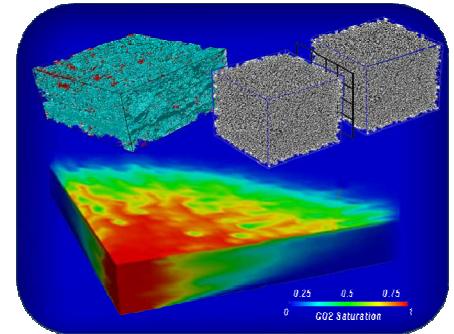
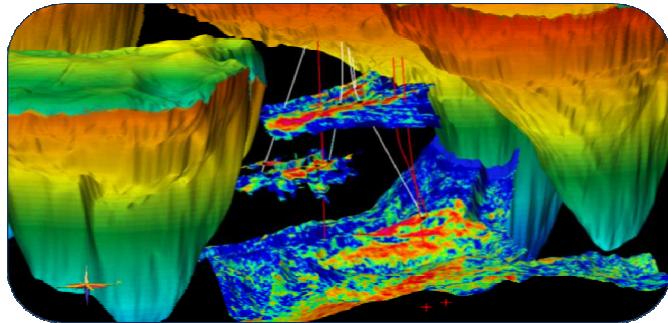


Exceptional service in the national interest



Center for Frontiers of Subsurface Energy Storage (CFSES)

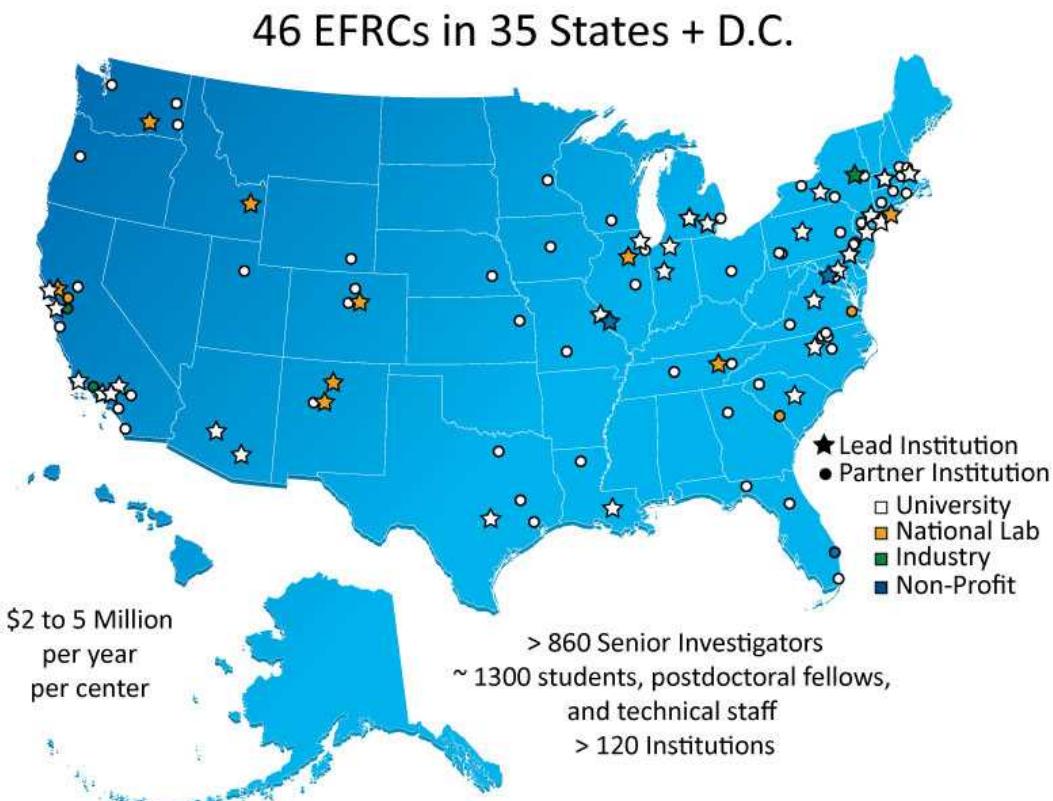
Susan J. Altman
January 16, 2013



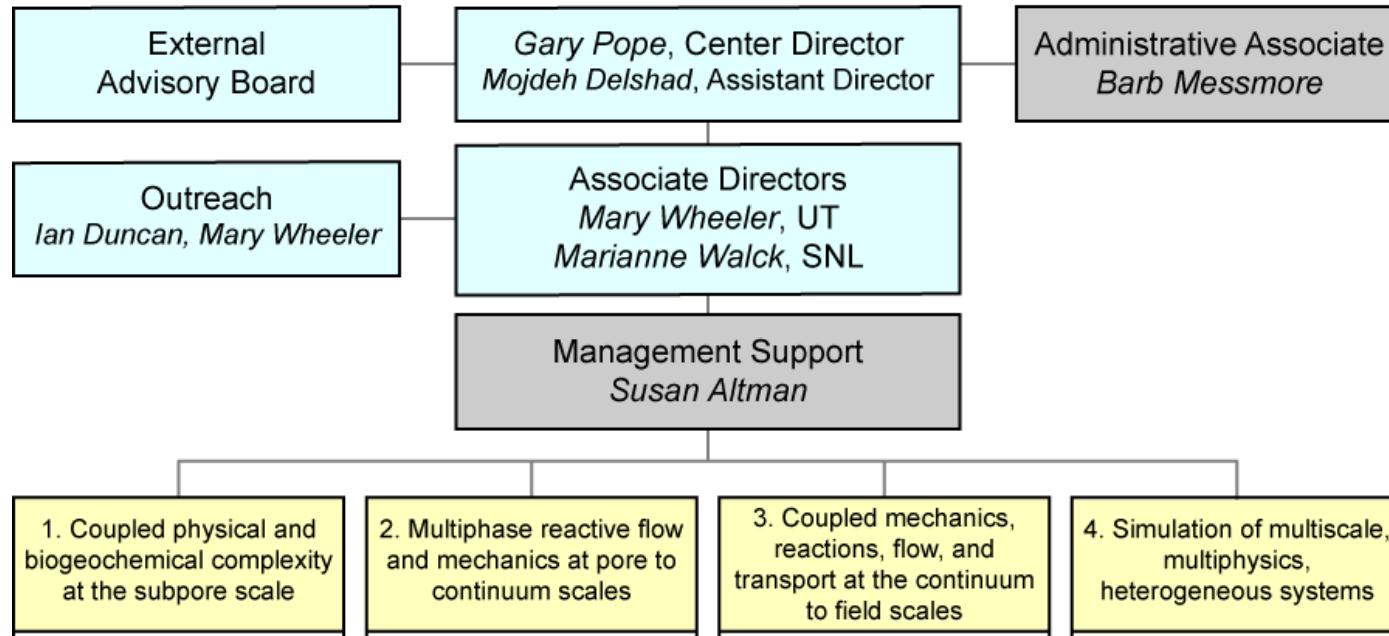
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2012-7171P

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

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



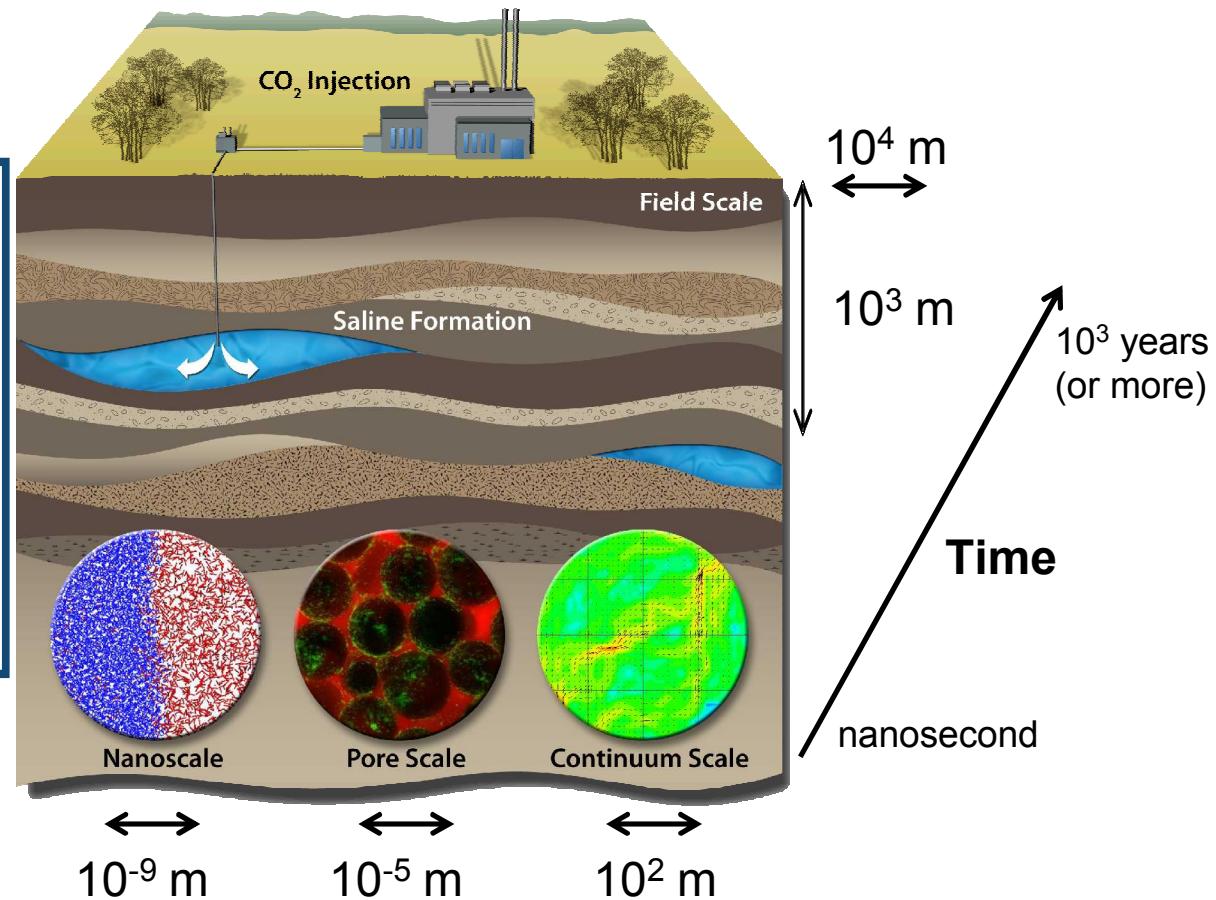
Management Structure



A Multi-scale, Multi-physics Approach is Needed to Study Underground CO₂ Storage

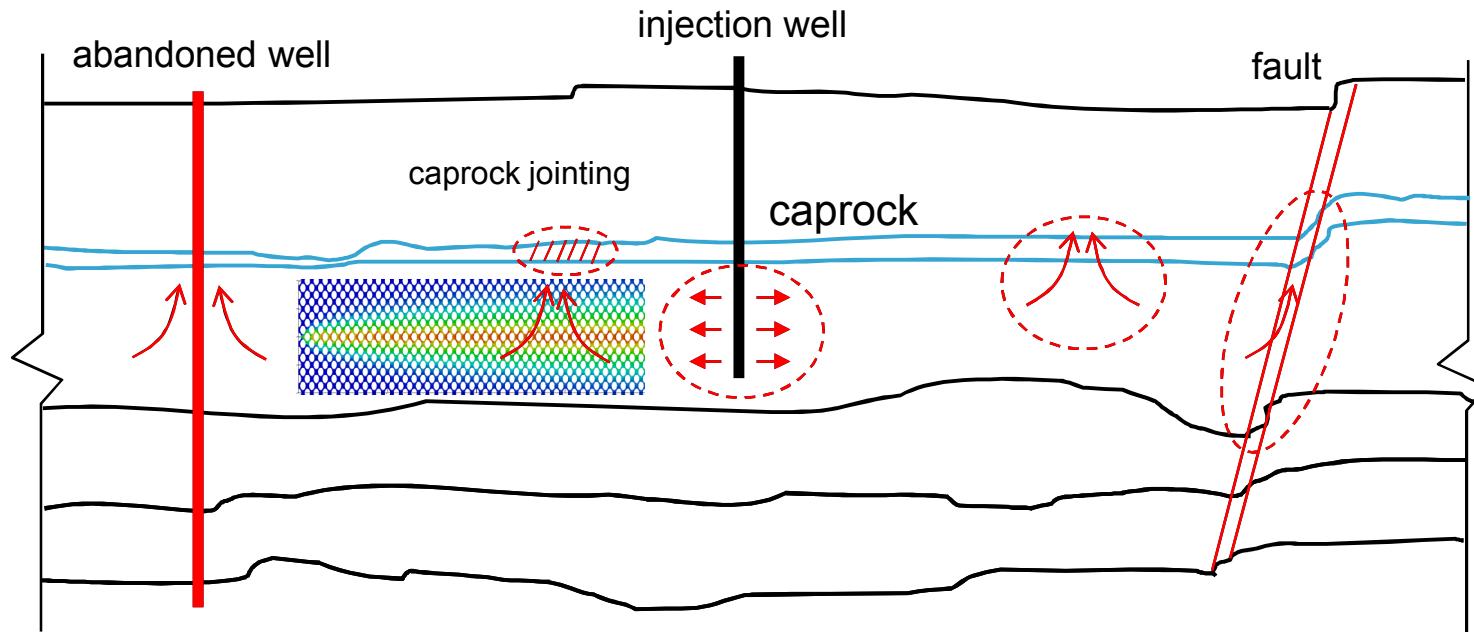
Goal

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



Ensure Safe Storage of CO₂

- Leakage
 - Wellbores
 - Faults
- Injection induced damage
- Brine migration to overlying aquifers
- Induced seismicity

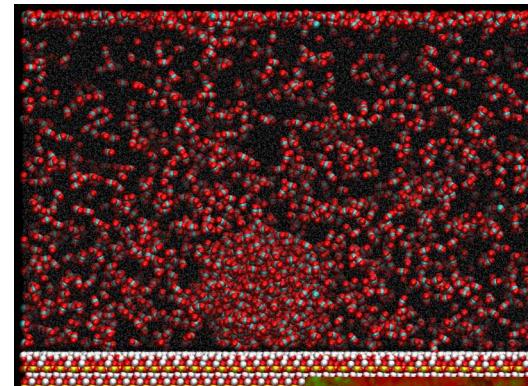


CFSES Benefiting from Sandia's Geoscience Capabilities

■ Molecular dynamics simulation

Cygan, R.T., Romanov, V.N., and Myshakin, E.M. (2012) Molecular simulation of carbon dioxide capture by montmorillonite using an accurate and flexible force field. *Journal of Physical Chemistry C*, 116(24), 13079-13091.

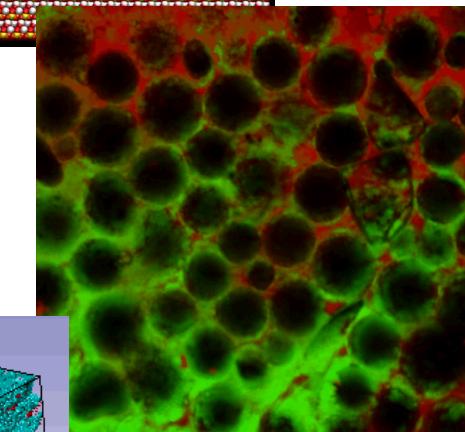
Criscenti, L. J., and R. T. Cygan (2013), Molecular Simulations of Carbon Dioxide and Water: Cation Solvation, *Environmental Science & Technology*, 47, 87-94.



■ Subsurface microbial geochemistry

Kirk, M. F. (2011), Variation in Energy Available to Populations of Subsurface Anaerobes in Response to Geological Carbon Storage, *Environmental Science & Technology*, 45(15), 6676-6682.

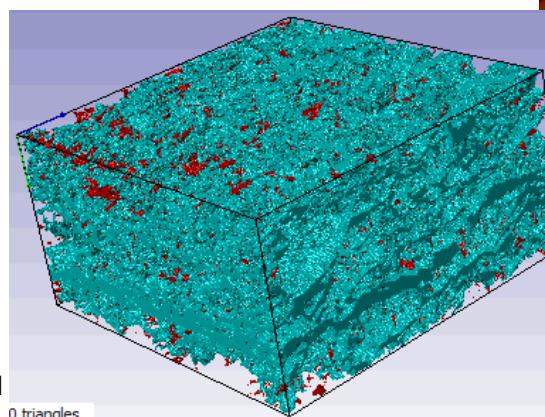
Kirk, M. F., E. F. Santillan, L. K. McGrath, and S. J. Altman (2012), Variation in Hydraulic Conductivity with Decreasing pH in a Biologically-Clogged Porous Medium, *International Journal of Greenhouse Gas Control*, 11, 133-140.



■ Nanometer scale research

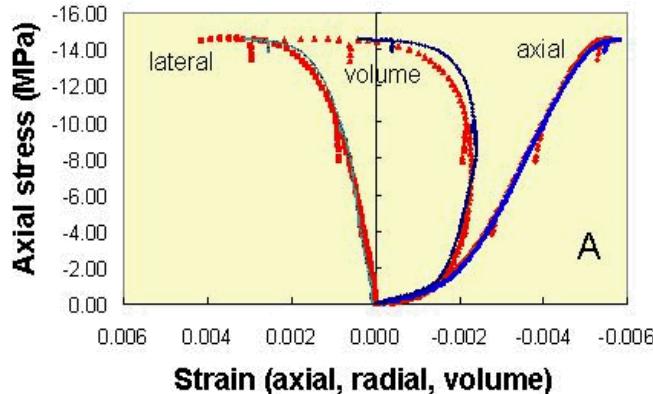
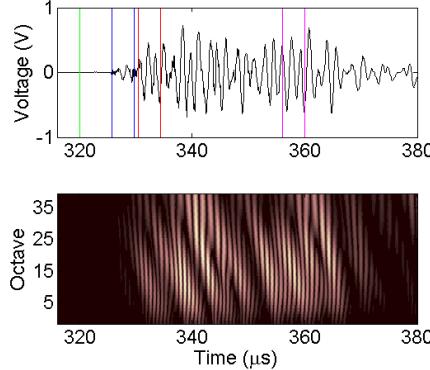
Dewers, T. A., J. Heath, R. Ewy, and L. Duranti (2012), Three-dimensional pore networks and transport properties of a shale gas formation determined from focused ion beam serial imaging, *International Journal of Oil Gas and Coal Technology*, 5(2-3), 229-248.

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CFSES Benefiting from Sandia's Geoscience Capabilities

■ Geomechanical Testing and Modeling



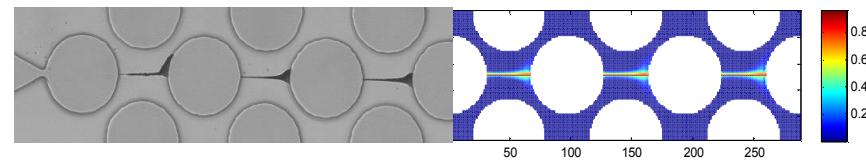
Dewers, T., P. Newell, S. Broome, J. Heath, and S. Bauer (In Review), Geomechanical Behavior of Cambrian Mount Simon 2 Sandstone Lithofacies, Iowa Shelf, USA, *Journal of Geophysical Research Solid Earth*.

Zhang, Y., et al. (In Review), Induced seismicity in crystalline basement rocks by fluid injection into basal aquifers, *Ground Water*.

■ Reactive Transport Modeling

Davison, S. M., H. Yoon, and M. J. Martinez (2012), Pore scale analysis of the impact of mixing-induced reaction on viscosity variations, *Advances in Water Resources*, 38, 70-80.

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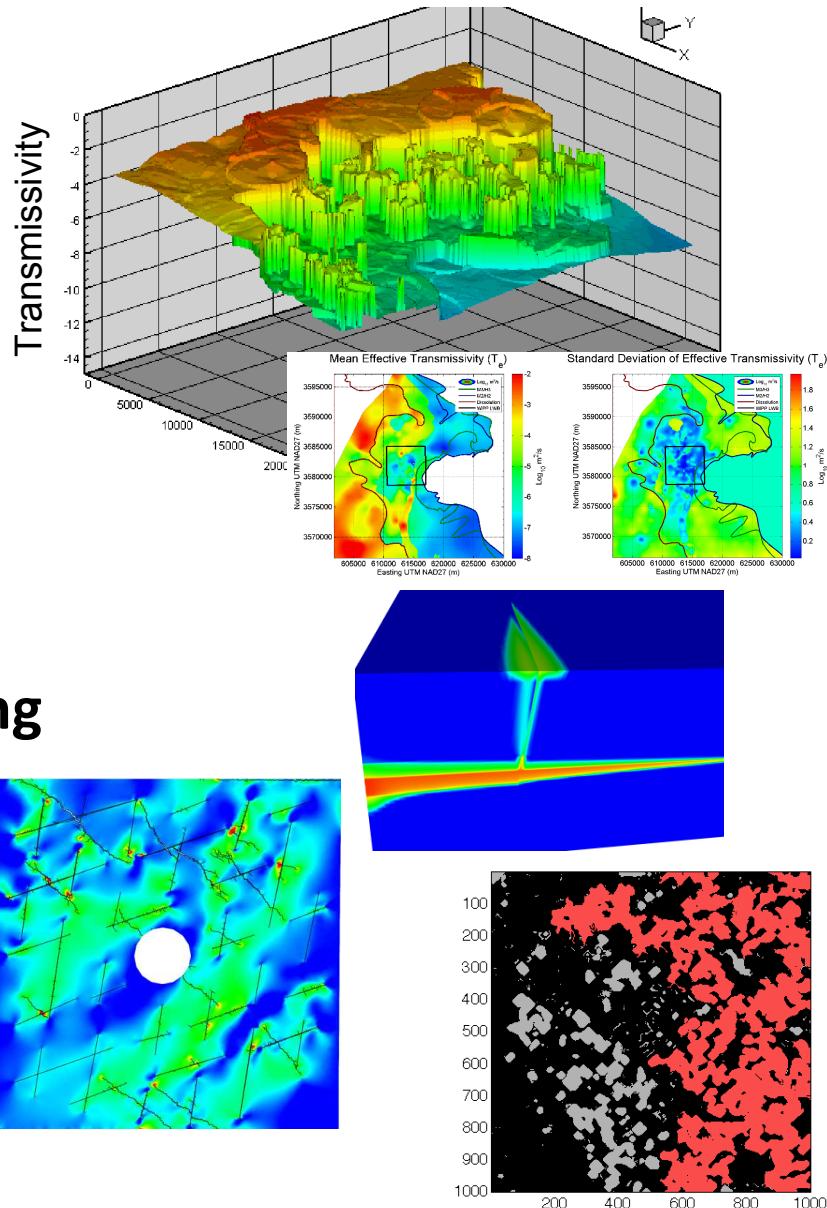
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■ Probabilistic Inverse Modeling

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■ Coupled Hydro-Mechanical Modeling

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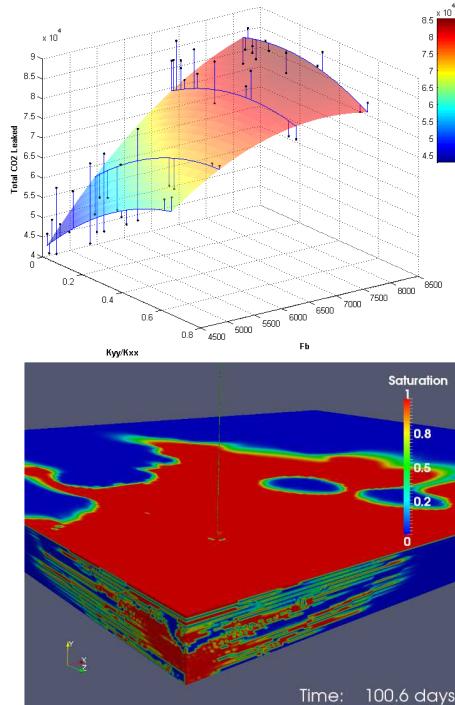
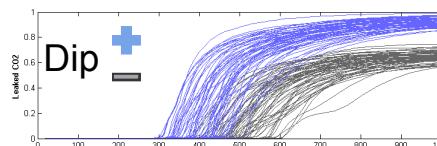
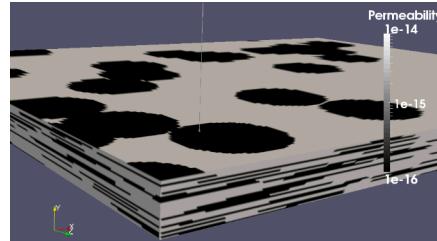
Martinez, M. J., P. Newell, J. Bishop, and D. Turner (In Review), Coupled multiphase flow and geomechanics model for analysis of joint reactivation during CO₂ sequestration operations, *International Journal of Greenhouse Gas Control*.

Related Work in Carbon Sequestration



■ CO₂ Injection in Heterogeneous Media

Martinez, et al., 2011, Computational Thermal, Chemical, Fluid and Solid Mechanics for Geosystems, Sandia National Laboratories report, SAND2011-6643, 222 pp.



■ National Scale Sequestration Economics

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