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Analogue modelling of ductile-to-brittle transition in viscoplastic anisotropic materials: influence of strength on shear fracture localization and network geometry

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Localization and propagation of fractures in an elastoviscoplastic material can be regarded as a competitive process between an external loading rate and the viscous relaxation rate of the material. Conceptually, if the first one is bigger than the second one, there is an increment of stress in the system until the strength limit of the material is reached. Then, a shear fracture network can nucleate and propagate, and the deformation imposed by the boundary conditions will be resolved in localized bands. Alternatively, if the viscous rate is able to relax the imposed stress, shear fractures will not nucleate and then the imposed deformation will be distributed (homogeneous or heterogeneously) within the material. The limit between the second condition and the first one traces the ductile-to-brittle transition, which is a clue to understand crustal dynamics.

This contribution presents an experimental study on shear fracture localization and networking by making a comparison between analogue materials with very different properties. Two types of plasticine multilayer models (relatively *hard* and relatively *soft*) have been deformed under pure shear boundary conditions and systematically studied. We have chosen plasticine because it is a widely used analogue material that can easily produce shear fractures.

Uniaxial compression and relaxation tests were carried out to analyze the mechanical properties of the experimental materials. At laboratory conditions this kind of commercially available plasticine shows a non-linear viscoplastic behaviour with a stress exponent of n=3-5. The softer plasticine, that was mixed with vaseline, is about 10 to 100 times less viscous than the harder one, and therefore their brittle strength is different. Both rock analogues show a Maxwell-like pattern at relatively low strain rates, and while the softer one registers a steady-state flow, the harder one exhibits a softening trend of evolution when deformation increases.

The models were made by stacking alternating 5 mm. thick layers of coloured plasticine oriented at different angles to the maximum extensional axis X (0º, 20º and 40º). Layering confers a composite anisotropy to the models that can be increased by adding paper flakes oriented parallel to it. All the blocks were deformed at a constant temperature of 26ºC. The studied parameters were the geometry of fractures, their orientation with regard to the foliation and to the stress field and the fracture index (FI).

Preliminary results evidence a very different response of the two types of models to the applied strain rate conditions. Strain is strongly localized for the hard plasticine models, and it is mainly controlled by a few active faults. There is a strong strain softening in the system because deformation is accommodated by these large faults, while viscous deformation is low in inter-fracture lozenges bodies. In this case, the fracture propagation rates are of an order similar than the boundary velocities. In opposition, the softer plasticine models evolve by coeval fracturing and viscous flow. Deformation is distributed in a large population of shear fractures of a limited length with low propagation rates. A close steady state flow or a slight hardening is registered by the soft models. For an elasto-viscous-plastic material, the viscous ductility of the material defines a change on the degree of shear localization and networking geometry. The presented models are illustrative examples of the transition between a localized and a distributed deformation system.