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Silica powder and vegetable oil for modelling magma emplacement into a deforming brittle crust

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In the brittle upper crust, magmatic activity concentrates at tectonic plate boundaries. It occurs in a wide range of tectonic settings, including extension and compression, and the resulting intrusive bodies have a correspondingly wide range of shapes. In both extension and compression, the intrusive bodies appear to concentrate along major fault zones.

A good way to understand the mechanical interactions between magmatic activity and tectonic deformation in the upper crust is through analogue experiments. The first technique to be developed was fluid injection in blocks of elastic gelatine. Such a technique is useful for studying hydraulic fracturing, as in dyke emplacement. However, the shear strength of gelatine is too high for models at crustal scale. In another technique, models consist of sand and stiff silicone. Sand is a Coulomb material and correctly simulates shear faulting in the upper crust. However, it is cohesionless and does not allow open fractures to form. Furthermore, stiff silicone represents very viscous magma and it emplaces by ballooning. Sand/silicone models are therefore not suitable for modelling the emplacement of low-viscosity magma in the brittle crust.

To solve these problems, we found new analogue materials. The model crust needs to be a cohesive Coulomb material. We chose fine-grained crystalline silica powder and siliceous microspheres, of which the cohesive strengths are 300 Pa and a few Pa, respectively. A mix of both powders gives an intermediate material of cohesion $\sim$60 Pa. The model magma needs to have a low viscosity. We chose a molten vegetable oil, of which the viscosity is 0.02 Pa s at 50˚C. It solidifies at $\sim$31˚C. The models were made of compacted silica powder, either homogeneous or stratified, in a rectangular

box. A moving piston was able to deform the model in extension or compression. During the experiments, a volumetric pump injected the oil into the model. At the end of each experiment, the oil solidified and the models were cut into longitudinal cross sections.

We did a set of preliminary experiments under various conditions of deformation. In the absence of deformation, oil injection resulted in an axi-symmetric saucer-shaped sill. Extensional deformation resulted in a rift, while simultaneous injection produced a sub-vertical dyke. The dyke was approximately perpendicular to the extension direction, but followed normal faults over some distances. Compressional deformation resulted in thrusts, while simultaneous injection produced a horizontal sill, branching into an inclined sheet along a thrust. Such features are very similar to those observed in nature in corresponding tectonic settings. Therefore fine-grained silica powder and vegetable oil appear to be suitable materials for modelling the emplacement of low-viscosity magma into a deforming brittle crust.