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The Influence of Crystal Shape and Ordering on the Mechanical Response of a Mush during Strain

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The mechanical behavior of crystal-rich mush controls the dynamics and evolution of magma bodies but is poorly understood, . The presence of a semi-rigid contact network in the crystal phase greatly affects the rheology of mush but the contributions of crystal shape to the force, contact and shape fabric remains poorly characterized. This in turn influences the transmission of stress in the mush, the packing stiffness, and the volume fraction at jamming. It is also unclear whether the total amount of deformation of a mush can be quantitatively determined from the shape preferred orientation of the crystals. We performed 3D numerical simulations using a coupled computational fluid dynamics and discrete element method to illuminate the dynamic states of non-spherical crystals in a viscous melt. Simulations consisted of the simple shear of a mush under a constant pressure upper boundary. Crystals are represented by elongated cuboids having an aspect ratio of four. Our results differ from those obtained with smooth spheres and shed light on the influence of the crystal shape and orientation fabric on the mechanical properties of a mush. We found two distinct behaviors associated with the transient and steady-state, however at all times strain is nonaffine. During the transient, the strain is accommodated by the emergence of multiple shear bands and tends to concentrate on a single one. The shear bands emerge because of steric blocking and space limitations preventing the rotation of elongated particles, generating the local and temporary jamming of the crystal network. On the contrary, in the residual and steady-state, the strain is accommodated by one main shear band. The analysis of the orientation of the crystals shows that the deformation of the mush tends to increase the foliation of the crystals more than their alignment.

Publication: AGU Fall Meeting 2021, held in New Orleans, LA, 13-17 December 2021, id. V11B-03.

Pub Date: December 2021

Bibcode: 2021AGUFM.V11B..03C

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