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First Results of Centrifuge Modelling of Plutons intruding Strike-Slip Shear Zones

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It is widely accepted within the geoscientific community that plutons use crustal scale strike-slip shear zones as pathways for their ascent. However, there is no agreement about the question how plutons rise within shear zones - diapirically or by dyking - and how plutons and shear zones interact.

To find solutions for these problems , combined simple shear and centrifuge experiments were carried out at the Hans Ramberg Tectonic Laboratory of Uppsala University (Sweden). Three centrifuge models (100 mm tall and 80 mm wide) were built: two with a semibrittle overburden of plastilina (25 mm thick, viscosity = 10^7 to 10^8 Pa s, density = 1.705 g/cm^3) and one with a non-Newtonian ductile overburden (24 mm thick) with a density of 1.725 g/cm^3 and a viscosity in the range of 10^5 to 10^6 Pa s (at a strain rate of 10^{-1} to 10^{-2} s^{-1}). Both overburden materials represented rocks of the middle crust with a viscosity of ca 10^{20} Pa s and a density of about 2.9 g/cm^3. The overburden was in all three cases stratified, consisting of differently coloured layers, to document deformation due to the rise of the buoyant material. A passive grid was put on top of the modell to record deformation of the model while shearing. PDMS (viscosity: $4*10^4$ Pa s, density: 0.964 g/cm^3) acted in all experiments as a buoyant layer, simulating an entirely molten granitic magma (viscosity: 10^4 to 10^9 Pa s, density: 2.0 to 2.4 g/cm^3). To make deformation structures within the buoyant material visible, two differently coloured PDMS layers (a yellow layer atop a blue one, each 3 mm thick) were placed at the bottom of the model. One of the aims of the experiments was, to find out, if shearing alone is able to initiate a diapiric rise of the buoyant layer. Therefore, no perturbation was initiated in the buoyant PDMS layer. However, cuts, simulating shear fractures were introduced in the two plastilina models in order to see if the buoyant material was using the fractures as pathway during its ascent eventually. Because shearing simultaneously with centrifuging was not possible with the used shear apparatus, shearing and centrifuging (in this order) were applied alternately to the models.

The model with the ductile overburden did not result in any diapir. Even at an angular shear strain γ of -1.07 (total dextral simple shear offset: 4 cm) and after centrifuging for -in total - 27 min at 700 to 720 G the PDMS did not manage to pierce through its viscous, but still competent overburden.

Two prescribed cuts were introduced in the plastilina overburden of the semibrittle models. The cuts, 20 mm long, penetrated the entire 25 mm thick overburden. The cuts were arranged at an angle of 45° and were parallel (in model 1) and perpendicular (in model 2) to the maximum principle stress.

In model 1, where the cuts were parallel to σ_1, the cuts opened up about 3 mm during the first 12 mm of dextral shearing (γ: -0.33). After centrifuging for 8 min at ca. 700 G the cuts had opened for additional 2 mm. The PDMS layer had risen through the opened cuts in the plastilina overburden and spread at the surface of the model. Further shearing for an additional 8 mm to a total angular shear strain of -0.38 and 5 min more of centrifuging at 730 G led to propagation of the cuts into shear-parallel tension fractures. More buoyant material extruded and caused merging of the two PDMS masses extruding from the cuts. Sections of this model showed clearly that the PDMS migrated as dykes through the initiated fractures with the yellow top layer followed by the blue bottom layer.

In model 2, which also had a semibrittle plastilina overburden. the cuts were arranged at 45° to the shear direction perpendicular to σ_1. Shearing and centrifuging increments were the same as during the model 1. During the first 12 mm of shearing the cuts closed and buckles formed where the cuts intersected the model´s surface. Centrifuging and further shearing resulted in the formation of three pull apart basins (up to 20 mm long, 7 mm wide and 15 mm deep), which have long axes perpendicular to the initial cuts. However, none of these pull apart basins reached deep enough to tap the buoyant PDMS layer. Consequently, no buoyant material intruded the overburden. Because plastilina is too stiff to allow the diapiric rise of the relatively low-viscous PDMS, no buoyant material at all left the source area.

Transferring the results back to nature, the three models indicate that movement along a strike-slip shear zone alone is not sufficient to generate the buoyancy driven ascent of igneous material. It is rather necessary for a successfull intrusion to rise along pre-existing mechanically weak zones (i.e. fractures). However, the ascent of the buoyant material then takes place by dyking and not diapirically.

Further experiments with a shear box which allows shearing while centrifuging will verify, if this is also true for synkinematic intrusions.