DeepNL Stakeholders meeting 2022

Geological Analysis of Multi-scale Faults in Reservoir Systems: Implications for Fault Mechanical Behaviour in the Groningen Field

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WP1

10^{-9}–10^{2} m

WP2

10^{-1}–10^{3} m

WP3

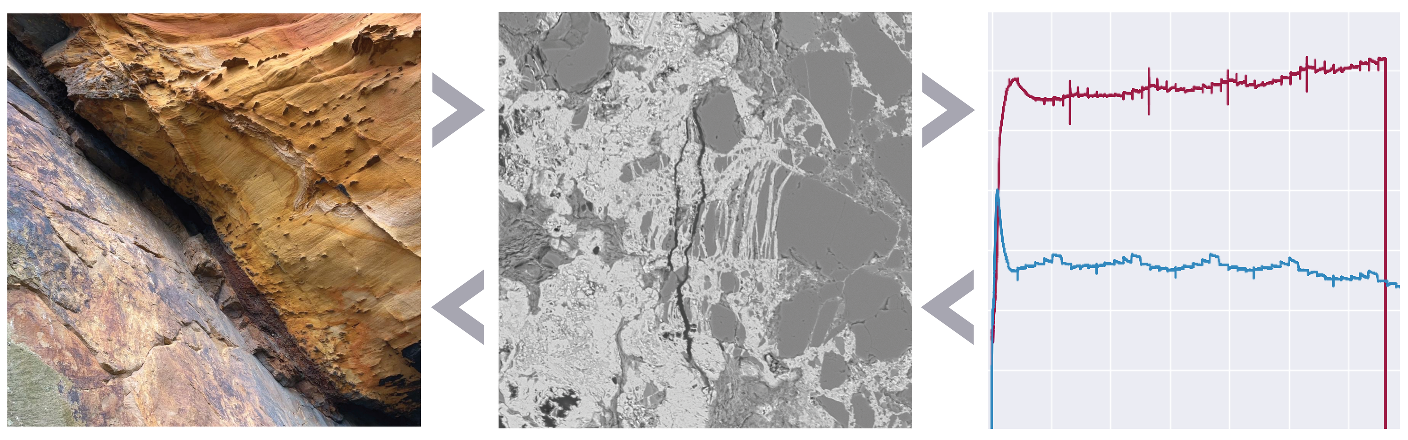
>10^{2} m

Introduction

Gas production from the Groningen gas field causes compaction and induced seismicity within the reservoir and overlying/underlying lithologies. Recent studies of earthquake localization have shown that seismicity dominantly occurs on complex normal fault systems that were formed by multiple tectonic phases during the Late Paleozoic to Mesozoic. However, little is known about the effects of the multi-phase tectonic history on the mechanical strength and the internal and external structure of Groningen-type faults at scales ranging from nm to 100 m. Modelling of induced fault rupture to quantitatively assess seismic hazards requires such knowledge.
The aim of this project is to constrain the structure, geometry and rheology of the Groningen fault zones at multiple scales. By using an interdisciplinary approach, quantitative relations between fault zone characteristics and kinematic evolution will be developed. The quantitative relationships and geometrical and mechanical constraints will be used further as critical input for geomechanical modelling studies in the DeepNL prgramme.

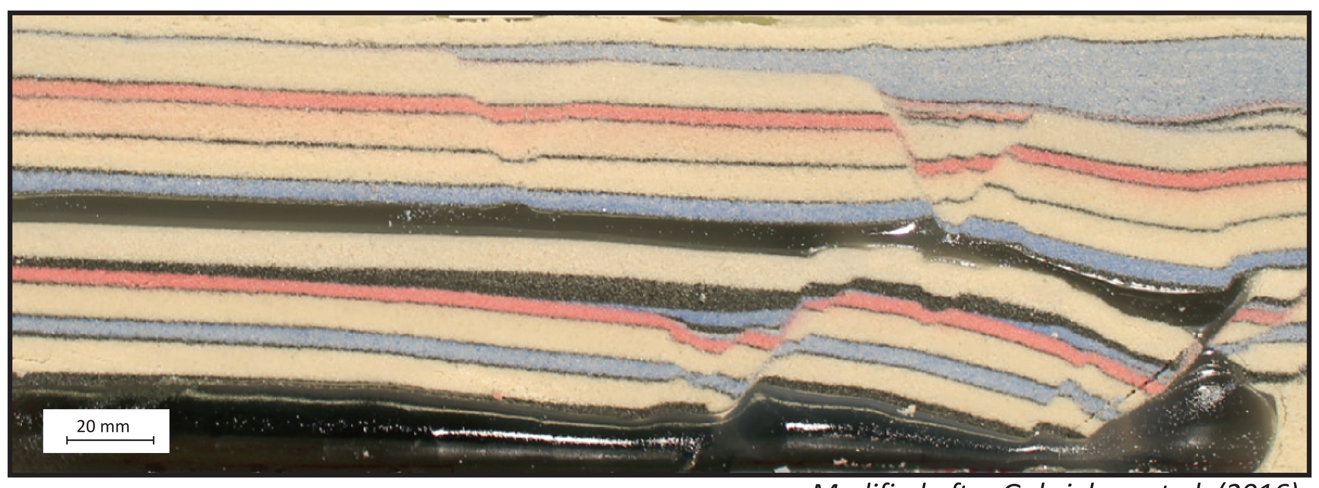
Natural Analogues & Rock Physics

Outcrop analogues provide insights into the geometrical and petrophysical properties of Groningen type faults below the seismic resolution. Rock physics experiments are performed in the rotary shear apparatus to determine the frictional strength and stability of fault gouge mixtures.



Physical Analogue Modelling

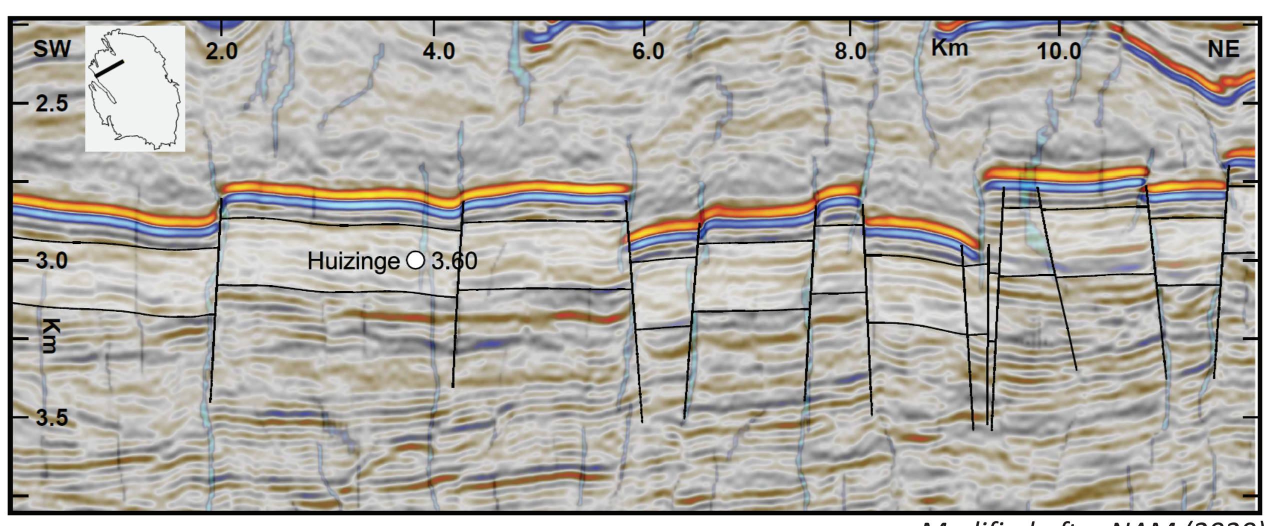
Physical analogue modelling is performed to systematically explore how faults and fault networks evolve as function of displacement, stratigraphy and kinematic boundary conditions. A second series of models focuses on favourable conditions for fault reactivation.



Modified after Gabrielsen et al. (2016)

Validation, Integration & Application

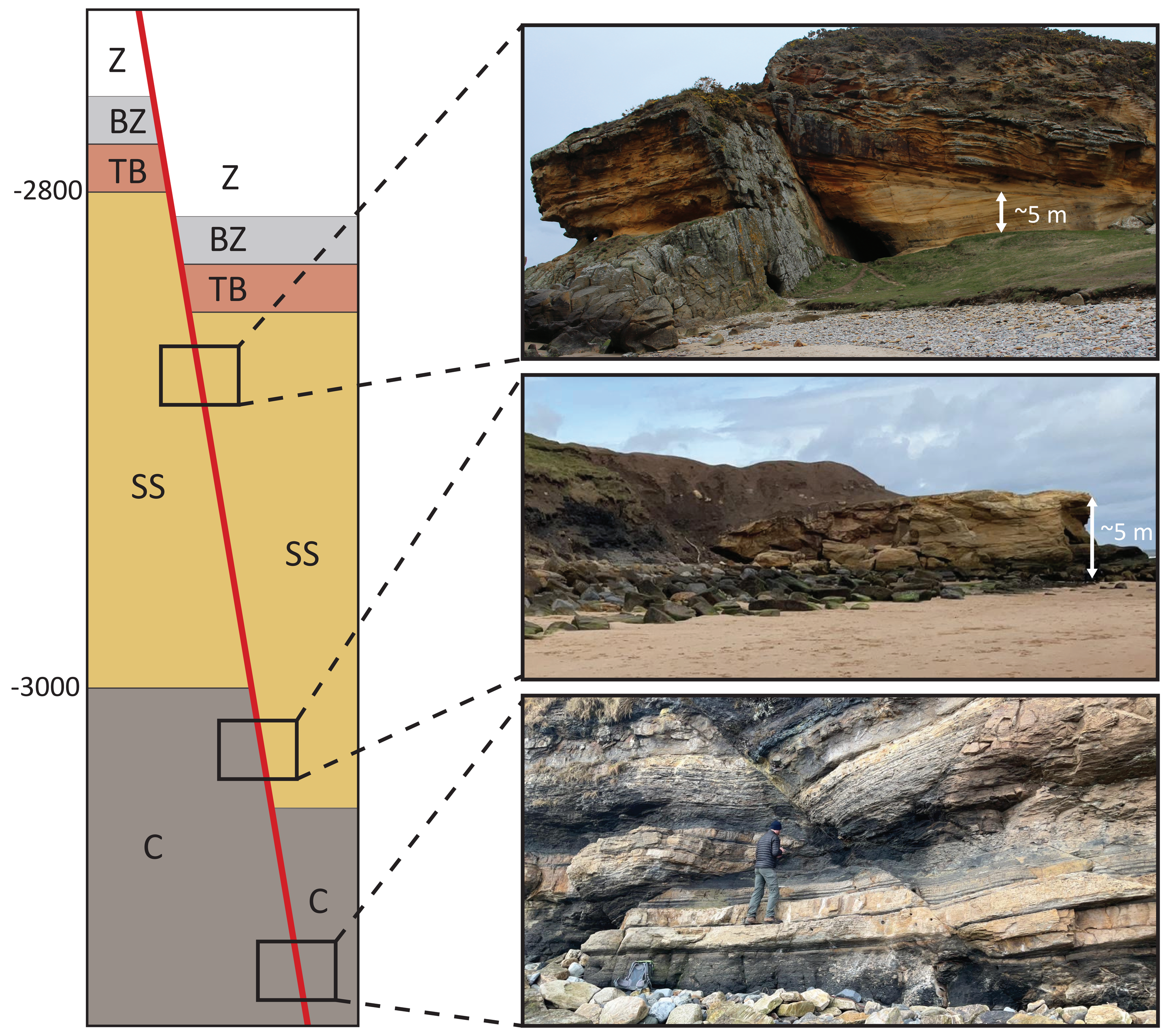
The results obtained by the micro- to outcrop scale analysis combined with physical analogue modelling will be tested with observations in the Groningen field to develop a new structural and kinematic model accounting for rock physics and fault properties.



Modified after NAM (2020)

Natural Analogues Northern UK

Outcrop analogues represent different sections along typical faults in the Groningen subsurface. Fault geometries and complexity highly depend on mechanical layering and juxtaposition of different lithologies.

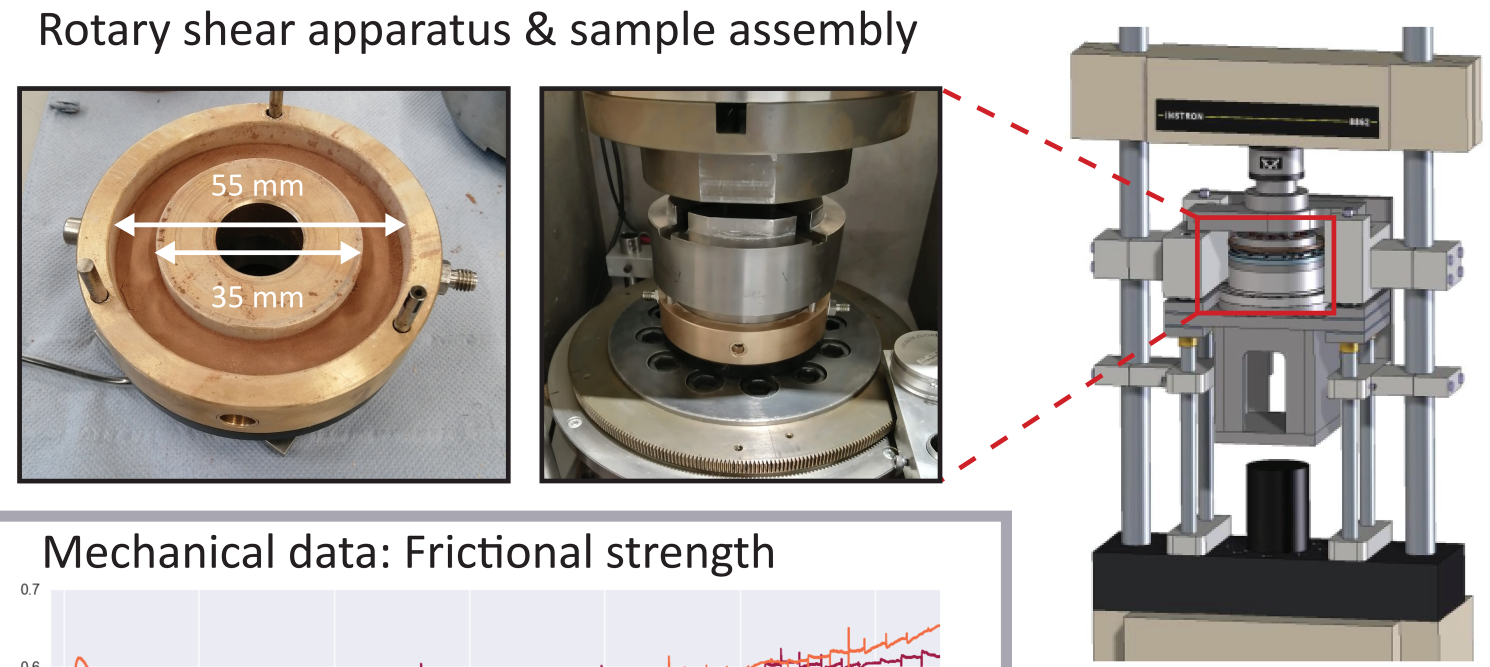


C - Carboniferous shale/siltstone; SS - Slochteren sandstoen; TB - Ten Boer claystone; BZ - Basal Zechstein anhydryte/limestone; Z - Zechstein salt

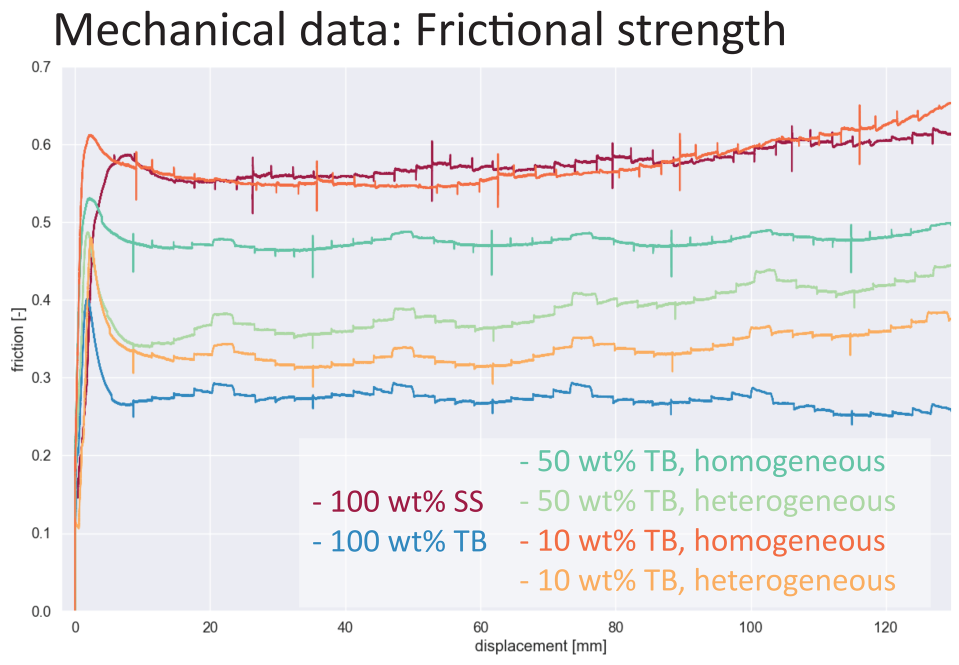
Friction Experiments on Simulated Gouges

Velocity stepping tests on both homogeneous and heterogeneous simulated fault gouge mixtures of Ten Boer claystone and Slochteren sandstone, are conducted in a rotary shear configuration in wet conditions and at a normal stress of 5 MPa. Preliminary results show that the mechanical behaviour of (layered) heterogeneous mixtures significantly differs from end-member gouges, but also from homogeneous gouge mixtures, used in previous experimental studies.

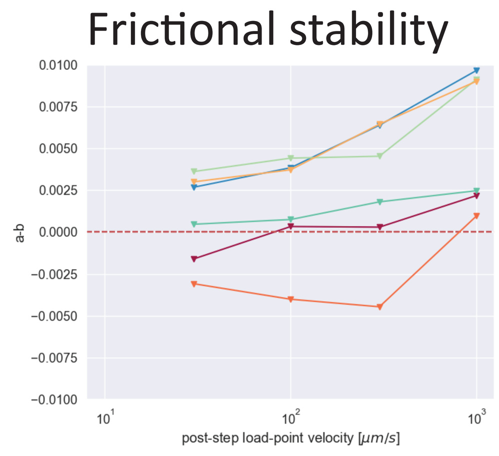
Rotary shear apparatus & sample assembly



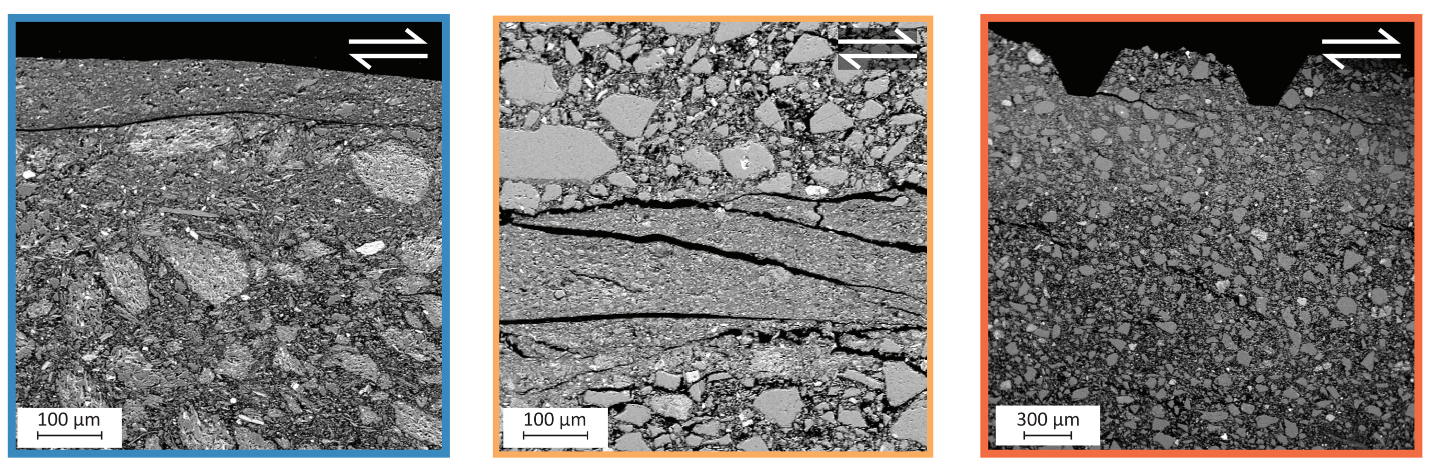
Mechanical data: Frictional strength



Frictional stability



Microstructural analysis of simulated fault gouges



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References
Gabrielsen, R.H, Sokoutis D., E. Willingshofer & J. I. Faleide (2016). Fault linkage across weak layers during extension: An experimental approach with reference to the Hoop Fault Complex of the southwestern Barents Sea. Petroleum Geoscience,22(2), 123-135.
NAM (2020). Petrel geological model of the Groningen gas field, the Netherlands. Open access through EPOS-NL, courtesy of NAM. DOI: https://doi.org/10.24416/UU01-HGMYV5