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Polycrystalline magma behaviour in dykes: Insights from high-resolution numerical models

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The presence of a crystalline load in magmas modifies their effective rheology and thus their flow behaviour. In dykes, for instance, the presence of crystals denser than the melt reduces the ascent velocity and modifies the shape of the velocity profile from a Newtonian Poiseuille flow to a Bingham type flow. Nevertheless, several unresolved issues still remain poorly understood and need to be quantified: (1) What are the mechanisms controlling crystals segregation during magma ascent in dykes? (2) How does crystals transportation within a melt depend on their concentration, geometry, size and density? (3) Do crystals evolve in isolation to each other or as a cluster? (4) What is the influence of considering inertia of the melt within the system?

In this study, we present numerical models following the setup previously used in Yamato et al. (2012). Our model setup simulates an effective pressure gradient between the base and the top of a channel (representing a dyke), by pushing a rigid piston into a magmatic mush that comprised crystals and melt and perforated by a hole. The initial resolution of the models (401x1551 nodes) has been doubled in order to ensure that the smallest crystalline fractions are sufficiently well resolved.

Results show that the melt phase can be squeezed out from a crystal-rich magma when subjected to a given pressure gradient range and that clustering of crystals might be an important parameter controlling their behaviour. This demonstrates that crystal-melt segregation in dykes during magma ascent constitutes a viable mechanism for magmatic differentiation of residual melts. These results also explain how isolated crystal clusters and melt pockets, with different chemistry, can be formed. In addition, we discuss the impact of taking into account inertia in our models.

Reference:

Yamato, P., Tartèse, R., Duretz, T., May, D.A., 2012. Numerical modelling of magma transport in dykes. Tectonophysics 526-529, 97-109.