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The permeability of magma mush assembled from anisotropic tabular crystals

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The extraction of melt from a mush in a magma reservoir is of wide interest. All models for melt extraction from a mush require knowledge of mush permeability, and yet this remains poorly constrained. This permeability is typically calculated using the Kozeny-Carman model or variants thereof, which require a priori knowledge of the microstructural geometry. Such models are not calibrated or tested for packs of crystals of a range of shapes found in natural mush piles, leading to the potential for oversimplification of complex natural systems.

Essentially, a magma mush with minimal crystal-crystal intergrowth is composed of packed crystals where the pore space is filled with interstitial melt. Therefore, this can be studied as a granular medium. We use numerical methods to create domains of closely packed, randomly oriented cuboids in which we keep the short and intermediate axes lengths equal (i.e. square cross section) and vary the long axis magnitude. Our synthetic 'crystals' therefore cover the range from oblate to prolate, passing through a cubic shape. We supplement these with 3D numerical packs of spherical particles in cubic lattice arrangements or random arrangements. For the sphere packs we use various polydispersivity of sphere sizes. The permeability of all of these pack types is calculated using a numerical simulation (both LBflow and Avizo-based algorithms) with imposed periodic boundary conditions. The preliminary results suggest that the permeability of a granular medium scales with the specific surface area exclusively, without requiring prior knowledge of the geometry and size distribution of the particles.

We suggest that the model toward which we are working will allow magma mush permeability to be modelled more accurately. If our approach is embedded in existing continuum models for mush compaction and melt extraction, then more accurate estimates of melt accumulation rates prior to very large eruptions could be found.

Keywords: melt segregation, compaction, granular media, fluid flow, numerical simulation