Source model of volcanic tremor: compressible hot water vibration

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1. Introduction

Excitation and resonance of volcanic fluid inclusions in a magma chamber, such as cylindrical conduit or crack have been investigated as a source of volcanic tremors. These models, which are based on infinitesimal amplitude approximation, have succeeded to explain basic characteristics of volcanic tremor. However, the compressibility of volcanic fluids is not taken into account. In this study, we examine waveform characteristics of tremor caused by compressible fluid oscillation in a chamber. We use hot water as a representative compressible fluid beneath active volcanoes.

2. Source model

Our model consists of cylindrical resonator that imitates a conduit in a homogeneous crust. The motion of hot water is represented by the equations of mass conservation and momentum conservation for compressible fluid and equation of state relating pressure and density. Crustal motions are expressed by the equations of elastodynamics. We further model the triggering mechanism of volcanic tremor, by relating the pressure drop with bulk modulus of water and volume increase rate at an edge of cylinder.

3. Results

We calculate fluid and elastic motions by using finite difference method under the conditions of water temperature of 673K-1073K, fluid pressure of 6.25MPa-87.5MPa (corresponding to the confining pressure for the depth of 230m-3240m), volume increase rate of 0.01 and 0.1. The simulation results show that the dominant frequencies of tremor waveforms are almost determined by the ratio of mean sound speed of fluid and resonator size. As sound speed of water varies from 80m/s to 700m/s by conditions of temperature and fluid pressure, the dominant frequencies show a 8-fold changes. When volume increase rate is large, that is, initial depressurization is large, the amplitude of tremor shows intense decay with time. This decay is caused from an effect of the propagation of expansion waves in the conduit: difference of propagation speed between the head and the tail of expansion wave makes expansion wave spread out with elapse of time. This effect is recognized only when compressibility of fluid is taken into account.

4. Application

We apply our model to the observed tremor at Asama volcano, which show temporal changes in dominant frequency, maximum amplitude and duration. Observed decrease of dominant frequency (2.7Hz to 0.8Hz) and increase of duration and maximum amplitude at Asama Volcano can be explained by decrease of temperature (713K to 673K) of hot water in a resonator of 50m length.

5. Summary

Our volcanic tremor model, in which fluid compressibility and quantitative trigger condition is taken into account, can relate the dominant frequency, maximum amplitude, and amplitude decay of tremor with the properties of compressible fluid. Most notable finding is that the amplitude decay, which has been explained by fluid viscosity and/or radiation of seismic energy, is explained by a spread of expansion wave in chamber.