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An experimental study on the rheology of partially molten silicate systems: implication for volcanic risk

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A set of experiments was performed at high degrees of crystallinity (60-80 vol. %) to investigate the rheology of magma as a function of the fraction of suspended crystals, the strain rate, the confining pressure, and the viscosity of the silicate melt in equilibrium with the crystals. Quartz grains of selected size (between 56 and 125 μm) were thoroughly mixed with powdered quartz-saturated haplogranitic melt, containing 2.68 wt. % of water. The viscosity of the pure melt phase was measured beforehand in a piston cylinder apparatus using the falling sphere method. Deformation experiments were performed between 600 and 900˚C and between 175 and 250 MPa confining pressure. In this temperature range the viscosity of the liquid varies between $10^{8.5}$ and $10^{4.4}$ Pa·s and for the applied range of strain rates the melt behaves as a Newtonian fluid. The transition from Newtonian to non-Newtonian behavior that is due to the suspension effect of the particles in the crystal-liquid experiments, is followed by a metastable Binghamian state characterized by a linear relationship between strain rate and stress and by a finite yield strength at zero strain rate.

Our experimental results supplemented with literature data are used to formulate a comprehensive description of the rheological behavior and the relative viscosities as a function of the degree of crystallinity and the strain rate.

Further work will focus on constraining the propagation of melt mixtures in conduits.