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New experimental approaches on the rheology of magma slurries

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The rheological behaviour of high (and low) temperature magmatic slurries remain poorly constrained, despite much theoretical and experimental work (e.g. Petford, 2009). We present new results based on rheometrical techniques routinely employed in materials science to better understand the fluid mechanics of particle-rich suspensions. We use as a magma proxy micronised muscovite with controlled particle size distributions suspended in poly(propylene glycol) fluid of varying viscosity. Measurements were made on the rheological properties of the mixture in both the fluid crystalline state and as a structured soft solid at room temperature through systematic variation of the particle volume fraction.

A vane and serrated cup measuring geometry was employed to avoid artefacts from wall slip in rotational experiments and a variety of methods for estimation of the shear stress and apparent deformation rate critically evaluated. Data from a range of experiments are presented including flow curves (controlled stress and controlled rate), creep studies ('static' yield stress) and stress ramps ('dynamic' yield stress), linear viscoelastic measurements (varying strain, frequency, temperature) and assessments of time-dependent structural recovery (thixotropy), and their geophysical significance highlighted.

Rheometrical experiments were also performed using a novel extrusion flow cell that allows observation of slurry flow through a cylindrical channel. Combination of dynamic yield stress data from rotational experiments and pressure drop measurements from extrusion studies allows the prediction of the slurry effusion rate, following the treatment of Benbow and Bridgwater commonly employed in industrial extrusion situations.

There is still much debate on the existence of yield stresses in complex fluids and the practical challenges of their measurement are significant. These challenges are reviewed and placed in a geophysical context. One implication is that reports of yield stress in magma under laboratoty conditions are an artefact.

Petford, N (2009) Which effective viscosity? Mineralogical Magazine, 73, 167-191.