Shear-Thinning and the Role of Particle Distribution on Fluid Viscosities of a Magma Analog System

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Effusive volcanism, like that found in Iceland's Reykjanes peninsula, poses a significant hazard to all living organisms in the vicinity of eruptive events. Magma that is transported to the surface contains three phases: exsolved volatile gases, crystalline solids, and a pseudo-plastic melt matrix. Compared to the thicker rhyolitic magmas of explosive eruptions, effusive basaltic flows, which have much lower crystal content and very little gas, have a much lower viscosity and travel farther across the surface at a greater rate. The purpose of this study is to use an NaCl+H_2O suspension to examine the material properties of an analogous two-phase mixture of crystalline solid and an equilibrium liquid melt. The use of the analog system allows us to greater control and manipulate crystal sizes and morphologies at easy to replicate laboratory conditions.

We used an Anton Paar Modular Compact Rheometer adapted to cold temperature with custom cooling to measure the shear stress and thus viscosity across intervals of increasing and decreasing shear rates, at a fixed temperature of -8ºC. Our slurry is comprised of various ratios (25:75, 20:80, 15:85) of sieved pure ice grains to 11.8 wt. % NaCl solution (the liquidus composition at that temperature), varying by both bulk composition and grain size. Of the three parameters tested, shear strain rate and composition showed the strongest trends. As shear rates increased, the viscosity of our suspension decreased across all compositions, which is consistent with the behavior of a shear-thinning non-Newtonian fluid. Crystal distribution and morphology in a suspension, like that of a basaltic magma, should also play an important role in its viscosity and surface behavior. We measured a clear relationship between solid fraction and viscosity, but the grain size dependence was not as uniform in this series of experiments. Additional work will explore this as well as the role of aspect ratio.