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A PROCESS OF MOUNT EREBUS ERUPTION

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Abstract: A program to continuously monitor the seismic activity of Mount Erebus (77°30′S, 167°09′E, 3794 m) in Antarctica and to identify the mechanism of its eruption was begun in December 1980. A video camera for monitoring explosions from the lava lake in the summit crater was installed at the crater rim of Mount Erebus in December 1986.

The video signals were transmitted to Scott Base by radio-telemetry recording with the same timecode as the clock of the seismic network. A strict comparison of the origin times of the explosions and the associated earthquakes was made using both seismic data and video recordings. It becomes clear in all of the explosions from the lava lake that the earthquakes occurred before the explosions; in other words, the explosion occurred as a result of the earthquake.

1. Introduction

Mount Erebus (77°30′S, 167°09′E, 3794 m) located on Ross Island, Antarctica, is the only Antarctic volcano with sustained eruptive activity in the past ten years and more. A program to continuously monitor the seismic activity of Mount Erebus and to investigate the mechanism of its eruption started in December 1980 as an international cooperative program among Japan, the United States and New Zealand (KIENLE *et al.*, 1981; TAKANAMI *et al.*, 1983a, b). This program has proceeded to the "International Mount Erebus Eruption Mechanism Study" between Japan and New Zealand since 1986.

During December 1986, six seismic stations were operated in the Erebus Mountain area. These stations were linked by radio-telemetry to Scott Base of New Zealand, at 77°51′03″S, 166°45′45″E, about 38 km south of the Erebus Summit.

The space-time behavior of earthquakes occurring in and around Mount Erebus in 1980–1986 has been studied previously by KIENLE *et al.* (1981, 1982), TAKANAMI *et al.* (1983a, b), SHIBUYA *et al.* (1983), UEKI *et al.* (1984), KAMINUMA *et al.* (1986, 1987) and KAMINUMA (1987). A new volcanic activity began on 13 September 1984 and continued until December. A remarkable decrease of the background seismicity was recognized after the September 1984 activity (KAMINUMA, 1987).

A video camera for monitoring eruptions was installed at the crater rim of Mount Erebus in December 1986. The relation between the eruptions of Mount Erebus and associated earthquakes is discussed in this paper.

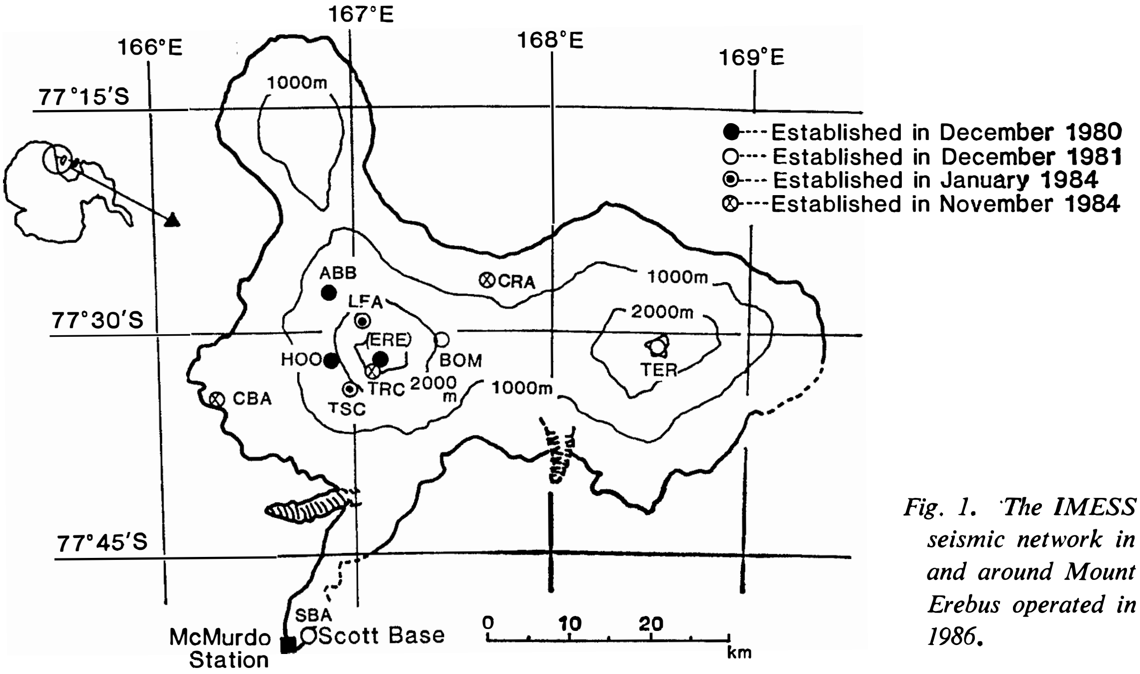

Fig. 1. The IMESS seismic network in and around Mount Erebus operated in 1986.

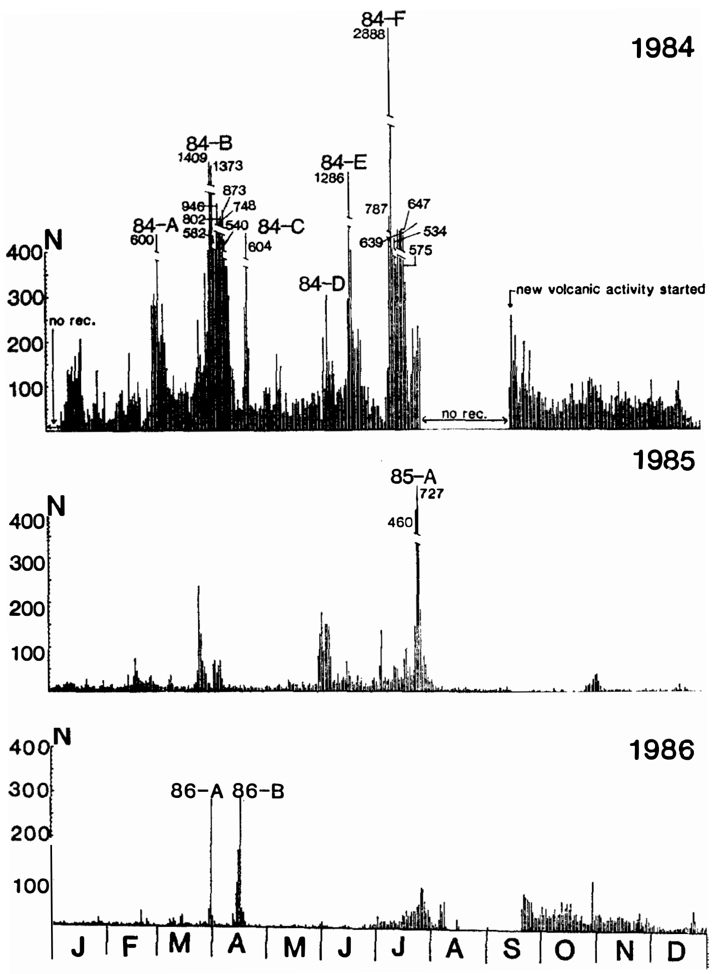

Fig. 2. Daily number of earthquakes in and around Mount Erebus counted at Hoopers Shoulder Station in 1984, 1985 and 1986.

2. Seismicity

The seismic network is given in Fig. 1. The system and characteristics of the network are the same as shown by KIENLE *et al.* (1981). The number of stations of the network was increased from three to ten during the three years of 1982–1984. The daily earthquake counts at Hoopers Shoulder Station (HOO) in 1984–1986 are given in Fig. 2. The threshold of counting is the same as in the previous papers (KAMINUMA, 1987).

The average daily number of earthquakes from January to July in 1984 was 146 and six earthquake swarms were reported during the period. The new volcanic activity started on 13 September 1984 and continued until December. After the 1984 activity, the daily earthquake counts decreased to be 23 and 18 in 1985 and 1986. Only one earthquake swarm occurred in 1985 and two swarms in 1986.

Figure 3 denotes the locations of earthquake hypocenters for the period from 13 September 1984 to December 1986. Almost all earthquakes in Fig. 3 clustered near the summit within the 4 km circle at depths of 2 to 8 km. However, the earthquakes in 1982–1984, before the September 1984 activity, were located throughout the Erebus Mountain area and Ross Island (KAMINUMA, 1987).

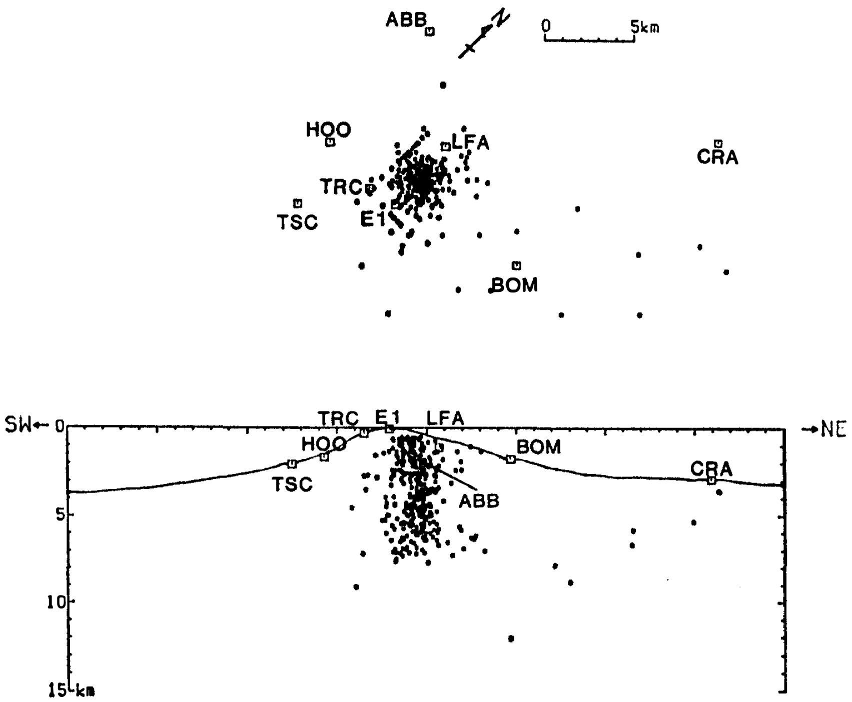

Fig. 3. Hypocenter locations of earthquakes recorded during the period from 13 September 1984 to December 1986.

3. Video Camera Recordings

A video camera for monitoring eruptions was installed at the crater rim of Mount Erebus in December 1986. The video signals were transmitted to Scott Base by radio-telemetry recording with the same clock as that of the seismic network. The timecode was recorded with the accuracy of 10 ms, but the exact time of explosion was determined with the accuracy of 100 ms on the video display of the digital timecode.

The main crater of Mount Erebus measures 500 to 600 m in diameter and is approximately 160 m deep. The elevation of the main crater rim ranges from 3720 to 3794 m. An inner crater approximately 250 m across and 100 m deep is situated at the northern end of the main crater. A lava lake was present in the inner crater for more than ten years, 1972–1984. In October 1984, it was recognized by the observation from the airplane that the lava lake disappeared after the September 1984 activity. An oval lava lake appeared again in the inner crater since December 1985. During the 1986/87 Antarctic field season, its diameter was about 30 m.

The monitoring of explosions by using the video camera was started on 16 December 1986 and continued for two weeks. Both the visual data of explosions and the seismic data were obtained during the period. The features of explosions were very similar to those of the last few years reported by KYLE and OTWAY (1982). The explosions occurred frequently from the lava lake, and a few explosions from active vents were located around the lava lake.

It is observed by the video camera recording that most of explosions with clear seismic events occurred from the lava lake. The explosions from the active vents were the so-called "gas jetting eruption" type and were recorded only at the summit station. These explosions seemed to be very weak events seismically even though visually big eruptions.

In the explosions from the lava lake the following three types were recognized based on the intensity of explosions and the volume of ejecta.

(1) Strong explosions with a large volume of ash and bomb.

(2) Medium explosions with incandescent bombs, but no ash.

(3) Weak explosions with an incandescent bubble dome on the lava lake surface.

More than fifty percent of explosions from the lava lake are of the third type. Twin bubble domes of the third type are observed sometimes. Sketches of the strong ex-

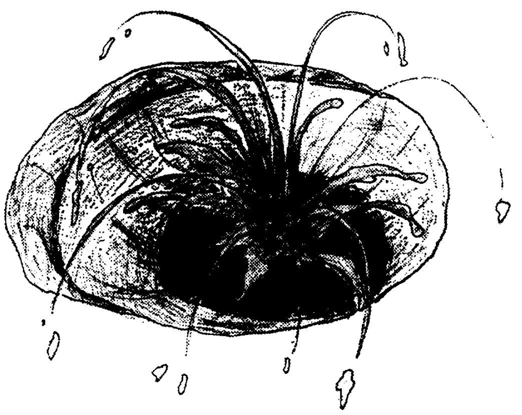

Fig. 4. A sketch of the strong explosion type from the lava lake.

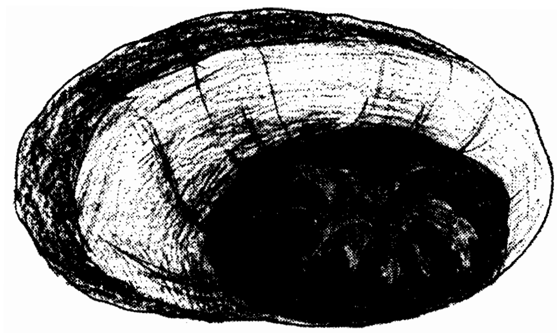

Fig. 5. A sketch of the weak explosion type from the lava lake.

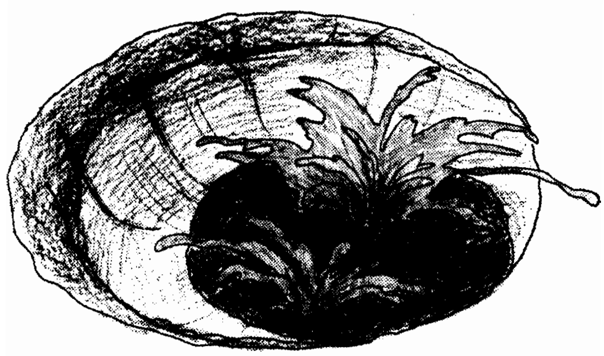

Fig. 6. A sketch of the twin bubble explosion from the lava lake.

plosion and weak explosion types, and twin bubble domes are illustrated in Figs. 4, 5 and 6.

4. Strong Explosions

An example of the seismogram of the earthquake accompanied with a strong explosion type is given in Fig. 7. The seismogram at the summit station (ERE in Fig. 1)

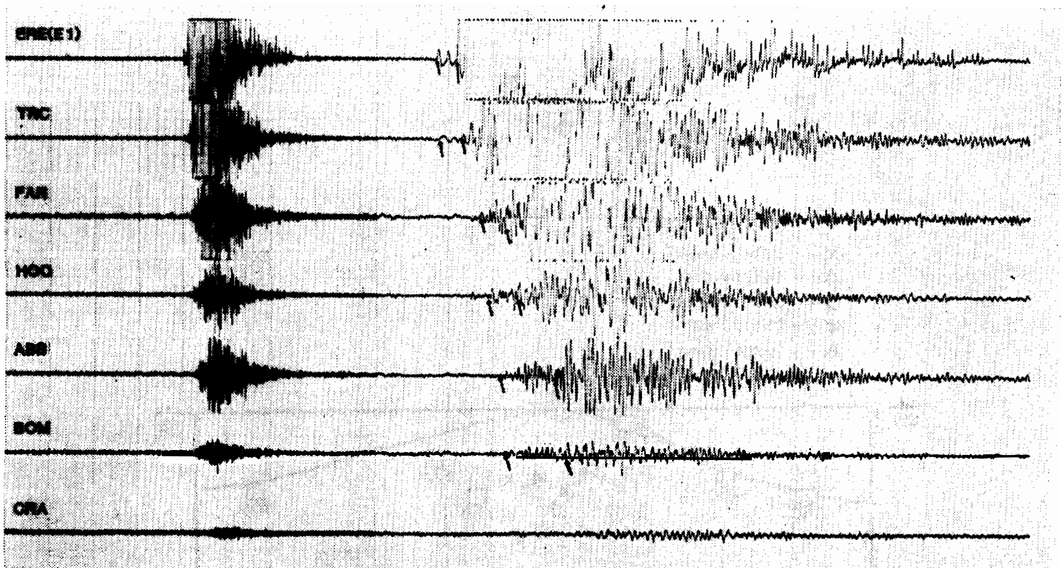

Fig. 7. A seismogram of the strong explosion.

is characterized by the sharp initial phase with clear forerunner phases. Ten events of the strong explosions were recorded during the two weeks of the video camera operating. Locations of five events out of the ten were determined as shown in Fig. 8. The two phases shown with arrows in Fig. 7 were used for determing the earthquake locations. The focuses of the first phases are shifted to those of the second ones as shown with arrows in Fig. 8. The second focuses are shallower than the first ones suggesting the focus of the events ascending.

The origin times of the first and second events, and those of accompanied explosions determined on the video display are given in Table 1. The origin times of the first and second events are earlier than those of the explosions. It is clear that the earthquakes occurred about 1.2–1.9 s before the explosions occurred.

According to the above facts, a process of the explosion is estimated as follows:

(1) A gas bubble started to rise and a shock occurred due to the bubble formation.

(2) The second event occurred due to the bubble ascending through the blocked-up vent.

(3) An explosion is triggered by the bubble.

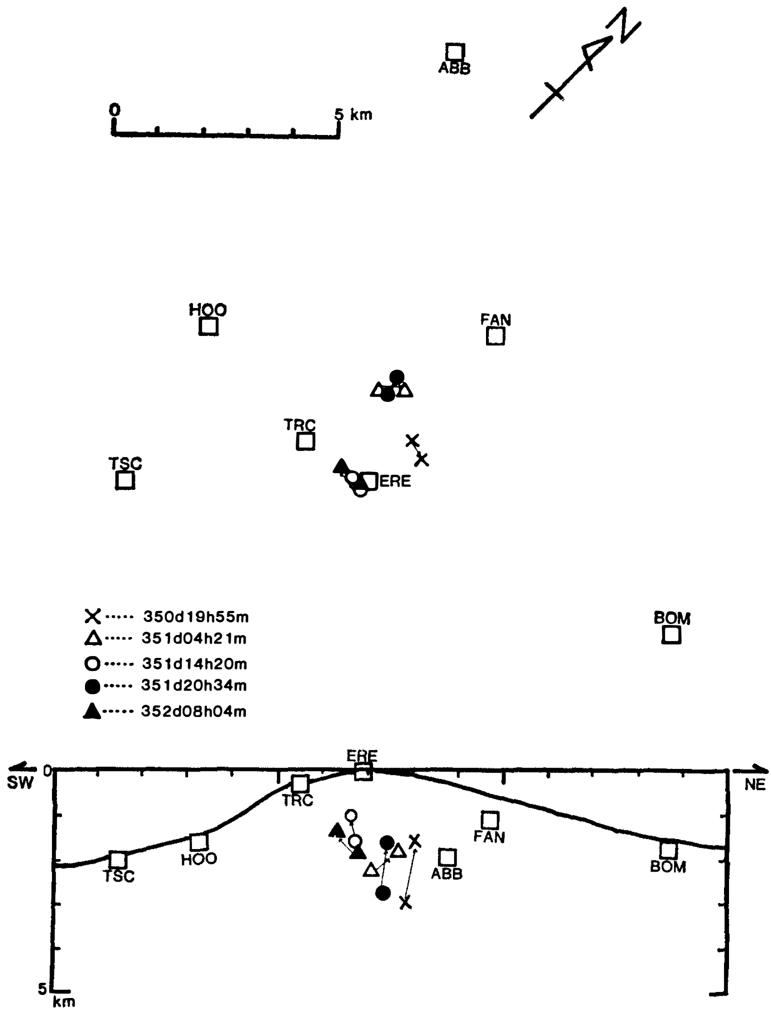

Fig. 8. Hypocenters of earthquakes accompanied with strong explosions.

Table 1. Origin times of earthquakes and accompanied explosions.

Strong explosion

Day	The first event / The second event (*A*) h m s	Explosions (*B*) h m s	Difference (*A*−*B*)
350	19 55 44.53	19 55 45.72	−1.19
	45.59		−0.13
351	04 21 08.25	04 21 09.52	−1.27
	08.93		−0.59
351	14 20 54.60	14 20 56.28	−1.68
	56.16		−0.12
351	20 34 34.37	20 34 36.20	−1.83
	35.45		−0.75
352	08 04 49.00	08 04 50.87	−1.87
	50.66		−0.21

Medium and weak explosion

Day	The first event / The second event (*A*) h m s	Explosions (*B*) h m s	Difference (*A*−*B*)
362	09 43 00.54	09 43 02.53	−1.99
	02.19		−0.34
366	08 50 17.08	08 50 19.57	−2.50
	18.31		−1.26

5. Medium Explosions and Weak Explosions

Figure 9 shows the seismogram of the earthquake accompanied by a medium explosion which occurred on the day 362. This event was well recorded at six stations, but no distinct initial phases were recorded at Crash Site station. Figure 10 shows the seismogram of the earthquake accompanied by a weak explosion which occurred on the day 366 (Jan. 1, 1987). The top line of the seismogram gives the infrasonogram of which sensor was installed near the summit seismic station, 500 m south of the lava lake. Before the shock wave of the explosion arrived at the summit station, the seismic wave arrived. The magnification of trace amplitude of seismograms in Figs. 9 and 10 is the same as that in Fig. 7. More than 80% of all explosions were medium and weak explosions. However, seismic energy of each explosion is not so large as to be recorded at more than five stations for determining their locations. Focuses of only two earthquakes were determined using the arrival times of the first and second clear phases. No clear focus movement from the lower part to the upper part was recognized for the earthquake accompanied with the medium and weak type explosions as shown in Fig. 11.

As shown in Table 1, the origin times of the first and second phase events are also earlier than those of accompanying explosions. In the case of the medium and weak explosion types, the earthquakes occurred about 2.0–2.5 s before the explosions occurred.

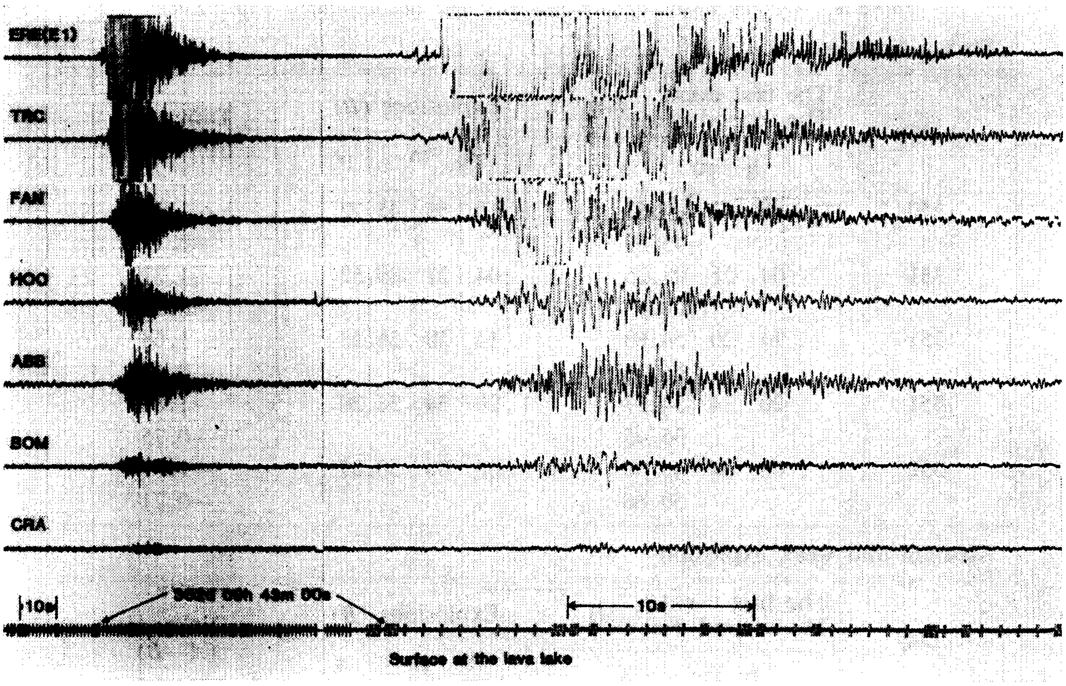

Fig. 9. A seismogram of the medium explosion.

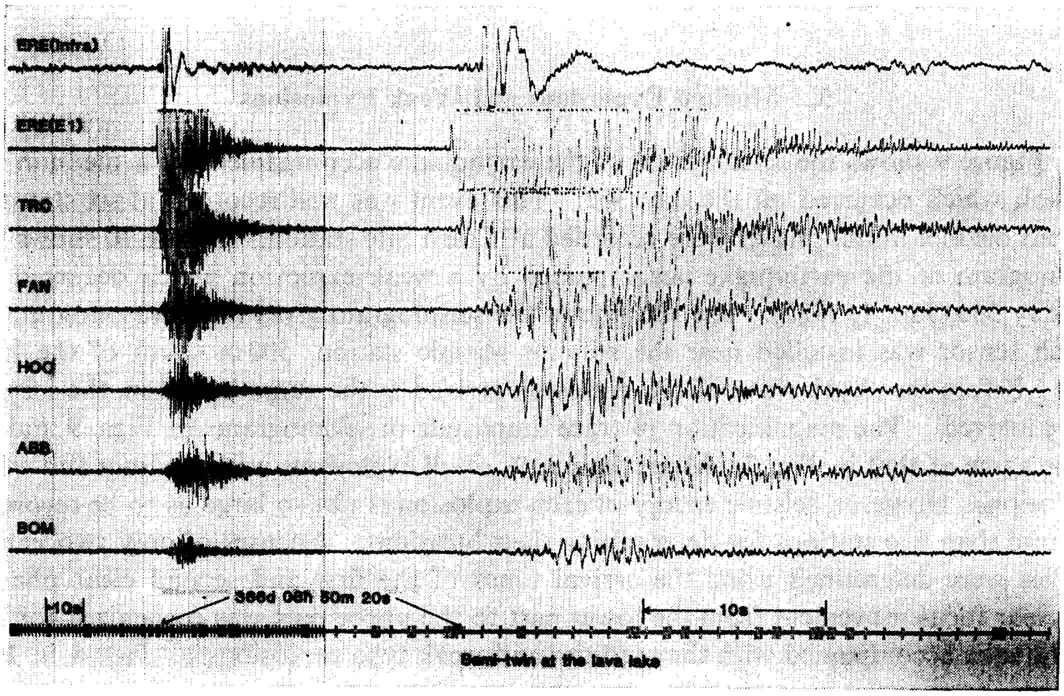

Fig. 10. A seismogram of the weak explosion.

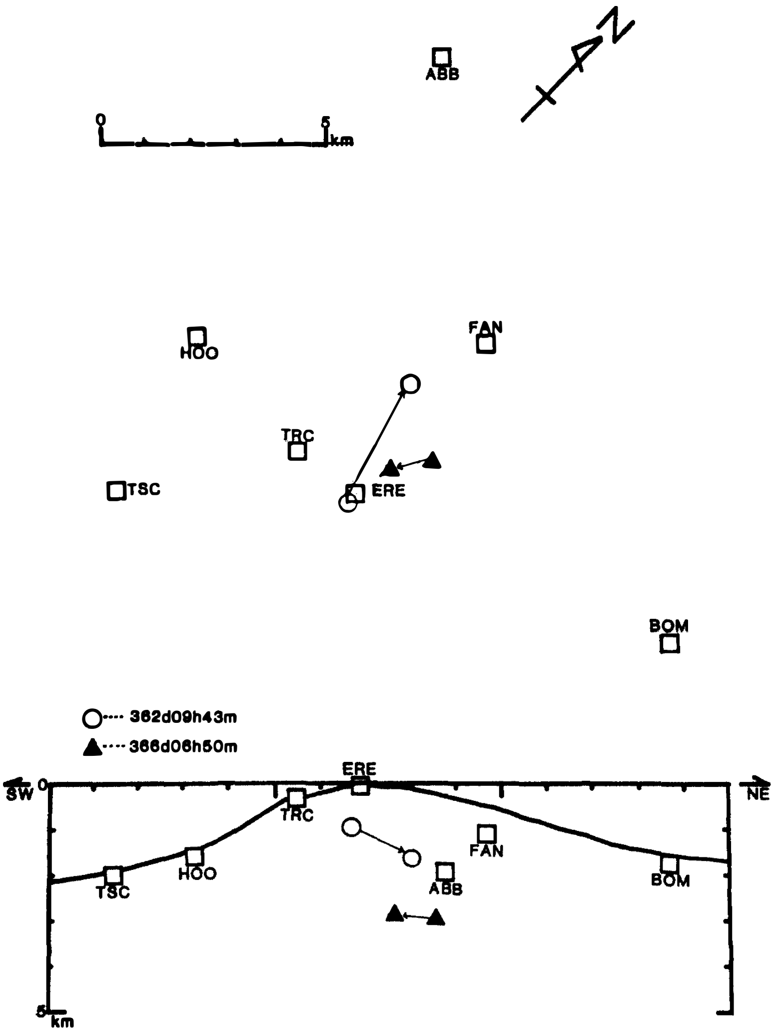

Fig. 11. Hypocenters of earthquakes accompanied with medium and weak explosions.

6. Discussion

Three types are recognized in the explosions from the lava lake in the Erebus summit using the video recording monitor of explosions. All these explosions were accompanied with earthquakes. The earthquakes are considered have been caused/ triggered by the shock of explosion, and are generally called "explosion earthquakes".

A close comparison of the origin times of the explosion and the associated earthquake was made. It becomes clear in all of the three type explosions that the earthquakes occurred about 1.2–2.5 s before the explosions occurred. The explosion occurred as a result of the earthquake, in other words, the earthquakes triggered the explosion.

In the case of the strong explosions, two clear focuses of the events were determined using the initial phases and the following clear phases of the seismogram of the earthquakes which were accompanied with the explosions. The first events and the second events occurred about 1.2–1.9 s and 0.1–0.7 s before the explosion occurred. The focuses of the second events are shallower than the first ones. This suggests that something was coming from the focus of the earthquake to the lava lake. This something is estimated to be a bubble in this paper. The earthquake triggered the second event and the explosion in this case.

In the case of the medium and weak explosions, no clear focus shift from the lower part to the upper part is recognized as in the case of the strong explosion. However, it is also clear that the origin time of the initial phase event is 2.0–2.5 s earlier than that of the explosion. The earthquakes triggered the explosion, too.

In both cases, the exact time difference between the origin times of the earthquake and the explosion depended on the structure model used for the focus determination. We are now studying the Erebus structure model using the data of the seismic explosion experiments which were carried out in December 1984. A detailed discussion will be made using a new structure model in the near future.

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