Failure mode transition as result of effective stress – insights from analogue modeling using hemihydrate powder and sand

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The transition of failure modes from dilatational mode I fractures to mode II shear fractures due to increasing normal stress in modeling materials such as hemihydrate powder ($CaSO_4 \cdot ½ H_2O$) or in natural prototypes (e.g. carbonates) was observed before (van Gent et al., 2010). Nevertheless, the effect of changing failure modes on three-dimensional fault geometry has not been studied so far in analogue models. We present an easy and cheap method of creating large three-dimensional analogue models with adjustable failure modes using only sand, hemihydrate powder and water. For this we build a layer-cake consisting of a basement of sand, an interbedded layer of hemihydrate powder and a top layer of sand. By adapting the thickness of the overburden sand layer, i.e. the effective normal stress, we can adjust the failure mode. Low stresses cause the creation of dilatational mode I fractures as well as steep cliffs due to a brittle behavior of the hemihydrate powder. At higher stresses the cohesion and tensile strength of the hemihydrate powder increases significantly, leading to pure mode II shear failure. Open fractures are scarce and fault dips are shallower. Intermediate normal stresses allow the formation of transitional cases. After the deformation we harden the hemihydrate layer by wetting the layer-cake slowly with water. Being hardened the plaster layer can be excavated quickly with brushes or a hot air gun.

In two series of experiments we show the effect of the failure mode transition exemplary by extensional graben faults and strike-slip faults, varying the overburden from 0 cm up to 6 cm of sand. Thus we cover the full range of failure modes. Resulting structures are studied using high resolution photographs and 3D models derived from photogrammetry. Investigation of characteristic structures for each failure-type might help to transfer this information to seismics and hence a better interpretation of subseismic-scale structures.

References:

van Gent, H. W., M. Holland, J. L. Urai, and R. Loosveld (2010), Evolution of fault zones in carbonates with mechanical stratigraphy - Insights from scale models using layered cohesive powder, Journal of Structural Geology, 32 (9), 1375 - 1391, doi:10.1016/j.jsg.2009.05.006.