Well and Seal Integrity

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Session: Wellbore Integrity, Brighton 3 & 4
Experimental Studies

• Materials
  – Caprock:
    ✦ Shale and anhydrite caprock
  – Wells
    ✦ Type G oilwell cement and wellbore composites (Shale-Cement-Steel)

• Permeability of damaged materials
• Plastic behavior of shale, cement and anhydrite
• Pure shear configuration
Triaxial Coreholder: Self-supported triaxial stress with permeability measurement
In Situ X-ray or Neutron Tomography with triaxial coreflood

- Triaxial Coreflood:
  - Confining pressure
  - Axial load
  - Multiphase fluid injection

- Portable for use in different facilities
- Max operating conditions: 100 °C, 350 bar confining/pore, 4,800 bar axial load
- Samples: 1x3"

- Strain measurement
- Piston displacement
- Acoustic velocity
- Fluid pressure
- Temperature
- Fluid samples
Fractured Cement with Supercritical CO₂

- Type G oilwell cement with cement/water ratio of 0.4
- Experiment at 45 °C and 1700 psi (117 bars)
- Multi-stage
  - Elastic measurements of intact cement (room temperature without confining pressure)
  - Fracture cement in pure shear
  - Measure permeability to water
  - Measure relative permeability of mixed water-supercritical CO₂ flow
  - Measure permeability to water
  - Repeat over the course of 7 days
    - Sample “rests” at ambient condition overnight
- X-ray tomography
Elastic Properties of Cement

Graph showing strain and differential stress over time.
Stress-Strain Curves

Young’s Modulus: 2.1E6 psi (14 GPa)
Poisson Ratio: 0.24
Fracturing Cement in Pure Shear

- Failure
- Recovering at hydrostatic conditions

Graph showing strain, differential stress, confining pressure, inlet pressure, and outlet pressure over time.
Fracture-Permeability in Cement

- Hydrostatic Perm Drop = 5 mD
- Water Relative Permeability = 0.14
- CO₂ Relative Permeability = 0.03
Strain-Stress-Permeability in Cement
X-ray Tomography

Non-transmissive Fracture
X-ray tomography
Water permeability as function of time

![Graph showing water permeability over time with two lines, one for initial water and another for final water, indicating changes in permeability over 7 days.](image-url)
Relative permeability as a function of time
Pure Shear Results

- Cement fractures in shear at 8000 psi (550 bars)
- Fracture occurs at 1% shortening
- Supercritical CO$_2$ dissolves cement and creates clear reaction patterns in x-ray CT
- Permeability initially 15 mD decreases to 7 mD over 7 days (17 hours CO$_2$ exposure)
- Relative permeability of water = 0.31
- Relative permeability of CO$_2$ = 0.04
Conclusions

• Extensive strain required to generate connected fractures
  – May limit consequences in actual field conditions
• Flow through damaged cement equivalent to 7 mD but relative permeability creates further limits to flow
• Supercritical CO\textsubscript{2} does not increase permeability of damaged cement (also see Carey et al. 2010; Walsh et al. 2013; Carey and Newell 2013; Huerta et al. 2013)
• Future work will measure fracture apertures and connectivity under in situ conditions

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