Characteristic fault zone architectures as result of different failure modes: first results from scale models of normal faulting

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It is known that fault zone architecture and structural style vary distinctly between tensile and shear failure modes, with strong effects on the associated fluid flow properties. A systematically comparative study in 3D has not been done so far, though. Inferring transport properties in sub-seismic scale from fault network geometries would have important applications in brittle lithologies such as carbonates or basalts. We present a method to investigate the structural properties of fault networks in 3D using cohesive hemihydrate powder ($CaSO_4 * 1/2H_2O$) embedded in two layers of dry fine grained sand. The material properties of the sand and powder are well known from previous studies. By increasing the overburden stress the failure mode of the powder can be changed from tensile to shear failure. Using hemihydrate powder allows us to harden and excavate the layer after the deformation by wetting the model slowly and brushing off the overburden sand. Visual investigation of the 3D structures is then possible in very high resolution. Analyses using photographs and 3D models from photogrammetry include qualitative observations as well as measurements of e.g. strike of fault segments, fault dip or graben width.

We show a total of eight experiments that produce graben faults at four different overburden stresses (0, 1.5, 3, 6 cm overburden thickness) and at two increasing stages of strain (3 and 5 mm). In this set of models we describe two structural domains that show characteristic differences in their defining attributes. The tensile domain at small overburden stress (0 and 1.5 cm overburden) shows strongly dilatant faults with open fissures, vertical faults and large changes in strike at segment boundaries. The shear domain, formed by larger overburden stress (6 cm overburden), shows shallower fault dips around 65˚ with striations, numerous undulating fault branches and splays with low-angle fault intersections. Models with 3 cm overburden show a hybrid failure type with features from both structural domains. Using these attributes could enhance the prediction of fault network structures in the subsurface with interest in fields like fractured reservoirs or ore mineralization. Validation of these results with seismic and outcrop data is primary goal of the consecutive work.