Evaluating Shale Creep for Wellbore Leakage Mitigation in CO_2 Storage

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Summary

One of the most effective approaches for storing CO_2 underground is injecting it into porous rock formations beneath caprock layers. However, subsurface containment in geological CO_2 storage faces two main challenges related to CO_2 leakage from the reservoir into groundwater resources, hydrocarbon reservoirs, and the environment: caprock integrity and wellbores (both new and legacy wells).
To address this matter, some studies suggest that shale creep deformation can develop a natural sealing barrier, potentially serving as an alternative to traditional plug and abandonment methods [1,2]. This study investigates whether the specific shale examined in this research exhibits sufficient creep deformation to form a natural seal capable of mitigating leakage from CO_2 storage reservoirs. A single stage triaxial creep test is conducted on shale specimens to analyze their deformation behavior. Additionally, numerical modeling using FLAC3D is performed, with the model validated against experimental results. The validated model can then be used to simulate creep deformation under various in-situ pressure conditions, providing further insights into the feasibility of shale as a long-term sealing material for CCUS (Carbon Capture, Utilization and Storage) applications.

Workflow

Shale specimens are subsampled at the University of Alberta from bulk samples either parallel or perpendicular to the bedding. The bulk samples were collected from depths ranging between 2,357 and 2,400 meters in Alberta. All cylindrical specimens have a diameter of 1.5 inches and maintain a standard 1:2 aspect ratio.
As the in-situ pore fluid is brine, brine is used for pore pressure in the tests. The specimens were saturated with brine prior to testing. The temperature is kept constant at 30°C. During the test, axial and radial deformations are recorded using two LVDTs.
Since the actual in-situ stresses exceed the capability of the testing apparatus, the confining pressure is set at 35 MPa, with a back pressure of 1 MPa. Various deviatoric stresses will be applied to assess their impact on creep deformation.
Following the experimental phase, Maxwell and Power models in FLAC3D are used to simulate creep deformation. These models are validated against laboratory results. Once verified, the model can be applied to simulate in-situ stress conditions and evaluate the behavior of this specific shale formation under actual subsurface conditions.

Observations and results

The test results will illustrate creep deformation and the variation of creep rate over time (test in progress). As the test is ongoing, expectations based on the literature review are provided:

- Creep strain exhibits an increase with deviatoric stress [3].
- Gas shales with bedding perpendicular to the load experience greater creep deformation than those with bedding parallel to the load [4,5].
- Rocks with higher clay and organic content exhibit more significant axial creep strain compared to carbonate dominated rocks [3,4,5].

Observing deformations under creep loading conditions will provide insight into the ability of this shale to form a natural sealing barrier, which may be utilized in plug and abandonment procedures.

References

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