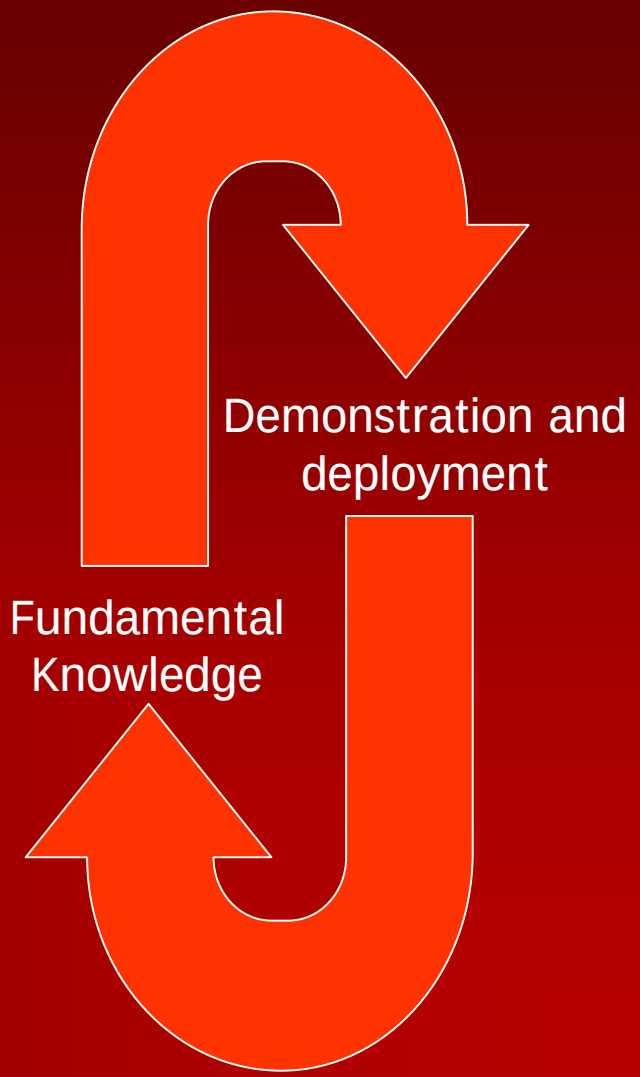
LBNL Research Overview
Carbon Dioxide Storage in Deep Geological Formations

Earth Sciences Division
Lawrence Berkeley National Laboratory

2005/2006

Major Research Program Elements

- ZERT (Zero Emissions Research and Technology): Fundamental research on geological storage
- GeoSeq: Scientific field testing and analysis of geologic storage
- WESTCARB: Pilot testing to demonstrate the potential for CO_2 storage in deep geological formations and enable deployment of CCS technology



ZERT Program at LBNL

- Reactive flow and transport modeling
  - TOUGH2
  - TOUGHREACT
  - TOUGH-FLAC
- Monitoring and verification
  - Seismic detection limits
  - Surface seepage
  - Novel methods
- Multiphase flow studies
  - Relative permeability
  - Capillary trapping

Berkeley Lab

Montana State University

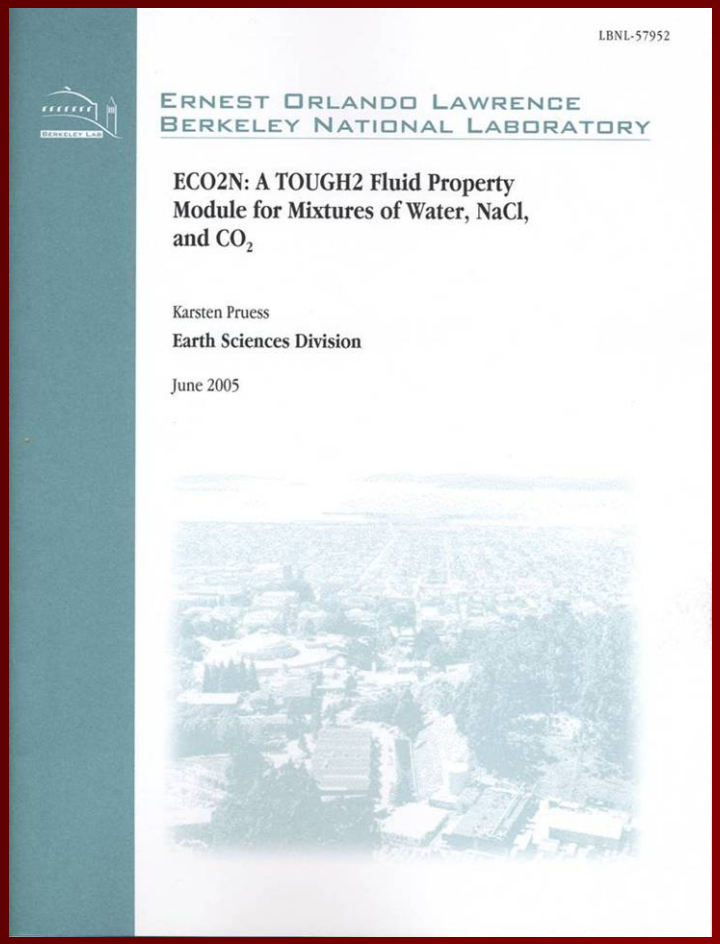
NETL

ZERT Zero Emissions Research and Technology

Pacific Northwest National Laboratory
...delivering breakthrough science and technology

Los Alamos National Laboratory

Accurate Multiphase Flow and Transport of CO_2: ECO2N


LBNL-57952

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

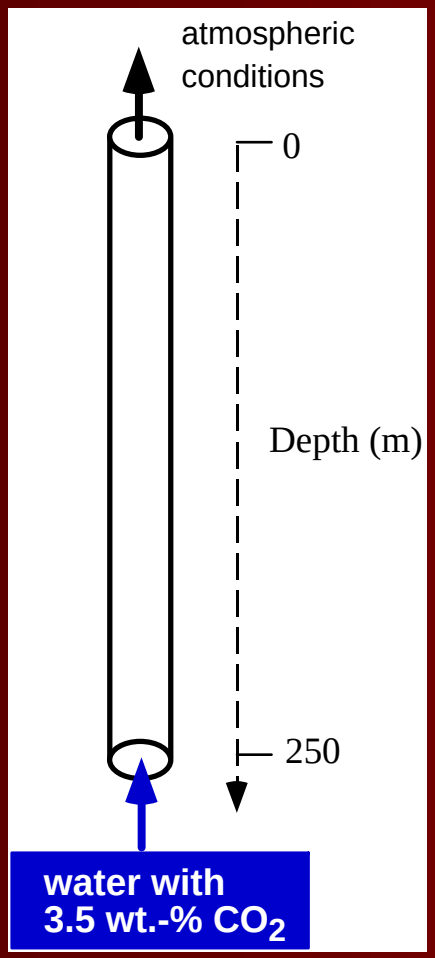
ECO2N: A TOUGH2 Fluid Property Module for Mixtures of Water, NaCl, and CO_2

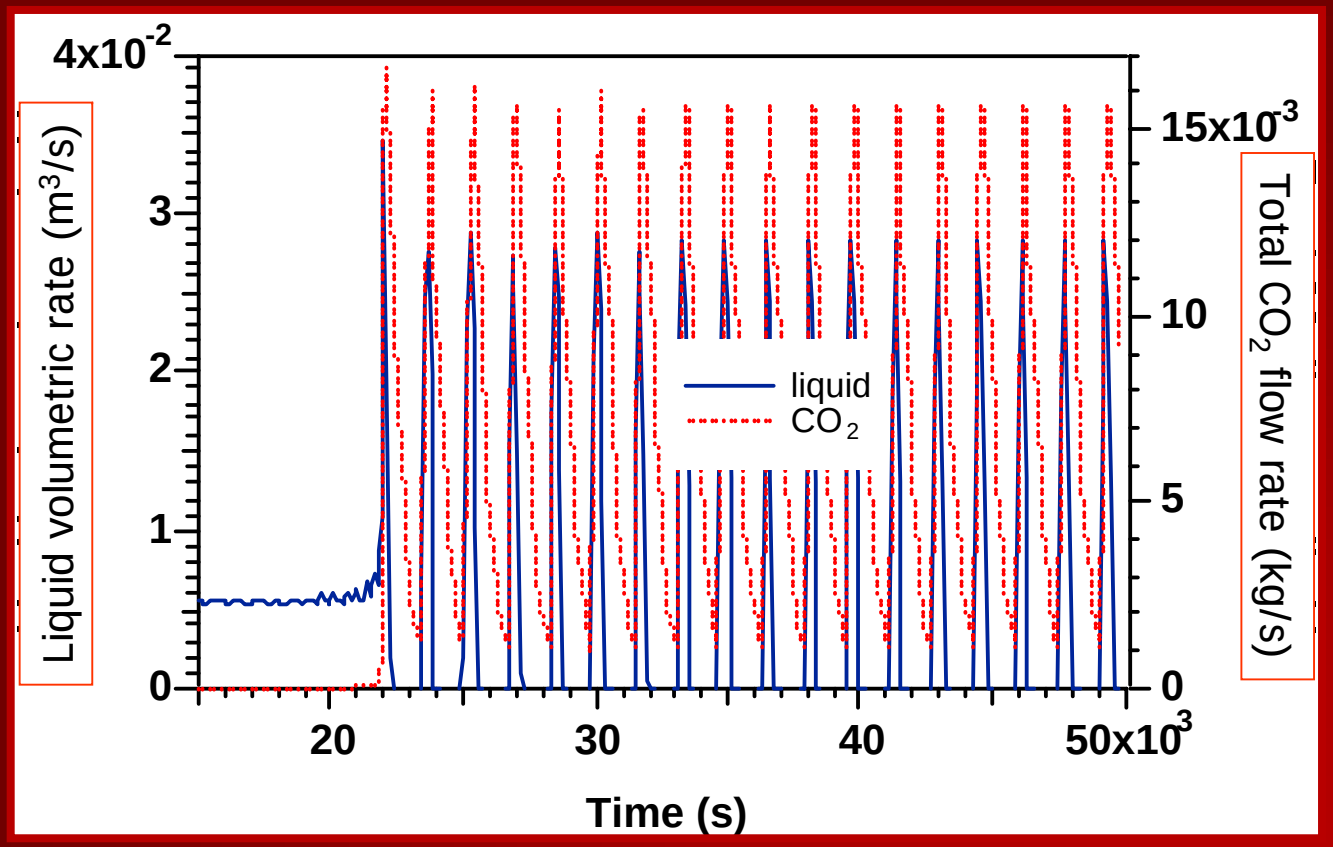
Karsten Pruess
Earth Sciences Division

June 2005

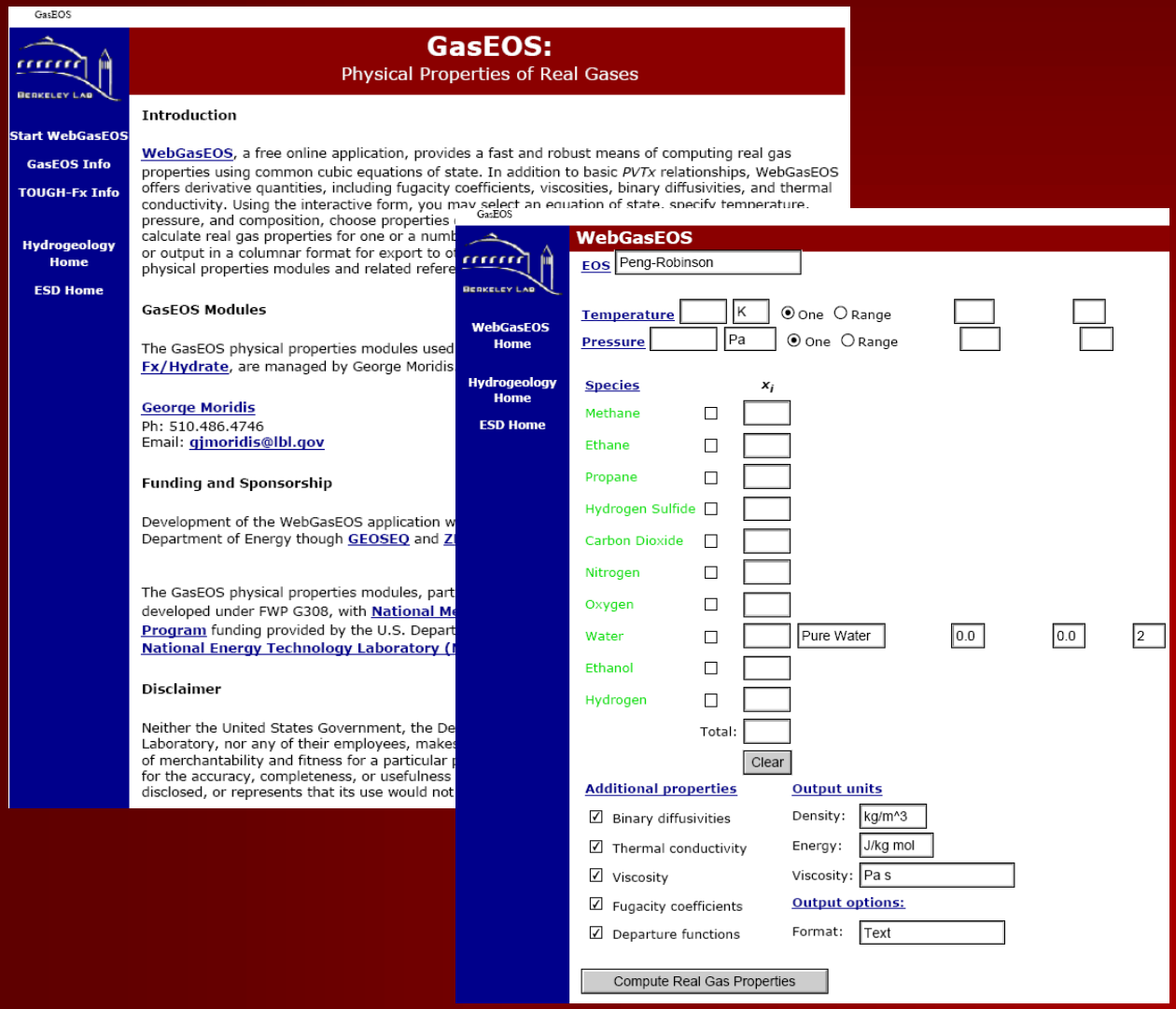
- Accurate fluid property description for water/CO_2/NaCl mixtures
- Two fluid phases and salt
- Applications to studies of reservoir dynamics, storage capacity, physics of immiscible displacement, CO_2 leakage

Application of TOUGH2 to Flow Up a Leaking Well





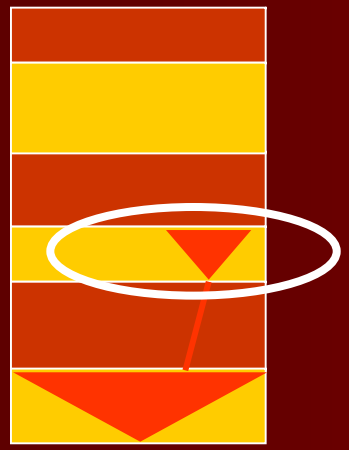
New Web-based Equation of State for CO_2-Gas Mixtures



- CO_2-gas mixtures
- PVT properties
- Web-based access

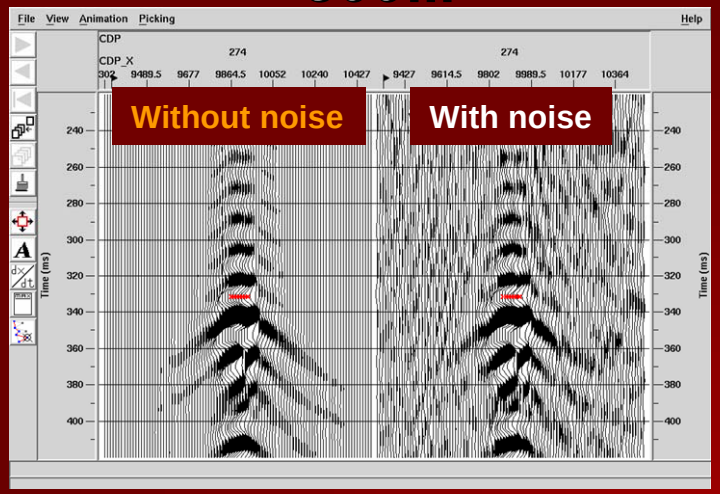
ZERT: Detection Limits for Seismic Imaging

Conceptual Model

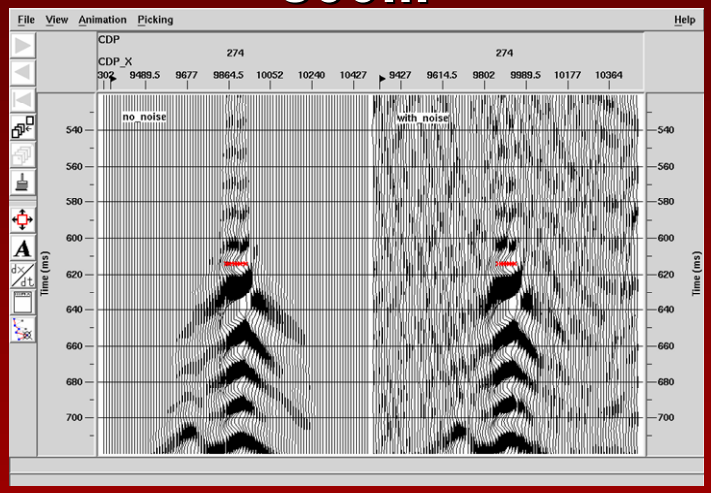


1000 tonne accumulation

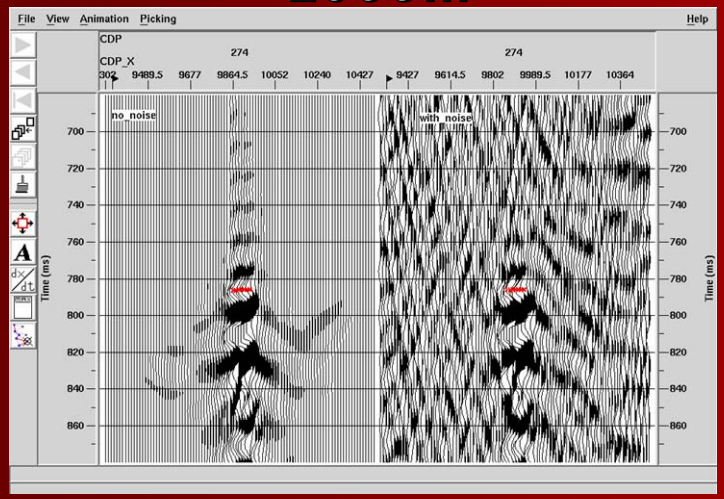
500m



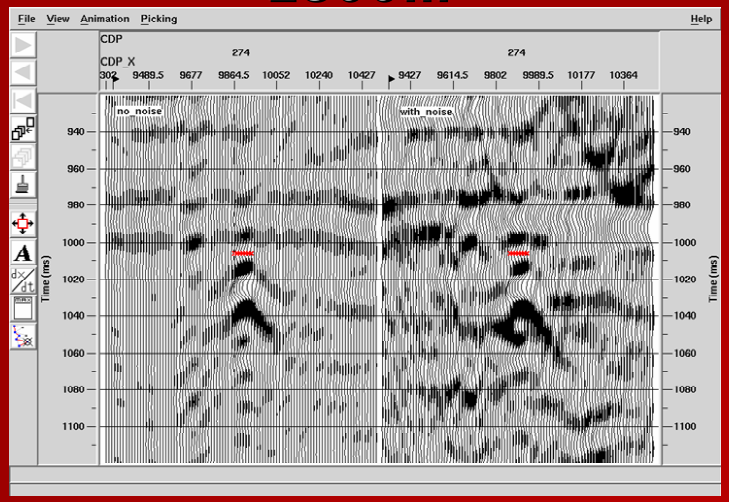
800m



1000m



1300m

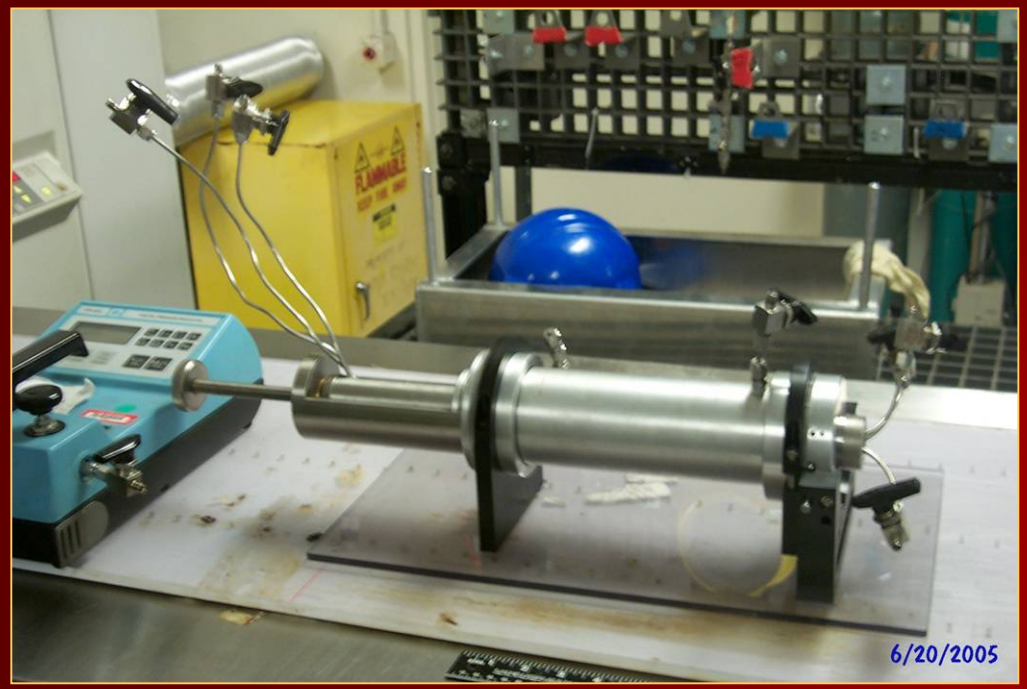


ZERT: Detection of Surface Seepage

- Controlled release experiments
  - Simulated leaking well
  - Simulated linear facture
- Bozeman, Montana
  - Agricultural experimental site
- Detect, locate, quantify
  - Eddy covariance
  - Flux accumulation chambers
  - Soil gas
  - Optical techniques
  - Etc.....

Courtesy of Jennifer Lewicki, LBNL

Core-Scale Studies of CO_2 Migration



Core holder used for CO_2 flood experiments with x-ray CT

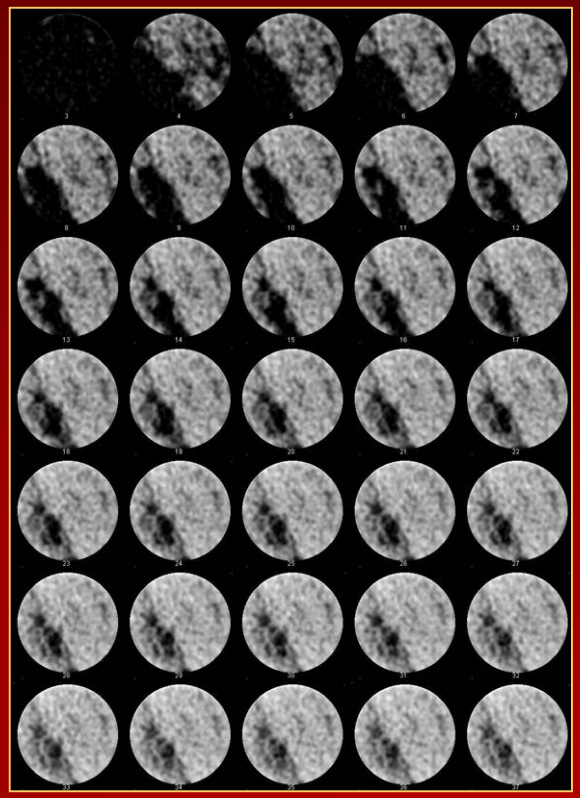
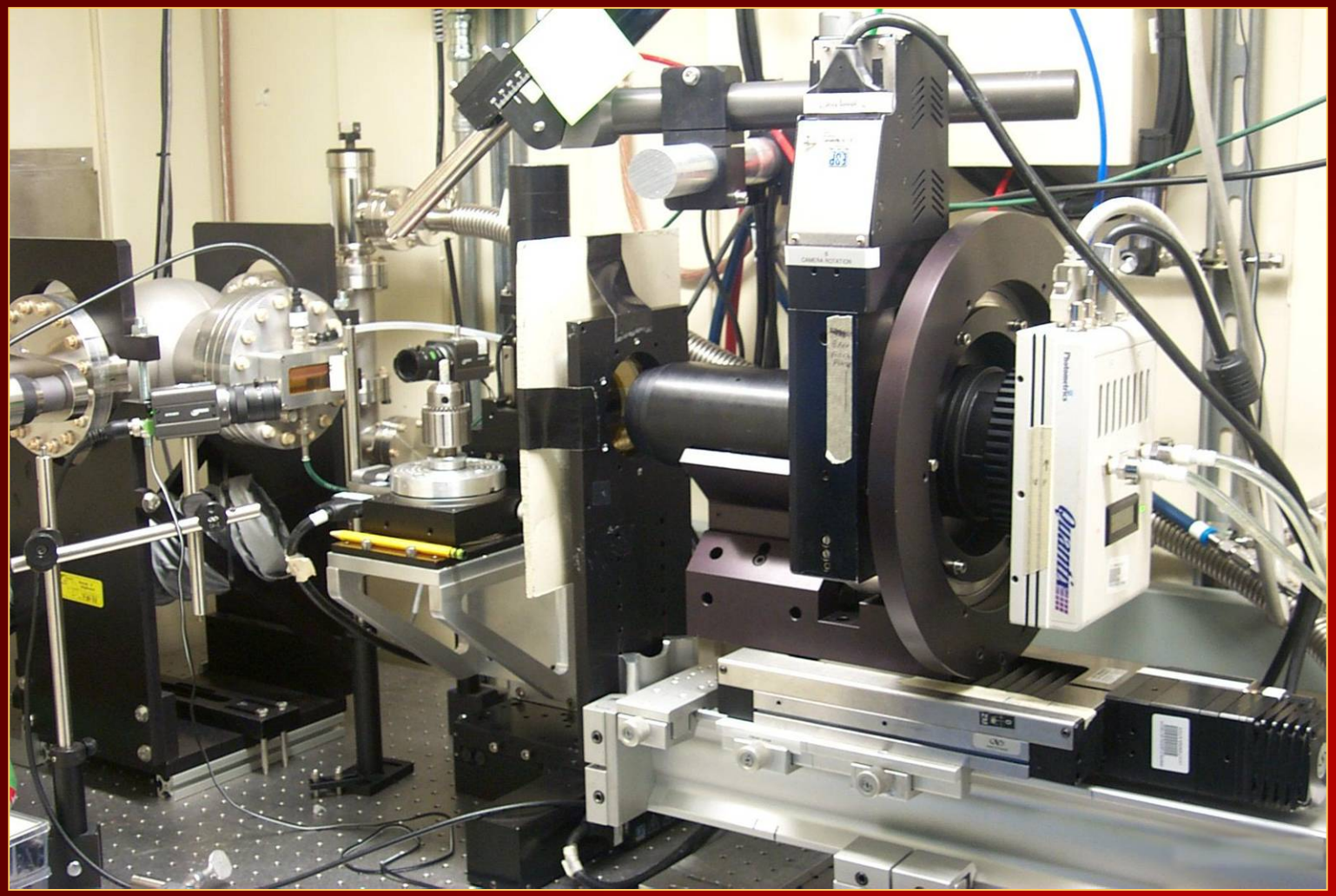


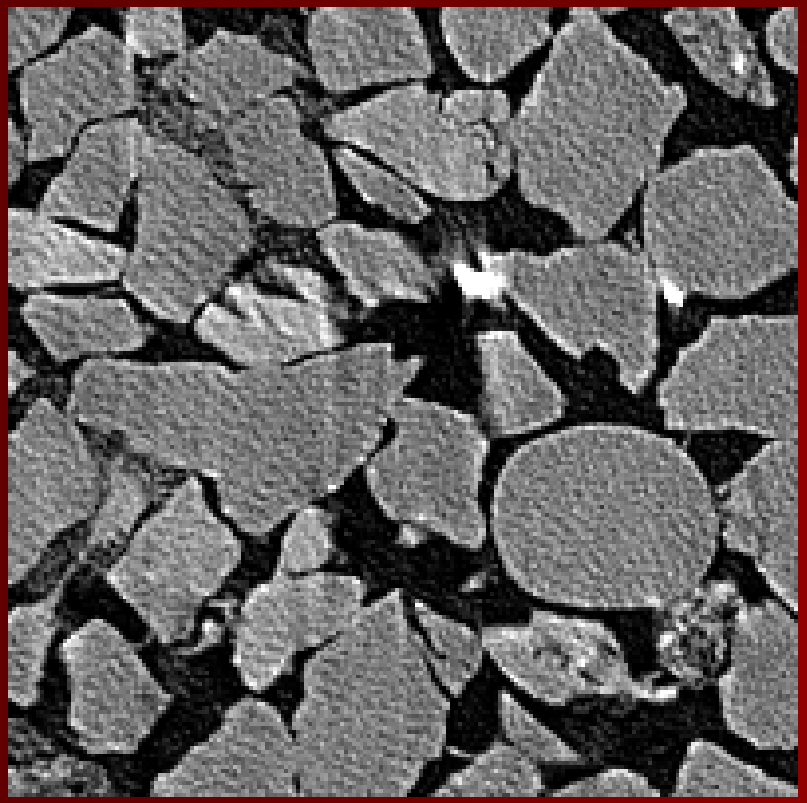
Photo montage of CO_2 saturation along the core. Dark areas have not been penetrated by CO_2.

Pore-Scale Studies of CO_2 Migration

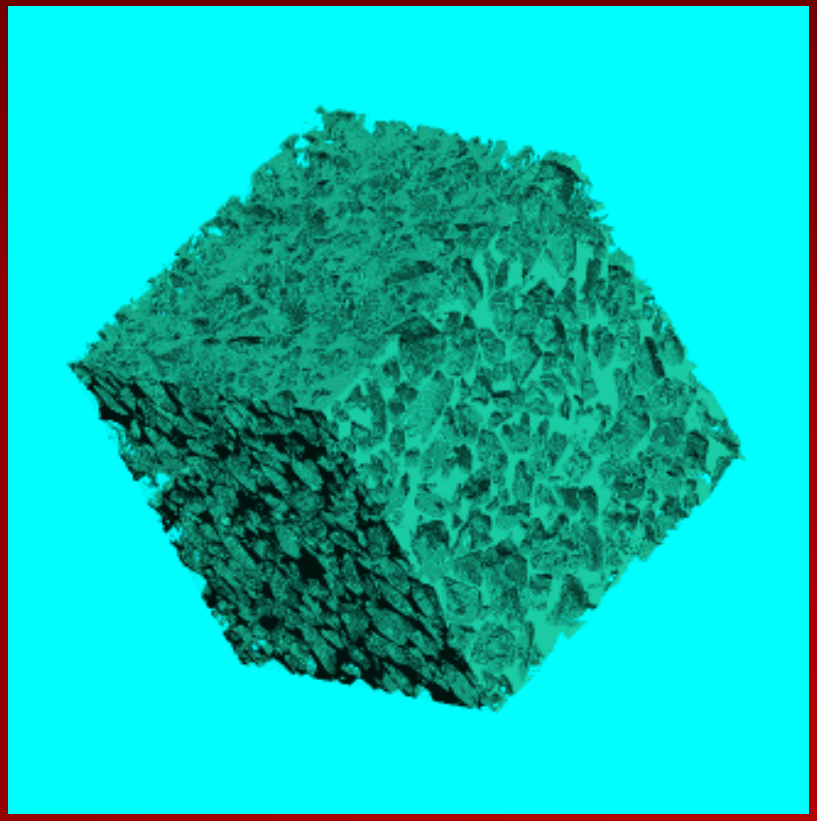


Microtomography Beamline at the Advanced Light Source

Pore-Scale Images of a Saline Formation



Pore network geometry from a sandstone



3D geometry of the pore space in a sandstone

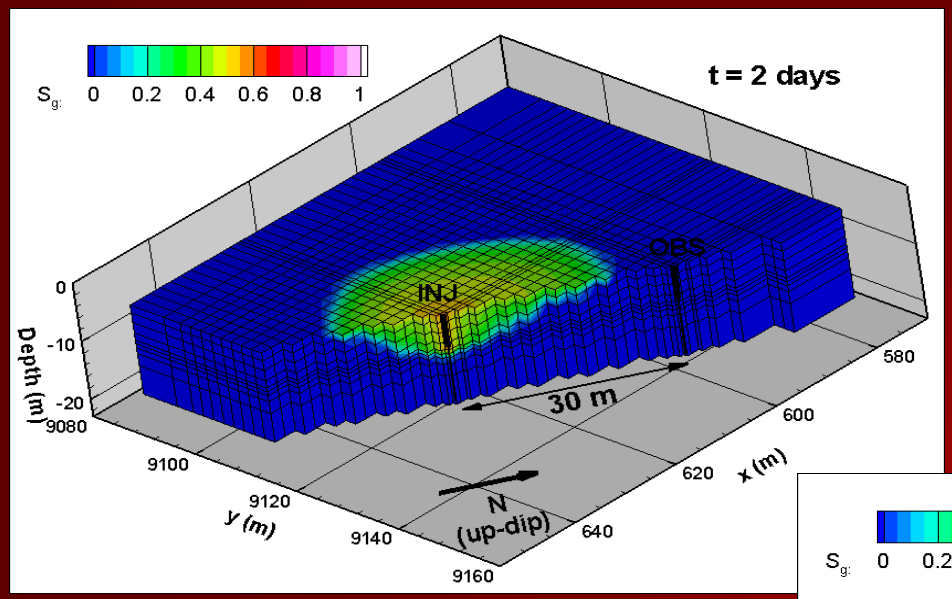
GEOSEQ: LBNL's Role in the Frio Brine Pilot

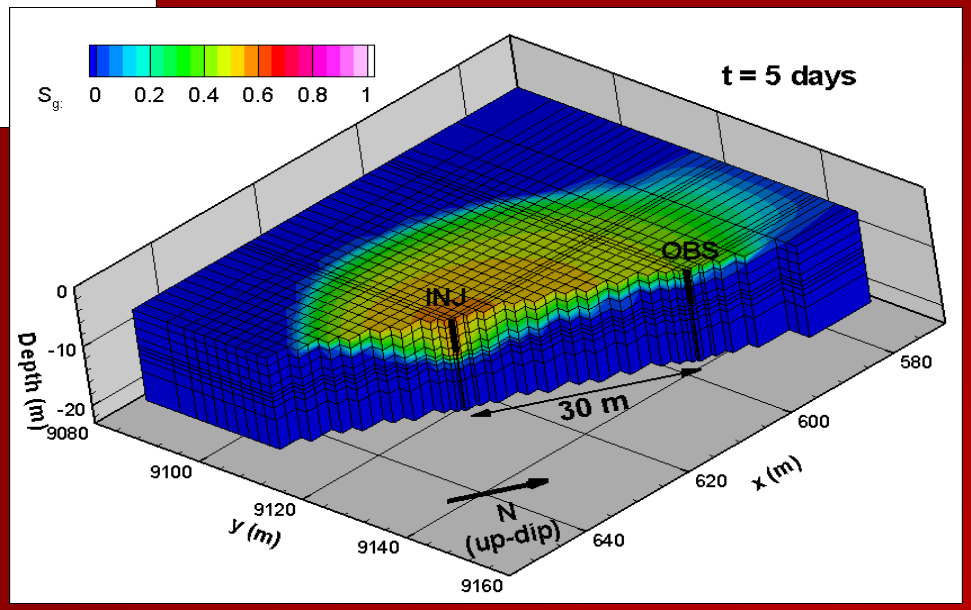
- Pre- and post-test modeling
- Geophysics
  - VSP
  - Cross-well
- Pressure transient analysis
- Tracers

Pre- and Post-test Modeling

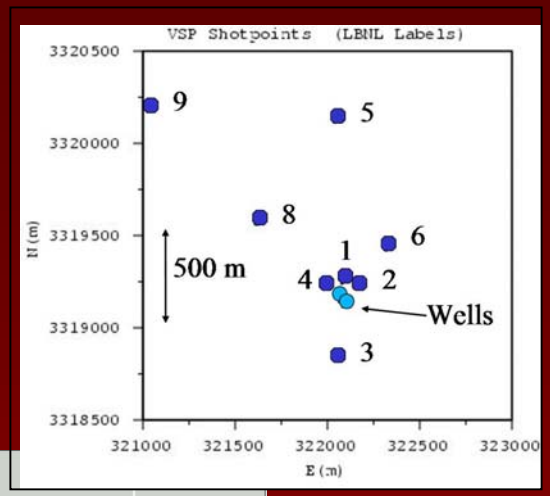
- Pre-Test Modeling
  - Design of Experiment
    - How much CO_2 to inject
    - Where to inject
    - Well separation for timely/economical breakthrough
  - Design Site-Characterization Studies
    - Interference well-tests
    - Doublet tracer test
  - Predict CO_2 arrival at observation well
  - Predict spatial distribution of CO_2 in subsurface
- Post-Test Modeling - compare model results to:
  - U-tube sampling – CO_2 arrival at observation well
  - RST – saturation profiles in wells
  - Crosswell seismic – saturation distribution between wells
  - VSP – saturation distribution beyond wells

Modeled CO_2 Distribution Agreed Well with Observations





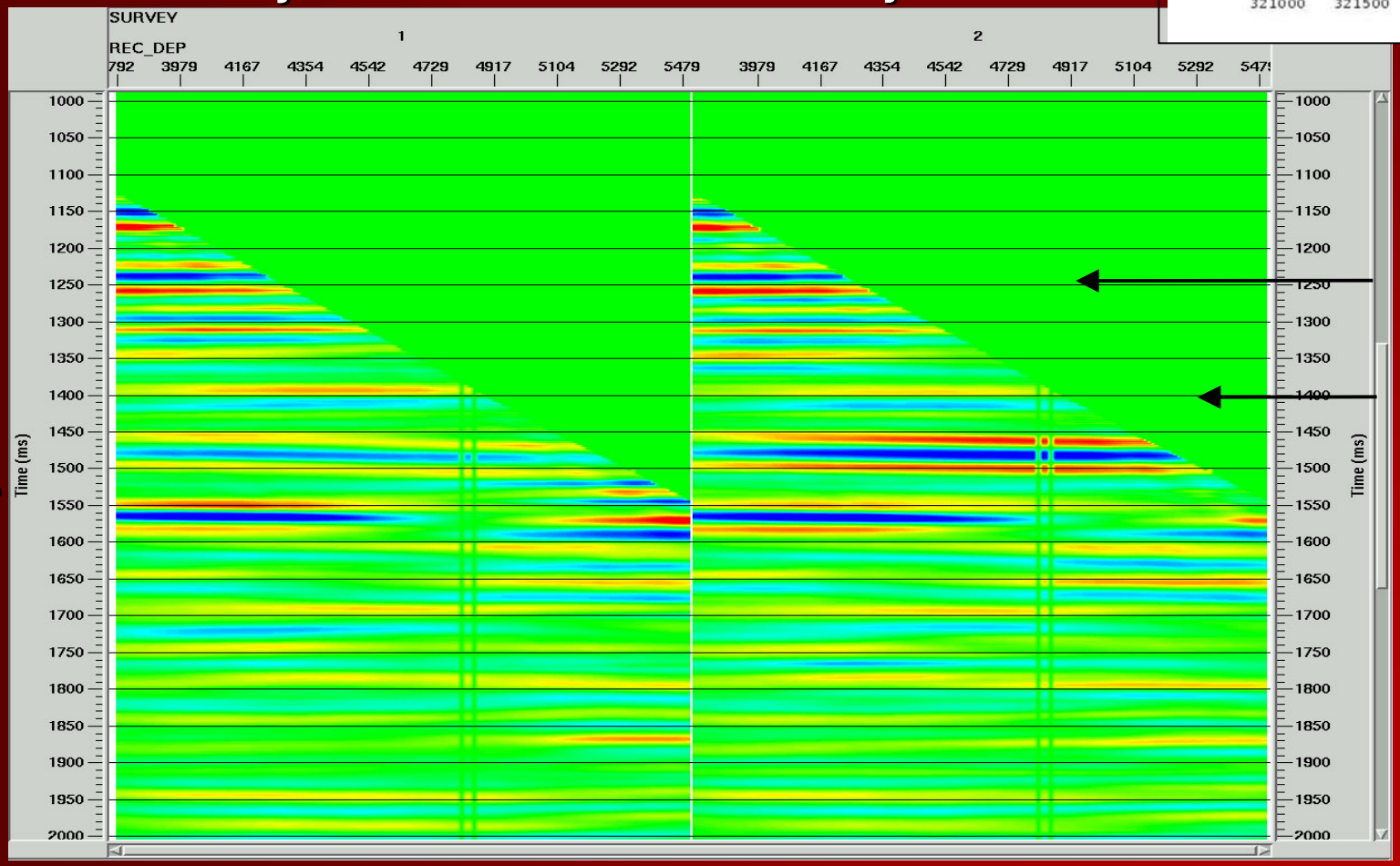
Geophysics: VSP



Pre Injection

Post Injection

Two-way travel time

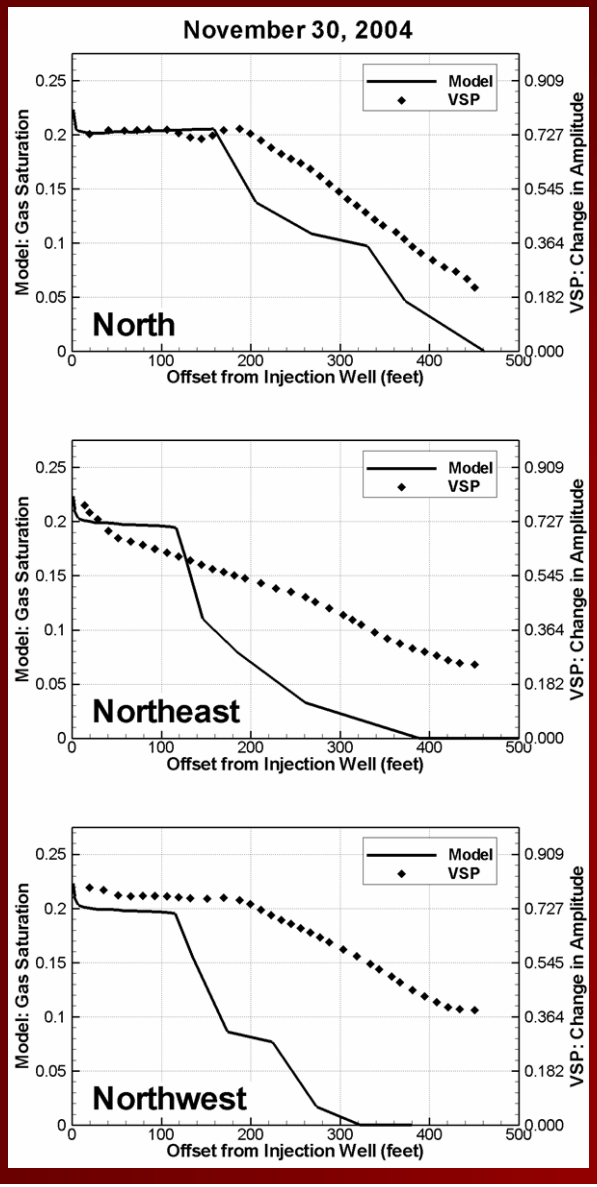


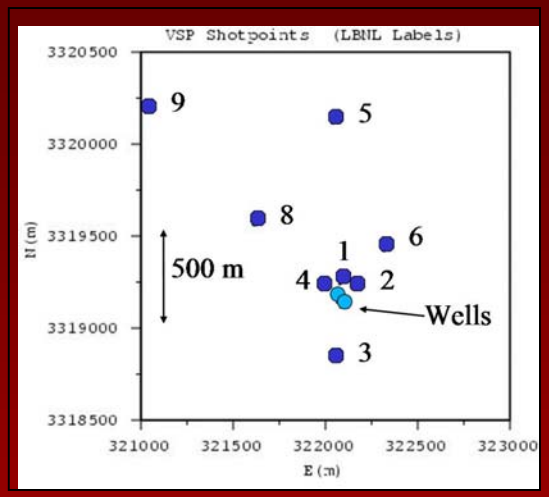
Control Reflection

Frio Reflection

Data from Tom Daley, LBNL

Extent of the CO_2 Plume VSP and Model

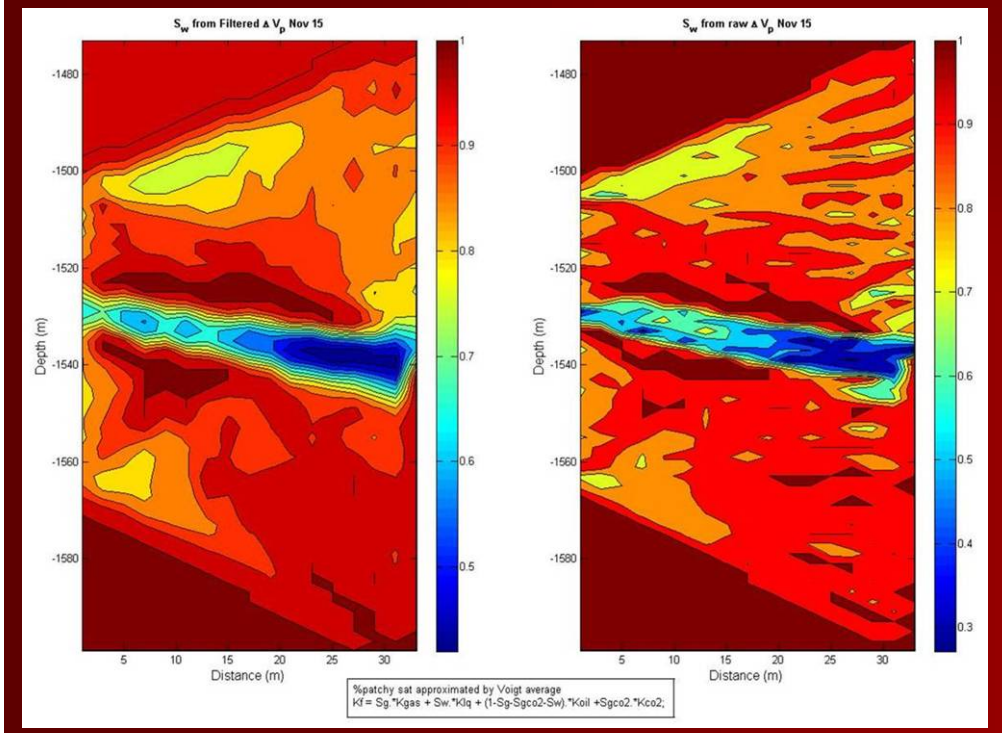




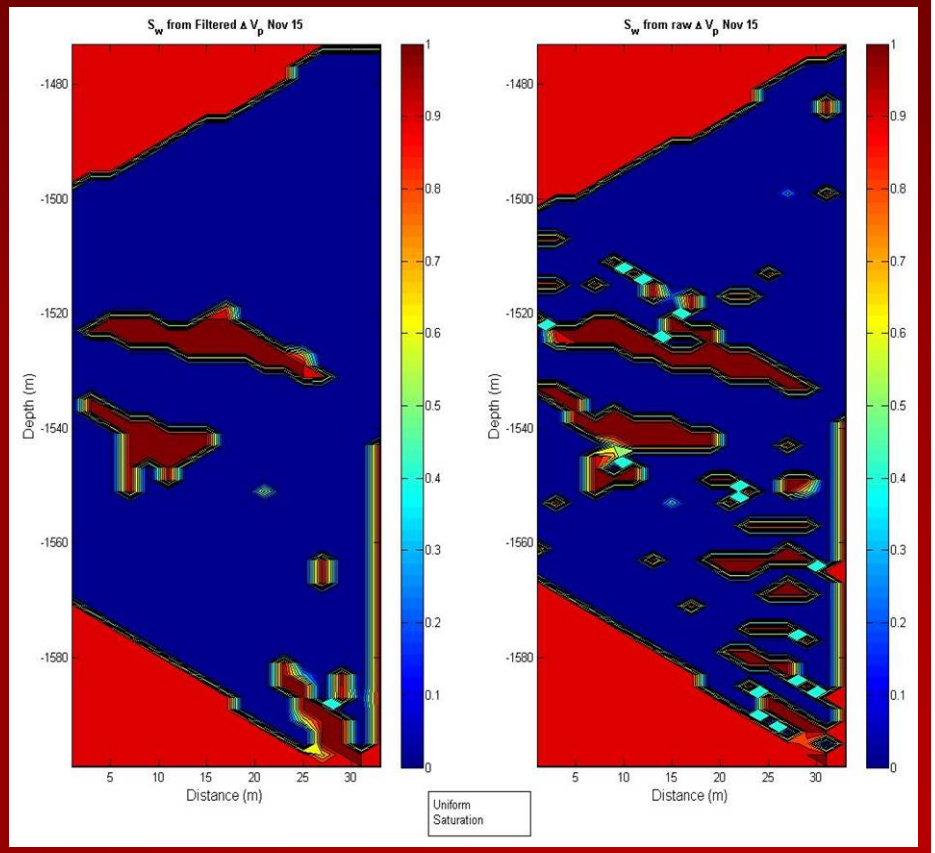
Courtesy of Chris Doughty and Tom Daley of LBNL

Geophysics:Cross-well Saturation

Patchy Model

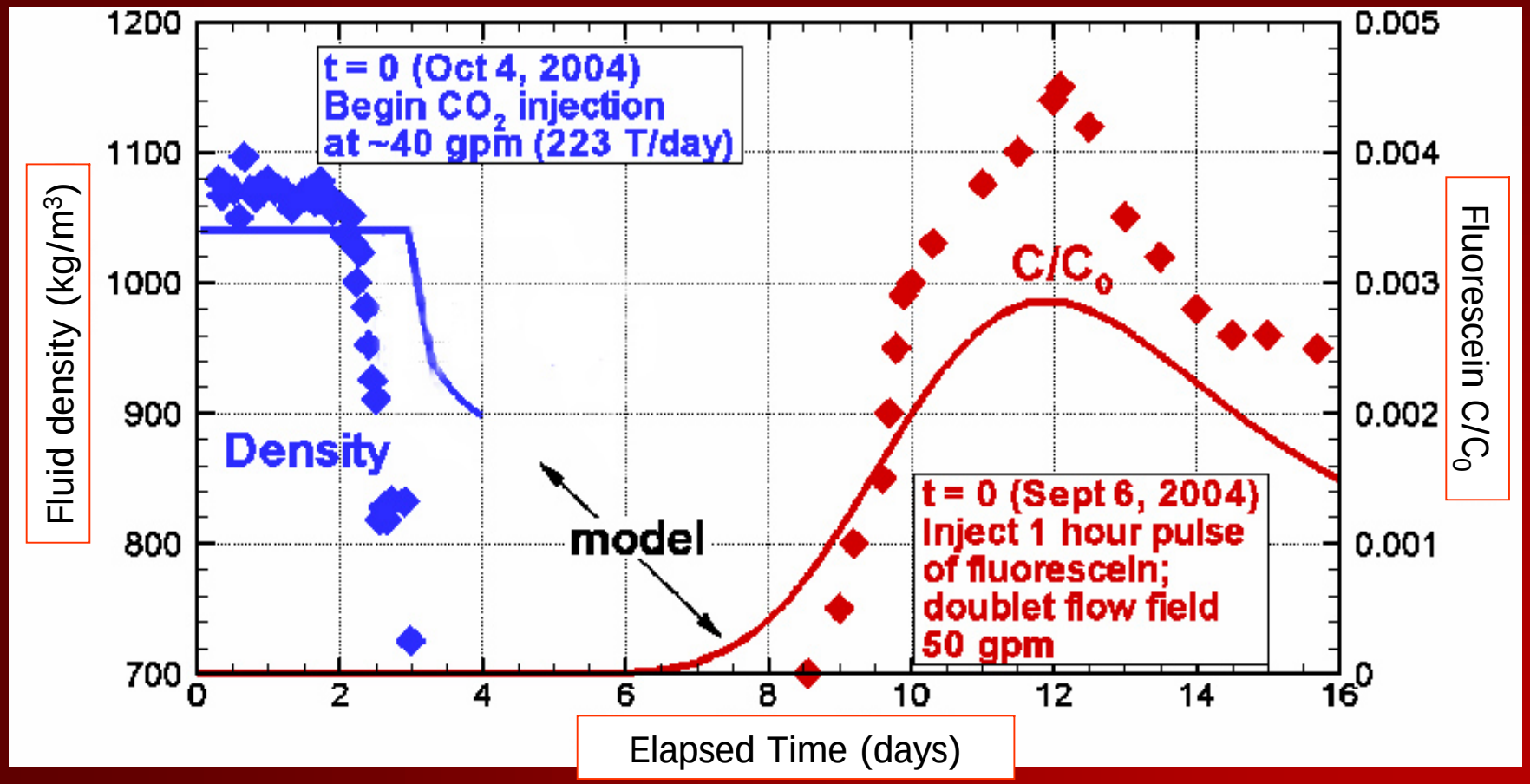


Uniform model



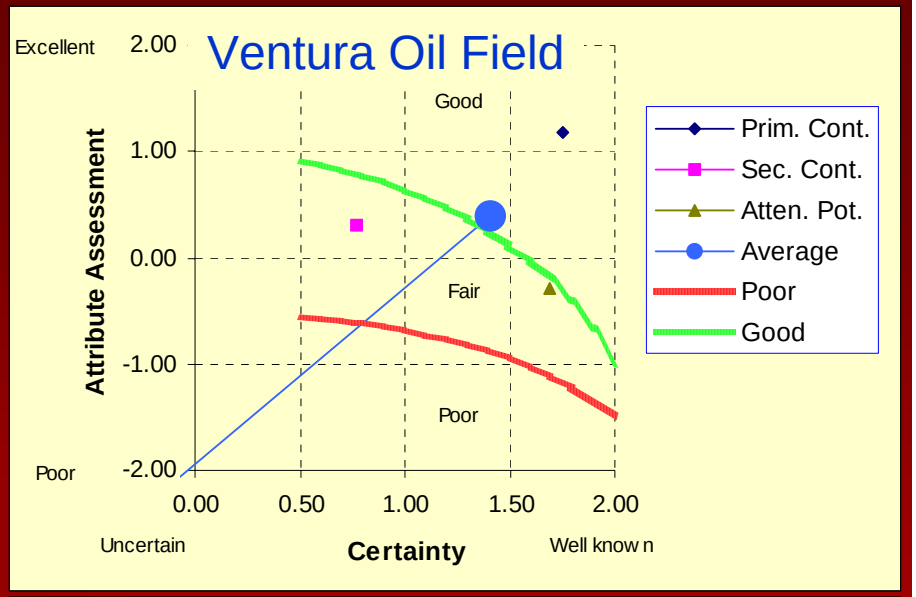
Data from Mike Hoversten, LBNL

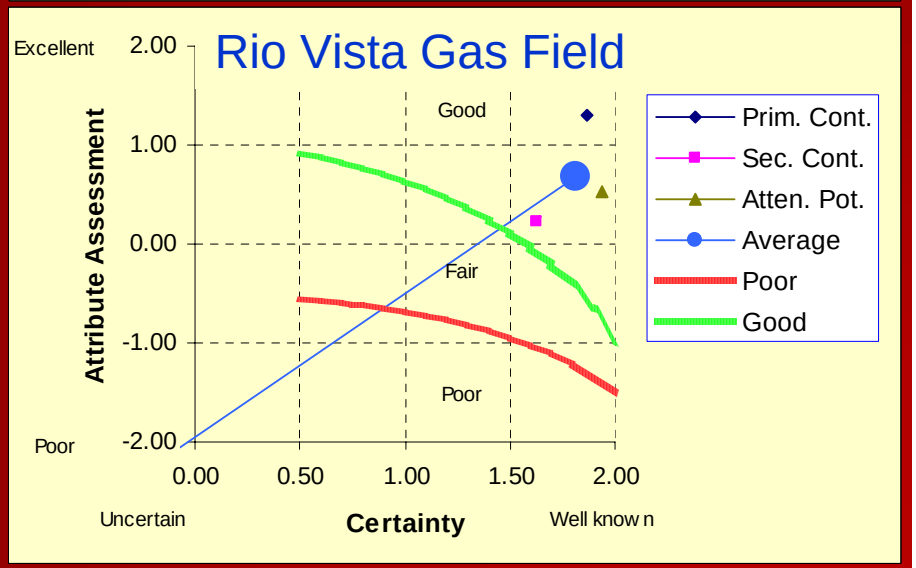
CO_2 Breakthrough and Tracer Recovery



Site Selection Tool Screening Geologic Storage Sites

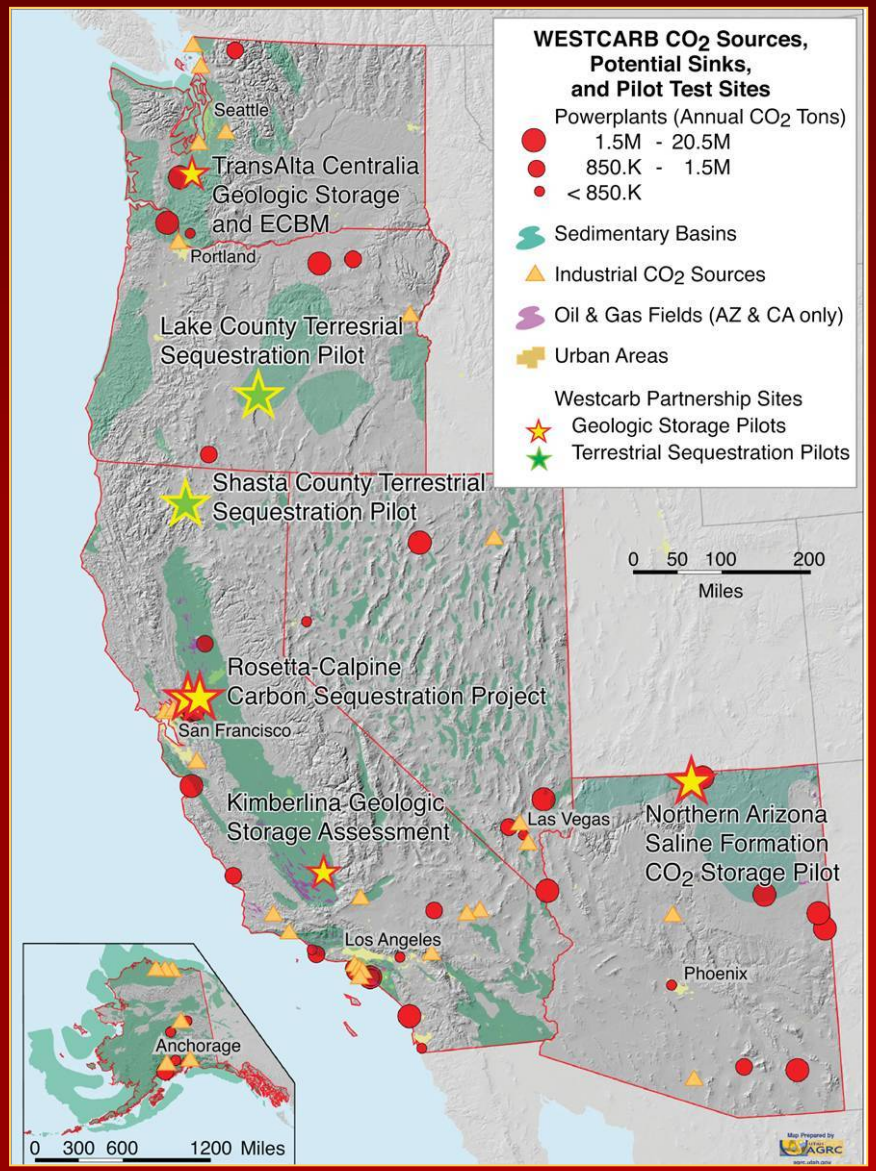
- Spreadsheet model for site selection has been developed
- User can
  - Evaluate and score various attributes
  - Specify the importance of various attributes through weighting factors
  - Specify uncertainty inherent at sites



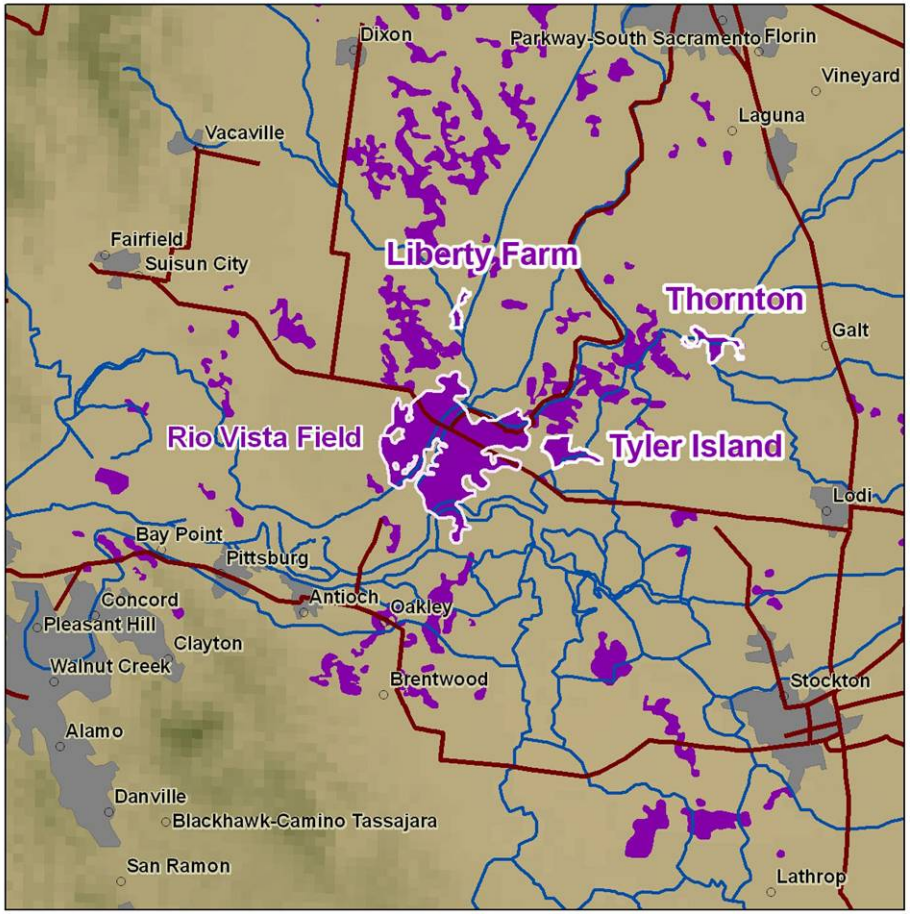


WESTCARB Pilot Tests

- Rosetta-Calpine Carbon Sequestration Project
- Northern Arizona Saline Formation CO_2 Storage Pilot
- Kimberlina Geologic Storage Assessment
- TransAlta Centralia Geologic Storage and ECBM Assessment

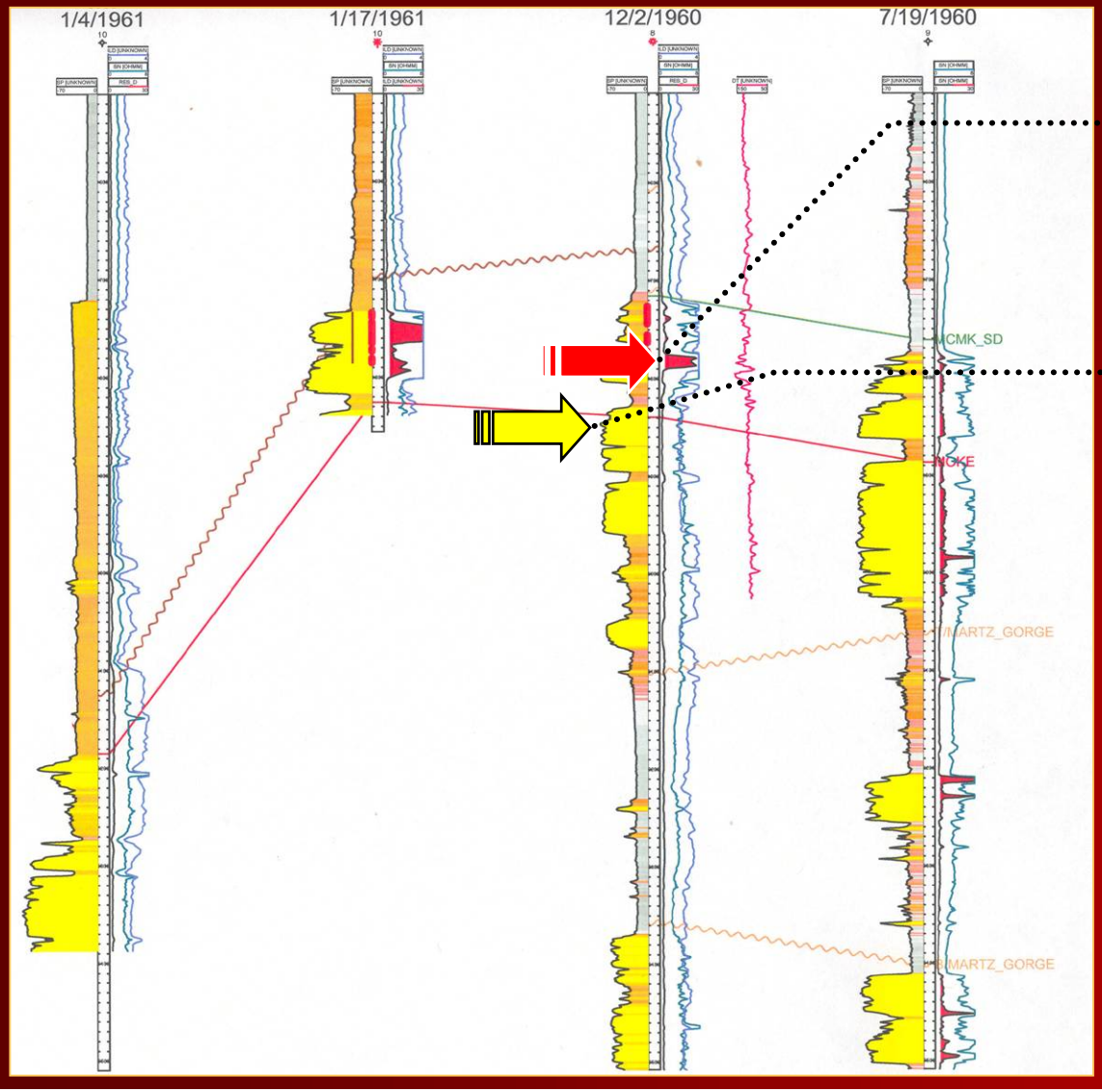


Rosetta-Calpine Carbon Sequestration Project



- 1.8 $GtCO_2$ storage capacity in depleted gas fields in Sacramento Valley (128 fields)
- Estimated 140-840 $GtCO_2$ storage capacity in saline formations in California based on ten largest basins

Rosetta-Calpine: Geological Cross Section



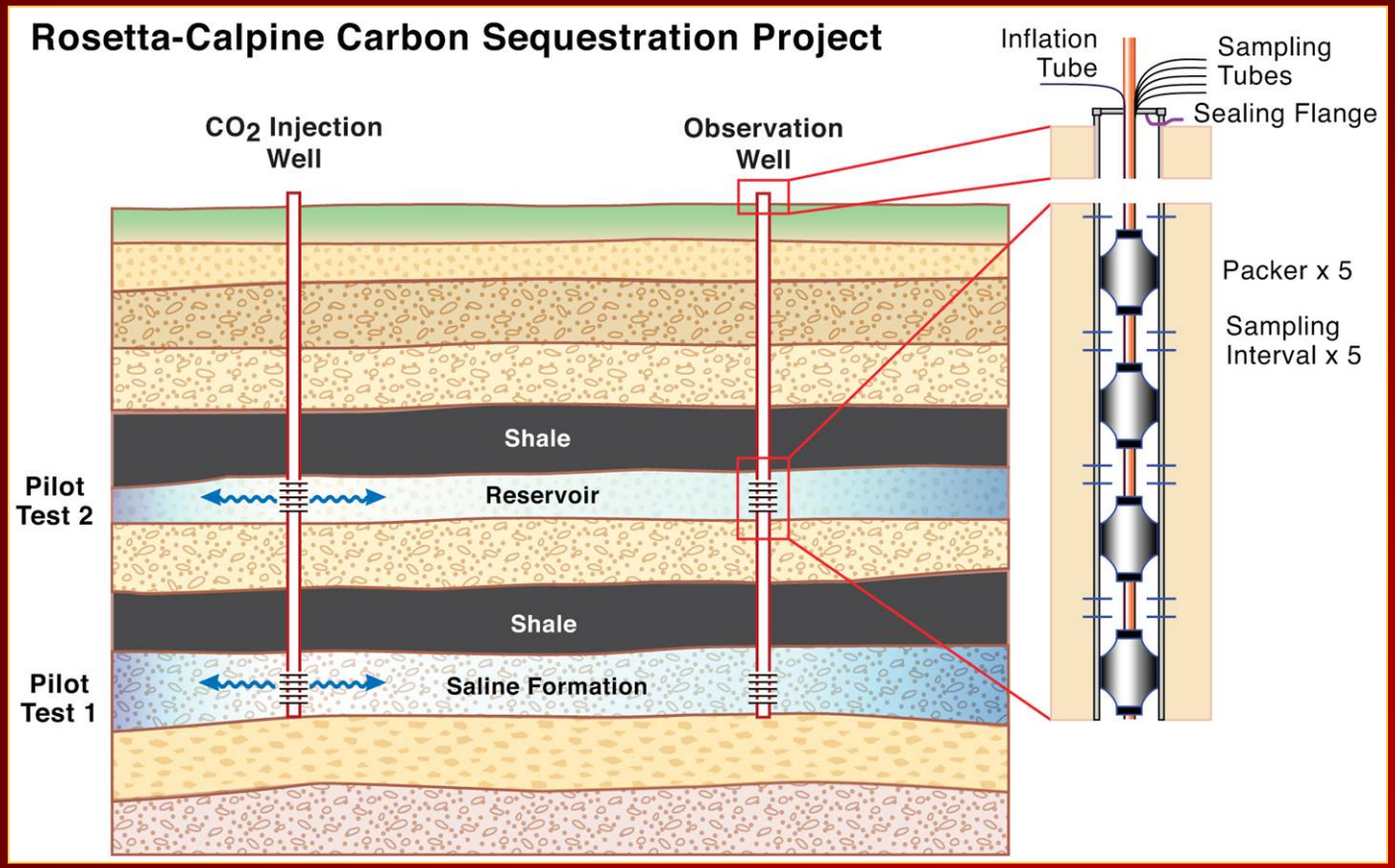
Depleted gas and EGR pilot test (~2000 tonnes CO_2 injection)

Saline formation pilot test (~2000 tonnes CO_2 injection)

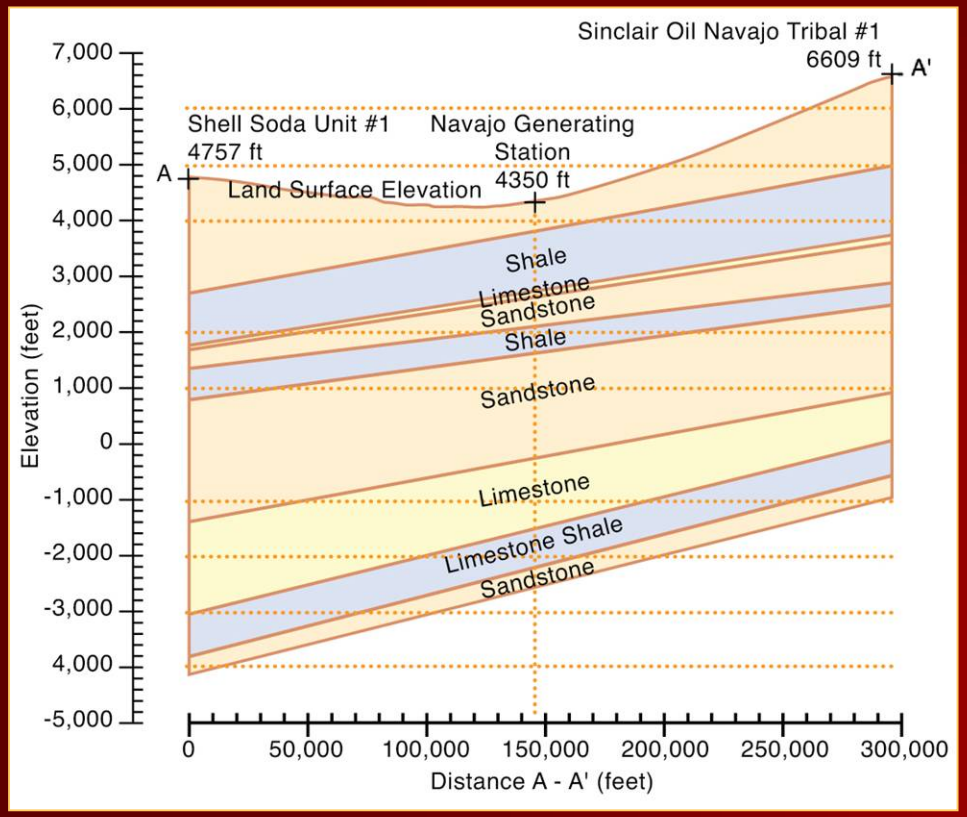
Compliments of Rob Trautz, LBNL

Rosetta-Calpine: Two-well Pilots

- Fluid and gas sampling
- Cross-well seismic
- VSP
- Reservoir pressure and temperature
- Well logs, including possible RST



Northern Arizona Saline Formation CO_2 Storage Pilot

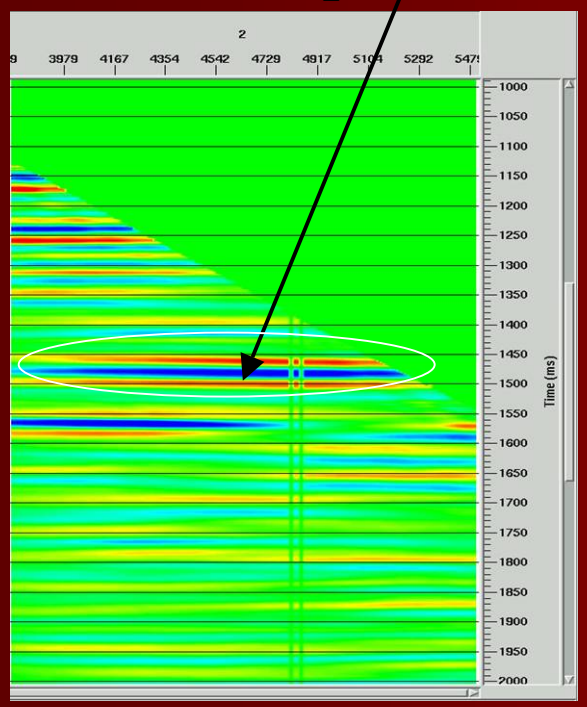


Large but uncharacterized storage capacity in the Colorado Plateau and basins of northern Arizona

North eastern Arizona

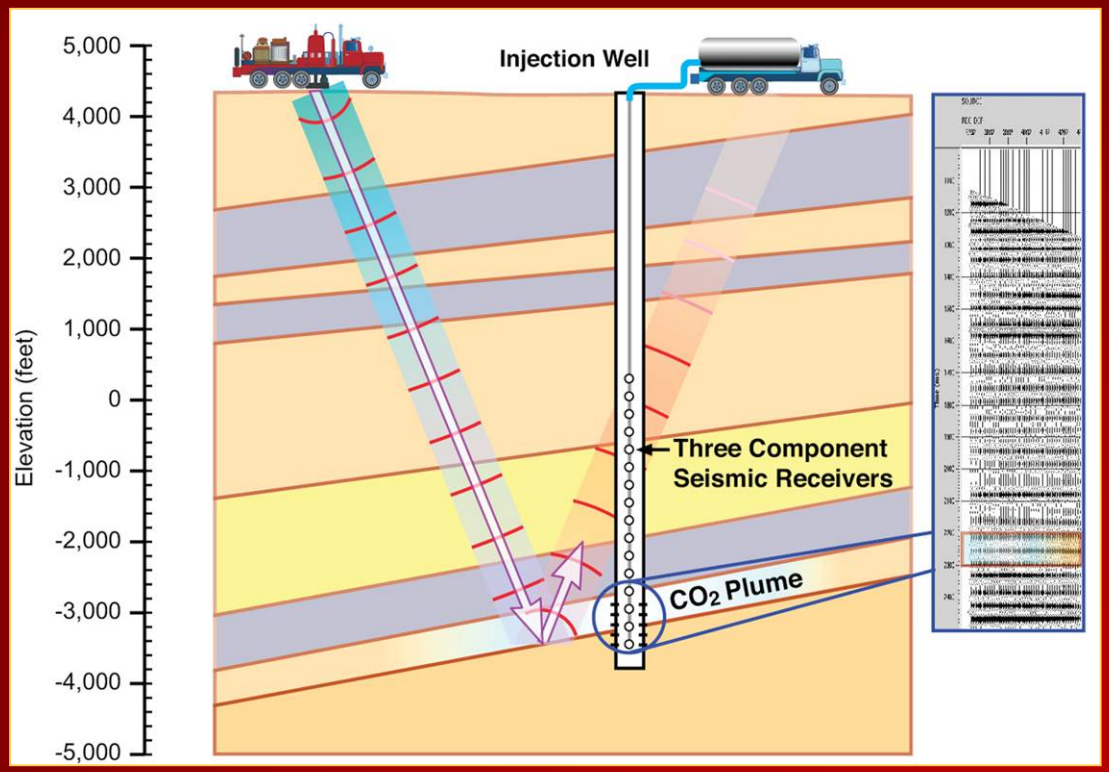
Northern Arizona Saline Formation CO_2 Storage Pilot

Reflection from 1600 tonne CO_2 plume



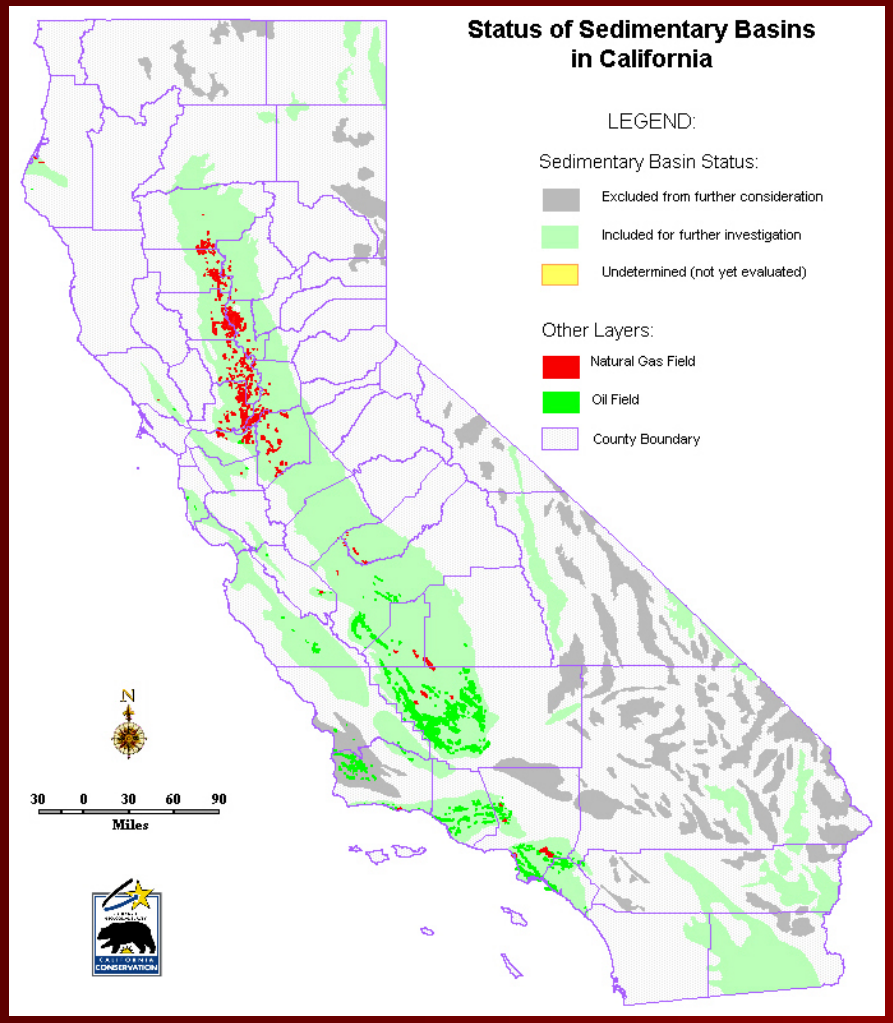
VSP Results from Frio Formation

Single well test plan



2000 tonne CO_2 injection

WESTCARB Capacity Estimates for California



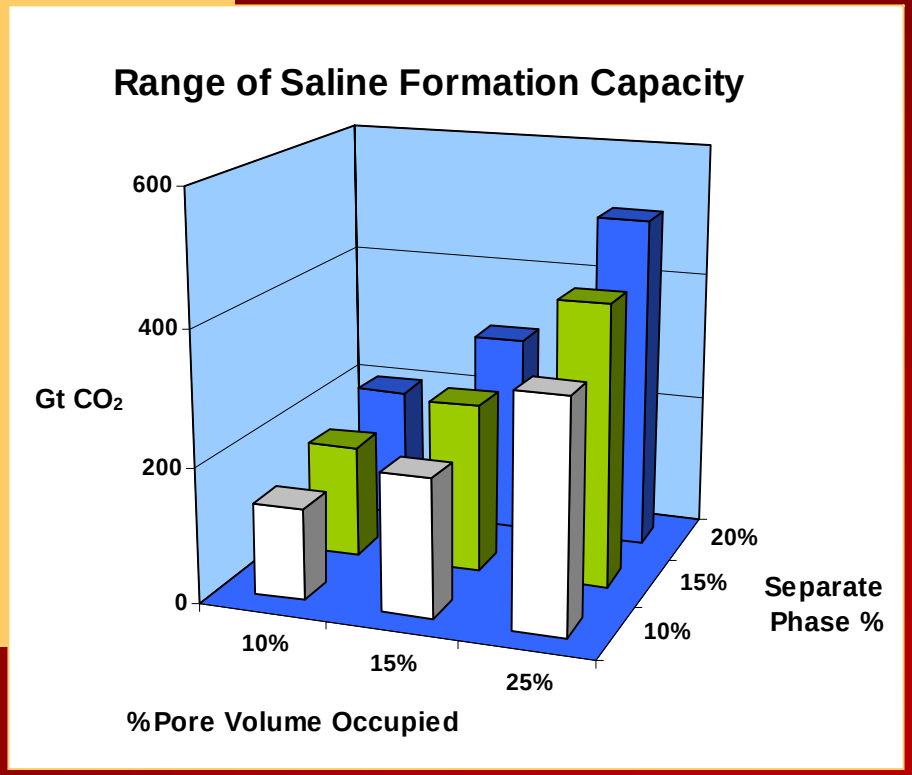
- Oil reservoirs
  - 3.4 Gt CO_2 with miscible displacement
  - 3.8 Gt CO_2 total
- Gas reservoirs
  - 1.8 Gt CO_2
- Saline formations
  - 140 to 500 Gt CO_2

Capacity of Saline Formations

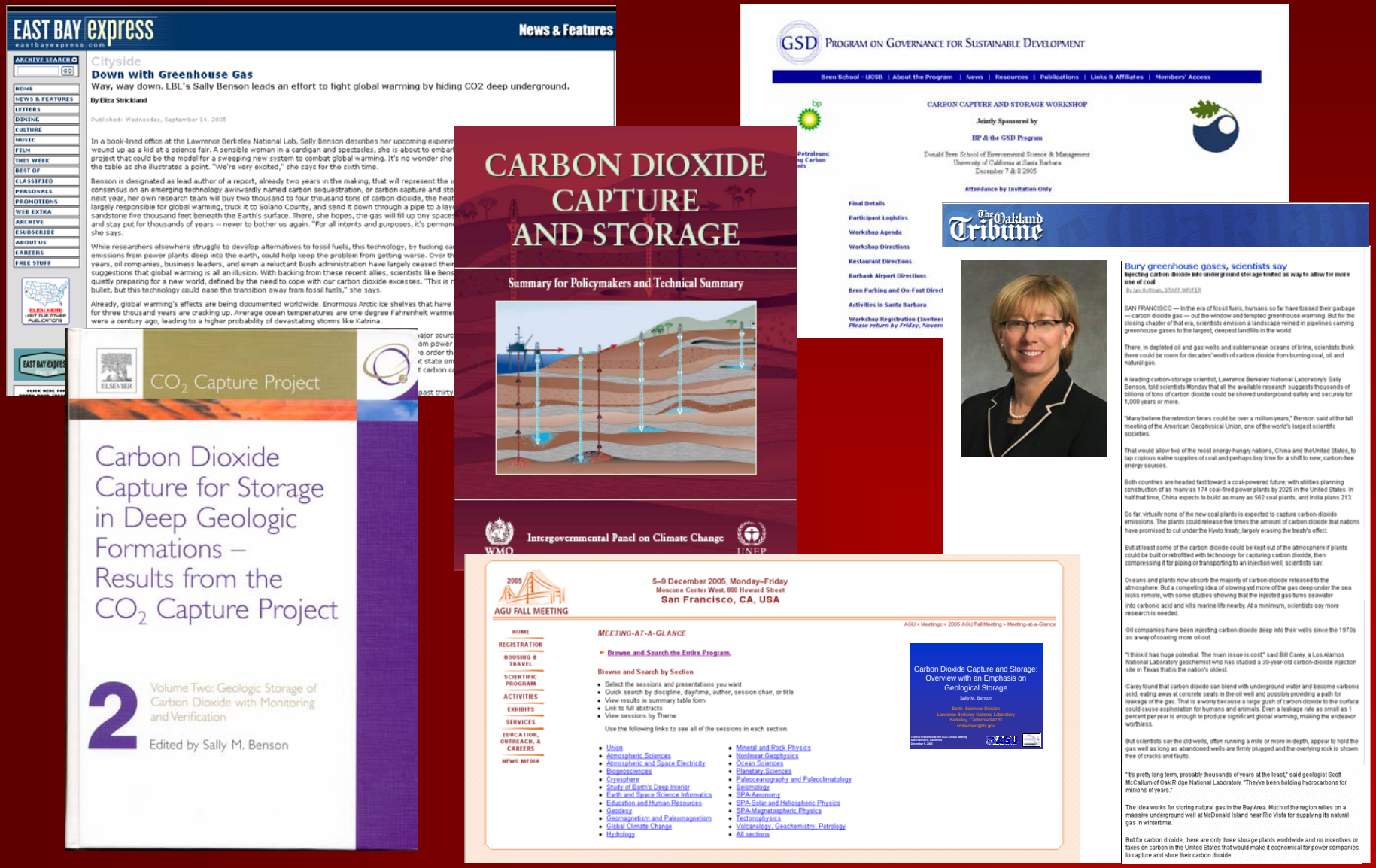
% separate phase CO_2

% pore volume occupied by dissolved CO_2

Calculated Pore Volume



Outreach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Down with Greenhouse Gas
Way, way down. LBL's Sally Benson leads an effort to fight global warming by hiding CO2 deep underground.
By Eliza Strickland
GSD Program on Governance for Sustainable Development
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CARBON DIOXIDE CAPTURE AND STORAGE
Summary for Policymakers and Technical Summary
Intergovernmental Panel on Climate Change
WMO
UNEP
The Oakland Tribune
Bury greenhouse gases, scientists say
Injecting carbon dioxide into underground storage touted as way to allow for more use of coal
By Jan Hoffman, STAFF WRITER
SAN FRANCISCO — In the era of fossil fuels, humans so far have tossed their garbage — carbon dioxide gas — out the window and tempted greenhouse warming. But for the closing chapter of that era, scientists envision a landscape veined in pipelines carrying greenhouse gases to the largest, deepest landfills in the world.
There, in depleted oil and gas wells and subterranean oceans of brine, scientists think there could be room for decades' worth of carbon dioxide from burning coal, oil and natural gas.
A leading carbon-storage scientist, Lawrence Berkeley National Laboratory's Sally Benson, told scientists Monday that all the available research suggests thousands of billions of tons of carbon dioxide could be shoved underground safely and securely for 1,000 years or more.
"Many believe the retention times could be over a million years," Benson said at the fall meeting of the American Geophysical Union, one of the world's largest scientific societies.
That would allow two of the most energy-hungry nations, China and the United States, to tap copious native supplies of coal and perhaps buy time for a shift to new, carbon-free energy sources.
Both countries are headed fast toward a coal-powered future, with utilities planning construction of as many as 174 coal-fired power plants by 2025 in the United States. In half that time, China expects to build as many as 562 coal plants, and India plans 213.
So far, virtually none of the new coal plants is expected to capture carbon-dioxide emissions. The plants could release five times the amount of carbon dioxide that nations have promised to cut under the Kyoto treaty, largely erasing the treaty's effect.
But at least some of the carbon dioxide could be kept out of the atmosphere if plants could be built or retrofitted with technology for capturing carbon dioxide, then compressing it for piping or transporting to an injection well, scientists say.
Oceans and plants now absorb the majority of carbon dioxide released to the atmosphere. But a competing idea of stowing yet more of the gas deep under the sea looks remote, with some studies showing that the injected gas turns seawater into carbonic acid and kills marine life nearby. At a minimum, scientists say more research is needed.
Oil companies have been injecting carbon dioxide deep into their wells since the 1970s as a way of coaxing more oil out.
"I think it has huge potential. The main issue is cost," said Bill Carey, a Los Alamos National Laboratory geochemist who has studied a 30-year-old carbon-dioxide injection site in Texas that is the nation's oldest.
Carey found that carbon dioxide can blend with underground water and become carbonic acid, eating away at concrete seals in the oil well and possibly providing a path for leakage of the gas. That is a worry because a large gush of carbon dioxide to the surface could cause asphyxiation for humans and animals. Even a leakage rate as small as 1 percent per year is enough to produce significant global warming, making the endeavor worthless.
But scientists say the old wells, often running a mile or more in depth, appear to hold the gas well as long as abandoned wells are firmly plugged and the overlying rock is shown free of cracks and faults.
"It's pretty long term, probably thousands of years at the least," said geologist Scott McCallum of Oak Ridge National Laboratory. "They've been holding hydrocarbons for millions of years."
The idea works for storing natural gas in the Bay Area. Much of the region relies on a massive underground well at McDonald Island near Rio Vista for supplying its natural gas in wintertime.
But for carbon dioxide, there are only three storage plants worldwide and no incentives or taxes on carbon in the United States that would make it economical for power companies to capture and store their carbon dioxide.
ELSEVIER
CO2 Capture Project
Carbon Dioxide Capture for Storage in Deep Geologic Formations – Results from the CO2 Capture Project
2
Volume Two: Geologic Storage of Carbon Dioxide with Monitoring and Verification
Edited by Sally M. Benson
2005
AGU FALL MEETING
5–9 December 2005, Monday–Friday
Moscone Center West, 800 Howard Street
San Francisco, CA, USA
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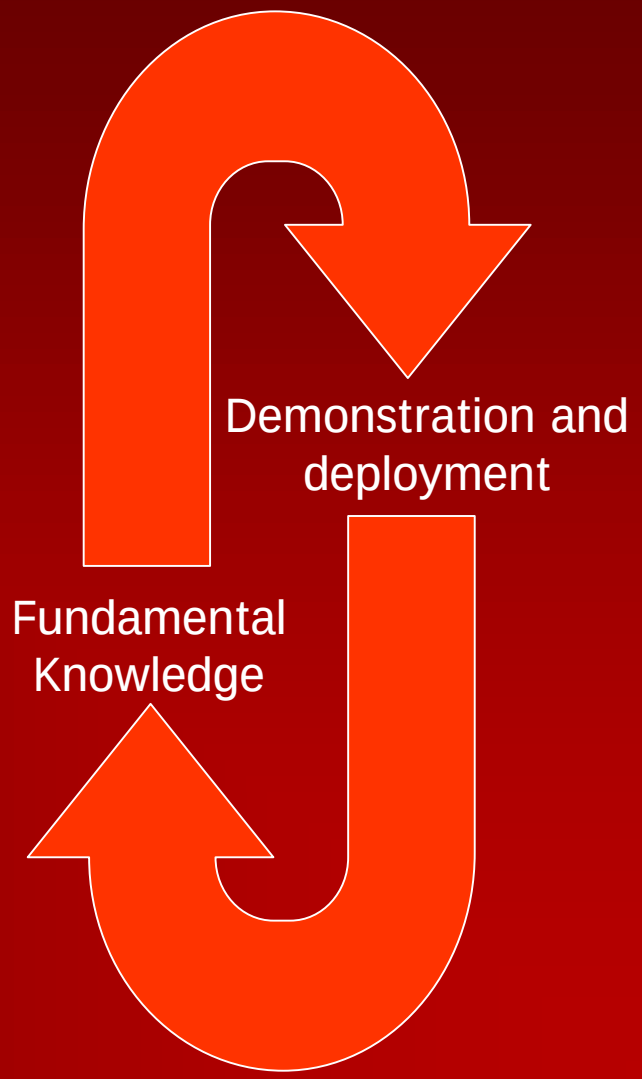
All sections
Carbon Dioxide Capture and Storage: Overview with an Emphasis on Geological Storage
Sally M. Benson

Major Research Program Elements

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