Nonlinear characteristic of magma rheology: implications for self-induced oscillation

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Volcanic tremor has been recognized as a useful precursory phenomenon of volcanic eruption and hence has been studied extensively. Although a wide variety of models have been proposed, most models can be applied in quite limited conditions and physical mechanism for volcanic tremor is not clarified yet. Here, we propose a mechanism of the self-induced oscillation caused by a nonlinear property of magma rheology, which is the multiplicity in the relation between driving pressure and flow rate. This property possesses a potential for applying volcanoes over a wide range since it is generated by changes of flow field called as wall slip or shear banding, which are probable situations in crystal-bearing magma system. In fact, this property is utilized to explain lava dome collapses and volcanic earthquakes [*A. Costa et al., 2012; A. J. Hale and H.B. Muhlhaus, 2007*]. However there is little evidence for its existence in magma and the mechanism is not revealed. To explore the possibility that magma has the multiplicity, we conducted laboratory experiments by using *p*-NIPAM aqueous suspension as an analogue of magma to see characteristics caused by the deformability of solid-phase networks, which is related to the multiplicity.

In this presentation, we focus on rheological and flow characteristics caused by aging effect, which are related to the multiplicity. In respect to rheology, firstly it is revealed that *p*-NIPAM aqueous suspension has the critical volume fraction for the emergence of yield strength, which is almost equivalent to that of magma. This result indicates *p*-NIPAM aqueous suspension can be an analogue of magma. At the same time we found this suspension has a multiplicity relationship between shear stress and shear rate that is linked to the yield stress inextricably via aging effect; the multiplicity appears only after long rest time while the yield stress exists just after the pre-shear. This should be a universal characteristic for two-phase mixture system, which can be applied to the magma system.

By flow experiments, it is revealed that pressure perturbations generated under careful treatment of aging effect, which suggest the induced pressure perturbations should be driven by non-linear rheological property; the multiplicity in the relation between the shear stress and the shear rate. By results from experiments under various flow conditions, changing the concentration, the volume of chamber and so on, we can conclude that the pressure perturbation is caused by the formation / destruction of networked structure of solid phase. Although the aging effect and resultant multiplicity are not yet confirmed for the magmatic suspension, this nonlinear characteristics should be responsible for generation of self-induced oscillations in volcanoes since it is universal to the suspension.