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On the physics of crystal-rich mush

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A crystal-rich mush is an endoskeleton immersed in a silicate liquid. The dynamics are controlled by the interplay of contact friction, pore pressure-lubrication, hydrodynamic drag and buoyancy. These in turn depend sensitively on intrinsic properties such as crystal shape (and hence coordination number), roughness, melt viscosity, and external factors such as history, strain rate and imposed stress. Suspension rheology is actually the result of (at least) three distinct micro-physical processes and the diversity of complex non-affine responses observed in Paterson rig experiments cannot be adequately described with solid volume fraction alone. The key piece of physical logic is the occurrence of force chains and normal forces, which are activated by the onset of frictional contacts. In polydisperse systems the force chains reside primarily in the larger crystals, so the shear strength is largely independent of the distribution of polydispersivity (within a single shape class). Shear strength increases with crystal elongation and faceted character and elongated crystals can have either unusually high or low packing fractions, which in turn dictates the conditions of hard jamming.

Macroscopic mush strength is a crystal network quantity that involves both structural and functional characteristics. These refer to the topology of the crystal contact network, and the orientations and magnitudes of the forces distributed in that network. We will rationalize many of these intrinsic and extrinsic controls by introducing the "f factor", which is a tensor describing the magnitude and orientation of contacts that are in friction. An f factor of zero indicates a system controlled by hydrodynamic interactions and steric effects, and an f factor of unity is one where the crystals are all in frictional contact. A full description of the strength network must also quantify force chain redundancy. Redundancy refers to the presence of multiple paths of force transfer, such that if contacts fail at one point, force can be redistributed within the network without large-scale failure.

Lastly, there are numerous routes to the formation of shear bands and localized strain. One is force chain buckling and the onset of local crystal vorticity that has a type of entrainment that makes the shear band grow. Another is the formation of crystal clusters by frictional entanglement during rotation that act as type of strain 'attractors' and/or blocking elements that can screen or redirect bulk strain.