BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
Vol. 48 (1970), pp. 205-233

14. *The Ebino Earthquake Swarm and the Seismic Activity in the Kirisima Volcanoes, in 1968-1969, Part 4.*

Shifts of Seismic Activity from the Kakuto Caldera to Simmoe-dake, Naka-dake and Takatiho-mine.

By Takeshi MINAKAMI, Michinori HAGIWARA,
Masaru YAMAGUCHI, Etsuro KOYAMA and Kakuko HIRAI,

Earthquake Research Institute.

(Read January 27, 1970.—Received January 31, 1970.)

1. Introduction

In the previous papers[1], the writers reported the geographical distribution of the hypocenters of the 1968 Ebino earthquakes which took place since the commencement of February inside the Kakuto caldera. The Ebino earthquake swarm was still continuing at the end of 1969, though the seismic frequency markedly decreased as compared with that of its earlier stage. The present report deals mainly with the seismic activity of the Ebino earthquake swarm after June 1968.

On the other hand, the writers[2] reported already briefly that the extremely shallow earthquakes and volcanic tremor of continuous train appeared near the summit crater of Simmoe-dake and Takatiho-mine, two of volcanic cones, after March 7, 1968. Especially, a number of shallow earthquakes occurred at Takatiho-mine in the form of a swarm in 1969, and volcanic tremors took place nearly at the same place in August, October and December, 1969.

According to the seismometric investigation of the Kirisima volcanoes, the 1968-1969 seismic activity of the region which started at the Kakuto caldera, situated at the north-west end of the Kirisima volcanoes, shifted to the south-east along the same volcanic belt. It is the main purpose of this paper to describe how the shift of seismic activity developed from the Kakuto caldera to Takatiho-mine, the south-east end of the Kirisima volcano group, based on the seismometric observation.

2. The 1969 seismometrical network of the Kirisima volcanoes

In the previous report[3], the writers introduced the seismometrical

1), 2) T. MINAKAMI et al., *Bull. Earthq. Res. Inst.*, **47** (1969), 721-744, 745-768.
3) T. MINAKAMI et al., *loc. cit.*, 2)

Table 1. The seismometrical net work of the Kirisima volcanoes, as of 1969–1970.

Stn. No.	Place of transducer	Component	Mag. on* smok. pr. & senstvy.	Magnification on oscillograph paper
1	Kirisima V.O.	2 horizontal	15,000	100,000—200,000
〃	〃	1 vertical	〃	〃
2	Kamimonzen	〃	〃	〃
3	Oonami-ike W.	〃	〃	〃
4	Kurino-dake W.	〃	〃	〃
5	Simmoe-dake W.	〃	30,000	〃
6	Karakuni-dake	〃	15,000	〃
7	Suwa-zinzya	1 horizontal	〃	〃
8	Okamoto P.S.	〃	〃	〃
9	Kawazoe	〃	〃	〃
10	Naka-dake	〃	30,000	〃
11	Oonami-ike S.	1 vertical	〃	〃
12	Takatiho W.	〃	〃	〃
13	Takatiho N.	〃	〃	〃
14	Takatiho S.	〃	〃	〃
15	Takatiho E.	1 horizontal	〃	〃
16	Kirisima V.O. (2)	1 vertical	2 gal/mm	
〃	〃	2 horizontal	〃	
17	Okamoto B.O.	1 vertical	〃	
〃	〃	2 horizontal	〃	
20	Yunono (Recorder station)			

*: Magnification on smoked paper and sensitivity

networks covering the Kirisima volcanoes, which included those for the permanent and temporary observations. Since the 1968 Ebino earthquake swarm gradually reduced its activity toward the end of June 1968, the second temporary net covering the Kakuto caldera and the third net covering Simmoe and Takatiho were changed in their original states as is shown in Table 1 and Fig. 1. Since March 1969, a series of shallow earthquakes increased near Takatiho, therefore, two new stations were added to the third seismometrical net around the summit of Takatiho, of which the instrumental magnification was adjusted to 30,000 on the seismograms.

On the other hand, the first net covering the middle part of the Kirisima volcanoes has been operated as the standard and permanent

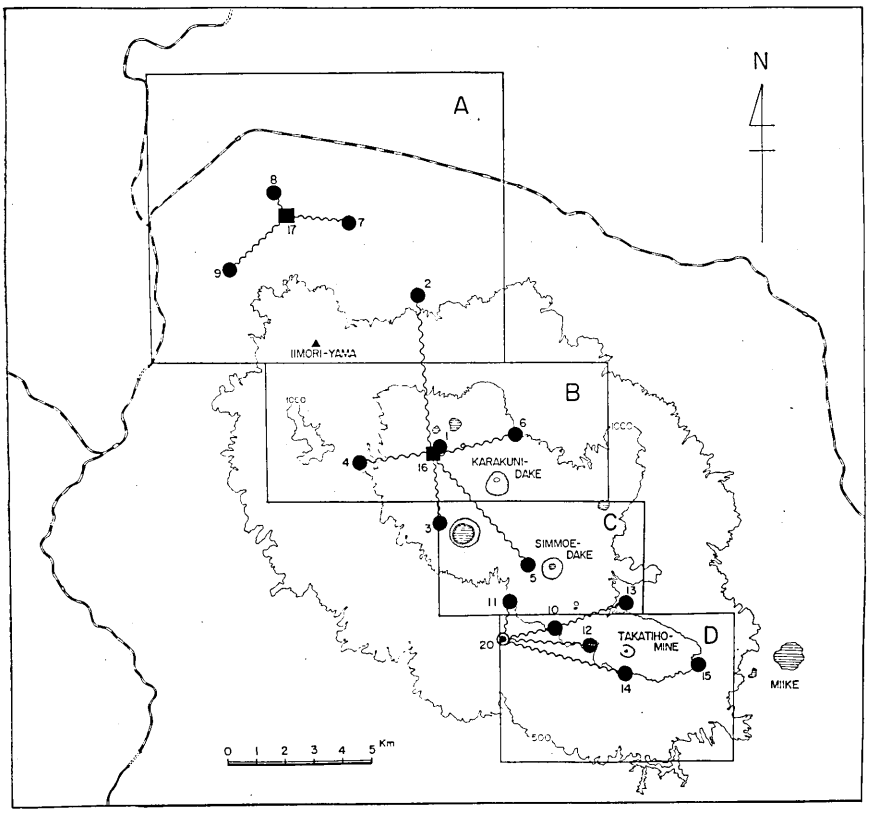


Fig. 1. The seismometrical net works on the Kirisima volcanoes as of 1969-1970.

seismic observation since the establishment of the Kirisima Volcano Observatory. The instrumental magnification of the first net is adjusted to 15,000 except that for Station Simmoe-dake which was changed to 30,000 on March 10, 1969, in order to get more precise information about shallow earthquakes from Simmoe-dake and Takatiho-mine.

The fourth net consisting of the Ishimoto's acceleration seismographs at four stations was operated during the period from February to December, 1968, for determining the hypocentral positions of the Ebino earthquakes. Since the Ebino earthquakes decreased not only in their frequency but also in their magnitude toward the end of 1968, the acceleration seismographs were operated only at two places, Kirisima Volcano Observatory and the Okamoto Branch Observatory after January 1, 1969.

However, the shallow earthquakes and volcanic tremors increased remarkably near Takatiho-mine after December 7, 1969. For investigating precisely the Takatiho-mine earthquakes, a new seismometrical net was established at the southern base of Takatiho-mine on December 26,

1969 and the instrumental magnification was adjusted to 30,000 in displacement type, and the vibration period of the used transducer was 1.0 sec.

The localities of these transducers and the recorder stations are illustrated in Fig. 1 as of the 1969 seismometrical net.

3. Seismic activities of the Kakuto caldera, or the A block of the Kirisima volcanoes

As reported before, the Kirisima volcanoes consist of the Kakuto caldera, the crater lakes and a lot of volcanic cones which are located in a narrow belt extending from north-west to south-east. For the convenience of description, the above volcanic region is divided into four geographical sections, the Kakuto caldera (A block), the Ebino Koogen area (B block) including Kurino-dake and Karakuni-dake, Oonami-ike and Simmoe-dake (C block), and Naka-dake and Takatiho-mine (D block).

As is shown on the map of Fig. 1, the seismometrical net-work of the Kirisima Volcano Observatory covers almost completely the above four blocks. As a consequence, it is not difficult to find the hypocentral positions of the earthquakes which took place in the above-mentioned four sections of the Kirisima volcanoes. However, the seismometric network was completed in 1966 and, therefore, the seismic activities at the four places were made clear after the year of 1966, and those in 1964～1965 were made clear only at the Kakuto caldera and the Ebino Koogen areas.

3.1. The 1964–1969 seismic activities of the Kakuto caldera

In a review of the historical earthquakes, the Kakuto caldera has been frequently attacked by a series of strong earthquake in a form of swarm. Although both of the 1913 Masaki[4] earthquakes and the 1961 Iimori-yama earthquakes[5] took place inside the same caldera, the 1968–1969 Ebino earthquake swarm was outstandingly of large scale not only in its magnitude, but also in the damage caused.

For the convenience of comparison of the seismic activity of the 1968–1969 seismic active state with those of 1964–1967, the monthly frequency of the earthquakes originating from the caldera is represented in Table 2, which were observed with the highly sensitive seismograph and the Ishimoto's acceleration one at Kirisima Volcano Observatory.

At a glance of the time distribution of the monthly seismic fre-

4) Y. SATAKE, The 1913 Masaki Earthquakes and the 1913 Takatiho-mine Eruption (*Masaki-zisin to Hunka Hokoku*), Miyazaki Meteorological Station, 1914, 1-68.

5) T. MINAKAMI et al., *Bull. Earthq. Res. Inst.*, **46** (1968), 965-992.

Table 2. Monthly frequencies of the Kakuto caldera earthquakes observed with highly sensitive seismograph (F_1) and with the Ishimoto's acceleration seismograph (F_2) at the Kirisima Volcano Observatory.

	1964		1965		1966		1967		1968		1969	
Month	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Jan.	2	—	5	0	10	0	27	5	26	0	389	29
Feb.	39	—	32	2	63	0	13	0	11393	400	312	11
Mar.	12	—	5	0	9	0	15	0	14352	745	334	9
Apr.	2	0	7	0	18	0	11	0	8629	363	243	6
May	5	0	7	0	12	0	14	0	4482	180	164	3
June	46	0	14	0	9	0	14	0	1194	47	531	5
July	20	0	11	0	16	0	0	0	1773	91	115	2
Aug.	7	0	15	0	6	0	3	0	553	19	124	3
Sept.	4	0	16	0	2	0	9	1	386	11	128	1
Oct.	8	0	37	0	3	0	11	0	507	15	121	1
Nov.	7	0	9	0	10	2	128	5	209	4	176	3
Dec.	8	0	10	0	16	0	60	0	170	2	90	3
Total	160	0	168	2	174	2	305	11	43674	1877	2727	76
Average	13.3	0	14.0	0.1	15.4	0.1	25.4	0.9	3639.5	156.4	227.2	6.3

quency in Table 2, it may be said that the seismic activity of the caldera had been in a calm or normal state in the period from 1964 to 1966, in which the monthly seismic frequency was in a range from 1 to 63 with the highly sensitive seismograph.

However, the seismic activity of the region was active on March 5, 1967, and during the period from November 17 to December 10, 1967, both of which consisted of a minor earthquake swarm in the Kakuto caldera. Therefore, the seismic activity in 1967 was seismically on a higher level than those of the preceding three years.

However, from the commencement of February 1968, a series of earthquakes were recorded on seismograms in which felt quakes also were included, some of them being accompanied with rumblings. The localities of these earthquakes during the period from 1st to 20th February were placed at the east of Yosimatu town, which agree with the epicentral area of the recent Ebino earthquakes. Although the geographical distribution of the 1968–1969 Ebino earthquakes was partly studied in the previous paper[5], that for the quakes after June 1968, will be reported later.

It is indeed remarkable that the frequency of the 1968–1969 Ebino earthquake swarm was still on a higher level at the end of 1969 than the normal one as in 1964–66 and the monthly frequencies of February, March and April, 1968, the most active state, were 11,393, 14,352 and

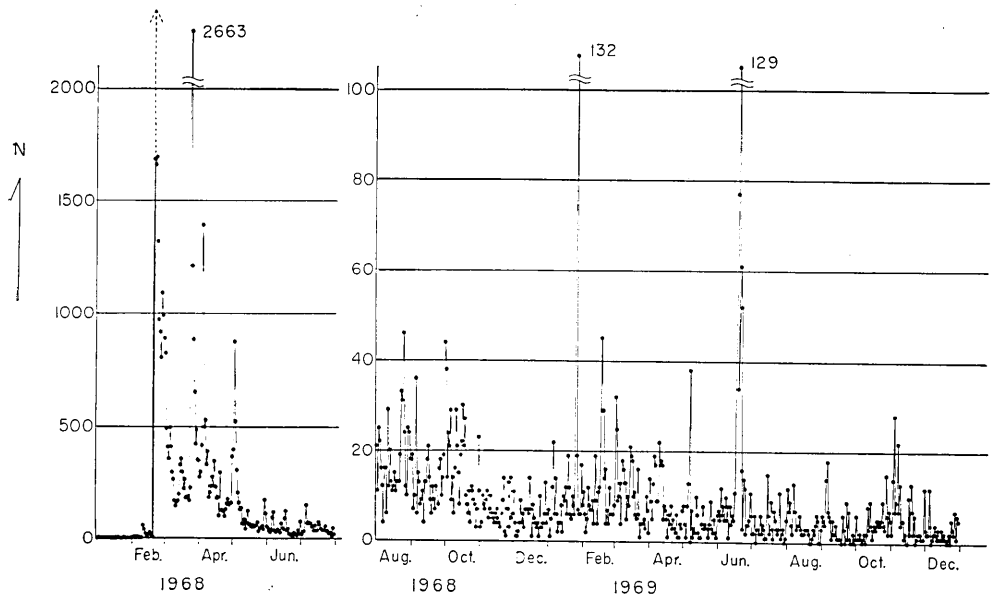


Fig. 2. The seismic daily frequency of the 1968-1969 Ebino earthquake swarm.

6) T. MINAKAMI et al., *loc. cit.*, 3).

8,629 respectively, notwithstanding the seismic observation was not made for several hours on February 21 and March 25, just after the strong earthquakes.

3.2. Geographical distribution of the Kakuto caldera earthquakes in 1968 and 1969

The writers had established a new net of seismometrical observation at Okamoto, the central part of the Kakuto caldera, in June 1966, one and half years before the commencement of the present Ebino earthquake swarm. This was nothing but we had expected a remarkable earthquake swarm every several years inside the same caldera from the historical view point and we questioned whether the earthquake swarm inside the caldera would have any connection with the seismic and volcanic activities of the Kirisima volcano group.

Subsequently, with respect to the 1968 earthquake swarm the hypocentral positions for its earlier stage from 1st to 20th February and during its main seismic activity from February 21 to the end of June were reported in the previous paper[7] of the same Bulletin.

In Fig. 3, the geographical distribution of the Ebino earthquakes of the later stage which took place during the period from September 1968 to May 1969, is illustrated.

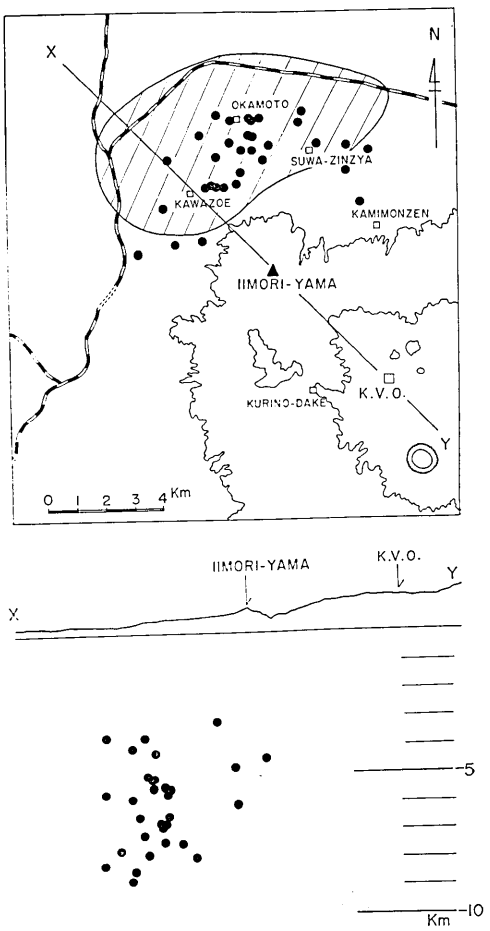


Fig. 3. The hypocentral distribution of the Ebino earthquakes during September 1968-May 1969. Hatched area indicating the epicentral area of the earlier stage of the Ebino earthquake swarm.

3.3. The 1961 Iimori-yama and the 1968–1969 Ebino earthquake swarms

The 1961 Iimori-yama earthquake swarm began to take place at

7) T. MINAKAMI et al., *loc. cit.*, 6).

03h 11m on February 27 and lasted about two months. As already reported[8], their hypocenters were placed on the northern side of Mt. Iimori-yama in the Kakuto caldera, based on the seismometrical observation. Since several strong earthquakes were included in the earthquake swarm, dwelling houses and other constructions situated at towns Yosimatu and Kyomati (Ebino) were damaged on account of strong shocks, but it was not so serious as compared with that of the recent Ebino earthquakes.

The 1961 Iimori-yama earthquake swarm started just after or in the midst of the 1961 Hyuganada earthquake ($M=7.0$), of which the epicenter was placed on the sea bottom of Hyuganada, 110 km east of the Kirisima Volcano Observatory.

The writers were attracted to the problem as to whether the occurrence of the 1961 Iimori-yama earthquake swarm was excited and accelerated by the seismic waves originating from the Hyuganada earthquake, or not. The problem will be dealt at an opportune date from the viewpoint of the probability with respect to the occurrences of earthquakes at the above two regions.

Comparing the 1961 and the 1968–1969 earthquake swarms, the latter one was on an outstandingly larger scale than the former not only in the seismic frequency but also in the magnitude of shocks. And it must be added that the epicentral area of the 1968–1969 earthquakes is located surely at a little more northern position than that of the 1961 ones judging from the distribution of S–P, observed at Ebino-Koogen or Kirisima Volcano Observatory.

As will be seen in Table 2, the average monthly frequency of the Kakuto caldera earthquakes was 13.3, 14.0 and 14.5 in the years 1964, 1965 and 1966 respectively, based on the result of seismic observation with the highly sensitive seismographs at Kirisima Volcano Observatory. However, it showed 29.8 in 1967, the year preceding the remarkable 1968 earthquake swarm, and 3639.5 in 1968, notwithstanding the fact that the seismic observation was not made for several hours on account of damage of the electric supply, simultaneous with the occurrence of the strong earthquake on February 21.

It will be reasonable to assume that the monthly seismic frequency of 1964, 1965 and 1966, showing from 13.3 to 14.5, will be the normal value of the seismicity originating from the Kakuto caldera. As a consequence, it can be said that the value in 1967, 29.8 earthquakes of average frequency, is remarkably larger as compared with those values of the preceding three years. On the other hand, it is important and also interesting in relation with the problem of prediction of strong

8) T. MINAKAMI et al., *loc. cit.*, 5).

earthquakes that the seismicity of the Kakuto caldera indicated the abnormally high value in 1967, one year before the outstanding earthquake swarm in the same caldera.

4. Seismic activities of the Kirisima-Koogen, or the B block of the Kirisima volcanoes

The Ebino-koogen area or the B block of the Kirisima volcanoes is situated at the middle part of the volcanoes as is shown on the map of Fig. 1. More precisely speaking, the above B block consists of a lot of extinct volcanoes of small size, Kurino-dake, Siratori-yama, Kosiki-dake and Karakuni-dake.

4.1. The 1965–1969, seismic activity of the Kirisima-Koogen

According to the result of the seismometrical observation, the earthquakes of the A type originated from these extinct volcanoes and their monthly average seismic frequency was 24.7 in the period from January 1965 to December 1968. In order to catch an outline of the seismicity in the area, it is represented in Table 3 in a form of the monthly frequency of the B block earthquake. In the above period, an earthquake swarm took place in the B block on April 28, 1966, lasting for three days and their daily frequencies are listed in Table 4, based on the seismometric observation of the first net adhering to the Kirisima

Table 3. Monthly frequency (F) of the B block earthquakes observed with the highly sensitive seismograph at the Kirisima Volcano Observatory

Month	1965 F	1966 F	1967 F	1968 F	1969 F
Jan.	18	12	11	14	22
Feb.	19	11	5	*	3
Mar.	18	15	47	*	9
Apr.	21	311	17	*	6
May	27	28	16	*	5
June	16	20	14	*	5
July	36	19	26	*	1
Aug.	6	7	10	*	8
Sept.	12	14	14	*	5
Oct.	20	20	10	*	3
Nov.	14	14	13	*	2
Dec.	10	13	11	*	4
Total	217	484	194	*	73

* On account of the 1968 Ebino earthquakes, it was difficult to pick up the numbers of the earthquakes originating from the Ebino-koogen area, the B block, from the seismograms.

Volcano Observatory.

4.2. The April 1966 earthquake swarm at the western foot of Karakuni-dake

On April 28, at 5h 44m 47s, a series of earthquakes began to take place at the western foot of Karakuni-dake or 0.5~1.5 km south-east of the Kirisima Volcano Observatory and lasted up to 8h 45m on April 30, in a form of an earthquake swarm. Although the intensity of these earthquakes were not so strong as being felt by persons even at the epicentral area, they were caught with the seismograph net covering the epicentral area and its vicinity. In Table 4, the seismic frequencies observed at the six stations are shown.

Table 4. The seismic frequency of the April 1966 earthquake swarm originating from the western base of Karakuni-dake.

Date	K. V. O. Stn. 1	Siratori Stn. S	Karakuni Stn. 6	Oonami W Stn. 3	Simmoe W Stn. 5	Ebino Stn. E
Apr.						
27	0	0	0	0	0	0
28	75	75	75	56	4	79
29	177	171	167	115	12	174
30	32	31	31	28	5	32
May						
1	0	0	0	0	0	0
Total	284	276	273	199	21	285

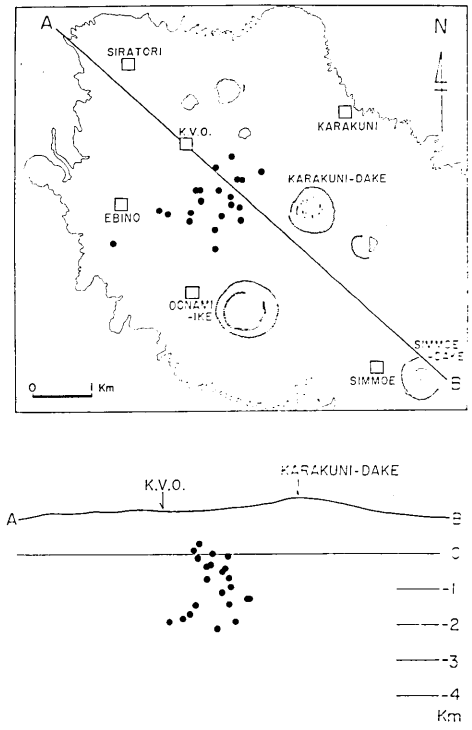


Fig. 4. The hypocentral distribution of the April 1966 earthquake swarm at the western foot of Karakuni-dake.

Of 285 earthquakes, the 22 earthquakes which were clear in the P and S phases on the seismograms at 4~6 stations, were studied with respect to their hypocenters based on S-P. According to the result of investigation, the epicenters con-

centrated in a narrow area and the hypocentral depths were in a range from 1 km to 3 km from the earth's surface, as being seen in Fig. 4. Judging from the pattern of occurrence and the hypocentral depth, the above earthquakes will be reasonably classified into the volcanic A type quake.

Since the hypocentral depths were quite shallow and a lot of seismograph stations cover on and around the epicentral area, it will be useful to check the hypocentral positions mentioned above by means of the comparisons of the maximum amplitudes obtained at these stations,

Table 5(a). The April 1966 earthquake swarm at the western foot of Karakuni-dake.

Eqk. No.	Date & Time	*K.V.O. (NS) S-P	A	Siratori-yama S-P	A	Karakuni-dake S-P	A	Oonami-ike S-P	A	Simmoe-dake S-P	A	Ebino-dake S-P	A
		sec	mm	sec	mm	sec	mm	sec	mm	sec	mm	sec	mm
	Apr. 28												
1	22 h 44 m 57 s	1.4	68.4	1.2	48.2	1.1	53.5	0.9	32.6	—	2.5	1.0	27.7
2	22 57 22	1.3	11.2	1.0	5.6	1.0	5.7	1.0	2.9	—	—	1.0	5.1
3	23 03 26	—	13.9	1.3	7.3	1.5	7.5	—	3.5	—	—	1.0	6.5
4	23 04 31	—	9.3	1.2	4.8	1.3	6.9	—	2.3	—	—	1.0	4.2
5	23 06 05	—	4.1	1.3	2.0	1.4	2.8	1.0	0.9	—	—	0.9	2.0
6	23 10 33	1.0	17.5	1.2	8.5	1.4	10.4	—	4.0	—	—	0.95	7.8
7	23 12 23	1.3	21.7	1.4	11.6	1.0	19.8	0.8	6.2	—	—	1.0	12.8
8	23 31 59	1.2	4.1	—	2.5	1.5	8.1	1.0	2.6	—	—	1.2	4.7
9	23 33 39	1.4	48.4	1.3	17.9	1.4	28.8	0.9	11.4	—	0.9	0.9	18.7
	Apr. 29												
10	00 41 44	0.9	5.4	1.5	4.0	1.45	3.1	0.9	2.4	—	—	1.0	2.2
11	00 45 55	1.0	9.1	1.4	8.2	1.1	13.1	—	7.4	—	0.9	1.3	8.0
12	00 46 37	1.3	67.6	1.5	41.4	—	33.1	1.2	28.5		2.1	1.1	20.5
13	00 51 04	1.0	5.5	—	4.4	1.7	4.0	0.95	2.9	—	—	1.0	4.6
14	01 20 56	1.4	8.0	1.6	3.1	1.4	12.3	0.9	3.0	—	—	1.3	5.1
15	11 37 27	—	9.8	1.3	7.3	1.5	12.4	1.0	3.0	—	—	1.2	6.5
16	11 43 31	—	3.6	1.5	1.7	1.4	3.3	—	—	—	—	1.2	2.0
17	12 14 23	—	5.4	1.3	4.1	1.1	5.1	1.4	1.5	—	—	1.1	3.2
18	12 22 37	—	5.4	1.3	2.6	1.3	4.1	0.9	1.2	—	—	1.1	2.9
19	23 24 34	—	5.5	1.3	3.5	1.3	5.3	1.2	1.3	—	—	0.9	2.3
	Apr. 30												
20	00 03 43	1.4	72.0	1.3	54.2	1.1	49.0	1.1	41.0	1.5	7.5	—	28.9
21	08 12 44	—	27.4	1.3	13.6	1.1	21.0	0.7	5.6	1.5	1.9	1.1	13.1
22	08 19 55	1.5	59.1	1.4	35.5	1.5	44.0	1.0	19.9	—	3.8	1.0	25.8

*K.V.O.: Kirisima Volcano Observatory

A: 1 mm in the trace amplitude is equivalent to 1/15 micron in the actual amplitude.

Table 5(b). The hypocentral depth (h) and distant coefficient (k) of the April 1966 earthquake swarm at the western foot of Karakuni-dake.

Eqk. No.	k	h	Eqk. No.	k	h
1	2.7	1.9 km	12	2.9	3.1 km
2	3.9	3.3	13	2.0	1.5
3	3.0	2.9	14	2.6	2.5
4	3.0	2.6	15	2.0	1.2
5	2.2	1.3	16	3.0	3.1
6	3.3	3.0	17	2.0	0.9
7	2.6	1.3	18	2.6	2.1
8	2.6	2.5	19	2.0	1.1
9	2.6	1.9	20	2.8	2.3
10	2.3	1.7	21	2.6	1.6
11	2.8	2.6	22	2.2	1.6

which are listed in Table 5 together with S–P. After examining the attenuation of the maximum amplitudes, it was evident that the hypocentral depths harmonize well with the remarkable attenuation of amplitude according to the epicentral distance.

5. Seismic activities of the Simmoe-dake, or the C block of the Kirisima volcanoes

On February 17, 1959, Simmoe-dake erupted after a long repose and the writers[9] made a temporary seismometric observation, as reported before. According to the result of the observation, a lot of the B earthquakes and volcanic tremors originated from the summit crater of Simmoe-dake and the newly opened crater-lets. However, these earthquakes decreased in their frequency day by day after the eruption and came to an end about one year after the eruption.

Since the Kirisima Volcano Observatory was newly established as a permanent observatory in April 1964, an electro-magnetic transducer was placed at the western flank of Simmoe-dake (Stn. 5) and its seismograms are obtained at the Observatory. On another side, however, a new seismograph network with Yunono R. S. was added in March, 1968 which was improved in July, 1969, in order to cover seismometrically more completely Simmoe-dake, the C block, and Naka-dake and Takatihomine, the D block.

On account of quite a long distance from Stn. 5 to the Observatory, the transmission wires connecting the transducers with the recorder

9) T. MINAKAMI et al., *loc. cit.*, 8).

station were often damaged and, as a result, the observation was frequently interrupted in the period of 1965 and 1966. But after 1967, the seismic observation has been satisfactorily made.

5.1. The 1965–1969 seismic activity of the Simmoe-dake

In order to make evident the seismic activity of the C block, the monthly frequency of the earthquakes originating in Simmoe-dake and the monthly number of days in which the seismic observation was

Table 6. The Simmoe-dake or C block earthquakes in 1965~1969.
N.: Number of days in which the observation was made,
F.: Seismic frequency of the Simmoe-dake quakes.

Month	1965		1966		1967		1968		1969	
	N days	F	N days	F	N days	F	N days	F	N days	F
Jan.	20	20	18	9	27	10	31	4	31	10
Feb.	17	2	18	8	28	11	29	3	28	15
Mar.	2	3	7	1	31	4	31	150	31	33
Apr.	0	—	30	2	25	9	30	64	30	38
May	31	9	31	0	31	4	31	88	31	17
June	13	4	27	1	27	6	29	33	30	13
July	0	—	21	5	21	35	31	40	31	14
Aug.	31	11	15	7	27	34	31	11	28	20
Sep.	30	5	5	0	24	19	29	8	30	27
Oct.	17	4	11	0	28	38	31	7	31	23
Nov.	5	0	19	1	30	19	30	11	30	15
Dec.	31	8	24	15	31	12	31	16	31	17
Total	197	66	226	49	331	201	364	435	362	242

made in the ordinary way are represented in Table 6 during the period from January 1965 to December 1969.

The daily seismic frequency of earthquakes originating in the C block is illustrated in Fig. 6 in the period from January 1968 to December 1969.

5.2. A minor earthquake swarm on the north-western flank of Simmoe-dake on March 7 and 8, 1968

As reported briefly in the previous paper[10], a series of small earthquakes were observed with the seismometrical net covering the Kirisima volcanoes and their seismic frequencies on record were 58 and 50 on

10) T. MINAKAMI et al., *loc. cit.*, 7).

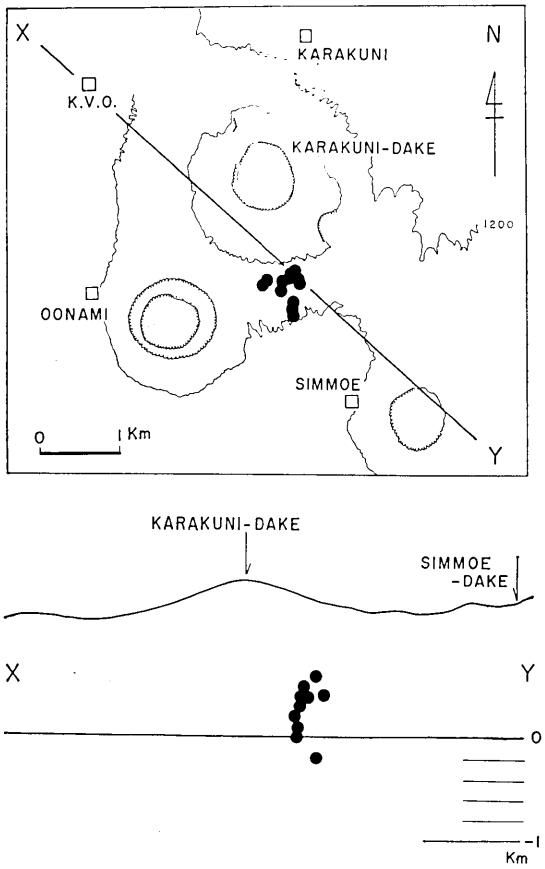


Fig. 5. The hypocentral positions of the March 1968 earthquake swarm near Simmoe-dake.

7th and 8th of March respectively, about 40 days after the commencement of the 1968 Ebino earthquakes. From the geographical distribution of amplitude also observed with a lot of stations on the Kirisima volcanoes, it was evident that these earthquakes originated from the outstandingly shallow place near Simmoe-dake. Since the P and S phases for several ones of these earthquakes were found on their seismograms, their localities being given on a basis of a series of S–P, which are listed in Table 7.

The average daily frequency of the quakes originating from the C block is as follows in the period from 1965 to 1969:

Year	1965	1966	1967	1968	1969
Daily freq.	0.34/day	0.15/day	0.61/day	1.20/day	0.67/day

On account of a short period of the seismic observation, it will be premature to conclude definitely about the seismic level of Simmoe-dake. However, it will not be unreasonable to assume that the seismic level at the calm or normal period of Simmoe-dake will be a range from 0.2/day to 0.6/day.

Table 7(a) and (b). The maximum trace-amplitude distribution and S-P of the March 7–8, 1968 earthquake swarm of the A and B types originating near Simmoe-dake.
(a). The maximum trace-amplitude distribution

No.	Time	K.V.O. Stn. 1	Oonami W. Stn. 3	Karakuni Stn. 6	Kamimon-zen Stn. 2	Kurino Stn. 4	Simmoe W. Stn. 5
	March 7						
	h m	mm	mm	mm	mm	mm	mm
1	09 00	3.5	2.0	3.2	0.9	2.4	27.7
2	09 01	1.7	0.3	1.3	0.6	0.6	7.5
3	09 02	3.6	1.3	3.4	1.7	2.2	26.0
4	10 17	0.6	—	1.0	0.3	—	6.0
5	13 18	4.0	0.9	3.9	1.7	1.0	18.0
6	13 19	2.2	0.8	1.5	0.5	0.8	12.8
7	13 31	1.0	0.1	1.1	—	0.9	10.0
8	15 17	6.8	2.4	2.3	1.1	—	26.5
9	21 47	2.5	0.5	0.9	0.5	—	5.9
	March 8						
	h m	mm	mm	mm	mm	mm	mm
10	05 03	1.5	0.5	0.7	0.3	0.7	0.8
11	05 52	7.3	3.6	4.5	2.3	2.9	31.0
12	05 53	11.5	4.7	9.8	4.7	5.7	37.5
13	08 04	2.0	1.1	2.2	0.9	0.8	23.7
14	15 09	1.0	0.5	0.9	0.5	0.5	9.5
15	15 10	0.9	0.3	0.7	0.4	0.4	8.3
16	15 11	4.6	3.1	4.8	1.4	3.0	30.3
17	15 11	3.9	2.2	2.8	1.9	2.5	27.0
18	20 27	0.8	0.7	1.0	0.4	—	11.4

According to the seismic and volcanic activities in the last 60 years, the remarkable seismic activities in the Kakuto caldera or the A block were followed by the abnormal seismic and volcanic activities of Simmoe-dake, Naka-dake and Takatiho-mine, C and D blocks of the Kirisima volcanoes, as in the cases in 1913 and 1961.

Therefore, as soon as the 1968 Ebino earthquakes started early in February, we expected a new seismic activity of the C and D blocks within one year, based on the above historical development. However,

a series of extremely shallow earthquakes began to occur in a swarm from 0h 40m on March 7, 1968 and its main part came an end at 4h 2m on March 9, but the high seismicity continued for about 3 months up to the end of May.

Table 7(b). S-P

No.	Time	K.V.O. Stn. 1	Oonami W. Stn. 3	Karakuni Stn. 6	Kamimon zen Stn. 2	Kurino Stn. 4	Simmoe W. Stn. 5
	March 7						
	h m	sec	sec	sec	sec	sec	sec
1	09 00	1.2	0.9	0.9	1.7	1.8	0.5
2	09 01	1.3	—	1.0	—	—	0.4
3	09 02	1.3	0.8	0.9	1.0	1.7	0.4
4	10 17	1.2	—	0.8	—	—	0.5
5	13 18	1.2	0.8	0.7	—	—	0.5
6	13 19	1.1	0.8	0.8	—	1.6	0.4
7	13 31	1.2	—	0.9	—	—	0.5
8	15 17	—	—	—	—	—	—
9	21 47	—	—	—	—	—	—
	March 8						
	h m	sec	sec	sec	sec	sec	sec
10	05 03	1.2	0.9	0.9	—	—	0.5
11	05 52	1.2	0.9	0.8	1.7	1.7	0.4
12	05 53	1.2	0.9	0.8	1.6	1.7	0.4
13	08 04	1.1	0.7	0.8	1.7	1.4	0.5
14	15 09	—	—	—	—	—	0.4
15	15 10	—	—	—	—	—	0.5
16	15 11	1.1	0.7	0.8	1.7	1.6	0.5
17	15 11	1.3	0.7	0.8	1.7	1.7	0.5
18	20 27	1.2	0.9	0.8	—	—	0.4

Besides these shallow earthquakes of the B type, volcanic tremors took place near the summit crater of Simmoe-dake for 2m 10 sec and 2m 30 sec in their duration on March 7, and for 6m 20 sec on the following day. Their average vibration periods of the above three tremors were 0.20 sec for the first one, 0.15 sec for the second and 0.08 sec for the last which were observed with the transducer set at Stn. 5, located near the summit crater of Simmoe-dake.

As will be seen in Table 8, the seismicity at the C block returned to the normal value after June 1968, and it has remained so at least till the end of 1969.

Table 8(a). Simmoe-dake earthquakes in 1967.

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	0	0	0	0	0	0	—	1	0	1	0	2
2	0	3	0	2	0	1	0	1	—	1	1	0
3	0	1	0	0	1	0	0	4	—	1	0	0
4	0	1	0	0	0	0	—	4	—	1	0	0
5	0	1	0	2	0	0	—	2	—	1	1	1
6	1	1	0	0	0	0	0	5	1	0	0	0
7	0	1	0	0	0	0	0	1	—	1	1	0
8	—	0	0	0	0	0	0	0	2	2	0	0
9	—	0	0	0	0	0	—	2	0	0	0	0
10	0	1	0	0	1	0	—	—	1	1	3	0
11	0	0	0	0	0	1	—	0	0	2	1	0
12	0	0	0	0	0	0	0	—	0	1	0	0
13	0	0	1	0	0	0	0	0	2	6	0	1
14	0	0	0	0	0	0	—	0	0	2	0	2
15	1	0	0	1	0	1	—	2	0	6	0	0
16	0	0	0	0	0	0	0	1	1	1	1	0
17	0	0	0	1	1	0	0	1	1	2	1	0
18	0	0	0	0	0	1	—	0	0	2	0	0
19	0	0	0	0	0	—	—	0	0	0	1	1
20	0	0	0	—	0	0	1	0	3	3	0	0
21	2	0	2	—	0	0	1	1	5	1	0	0
22	0	0	1	—	1	0	0	0	1	0	3	1
23	0	0	0	—	0	1	0	2	0	0	3	0
24	3	0	0	—	0	0	0	1	0	0	0	2
25	1	0	0	0	0	—	0	—	0	1	1	0
26	0	0	0	0	0	0	3	0	0	—	0	0
27	0	1	0	1	0	0	11	0	—	—	0	0
28	—	1	0	2	0	0	19	2	1	—	0	0
29	—		0	0	0	—	0	3	1	1	0	1
30	1		0	0	0	1	0	1	0	0	2	1
31	1		0		0		0	—		1		0

Table 8(b). Simmoe-dake earthquakes in 1968.

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	0	0	0	3	4	1	0	1	0	0	0	0
2	0	0	0	2	17	1	0	0	0	0	0	1
3	0	0	0	2	2	9	2	2	0	1	0	0
4	0	0	0	2	1	0	2	0	1	0	0	4
5	0	0	0	5	1	2	3	0	0	0	2	0
6	0	1	1	3	4	2	1	0	0	2	0	0
7	0	0	58*	6	7	0	5	0	0	0	1	0
8	0	1	50*	7	3	2	2	0	1	0	1	0
9	0	0	6	1	0	2	1	0	0	0	0	0
10	0	0	1	5	3	6	1	0	1	1	0	1
11	0	0	1	1	0	1	0	2	0	0	0	1
12	0	0	2	0	0	0	0	0	0	0	0	0
13	0	0	2	1	2	1	1	0	0	1	0	1
14	0	0	1	0	4	0	2	0	0	0	0	1
15	0	0	0	1	4	2	2	0	0	0	0	3

(to be continued)

Table 8(b). (continued)

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
16	1	0	3	0	5	0	2	0	0	1	0	0
17	0	1	0	0	4	0	4	1	0	0	0	0
18	0	0	0	0	4	0	2	0	0	1	1	1
19	0	0	0	2	3	0	3	0	0	0	0	0
20	0	0	5	0	0	0	0	0	0	0	0	0
21	0	0	5	3	2	—	2	0	1	0	2	0
22	0	0	3	0	2	0	2	0	0	0	0	0
23	0	0	2	1	0	0	0	0	0	0	1	3
24	0	0	4	3	0	0	0	0	—	0	0	0
25	0	0	2	0	1	0	1	0	0	0	2	0
26	0	0	0	3	1	0	0	0	0	0	0	0
27	0	0	0	2	1	0	1	0	4	0	1	0
28	1	0	1	5	1	1	0	0	0	0	0	0
29	1	0	0	4	10	2	1	1	0	0	0	0
30	1		1	2	1	1	0	3	0	0	0	0
31	0		2		1		0	1		0		0

* volcanic tremor

Table 8(c). Simmoe-dake earthquakes in 1969.

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	1	0	2	3	0	0	0	2*	1	2	1	3
2	1	3	2	12	1	2	0	1	2	1	0	0
3	0	1	1	2	0	0	1	2	0	0	2	0
4	0	1	1	2	0	1	0	0	1	0	0	2
5	0	0	2	2	1	0	0	2	0	0	1	0
6	1	2	2	0	2	0	0	0	4	1	0	0
7	1	0	0	3	0	0	0	2	0	0	2	0
8	0	0	3	0	0	1	0	0	0	1	1	2
9	0	0	0	1	0	2	0	0	0	1	1	0
10	0	1	0	0	0	0	0	0	0	1	0	2
11	0	0	6	0	1	1	0	1	2	0	0	0
12	0	1	0	0	2	2	1	1	0	0	0	0
13	0	3	0	1	0	0	1	1	3	0	0	1
14	0	0	0	0	0	0	0	0	1	1	0	0
15	1	0	1	1	0	1	0	0	1	0	0	1
16	0	1	2	0	2	0	0	0	0	0	0	1
17	0	0	0	1	1	2	0	1	0	1	0	0
18	0	0	0	0	1	0	0	1	0	2	1	0
19	0	0	1	1	0	0	0	0	0	1	0	0
20	0	0	3	2	0	0	1	1	1	0	3	0
21	2	0	1	0	0	0	1	1	2	1	0	2
22	0	1	0	2	1	0	4	0	1	0	1	2
23	0	0	0	0	1	0	1	—	2	1	1	0
24	0	0	0	0	0	0	1	1	0	1	0	0
25	0	0	0	4	0	0	1	—	2	1	0	1
26	1	0	0	0	2	0	1	—	1	0	0	0
27	1	0	0	1	0	1	1	2	0	1	1	0
28	0	1	1	0	0	0	0	1	2	1	1	0
29	0		1	0	0	0	0	0	1	1	0	0
30	0		2	0	2	0	0	0	0	3	0	0
31	1		2		0		0	0		1		0

* volcanic tremor

6. Seismic activities of Naka-dake and Takatiho-mine, or the D block of the Kirisima volcanoes

Takatiho-mine, which is located at the southern most end of the Kirisima volcanoes, has erupted often in historical time as well as Simmoe-dake. Since Takatiho-mine[11] broke out in November 1913 after the 1913 Kakuto caldera earthquake swarm or the Masaki earthquakes, the writers paid special attention to the seismic activity and the volcanic phenomena originating from Takatiho-mine as soon as the 1968 Ebino earthquake swarm took place.

6.1. The 1968–1969 seismic activity of Naka-dake and Takatiho-mine

A minor earthquake swarm took place during March 22–25, 1969, and these earthquakes were caught by the transducers placed near Naka-dake. The earthquake swarm lasted for four days from March 22, and the daily seismic frequency during the four days was 33, 30, 25 and 12 respectively. Of these earthquakes, eight were observed at Stations Takatiho W, Oonami-ike S. and Simmoe-dake W. with S–P which are listed in Table 10.

The hypocentral positions of these earthquakes were given by using S–P at the three stations and by assuming the value of the distance coefficient as 3.0. As a result, it was made clear that the localities of the earthquakes concentrated near the summit of Naka-dake which is located

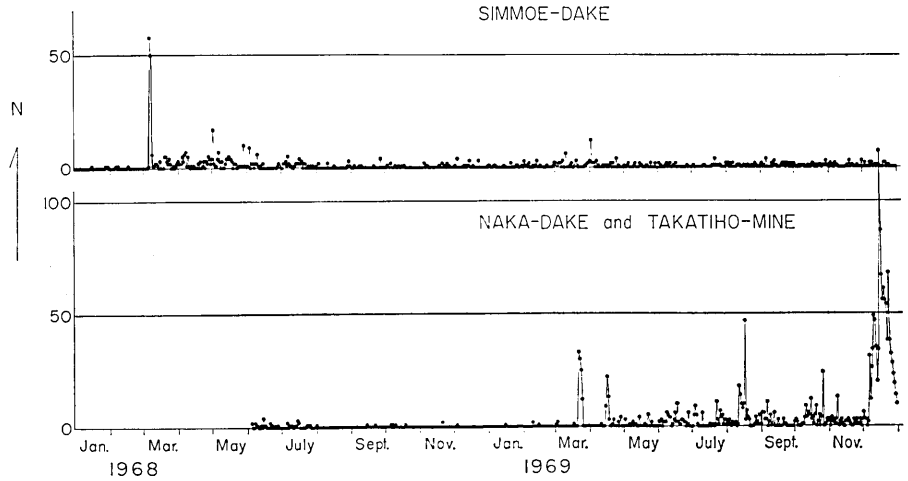


Fig. 6. Daily seismic frequencies which took place at the Simmoe-dake area, or the C block of the Kirisima volcanoes, and at the Naka-dake and Takatiho-mine area, or the D block.

11) A. IMAMURA, *Bull. Imp. Earthq. Invest. Comm.*, **92** (1920), 1–94.

Table 9. Seismic frequency of Naka-dake and Takatiho-mine earthquakes in 1968 and 1969.

Date	1968							1969											
	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1		0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	3
2		0	0	0	0	0	0	0	0	1	0	3	2	0	2	6	3	0	6
3		0	0	0	0	0	0	0	0	2	0	0	0	5	3	6	2	4	3
4		0	0	0	0	0	1	0	0	0	0	0	3	9	1	3	0	2	3
5	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	3	0	3	0
6	0	2	0	0	1	0	0	0	0	0	0	1	2	1	2	11	0	1	2*
7	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0*	3	31
8	2	1	0	0	1	0	0	0	0	0	0	1	2	0	1	2	1	13	12*
9	1	1	0	0	0	0	0	0	2	0	0	2	6	0	2	5	1	1	26*
10	1	1	0	0	1	0	0	0	0	0	0	0	5	6	0	0	4*	0	34
11	0	0	0	0	0	0	0	0	0	0	1	1	4	0	1	1	9*	2	49*
12	0	0	0	0	0	0	0	0	0	0	0	1	4	0	18*	6	4*	3	47*
13	1	1	0	0	0	0	0	0	0	0	0	0	0	0	14*	0	6*	1	35
14	0	1	0	0	0	0	0	0	1	0	0	0	1	0	10	0	5*	0	20*
15	4	3	0	1	0	0	0	0	0	0	9	4	3	0	8	0	12	0	31*
16	1	2	0	0	0	0	0	1	0	0	22	0	6	0	10	3	3	2	122*
17	1	0	0	0	0	0	0	0	0	0	13	0	2	1	47*	0	4	2	87
18	0	0	0	0	0	0	0	0	0	1	3	0	10	0	3*	0	1	3	67
19	0	0	0	0	1	0	0	0	0	0	0	0	2	1	7	0	5	2	56
20	0	0	0	0	0	0	0	0	0	0	0	1	1	1	4	0	9	1	61
21	2	0	0	0	0	2	0	0	0	0	1	0	1	0	3	3	0	0	56
22	0	0	0	1	0	0	0	0	0	33	3	0	3	1	0	1	2	0	54*
23	1	0	0	0	0	0	0	0	0	30	0	5	3	11	0	1	5	3	38*
24	0	0	0	0	0	0	0	0	0	25	0	0	2	3	0	0	0	2	68
25	0	0	0	0	0	0	0	0	0	12	0	0	2	1	0	0	4	1	38
26	1	0	0	0	0	0	0	0	0	0	2	2	0	7	1	0	24	3	32
27	0	0	0	0	0	0	0	0	0	0	0	0	1	4	4	0	0	1	28
28	1	1	0	*	0	0	0	0	0	0	4	0	6	5	2	0	0	1	23
29	0	1	0	0	0	0	0	0		0	0	0	0	1	1	0	1	3	19
30	0	1	0	0	0	0	0	0		0	0	0	0	3	5	0	3	0	14
31		1	0		0		0	0		2		0		3	5		2		10
Total	19	16	1	3	4	2	1	1	3	106	58	21	73	68	156	52	112	60	1078

* volcanic tremor

between Simmoe-dake and Takatiho-mine, or more strictly speaking, 0.1–0.5 km east and slightly south of the summit of Naka-dake. Further, their hypocentral depths were in a range from 0.5 km to 2.5 km. Judging from the attenuation of the maximum amplitudes at the above three stations and those of other stations located at more distant places, the above result concerning the locality of these earthquakes can be reasonably accepted.

After the 1969 Naka-dake earthquake swarm died down, it seemed that the Takatiho-mine earthquakes increased in their frequency as compared with the seismic level of the D block in 1968.

In order to make clearer the seismic feature of Takatiho-mine, the writers investigated the seismic frequency of earthquakes originating from the D block, or Naka-dake and Takatiho-mine, based on the seismograms. The seismic frequency before March 11, 1968, was not so accurately made clear as that after the above mentioned date, on account of the incomplete seismograph net. But, it was evident on the basis of the seismic observation with the first net that no remarkable seismic activity in the D block appeared during the period from October 1964 to May 1968.

Table 10. The Naka-dake earthquake swarm on March 22, 1969.

Date	Time	Stn. No.	Place	Hypo. depth	Init. motn.	S-P	Maximum trace amp.
	h m			km		sec	mm
March 22	18 16	5	Simmoe-dake W.	0.7	down	1.1	4.0
		11	Oonami-ike S.		up	1.1	3.4
		12	Takatiho W.		up	0.5	23.8
March 22	18 16	5	Simmoe-dake W.	0.5	up	1.0	4.3
		11	Oonami-ike S.		down	1.0	3.8
		12	Takatiho W.		up	0.5	22.2
March 22	18 17	5	Simmoe-dake W.	0.9	up	1.1	1.5
		11	Oonami-ike S.		up	1.1	1.3
		12	Takatiho W.		down	0.5	12.0
March 22	18 18	5	Simmoe-dake W.	0.8	up	1.1	0.9
		11	Oonami-ike S.		up	1.2	1.3
		12	Takatiho W.		down	0.5	9.2
March 22	18 19	5	Simmoe-dake W.	0.9	up	1.0	1.0
		11	Oonami-ike S.		?	1.0	1.1
		12	Takatiho W.		down	0.5	7.3
March 22	18 20	5	Simmoe-dake W.	0.7	up	1.1	1.0
		11	Oonami-ike S.		up	1.1	0.7
		12	Takatiho W.		up	0.5	3.9
March 22	18 22	5	Simmoe-dake W.	1.5	up?	1.2	0.8
		11	Oonami-ike S.		up?	1.2	0.7
		12	Takatiho W.		down	0.6	4.4
March 22	18 27	12	Takatiho W.	1.2	down	0.5	35.3

Table 11. The Naka-dake and Takatiho-mine earthquake swarms, during May~September, 1969.

Date & time	Stn. No.	Place	Arrival time	S-P	Maximum trace amp.
			sec	sec	mm
May 30 06 49	5	Simmoe-dake W.	25.2	0.8	7.3
	11	Oonami-ike S.	25.5	0.9	7.1
	12	Takatiho W.	25.3	0.7	20.8
	13	Takatiho N.	25.3	0.7	11.4
Jun. 22 22 18	5	Simmoe-dake W.	50.8	0.4	5.3
	11	Oonami-ike S.	51.3	0.7	4.8
	12	Takatiho W.	51.6	0.8	3.8
	13	Takatiho N.	51.6	0.7	9.3
Jun. 22 22 29	11	Oonami-ike S.	51.4	1.5	7.7
	12	Takatiho W.	50.7	0.6	15.2
	13	Takatiho N.	51.0	0.7	7.2
	14	Takatiho S.	49.8	0.6	15.7
Jun. 23 09 25	11	Oonami-ike S.	04.6	1.6	9.5
	12	Takatiho W.	04.2	0.9	19.0
	13	Takatiho N.	04.2	0.9	8.8
	14	Takatiho S.	04.2	0.8	30.0
Aug. 11 13 58	10	Naka-dake	53.5	0.4	11.1
	11	Oonami-ike S.	53.5	0.5	9.6
	12	Takatiho W.	53.5	0.6	4.5
	13	Takatiho N.	53.4	0.5	8.6
Aug. 16 05 08	10	Naka-dake	27.9	1.2	4.2
	12	Takatiho W.	27.5	1.0	23.2
	13	Takatiho N.	27.6	1.0	6.5
	14	Takatiho S.	27.1	0.9	19.4
Aug. 16 12 38	10	Naka-dake	47.8	0.8	2.3
	12	Takatiho W.	47.3	0.6	11.6
	13	Takatiho N.	47.4	0.6	3.6
	14	Takatiho S.	47.0	0.5	10.5
Aug. 17 02 39	10	Naka-dake	28.6	0.8	3.1
	12	Takatiho W.	28.3	0.6	9.6
	13	Takatiho N.	28.4	0.7	4.3
	14	Takatiho S.	28.3	0.5	10.7
Aug. 18 23 59	10	Naka-dake	27.5	0.9	3.2
	12	Takatiho W.	26.9	0.6	15.5
	13	Takatiho N.	27.0	0.8	5.2
	14	Takatiho S.	26.8	0.7	8.6
Aug. 31 20 08	10	Naka-dake	26.3	0.7	0.3
	12	Takatiho W.	26.1	0.4	1.1
	13	Takatiho N.	26.2	0.5	0.5
	14	Takatiho S.	26.0	0.3	1.3
Sep. 4 07 33	10	Naka-dake	09.3	1.3	6.5
	11	Oonami-ike S.	09.7	1.7	2.6
	12	Takatiho W.	08.8	1.0	37.0
	13	Takatiho N.	09.0	1.1	6.8
	14	Takatiho S.	08.7	0.9	20.8

(to be continued)

Table 11. (continued)

Date & time	Stn. No.	Place	Arrival time	S-P	Maximum trace amp.
			sec	sec	mm
Sep. 4 12 15	10	Naka-dake	39.9	0.5	6.0
	12	Oonami-ike S.	39.9	0.6	4.5
	13	Takatiho W.	40.4	0.8	1.8
	14	Takatiho N.	40.4	0.9	2.5
Sep. 6 01 12	11	Simmoe-dake W.	01.0	0.4	5.8
	12	Oonami-ike S.	01.2	0.5	8.8
	13	Takatiho W.	01.4	0.5	3.1
	14	Takatiho N.	01.5	0.6	8.0
Sep. 6 03 04	5	Oonami-ike S.	48.1	1.3	7.6
	11	Takatiho W.	46.6	0.6	80.0
	12	Takatiho N.	46.6	0.7	19.3
	13	Takatiho S.	46.6	0.6	61.3
Sep. 28 05 43	5	Simmoe-dake W.	12.5	0.5	4.4
	10	Naka-dake	13.1	0.5	7.7
	11	Oonami-ike S.	13.1	0.6	7.3
	12	Takatiho W.	12.9	0.6	3.0
	13	Takatiho N.	12.9	0.5	8.0

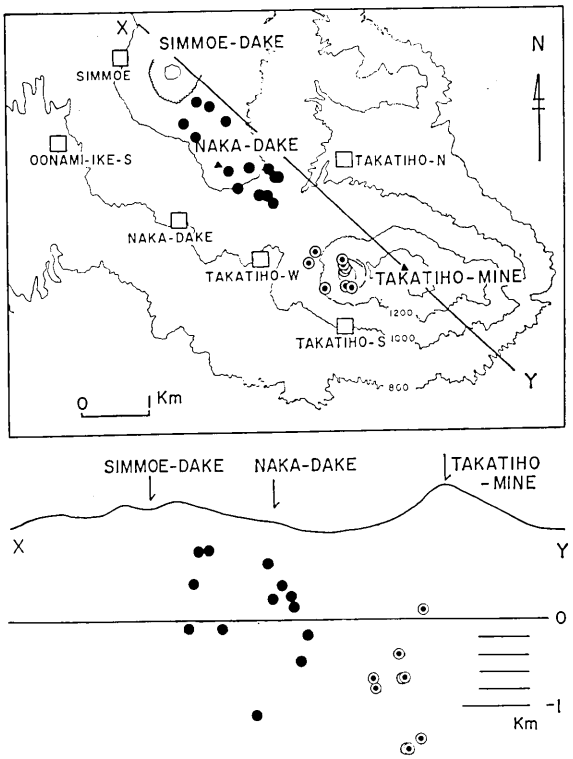


Fig. 7. Hypocentral positions of the 1969 Naka-dake and Takatiho-mine earthquake swarms.

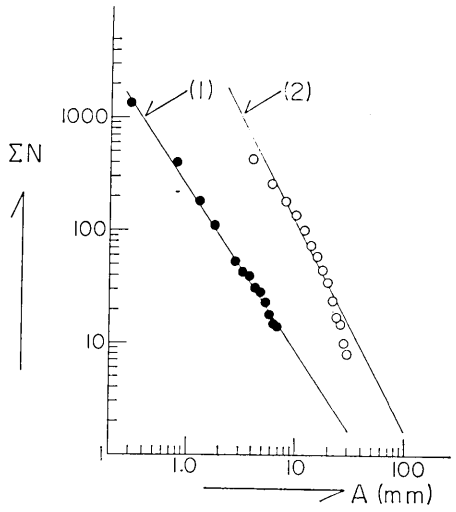


Fig. 8. The maximum trace-amplitudes and the seismic frequency for the 1968 Ebino earthquakes (1) and the 1969 Takatiho-mine earthquakes (2).
m=2.6 for (1),
m=3.4 for (2).

Besides the above shallow earthquakes, volcanic tremors appeared now and then on the seismograms which were obtained with the transducers placed near Takatiho-mine. Since August 12, 1969, the seismic activity of the D block increased remarkably not only in the extremely shallow earthquakes, but also in the volcanic tremors. Especially, a lot of the A and B quakes and volcanic tremors increased outstandingly in and around the Ohati crater, located at the western side of the summit of Takatiho-mine, as will be seen in Fig. 6.

With respect to the March 1969 earthquake swarm and the August-December earthquake one, the writers studied their hypocentral positions based on S–P, the P arrival times and the maximum amplitudes in Tables 10 and 11, and the results are illustrated in Fig. 7.

From the maximum amplitude at each station, it was made clear that these volcanic tremors originated also from the Ohati crater and its vicinity. The earthquakes which originated from Takatiho-mine and Naka-dake in 1967 were very few, though small ones took place on July 31 and on September 15.

It will be necessary to add here about the distribution of the maximum trace-amplitude and the seismic frequency of the 1969 Takatiho-mine earthquakes. For the purpose, the above relation is illustrated in Fig. 8 in comparison with that of the 1968 Ebino earthquakes.

6.2. Shifts of the seismic activity along the Kirisima volcanoes after the outbreak of the 1968 Ebino earthquakes

As described above, the main shocks of the 1968 Ebino earthquakes began to occur on February 21, though a series of shocks including the felt quakes preceded them. Through the development of the seismic activity for nearly two years, the mode of occurrence of the 1968–1969 Ebino earthquakes was classified as an earthquake swarm of a big scale inside the Kakuto caldera as in the cases of the 1913 and 1961 earthquakes in the same caldera.

According to the comparison of the seismic activity in the same area during the period 1964–1967, it seems that the seismic level in the Kakuto caldera had risen in November 1967, three months preceding the 1968 February Ebino earthquakes. On the other hand, after the outbreak of the Ebino earthquakes, a series of minor earthquake swarms took place successively at the north-west foot of Simmoe-dake on March 7–9, 1968, at the north-west and south-east flanks of Naka-dake on March 22–25 and on April 15–18, 1969, and on and near the Ohati crater of Takatiho-mine during the period from August 12 to December 31, 1969.

These earthquakes originated from the depth of 3～5 km to the earth's surface along the Kirisima volcanic belt, which consists of the Kakuto caldera and a lot of extinct and dormant volcanic cones, extending from the north-west to the south-east, 30 km in length. Therefore, the seismic activity which started inside the Kakuto caldera shifted in succession toward the south-east along the Kirisima volcanic belt, and after one and half years of the outbreak it arrived at Takatiho-mine, situated at the southeast extremity of the Kirisima volcanic belt.

According to the precise investigation of the hypocentral distribution of the 1968 Ebino earthquakes, the hypocentral positions of the earthquakes which took place during the earlier stage up to March 25 were found mainly in the western side of the Kakuto caldera. However, soon after the strong earthquake on March 25, at 00h 58m which took place near Town Kakuto, the hypocentral positions shifted toward the eastern side of the caldera as is seen clearly in the diagram of Fig. 10. The same phenomenon[12] or the shift of the hypocentral positions from west to east in the Kakuto caldera was reported on the occasion of the 1913 Masaki earthquake swarm in the same caldera. On the other hand, the above Masaki earthquakes which had occurred in the pattern of earthquake swarm mainly during May～October 1913 were followed by a series of eruptions of Takatiho-mine on November 8, December 9, 1913 and January 8, 1914.

The 1961 Iimori-yama earthquake swarm was also followed by a series

12) Y. SATAKE, *loc. cit.*, 4).

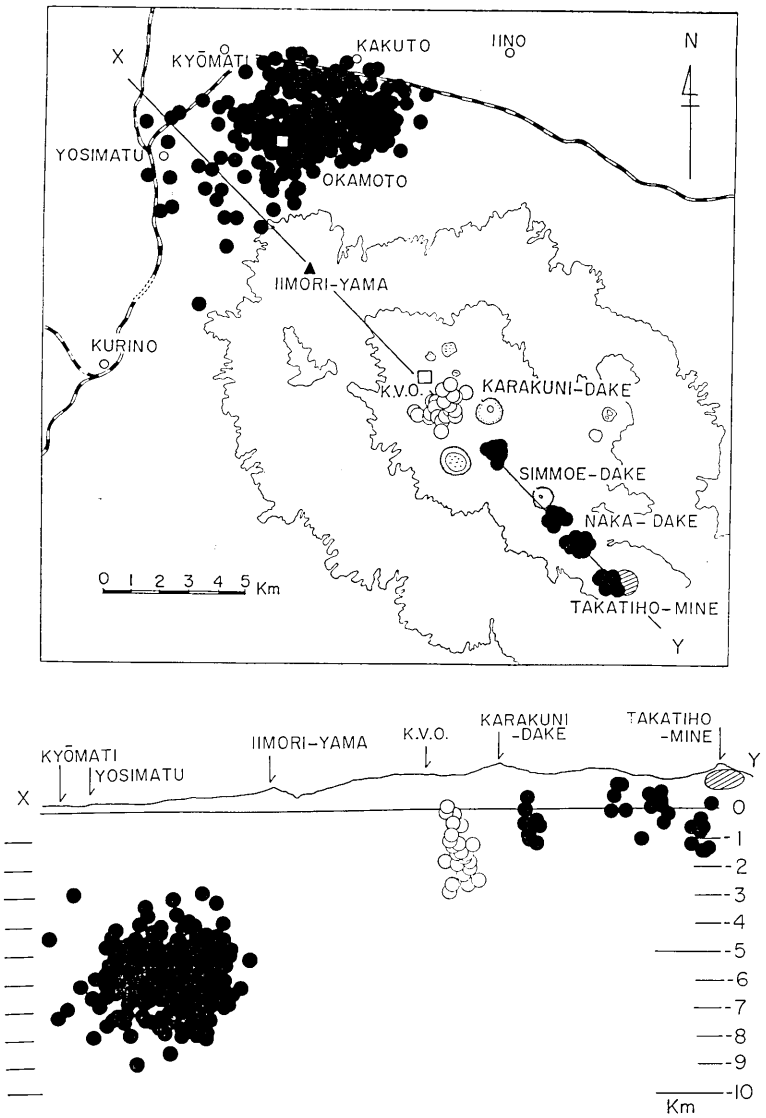


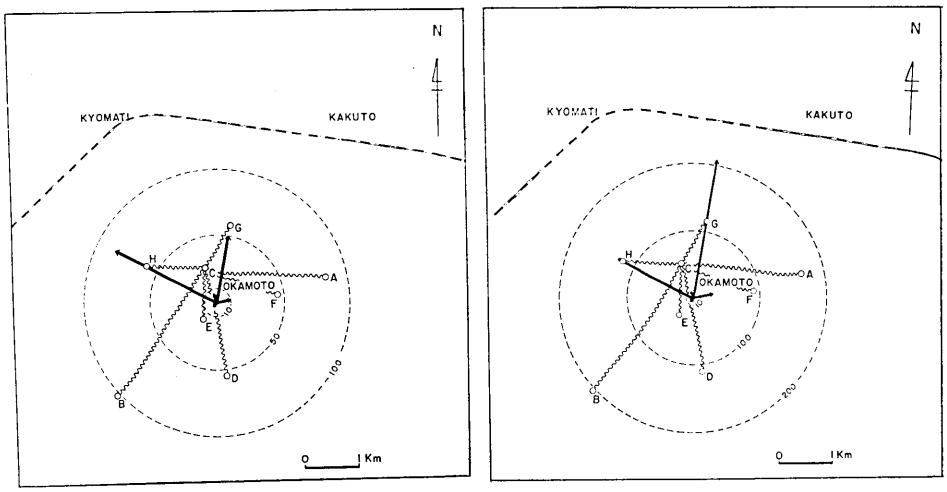
Fig. 9. The hypocentral distributions of a series of the earthquake swarms in the Kirisima volcanoes.

solid circle; the 1968-1969 Ebino earthquake swarm,
the March 1968 Simmoe-dake earthquake swarm,
the March 1969 Naka-dake earthquake swarm,
the Oct.~Dec. 1967 Takatiho-mine earthquake swarm,

hatched area; the Oct.~Dec. 1969 Takatiho-mine earthquake swarm (B type),

open circle; the April 1966 Karakuni-dake earthquake swarm.

of shallow earthquakes at Simmoe-dake and Takatiho-mine, though it was not so remarkable.



(a) (b)

Fig. 10. The frequency distribution of the epicentral directions of the Ebino earthquakes seen from the Okamoto Branch of K.V.O.
(a): the frequency distribution of the epicentral direction during February 28-March 24, 1968.
(b): the frequency distribution of the epicentral direction during March 25-May 7, 1968.

Judging from the above phenomena, it seems that the seismic activity in the Kakuto caldera is closely related with the seismic and volcanic activities of Simmoe-dake and Takatiho-mine.

7. Resumé

The writers reported in the previous papers with respect to the development of the 1968 Ebino earthquake swarm in the Kakuto caldera during the period from February to July of the same year. The present report deals not only with the same problem but also with the unusual seismic activity of the Kirisima volcanoes, which appeared successively soon after the commencement of the 1968 Ebino earthquakes.

In order to make evident whether the 1968–1969 seismic activity of the Kirisima volcanoes was unusual or not, the writers studied the seismic level in the volcanoes during the period from 1964 to 1967.

Judging from the seismic activity of the Kirisima volcanoes since 1964, it will be reasonably to say that the shallow earthquakes of the A and B type, and volcanic tremors not only increased in frequency after March 1968, but also shifted along the Kirisima volcanoes from north-west to south-east.

In reviewing the 1913 and 1961 earthquake swarms in the Kakuto caldera, it seems that the similar shifts of seismic activity occurred in

the Kirisima volcanoes. Based on the development of the phenomena mentioned above, it will be reasonable to assume that the earthquakes originating from the Kakuto caldera and a series of extremely shallow earthquakes originating from volcanic cones of the Kirisima volcanoes are closely connected one with another in their occurrences. It may suggest the mechanism of the earthquakes of the Kirisima volcanoes or the pattern of the stress accumulated in the Kirisima volcanoes or the modes of the stress accumulation and the stress release, both of which depend on the geological and geophysical formation of the Kirisima volcanoes.

In conclusion, the writers wish to express their thanks to Miss T. Utsunomiya, Miss K. Kurosaki and Mrs. T. Kinoshita for their help in the preparation of the manuscript.

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14. 1968-1969 年のえびの地震群及び霧島火山群の地震活動 (第 4 報)

加久藤カルデラより新燃岳，中岳及び高千穂峰への地震活動の移動

地震研究所 水上 武，萩原道徳，山口 勝，小山悦郎，平井かく子

1968 年 2 月初めより加久藤カルデラ内に発生したえびの地震群については同年 7 月までの地震活動の概要，震源分布，初動分布及び霧島火山群に沿う走時曲線等について既に報告した．

本報告は 1968 年 7 月以後 1969 年 12 月末に至るえびの地震群の活動の進展，1968 年 3 月の新燃岳の B 型地震群の活動，1969 年 3 月～12 月に至る中岳，高千穂峰に発生した A 型及び B 型地震群，火山性脈動について記述してある．

1968 年 2 月のえびの地震群の発生以来，予期されていたことではあるが，新燃岳，中岳，高千穂峰へと地震活動が霧島火山群に沿つて北西の加久藤カルデラより順次に南東へ移行した．この現象は，1913 年の加久藤カルデラの地震発生後にも似た現象があるので筆者等が特に注目したものであるが，この現象をやや詳細にするためには，30 km 以上に亘る霧島火山群の各地区の平常時における地震活動のレベルを明らかにすることが先づ必要である．

そのため霧島火山群を西北より東南に次の 4 地域に分けて，それぞれの地域の地震活動を 1964 年 4 月より 1969 年 12 月末に至る期間に亘つて調べた．

1. 加久藤カルデラ地域　A ブロック，
2. 霧島高原地域　B ブロック，
3. 新燃岳地域　C ブロック，
4. 中岳・高千穂峰地域　D ブロック．

1964 年 4 月に霧島火山観測所が設立され，地震観測網が整備されたが，1959 年新燃岳の噴火以来，不充分ではあるが地震観測を実施していたのでその結果をも参照した．

各地域に発生する平常時の地震頻度は 15,000 乃至 30,000 倍の高倍率地震計で観測した結果について，最大振幅 0.02μ 以上の地震を採用すると，

A 地域では　平穏時の月平均頻度約 11～30 個,
B 地域では　〃　〃　約 6～18 個,
C 地域では　〃　〃　約 5～17 個,
D 地域では　〃　〃　約 7～ 8 個であった.

しかるに 1968 年 3 月には新燃岳の地震頻度は月 150 回と著しく増加したがその後平常の状態に戻り，1969 年 3 月には，地震活動は新燃岳の東南の中岳に移行した．さらに同年 10 月から 12 月に亘つて中岳の南東に接し，霧島火山群の南東端に位置する高千穂峰の御鉢火口を中心として 1 日 100 回以上の A 及び B 型地震の発生をみた．高千穂峰付近の平常時の地震数は月数回であるのでそれに比較して地震活動が著しく活発になつたと言わざるを得ない．

以上のように加久藤カルデラに端を発した群発地震が霧島火山群の南東に時と共に活動が移行したことは注目され，霧島火山群の生成に関係する構造と密接な関係を持つことを示すものであろうか．そのため同火山地域に貯えられる地殻の歪は地震となつて発散する機巧に互いに関係を持つのであろうか．等の問題が提起される．

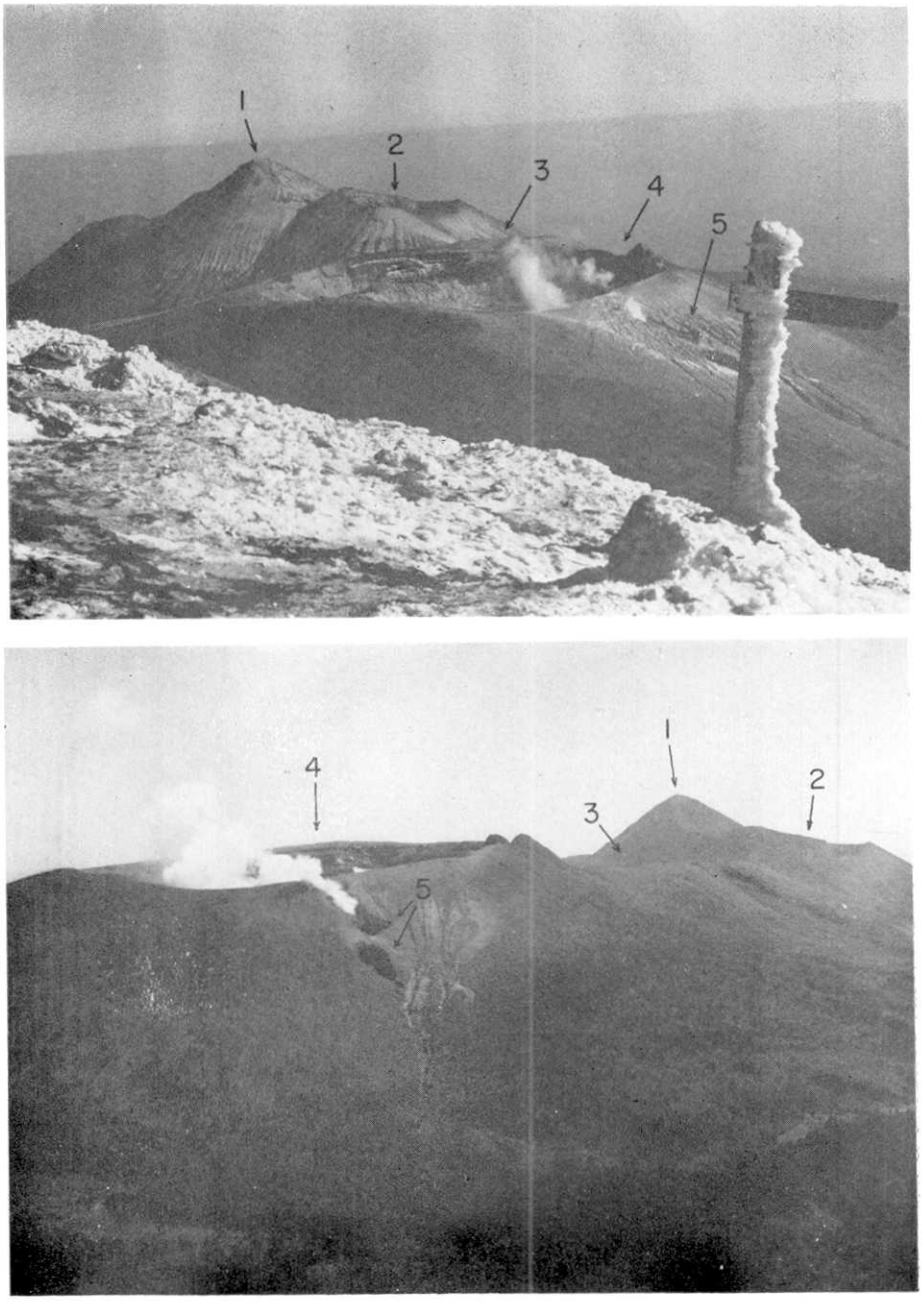

Fig. 11. Takatiho-mine (1), Takatiho-Ohati crater (2), Naka-dake (3), Simmoe-dake (4), and the 1959 craterlets on Simmoe-dake (5).
A series of volcanic cones located at the south-eastern part of the Kirisima volcanoes.

Fig. 12. The Okamoto branch of the Kirisima Volcano Observatory.

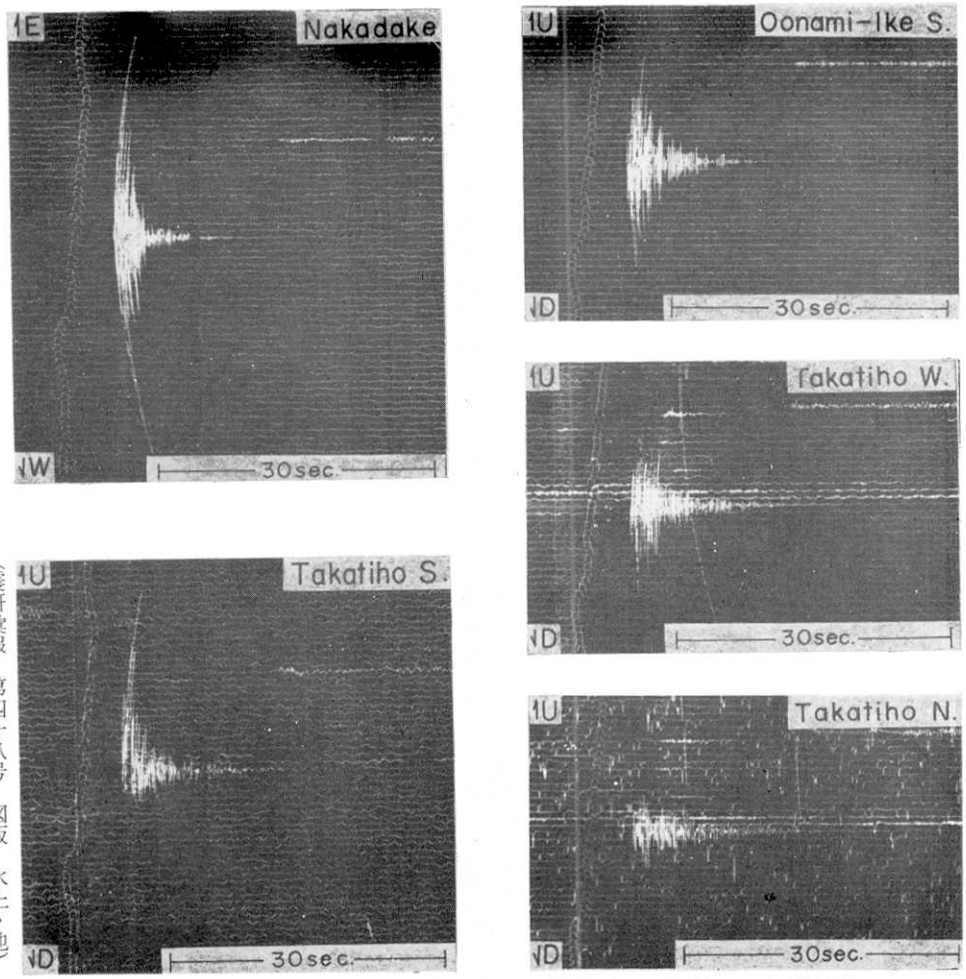

Fig. 13. The Naka-dake earthquake observed at five stations at 9h 23m, on December 9, 1969.

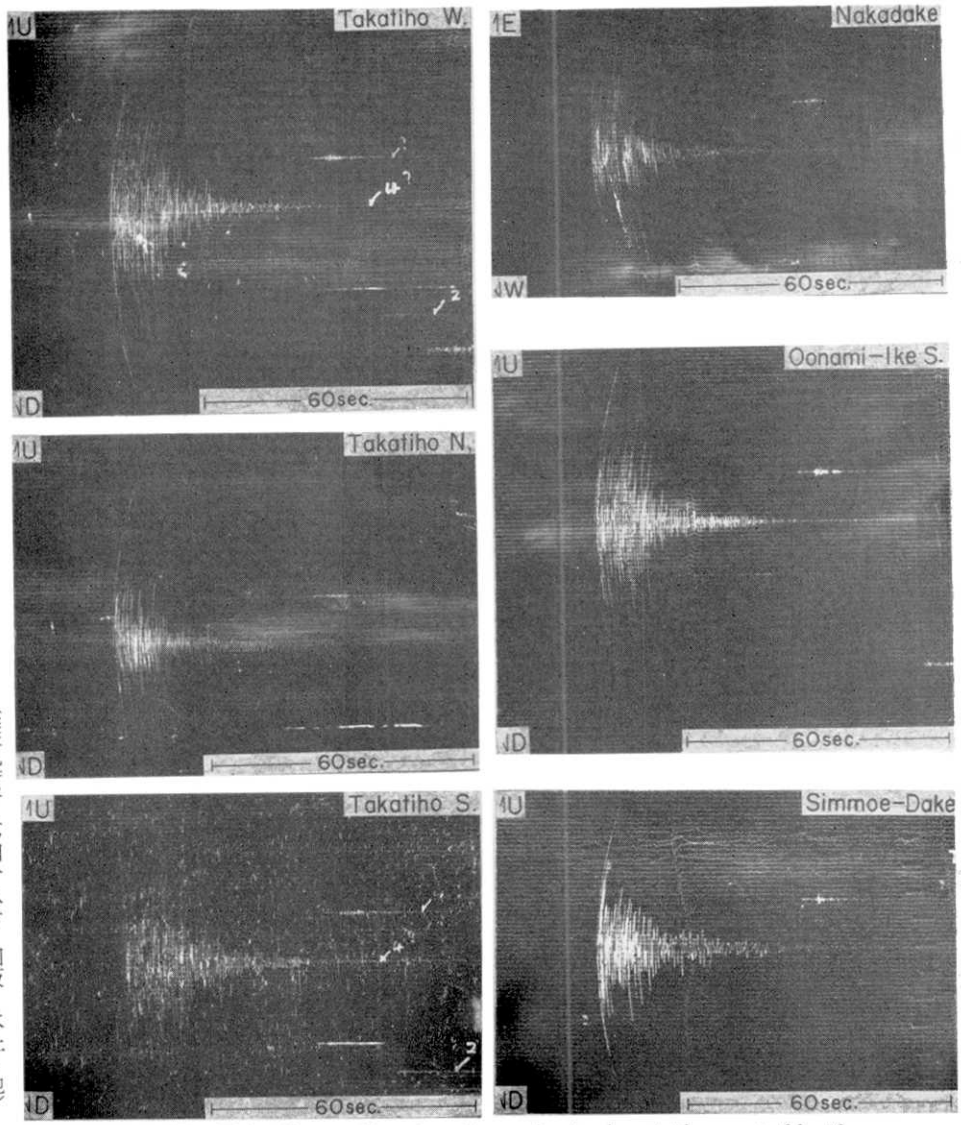

Fig. 14. The Takatiho earthquake observed at six stations, at 0h 48m, on December 2, 1969.

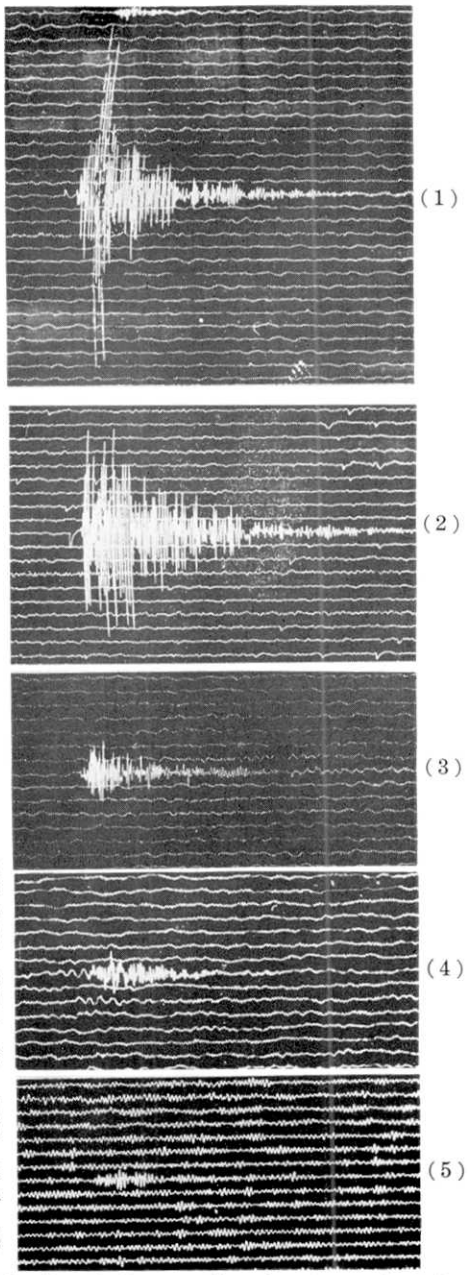

Fig. 15. The Takatiho shallow earthquake observed at five stations, at 4 h 15 m on December 24, 1969.
(1): Takatiho W. (Stn. 12), (2): Takatiho S. (Stn. 14), (3): Takatiho N. (Stn. 13), (4): Naka-dake (Stn. 10), (5): Oonami-ike S. (Stn. 11).

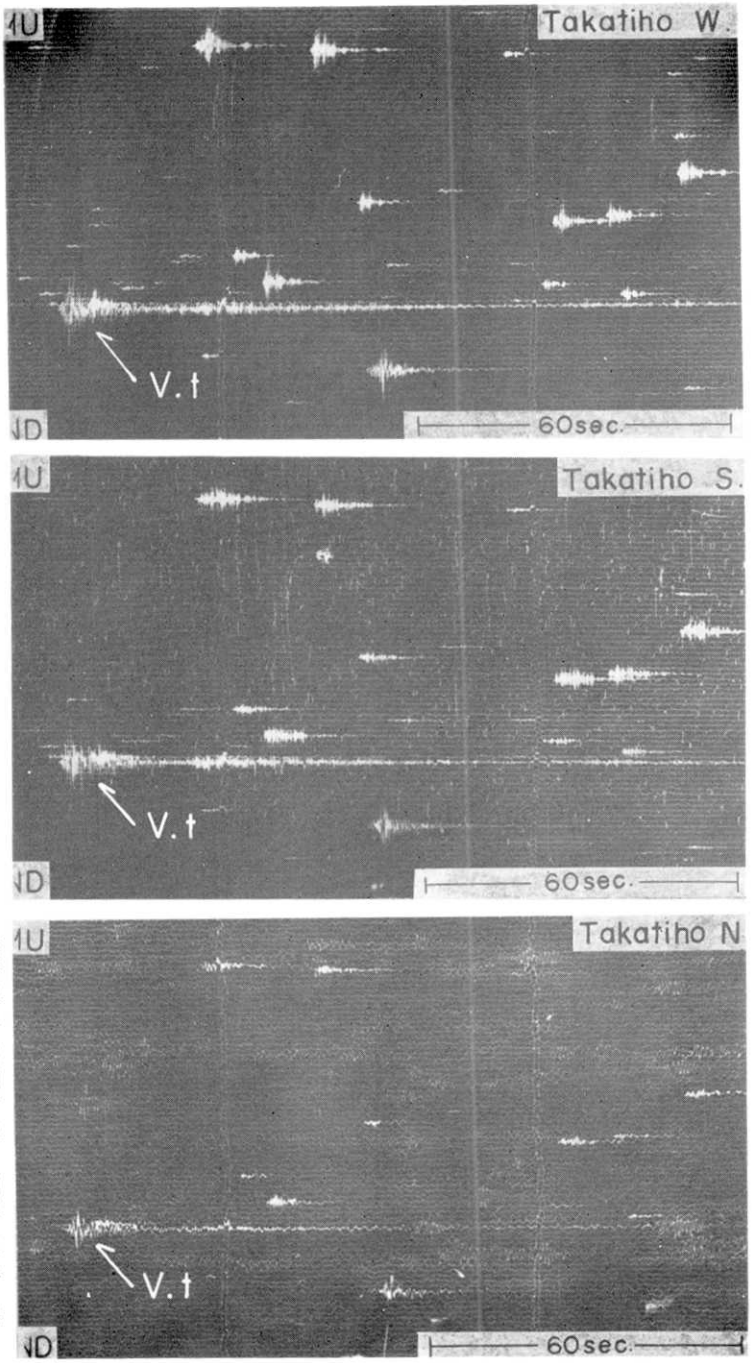

Fig. 16. The Takatiho-mine earthquakes on December 16-17, 1969.
V.t.: volcanic tremor.