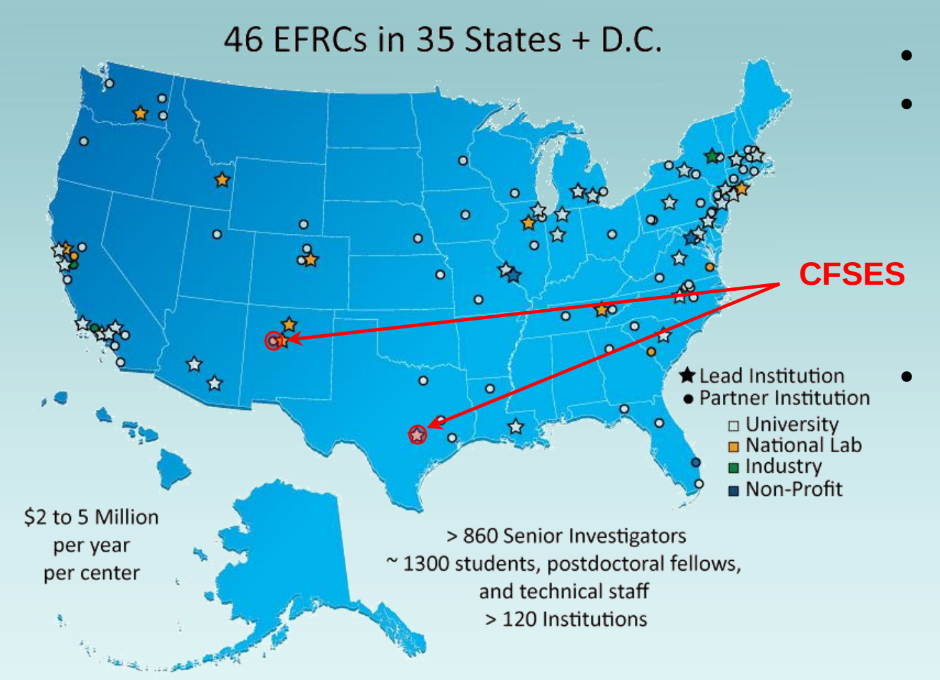
SAND2011-2818C

Center for Frontiers of Subsurface Energy Security: A DOE Energy Frontier Research Center

Marianne Walck[1], Gary A. Pope[2] (Director), Susan J. Altman[1], and Mojdeh Delshad[2]
[1]Sandia National Laboratories and the [2]University of Texas at Austin

Introduction

The Energy Frontier Research Centers Program Aims to Accelerate Discovery Science for Energy Technologies

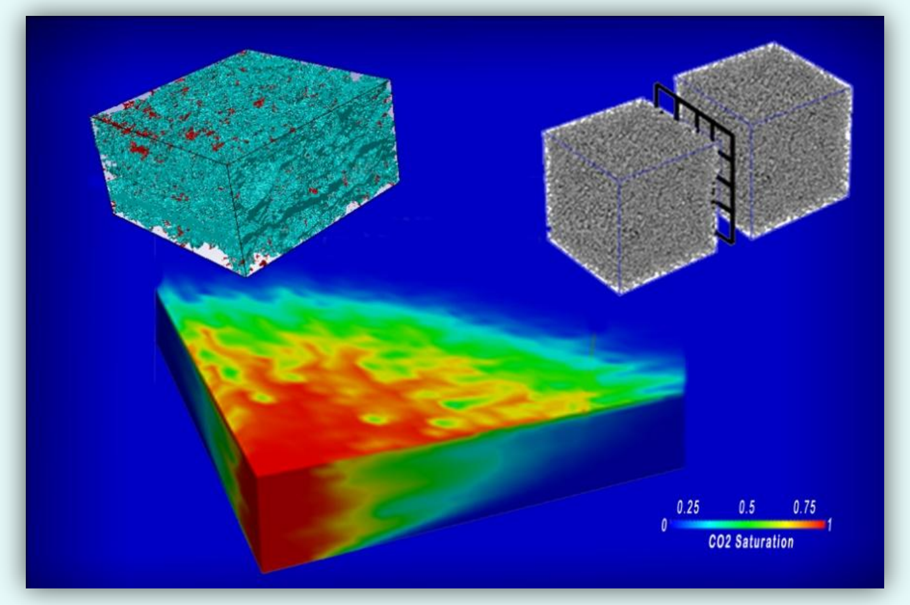


- **Funded by DOE, Office of Science**
- **Two EFRCs focused on carbon capture:**
  - Center for Gas Separations Relevant to Clean Energy Technologies (UC, Berkeley)
  - Molecularly Assembled Material Architectures for Solar Energy Production, Storage, and Carbon Capture (UCLA)
- **Two EFRCs focused on carbon sequestration:**
  - Center for Nanoscale Control of Geologic CO_2 (LBNL)
  - **Center for Frontiers of Subsurface Energy Security (CFSES)**

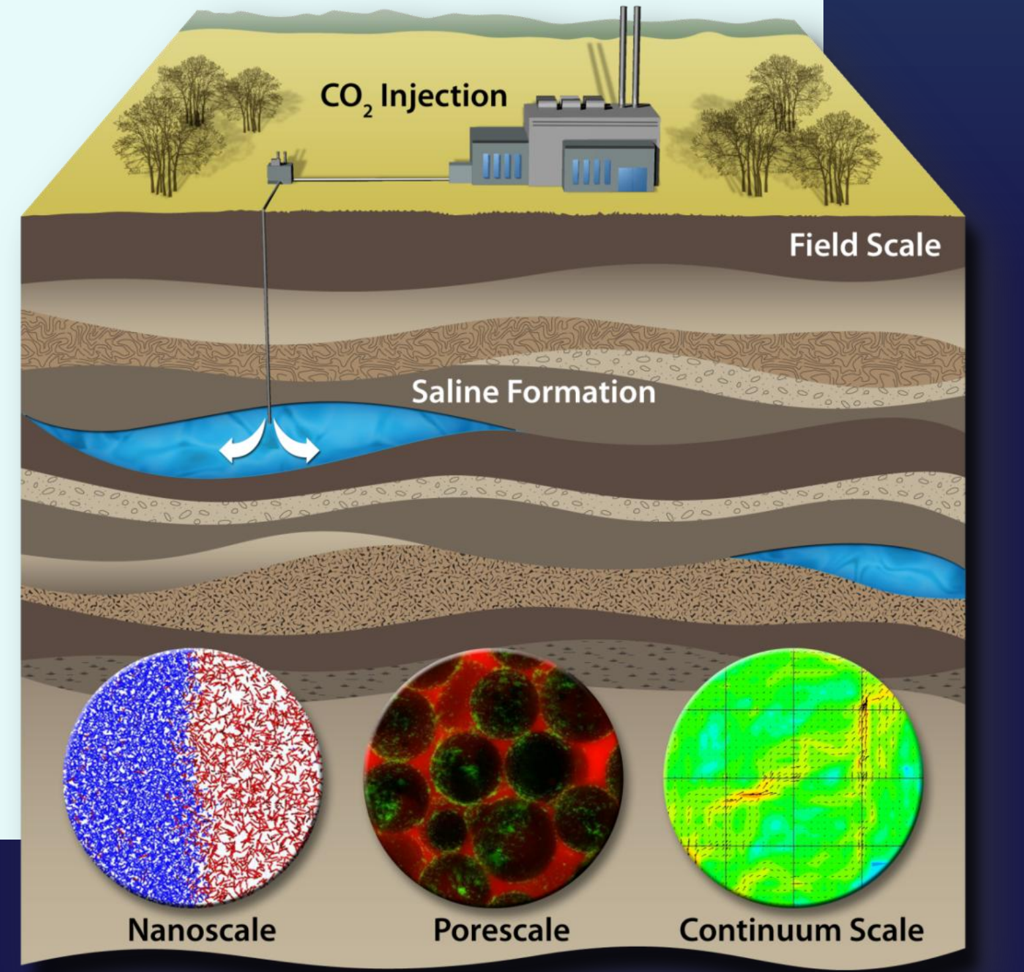
The Center for Frontiers of Subsurface Energy Security (CFSES) is pursuing scientific understanding of multiscale, multiphysics processes to ensure safe and economically feasible storage of carbon dioxide and other byproducts of energy production without harming the environment.

Research Questions:

- How does supercritical CO_2 interact with water, brines, mineral surfaces, and bacterial growth as it flows through the subsurface?
- What are the relevant physics of CO_2 fate and transport in the subsurface, and how can these be synthesized, upscaled, and incorporated into more powerful continuum models?
- Can we engineer solutions to mitigate contaminant leakage from natural and anthropogenic leakage pathways?
- How can we represent the essential features of large-scale behavior (flow, transport, reaction and deformation in the Earth's subsurface) that emerge from small-scale phenomena, without resolving all small-scale features?

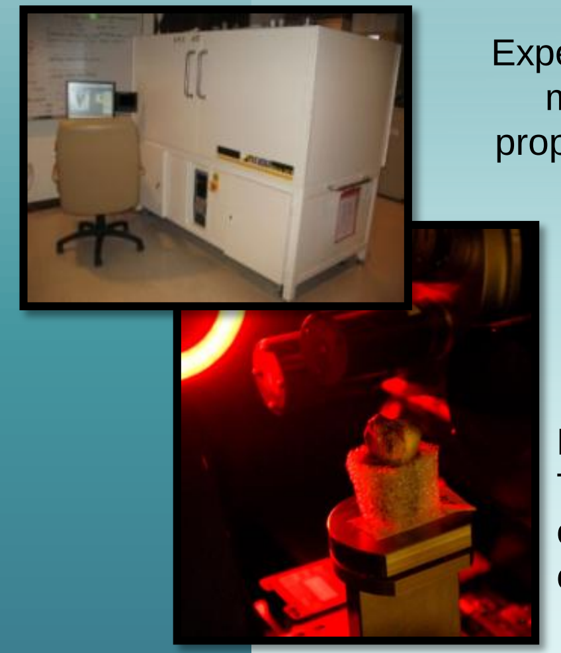


Detailed small-scale experimental results are being integrated with state-of-the-art numerical methods to develop computational tools that capture geological complexity, variability, and uncertainty. These tools will be used to determine what will happen when CO_2 is injected underground.

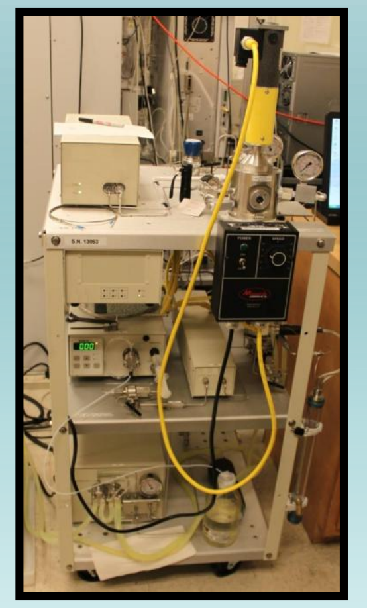


Capabilities

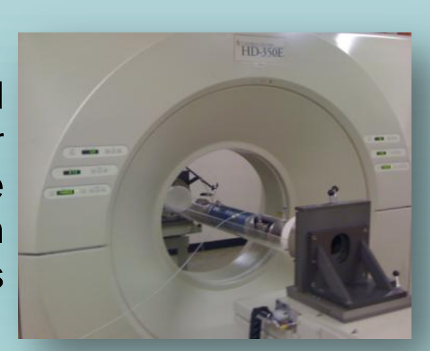
Experimental



Experimental systems to measure the physical properties of CO_2 -brine-mineral systems



Micro Computerized Tomography for imaging of multiphases and contact angles



Computerized microtomography for imaging multi-phase fluid flow through cores

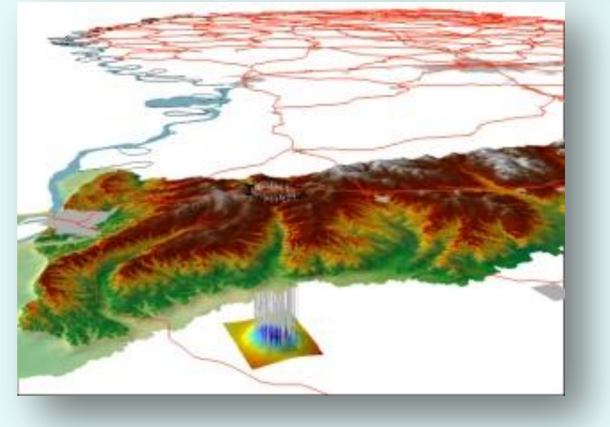
High pressure and multiphase fluid delivery system for pore-scale flow experiments

Laser scanning confocal microscopy for imaging bioclogging at the pore scale

Geomechanical testing for acoustic and ultrasonic imaging of rock deformation

Field

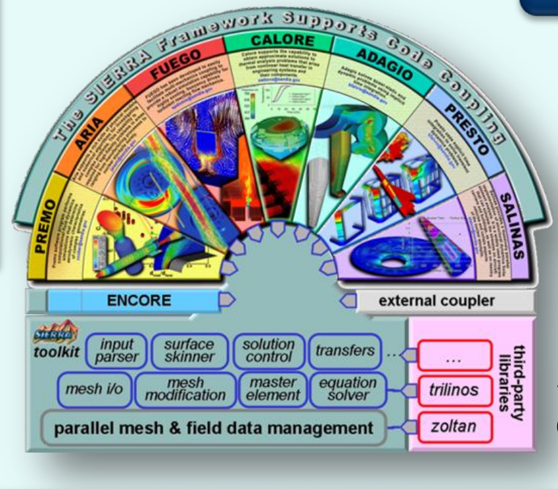
Little Grandwash Fault, Utah
Natural analog of CO_2 leakage



Cranfield Field CO_2 injection Study - Providing data for modeling validation and verification. (Data courtesy of University of Texas Bureau of Economic Geology)

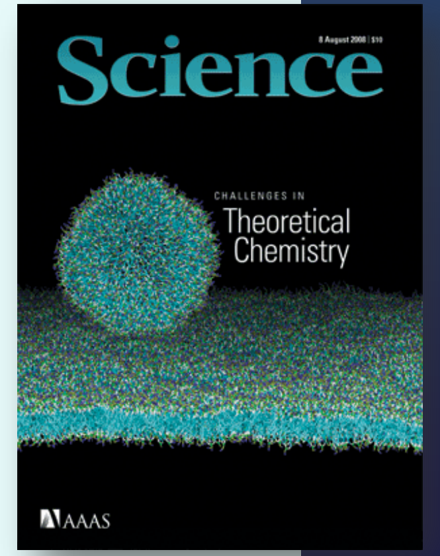
Computational

Sandia National Laboratories' Super Computer Red Sky

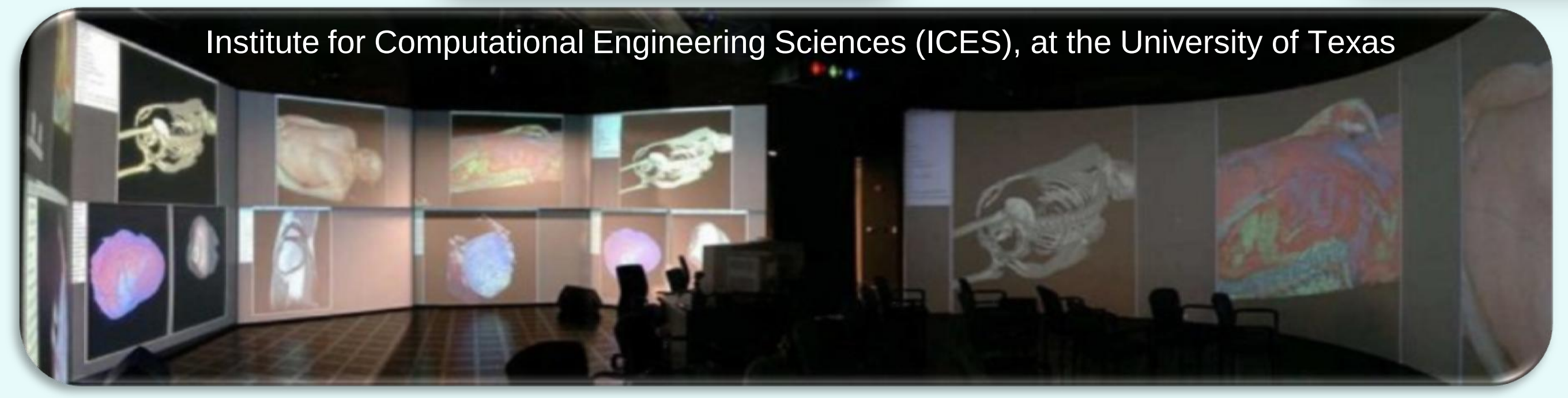


Sierra Mechanics engineering analysis codes

Molecular Dynamics Code LAMMPS (Large-scale Atomic/Molecular Massively Parallel Simulator)

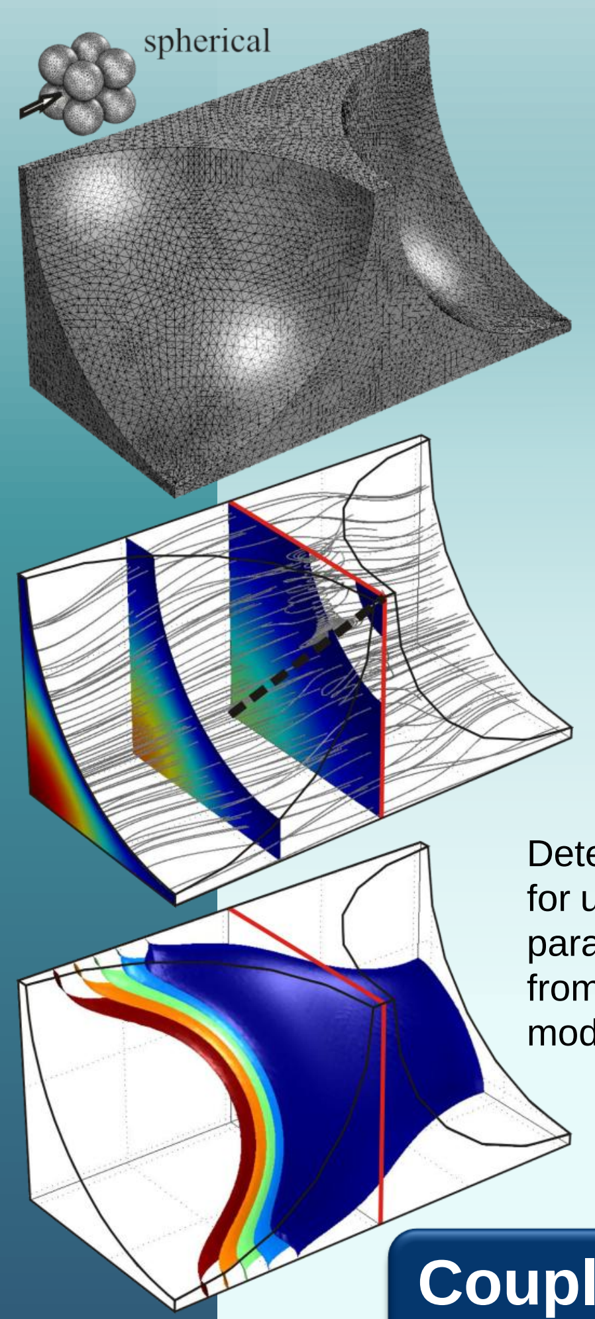


Institute for Computational Engineering Sciences (ICES), at the University of Texas

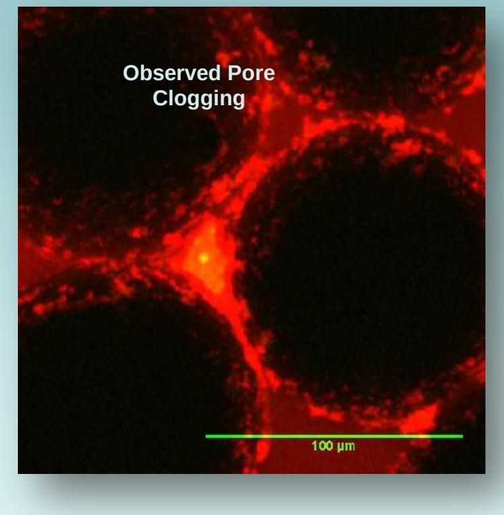


Research Highlights

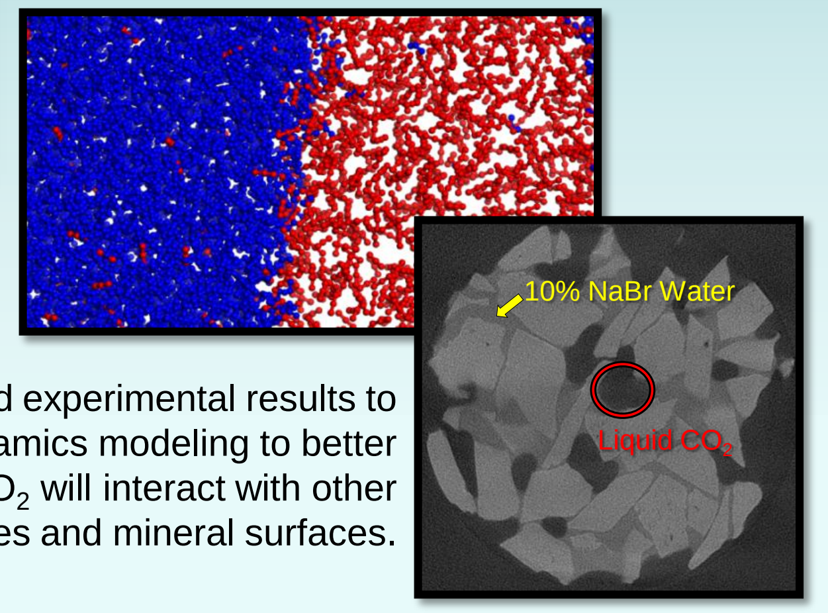
Coupled Physical and Biogeochemical Complexity at the Subpore to Pore Scale



Determined methods for upscaling flow parameters derived from pore-scale modeling.

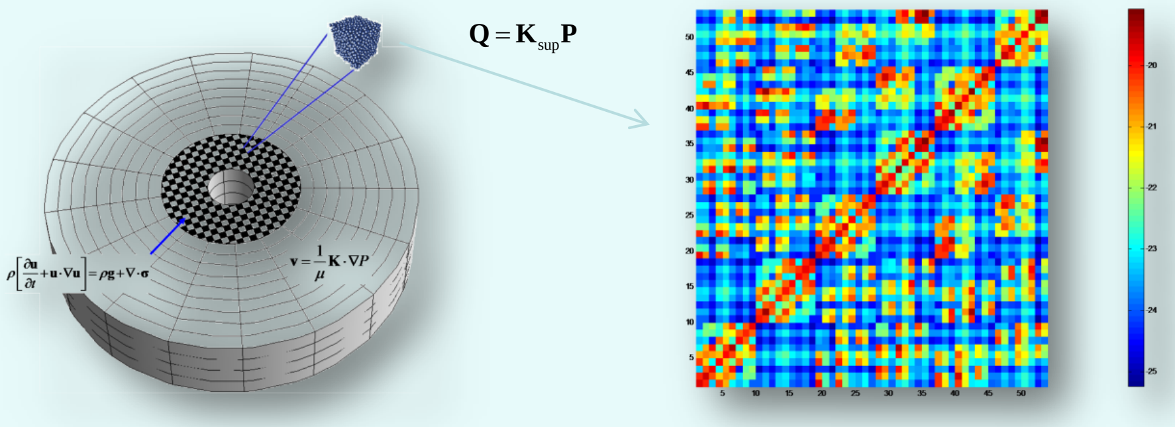


Determined that mineral surfaces affect microbial survival which, in turn, impacts hydraulic properties. This is important for understanding how hydraulic properties will change during and after CO_2 injection due to biological activity.

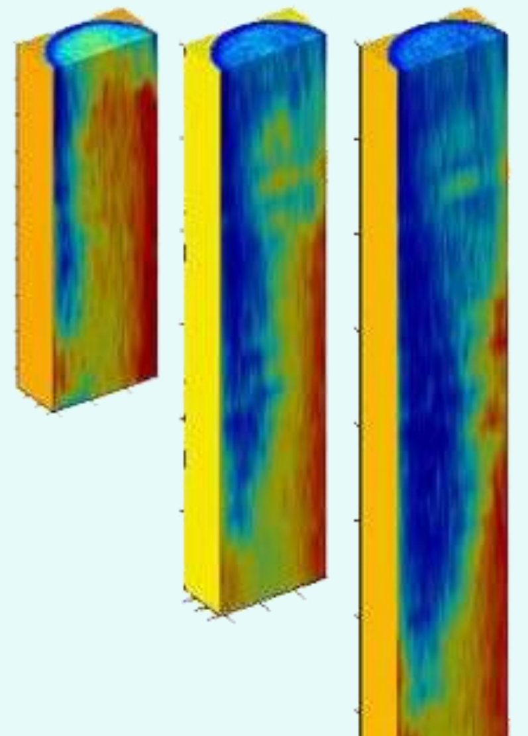


Connected experimental results to molecular dynamics modeling to better understand how CO_2 will interact with other dissolved species and mineral surfaces.

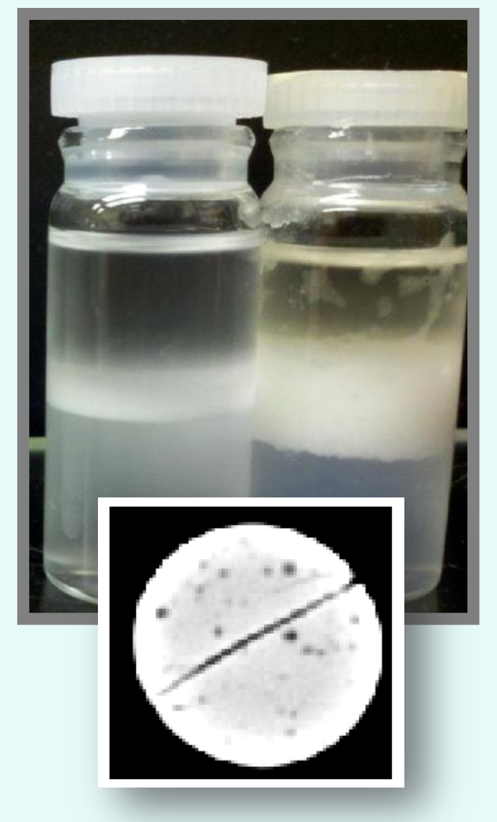
Coupled Mechanics, Flow & Reactive Transport at the Pore to Continuum Scales



Invented and tested an upscaling approach (super-permeability tensor) that permits detailed pore-scale physics to be included in continuum-scale models. This allows development of efficient models for predicting CO_2 migration spanning multiple temporal and spatial scales.

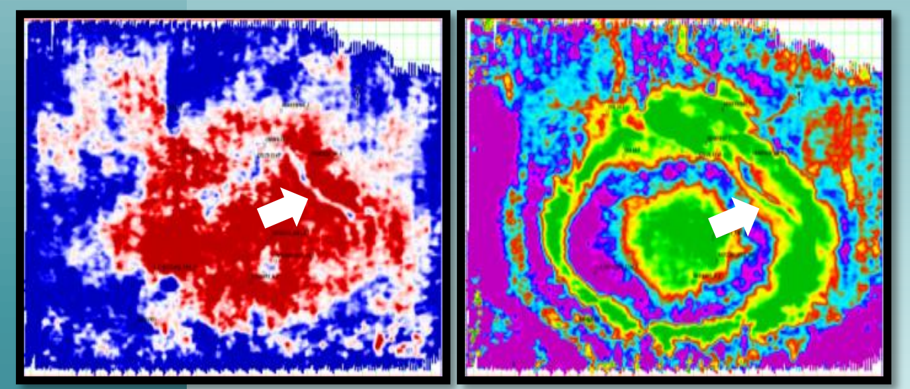


Experimentally observed a "viscous coupling" effect in three-phase (oil, water and gas) flow, relevant to mobility of CO_2 injected and stored in depleted oil reservoirs. Flow coupling (flow driven through viscous drag) is 10-100 times greater when three phases are present compared to two phases.

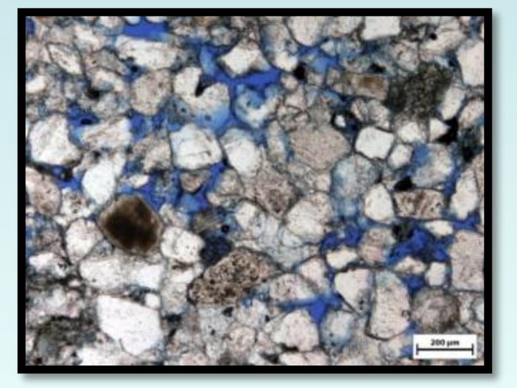


Provided experimental proof-of-concept for use of nanoparticle-stabilized emulsions as a CO_2 leakage deterrent in subsurface flow.

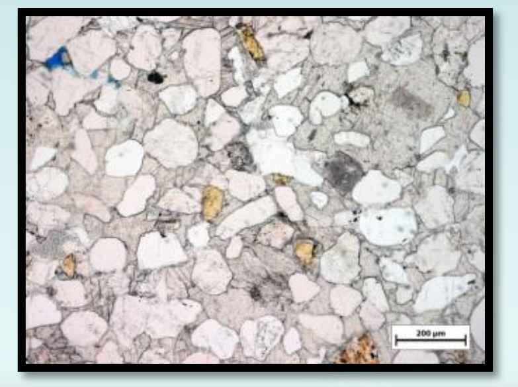
Coupled Mechanics, Flow & Transport at the Continuum to Field Scales



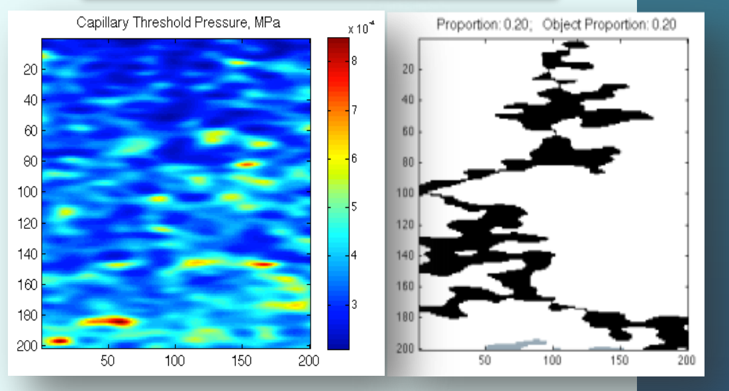
Developed new theory to calculate changes in large-scale properties of rocks due to chemical dissolution and changes in mechanical stress. Incorporation of this theory into seismic imaging improves our ability to better discern fine-scale flow channels, important to detecting potential CO_2 leakage pathways.

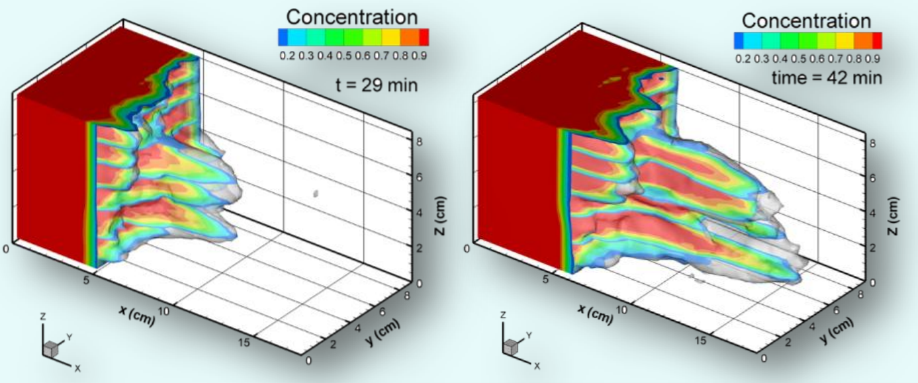


Collected field data that demonstrated carbonate cementation obstructs permeability at the pore scale but not potential CO_2 leakage pathways at the field scale.



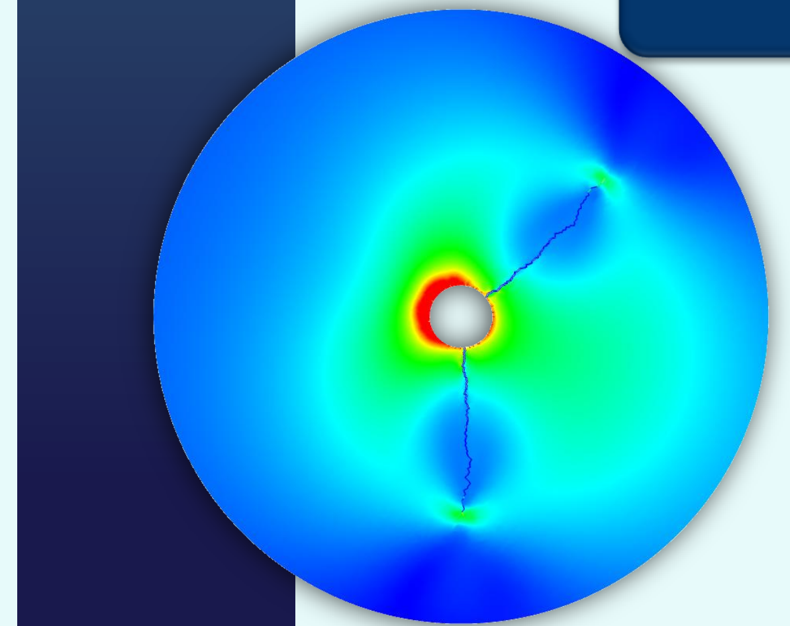
Gained better understanding of the complex control that the spatial patterns of the rock properties exert on invading fluids. This is important to understanding how CO_2 will move in pre-existing fault zones in the overlying caprock.



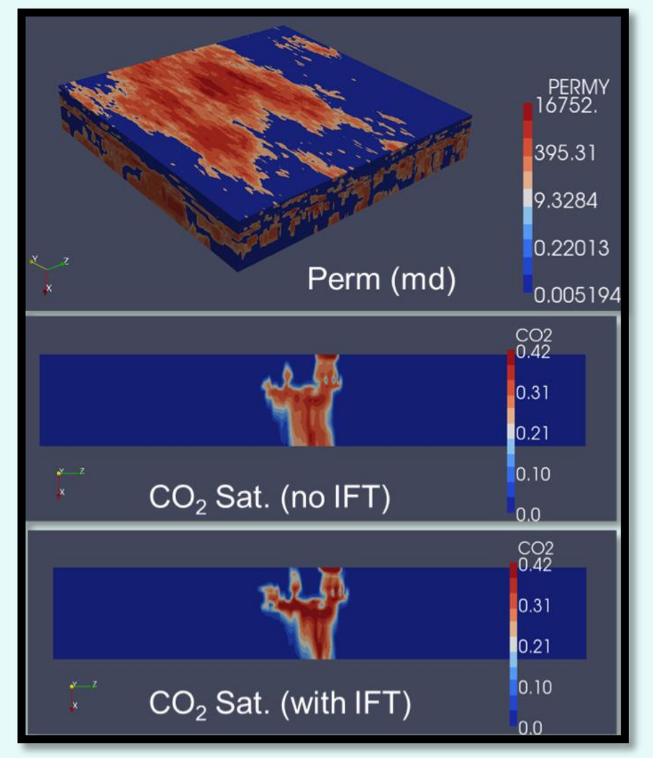


Improved our ability to estimate heterogeneous formation properties from limited measurements using inverse modeling. This is important for accurate predictions of the migration of injected CO_2.

Simulation of Multiscale, Multiphysics, Heterogeneous Physics

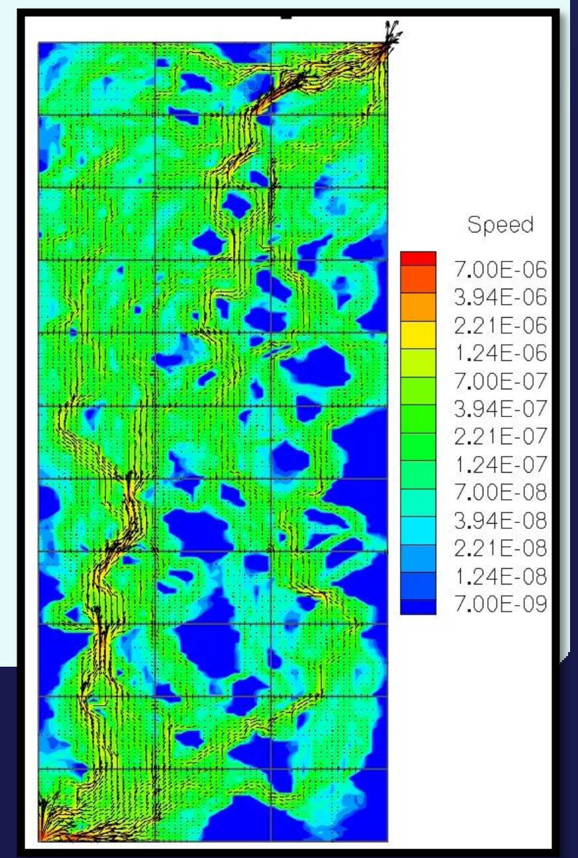


Developed new computational methods for modeling the coupling of hydrological and mechanical processes in fractures for the prediction of fracture growth due to CO_2 injection.



Added additional processes to the models (interfacial tension and buoyancy effects) so that they more accurately predict the migration of CO_2.

Developed new numerical methods for large-scale simulation of CO_2 sequestration to increase the accuracy and speed of models for large-scale CO_2 storage predictions.



This material is based upon work supported as part of the Center for Frontiers of Subsurface Energy Security, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Award Number DE-SC0001114.

printed by MegaPrint Inc. www.postersession.com