7. *Explosive Activity of Volcano Kusatu-Siranê*[1] *in October, 1932.*

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Introduction.

Tokyo newspapers of Oct. 2, reported the volcanic explosion of Siranésan, Province of Koduké,[2] at about 2^h p. m. on Oct. 1, 1932, and that, of the sulphur workers in the crater bowl called Yugama,[3] two were killed and seven injured by falling stones thrown out at the time of the explosion. This explosion marked the beginning of activities of this volcano in 1932, and, while nothing more as to further developments during the succeeding days was reported except the second explosion on Oct. 4, activities continued with rather increased intensity, particularly towards the end of that month. Thus, the third, forth, fifth, sixth, and seventh explosions occurred on Oct. 6, 8, 23, 25, and 27, respectively, of which the fifth, which the writer experienced on the summit of the volcano, appears to have been the worst of all. Of the sixth explosion, which occurred at midnight, Oct. 25, and of the seventh explosion, which occurred on Oct. 27, just after the writer's departure from the volcano, nothing definite is known.

In this paper the writer records his observations of the volcano, carried out during the four days from Oct. 21 to Oct. 24, 1932, and presents an account of the explosion of Oct. 23, of which he was an eye witness on the mountain viewing its various phenomena at close range. A short account of the past activities of the volcano will also be given. Of the structure of the volcano and its products only brief notes are given here, a detailed account of them being left for another occasion.

Morphology and Structure.

Volcano Siranésan in the Province of Koduké, or Kusatu-Siranê, as

1) 草津白根. 2) 上野國. 3) 湯釜.

it is frequently called to distinguish it from Nikko-Sirané,[4] lies in the northwest part of the province, near the northeastern boundary of the Province of Sinano,[5] about 25 km. north from the active volcano Asamayama,[6] (Fig. 1.) extending over 36°31′–39′ N and 138°31′–39′ E. The morphology and structure of this volcano have been investigated by R. Ohashi,[7] whose work has been freely drawn on in the account that follows.

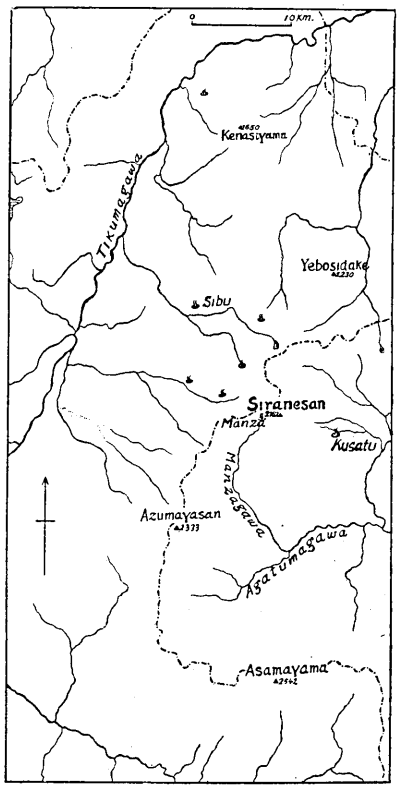

Fig. 1. Index map showing the position of the Kusatu-Sirané volcano.

Foundation. The immediate foundation on which the present volcano has been built up may be conjectured from the geology of the neighbouring districts. According to R. Ohashi, the districts adjoining the volcano are built up of various rocks, igneous as well as sedimentary, whose succession may be shown in the following scheme.

Younger Tertiary.....

Tuffs, mud-stone, clay, sand, gravel, and breccia.

Unconformity

Local lavas: A-lava (two-pyroxene-andesite) and Blava (two-pyroxene-andesite).

Unconformity

Older Tertiary .....Hypabyssal igneous body (quartz-bearing augite-hypersthene-porphyrite).

The porphyrite, which occupies extensive areas adjoining the west, northwest, and northeast of the volcano, constitutes the principal founda-

4) 日光白根 This is another volcano, 2578 m. above sea level, situated at the boundaries of the provinces of Koduké and Simotuké, (下野), over 70 km. northeast of the present volcano, and which has exploded four times during historic times, in 1625, 1649, 1872-73, and 1889.

5) 信濃. 6) 淺間山.

7) R. Ohashi, *Report Earthq. Invest. Com.*, 78 (1913), 1-47, (in Japanese).

tion, forming a great continuous mass within which various rock-facies[8] occur with gradual transition between any two facies. To the west and northwest of the volcano, it is exposed in the valleys of the rivers Manzagawa,[9] Matukawa,[10] and Kakumagawa,[11] extending far northwestward to the Yamanouti[12] hot-spring region in the Province of Sinano. The hot-springs in the region about volcano Kusatu-Siranê, with a few exceptions, occur in the porphyrite areas. At the western foot of the volcano, near the Manza spa, the writer collected specimens of the so-called porphyrite. It occurs as a partly decomposed massive rock covered with the Siranê ejecta. It is dark gray with a tinge of green, and consists microscopically of more or less altered phenocrysts (plagioclase, augite, and hypersthene) and a devitrified base, resembling the so-called propylite which, in the Idu region, is an important member of the lower Miocene formations.

Lying directly on the porphyrite mass, A-lava and B-lava are exposed on the banks of the River Kosame,[13] which bounds the east foot of the volcano. They are only local lavas fed from the ancient volcanoes lying east and south-east of volcano Siranê, and having no direct structural relation to it.

Younger Tertiary beds are exposed on the banks of the rivers Manzagawa, Agatumagawa,[14] Kosamegawa, and Nagasasagawa,[15] which bound the west, south, east, and northeast foot of the volcano respectively. These beds rest on the porphyrite masses, together with the last-mentioned local lavas, and are covered by the products (tuffs and breccia) of volcano Siranê. They have been subjected more or less to either tilting or slight folding that resulted from later disturbance, and show gentle dips generally no more than 10° to 20°, with various strikes. The materials constituting the younger Tertiary beds are largely volcanics of andesitic nature, supplied by local vents, but are partly detritus, among which porphyrite pebbles are frequently found.

As to the geological age of the foundation, Ohashi has been led to infer that the porphyrite mass is a hypabyssal intrusive in an older Tertiary, and that the last-mentioned beds are a shallow-sea deposit which took place at the close of the Tertiary; an inference however that

8) S. SHIMIZU mentions diorite exposed in the valleys of Matukawa and Kakumagawa, which, according to R. OHASHI, is nothing but a facies of the porphyrite. *cf.*, S. SHIMIDZU, *Report Earthq. Invest. Com.*, 8 (1896), 137–185, (in Japanese).

9) 萬座川. 10) 松川. 11) 角間川.

12) 山の内温泉. *cf.*, T. YAGI, *Jour. Geogr.*, 44 (1932), 126~132, (in Japanese).

13) 小雨川. 14) 吾妻川. 15) 長筬川.

is not supported by palaeontological or any other evidence.

The distributions of the above-mentioned members of the Tertiary terrane about volcano Siranê suggest that it is not at all improbable that they extend beneath the volcano. Their thicknesses at the bottom of the volcano and the tectonic lines with which they have been disturbed, if disturbance there has been, are unknown. But it may be said that at the bottom of the volcano exists a group of tectonic lines, mainly faults, which lie parallel with the volcanic chain that is made up of the volcanoes Asama, Siranê, Kenasi,[16] etc. It is evidently in this structural belt, in which are aligned several volcanoes in a N.-S. direction, that numerous craterlets of volcano Siranê are formed (see Fig. 3). The Siranê magma may have been forced upward through this structural belt, and its volcanic products ejected from the aligned openings that have spread down for the most part to the east and the southeast terranes, where the grounds composed of the basement complex are far lower in altitude than they are at the west of the volcano.

Volcano Siranê. This volcano consists of a main body called Moto-Siranêsan[17] and a satellitic one called Siranêsan, forming the southern extremity of a plateau-like volcanic field of an older and much greater centre (Kenasi volcano group) of volcanic activity of which little now remain. Thus, although from the south it appears isolated and stands out conspicuously as a truncated conical volcano (Fig. 2), its extension when viewed from other directions is a succession of elevations and depressions.

Fig. 2.—Oct. 19, 1932. Volcano Kusatu-Siranê as seen from the northeastern flank of Volcano Asama. Photo Tsuya.

The main body—Moto-Siranêsan: Moto-Siranêsan, which means older Siranêsan, is a stratified volcano, built up of various lava-flows and fragmentary materials. Its height is 2176 m. above the sea, but it

16) 毛無山. *cf.*, S. Shimizu, *loc. cit.*

17) 本白根山.

is no more than 1300 m. above the adjoining terranes.

The flanks of the main body show various topographical features when viewed from different directions. On the eastern and southern sides, the outer slopes are relatively regular, but do not make a continuous curve. The inclination decreases uniformly toward the foot on those two sides, varying from 5° up to 30°, stepwise from the summit halfway down, until, on approaching the skirts of the mountain, they suddenly dwindle down to as little as 0°–3°. On these sides, the skirts of the main body are particularly well developed, whereas, on the west, where the steep upper slope of that body faces abruptly the Tertiary terrane (porphyrite and Tertiary sediment) on the banks of the River Manza, and on the north, where the satellitic body (Siranésan proper) and its nearest neighbour (Yokotéyama[18]) stand closely together, the skirts of the main body are not developed.

The main body has neither parasitic knobs, except the satellitic body, nor flank-openings on its flanks. But on its flanks there are two sulphur mines—one at Sessyogawara[19], a feeble solfatara or fumarole, on the east flank, and the other, Koménasi[20] sulphur mine, on the south flank, probable witnesses of volcanic activities in the remote past.

The summit of the main body shows a complicated morphological feature, presenting a succession of elevations and depressions owing to the numerous craterlets and conical hills packed close together. The craterlets and the conical hills however are not disposed in such a manner (cone-in-cone structure) as might be expected in a so-called somma-volcano, but are arranged roughly in two rows, each of which run in a N.-S. direction. According to Ohashi, there are six morphologically distinct craterlets, besides numerous explosion-craters, at present. The largest of these craterlets, the most southerly but one, is nearly oval, 400 m. by 250 m., dish-

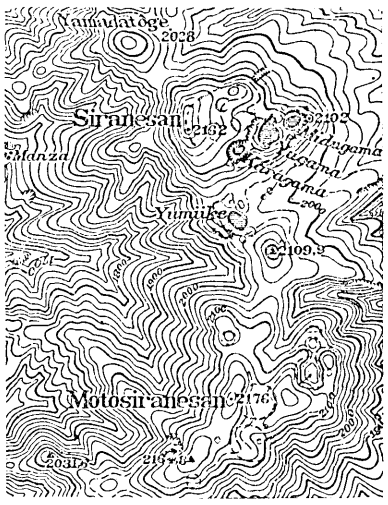

Fig. 3. Map (1:50000) of the summit of Kusatu-Siranésan showing location of the craterlets. (After Ohashi).

18) 横手山. 19) 殺生河原. 20) 米無硫黄山.

shaped, with a narrow gap in its east rim. The rest, except the northernmost one which is a crescent-shaped hollow, are nearly circular. About 1 km. west of the northernmost craterlet is a truncated conical hill, with a crater (?) at its top. About 1 km. northeast of the last-mentioned conical hill is another one (2109·9 m. above the sea) with numerous explosion-pits on its northwest side near the southwest foot of the satellitic body (Siranêsan proper). The activity of the craterlets at the summit of the main body, except one at the northeast bank of Yumiikê, an explosion-crater lake on the northwest side of the last-mentioned conical hill, has been long quiescent as far as historic records go.

The inner structure of the main body can be conjectured from the exposures on the valley-walls, which are developed radially on the flanks of the mountain, having reached a stage of development in which the mountain slopes are excavated to a depth as much as 300 m. But, although the development of the valleys is attributable principally to surface agencies (streams of meteoric water, snow-avalanches, etc.), numerous thick lava-flows, not all of which have extruded from a vent, have formed relatively deep intervales between any two adjoining lava-flows, with the result that meteoric water has flowed down the natural slopes of the intervales, further deepening the latter. The valley-walls thus formed not only make good natural profiles showing the order of succession of the volcanic products of the mountain, but also show the boundaries of any two adjoining superficial lava-flows that may occur.

According to Ohashi, the south side of the main body is built up of a lava called Komênasi lava; while its remaining part is younger in formation than that side, being built up of two successive lavas—the first (older) and the second (younger) types of the Siranê lavas—besides fragmentary material underlying them. The Komênasi lava is petrographically a gray augite-hypersthene-andesite, while the first and the second types of the Siranê lavas are a whitish quartz-augite-hypersthene-andesite and a dark olivine-augite-hypersthene-andesite respectively. He speaks of biotite as one of the subordinate components of these lavas, but made no attempt to unravel the sequence of eruptions of the numerous lava-flows, which he divided only roughly into the above-mentioned three kinds.

The writer has not yet studied in detail the structure of the main body. But, of the east flank from the top of the mountain half way down to the Kusatu spa, it may be said that its structure is represented in a complicated manner by numerous layers of lava-flows and fragmentary ejecta, disposed in the following succession:

	18. Explosion products	Olivine-two-pyroxene-andesite. / Two-pyroxene-andesite.
Upper	17. F—lava	Olivine-two-pyroxene-andesite.
	16. Agglomerate	Two-pyroxene-andesite.
	15. E—lava	Two-pyroxene-andesite.
	14. Volcanic ashes, sands, and lapilli.	
	13. D—lava	Two-pyroxene-andesite.
	12. Mud-flow	Two-pyroxene-andesite. / Two-pyroxene-dacite.
	11. C—lava	Biotite-bearing-two-pyroxene-andesite.
	10. B—lava	Two-pyroxene-dacite.
	9. Agglomerate	Two-pyroxene-dacite.
	8. Volcanic ashes.	
	7. A—lava	Two-pyroxene-andesite.
	6. Pumice-lapilli.	
	5. Agglomerate	Two-pyroxene-dacite.
Lower	4. Pumice-blocks.	
	3. Volcanic ashes.	
	2. Pumice-lapilli.	
	1. Pumiceous massive tuff and tuff-breccia.	

So far as the writer's observations go, the lava-flows are for the most part products of later eruptions of the main body, distributing from the top half way down, while the bulk of the fragmentary materials belong to the earlier eruptions that form the basal part of that body. The lava-flows are generally thick, sometimes attaining a hundred meters in thickness. Each of these thick lava-flows form flat-topped and steep-sided ridges, lava-coulee or Japanese *butai*[21], causing the stepped outline of the east flank of the mountain (Fig. 4).

As is usually the case with extrusive rocks of acid composition, the lavas of the main body are relatively glassy with fairly diversified appearance. They vary from white to black, phyric to aphyric, and dense to highly vesicular. Spherulitic structure, due to small spherulitic growths in the groundmasses, is seen in some of these lavas.

The fragmentary materials are of all grades, in size, from huge blocks to fine ash, and are stony, vitreous, or pumiceous, in appearance. Their deposits show some signs of stratification, often very finely laminated. They have yielded yet no organic remains, with the exception of small pieces of carbonized wood. Ohashi, referring to some volcanic material in the Tertiary beds which underlie the present volcano as the oldest ejecta of the same volcano, was led to believe that the

21) 舞臺.

earliest eruption of the volcano had occurred in shallow water at the end of the Tertiary. These statements have not however been proved by any evidences, petrological or stratigraphical, and are subjects of further study.

The satellitic body—Siranėsan proper: Siranėsan proper, which lies to the north of the main body, is a conical volcano composed of a few lava-flows and much fragmental material. Its height is 2162 m. above the sea, but less than 300 m. above its base.

The immediate base on which the cone has grown consists practically of products of the main body (Moto-Siranėsan), except the Yokoté-yama volcanic body.[22] The terranes adjoining the south, the east, and the northeast, of the cone are lava-flows (biotite-bearing two-pyroxene-andesite, two-pyroxene-andesite, and two-pyroxene-dacite); while the districts immediately to the northwest and the west are of Yokoté lava

Fig. 5. The northeastern flank of the satellitic body, Siranėsan proper, showing a lava-flow of two-pyroxene-andesite. Photo. Tomizawa.

Fig. 4. An ideal section of volcano Kusatu-Siranė showing succession of lavas and fragmentary material. T—tuff, tuff-breccia, pumice, etc.; l_1—two-pyroxene-dacite lava; l_2, l_3—two-pyroxene-andesite lavas; l_4—biotite-bearing two-pyroxene-andesite lava; l_5—olivine-two-pyroxene-andesite lava; L_1—two-pyroxene-andesite lava; L_2—olivine-two-pyroxene-andesite lava; Y—Yokoté lava?; P—porphyrite?

22) This forms the high rugged mountain, Yokotéyama (2304·9 m. above the sea), adjoining the north of Siranésan proper. According to Ohashi, this is an older member of volcano Siranė, consisting of a gray-colored augite-hypersthene-andesite (Yokoté lava) supplied by its own vent. But it has no direct structural relation to either Moto-Siranė-san or Siranésan proper; while the northern skirt of Siranésan proper lies on the south flank of Yokotéyama in a discordant relation. On these grounds, the writer has left this mountain out of the present discussion on volcano Siranė.

which, in turn, overlies the so-called porphyrite mass.

The development of the flanks of the cone is not uniform in all directions. The eastern flank is relatively well developed, with slopes whose inclinations are about 25° near the summit and 3–0° near the foot (Fig. 5). The northern and southern flanks (see Fig. 31) are equally developed, showing a slope as steep as 30°. But, in these directions, the skirts with gentle slopes are not so well developed as in the eastern direction. This is due to the existence of the Yokotéyama volcanic body on the north and a high lava-coulee of Moto-Siranê on the south, each of which has obstructed extensive development of the cone-skirts adjoining them. The western flank of the cone is abnormal, its steep upper slope facing abruptly on the upper course of the River Manza.

The satellitic cone is truncated at the top with an old crater-wall, whose northwest segment is clearly represented by an arciform crest line around it. The highest point (2162 m. above the sea) of the present

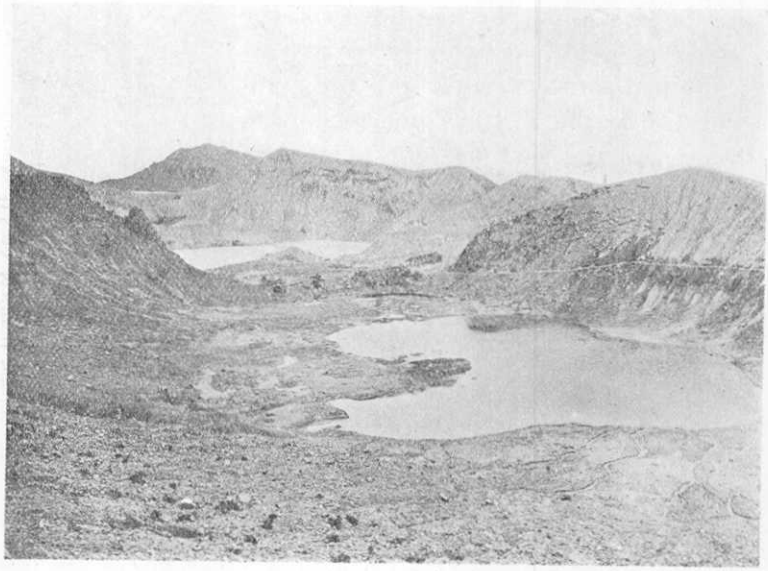

Fig. 6.—June, 1931. General view of the triple crater at the summit of Siranésan proper. Center, Yugama; upper left, Midugama; and lower, Karagama (*cf.* Fig. 34). Photo Tomizawa.

cone is the western crest of this old crater-wall. The southeastern segment of the old crater-wall cannot be traced at present. The crater, which, encircled with the old crater-wall, must have been about 1 km. in diameter, has been buried almost completely under the products of

later eruptions that took place in and around it. The morphologically quite young triple crater (Fig. 6), consisting of three crater-bowls—the central one called Yugama, the southwesterly one Karagama,[23] and the northeasterly one Midugama[24]—is a mute witness of these eruptions.

The Midugama, which contains cold water, is a nearly rectangular crater-bowl, the longer and the shorter sides of which are 250 m. from N. E. to S. W. and 200 m. from N. W. to S. E. respectively. The crater-bowl is surrounded by steep walls on all sides, except on the southwest, where there is a great V-shaped gap in the wall which serves as a passage to the adjoining crater-bowl (Yugama). The rim of the encircling wall is higher on the southeast than on the northwest, its highest point being 2102 m. above the sea on the east side. The bottom of the crater-bowl is about 80 m. deep from the highest point of the encircling rim, whereas it is only a few meters deep from the lowest point in the V-shaped gap in the southwest wall. The cold water occupies an oval pool measuring about 150 m. across from N. E. to S. W. and about 100 m. across from S. E. to N. W., covering the greater part of the bottom. Outside, near the northwest rim of this crater-bowl, is a small horseshoe-shaped explosion-crater.

The Karagama ("dried-up cauldron") is an oval crater-bowl, the major and minor axes of which are 200 m. from N. E. to S. W. and 100m. from N. W. to S. E. respectively. The northern wall of this bowl is an almost perpendicular cliff, whereas the southwestern wall is so gentle in slope as to be easily passable. A great V-shaped gap in the northeast wall of the bowl opens into the Yugama crater-bowl. The bottom of the Karagama crater-bowl is about 80m. deep from the highest point of the northern rim and about 30 m. from the southwestern rim. It is a flat ground, usually dry, but at the time of the writer's visit there was water in a small pool in the southeastern half of the bottom (Fig. 6).

The Yugama ("hot-water cauldron") lies between the above-mentioned two crater-bowls, into both of which it opens. It is an indented bowl, about 300 m. in diameter and surrounded by an almost perpendicular wall, except the V-shaped gaps in the wall on the southwest and northeast sides where it opens into the Karagama and the Midugama respectively. The rim of the rugged encircling wall is higher on the north than on the south. The bottom of the bowl is not level, its north-

23) 空釜. 24) 水釜.

eastern half being lower than the southwestern half. The former is occupied by a hot-water pool, about 150 m. in diameter, while upon the latter, which is dry ground, the sulphur miners have built sheds. The level-difference in these two parts of the bottom is about 10 m., the higher northeast margin of the dry ground forming steep scarp of this height fronting the adjoining hot-water pool (Fig. 7). The level of the hot-water pool is about 100m. below the highest point of the northern rim of the crater-bowl and about 20 m. below the lowest point in the V-shaped gap in the northeastern wall. The dry ground in the southwestern half of the Yugama is separated from the bottom of the Karagama by a low ridge in the V-shaped gap in the wall between them, the former being a few meters lower than the latter. Shiranê's activities in historic times, except that in 1902, were manifested exclusively in this crater-bowl, changing more or less the feature of its interior whenever it occurred, as will be described in the next chapter.

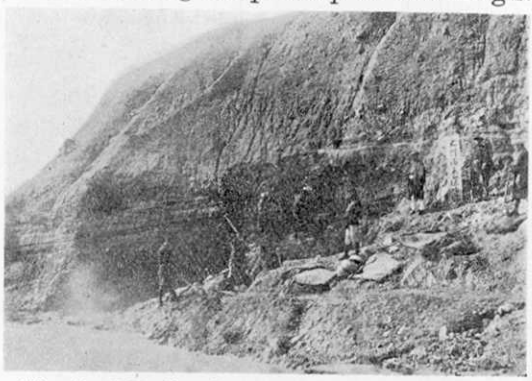

Fig. 7.—1921. Showing numerous layers, alternately accumulated sulphur and explosion products. Lower left, a portion of the hot-water pool in the northeastern half of the bottom of the Yugama crater-bowl; and upper middle, a portion of crest line of the northeast margin of the dry ground in the southwestern half of the bottom of that bowl, looking south.
Photo Tomizawa.

The inner structure of Siranésan proper may be conjectured from exposures on the encircling cliffs of the triple crater, as well as from those on the outer sides of the cone, where excavations in the rocky skin show frequent scars and slips. Structurally the mountain is a diminutive composite cone,[25] consisting of the somma represented by the older crater-wall and the one-sided cone with the triple crater at its top, whose northwest side is hemmed in by the old crater-wall.

The somma is a stratified cone built up of several layers of alternate accumulations of lava-flows (massive lava-flows and agglomerate lava-flows) and fragmentary materials (volcanic ash, sand, lapilli, and

25) Ohashi is of opinion that the mountain is a lava-dome with a summit-crater, about 1km. in diameter, and six explosion-craters within the host crater. This opinion however could not be verified so far as the writer's observations went.

blocks). The best exposures of the inner structure of this cone are found on both the northern flank and on the western flank near the crest of the arc-shaped older crater-wall. The materials composing this cone are petrographically quartz-bearing two-pyroxene-andesite and two-pyroxene-andesite. On the crest around the old crater-wall are to be found abundant explosion products, among which bread-crust bombs of olivine-two-pyroxene-andesite are frequently met with. These products were probably supplied through some vent or outlet represented by the triple crater.

The southeastern half of the mountain consists of lava-flows and fragmentary materials, probably ejected from the triple crater. The lava-flows are exposed on the surrounding walls of the crater, being overlain by numerous layers of fragmentary ejecta. The lava exposed on the southeast wall of the Karagama crater-bowl is petrographically an olivine-two-pyroxene-andesite, while the lava exposed on the southeast wall, below the highest point of the southeast rim of the Mizugama crater-bowl, is a two-pyroxene-andesite. The northern wall of the Yugama crater-bowl is a lava-cliff attaining a height of about 80 m. from its base near the northern shore of the hot-water pool up to near its upper rim. The lava exposed there, according to K. Nakajima,[26] is petrographically a two-pyroxene-andesite with the following chemical composition :

	Wt. %		Norm	Ratios
SiO_2	62·66	Q	41·20	$\frac{Sal}{Fem}=4·57$
Al_2O_3	15·91	Or	2·23	
Fe_2O_3	5·91	Ab	1·57	$\frac{Q}{F}=1·17$
FeO	2·11	An	31·43	
MgO	3·52	C	3·67	$\frac{Na_2O'+K_2O'}{CaO'}=0·06$
CaO	6.70	Hy	8·93	
Na_2O	0·17	Mt	6·71	$\frac{K_2O'}{Na_2O'}=1·33$
K_2O	0·36	Ap	0·62	
H_2O	1·32	Hm	1·28	
P_2O_5	0·31	Symbol (C. I. P. W.)		"II. 3. 5."3.
Total	99·97			

It is difficult to ascertain the distributions of these lavas on the outside of the crater-bowls, where the ground is thickly covered with

26) K. Nakajima, *Expl. Text, Geol. Map*, "Nagano" sheet (1:200000), (1888), 25, (in Japanese).

explosion products. These explosion products are mostly rock-fragments of various sizes, ranging from ash-grade to blocks of more than one meter in diameter, in which are not a few bread-crust bombs (olivine-two-pyroxene-andesite), similar petrographically to those just mentioned.

The bottom ground, except the water pools, of the triple crater are covered with explosion products. The southwestern half of the bottom of the Yugama crater-bowl is built up of numerous layers of alternately accumulated explosion-products and sulphur deposits (*yunohana*).[27] The sulphur deposit is being worked on a substantial scale (see Fig. 7).

Volcanic Activity in Historic Times.

The volcano has been active eight times during the last fifty years. The first activity in this period was the explosion that took place on Aug. 6, 1882. The last period of activity prior to this is supposed to have ended at least 120 years ago, as may be inferred from oral informations that during about seventy years before the explosion in 1882 the volcano was entirely quiescent without any trace of volcanic activity, but that previous to this dormant period it was issuing smokes from its summit. But nothing regarding this former active period has been recorded, the explosion of 1882 being the first ever mentioned in our chronology. A short account of the activities of the volcano in historic times will now be given.

1. The activity of 1882 A. D.[30] At about 2^h p. m. on Aug. 6, 1882, when an explosion of this volcano occurred, a strong detonation was heard at Yosigataira,[28] about 2km. distant northeast, but the mountain being concealed from view by heavy clouds, the explosion remained unsuspected until two days afterward, Aug. 8, when the mountain was seen to be emitting dark smoke.

As a result of this explosion, the Dokumidusawa[29]—a valley on the east flank of the mountain—into which flowed the mud-water expelled from the summit crater, inundated its banks in many places. Volcanic ashes fell in Sinano province northwest of the mountain.

This explosion took place in the floor of the Yugama crater-bowl and in eight other places near it, resulting in the formation of numerous

27) 湯花. 28) 芳ケ平. 29) 毒水澤.

30) E. NAUMANN, *Petermanns Mitteilungen, Ergänzungsband,* **23** (1893), 1~9; S. KANDA, *Tôyô Gakugei Zassi,* **37** (1920), 45~46, (in Japanese); F. OMORI, *Report Earthq. Invest. Com.,* **86** (1915), 80~82, (in Japanese).

hollows, from which vapors, hot water, mud, and stones were thrown out. These hollows were of varying sizes and depths, the largest being about 150 m. in diameter and about 90 m. in depth.

On Aug. 8, according to the then village master of Kusatu, who, on that day inspected the scene of the explosion, a succession of fairly strong vapor-clouds threw up before his eyes showers of rock-fragments to heights of at least 60 m. above the crater bottom. These fragments of varying sizes, the largest about 0·6 m. by 0·3 m., were projected northwestward to a distance of 2000 m. from the crater. At noon of the following day numerous openings, the largest of which was about 5·5 m. in diameter, were formed near the crater-rim on the southeast side, and from these openings hot water poured out for a week until Aug. 16.

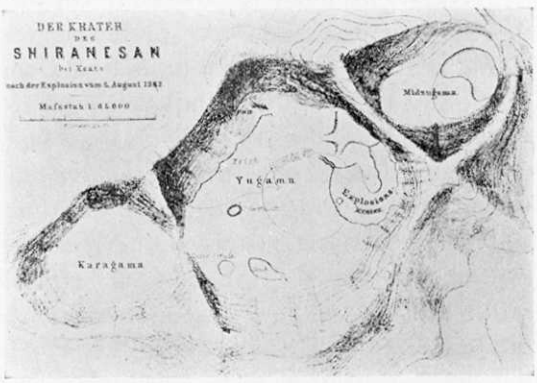

Fig. 8.—Sept. 5, 1882. (After Naumann).

Before this explosion, the ground in and around the Yugama crater-bowl had been covered with trees and bushes, with a pool of cold water at the centre of the bottom of the crater-bowl, but by the explosion the trees and bushes were completely ruined, and the position of the pool changed to another part near the base of the northern crater-wall, its old site becoming partly dry ground and partly a new pool of hot-water.

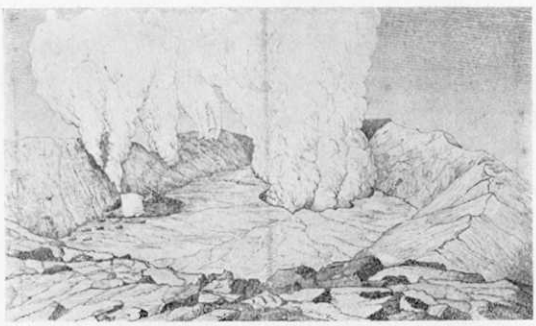

Fig. 9.—1882. The Yugama crater-bowl after the explosion on Aug. 6, 1882. (After Jingoro Yanazawa).

E. Naumann[31] visited this mountain on Sept. 5 and 7 of the same year, and made some geological observations. During his visit to the mountain, according to him, fairly strong emissions

31) *loc. cit.*

of dense vapor-clouds were taking place from several fissures on the northern wall of the Yugama crater-bowl, as well as from the horse-shoe-shaped explosion-crater and hot fountain (heisse sprudel) on the bottom of the crater-bowl (see Fig. 8). He observed that the horseshoe-shaped explosion-crater, which contained some milky white water, was very active, throwing out water to a height of about 4 m. above the water level at intervals of one minute or more with roaring sound.

When K. Nakajima[32] visited the mountain in 1888, he found that the explosion-crater in the Yugama crater-bowl was emitting white vapors from several places in its northern part.

2. Explosion of 1897.[33] On July 8, 1897, another explosion of the volcano occurred. As preliminary sign of this explosion, vapors mixed with sulphur actively issued from the Yugama since a month previously and slight earthquakes were frequently felt on the mountain. Since the afternoon of July 7, roarings were of frequent occurrence, until, at about 4^h a.m. the next day, an explosion took place, ejecting volcanic ashes and sand from an opening about 100 m. in circumference and 20 m. in depth, between the rocky ridges, and about 200 m. northeast of the centre of the former explosion crater (the hot-water pool called Oikê[34]) in the Yugama crater-bowl. An hour later, a second explosion occurred on the southwest side of the explosion crater and lasted for about three hours during which time hot water and mud were often thrown up to a height 150 m. above the level of the pool. As a result of this explosion, another explosion-crater was formed, about 80 m. in diameter and opening into the former pool.

On July 31 of the same year, an explosion took place about 5^h a.m., with slight earthquakes. Several explosion-holes, one of which measured 7 m. across, were formed in front of the lock-gate of the drainage tunnel at the southern shore of the pool (Oikê). About 40 m. eastward of these holes there appeared a fissure through which hot mud and blocks weighing nearly 150 kg. were projected northwestward over the crater-rim during the explosion.

On Aug. 2 violent rumblings were heard at 2^h a.m., followed by a period of paroxysmal activity with frequent ejections of rock-fragments that lasted until dawn. The next day, at about $2^h\ 30^m$ p.m., an explosion

32) *loc. cit.*

33) *Jour. Geol. Soc.*, Tôkyô, 4 (1897), 437~438; *Jour. Geogr*, 9 (1897), 389~390, (in Japanese).

34) 大池

took place from an opening near the lock-gate with violent ejections of rock-fragments. One person was wounded. From then on till Aug. 16, rumblings and minor explosions were of frequent occurrence.

The next year (1898), according to K. Jimbo,[35] it was found that as a result of the last explosions, the level of the former pool (Oikê) had fallen about 5 m. When he visited the mountain on August 17, vapor-clouds were issuing from the northeast corner of the pool.

3. The explosion of 1900.[36] On Oct. 1900, feeble rumblings and explosions occurred at about 3^h a. m.

4. The explosion of 1902.[37] On July 15, 1902, an explosion occurred at about 4^h p. m. in a small conical mound on the northeastern shore of the Yumiike,[38] an explosion-crater lake on the saddle between Moto-Sirané and Sirané proper. Emissions of vapors and ejections of rock-fragments continued to the next evening. Four days later, on July 19, only a faint vapor-cloud was issuing.

On Aug. 20, occurred the second explosion which however was of moderate violence.

On Sept. 3, vapor-clouds were issuing from several openings within the explosion-crater at the top of the conical mound. Next day a violent explosion occurred, resulting in the formation of another explosion crater which was separated from the former one by only a narrow ridge.

On Sept. 17, an explosion occurred at about 1^h p. m., shooting up a column of black smoke to a height of several hundred meters above the top of the conical mound. Rumblings were then heard at Kusatu in the direction of the mountain. Volcanic ashes fell to the leeward within a distance of about 2 km., and accumulated to a depth of about 9 cm. not far from the crater. Although explosions continued intermittently throughout the following two days, the intensity gradually diminished. On Sept. 19, rumblings were heard at about 11^h a. m., with emission of smoke.

On Sept. 23, according to S. Kawasaki who was on the mountain that day, vapor began to issue violently from the top of the conical mound, and continued to issue with increasing intensity, until at about 11^h a. m. when it suddenly changed to black smoke densely charged

35) K. Jimbo, *Jour. Geol. Soc.*, Tôkyô, 5 (1898), 500~501, (in Japanese).

36) F. Omori, *loc. cit.*

37) S. Kawasaki, *Jour. Geol. Soc.*, Tôkyô, 9 (1902), 461~465, (in Japanese); *Jour. Geogr.*, 14 (1902), 647; 711.

38) 弓池

with volcanic ashes. For thirty minutes explosions were frequent, ejecting rock fragments to heights nearly 30 m. above the top of the mound. During this period rumblings were of continual occurrence. After that came a period of relative calm, but twenty minutes later emissions of black smoke and ejections of rock-fragments were repeated with rumblings, and in the afternoon, from 0^h15^m to 2^h, these phenomena occurred at intervals varying from 15 seconds to a minute. The same activity continued through the next day.

Fig. 10.—1902. The explosion crater of 1902. Lower, a portion of the Yumiiké; upper, the southwestern flank of Siranésan proper. Photo Tomizawa.

On Oct. 18, hot water was seen spouting from several places in the crater at the top of the conical mound near the Yumiiké.

All through the explosions of this year the Yugama crater-bowl remained quiet.

5. The explosion of 1905.[39] In Oct., 1905, another explosion of the volcano took place.

In 1910, according to R. Ohashi,[40] steam was issuing from the hot-water pool in the bottom of the Yugama crater, near the base of the inside northern wall. Water was also being projected.

In 1916, according to K. Aomi,[41] feeble fumaroles and fountains were observed at several places in the hot-water pool inside the Yugama crater. A very active fumaroles was noticed in the northwestern part of the pool. At that time the water in the pool was about 50°C.

6. The explosion of 1925.[42] On Jan. 22, 1925, an explosion took place on the inside northern wall of the Yugama crater, ejecting ash-laden clouds and rock-fragments with rumblings. On Jan. 25, it was found that a new explosion-pit, about 20 m. by 7 m., had opened near the upper rim of the inside northern wall of the crater. On that day, vapor-clouds were issuing from the new pit. About 35 m.

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

40) *loc. cit.*

41) K. AOMI, *Tôyô Gakugei Zassi*, **33** (1916), 828~832, (in Japanese).

42) *Kisyôyôran*, (1925), 26~27.

westward of this opening appeared a detatchment scar, 15 km². in area, on the inside crater-wall. The Yugama crater-bowl was, as before, emitting a feeble vapor-clouds from its floor. As a result of the explosion, the volcanic ashes, which fell on the southeast side of the mountain, accumulated to a depth of about 20 cm. for a distance of about 3 km.

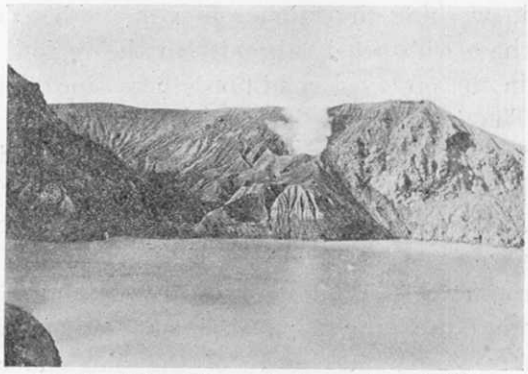

Fig. 11.—1925. The explosion crater of 1925, looking northeast. The crater is emitting only white vapors. In the foreground is the pool in the bottom of the Yugama crater-bowl. Photo Tomizawa.

7. The explosion of 1927.[43] On Dec. 31, 1927, an explosion occurred at about 11ʰ a. m. As a preliminary sign of this explosion, rumblings were heard twice during the preceding two days, viz., at 7ʰ a. m. on Dec. 29 and 9ʰ a. m. on Dec. 30. The explosion shot out enormous columns of vapor heavily charged with volcanic ashes from a fissure nearly 100 m. long at the base of inside northern wall of the Yugama crater, as well as from numerous other fissures on the southern flank adjoining the southern rim of the Yugama crater. At the same time, the inside northeast wall of the Yugama crater, which formerly had been a vertical cliff, caved in. As results of this explosion, the vent that opend in 1925 ceased activities, the water in the Yugama crater-bowl rose in temperature from 15° to 24°C., while its level sank about 14 m. On the southern flank near the south rim of the crater, a hot spring 80°C. began to gush out.

Since then fairly strong emissions of vapor-clouds continued during the following three months, but these gradually declined in intensity until, on June 26, 1928, when M. Kajima and K. Gomi visited the mountain, only gentle fumaroles, one of which was 64.5°C., was emitting white vapors from several places in the explosion-fissures of the preceding year.

The Explosions of Oct. 1932.

Sequence of events. The seasonal appearances of the crater region of Siranésan proper were well known to those who were engaged

43) M. Kajima and K. Gomi, *Kisyôsyûsi*, (1928), 400~408.

in working the sulphur deposit in the Yugama crater-bowl and also to those who acted as guides in the region. There is no record of changes in the observed conditions there since the last explosion (Dec. 31, 1927). The fumarolic activity, which at the time of Kajima's visit to the mountain was observed in several places, had been growing weaker, until, last year it became almost extinct (see Fig. 6). But gentle fumaroles had been observed before the outburst of Oct. 1, 1932, on the inside northeastern wall of the Yugama crater, as well as in a fissure on the southern flank near the southern rim of the crater. These fumaroles were the only signs of latent activity of the volcano during the last few years, the inside of the Yugama crater being very quiet. The explosive activities of 1932 began on Oct. 1, and repeated themselves several times during the succeeding days towards the end of that month. From accounts of eyewitnesses and of people living in the terranes about the mountain, the sequence of activities was as follows:

Oct. 1. Fine weather. Twenty nine miners were engaged working the sulphur deposit at the bottom of the Yugama crater. The first explosion came without warning at about 2^h5^m p. m.[44] No change was noticed either in the temperature or in the activity of the pre-existing fumaroles in and about the Yugama crater, neither were there any local earthquakes to attract particular attention. The miners, who were at work in the bottom of the Yugama crater, had no inkling of the danger until they were faced suddenly with the explosion. Two of them were instantly killed and seven seriously injured by stones that were thrown out by the first outbreak.

The first explosion occurred in the inside northeastern wall of the Yugama crater, as well as in the fissures on the outside of the southern rim of the crater, with ejection of old cone material ranging in size from ash-grade up to blocks about 100 cm. in diameter, besides vapors.

The explosion-clouds were clearly seen from Kusatu (Fig. 22). According to K. Yumoto, who witnessed the first explosion when it occurred, a small black mass of smoke was first seen to rise above the level of the mountain, and then to expanded outwardly, cauliflower-shape, against the surrounding air, and bent by the wind which was blowing from the southwest, without being projected into the upper region of the air. He dit not hear the first explosion, although it was

44) A seismogram set up at Minenotyaya (峯ノ茶屋) on the eastern flank of volcano Asama, 25 km. south of the volcano Sirané, recorded a minor volcanic tremor at 1^h50^m p.m. on Oct. 1.

heard in Kusatu. About fifteen minutes later, ashes began to fall in Kusatu and continued for about five minutes.

At the Manza spa, the explosion was clearly heard, like the noise caused by firing a heavy gun. There the rumblings were heard through out the day and into the evening hours but there was no fall of ash.

The first explosion was followed by a slighter one a few hours later.

After the explosions of Oct. 1, the mountain was relatively quiet, without issuing any noticeable amount of ash-laden cloud, until the afternoon of Oct. 4, when an explosion of the mountain occurred. During this period of relative quiescence a number of people visited the scene of the last explosions. Tomizawa, a Photographer of Kusatu, who visited the scene on Oct. 2, took the photographs that are shown in Fig. 25 and 29. He saw a tremendous volume of white vapors issuing with a hissing sound and heard rumblings from the crevices on the inside northeastern wall of the Yugama crater and also from the fissures on the outside of the southern rim of the crater.

Oct. 4. Rumblings of the mountain were heard frequently this day at Kusatu. An explosion took place at about 2^h 30^m p. m., and a moderate quantity of volcanic ashes was thrown out, while a vertical column of black smoke was seen from Kusatu (Fig. 23) to rise upward into the upper region of the air. But the explosion was not heard at Kusatu, nor did any ashes fall there.

During the next day rumblings of the mountain were frequently heard at Kusatu.

Oct. 6. On this day, at about 3^h a. m., there was an explosion with a detonation much stronger than was heard previously. Since it occurred at night nothing could be seen. From this day on the mountain was fairly quiet until the dawn of Oct. 23, when it seemed to have awaken from that tranquility into which it had elapsed during the preceding eighteen days. During this period of repose neither explosion nor ash-fall is said to have occurred,[45] and rumblings were seldom heard at Kusatu although a moderate quantity of vapors never ceased to issue from the mountain. The writer, observing from Asama-yama during the four days since Oct. 17, saw nothing but a column of vapor-cloud, bent by wind from the west, issuing constantly from the summit of the present volcano (see Fig. 2).

45) S. Kunitomi mentioned an explosion as having occurred at 6^h40^m a. m. on Oct. 8. *cf.*, *Kisyôyôran*, (1932), 998~1005.

In the afternoon of Oct. 20, when the writer arrived at Kusatu, the mountain was quiet, and nothing of its activity was noticed in Kusatu except the white vapors that rose slowly from its summit. The day after his arrival at Kusatu, a light rain was falling and the mountain shrouded so thickly in rain clouds, that he gave up the idea of gaining the summit of the mountain when he arrived at Yosigataira. At about 1^h30^m p. m. rumblings were heard at Yosigataira in the direction of the summit, but nothing of the summit could be seen. He visited the summit thrice, on Oct. 22, 23, and 24, and examined the present activity, besides making some geological observations. The conditions on the summit during these three days were as follows:

Oct. 22. was fine. Shortly after 5^h a. m. a loud noise was heard at Kusatsu in the direction of the mountain, of which it might have been an explosion. Two hours later, all that could be seen from Kusatsu was the usual vapor-cloud rising from the mountain. An ascent of the mountain was made this day by a short cut passing through Sainokawara[46] (a seat of a group of fumaroles, in Kusatu) and Sessyôgawara (a valley situated about 3·5 km. west of Kusatu, presenting a fumarolic activity). When he came near the Sessyôgawara rumblings and hissing noises became audible in the direction of the summit of the mountain. On approaching the summit the noises grew clearer and louder. When he arrived at the southern foot of the volcanic cone, Siranésan proper, a distance of about 1 km. south from the summit triple crater, he saw vapors together with ash, sand, and stones being blown out from a number of vents in fissures on the southern flank of the cone (see Figs. 12, 13, 14, 15, and 28). The hissing noise was continual. The number of these vents then would be more than fifteen, although no accurate count could be made owing to the dense vapor-cloud which completely veiled the eastern half of the southern flank of the cone, where several vapor-columns were seen through rifts in the cloud. The most active vent was in a fissure situated a short distance below the top of the southern rim of the Yugama crater-bowl (see Fig. 12).

The inside of the Yugama crater-bowl was quiet with a glassy pool of hot (?) water in its bottom except in the southern inlet of the pool, where the water had become milk-white, evaporating misty vapors. There were two fumaroles on the inside wall of the crater—one situated

46) 西ノ河原.

at the base of the northern wall, emitting vapors plentifully but slowly from a cleft which was separated from the bottom of the Yugama crater-bowl by a narrow ridge (C_2 in Fig. 34), the other from a cleft that had been formed by explosions early in the month on the inside southeastern wall of the crater, extending from near the upper rim downward to the base of that wall. This latter fumarole was emitting volumes of white vapors with a continual hissing noise (Fig. 26). Besides these, there were a number of gentle fumaroles on the eastern half of the inside wall of the crater.

These activities of the mountain continued day and night.

Oct. 23 was also very fine. In the early morning the usual white vapors issuing from the summit of the mountain were seen from Kusatu, but the rumblings could not be heard. The writer ascended the mountain by the same route as that of the preceding day. At 10^h25^m a. m., when about 2 km. southeast of the summit, he saw a small mass of dark ash-cloud being injected into the white vapor-column which had been rising above the level of the mountain up to that time. The heavy charge of ashes clearly indicated an attack of a higher vapor pressure upon the crater-wall. But no noise other than rumblings was heard. From this time on, the emission of ash-laden cloud increased in violence. At about 11^h a. m., within distance of 1·5 km. from the scene of the explosion, he saw dense, dark whorles of ash-laden cloud shoot straight upward incessantly from the summit of the mountain. Simultaneously with these emissions, ejections of rock-fragments occurred frequently. Among these rock-fragments were blocks so large that their flights through the clear air on the weather side were readily seen at a distance of 1·5 km. A clinometer measurement at that distance showed that the maximum height of the column of the ash-laden cloud was about 1300 m. above the level of the mountain. The writer braved the light showers of ashes which he encountered at a distance of about 1 km. southeast from the summit in order to view the explosion at close range, but found it necessary to make a wide detour, owing to large blocks falling as far as almost to the foot of the cone itself.

At 11^h30^m a. m., when he stood watching the explosion from the shortest safe distance (about 750 m. south of the summit crater), the explosive activity at the summit crater (Yugama) culminated in paroxysmal conditions, with long, roaring explosions and emissions of dark clouds densely charged with solid materials. At the same time, the numerous vents in the fissures on the southern flank of the cone were

at the height of their activity, emitting dense whorls of ash-laden clouds (Figs. 17, 19, and 24). The explosions, which occurred at intervals of a few seconds at the summit crater, were often so powerful as to shoot upwards rock-fragments, non-incandescent, to heights at least 700 m. above the crater-rim, and send a tremendous column of heavily ash-laden cloud to heights of more than 1000 m. But no electrical phenomena could be discerned in these clouds. Heavy rumblings without any sensible air-concussion, and noises recalling rock-slides were of almost continual occurrence. Occasionally sharp staccato sounds like those of pistol shots in the open air were heard in rapid succession. Successive showers of rock-fragments upon the southwest flank of the cone, where the air was clear of the ash-laden cloud, raised a dust-cloud from the ground upon which they fell, forming a brilliant spectacle due to the continually changing directions of the particles composing it. Southwestward the rock-fragments reached as far as 500 m. from the summit crater whence they were ejected. They were of varying sizes, the largest appeared at that distances to be about 50 cm. in diameter. In falling upon the cone flank they rebounded to be broken into several fragments, or otherwise they sank deep into the ground upon which they fell.

Although the paroxysmal activity lasted throughout the entire afternoon, discharging vast quantities of solid material, the intensity of the forces gradually diminished, the greater projections of ejecta and the heavier rumblings being synchronous with the explosive maxima. After the explosive maxima, which lasted without any notable intensity variation for about one hour since 11^h30^m a. m., had passed, a visit to the southwestern rim of the Yugama crater-bowl showed that a new explosion-pit had been opened at the base of the inside southeastern wall of the bowl (C_3 in Fig. 34). This pit was the main one, so far as the writer could observe, that gave rise to the explosions of the day. By that time, the activity at this new pit was taking place in the form of a series of very sharp and sudden but moderate explosions in rapid succession, at intervals of 10–15^m, emitting enormous whorls of ash-laden cloud. From time to time there were greater explosions with a roaring sound. They sent showers of rock-fragments to heights of 150–200 m. above the pit, and so nearly vertical that they invariably fell inside the crater-bowl (Figs. 18, 20, and 21). The bulk of the solid materials ejected by these explosions, except the ashes, fell into the pool in the bottom of the crater-bowl, raising splashes of mud-water, none of which

reached the writer as he stood watching the explosions at the highest point of the northwest rim of the crater-bowl. During these explosions, the ground upon which he stood vibrated continuously, but with a period and amplitude that could not be determined. In the central part of the pool in the bottom of the crater-bowl there appeared gentle fumaroles in two places, emitting white vapors, while numerous fumaroles on the inside wall of the bowl, except the one near the south shore of the pool which was more active than in the preceding day, did not show any notable change in activity.

The explosive conditions of the new pit continued all day and into the evening hours, while rumblings were heard in the night, 7^h p. m. at Manza.

Oct. 24. On visiting the summit again, the writer found, as a result of the explosions of the preceding day, some changes in the activity in and around the Yugama crater-bowl. The explosion pit, which the preceding day had been the centre of the paroxysmal activity, quieted down without emitting any vapors, while three new adjoining southerly pits, which, including the former one, lay side by side in the bottom of the large fissure in the southeastern wall of the crater-bowl, were fiercely throwing out spiral columns of ash-laden vapors with a roaring sound (Fig. 27) These sounds were recurrent, stopping suddenly for a few minutes at intervals of about fifteen minutes. The pool at the bottom of the crater-bowl was at the same level as that observed two days before, with two gentle fumaroles in its middle, while its southern shore became much indented with two circular inlets and a small pool, where white vapors were issuing, along with mud-waters spouting at intervals of a few seconds from a number of temporary vents of no fixed location (Fig. 27).

It was found this day that the number as well as the activity of the fumaroles on the southern flank of the cone had greatly diminished permitting a much better view of the fissures than formerly (Figs. 30, 31, and 32).

At 10^h30^m p. m., or a little later, the same day, the writer at Kusatu thought he could hear detonations in the direction of the mountain.

Oct. 25. At daybreak it was found that 1 mm. of volcanic ash had fallen in Kusatu during the preceding night.

During the remaining days of that month, ash-laden clouds were seen from Kusatu to rise continually from the summit[47]

47) According to Kunitomi, an explosion occurred at 1^h17^m a. m. on Oct. 26, and another one at 9^h3^m a. m. on Oct. 27. *loc. cit.*

In the early days of the succeeding month, according to Tomizawa of Kusatu, the volcano continued its activity as usual, throwing out a moderate quantity of ash-laden clouds which, arching eastward, dropped ashes in Kusatu and vicinity much as if snow had fallen.

Topographical Changes. During the paroxysmal phases of the recent activity, a certain quantity of solid materials that was projected accumulated on the ground in and about the Yugama crater-bowl. But the accumulation of the ejected materials has not made much morphological changes. The only noticeable topographical change was the fissuring, both inside and outside the Yugama crater-bowl, a direct result of the recent explosion. Fig. 34 is a sketch map showing the configuration of the Yugama crater and neighbourhood at the time the writer visited it.

Crater: The bottom of the Yugama crater-bowl, except its southeastern part near the base of the inside southeastern wall of the bowl, did not change either in its depth below the encircling rim or in its configuration. Its southwestern half was as dry as before, the recent ejecta having accumulated to a little less than a quater of a meter, while its northeastern half was a pool of hot (?) water whose level was about 10 m. below the southwestern dry ground. The south shore of this pool was somewhat altered in outline by the explosions of Oct. 23. On Oct. 22, there was an inlet about 10 m. in diameter on the south shore of the pool, and 20 m. northwest of this inlet was another smaller one. On Oct. 23 and 24, the south shore of the pool was indented by two circular inlets which had been formed during the explosions of Oct. 23 at the place where on the preceding day only one inlet was seen. West of these two inlets there was a small pond, about 7 m. in diameter.

The inside southern wall of the Yugama crater-bowl was scored with shallow vertical grooves. These grooves may have been formed by explosions that probably occurred in the last-mentioned inlets on the southern shore of the pool.

The inside southeastern wall of the Yugama crater-bowl was fissured deeply in nearly a north-and-south direction, whereas formerly it was an almost perpendicular cliff encircling the crater-bowl (see Fig. 6, p. 90). The fissure there appeared to extended the whole length from near the upper rim of the crater wall downward to the base near the shore of the pool, but separated from the pool by a narrow ridge. This fissure was probably formed by the explosions early on Oct. 1,

but in which, on Oct. 22 were found only fumaroles emitting white vapors (see Fig. 26). The centre of the explosive activity of Oct. 23 was located within this fissure, near the shore of the pool.

The inside northeast wall (C_1 in Fig. 34) of the Yugama crater-bowl, half way down on which the explosion of Oct. 1 occurred and where, on Oct. 2 occurred a continuous emission of vapor-clouds (see Fig. 25), was not much altered by the explosion of Oct. 23, remaining as before an almost perpendicular rocky cliff with a talus conoid at its base.

No change, except accumulation of solid ejecta, was noticed inside the Midugama and the Karagama crater-bowls.[48]

Fissures: Outside of the Yugama crater-bowl on the southeast were two noticeable fissures as indicated by new lines of fumaroles—one (F in Fig. 34) near the crest of the southeastern rim of the crater-bowl and the other ($f_1, f_2 \ldots$ in Fig. 34) half-way down on that side of the cone. The former, running in the S. W.-N. E. direction, is more than 50 m. long, and about 15 m. in its widest part, and separated by a thin wall of less than 15 m. in thickness at any point from the inside of the Yugama crater-bowl. The inside walls of the fissure form nearly perpendicular cliffs, with precipices overhanging the abyss in places (Fig. 12). A wire measurement of the fissure showed it to be over 30 m. deep, with mud and water at the bottom, although the bottom could not directly be seen owing to the thick vapors issuing violently from the fissure. To the southwest the fissure shallows stepwise, ending in the cone surface; while it extends northeastward toward the upper margin of the southeastern rim of the Yugama crater-bowl and appears to continue to the fissure on the inside southeastern wall of that bowl, although their actual connection at the surface could not be seen. The south wall of the fissure is opened by another branch fissure which extends southeastward

Fig. 12.—Oct. 22, 1932. The fissure (F in Fig. 34) near the crest of the Yugama crater-bowl, looking northeast from its southwestern end. Photo Tsuya.

48) According to Kunitomi, there was a fumarole in the bottom of the Karagama crater-bowl on Oct. 29. 1932. *loc. cit.*

for a short distance and which seems to merge into the other lateral fissure.

The fissure half-way down on the southeast flank of the cone is more than 300 m. long, extending in a N. N. E.—S. S. W. direction with a zigzag course. It does not reach the surface at all points along its whole length, but, as indicated by a number of fumaroles, is represented at the surface by a long chain of minor clefts and hollows of various sizes. At the time of the first explosion on Oct. 1, vapor-clouds heavily charged with solid materials were violently projected from this fissure (Fig. 29), but later it gradually lessened in violence, until, on Oct. 22, vapor was seen only in a number of the fumaroles. The extraordinary length of the fissure was readily apparent, but only eye-measurements of its southern wing could be made owing to the presence of dense vapors which made it unsafe for the writer to trace the fissure further northward when he approached the seventh fumarole (f_7 in Fig. 34). The southern wing of the fissure consists of the following parts (see Fig. 34.):

f_1. A sigmoidal fissure, about 10 m. long, and a meter wide. Its bottom, except a place whence vapors were issuing, was about a meter deep. A fumarole within it was emitting white vapors charged with small rock-fragments, less than 3 cm. in diameter, from a cleft, about 10 cm. wide (Fig. 13). On the north, this fissure opens into an oval hollow, about 3 m. wide, 5 m. long, and 2 m. deep, which however had ceased to emit anything.

Fig. 13.—Oct. 22, 1932. The most southerly lying fumarole (f_1 in Fig. 34.), looking north. Photo Tsuya.

f_2. A lenticular opening, about 10 m. long, 4 m. wide, and more than 3 m. deep, surrounded by an almost perpendicular wall. Ash-laden vapors were issuing from the southern corner of its bottom. On the north of this opening was an oval hollow, about 3 m. long, 2 m. wide, and 2 m. deep, which however had ceased to emit anything.

f_3. A hunchback-shaped opening, about 3 m. wide, 10 m. long, and a meter deep. Vapors were issuing with ejection of rock-fragments of less than 5 cm. in diameter, from a round vent, about a meter in diameter, at the central part of its bottom

(Fig. 14). On the north of this opening was a lenticular one (f_4), about 10 m. long, 7 m. wide, and 2 m. deep, in which stood water in a small pool.

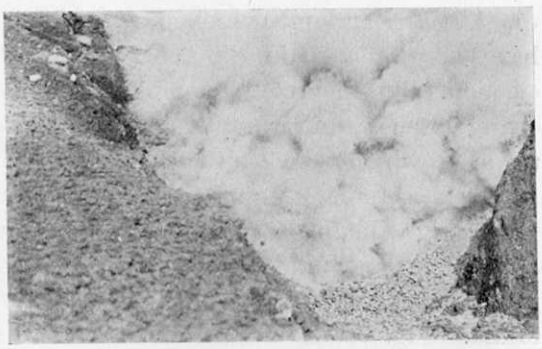

Fig. 14.—Oct. 22, 1932. f_3 fumarole looking north. Photo Tsuya.

f_5. A circular opening, about 10 m. across, and 6 m. deep. It is encircled by an almost perpendicular wall. Vapors were issuing from a circular vent, about a meter in diameter, at the northeast corner of its bottom (Fig. 15). A miniature mud-flow gushed out of this opening, extending southeastward for a distance of about 50 m.

f_6. An oval opening, 3 m. long, and 2 m. wide. Vapors were issuing from its unknown bottom.

f_7. A circular opening, about 5 m. across and a meter deep. Vapors were issuing from four holes at the centre of its bottom.

f_8. A circular dish-shaped hollow, about 2 m. across. Vapors were issuing from its bottom.

There were about six fumaroles north of the one last-mentioned. They were nearly in a line on the northern extension of the fissure represented by the above-mentioned seven openings (Fig. 32)

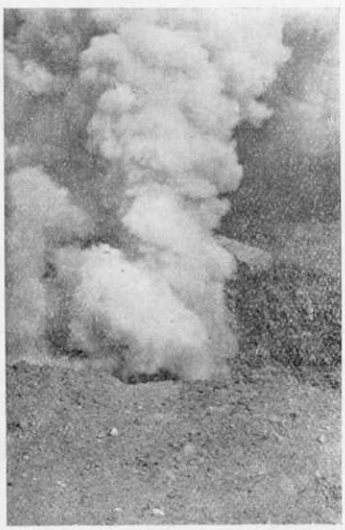

Fig. 15.—Oct. 22, 1932. f_5 fumarole looking east. Photo Tsuya.

Ejecta. *Solid ejecta.* Neither molten material nor incandescent blocks were thrown out by the recent explosions. The solid ejecta consist wholly of non-incandescent detritus, all coming under the title "accessory ejecta." They were projected from new explosion-craterlets within the Yugama crater-bowl as well as from the fissures on the outside, in many directions, not all of which ejecta, naturally, were the products of one and the same explosion. Since during the paroxysmal phases the centres of activity had shifted from place to place in and about

the Yugama crater-bowl, the products ejected from these centres must have accumulated in different areas, each according to the source of ejection. But they could not be distinguished the one from the other, owing to their uniform petrographic characters and to the thickness of the ashes which were emitted even during the relatively quiet period that followed each paroxysmal phase, and which under the influence of the prevailing wind had covered the greater part of the cone. Consequently any particular limit of distributions of solid ejecta, which might have furnished a clear picture of the explosion mechanism, was not to be found. Fig. 33 shows the distributions of the solid ejecta as observed on Oct. 22.

Stones from a few centimeter to more than 100 cm. in diameter were scattered in and around the Yugama crater-bowl, reaching an extreme distance of about 700 m. on the northwest and the southeast side of the cone. Their total quantity however may not be very large, as inferred from the density of the holes on the roofs of the cottages in the Yugama crater, which were riddled with the falling stones during the recent explosions.[49]

The large-sized ejecta are angular or subangular, but occasionally their corners are rounded off. They are generally dull gray, but often grayish white or yellow with a coating of salts. So far as microscopical observations go, they are olivine-two-pyroxene-andesite. Among the medium-sized ejecta, 10–5 cm. in diameter, were found quite a number of fragments of laminated ash-deposit, besides the olivine-two-pyroxene-andesite.

Volcanic ash and sand covered the country to the northeast side of the volcano, their deposits being the thickest in a zone running from the summit-crater northeast toward Yosigataira where it attained a thickness of about 3 cm. Toward the crater there is naturally an increase in the thickness of their deposits as well as in the size of the individual particles. Their accumulation upon the flanks of the cone, near the upper rim of the summit-crater, except the southwestern flank, attained a depth which in places was not less than a meter. They are light gray with a bluish tint, whereas in places where they are still damp with water condensed from the vapors with which they were ejected, they are dark gray. Petrographically they are nothing but finely divided

49) Kunitomi found on Oct. 29 that the cottages had been seriously damaged. It is probable therefore that not a few solid ejecta were projected to this direction by the explosions that followed the one of Oct. 23.

fragments of the old cone material.

On the southern flank of the cone were two small mud-flows one (Fig. 16) extending southeastward from fumarole f_5 in an area of about 5 m. in width and 50 m. in length, with a depth of about 20 cm., and the other, whose sourse could not be discovered, extending in a fan-shaped area to a distance of about 10 m. west of that fumarole. They are a mixture of rock-fragments of varying sizes, besides sulphur and other constituents of gaseous emanations. Their surface conformation is virtually that of a thin fluid, indicating that they must have possessed great fluidity through their large water content.

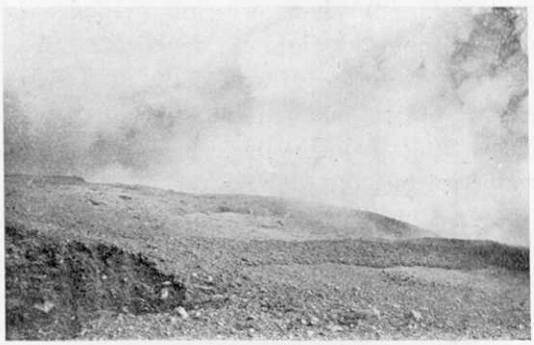

Fig. 16.—Oct. 22, 1932. A mud-flow on the southern flank of the mountain. Lower left, a portion of the f_5 fumarole. Photo Tsuya.

Fumaroles: All the fumaroles in and around the Yugama crater-bowl are of primary origin, having direct connection with explosive channels within the volcano, as inferred from the fact that they fluctuate in number, intensity, and location, according to the rise and fall in the activity of the main centres of the recent explosions.

The principal emanation from the fumaroles was steam, but some acid, among which sulphur dioxide and hydrogen sulphide were clearly detected, must have been present, as inferred from incrustations around the fumaroles. Qualitative analysis of the soluble matter from the volcanic ash showed fairly large amounts of Cl and SO_4 along with lesser amounts of Fe″, Ca, Al, Na, and Mg.

The temperature of a fumarole on the southern rim of the Yugama crater on Oct. 22, 1932, was as high as 98°C. (atm. temp. 11°C.).

Character of the Explosions of Oct., 1932.

The explosions of 1932 were of the same nature and of about the same intensity as previous explosions of the mountain, whose historic records provide us with a very clear picture of the character of the volcanic activities that have taken place on the mountain since 1882. They are just the type of volcanic activity that would be expected of a not very active,

long-dormant volcano, with characteristics as follows: (1) The solid materials ejected during the recent explosions were entirely old cone material. (2) There was no evidence of extremely high temperature on the mountain and in the ejecta. A new fumarole on the summit showed a temperature of 98°C.[51] (3) Steam was at all times the dominant gaseous emanation, both in the explosion clouds and in the outpourings from cracks, during as well as after the explosions. Mud-water gushed out during the explosions.

In short it may be said that the explosions of 1932 did not reach down to the zone of red heat, and that they were altogether of the so-called "steam-explosion," taking place near the earth's surface without the participation of fresh lava or more than insignificant quantities of the more active chemical constituents. The locations of the recent explosions are limited to a narrow zone which, passing through the inside northeastern wall of the Yugama crater-bowl, runs in a nearly N.-S. direction. The previous historic explosions of the volcano occurred for the most part in this zone. It is interesting to note in this connection that the arrangement of the craterlets on the main body—Moto-Sirané, and the general trend of volcanoes of this region is in this azimuth, all probably indicating structural weakness in this azimuth of the earth's crust of this region.

In the light of previous activities of this volcano during historic times, it may be said that the present activity of the volcano is not likely to be of long duration.

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7. 昭和 7 年 10 月草津白根山の爆發

地震研究所 津 屋 弘 達

昭和 7 年 10 月 1 日午後 2 時頃草津白根山が爆發し，2 名の卽死者と 7 名の負傷者とを生じた．この爆發を最初として同月中に數回の爆發があり，その一は筆者が同山頂に居た同月 23 日に起つた．

本文では筆者がこの數回の爆發に就いて 10 月 20 日より 25 日までに同地に於て調査し得た結果を主として報告し，尙同火山の地質及び記錄に殘つてゐる爆發の概略を述べた．

50) It is noteworthy that measurements have revealed scarcely any changes in the temperatures of the hot springs in the Manza spa nor in the old fumaroles in the Sessyôgawara.

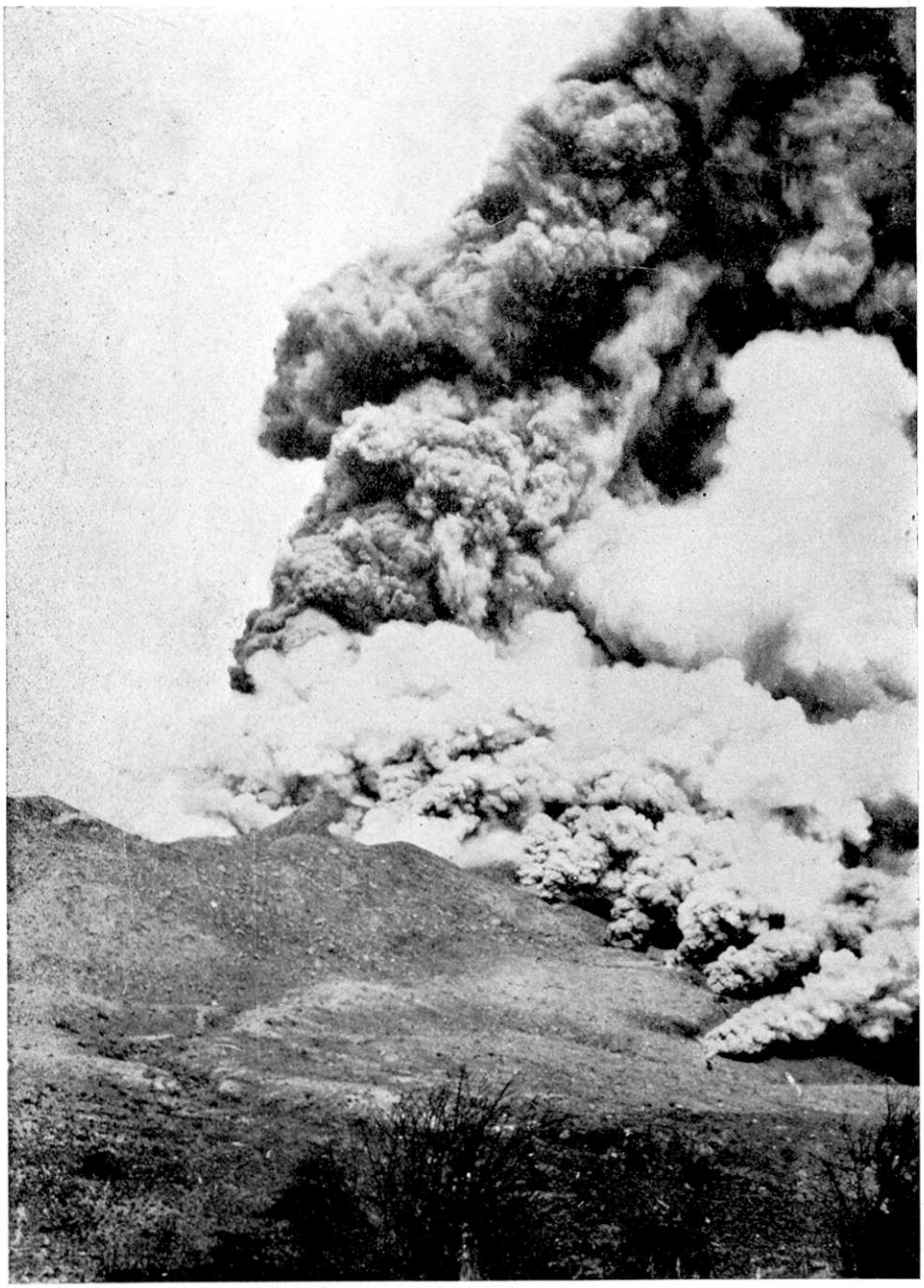


Fig. 17.—Oct. 23, 1932. The explosive culmination of Kusatu-Sirané at 11^h30^m a. m., taken near Yumiiké, 750 m. southwest by south of the summit crater (Yugama). Photo Tsuya.

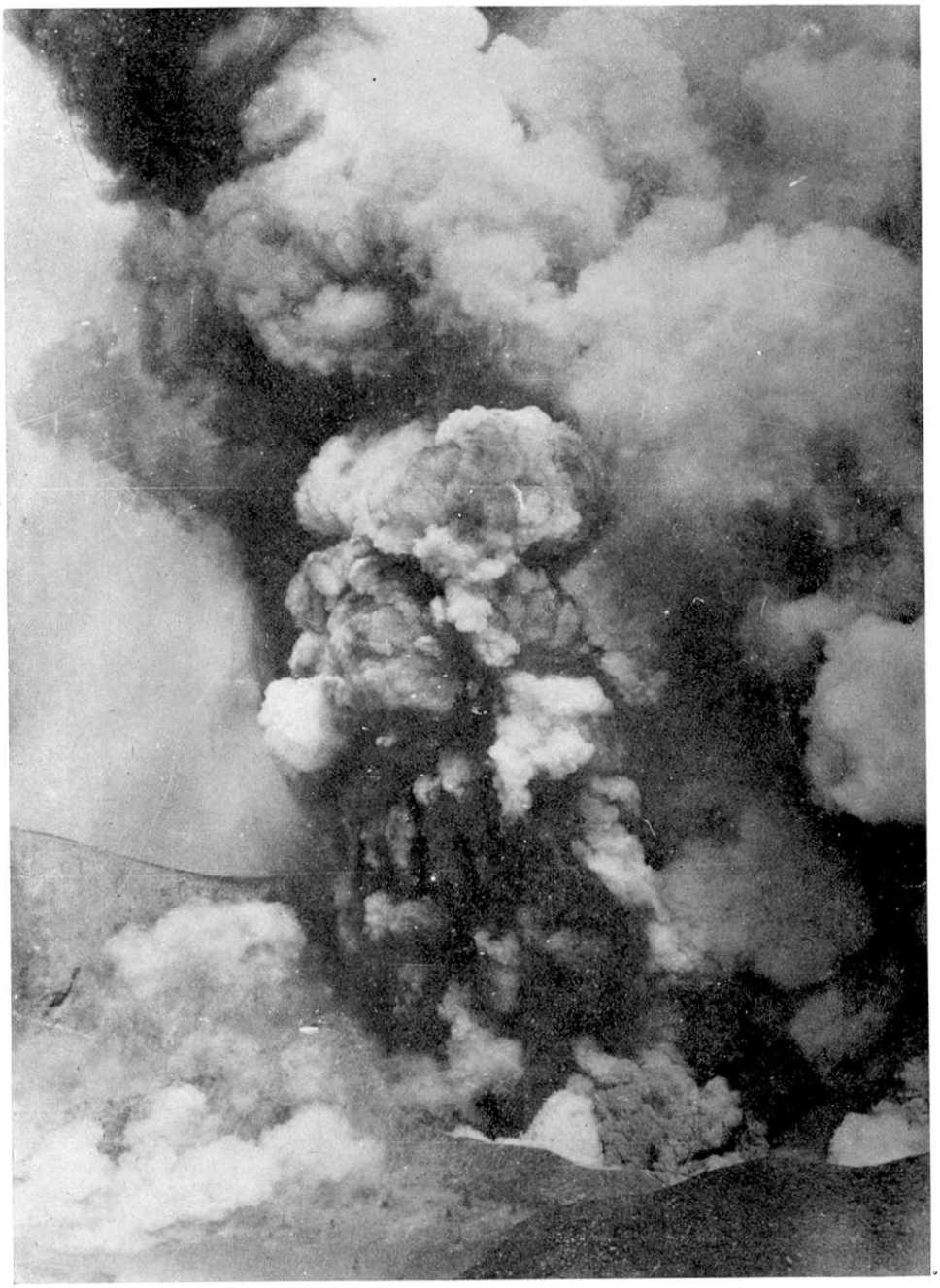


Fig. 18.—Oct. 23, 1932. An explosion of Kusatu-Siranê at 1^h30^m p. m. Looking northeast from the southwestern rim of the Yugama crater-bowl. Note the splashes (black spots above the pool, lower left in the figure) caused by falling stones. Photo Tsuya.

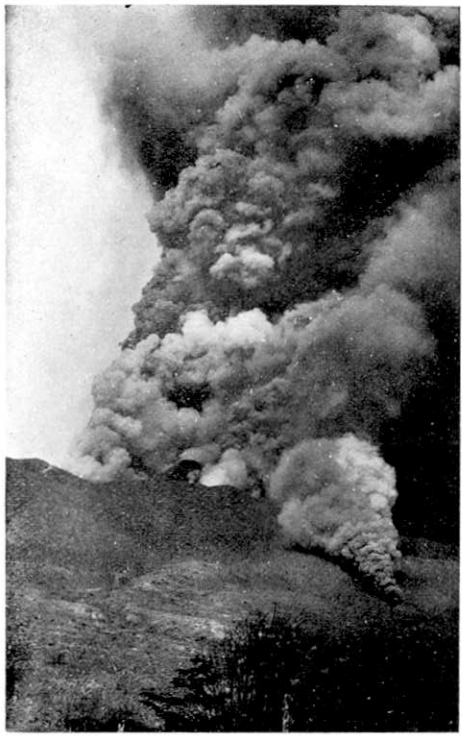
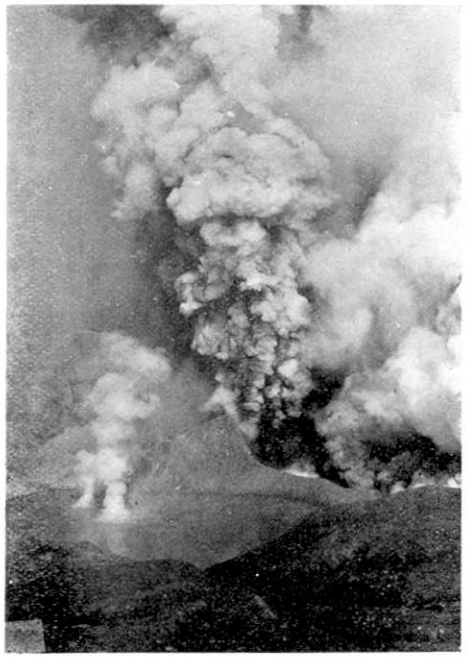


Fig. 19.—Oct. 23, 1932. Another view of the explosive culmination of Kusatu-Sirané at 11^h30^m a. m. (*cf.* Fig. 17).
Photo Tsuya.



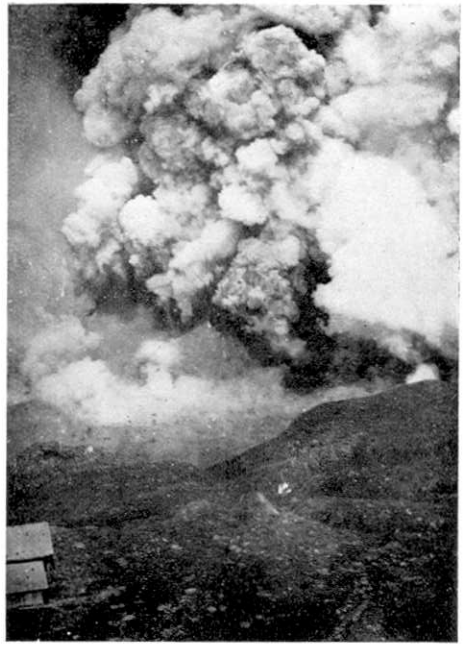


Fig. 20, and 21.—Oct. 23, 1932. Two different phases of the explosion of Kusatu-Sirané in the afternoon (*cf.* Fig. 18).
Photo Tsuya.

Fig. 22.—Oct. 1, 1932. The explosion of Kusatu-Siranê at 1^h50^m p. m., viewed from Kusatu. Photo Tomizawa.

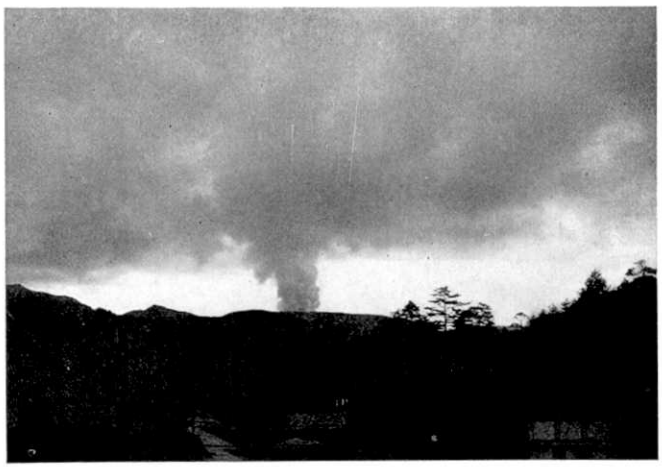


Fig. 23.—Oct. 4, 1932. The explosion of Kusatu-Siranê at 2^h p. m, viewed from Kusatu. Photo Tomizawa.

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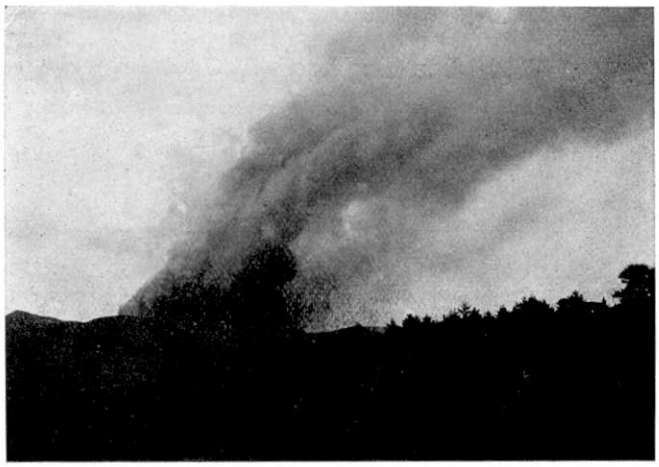

Fig. 24.—Oct. 23, 1932. The explosive culmination of Kusatu-Sirané at 11^h30^m a. m., viewed from Kusatu.
Photo Tomizawa.

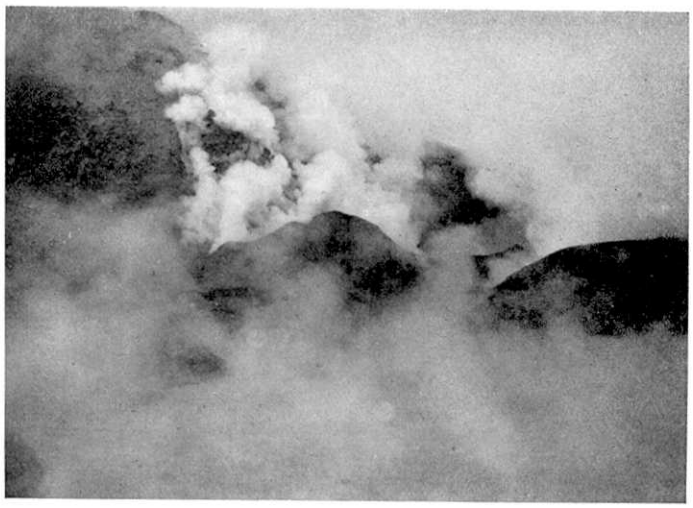

Fig. 25.—Oct. 2, 1932. View of the northeastern inside wall of the Yugama crater-bowl at the summit of Kusatu-Sirané, where the explosion on Oct. 1, 1932, occurred.
Photo Tomizawa.

Fig. 26.—Oct. 22, 1932. General view of the northeast inside wall of the Yugama crater-bowl at the summit of Kusatu-Siranê. Photo Tsuya.

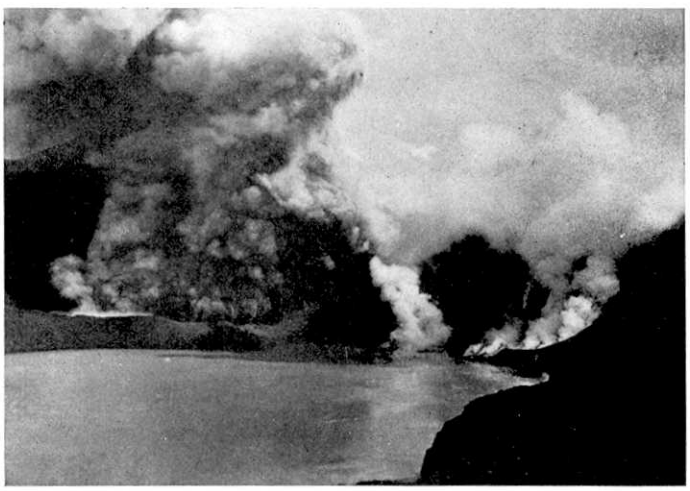

Fig. 27.—Oct. 24, 1932. View of the southeastern side of the Yugama crater-bowl, where the explosion on Oct. 23, 1932, occurred (right half of Fig. 26). Photo Tomizawa.

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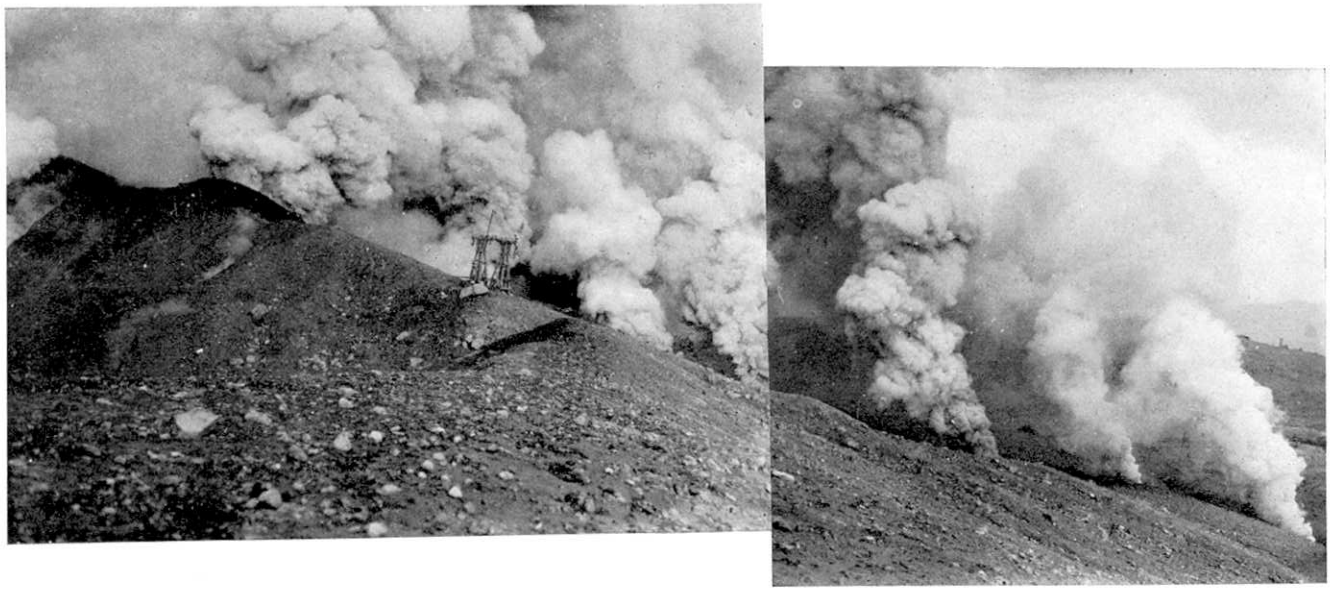


Fig. 28.—Oct. 22, 1932. A view of the southern flank near the summit of Kusatu-Siranê, showing a line of fumaroles on the fissure extending in N. N. E.-S. S. W. direction down the flank. Looking southeast from the southwestern rim of the Yugama crater-bowl. Photo Tsuya.

Fig. 29.—Oct. 2, 1932. View of the fissure extending in N N. E.-S. S. W. direction on the southern flank near the summit of Kusatu-Siranê after the explosion of Oct. 1, 1932. Photo Tomizawa.

Fig. 30.—Oct. 24, 1932. Ditto (*cf.* Fig. 19). Photo Tomizawa.

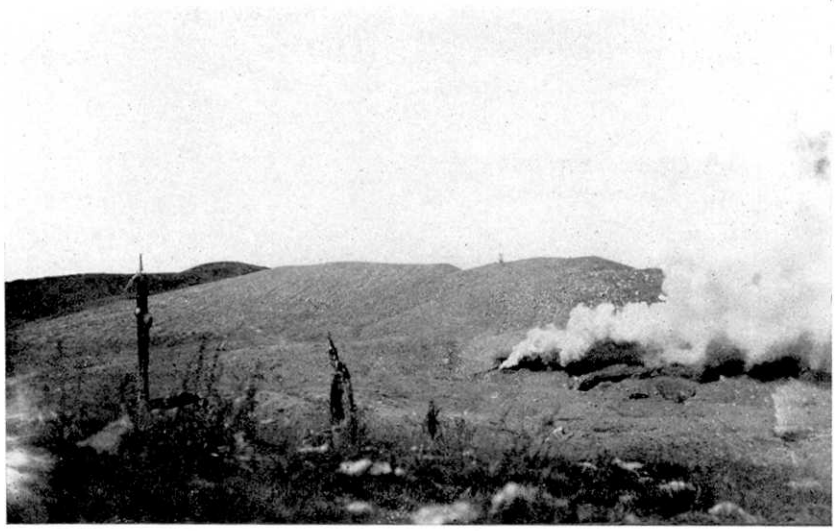


Fig. 31.—Oct. 24, 1932. View of the western half of the southern flank of Kusatu-Siranê proper after the explosion of Oct. 23, 1932. Photo Tsuya.

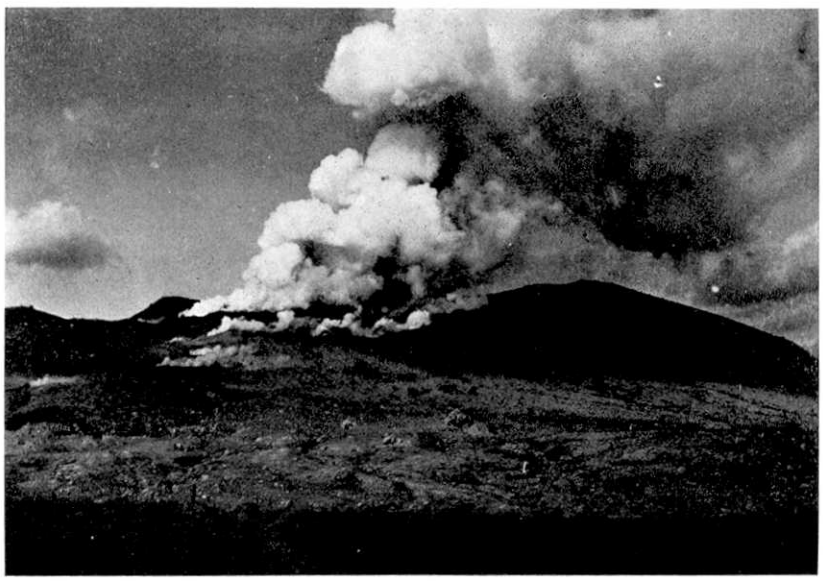
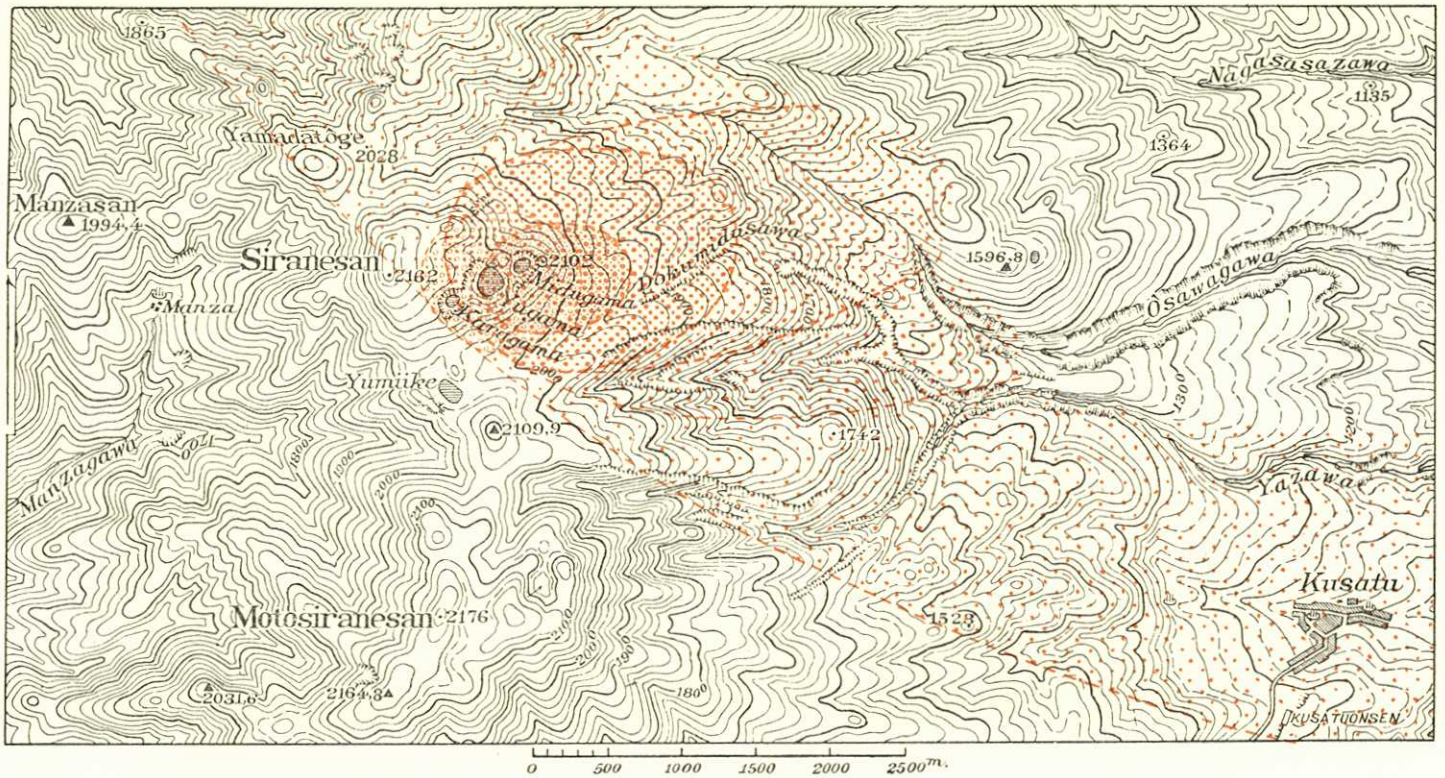
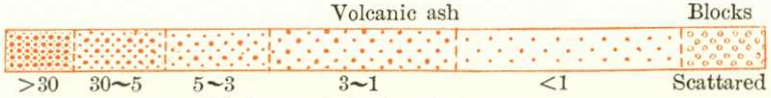


Fig. 32.—Oct. 24, 1932. View of the eastern half of the southern flank of Kusatu-Siranê proper after the explosion of Oct. 23, 1932.
Photo Tomizawa.





Fig, 33. Map of a portion of volcano Kusatu-Siranê showing distribution of the solid ejecta of Oct. 1-24, 1932.

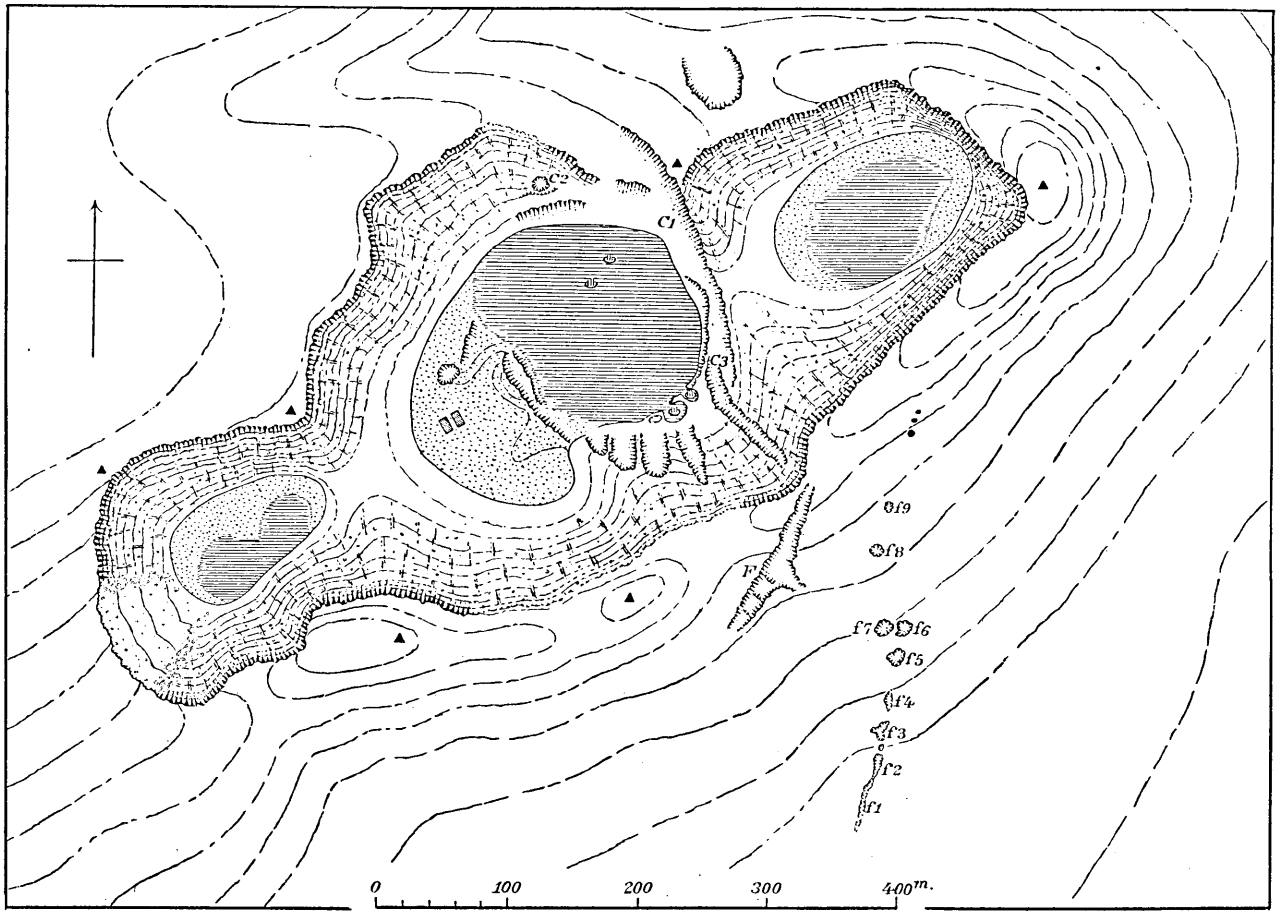


Fig. 34. Sketch map showing the state of the summit crater of volcano Kusatu-Siranê after the explosion of Oct. 23, 1923. See pp. 106~111.