Flowers, snowflakes and crystalline magmas - insight into gas migration regimes in crystalline viscous melts

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Magmatic volatiles affect eruption processes, and are therefore widely studied. However, the physical effects of crystals on degassing processes are often disregarded, except for considerations of their role on the bulk viscosity of the magma. Here we address this issue by asking the fundamental question: How do crystalline magmas degas?

We have started to answer this question by running a set of experiments in a Hele-Shaw cell to map gas flow regimes in 3-phase systems (sugar syrup, air, and $\sim$ 100μm polydisperse glass beads). The experimental apparatus consists of two glass plates separated by a 0.48mm gap. During an individual experiment, air is injected into the mixture at a steady rate using a syringe attached to a mechanical pump. Air influx, viscosity and particle volume fraction are varied between experiments.

We consider three main regimes, as identified by patterns of gas distribution: (1) fingering, characterized by long, irregular, smooth intrusions of air into the mixture at a relatively steady rate; (2) fracturing, whereby the gas penetrates the mixture in bursts, and forms a trail of thin cracks; and (3) gas filter pressing (or capillary fingering) which is the advance of gas between the particles, pushing out the liquid without disrupting the particle network. We therefore expect distinctive air pressure profiles for each regime. These will support the interpretation of 3D experiments, for which bubble shapes will no longer be visible.

Preliminary results suggest that transitions between regimes do not depend on the liquid viscosity (for $\mu \leq$ 100 Pas) but are strongly dependent on crystal volume fraction. Specifically, gas flow transitions from fingering to fracturing $\sim$54% crystals, which is close to, but not at, the maximum packing fraction. When the maximum packing is reached, the gas flow regime changes from fracturing to gas filter pressing. These observations have important implications for gas escape from crystal mush zones. Other interesting results include (1) a transition from fracturing to fingering when the gas front approaches the edge of the experimental set-up; (2) local variations in crystal volume fractions due to the advancing gas fronts, which can cause a change in regime; (3) the development of preferential flow paths towards zones of higher or lower crystal fractions (depending on the regime), therefore shifting the location of degassing; and (4) the development of new degassing pathways, replacing the existing primary channel, in a manner reminiscent of the irregular degassing observed at some volcanoes.