SEISMOLOGICAL OBSERVATIONS ON MOUNT EREBUS, ROSS ISLAND, ANTARCTICA, 1980–1981

Tetsuo TAKANAMI,

Research Center for Earthquake Prediction, Faculty of Science, Hokkaido University, Kita-10, Nishi-8, Kita-ku, Sapporo 060

Katsutada KAMINUMA, Kei TERAI

National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173

and

Noboru OSADA

Earthquake Research Institute, University of Tokyo, 1–1, Yayoi 1-chome, Bunkyo-ku, Tokyo 113

Abstract: Mount Erebus (3794 m) on Ross Island is one of active volcanoes in Antarctica. Two high sensitive seismic networks were installed during the 1980–1981 austral summer field season for studying seismicity in Ross Island. The one was a three-station radio telemetry network, and the other was a six-station network with long-life portable data recorders. The latter was installed temporarily around the main crater near the summit from December 20, 1980 to January 6, 1981. In spite of wild and harsh environment for the seismic observations, many volcanic earthquakes were recorded by the seismic networks.

The number of 111 shallow events were located using the data of the above two networks. The hypocenters clustered beneath the summit in a range from near the surface to 6 km. Many events accompanied the explosive eruptions were recorded at summit stations around the main crater.

1. Introduction

Mount Erebus on Ross Island is one of active volcanoes in Antarctica. The main crater at the summit of Mount Erebus is an ellipse, 500 m in diameter east-west and 600 m north-south. The highest point is 3794 m at the southern crater rim. The main crater floor is 100 to 160 m below the rim. The inner crater, which is 200 m in diameter and 100 m deep, is situated at the northern end of the main crater. A lava lake has been located in the inner crater since December 1972 (KYLE *et al.*, 1982). Stromobolian eruptions have occurred around the lava lake.

During November 1974 the joint New Zealand/French expedition visited the summit of Mount Erebus. Temporary seismic observations were carried out around the main crater for the first time (KYLE *et al.*, 1982). Following a preliminary seismic observation in the 1979–1980 field season (KAMINUMA, 1980), a project of International Mount Erebus Seismological Studies (IMESS) was started in cooperation with Japan, New Zealand and the United States from the field season of 1980–1981 to know a detailed and accurate seismic activity of Mount Erebus. A radio-telemetry network with three stations was established in December 1980 (KIENLE *et al.*, 1981; TAKANAMI *et al.*, 1982).

In addition to this network, a six-station seismic network with long-life portable data recorders was also installed in the vicinity of the main crater from December 20, 1980 to January 6, 1981 when the Japanese party had stayed at the summit.

The seismic activity of Mount Erebus is discussed in this paper using the data of both the temporary and telemetry seismological networks.

2. Temporary Wire-telemetry Network

The locations of six temporary seismic stations are shown in Fig. 1. Eight or nine seismological stations on Mount Erebus were occupied from December 23, 1980 to January 6, 1981 as tabulated their locations, elevations and date of installation in Table 1. A velocity-sensitive seismometer with 1 Hz of vertical or horizontal component was installed at each station except Station No. 6. The seismic signals were transmitted through twisted, shielded, teflon covered cables to the Erebus summit hut, which was situated at altitude of 3607 m, about 150 m below the crater rim.

Seismic signals were recorded by two low-speed, direct-recording tape recorders in the summit hut. The data recorders were operated continuously about 20 days with tape speed of 0.24 mm/s. Each data recorder had its own amplifier, filter, and timing system. The time signal generated from the clock was serial time-code at 1 pulse/s. The stability of the quartz of the clock was 5×10^{-7} for a temperature range of 0 to 40°C. The room temperature in the summit hut was 0 to 5°C, mostly within the above tolerable limits. Radio signals of WWV were recorded for time calibration of the timing system. Both signals of serial time-code and of 1 pulse/s markers of WWV were

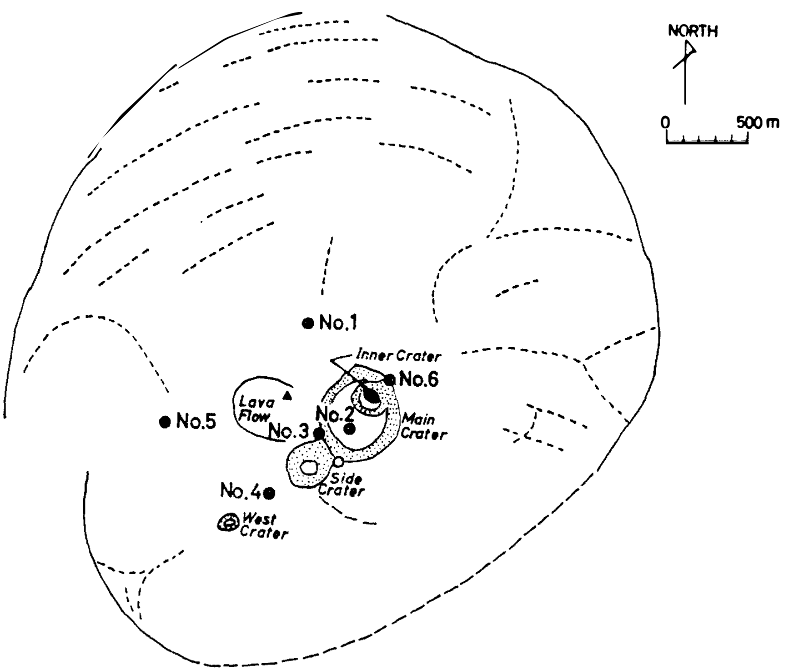

Fig. 1. Locations of seismic stations at the summit of Mount Erebus. Temporary seismic stations (solid circles), the recording site (triangle), and the radio-telemetry summit station (open circle).

Table 1. Seismic station data.

Location	X (m)	Y (m)	Elevation (m)	Observation period
Permanent network				
Summit	0.0	0.0	3780	Dec. 23, 1980 to July 1981
Abbott Peak	−5900.0	7500.0	1793	Dec. 15, 1980 to July 1981
Hoopers Shoulder	−5700.0	−700.0	1900	Dec. 17, 1980 to July 1981
Summit temporary network				
No. 1	27.52	895.51	3625	Dec. 20, 1980 to Jan. 6, 1981
No. 2	−174.84	169.01	3650	Dec. 26, 1980 to Jan. 6, 1981
No. 3	−76.78	169.11	3754	Dec. 20, 1980 to Jan. 6, 1981
No. 4	−462.48	−94.49	3644	Dec. 20, 1980 to Jan. 6, 1981
No. 5	−1158.48	512.51	3462	Dec. 20, 1980 to Jan. 6, 1981
No. 6	380.82	454.11	3767	Dec. 27, 1980 to Jan. 4, 1981

recorded once a day on a compact stereo-cassette tape recorder with a tape speed of 4.76 cm/s. The power of recording systems was supplied by zinc-air batteries.

Station No. 6 was established on the main crater rim. This recording system consisted of a cassette tape recorder, an amplifier, a serial time-code generator, batteries, and a velocity-sensitive seismometer with 2 Hz natural frequency of the vertical component. The serial time-code generator was developed by INATANI and FURUYA (1980) for an Ocean Bottom Seismograph system and had also a sufficient accuracy of 5×10^{-7}. The recording system was housed in a wooden box insulated with styro-foam pads of 1 cm thick, and was buried in warm ground on the crater rim. This system could record seismic signals with frequency ranging from 0.1 to 20.0 Hz with tape speed of 0.1 mm/s. It had a wide dynamic range using three gain tracks of cassette tape. Seismic observation at this station began one week later than at the other stations due to bad weather condition.

3. Number of Earthquakes

Figure 2 shows the daily frequency of earthquakes recorded at three radio-telemetry stations of the Summit, Abbott Peak and Hoopers Shoulder from mid-November 1980 to February 17, 1981. The mean number of events per day was approximately 50 for each station (TAKANAMI *et al.*, 1982).

A high seismicity was recorded at the three stations in late December 1980 and mid-February 1981. Most events in late December seemed to be associated with volcanic surface phenomena such as eruptions, because eruptions were recorded during our stay at the summit from December 20, 1980 to January 9, 1981.

Typical wave forms of the events associated with the volcanic surface phenomena are shown in Fig. 3. The upper part (A) of Fig. 3 shows a record of a high-frequency harmonic type. This had a simple impulsive onset and a long regular coda with a prominent frequency of about 10 Hz, and its duration was sometimes more than 20 s. The harmonic type events were frequently recorded at the summit stations and rarely at the flank stations.

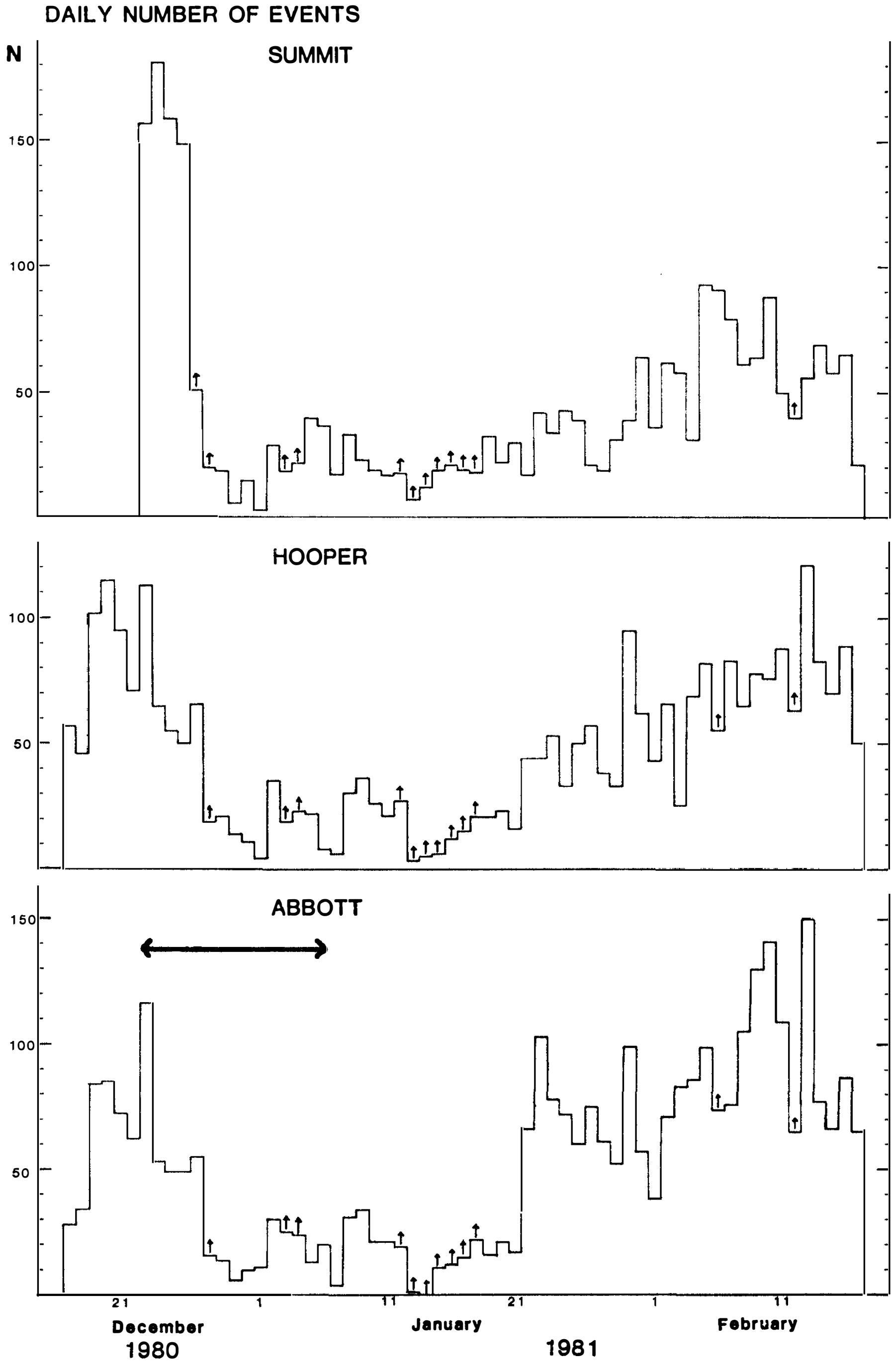

Fig. 2. Daily number of events observed at the Summit, Hoopers Shoulder and Abbott Peak stations. Arrows indicate that the exact number of events could not be counted because of high micro-seismic activity. The period of the temporary seismic network operated is shown with a solid line.

A typical explosive event recorded at all radio-telemetry stations is shown in the lower part (B) of Fig. 3. The signals of the event were passed through seven different bandpass filters. The band-pass filtered seismograms indicated that the event was an impulsive onset at the summit, but an emergent at the flank stations.

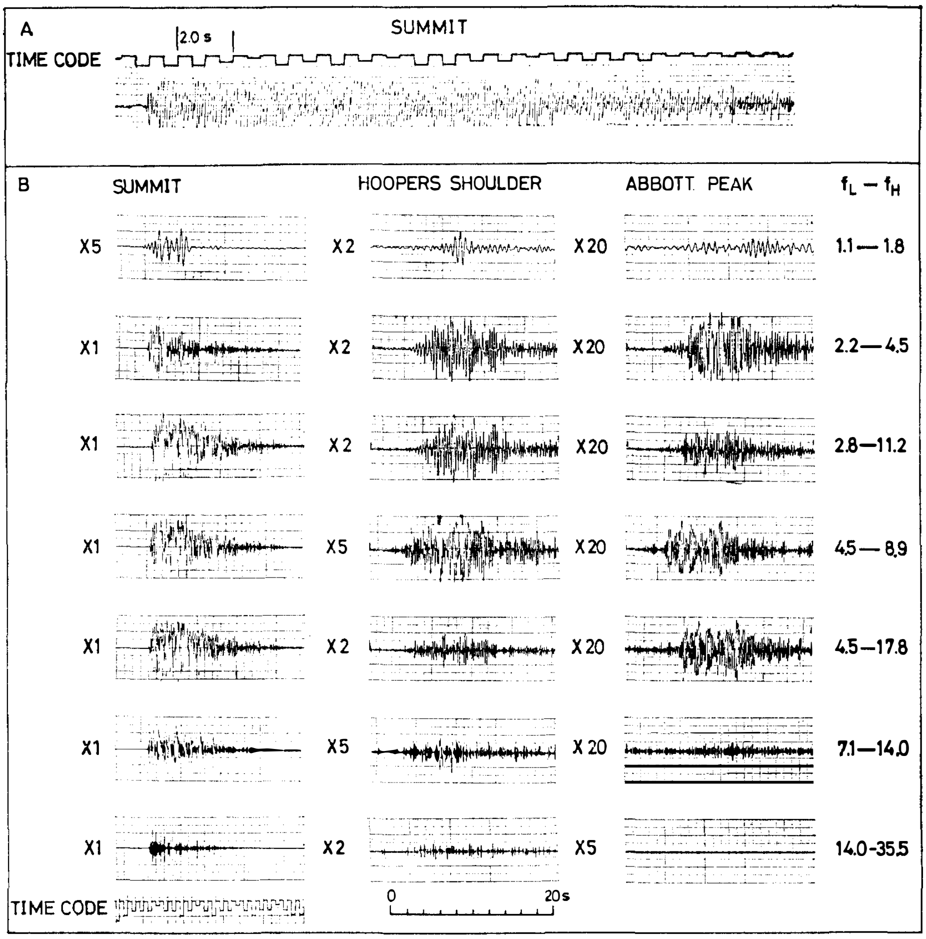

Fig. 3. Typical seismogram of volcanic earthquake of high-frequency harmonic type in the top (A). Band-pass filtered seismograms of an explosion earthquake recorded at the telemetry stations in the bottom (B). Relative magnifications are given in the left side of each seismogram.

4. Location Procedure and Hypocenter Parameters

About 240 events were identified as *P*- and *S*-phases at more than three stations, and their hypocenters were computed. We tentatively assumed a velocity model similar to Kilauea Volcano, Hawaii (CROSSON and KOYANAGI, 1979). The ratio of V_p to V_s was assumed to be 1.78 in all layers. The summit station of the telemetry network was chosen as the coordinate origin. The *X*-axis is along the east-west direction, the *Y*-axis along the north-south, and the *Z*-axis is vertical. Hypocenters were obtained using Geiger's computer location method. To prevent an ill-condition in the least squares method, we used a stepwise multiple regression technique in the location procedure (*e.g.*, DRAPER and SMITH, 1966). If the focal-depth *Z* was determined above the summit, 3794 m in altitude, the depth adjustment term *DZ* was reset to $DZ = -0.5Z$ for the recalculation. The trial hypocenter was assumed to be at an altitude of 3000 m, which resulted in a maximum number of nine iterations for 111 locatable events. The hypocenters of 111 events could be determined out of 240 data sets.

Figures 4–6 show the epicenter locations and vertical profiles of hypocenters along

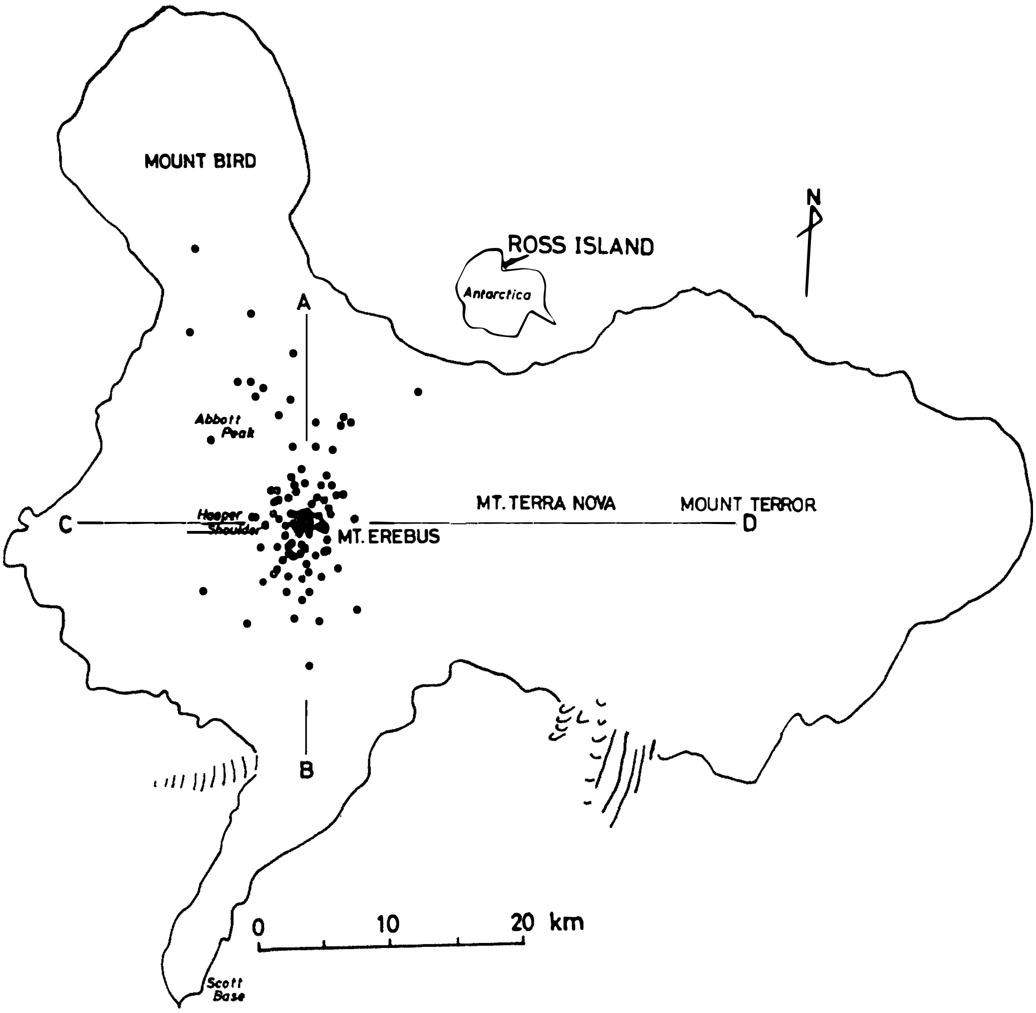

Fig. 4. Epicenters determined by both the radio-telemetry and the temporary networks' data between December 20, 1980 and January 6, 1981.

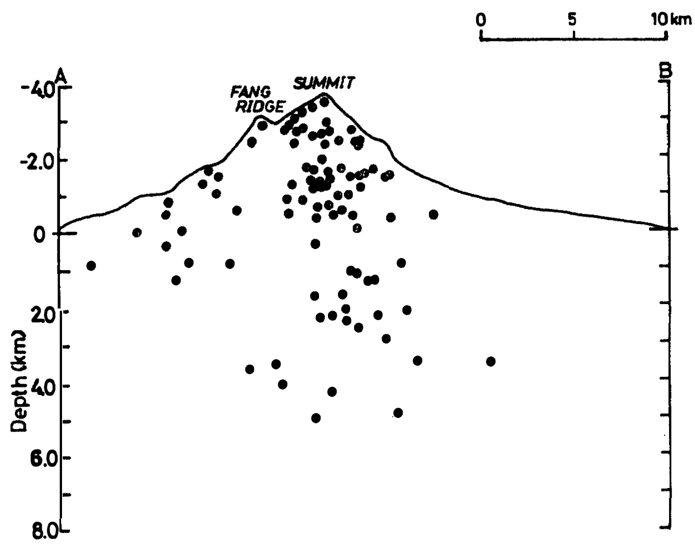

Fig. 5. The vertical projection of hypocenters along the line A–B in Fig. 4.

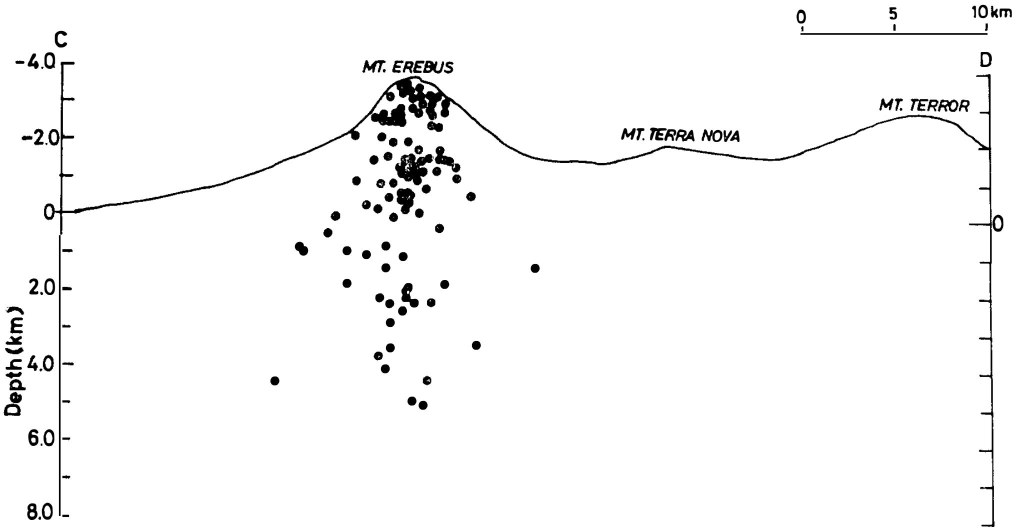

Fig. 6. The vertical projection of hypocenters along the line C–D in Fig. 4.

the *X*- and *Y*-axes. Hypocentral depth ranged from near the summit to 6.0 km. The hypocenters clustered at 0 to 3 km depth just beneath the summit as shown in Figs. 5 and 6. As most of the events were associated with the volcanic surface phenomena, the hypocenters that clustered beneath the summit seemed to be reasonable. The epicenters scattered along a north-south trend. Several events had the shortest travel times to the Abbott Peak station and were probably of tectonic origin.

5. Conclusion

The present report summarizes the volcanic earthquake activity and the space distribution of hypocenters of Mount Erebus, recorded during the first (1980–1981) IMESS field season. A large number of microearthquakes occurred beneath the volcano, sometimes accompanied by Strombolian eruptions. The distribution of the calculated hypocenters was concentrated mainly beneath the summit and suggested the existence of a high stress area, which might be elongated in a north-south direction.

Band-pass filtered seismograms suggest that a variety of wave-form is mainly due to difference of path effects and also probably due to the different source mechanisms.

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