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Rheological transition of plagioclase-bearing magma: high-temperature uniaxial deformation experiments of sanukite lava

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High-temperature uniaxial compression experiments were done for bubble- and phenocryst-free, plagioclase-bearing lava to investigate the effect of tabular crystals on rheological properties of highly crystalline magma. High-Mg andesite lava from Goshikidai lava plateau, southwest Japan, was used for starting material. The lava is bubble- and phenocryst-free, composed of 60 vol.% rhyolitic glass, 36 vol.% of tabular plagioclase and 4 vol.% of pyroxenes and magnetite and plagioclase crystals are well aligned parallel. High-temperature uniaxial defomation apparatus at Earthquake Research Institute, the University of Tokyo, was used for experiments. The lava was cut to 10 x 10 x 20 mm rectangular solids and deformed under conditions of temperatures of 1238, 1188, and 1138 K and deformation rates from 3.16 to 0.003 mm/min. Run samples were quenched and processed to thin section for textural and compositional analyses by using EPMA.

Phase proportions in all run samples were the same as that of starting material, indicating crystallization did not occur during experiments. The lava behaves as shear thinning fluid under all temperature conditions. Viscosity at strain rate of 10^{-4} s^{-1} increases from $10^{8.7}$ to $10^{9.4}$ Pas with decreasing temperature. Power law exponent [= d(log viscosity)/d(log strain rate)] is ca. 0.64, which is consistent with extrapolation of previous studies for natural plagioclase-bearing magmas. Relative viscosity [= (bulk viscosity)/(melt viscosity)] is ca. $10^{2.4}$ at strain rate of 10^{-4} s^{-1} under all temperatures, indicating that the concept of relative viscosity works well under present experimental condition. The relative viscosity-crystal fraction relation is also consistent with extrapolation of previous studies for natural plagioclase-bearing magmas. Marron-Piece equation well explains the relation with the maximum packing fraction of 0.43. Present results suggest that rheological transition occurs at crystal fraction near 0.43 for plagioclase-bearing natural lava in which plagioclase crystals are well aligned parallel. The value is higher than ca. 0.3 proposed by Picard et al. (2013)'s experiments in which plagioclase orientation is random in starting materials, indicating the first order importance of plagioclase orientation distribution on rheological transition.

Keywords: rheological transition, viscosity, magma, plagioclase, non-Newtonian fluid, sanukite