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Characterization of Fault and Top Seals from Laboratory Experiments

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SUMMARY

The aim of the poster is to present recent laboratory experiments carried out at the Norwegian Geotechnical Institute to characterize the petrophysical, mechanical and hydraulic properties of faults and top seals. Three specific studies are detailed which address: 1) strength and deformation properties of argillaceous materials 2) formation of clay smear during faulting in sand - clay sequences 3) characterizing faulting during extension in unconsolidated sediments.

Faults and seals play a major role in the distribution and movement of fluids, hydrocarbons or groundwater in the Earth's crust. An understanding of their petrophysical structure, mechanical and hydraulic properties is necessary in many fields such as petroleum exploration and production, groundwater modelling, earthquake rupture, and sequestration of CO_2. In this paper, we describe a suite of laboratory experiments conducted in NGI's soil and rock mechanics laboratories which address issues pertaining to the characterization of fault and top seals:

- strength and deformation properties of argillaceous sediments
- development of clay smear in unconsolidated sediments during faulting
- faulting in unconsolidated sediments during extension

Strength and deformation properties of argillaceous sediments

Strength and deformation properties of argillaceous sediments are routinely tested at NGI throughout research and consulting projects. Existing triaxial tests have been compiled into a unique database. Correlations are inferred from the database between mechanical properties and P and S wave velocities for different groups according to burial depths of the sediments. The resulting trend lines can be used for instance to predict the behaviour of reservoir seals during production. In the example shown, sea bed subsidence associated with production induced reservoir compaction is predicted based on the correlation in an area with only few core data. The analyses show the importance of using stiffness moduli corresponding to the relevant degree of shear mobilisation. In particular, using a shear modulus at 50% mobilisation for these formations may overestimate sea bed subsidence.

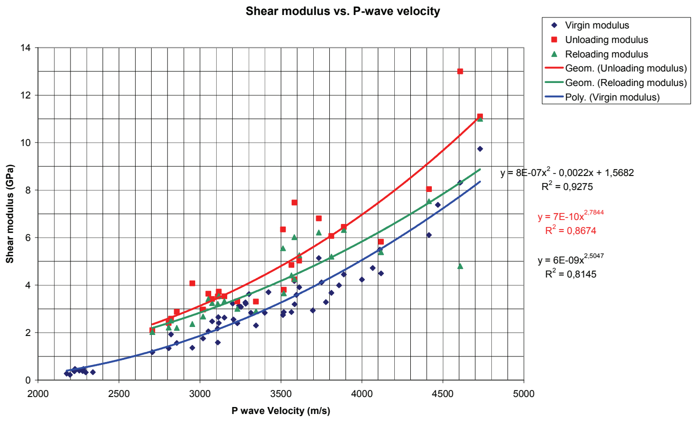

Figure 1 *– Correlation between shear modulus and shear wave velocity from database.*

Development of clay smear in unconsolidated sediments during faulting

Basic mechanisms during faulting and formation of clay smears in un-cemented sediments are simulated in a newly developed high stress ring shear apparatus (Cuisiat and Skurtveit, 2009; Cuisiat et al, 2007) with tests on sand with embedded clay segments. Visual inspection of the samples after testing, analyses of thin sections and permeability measurements across the faulted structure are used to characterize geometrical continuity, thickness and sealing potential of the smear. Deformation processes such as grain reorientation, clay smear and cataclasis are identified from the tests. The complexity of the shear zone is observed to increase with greater burial depth at the time of faulting. At shallow burial depth, in clay rich sediments, clay smear is the most efficient mechanism for permeability reduction. At this depth, sand-sand juxtaposition shear is dominated by grain rolling causing only minor permeability reduction. At greater burial depths, permeability reduction is dominated by grain size reduction.

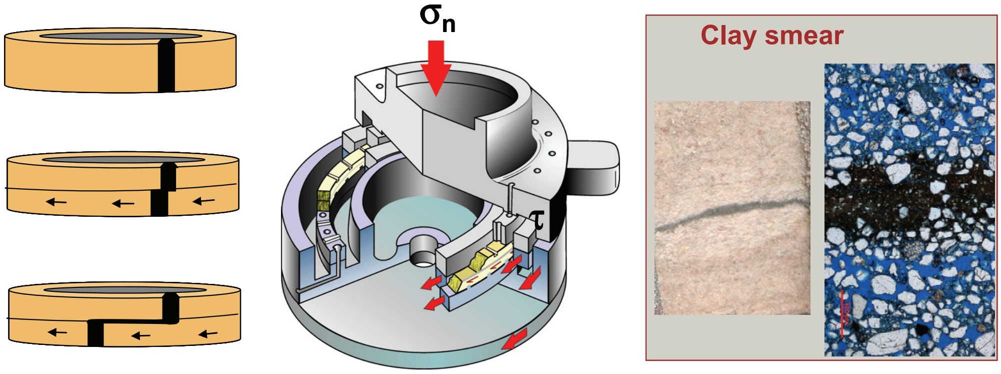

Figure 2 – Ring shear experiments in sand-clay sequences for investigation of clay smears.

Faulting in unconsolidated sediments during extension

Biaxial plane strain extension experiments are performed to quantify the conditions leading to faulting during basin extension, in relation to burial depth, strain and strain rate for sand analogous to the Brent Group reservoirs (Rykkelid and Skurtveit, 2008). The stress and strain conditions achieved in the sample during testing are more representative of in situ conditions during extension faulting compared to the experiments described above. Experiments performed down to a burial depth of 800m show mostly grain rolling and grain boundary sliding with little damage. Shallow burial exhibit more strain softening and shear band localization than deeper burial experiments.

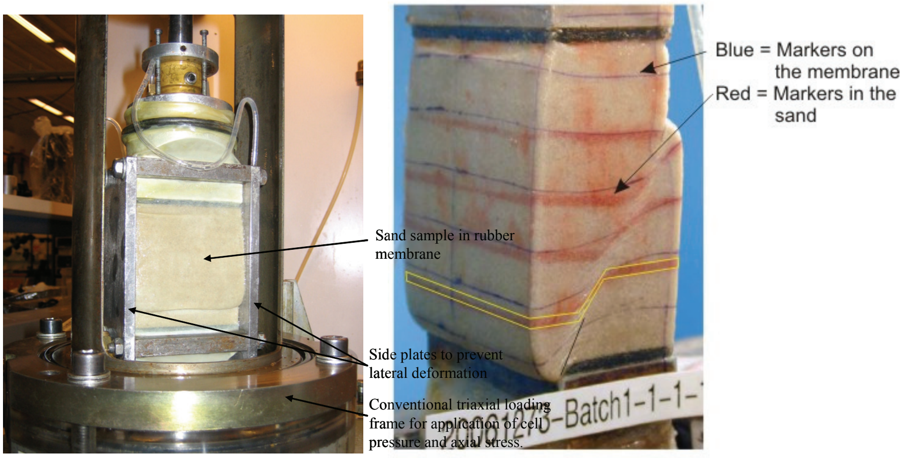

Figure 3 – Fault formation in biaxial plane strain experiments.

Conclusion

This paper has shown some of the experimental facilities available at NGI for the characterization of fault and top seals. Through a combination of different experimental set-ups, a better comprehension of the petrophysical, hydraulic, mechanical and acoustic properties of fault and top seals can be achieved. Work is ongoing to increase our database.

References

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