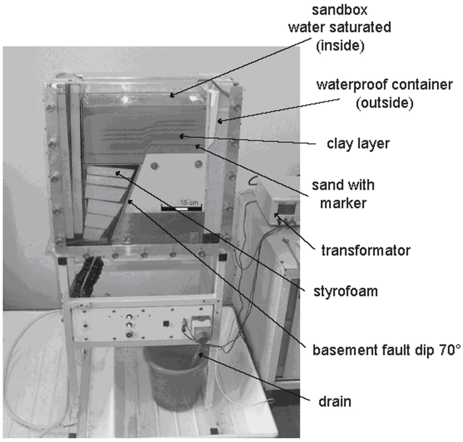

Figure 1: Sandbox-apparatus. Water-saturated setup of layered sand-clay experiment. Stage: Immediately after deformation.

Experimental study of the evolution of fault gouge in layered sand–clay sequences *Poster*

Joyce Schmatz[1] Peter Vrolijk[2] Janos L. Urai[1] Steffen Giese[3] Martin Ziegler[3] Wouter van der Zee[4]

This study focuses on clay smear processes during fault gouge evolution in sand-clay sequences at depths up to 2 km. A clay-rich fault gouge can dramatically lower the fault's permeability, and prediction of this process is therefore relevant in groundwater modelling and hydrocarbon geology (Fulljames et al. 1997, Yielding et al 1997, van der Zee et al. 2003, 2005).

We constructed an 'underwater' sandbox to deform layered sand-clay models of 20 × 40 × 20 cm above a 70°-dipping rigid basement fault (Fig. 1). The experiments are run completely water-saturated to allow deformation of wet clay and cohesionless sand. The basement fault moves at 20 to 120 mm h^{-1} to a maximum offset of 60 mm. We use quartz sand with grain size between 0.1 to 0.4 mm and an illite-rich clay with a water content between 28 and 55 wt.%. Water content of the clay is used to control its shear strength and state of consolidation. We defined three strength classes: *soft clay* (up to 55 wt% water), *normal clay* (around 40 wt% water) and *firm clay* (less than 30 wt% water). *Soft* and *firm clay* represent underconsolidated and overconsolidated end-members, respectively. The *normal clay* is in equilibrium with the overburden load. In a number of experiments 0.25–10 wt% 'Portland Cement' was added to the clay to make it strong and brittle. Material properties were carefully characterized by a series of geotechnical measurements.

Our sandbox experiments are governed by two important boundary conditions. The basement is a well-defined plate acting as a rigid guide compared to the properties of the sediment. The interface on top of the model material is either water or aluminum plates precut along the kinematically ideal plane. These two points of discontinuity in the boundary velocity field initiate a deformation band curving away from the kinematically preferred plane. On the other hand, the boundary plates force the two deformation bands to join into a continuous zone. Results of ten series of experiments will be presented. We systematically studied the effect of clay strength, thickness, number and posi-

[1] Geologie-Endogene Dynamik, RWTH Aachen, Germany [2] ExxonMobil Upstream Research Co., Houston, TX, USA [3] Geotechnik im Bauwesen, RWTH Aachen, Germany [4] GeoMechanics International, Mainz, Germany

tion of the clay layers and thickness of the cover sand.

Around 300 high resolution digital images for each experiment were processed into time-lapse movies and analyzed using PIV (Particle Image Velocimetry). PIV calculates the displacement field (Fig. 3) at the scale of individual sand grains, and allows calculation of all components of the incremental strain field.

The main effects of the different parameters are as follows:

1. absence of the top pre-cut plate makes the fault zone much wider, and renders the formation of a continuous clay gouge more difficult.

2. in models containing soft clay and a pre-cut top plate, a continuous clay smear is formed irrespective of the details of geometry, and deformation approaches simple shear with mechanical mixing of sand and clay (Fig. 2)

3. lateral clay injection is a rare process in our experiments, even for soft clay;

4. stiff clay behaves in a brittle fashion, fault motion is associated with rotation of rigid blocks and no continuous clay gouge is formed (Fig. 2);

5. for the same amount of clay in the sequence the presence of many thin layers prefers the formation of a continuous clay gouge.

High resolution PIV shows details of the initial phase of deformation, when elastic strain is overprinted by plastic strain and localization (Fig. 3). This shows that the structure of the later deformation bands is already present in the models after the first increment of deformation.

The validity of statistical methods to predict fault seal by a clay gouge (SGR — Shale Gouge Ratio, CSP — Clay Smear Potential) was examined critically. Our results clearly show that these methods can be unreliable if the effects of clay properties and geometry are not included in the analysis.

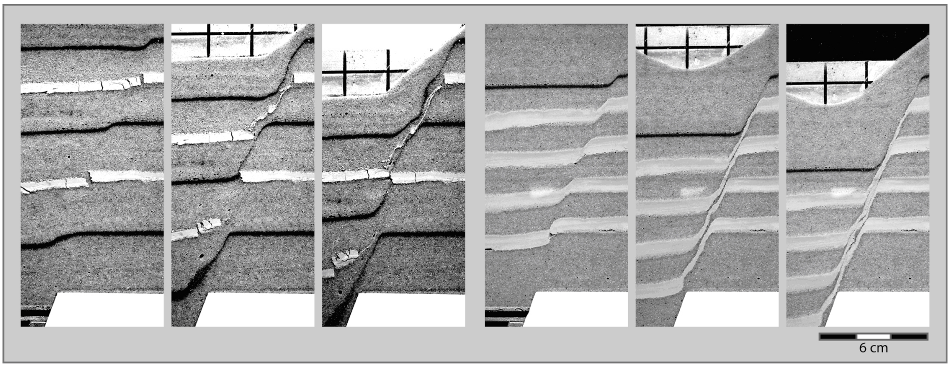

Figure 2: Image sections of experimental results. Images 1–3 show three stages (16, 24 and 50 mm offset) of deformation of sequence with two cemented clay layers. Images 4–6 show the same stages for setup with four soft clay layers.

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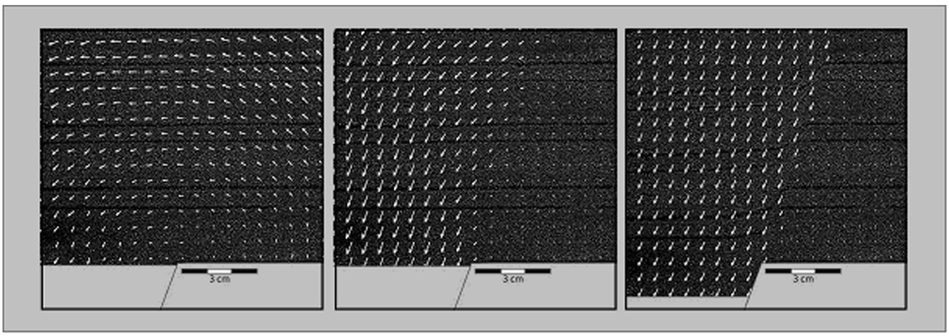

Figure 3: PIV-results for a water-saturated sand experiment. Vector field points to elastic behaviour in the initial phase followed by plastic strain with localization of a fault zone (last image).