

Center for Geologic Storage of CO₂ (GSCO2)
EFRC Director: Scott M. Frailey
Lead Institution: University of Illinois at Urbana-Champaign
Start Date: August 2014

Mission Statement: *To generate new conceptual, mathematical, and numerical models applicable to geologic storage systems in specific and strategically identified research areas, based on uncertainty and limitations observed in field pilots and CO₂ injection demonstration projects, laboratory experiments, and the experience of researchers.*

The Center for Geologic Storage of CO₂ aims to improve fundamental understanding of one of the most important questions regarding the geologic storage of CO₂ and other fluids: ***What are the mechanisms of injection-induced microseismicity, and can we control and predict its occurrence?*** Five specific research questions have been designed to address this overarching question.

How can we unravel the links between induced microseismicity and the stress field?

The *central hypothesis* is that small, critically stressed fractures in the subsurface, distributed in clusters with variable orientation, are triggered to slip as a response to small changes in the *in situ* stress field, associated with minor changes in pore pressure. This research question includes aspects of processing, interpreting, and understanding the relation between microseismic waveform data and anisotropic changes of the *in situ* rock conditions. Rock samples will be prepared in the laboratory to mimic a fracture zone at *in situ* stress and pressure conditions. By injecting fluids at low pressures, the artificial fracture will be tested for slip. This research will compare field-scale observations of induced seismicity with acoustic emission (AE) data from laboratory experiments by using waveform data from AEs and field-scale observations of microseismic events, to establish and describe links between microseismicity and the stress field. Numerical experiments will be conducted to assess pore pressure propagation at the continuum scale to simulate slip on critically stressed fractures with very small changes to pore pressure.

How do reservoir-scale geologic features relate to geomechanical and seismic properties of rocks?

The *central hypothesis* is that new research on geologic architecture, approaches relating geomechanical properties and seismic velocities to geologic facies, and depositional-based approaches to simulating geologic facies will lead to significant advances in modeling three-dimensional (3-D) spatial variation in geomechanical properties and seismic velocities. Reservoir geology will be related to geomechanical properties through studies and quantitative analysis of combined borehole data sets. The contribution of geologic factors, across scales, to the variance in geomechanical and petrophysical properties will be quantified. The results will be expanded to scenarios for 3-D sedimentary architecture and structure. The 3-D models for geomechanical properties and seismic velocities will be incorporated into geologic models and used in interpretive forward modeling of seismic velocities.

How can measurements of geomechanical properties at pore and core scales be improved?

The *central hypothesis* is that completion of coordinated but distinct laboratory-scale experiments focusing on characterization of thermo-hydro-mechanical properties of rock will provide improved measurement capability and will enable the linkage of important reservoir material behavior processes, specifically injection-induced microseismicity, across the pore and core scales. This research question includes new (e.g., X-ray computed tomography [CT] scanning, advanced ultrasonics) and conventional (e.g., AE, electrical resistivity) experimental measurement methods to study the effects of brine and CO₂ injection on the stress field, mechanical properties, and induced microseismic activity of rock samples. The influences of stress and saturation on the observed behavior will be separated by testing different sample sets similarly. Intact samples will be tested to establish baseline behavior. Samples that contain

modified simulated defects will be tested under the same saturation to enhance stress fields and thus understand those influences.

How do pore fluid pressure fluctuations transmit in, and affect the state of, realistic porous and fractured media? The *central hypothesis* is that modeling coupled stress, strain, and multiphase flow processes that induce microseismicity must have pore-scale geologic heterogeneity represented. Geologic heterogeneity of flow paths within rock samples can lead to localized increases in pore pressure, leading to localized failure within the rock matrix or slippage of preexisting fractures across scales, thus inducing microseismic events. Models of pore-scale heterogeneity will be developed based on high-resolution CT scans of rock core. Simulators that couple multiphase flow and geomechanical response will be used to investigate key mechanisms triggering microseismic events in various stochastic realizations of the rock. The models will be validated through comparison with pore- and core-scale experiments.

In the presence of specific geologic attributes/features, how do CO₂ and brine mixtures affect the geomechanical and seismic properties of rocks? The *central hypothesis* is that geochemical reactions promoted by CO₂ alter the stress field and reduce mineral strength along grain boundaries, thus promoting fracture propagation. These geochemically induced fracturing events are hypothesized to be the main cause of postinjection microseismic events when pore pressures are decreasing. This research is differentiated by spatial scale. Similar cores will be characterized, exposed to CO₂-saturated brine, and then evaluated for changes in mineralogy, rock mechanical properties, and fracturing. Nanoindentation, sliding friction, and scratch tests will be used to assess changes to mechanical properties of rocks exposed to CO₂-saturated brine. Cores will be subject to triaxial pressure cycling before and after exposure to CO₂-saturated brine. The effect of pressure cycling on mineralogical alteration, and the effect of mineralogical alteration on stress-strain during pressure cycling, will be evaluated using high-resolution pore-scale imaging, strain gauge measurements, and nano- to micro-scale mineralogical analyses.

To test the hypothesis and validate models, a subsurface observatory, the Illinois Basin–Decatur Project, will be used within each of these research questions.

Center for Geologic Storage of CO₂ (GSCO2)	
University of Illinois at Urbana-Champaign	S. Frailey (Director), S. Whittaker (Associate Director), R. Bauer, J. Best, A. Bezryadin, J. Druhan, A. Elbanna, R. Makhnenko, S. Marshak, R. Okwen, J. Popovics, A. Valocchi
UT Austin	C. Werth, N. Espinoza
NORSAR	V. Oye, B. Goertz-Allmann
Northwestern	A.-T. Akono
Wright State	R. Ritzi, D. Dominic, N. Gershenzon
Schlumberger	S. Stanchits
U. Southern California	K. Jessen, M. Sahimi, T. Tsotsis
CSIC	V. Vilarrasa
SINTEF	M. Jordan, P. Cerasi
LANL	P. Johnson, P.-Y. Le Bas
Notre Dame	K. Christensen
Texas Tech	D. Sweet, C. Barnes, M. Barnes, P. Sylvester, B. Segvic
NETL	A. Goodman, D. Crandall, W. Harbert

Contact: Scott M. Frailey, GSCO2 Director, SFrailey@illinois.edu,
217-244-7412, <http://www.gSCO2.org/>