Quantitative modeling of volcano-seismic signals

Hiroyuki Kumagai[1]

[1] NIED

Long-period (LP) and very-long-period (VLP) events and tremor are seismic signals commonly observed at active volcanoes. These signals may be viewed as the manifestation of resonances and/or transports of volcanic fluids in magmatic and hydrothermal systems. A number of resonator models have been proposed for the sources of volcano-seismic signals. Models with spherical geometry were used in various studies, despite that the spherical models require unrealistically large radius and volume for the resonator. A fluid-filled crack model was proposed by Aki et al. [1977] to explain tremor signals at Kilauea. Aki et al. [1977] pointed out that the crack model offers both the driving force of tremor and the geometry adequate for mass transport conditions. Chouet [1986, 1988] extensively studied the crack model using the finite-difference method. These studies demonstrated that the existence of a very slow wave in the fluid-filled crack due to the deformation of the crack wall. This wave, named the crack wave, leads to more realistic estimates of the size and volume of a fluid-filled resonator as compared to a spherical resonator. Kumagai and Chouet [2000] comprehensively estimated acoustic properties of a crack containing various types of magmatic and hydrothermal fluids based on the crack model. The estimated acoustic properties have been successfully used to interpret temporal variations in frequencies and Q factors of LP and VLP events observed at various volcanoes. Recent studies based on waveform inversions of LP and VLP events consistently point to the crack geometry at the sources of these events. Therefore, Aki's idea of the resonance of a fluid-filled crack has been successfully validated through recent advances in volcano seismology. For our better understanding of the state of fluids and dynamic processes associated with volcano-seismic signals, future studies should include the following directions: (1) further numerical development of the computational procedure of the crack model to incorporate more realistic fluid acoustic properties, (2) extended-source waveform inversions of volcano-seismic signals to reveal the resonance characteristics and triggering mechanisms, (3) theoretical and experimental investigations of the triggering mechanisms, and (4) deployments of dense seismic and geodetic networks on active volcanoes. Advances in the analysis techniques as well as our knowledge of source processes associated with these signals will greatly contribute to image and monitor hydrothermal and magmatic systems beneath active volcanoes.

References

Aki, K., M. Fehler, and S. Das, J. Volcanol. Geotherm. Res., 2, 259-287, 1977.
Chouet, B., J. Geophys, Res., 91, 13967-13992, 1986.
Chouet, B., J. Geophys. Res., 93, 4375-4400, 1988.
Kumagai, H. and B. Chouet, J. Geophys. Res., 105, 25493-25512, 2000.