EXPLOSION EARTHQUAKES OF MOUNT EREBUS, ANTARCTICA

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Abstract: The characteristics of explosions of Mount Erebus, Antarctica are analyzed using the data of the seismic network operated by the International Mount Erebus Seismic Study (IMESS). About 70 earthquakes have been located by the network between 16 February and 29 June 1982.

An aseismic zone is recognizable in the southeastern part of Mount Erebus on the vertical projection of hypocenter distributions. The aseismic zone seems to suggest the existence of a magma reservoir which is estimated to be located beneath the summit.

Three types of explosions are recognizable by the seismic and the infrasound signals. The types are named α-, β- and γ-types and characterized as follows: 1) the α-type explosion has high infrasound frequency and high frequency spectra of explosion earthquakes, 2) the β-type has low infrasound frequency and low frequency spectra of explosion earthquakes and 3) the γ-type has low infrasound frequency and small elastic vibrations at the summit station. About 110 explosion earthquakes of both α- and β-types are counted and 14 clear γ-type events were recognized during the period.

1. Introduction

Mount Erebus, located on Ross Island in the McMurdo Sound is one of the few active volcanoes in Antarctica. The elevation of the main crater rim of Mount Erebus ranges from 3720 to 3794 m, its diameter measures 500 to 600 m and the nearly flat main crater floor is at elevation 3630 m. An inner crater measuring 250 m across and 100 m deep is situated within the north end of the main crater. An anorthoclase phonolite lava lake has been present in the inner crater since before December 1972 and Strombolian type eruptions have occurred repeatedly at the lava lake and the surrounding active vents (GIGGENBACH *et al.*, 1973; KYLE *et al.*, 1982).

A seismic network on Mount Erebus has been established by the International Mount Erebus Seismic Study (IMESS) organized by Japan, New Zealand and the United States in 1980. The network originally consists of four seismic stations and one infrasound sensor in 1980 and 1981; two more seismic stations have been installed since December 1982. The seismic and infrasound signals are telemetered to Scott Base, the New Zealand Antarctic Station, 37 km to the south of the Erebus summit. Seismic activity of Mount Erebus and Ross Island is better understood due to the

presence of the IMESS seismic network (KIENLE *et al.*, 1981, 1982; TAKANAMI *et al.*, 1983a, b; SHIBUYA *et al.*, 1983; KAMINUMA *et al.*, 1985).

Three types of explosions are recognizable on the infrasonogram and the seismogram. The characteristics of these explosions are analyzed in this paper using the records between 16 February and 29 June 1982.

2. Seismicity

Seismicity in Mount Erebus is summarized as follows (TAKANAMI *et al.*, 1983a, b; SHIBUYA *et al.*, 1983):

1) On the average, some ten micro and/or small earthquakes occur each day with a periodic variation of 1.5–2.0 months.

2) A few eruptions accompanied with explosion earthquakes occur each day.

3) Earthquake swarms occur a few times each year.

The seismic network functioning during the period between February and June 1982 is shown in Fig. 1. The seismic stations operating during this period were as follows: Summit Station (ERE), Hoopers Shoulder (HOO), Abbott Peak (ABB), Bomb (BOM), Mount Terror (TER) and Scott Base (SBA). That period had been remarkable in that the summit station, with both a seismograph and an infrasound sensor, had been functioning; it worked only during part of December and January in the following two years of 1983–1984.

Daily number of earthquakes registered at Hoopers Shoulder is shown in Fig. 2 in which three seismic swarms having daily number of earthquakes over 200 are recognized. The first one occurred on March 20; 229 events were counted on the

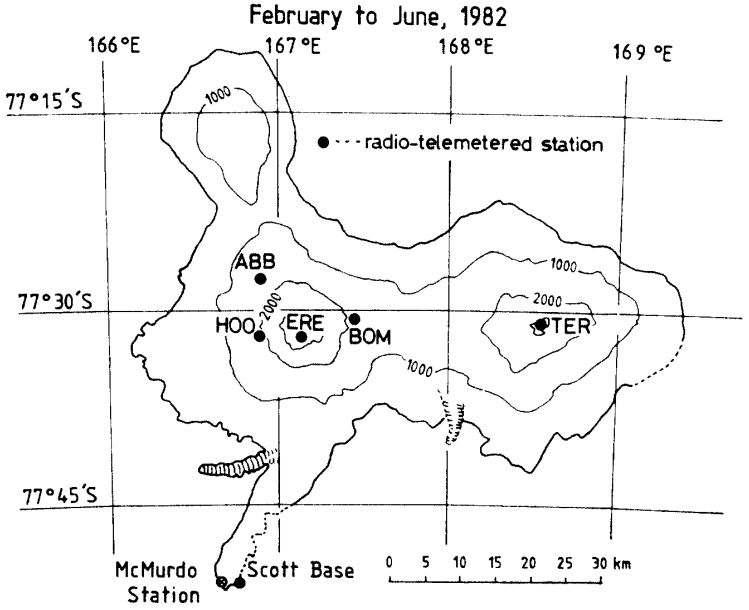

Fig. 1. Location of radio-telemetered seismic stations of IMESS in 1982 in Ross Island, Antarctica: Summit Station (ERE), Hoopers Shoulder (HOO), Abbott Peak (ABB), Bomb (BOM), Mount Terror (TER) and Scott Base (SBA).

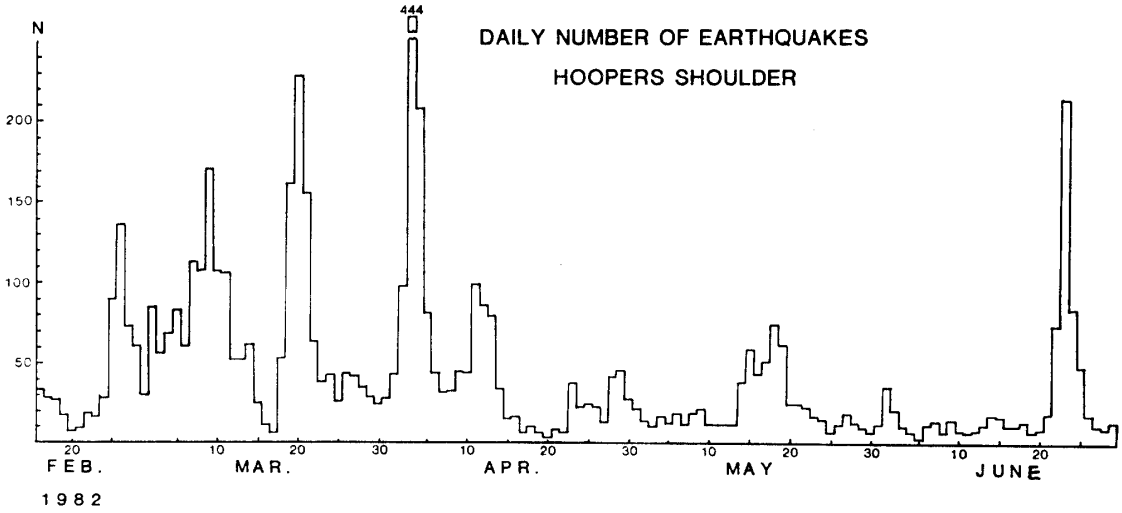

Fig. 2. Daily number of earthquakes counted at the Hoopers Shoulder station.

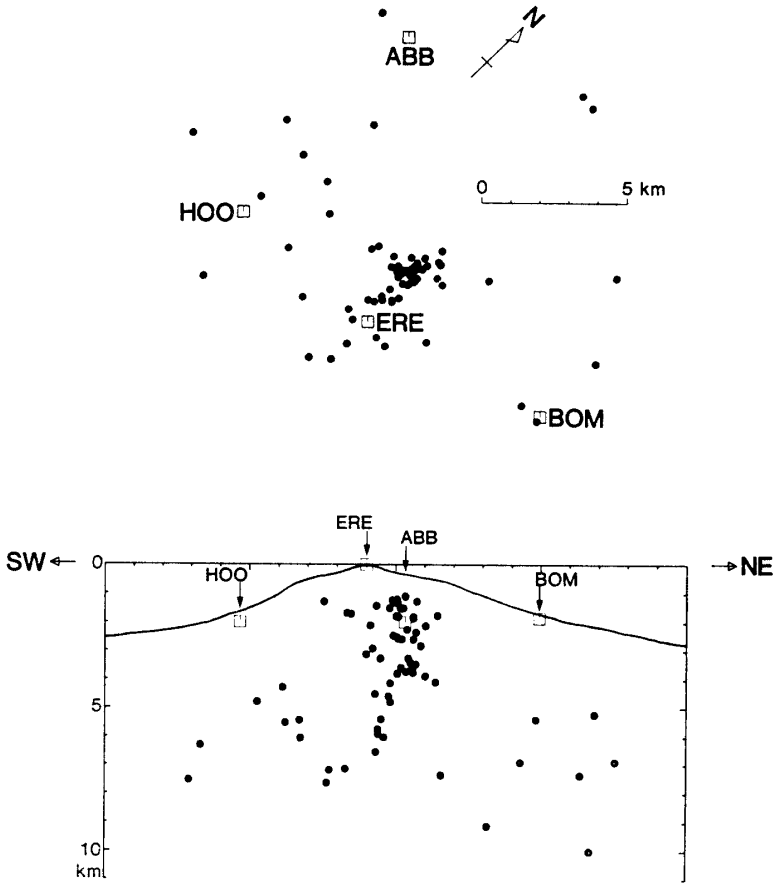

Fig. 3. Top: Epicenter location of earthquakes during the period between February 16 and June 29, 1982. Bottom: Focal depth distribution projected onto vertical cross section oriented SW-NE.

seismogram. The magnitude of the events seems to be very small, as most were recorded only at HOO and ABB. The second swarm with 444 events and the third one with 216 events occurred on April 2 and June 23; these events were also small, and were recorded at only two stations. So the hypocenters of the three seismic swarms were not determined. The seismicity during the period seemed to be normal. About 70 earthquakes have been located by the network during the four months between February and June 1982.

Figure 3 shows the hypocenter locations of the earthquakes which were recorded at more than four stations. The errors of the hypocenters in the horizontal direction are less than 2 km and those in the vertical direction are less than 3 km. An aseismic zone measuring 3×5 km is recognizable in the southwestern part of Mount Erebus in Fig. 3. Even though the accuracy of the hypocenter determination is not satisfactory, the location of the zone may be relatively correct and the aseismic zone seems to suggest the existence of a magma reservoir.

3. Explosion Earthquakes

About 110 explosion earthquakes were counted during the four months in which two types of explosion earthquakes are recognizable. One was named α-type and the other β-type by SHIBUYA *et al.* (1983) depending on the wave form of the infrasound data. The α-type is characterized by high infrasound frequency and the β-type by low frequency. Approximately equal numbers of α- and β-type events were recorded. Figures 4 and 5 show sample seismograms at four stations and the infrasonogram at the summit station. The spectra of the infrasonograms are given in the upper parts

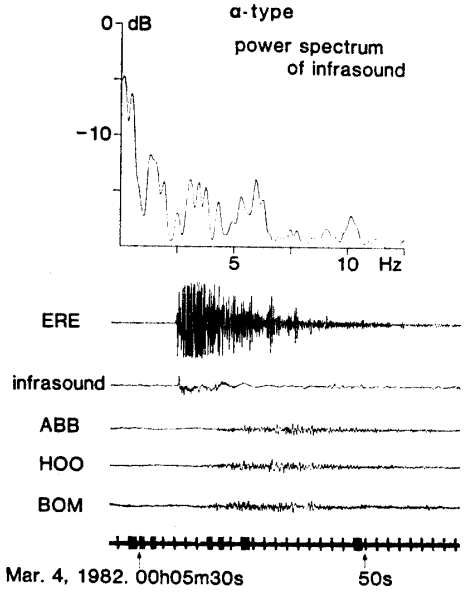

Fig. 4. Bottom: Seismogram of an α-type explosion earthquake at four stations and the infrasonogram at the summit station. Top: Spectrum of the infrasonogram.

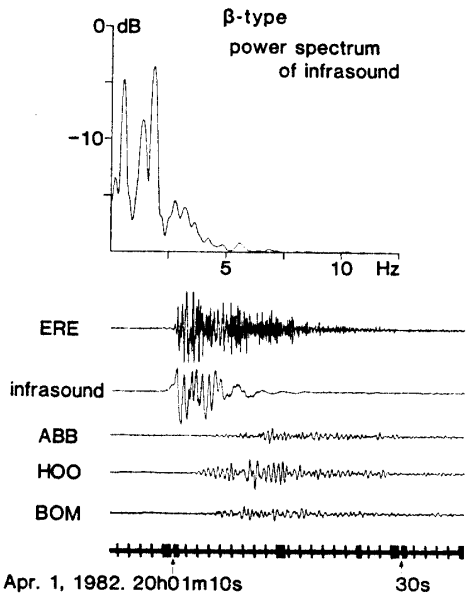

Fig. 5. Bottom: Seismogram of a β-type explosion earthquake at four stations and the infrasonogram at the summit station. Top: Spectrum of the infrasonogram.

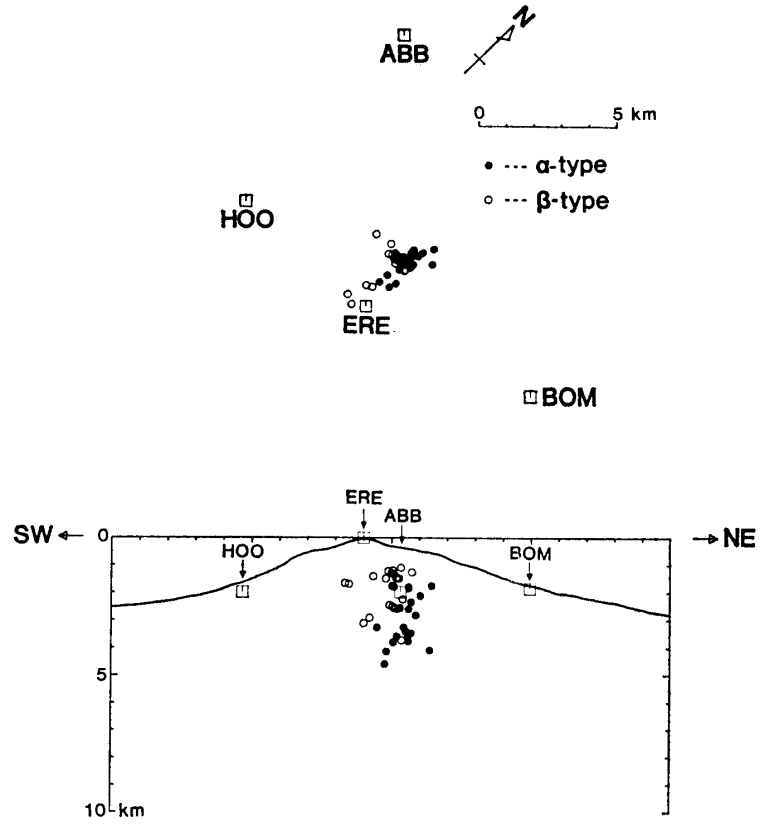

Fig. 6. Top: Epicenter location of explosion earthquakes during the same period as Fig. 3. Bottom: Focal depth distribution projected onto vertical cross section oriented SW-NE. Open circles for β-type events and solid circles for α-type events.

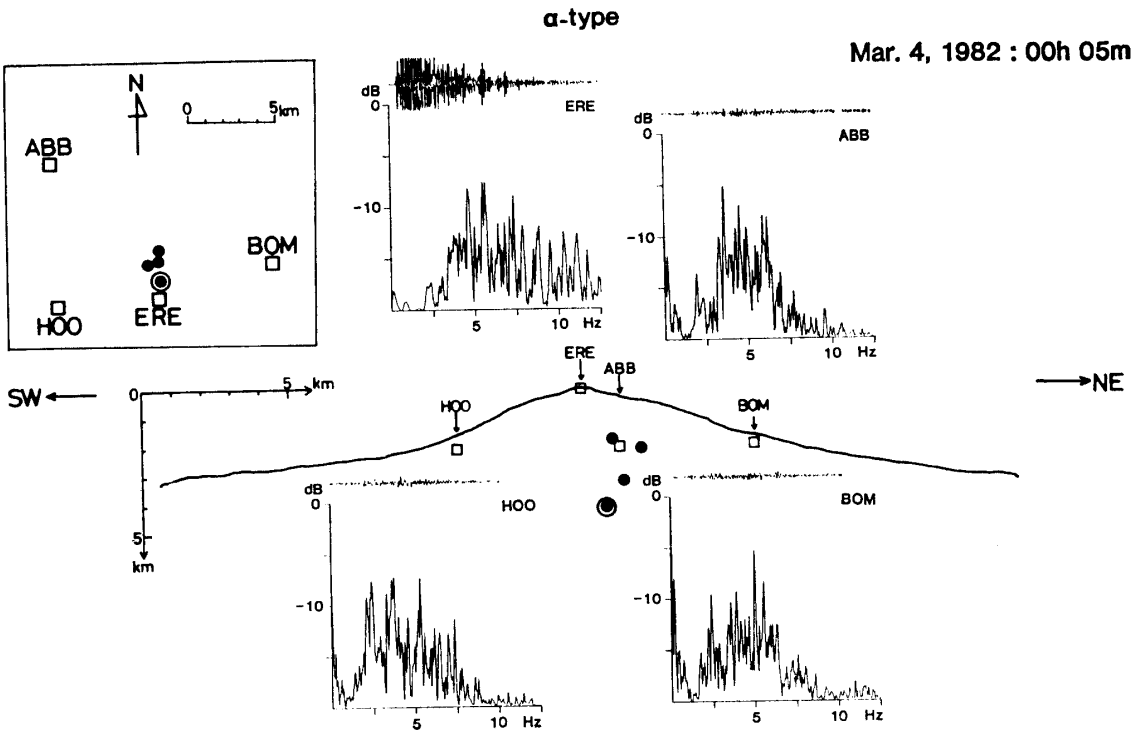

Fig. 7. Spectra of seismogram for the α-type explosion earthquake of which location is given in the top left and the center with the double circle. Top left of figure; solid circles indicate the epicenter location of some α-type events. Center; vertical cross section for the focal depth distribution of α-type events.

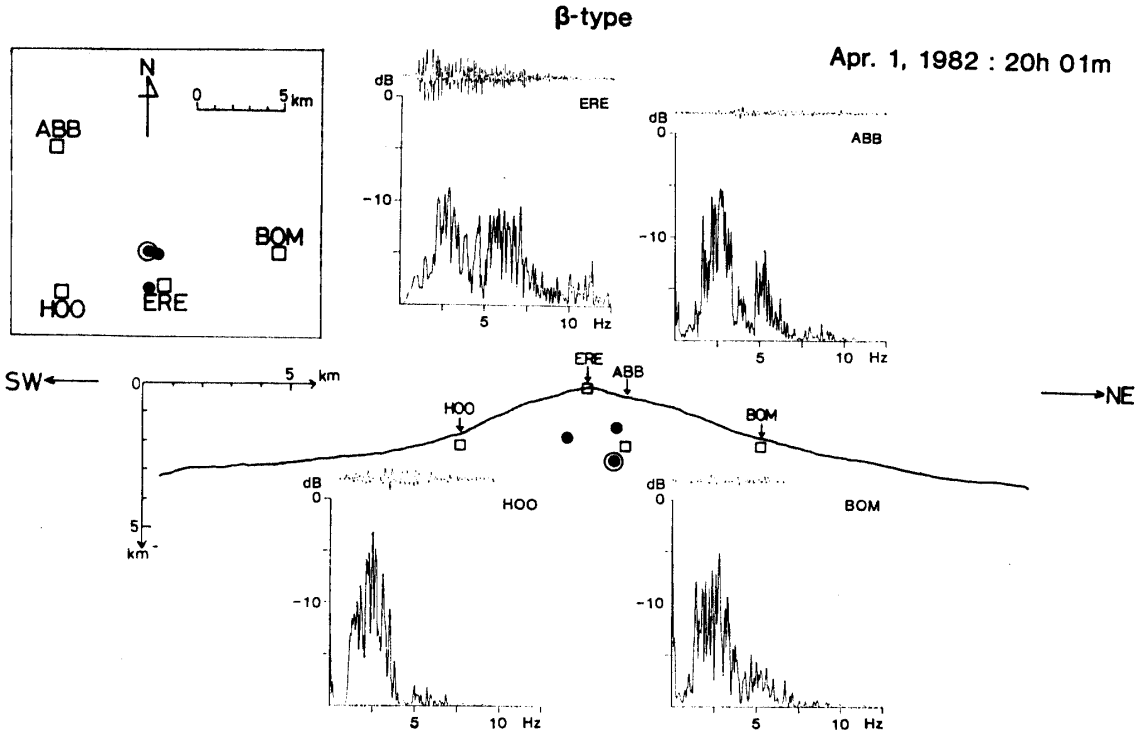

Fig. 8. Spectra of seismogram for the β-type explosion earthquake of which location is given in the top left and the center with the double circle. Top left of figure; solid circles indicate the epicenter location of some β-type events. Center; vertical cross section for focal depth distribution of β-type events.

of Figs. 4 and 5. It is clear from the figures that the spectra of α-type have peaks in the range of 1–7 Hz and that of β-type have a large peak at 1–2 Hz.

Hypocenters of these α- and β-type explosion earthquakes counting 21 each out of 110 are located as shown in Fig. 6 of which accuracy was better than 0.3 s of O−C (observed arrival time minus calculated one) with mean-square root residuals as shown in Fig. 6. The focal depths of the α-type (solid circles in Fig. 6) range 2.5–5 km and those of the β-type (open circles) 1.5–4 km. The focal depths of the β-type are relatively shallower than those of the α-type.

Seismograms and their sepctra for the α-type and the β-type events at four stations (ERE, ABB, HOO and BOM) are shown in Figs. 7 and 8. The spectra of the α-type at HOO, ABB and BOM are characterized by the peaks of 3–7 Hz and those of the β-type 1.5–3.5 Hz as is obvious from Figs. 7 and 8.

4. The Other Type of Eruptions

Fourteen clear events occurred during the period discussed herein did not fit into either the α-type or the β-type category. Records of the largest event of this type is shown in Fig. 9. Compared with the other two types, the events were characterized by a low frequency infrasonogram and a small amplitude seismic signal at the summit station. The hypocenters of these events were not determined, because their seismic signals were so small as to be nearly unidentifiable at the flank stations. This type of

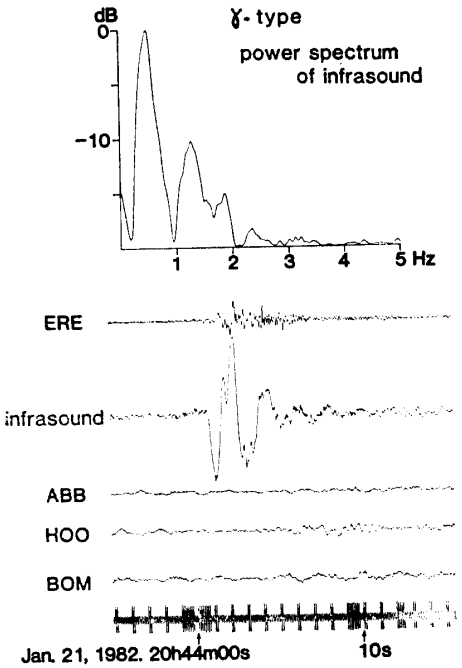

Fig. 9. Bottom: Seismogram of a γ-type explosion earthquake at four stations and the infrasonogram at the summit station. Top: Spectrum of the infrasonogram.

eruptions is called the γ-type according to the naming for α- and β-types by SHIBUYA *et al.* (1983).

It was recognized by visual observations at the summit crater rim that eruptions occurred in the lava lake and its surrounding vents (DIBBLE *et al.*, 1984). On one occasion a huge bubble 100 m across was seen to be formed in the lava lake. On another occasion a roar was audible at the crater rim and weak white smoke was seen around vents, but no seismic signals were recorded even at the summit station. Judging from large infrasounds and small seismic signals at the summit, the eruptions with such a roar as mentioned above seem to be the eruptions of the γ-type.

The eruptions with the huge bubble are estimated to be the one of the α-type which occurred in the lava lake, producing large elastic vibrations but small accompanying infrasounds.

5. Discussion and Conclusion

Three types of explosions were recognized by the infrasound and the seismic signals of IMESS record between February and June 1982. The characteristics of each type are summarized on Table 1.

The locality of explosion is estimated by the seismic and the infrasound signals, and visual observations at the summit crater rim as follows:

1) Because of very small infrasound and large seismic signals, the explosions of the α-type seem to have occurred in the lava lake.

2) Judging from large infrasounds, the explosions of both β- and γ-types may have occurred in the vents surrounding the lava lake.

3) The explosions of the γ-type seem to be gas explosions estimating from large infrasounds and small seismic signals at the summit station.

Table 1. Characteristics of explosion earthquakes.

	α-type	β-type	γ-type
Focal depth	2.5–5 km	1.5–4 km	—
Spectra	High frequency (3–7 Hz)	Low frequency (1.5–3.5 Hz)	—
Infrasound	Small amplitude High frequency (0.5–7 Hz)	Large amplitude Low frequency (0.5–4 Hz)	Large amplitude Low frequency (0.5–2 Hz)
Place of explosion occurred	Lava lake	Vent	Vent

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