Magma accumulation and differentiation in a mushy magma chamber: Insights from numerical modelling

MATTHEW JACKSON[1], JAMES SOLANO[1,2], JON BLUNDY[3], STEVE SPARKS[3]

[1]Department of Earth Science and Engineering, Imperial College London, UK, m.d.jackson@imperial.ac.uk
[2]Now at Brevan Howard
[3]School of Earth Sciences, University of Bristol, UK

We present a quantitative model of heat, mass and both major and trace element transport in a compacting crustal mush which accounts for phase change and chemical reaction. We find significant modifications to melt composition that are not captured by batch/fractional melting/crystallisation models, or by models that fail to capture the evolution of local bulk composition when calculating phase equilibria. Within an upwards-cooling crustal mush, a high porosity layer forms which migrates towards the top of the mush defined by the solidus isotherm. Despite occupying a high porosity, the melt in this layer has a major element composition corresponding to a progressively smaller fraction of batch (static) melting, because it is migrating into, and locally equilibrating with, mush at lower temperature. The high porosity layer resembles a conventional magma chamber, but is produced by changes in bulk composition in response to melt migration, rather than the addition of heat. Indeed, such a layer can form even when the mush is cooling overall. Moreover, the magma chamber is located in the coolest part region near the top of the mush, rather than the hottest region near the base.

This is a new method to produce a magma chamber within a crustal mush, and also to evolve the major and trace element composition of the melt in the chamber. The accumulated melt is less enriched in incompatible trace elements than predicted if it is assumed that melt with the same major element composition has been produced by batch or fractional melting. Thus trace elements appear to be less fractionated than major elements: the melt is under enriched, and the crystal cumulates are over enriched, in incompatible elements compared to batch/fractional melting model predictions. The creation of evolved magmas within the crust can be explained by melt migration and component transport through a reactive crystalline mush, with timescales, rates and thermal budgets consistent with natural systems.