FUNDAMENTAL STUDIES OF MULTIPHASE FLOW OF CO₂ AND BRINE: EXPERIMENTS AND SIMULATIONS

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OPPORTUNITY

OVERVIEW OF GEOLOGIC STORAGE OPTIONS

SALEINE AQUIFERS HAVE THE GREATEST STORAGE CAPACITY

KEY ISSUES FOR CO₂ STORAGE IN DEEP SALINE AQUIFERS

SIMULATION

MEASUREMENTS ARE MADE AT REALISTIC RESERVOIR CONDITIONS

LABORATORY EXPERIMENTS

ADDITIONAL PUMPS:

- Pump D applies confining pressure around the core to mimic reservoir conditions.
- Pump C creates back pressure after separation. Also serves as a buffer container between separator and injection pumps.

SEPARATOR:

- Used to separate two fluids after they flow through the core.

A NOBLE EXPERIMENT:

- The experimental setup can be moved from the lab to the CT scanner room.

CT MAP OF CORE POROSITY IS USED TO CALCULATE PERMEABILITY

NEW CAPILLARY PRESSURE FUNCTIONAL FORM

A NOVEL FUNCTIONAL FORM IS FIT TO THE EXPERIMENTAL DATA

A MEDICAL CT SCANNER PRODUCES IMAGES OF THE CORE’S INTERIOR DISTRIBUTION OF CO₂ AND BRINE

Heaters keep fluid inside the core holder at reservoir temperatures.

A Fluid heater keeps CO₂ and brine at up to 80°C before entering the core.

A MEDICAL CT SCANNER PRODUCES IMAGES OF THE CORE’S INTERIOR DISTRIBUTION OF CO₂ AND BRINE

These measurements are necessary for relative permeability calculations.

Images are taken in real time during injection experiments. Saturation profiles can be derived from these images.

SUMMARY

- Core-scale lab experiments were simulated to investigate cause of CO₂ saturation variations.
- Only variable capillary pressure curves seem to account for this.
- Variable Pᵥ reduces overall CO₂ saturation.
- CO₂ saturation is functions grid-size dependent.
- Current field-scale simulations most likely overestimate CO₂ saturation.

IMPLICATIONS FOR CO₂ STORAGE

FLOW RATE DEPENDENCE

DECREASED SHEAR EFFICIENCY

SIMULATION GRID SIZE DEPENDENCE

RELATIVE PERMEABILITY CURVES ARE BASED ON EXPERIMENTAL DATA

NEW CAPILLARY PRESSURE FUNCTIONAL FORM

A new functional form is fit to capillary pressure data from the rock lab.

The shape of the curve can vary with respect to the porosity and permeability of each grid element i:

\[ P_{c,i} = \sqrt{\frac{\phi_i}{k_i}} J(S) \]

To investigate capillary trapping of CO₂, 1.5 L of CO₂ is injected into a 2.54 cm o.d. aluminum core.

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SIMULATION GRID SIZE DEPENDENCE

AN ALUMINUM CORE-HOLDER CONTAINS THE CORE

- Aluminum ½ inch thick.
- Rated to 3000 psi, 120°C.
- For use with cores up to 8 in. (2 inch) diameter.
- Fluids are distributed at the inlet and outlet ends by concentric grooves machined into the aluminum.

PUMPS INJECT HIGH-PRESSURE CO₂ AND BRINE INTO THE CORE-HOLDER

- A system of dual pumps (A & B) using electric valves injects fluids continuously and refills automatically.
- Max Pressure: 3500 psi.
- Flow rate: 1.5 L/min - 200 mL/min.
- CO₂ is kept at 8°C in the pumps to keep it liquid.
- Brine is kept at soak temp.
- Band heaters hold core at up to 80°C.
- A Fluid heater keeps CO₂ and brine at up to 80°C before entering the core.

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