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Re-awakening Magmatic Systems: The Mechanics of an Open-system Event

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The re-awakening of magmatic systems requires new magma input, which often induces mixing with a resident magma existing as a crystal-rich mush. This is expressed by complex phenocryst populations, many of which preserve evidence of multiple episodes of recycling. The unlocking and mobilization of these resident mushes conditions the progress of re-awakening, however their processes are poorly understood. Crystal-rich but mobile systems, dominated by their granular mechanics, are not satisfactorily explained from either fluid or solid-like models.

We will present a generalizing framework for describing the mechanics of crystal-rich mushes based on the notion of force chains. 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 the populations of crystal mush force 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 processes of magma mush unlocking, mobilization and fabric formation. We will also describe non-intuitive constitutive behavior such as non-local and non-affine deformation as well as complex, rheological transitions from continuous to discontinuous shear thickening as a function of the dimensionless shear rate. 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 help to identify the volumes of resident magma re-mobilized during magma system re-awakening.