DOE Award #: DE-FE0000730

Project title: CO_2 Saline Storage Demonstration in Colorado Sedimentary Basins: Applied Studies in Reservoir Assessment and Dynamic Processes Affecting Industrial Operations

Performance Period:

October 1, 2009 - Sept 30, 2011; 24 months

No-cost extension from Oct. 1, 2011 – Sept. 30, 2012

Total project cost to NETL: $1,295,220

State of Colorado cost share: $ 342,744

Performing institutions

Colorado School of Mines, CU Boulder, IUPU Indianapolis, (USGS, Lakewood, CO)
Project Manager: Dag Nummedal

DOE Technical Contacts: Karen Cohen, Dawn Deel
DOE Contract Specialist: Raelynn Noga

Project tasks

Task 1. Project Management and Planning (Dag Nummedal)

Task 2. Geomechanics of CO_2 Storage Reservoirs Applied to Saline Storage (Marte Gutierrez)

Task 3. Mineral Dissolution and Porosity/Permeability Changes in Response to CO_2 Injection (Alexis Sitchler)

Task 4. Geomicrobiological Influence on Carbon Storage and Conversion Applied to Saline Reservoir Storage (Kevin Mandernak)

Task 5. Reservoir Characterization of the Subsurface Dakota Group in the Denver Basin and Other Colorado Basins (Dag Nummedal)

Task 6. Assessment of Scale on Pore-volume and Permeability Estimates for Geologic Storage of CO_2 in Saline Aquifers (Matt Pranter)

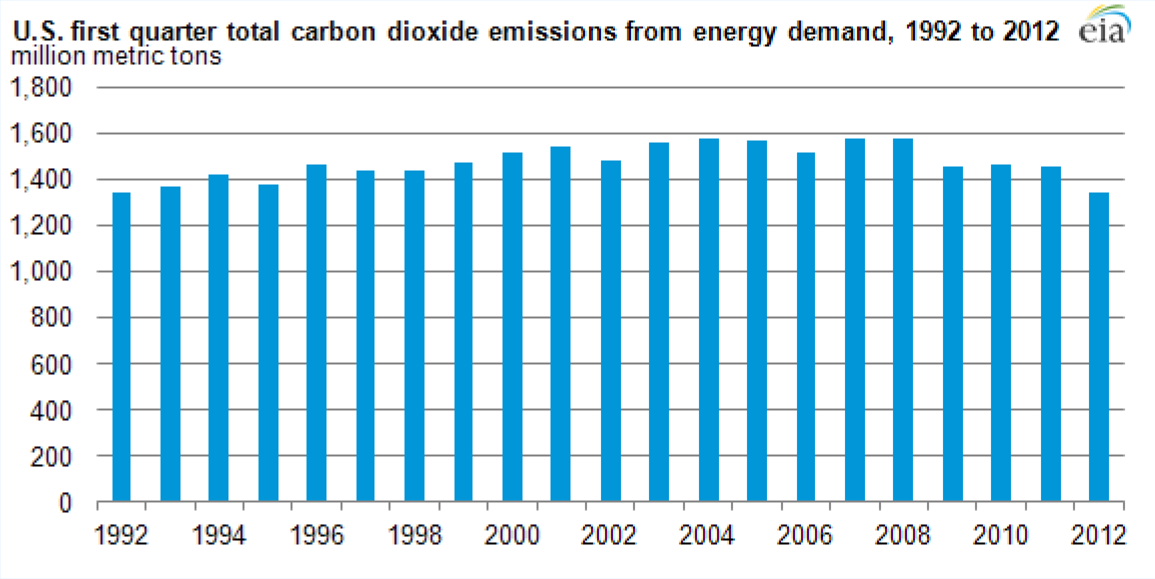
Task 7. Regulatory Regimes and Enforcement Structures (Kevin Doran)

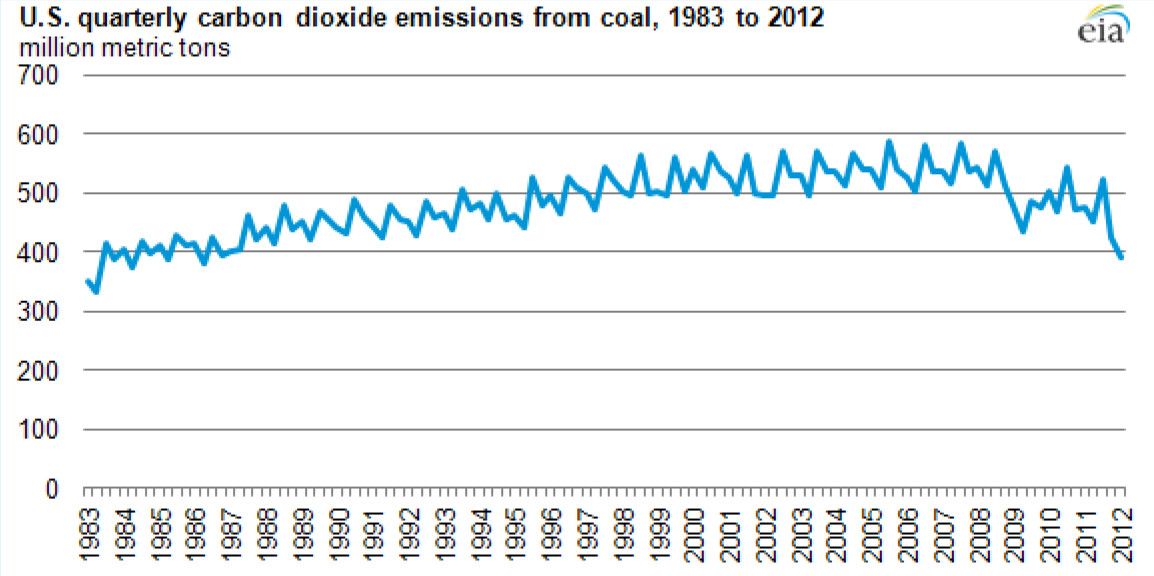
Task 1. Project Management and Planning

Ensuring focus on issue at hand: R&D to help reduce CO_2 emissions.

CCS started to reduce emissions from coal plants
Changed to CCUS – with industrial use of CO_2 in enhanced oil recovery
Now changing further to CO_2 capture from natural gas and use in EOR
Major opportunity for tech transfer back to the EOR industry
This project is the foundation for the Colorado CMC (Carbon Management Center)
Strong ties with the unconventional natural gas industry – because:

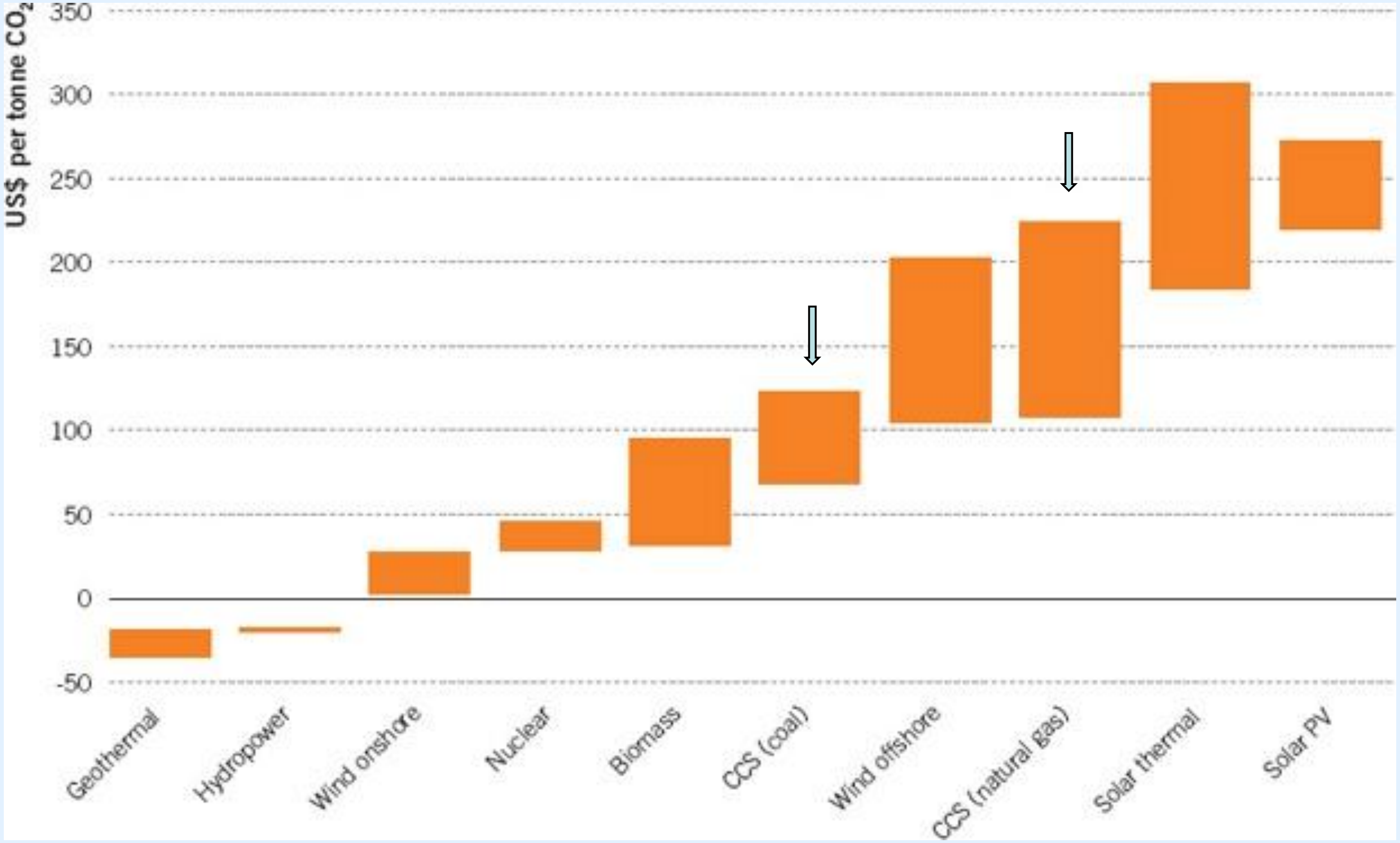
US Emissions Cuts Due to Shift from Coal to Natural Gas





EIA - Today in Energy, Aug. 1, 2012

Relative Costs of CO_2 Emissions Avoidance



Global CCS Institute, 2012

CO2 TECHNOLOGY CENTRE MONGSTAD

TCM located next to Statoil's refinery

Mongstad, Norway, $1 bbn

Gas CO_2 capture research/test facility

Open for:

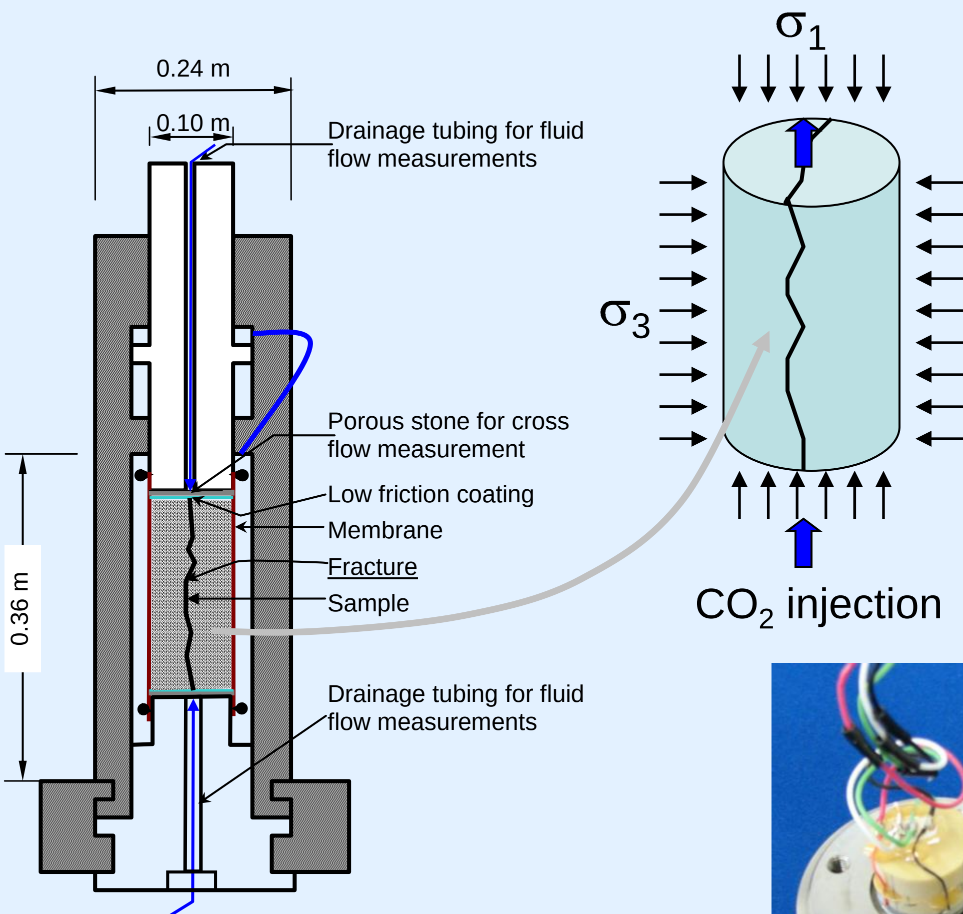
- Visitors
- R&D Collaboration
- Media and NGO collaboration
- Proprietary corporate testing

Task 2

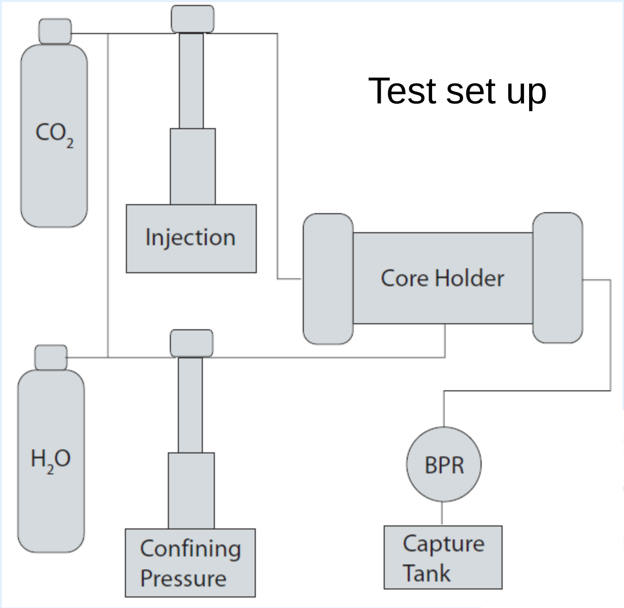
Geomechanics of CO_2 Storage Reservoirs: Focus on Rock Fracture Response to CO_2 Injection

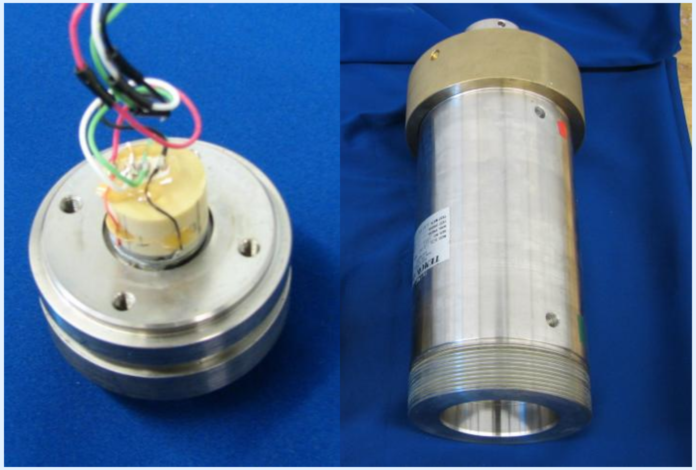
Marte Gutierrez

Laboratory Studies of Non-isothermal and Multiphase Fluid Flow and Transport in Fractured Porous Rocks



Triaxial cell for testing of the hydro-mechanical behavior of fractured rock specimens during CO_2 injection

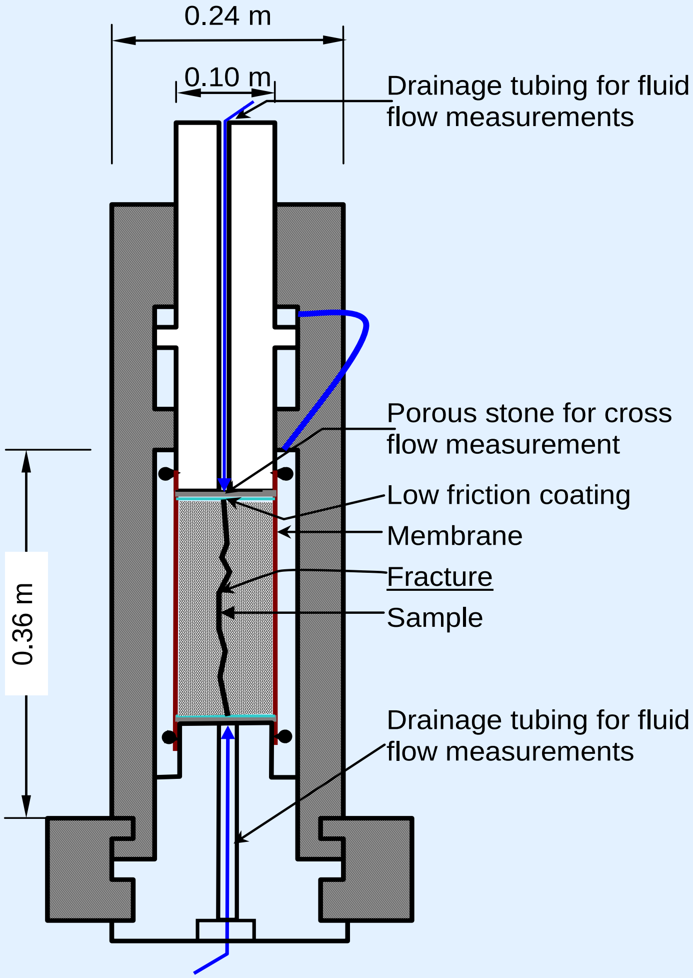




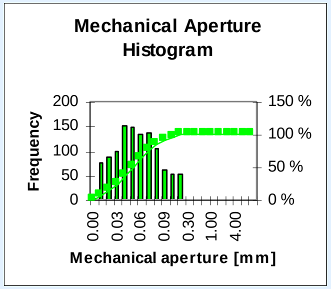
Temco triaxial cell with P&S wave measurement

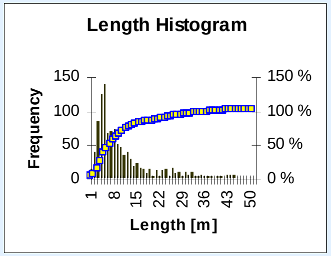
Teledyne Isco pump for CO_2 injection

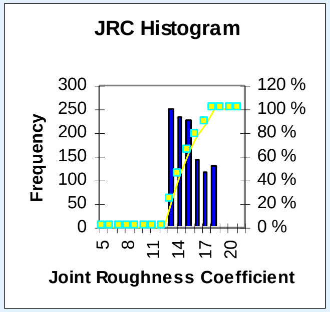
Characterization of Injectivity and Storativity of CO_2 in Fractured Porous Rocks

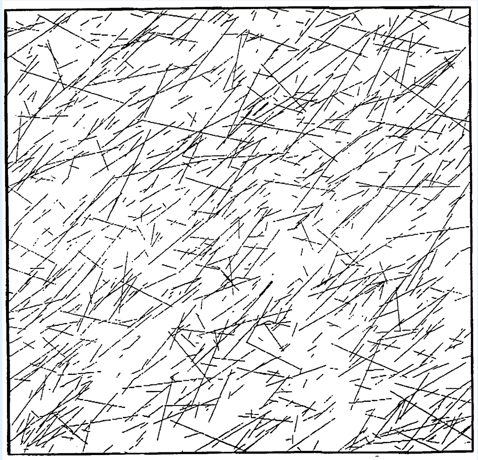


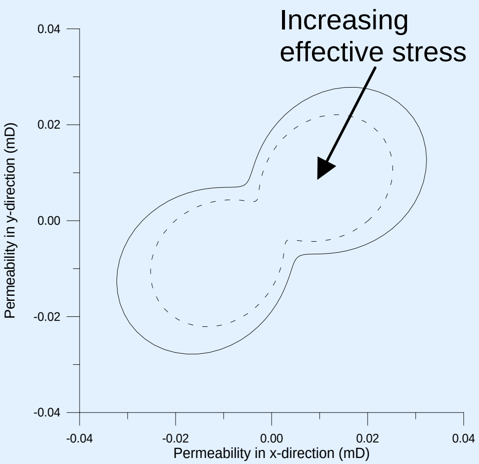
Experimental details of CO_2 injection in fractured porous rock





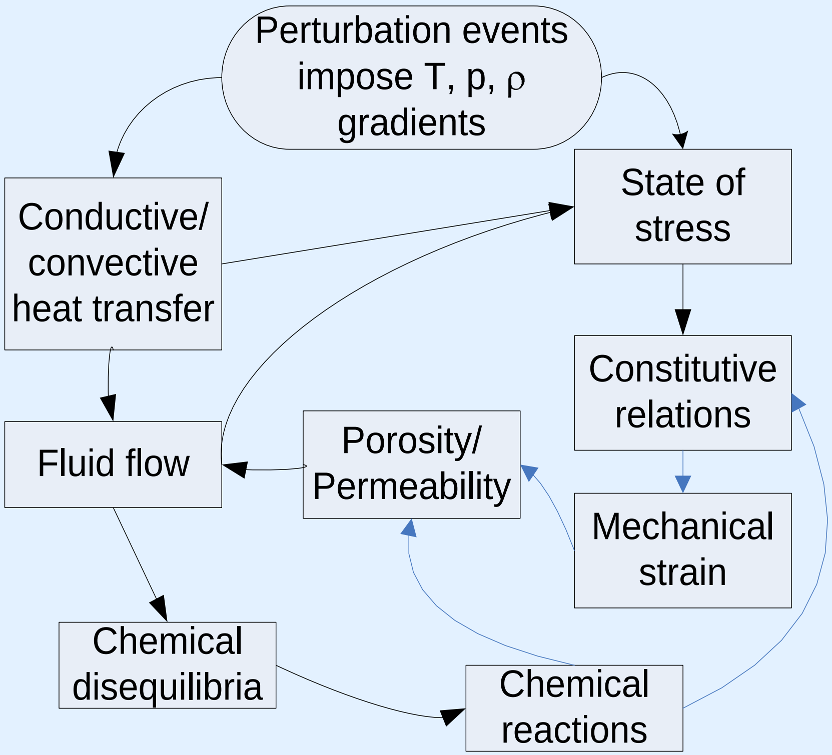




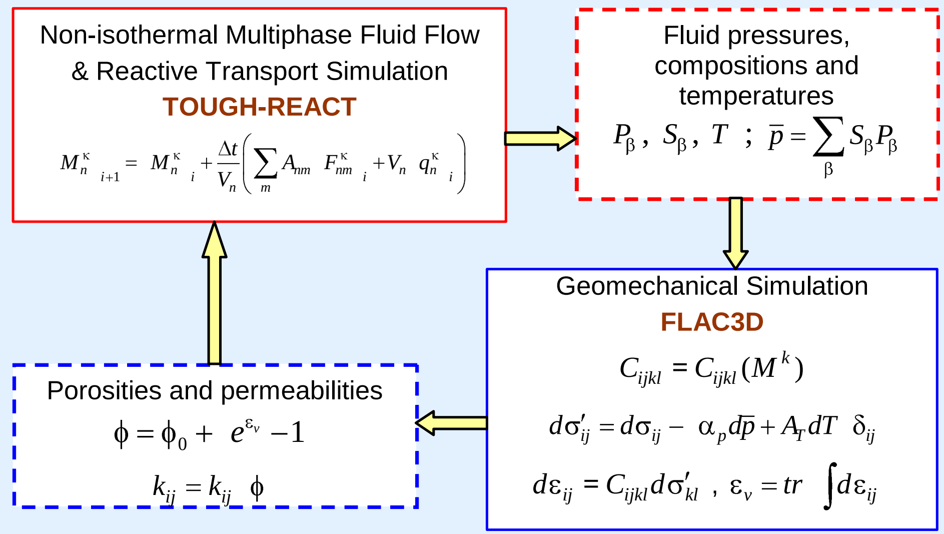


Use of Oda's crack tensor to model the anisotropic permeability of fractured formations for CO_2 storage

Coupled Hydro-Thermo-Chemo-Mechanical (HTCM) Modeling of CO_2 Geological Storage



Coupled processes involved in CO_2 geological sequestration



Use of TOUGH-REACT and FLAC3D for coupled HTCM modeling of CO_2 geological sequestration

Key Results of Task 2 Rock Fracture Studies

Developed new laboratory facilities capable of simulating deep reservoir storage conditions (confining stress to 70 Mpa; pore pressure to 35 Mpa)

Data on relative permeabilities of brine and supercritical CO_2 consistent with literature data

Data on P wave velocity response to CO_2 concentrations

Development of fractures by indirect tension; study effects of fracture morphology

Task 3

Mineral Dissolution and Porosity/Permeability Changes in Response to CO_2 Injection

Alexis Sitchler and John McCray
Colorado School of Mines

Sandia National Laboratories

Tom Dewers
Jason Heath

Oak Ridge National Laboratory

Gernot Rother

Pacific Northwest National Laboratory

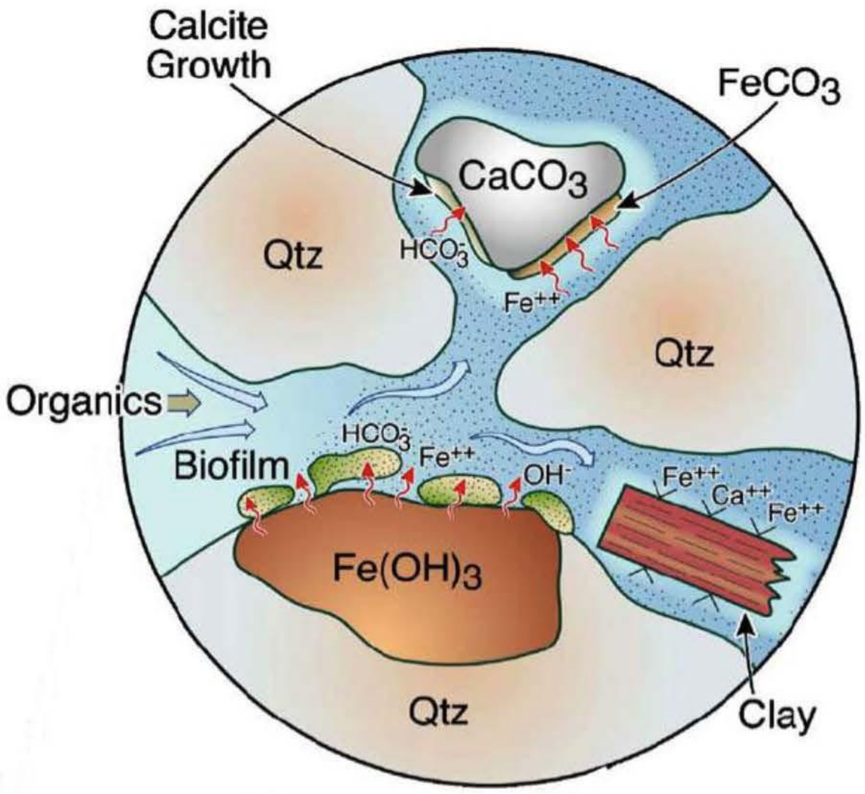
Glenn Hammond

Los Alamos National Laboratory EST. 1943

Peter Lichtner

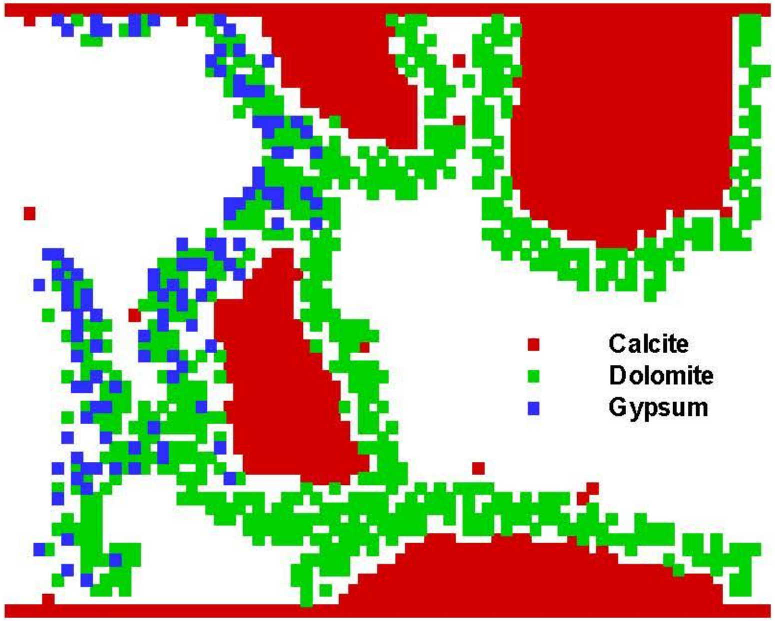
John Kaszuba
Xiuyu Wang

Geochemical reactions occur at the interface between the pore network and mineral grains



Steefel et al., 2005

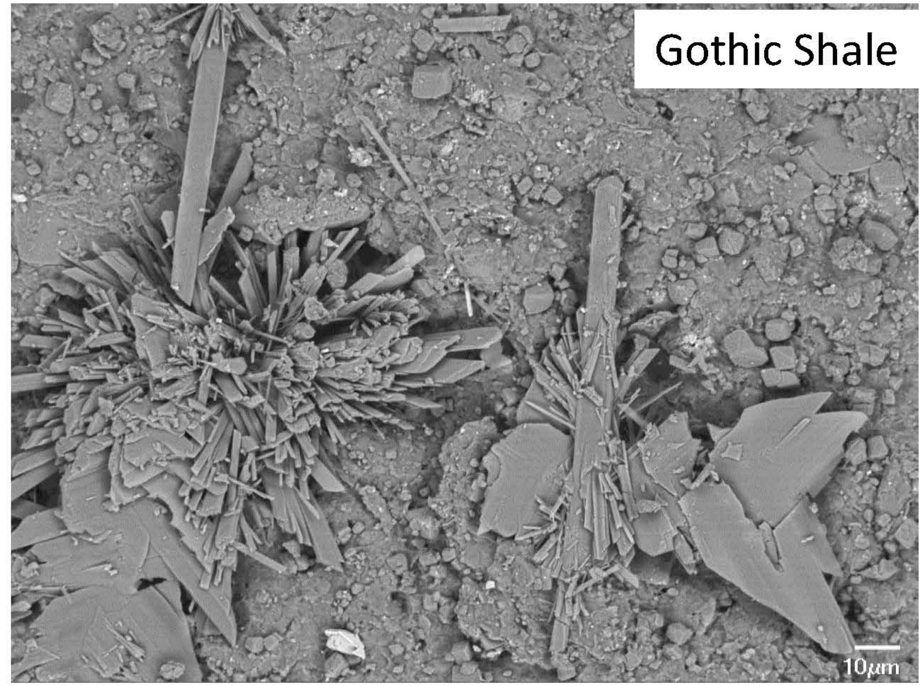
Lattice Boltzmann modeling can capture pore scale

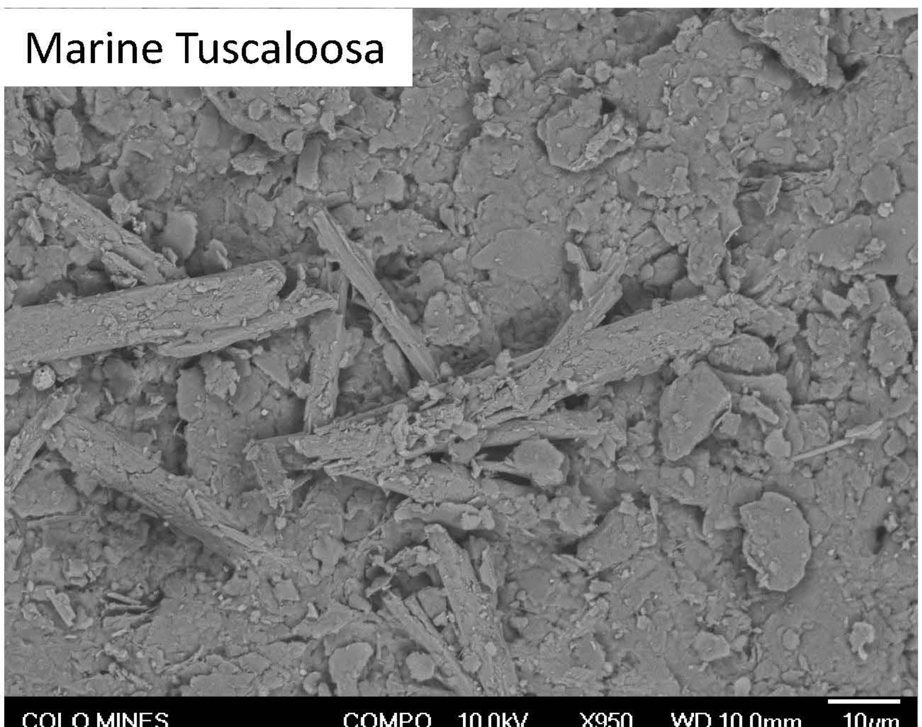


Q. Kang and P. Lichtner - LANL

There is a need to examine these processes at the scale at which they occur – the pore scale

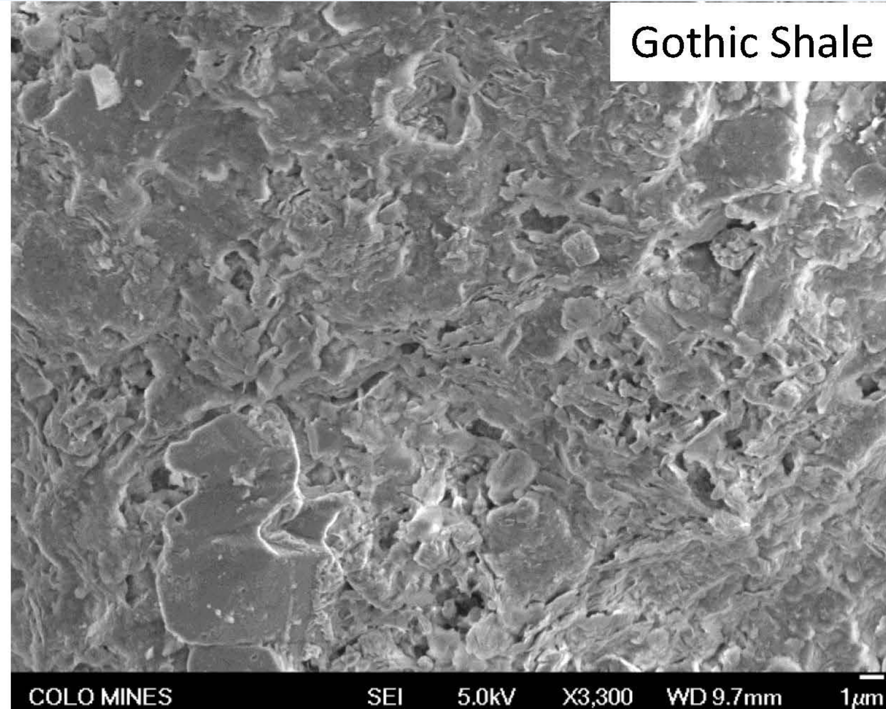
New precipitates were observed in both Marine Tuscaloosa and Gothic Shale after reaction with CO_2

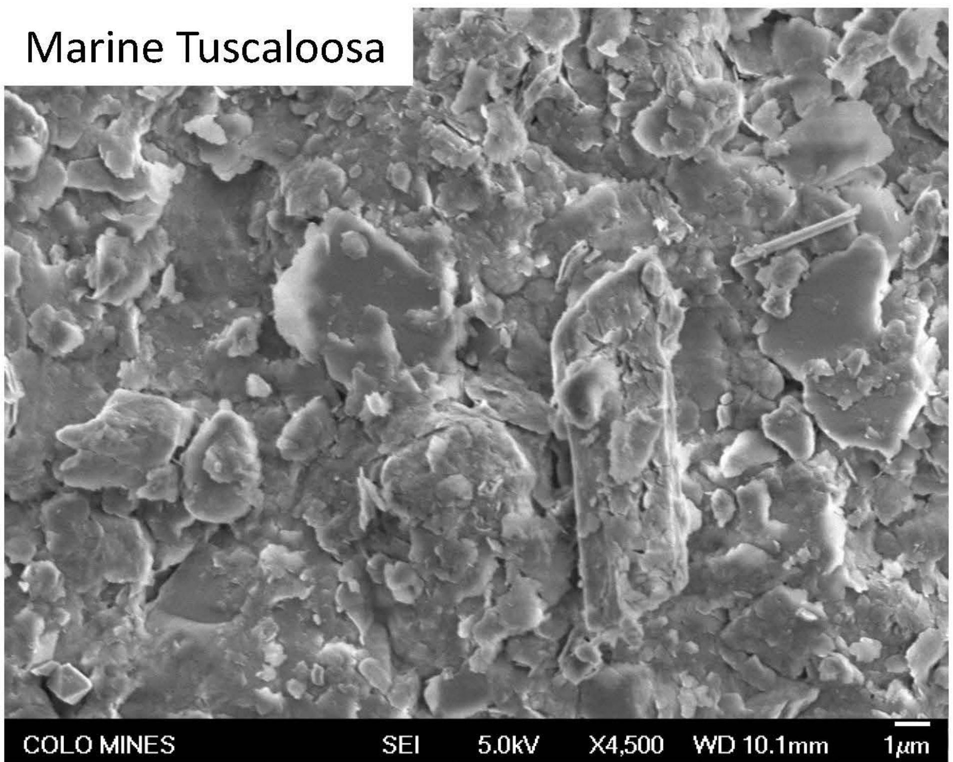


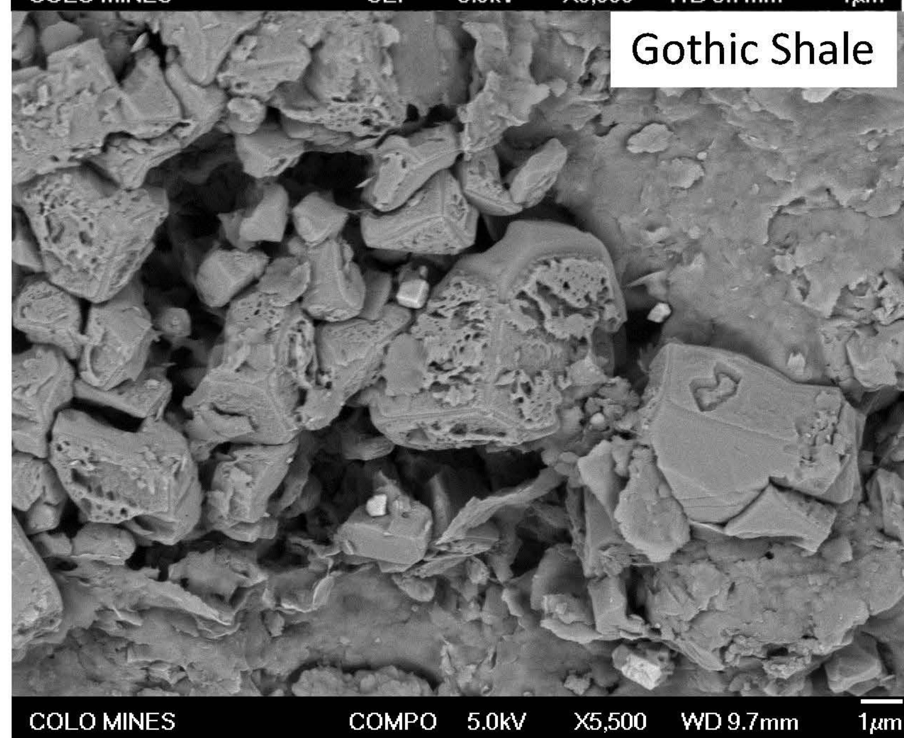


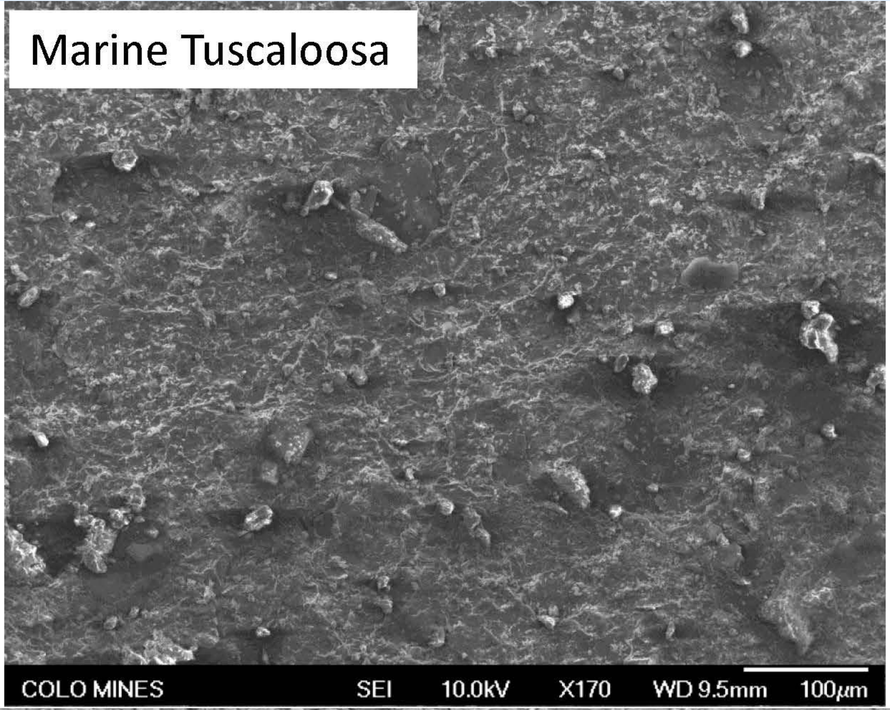
Dissolution features were observed in both Marine Tuscaloosa and Gothic Shale after reaction with CO_2

- Pitting
- Smoother mineral grain surfaces



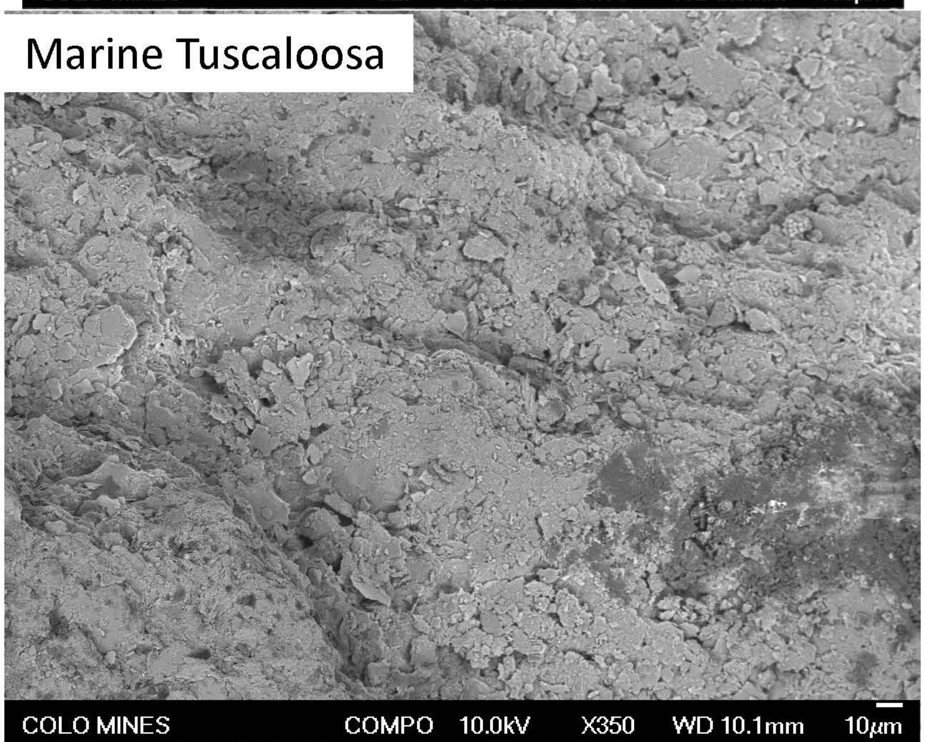


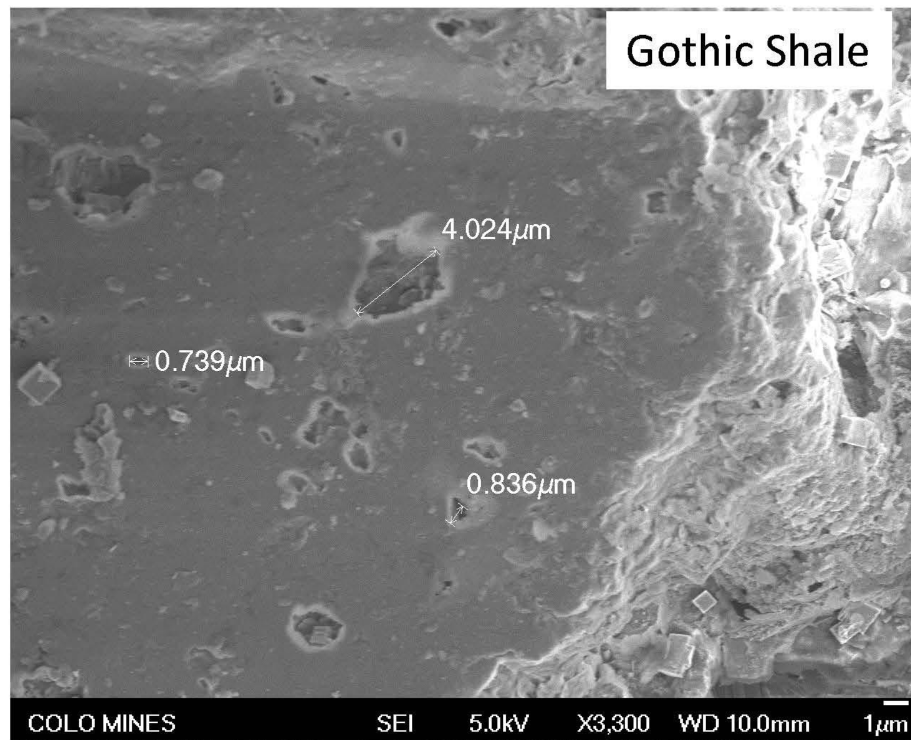




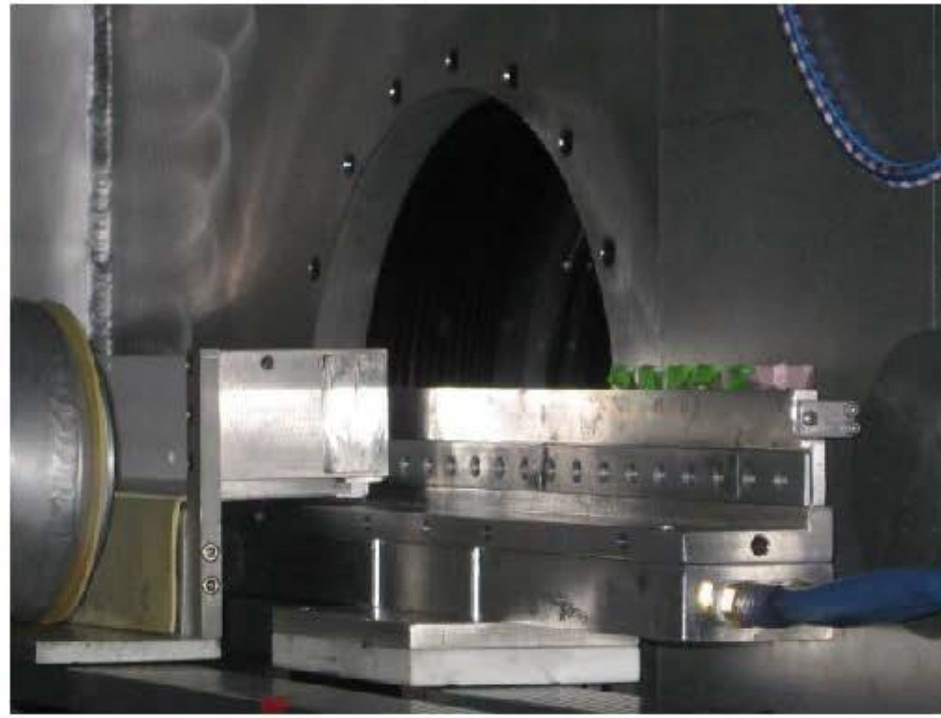
Increased number of pores after reaction

- MT – more pores ~10 microns
- GS – more pores > 10 microns





Small angle neutron scattering was used to quantify changes to the pore network at 10 to 400 nm length scales



$$I(Q) = 4\pi(\Delta\rho)^2 \phi(1-\phi)F(Q)$$

Intensity of scattered neutrons is proportional to porosity

Key Results of Task 3
Mineral Dissolution and Precipitation Studies

New precipitates and dissolution features observed in all shale samples after injection of CO_2

Increased abundance of pores, ~ 10 μm in size, observed in all treated samples

Neutron scattering is an effective tool to quantify the porosity changes at these scales

Task 4

Geomicrobiological Influence on Carbon Storage and Conversion Applied to Saline Reservoir Storage

Andy Glossner, CSM
Kevin Mandernack, IUPU, Indianapolis
Chris Mills, USGS, Lakewood, CO

Key Results of Task 4

See Poster at this meeting: Effects of nutrient amendment and elevated *p*CO_2 on a methanogenic microbial consortium from the Powder River Basin, WY, USA

Ubiquity and metabolic activity of subsurface microbes mean they require attention in the planning and execution of CCUS projects

Increasing *p*CO_2 from 0.2 to 1.3 atm affects rate but not total methanogenesis potential from coal

Urea amendments >2.5 g/L inhibit methanogenesis due to pH effect

Potential to sequester CO_2 without negative effects for methanogenic community in coal seams

Wallula Pilot Site, WA

Wallula Pilot Site, WA
World's first CCS project in basalt
1000 tons injected
Summer, 2011

Plan for microbial sampling is in place, with the Big Sky Partnership

Tasks 5

Reservoir Characterization of the Subsurface Dakota Group in the Denver Basin and Other Colorado Basins

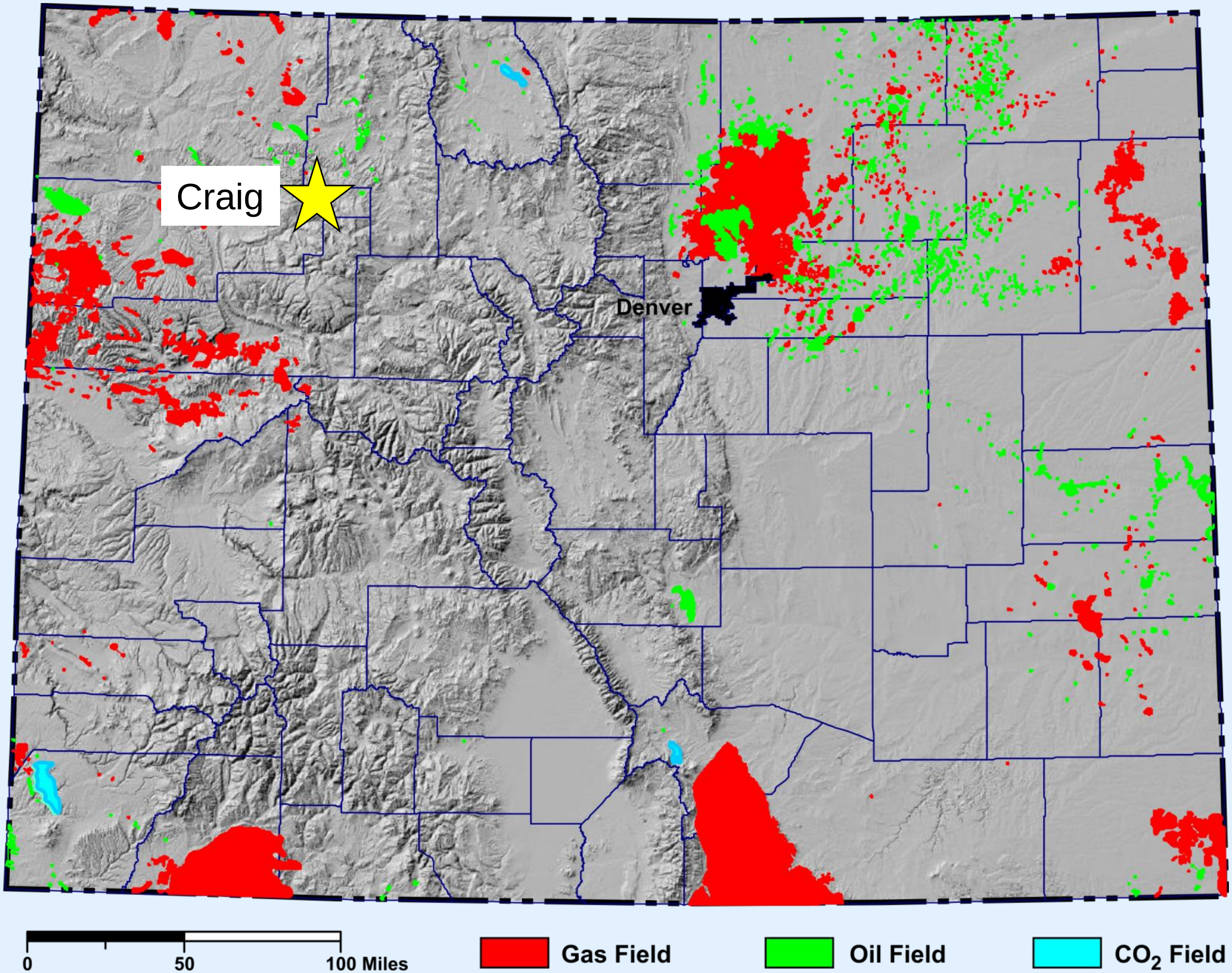
Dag Nummedal, CSM
Jason Deardorff, EPA Denver
Vince Matthews, Colorado Geological Survey
Chris Eisinger, Colorado Geological Survey

Task 6

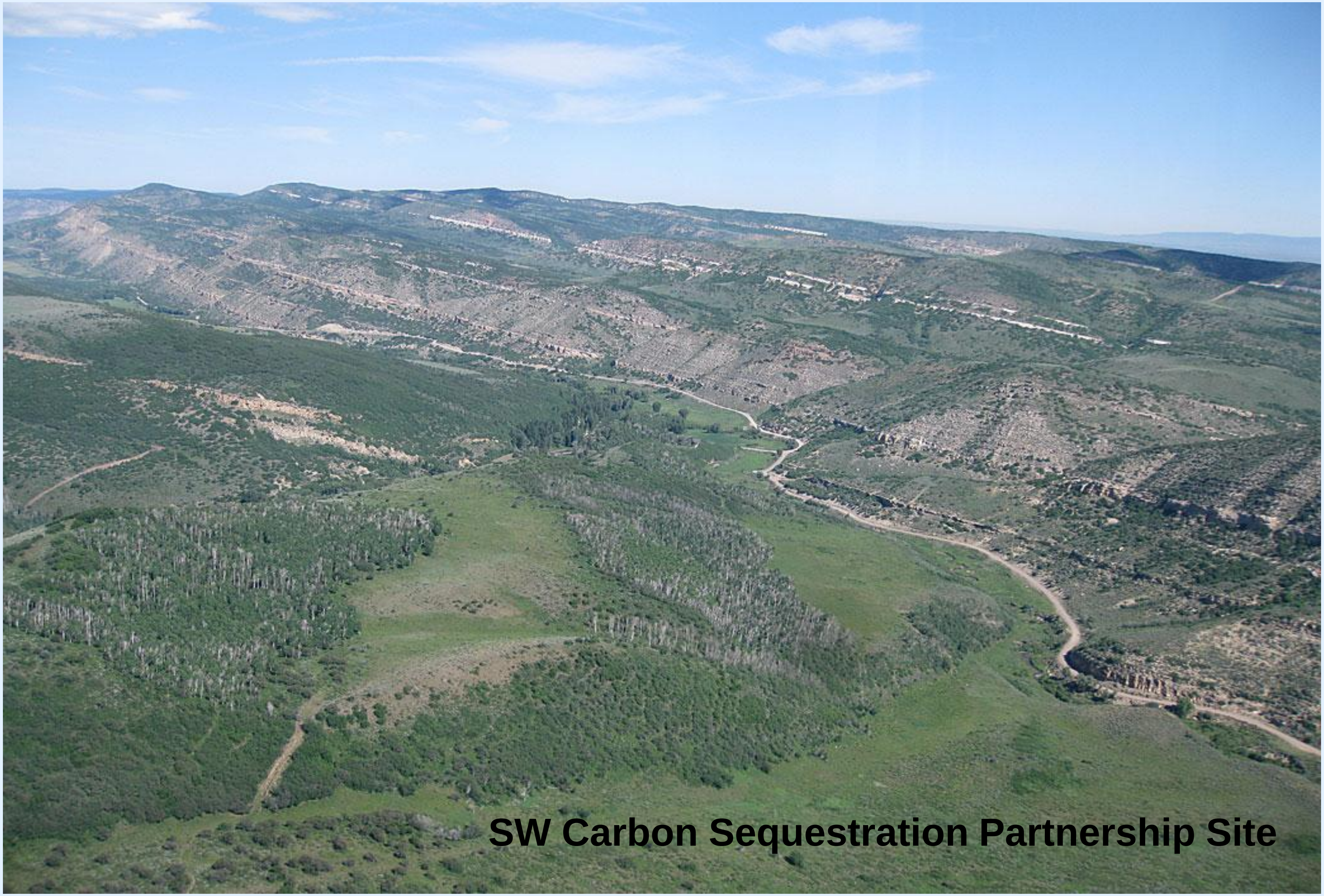
Assessment of Scale on Pore-volume and Permeability Estimates for Geologic Storage of CO_2 in Saline Aquifers

Matt Pranter, CU Boulder
Chris Rybowiak, CU Boulder

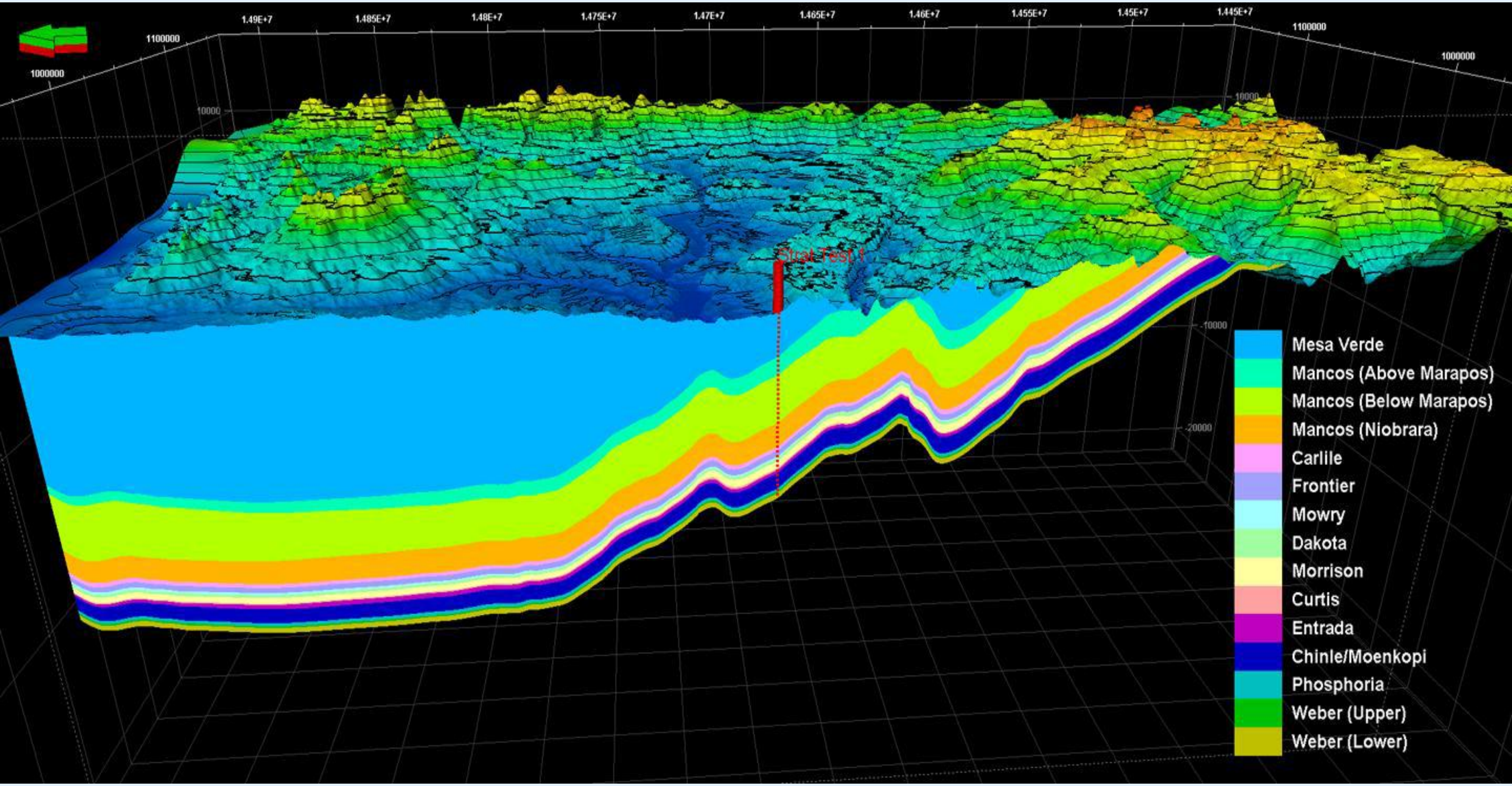
Colorado Oil and Gas Fields



The Craig Project Site: Williams Fork Mountains

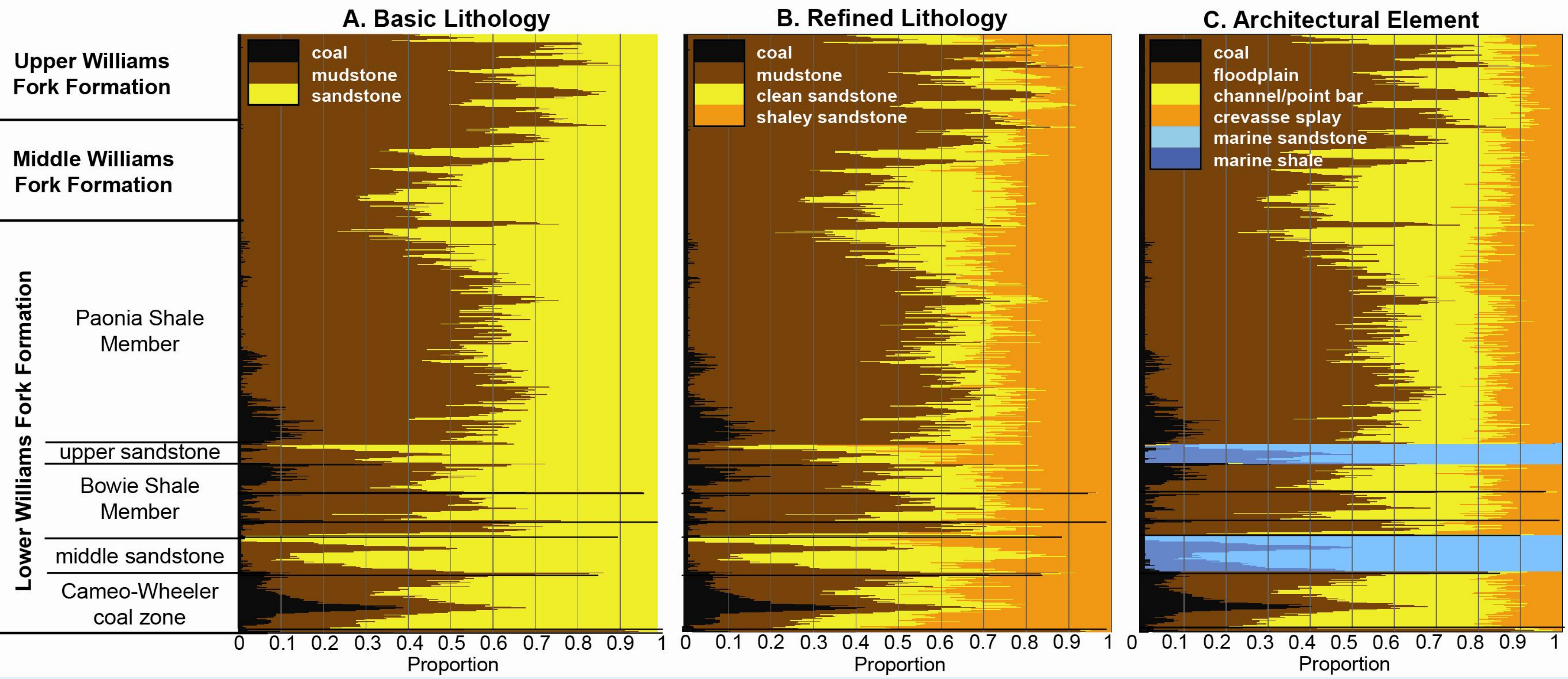


Petrel Model of Williams Fork Site



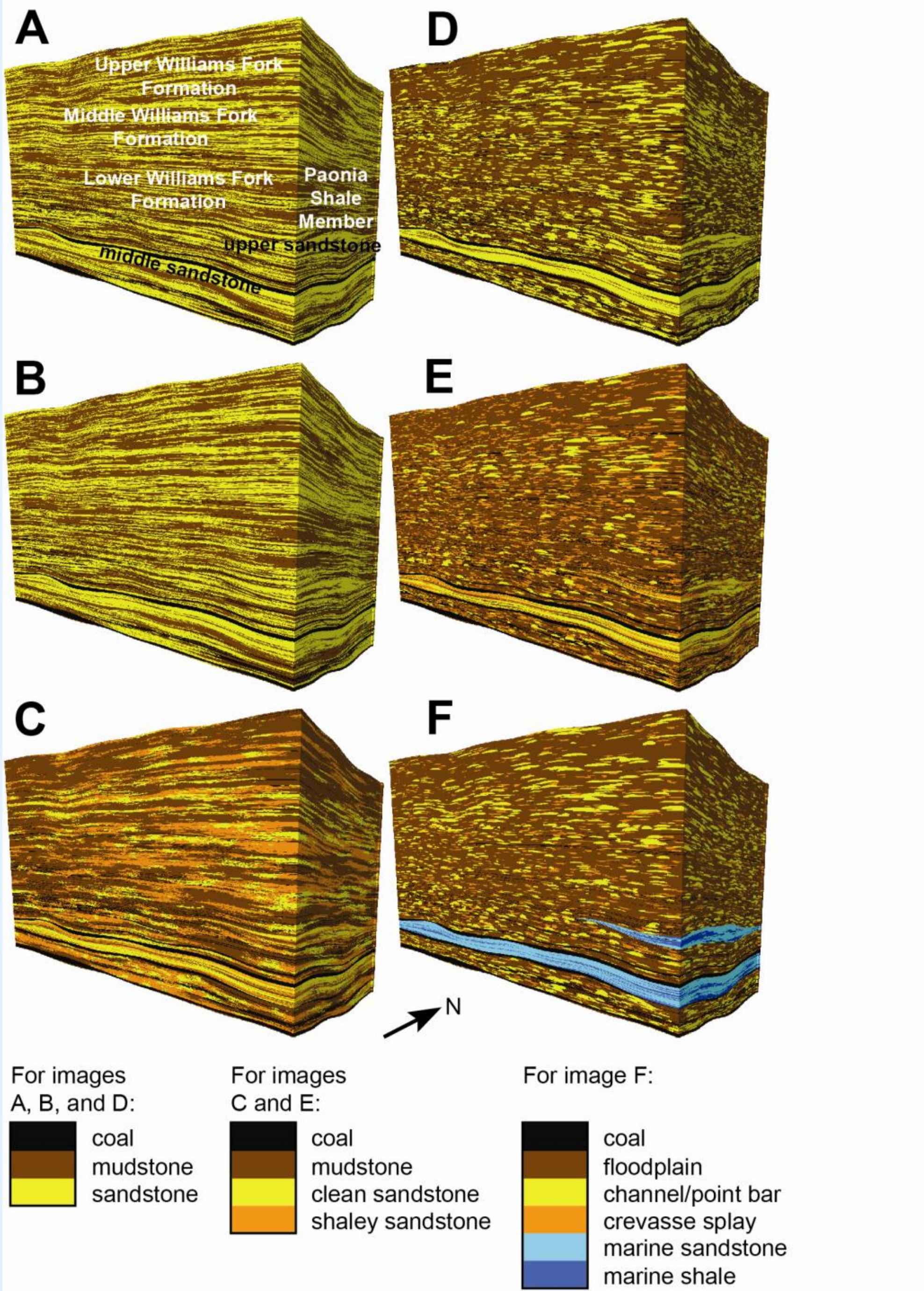
Colorado Geological Survey

Vertical proportion curves for original (input) logs showing the proportion of lithology and architectural elements by layer. A) basic lithology; B) refined lithology; and C) architectural element



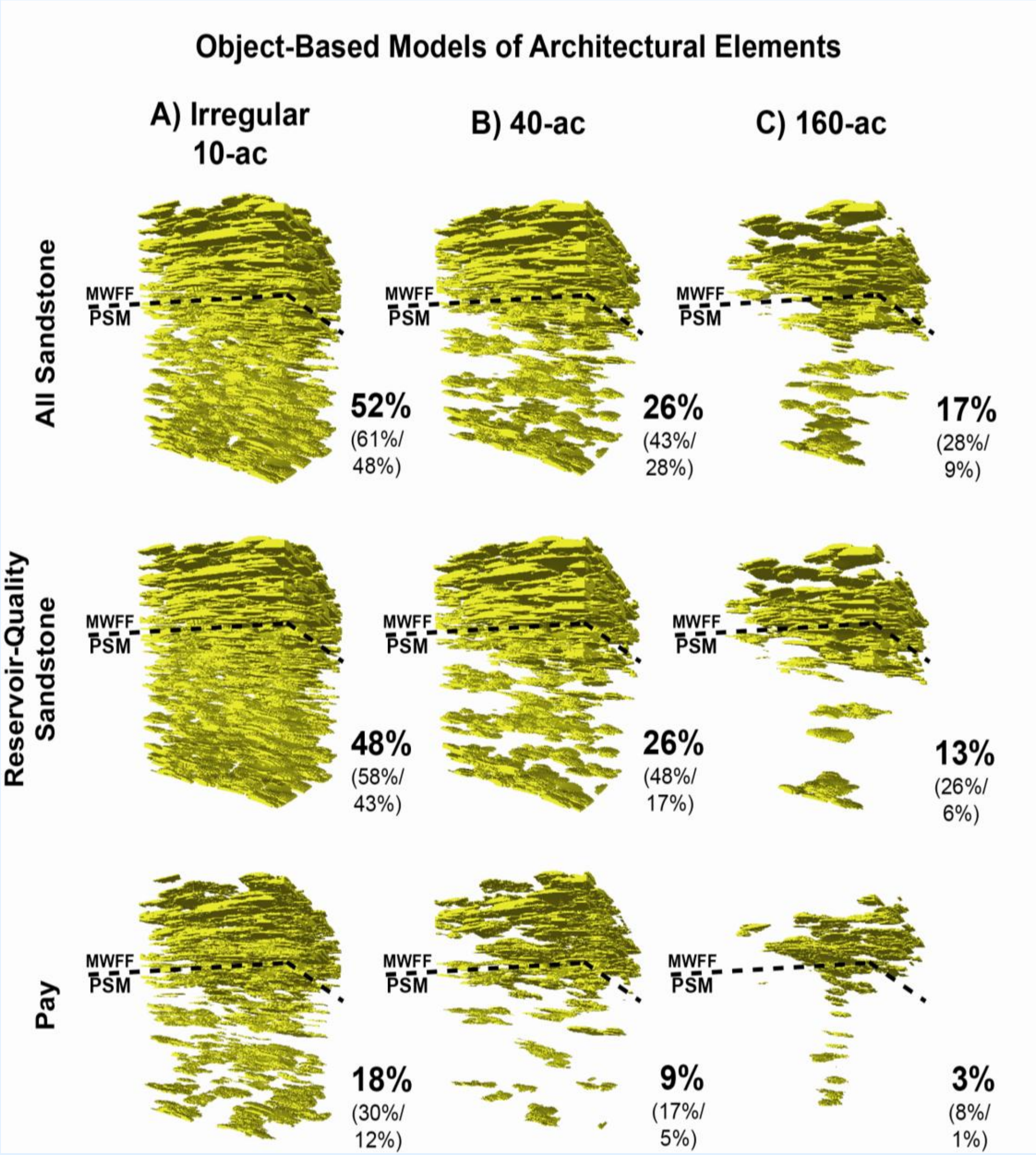
Reservoir Model Examples

A) indicator-based model of basic lithology
B) indicator-based model of basic lithology constrained to 3-D seismic-derived probability volume
C) indicator-based model of refined lithology
D) object-based model of basic lithology
E) object-based model of refined lithology
F) object-based model of architectural elements. Each image is approximately 2 mi^2 and 2,200 ft thick. Vertical exaggeration = 3x.



Connected Sandstone Bodies

1) All sandstone, 2) reservoir-quality sandstone, and 3) pay scenarios for object-based models of architectural elements. Non-reservoir rock has been rendered transparent in the images. Column A) shows sandstone-body connectivity for the current irregular 10-ac (4 hectare) well pattern (16 wells) for each connectivity scenario. Column B) shows sandstone-body connectivity for a hypothetical 40-ac (16 hectare) well pattern (4 wells). Column C) shows sandstone-body connectivity for a hypothetical 160-ac (64 hectare) well pattern (1 well). Connectivity (%) of the total interval is shown in bold and the connectivity of the middle Williams Fork Formation and Paonia Shale Member are shown in parentheses. MWFF = middle Williams Fork Formation and PSM = Paonia Shale Member (lower Williams Fork Formation). Vertical exaggeration = 3x.



Key Results of Task 5 and 6

The NW Colorado (Craig) project remains a viable target for CO_2 storage in the Cretaceous Dakota and deeper reservoir units.

Lithology and architectural element analysis of well log suites allow determination of sandstone body architecture, size and stacking patterns.

The resulting digital reservoir models are powerful tools for evaluation of connectivity between targeted CO_2 storage compartments.

Currently, such models are being developed for several Cretaceous sandstones in Colorado that may become storage targets and/or developed for EOR.

Task 7

Regulatory Regimes and Enforcement Structures

Kevin Doran
University of Colorado Boulder
Fleming Law School

Current state of regulations is that the pore space belongs to the surface land owner in the states of MT, WY and ND.

The SRHA (Stock Raising Homestead Act) of 1916 did transfer land to homesteaders for agricultural use while reserving subsurface resources to the U.S. government.

Through the SRH Act, Congress clearly intended to retain subsurface resources, particularly sources in energy, for development in the public interest.

Several resource suits since, including one by Union Oil of California in 1977, upheld Federal ownership of such resources.

Therefore: there is a fairly strong argument that the federal government owns the pore space beneath some 70 million acres of land in the West..

This could be a big deal for subsurface CO_2 storage!

Conclusions

Massive shift from coal to natural gas-fired power generation is driving a dramatic reduction in US CO_2 emissions

A research focus on CO_2 capture from natural gas and its use in EOR and saline brine storage would further accelerate this rate of emissions decline

Research on:

- geomechanics
- mineral dissolution and precipitation
- geomicrobiological pathways related to carbon storage
- reservoir connectivity modeling
- and legal analysis of pore space ownership issues are the core of the CCUS research program at CSM and CU Boulder

An expanded Carbon Management (research) Center has been established linking CSM, CU, CSU and NREL