Geophysical Research Abstracts
Vol. 15, EGU2013-5334, 2013
EGU General Assembly 2013

Existence, morphology and persistence of intrusions as a probe for lithosphere rheology

Anna Massmeyer (1), Anne Davaille (1), Erika Di Giuseppe (1,2)
(1) FAST (CNRS / UPMC / Univ. P-Sud), FAST, ORSAY, France (davaille@fast.u-psud.fr), (2) IPGP, Paris, France

The development of intrusions in the lithosphere depends strongly on its rheology. Less viscous mushroom-shaped plumes or more viscous finger-shaped diapirs, depending on the viscosity ratio between the rising and the matrix materials, are known to migrate through ductile, quasi-newtonian lithosphere; while dikes fracture and propagate through a solid matrix. However, the lithosphere presents solid as well as viscous properties. To determine what happens in this complex case, we performed a combined study of laboratory experiments and numerical simulations on the development of thermal plumes in aqueous solutions of Carbopol, a polymer gel suspension forming a continuous network of micrometric sponges. This fluid is shear thinning and presents a yield-stress, whereby flow occurs only if the local stress exceeds a critical value σ_0. Below this value, the fluid acts as an elastic solid. The rheological properties of the solutions can be systematically varied by varying the Carbopol concentration. Our experimental setup consists of a localized heat-source of constant power, placed in the center of a squared plexiglas tank.

Two conditions must be fulfilled for an instability to develop and rise: 1) the Yield number ψ_0 comparing the buoyancy-induced stress to the yield stress, should be greater than a critical value $\psi_c \sim 6$; and 2) the Bingham number Bi, comparing the yield stress to the viscous stresses, needs to be locally smaller than 1. Then, a plug flow develops inside the plume thermal anomaly, producing a rising finger-shape with strong shear zones confined along its edges. Moreover, the instability halts its ascent as soon as $\psi_0 < \psi_c$ or $Bi > 1$.

Those finger-shaped diapirs show strong similarities with an off-axis diapir in Oman emplaced in a ridge context. This geological object, a few kilometers in diameter, presents strong shear localization along its edges. Our fluid dynamical analysis places constraints on the parameter range within which such an object may be emplaced. It suggests that a purely thermal anomaly could only be emplaced in a partially molten lithosphere (with σ_0 ~100 kPa). But the yield stress of the surrounding matrix might be much higher (up to $\sigma_0 \sim 50$ MPa), if the instability also exhibits a chemical density anomaly. On the other hand, this critical yield stress constitutes a lower value of σ_0 for an intrusion to remain trapped in the lithosphere.