Measurements and modeling of high pressure CO_2 trapping in heterogeneous rocks

Scientific Achievement

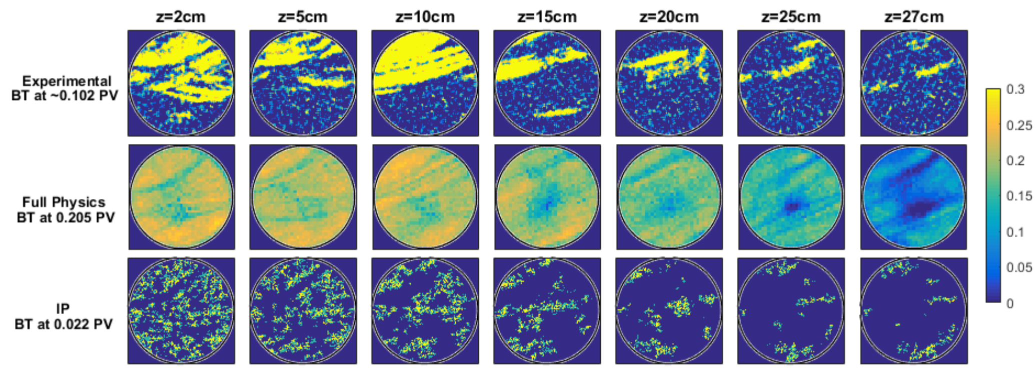
Experimentally measured and modelled buoyant CO2 flow in cross-bedded sandstone.

Significance and Impact

CO2 will rise buoyantly when emplaced in the subsurface, and there is a need to predict and model the CO2 movement and trapping in heterogeneous reservoirs. We measure rock properties and buoyancy-driven CO2 flow at the millimeter scale in order to determine deficiencies and strengths of full physics and invasion percolation models.

Research Details

- High pressure CO_2 is allowed to rise buoyantly into a 2 ft long cross-bedded sandstone core. Computerized tomography (CT) is used to measure in-situ CO2 preferential paths development.
- Experiments are compared to continuum scale models run at Sandia (Hongkyu Yoon) and invasion percolation (IP) models run at BEG (Prassana Krishnamurthy)
- The CO_2 moves preferentially through the column - Both IP and continuum scale models match different features of the flood.
- Leads to an integrated model to predict behavior



Top row: CT Slices along core, with yellow representing measured CO2 invasion. CO2 is injected at bottom and rises buouyantly to the top (left to right)
Middle row: Predictions of CO2 flow from continuum model,
Bottom row: Predictions of CO2 flow from invasion percolation model.

P.G. Krishnamurthy, S. Senthilnathan, H. Yoon, D. Thomassen, T. Meckel, and D. DiCarlo, " Comparison of Darcy's Law and Invasion Percolation Simulations with Buoyancy-Driven Vertical Core Flood Experiments in a Heterogeneous Sandstone Core," Journal Of Petroleum Science and Engineering (iaccepted).

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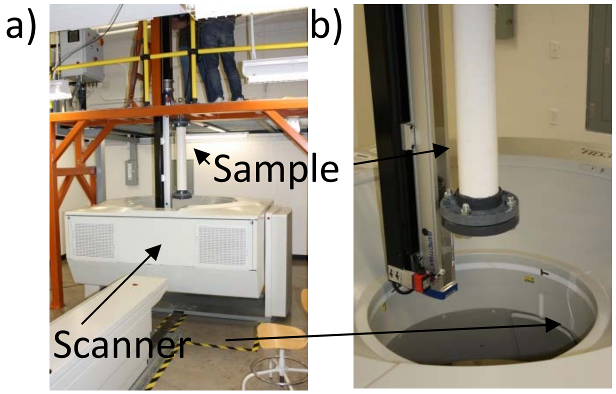
Background – CO_2 Buoyant Flow

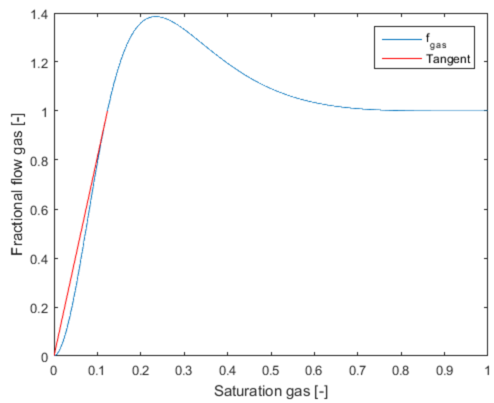
- Buoyancy is the dominant force affecting CO_2 emplacement and trapping everywhere except near the injection site (well bore)
- Almost all measurements of CO_2 trapping have been done for viscously driven flow in homogenous rocks
- Buoyancy driven flow has been studied for analog fluids, but not for CO_2 in cross-bedded rocks
- Goal: Study buoyantly driven CO2 movement
  - a) experimentally in cross bedded rocks at reservoir pressure
  - b) compare to standard continuum model
  - c) compare to invasion percolation model
  - d) determine best modeling for reproducing buoyant structures

Experimental measurements of CO_2 trapping in heterogeneous rocks

- Rock is scanned before experiments to get porosity of the core. The porosity is used to obtain permeability and entry pressure heterogeneity of the cross-bedded sandstone core
- Flow experiments take place at 1500 psi where CO_2 becomes dense (but still is buoyant)
- CO_2 is injected like in a core flood, but flow rate is chosen to be below critical velocity to ensure that buoyancy is dominant
- Monitor CO_2 invasion pattern on a slice by slice basis



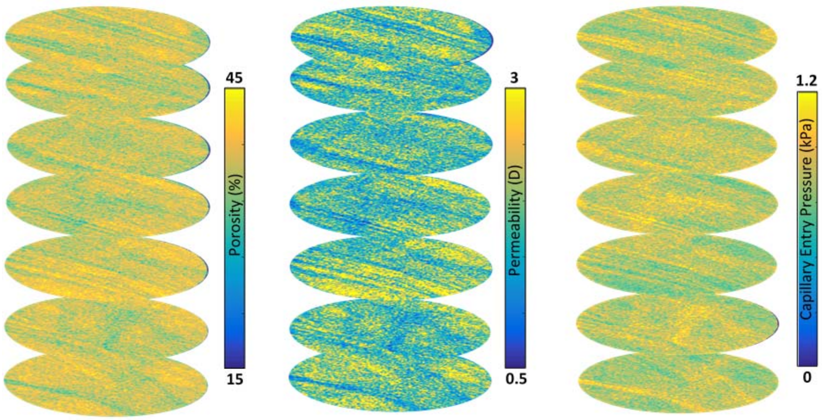
Long cross-bedded Boise core placed vertically in CT scanner for saturation measurements



Fractional flow construction to determine that buoyancy is dominant

Modeling of CO_2 trapping in heterogeneous rocks

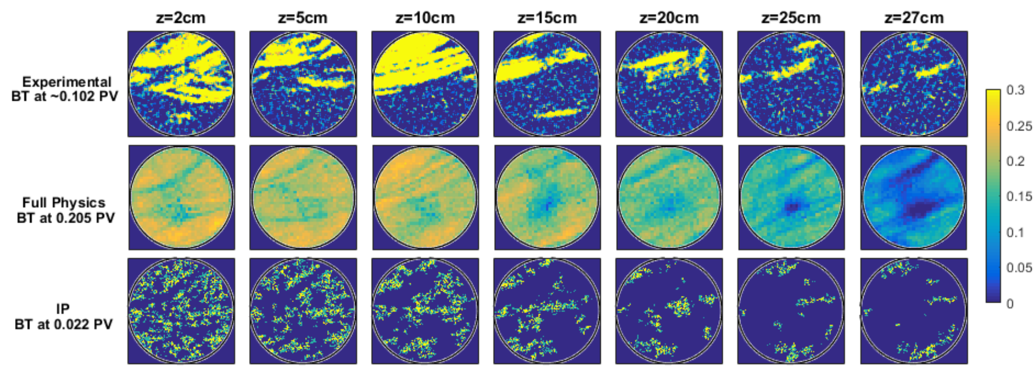
- In buoyancy driven flow there are two ways to model flow
- Standard continuum scale
  - Heterogeneity is put in block to block
  - Continuous variations of saturation and permeability
- Invasion percolation (IP)
  - Each block is filled or unfilled
  - Capillary entry pressure
  - Much finer model - discrete
- Run both models with input based on dry scan of cross-bedded cores
- Predict flow patterns



Obtaining permeability and entry pressure from measured porosity

Results and summary

- CO_2 moves preferentially Continuum scale model
  - Matches overall saturation
  - Much more smeared than in actual flow (see 2nd row)
  - Sharper P-S curves may be solution
- Invasion percolation (IP)
  - Gets high and low saturations correct
  - Pattern too filamentary (see 3rd row)
  - Heterogeneity not accurately represented?
- Results lead way to better models



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