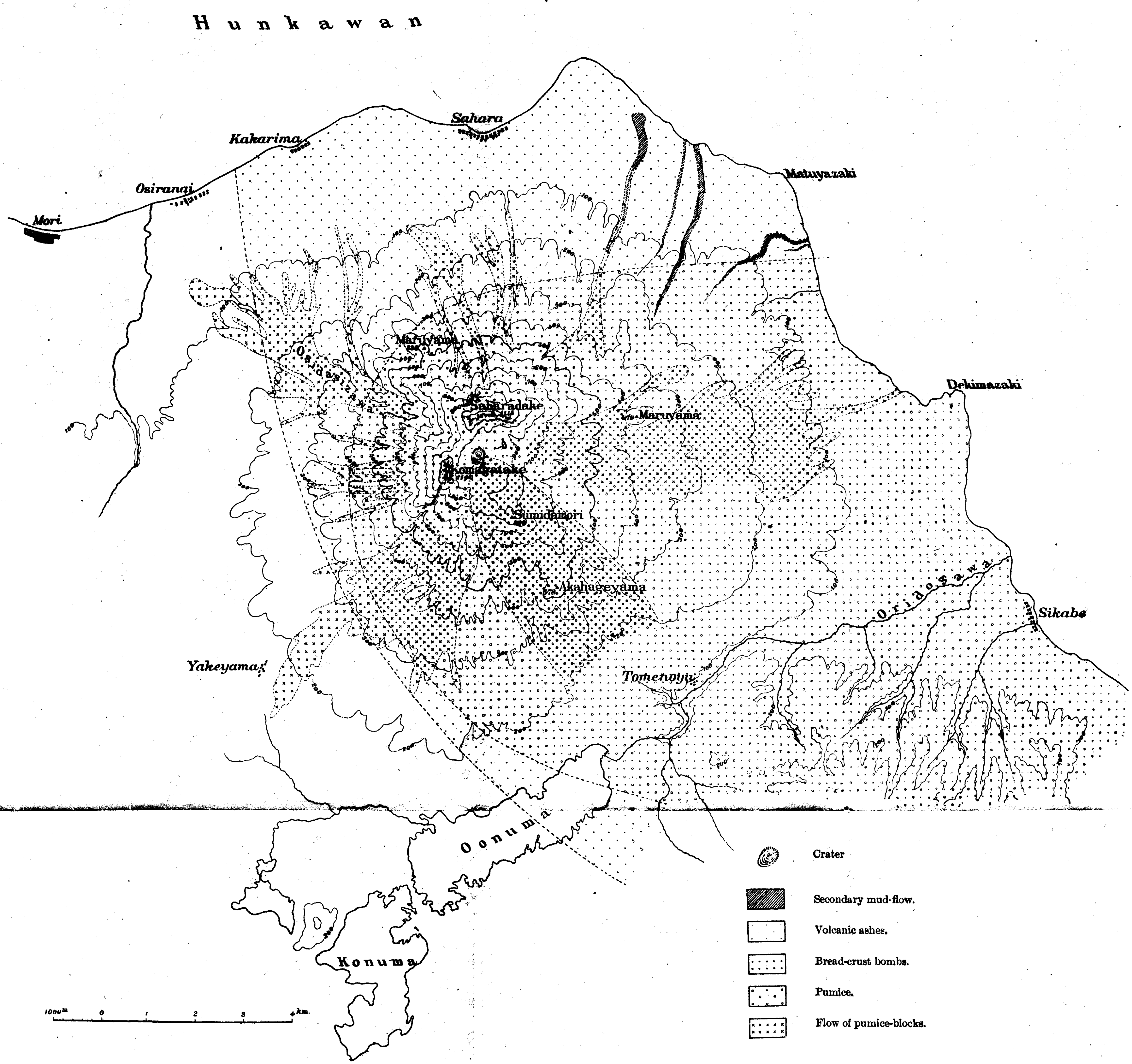


Fig. 3. Quartz-augite-plagioclase-wollastonite-rock. Accidental xenolith. See p. 267. Crossed nicols × 60

（震研彙報第八號、圖版、津屋）



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Part II. On the Temperature of the Pumiceous Ejecta of Komagatake, Hokkaidô, as inferred from their Modes of Oxidation.

By Seitarô TSUBOI and Hiromichi TSUYA,

Earthquake Research Institute.

(Received March 20, 1930.)

By the eruption of Komagatake, Hokkaidô, on June 17th, 1929, a large quantity of pumiceous lava-blocks were ejected from the summit-crater of the volcano. They are exploded fragments of molten magma, and were in a heated condition at the time of their ejection. Some of these fragments merely accumulated on the ground ; while others, being dashed together on the mountain slope, flowed subsequently like fluent lavas, resulting in "pumice-flows". The fragments vary in size mostly from a few centimeters to a few decimeters across, but sometimes reach as large as over a meter in diameter. Petrographically they belong to augite-hypersthene-labradorite-andesite. As to their modes of ejection, their distribution, their petrographic characters, etc., details are given in the preceding paper by H. Tsuya.

In the present short note we are concerned only with the modes of oxidation of the pumiceous blocks. To these a special attention is directed here, since they are interpreted as giving a clue to the temperature of the ejecta.

A representative specimen of the pumiceous lava-block, collected on the southern slope of the mountain at the height of about 300 m. above sea-level is roughly polyhedral with the diameter of some 25 cm. The mode of oxidation observed on this specimen may be described as a typical example. Its surface is gray in colour, but inside, at a depth of 1 to 2 cm. from the surface, there is an oxidized zone, about 1 cm. wide, of light yellowish to reddish colour, parallel to the surface. Still inner part is only very slightly reddish, being almost unoxidized. (See Fig. 1.) The boundary between the reddish (oxidized) zone and the outer gray (non-oxidized) zone is not sharply defined, the two zones being transitional to each other; while that between the reddish zone and the inner gray zone is rather sharp and abrupt. Under the microscope, the reddish zone is found to contain oxidized magnetite dusts finely disseminated through the glassy base.

The mode of oxidation as described in the above is very common, especially among the blocks that fell to deposit. A probable cause for this zonal oxidation is as follows: Fragmented pieces of molten magma were ejected from the crater still in a heated condition. Then, on contact with the cool air the surficial part of each block was quenched, while the inner part retaining still a high temperature. For oxidation of a pumiceous block, a sufficient supply of air and a sufficiently high temperature are combiningly needed. On the surface of each block which is exposed directly to the air, the air supply was of course sufficient, but there the temperature became soon too low for oxidation. In the inner portion of the block the temperature must have been high enough for oxidation, but there the supply of the air being insufficient, it was left unoxidized. The oxidized zone which lies at the depth of about 1 to 2 cm. from the surface corresponds to the zone where the supply of air was enough and the temperature was sufficiently high for oxidation.

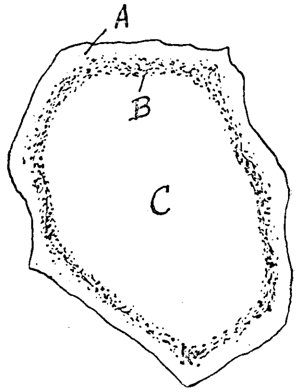

Fig. 1. Zonal oxidation of pumiceous block.
A...Surficical non-oxidized zone
B...Oxidized zone
C...Inner non-oxidized zone

In connection with the above inference it was attempted to determine the temperature necessary to produce the same degree of oxidation effect as that in the oxidized zone of the pumiceous block. For this purpose, a series of experiments were carried out as follows: Pieces of non-oxidized part (gray-coloured part) of pumice were put in an open crucible and were kept at different temperatures under an ample supply of air for different lengths of time. The samples were then compared with the naturally oxidized pumices as to their colour. In these experiments the temperatures at which the samples were kept were determined by means of a Pt-Pt-Rh thermocouple connected to a millivoltmeter.

It has been found from these experiments that:

(1) The sample is oxidized to the same degree as in the oxidized zone of the pumiceous block, when it is kept at 730°C. for 1–4 hours.

(2) At lower temperatures the degree of oxidation of the sample is much lower. For example the sample kept at 660°C. for 2 hours shows but a very slight oxidation effect; while that kept at 530°C. practically none, even after such a prolonged heating as for 8 hours.

From what have been stated in the above, an inference may now be made as to the temperature of the pumiceous lava-blocks at the time of their ejection. It is evident that their temperature was *at least as high as 730°C.*, as is indicated by the existence of the oxidized zone; *but not very much higher than this*, for they must have cooled on their surface below 730°C. too soon to be oxidized, as is inferred from their non-oxidized surface.

Some of the pumiceous blocks which constitute the pumice-flows are peculiar as to the mode of oxidation. For example, the pumiceous blocks, constituting the Akaigawa pumice-flow on the western flank of the volcano, show not infrequently oxidation effect even on the surface. This may be interpreted as indicating that these blocks retained temperatures above 730°C. for a period sufficiently long for oxidation. It is probable that this is due to the peculiar mode of ejection of the pumiceous blocks, which favoured their flowing down like fluent lava.

Part III. Meteorological and Seismological Observations.

By Fuyuhiko KISHINOUYE,

Earthquake Researth Institute.

(Received March 20, 1930.)

1. Meteorological and Seismological Conditions of the Volcano Komagatake at the time of its Eruption.

The nearest meteorological and seismological station to Komagatake is the Hakodate Meteorological Station in the city of Hakodate, about 33 km. south of the crater. Oonuma Forestry Meteorological Station in the Oonuma Park at the south-western foot of the volcano is nearer than Hakodate, but there merely meteorological observation is taken once a day. On the other hand, at Hakodate meteorological observations are made hourly, and continuous recording of seismometers are kept. Then the results of the Hakodate Meteorological Station were mostly used for the investigation.

Hakodate is moderately far from the volcano, and moreover mountain range lies between the two. So the meterological conditions near the volcano may be different from those at Hakodate, but their general features will be equal at the both places.

The great change of atmospheric pressure is said as one of causes of volcanic eruption by many authors. In this case, the pressure was depressing at the time of the eruption since June 13 from 762 mm. to 748 mm. (Fig. 1) The centre of low pressure would have passed near the volcano at the time of the eruption from south to north, and the pressure gradually reduced to 736 mm. till 18h. on June 17.

It was no precipitation for ten days before the eruption, but on the previous day it rained as much as 19·3 mm. The precipitation of water is sometimes thought as the source of the vapour, the chief constituent of the volcanic smoke, and then the vapour-pressure make the volcano erupt.

Consequently passing of the low pressure and the precipitation of the previous day may be regarded as the secondary causes in this case.

On June 17. moderate breeze blew from south before 6h., from east since 6h. till 12h., and gradually changed to south. After 16h. till 22h. wind-direction was NW, and early on that day the western villages from the volcano, Mori, Sahara, and so on, were suffered from volcanic ashes. In the afternoon, the direction of wind changed to north-west, and on the other hand eruption became vigorous, Sikabe and its neighbouring villages were thickly covered with ashes and small pumice-stones. The damages of farms and pastures were generally depend upon the wind-direction when the eruption was energetic.

The volcanic smoke containing much ashes and small pumice-stones went vertically in the air, and its summit sustained an angle of elevation of 22° from Hakodate Meteorological Station at 14h. 17m. on the day of the eruption. Its height was calculated as about 13000m. above the sea level under simple assumptions that the smoke column was vertical and narrow. The angle became 10°—its height about 6000m.—at 15h. on the next day. A photograph taken at 17h. on June 17. from Mori (see Fig. 2 in Pl. I), shows the smoke as a typical example of cauliflower shape, and at the middle height of it vortex of air and skirf-cloud are seen.

No sign of eruption was found on seismograms at Hakodate, before the eruption. But on June 17. at 0h. 23m. 43s., the seismometer registered the earth-vibrations like earth-pulsations which last for about eight minutes, and it was thought as the volcanic disturbances recorded at the first time. The vibration of the same type was recorded again at 8h. 0m. 30s., and an earthquake of ordinary type at 9h. 53m. 37·5s. on the seismogram. These vibrations were not felt by men. The vibrations of long period similar type as occurred at 0h. were recorded incessantly since 11h. on that day, till 0h. of the next day, and during that time houses in the city of Hakodate were frequently shaken and their doors rattled. According to the observations at the Oonuma Forestry Meteorological Station (Table I), the eruption was violent at that time. From this fact, the vibrations recorded at 0h. will be the first record of the eruption, though the activities of the volcano were not recognized by people till the early morning. The period of the vibration was about 3 sec. and the maximum double amplitude 185 microns.

2. Seismological Observations at Sahara.

The eruption of the volcano Komagatake attracted attentions of all who have interest in the volcano. From several institutes, men were

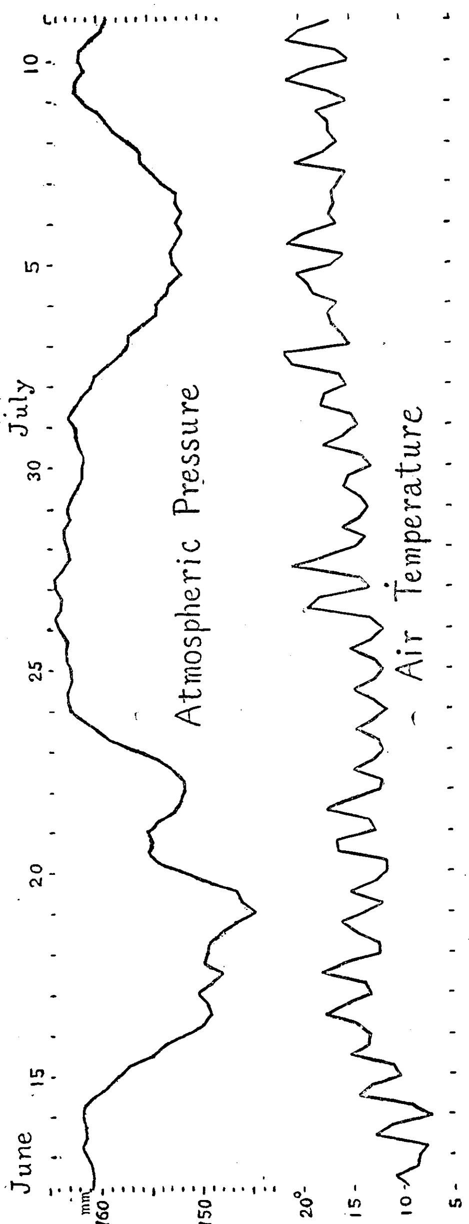

Fig. 1. Observations at Hakodate Meteorological Station.

Table I.

Observations at the Oonuma Forestry Meteorological Station.
(Observed by Mr. Sentaro Mito.)

Date (1929)	Air temperature			Wind (10^h)		Precipitation	Cloudiness (10^h)	Weather (10^h)	Remark
	10^h	Max.	Min.	Direction	Force				
June 15	16·5	20·0	11·0	N	light breeze	25·3	10	cloudy	rain from midnight.
16	15·5	25·0	10·0	W	„	1·4	10	rainy	rain continued till 11^h. (strong on morning).
17	16·5	22·0	10·5	NE	„	—	10	cloudy	1^h—$1^h 30^m$ Komagatake erupted. $10^h 04^m$ erupted again, continued furiously till 24^h. 10^h 20^m—24^h thunder 22^h—$22^h 30^m$ volcanic ash fell.
18	13·0	22·0	8·0	W	moderate breeze	1·3	10	cloudy	18^h—20^h foggy. 20^h rain. after 1^h eruption became calm. $3^h 45^m$ slight shock. (duration 5 sec.).
19	13·0	17·0	11·5	W	light breeze	4·5	10	rainy	11^h heavy rain. $17^h 30^m$ rain stopped.
20	16·0	20·0	9·0	W	„	—	7	clear	23^h slight shock (duration 4 sec.).
21	19·5	21·0	12·5	W	„	2·2	10	cloudy	$8^h 40^m$ slight shock (duration 3 sec.). from $16^h 30^m$ rain. $16^h 30^m$ slight shock (dur. 5 sec.).
22	14·5	16·5	11·0	N	„	2·5	10	rainy	$12^h 15^m$ shock (dur. 2 sec.).
23	15·0	16·5	11·5	NE	„	—	10	cloudy	4^h shock (dur. 2 sec.). $4^h 30^m$ shock (dur. 3 sec.).
24	11·5	15·5	9·5	N	„	—	10	foggy	
25	15·0	21·0	10·0	N	„	0·9	7	clear	
26	20·0	25·5	11·5	SW	„	—	1	fine	
27	22·5	25·0	9·0	W	„	—	5	clear	
28	12·5	14·5	10·0	E	moderate breeze	—	10	cloudy	$18^h 50^m$ shock (dur. 3 sec.).
29	12·0	16·5	10·5	N	light breeze	—	10	cloudy	
30	16·5	20·0	11·0	N	„	—	10	cloudy	

sent to observe the eruption, and from the Earthquake Research Institute five observers were ordered to go to the volcano and they started at the midday on June 20.

Two men of the party took charge of geological and topographical survey, and the others instrumental observations of the volcanic activity. The instruments brought were an one-component microseismometer, a pair of the Ishimoto's tiltometer, a pair of Tsuboi's gravity-variometer. Besides these, Dr. Nakata who joined the party carried two galvanometers, with which he observed earth-current and potential of atmospheric electricity.

In the afternoon on 21., they arrived at Oonuma, a village at the south-western foot of Komagatake, and soon sought a place to set the instruments. The conditions of the place suitable for observation are as follows: the volcanic activities are directly observed, in other words, the observing station is not on the different block of the earth's crust from that of the volcano; the location is handy to means of trancit for observers; natural bed of hard rock is best as the floor of the station, but if such place could not be found, stable hard rock or concrete floor must be provided; the room for the observation is dark and supply of electric current is near at hand, for all instruments brought were optical self-recording on the bromide papers and use electric lamp lighted by six volt secondary batteries.

The instruments were equipped in one of the storehouses of the Maruyama marine products factory which has concrete floor and also meet all the other conditions required, on 22. at Sahara ($\varphi=42°07'$, $\lambda=140°41'$), about 8 km. north of the crater.

The writer took charge of seismometrical observation with an one-component microseismometer stated above, which had been invented by Proffesor Ishimoto[1] and Dr. Takahasi, and details of its construction would be omitted here for that is written in the previous volume of this Bulletin. But now the constants of the seismometer are to be mentioned. The recording magnification was made 500, period of self-vibration 1.5 sec., and oil-damper was attached to the insutrument. The period may be rather small for recording of ordinary earthquakes, but that of volcanic earthquakes is so small that the seismometer has no difficulties in

1) M. ISHIMOTO et R. TAKAHASI, *Bull. Earthq. Res. Inst.*, 7 (1929), 176–178.

resonance. To make sure of this supposition, the writer set the seismometer on the ground-floor of the institute to compare with the ordinary horizontal pendulum seismometers after he returned to Tokyo. Of course the former did not record the long period vibrations as theoretically known, but vibrations of small period were well recorded.

The recording was photographical on bromide paper. The weak point of this means of recording is bromide paper is not sensitive to the image of fast motions. On seismograms P phase is registered in many cases, but S phase of earthquake is hardly recorded. This fact tells that the vibration of S phase is fairly faster than that of P phase. But by use of photographic film, good records of both phases were obtained.

According to Omori's investigation[2] at the volcano Asamayama, the initial movement of volcanic earthquakes is sharp in the radial direction from the crater. So the writer set the seismometer to record NS-component of the earthquake motions, that is nearly radial direction at Sahara.

The recording was begun at 1h. on June 23., and continued till July 10. Though the recording was broken accidentally, more than three hundred earthquakes were recorded during eighteen days.

The seismograms are divided in four classes: the first class includes impulsive earthquakes, amplitudes of which become suddenly large and decrease exponentially in a few seconds (denoted I in Table II, see Pl. IX, Fig. 2); the second very near earthquakes of ordinary type, (II, Figs. 3 and 4) preliminary tremors are seen distinctly; and the third cluster of the small earthquakes (III, Fig. 5); the fourth comparatively distant earthquakes (IV in Table II, Fig. 1); Omori[3] classified the earthquakes of Asamayama in two, non-eruptive and eruptive. The former is impulsive, the later somewhat long in duration. These may be correspond to the first and second class of Table II. But unfortunately it was mostly cloudy while the writer stayed in Hokkaidô, and the volcanic smoke could not be seen, so the volcanic activities were known only through the instrumental records. Under such state, the writer can not say about

2) F. Omori, *Bull. Earthq. Inv. Comm.*, 7 (1914).

3) *ditto.*

the relation between the seismographical types of the earthquakes and the volcanic activities.

The recorded amplitude of the earthquakes was mostly less than 1 mm., and even the greatest 6 cm. These earthquakes were local and hardly felt by men. For instance, on July 4. several moderate shocks occurred at Oonuma, but the instrument at Sahara did not record it. The writer felt a shock at about 17h 57m, on June 23. in a house of Osiranai, a village 6 km. apart from the station. Then the writer soon went to see the seismogram, but he could not find record of the shock. Only one earthquake was felt by him, which belongs to the impulsive class, and its velocity of motion was too fast to be recorded on bromide paper, so its record was not photographed. Mr. Iwasita, who stayed for the observation at Sahara till July 10 after the writer returned to Tokyo, felt an earthquake which occurred at 17h 28m on July 10. Its record shown in Fig. 4 on Pl. IX was obtained in a good chance when the vibration was recorded on photographic films, and driving rate of recording-drum made as fast as 26·1 cm./min. That was the only one record with which the vibration-period of principal portion of the earthquake could be measured. Its period obtained was about 0·2 sec. The more accurate measurement of the duration of the preliminary tremours are also got with it.

It is known as mentioned before that the small period seismometer does not record the true motion of earthquake, but resonances with the motion of the period equal to that of the self-vibration. If measurement of only preliminary tremours were required, for at present it is the most important factor in practical seismometry, small-period seismometer may serve for the purpose in some cases. For example, on the seismogram of an earthquake occurred on June 24. off the coast of Iwaki is shown in Fig. 1 on Pl. IX, P phase and S phase of it are distinguished by vibration-period and amplitude as in the case usual seismometers. But the amplitude of both phases are very small, and amplitude difference is little.

The Hakodate Meteorological Station is the nearest place where continuous meteorological and seismometrical observations are done as before mentioned. The writer called at the station and was allowed by the director of the station to inspect the records. There is an

Omori's portable seismometer, its magnification is 10, and its self-vibration period of EW and NS components are 6·1 sec., 4·5 sec. respectively.

Its magnification is too small to recognize the local volcanic earthquakes at about 30 km. distant, for seismic waves soon damped away in the vicinity of the volcano because of its amplitude and period of vibration is very small, and then the shaken area is small. Mainly by such reason only three earthquakes which took place at 18h 48m on June 28., 3h 07m and 11h 05m on July 4., were measured their duration of preliminary tremors at both Hakodate and Sahara.

The duration of preliminary tremours had been measured, and the focus was found under the assumption that the focal distance from each station is proportional to its duration of preliminary tremours. Then by Appolonius theorem in geometry, the locus of the earthquake-foci whose distances from two stations are in the constant ratio of the durations of the preliminary tremors is a sphere, the centre of which lies on the straight line joining the two observing points. The circles in Fig. 2 show the section of the above-mentioned spheres. All cireles passes near the crater, and morever the disturbed area was very small in these cases, then it would be natural to think that the earthquakes have their foci near of the crater. Simply assuming as the stations and the foci are on one plane, the velocity of the virtual wave S—P was calculated as from 2·4 km./sec. to 3·2 km./sec. and in the average 2·9 km./sec. This value, commonly said as k by seismologists, is remarkably small as compared with Omori's value, 7·42 km./sec. But it may be natural result, for Proffesor Imamura[4] and others stated that in upper layer of the earth's crust, the value of k is very small. For instance, it is 3·0 in the case of earthquakes which occur in the neighbourhood of Wakayama City, 5·0 in some district of Kwantô. The earthquakes of Komagatake have their origin very near the earth's surface, and seismic waves pass through rocks that has been less firmly consolidated. So the value of k will be smaller than usual cases.

4) A. Imamura, F. Kishinouye and K. Kodaira, *Bull. Earthq. Res. Inst.*, 7 (1929), 471.

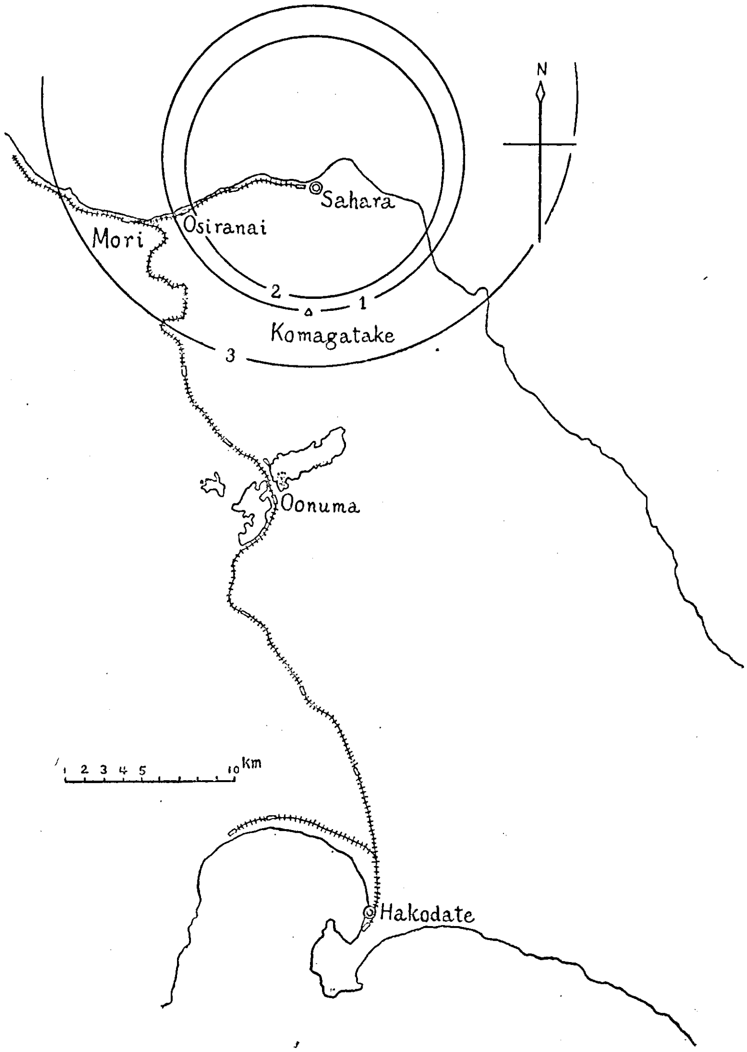

Fig. 2.

No. 1. June 28, 18h 48m
No. 2. July 4, 3 07
No. 3. July 4, 11 05

Table II.

Seismometrical Observations at Sahara from June 23 to July 10, 1929.

D.P.T. = Duration of preliminary tremours.
T.D. = Total duration of earthquake.
Cl. = Class (see p. 279).
M.A. = maximum double amplitude in mm. on the seismogram.

No.	Date	Arrival time	D.P.T.	T. D.	Cl.	M.A.	Remark
		h m	s	s			
1	VI 23	21 44·5		2	II	2	$11^h 37^m$ recording began.
2		21 44·6		2	I	2	$12^h 30^m$—$21^h 30^m$ recording drum stopped.
3		22 22	1·1	13	II	1·6	
4		23 23	0·9	16	II	1	Till VI 24. 0^h no time mark.
5		23 27	1·2	19	II	1·3	
6		23 50	1·9	7	II	1·5	
7	24	1 13	1·5	10	II	1·5	
8		2 15	0·7	1	II	2	
9		8 54·7	1·8	15	II	1	
10		8 55·0	2·7	11	II	1	
11		9 29		120	III	1·5	
12		9 46		60	III	0	
13		10 07·7	0·9	2	I	1	
14		10 08·3	3·3	6	I	1	
15		10 55	0·6	6	II	2·6	
16		11 04	60·0	300	IV	1	
17		11 59		80	III	0	
18		12 19·2		10	II	0	
19		12 19·9	1·4	10	II	1·5	
20		16 05		300	III	1	$15^h 30^m$—$22^h 10^m$ no time mark.
21		16 19		150	III	1	
22		16 23		50	III	1	
23		16 24	0·7	16	II	1·5	
24		16 33		300	III	1	
25		17 14		150	III	1	
26		17 17		15	III	1	
27		20 52	2·5	40	II	1	
28		21 50	12·0	20	II	1·4	
29	25	4 03			II		Records overlapped, and unmeasurable.
30		4 30			II	56	Then the arrival-times are due to the
31		5 48			II		Hakodate Meteorological Station.
32		9 52	2·4	10	II	1·5	
33		11 51		20	II	1·5	
34		11 55	3·1	10	I	2·0	
35		11 57	3·0	10	I	1·5	
36		12 30	2·9	25	I	4·0	
37		14 05		70	III	1·2	
38		14 49		90	III	0	
39		15 40		5	I	1	
40		15 47		90	III	1·4	
41		15 52		2	I	1·5	
42		15 59		2	I	1·4	
43		16 00	2·3	20	I	8·5	
44		16 04		25	II	1·2	
45		16 08		10	II	1	
46		16 22		5	II	0	
47		16 25		40	III	0	

(to be continued.)

Table II. (*continued.*)

No.	Date	Arrival time	D.P.T.	T. D.	Cl.	M. A.	Remark
		h m	s	s			
48	VI 25	16 44		60	III	1	
49		17 16		20	II	2.5	
50		17 35		10	II	1·5	
55		18 00		60	III	1·2	
56		18 25		15	I	0	
57		19 47		10	I	1·2	
58		20 06		10	II	1	
59		20 21		25	I	2·6	
60		20 22		20	I	2·5	
61		21 02	4·3	30	II	2·1	
62		21 04	4·2	50	II	3·0	
63		22 25		25	III	1	
64		22 26		5	I	1·6	
65		23 23		30	II	1	
66	26	0 02	2·1	30	I	4	
67		1 58		15	II	1	
68		2 24		1	I	0	
69		8 40		180	III	1	
70		9 00		30	II	1	8h 20m—14h 50m development of recording bromide paper was failed, and measuring is very hard.
71		9 45·5		15	II	1	
72		9 45·9		10	II	1	
73		12 08		15	II	1	
74		14 53		20			
75		15 40		5	I	1·5	
76		15 55		25	II	1	
77		16 01	5	25	II	1·4	
78		16 09		20	II	1	
79		16 14		80	III	1	
80		16 18		50	III	1·2	
81		16 27		60	III	1	
82		16 28		10	II	0	
83		16 53		100	III	1	
84		17 12		50	III	1	
85		17 32	3·6	40	II	3·5	
86		19 21		70	III	0	
87		20 07		30	II	1	
88		22 04		50	II	0	
89		23 13	2·0	50	I	4·0	
90		23 47		10	II	1·2	
91		23 53	1·8	30	II	2·5	
92	27	1 29		30	II	1·2	
93		1 47	71	600	IV	1·0	
94		5 05		15	I	3·5	
95		6 35		10	I	3·4	
96		7 33		3	I	1	
97		8 09	3·6	50	II	3·2	8h 50m—10h 17m records overlapped.
98		16 48		100			12h 20m—15h 10m filament of electric lamp was broken, and no record.
99		16 51		50			
100		19 16		20	II	1·5	
101		21 58		1	I	1·2	
102		22 17		1	I	1·4	
103		22 26		20	III	0	
104		22 27		40	III	0	
105		22 28		30	III	1	
106		22 32		20	II	1	

(*to be continued.*)

Table II. (*continued.*)

No.	Date	Arrival time	D.P.T.	T. D.	Cl.	M. A.	Remark
		h m	s	s			
107	VI 27	22 38		3	II	0	
108		22 40		50	III	0	
109		22 42		30	III	0	
110		22 46		40	III	0	
111		22 48		30	III	0	
112		22 56		50	III	0	
113		23 02		50	III	0	
114		23 04		60	III	0	
115		23 07		10	II	0	
116		23 12		25	III	0	
117		23 13		40	III	0	
118		23 24		2	I	0	
119		23 26		40	III	0	
120		23 28		30	III	0	
121		23 30·5		30	III	0	
122		23 31·0		20	III	0	
123		23 40		40	III	0	
124		23 42		10	II	0	
125		23 44		40	III	0	
126		23 48		15	III	0	
127		23 50		15	II	0	
128		23 51		30	III	1	
129		23 52		30	III	0	
130		23 56		20	II	0	
131		23 59		15	II	0	
132	28	0 04		10	II	0	
133		0 07		35	III	0	
134		0 10		60	II	0	
135		0 12		240	III	1	
136		0 33		80	III	0	
137		0 35		10	II	0	
138		0 37		20	III	0	
139		0 40		15	II	0	
140		0 41		10	III	0	
141		0 42·0		15	III	0	
142		0 42·5		10	II	0	
143		0 46		20	II	0	
144		0 48		10	I	0	
145		0 59		10	II	0	
146		1 14	1·6	20	I	20	
147		1 36		20	II	0	
148		1 44		10	II	0	
149		1 45		60	III	0	
150		1 47		30	III	0	
151		1 53		30	III	0	
152		1 55		20	II	0	
153		2 18		80	III	1	
154		2 27		80	III	1	
155		2 35		50	III	0	
156		2 50		10	II	1	
157		2 58		10	II	0	
158		3 58		15	III	0	
159		4 01		250	III	0	
160		4 05		250	III	0	
161		4 21		20	III	1	

(*to be continued.*)

Table II. (*continued.*)

No.	Date	Arrival time	D.P.T.	T. D.	Cl.	M. A.	Remark
		h m	s	s			
162	VI 28	5 39	2·4	30	II	1·5	
163		6 47		45	III	1·4	
164		7 14		540	IV		Period of vibration is long.
165		7 23	3·0	60	II	1·2	
166		12 00	1·1	30	I	1	
167		14 17	1·6	20	I	1	
168		14 32		60	II	1	
169		14 41		10	I	0	
170		18 48	2·6	80	I	2	D.P.T. of Hakodate = 12·8^s.
171		19 12		10	II	0	
172		20 02		20	II	0	
173		20 17		30	II	1	
174		20 36		30	II	0	
175		20 46		20	II	0	
176		21 20		140	III	1·2	
177		22 03		20	II	0	
178		22 37		10	II	1	22^h 45^m—VI 29. 12^h 30^m voltage of electric cells dropped, and light gave out.
179	29	12 39	1·5	40	I	1	
180		12 47	1·4	30	II	1·7	
181		12 53		20	III	1	
182		13 05		10	II	1	
183		13 25		15	III	1	
184		14 00		110	II	0	
185		14 11		100	III	1	
186		14 32		15	II	1·6	
187		14 59		25	II	0	
188		18 50		15	II	0	
189		19 11		20	II	1	
190		19 42	2·0	25	II	2·0	
191		21 56		50			Felt.
192		23 29		10	II	0	
193	30	4 41		15	II	1	
194		7 25		20	II	0	
195		8 25		50	I	1	
196		8 47		20	II	1·5	
197		9 05		30	II	0	
198		10 17·7		15	III	1	
199		10 18·5		5	I	1·2	
200		11 14		50	III	1	
201		11 16		20	III	0	
202		11 57		20	III	1	
203		11 58		40	III	1	
204		12 25		60	II	0	
205		13 00		10	II	0	
206		13 29		10	II	0	
207		15 33		80	III	0	
208		16 14		100	III	1	
209		16 31		15	II	1	16^h 50^m—21^h 08^m records overlapped.
210	VII 1	1 16		15	II	0	
211		8 06		10	II	0	
212		8 09		40	III	0	20^h 40^m—22^h 25^m drum stopped.
213		8 12		40	III	0	
214		9 04		20	III	1	
215		10 47		20	II	1	
216		10 56		20	II	1	

(*to be continued.*)

Table II. (*continued.*)

No.	Date	Arrival time	D.P.T.	T. D.	Cl.	M.A.	Remark
		h m	s	s			
217	VII 1	11 15		10	II	1	
218		12 22		20	II	0	VII 2. $6^h 00^m$—$21^h 40^m$ drum did not rotate, and records overlapped.
219		17 18		15	II	0	
220		17 23		15	III	0	
221		20 17		10	II	0	D.P.T. of Hakodate=11^s.
222	3	2 08		40	II		$2^h 00^m$—$9^h 30^m$ record is faint.
223		12 18		180		1	
224		12 43	2·2	30	II	1·5	
225		12 57		20	II	1	
226		15 03		90	II	1	
227		18 00		50	II	0	
228		18 01		60	II	0	
229	4	0 16		30	II	1	
230		3 07	1·9	60	II	2	D.P.T. of Hakodate=11^s.
231		3 34	1·8	30	II	1·5	
232		5 35		180	II	0	
233		5 39		60	II	0	
234		9 27		110	III	1·0	
235		9 30		60	II	0	
236		9 34		30	II	1·5	
237		10 02		70	II	1	
238		10 11		20	II	0	
239		10 19		5	I	1·5	
240		10 57		90	II	1	
241		11 02		50	II	2	
242		11 05	3·0	130	II	2	D.P.T. of Hakodate=$9{\cdot}0^s$.
243		11 18		50	II	1	
244		11 33		50	II	3	D.P.T. of Hakodate=$10{\cdot}0^s$.
245		11 36	1·4	30	II	2	D.P.T. of Hakodate=$9{\cdot}0^s$.
246		12 08		40	II	1	
247		12 27		10	II	1	
248		12 40		10	II	0	
249		12 41		15	III	1	
250		12 50		30	II	1·2	
251		14 33		20	II	0	$15^h 00^m$—$16^h 40^m$ records overlapped.
252		17 33		5	I	0	
253		17 51		5	I	0	
254		18 37		25	III	0	
255		18 55		5	II	0	
256	5	5 03		180	III	0	
257		6 56		150	III	1·2	
258		8 24		5	II	1	
259		8 29		40	II	0	
260		8 49		30	II	1	
261		8 55		10	I	1	
262		8 59		60	II	1	
263		9 08		25	II	1	
264		9 10		20	II	0	
265		10 07		30	II	0	
266		10 43		150	II	1	
267		11 52		40	II	1	
268		12 27		60	III	1	
269		14 08		40	II	0	
270		14 19		20	II	0	
271		15 09		20	II	0	

(*to be continued.*)

Table II. (*continued.*)

No.	Date	Arrival time h m	D.P.T. s	T. D. s	Cl.	M. A.	Remark
272	VII 5	15 18		50	III	1	
273		15 29	4·0	30	I	3	14h 40m —16h 06m records overlapped.
274		17 57		100	III	1	
275		18 39		20	II	1	
276		19 25		10	II	0	
277		20 12		15	II	0	
278		22 00		40	II	1	
279		22 07		25	II	1	
280		23 25		40	II	0	
281		23 32		40	II	0	
282	6	2 10		30	II	1	
283		8 17		80	IV	0	
284		8 51		10	II	0	
285		9 29		20	II	1	
286		10 04		15	II	0	
287		10 06·5		50	II	0	
288		10 07·2		50	II	0	
289		10 08·0		30	II	1	
290		10 08·7		180	III	1	
291		16		100	III	1·1	11h 22m—14h 59m records overlapped, and no time-mark.
292		16 30		60	II	1	
293		19		40	III	0	
294		20		40	III	1·2	
295	7	3 22		10	II	2·0	D.P.T. of Hakodate = 9·5s.
296				60	II	5	records overlapped, and the arrival-time is unmeasurable.
297		9 00		170	III	1	
298		15 45	8·9	150	II	20·	11h 45m—16h records are indistinct.
299		18 14		20	II	1	16h 00m—16h 30m records overlapped.
300		18 24	2·1	20	II	4·4	
301		18 47		30	III	1·4	
302		19 02		60	III	1·5	
303		20 16		50	III	1·7	
304		22 34		20	III	1·4	
305		22 38		20	III	1·8	
306		22 48		10	III	1·2	
307		22 49		10	III	1·2	
308		22 50		40	III	1·6	
309		23 47	2·1	50	II	2·4	
310	8	0 06		45	III	1	
311		0 22		160	IV?	0	
312		0 42		50	III	1	
313		4 48		60	III	1·6	
314		5 18		5	II	0	
315		5 21		40	III	1	
316		5 24		50	III	0	
317		5 31		60	III	1·4	
318		6 07		40	III	0	
319		6 29	2·5	80	II	12·	
320		6 38		50	III	0	
321		6 41·0		60	III	0	
322		6 41·5		10	II	1	
323		6 42·0		10	II	1·2	
324		6 43·0		15	II	1·4	
325		6 43·6		15	II	1	
326		6 45		60	III	0	

(*to be continued.*)

Seismograms recorded at Sahara.

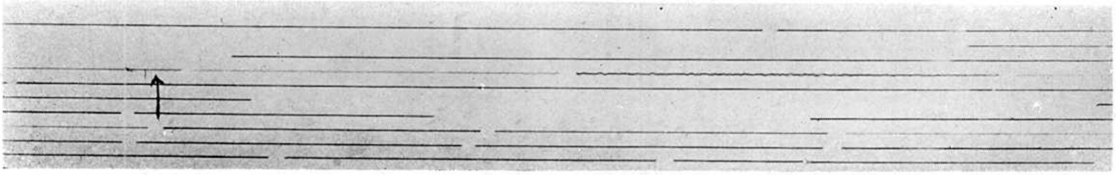

Fig. 1. June 24, 11h 04m. Class IV. Reduced photographically in half.
(see P. 280)

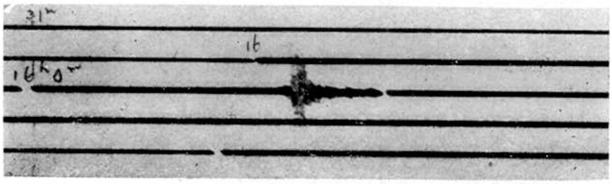

Fig. 2. June 25, 16h 00m. Class I

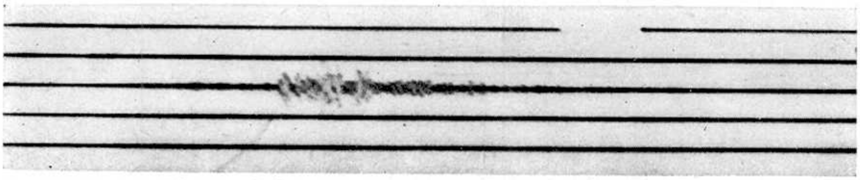

Fig. 3. July 10, 3h 10m. Class II. 1 min. = 132 mm.

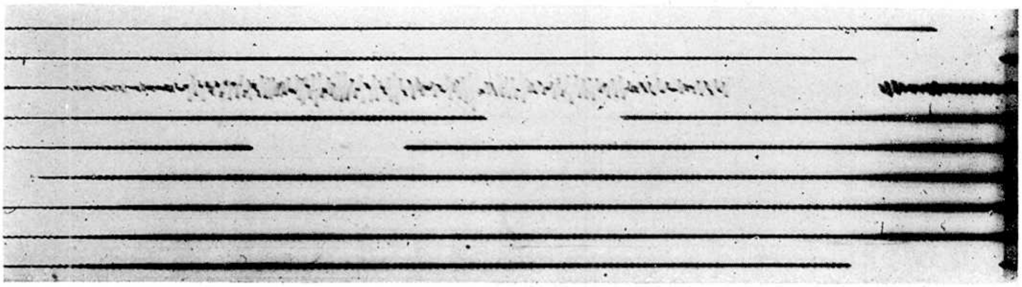

Fig. 4. July 10, 17h 28m. Class II. Recorded on film.
1 min. = 261 mm. (see P. 280)

Fig. 5. July 8, about 6h 40m. Class III. 1 min. = 236 mm.
Many small earthquakes are seen.

（震研彙報第八號、圖版、岸上）

Table II. (*continued.*)

No.	Date	Arrival time	D.P.T.	T. D.	Cl.	M. A.	Remark
		h m	s	s			
327	VII 8	6 46		70	II	1	
328		6 49		60	III	1	
329		6 56		15	II	1·4	
330		6 57		25	III	1	
331		6 58		25	II	1·8	
332		6 59		60	II	1·4	
333		7 11		40			
334		7					7h 30m—9h 30m records overlapped.
335		7					
336		9 43		30	II	1	
337		9 44		60	III	1·4	
338		9 45	1·1	10	I	2·0	
339		10 23		30	II	1	
340		10 47		120	III	1	
341		11 05		10	III	0	
342		11 15		10	I	1·2	
343		11 30		60	III	0	12h—15h records overlapped.
345		17 30	3	180	III	1	
346		18		30	II	1·4	
347		21 32	2·3	40	I	11	21h 17m—VII 9. 6h 01m recorded on film.
348		23 03	1·0	30	I	3	
349	9	0 53	1·4	50	I	3·8	
350		0 59		30	II	1	
351		2 31		30	III	0	
352		3 07		10	I	1	
353		3 18		180	III	0	
354		3 26		230	III	0	
355		3 30		250	III	0	
356		3 42		80	III	0	
357		3 44		120	III	1	
358		3 47		80	III	0	
359		4 01		140	III	0	
360		4 13		70	III	0	4h 30m—7h 00m incessant microseisms.
361		4 54		60	III	0	
362		6 55	2·3	25	II	1	
363		7 57		20	III	1	8h 07m—19h 30m records overlapped.
364	10	3 10	13	40	II	5·2	14h 04m small earthquake-sounds.
365		3 20	2·3	30	II	2	20h 30m—VII 10. 0h drum stopped.
366		4	3·4	60	II	12	19h 40m—VII 10. 0h recorded on film.
367		7 04		40	II	1	
368		8 27		130	III	0	
369		9 08		70	III	1	
370		11 51		20	III	2·5	
371		12 05	7·2	50	II	2·0	12h 25m—14h microseisms.
372		12 32		35	III	1·8	
373		12 34		10	III	1·4	12h 40m—14h 15m records overlapped.
374		15 49		40	III	1·2	15h 47m—22h 30 recorded on film.
375		15 55		30	III	1·6	
376		16 15		40	II	1·4	22h 50m—VII 11. 0h recorded on film.
377		17 28	3·7	40	II	5·2	23h 30m—VII 11. 0h drum stopped.

Part IV. Observations of the Tilt of the Ground accompanying the Eruption. (*With one figure.*)

By Ryutaro TAKAHASI,

Earthquake Research Institute.

(Read March 18, 1930.—Received March 20, 1930.)

1. An eruption of a volcano is often accompanied by the depression or the upheaval of the volcanic mass itself or of the region surrounding it. As one of the typical example of such phenomena, we can point out those in the case of the eruption of the volcano Sakurazima in Kagosima Bay in 1914[1]. Precise levellings along the coast of Kagosima Bay were repeated twice after this eruption. The first levelling was executed in 1914 and the second in 1915. By the comparison of the results of these levellings with those before the eruption, it was found that the circumferential region of the volcano was depressed by an amount of ca. 50 cm. and that the depressed area extended to the distance of more than 30 km. from the volcano, though the amount of the depression diminished with the increasing distance. Another example was furnished by the eruption of Usu volcano in 1910[2], but the case is more complicated. In this case the volcanic region made an upheaval of an amount as large as 2 metres, while its surrounding regions a depression on the contrary. Moreover, it was revealed in this case by the second levellings carried out in 1911, that the disturbed area made a small amont of recovery within a year after the eruption.

Recently a report of observations for thirteen years of the tilt of the ground of Hawaii Island was given by T. A. Jaggar[3]. In his report we can notice a very close relation between the tilt of the ground and the activity of the Kilauea volcano.

Is it not possible to observe such depression or upheaval accompanying the eruption of a volcano, not only after but also before or during the

1) F. Omori, *Bull. Imp. Earthq. Inv. Comm.*, **8** (1916), 152–179.

2) F. Omori, *Bull. Imp. Earthq. Inv. Comm.*, **5** (1911), 1–38.

3) T. A. Jagger and R. H. Finch, *Bull. Seism. Soc. Amer.*, **19** (1929), 38–51.

event? For the purpose of doing this, it will be a short way to make a continuous observation of the tilt of the ground at a point at the foot of the mountain, as it is practically impossible to carry out precise levellings continually over the area including the volcano.

In these views, we have made a series of continuous observations of the tilt of the ground in the case of the recent eruption of Komagatake. The results of the observation will be described in the following pages.

2. The instrument used in this observation is a pair of Ishimoto's tiltmeters[4]. It is a small horizontal pendulum of Zöllner's suspension type, of which the frame work, the movable horizontal rod and two suspension fibres are all made of fused silica. The quartz suspension fibres are directly fused to the frame work and horizontal rod. No use was made of other materials than fused quartz in the essential part of the pendulum. It is therefore entirely free from elastic after-effect, thermal deformations of the instrument and any kind of frictional resistances. The deflection of the horizontal rod is recorded optically on sensitized photographic paper wound on a drum which make revolutions once a week by a clock work contained in it. The sensitivity of the tiltmeter can easily be adjusted by regulating its period of free oscillations. A 6-volt electric lamp fed by a portable storage battery serves as the light source of the optical system of the instrument.

The tiltmeters were installed, together with a microseismograph and a gravity variometer as described in other part of this report, in a hut at Sahara, a lonely fishing village at the northern skirt of Komagatake. The hut is built on a terrace and is about 250 metres apart from the sea. The soil near the hut is of old mud-flow of Komagatake, composed of sands and gravels. The hut has a concrete floor 15 cm. thick and the instruments were installed directly on this floor. The tiltmeters were set up in such directions as to record N-S component and E-W component of tilt respectively. N-S direction coincides roughly with the radial and E-W with the circumferential direction with regard to the volcano. The sensitivity of the tiltmeters was adjusted to be such that a tilt of 1 second of arc will produce a deflection of 0·5 cm. on the record. It was necessary to protect the glass bell-jar containing the quartz part of the tiltmeter with cotten wool to minimize the convection of air in it.

The observation was commenced at 22 h. on 22nd. of June, the next day of our arrival at Hokkaidô. After two weeks' observation made by ourselves, the managements of the instruments were left to Mr. Z. Sato, the owner of the hut.

3. Fig. 1 shows the north-south and east-west component curves of the tilt of the ground obtained at Sahara, starting from an arbitrary zero,

4) M. Ishimoto, *Bull. Earthq. Res. Inst.*, 2 (1927), 1–12.

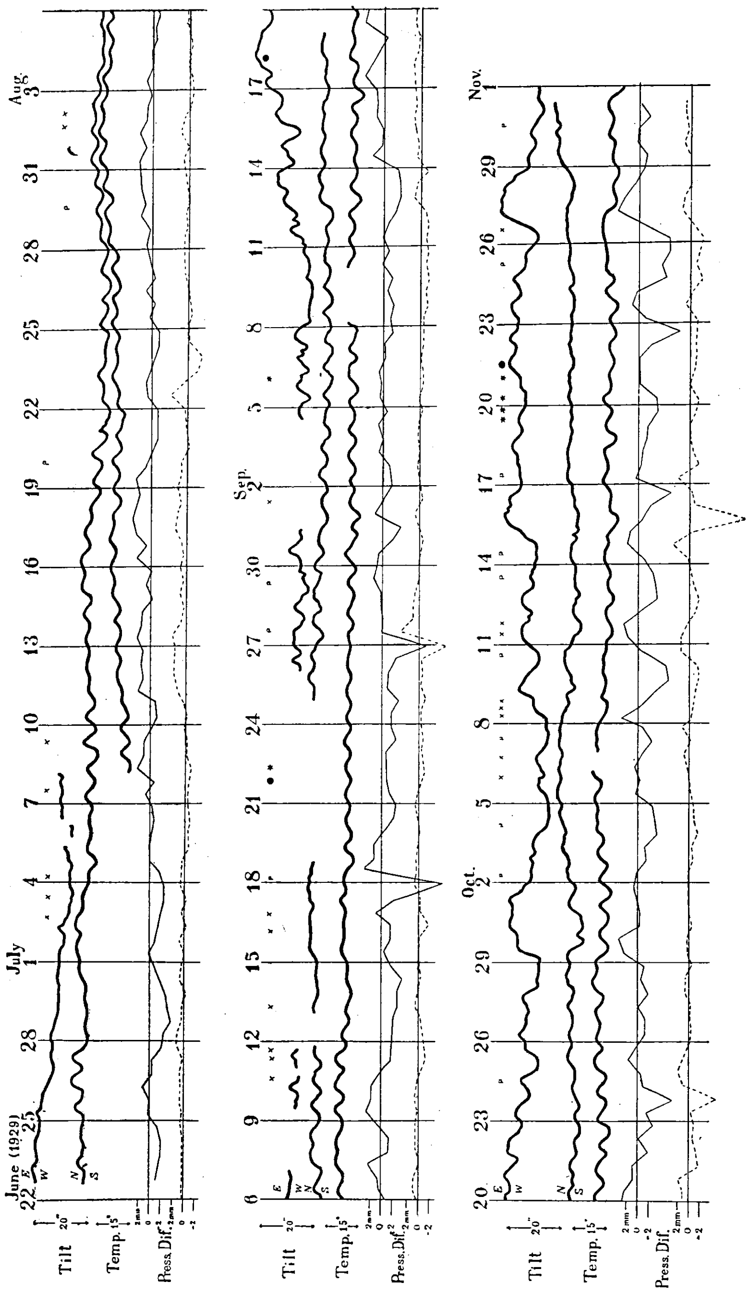

Fig. 1.

together with a curve of atmospheric temperature at Sahara recorded by a Richard thermograph and two curves showing the difference in atmospheric pressure Hakodate-Obihiro and Hakodate-Sapporo. In the former half of the period of observation, the observation was often interrupted, in times by instrumental troubles and in other times by the uncostumnedness of the manager to the manipulation of the instrument.

Superimposed on the tilt curve in Fig. 1, small indentations with daily period are to be seen. These indentations are common in district having a weak superficial layer of soil. They are generally small in amplitude when it is rainy of cloudy. They are almost in phase with the atmospheric temperature variation. The cause of these indentations is already ascertained by the tilt observations at Mitaka, Tukuba, Misaki, Tokyo etc., and is attributed to the effect of thermal strain in the ground.

In addition to these daily variations, there are tilt of the period of several days. Some of these tilt correspond to the long period variation of the atmospheric temperature, but there are others which do not.

Daily tilt in N-S and E-W components do not differ much in amplitude, so that their resultant tilt is directed to N-W when the temperature rises, while E-W tilt of longer period is about two times as large as that of N-S, so that their resultant is directed to NWW, differing from that of the daily variation.

Besides these thermal tilt there are tilts which do not correspond to the variation of temperature. For instance, E-W component of tilt has made a marked variation towards west at the beginning of the observation and continued till July 4th., as can be seen in Fig. 1. From September 10th. to 23th. of the same month E-W component made a large variation than can be expected from the temperature variation. Such variations which do not correspond in amount to the temperature variation can also be seen in N-S component. From October 17th. N-S component ceased to follow the temperature variation and remained in a state inclined to the north for some ten days. It will be worthwhile to notice here that the daily variation in N-S component of tilt becomes small in amplitude when there is non-thermal eastward tilt in E-W component curve.

Correlations of these abnormal tilt with the activity of the mountain and with other meteorological factors will be studied in the next.

4. In Fig. 1 the atmospheric pressure differences between Hakodate and Obihiro and that between Hakodate and Sapporo are shown by full thin line and dotted thin line respectively. Both differences are taken as positive when Hakodate is higher in pressure than others. The values of the atmospheric pressure are those at 6h. and 18h. of every day taken from the weather map issued from the Central Meteorological Observatory. As can be seen in the figure, there exists a remarkable correlation between these pressure differences and the tilt of the ground observed at Sahara.

Of course there is also a correlation between the atmospheric pressure difference and the atmospheric temperature.

When the pressure at Hakodate is higher than those at two other stations, the ground tilts to the directions south and west, against the expectation of common sense but suggesting some mechanisms of the volcanic action and the block movements. In the earlier part of the period of observation, or in the period soon after the eruption, N-S component of tilt seems to have followed very easily to the variation in pressure difference, while in the later period it has become not to follow the pressure difference variations so easily. As to E-W component of tilt, westward tilt which is independent of pressure and temperature has been very remarkable soon after the eruption and after that the tilt has become oscillatory, controlled by the temperature and pressure.

The tilt seems not to reply the short period variation of the atmospheric pressure difference such as caused by the passage of a cyclone.

In connection with the sharp westward tilt stated above of the ground at Sahara soon after the eruption, we must point out the results of the precise levellings carried out by C. Tuboi and by the Land Survey Department over the route Sahara-Mori-Onuma. According to the results of these surveys, the ground at Sahara tilted towards west, in agreement with the results of our tiltmeter observation. As to the detail of the levellings, readers are requested to refer the part of this report written by C. Tsuboi.

Next we will proceed to describe the relations between the tilt of the ground and the volcanic activity of the mountain. As the measure of the activity of the volcano we will take the frequency of the earthquakes of volcanic character observed at Sahara, the rumbling of the mountain and the pulsation of the ground which is recorded by the tiltmeters. The quantity of the smoke exausted from the crater may serve as another measure of the activity of the volcano. But in our case, there being collected few data concerning this point, we cannot, to our regret, utilize this phenomenon. The tremors of the ground called here as pulsation are of different nature from the ordinary pulsation. It seems to continue only for a short time interval of half a day or less with the mean amplitude diminishing with the time. It occurs in successsion in an active period of the mountain.

In addition to these data, the earthquakes of inland character observed at Hakodate Meteorological Station were taken into consider-ation. Some of these earthquakes can be regarded to have their origins at Komagatake.

In Fig. 1 the earthquakes observed at Sahara are shown by black dotts, the rumblings of the mountain by stars, the pulsation of the ground by the letter p and the earthquakes observed at Hakodate by small crosses. Of course it must be remembered that the earthquakes, the rumblings of the mountain and the pulsations of the ground listed here are only a few percentage of the whole, and there must be great many of them that have escaped our attension. From the figure it can be seen that the pulsation is predominant in the period when the tilt is going on independently of the variation in temperature.

The frequency of the earthquakes seems to be large when the ground is remaining in a state tilted to the direction EEN or in times when it is recovering from the tilted state to the original. In an active period of the volcano, it seems therefore that the tilt of the ground in the direction EEN occurs in the first place with the pulsation of the ground and then the rumbling of the mountain and earthquakes follow. In this later stage of an active period, the tilting of the ground already ceases and is recovering to its natural state.

It will be worthy to notice that these active periods seem to coincide with the time when there is continually for several days a pressure gradient of the constant sign over the mountain, as can be seen in Fig. 1.

It seems that there is no remarkable correlations between tilt and precipitations, humidity etc.

5. There are many alternative explanations by which we can elucidate the correlations between the atmospheric pressure difference, the tilting of the ground, the variation of air temperature and the outburst of a volcano. It cannot easily be determined which is the original cause and how they are connected to each other. It will however provide one explanation of the relations existing among them to think that the pressure differnce is the radical cause of these phenomena provoking the other three. If this assumption be granted, the relations among these phenomena seems to be anyhow explained.

In the first place, an explanation of the relation between the pressure difference and the tilting of the ground will be tried. In volcanic regions the tilt of the ground is considered to be composed of the general tilt of the block on which the volcano rests and the tilt of the ground caused by the tumescence or the depression of the volcano.

Correlations between the pressure difference or gradient and the tilting of a land block was for the first time verified by M. Ishimoto[5]. M. Ishimoto found some relations among the atmospheric pressure gradient, tilting of Miyadu block and the occurrence of the aftershocks of the Tango Earthquake. He also noticed in one of his paper[6] that the north-south gradient of the atmospheric pressure over the Kwanto district reflects the east-west tilting of the land block containing Mt. Tukuba. W. Inouye[7] gave recently an interesting paper in which he remarked that whenever the tilt of the Tukuba block which is usually monotonous and one-directioned, changes itself into an oscillatory, to and fro tilting, it is always followed by the occurrence of an earthquake.

Of late block movements of the earth's crust in various part of this country were revealed by precise levellings or triangulations. After the Tango Earthquake levellings and triangulations were repeated four times. According to the results of these surveys, the triangulation points and bench marks in the disturbed area have always showed some displacements and they show no sign of stopping the movements[8]. As cited in the introductory part of this paper, the blocks arround the Sakurazima volcano made remarkable tilts and depressions in the case of the eruption of 1914 and the motion of the blocks was proved to have existed even in the interval between the second and third surveys in a reduced amount.

Even in such districts, not distribed by an earthquake nor by an eruption of a volcano, tilting of blocks are to be seen. Levelling surveys executed in Hokuroku district revealed a chronic tilting of the land blocks consisting the district[9].

In these views of the behaviours of land blocks, they must be considered as if they were wood blocks floating side by side on water. In case of the eruption of a volcano or of an earthquake, this substratum of blocks likened above to water may be considered to become by some

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5) M. Ishimoto, *Bull. Earthq. Res. Inst.*, **4** (1928), 203–222.

6) M. Ishimoto, *Jap. Journ. Astron. Geophys.*, **6** (1928), 116.

7) W. Inouye and T. Sugiyama, *Proc. Imp. Acad.*, **5** (1929), 457–459.

8) Land Survey Department, *Bull. Earthq. Res. Inst.*, **3** (1927), 167; **4** (1928), 223, 225; **5** (1928), 165; **7** (1929), 185, 381, 587.

9) N. Yamasaki, *Proc. Imp. Acad.*, **4** (1928), 60–63.

effect more easy to move or less viscous, and the thickness as well as the size of blocks become at the same time small. If this consideration be allowed, a change in the pressure distribution over the block system may result in the tilting of each block of the system, because the block system must change its configuration to keep its stability.

In the time of a volcano, the molten lava is raised to the level just beneath the crater, then the volcano must be under a very critical state and a slight variation, physical or chemical, of its external conditions may be able to become a cause to put the volcano into action. It is not impossible that the pressure gradient over the block system around the volcano can be such a cause. The change of the configuration of the block system caused by the variation of the pressure distribution must necessarily provoke the flow of the substratum of the blocks or of the lava in the lava pocket of the volcano. If this flow of lava can accelerate the cooling of the lava, the pressure in the lava may be increased and the explosion of the volcano may follow it.

On the other hand, a tumescence of the mountain must accompany an explosion of the volcano, and the tumescence must necessarily cause the tilting of the ground at the skirt of the mountain.

That the tilt does not answer to the short period variation of pressure may be attributed to the viscosity or plasticity of the substratum and of the crust itself.

Now we will proceed to the explanation of the relation between the pressure difference and the variation of the atmospheric temperature. If there existed for a few days a pressure difference between two districts, the transmission of air masses must naturally arise, and the atmospheric temperature of the district under consideration must suffer variations, provided that the mean temperature of the districts is different in value. It is also able to refer to the favour of this explanation that a high pressure is a mass of cold air, and that the air temperature controlls the density of air and can become a factor to determine the pressure distribution.

It must be remembered, however, that these explanations are nothing but imaginations, not based on any decisive facts. Further studies in various branches of geophysics must be performed for the elucidation of these interesting phenomena.

In conclusion, the author wishes to express his most cordial thanks to Professor Mishio Ishimoto for his valuable advices and discussions which he has constantly given.

Part V. Precise Levellings around the Volcano.

By Chûji TSUBOI,

Earthquake Research Institute.

(Received March 20, 1930.)

In order to find the deformation, if any, of the ground near Komagatake connected with the eruption, precise levellings were carried out around the volcano. There are two series of levelling route around the volcano, the one along its northern skirt, the other along its western skirt. The former was surveyed by the writer, and the latter by the experts of the Land Survey Department of the Imperial Army. The results of the latter series of the levelling were kindly placed at our disposal through the courtesy of Rare Admiral Oomura, the Chief of the Land Survey Department. The results of these surveys after the eruption were compared with those of the old surveys along the same routes. It was found that the ground around the volcano was deformed sensibly. In the following tables are given the changes in heights of the bench marks in the interval between the old and new levellings.

Table I.

Bench Marks	Δh
5967	assumed unchanged
Junction Pt. 19	−22 mm.
7062	—
7061	−81
7060	−83
7059	−82
7058	−61
7057	−71

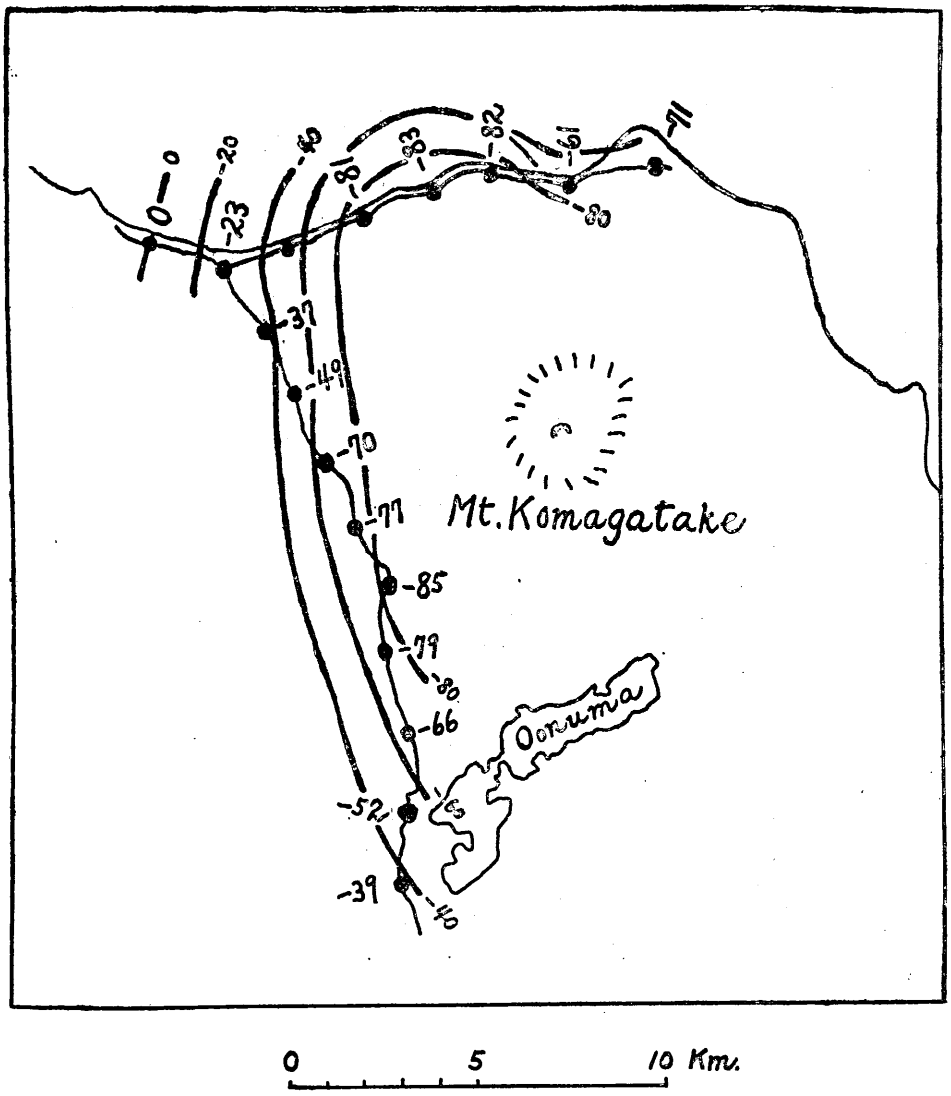

Fig. 1. Lines of Equal Depression in mm.

Table II.

Bench Marks	Δh
5967	assumed unchanged
Junction Pt. 19	−23 mm.
7063	−37
7064	−49
7065	−70
7066	−77
7067	−85
7068	−79
7069	−66
7070	−52
7071	−39

The deformation of the ground around the volcano is shown in Fig. 1. by lines of equal depression. It will be seen that these lines are roughly elliptic in their forms with their centres at the crater of the volcano.

The discovered changes in heights of the bench marks, being those between the old and new surveys, must not be regarded to have wholly been produced at the time of the eruption. Some chronic changes must be involved in them. The writer, however, believes that at least a sensible part of them was directly produced at the time of the recent eruption.

It will be of some interests to remark here that the deformation of the similar type was found in the case of the eruption of Sakurazima of 1914. It appears as if the eruption of a volcano, as a rule, produces the depression in the ground around its scarp.

Part VI. Observation with Gravity Variometer.

By Chûji TSUBOI,

Earthquake Research Institute.

(Received March 20, 1930.)

In view of getting if possible some information regarding the time variation in the subterranean mass distribution in the neighbourhood of the volcano Komagatake, continuous observation was commenced at Sahara with a gravity variometer. This is a kind of torsion balance made of vitreous silica. The theory and the design of this instrument were given by the writer in his previous paper[1]. By this instrument, it is possible to detect some time variation of the order of 10^{-10} c.g.s. in the second space derivatives of the gravitational potential. The instrument was installed at Sahara on 24th of June, 1929, and the observation with it was continued for about half a year. But no trace of change in the gravitational field was detected which was large enough to be recorded by the instrument.

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1) *Bull. Earthq. Res. Inst.*, 6 (1929), 457.

Part VII. Electrical Phenomena caused by the Eruption of Komagatake.

By Kin'ichi NAKATA.

(Received March 20, 1930.)

Introduction.

The electrical spark discharges caused by the great explosions of volcanoes were recognized by our countrymen from ancient times. A picture of the eruption of Mt. Asama[1] on 5th of July in the third year of Tenmei (1783), illustrating many spark discharges in the cloud of smoke from the crater, still remains. Such phenomena were also recognized when Mt. Sakurajima[2] erupted during the year of An-ei (1779), and an interesting picture of the sparks drawn by Ijichi Kiken, is still in existence. Recently, late Prof. F. Omori[3] gave in his report on the eruption of Mt. Sakurajima in the third year of Taishô, some interesting photographs of spark flashes in the cloud of smoke. But little was studied on these phenomena.

One of the most interesting phenomena caused by the explosion of a volcano is the electrical one which have, as stated above, not been fully studied up to this time. The eruption of Mt. Komagatake in Hokkaidô last year gave us many valuable data in these lines.

This volcano erupted on 17th of June last year, and newspapers reported that furious lightning flashes were observed in the smoke blown up from the crater. I joined the party which was sent from the Earthquake Research Institute to investigate the volcano from every point of view. The object of my investigation was to study the variation of the atomspheric potential gradient and earth current caused by the eruption. In the following, a little note is given on the results of the investigation on these subjects.

1) *Rep. Earthq. Inv. Comm.*, (in Japanese) 73 (1911), Fig. 14.
2) *Pub. Earthq. Inv. Comm.*, 8 (1914), PL. XV.
3) *ibid.*, 8 (1914), PL. V.

Spark discharges on the day of the eruption.

The people near the foot of Mt. Komagatake were astonished at a horrible explosion at about 10 o'clock a. m. on 17th of June, 1929. They were not long in understanding the eruption of the mountain by finding out a tremendous mass of smoke blown out very high from its top. From about 11-30 a.m. they recognized many lightning flashes in the cloud of smoke and thunder claps were incessantly heard. When night came, the sparks increased their brilliancy and vigour and were unceasingly flashing above the fire column ejected from the crater. These flashes were seen not only at Ônuma, Mori and other towns situated near the foot of the mountain but also from Muroran and Hakodate which is situated at the distance of 34 kilometers from the mountain.

These spark discharges continued until about midnight and ceased entirely at about 1-30 a. m. on 18th. Though the intensity of the spark discharges was varied from time to time, the maximum intensity was said to have been experienced during the hours of 7 to 8 o'clock p. m. on 17th.

The wireless engineer on the Shôhô maru, the connecting steamer between Aomori and Hakodate, told us that the disturbance of radio communication caused by atmospherics was first noticed at about noon on 17th, but the transmission and reception of signals was maintained with difficulty until about 3 p. m. Since then the radio communication was completely hindered by the heavy atmospherics and this condition lasted until about 1-30 a. m. next morning. According to his statement, the severest atmospherics were experienced about 7 o'clock p. m. on the day. This corresponds well with the time of the severest lightning flashes observed. The intensity of the atmospherics was not so great as ordinary ones caused by the meteorological lightning discharges, judging from the fact that no spark was observed in a small spark gap connected in parallel with the antenna circuit. It was also pronounced at Hakodate that the JOIK broad casting transmitted from Sapporo was not accepted during these hours.

Many photographs of these spark discharges were taken at Mori, Hakodate, Muroran and other towns near the mountain. They are shown in the following pages. Figure 1 was taken at Mori, situated at 10 kilometers off the north-west of the mountain. The time of exposure was nearly 40 seconds. Figure 2 was taken at Hakodate at about 11 p. m., the time of exposure being nearly one hour. As is seen from these photographs, the sparks are somewhat different from those of the ordinary lightning flashes. They have no branches and the bending is prominent than in the ordinary ones. The length of the individual spark appears to be a little shorter than usual.

It must be noted that no sparks are to be seen just above the crater though we can see many of them around the crater to a considerably lower position. This might give some light on the mechanism of the generation of the spark discharges in the smoke of a volcano. The spark discharges seen in these photographs must be considered to have been developed in the front side of the dense cloud and the greater number of them must be hidden inside or behind of the smoke, and so, the frequency of spark discharges must be much greater than in the case of ordinary thunder storms.

The mechanism of the accumulation of electric charge in thunderclouds is not yet fully known. It has been ascertained by many observers that electric charge is produced in the case when water drops are blown into small droplets. This is known as Lenard effect. It is also well known that electric sparks are occasionaly observed in the sand or snow storms, when sand or snow particles are driven by strong winds. There are many experimental works dealing with the charge production when solid particls are blown and are collided with each other. In the case of the eruption of a volcano, vast amount of water vapour as well as ashes, sand and rack scraps are blown out furiously. The mechanism of the charge production in the cloud of volcanic smoke may be assumed from the above mentioned phenomena, but it must be borne in mind that the conditions are more complicated in the actual case. Judging from the fact that the spark discharges ceased nearly at the same time when the falling of rock scraps was scarcely recognized although the gush of water vapour and ashes lasted long afterwards, it may be decided that the greater part of the electric charge was produced by the friction between the rock scraps themselves or rock scraps and other materials.

Measurements of atmospheric potential gradient and earth current.

When we arrived at Ônuma (at the southern foot of Mt. Komagatake) on 20th of June, the mountain was seen in the evening light giving a vast amount of grayish smoke and white steam from several places on the upper portion of the mountain. Yet the amount of the smoke was considerably diminished compared with that of the day of explosion.

The spark flashes, of course, could not be seen by our own eyes at that time. At any rate, we had to commence our investigations as soon as possible. I intended, as above mentioned, to study the variation of the atmospheric potential gradient and the earth current in connection with the action of the volcano.

Measuring instruments were set on a flat floor made of concrete about 20 cm thick inside of a wooden warehouse at a village of Sahara. The house was situated at the northern foot of the mountain about 200 meters from the seashore and about 20 meters high above the sea level. Tiltometers, a gravity variometer and a seismometer were also set in the same house.

The measurement of the atmospheric potential gradient was performed after the method adopted by Prof. D. Nukiyama and Mr. H. Noto.[4] A copper wire, the diameter being 0·5 mm, was stretched as an antenna above the ground nearly parallel to the contour line of the mountain (i. e. E-W direction). The length and the height of the antenna were 77·5 and 4·1 meters respectively. A sensitive galvanometer (sens. $4{\cdot}25 \times 10^{-8}$ amp per mm. deflection) was connected to the antenna and the other terminal of the galvanometer was connected to the earth. The insulation of the antenna was prepared by porcelain insulators and the protection from being wetted by rain was done with some specially constructed apparatus which was kindly offered by H. Noto.

The earth plate was made of copper (30×30 cm^2). It was buried surrounded by charcoal at the depth of 1 meter under ground. The deflection of the galvanometer was recorded on a bromide paper rolled aronnd a rotating drum.

The earth current was also measured with a simple method. Many difficulties have been experienced in the measurement of earth current. The problem is how to avoid the contact patential at the electrodes, thermoelectric effect and polarisation. Several methods have been proposed for this purpose but we were in such haste to arrive at the actual place as quickly as possible that I was obliged to adopt the most primitive one.

Two copper rods of the diameter 1·5 cm were driven into the earth and were used as electrodes. A galvanometer was inserted between these electrodes with a high resistance connected in series with it. In this manner the potential difference between two positions was measured.

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4) D. Nukiyama & H. Noto, *Japanese Jour. Astr. Geophys*, 4 (1928), 71.

It was obvious that there must arise some ambiguities due to the polarisation and many other sources of errors. As has been already mentioned only the variation of the earth current was necessary, and so, the method adopted was enough to serve the purpose. The distance between these two electrodes was made 150 meters apart, one near the warehouse and the other put in the southern direction (i. e. perpendicular to the contour line) about 5 meters higher than the former. The leading wire connecting these electrodes and the galvanometer was insulated from the earth by small pieces of porcelain.

Results.

At first many unexpected difficultes were met with and the observations were commenced from 11 p. m. on 22nd of June, about 6 days after the first sign of the eruption was recognized.

The records of the atmospheric potential gradient show no special deflection before 26th of June. The record on 26th is characterised by some oscillations of the galvanometer as shown in fig. 5. This disturbance was recorded from about 4-30 a. m. on 26th and lasted about one hour. A smaller disturbance was also recorded about one hour later. The feature of this record is somewhat like that of a distant thunder storm. This can not be considered as due to the instrumental error, for the record of the earth current shows no such a disturbance, while the two galvanometers were set on the same table and the both records were taken on the same bromide paper. The cause of this disturbance must be attributed to a purely meteorological origin or the action of the volcano. As for the meteorological origin, no thunder storm was recognized near that district at that time, while it must be noted that the number of small earthquakes recorded on the seismograph increased from the night of 25th to 26th.

Observations were continued until 10th of July, no other record such as fig. 5 was obtained. The records appeared as smooth straight lines except on rainy days, when, as well known, the oscillations of large amplitudes were recorded. While the records of the seismometer showed that the number of the earthquakes on 28th was more than that on 26th. This seems very unfavourable to the result above obtained, but we must bear it in mind that there is no direct relation between the variation of the atmospheric potential gradient and the earthquake. The number of earthquakes was only considered as a measure of the volcanic

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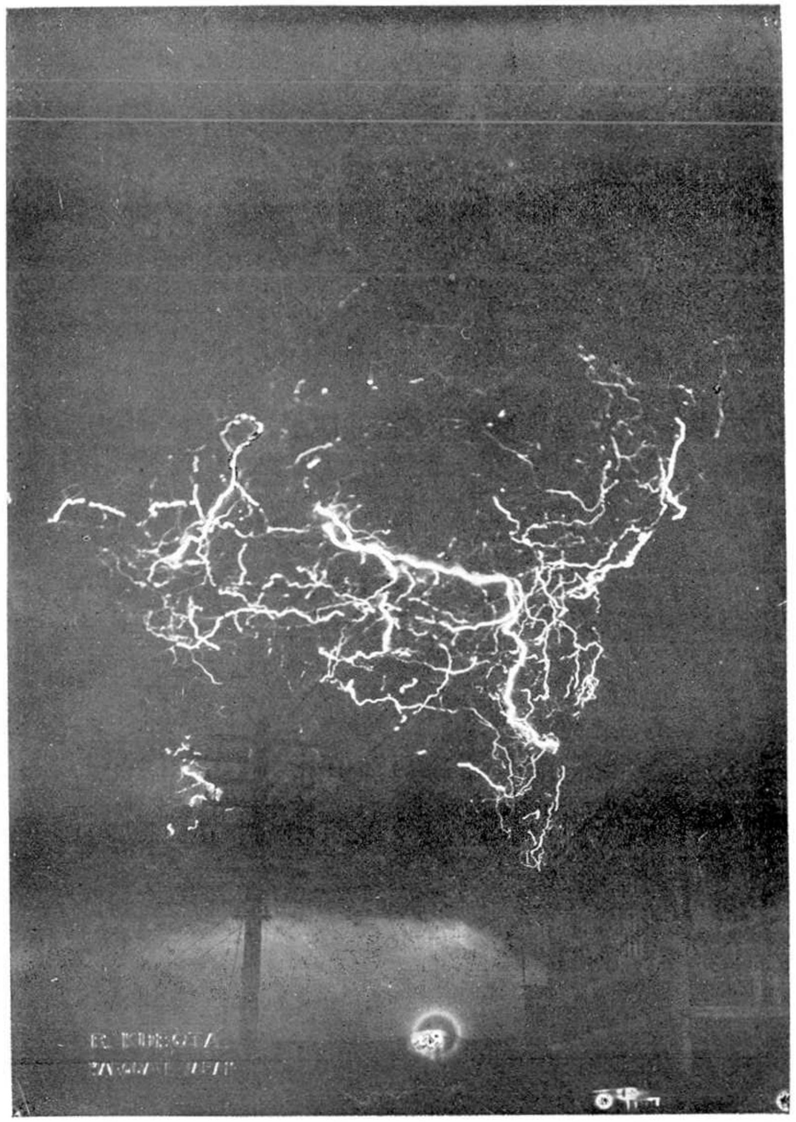

Fig. 1 At Mori, at 7-30 p.m. exposure, 40 sec.

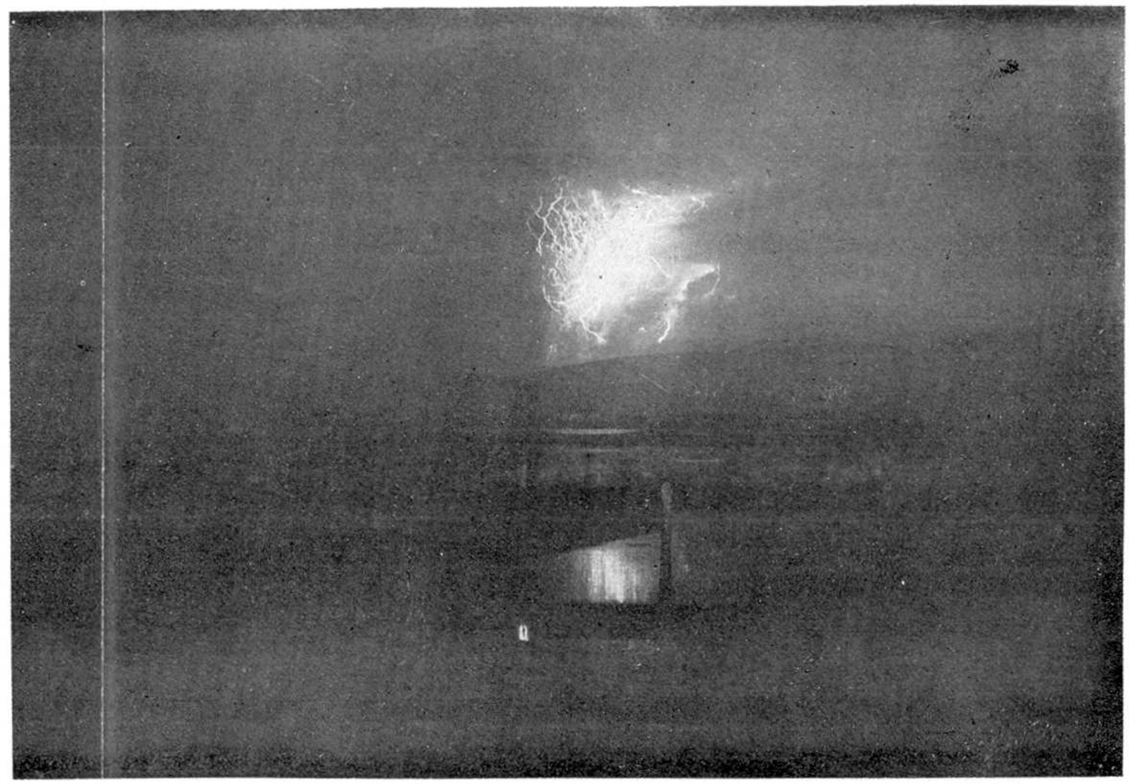

Fig. 2. At Hakodate, at 11 p.m. exposure 1 hour.

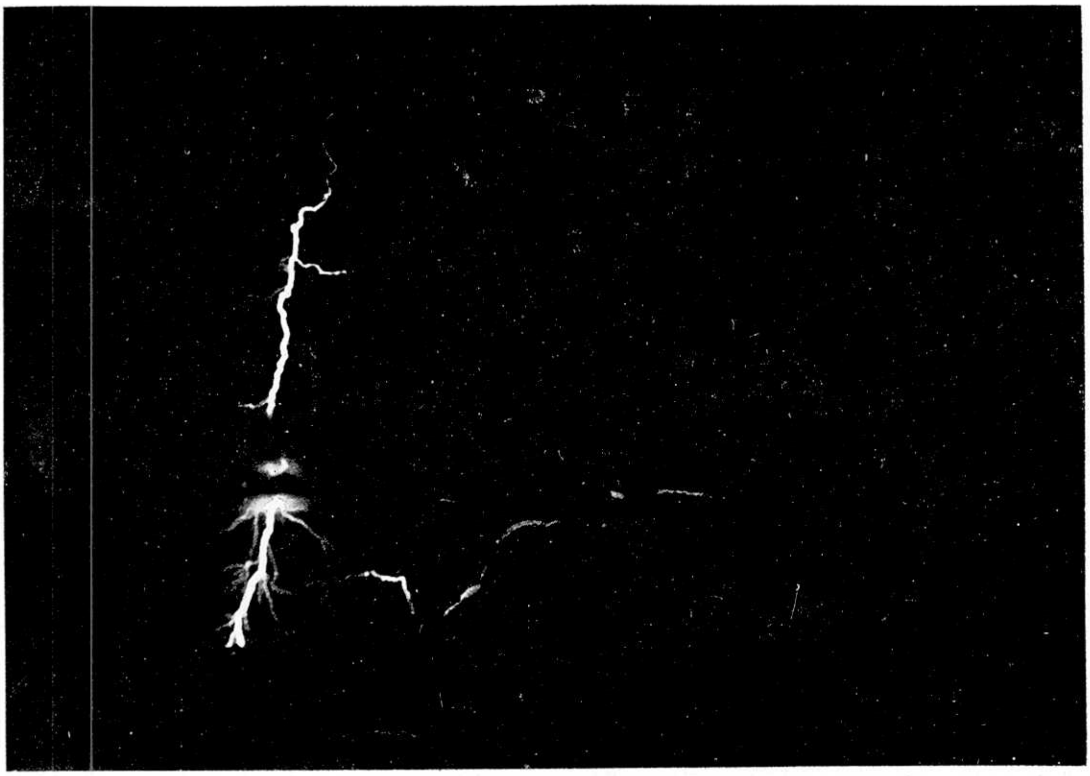

Fig. 3. At Muroran.

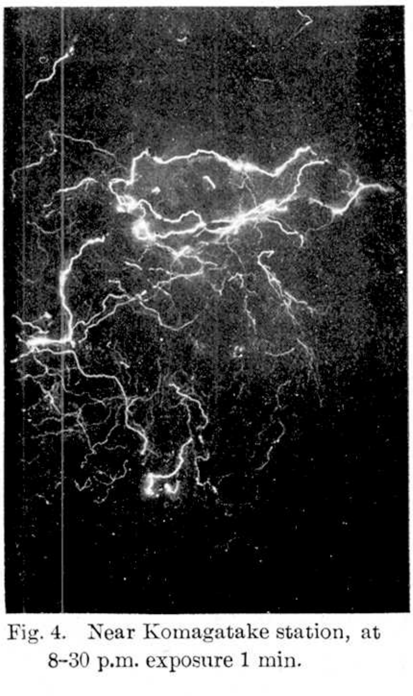

Fig. 4. Near Komagatake station, at 8-30 p.m. exposure 1 min.

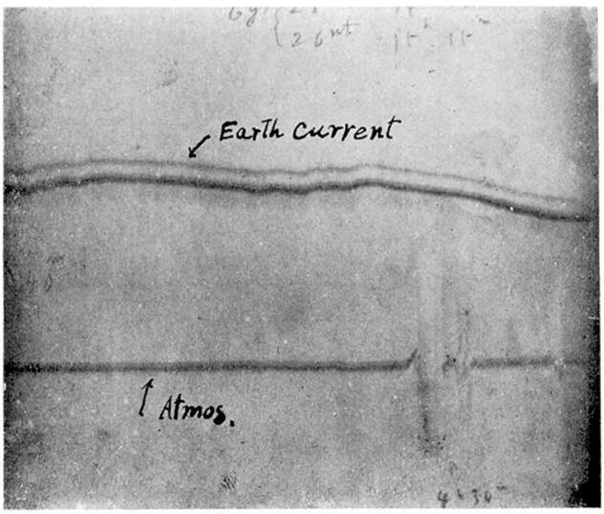

Fig. 5

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activity at the time for convenience. The above results might well be understood as such that they only show the fact that on 26th the action of the volcano was favourable to the change of the atmospheric potential gradient, while on 28th it was unfavourable. At any rate, the result of the present investigation is too poor to give any decided conclusion. I hope many investigations will be made on these lines in the future opportunities.

As for the records of the earth current, no positive result was obtained from such a degree of investigation, owing to the difficulties of its measurements.

In conclusion, I must give my hearty thanks to Prof. M. Ishimoto for his kind invitation to join the party and many facilities he was good enough to give me for the present investigation.

Part VIII. Observations on Komagatake.

By Naomi MIYABE,

Earthquake Research Institute.

(Read Dec. 18, 1929.—Received March 20, 1930.)

1. Immediatly after the recent eruption of Komagatake, which occurred on 17th. June 1929, some members of our Institute were despatched there to make observations of the activity of the volcano from topographical, geological and physical points of view. The results of these observations are given in the preceding reports. It was a month later that the present writer went there with the purpose of observing the subsequent stage of activity and making some supplementary observations if possible. He found, however, no remarkable difference in the general features of the volcanic activity from those described in the preceding reports. Hence, the writer is going to give below the descriptions of some fragmentary facts which he happened to notice during his expedition.

2. The wide area including a number of villages at the foot of Komagatake is covered with pumices and ashes projected from the craters in the recent eruption. Cracks, larger and smaller, are seen everywhere on these piled ejecta. From some of these cracks are being emitted gases smelling of sulphur or its derivatives, while there are found some fissures showing needle-like crystalline incrustations at their openings. A glance from distance on the field with many cracks of this sort reminds us of a green pasture. Cracks observed in these portions are those of smaller scales and are alike to those which are often produced on dried up rice fields.

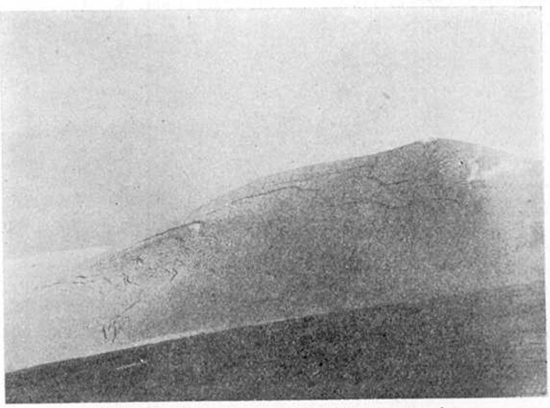

Fig. 1. Cracks on Sumida-no-mori.

Fig. 1 illustrates these cracks produced on the surface of piled ejecta at Sumida-no-mori, as seen from north. These cracks are the larger ones and are continuation of the crack *a* which will be referred to later. Fig. 2 is the schematical sketch. Some of them consist of a numder of cracks arranged *en échelon*. They were probably produced by down-slipping of the part "*B*" relative to the part "*A*".[1]

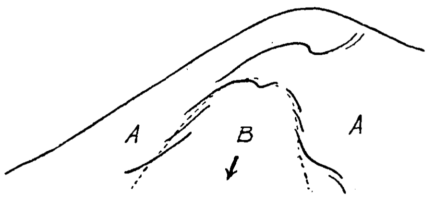

Fig. 2. Schematical Sketch of cracks on Sumida-no-mori.

In the old crater, many cracks are developed in radial and concentric directions with the Ansei Crater (*D*) as their approximate centre. These cracks are shown in Fig. 3 by *a*, *b*, *c*, *d*, *e*, f_1, f_2, *g* and *h*. Among them, *g* is the group of cracks on Sumida-no-mori which was mentioned above. In the region "*H*", there were many radial and concentric cracks, though the writer could not approach them and trace their trend owing to dense fumes emitted out of these cracks.

The largest crack of all was the one that runs southward from the inner side of Sawara-dake along the old crater ridge to Sumida-no-mori, which is denoted by "*a*" in Fig. 3. The breadth of this crack amounts to one metre at Komanose and also at Umanose, and in the neighbourhood of Kengamine it is so wide that we can observe its reddish brown trace from a place several hundred metres apart.

The crack "*b*" is divided into two branches near the Ansei Crater.

f_1, f_2 and the crack nearly perpendicular to "*e*" are recognized by the emission of gases along them.

Some more cracks are observed around the crater *D*.

These cracks, except those of curious shapes observed on Sumida-no-mori, were probably produced by the settling of the piled ejecta in the old crater, as a whole, having the crater *D* as the approximate centre of subsidence. It may be interesting to remark that, in comparing Fig. 3 with Fig. 4 of Dr. Tsuya's report[2], these cracks appear to have grown sensible in their sizes during the interval of time elapsed between the two observations. For confirming this point, however, some more data will be needed.

1) As for the formation of *en échelon* cracks, Prof. Fujiwhara has made some experiments. S. Fujiwhara, *Jap. Journ. Geophys.*, (1927), No. 2.

2) H. Tsuya, This *Bull.*, p. 238 of this volume.

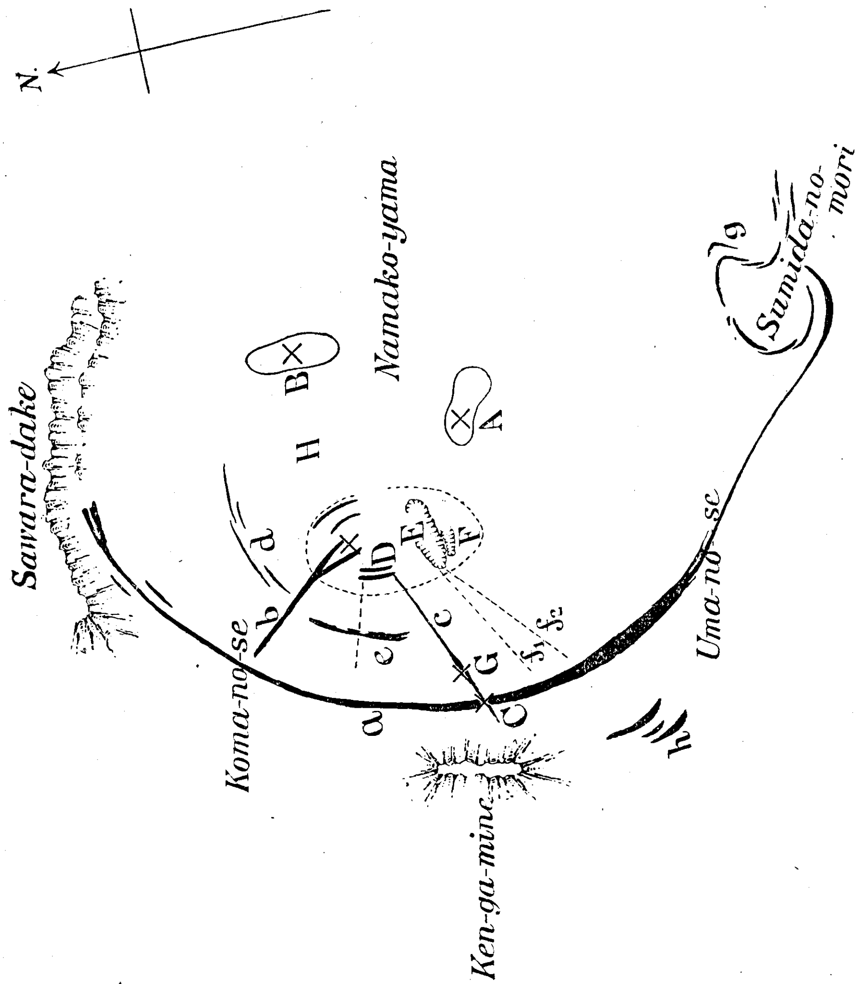

Fig. 3. Cracks and fumaroles in the old crater.

The upper part of the inner side of the cracks "*a*" and "*c*" was reddish in colour, while the lower part was milky white and the exposed surfaces of the deposited layer were covered with ashes. This reddish colouring of the ejecta may be due to the oxidation effected by the high temperature and sufficient supply of air, as will be referred to later. In the neighbourhood of the cracks *b*, *d* and *e*, the surface is covered with dark green ashes in which sulphur is richly contained so that the fresh surface of the inner side of the crack is not exposed.

3. Fumaroles observed are represented by × in Fig. 3, as *A*, *B*, *C* and *D*. Among them, *A* was most active at the time of observation and a rumbling sound was heard every now and then. Activity of *B* was next to that of *A*, but it was without the rumbling sound. From *C* and *D* was being emitted much less quantity of gases than from *A* and *B*. Moreover, as shown in Fig. 4, *C* may not be a crater proper, but only

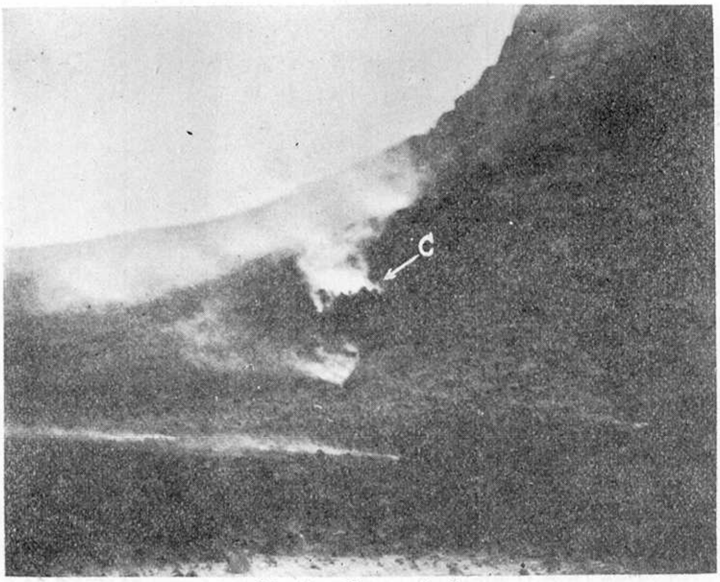

Fig. 4. Fumarole C.

a variety of crack. The gases emitted from it may be supplied from the other fumaroles through the underground channels which may be supposed to exist in the piled ejecta or they may be what was once occluded in the ejecta, and now being released and emitted at last through this crack or vent. *C* was just at the intersection of the cracks "*a*" and "*c*". A halbard-shaped crater adjoining *D* has some fresh indication on its crater wall that it was destroyed by some eruptions from it, but gas was not being emitted at the time of observation. Emission of gas was also seen faintly on a hill dividing the above mentioned crater from the crater *D*.

A little more detailed sketch of the crater *A* is shown in Fig. 5. Fig. 6 shows the same crater as peeped in from the western edge of it. The Circumference of this crater at its opening was estimated at about

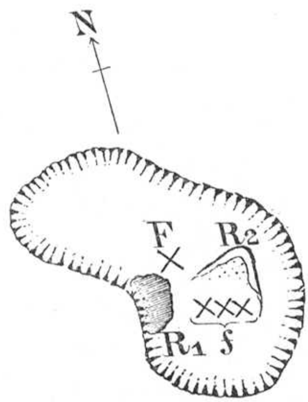

Fig. 5. Fumarole *A*.

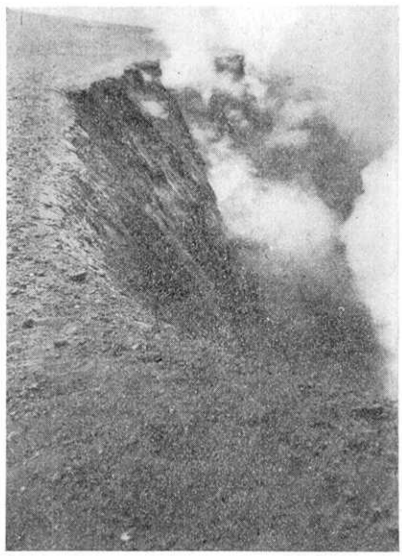
Fig. 6. Fumarole *A*. (peeped in from the west edge of the opening.)

200 m. Its form is just like a gourd and its axis directed towards SE or to the village of Sikabe. At the time of rumbling which occurs once per about five minutes, the gas was emitted out of *F*, in Fig. 5, apparently with a considerable pressure. This rumbling continued for about half a minute, and after that the pressure of the emitted gas seemed to abruptly fall back to its former value. Besides *F*, some more minor fumaroles are seen (f' s) in the crater A. R_1 and R_2 are huge masses of rocks visible through the smoke at the bottom of the crater. R_1 was greyish black in colour, while R_2 was painted with fresh yellow of sulphur at its top and the rest part was reddish black.

The rumbling of this fumarole *A* was heard, from July 18 to July 20, in many villages situated at the foot of Komagatake, except for several villages such as Mori, Sawara, Osironai, Akaigawa and those in the neighbourhood of the railway station of Komagatake. In these latter villages, the rumbling was scarcely heard or none. These villages are situated mainly in N or NW part of the volcano. On the other hand, the direction of wind then prevailing in this region was NW-SE. Hence, this prevailing wind might probably have affected the sphere of audibility of the rumbling sound of the volcano in the villages surrounding the foot of Komagatake.

4. The piles of pumice covering the area extending from Umanose of the old crater ridge to the northern bank of Lake Oonuma are generally grey in colour. There are also some blocks containing thin white layers. As for their sizes, those of 30–50 cm. in linear dimension are most frequently observed. These pumice piles, at a glance, form a step-like slope somewhat similar to the case which we have demonstrated in the model experiment of deformations of sand mass[3]. A brief description of this pumice pile is as follows. The first step of this slope begins at about one hundered metres down from the ridge of Umanose. The second step succeeds to the first step and so on to the seventh step. The eighth step is more or less deformed and the ninth step was not clearly recognized as it was pushed into the woods on its way. As we have quoted above as "step like", a part with a steeper slopes s_1 and the other part with a more gentle slope s_2 are more or less distinctly recognized (Fig. 7). From the first to the seventh step the distances s_1 and s_2 are roughly the same and so are the height differences at the parts of steeper slopes. The formers are generally

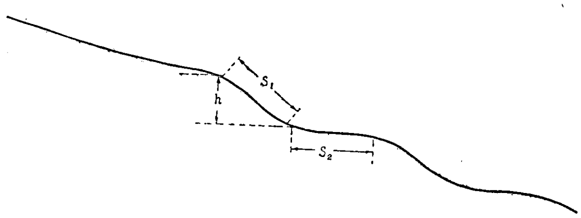

Fig. 7. Supposed slope of pumice pile near Uma-no-se.

20–30 m., while the latters are 15 m. or a little more. Hence, the angle of the slope at the steeper part is about 30° or a little more. As was already mentioned, this step-like pile of pumice is similar to the stepped figure of deformed sand mass experienced in the laboratory experiment. The

3) T. TERADA and N. MIYABE, *Bull. Earthq. Res. Inst.*, 4 (1928), 33; 7 (1929), 65.

observed angle of the steep slope in the pile of pumice cannot be identified with the angle of the slip-plane which may be hidden beneath the surface layer. Even when these portions of the steep slope correspond to the slip-planes in the pumice mass, the original slip-planes may not have been maintained. The slope may gradually be deformed, its angle of dip tending to the natural angle of repose of the pumice mass[4]. It may, therefore, be said that the lower limit of the observed angle of the slopes is more significant, being closer to the angle of repose of the pumice mass.

5. Pumice flows are found most remarkable in the neighbourhood of Akaigawa, Osironai and Dekimazaki, while the piles of fallen pumices and ashes are so in the neighbourhood of the villages Sikabe and Honbetu. Descriptions of these pumice flows and piles of pumices and ashes are given in detail in the preceding reports, so that they may be omitted here as superfluous. It is noticeable, however, that these pumice flows contain sometimes reddish coloured blocks while the greatest majority of the blocks are of milky white colour. In an individual block of pumice, we can sometimes find a reddish coloured zone in its outer portion, while the block as a whole looks milky white. The milky white inner portion of the block becomes reddish when it is heated in air. Hence, the reddish coluring of the rocks may be regarded as due to the oxidation resulting from the sufficient supply of air and heat.

The same phenomenon is seen in the pile of ejecta of the former eruptions. Some distances southward of the recent pumice flow of Dekimazaki, an exposure of the pile of a former eruption is seen. Looking at this exposure, we noticed the distinct layers of differently coloured piles of eruptive ejecta: the uppermost layer is of milky white pumice blocks with the thickness of about half a metre; the second is coloured like cinnaber with a thickness of 0·5–1·0 m.; and the lowest consists of the layer of dark yellow materials with a greater thickness. A part of the material from the lowest layer was taken home, and when it was heated for a sufficient time in air, it became reddish or cinnabar-coloured just like that of the second layer. Hence, the existing layers of different colours may be due to the appropriate thickness of the uppermost layer which served in keeping the temperature of the lower layer together with the ventilation of air in the mass just in such a way as to produce the cinnabar-coloured layer within the extent of thickness observed.

4) The term "angle of repose" is used here, if it is allowed, in the sense of the angle of natural slope. The term is used ordinary in civil engineering.

From the observations which we have referred to in preceding pages, we may get a hint on the significant tectonic structures of the region in the vicinity of this volcano. One of the structural lines suggested is the line in the direction of NW-SE along which Osidasizawa, the Craters *D* and *A* lie. Along this line, the eruptive phenomena were comparatively active in recent ages. Another is a line in the direction NE-SW (approximately perpendicular to the former line), along which lie the Fifth-Valley, Crack *c*, Craters *D*, *E* and *B*, fumaroles *C* and *G* and the region *H*. The Fifth-Valley is generally considered as produced by erosion, and yet the grade of erosion of this valley seems to be much more steep compared with the other erosion-valleys of the same mountain. This suggests us that some other primary agency might have been here in action besides the usual erosion to build up such a sharply eroded valley.

The above conjecture regarding the structural lines in the region of the Komagatake is based merely on a scanty number of the facts and phenomena observed in the field. It may, however, be allowed at least to say that the two lines mentioned above are to be considered as something very significant for the tectonic structure in this region and that their existence seems rather natural from the point of view of the theory of elastic deformation.

6. In addition to the above descriptions, the following may be of some interest as it may have some significant bearings on the phenomena of eruption of Komagatake:

a). In the valley of the Kadiyagawa, one of the rivers flowing eastward from Komagatake, we can see a fine exposure of the layers of ejecta as shown in Fig. 8. Notations in the figure means as follows:

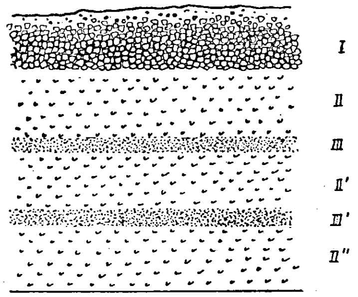

Fig. 8. Strata exposed in the valley of the Kadiyagawa.

I ······ Pumice layer, about 80 cm. thick;

II, II′, II″ ······ Sand or ash coloured yellowish brown, about 70 cm. thick;

III, III′ ······ Layers of sand which may generally be seen at the bottom of the river or sea shore of this district, about 10 cm. thick.

In the layers II, II′ and II″, blocks of pumice are seen which indicate that these layers consist of the ejecta of earlier eruptions. The layers III and III′ seem to be those which have been deposited in the river bed or sea bottom. As these deposits are seen at the height of about 10 m. above the present sea level, these portions may have been upheaved to a certain amount during the life history of the volcano. This supposition conforms with Professor Kato's opinion[5] that the terraces found in these regions resulted from the upward movement of the coastal zone.

b). Everyone visiting this district will take special notice of the large number of islets scattered in Lake Oonuma and also of the small knolls near the village of Sikabe (called Nagareyama). Larger knolls of this sort are also seen on the slope of Komagatake which are called Maruyama. Moreover, the points on the slope of the mountain where the triangulation points are situated are a little higher than the surrounding portions, or the slopes at these points are more gentle than the other. These so-called Maruyama's and triangulation points seem to be somewhat regularly distributed around the mountain. The regularity is such as shown in the following tables (Tables I and II). In these tables, the radial distances of the points are taken from the crater *D*.

Table I.

	N. Maruyama	E. Maruyama	Butai (Tennenkôsin)
Radial distance	2·4 km.	3·3 km.	2·9 km.
Height above sea level	538·0 m.	479·1 m.	418·2 m.

Table II.

Triangulation point	1	2	3	4	5	6
Radial distance	3·5 km.	5·0 km.	5·2 km.	5·4 km.	3·9 km.	3·4 km.
Height above sea level	283.5 m.	286·6 m.	249·4 m.	210·1 m.	310·8 m.	266·9 m.

We are at present absolutely ignorant as to what this apparent regularity may mean, though it may be due less probably to a mere chance than to some physical or mechanical cause.

5) T. Katô, *Sinsaiyobô-tyôsakai Hôkoku*, No. 62 (1909).

11. 昭和四年六月北海道駒ヶ嶽の噴火

第一部 駒ヶ嶽火山の地質活動狀況及び岩石

地震研究所 津屋弘逵

北海道渡島國駒ヶ嶽火山は「ホマーテ」型の成層火山で、主として複輝石安山岩質の熔岩流とその岩屑とより成る。其頂上には東に開く爆發「カルデラ」があつて、その中に更に楕圓形の火口がある。此楕圓形火口内に從來屢々爆發が繰返されて數個の小火口及び裂罅が出來、夫等から噴氣してゐた。近くは明治三十八年と大正八年とに爆發が起つたが、今回の噴火は安政の噴火以來の大噴火である。

今回の噴火は昭和四年六月十七日の早朝初まつたが、午前十時頃劇くなり、同日午後十一時過まで續いた。その後噴火は漸次鎭まつて、翌朝には最早噴煙のみとなつた。この噴火によつて噴出した多量の輕石は同火山の南東方面に落下堆積したのみでなく、四周の山側を流下して山麓に集積した。是等の輕石は岩石學上複輝石安山岩に屬し、火山體を構成してゐる從來の噴出物と類似してゐる。

第二部 駒ヶ嶽噴出物の酸化狀態より推定せる其の溫度に就て

地震研究所 坪井誠太郎
津屋弘逵

昭和四年六月十七日北海道駒ヶ嶽より噴出せる浮石質岩片に於ける酸化狀態を記述し、之より其の噴出當時の溫度を推定し730°Cより高きも是より甚だしく高溫には非ざるべきを論ぜり。

第三部 氣象及び地震觀測

地震研究所 岸上冬彦

1. 駒ヶ嶽火山噴火前後の狀態

噴火の始まつた六月十七日の朝、低氣壓の中心が駒ヶ嶽の附近を南から北に向けて進行中であつた。又十日間程降雨がなかつたのが、噴火の前日、低氣壓に伴つて雨が降つた。南東の麓の鹿部方面に火山灰及び浮石が積つたのは主として當時の風向が北西であつたからであると思はれる。

噴煙の高さは函館測候所の觀測によると十七日の午後二時頃には約 13000 m. であつたが、翌日の午後三時には約 6000 m. に減じた。

函館測候所の地震記象を見ると零時二十三分に週期の長い脈動狀の振動をかいてゐる。同様な振動が、午前十一時から午後十二時まで絕え間なく續き、丁度その時、大沼森林測候所の報告を見ると、噴火が烈しかつた。この事實から考へると午前零時二十三分の振動も噴火によると考へられる。卽ち此の時が噴火の始つた時刻と思はれる。

2. 砂原に於ける地震觀測

本研究所の石本敎授と高橋學士の製作された微動計を駒ケ嶽の北方砂原村に据ゑつけて、六月二十三日から七月十日まで地震觀測をした。その間、時々故障の爲に止つたが、377 回の地震を記錄した。此等の地震を第二表には四種に分けた。I は衝動の樣に急に振幅が大きくなり直に減衰する振動、II は初期微動が明かに見え、次に振幅の大きい主要動となる。III は小さい地震が連續して起るもの、IV とかいてあるのは比較的遠い地震である。

駒ケ嶽の地震の多くは人體に感じなかつたが、感じたものもその有感區域は局部的である。七月四日に大沼方面に弱震程度の大きな地震が多數あつたが、砂原では其の大部分は器械にさへ記錄されなかつた。

第四部 噴火に伴ふ地表傾斜變化の觀測

地震研究所 高橋龍太郎

火山の噴火は屢〻其の火山の山麓地域の土地の沈降、隆起を伴ふのである。今回の駒ケ嶽の噴火に際し、此樣な土地の隆起沈降と噴火現象との關係を研究する目的を以て、駒ケ嶽北麓なる砂原村に傾斜計を据付けて、六月二十二日より十二月末日迄地表の傾斜變化の觀測を行つた。其觀測の結果に依れば噴火現象の活動期に於ては砂原村の土地は北東東の方向に傾斜し、同時に土地の脈動を伴ひ、其に次いで地震と鳴動とが起る樣である。土地の傾斜と噴火活動期と、歷の數日間に亙る長週期間の配置と相互に關聯してゐる事も注目に値する事柄である。

第五部 駒ケ嶽噴火に關連せる地盤の垂直變動

地震研究所 坪井忠二

噴火に關連して地盤の垂直變動が起るといふ事は之まで度々經驗された所であつたから、今回の駒ケ嶽噴火に際して、其の北側の水準測量を行つて見た。果してかなり著しい沈降が見出された。尙陸地測量部も駒ケ嶽火山の西側の水準測量を施行され、やはり著しい沈降を見出された。夫等の結果は第一、二表に示した通りで、第一圖は等沈降線のコントルである。

第六部　駒ヶ嶽噴火に關連せる重力の變動

地震研究所　坪　井　忠　二

噴火に關係して若し地下の物質配置の狀況に變動があるならば之を檢出し度いと云ふ目的でシリカ製重力偏差計を砂原に据付けて連續觀測を行つたが、持參した偏差計の精度 (10^{-10}) に現れる位の變動は認められなかつた。

第七部　爆發に伴ふ電氣的現象

中　田　金　市

昭和四年六月十七日に起つた北海道駒ヶ嶽の爆發に伴つて生じた電氣的現象の記述で、火山活動につれて、空中電位、地中電流の變化が起るか否かに就て調べたものである。

第八部　駒ヶ嶽に關する調査報告

地震究研所　宮　部　直　巳

一九二九年六月一七日に爆發した北海道駒ヶ嶽に關する野外調査の報告である。今度の噴火と直接に關係ある噴出物や噴火現象に關しては、津屋氏其他の人々の報告があるから、こゝには舊噴火口內に堆積した新らしい噴出物上に生じた裂罅に關する記載を主とした。尙、筆者の經驗した中、特に印象されたことで、駒ヶ嶽の噴火と關係ある事項についても簡單に記載しておいた。
