Seismic observations at the Mount Erebus Volcano Observatory: 1997-1998

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The Mount Erebus Volcano Observatory (MEVO) seismic network (figure 1, Rowe, Aster and Kyle *Antarctic Journal*, in this issue) continues to provide new insights into the nature of Mount Erebus seismic events. The addition of continuous digital recording in 1997 has permitted detailed analysis of sustained signals that previously were available only in analog form. Discrete seismic signals are dominated by lava lake explosions and icequakes within or beneath Ross Island glaciers. Sustained signals include lava lake degassing, glacier movement on the volcano's flanks, and volcanic tremor.

Lava lake explosion counts vary from several per day up to swarms of 900 per day. Explosion behavior is likely controlled by the shallow magmatic volatile budget. The gas source is generally considered to be exsolution of magmatic volatiles, although external contributions may also be important. On 19 December 1997, an avalanche of rock, snow, and ice was observed to slump off the crater wall into the lava lake. Within seconds, MEVO personnel on the crater rim observed numerous small bubble bursts. This elevated activity comprised a 3-day swarm of over 630 events. Such occurrences are probably infrequent, however, and the usual mechanism for triggering explosion swarm activity may be a combination of factors perturbing the shallow volatile regime.

Cumulative explosion size at station ABB (figure 1, Rowe, Aster and Kyle, *Antarctic Journal*, in this issue), calculated from triggered seismic records, is shown in figure 1a for 364 events from October 1997 to July 1998. The overall curve is comprised of distinct pulses of activity, corresponding to episodic swarm behavior illustrated in figure lb, wherein explosions and their relative sizes are plotted against time. This behavior may represent cycles of volatile recharge. Explosion sizes follow an approximate power law distribution. Figure lc illustrates the histogram of event numbers as a function of maximum ground velocity. Figure ld shows the corresponding cumulative log(count)/log(size) slope (b-value) is approximately 1.7. This power law distribution indicates self-similarity in the explosion population and thus argues against a preferred size over the range examined; however, Rowe et al. (2000) note that the significant break in slope corresponds to an observed decay in seismic vs. acoustic amplitude for these explosions, and suggests poorer seismic coupling among small events.

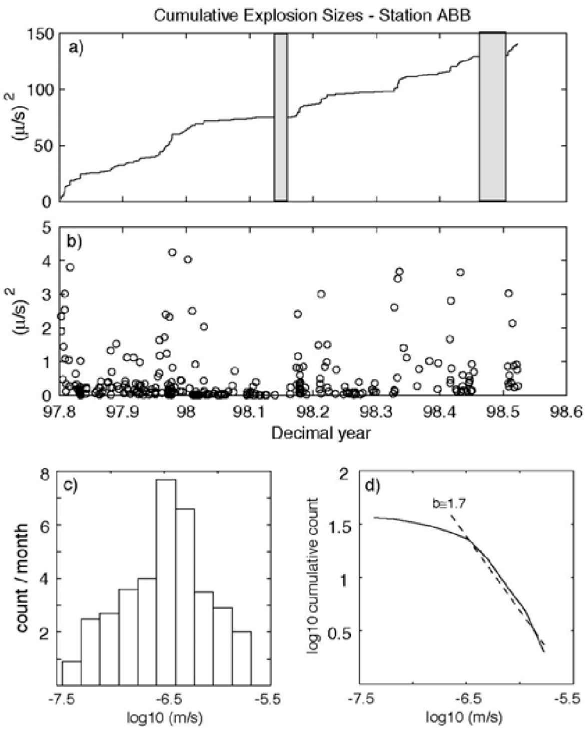

Figure 1. Explosion behavior between October 1997 and July 1998.

d) ***Cumulative curve of explosion size (maximum ground velocity at station ABB); 364 events showing that explosive volatile release proceeds in pulses, corresponding to explosion "swarms" indicated in b). Shaded areas of the cumulative curve represent times of high wind noise (near 98.1) or network outages (during winter months near 98.5) that resulted in a reduction or inability of the event detection algorithm to detect explosive seismicity.***

e) ***Explosion sizes (vertical scale) plotted as a function of time (horizontal axis) illuminating swarm-type behavior.***

d) ***Size distribution plotted as a histogram of counts per month versus size, and d) as log(count) vs. log(size), showing an approximate slope (b-value) of 2 (dashed line) indicating an approximate power law distribution over the range considered.***

An evaluation of discrete non-explosion events suggests that most originate within Ross Island glaciers. The strongly seasonal nature of overall triggered seismicity counts (figure 2), with seismicity peaks during the late summer and early autumn, suggests that many non-explosion events represent glacier activity.

Many extended, chaotic signals appear to originate within the summit crater and may arise from degassing within the lava lake (e.g., Dibble et al 1988). Because no evidence exists for rock avalanches outside of the crater, nor current eruption or fumarolic emissions on the volcano's flanks, we believe most extended flank signals probably arise from glacier activity.

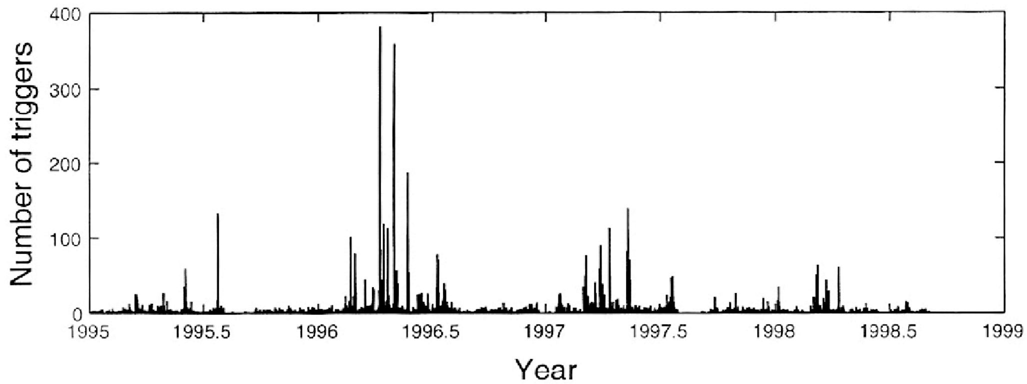

Figure 2. Three-year histogram of triggered event counts for the MEVO network. The annual cycle peaking in late summer/ early autumn shows that the source of most triggered events is seasonally-dependent; this supports the interpretation of much non-explosion seismicity as ice/temperature-related. Variation between annual maxima is partly due to modification of triggering parameters in the data acquisition system. Brief periods of zero triggering near 1995.5, 1996.5 and 1997.5 represent seasonal network outages due to power loss during the austral winter.

Erebus has exhibited surprisingly few instances of harmonic tremor, despite its ongoing eruptive behavior. Tremor was observed on analog records in October 1982 (Kienle et al. 1983). In January 1985, the MEVO triggered digital system captured a 20-minute episode of monochromatic tremor (Knight et al. 1996).

On 11 May 1998, a more complex episode of tremor occurred (Rowe et al. 2000). A 30-second sample of the 50-samples-per-second, continuous digital recording is shown in figure 3a. This instance of tremor exhibits at least 12 strong spectral peaks (figure 3b). Highest amplitudes of -0.6 mm/s occur at station EIS (figure 1, Rowe, Aster and Kyle *Antarctic Journal*, in this issue), nearest the central conduit and lava lake. Gliding—a gradual, proportional frequency shifting of spectral peaks (e.g., Hagerty et al. 1997)—is clearly evident (figure 3b). Gliding may represent alteration of the physical dimensions of a resonating chamber (e.g., Chouet 1996) or a change in acoustic properties of the melt (e.g., Garces et al. 1998). Another episode of complex tremor occurred on 2 September1998. Tremor amplitudes are about five times less attenuated with distance than those of lava lake explosions, implying a comparatively deep tremor source. Since 1998, additional episodes of tremor-like signals have been noted; however, these have been determined to arise from interaction of mega-icebergs, and are not attributable to activity within the volcano (Ruiz, 2003).

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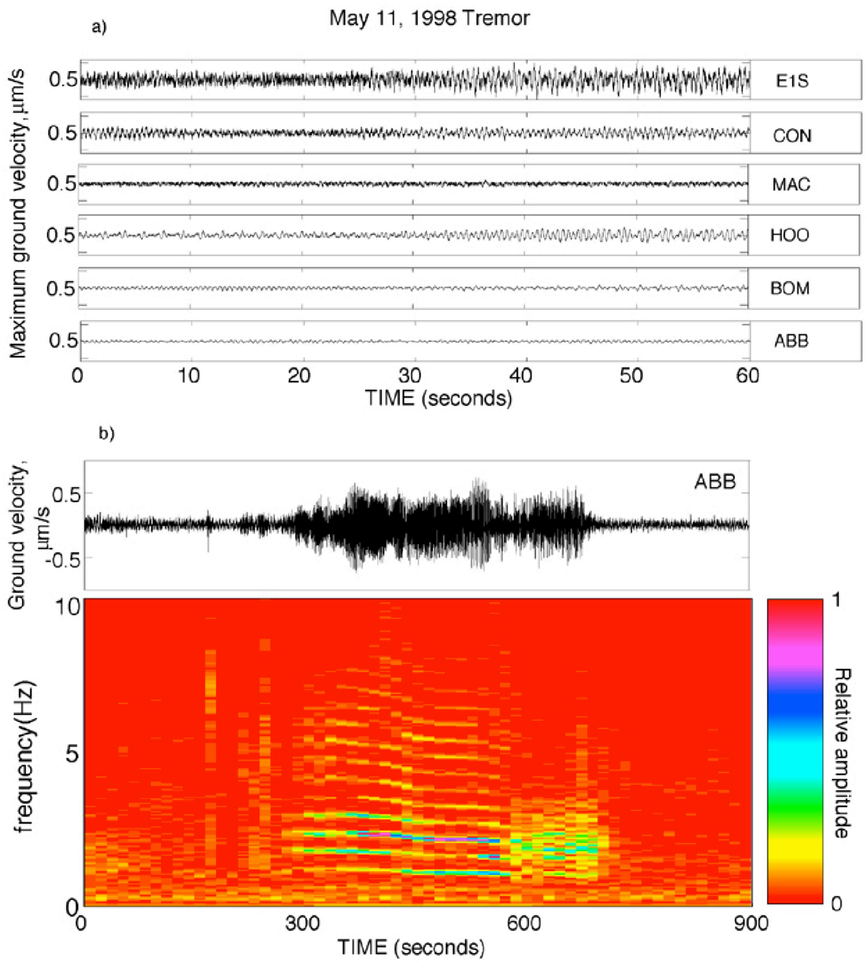

Figure 3. Polychromatic tremor recorded 11 May 1998 (after Rowe et al., 2000). More recently recorded episodes of tremor have been linked to ice-ground and/or ice-ice collisions associated with very large icebergs calved from the Ross Ice Shelf (Ruiz, 2004). Data quality for this 1998 example are inadequate to unambiguously determine the source.

a) Example seismograms showing the complex nature of the signal.

b) Seismogram for station ABB showing 900 seconds of signal and associated spectrogram.

Note at least 12 identifiable spectral peaks during this short (approximately 10-minute) episode of tremor.

Gliding (proportional shifting of all visible spectral peaks) can be clearly seen as the signal evolves.

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