The Long-Period (LP) seismicity before and during the volcanic crises: examples from two case studies

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Abstract

The Long-Period (LP) seismicity is common at active volcanoes and is usually modeled as due to pressurized magmatic fluids flowing through rock cavities. These signals are sensitive to the thermodynamic conditions of the magma-gas mixture in the shallow plumbing system and can thus be adopted as “detectors” of an impelling eruption. We found that at Stromboli (Italy) and/or during recent volcanic crises the LP events can occur in swarms, which show different statistics, higher energy and shallower location than the stationary LP activity. We imputed the LP swarms to a quick depressurization (ΔP≈105 Pa) of the shallowest (<0.8 km) part of the conduit. At Shishaldin (Alaska) the 2004 eruption is anticipated by a migration towards the surface of the LP source, which moves from ~8 km to ~0.5 km below the crater rim. By simple assumptions, we modeled this source change as produced by an increase of the confining pressure within the plumbing system of ~5×105 Pa, possibly induced by an upward migration of ~1010 kg of magma.

Bibliography


Long-Period (LP) seismic signals as detectors of the internal volcanic conditions

Long-Period (LP) events are seismic signals induced by the flowing of pressurized magmatic fluids through cavities in the volcanic rock whose source is normally modeled as gas pockets or slugs ascending along the conduit (Fig. A1). LPs are rich in low frequencies (<3Hz) and are mostly independent of the case study, making them a universal signature of active volcanoes (Fig. A2). As they are produced by pressure inhomogeneities within the volcanic edifice, their occurrence is linked to the thermodynamic state of the gas-phase magma filling the shallow plumbing system. Indeed, before and during the volcanic crises, the LP process shows modifications as an effect of the changes of the internal state induced by magma dynamics.

Here we have defined a set of parameters to monitor the LP process: occurrence rate, variation coefficient (CV, which is the ratio between standard deviation and mean value) of the inter-event times, frequency content, energy and nucleation depth of the LP events. The LP events have been picked from the continuous seismic signal by a revised version of the Short-Term-Average/Long-Term-Average technique (Fig. A2, example from Shishaldin volcano, Alaska).

The nucleation dip, that is the dip angle produced by the impulse of the nucleation of the gas aggregation generating the LP events. The nucleation dip is thus directly linked to the nucleation depth of the gas aggregation.

The nucleation dip is time-dependent and assumes a minimum in the phase II (January 2004) and a maximum in the phase IV (May 2004) (S2, S3c). During the LP swarms, the LP process becomes more periodic (S1). During the Eruptive Phase the energy of the LP events is not log-normally distributed as in the stationary (NEP) activity (g).

We define ε as the dip angle of the polarization vector. The LP migration responds to a pressure increase due to an increase of the internal confining pressure, which would lead to a change of the gas aggregations to nucleate upper and upper in the conduit. In this framework, the change of hydrostatic pressure would equal the change of confining pressure:

\[ \Delta P_{\text{conf}} = \frac{\Delta M \cdot g \cdot V}{m} \]

where \( K = \frac{\rho h}{m} \), \( \rho = 1500 \text{ kg/m}^3 \), \( V = 10^{-5} \text{ m}^3 \), m = 10^7 kg.

Shishaldin volcano is the second most frequently active of the Aleutians archipelago with nearly 40 eruptions in the last 250 years. After the significant sub-Plinian basaltic eruption of 1999, the volcano reactivated in 2004, reaching the strongest phase of a minor eruption in May. This eruption was accompanied by an intense LP activity that is here described.