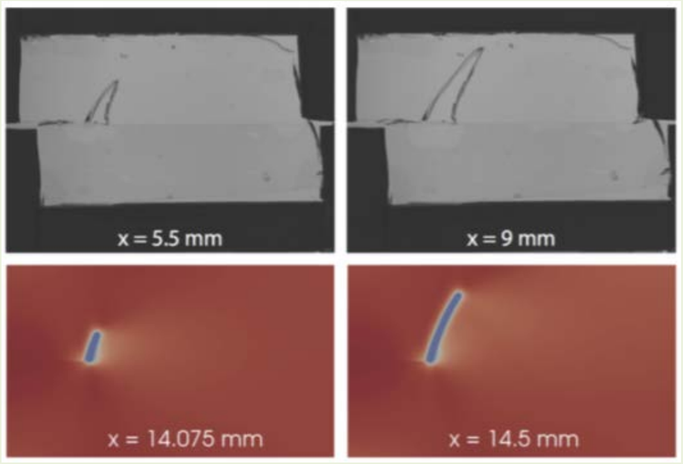
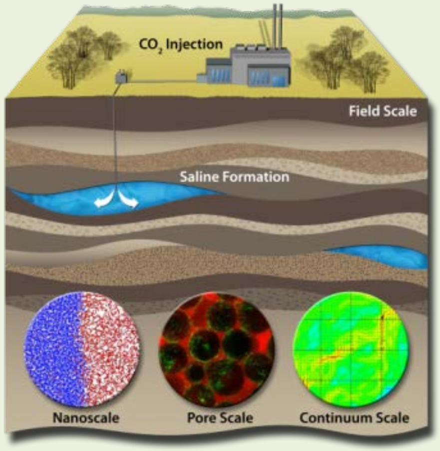
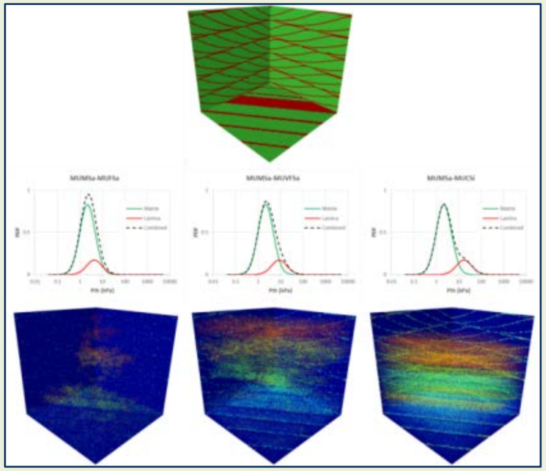
SAND2016-6889PE







The Center for Frontiers of Subsurface Energy Security (CFSES)

Mario Martinez, Susan J. Altman

July 13, 2016

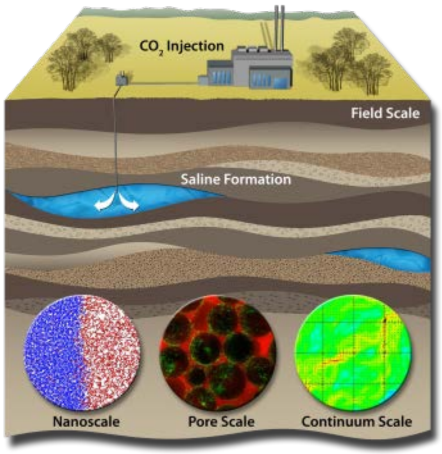
U.S. DEPARTMENT OF ENERGY | Office of Science

CFSES Center for Frontiers of Subsurface Energy Security

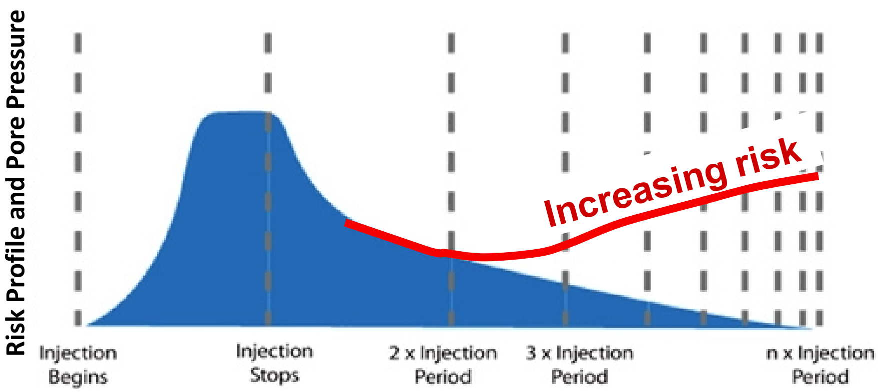
THE UNIVERSITY OF TEXAS AT AUSTIN

Sandia National Laboratories

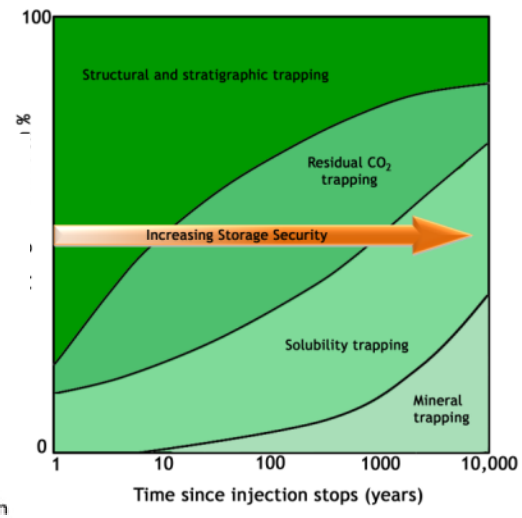
Science to Inform Geological CO_2 Storage Security



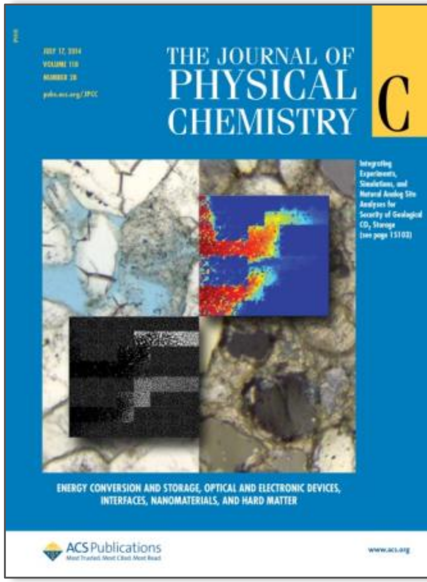
Mission: Understand and control emergent behavior arising from coupled physics and chemistry in heterogeneous geomaterials, particularly during the years to decades time scale.



Benson, IPCC, 2007



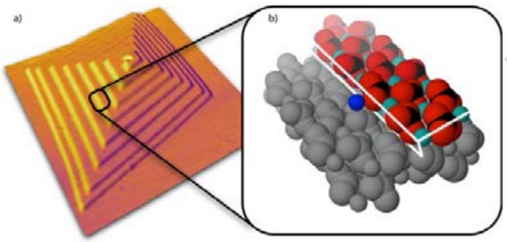
Modified after Benson et al., 2005



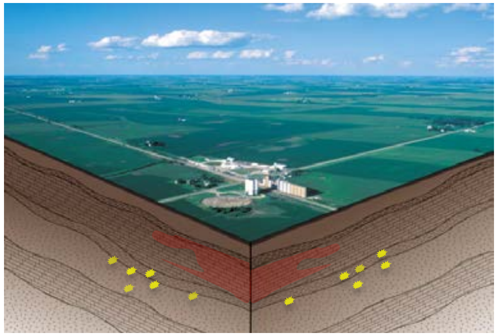
Basic Science → **Risk Assessment** → **Mitigation and Management**

Three GCS EFRCs Complement Each Other

Center for Nanoscale Control of Geologic CO_2 (NCGC)



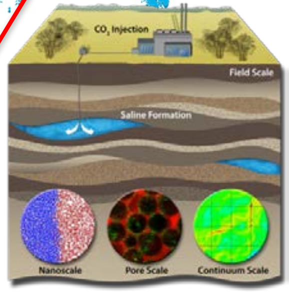
Center for Geologic Storage of CO_2 ($GSCO_2$)



32 EFRCs in 32 States + D.C.

~ 525 Senior Investigators
~ 900 students, postdoctoral fellows, and technical staff
~ 100 Institutions

Center for Frontiers of Subsurface Energy Security (CFSES)



Collaborations of Institutions within Institutions

TEXAS
The University of Texas at Austin

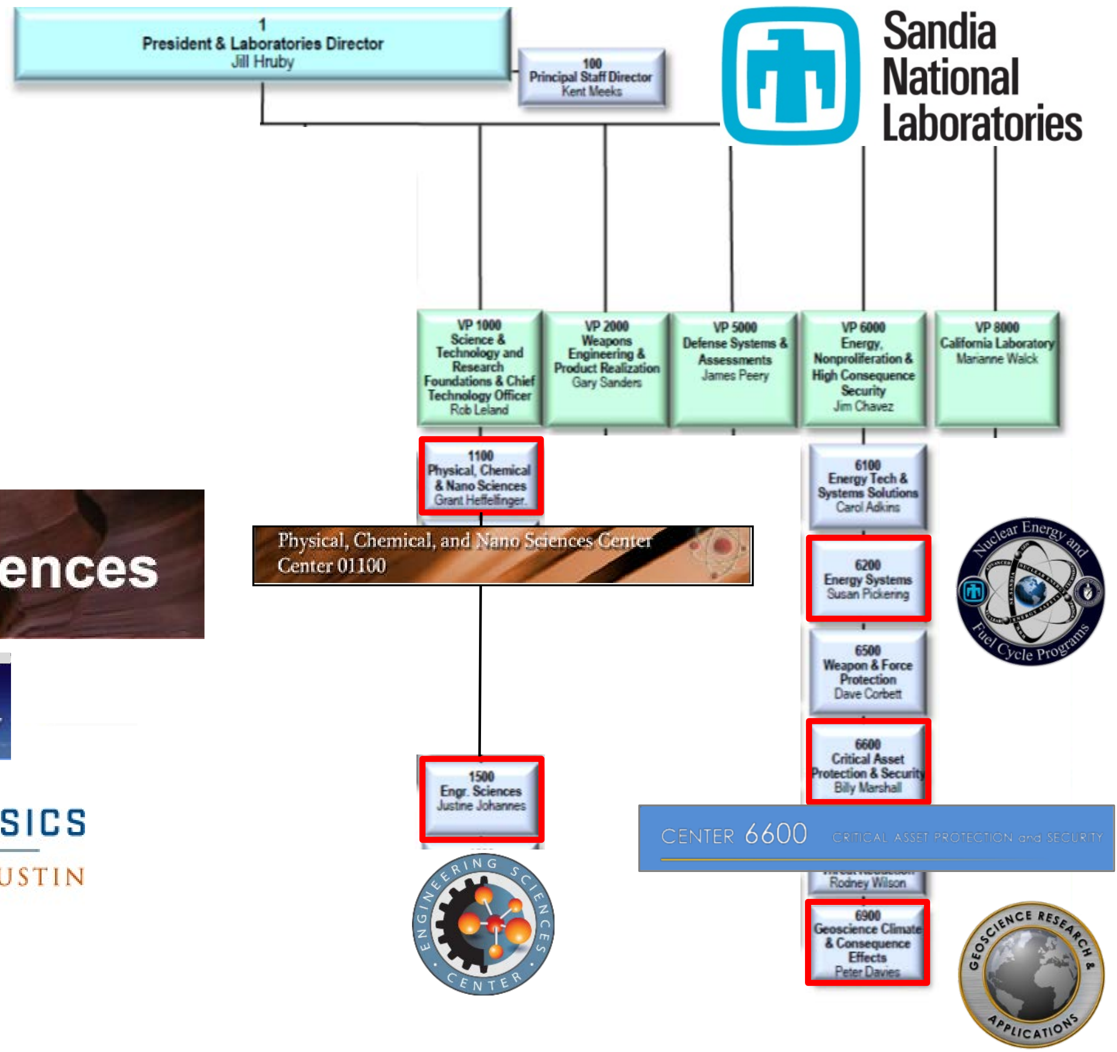
Cockrell School of Engineering

- The University of Texas at Austin Petroleum and Geosystems Engineering
- The University of Texas at Austin McKetta Department of Chemical Engineering

Jackson School of Geosciences

- DGS — The Department of Geological Sciences
- Bureau of Economic Geology
- UTIG — Institute for Geophysics, The University of Texas at Austin

The University of Texas at Austin Institute for Computational Engineering and Sciences (ICES)



CFSES Organizational Structure


EAB
Steve Bryant
Michael Carney
Charles Christopher
Don DePaolo
Derek Elsworth
Scott Frailey
Kurt House
Jean Roberts

Management Team
Larry W. Lake – Director
Grant Heffelfinger– Associate Director
Susan Altman, Hilary Olson – Assistant Directors

Administrative Associate
Barb Messmore

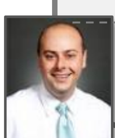

THEME 1: FLUID-ASSISTED GEOMECHANICS

Matt Balhoff, Tom Dewers

P. Eichhubl, D. N. Espinoza, A. Ilgen, M. Martinez, P. Newell, M. Prodanovic, M. Wheeler, H. Yoon, N. Hayman

C. Choens, S. Lee

M. Aman, J. Major, Z. Sun, M. Mirabolghasemi, M. Shafiei



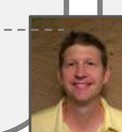

THEME 2: MULTIFLUID GEOCHEMISTRY

Anastasia Ilgen, Marc Hesse

P. Bennett, B. Cardenas, R. Cygan, O. Ghattas, T. Larson, C. Tenney, C. Yang

T. Ho, L. Wang, B. Wen

K. Gilbert, E. Guiltinan, H. Christensen, C. Mcneece



THEME 3: BUOYANCY-DRIVEN MULTIPHASE FLOW

Tip Meckel, Mario Martinez

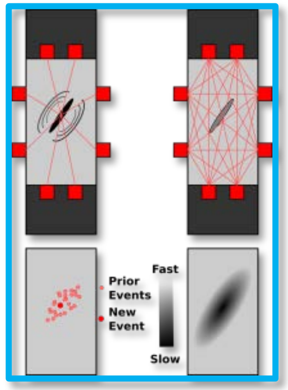
B. Cardenas, D. DiCarlo, S. Hovorka, C. Huh, K. Johnston, Y. Wang, H. Yoon

K. Chojnicki, A. Kucala, L. Trevisan, I. Kim

X. Chen, C. Da, E. Guiltinan, P. Krishnamurthy, S. Senthinalthan, A. Worthen, Z. Xue

Partnership Enables a Unique Combination of Laboratory Facilities

Micro Computed Tomography for imaging of contact angles and fracture geometry



Computed tomography for imaging multi-phase fluid flow through cores

Computed tomography for imaging multi-phase fluid flow through cores with or without nanoparticles

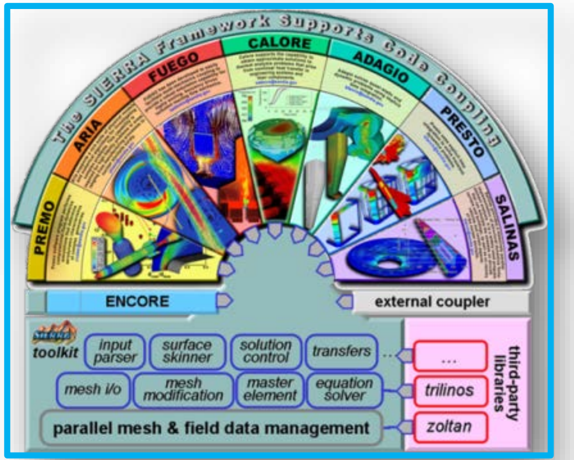
High pressure and multiphase fluid delivery system for pore-scale flow experiments

Laser scanning confocal microscopy for imaging reactive transport at the pore scale

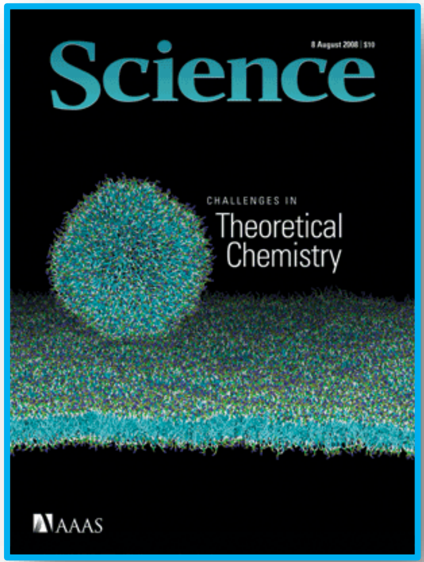
Geomechanical testing for acoustic and ultrasonic imaging of rock deformation

World-Class Computational Facilities and Software

Sandia National Laboratories' Super Computer Red Sky



Sierra Mechanics engineering analysis codes

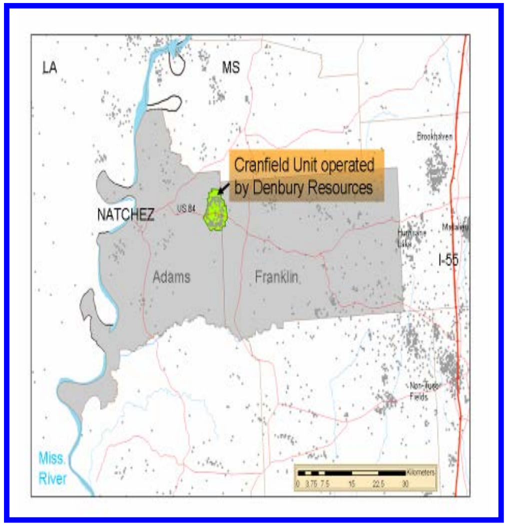


Molecular Dynamics Code LAMMPS

Connection to Field Sites

Little Grand Wash Fault Zone

Bravo Dome Natural CO_2 Field

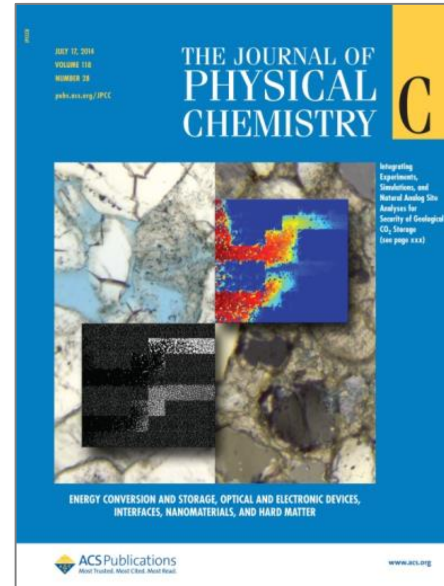


Core from Cranfield Pilot Test

Publications

- **110 Publications**
- **1209 Citations**
- **42 Journals**

Cover Article



5.5 Impact Factor

ACS Publications
Most Trusted. Most Cited. Most Read.

Environmental Science & Technology

4 publications

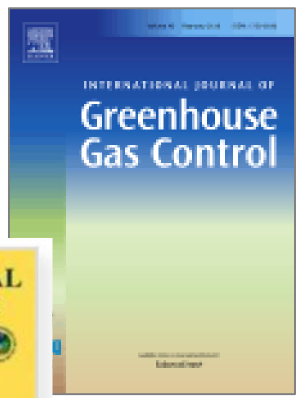
Geophysical Research Letters
AN AGU JOURNAL

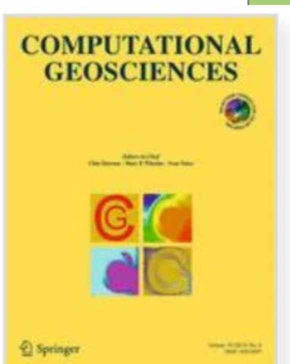
4.5 Impact Factor 6 publications

Water Resources Research
AN AGU JOURNAL

3.7 Impact Factor 11 publications

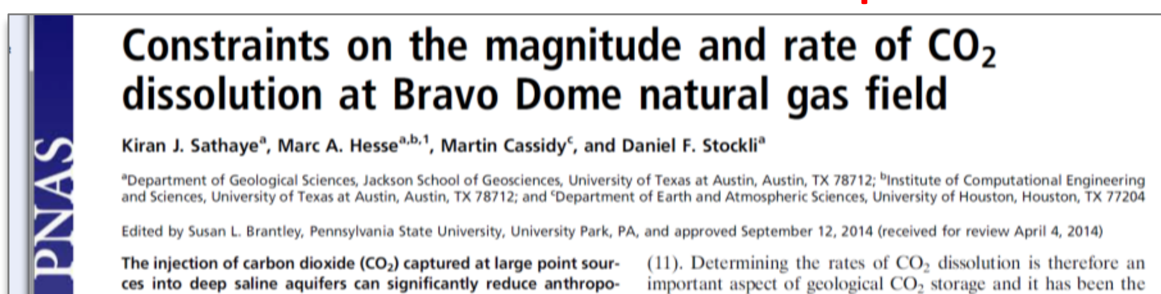
5 publications





6 publications

9.8 Impact Factor



PNAS

Constraints on the magnitude and rate of CO_2 dissolution at Bravo Dome natural gas field

Kiran J. Sathaye[a], Marc A. Hesse[a,b,1], Martin Cassidy[c], and Daniel F. Stockli[a]

[a]Department of Geological Sciences, Jackson School of Geosciences, University of Texas at Austin, Austin, TX 78712; [b]Institute of Computational Engineering and Sciences, University of Texas at Austin, Austin, TX 78712; and [c]Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX 77204

Edited by Susan L. Brantley, Pennsylvania State University, University Park, PA, and approved September 12, 2014 (received for review April 4, 2014)

The injection of carbon dioxide (CO_2) captured at large point sources into deep saline aquifers can significantly reduce anthropo-

(11). Determining the rates of CO_2 dissolution is therefore an important aspect of geological CO_2 storage and it has been the

Challenges

Challenge 1 → Sustaining large storage rates

Challenge 2 → Using pore space with unprecedented efficiency

Challenge 3 → Controlling undesired or unexpected behavior

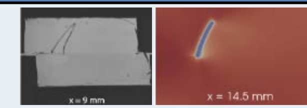
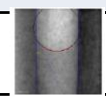
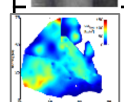
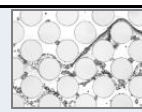
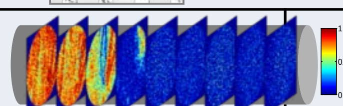
CHALLENGES

Sustaining Injectivity
Control wellbore failure
Enhance permeabilty/avoid precipitation during injection
Guide injection limits

Storage Efficiency
Improve sweep efficiency
Predict solubility trapping
Predict mineral trapping
Enhance capillary (ganglion) trapping

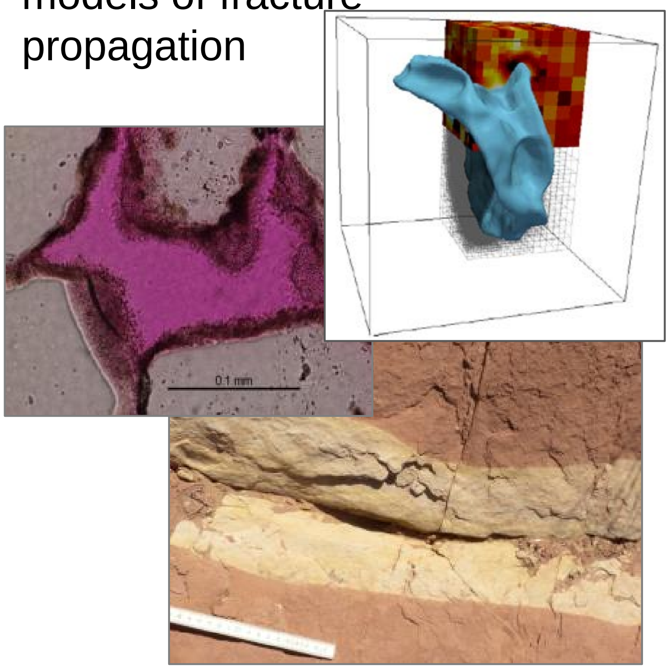
Controlling Emergence
Prevent unwanted fracturing
Control pathway development
Prevent unexpected migration of CO_2

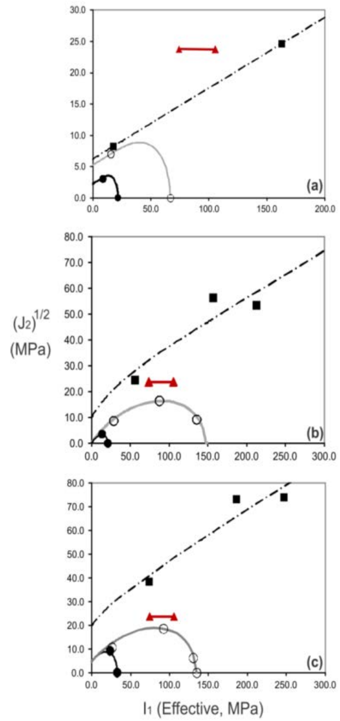
Research Activities

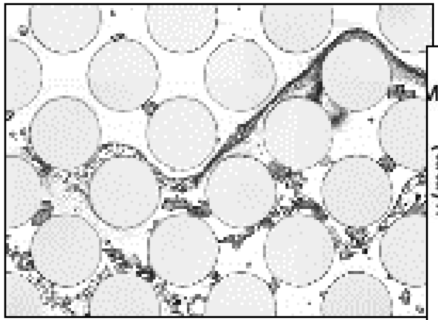
CFSES	Challenge 1: Sustaining Large Storage Rates	Challenge 2: Using pore space with unprecedented efficiency	Challenge 3: Controlling undesired or unexpected behavior
Theme 1 Fluid-Assisted Geomechanics	Chemo-mechanical coupling during fracture propagation 		
	 Chemo-mechanical effects on reservoir rock weakening		
	---		 Coupled chemo-mechanical processes in shale caprock
Theme 2: Multifluid Geochemistry	---	 Geochemistry at the fluid-fluid interface	
		 Reservoir dynamics of Bravo Dome natural CO_2 reservoir	Reactions of CO_2 with clay minerals
Theme 3: Buoyancy-Driven Multiphase Flow	 Multiphase flow and reactive transport at the pore scale		
	 ---	CT high pressure CO_2 core flood experiments with and without nanoparticles	
		 Experimentally tested invasion percolation modeling of buoyancy driven flow	

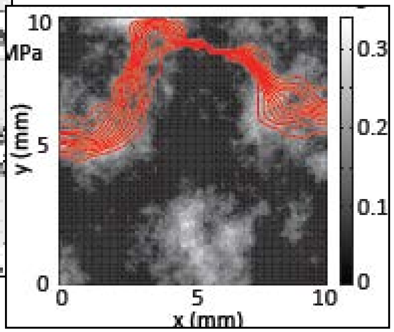
Challenge 1 – Sustaining Large Storage Rates

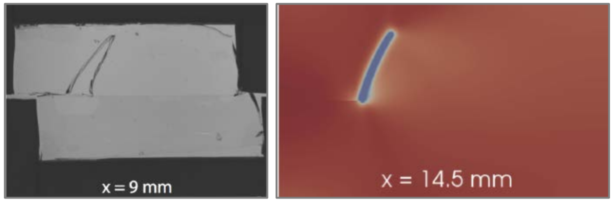
Control wellbore failure	Enhance permeabilty/avoid precipitation during injection	Guide injection limits
• Experimentally validated chemo-mechanical models • Experimentally validated constitutive models • Experimentally validated models of fracture propagation	• Pore-scale experiments linked to flow and reactive transport models	• Experimentally validated chemo-mechanical models • Experimentally validated constitutive models • Injection pressure coupled fracture closure model







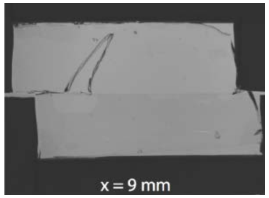


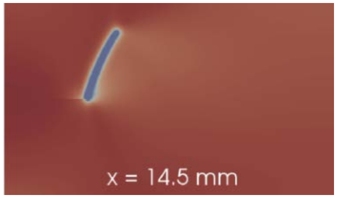


Challenge 2 – Using Pore Space with Unprecedented Efficiency

Improve sweep efficiency

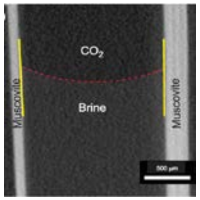
- Experimentally validated chemo-mechanical models
- Experimentally validated invasion percolation simulations

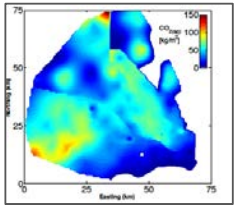




Predict solubility trapping

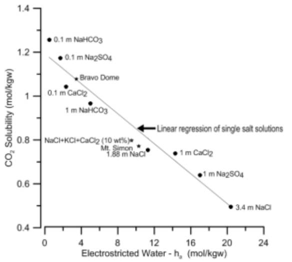
- CO_2 solubility model
- Molecular level understanding of solvation of ions and CO_2 in brines
- Bravo Dome studies
- Experimentally validated invasion percolation simulations

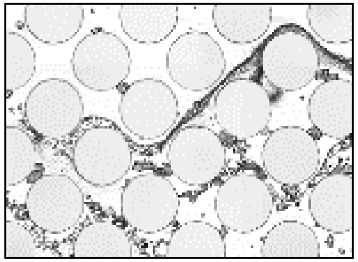




Predict mineral trapping

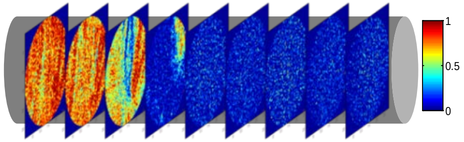
- CO_2 solubility model
- Pore-scale experiments linked to flow and reactive transport models

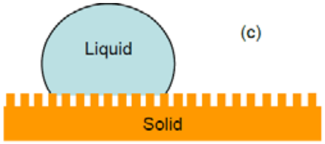




Enhance capillary (ganglion) trapping

- Modeling of impact of roughness on wettability
- Experimentally validated invasion percolation simulations
- Surface-treated nanoparticle synthesis and testing
- Pore-scale experiments linked to flow and reactive transport models





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Challenge 3 – Controlling Undesired and Unexpected Behavior

Prevent unwanted fracturing

- Experimentally validated chemo-mechanical models models
- Experimentally validated constitutive models
- Experimentally validated of fracture propagation
- Caprock alteration experiments

Control pathway development

- Caprock alteration experiments
- Surface-treated nanoparticle synthesis and testing

Prevent unexpected migration of CO_2

- Wettability measurements and simulations on shales
- Pore-scale experiments linked to flow and reactive transport models
- Experimentally validated invasion percolation simulations
- Surface-treated nanoparticle synthesis and testing