

Viscosity of magmas at high pressure

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The viscosity of silicate magmas controls their mobility, and gives us an important knowledge about the time scale of volcanic activities and eruption styles in the present Earth. In addition, viscosity plays a central role in modeling magma ocean formation, chemical differentiation of the silicate mantle, core formation, and evolution of the atmosphere in the Earth's early history. In this presentation, I would like to review several viscosity measurements of silicate melts for understanding the fundamental laws of the viscosity.

The degree of polymerization, which increases with decreasing NBO/T, has long been recognized as a fundamental structural factor influencing physical properties. The viscosity of silicate melts is also characterized by the degree of polymerization. Polymerized melts show high viscosity at ambient pressure due to a forming three-dimensional network: every oxygen bridges between tetrahedral cations.

Depolymerized melts have lower tetrahedral connectivity and lower viscosity. The contrasting behavior between polymerized and depolymerized melts is also shown in the pressure dependence of viscosity.

Although free-volume theory, which showed a positive correlation between free-volume and diffusion coefficient, predicts that viscosity increases with pressure, isothermal viscosity of polymerized melts rapidly decreases with pressure up to ~3-5 GPa, above which it turns over to normal (positive) pressure dependence. In the case of depolymerized melts, the viscosity is less sensitive to pressure.

Comparing with pressure-induced structural evolution of silicate melts, there is a clear correlation between the viscosity and structure. The structure of depolymerized liquid is more close packed and shows little change with increasing pressure, resulting in a less sensitivity of viscosity. In sharp contrast, the negative pressure dependence of viscosity in polymerized melts is related to the shrinkage of the intermediate-order network structure, which causes the narrowing the T-O-T angle and weakening the T-O-T network. Although NBO fraction in the silicate melt/glass decreases gradually with pressure, NBO/T value under ambient condition seems to be a good indicator to understand the behavior of silicate melts.

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