Rheological law and viscous-brittle transition of 3 phase magma; a case study for the 1946 andesitic lava from Sakurajima volcano, Japan

*Hidemi Ishibashi[1], Takahiro Miwa[2], Yuta Mitsui[1]

1.Faculty of Science, Shizuoka University, 2.NIED

Uniaxial compression deformation experiments were done for the 1946 andesitic lava from Sakurajima volcano, Japan, under conditions of temperatures from 1300 to1130 K, strain rates from $10^{-2.5}$ to $10^{-5.5}$ s^{-1}, and ambient pressure. The starting lava sample has ca. 20 vol. % of bubbles and the solid part consists of ca. 47 vol.% of rhyolitic glass, ca. 23 vol.% of microlites and ca. 30 vol.% of phenocrysts of plagioclase, pyroxenes, and Fe-Ti oxides. The experiments were done by using the uniaxial deformation apparatus at ERI, University of Tokyo. Deformation experiments were done after ca. 2h pre-heating at the experimental temperatures and the samples were quenched to 873 K with 15 min after the deformation was finished. During the experiments, stress and sample high were monitored under constant temperature. Deformation rate was changed stepwise due to examine non-Newtonian behaviors. Viscosity was calculated by the equation of Gent (1960) from the monitored stress-sample high dataset.
The lava behaves as a power law shear-thinning fluid at temperatures from 1300 to 1160 K under the experimental strain rate conditions. Viscosity increases from ca. $10^{7.3}$ to ca. $10^{11.3}$ Pa s with decreasing temperature and strain rate. An equation describing its dependence on temperature and strain rate was proposed. Relative viscosity, defined as the ratio of magma viscosity/melt viscosity, is almost constant around 100 (with assumption that melt water content is 0.2 wt. %) regardless of experimental temperature. At 1130K, fracturing occurs at strain rate of $10^{-3.5}$ s^{-1} whereas the lava behaves as viscous under strain rate of 10^{-4} s^{-1}. Crystallinity is almost constant around 0.53 regardless of temperature.
Deborah numbers are calculated to be lower than $10^{-2.65}$ for non-fractured samples and ca. $10^{-2.65}$ for the fractured sample. The relation between crystallinity and critical Deborah number for viscous-brittle transition is consistent with the criteria for crystal-bearing magmas proposed by Cordonnier et al. (2012). Present results indicate that the critical stress for viscous-brittle transition is ca. $10^{7.4}$ Pa. The present rheological law was used to calculate flow velocity of the 1946 andesitic lava flow; the result calculated at 1273 K well explains the field observation of Hagiwara et al. (1946). The temperature is consistent with petrological constraints. The calculated maximum shear stress in the lava flow is lower than $10^{6.5}$ Pa, indicating that any process concentrating stress on the lava surface is required to form the blocky structure.

Keywords: Rheological law, Lava flow, brittle-viscous transition, magma, Sakurajima volcano

