36. *Explosive Activities of Volcano Kusatu-Sirane during 1938 and 1942.* (*Part II*)

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1. Introduction.

One of the writers[1] has already reported on the explosions that occurred during November 27, 1937, and January, February and March, 1938, in the Yugama (Y-crater), one of the three craters on the summit of Volcano Kusatu-Sirane. In that paper, volcanic phenomena displayed by the Y-crater until December, 1938, together with some results of the observations made in the neighbourhood of the Y-crater were described.

In this paper, the authors give a descriptive outline of the violent explosions[2] that occurred in the Y-crater in March, April, and May, 1939, to which are added observations of earthquakes, volcanic pulsations, tilts of the earth's surface, and topographical changes in the Y-crater; the explosions that occurred half-way up the central cone in February, 1942, are also described.

2. Volcanic Activities during March and April, 1939.

The Y-crater remained fairly calm after the small explosion of October 5, 1938, but in April and May, 1939, from 20 to 30 explosions, strong and weak, occurred, and large quantities of volcanic detritus and ash were ejected. The ash, which contained large quantities of sulphur, fell into the River Agatuma, 10 km south of Volcano Sirane, causing great damage to bank fisheries, irrigation work, and agriculture in its neighbourhood.

As in 1938, all the explosions occurred in the Y-crater. The dates and times of the explosions, and their magnitudes, according to the following scale, will be found in the annexed Table I.

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1) T. MINAKAMI, *Zisin*, **11** (1939), 207~228; *Bull. Earthq. Res. Inst.*, **17** (1939), 590~623.

2) T. KUBO, *Kensin-Zihô*, **11** (1940), 164~173.

Table I. Explosions that occurred during the period from March to August, 1939.

Dates		Times of Occurrence	Scale of Magnitude
March	24	11^h 40^m	III
March	30	details unknown	III
April	11	5 40	III
April	13	do unknown	II
April	18	do unknown	II
April	19	do unknown	III
April	24	12 20	III
April	28	do unknown	III
April	30	do unknown	III
May	3	do unknown	III
May	10	1 10	III
May	19	do unknown	III
August	28	18 00	II

Scale I of Magnitude of Explosion (about 10^{16} erg).

This explosion could be observed only in the neighbourhood of the crater; ash fell in the vicinity of Yosigataira and Nyûdôsawa, east of the Y-crater.

Scale II (about 10^{17} erg).

Most of the ejected detritus fell inside the Y-crater; a part of it fell into the Karagama (K-crater) and near the summit of the central cone, that is, inside and outside of the Y-crater wall. Ash fell in the region from the summit of the volcano to the vicinity of Kagusa Hot-spring and Sessyôgawara, east of the crater. To one listening with care, the explosion could be heard even in Kusatu, 6 km south-east of the crater.

Scale III (about 10^{18} erg).

Large quantities of volcanic detritus were ejected and scattered over an area from south-east to south-west of the Y-crater. They reached the great distance of 700～1000 m, consequently including the neighbourhood of the road from Kusatu Hot-spring to Manza Hot-spring through the foot of the central cone. Ash fell in Kusatu and as far as Naganohara.

Since the larger part of these observations was made at Kusatu, little is known of small explosions corresponding to Scale I, but it is supposed that they occurred about 30～40 times, and that some explosions of Scale II are not recorded.

Of these explosions, those of April 18 and 24 were the most

violent, and the quantity of ejecta most abundant, particularly so in the explosion of April 24, which occurred at about noon, when owing to the abundant ash flying over and falling into Kusatu, the streets became dark and lamps had to be lit for about an hour.

3. Topographic Changes in the Y-crater.

All the explosions of 1937, 1938, and 1939 occurred from the fissure, extending in a nearly straight line from the south-eastern to the north-western side of the Y-crater. Most of the explosions during March and May, 1939, occurred in that area from the north-western end of the fissure to the centre of the Y-crater.

After the explosion of October 5, 1938, the maximum depth of the explosion craters on the line of fissure was about 25 m, but the occurrence of many explosions during March and May, 1939, enlarged this explosion crater, and it became deepest on May, 1939, for example, 120 m at the south-eastern part of the crater. Soon after that, the volcano became calm, and immediately following the cessation of the explosions, ejecta accumulated in the neighbourhood of the new explosion crater, and soaked and accumulated with the rain and melted snow in the explosion crater, gradually filled the crater—a state of things that has continued to the present time (June, 1942). Although the eruptions from this explosion crater ceased toward the end of May, 1939, and the intensity with which steam, containing sulphur dioxide,

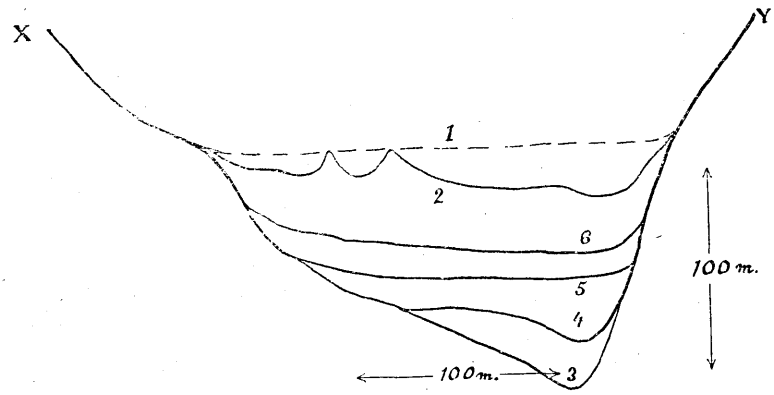

Fig. 1. Profile of the Y-crater. Changes in the bottom of the explosion crater.

1. November, 1937.
2. April, 1938.
3. April, 1939.
4. October, 1939.
5. October, 1940.
6. June, 1942.

was ejected from several places in the explosion crater, was violent throughout the whole of 1939. This steam sometimes held a small quantity of ash. With the passage of 1940 and 1941, the explosion craters became filled with soil, ash, and volcanic detritus and became shallow, with the result that the fumaroles at depths in this crater became filled with these ejecta, the quantity of smoke decreased by degrees, and volcanic activity calmed down, apparently, at any rate. At the end of 1941, the volcano was throwing out only a very small quantity of water vapour. This is the development of the activity of the Y-crater during the last three years, from 1939 to the explosion of February, 1942. The topographic changes in the Y-crater are shown by a profile of it in the direction of the fissure, in which last a number of explosion craters opened. Fig. 1 shows the progress in their activity, and the state of the crater as altered by soaked and accumulated volcanic ash and sand. The topographic changes in this crater are shown in plan, in Fig. 2, and also by photographs, Figs. 13~18.

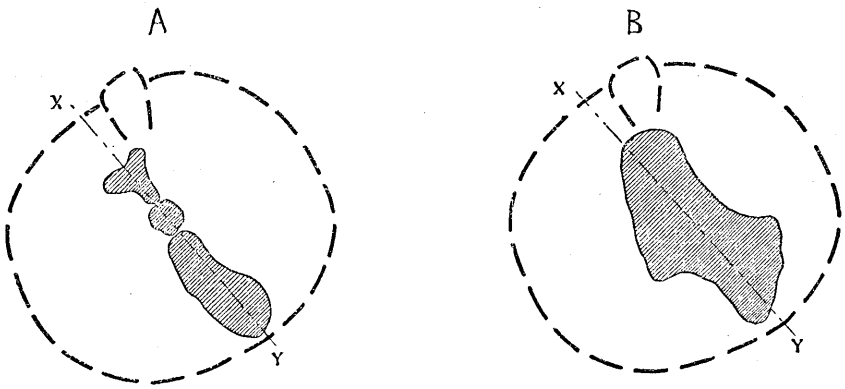

Fig. 2. Topographical changes in the Y-crater.
A; October, 1938. B; May, 1939.
▨; explosion crater.

The main damage from this activity was, as already mentioned, the wide distribution of the volcanic ash in a south-eastern direction from the volcano, which flowed out mingled with rain water to the River Agatuma, causing damage to bank fishery and agriculture. On the other hand, the falling rocks did much damage to the cottage situated south-west of the Y-crater, where the seismograph was installed and observations had been continued since May, 1938. Unfortunately, the volcanic detritus penetrated the roof of this cottage and fell on the seismograph, damaging a part of the instrument.

The volcanic detritus, as above mentioned, were sent far, mostly on the southern side of the Y-crater, the farthest distance being 1000 m from the position of the explosion. They fell near Yumi-ike and the

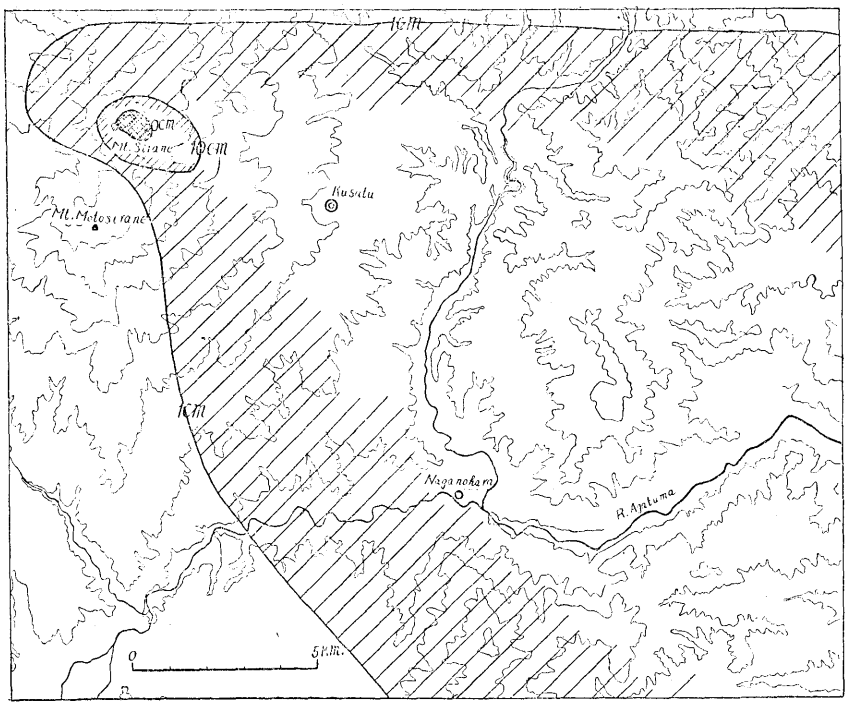

Fig. 3. Area of ash fall. (May, 1939.)

Penetralia of Sirane Shrine. At the same time, the ash fell in a south-eastern direction, where the thickness of the accumulation at distances of 0·5 km, 1·0 km, and 2·0 km amounted respectively to 150 cm, 80 cm, and 20 cm. (see Figs. 3, 4). For example, at Kusatu, 6 km south-east of the crater, the ash was about 5 cm thick. The total mass of these ejecta amounted to about 5×10^5 tons. An accumulation of volcanic ash on a bridge about 500 m south of the Y-crater is shown in Fig. 19.

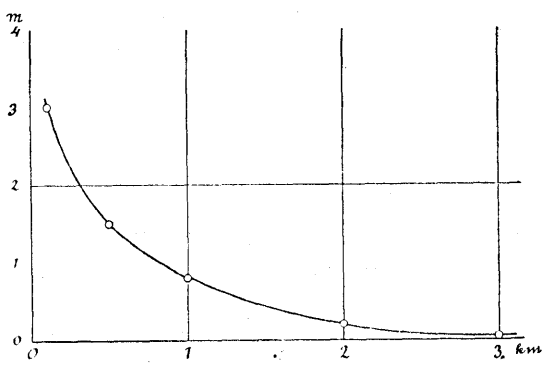

Fig. 4. The thickness of the accumulated volcanic ash in the central direction of fall area and their distances from the crater.

4. Results of Instrumental Observations.

A seismograph and a pair of clinographs were installed in May, 1938, and used until April, 1939. Measurements of the earth-current, the water-level, and geothermal temperature were made during 1938 and 1939. Of these various observations, the measurements of the earth-currents and the geothermal temperature have already been reported in a previous paper. This paper deals with the results of observation of changes in inclination of the earth's surface, and volcanic pulsations.

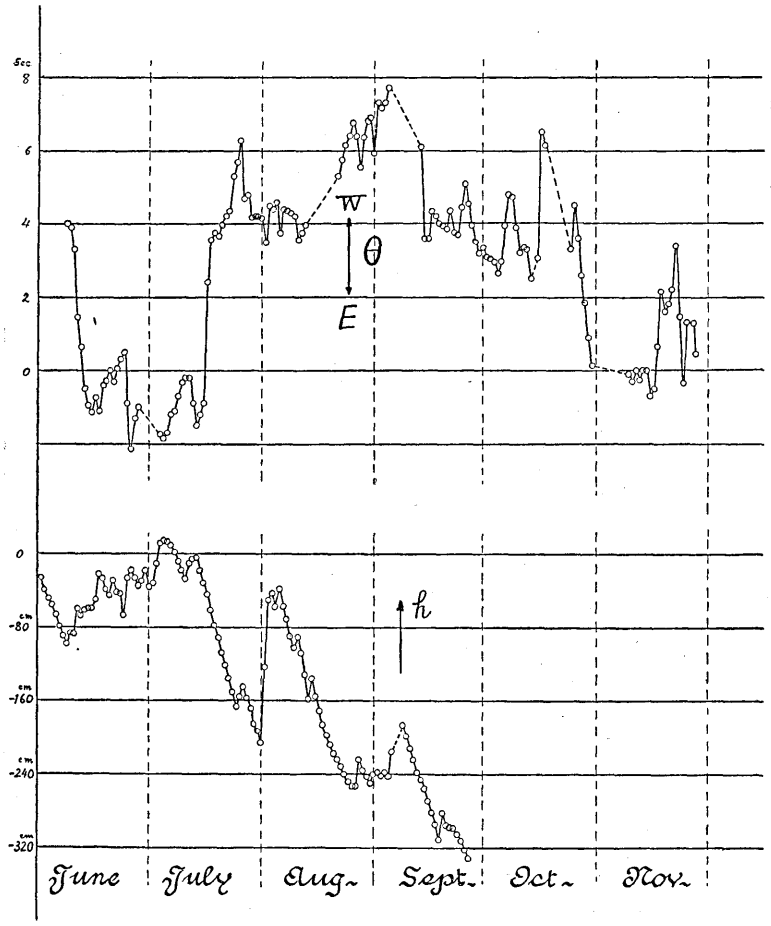

Fig. 5. Tilt-changes (θ) and the water-level (h) in the Y-crater in 1938.

For observing the tilts of the earth's surface, a pair of silica clinographs was installed in the underground room, which was made

by boring through the crater wall of Karagama, south-west of the Y-crater. Since this observation room was only 200m south-west of the active explosion crater, owing to unfavorable conditions, observations could be continued for only six months; the N-S component of this instrument was injured soon after observations were begun, for which reason, only tilts of the E-W component were observed. Fig. 5 gives the result of observations of the E-W component of the tilts, in which are also shown the changes in water-level of the pond in the Y-crater.

It will be seen from these two curves that as the water-level of the Y-crater increases, the ground, on which the clinograph was installed, tilts in the direction of the Y-crater—a change probably due to sinking, owing to the water load in the Y-crater.

In order to verify this supposition, we let h_n and θ_n be the daily readings of the water level and tilt and took the difference of their mean values $[(h_0), (\theta_0)]$. Fig. 6 shows the relation between them, namely,

$$\Delta\theta = \theta_n - \theta_0$$

$$\Delta h = h_n - h_0,$$

where

$\Delta\theta$ = change in inclination of the ground,

Δh = change in water-level.

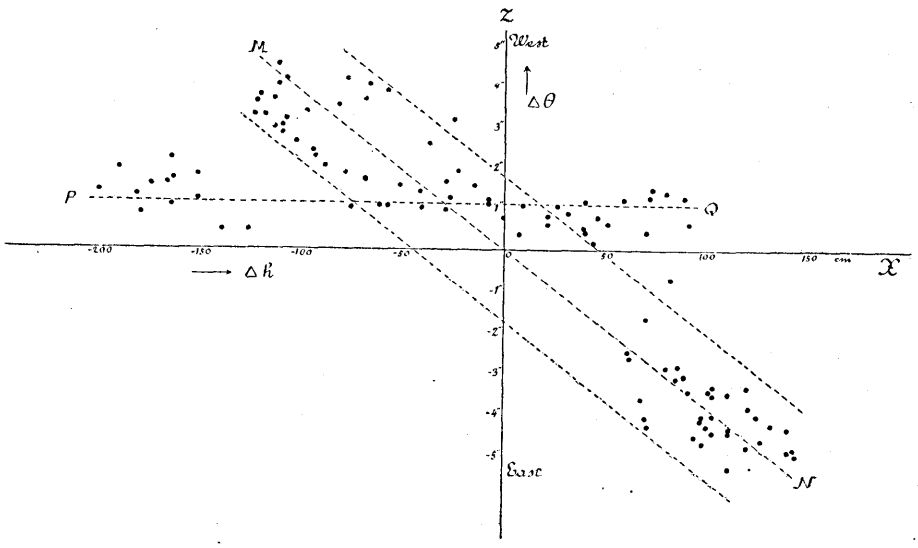

Fig. 6. Relation between changes in the tilt and the water-level in the Y-crater.

As shown in Fig. 6, there are two properties in the variation of inclination of the ground, the one, in which the earth's surface shows a tilt in the direction of the Y-crater nearly proportionally to the increase in water-level of the Y-crater, the other, in which the earth's surface tilts independently of the water-level. The latter shows that the earth's surface tilts about 1″ of arc in the direction of the western side, regardless of the water-level changes. Investigating this relation with respect to time, most of the tilt-changes during July and August are represented by the straight line MN in Fig. 6, and most of those during September and October by the straight line PQ. It is supposed that the tilt change may show change in weight, which is due to the change in water-level of the Y-crater and to the subterranean character of the neighbourhood. As the result of this the tilt-changes that are related to the activity of the Y-crater are not obvious, the reason for which is that there was no violent volcanic activity during the period of our observations.

The seismograph was installed at the foot of the central cone, about 500 m south-west of the Y-crater, and observation made with it during the period from May, 1938, until April, 1939. It is to be regretted that we could not observe for about thirty days owing to interferences by electric transmission wires. We were, however, able to observe the volcanic pulsations that accompanied the most violent eruptions of the Y-crater during the period from January to April, 1939. These laborious observations were executed mostly by Mr. A. Utizima.

The seismograph used in the observation had a magnification of 350 and the period of 1·0 second.

In a previous paper we reported that on May 30, 1938, a number of small earthquakes, with their origins in the volcano, had occurred in a swarm, since when hardly any earthquake has occurred here. On the other hand, volcanic pulsations occurred almost always during that period, although these seismic activities were not constant in their occurrence. In order to indicate these pulsation activities, a scale for the purpose was made by integrating the total amplitude of the pulsation $A(t)$ with respect to time. These integrations, namely,

$$K=\int_{t=0\,\mathrm{h}}^{24\,\mathrm{h}} A(t)\,dt$$

were done for every day.

Reviewing these seismograms, two kinds of pulsations were found,

the one with a period shorter than 0·3 sec. and the other with one longer than 0·3 sec. Representative types are shown in Figs. 29, 30. The former is now called the S_1 type and the latter the S_2 type, the values of K, which are for both types, are separately shown in Fig. 7 and Table II. Comparing S_1 and S_2, the pulsations of S_1 type were

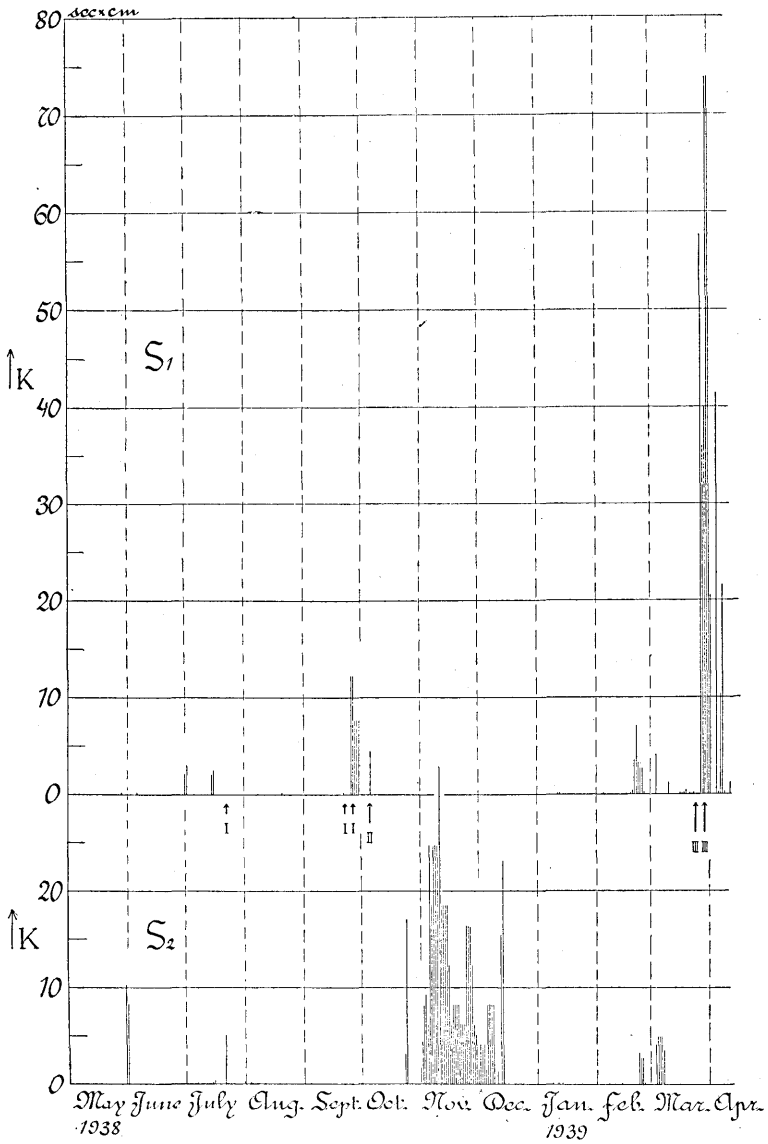

Fig. 7. Variation in volcanic pulsations S_1, S_2, and the occurrence of explosions.
↑ ; date and magnitude scale of explosion.

Table II. Volcanic Pulsations during May, 1938, and April,1939.

Date		$K(S_1)$	$K(S_2)$	Date		$K(S_1)$	$K(S_2)$
		cm×sec	cm×sec			cm×sec	cm×sec
May	12	0	0	June	19	0	0
	13	0	0		20	0	0
	14	0	0		21	0	0
	15	missed			22	0	0
	16	missed			23	0	0
	17	missed			24	0	0
	18	missed			25	0	0
	19	0	0		26	0	0
	20	0	0		27	0	0
	21	0	0		28	missed	
	22	0	0		29	missed	
	23	0	0		30	2·06	0
	24	0	0	July	1	3·09	0
	25	0	0		2	0	0
	26	0	0		3	0	0
	27	0	0		4	0	0
	28	0·01	0		5	0	0
	29	0	0		6	0	0·04
	30	0	10·28		7	0	0
	31	0	9·26		8	0	0
June	1	0	0		9	0	0
	2	0	0		10	0	0
	3	0	0		11	0	0
	4	0	0		12	0	0
	5	0·01	0		13	0	0
	6	0	0		14	2·06	0·01
	7	0	0		15	2·57	0·13
	8	0	0		16	0	0
	9	0	0		17	0	0
	10	0	0		18	0	0
	11	0	0		19	0	0
	12	0	0		20	0	0
	13	0	0		21	0	5·14
	14	0	0		22	0	0
	15	0	0		23	0	0
	16	0	0		24	0	0
	17	0	0		25	0	0
	18	0	0		26	0	0

(to be continued.)

Table II. (*continued*).

Date		$K(S_1)$	$K(S_2)$	Date		$K(S_1)$	$K(S_2)$
		cm×sec	cm×sec			cm×sec	cm×sec
July	27	0	0	Sept.	4	missed	
	28	0	0		5	missed	
	29	0	0		6	missed	
	30	0	0		7	missed	
	31	0	0		8	missed	
Aug.	1	0	0		9	missed	
	2	missed			10	0	0
	3	0	0·02		11	0	0
	4	0	0		12	0	0
	5	0	0		13	missed	
	6	0	0		14	0	0
	7	0	0		15	0	0
	8	0	0		16	0	0
	9	0	0		17	0	0
	10	0	0		18	0	0
	11	0	0		19	0	0
	12	0	0		20	0	0
	13	0	0		21	0·005	0
	14	0	0		22	0	0
	15	0·002	0		23	0	0
	16	0	0		24	0	0
	17	0	0		25	12·34	0
	18	0	0		26	12·34	0
	19	0	0		27	7·71	0
	20	0	0		28	7·71	0
	21	0	0		29	7·71	0
	22	0	0		30	0	0
	23	0	0	Oct.	1	0	0
	24	0	0		2	0	0
	25	0	0		3	0	0
	26	0	0		4	0	0
	27	0	0		5	4·57	0
	28	0	0		6	0	0
	29	0	0		7	missed	
	30	0	0		8	missed	
	31	0	0		9	0	0
Sept.	1	missed			10	0	0
	2	missed			11	0	0
	3	missed			12	0	0

(*to be continued.*)

Table II. (*continued*).

Date		$K(S_1)$	$K(S_2)$	Date		$K(S_1)$	$K(S_2)$
		cm×sec	cm×sec			cm×sec	cm×sec
Oct.	13	0	0	Nov.	21	0	6·17
	14	0	0		22	0	6·17
	15	0	0		23	0	6·17
	16	0	0		24	0	16·46
	17	0	0		25	0	12·34
	18	0	0		26	0	6·17
	19	0	0		27	0	5·14
	20	0	0		28	0	1·54
	21	0	0		29	0	4·11
	22	0	0		30	0	3·77
	23	0	3·09	Dec.	1	0	4·11
	24	0	17·40		2	0	1·54
	25	0	0		3	0	8·23
	26	0	0·02		4	0	8·23
	27	0	0		5	0	8·23
	28	0	0		6	0	8·23
	29	0	0		7	0	0
	30	0	0		8	0	1·29
	31	0	1·77		9	missed	
Nov.	1	0	4·36		10	0	15·43
	2	0	8·10		11	0	23·14
	3	0	9·26		12	0	0
	4	0	6·17		13	0	0
	5	0	24·69		14	0	0
	6	0	18·51		15	0	0
	7	0	24·69		16	0	0
	8	0	24·69		17	0	0
	9	0	24·69		18	0	0
	10	0	32·91		19	missed	
	11	0	18·51		20	missed	
	12	0	18·51		21	missed	
	13	0	18·51		22	missed	
	14	0	18·51		23	missed	
	15	0	12·34		24	0	0
	16	0	6·17		25	0	0
	17	0	8·23		26	0	0
	18	0	8·23		27	0	0
	19	0	8·23		28	0	0
	20	0	8·23		29	0	0

(*to be continued.*)

Table II. (*continued*).

Date		$K(S_1)$	$K(S_2)$	Date		$K(S_1)$	$K(S_2)$
		cm×sec	cm×sec			cm×sec	cm×sec
Dec.	30	missed		Feb.	7	0	0
	31	missed			8	0	0
Jan.	1	0	0		9	0	0
	2	0	0		10	0	0
	3	0	0		11	0	0
	4	0	0		12	0	0
	5	0	0		13	0	0·09
	6	0	0		14	0	0
	7	0	0		15	0	0
	8	0	0·16		16	0·05	0
	9	0	0		17	0	0
	10	0	0		18	0·05	0
	11	0·03	0		19	0·33	0
	12	0·06	0		20	3·53	0
	13	0	0·02		21	7·41	0
	14	0	0		22	3·70	3·70
	15	0	0		23	2·64	2·64
	16	0	0		24	2·64	2·64
	17	0	0		25	0·26	0·26
	18	0	0		26	0	0
	19	0	0		27	0	0
	20	missed			28	0	0
	21	missed		March	1	0	0
	22	missed			2	0	0
	23	missed			3	4·11	4·11
	24	missed			4	0	4·94
	25	0	0		5	0	4·94
	26	0	0		6	0	4·94
	27	0	0		7	0	3·53
	28	missed			8	0	0
	29	missed			9	0	0
	30	missed			10	1·23	0
	31	missed			11	0	0
Feb.	1	missed			12	0	0
	2	0	0		13	0	0
	3	0	0		14	0	0
	4	0·003	0		15	missed	
	5	0	0		16	0·10	0
	6	0	0		17	0·13	0

(*to be continued.*)

Table II. (*continued*).

Date	$K(S_1)$	$K(S_2)$	Date	$K(S_1)$	$K(S_2)$
	cm×sec	cm×sec		cm×sec	cm×sec
March 18	0·10	0	March 31	74·06	0
19	0·27	0	April 1	20·57	0
20	0	0	2	missed	
21	0·08	0	3	missed	
22	0	0	4	41·42	0
23	0·03	0	5	0·19	0
24	0	0	6	10·29	0
25	0	0	7	21·60	0
26	0	0	8	0·26	0
27	57·60	0	9	0	0
28	36·00	0	10	0	0
29	40·11	0	11	1·03	0
30	74·06	0			

accompanied by the violent explosions in the Y-crater of March and April, 1939, and the small explosions of June and October, 1938. The pulsations of S_2 type, however, did not appear when the explosion occurred in the Y-crater, but did so when things were comparatively calm there. Pulsations of S_1 type caused by the explosion in the Y-crater, seem to be the same kind as those that were accompanied by explosions of Strombolian type in the Ôsima island[3] and the Miyake-sima island.[4] In the present explosions of Volcano Kusatu-Sirane, no ejection of juvenile lava could be seen, although in the character of eruption, these explosions resembled the Strombolian type. That is, the many explosions continued for from 5 to 6 hours to from 20 to 30 minutes, during which time intervals volcanic pulsations of S_1 type occurred, their amplitudes being proportional to the intensities of explosion. In addition, it may be pointed out that pulsations of S_2 type have smaller amplitudes than those of S_1 type, while underground activities very near the earth's surface may accompany pulsations of S_2 type, although the mechanism of their occurrence is not yet known.

On the other hand, for about three months from June 5, 1942, seismic observations were made at the same place with a seismograph of 150 magnification and of 1·0 sec. period, but neither volcanic earthquake nor pulsations were observed in that interval. From the fact

3) M. TAKEHANA, *Kensin-Zihô*, **11** (1940), 321~324.
4) T. MINAKAMI, *Bull. Earthq. Res. Inst*, **19** (1941), 331~334.

that a large quantity of water vapour in the period of seismic observation was being ejected from a number of new explosion craters, it is supposed that no disturbance so serious as to cause pulsations occurred.

5. Explosion of February, 1942.

As just mentioned, after the activity of March, 1939, the amount of vapour gases emitted from the Y-crater gradually decreased, and the velocity of their emission also diminished. Investigations made on April, 1941, showed many fumaroles at depths of the explosion crater, buried underneath ash and sand, and that the volume of the smoke was small. Before the explosion of February, 1942, the volume of smoke had been decreasing.

The localities of the present explosion craters differ from the previous ones, the Y-crater being quiet. A large number of new explosion craters opened on the southern central cone of the Y-crater and Mizugama (M-crater) and on the northern foot of the central cone the groups of small craters appearing like fissures. Since this was in winter, the volcanic phenomena at the time of the explosion were not clear. According to the directer of the Kusatu Forestry Station, a member of the Taiyo Industrial Company and the manager of the Tokiwaya Hotel, Manza Hot-springs, a great number of explosion craters suddenly formed at 19 o'clock, February 2, 1942, when at the same time, water vapour arose. This vapour was seen and the rumbling heard as far as Kusatu. At the mining cottage of Sessyôgawara, also, rumbling was heard and ash fell, whereas at the Manza Hot-spring, nothing occurred, and neither was the explosion seen. Although a hotel porter of the Manza Hot-springs passed almost daily the spot where the present explosion occurred,no changes were seen even several hours before the occurrence of the explosion.

Of the numerous explosion craters, a group of new craters (III) on a fissure on the north western side of the Y-crater very early became inactive (Fig. 8, 9). But in the middle of March a number of the explosion craters on the fissures, extending to the southern side of the Y-crater, markedly diminished their vapour emissions, since when the quantity of smoke from the other craters in the south-eastern side gradually diminished. In early June, not even a small quantity of water vapour was emitted from the 3 or 4 craters on the south-western side. The other explosion craters on the fissures are on the south-eastern side of the Y-crater (I), on the southern side of the M-crater (II) and, two small craters at the northern and north-

eastern corners of the M-crater. At this time (early June) they were violently emitting large quantities of water vapour and sulphurous acid gas.

Figs. 28~30 show steam issuing from the groups of craters on southern side of the Y-crater and from those on the northern part of the M-crater. As to the activity of the Y-crater, nothing specially interesting was noticed during the occurrence of these fissure eruptions, things being very calm.

6. Topographical Survey of the Newly Formed Explosion Craters.

In order to determine the positions and the forms of these new explosion craters, a topographical survey was made during the four days following June 6, 1942. First, twenty five base points for topographical survey were fixed with a Wild theodolite. Taking these points as standard, the forms and positions of the craters were determined on a plane-table, Fig. 8 being a map thus drawn. As will be seen from this figure, a number of small craters lie on straight lines, the lengths of all the craters being mostly in the direction of alignment of the craters. Judging from the arrangement of these craters and their forms, there are supposed to be several fissures on which the present explosion craters are arranged. The longest one of these craters, that in the group (I) on the southern side of the Y-crater, is 150 m long, 50 m wide, and 10 m deep. The volcanic detritus are scattered within 50 m of the peripheries of these explosion craters. Judging from the distribution of the detritus and the form of the crater, the intensity of the explosion on the southern side of the Y-crater is supposed to have been stronger than that on the northern side half-way up the central cone.

The three craters at the south-western end of the southern group (I) of the craters, which had already ceased to emit vapours, in May, 1942, were filled with green hot water, the sulphur being precipitated. Of these hot-springs, one on the southern side had a temperature of 97°~93°C on June 6, 1942, whereas on the northern side, the temperature of the hot springs and the issuing gas had already become fairly low.

A very remarkable condition noticed was that, although the M-crater was filled with cold water before its activity, this water dried up completely as the result of the present activity. In June, 1942, vapour issued violently from the two small fumaroles on the northern

wall of this crater, the subterranean temperature in it being very high. Infering from these two facts, the water in the crater seems to have evaporated owing to elevation of the subterranean temperature.

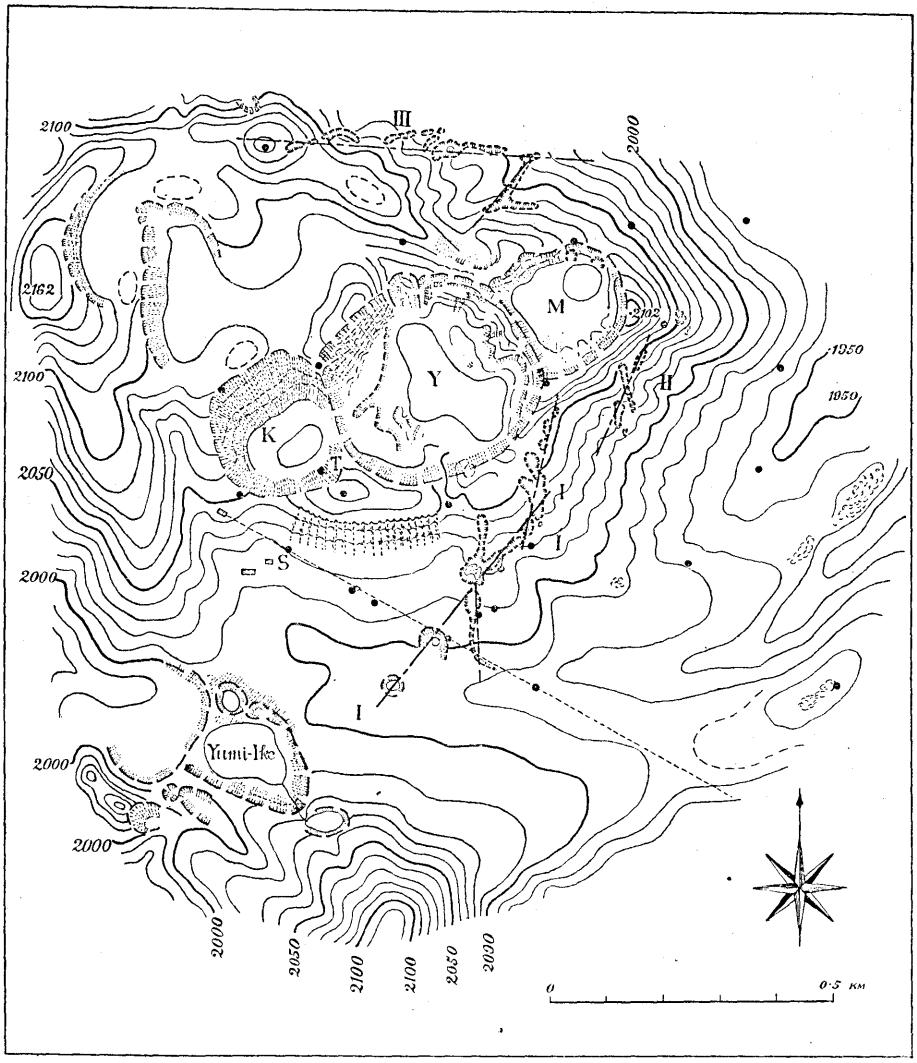

Fig. 8. Topographical map of area near the summit of Volcano Kusatu-Sirane.
M=Mizugama, Y=Yugama, K=Karagama,
S=Seismograph station, T=Clinograph station.
• =Base point for topographical survey.

The intensity of the present activity is very much less than in the previous one, although the area covered by the new explosion craters is very wide, and the craters formed at the time, amount to

very large number. From the recent history of the activity of Volcano Kusatu-Sirane, there were previously no explosion craters on the northern side of the Y-crater and in the M-crater —— the most remarkable phenomenon in connexion with the present activity.

In short, in the activity of 1939, many craters and orifices for the escape of gases were formed. These fumeroles were closed up with volcanic ash, detritus etc, ejected by the explosions of 1939, with the result that it prevented the escape of the water vapour.

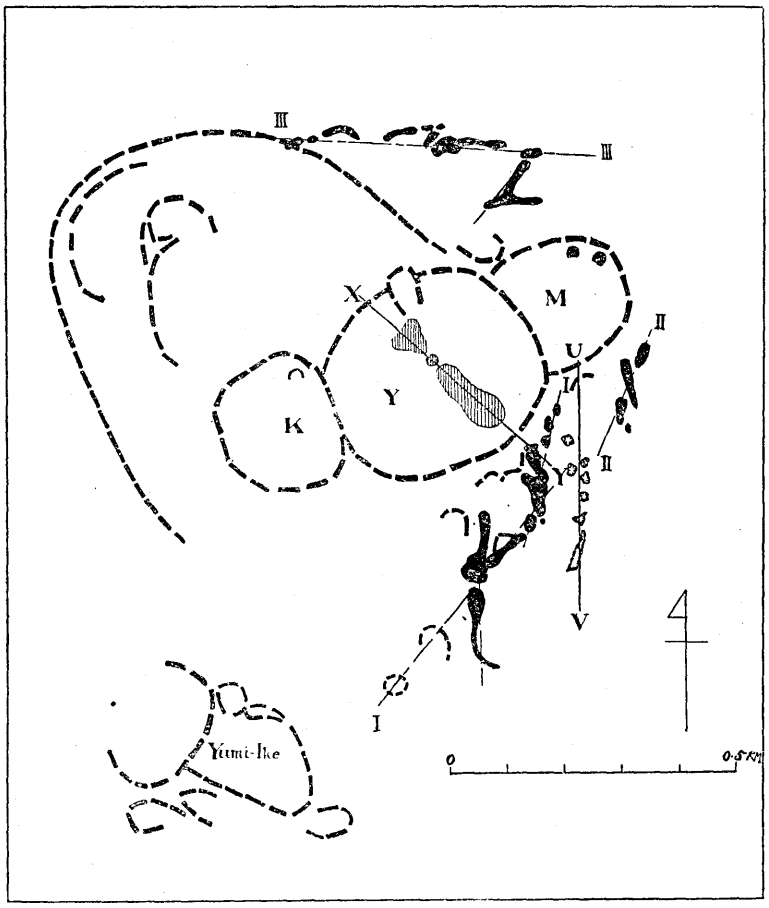

Fig. 9. Topographical map of area near the summit of Volcano Kusatu-Sirane.

U–V; fissure opened in 1932.
X–Y; fissure opened in 1937~1938.
I, II, III; fissures opened in 1942.
explosion crater opened in 1932.
explosion crater opened in 1937~1938.
explosion crater opened in 1942.

In the present activity, these pent up gases found their way into the fissures half-way up the cones of the Y-, K-, and M-craters. From the history of the recent activities of Volcano Sirane, activities lasting one or three months occurred every 3~5 years, for example, those of 1927, 1932, 1937, 1939, and 1942. The situations of the recent explosion craters are shown in Fig. 9. These cycles of activities may be explained by the fact that through various causes of nature, although the orifice for the escape of gases fill up with soil and ash during 3~5 years, fumaroles and new craters are formed by new explosions. This phenomenon seems, at any rate, to be one of the causes of the cycles of activities. Fig. 10 is a presumed profile of the Y-crater in order to illustrate the cycles of activities.

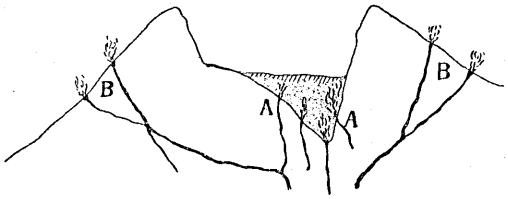

Fig. 10. Presumed profile of the neighbourhood of the Y-crater.
A: fissures active during 1938 and 1939.
B: fissures active on February, 1942.

7. Orifice Temperature of Kusatu Hot-spring.

Concerning the measurement of the orifice temperature of Kusatu Hot-spring, the results during 1910 and 1914 have been reported by

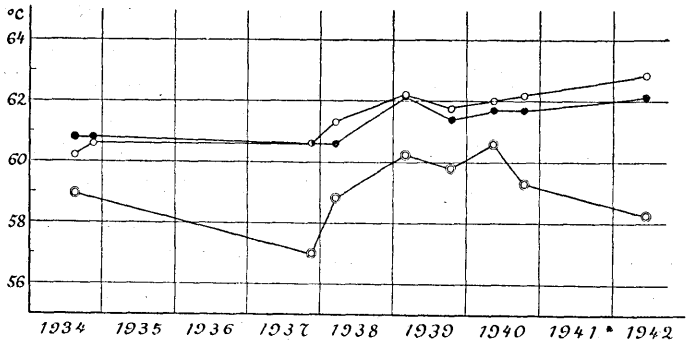

Fig. 11. Orifice temperature of Kusatu Hot-spring during 1934 and 1942.
○ ; Yubatake,
● ; Sirahata-no-yu,
◎ ; Zizô-no-yu.

Table III. Orifice Temperature of Kusatu Hot-spring.

Date		Place of Orifice		
		Yubatake	Sirahata-no-yu	Zizô-no-yu
Sept.,	1910	59°C	59°C	57°C
Aug.,	1911	59	59	57
Aug.,	1912	58·5	58·5	57
Aug.,	1913	58	58	57
July,	1914	58	58	57
July,	1934	60·2	60·7	59·0
Aug.,	〃	60·4	60·9	58·9
Sept.,	〃	59·9	60·8	
Nov.,	〃	60·6	60·8	
Nov.,	1937	60·6	60·6	57·0
Mar.,	1938	61·3	60·6	58·8
Mar.,	1939	62·3	62·2	60·3
May,	〃	62·2	62·1	
Oct.,	〃	61·8	61·4	59·8
May,	1940	62·0	61·7	60·6
Oct.,	〃	62·2	61·7	59·3
June,	1942	62·9	62·2	58·3

R. Ôhasi and H. Yumoto.[5] The chief orifices at the Kusatu Hot-spring are Yubatake, Sirahata-no-yu, Zizô-no-yu, Sai-no-kawara, etc. Artificial changes in the conditions of the orifices have scarcely been made since then.

The writers, since 1934, have carried out measurements of the orifice temperature two or three times every year, the results being shown in Table III and Fig. 11, from which it is remarkable that the temperature of Yubatake and Sirahata-no-yu gradually increased in the time interval from 1934 to 1942. Before November, 1937, the orifice temperature of Sirahata-no-yu barely exceeded that of the other, after which the temperature of Yubatake has been higher, with the result that in November, 1937, they were alike in temperature. November, 1937, the time when the curves of the orifice temperature of the two hot-springs intersect, corresponds with the time when the first explosion of the Y-crater, as just mentioned, occurred.

5) R. ÔHASI, *Pub. Imp. Earthq. Invest. Comm.*, **79** (1915), 20~32.

From measurements of Yubatake and Sirahata-no-yu taken by Ôhasi and Yumoto, their temperatures during the period from 1910 to 1914 had dropped from 59° to 58°C. In contrast to this, since 1934, their temperatures increased from 60° to 62°C. Assuming that their temperature, which continued to decline ever since 1914, increased since then until they reached the present state. They were lowest in 1919, being 57°C, but have increased by 5° to the present time, as shown by the dotted line in Fig. 12.

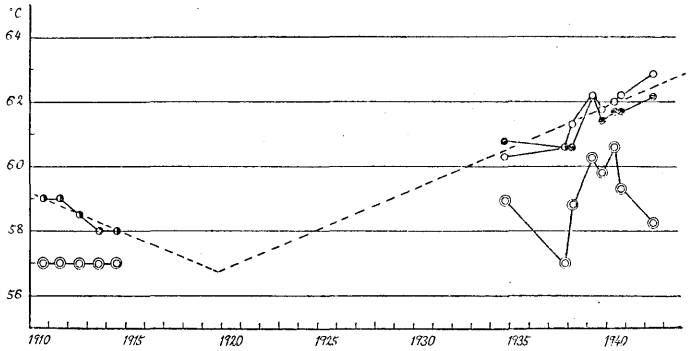

Fig. 12. Orifice temperature of Kusatu Hot-spring during 1910 and 1942.
○ ; Yubatake,
● ; Sirahata-no-yu,
◎ ; Zizô-no-yu.

During the period from 1926 to the present, Volcano Sirane, became active as just mentioned, every 3 or 5 years; it has been more violent than that during the period from the latter half of the 19th. century to the earlier half of the 20th. If the increase in the orifice temprature of the Kusatu Hot-spring is related to the activity of Volcano Sirane, it seems a very interesting phenomenon. The Zizô-no-yu Hot-spring, probably because its orifice volume is small, is easily affected by the influence of the earth's surface, so that changes in its orifice temperature are more marked than in the former two hot-springs.

8. Résumé and Acknowledgement.

This paper reports, firstly, the violent activities that occurred during the period from March to May, 1939, and the changes in the activity of the Y-crater during its period of activity to the end of 1941, with results of the seismic and tilt observations in that interval. In addition to these, it also reports the results of measurements

of the orifice temperature of Kusatu Hot-spring, and the topographical survey of the explosion craters that occurred in February, 1942.

In conclusion, the writers wish to express their cordial thanks to Mr. Hideo Tino, directer of the Kusatu Forestry Station; Mr. Yasuzi Tamino, superintendent of the Kusatu works of the Toyama Chemical Industrial Company; and Mr. Yosio Tasiro, superintendent of the Kusatu works of the Taiyô Industrial Company, for assistance in the course of their observations on the summit of Volcano Kusatu-Sirane. Their hearty thanks are due also to the Department of Education for the Science Research grant received.

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36. 最近の草津白根火山の活動 (其の 2)

地震研究所 水上 武
松下 和則
内堀 定市

昭和 12 年 12 月より昭和 13 年 10 月に至る期間に發生した草津白根火山の山頂湯釜内の活動狀況並に二，三の器械觀測の結果に就いては既に報告した．本文は夫れ以後，昭和 17 年 6 月迄に至る期間に發生した昭和 14 年 3，4 月の著しい爆發，並に湯釜の地形變動，昭和 17 年 2 月に湯釜，空釜の火口丘上に發生した裂罅噴火の狀況及びこれ等多數の爆裂火口群の地形測量結果に就いて報告してある．又昭和 13 年より 14 年に亘つて湯釜附近に於いて行つた地表傾斜變化及び火山性脈動の發生，消長に就いて記述した．尙火山性脈動は湯釜の直接の噴火に伴つて發生したものと地表上の火山現象には直接關係なく發生したものとはその周期に於いて相異する事を知つた．最後に草津溫泉の湧出溫度の永年變化に就いて述べた．

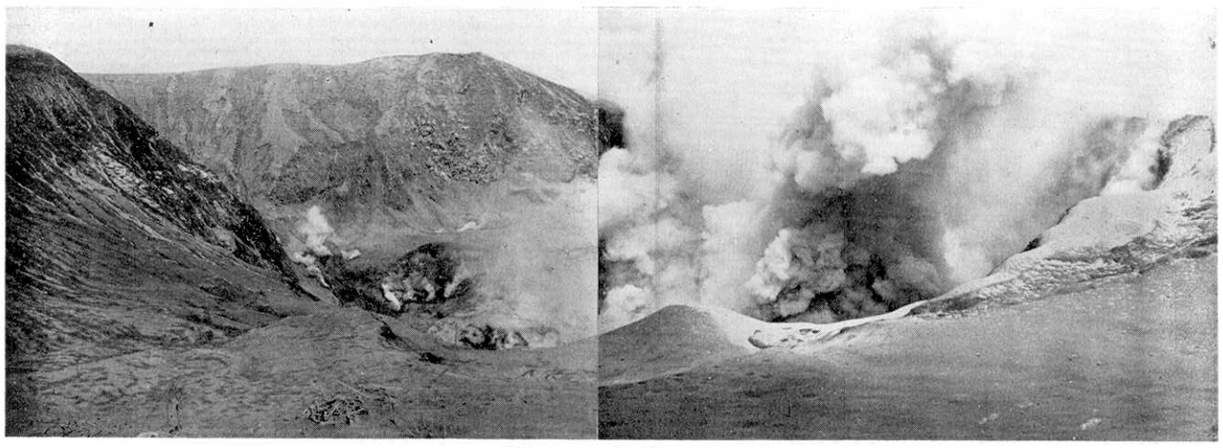

Fig. 13. April, 1939.

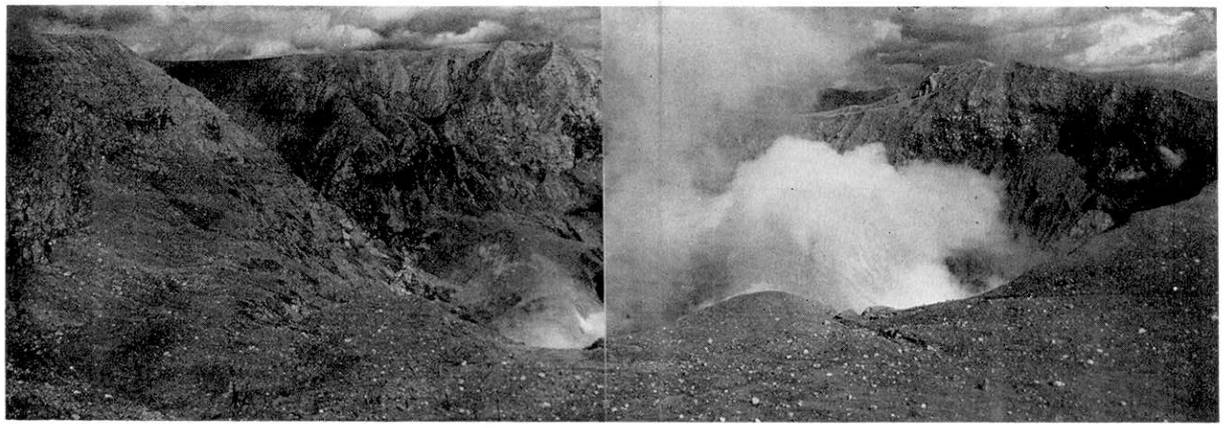

Fig. 14. June, 1940.

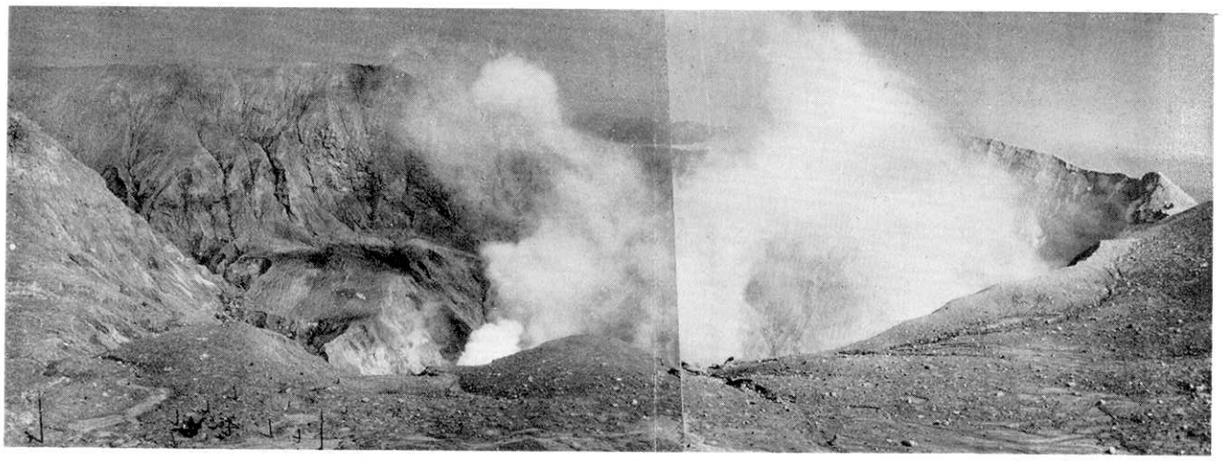

Fig. 15. October, 1940.

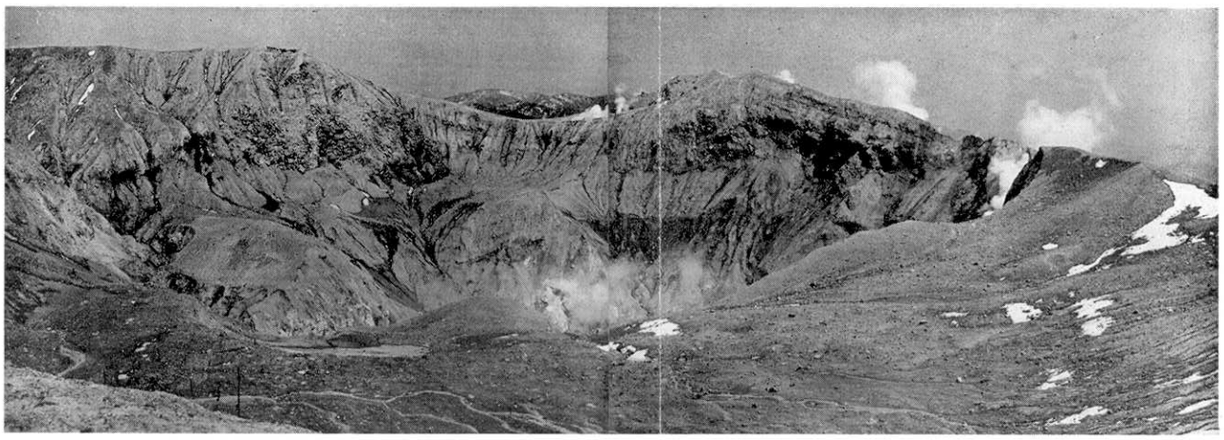

Fig. 16. May, 1942.

Fig. 13, 14, 15, 16. The state of the Y-crater. Photographed from the same point.

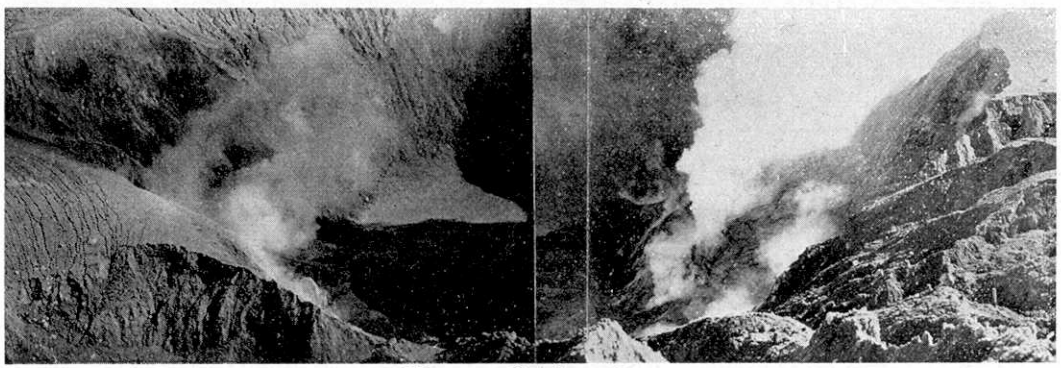

Fig. 17. October, 1940.

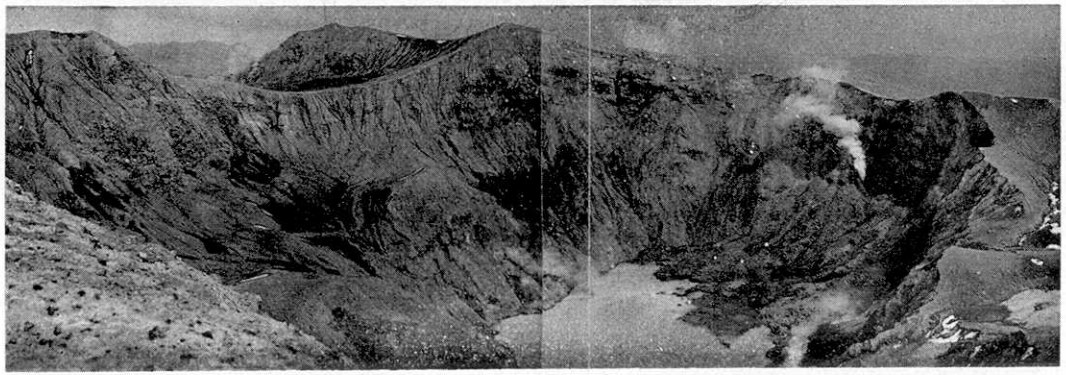

Fig. 18. May, 1942.

Fig. 17, 18. The state of the Y-crater. Photographed from another point.

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Fig. 19. Ash, accumulated on the bridge.

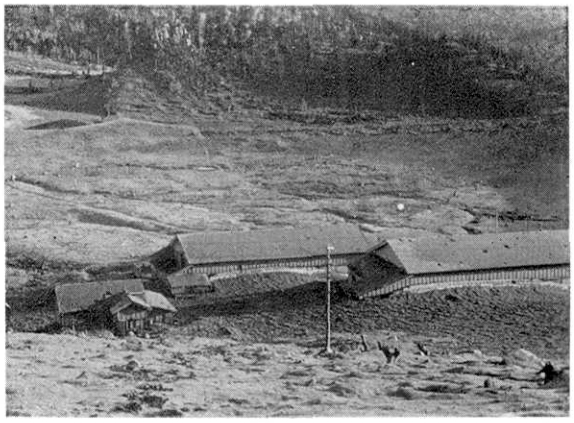

Fig. 20.

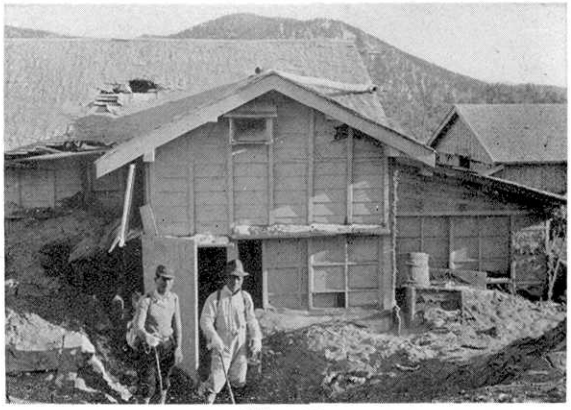

Fig. 21.

Figs. 20, 21. The cottage, damaged by fall of rocks in the explosion on April, 1939.

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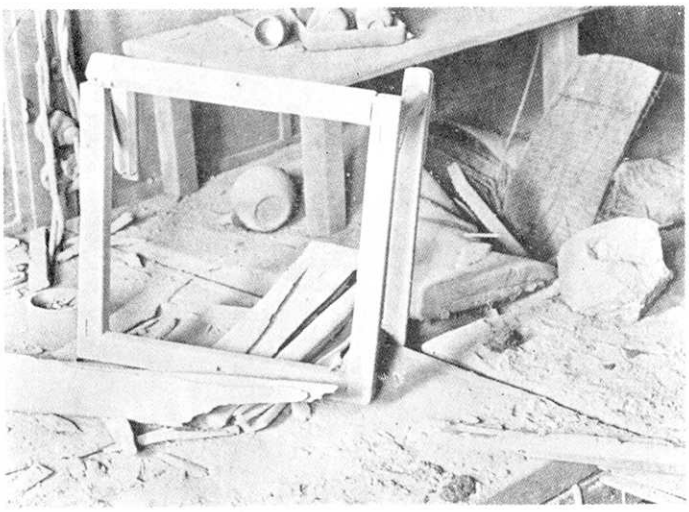

Fig. 22.

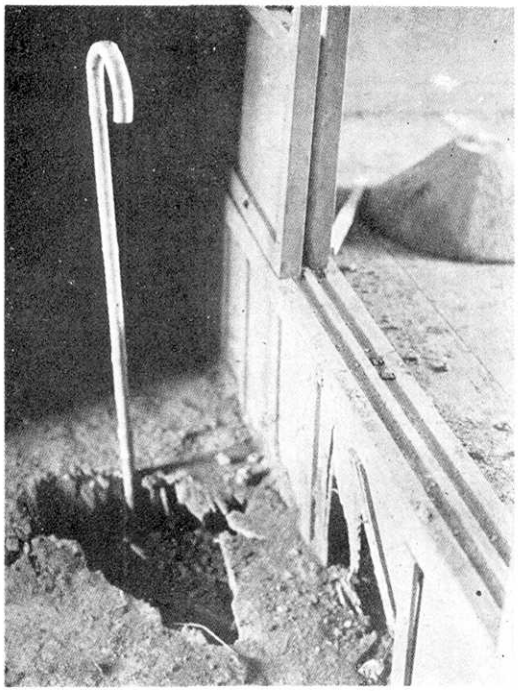

Fig. 23.

Figs. 22 and 23. Interior of the mining cottage. Volcanic detritus penetrated the roof, the ceiling, and the floor boards.

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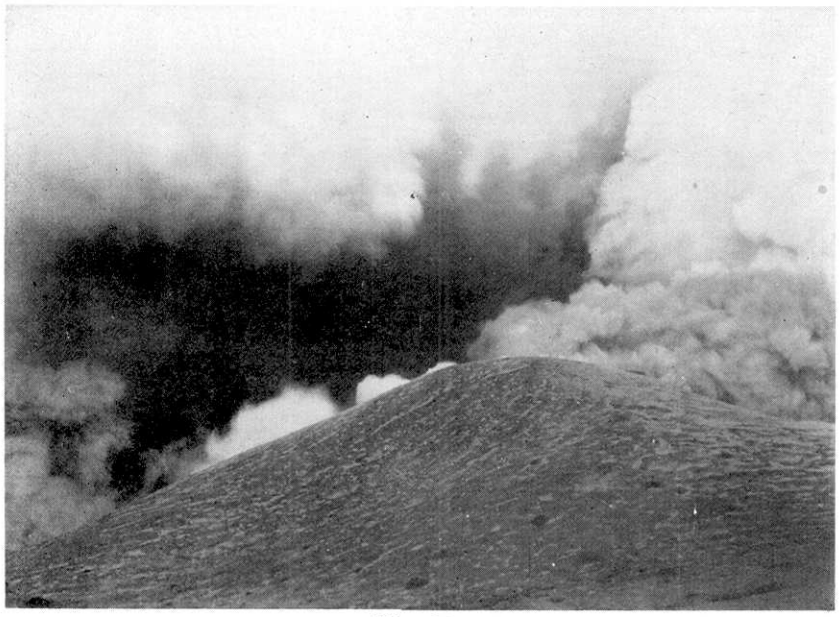

Fig. 24.

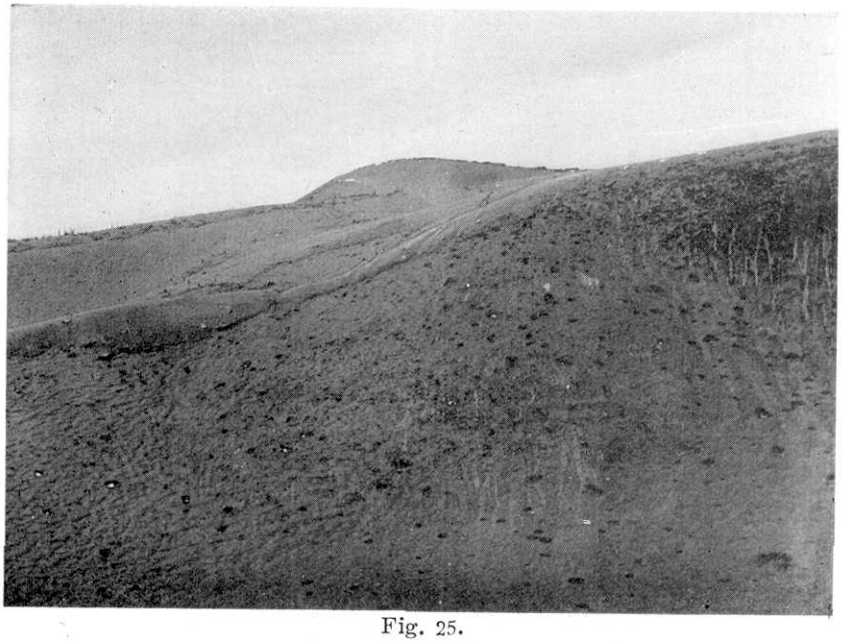

Fig. 25.

Fig. 24, 25. The holes formed by fall of volcanic detritus in the explosion of April, 1939.

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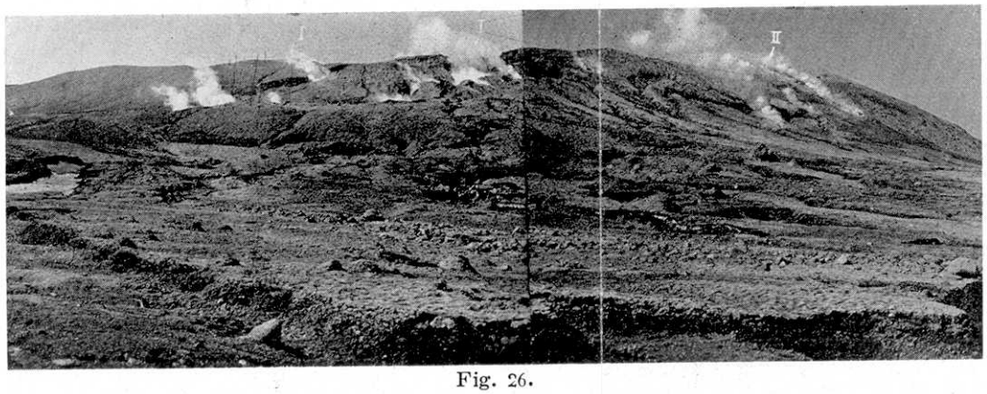

Fig. 26.

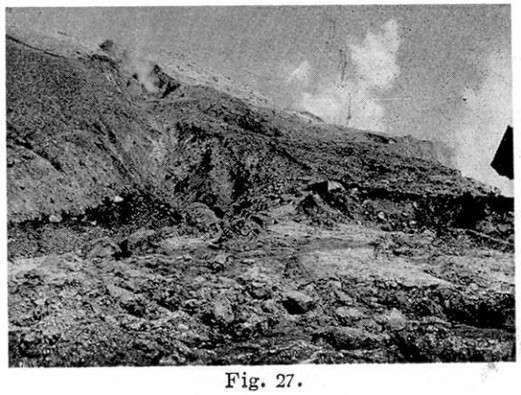

Fig. 27.

Figs. 26, 27. Fissures on the southern side of the Y-crater produced by the explosion on February 2, 1942.

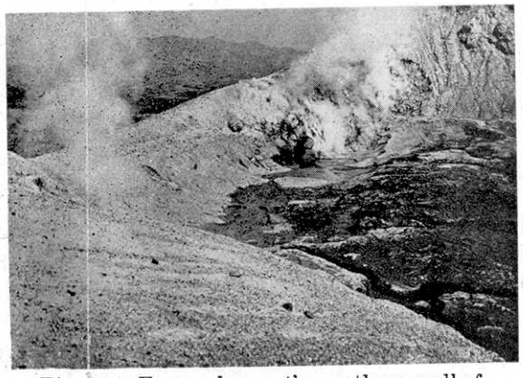

Fig. 28. Fumaroles on the northern wall of the M-crater produced by the explosion on February 2, 1942.

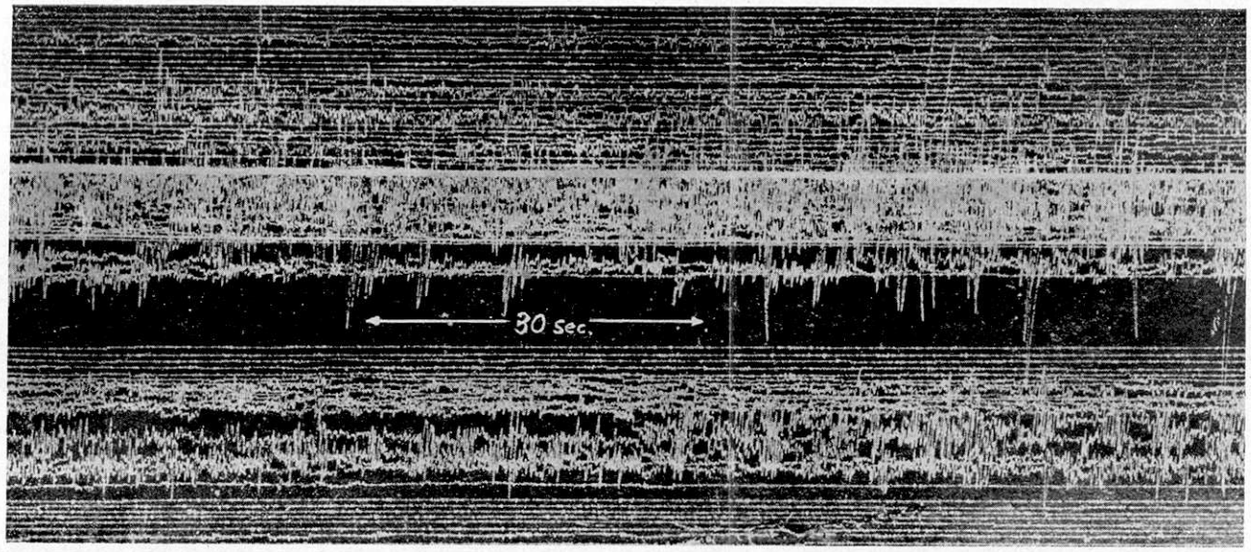

Fig. 29. A record of volcanic pulsations. S_1 type. (March 29, 1939.)

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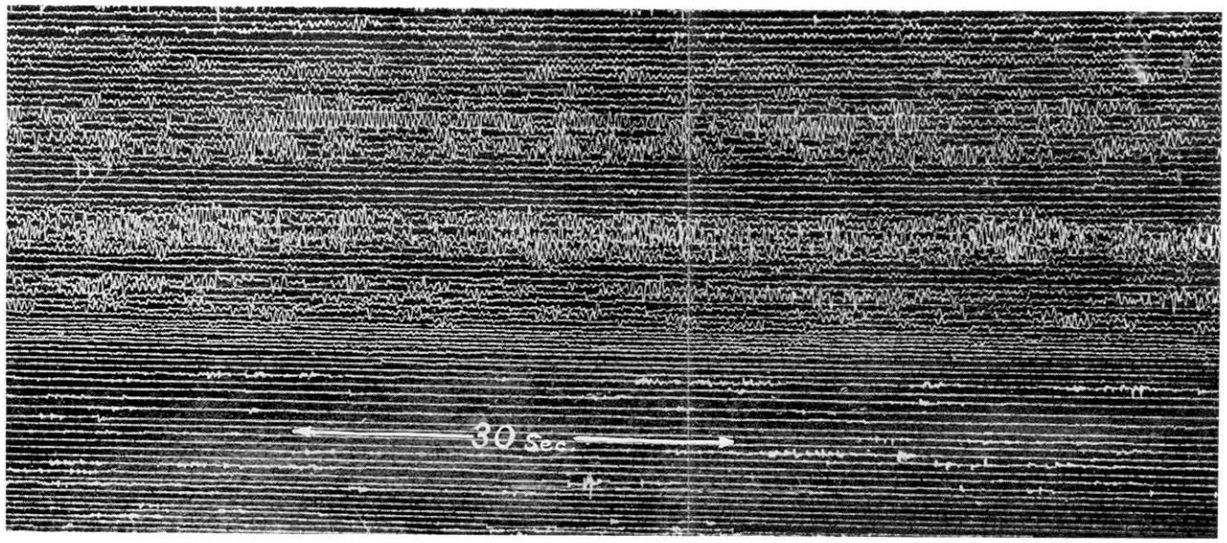

Fig. 30. A record of volcanic pulsations. S_2 type. (October 23, 1938.)