

Viscosity of CO₂-bearing silicate melts at high pressure

Akio Suzuki^{1*}

¹Tohoku University

Viscosity is an important property of magma (silicate melt), because it controls the transportation of magma in the planetary interior. Traditionally, viscosity at high pressure was measured in quenching experiments. At the beginning a metallic sphere was placed at the top of a sample chamber. The falling velocity was determined from the falling distance during the molten period of sample. The movement of a metallic sphere in a sample chamber was recorded in X-ray radiography image. We have used this technique to determine the pressure, temperature and compositional dependence of the viscosity of silicate melts. The main goal of our study is to determine the effect of dissolving carbon dioxide on the viscosity of silicate melts at high pressure. It has been known that volatiles are dissolved in natural magmas and affects the physical properties. However, very few studies have been performed to investigate the effect of carbon dioxide on the viscosity of silicate melts at mantle pressures. In the present study, the viscosity of carbon-dioxide bearing CaMgSi₂O₆ and NaAlSi₂O₆ composition melts have been determined up to 5 GPa.

We installed an X-ray radiography system at the NE7A station at High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan. A charge-coupled device (CCD) camera with a YAG:Ce fluorescence screen was used to obtain the X-ray absorption contrast image. High-pressure was generated using a Kawai type multi-anvil apparatus, which was driven by a DIA type guide block in the MAX-III system. The pressure was determined by using an equation of state for MgO. A pure-Ge solid state detector was used to collect the X-ray diffraction data of the pressure standard by energy-dispersive method. The starting mixture was synthesized from reagents at 1 atm. A powder mixture of oxides and carbonates were fused and quenched to make a glass. Carbonate powder was finally added as a source of carbon dioxide.

Structural study has suggested that the CaMgSi₂O₆ composition melt is depolymerized. The viscosity of pure CaMgSi₂O₆ melt increases with increasing pressure. By the addition of 1.0 wt % of carbon dioxide produces about 50% decrease under pressure. NaAlSi₂O₆ composition melt has polymerized structure. In our previous study, we observed the decrease of viscosity of the pure NaAlSi₂O₆ melt with elevating pressure. In this study, we measured the viscosity of NaAlSi₂O₆ + 0.5 wt% CO₂ melt. The viscosity of CO₂-bearing NaAlSi₂O₆ melt decreases by about one order of magnitude. Our results suggest that the viscosity of the polymerized silicate and aluminosilicate melts are relatively reduced by the addition of CO₂, because CO₂ depolymerizes the SiO₄ and AlO₄ networks.

Keywords: magma, viscosity, high pressure, CO₂, volatile element, synchrotron radiation