

A nighttime photograph of an oil well rig. The rig is illuminated by several bright lights, creating a stark contrast against the dark sky. A sign on the rig reads "NICKLOS". The rig is a complex structure of metal beams and scaffolding, extending upwards into the night.

Update on the Frio Brine Pilot: 15 months after injection

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Presented at RITE
International Workshop,
Tokyo, February 2006

Frio Brine Pilot Research Team

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- Schlumberger: T. S. Ramakrishna, Nadja Mueller, Austin Boyd, Mike Wilt
- Oak Ridge National Lab: Dave Cole, Tommy Phelps, David Riestberg
- Lawrence Livermore National Lab: Kevin Knauss, Jim Johnson
- Alberta Research Council: Bill Gunter, John Robinson, Bernice Kadatz
- Texas American Resources: Don Charbula, David Hargiss
- Sandia Technologies: Dan Collins, “Spud” Miller, David Freeman; Phil Papadeas
- BP: Charles Christopher, Mike Chambers
- SEQURE – National Energy Technology Lab: Curt White, Rod Diehl, Grant Bromhall, Brian Stratizar, Art Wells
- Paulsson Geophysical – Bjorn Paulsson
- University of West Virginia: Henry Rausch
- USGS: Yousif Kharaka, Bill Evans, Evangelos Kakauros, Jim Thorsen
- Praxair: Joe Shine, Dan Dalton
- Australian CO2CRC (CSIRO): Kevin Dodds, Don Sherlock
- Core Labs: Paul Martin and others



Frio Experiment: Monitoring CO₂ Storage in Brine-Bearing Formations

Project Goal: Early success in a high-permeability, high-volume sandstone representative of a broad area that is an ultimate target for large-volume sequestration.

- **Demonstrate that CO₂ can be injected into a brine formation without adverse health, safety, or environmental effects**
- **Determine the subsurface distribution of injected CO₂ using diverse monitoring technologies**
- **Demonstrate validity of conceptual and numerical models**
- **Develop experience necessary for success of large-scale CO₂ injection experiments**

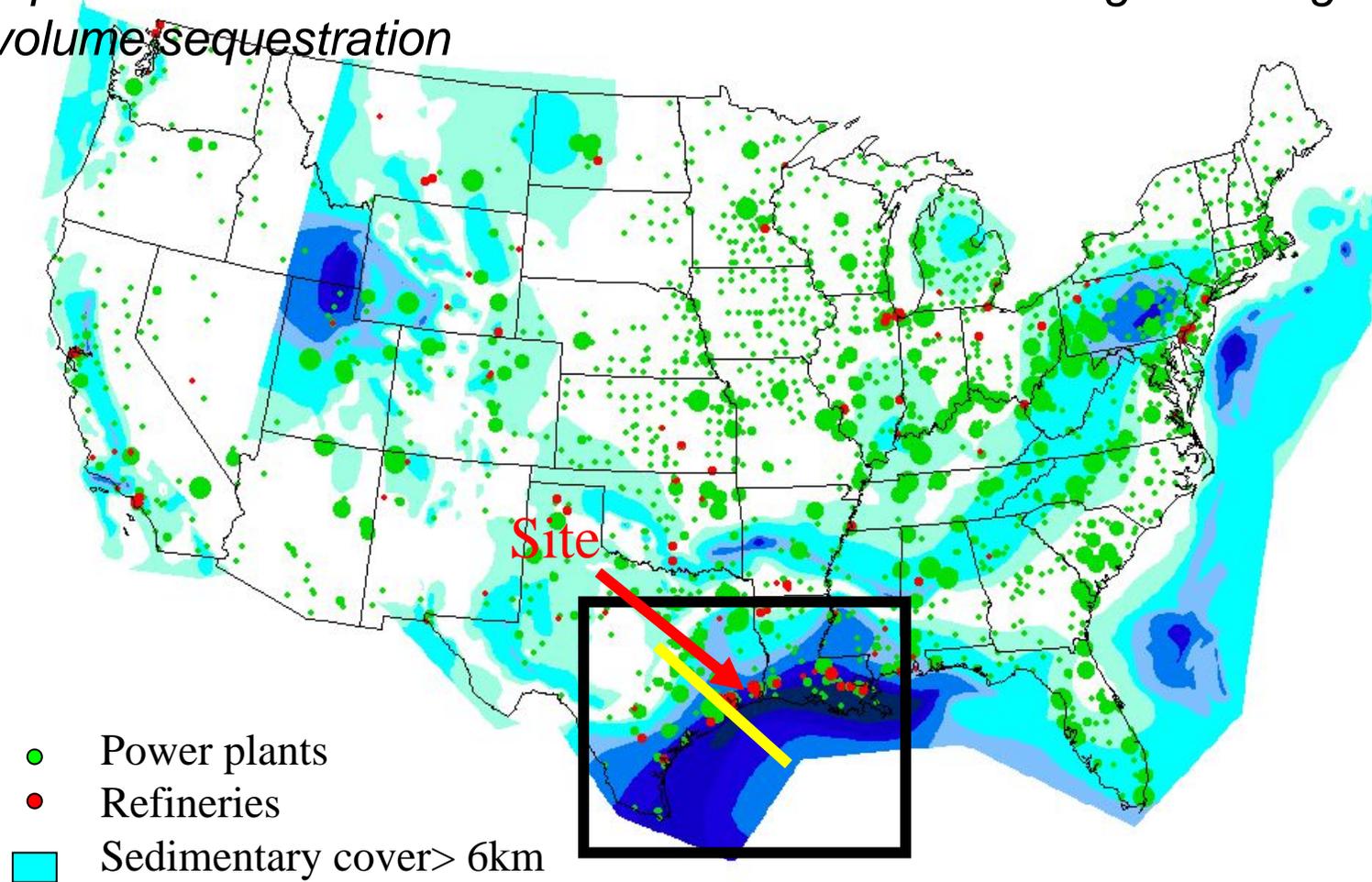
Frio Experiment: Status of Results

1600 metric tons CO₂ was introduced into well-characterized relatively homogenous high permeability sandstone system characteristic of the Gulf Coast region of the US and monitored before, during, and after injection

- Vigorous public/industry outreach - favorable response
- Saturation and transport properties measured horizontally, vertically, and through time using multiple tools
- Improved model conceptual and numerical inputs
- Make results available to US and international field projects, **compare results**
- Frio 2 injection is planned for May 2006

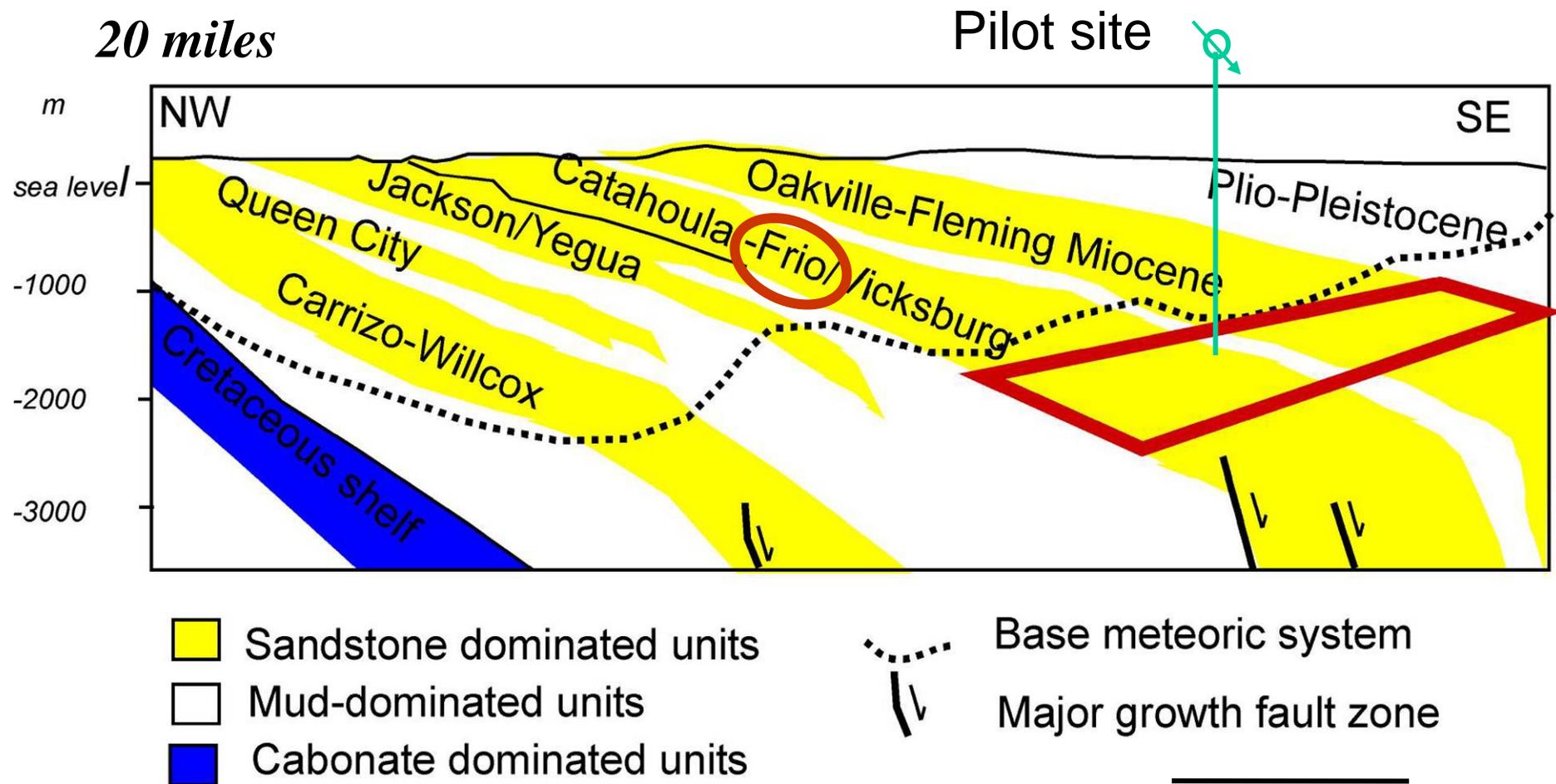
Site Search

Locating a high-permeability, high-volume sandstone representative of a broad area that is an ultimate target for large-volume sequestration



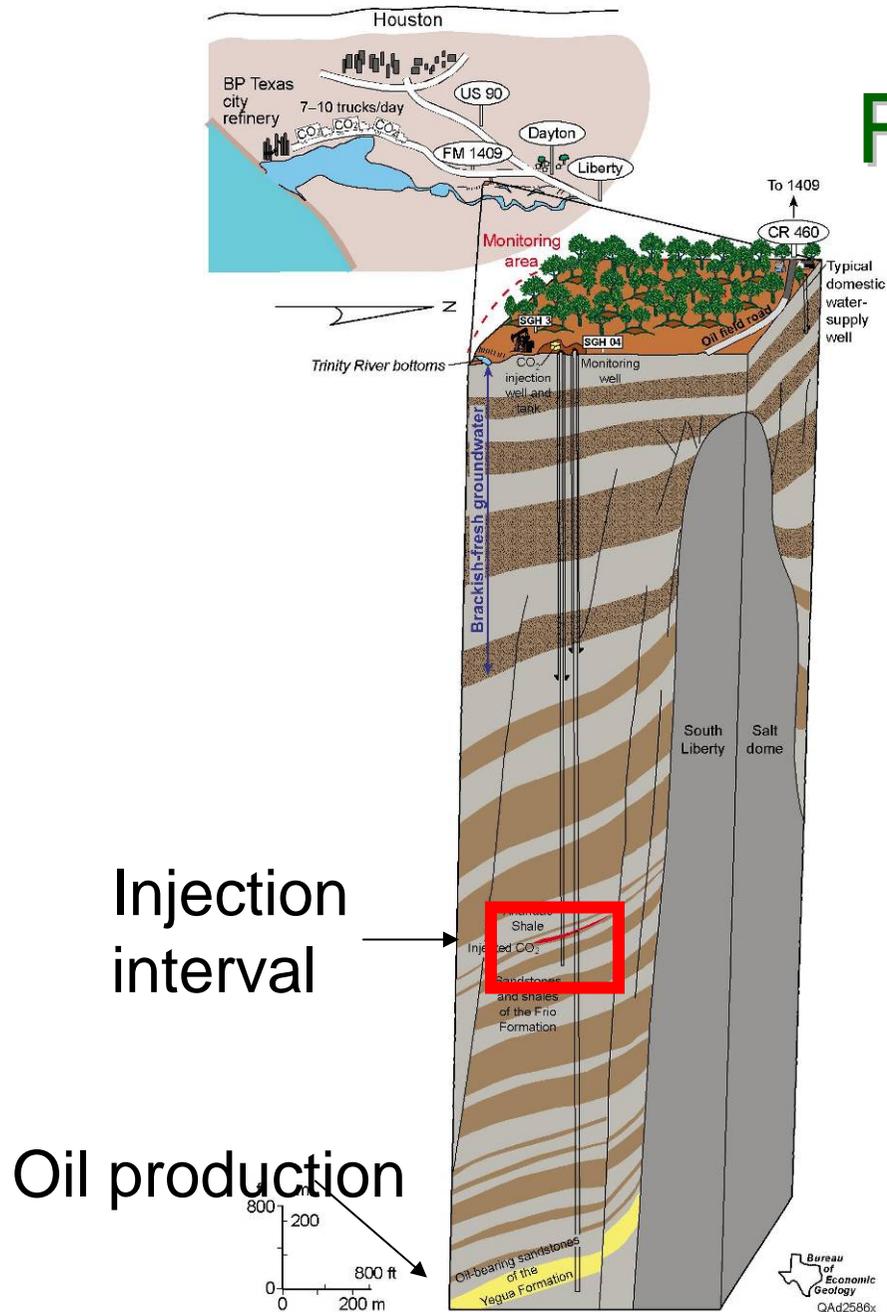
Sources: USGS, IEA Source database

Regional Geologic Setting – Cross Section



Modified from Galloway and others, 1982

Frio Brine Pilot Site

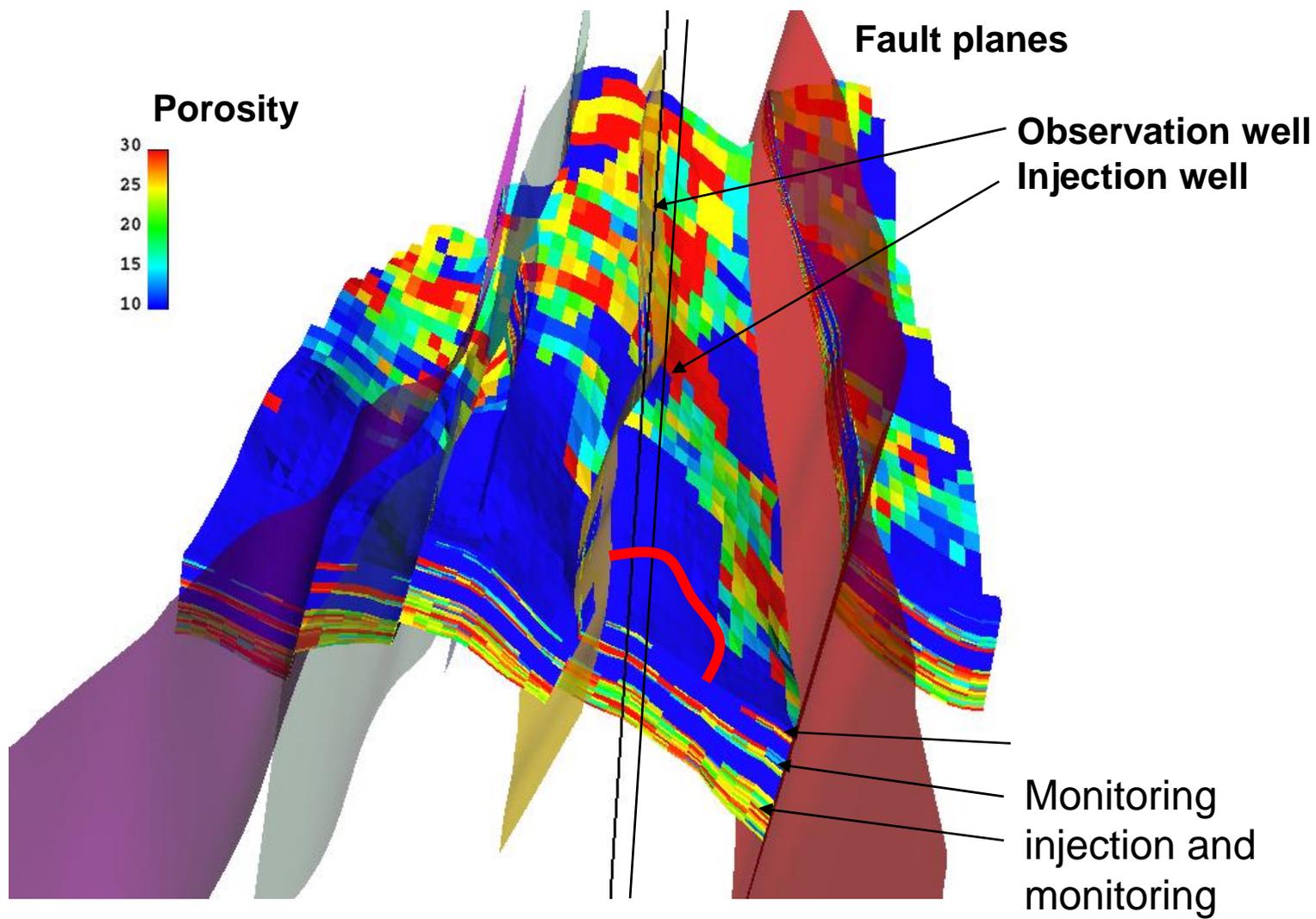


Injection interval

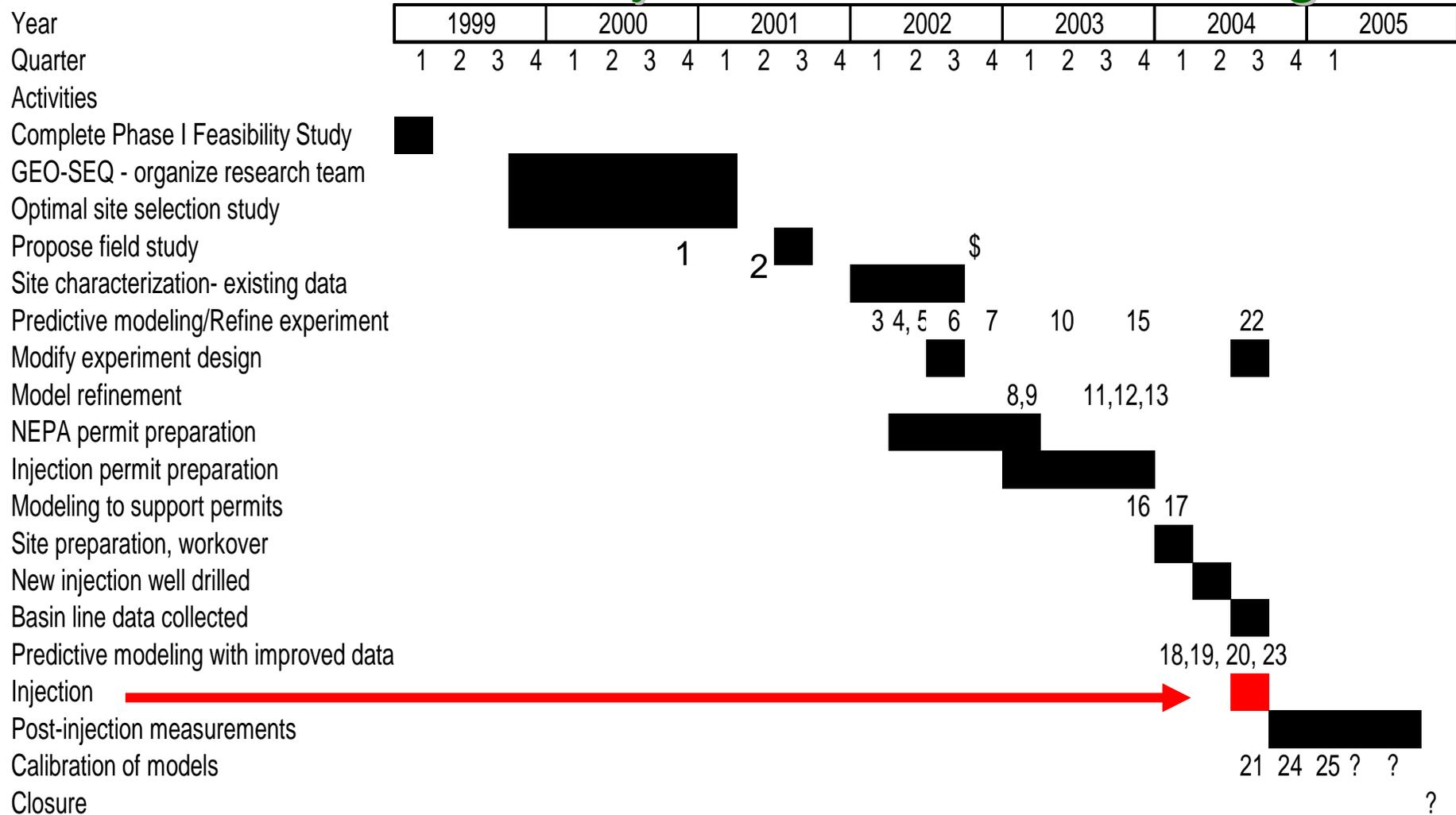
Oil production

- Injection interval: 24-m-thick, mineralogically complex Oligocene reworked fluvial sandstone, porosity 24%, Permeability 2.5 Darcys
- Steeply dipping 18 degrees
- 7m perforated zone
- Seals – numerous thick shales, small fault block
- Depth 1,500 m
- Brine-rock system, no hydrocarbons
- 150 bar, 53 degrees C, supercritical CO₂

Reservoir Model

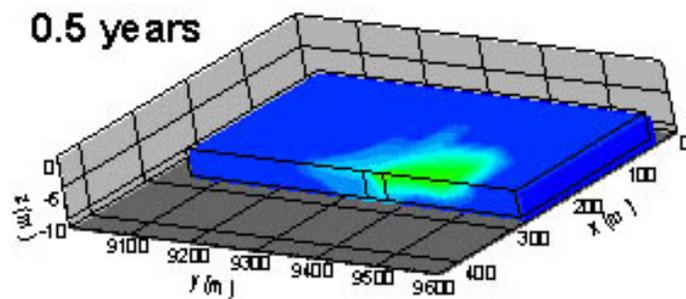


Evolution of Frio Project – Role of Modeling

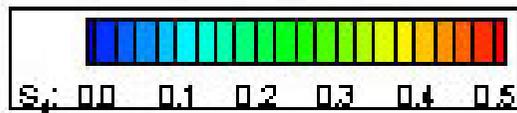
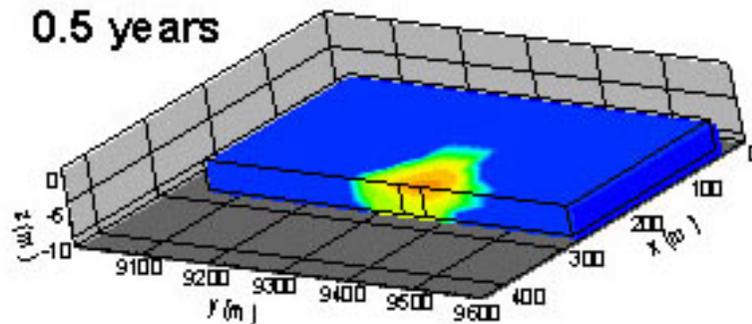


How Modeling and Monitoring Demonstrate Permanence

Residual gas saturation of 5%

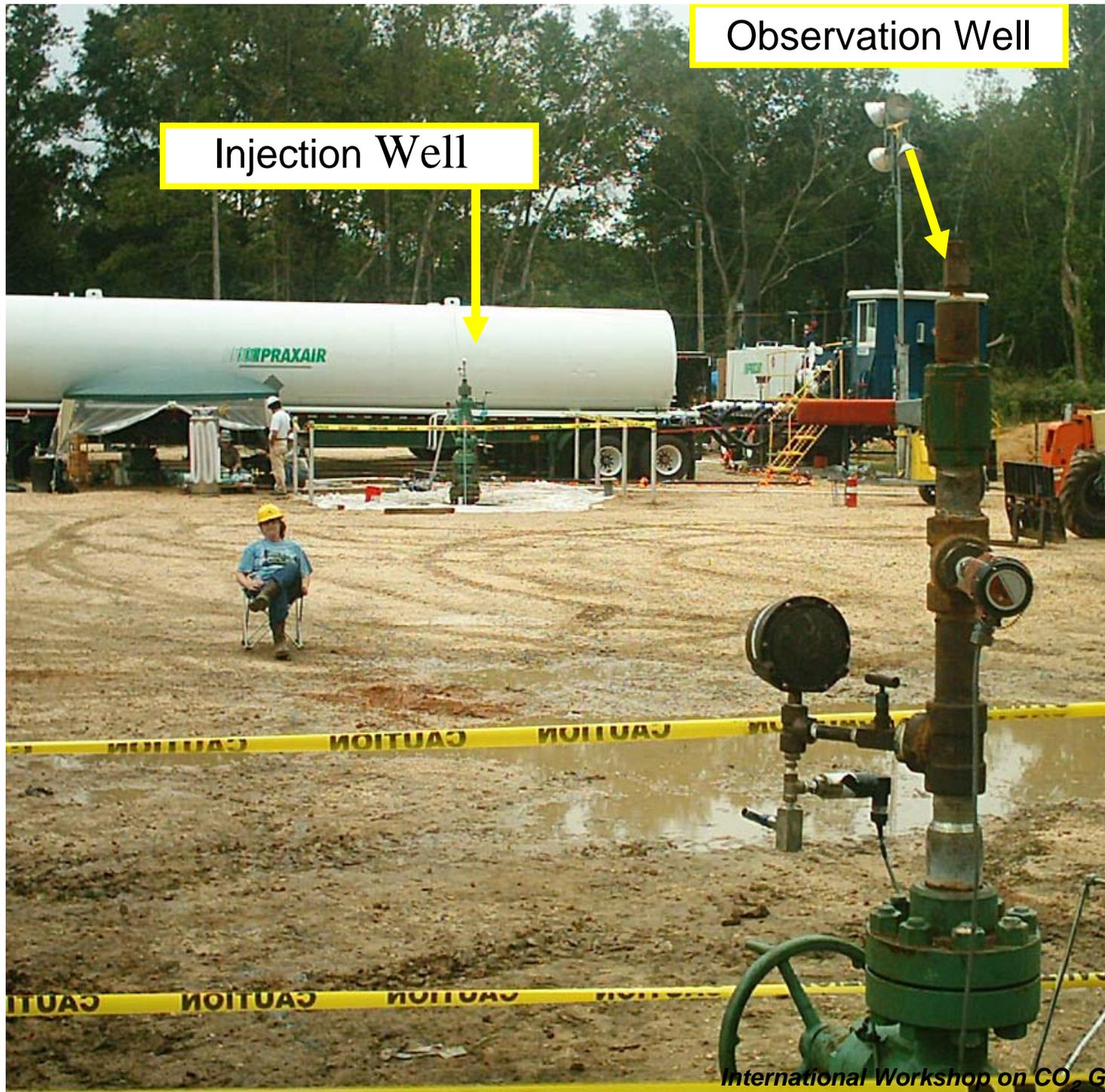


Residual gas saturation of 30%



- Modeling has identified variables which appear to control CO_2 injection and post injection migration.
- Measurements made over a short time frame and small distance confirm the correct value for these variables
- Better conceptualized and calibrated models will now be used to develop larger scale longer time frame injections

TOUGH2 simulations
C. Doughty LBNL

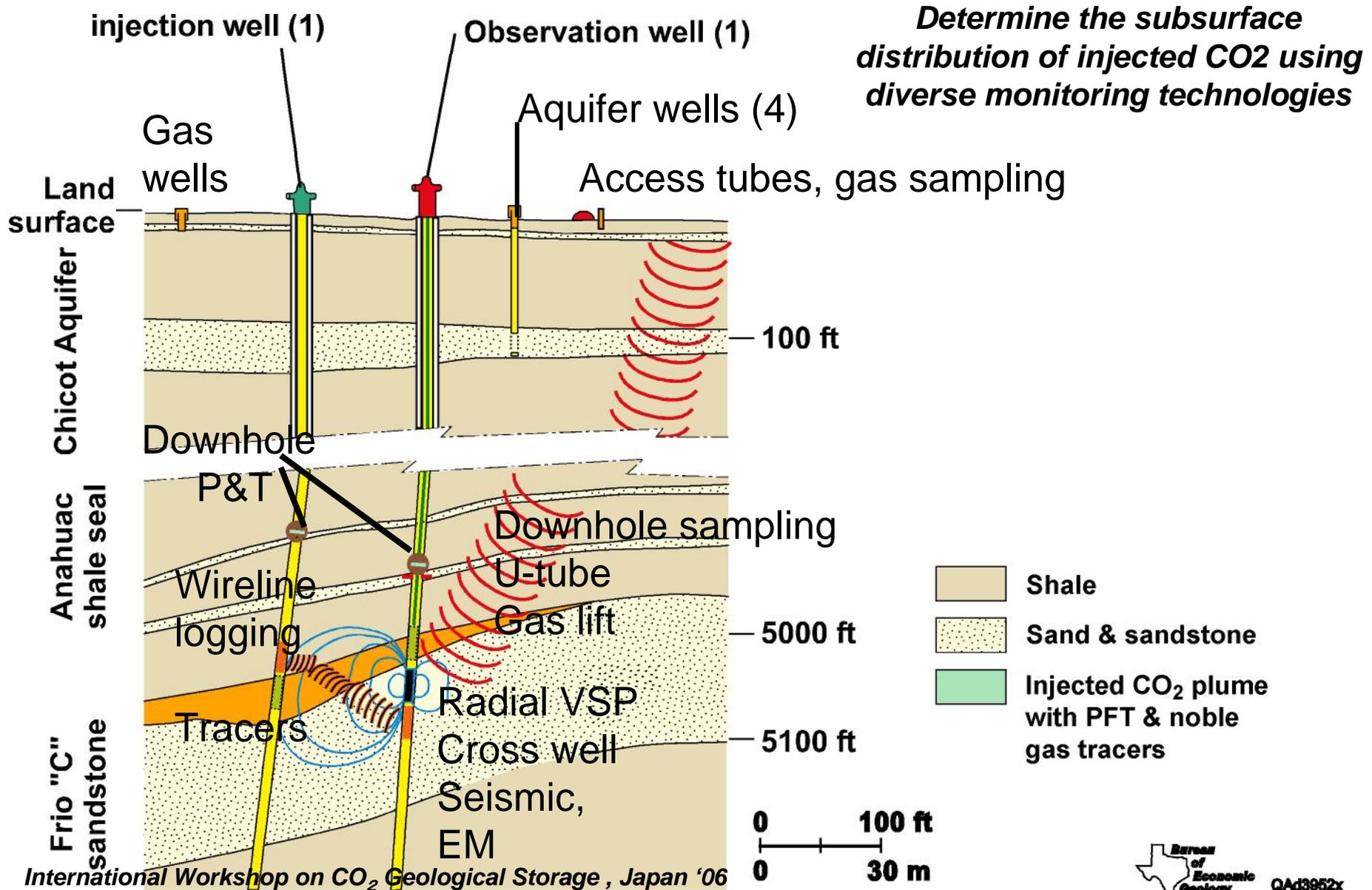


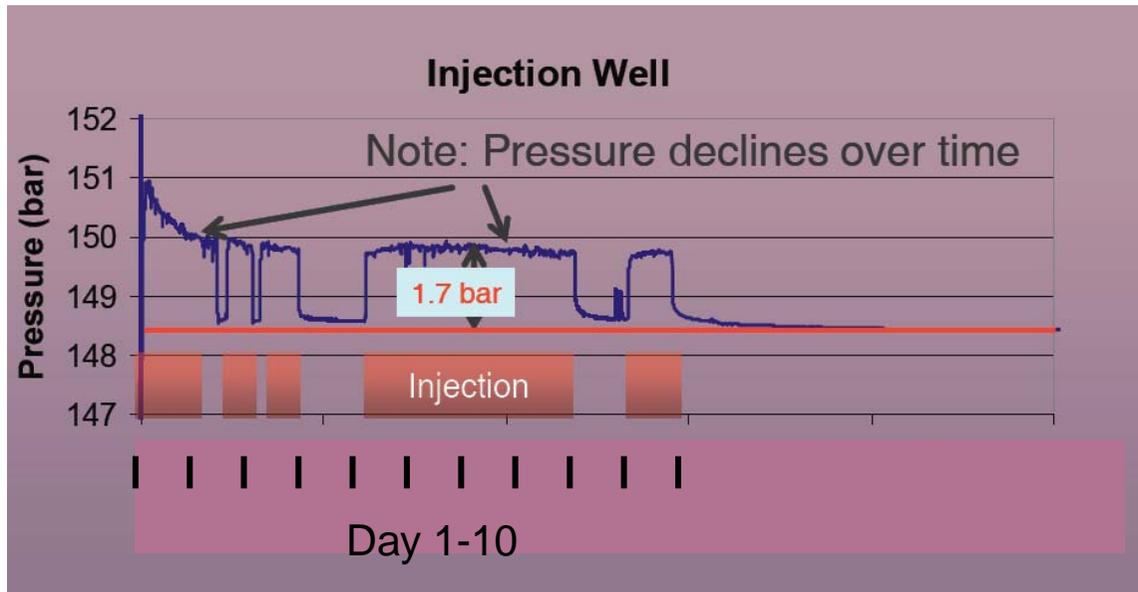
Observation Well

Injection Well

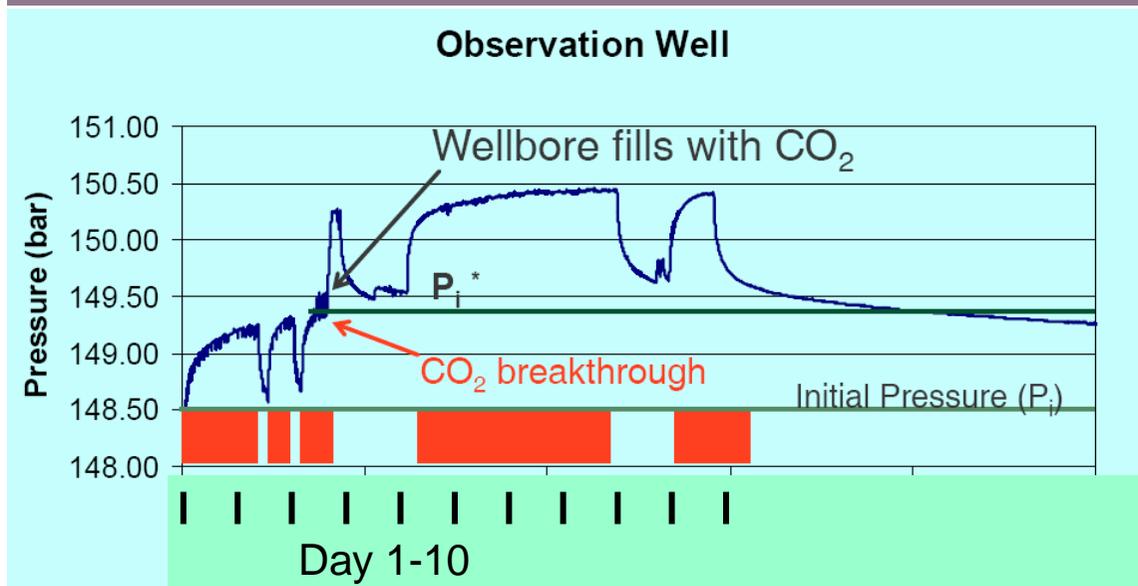
*Closely spaced
measurements
in time and space*

Monitoring at Frio Pilot



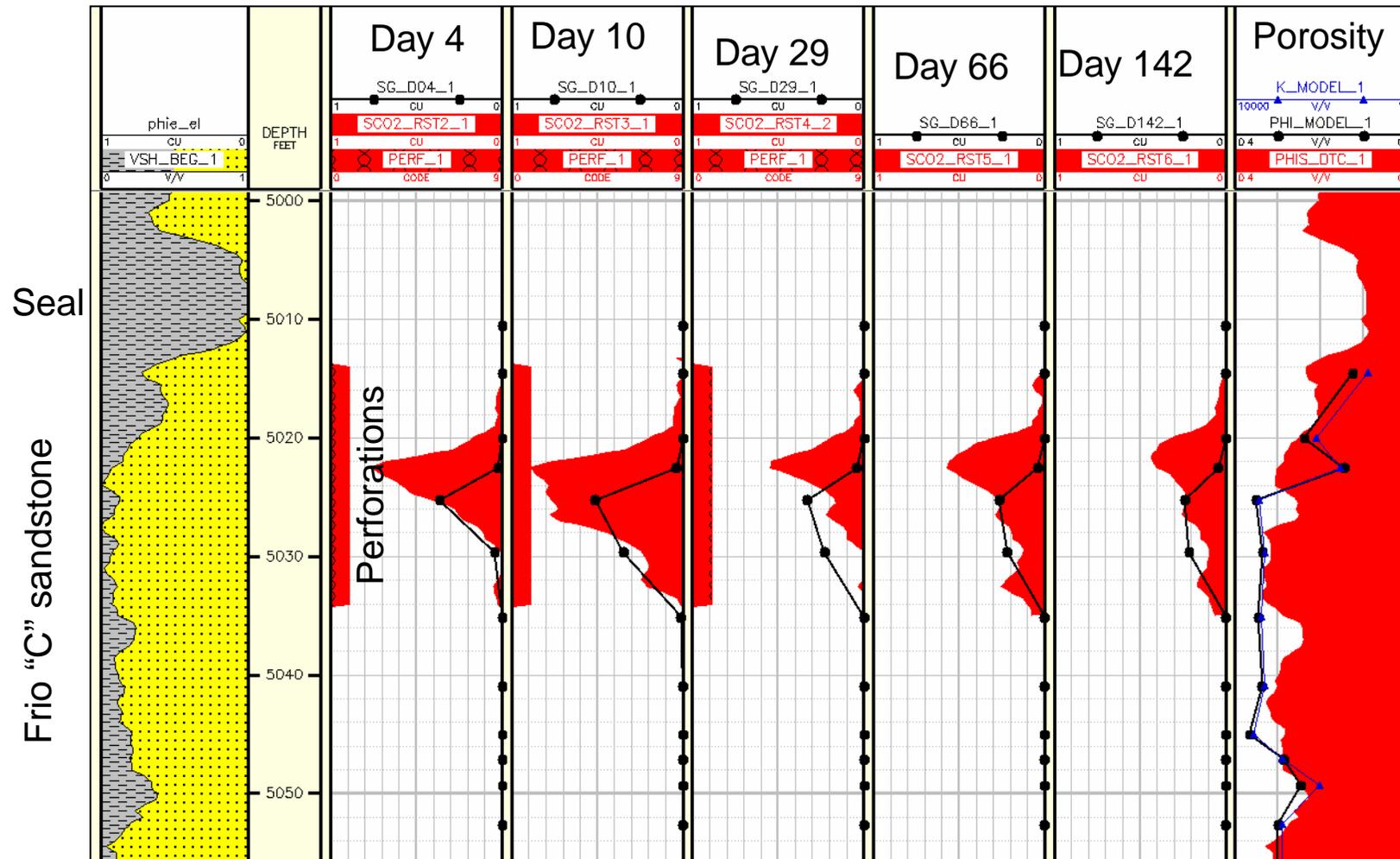


*Pressure response:
A powerful and low-cost
measurement
of reservoir properties*



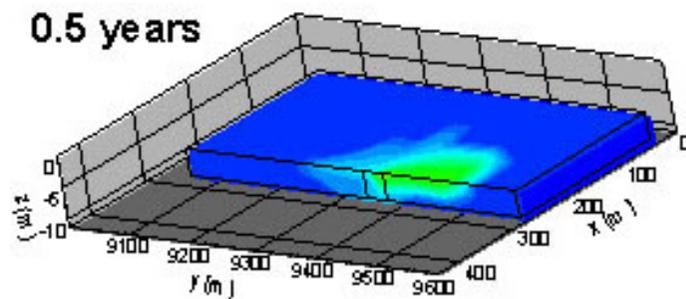
Sally Benson

Wireline logging observation well to measure changes in CO₂ saturation – match to model

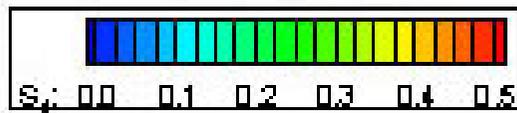
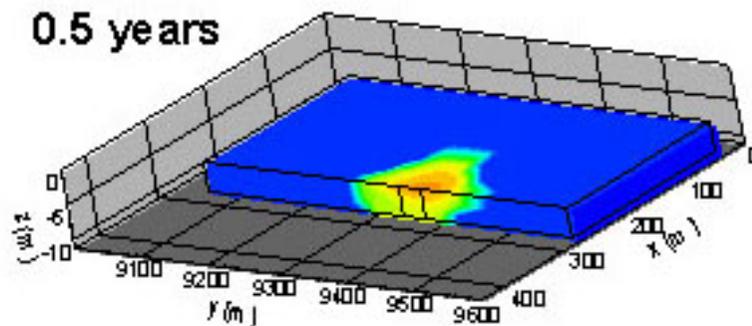


How Modeling and Monitoring Demonstrate Permanence

Residual gas saturation of 5%



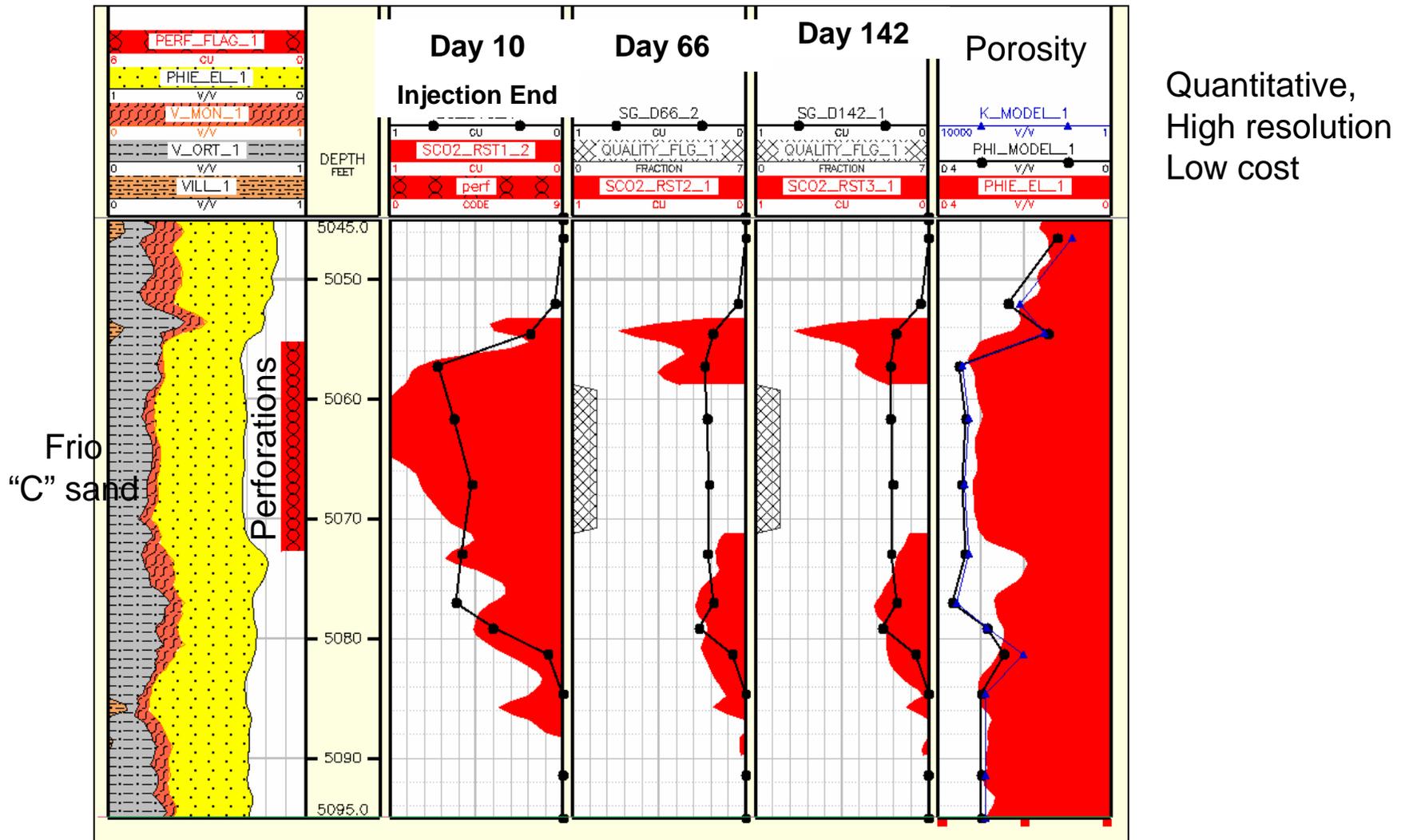
Residual gas saturation of 30%



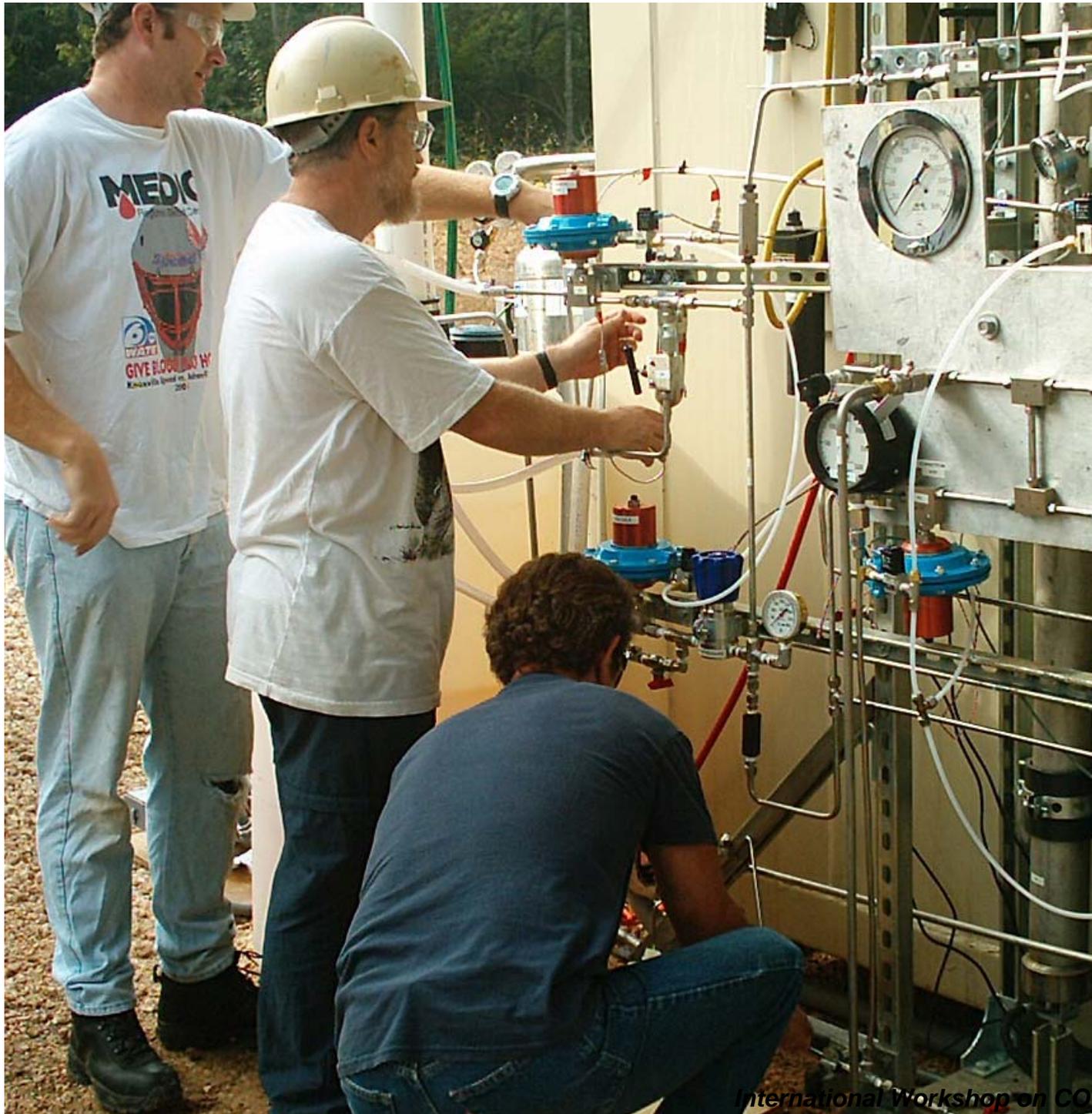
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TOUGH2 simulations
C. Doughty LBNL

Wireline logging to measure changes in CO₂ saturation – match to model



Quantitative,
High resolution
Low cost



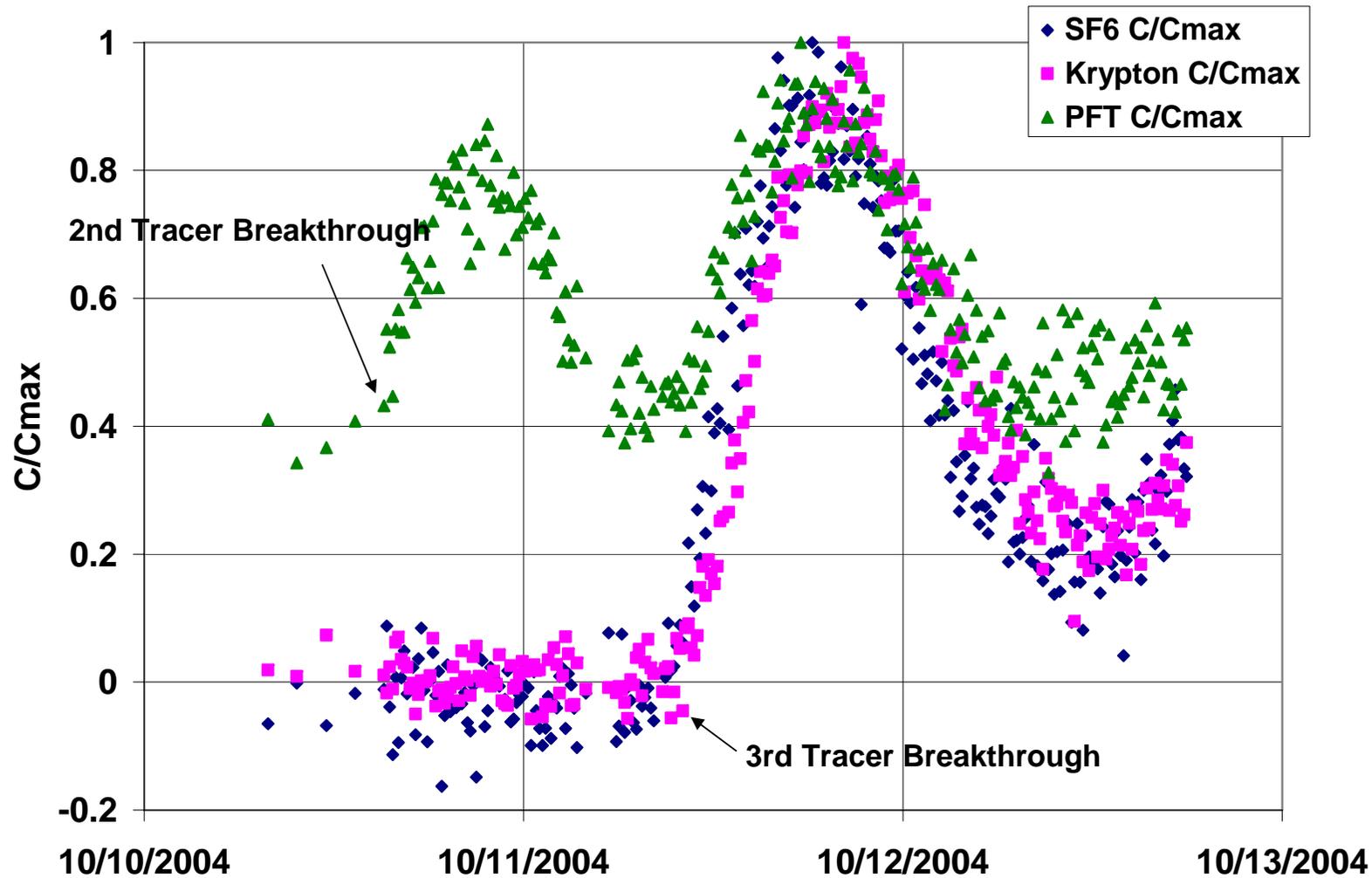
*New tool to do the
job:
LBNL U-tube*

*instrument to
collect high
frequency,
high quality two-
phase samples*

Tommy Phelps
Dave Ristenburg
Oak Ridge National Lab

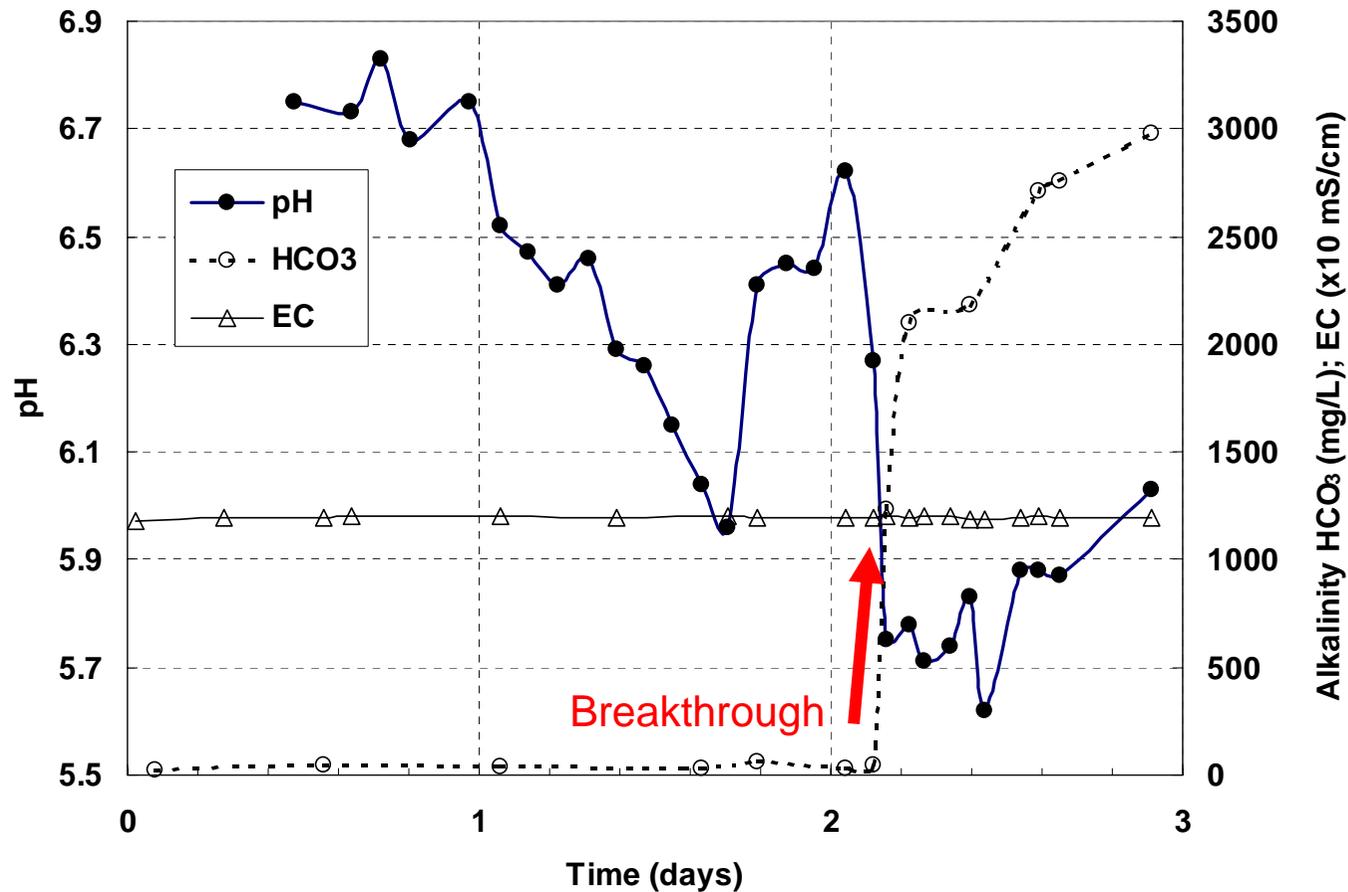
Seay Nance
BEG

Tracer Breakthrough

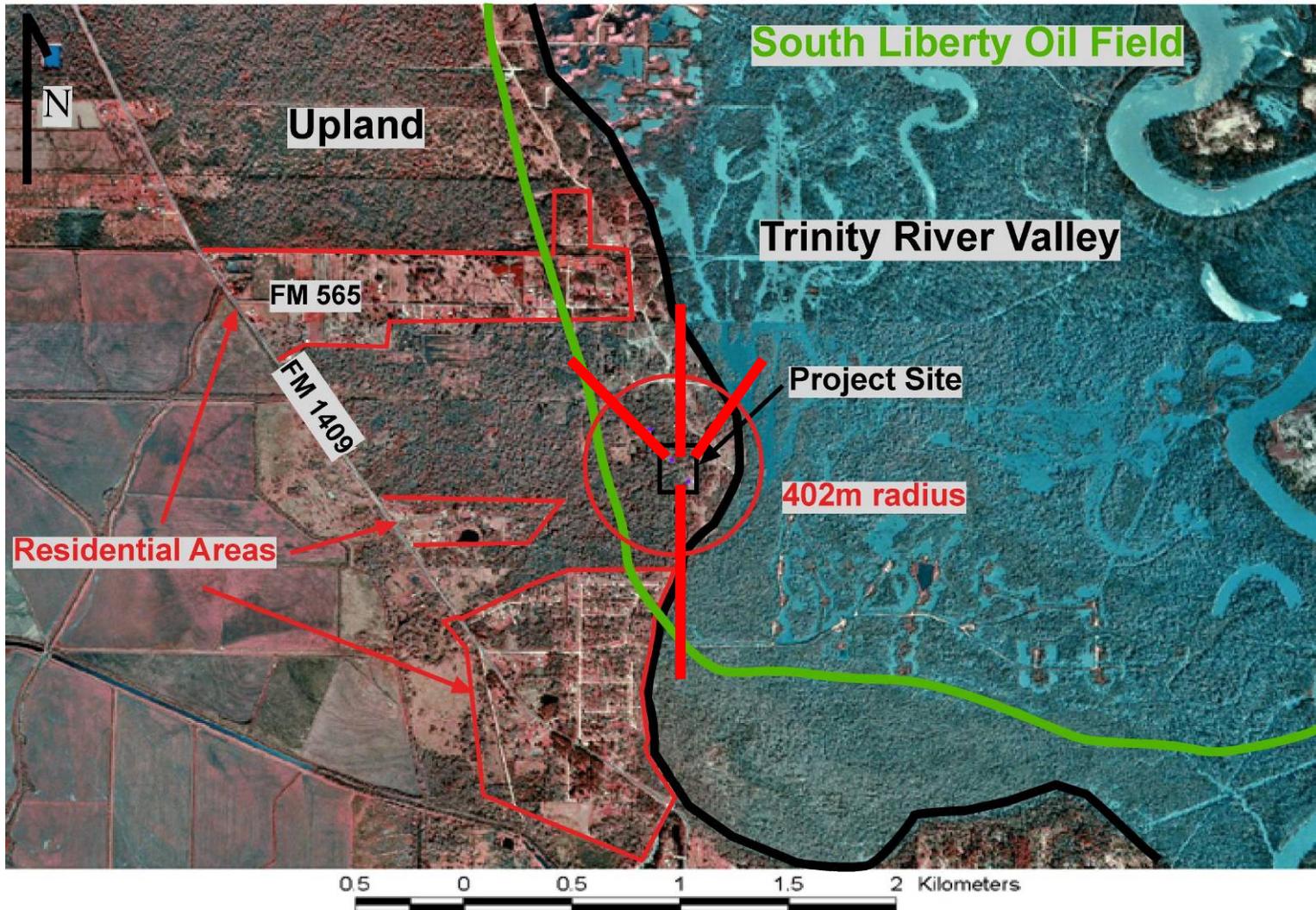


Barry Freifeld, LBNL; Tommy Phelps ORNL

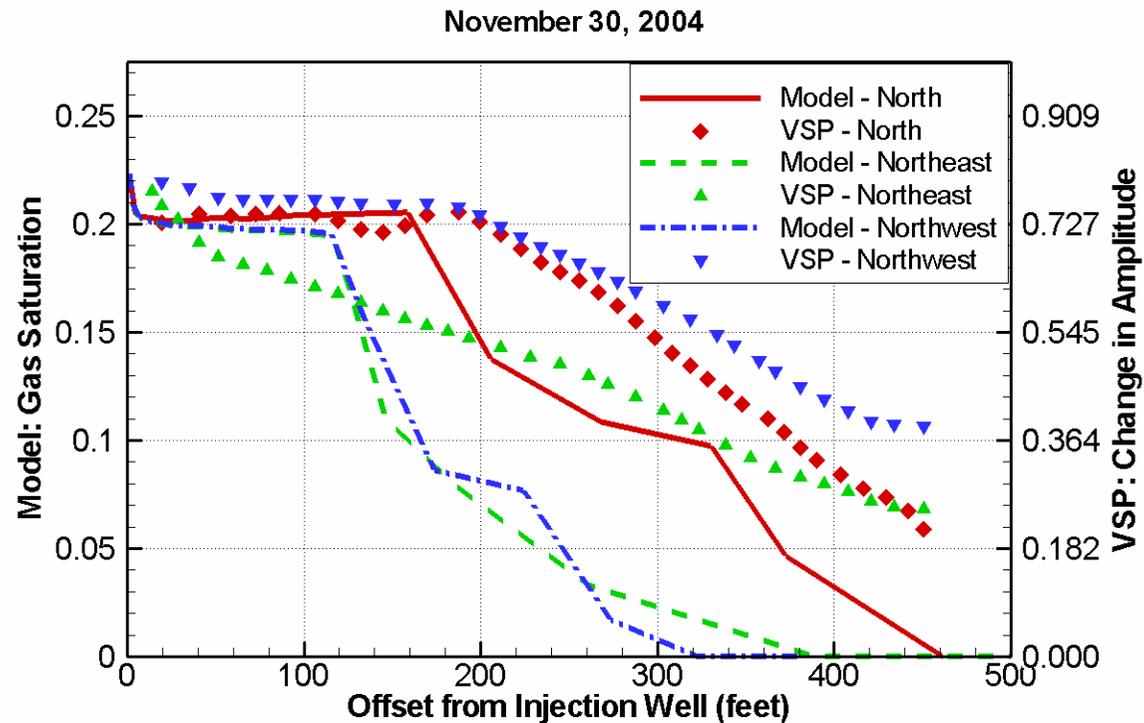
Fluid Chemistry: alkalinity and pH of brine from Observation Well During CO₂ Injection



Azimuthal Array of Vertical Seismic Profiles

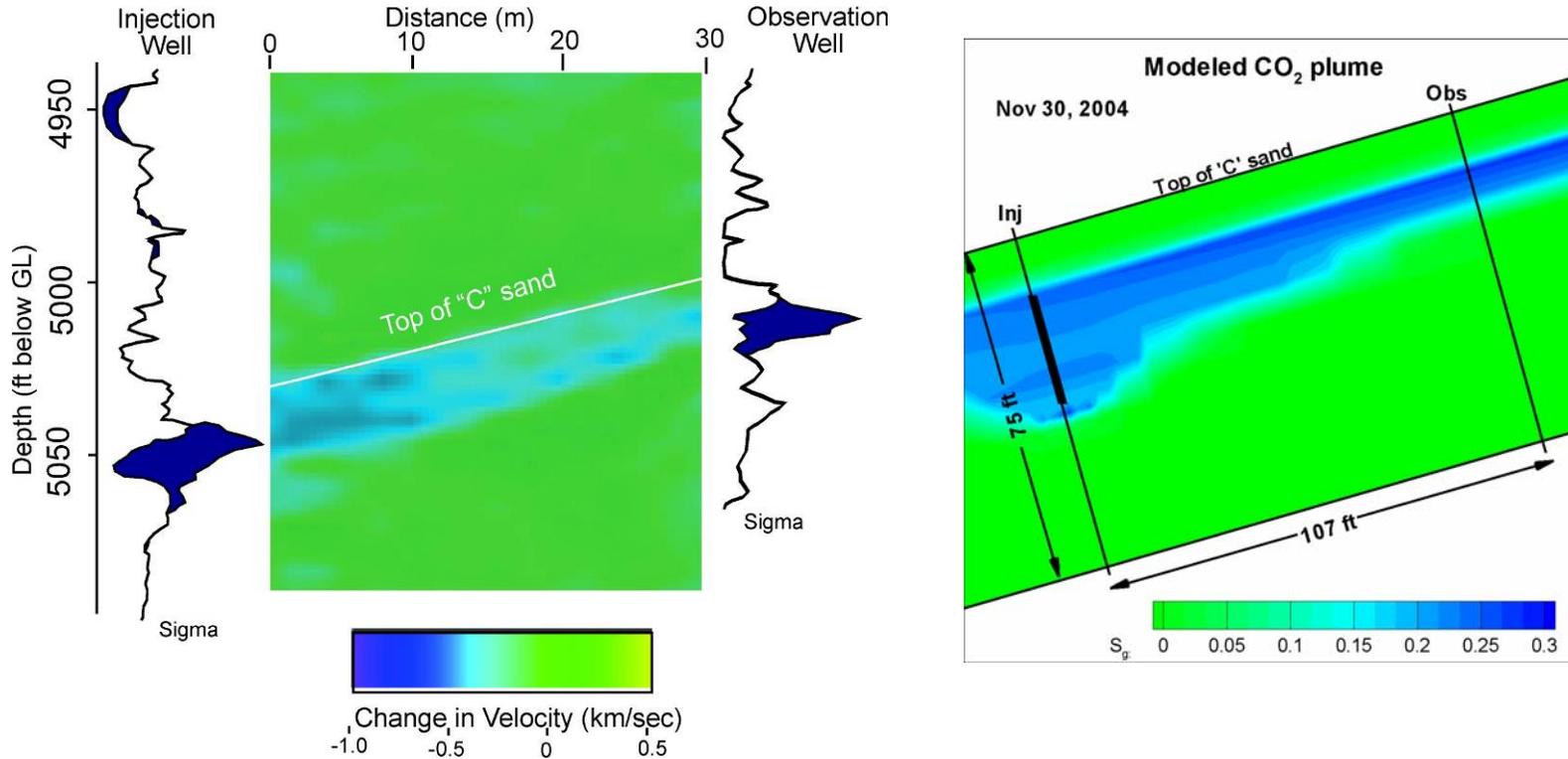


Plume Size Measured with VSP vs. modeled plume size

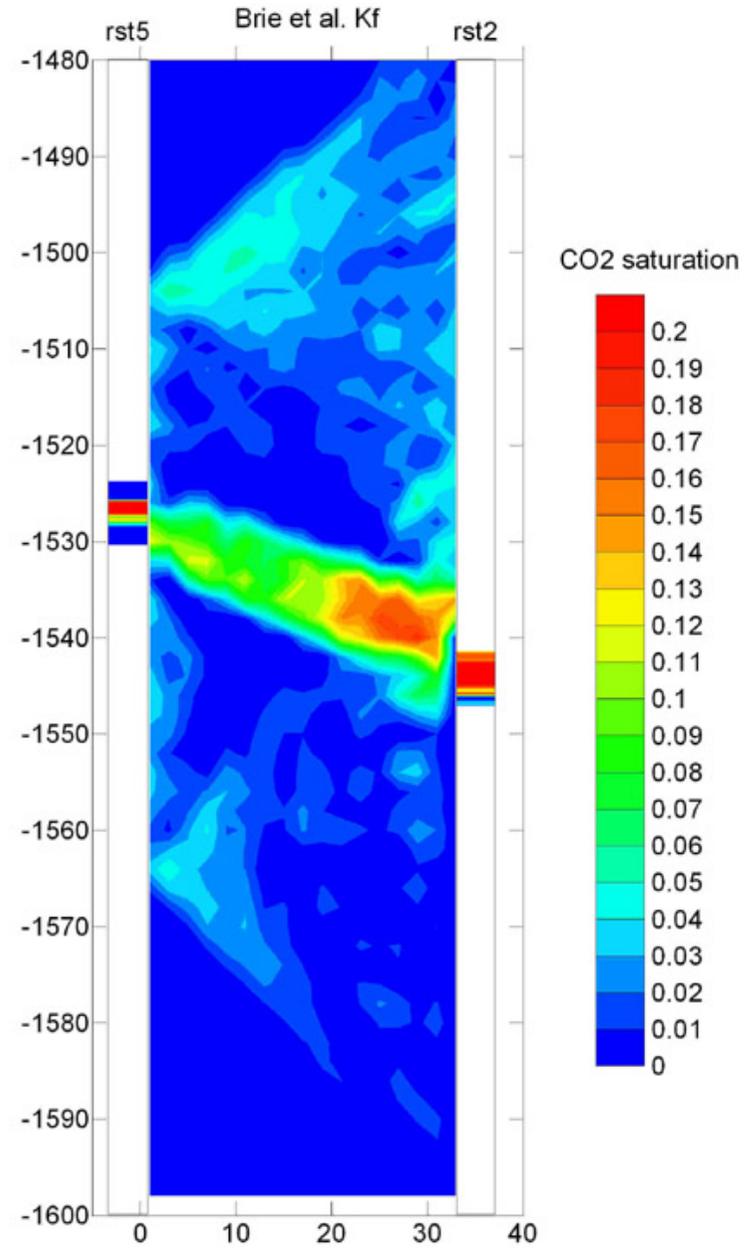
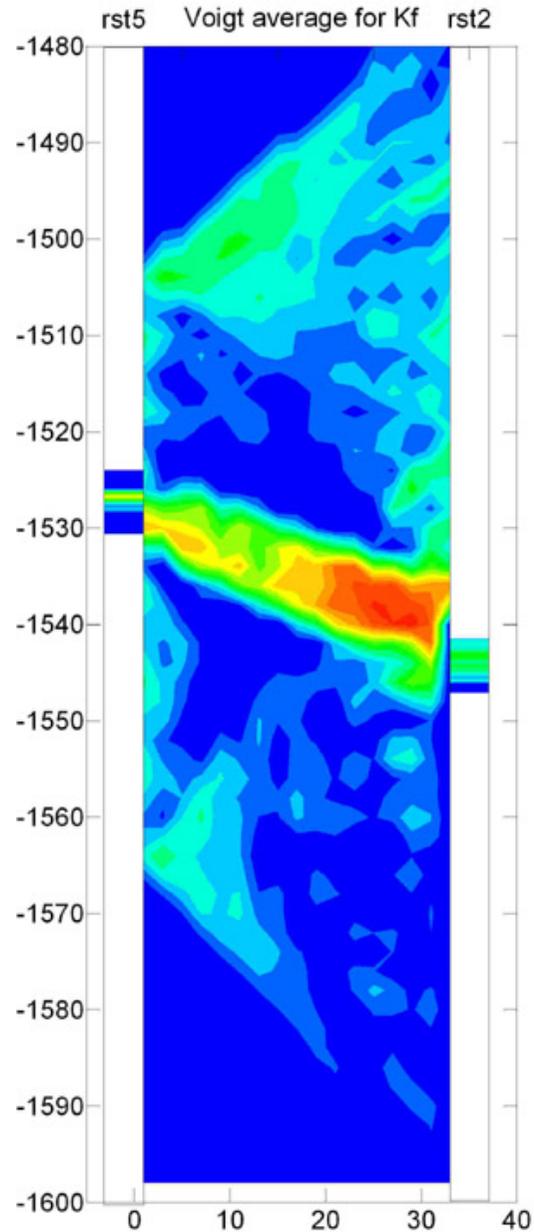


Tom Daley and Christine Doughty LBNL

CO₂ Saturation Observed with Cross-well Seismic Tomography vs. Modeled



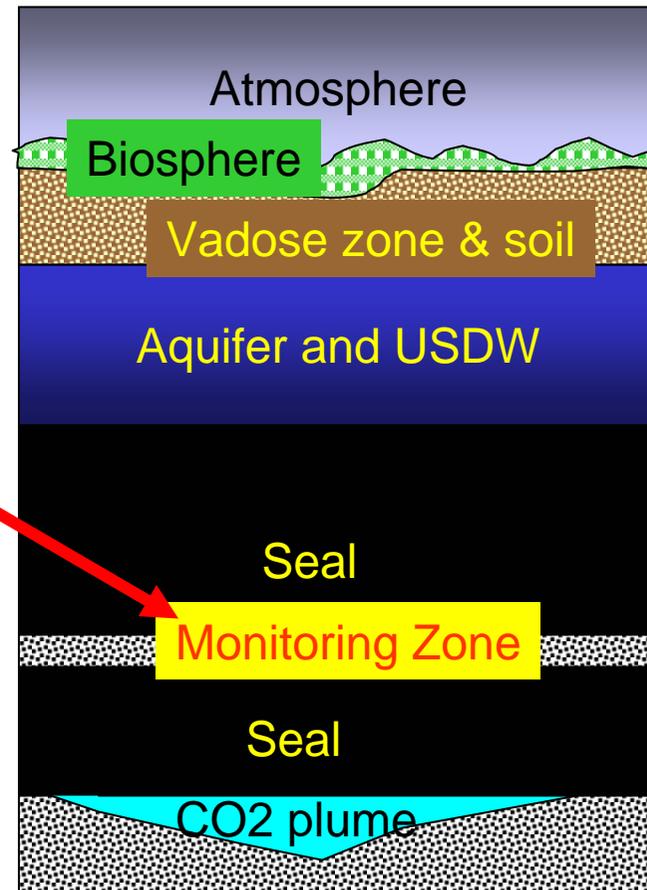
Saturation from Cross Well Seismic Tomography



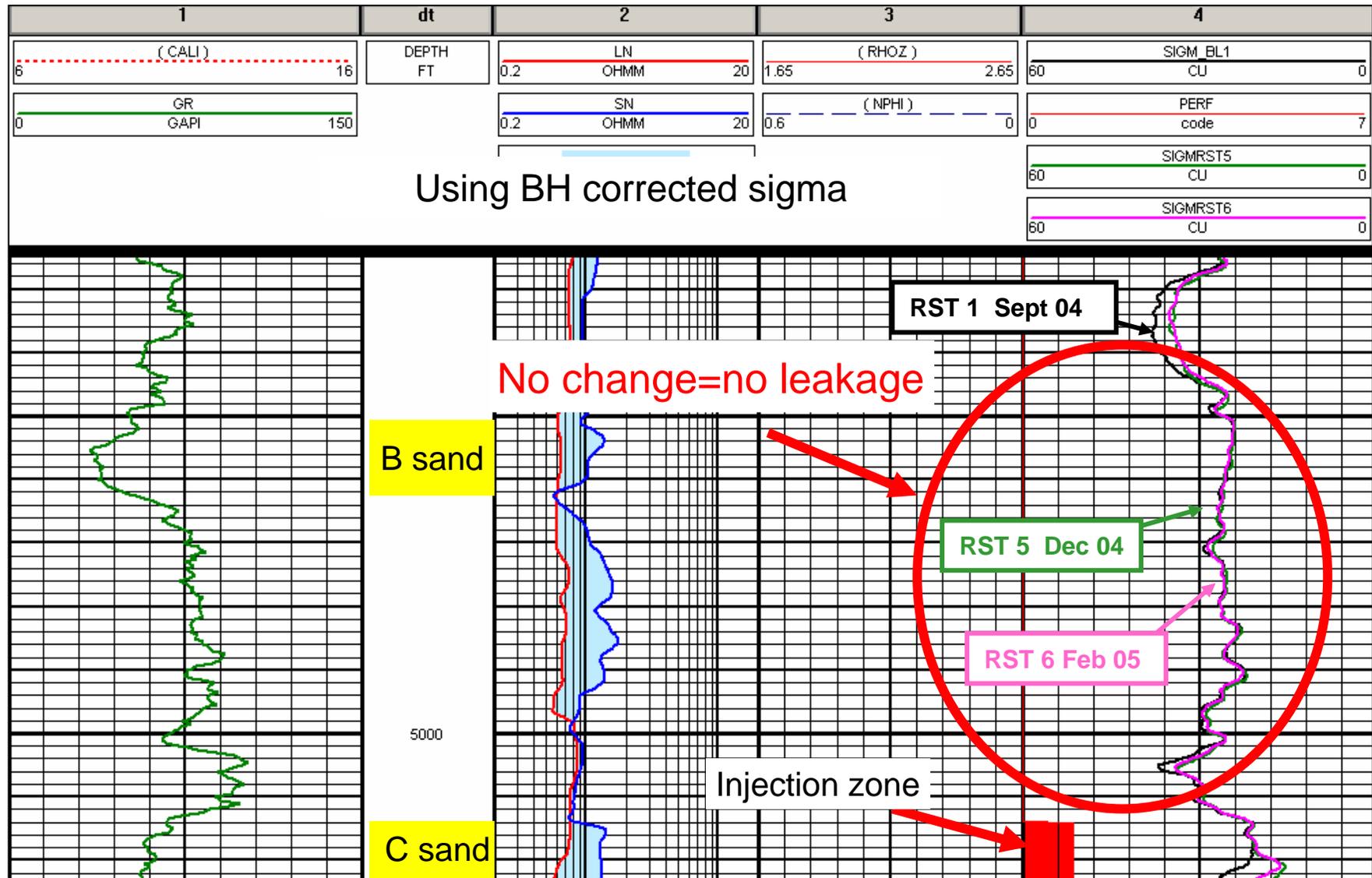
Mike Hoversten

Subsurface Monitoring Above Injection Zones

- Close to perturbation
- Quiescent relative to the surface
- High signal to noise ratio

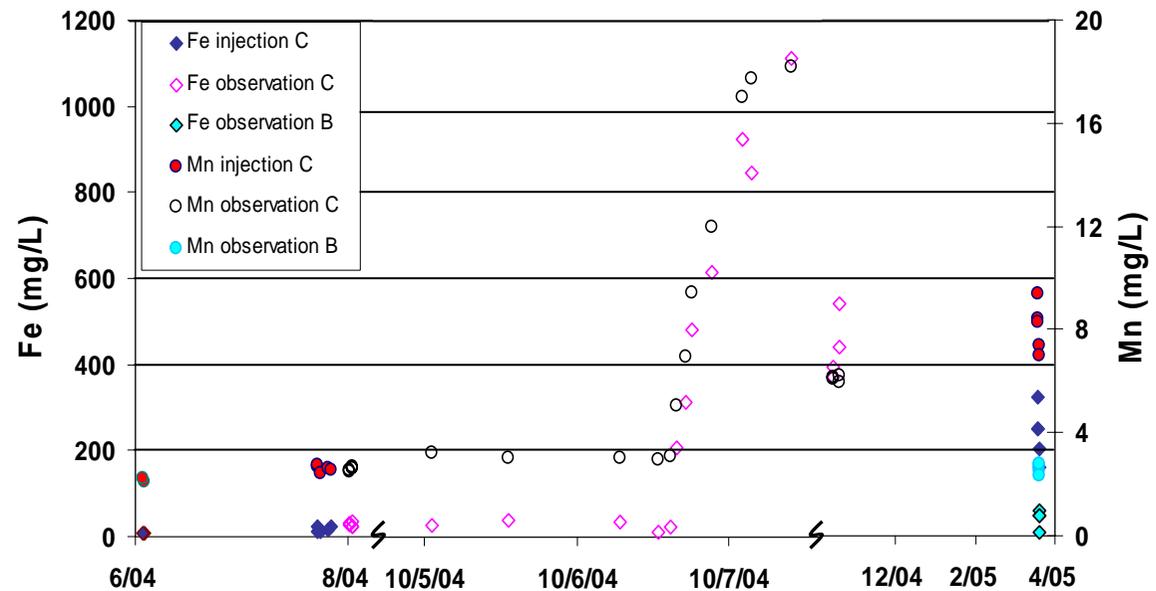


Evidence of upward leakage? From saturation logs: No



Perturbations

- Sonic signal “bubbling”
- Tracer and geochemical change

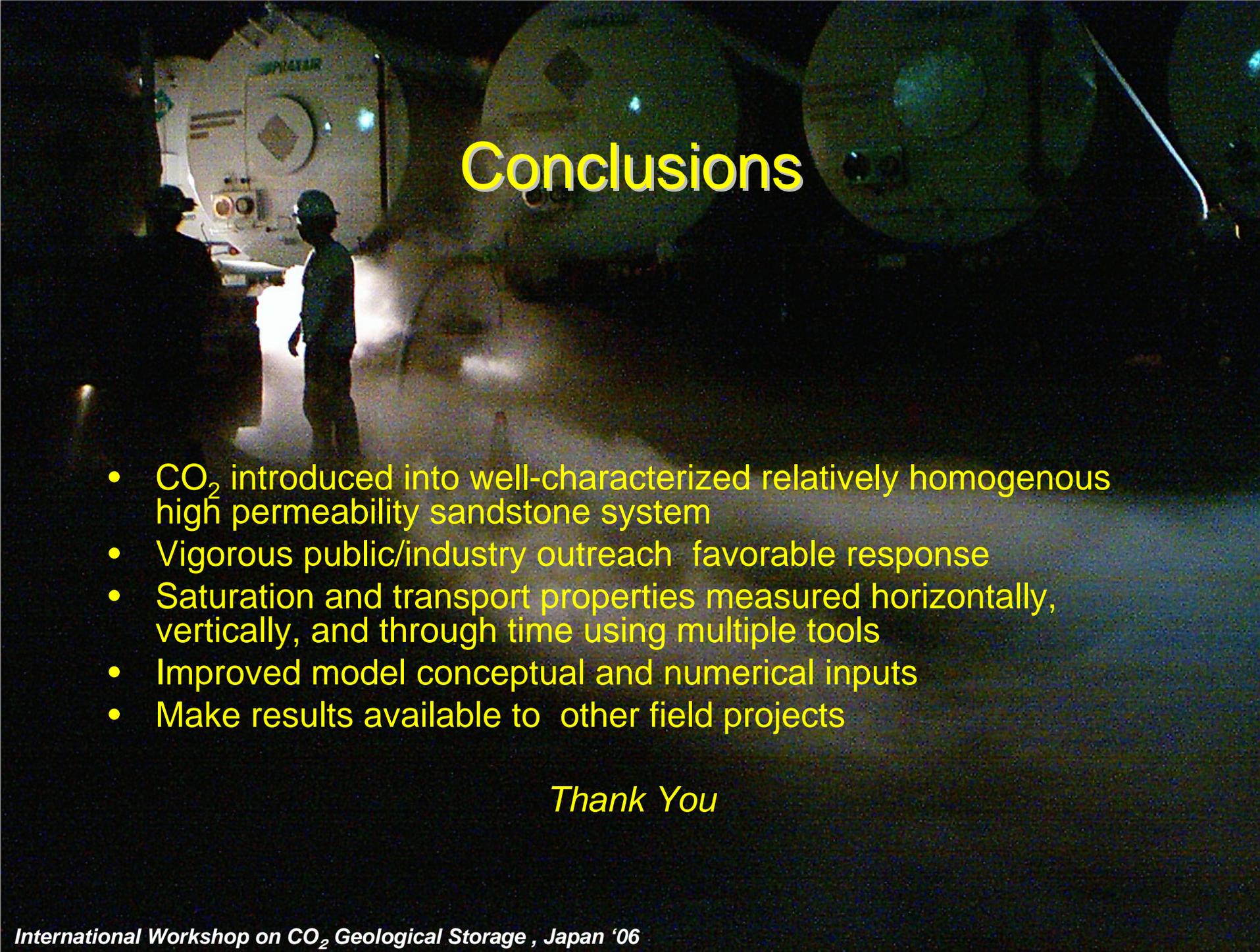


Surface Monitoring: No Clear Signal



Water well sampling





Conclusions

- CO₂ introduced into well-characterized relatively homogenous high permeability sandstone system
- Vigorous public/industry outreach favorable response
- Saturation and transport properties measured horizontally, vertically, and through time using multiple tools
- Improved model conceptual and numerical inputs
- Make results available to other field projects

Thank You