

Critical Geomechanical Parameters in CCS Projects: Essential Experimental Measurements

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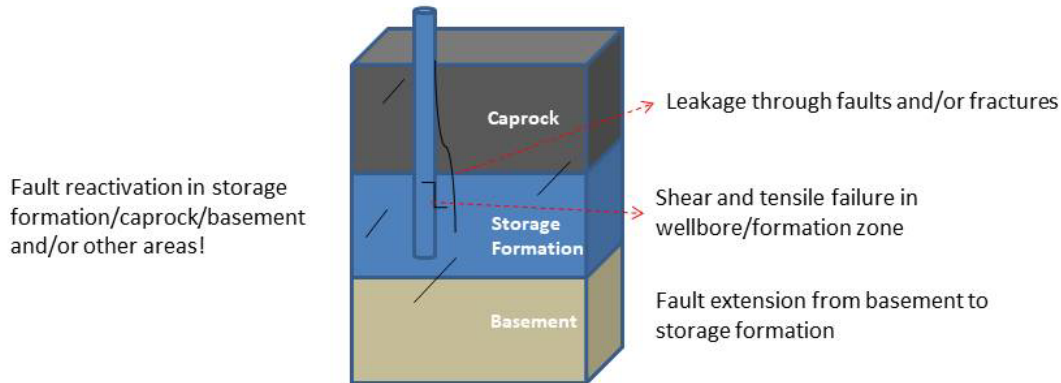
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Summary

The International Energy Agency (IEA) analysis of major technology challenges considers carbon capture and storage (CCS) one of the critical technologies for reaching net zero targets. IEA 2°C scenario (2DS) requires CCS to deliver 94 Gt of CO₂ emission reductions by 2050. According to Global CCS Institute's 2021 report, there are more than 27 active large-scale commercial CCS projects around the world; or more than 50 projects if small/pilot projects are included in the stats. These sites inject approximately 20 Mt CO₂/year, much lower than the injection target of 1 Gt scCO₂ by 2030. Currently, most injections are performed in sandstone reservoirs and saline aquifers, where the reservoir has excellent petrophysical properties for storage (volumetric storage capacity, porosity, permeability, etc.). For instance, the Cambrian Basal Sandstone Unit, which is the target CO₂ storage interval in the Quest and Aquistore sequestration projects, is a large aquifer with good petrophysical attributes resulting in potential storage of about 3Gt of CO₂. As a result of CO₂ injection, various geomechanical, thermal, hydrological, and geochemical parameters undergo complex and interrelated transformations and changes. In recent years, there have been controversies over the success of such projects from a geomechanical perspective. Zoback et al. (2012) questioned the potential of large-scale geologic storage projects in accomplishing their goals, claiming that large injection volumes could trigger faults and induce earthquakes which in turn threaten the seal integrity of geological structures. Through modeling and experimental studies, several researchers have pushed back and showed that the faults are not likely to become activate during CO₂ injection operations (Vilarrasa and Carrera, 2015; Vilarrasa et al., 2016). Although promising results in projects such as Shell's Quest have been observed in recent years, it appears that it is still too soon to tell if the project has been or will be successful. Pressure build-up with time, transfer of pressure to other layers such as the basement, creep, and other geochemical transformations that take place in the long term change the state of strain and rock properties and determine the long-term performance of CCS projects. This study discusses the short and long-term geomechanical threats to CCS projects through the review of previous projects design and the related data. Additionally, this presentation addresses the critical geomechanical parameters that need to be measured and monitored during the CCS projects, the types of testing that provide the required dataset for geomechanical models, customized testing that should be introduced for CCS applications, the formations from which cores should be collected for testing purposes, and the timing of sample collection for testing are discussed in the context of CCS operations.

Observations



Mechanisms

- Pore pressure changes and perturbations
- Critically stressed faults
- Thermal effects
- Brittle failure in critically-stressed crust
- Creep in lower crust and upper mantle
- Injection pressure $> S_h$
- CO₂/brine/rock and mineral interactions
→ Change in porosity, permeability, rock compressibility
- Cap rock seepage and/or leakage through diffusive processes, enhanced caprock permeability, changes in effective stress



Threats

- Caprock seal integrity
- Fault reactivation, leakage and induced seismicity in reservoir/caprock/basement and/or other areas
- Wellbore issues – Leakage, casing shear failure, borehole tensile failure, etc.
- Tensile and shear failure in the reservoir
- Hydraulic fracture in the wellbore adjacent area
- Thermal fracturing and consequent leaking in reservoir and cap rock
- Reservoir dilation and heave
- Reservoir compaction in creep processes (targeting integrity of the wellbore, caprock, and fault/seal systems)



Useful Experiments

- Customized triaxial tests – drained/undrained, coupled with CO₂ saturated brine flow at various confining pressures
- Tensile strength tests (Direct, Brazilian)
- Fracture shear strength – Direct shear testing
- Shear failure envelope – Multistage or several single stage triaxial tests at various confining pressures
- Creep test
- Rock compression tests
- Determination of rock elastic constants through single stage triaxial tests and ultrasonic measurements under stressed conditions
- Determination of coefficient of thermal expansion (CTE) in rocks using strain gauges
- Interfacial tension measurements of rock-CO₂-brine systems
- Determination of Biot's coefficient

Figure 1- Overview of geomechanical threats in CCS operations and the responsible mechanisms

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