How does crystal-rich magma erupt? A preliminary model for the rheology of three-phase suspensions

Jen Truby[1], Edward W Llewellin[1], Richard J Brown[1], Michael A Dungan[2]

[1]Department of Earth Sciences, Durham University, Durham, UK, [2]University of Oregon, Eugene, USA

E-mail: j.m.truby@durham.ac.uk

Current models of highly-concentrated particle suspensions predict that magma with very high crystal content should not erupt. However, field observations demonstrate not only that such magma can erupt, but that it can form fluidal pahoehoe flows. For example, the lava flows produced by the 1780 eruption of Volcan Llaima have well-developed pahoehoe textures, yet contain up to 60 vol. % phenocrysts. These observations beg the question: how does such crystal-rich magma erupt and flow?

We propose that the magma was made mobile by the presence of a distributed gas phase; i.e. the magma contained bubbles as well as crystals on eruption. Subsequent to emplacement, the gas was lost, leaving lavas that are crystal-rich, but almost bubble-free. As the lavas appear today, their crystal content is high enough that the crystals are all in contact, forming a dense framework throughout the lava. The crystal volume fraction is well above the maximum packing fraction (given the aspect ratio of the crystals) which should prevent flow of the lava.

Modelling such a lava as a two-phase suspension (crystals and melt) may not be truly representative of its state at the point of emplacement - the gas phase, no longer present, must also be accounted for. We present a preliminary model that accounts for the impact that gas bubbles have on the effective viscosity of the fluid phase surrounding the crystals. The model follows the approach of Farris (1968) and treats the bubbly liquid as an ‘effective medium’ in which the crystals are suspended; i.e. the crystals do not ‘feel’ the effect of individual bubbles, only the altered viscosity of a continuum fluid phase. The model predicts that the effective viscosity of the suspension will drop considerably above a certain bubble fraction, potentially allowing a locked suspension to flow.

Reference:

Farris, R.J. (1968) Prediction of the viscosity of multimodal suspensions from unimodal viscosity data. Trans. Soc. Rheol. 12, 281-301.

