SAND2014-16947PE

Exceptional service in the national interest

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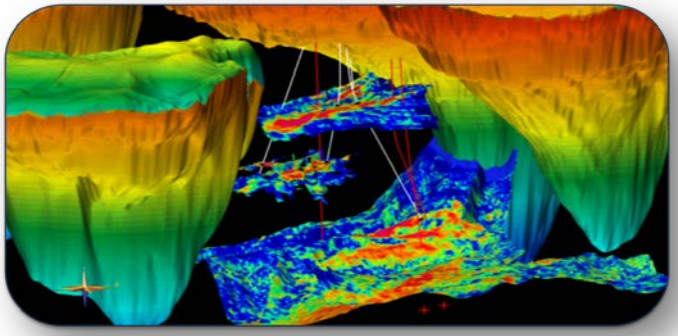

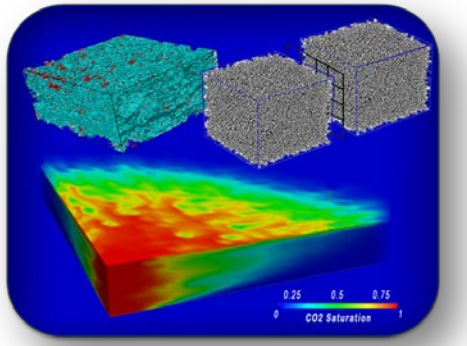

Center for Frontiers of Subsurface Energy Security

Susan J. Altman

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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The Energy Frontier Research Centers Aim to Accelerate Discovery Science for Energy Technologies

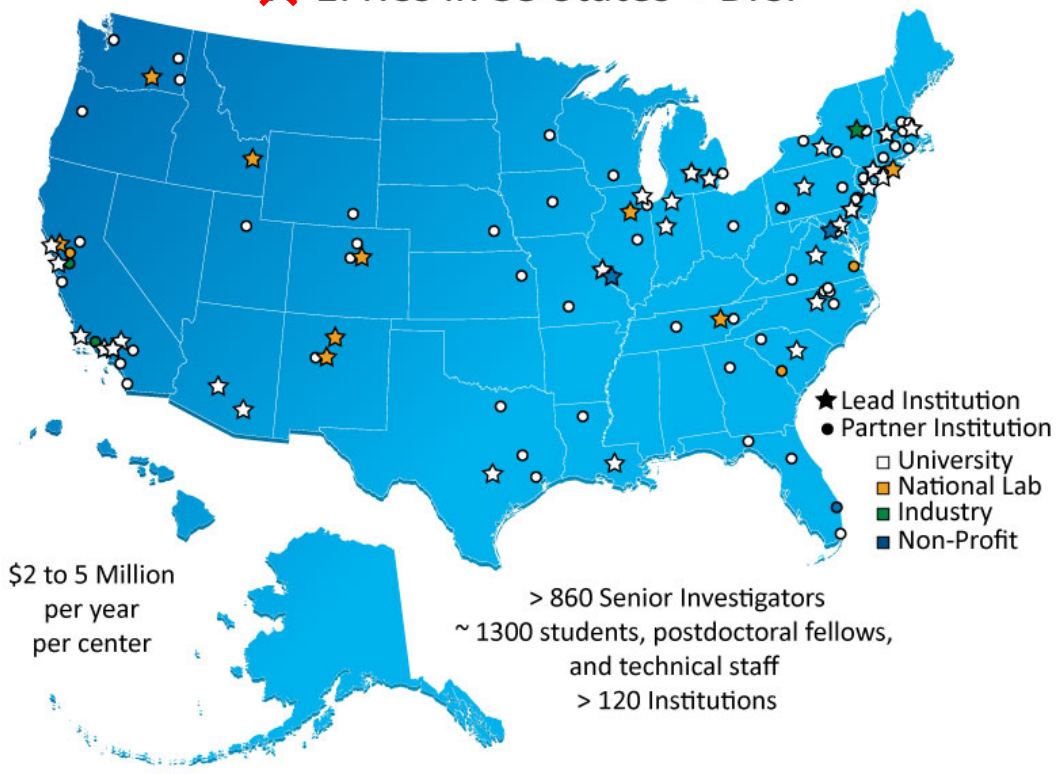
Sandia National Laboratories

- Center started August 2009
- 5 year program
- $15M ($7M to SNL)
- **CFSES is one of 2 geosciences related EFRCs**

- Renewal starts August 2014
- 4 year program
- $12M ($5.6M to SNL)
- **CFSES is one of 3 geosciences related EFRCs**

- Over 200 proposal submitted
- 22 of 46 renewed centers
- 10 new centers

32
~~46~~ EFRCs in 35 States + D.C.



Largest Increase in the Number of Carbon Storage EFRCs

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	Solar	Materials	Biofuels	Batteries	Catalysis	CCS
# in EFRC1	13	12	6	5	4	3
# renewed	7	3	3	4	1	3
# declined	6	9	3	1	3	0
# in EFRC2	7	6	3	5	5	4
new in EFRC2	0	3	0	1	4	1

	Lighting	Combustion	Nano Elec	Supercond.	Total
# in EFRC1	1	1	0	1	46
# renewed	0	0	0	1	22
# declined	1	1	0	0	24
# in EFRC2	0	0	1	1	32
new in EFRC2	0	0	1	0	10

Reviews Made it Difficult for DOE to Reject The Renewal Proposal

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Seven reviewers → Five "Excellents" → One "Very Good"

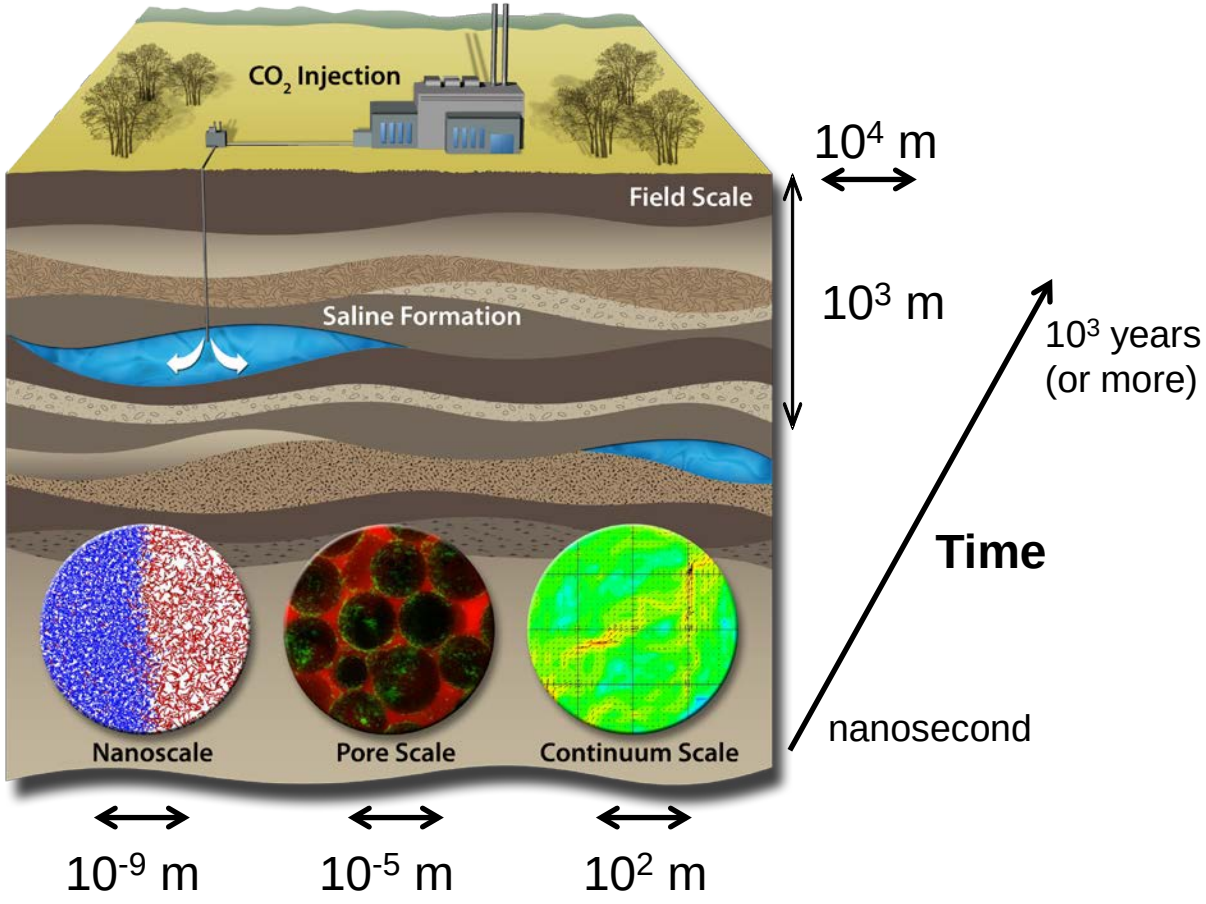
- "***Outstanding*** proposal that is well conceptualized."
- "This proposal is a ***winner***."
- "I suspect that this EFRC many have the ***most cohesive team of researchers*** among all the proposals submitted for this FOA …."
- "… the ***results will be important*** for a number of fundamental problems in subsurface fluid-rock-chemistry-geomechanics that are much broader than the issues related to CO_2 sequestration that are described in this proposal."
- "It is ***extremely well-written*** and concise."
- "I would recommend that the succinctly written Section 1.2 be ***used as a model*** for future EFRC proposals if this program continues. It is very well written."
- "The management plan clearly describes mechanisms to encourage synergy among the investigators through discussions and decision-making about progress at all levels of activities in the EFRC."
- "It has a solid, proven management and research team that will move the science forward."

A Multi-scale, Multi-physics Approach is Needed to Study Underground CO_2 Storage

Sandia National Laboratories

Goal

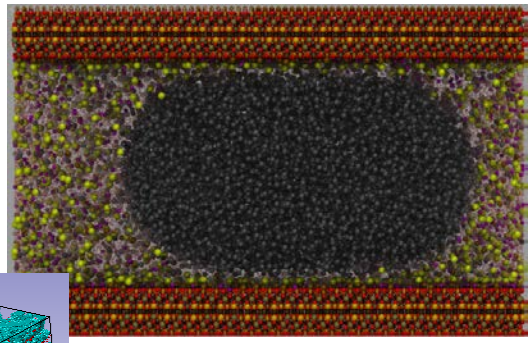
Advance scientific understanding of subsurface biological, chemical and physical phenomena related to the storage of energy byproducts using an integrated experimental and modeling approach

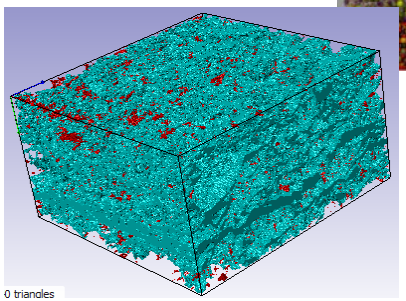


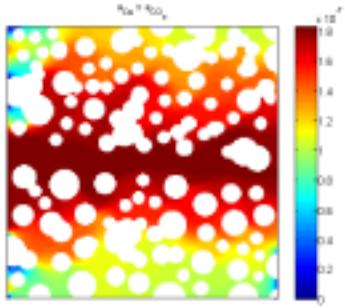
Depth in Geoscience Research Capabilities

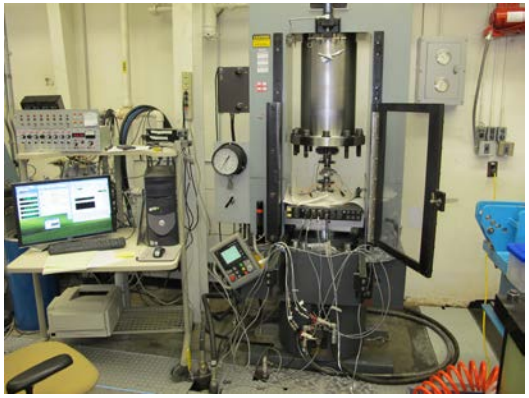
Sandia National Laboratories

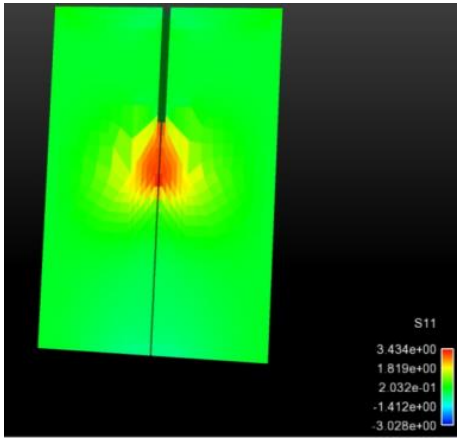
- Molecular dynamics simulation
- Subsurface microbial geochemistry
- Geomechanical testing
- Nanometer scale research
- Pore-scale reactive transport
- Coupled hydromechanical modeling











Understand Caprock Integrity

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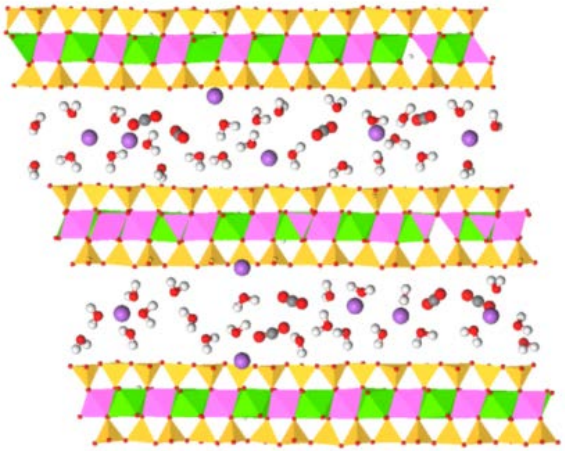
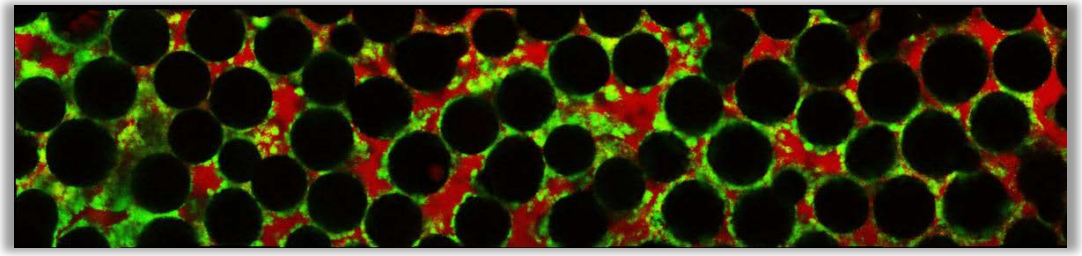
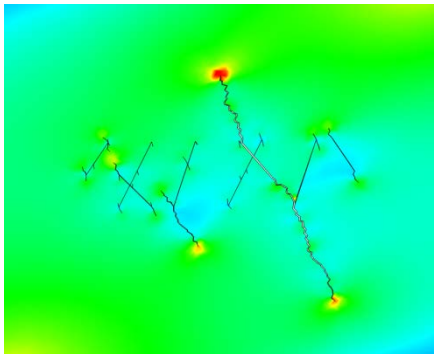


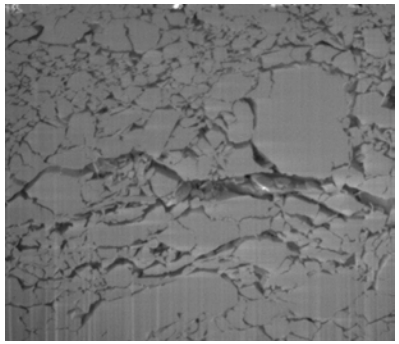
Intercalation of CO_2-H_2O by clay minerals

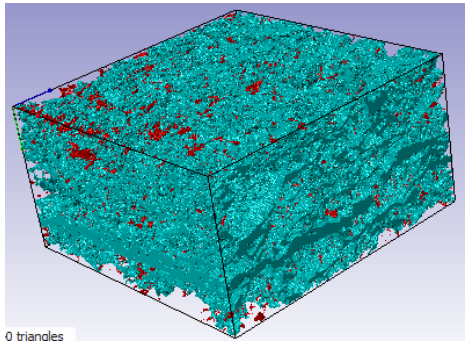


Engineered bioclogging of caprock

Model injection induced damage to caprock

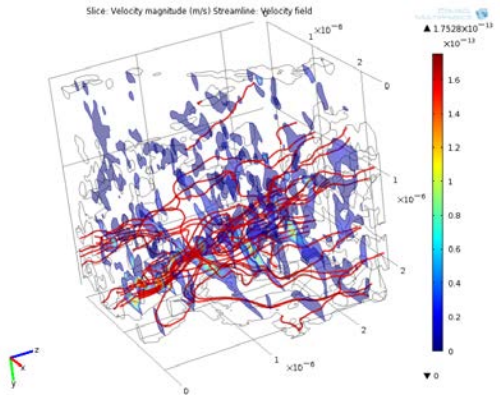






Measure mudstone porosity

Pore-scale modeling



How Important is CO_2 Dissolution?

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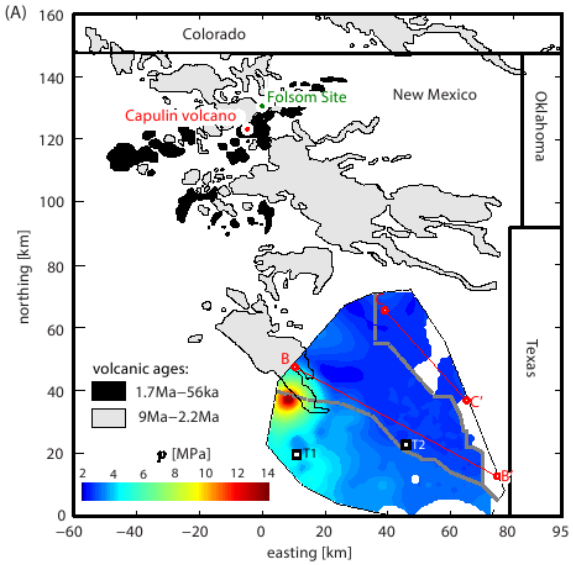
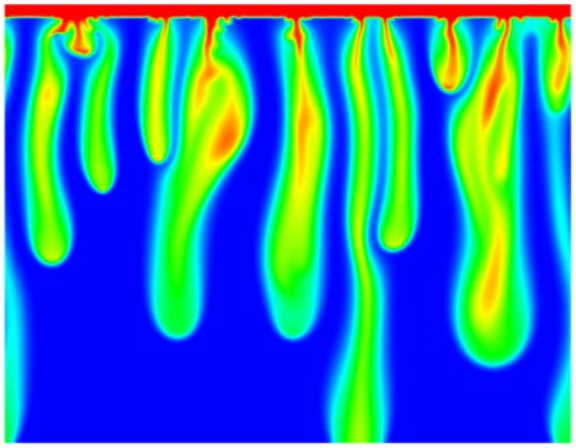
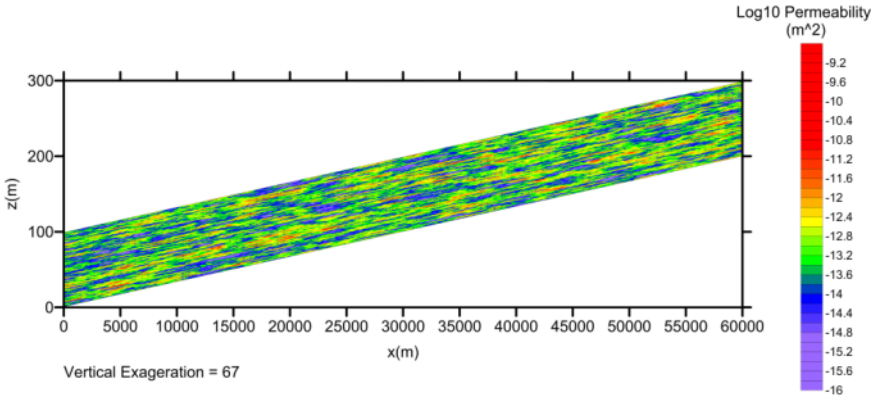


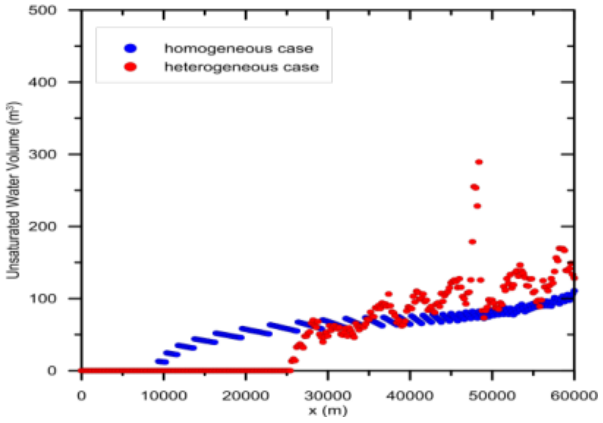
Bravo Dome Site:
360Mt CO_2 dissolved over 1.5Ma



Convectively driven dissolution flux may be roughly 3x larger than current estimates

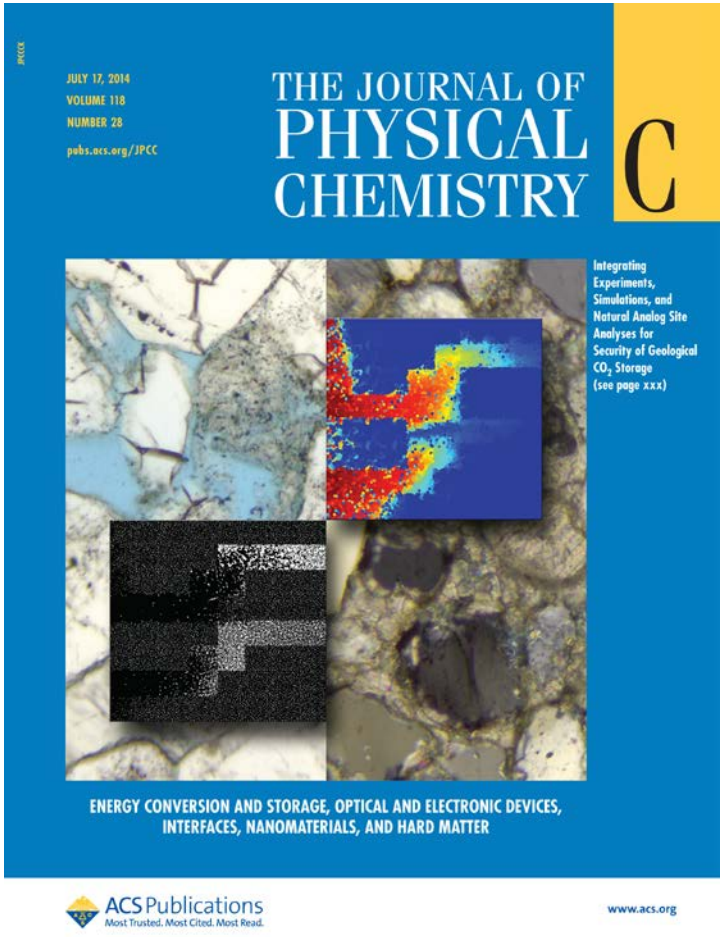


Dissolution is enhanced by heterogeneity



CFSES Has Produced Publications

- 80 CFSES publications
- 25 publications with Sandia authors
- 4 - 8 more papers expected from CFSES 1

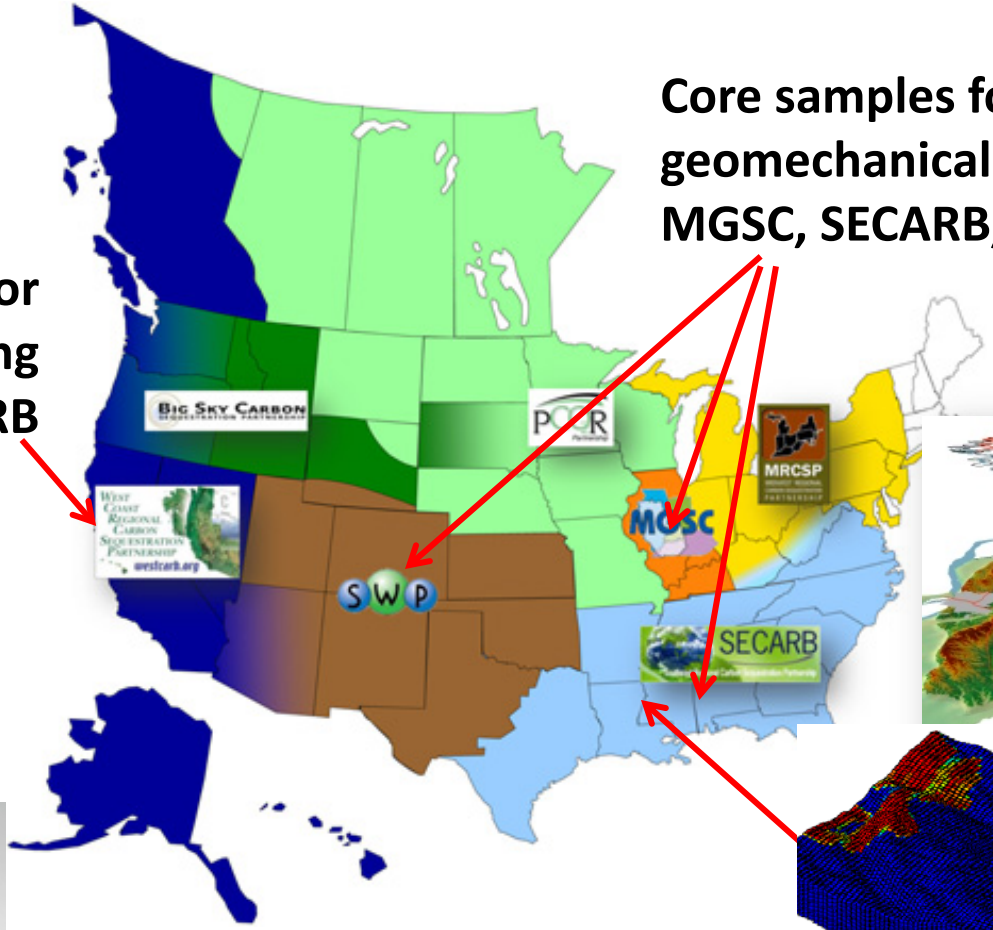


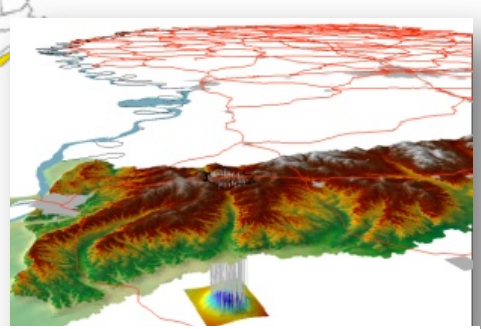
Integrating with NETL Partnerships and UT-Bureau of Economic Geology

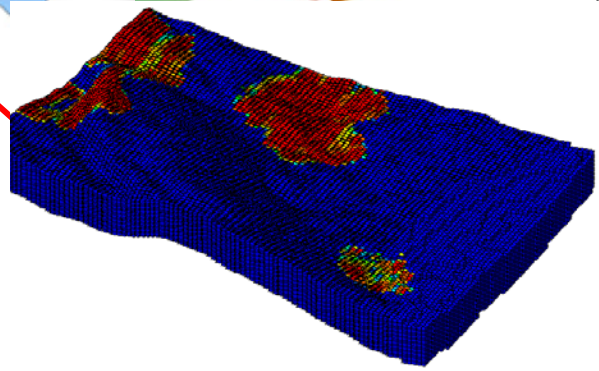
Sandia National Laboratories

Core samples for geomechanical testing from MGSC, SECARB, and SWP

Samples for microbiological testing from WESTCARB







3D simulation of Cranfield demonstration project

Change in CFSES Leadership

Gary Pope
July 31, 2009 – July 1, 2013

Steven Bryant
July 1, 2013 – July 31, 2014
Leaving UT 9/1/2014

Larry Lake
CFSES 2
(See reviewer comments, below)

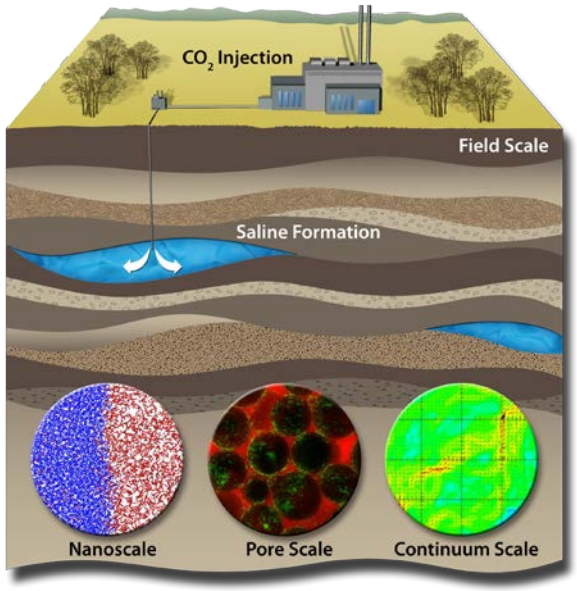
"Larry Lake has excellent qualifications and experience to be Director"
"Professor Larry Lake is superb."
"Larry Lake … will provide insightful guidance to the project"
"Larry Lake has strong qualifications as Director"
"Professor Lake is a strong addition to the team"
"Lake has the stature & credentials to effectively communicate the importance of energy science and technology"

Injection For Geologic CO_2 Storage Will Drive Natural Systems Far From Equilibrium

Sandia National Laboratories

Goal

To understand and control emergent behavior arising from coupled physics and chemistry in heterogeneous geomaterials.



RESEARCH PLAN

CFSES will pursue scientific advances to understand chemico-mechanical coupling between supercritical CO_2 and clay minerals, understand and predict modes and fluxes of reactive CO_2 migration, and design, develop and apply novel materials that will alter fluid-assisted perturbations in heterogeneous geomaterials.

Integrating Research Themes with Challenges

Sandia National Laboratories

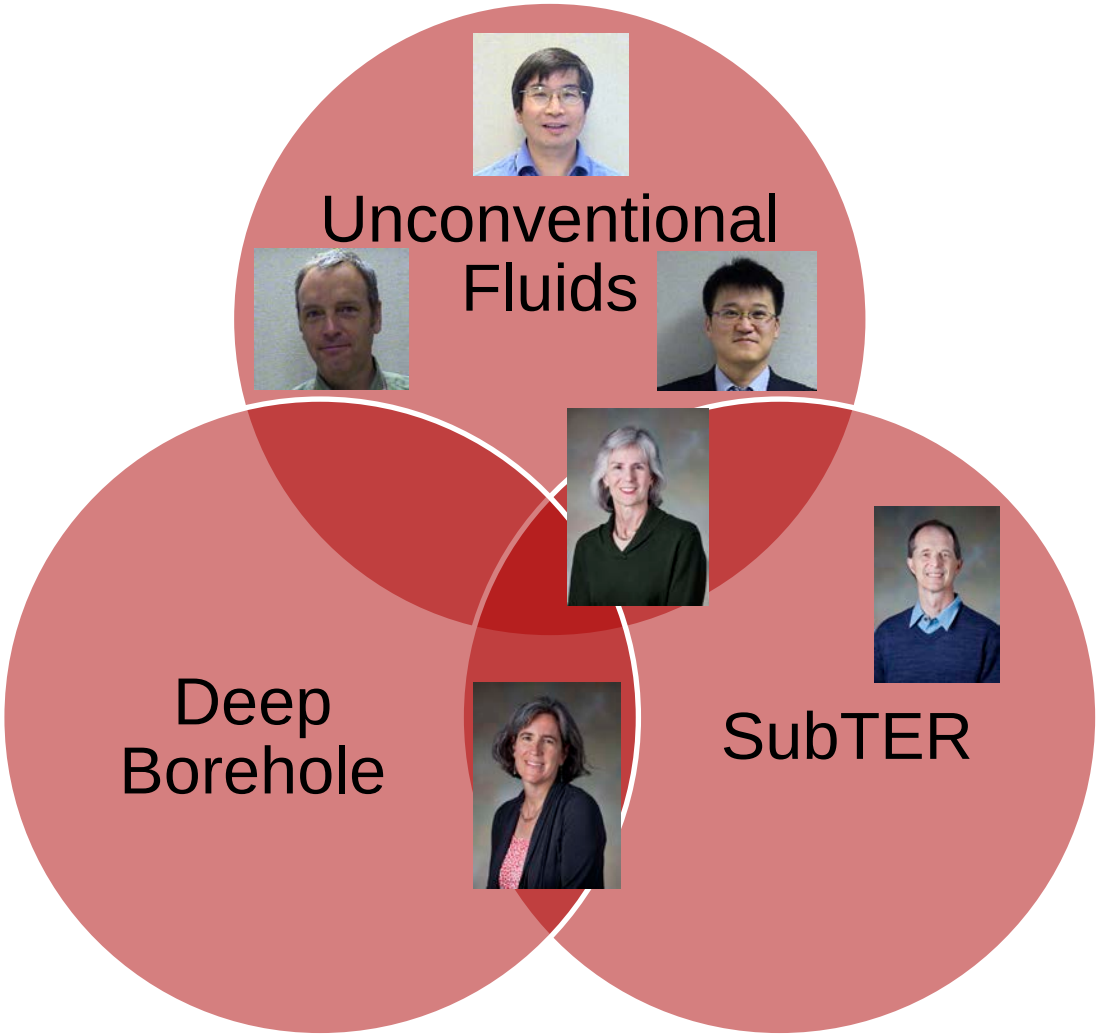
	Challenge 1: Sustaining Large Storage Rates	Challenge 2: Using pore space with unprecedented efficiency	Challenge 3: Controlling undesired or unexpected behavior
Theme 1: Fluid-Assisted Geomechanics	• Fracture propagation and rock deformation • Coupled modeling • Phase-field modeling	• Cohesive zone modeling • Fracture network analog sites • Acoustic wave propagation modeling	• Bulk rock weakening evaluation • Influence of chemistry in frictional slip
Theme 2: Multifluid Geochemistry	• Caprock chemical and mechanical stability	• Bravo Done brine-gas mass transfer • Chemistry at the fluid-fluid interface	• Caprock chemical and mechanical stability • Reactions of CO_2 with clay minerals
Theme 3: Buoyancy-Driven Multiphase Flow	• Meter-scale experiments • Core-scale X-ray CT experiments	• Meter-scale experiments • Core-scale X-ray CT experiments • Mesoscale modeling and invasion-percolation modeling • Ganglion dynamics modeling	• Nanoparticle experiments

Success of LDRD Seed Money and UT Partnership Beyond CFSES

Sandia National Laboratories

BEFORE CFSES	CFSES	BEYOND CFSES
LDRD **Computational Thermal, Chemical, Fluid, and Solid Mechanics for Geosystems Management** Enable Predictive Simulation and Strategic Partnerships ($3M)	CFSES 1 ($7M)	NETL FOA-0001037 Research for Safe and Permanent Storage of CO_2 **Geomechanics of CO_2 Reservoir Seals** ($248K to SNL) ($744 to UT)
	CFSES 2 ($5.6M)	

CFSES PIs' Research Interests Overlap With Other GRF Key Areas



Hiring Five Post-Docs

The Center for Frontiers of Subsurface Energy Security (CFSES) is seeking five new post-doctoral fellows to work at Sandia National Laboratories (Sandia). CFSES, a partnership between Sandia and the University of Texas at Austin, is an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science. The objective of CFSES is to understand and control emergent behavior arising from coupled physics and chemistry of geologic carbon dioxide storage in heterogeneous geomaterials. Sandia is the nation's premier science and engineering lab for national security and technology innovation with a focus on cutting-edge research and technology (www.sandia.gov). We currently have openings in:

Experimental Geomechanics (ID# 646223) conduct fracture propagation, rock deformation, and bulk rock strengthening/weakening experiments to develop and validate constitutive hydro-mechanical-chemical models.

Geochemistry (ID# 646225) use laboratory experiments to examine how geochemical changes during reactions with CO_2 and brine control the geomechanical behavior of caprocks and reservoir rocks.

Computational Fracture Mechanics (ID# 646179) contribute to computational fracture mechanics with an emphasis on local crack-tip and phase-field modeling and multiscale/multiphysics coupling with pore-scale models. Develop fundamental models of multiphase flow in heterogeneous capillary-porous media.

Molecular Simulation (ID# 646226) contribute to classical molecular simulation of bulk and interfacial phenomena associated with multifluids, and the interaction of water and CO_2 in clay interlayers.

Multiphase Flow Experiments and Modeling (ID# 646224) experimentally and numerically characterize capillary/buoyancy driven flow of carbon dioxide from pore to meter scale and develop upscaling techniques for multiphase flow and reactive transport.

Positions require a PhD in a relevant science or engineering discipline. A strong academic record and a demonstrated commitment to publication are essential. The ability to obtain and maintain a DOE security clearance is normally required. Sandia National Laboratories is an Equal Opportunity Employer M/F/D/V. Please visit Sandia's Careers website at **www.sandia.gov/careers** and access the position of interest by the above ID#.

Operated by LOCKHEED MARTIN

The Success of CFSES

Sandia National Laboratories

- Effective partnership with UT
- World-class, long-term, basic research program
- Key to success of the Geoscience Foundation strategy
- Raised reputation with the Office of Science