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Probing the characteristics of mush-magma transition: insights from laboratory experiments

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The mush-magma transition (MMT) marks a profound change in rheological properties between two of the principal magmatic reservoirs that constitute a magmatic system. Mush behaves as a solid and its rheology is largely dominated by the deformation of the crystals network whereas magma is a liquid and has a rheology dominated by melt.

To better understand the solid-liquid transition in such crystal-rich systems, we present here an experimental study using mixtures of aqueous superabsorbent polymers (SAPs). SAPs are constituted of polymer grains that in water can swell up to 100 times and form gel grains whose size can be controlled by controlling the size of the initial powder. Particle fractions between 60% and 80% are easy to reach, making this system a promising analog of mush. The non-Newtonian rheology of the mixture of water and touching grains combines viscous, elastic and plastic aspects and can be characterized using the free-fall of spheres of different diameters and densities.

We observe five different regimes of motion for the settling of a sphere: (1) A linear regime where the sphere has a rapid and linear fall and reaches a constant terminal velocity. (2) An irregular regime where the sphere's velocity fluctuates around a constant value. (3) A stop&go regime where periods of no-motion and periods of irregular falls follow one another. (4) A slow fall regime where the sphere's velocity progressively decreases in a logarithmic way. And (5) a no-motion regime when spheres are not buoyant enough to overcome the yield stress of the mixture or are too small compared to the grain size. So, the Yield number (ratio of the yield stress to the sphere buoyancy-induced stress), critical value Yc above which there is no motion decreases as the sphere to grain diameters ratio becomes smaller than 2. This enlarges the domain of conditions under which the mush strength will lead to the entrapment of the intruder. Moreover, the mixture structure strongly affects the path that a buoyant melt pocket can follow through the mush, and the time it spends motionless. The latter will increase the time available for reactions between melt and surrounding crystalline matrix.