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The origin and micromechanics of the preferential orientation of crystals in mush

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An obstacle to developing a general mechanical framework for magma mush is the emergence and complexity of a crystal fabric. To illuminate the conditions that produce a crystal fabric we performed time-dependent numerical simulations using a Computational-Fluid-Dynamics and Discrete-Element-Method (CFD-DEM) model in three dimensions. The specific focus was on the role of shear strain in the creation of a preferential orientation of crystals in mush. CFD-DEM method allows for the simultaneous coupling and frictional interactions of melt and crystals undergoing shear strain. The crystal shapes are represented using spheroids (either oblate or prolate). Simulations consist in imposing a compression stress (pressure) and a simple shear to a dense suspension of crystals in a viscous liquid, and monitoring the evolution of the orientation and strength of the shape fabrics. We ran a series of simulations by varying the size and aspect ratio of the particles. We considered samples in which all the solids have the same volume and shape, and cases including size and aspect ratio distributions. Results show that the strength of the shape fabric and the angle between the crystal preferential orientation and the compression plane both increase with the shear strain up to steady state values, which are primarily controlled by the aspect ratio of the particles. The stronger the aspect ratio, the greater the magnitude of the preferential orientation and the lower its angle relative to the compression plane. When introducing a distribution in the size of the crystals, we observed a decrease in the strength of the shape fabric and an increase in the angle between the preferential orientation of the crystals and the compression plane compared with samples composed of crystals having the same shape and size. Similarly, the distribution in the aspect ratio further decreases the strength of the shape fabric and increases the angle between the preferential orientation of the solids and the compression plane. Finally, we employed an alternative approach to quantify the amount of foliation and lineation and show that the samples always display a stronger foliation than lineation, although the shear strain increases both the foliation and the lineation.