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The permeability of loose magma mush

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Large-volume rhyolitic eruptions are characteristically crystal-poor yet are thought to originate from crystal rich magma mush bodies. This contradiction is explained by the interstitial melt being extracted prior to the eruption, generating large volumes of crystal-poor magmas. The timescale for melt extraction is inversely correlated to the permeability of the mush, defined by the shape of the crystals. Yet, existing approaches for estimating the crystal framework permeability do not account for crystal shape. Here, we represent magma mush by using numerically generated packs of hard cuboids with a range of aspect ratios and at their maximally dense random packing. We use lattice-Boltzmann simulations to constrain the permeability of the cuboid packs, showing that crystal shape exerts a first-order control on both the melt fraction at maximum packing, and on the constitutive relationship between permeability and melt fraction. Using percolation theory and a validation dataset, we develop a predictive scaling framework to compute permeability for mush comprised of crystals that can be approximated by cuboids, valid at melt fractions down to, and including the random maximum packing of crystals. We show that for packs of prolate cuboids, the melt extraction timescale can be reduced by almost two orders of magnitude relative to a pack of oblate cuboids, implying that rejuvenation timescales leading to eruption could be much shorter than previously predicted, using our novel permeability model that is sensitive to crystal shape.