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SEISMIC ACTIVITY OF MOUNT EREBUS IN 1981–1988

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Abstract: Seismic observations by radio-telemetry has continued in the summit area and on the slopes of Erebus Volcano (77°37′S, 167°09′E, 3794 m) in Ross Island, Antarctica since 1980. Remarkable changes of seismic activity were recognized before and after the new phase of volcanic activity in September 1984. The activity had been increasing from the early stage of the observations until the new phase in 1984. It then decreased quickly after the activity ended in December 1984. The daily number of earthquakes was over 150 in 1984 and less than 20 in 1988. The volcanic activity of Mount Erebus seemed to become quiet after the 1984 activity. The seismic activities of Mount Erebus in 1981–1988 are divided into the following four stages; 1) Normal High Activity, 2) Preceding the New Phase, 3) New Phase in Activity and 4) Low Seismic Activity.

1. Introduction

The seismic network of Mount Erebus (77°37′S, 167°09′E, 3794 m) in Ross Island, Antarctica was established in December 1980 by IMESS (International Mount Erebus Seismic Study) of Japan, New Zealand and the United States, and the observations by the network were continued until December 1986 (KIENLE *et al.*, 1981; TAKANAMI *et al.*, 1983a, b; KAMINUMA, 1987). The network has now been taken over by IMEEMS (International Mount Erebus Eruption Mechanism Study) of New Zealand and Japan, but the number of stations has been reduced from ten to six since January 1987 (KAMINUMA *et al.*, 1987). The goal of IMEEMS is to study the eruption mechanism and the seismic activity of Mount Erebus.

The seismic network of Mount Erebus in 1988 shown in Fig. 1, and was the same in the previous year; E1 and TRC in the summit area, HOO, ABB and BOM on the flanks and TER at the summit of Mount Terror. The seismic signals were transmitted to Scott Base of New Zealand by radio-telemetry, and recorded on a 14-channel FM data recorder and a one-channel chart recorder for monitoring.

A new phase in activity started on 13 September 1984 with a number of large explosions and lasted until the end of the year. A remarkable change of seismicity around Mount Erebus was recognized before and after the activity (KAMINUMA, 1987). The seismic activity became very low after the 1984 activity and the trend of the low seismic activity has continued to 1988.

A TV camera has been installed at the rim of the main crater of Mount Erebus for observing eruptions from the lava lake since December 1986. The camera and TV transmitter were operated with solar power between spring (September) and autumn

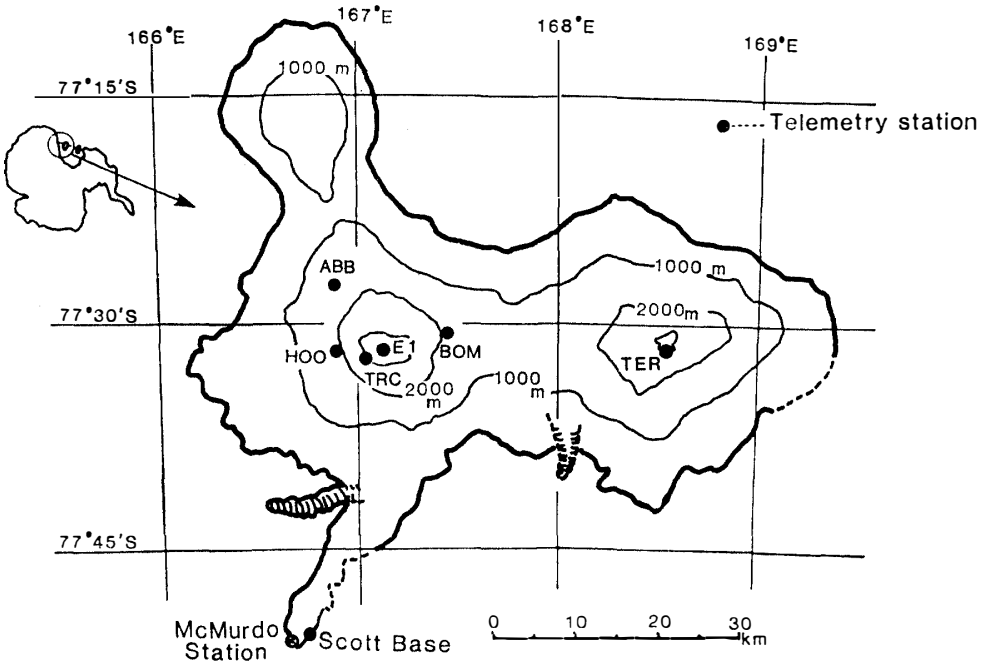

Fig. 1. The seismic network of Mount Erebus in 1988. The abbreviations of the stations are as follows: ABB (Abbott Peak), BOM (Bomb), E1 (The Erebus summit area), HOO (Hoopers Shoulder), TER (Mount Terror) and TRC (Truncated Cone).

(April) each year, but in 1987 and 1988 corrosion of the camera window by volcanic gas obscured the pictures between September and December.

The seismic activity of Mount Erebus in 1988 is summarized and compared with that in 1980–1987 in this paper.

2. Lava Lake and Explosion

A distinctive feature of a volcano of Mount Erebus is that a lava lake has been present in the inner crater at the summit for more than ten years, 1972–1984. A new activity started on 13 September 1984 with a number of large explosions and lasted until the end of the year. The lava lake disappeared after this September 1984 activity. By December 1985, an oval lava lake reappeared in the inner crater (KAMINUMA *et al.*, 1988). The surface of the lava lake was mostly solidified in December 1988. However, explosions of molten lava continued from four vents in the solid crust in 1988.

The lava lake measured 20 m in diameter when it was discovered in 1972 (GIGGENBACH *et al.*, 1973). Its diameter expanded to 100×60 m in December 1983. Strombolian type explosions occurred frequently from the lava lake and active vents beside the lava lake in 1981–1983. The number of explosions per day counted by the scientists who stayed at the summit during the austral summer field season ranged from 2 to 10. During the 1984 activity, up to 20 per day were often counted (KAMINUMA, 1987).

The central cone of Mount Erebus was covered with volcanic ejecta such as ash and bomb during the new activity which started on 13 September 1984, and the white

snow on the cone changed to gray. In normal times, very little ejecta is thrown outside the crater rim.

A TV camera for monitoring eruptions was installed at the crater rim of Mount Erebus in December 1986. The video signals were continuously transmitted to Scott Base of New Zealand by radio-telemetry, and recorded on the video tape with the same clock as that of the seismic network. Three types of explosions accompanied by explosion earthquakes were recognized from the video recordings. All three types of explosion earthquakes were sometimes preceded by premonitory earthquakes occurring 1.2–2.5 s or even earlier before the explosive eruptions occurred (KAMINUMA *et al.*, 1988; DIBBLE *et al.*, 1984, 1988).

In December 1988, the surface of the lava lake had a solid crust except on four vents from which explosions of molten lava occurred at average intervals of several days. When the lava lake crusted all over, the volcanic activity of Mount Erebus seemed to come to the end of a cycle of activity.

3. The 1988 Activity

The daily number of earthquakes counted at TRC, 2.3 km southwest from the lava lake in the inner crater, is shown in Fig. 2. The daily numbers until 1986 in our previous papers of the Erebus seismic studies were counted at HOO (*e.g.*, KAMINUMA *et al.*, 1986, 1987; KAMINUMA, 1987). However, the recordings from HOO became intermittent during 1987 because of electric power trouble, and the daily numbers at TRC were estimated to be about four times larger than those at HOO (KAMINUMA and MURAKAMI, 1989). A reduced scale is given for HOO in the right side axis of Fig. 2 for easy comparison with the figures in the previous papers.

The average daily counts at TRC in 1988 are 15, then the reduced counts at HOO become 4. This value is lower than that of the previous years (KAMINUMA, 1987; KAMINUMA and MURAKAMI, 1989). There were several earthquake swarms which were defined by UEKI *et al.* (1984) and BABA *et al.* (1985) in 1983 and 1984. Not only the number of earthquake swarms but also the scale of each earthquake activity, such as the total number of earthquakes, and the duration of the activities, decreased after

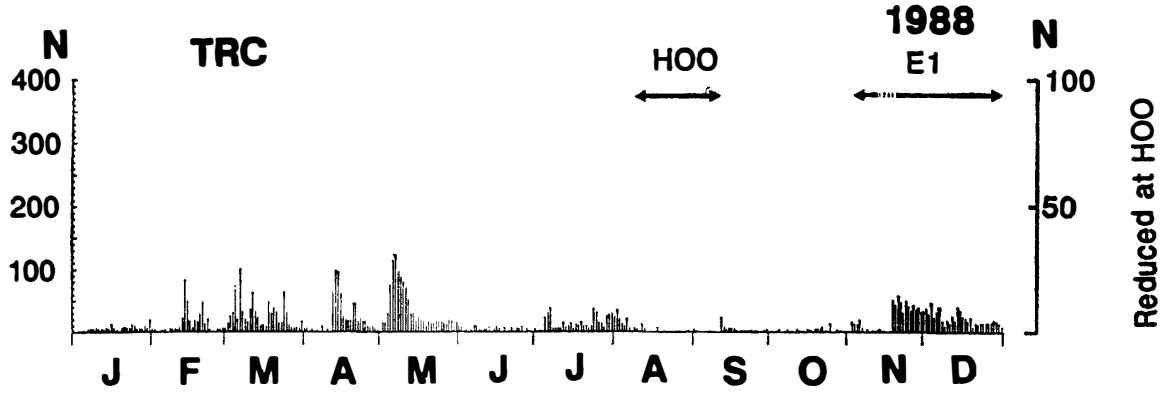

Fig. 2. The daily number of earthquakes counted at TRC in 1988. In the periods indicated with two bars, the numbers were counted at Hoopers Shoulder (HOO) and E One (E1) stations.

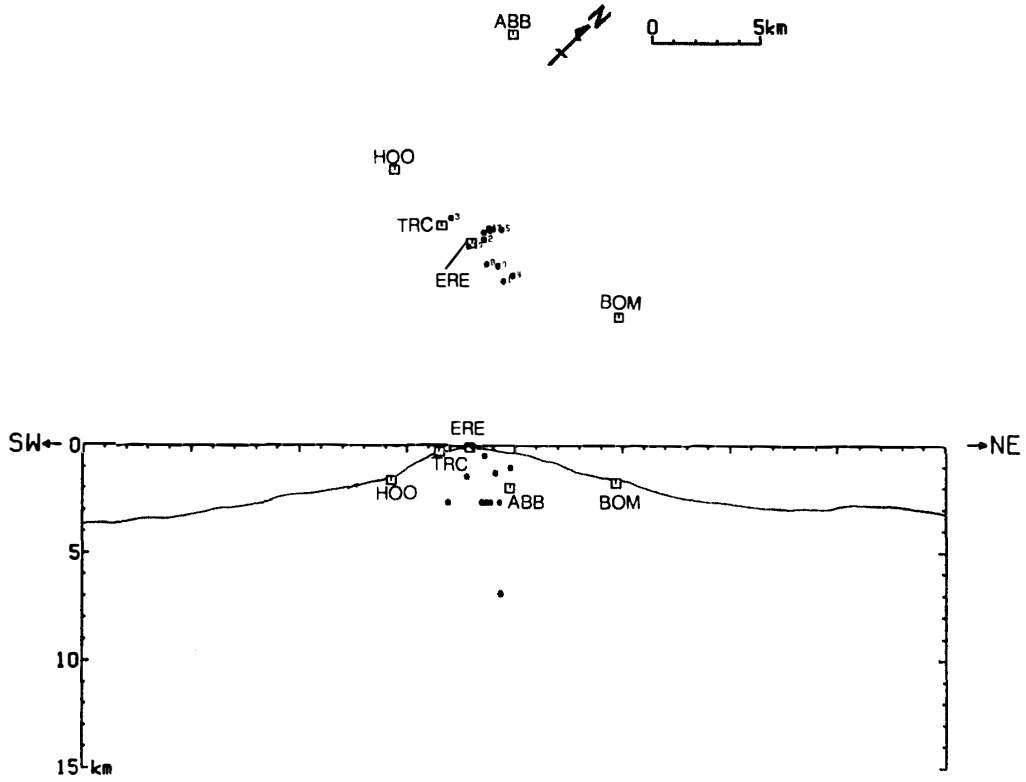

Fig. 3. The hypocenter distribution of earthquakes in 1988. The "ERE" is the same location as E1 in Fig. 1.

the 1984 activity. Only a few earthquake swarms were recorded in 1985 and 1986 and a swarm-like activity was recorded in 1987, but no earthquake swarms were recognized in 1988 (see in Fig. 2). The trend of low seismic activity since 1985 also continued into 1988.

The locations of some tens of earthquakes had been determined every year, but in 1988 locations of only 12 earthquakes have been determined. This very small number of located earthquakes was partly due to the short period when more than two stations (TRC and E1) were operating well. As shown by hypocenter distributions in Fig. 3, most earthquakes are clustered around the summit in the area within 5 km in horizontal and less than 4 km in vertical distances from the summit, nearly the same as the hypocenter distributions in the previous three years (KAMINUMA and MURAKAMI, 1989). After the 1984 volcanic activity, the earthquake locations became more localized around the summit area (KAMINUMA, 1987). The trend of localized hypocenter locations also continued into 1988.

4. Seismic Activity in 1981-1988

Figure 4 shows the mean number of earthquakes per day in each month at HOO from 1981, when the count was started, to 1988. In 1987 and 1988, the numbers were counted at TRC. As mentioned in the previous section, the daily numbers at TRC are about four times larger than those at HOO. A reduced scale is given for HOO in

the right side axis of Fig. 4, same as in Fig. 2. It is clear in the figure that the number of earthquakes was increasing until the 1984 activity occurred. The mean numbers were 64 per month in 1982, 134 in 1983, and 146 in January–July 1984. The number of earthquake swarms in 1982 was three, but increased to seven in 1983 and six during seven months in 1984 (KAMINUMA *et al.*, 1986).

In 1985 and 1986, soon after the activity occurred, the mean numbers were around 20 earthquakes per day. The reduced daily ocunt at HOO in 1987 was 16. It decreased to several earthquakes per day in 1988. The numbers of earthquake swarms in 1985 and 1986 were one and two, respectively, but no earthquake swarms where recorded in 1987 (KAMINUMA and MURAKAMI, 1989), nor in 1988 either. Even fewer eruptions were seen or heard by people on the summit plateau in the austral summer field seasons in 1986/87 and 1987/88, and the seismic activity of Mount Erebus became very low in 1988. Only one eruption every few days were seen on the TV monitor in the 1988/89 field season.

The seismic activity in the period of 1981–1988 are divided into the following four stages:

1) Normal High Activity (–September 1982)

This stage probably started in December 1972 when the lava lake was first recognized. The lava lake was expanding during this stage. The daily counts were 50–100 with one or two earthquake swarms every year and the earthquakes were located throughout Ross Island.

2) Preceding the New Phase (October 1982–August 1984)

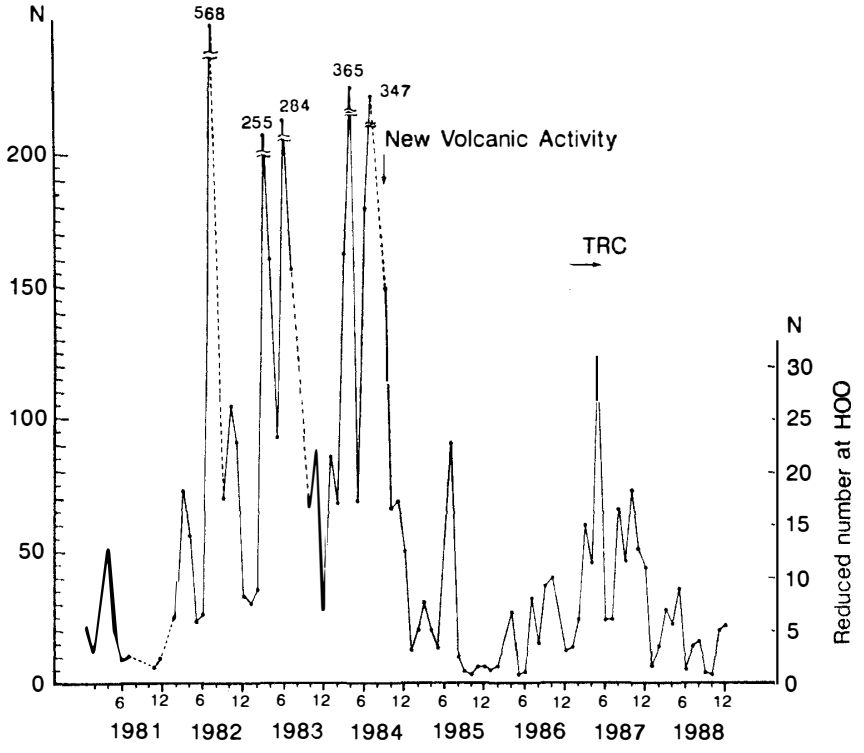

Fig. 4. The mean number of earthquakes per day in each month counted at HOO in 1981–1986 and at TRC in 1987–1988.

This stage might start from the earthquake swarm in October 1982 (KAMINUMA *et al.*, 1985). Energy for the new phase in activity was accumulating and the size of the lava lake was in the maximum in this stage. The seismic activity was very high; the daily counts were over 100 and several earthquake swarms occurred every year. The earthquakes were located throughout Ross Island.

3) New Phase in Activity (September–December 1984)

A lot of big explosions with volcanic ejecta occurred. The lava lake disappeared.

4) Low Seismic Activity (1985–1988)

The lava lake, 20 m in diameter, reappeared in 1985. But most of its surface was solidified in December 1988. The daily earthquake counts were less than 20. The earthquake epicenters were located only in the summit area.

The daily number of explosions for each stage is not discussed because explosions can be recognized only by audiovisual, video and infrasonic observations, which are much less continuous than the seismic observations.

5. Conclusion

The seismic activity of Mount Erebus in 1988 is summarized as follows:

1) The average daily number of earthquakes counted at TRC is 15. The reduced daily counts at HOO is 4 (see Fig. 2).

2) The hypocenter distributions are clustered around the summit area (see Fig. 3).

3) No earthquake swarms are recorded during 1988 (see Fig. 2).

The seismic activity around Mount Erebus in 1988 was as low as that in the previous three years. The trend of the low seismic activity began after the 1984 volcanic activity.

The seismic activities in 1981–1988, during the period of the IMESS and IMEEMS seismic observations, are divided into the following four stages; 1) Normal High Activity (–September 1982), 2) Premonitory activity to the New Phase (October 1982–August 1984), 3) New Phase in Activity (September–December 1984) and 4) Low Seismic Activity (1985–1988).

The seismic activity of Mount Erebus in 1988 seems to be in the last stage of a series of volcanic activities.

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