Viscosity of depolymerized silicate melt and magma in the Earth’s deep interior

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Viscosity is one of the important transport properties controlling the migration of magma in the Earth’s interior. The effect of temperature on the viscosity of silicate melts has been extensively investigated at high pressure (Wang et al., 2014 Nature Geosci.). It is well known that the pressure dependence of the viscosity of polymerized silicate melt is negative, however the viscosity of depolymerized melt has a positive pressure dependence. Previously, we reported that the basaltic liquid has a minimum in viscosity under high pressure. However, our knowledge of the pressure dependence of the viscosity of magma (silicate melt) under high pressure is still limited. In this work, the viscosity of a molten sodium aluminosilicate with depolymerized structure was measured. A powder of the sample was prepared from the reagents of SiO_2, Al_2O_3, $CaCO_3$ and Na_2CO_3. The viscosity was measured by the falling sphere method using X-ray radiography. Experiments were carried out using the MAX-III apparatus installed at the NE7A station of the PF-AR synchrotron radiation facility at KEK (High Energy Accelerator Research Organization), Tsukuba, Japan. The falling of the Pt sphere was observed using an X-ray camera. This study shows that the viscosity of $NaCaAlSi_2O_7$ melt decreased initially with increasing pressure and then increased above 3 GPa. The viscosity of molten silicate is strongly related to the structure. The ratio of non-bridging oxygen and tetrahedrally-coordinated cation (NBO/T) of $NaCaAlSi_2O_7$ melt is similar to that of basaltic melt. Our results suggest that the viscosity of the depolymerized silicate is affected by the structural change of SiO_4 and AlO_4 networks. It has been reported that the composition of magma in the Earth’s deep interior is basic to ultrabasic. And it has been believed that the viscosity of basic to ultrabasic magma is very low. However, this study implies that the mobility of magma decreases in the deep interior of the Earth because of the viscosity minimum.

Keywords: Viscosity, Magma, Mantle

