Rhythm of magma transport in deformable porous media

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Volcanic activity, which is the surface manifestation of magma transport, appears to be intermittent. Moreover, the distribution of volcanic activity often shows a characteristic spacing along intra-continental rifts, mid-oceanic ridges, subduction related volcanic arcs, or rift zones in volcanic complexes (e.g. Iceland, Hawaii). However the physical mechanisms at play to create these spatio–temporal patterns are still debated. Magma transport in the Earth involves flow of a slurry (crystals, liquid and bubbles) into an elastic solid matrix which can undergo compaction. A quantitative understanding of such a complex system is lacking. Here, we attempt to bridge this gap and to explain the origin of intermittency in magma transport system, using fluid dynamic modeling of buoyant plumes in a deformable–gel beads layer.

A thin transparent tank ($2\times20\times18$ cm^3) is filled with a mixture of hydrogel beads and a viscous fluid, as an analog to an elastic compacting lithosphere or crust containing some partial melting; a viscous fluid ($\sim$10 Pa.s) is supplied from a nozzle (inner diameter: 7.5 mm) or from a slit (gap: 5 mm) at a constant volume flux. The hydrogel beads (polyacrylamide, diameter: $\sim$5 mm, shear modulus: 1.2×10^4 Pa) are deformable and the volume fraction of the interstitial fluids is about 15%. For the point source experiments, we identify at least three types of fluid flow: homogeneous permeable flow, pulsating flow, and localized continuous flow. The flow behavior depends on the injection flow rate, the rheological properties of the mixture, and the volume fraction of the interstitial fluid. For the line source experiments, the flow pattern always shows a time-dependent behavior. As the viscous fluid is supplied from the source at a constant volume flux, the fluid percolates into the gel beads layer until a gravitational instability (Rayleigh–Taylor instability) occurs. Then, the flow is localized through channels with a characteristic spacing. The plume flow is relatively continuous around the source region; however, the flow along the channels can become unstable and create pulses. Their characteristic frequency is obtained by image analysis.

Our experimental model suggests that the spatio-temporal distribution of volcanic activity is inherent to magma transport in a weak elastic and compacting lithosphere or in a partially molten zone (like for exemple a magma chamber).