AN APPROACH TO THE SEISMICITY OF MT. MELBOURNE VOLCANO (NORTHERN VICTORIA LAND—ANTARCTICA)

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Abstract: A seismic network consisting of four permanent digital stations was installed on Mt. Melbourne Volcano (2732 m) in Northern Victoria Land, Antarctica, at the beginning of 1990. A mobile array formed by 4 digital seismic stations was also operated in the same area during the 1990-91 Antarctic summer. Most of the recorded events were icequakes and a survey performed on and near the Campbell Glacier furnished information for a better definition of some characteristics of this class of events. The network station located at higher elevation on the volcano slopes detected the most interesting seismic signals, showing waveforms and related spectra, typical of volcanic earthquake. About 20 regional tectonic shocks were also recorded during the sixth Italian Expedition in Antarctica (1990-91). These earthquakes appear to be located within a radius of about 150 km from Mt. Melbourne. The aim of this paper is to supply some preliminary data of the seismicity of the region where no previous data are available.

Key words: Antarctica, Mt. Melbourne, volcano, monitoring, seismicity

Introduction

Neogene to Quaternary volcanic activity in Northern Victoria Land has been widely reported and the related volcanic products, outcropping along the western border of the Ross Sea embayment, are well known by the name of McMurdo Volcanic Group (Harrington, 1958). Volcanism affected a wide area that extends inland from the coast of the Antarctic Continent for several tens of kilometres.

The oldest outcropping volcanics have been dated at about 37.9–28 Ma in the Mariner Glacier area (Armienti et al., 1988). A few central volcanoes (Mt. Erebus, Mt. Melbourne) are considered to be still active: Mt. Erebus is characterised by persistent volcanic activity (strombolian and lava lake) in the main crater area, while Mt. Melbourne is currently showing mild fumarolic degassing from the summit crater.

Mt. Melbourne and its surroundings are clearly dissected by two main fault directions. The first strikes parallel to the Rennick graben fault system (NW-SE), and, more in general, parallel to the Transantarctic Chain, while the second is coherent with the western margin of the Ross Sea (NNE-SSW). Recent studies (Lanzafame and Villari, 1991) showed that normal faulting has been active very recently at both the NW-SE and the NNE-SSW structural systems. The trend of eruptive fissures, the alignment of cinder and spatter cones and the orientation of dikes show that volcanic activity developed along both structural systems. This structural and volcanic framework suggests a deformation model that usually applies to regions affected by an overall tectonic uplift.

Mt. Melbourne (74°21′ S, 164°43′ E) is a 2732 meter high composite volcano standing along the Ross Sea coast, North of Terra Nova Bay. The occurrence of pyroclastic layers interbedded with the unconsolidated snow cap on the high slopes of the volcano suggests its recent eruptive activity (about 300–500 years ago).

A research programme on physical volcanology was recently developed on Mt. Melbourne in order to investigate its internal dynamics. Continuously recording tilt (5 stations operating since the end of 1988) and seismic stations (4 stations operating since the beginning of 1990) were set up within the framework of this research project.

Seismic stations are equipped with short period Geotech S-13 Geophones and signal conditioning is carried out by an expressly designed data acquisition system, based on Geotech Pdas-100. A 50 Hz signal sampling at the remote station is constrained by local trigger and the detected events are recorded on a non-volatile memory. Two of the four seismic stations (3 component), located in a line of sight to the Terra Nova Italian base (SHN and VIL), are programmed to sent daily, by radio frequency digital telemetry, the collected data to the Volcanological Observatory, where they are recorded on a PC hard disk. At the other two stations (only vertical component) of the network, on the opposite side of the volcanic structure, data are locally stored on a solid state memory and periodically retrieved by a “lap-top” computer.

Further technical details concerning the instrumental networks are given in Bonaccorso et al. (1991).

The present paper reports the seismicity recorded by the permanent seismic network (Fig. 1), integrated with a mobile array composed of 4 digital stations during the Antarctic summer 1990–1991.

Data Analysis

In spite of the short operative periods of the seismometric network (January 1990–April 1990 and November 1990–January 1991), several hundreds of seismic events (80 Megabyte) were recorded by the permanent stations and the mobile array.

The following notes are only the first step towards defining the seismic characteristics of the area as a starting point for further research.
Fig. 1. Location map of the permanent tilt and seismic networks set up in the Mt. Melbourne area.

A preliminary analysis of the waveforms and related spectra collected up to now identified at least three classes of events (Fig. 2):

1) events linked to the dynamics of glaciers (icequakes);
2) local events of Mt. Melbourne;
3) regional tectonic events linked to the activity of the seismogenetic structures within a radius of about 150 km from Mt. Melbourne.

Mt. Melbourne is almost unknown from a seismological point of view. Lack of knowledge (such as characteristics of the events, occurrence modality, velocity models, data about media and source, etc.) make analyses of the collected seismic data particularly complex, but very stimulating. The situation is further complicated by the presence of the Campbell glacier and by an extended and thick glacial cap on Mt. Melbourne that generates a great quantity of seismic signals. These signals, as already observed (Weaver and Malone, 1976; Weaver and Malone, 1979; St. Lawrence and Qamar, 1979; Takanami et al., 1983; Cichowiz, 1983; Dibble et al., 1984) can only be distinguished from some classes of volcanic events (i.e. Minakami’s B-type events; Minakami, 1963) by means of high resolution techniques.

Icequakes

The great majority of recorded events seem to be icequakes. An accurate analysis of these signals was carried out in order to distinguish them from seismic events linked to the internal dynamics of the volcano.

An experiment was performed on the Campbell Glacier with two mobile stations (S30, S40) located at short distance from the third permanent station (SHN in Fig. 1).

Many icequakes were recorded at one of the mobile stations located directly on the glacier (Fig. 3). The occurrence rate of events sharply decreased at the other station sited at the periphery of the glacier. Moreover, even the events characterized by relatively high amplitude were not recorded by the closest station of the permanent network (SHN), which was only 2 km away. This means that in this region, the generation mechanism of icequakes is surely a source of noise. The seismic waves rapidly lose the high frequency content and successively the transient characteristics, producing surface waves at short distance from the source and mixing with waves generated by other noise sources.

Exhaustive characterization of the icequakes recorded near Mt. Melbourne is not available yet, because of the recording characteristics forcedly set at the stations. In fact, the limited recording memory called for a 50 Hz sampling frequency with an anti-aliasing low-pass filter at 20 Hz. As can be seen in Fig. 4, the spectra carried out on a large number of icequakes are interrupted at 20 Hz and the waveforms are filtered, preventing any careful quantitative analysis. The seismic network structure is currently being redesigned on the basis of these and the other results obtained, in order to repeat this experiment with more appropriate sampling frequencies.

Nevertheless some general remarks are possible. Icequakes recorded near their source (Fig. 4) show weak onset, no evidence of S phase, sharp amplitude decrease, high spectral content (>10 Hz) and short duration. A peculiar characteristic observed for most icequakes consisted of a wave-train preceding the first arrival of P phase by about 1.5–2.0 s (see arrow in Fig. 4), and lasting about 1.0–1.5 s.

Local seismic events

The preliminary results obtained with the permanent
seismic network allowed a more appropriate analysis of data from the station (VIL) located at higher elevation (about 2200 m), which detected the most interesting events for framing the seismicity of Mt. Melbourne.

Data from this station allowed recognition of different waveforms, mostly recorded only at VIL. Some examples of waveforms attributed to the different event classes and related spectra are shown in Fig. 5.

Nevertheless, we think that at least one of the event classes recognised at VIL, is of endogenous origin (Fig. 6). In fact, this class shows all the typical characteristics of Minakami's B-type events: emergent onset, no evidence of "S" phases, low frequency spectrum and shallow focal depth (about 1 km).
Fig. 3. Icequakes recorded by the mobile array operated during the 1990–91 Antarctic summer in the Campbell Glacier area.

Fig. 4. Typical waveform and related spectrum of icequakes recorded in close proximity of the source. A peculiar character is represented by a wave-train (see arrow) preceding the P phase first arrival.

Further analysis, including particle motion and polarization studies, should prove the origin of these events. It is known that B-type events are in fact typical of active volcanic areas and their occurrence, if confirmed by the analysis in progress, could contribute some insight into the present quiescent state of Mt. Melbourne, a still living volcano in Antarctica.

Regional earthquakes
At least 20 regional earthquakes were recorded during the sixth Italian Antarctic Expedition (November 1990–January 1991). The fact is noteworthy since no information about seismic activity in Northern Victoria Land was available up to now.

The events observed have shown an "S-P" interval ranging from 15 to 25 s. This suggests that these earthquakes may be located within a radius of about 90–160 km from Mt. Melbourne. Hypocentral calculation was normally out of the reach because of the local character of the Mt. Melbourne seismic network. Nevertheless, thanks to an exchange of data with the New Zealand colleagues from Scott Base, location of an event which occurred on 1st December 1990 was made possible. The analytical localization put the epicentre near the coast in correspondence of the Drygalski glacier (about 110 km south of Mt. Melbourne). Unfortunately, the high azimuthal gap between the stations and the unknown velocity structure prevented any estimation of depth.
Fig. 5. Wave forms and related spectra of local seismic events (vertical component) recorded at the permanent network station (VIL) located on the upper slope of Melbourne volcano.

Concluding Remarks

The analysis of seismic data carried out up to now allow us to point out the following:

1) high occurrence rate of icequakes is recorded only near the source; waves generated by icequakes rapidly lose the high frequency content and successively the transient characteristics;

2) the seismic network station (VIL) located at higher elevation on the Mt. Melbourne slopes has recorded waveforms with different characteristics;

3) at least one of the waveform classes recorded by VIL is of endogenous origin (Minakami’s B-type event’); if so, it will be proved that Mt. Melbourne is a quiescent state still living volcano;

4) up to 20 regional earthquakes were recorded within a radius of about 90–160 km from Mt. Melbourne, during the Antarctic summer 1990–91; one of these was localized at the Drygalski Glacier.
Fig. 6. Some of the events recorded at VIL show the typical character of Minakami's B-type earthquakes, notably weak onset, no evidence of "S" phases, low frequency content. The three graphs of lower part shows an event recorded at three stations on December 9, 1990, 18:14 UT.
REFERENCES


