Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SVC047-07 会場:301B 時間:5 月 24 日 10:00-10:15

急激な発泡によって誘発される長周期地震動：SPH 法シミュレーションが示唆する新機構
Long-period seismic events induced by quick bubble formation: a new source mechanism predicted by SPH simulations

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Long-period seismic signals whose periods are several seconds or longer are often observed in active volcanoes and suitable interpretations of these signals are expected to give important information about underground volcanic activities. In fact, the source process that causes long-period oscillations is not always understood satisfactorily. If elastic resonance produces such long-period oscillations the resonator must have sizes of kilometers (Fujita and Ida, 1999; Fujita et al., 1995) which are not usually compatible with known structures of volcanic interiors. Fluid-filled cracks can be a source of long-period oscillations with smaller sizes (Chouet, 1986; Ferrazini and Aki, 1987) but they are not well fit to axial symmetry that is required for such seismic events as observed at Miyakejima volcano in 2000 (Kobayashi et al., 2009). In this context a new mechanism of long-period oscillations is proposed here based on computer simulations in an SPH (Smoothed Particle Hydrodynamics) method.

The SPH method is one of the particle dynamics in which deformation and flow of materials are analyzed based on motions of particles subjected to suitable mutual interactions. Compared with other particle dynamics like DEM (Discrete Element Method) an important character of the SPH method is that interactions between particles are determined using the same physical concepts and the same equations as in corresponding continuum mechanics. Namely, velocity, density, stress and other physical properties are allocated to each particle and the relations that control the state and motion of particles are derived from the equation of motion and constitutive equations that hold for continuums. In this paper the SPH method has been further developed so as to apply to magmatic processes involving the effects of included volatile components. In particular, the particles that represent magma are assumed to meet the equation of state for bubbly magma when some of the volatile component has deposited as bubbles.

If some area of magma is over-saturated with volatile components this area should be released from the over-saturated condition sooner or later and should form bubbles in it with almost instantaneous volume expansion at that time. Our numerical experiments in the SPH method have revealed that quick bubble formation can induce long-period oscillations of the fluid system. The oscillations attenuate slowly and disappear after about ten cycles. The numerical experiments further point out that the long-period oscillations are realizable when the magma system has both a very compressible bubbly area and a free surface. The period of oscillations that has been obtained from the numerical experiments is about two seconds for the magma system that contains a bubbly area of radius 5m in a 50m-wide normal fluid with a density, viscosity, bulk modulus and volatile solubility similar to real magmas.

A simplified model of the long-period oscillations has been constructed based on the numerical experiments. In this model the fluid system is treated as consisting of the upper part participating in vertical rigid motions and the other lower part that transmits pressure between the upper part and the bubbly compressible area. An arithmetic expression of the period of the long-period oscillations is given by the model and predicts that the period depends on gravitational acceleration as well as an effective bulk modulus of the bubbly area and sizes of the fluid system. The model may be useful in getting an intuitive idea of the source process and applying it to observed long-period seismic events.

キーワード: 長周期地震動, 火山性地震, マグマ, 発泡, SPH 法, 数値シミュレーション
Keywords: long-period seismic event, volcanic earthquake, magma, bubble formation, SPH method, computer simulation