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The effects of solidification on sill propagation dynamics and geometry

Chanceaux Lola (1) and Menand Thierry (2)

(1) Laboratoire Magmas et Volcans, Université Blaise Pascal, Clermont-Ferrand, France (l.chanceaux@opgc.univ-bpclermont.fr), (2) Laboratoire Magmas et Volcans, Université Blaise Pascal, Clermont-Ferrand, France (t.menand@opgc.fr)

The effects of solidification on sill propagation dynamics and geometry are studied by means of analogue laboratory experiments. Hot fluid vegetable oil (a magma analogue), that solidifies during its propagation, is injected as a sill in a colder layered gelatine solid (an elastic host rock analogue). The injection flux and temperature are maintained constant during an experiment. In order to vary the importance of solidification and quantify its effect on sill propagation, the injection flux and temperature are systematically varied between each experiment.

Depending on the importance of solidification effects, two extreme behaviours for sill propagation dynamics and geometry are observed. When solidification effects are small (high injection temperatures and fluxes), the propagation is continuous and the sill has a regular and smooth surface. Inversely, when solidification effects are important (low injection temperatures and fluxes), sill propagation is discontinuous and occurs by steps. After each propagation step, the sill stalls, thickens progressively by storing hot fluid vegetable oil beneath the partially solidified intrusion, without growing neither in length nor in breadth, and after a pause, the propagation initiates again, soon followed by a new episode of momentary arrest. The geometry of these sills displays folds, ropy structures on their surface, and lobes with imprints of the leading fronts that correspond to each step of surface creation.

These experiments show that for a given, constant injected volume, as solidification effects increase, the surface of the sills decreases, their thickness increases, and the number of propagation steps increases. In the same way lower solidification effects promote larger sill surfaces, lower thicknesses, and a lower number of propagation steps.

These results have various geological and geophysical implications. Regarding the geometry of sills, 3D seismic studies in sedimentary basins reveal sills with lobate structures similar to those of lava flows. Our experiments show how these lobate structures could reflect the effect of magma solidification during their emplacement. Moreover, these experiments show also that a non-continuous geometry as observed in the field does not necessarily involve multiple injections. Also, like dykes, a discontinuous propagation should be associated with bursts of seismic activity (e.g. Taisne and Tait, 2011; Taisne et al., 2011). Finally, sills are considered as the building blocks for constructing larger magmatic bodies as plutons. Our study shows how solidification effects restrict the surface of sills, which impacts directly the size of plutons constructed incrementally by amalgamated sills.