EGU23-11236
https://doi.org/10.5194/egusphere-egu23-11236
EGU General Assembly 2023

Reactivation envelopes of immature and mature faults of Dinantian carbonates targeted for geothermal energy

Entela Kane[1,2], Anne Pluymakers[1], and André Niemeijer[2]
[1]Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Geosciences and Engineering, Delft, Netherlands (e.kane@tudelft.nl)
[2]Utrecht University, Faculty of Geosciences, HPT Laboratory, Utrecht, The Netherlands

Human intervention in subsurface geoenergy systems, such as fluid injection, can lead to induced seismicity. Particularly in geothermal systems where faults or fractures serve as fluid pathways, fault reactivation is a significant risk. Therefore, we must elucidate under which stress conditions faults become reactivated. The geometry of fault planes evolves as a function of fault displacement. Mature faults (i.e. with 10-100 m displacement) are most likely gouge-filled due to material weathering during movement. This study investigates the Lower Carboniferous system and specifically the Dinantian formation. This specific formation is particularly interesting for deep geothermal energy in the Netherlands, Belgium and Germany but can serve as a proxy for fractured carbonate deep geothermal reservoirs worldwide. The Dinantian carbonates exhibit pre-existing fractures which mainly contribute to rock permeability. However, there is little or no knowledge of the fault geometry and filling material. Subsequently, it is essential to investigate a spectrum of carbonate fault geometries and gouge material to deliver fault stability conditions.

Here, we aim to experimentally characterise fault strength through all stages of their temporal evolution, from bare rock to highly strained fault gouges at a range of normal stresses. All experiments are performed at room temperature, using de-ionised (DI) water as pore fluid. The bare rock surfaces are gouge-free saw-cut samples, loaded into a Hoek cell embedded in a 500 kN uniaxial loading machine. These experiments are performed at a range of confining pressure from 10 to 50 MPa, corresponding to normal stresses from 60 to 90 MPa and undrained conditions. We determined the critical range of axial, shear and normal stress values per experiment at which fault reactivation was initiated. We used a rotary shear apparatus to increase fault gouge maturity through the shearing of a simulated gouge material in drained conditions. In a single experiment and sample, we changed the normal stress with a protocol of 2-4-6-8-10-8-6-4-2 MPa. For every stress interval, we performed a slide-hold-slide procedure, where the slide-hold times were 10-10-10-100-10-1000-10 sec and the velocity was 20-0-20-0-20-0-20 μm/sec respectively. After each hold time, the reactivation leads to a different peak shear stress. By characterizing the different peak stresses we can quantify the evolution of critical shear stress as a function of fault inactivity time. We used the reactivation stresses for both experimental types to calculate the intercept and angle of the reactivation envelopes in a Mohr-Coulomb context using linear regression, which corresponds to the cohesion and friction coefficient of the laboratory faults.

Our preliminary results for the rotary shear experiment show that mature carbonate laboratory faults exhibit a cohesion of <1 MPa and friction coefficient up to 0.65 under wet conditions. Moreover, the cohesion of the fault decreases as a function of healing time and the friction coefficient increases. Future plans include the investigation of fluid chemistry on the reactivation envelope. To conclude, we aspire to give insight to the operators on how to safely design the geothermal injection and production schemes accounting for the geomechanical constraints.

How to cite: Kane, E., Pluymakers, A., and Niemeijer, A.: Reactivation envelopes of immature and mature faults of Dinantian carbonates targeted for geothermal energy, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-11236, https://doi.org/10.5194/egusphere-egu23-11236, 2023.