On the dynamics of mixing in crystal-rich magmas

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Open system events in magmas often involve interactions between an incoming crystal-poor magma and a resident crystal-rich mush. This is expressed by complex phenocryst populations, many of which preserve many episodes of recycling within the same thermal prograde envelope. The unlocking and mobilization of resident mushes conditions the progress of mixing, however the processes are poorly understood. Crystal-rich, but mobile systems, dominated by granular mechanics, are not satisfactorily explained by either fluid or solid-like models.

We will present a generalizing framework for describing the dynamics of crystal-rich mushes based on the notion of forces chains immersed in a viscous fluid. Force chains arise from crystal-crystal contacts and describe the highly non-uniform way that stress is transmitted in a crystal-rich mush. Using CFD-DEM simulations that resolve crystal-scale mechanics we will show how populations of crystal mush chains and their spatial fabric change during an open system event. We will show how the various forms of dissipation such as, fluid drag, particle-fluid drag, particle normal and shear lubrication and contact friction jointly contribute to the processess of mush unlocking, mobilization and fabric formation. One implication of this is that many of the commonly invoked postulates about magma behavior such as lock-up at a critical crystallinity and suspension rheology are better understood from a micro-physical (crystal-scale) perspective as a combination of far-field geometrical controls, local frictional thickening and shear jamming, each with distinct time-scales. This kind of crystal-based unifying framework can simultaneously recover diverse processes such as strain-localization, shear-induced dilatency, and also to help identify the volumes of resident magma re-mobilized during an open-system event.

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