Low frequency earthquake induced by magma vesiculation

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In this study, we consider a system consisting of a magma chamber and the conduit. In the magma chamber, as the crystallization due to cooling makes the melt supersaturated for volatile, eventually the heterogeneous nucleation of bubbles occurs. Although in reality, the magma chamber is spatially heterogeneous in temperature and concentration of volatile, here we deal with this spatial heterogeneity as the fluctuation of degree of supersaturation. As a result, the temporal change of overpressure in magma chamber is elastically determined by the interplay between the volume increase due to magma vesiculation and the volume decrease due to outflow to the conduit. The magma velocity in the conduit which is represented by the Navier-Stokes equation, can be reduced to the ordinary differential equation describing the temporal change of the mean ascent velocity, similar to the Langevin equation with the overpressure term as the fluctuation term, by appropriately integrating the equation as for the radial and axial coordinates. Combining the magma mean velocity equation and the equation of overpressure in the magma chamber, the evolution of mean ascent velocity in the conduit is described by the linear oscillation equation with a forced term excited by the volume change of gas phase in the magma chamber. The analysis for these equations leads to the following results.

1) The case without the forced term: 1-1) The damped oscillation occurs when the time scale of viscous relaxation for the magma ascent velocity in the conduit is longer than the time scale of the free oscillation of the magma chamber, otherwise the overdamping without oscillation occurs. 1-2)The time scale of the free oscillation, represented by (LM/AK)ˆ1/2, decreases with the increase of the mass of the magma chamber (where, L is the length of magma column in the conduit, A is the cross sectional area of the conduit, and K is the effective bulk modulus of the magma chamber). 1-3) The relaxation time of magma ascent velocity, represented by (A/rho/mu), increases with the decrease of the effective viscosity of magma, mu (where rho is the density of magma).

2)The case with the forced term: 2-1)The pressure fluctuation in the magma chamber makes the resonance with the free oscillation at the eigenfrequency, and results in the periodic change in mean magma velocity in the conduit and in the overpressure in the magma chamber. 2-2) The periodic change in the overpressure in the magma chamber regulates the bubble nucleation and growth in the magma chamber by the periodic manner. 2-3)As a result, the magma vesiculation is synchronized by the dynamic behavior of conduit-chamber system.

3)The application to the natural system: The proposed mechanism of periodic vesiculation accounts for some of low frequency earthquake at the volcano or geyzer (low M and mu) during and just before eruptions.