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High temperature uniaxial deformation experiment for Sakurajima Showa Lava

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Flow law of magma is a critical property to understand magma dynamics during eruption. The effects of suspended crystals on flow law of magma is especially important because suspended crystals induce viscosity increase and non-Newtonian behavior of magma with increasing crystallinity, which results in rheological transition of magma. However, our knowledge about the effects of suspended crystals on flow law of magma, especially those under high crystallinity condition, is not enough despite of recent efforts. In this study, we performed a high-temperature deformation experiment for natural lava to understand the effects of suspended crystals on flow law of high-crystallinity magma.

In this study, Showa lava effused by 1946 eruption at Sakurajima volano was used for a starting material. The volcano effuses lava flows at least five times in historic times, and the Showa lava is the latest one. The lava sample is two pyroxene andesite, contains ca 60 vol.% of crystals (phenocryst and groundmass crystal) and ca. 10 vol.% of vesicles. High-temperature uniaxial compression experiment was done for the lava using the uniaxial deformation apparatus at Earthquake Research Institute, the University of Tokyo. Experimental conditions are as follows; temperature from 1024 to 886 degree C, strain rate from $10^{-2.4}$ to $10^{-5.5}$ s^{-1}, and atmospheric pressure.

Under present experimental conditions, apparent viscosity of the lava varies from ca. $10^{-7.8}$ to $10^{-11.8}$ Pa s. Apparent viscosity systematically increases as temperature decreases. In addition, shear thinning behavior (apparent viscosity decrease with increase of strain rate) is observed at each temperature. Log apparent viscosity linearly correlates with log strain rate with the slope of -0.505 (1sigma = 0.06). At constant strain rate, log apparent viscosity shows linear relation with reciprocal temperature; apparent activation energy was estimated to be ca. 1.7 kJ, which is similar to that of silicatemelt in Showa lava at the same temperature range. This may suggest that the temperature-dependence of apparent viscosity of the lava is attributed to that of the silicate melt. The ratio of measured bulk viscosity to that of the melt (relative visocosity) increases from $10^{2.7}$ to $10^{4.4}$ as strain rate decreases from $10^{-2.5}$ to $10^{-5.5}$ s^{-1}. Because silicate melt behaves as Newtonian fluid under our experimental conditions, the strain rate-dependence of interaction among crystals may responsible to the shear thinning behavior. We will perform quantitative textural analyses of our deformed run samples and examine the relation between flow law and texture of the lava.

Keywords: magma, rheology, Sakurajima volcano, non Newtonian, crystal, viscosity