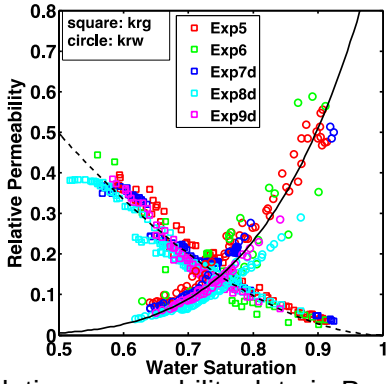
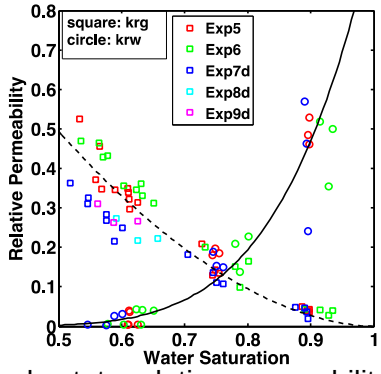
New Unsteady State Method for Obtaining CO_2 Relative Permeability



a) Relative permeability data in Berea Sandstone obtained using unsteady-state method consists of over 100 data points.



b) Steady-state relative permeability matches unsteady data but with much fewer data points

Scientific Achievement

Developed a method for obtaining accurate and quick measurements of high pressure CO_2 relative permeability.

Significance and Impact

Relative permeability is the crucial parameter for predicting fate, transport, and trapping of CO_2 on reservoir scales.

Research Details

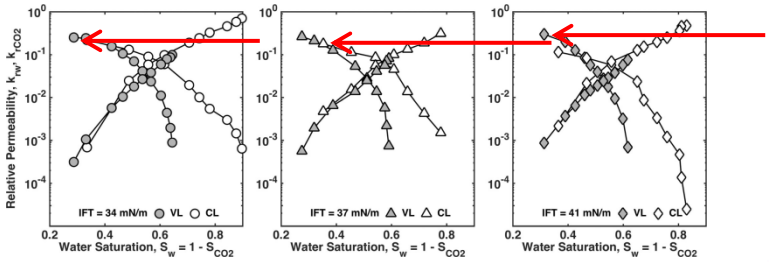
- By using in-situ saturation measurements, long cores (2' as opposed to 2"), and pressure taps, we can avoid end effects which are great with low viscosity fluids such as CO_2.
- With a unique mathematical inversion, we determine in-situ fluxes during a CO2 displacement allowing for an increase by a factor of 10 of the amount of rel perm data.

Chen, X. and D.A. DiCarlo, "A new unsteady-state method of determining two-phase relative permeability illustrated by CO 2 -brine primary drainage in Berea sandstone," Advances in Water Resources, 96, 251-265 (2016)

Work was performed at the University of Texas at Austin

Background – Accurate CO_2 Relative Permeabilities

- **Relative permeability is the key parameter for predicting fate of CO_2 at reservoir scale**
- **Previous measurements of CO_2 relative permeability show low CO_2 permeabilities when compared to other fluids (see figure)**
- **This has been interpreted to CO_2 having special wetting properties, but more likely is just an experimental artifact due to the low viscosity of CO_2 compared to most other fluids tested (usually a hydrocarbon)**
- **Goal: Develop a robust method that**
  - **a) obtains accurate relative permeability data without artifacts**
  - **b) obtains data quickly (less than 1 week)**
  - **c) greatly increases the number of data points**

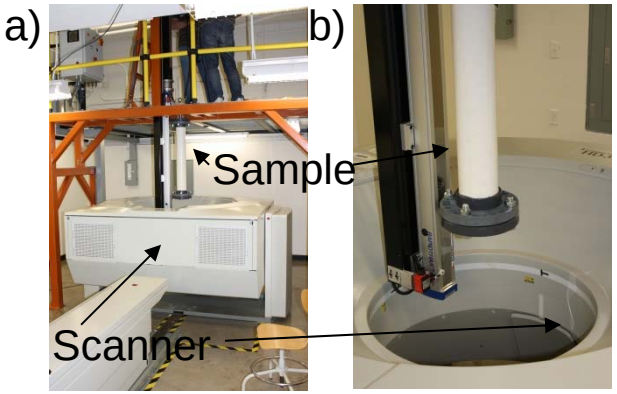


Many previous measurements of relative permeability a factor of 5 lower than expected. If true, this has great implications on fate of CO_2.

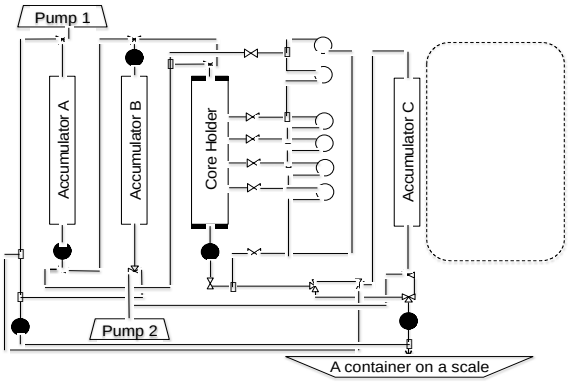
Data from Reynolds and Krevor, Water Res. Res. (2015) doi:10.1002/2015WR018046

New Unsteady-State Method

- **To avoid the experimental artifacts caused by CO_2's low viscosity, we use**
  - **CT scanning to obtain in-situ saturation measurements**
  - **Pressure taps to obtain in-situ pressure measurements**
- **We developed a new mathematical inversion to obtain local CO_2 velocity during a displacement**
- **This allows direct calculation of relative permeability**



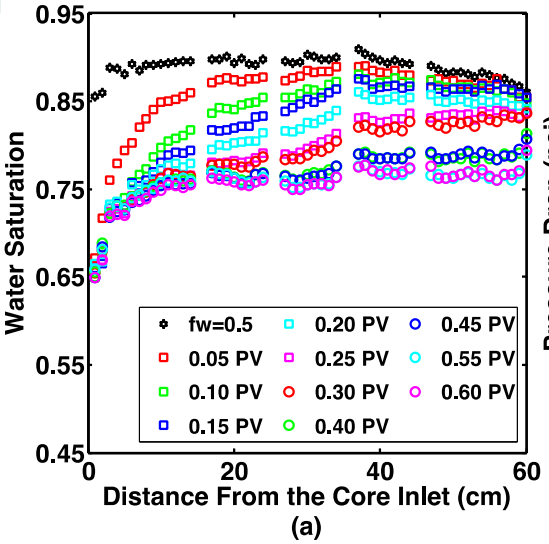
Long Berea core placed vertically in CT scanner for saturation measurements



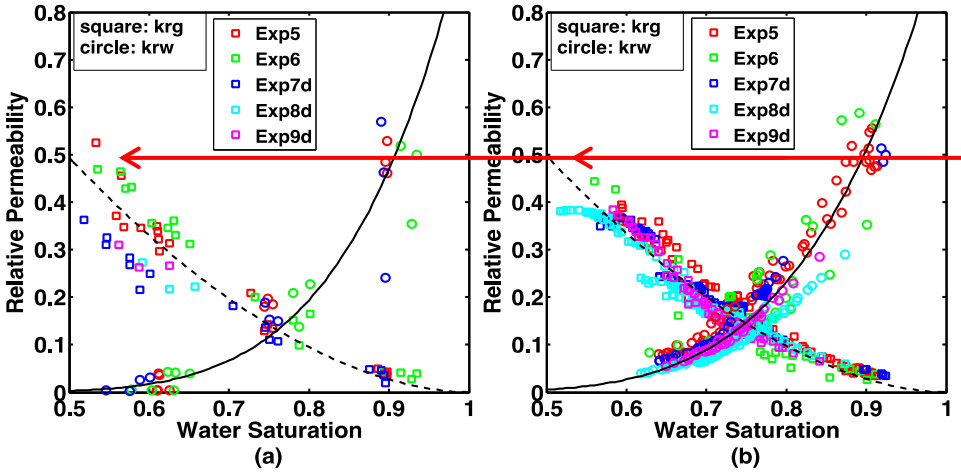
Flow schematic with 4 pressure taps for in-situ pressure measurements

Results: CO2 behaves normally

- New method obtains 100s of data points in less than 1 week
- Data is clear of end effects
- CO2 relative permeability is very similar to hydrocarbon permeability, and a factor of 5 higher than previously measured



In-situ saturations versus time during displacement



CO_2 permeabilities in line with hydrocarbon permeability

a) Steay state, and b) new unsteady state measurements. Many more data points using new method reducing the error in the measured relative permeability