Effects of crystal size and shape distribution on the rheology of magmas: insights from analogue experiments

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Dynamics of magma in volcanic conduits is strongly influenced by rheological changes due to several microphysical processes such as vesiculation, degassing, and crystallization. Increase in crystal content can lead to strong increase in magma viscosity. Commonly in volcanic rock textures, prolate microlites are found in association with pre-existing phenocrysts which nucleated in deeper portions of the volcano plumbing system. Progressive increase of microlite percentage can thus dramatically affect magma rheology during its ascent and consequently influence the eruption style. This process is relevant over a broad spectrum of magma compositions. We performed analogue experiments simulating increasing prolate microlite content using different starting amounts of equant phenocrysts. Samples rheology was measured using a rotational controlled shear stress rheometer. Investigated samples were made of finer solid fibres and coarser spherical particles immersed in a Newtonian liquid. We found that blends of spherical and elongated particles are satisfactorily described using an interpolation of the adjustable parameters of Costa et al. (2009) model (Geochem. Geophys. Geosyst., doi:10.1029/2008GC002138) between the values obtained for the monodisperse spheres and those obtained for the monodisperse fibres. Results confirm the influence of particle size and shape distribution on the deviation from Newtonian behaviour. Such an effect is anticipated at lower solid fractions for high aspect ratio particles. Above a critical solid fraction, where particle-particle interaction is significant, the onset of yield stress is registered. Particle-particle interaction is also effective in establishing both concentration and grainsize distribution profiles of crystals, affecting effective flow viscosity.