Introduction

One of the main issues for CO2 sequestration is the risk of CO2 leakage. Reservoir seal capacity is affected by short-term integrity during CO2 injection, and long-term stability of the seal after injection. During injection, increased pore pressure may cause hydraulic fracturing of the caprock or triggering slip on pre-existing faults. Subcritical crack growth is the main concern for long-term seal integrity. Stress analysis and geo-mechanical tests such as leak-off and mini-frac tests are used to evaluate the hydraulic fracturing and fault reactivation potential, while fracture tests are used to study subcritical fracture growth.

Fracture growth is divided into three regimes based on the relationship between the stress intensity factor (K) and the crack velocity (V). At large Kc close to fracture toughness (Kc), crack growth is controlled by mechanical rupture (region III); at intermediate Kc, the rate of transport of corrosive species controls crack growth (region II); at low Kc, the rate of stress corrosion reaction near the crack tip controls crack growth (region I).

Considering the sensitivity of stress corrosion reactions, coupled chemical-mechanical interactions could significantly affect seal integrity during timescales of CO2 storage in subsurface CO2 reservoirs. Injection and subsequent dissolution of CO2 into the aqueous pore fluid are likely to alter the natural water-rock system by accelerating chemical reactions, such as selective dissolution and solution-precipitation, that affect mechanical properties and lead to reduced seal integrity.

Methods

We use the double torsion (DT) load relaxation technique to study subcritical fracture growth (Williams and Evans, 1973). The specimen is sliced into a thin rectangular shape (1.25 in. x 3 in. x 0.075 in.) with a central groove to guide fracture growth. The specimen is supported with four ball-bearing supports from below, and the load is applied by the ball bearings near the center of sample axis from above at a constant displacement rate by the step motor. The load and crosshead speed are continuously monitored. After the peak load is reached, the crosshead is then held at a fixed position by stopping the step motor. The load relaxes with time due to subcritical crack growth. The stress intensity factor (K) is proportional to the load (P), and the crack growth rate can be derived from the load relaxation P(t) by

\[ K(t) = \frac{P(t)}{B W^{1/2}}, \]

\[ V = \frac{dP}{dt} \]

Maximum load is used to determine the fracture toughness (equation 1). Multiple stress intensity factor vs crack growth rate curves (K-V curves) can be obtained from a single specimen from load decay relationships. Cracking velocity is related to stress intensity factor by

\[ V = A - K^b \]

with the subcritical index (SCI, Atkinson, 1987). The subcritical crack growth index can be found by fitting the K-V curves with a power law relationship.

Discussion and conclusions

Materials

The materials tested here include Woodford shale purchased from TerraTec Schlumberger, Marcellus shale cored from the Appalachian Basin, and Mancos shale from outcrop near Crystal Geysers, UT.

References


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