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Melting and melt transport mechanisms in the dynamic earth: from melt segregation, extraction to the formation of crustal magmatic systems

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Introduction

At various regions within the dynamic earth melts are generated due to decompressional melting, reduction of the solidus temperature due to volatiles or due to elevated temperatures. They segregate from these partially molten regions, rise by various transport mechanisms and may form crustal magmatic systems where they are emplaced or erupt. The physics of various aspects of this magmatic cycle will be addressed.

Melt transport mechanisms

Starting from a partially molten region by which mechanism(s) does the melt segregate out of the melt source region and rise through the mantle or crust? The basic mechanism is two-phase flow, i.e. a liquid phase percolates through a solid, viscously deforming matrix. The corresponding equations and related issues such as compaction or effective matrix rheology are addressed. Beside simple Darcy flow, special solutions of the equations are addressed such as solitary porosity waves. Depending on the bulk to shear viscosity ratio of the matrix and the non-dimensional size of these waves, they show a variety of features: they may transport melt over large distances, or they show transitions from rising porosity waves to diapiric rise or to fingering. Other solutions of the equations lead to channeling, either mechanically or chemically driven. One open question is how do such channels transform into dykes which have the potential of rising through sub-solidus overburden. A recent hypothesis addresses the possibility that rapid melt percolation may reach the thermal non-equilibrium regime, i.e. the local temperature of matrix and melt may evolve differently. Once dykes have been formed they may propagate upwards driven by melt buoyancy and controlled by the ambient stress field. Often in dynamic models the complexities of melt transport are simplified by parameterized melt extraction. The limitations of such simplifications will be addressed.

Modelling magmatic systems in thickened continental crust

Once basaltic melts rise from the mantle, they may underplate continental crust and generate silicic melts. Early dynamic models (Bittner and Schmeling, 1995, *Geophys. J. Int.*) showed that such silicic magma bodies may rise to mid-crustal depth by diapirism. More recent approaches (e.g.

Blundy and Annan, 2016, *Elements*) emplace sill intrusions into the crust at various levels and calculate the thermal and melting effects responsible for the formation of mush zones. Recently Schmeling et al. (2019, *Geophys. J. Int.*) self-consistently modelled the formation of crustal magmatic systems, mush zones and magma bodies by including two-phase flow, melting/solidification and effective power-law rheology. In these models melt is found to rise to mid-crustal depths by a combination of compaction/decompaction assisted two-phase flow, sometimes including solitary porosity waves, diapirism or fingering. An open question in these models is whether or how dykes may self-consistently form to transport the melts to shallower depth. First models which combine elastic dyke-propagation (Maccaferri et al., 2019, *G-cubed*) with the two-phase flow crustal models are promising.