Ensuring & Monitoring Secure Storage for Carbon Dioxide Carbon Capture and Storage (CCS) Projects

Susan D. Hovorka
Gulf Coast Carbon Center
Bureau of Economic geology
Jackson School of Geosciences
The University of Texas at Austin

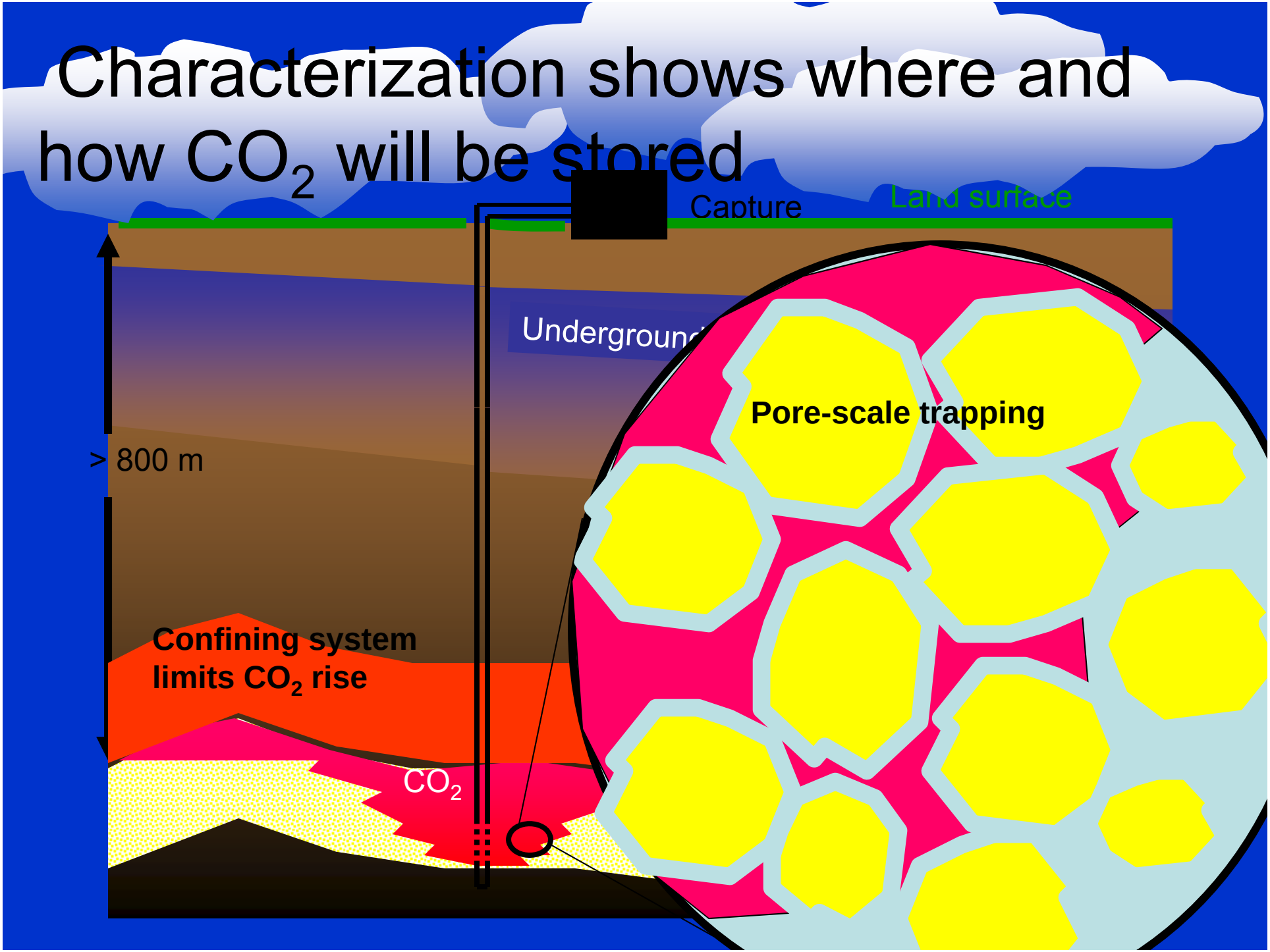
Presented to Carbon Capture & Sequestration Public Workshop, June 10, 2010 Sacramento, CA

Ensuring storage is permanent requires..

- Characterization and predictive modeling to select a geologic site that will accept and retain CO_2
- Operation of the injection process to conserve site geologic integrity

Monitoring can be used to document the correctness of characterization, modeling, and operation

Characterization shows where and how CO_2 will be stored



Safe Operation of Injection wells

- Management of wells to insure that fluids are retained
- Management of pressure to insure that integrity of the geologic system is retained

These activities are required by federal law for all injection wells under the Safe Drinking Water Act of 1974

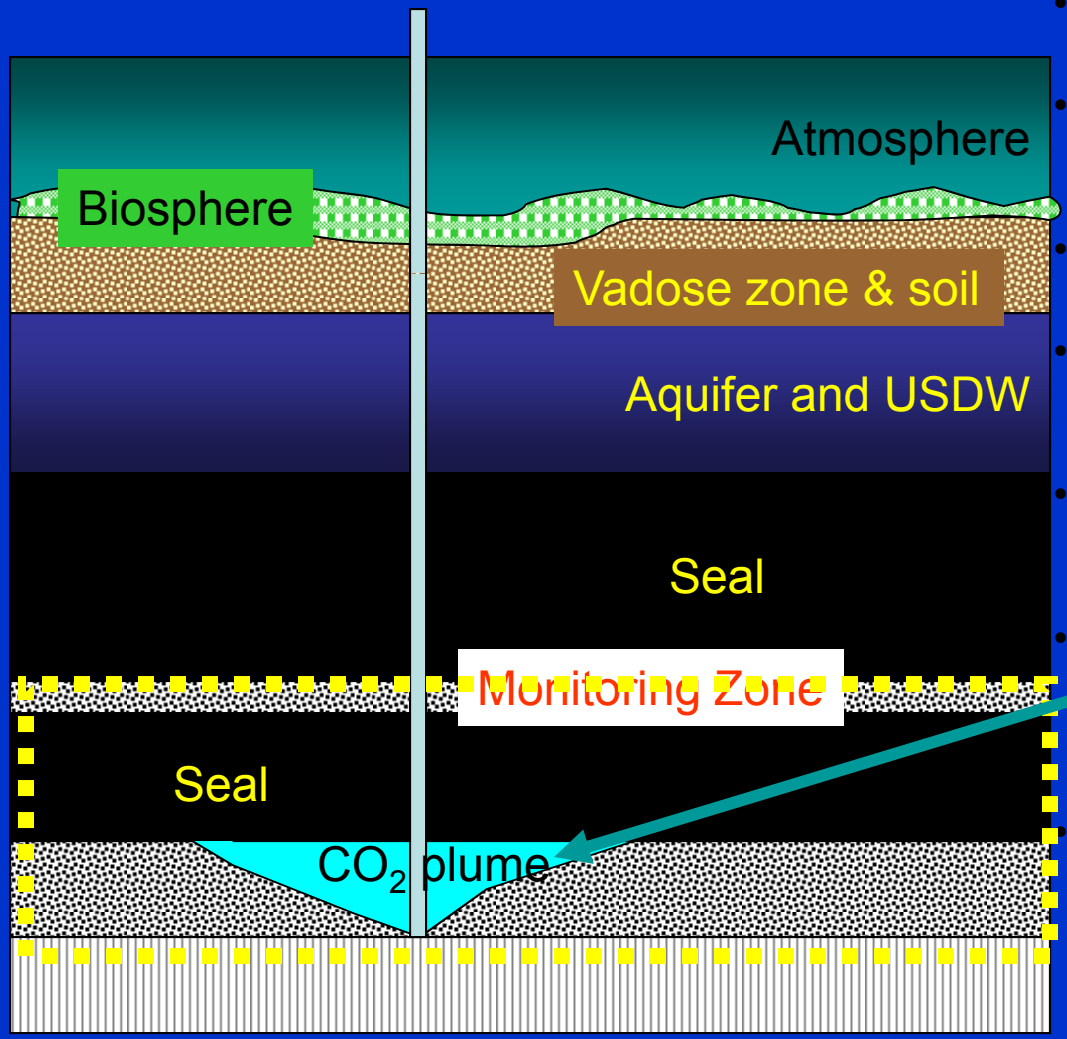
Monitoring to test the correctness of characterization, modeling, and operation

- Imaging CO_2 in the subsurface
- Measuring pressure changes
- Tools to assess compositional changes

Match to predictive model

- Surveillance of protected resources

Settings that can be monitored



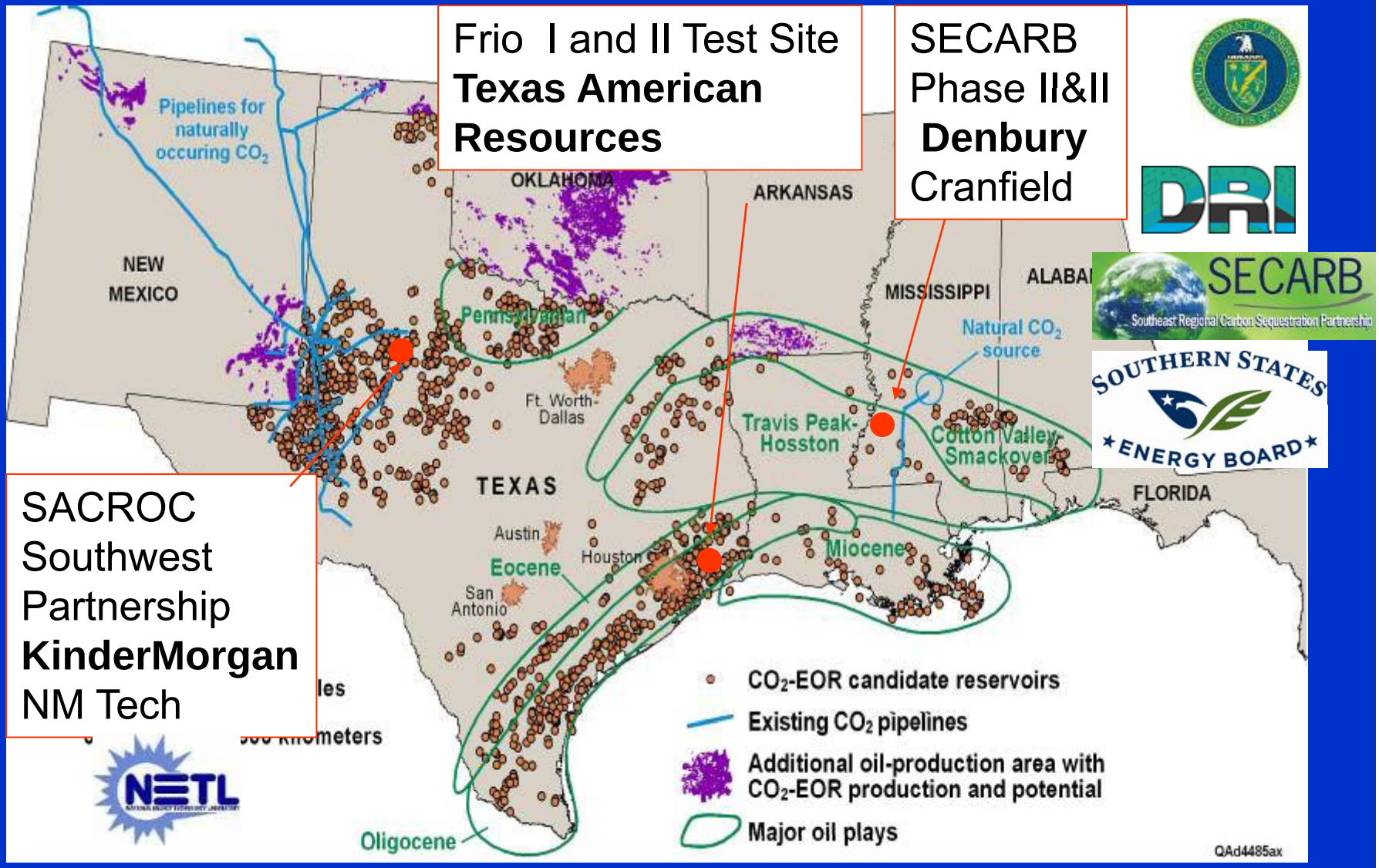
- Atmosphere
  - Ultimate receptor but dynamic
- Biosphere
  - Assurance of no damage but dynamic

Complex!

- Soil and Vadose Zone
  - Integrator but dynamic
- Aquifer and USDW
  - Integrator, slightly isolated from ecological effects
- Above injection monitoring zone
  - First indicator, monitor small signals, stable.
- In injection zone - plume
  - Oil-field type technologies. Will not identify small leaks **Complex!**
- In injection zone - outside plume
  - Assure lateral migration of CO_2 and brine is acceptable

Monitoring box

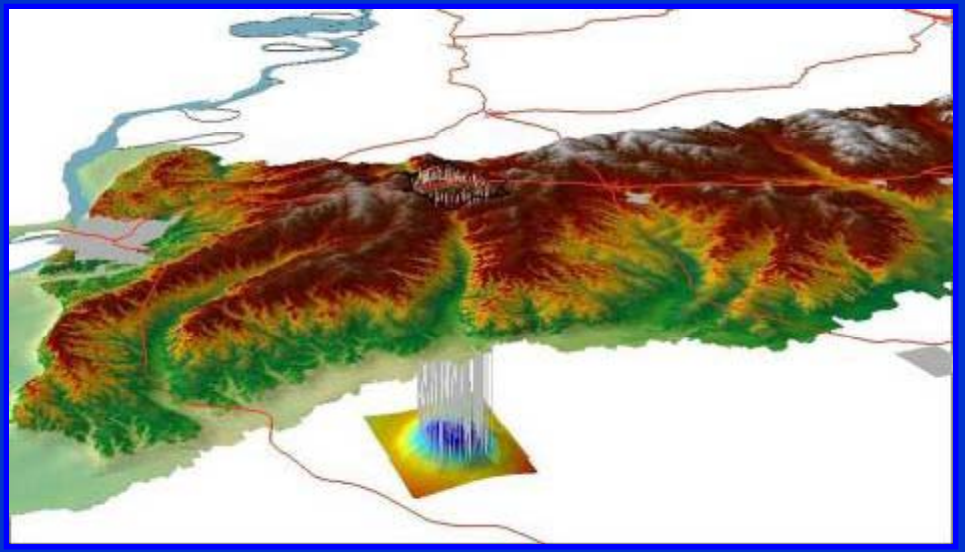
Gulf Coast Carbon Center Field Tests



Other projects with strong monitoring programs provide experience

- Sleipner, North Sea
- Weyburn, Saskatchewan
- Nagaoka, Japan
- Ketzin, Germany
- Gaylord, Michigan
- In Salah, Algeria
- Otway, Australia

Example of a research project DOE funded SECARB Phase III at Cranfield, Mississippi



3,000 m depth (10,300 ft)
Gas cap, oil ring, downdip water leg
Original production in 1950's
Strong water drive
Shut in since 1965
Returned to near initial pressure
CO_2-EOR initiated 2008 with coincident pressure monitoring
Hosted by **Denbury Resources**

SECARB
Southeast Regional Carbon Sequestration Partnership

SSEB

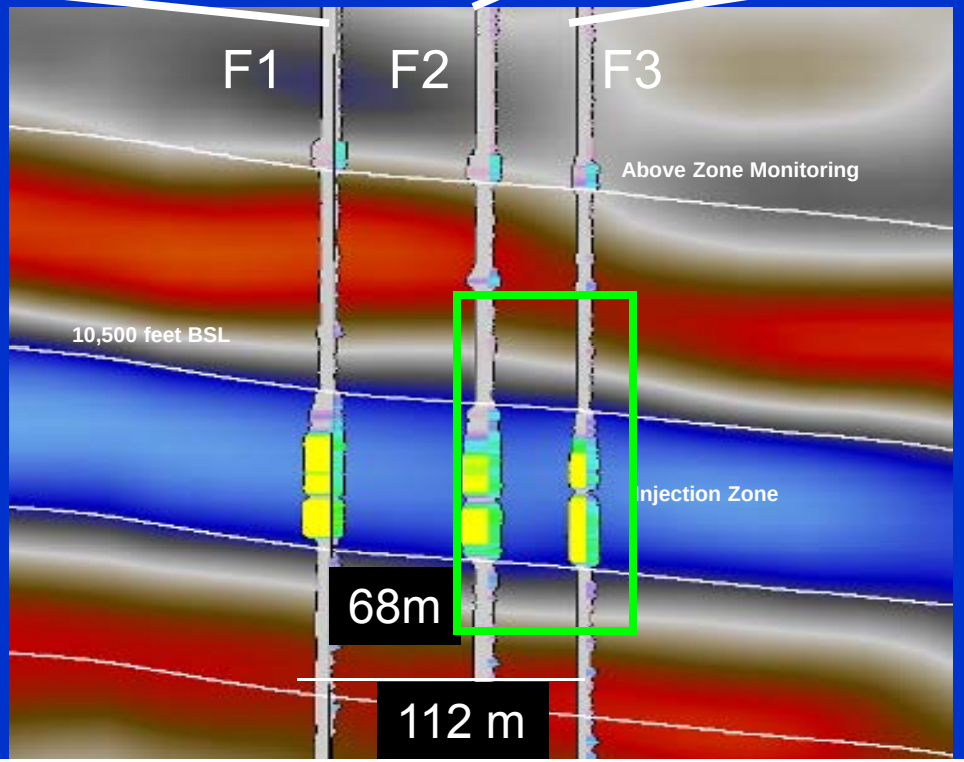
NETL

Southern States Energy Board
Ken Nemeth Dir, Jerry Hill PI
Bruce Brown NETL manager

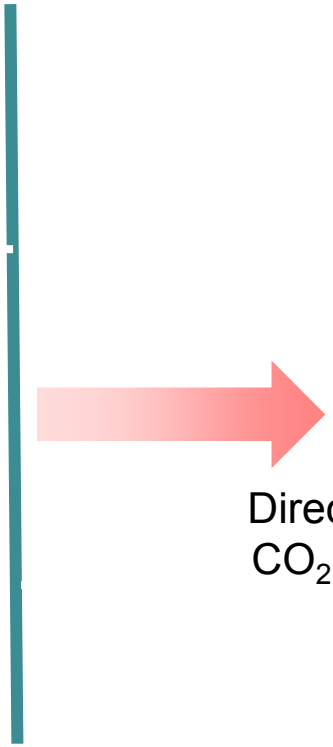
Research collaborators: Denbury Onshore LLC site host LBNL, LLNL, ORNL, USGS NETL, Mississippi State, University of Mississippi, Schlumberger, Sandia Technologies, Pinnacle, QEA

Cranfield DAS Monitoring

Closely spaced well array to examine flow in complex reservoir

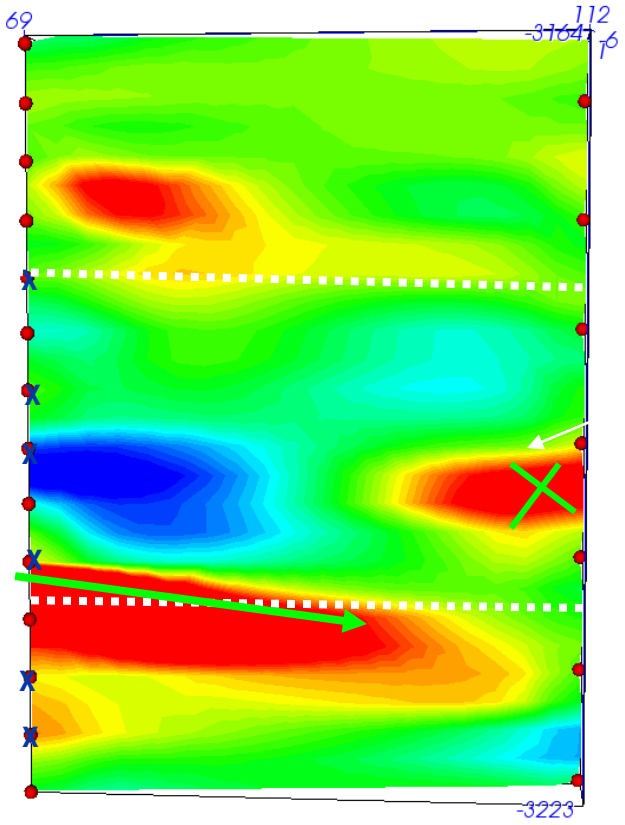


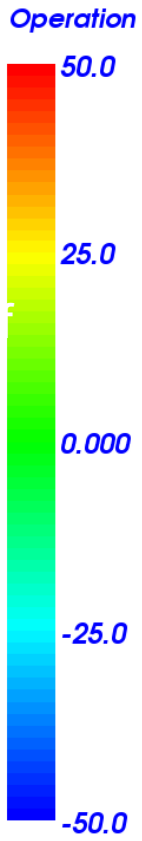
Cross Well ERT tells us how flow occurred



Injector

Direction of CO_2 plume

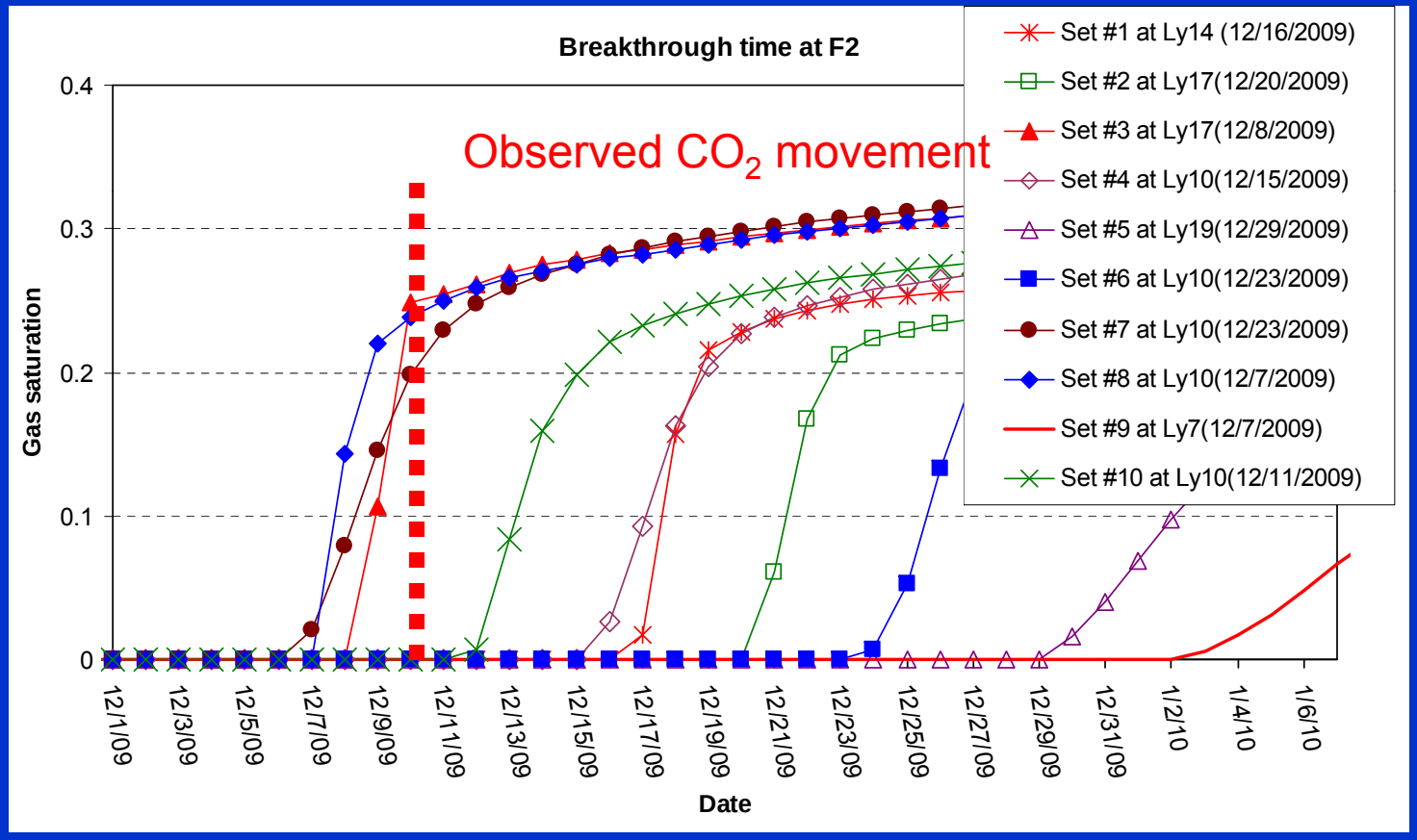




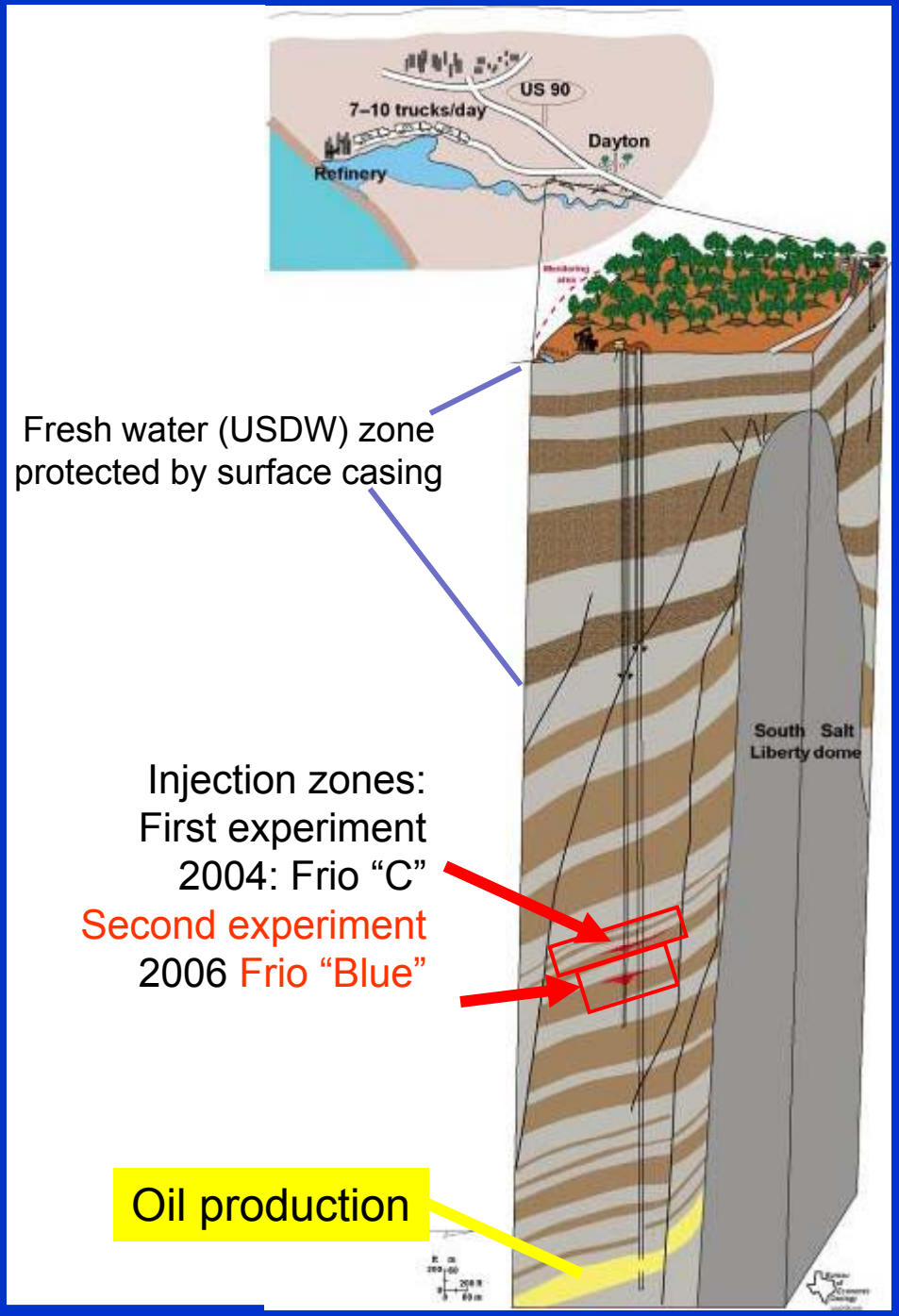
Resistive plume = CO2 in reservoir

Charles Carrigan, LLNL

Fluid flow observed falls in the modeled range

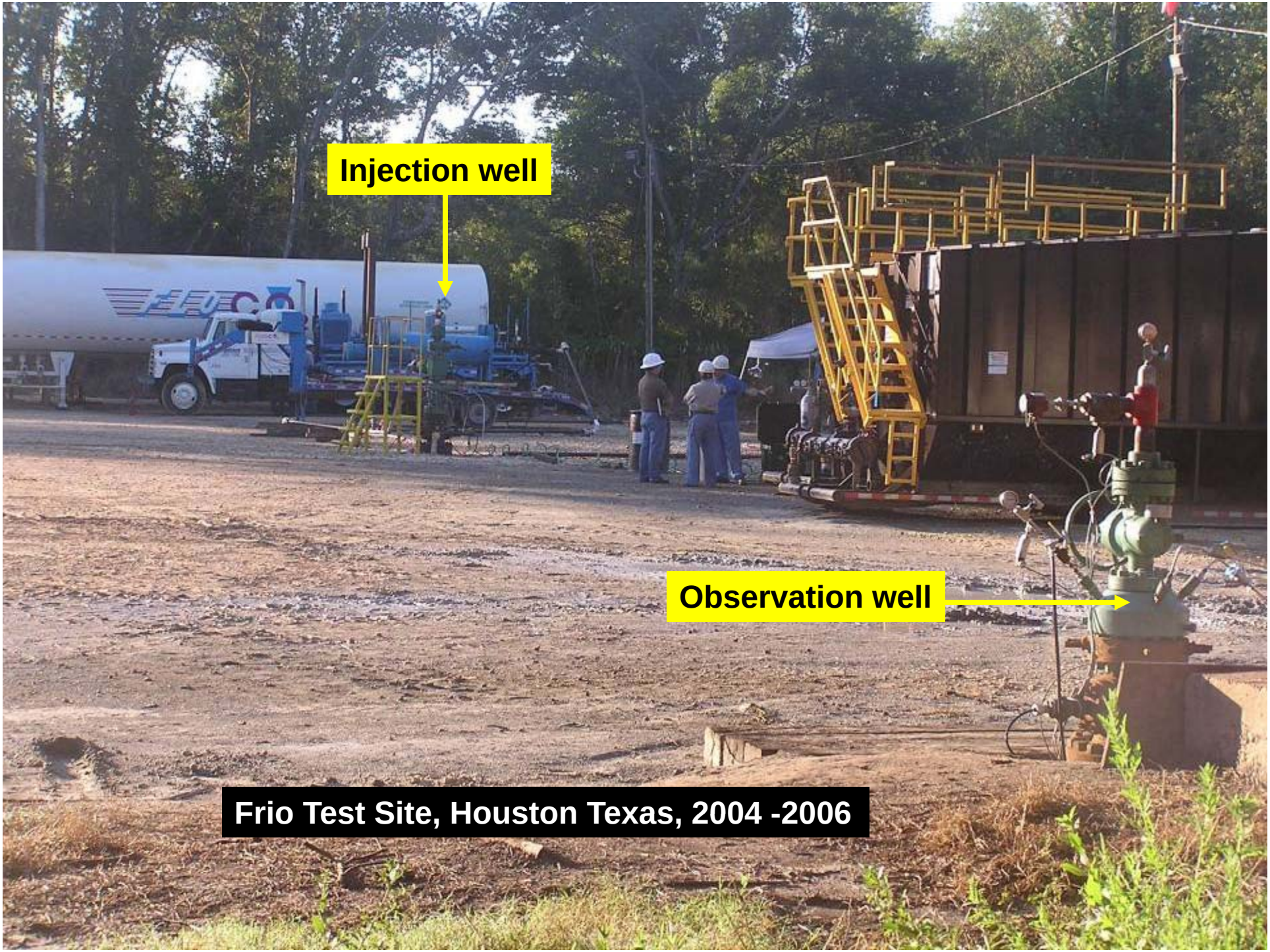


Jong-won Choi and JP Nicot BEG

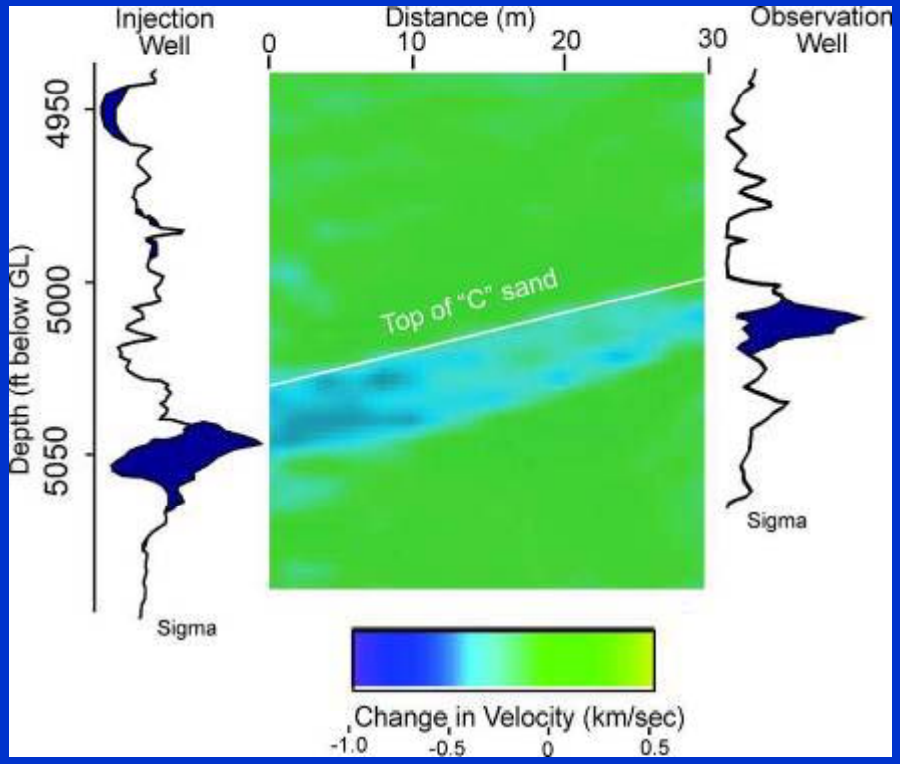


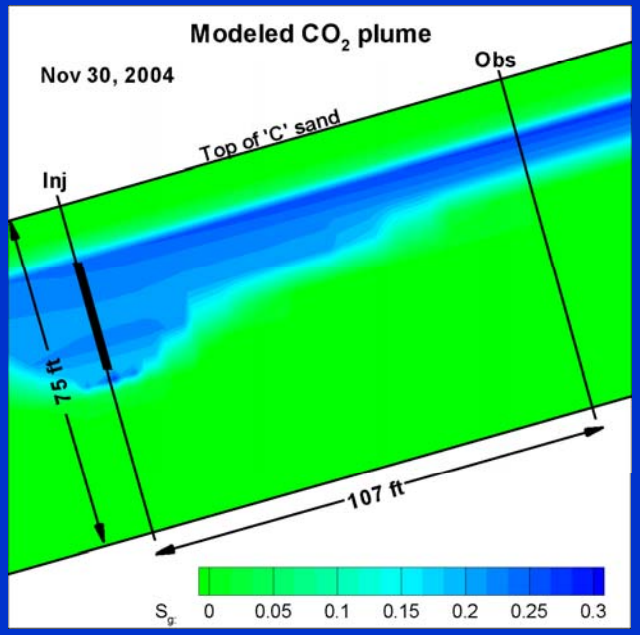
Frio Brine Pilot Site tests Near Houston TX

- **High Permeability**
  - **4.4 to 2.5 Darcys**
- **Steeply dipping**
  - **11 to 16 degrees**


Injection well
Observation well
Frio Test Site, Houston Texas, 2004 -2006

CO_2 Saturation Observed with Cross-well Seismic Tomography vs. Modeled

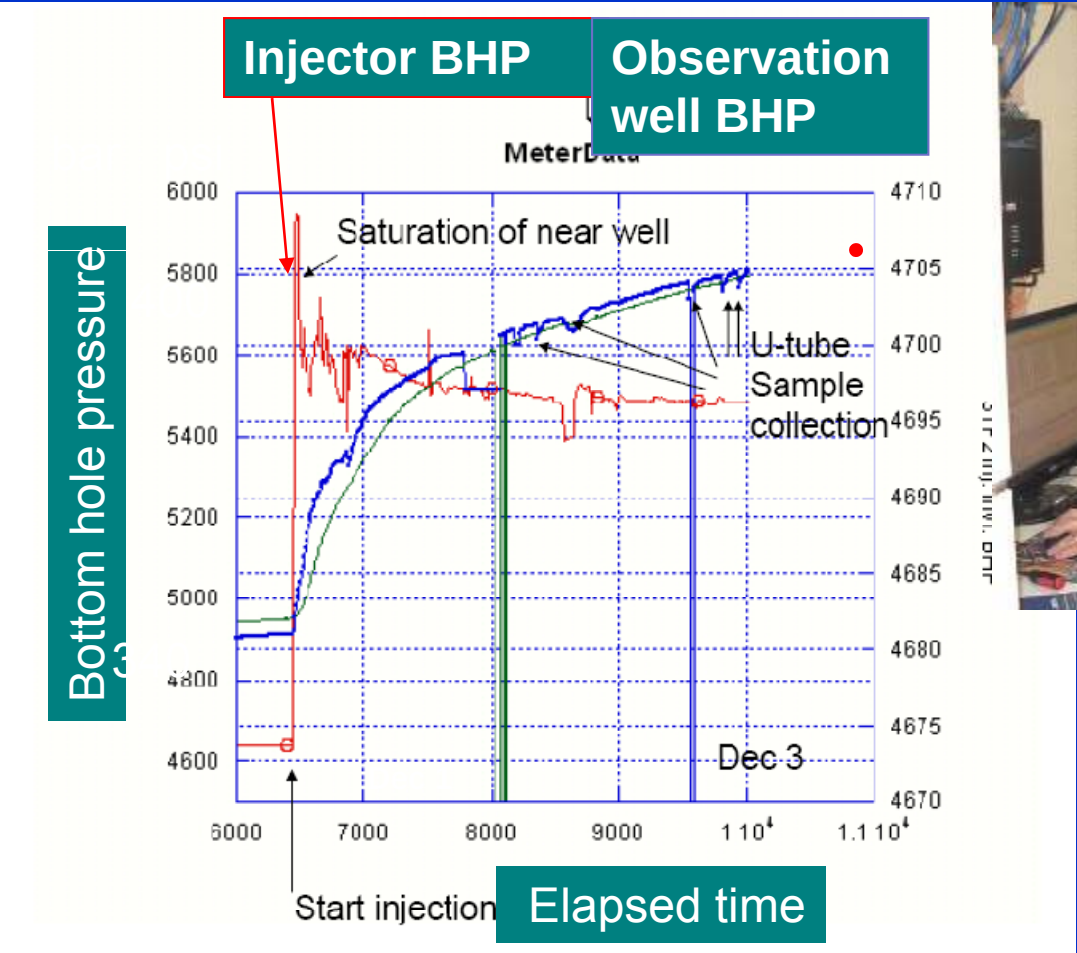




Tom Daley and Christine Doughty LBNL

Pressure as a powerful tool for monitoring

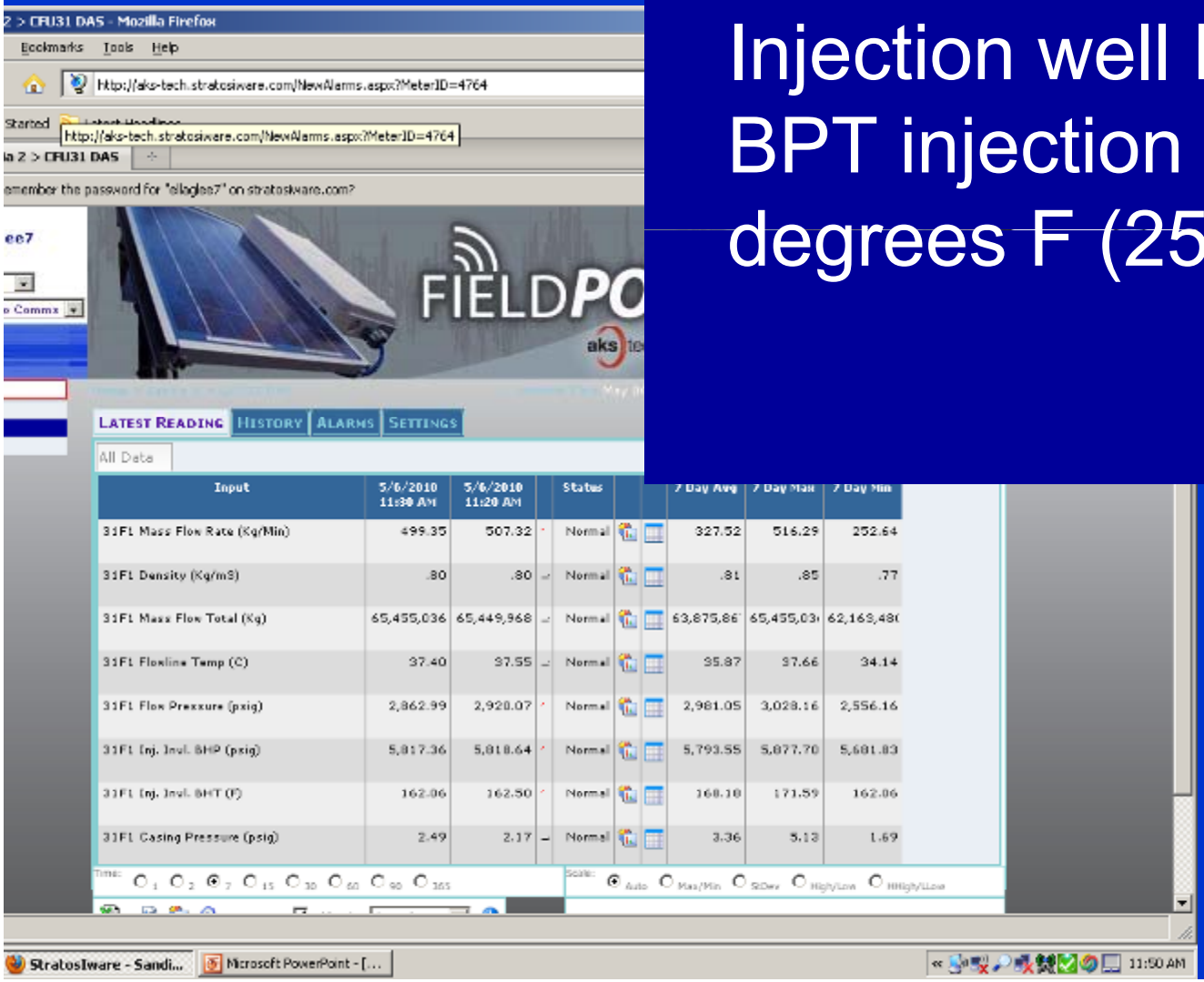
Start injection at DAS Dec 1, 2009



It's all about pressure

Real-time data from DAS

- Mass flow increased to 507
  Injection well BHP 5,818 psi
  BPT injection well 162 degrees F (252 F original)

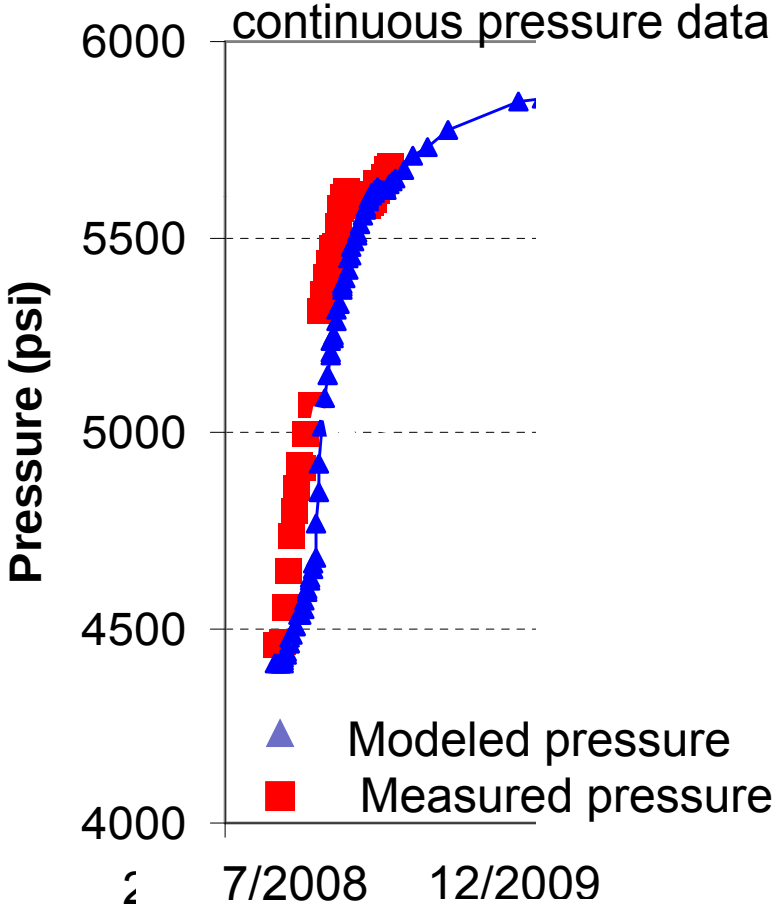


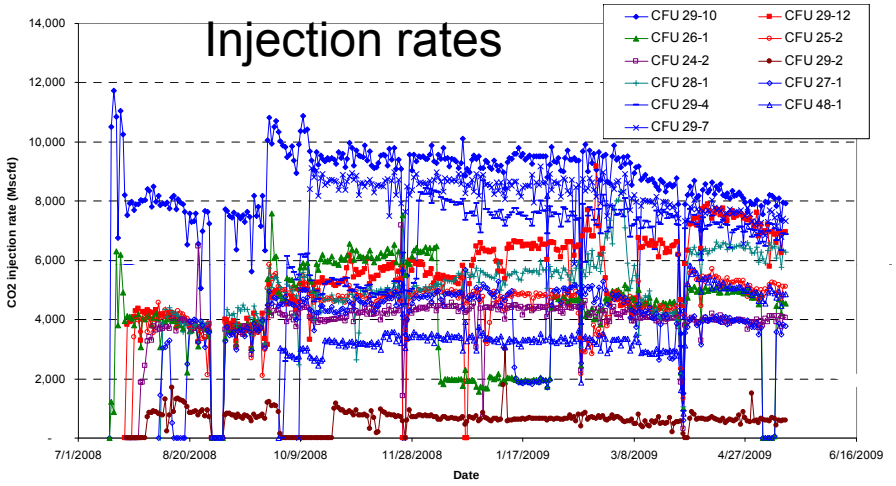
Fluid Displacement as a Limit on Capacity

- Depends on boundary conditions

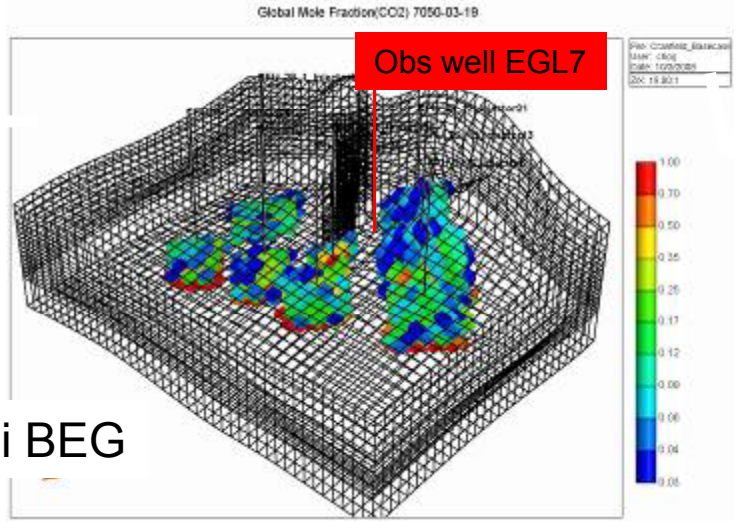
Model –history match pressure at real-time monitoring well

Results of 1 year model continuous pressure data



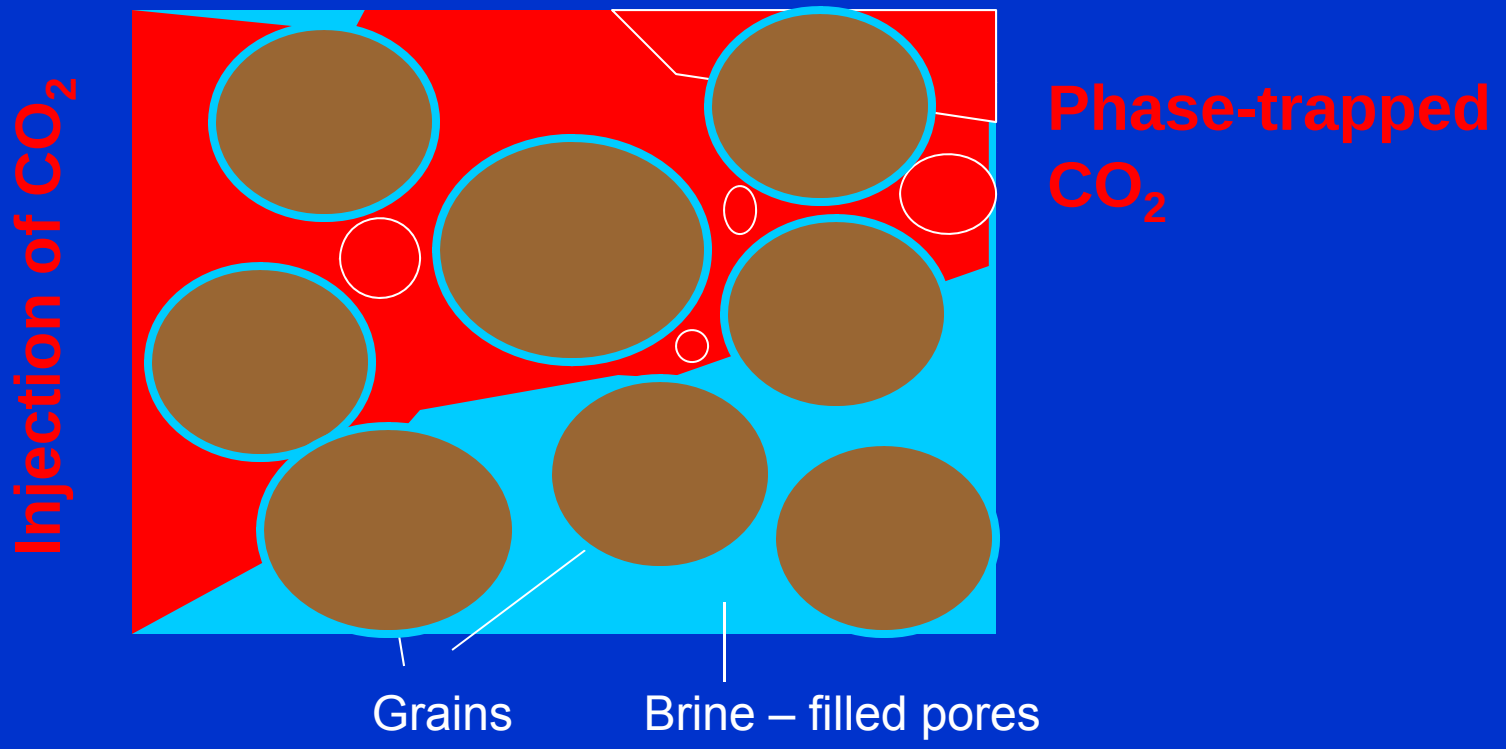


Rock and fluid properties in simulator

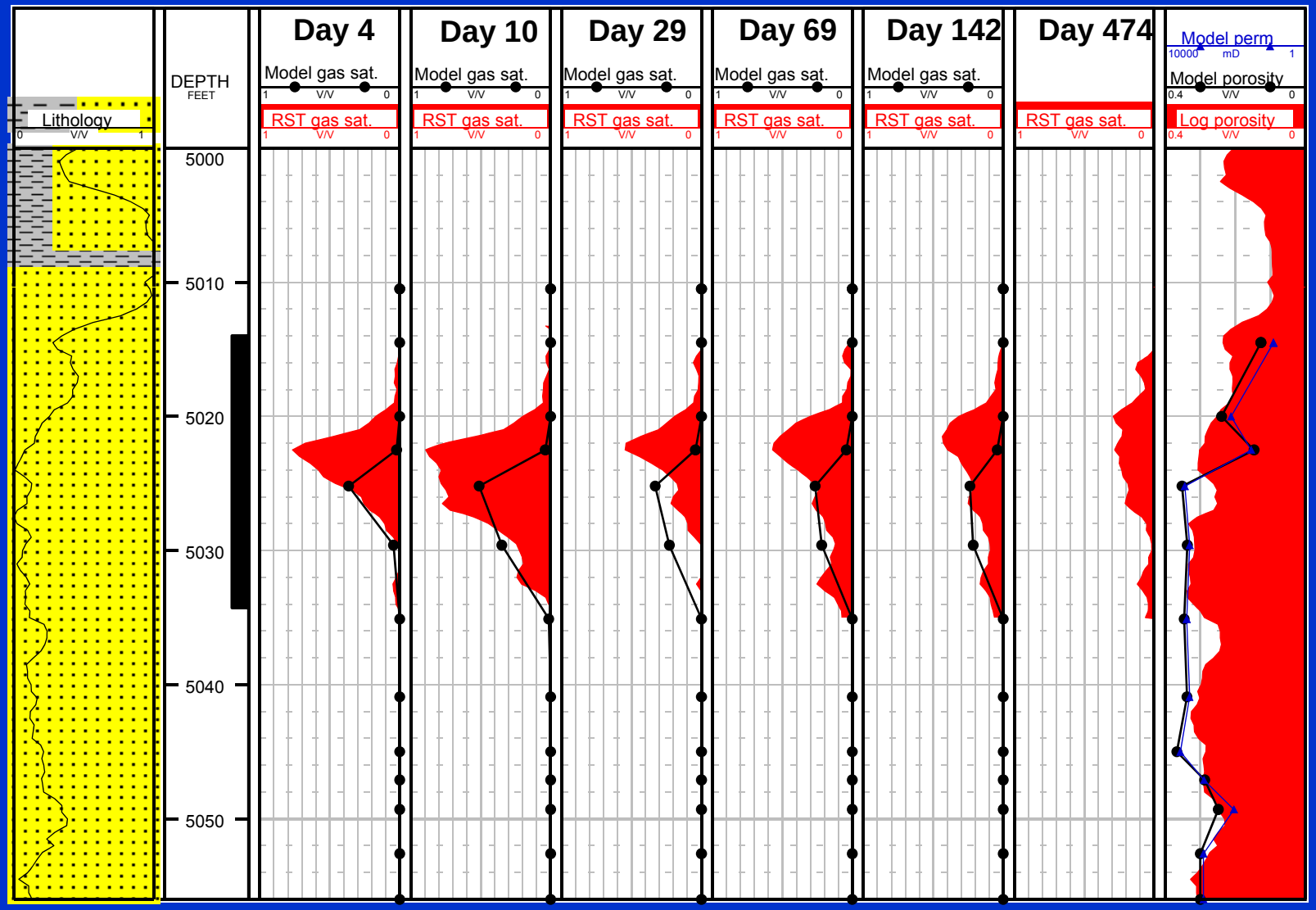


JP Nicot Jong Won Choi BEG

Assurance Permanence via Phase Trapping – the power of capillary pressure



Measurement at a Well:
Saturation logging (RST) Observation well to measure changes in CO_2 saturation – match to model



Shinichi Sakurai, Jeff Kane, Christine Doughty

How CO_2 dissolved in aquifers could damage water quality

CO_2 dissolves in water = dissolution trapping

$$CO_2(g) + H_2O \leftrightarrow H_2CO_3(aq)$$
$$H_2CO_3(aq) \leftrightarrow HCO_3(aq)^- + H^+$$
$$HCO_3(aq)^- \leftrightarrow CO_3(aq)^{--} + H^+(aq)$$

Acid= tang in carbonated water

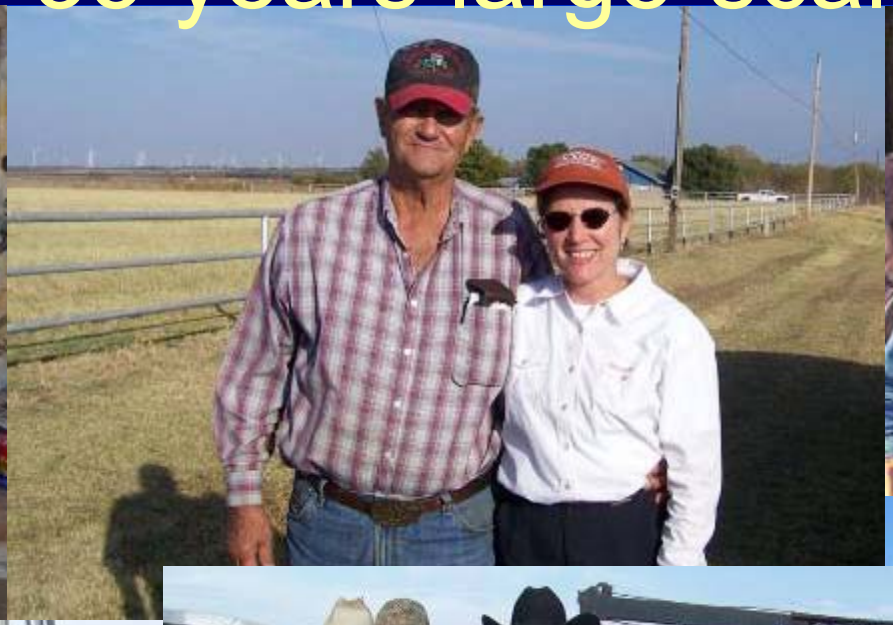
Acid is buffered by rock-water interaction

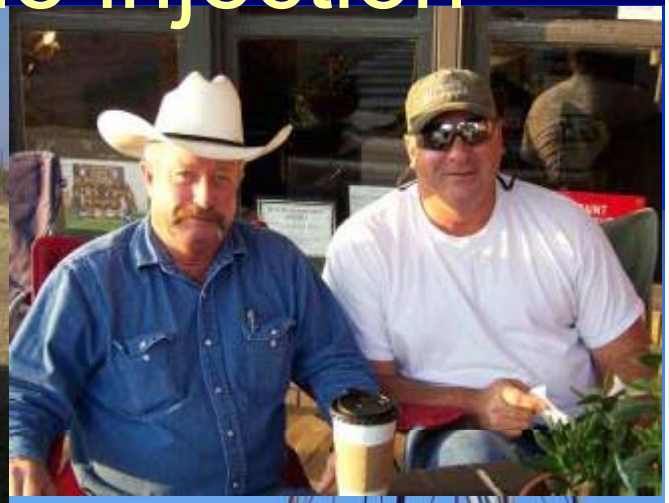
increase Ca, Mg, Fe, Na, Si, HCO_3, SO_4, etc. in solution

What could the etc. be?

Mn, As, Pb, Sr, Ni, Zn, Ag, U, Ni, Cd……

SACROC- testing fresh water after 35 years large-scale injection





Smyth, BEG 2009

Fresh water quality at SACROC undamaged

- CO_2 injection at 6000-7000 ft
- Fresh water at <1000 feet
- No systematic compositional changes in fresh water through time or by comparison to region
- However, complex natural and manmade processes in fresh water limit ability to detect CO_2, should it leak into fresh water.

Goals of monitoring at a long term, full scale commercial project

- Confirm that the predictions of containment made based on site characterization at the time of permitting are valid
- Confidence to continue injection is gained from monitoring observations that are reasonably close to model predictions
- Confirm that no unacceptable consequences result from injection.
- Monitoring during injection should be designed to prove-up confinement so that monitoring frequency could be diminished through the life of the project and eventually stopped, allowing the project to be closed.

Gulf Coast Carbon Center (GCCC)

Gulf Coast Carbon Center

BEG Team

Scott Tinker
Ian Duncan
Sue Hovorka
Tip Meckel
J. P. Nicot
Rebecca Smyth
Ramon Trevino
Katherine Romanak
Changbing Yang
Dave Carr
Jiemin Lu
Jong Won Choi
Woodong Yung
Carey King students
and others

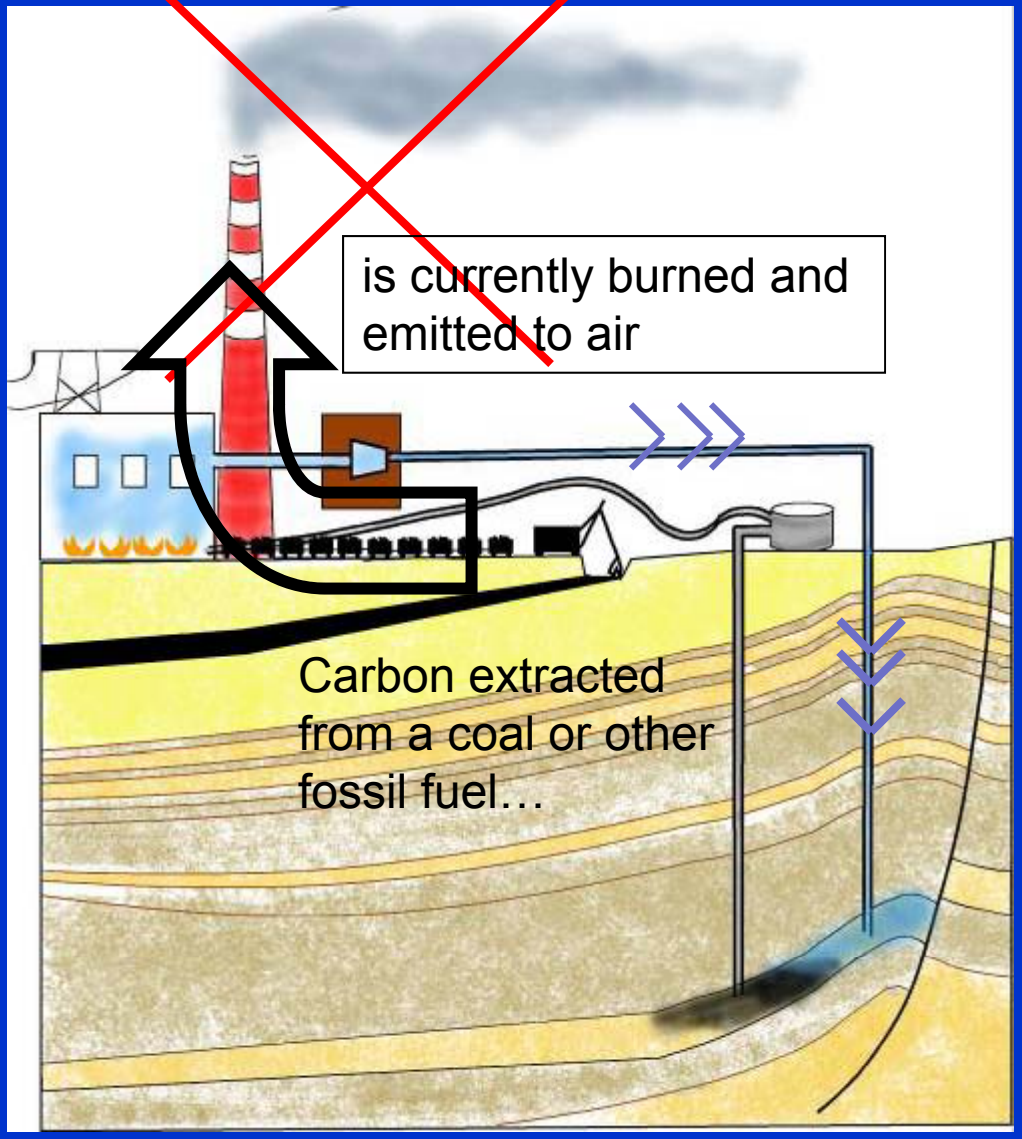
Collaborators

BEG- CEE
LBNL
LLNL
ORNL
USGS
New Mexico Tech
Mississippi State U
U of Mississippi
SECARB
SWP
UT-PGE
UT- CCEP
UT- DoGS
Univ Edinburgh

IA sponsors

bp
Chevron
MARATHON
KINDER MORGAN
Schlumberger
Saudi Aramco
ConocoPhillips
Luminant
ExxonMobil
Entergy
AUSTIN ENERGY
LCRA
JACKSON SCHOOL OF GEOSCIENCES
EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

If you use carbon .. Put it back



To reduce CO_2 emissions to air from stationary (point) sources

CO_2 is captured as concentrated high pressure fluid by one of several methods..

CO_2 is shipped as supercritical fluid via pipeline to a selected, permitted injection site

CO_2 injected at pressure into pore space at depths below and isolated (sequestered) from potable water.

CO_2 stored in pore space over geologically significant time frames.

www.gulfcoastcarbon.org

Gulf Coast Carbon Center