Fault Nucleation and Reactivation in Displaced Fault Systems: An Experimental Study

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1. Introduction

In the last few decades, human activities concerning geo-reservoirs, including gas extraction, hydraulic fracturing, carbon storage, and geothermal energy production have caused seismicity. Earthquake events and earthquake sequences are attributed to injection or extraction.

It is essential to understand fault slip nucleation within the reservoir interval and its propagation beyond the reservoir. Analytical and numerical studies have shown that, depending on the type of operation (injection/depletion), fault slip can nucleate at external or inner corners along the displaced fault system, driven by positive peak shear stresses (Buijze et al., 2019; Jansen et al., 2019, and 2022).
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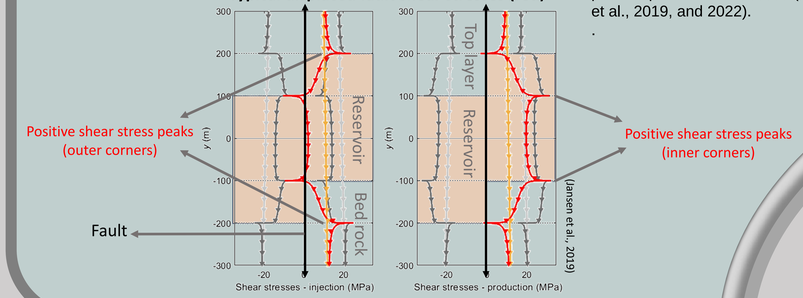
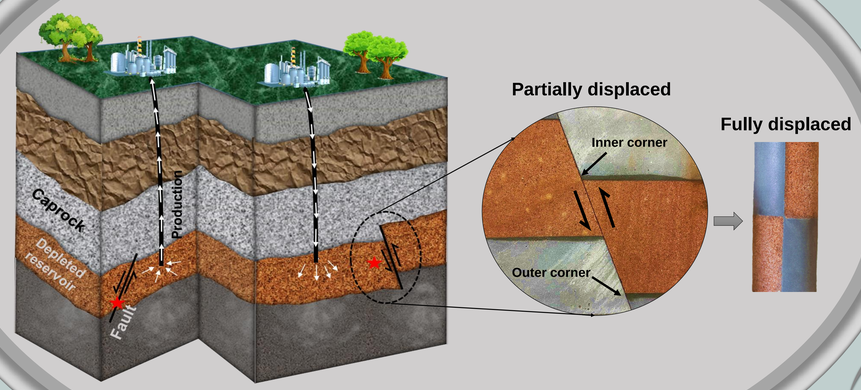
Our study aims to examine and validate the initiation of slip nucleation patches in both the inner and outer corners of the displaced fault setting under triaxial stress path conditions.

Typical displaced fault shear stresses (red)

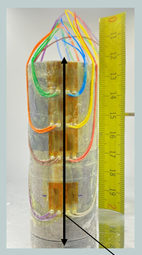


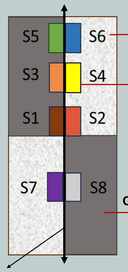
Displaced fault system



2. Methodology and protocol

Fully displaced Faulted Glue-Mortar



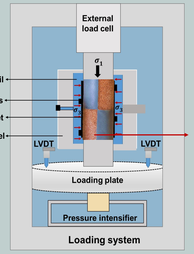


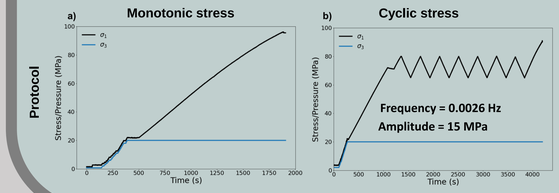
Mortar
- Young's Modulus: 19.6 GPa
- Poisson ratio: 0.115

Strain Gauges (SG)

Glue
- Young's Modulus: 5.2 GPa
- Poisson ratio: 0.34

Experimental set-up





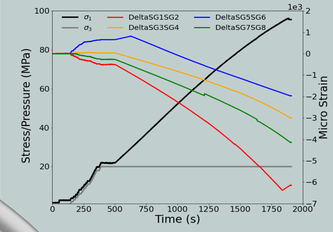
- **Radial pressure in both tests was 20 MPa**
- **Main Goal:** To capture deformation near the vertical fault using Strain Gauges (SGs) in order to monitor differential displacement from the top of the sample to the internal corner at the fault's center.

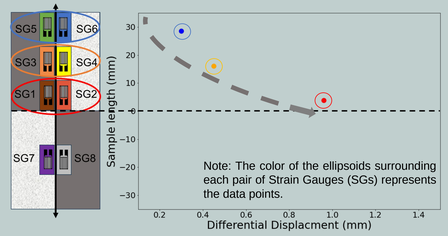
5. Conclusions

- **The deformation gradient and total deformation, as measured by Strain Gauges (SGs) in the same material row, increase from the top towards the central corner.**
- **Differential compaction intensifies from the top of the sample towards the internal corner at the center of the fault. This signifies a variation in the stress field surrounding the fault plane.**
- **Our direct measurements near the displaced fault plane corroborate the anomalies and peaks in stress observed in previous numerical and analytical studies.**

3. Results (differential displacement)

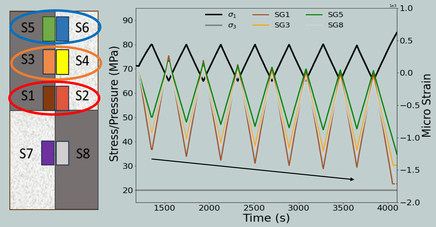
- The differential compaction between SG pairs (SG1SG2, SG3SG4, SG5SG6).



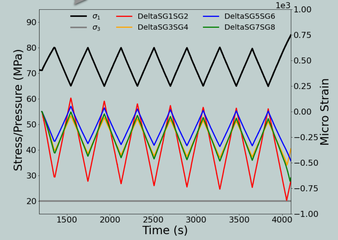


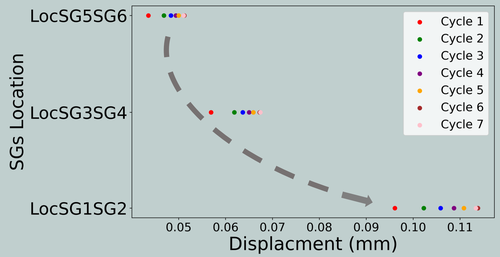
- **A nearly exponential increase in differential compaction was observed from the top to the center of the fault.**
- Differential compaction increases from the top of the sample toward the internal corner at the center of the fault. Additionally, given their symmetrical counterpoint mounting, the gradient of the differential strain between SG4SG4 and SG7SG8 is very similar, as expected.

4. Results (effect of cyclic stress)



- The transition from SG5 to SG1 reveals an increasing gradient of deformation, culminating in SG1 recording the maximum amount of deformation.
- Inelastic deformation induced by each cycle





- The measured differential displacement at the peak of each cycle at the locations of SG pairs (SG1SG2, SG3SG4, and SG5SG6) increases as the number of cycles increases.

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