Update on the Frio Brine Pilot: Eight months after injection

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- Praxair: Joe Shine, Dan Dalton
- Australian CO2CRC (CSIRO): Kevin Dodds, Don Sherlock
- Core Labs: Paul Martin and others

Additional participation welcome

Frio Experiment: Monitoring CO_2 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 CO_2 can be injected into a brine formation without adverse health, safety, or environmental effects**
- **Determine the subsurface distribution of injected CO_2 using diverse monitoring technologies**
- **Demonstrate validity of conceptual and numerical models**
- **Develop experience necessary for success of large-scale CO_2 injection experiments**
- **Follow on study – improve quantification of two phase trapping, gravity effects, and interwell heterogeneity**

Frio Experiment: Status of Results

1600 metric tons CO_2 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**

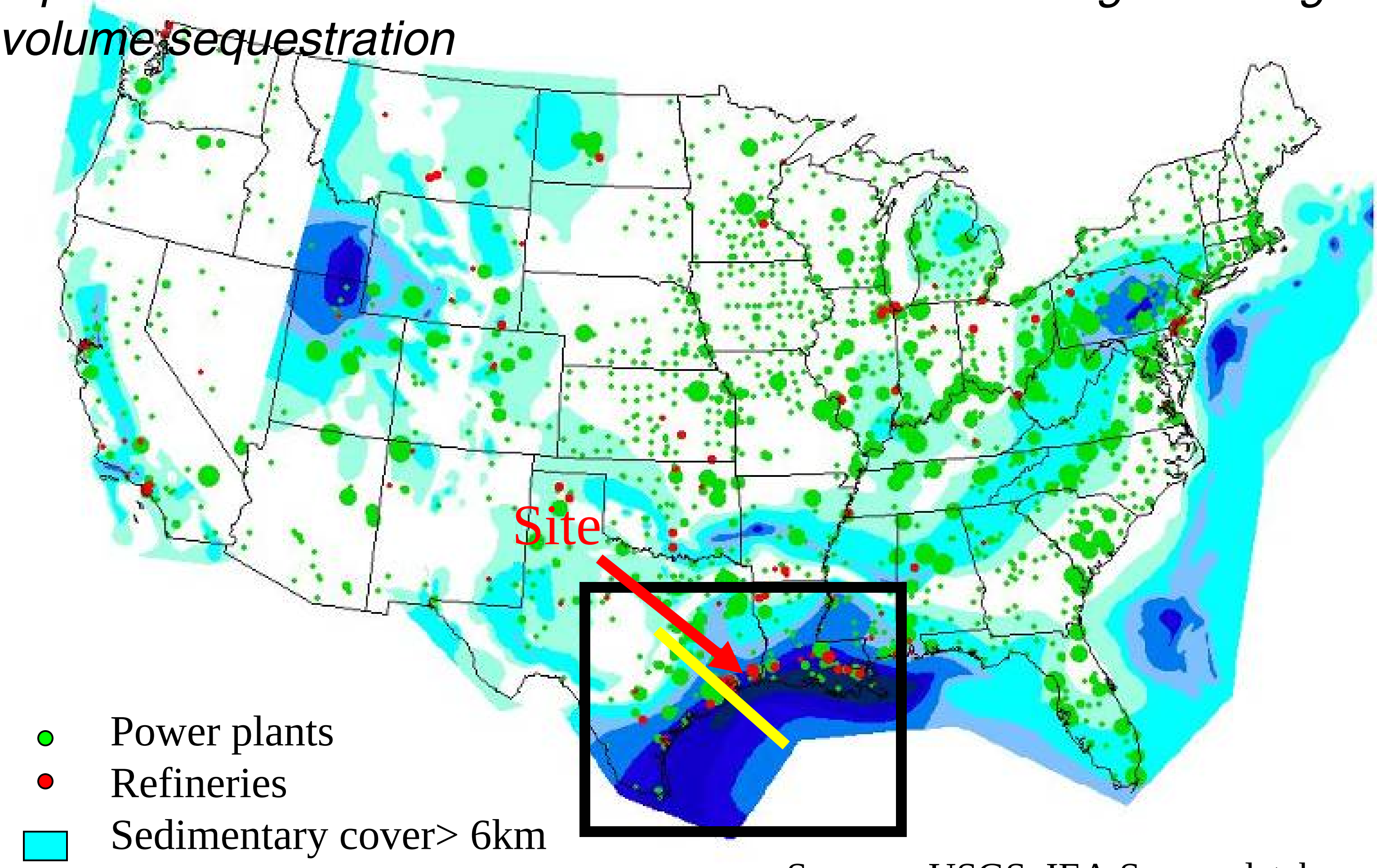
- **Improved model conceptual and numerical inputs**

- **Make results available to field projects planned by Regional Sequestration Partnerships and to Carbon Sequestration Leadership Forum Projects**
  - **www.gulfcoastcarbon.org**

- **Analysis continues, follow-on study planned**

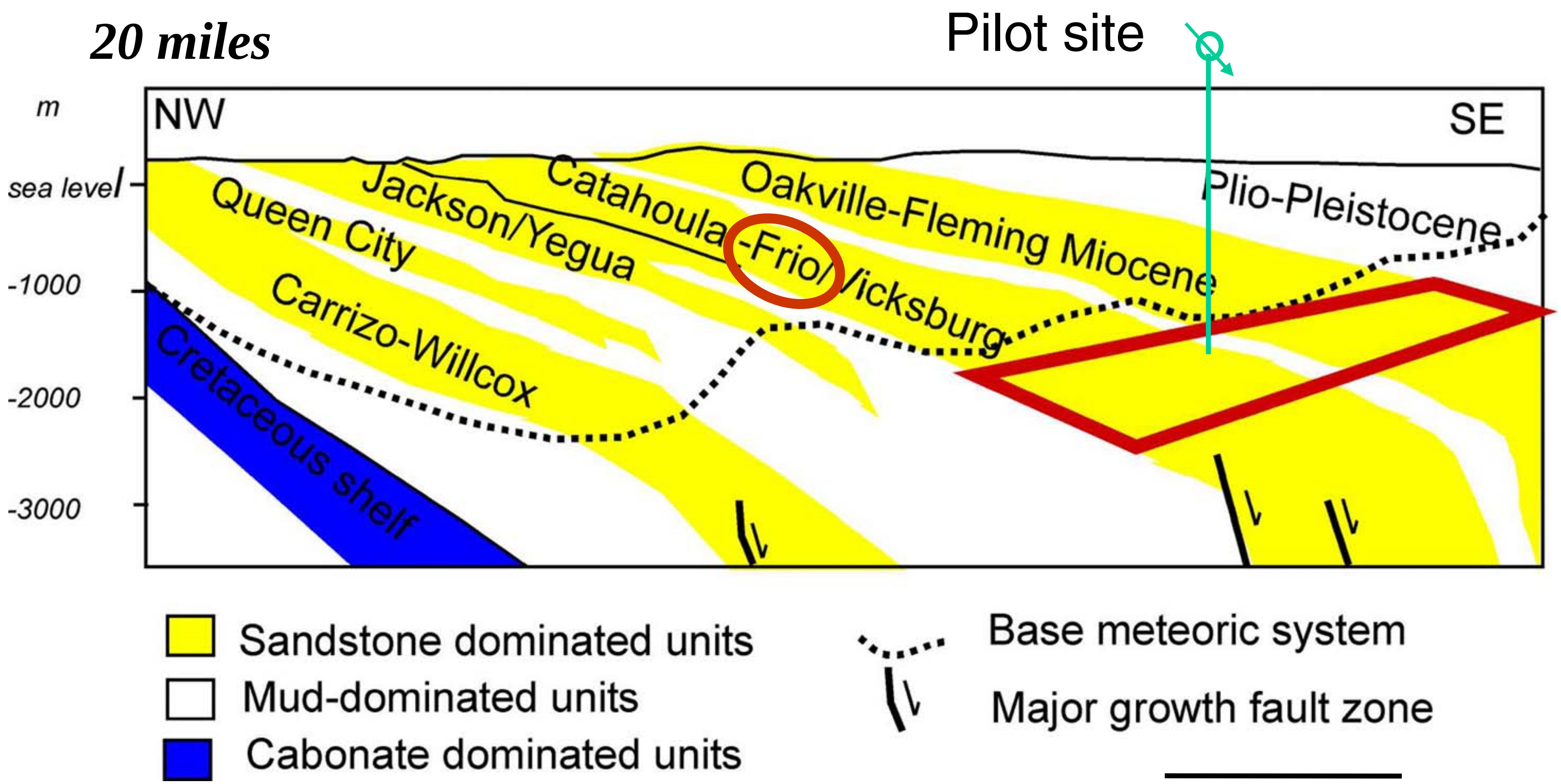
Site Search

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



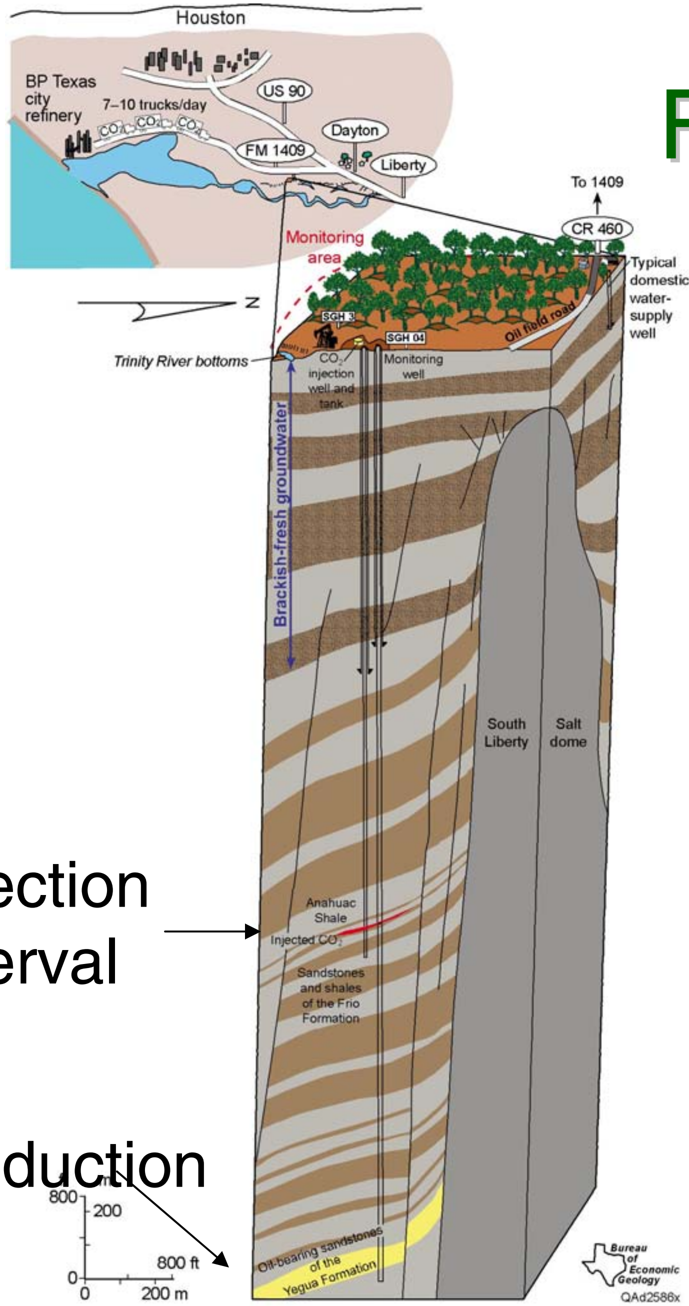
Sources: USGS, IEA Source database

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 CO_2

Health, Safety, and Outreach Activities

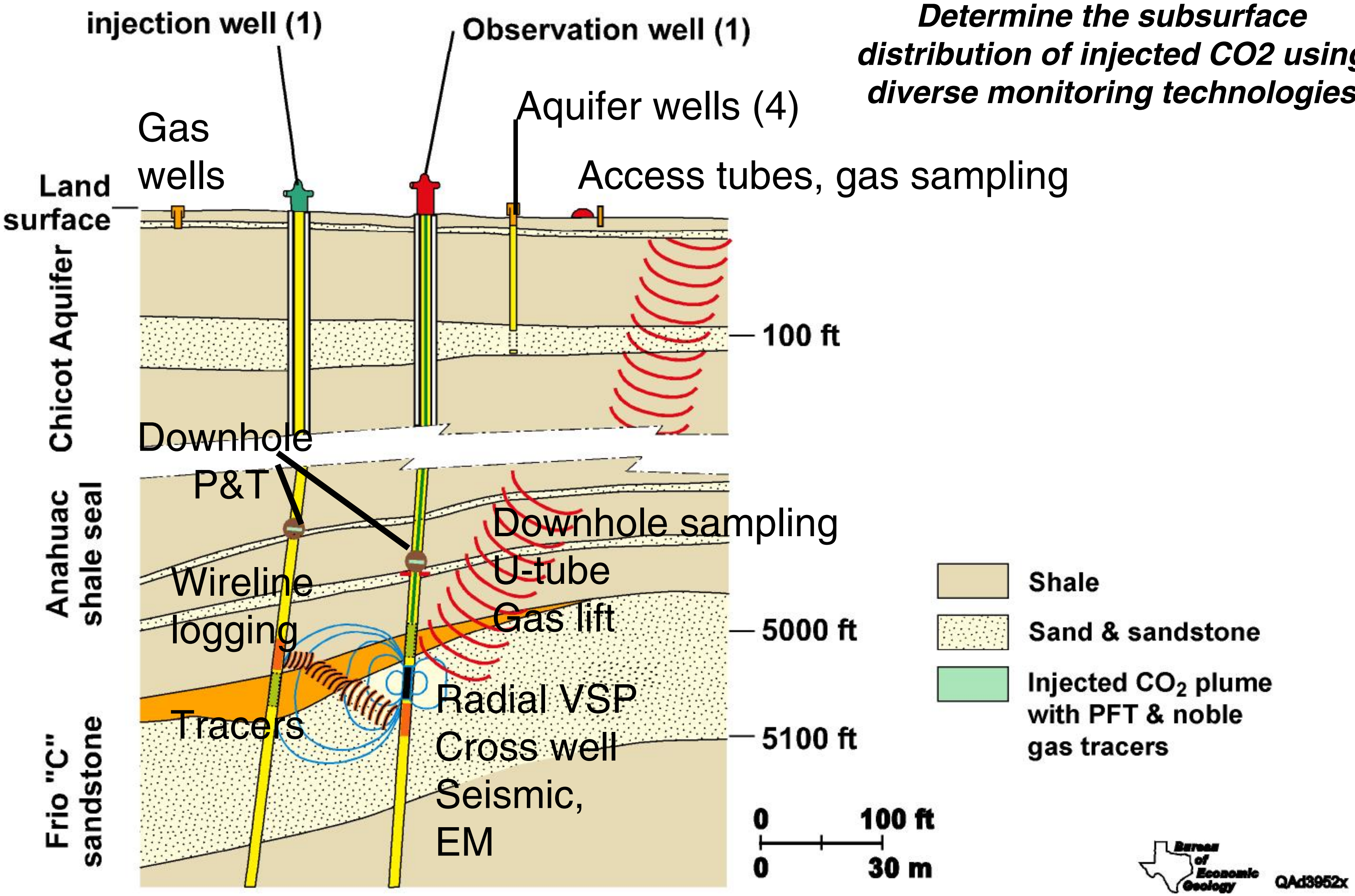
Demonstrate that CO_2 can be injected into a brine formation without adverse health, safety, or environmental effects

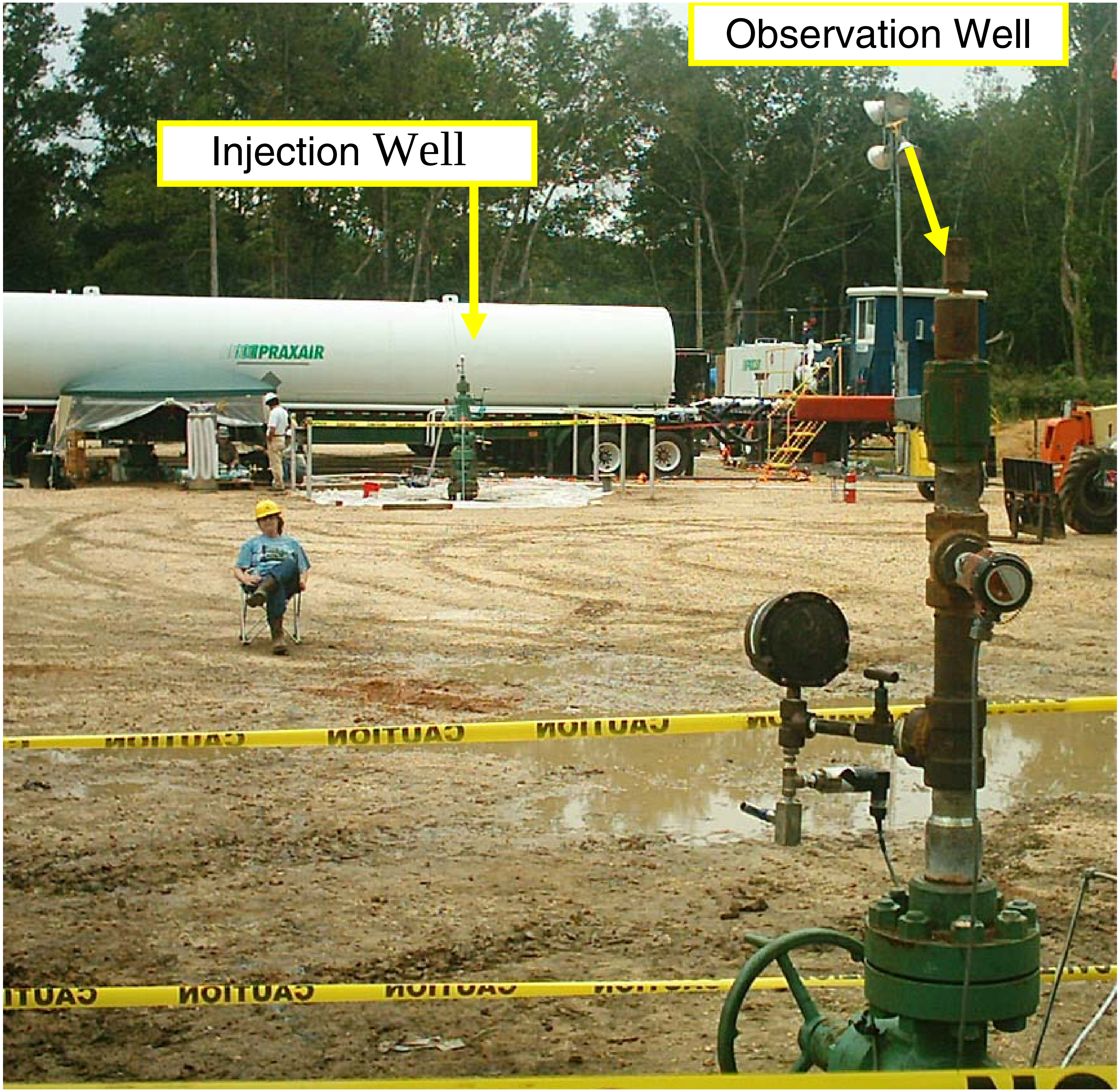
- **15 news articles**
    - **Houston Express-News**
- **Reuters, BBC**
- **100 visitors**
- **Reports at www.gulfcoastcarbon.org**

Regional Sequestration Partnerships visit the Frio Site

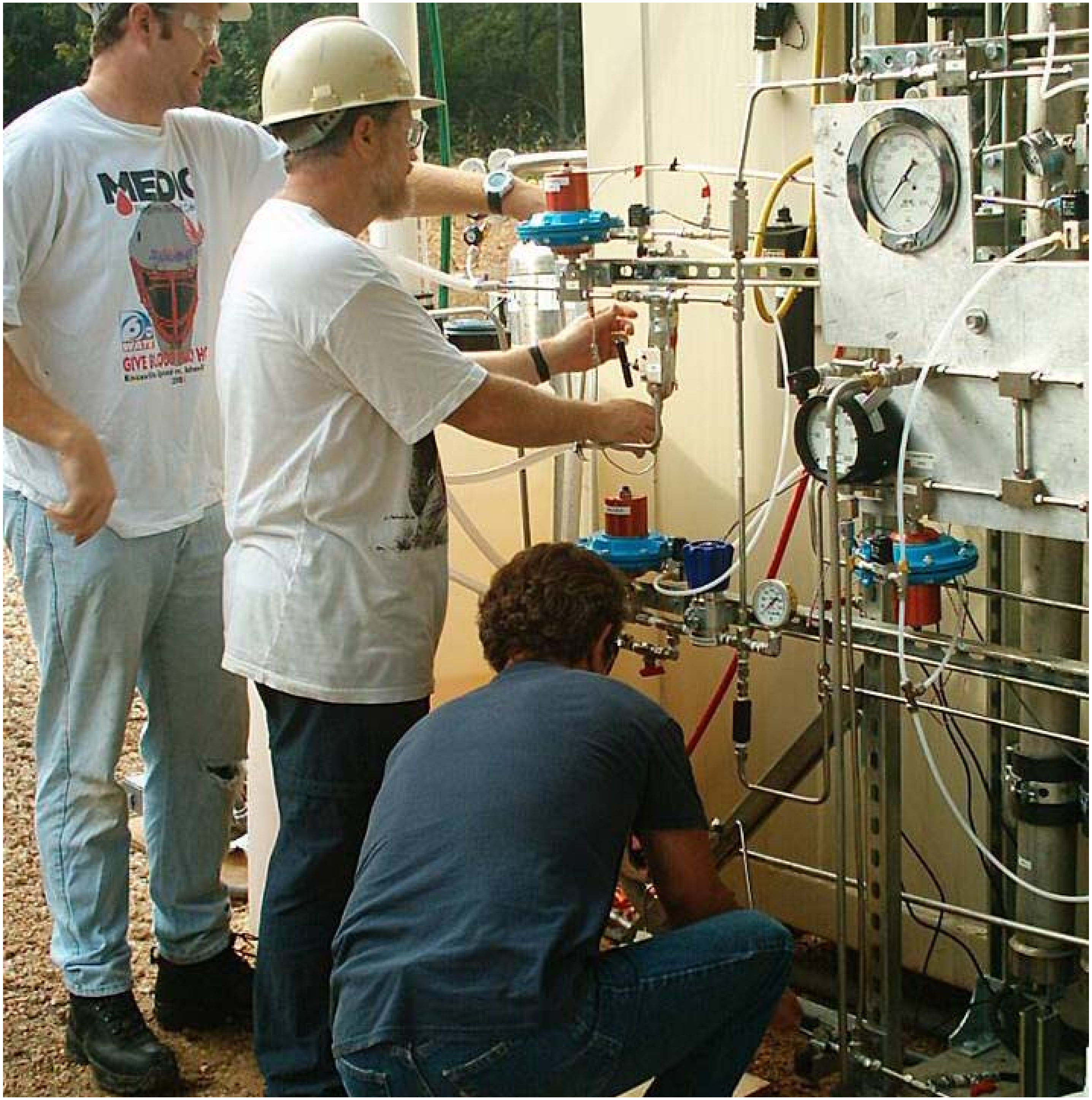
Monitoring at Frio Pilot

Determine the subsurface distribution of injected CO2 using diverse monitoring technologies





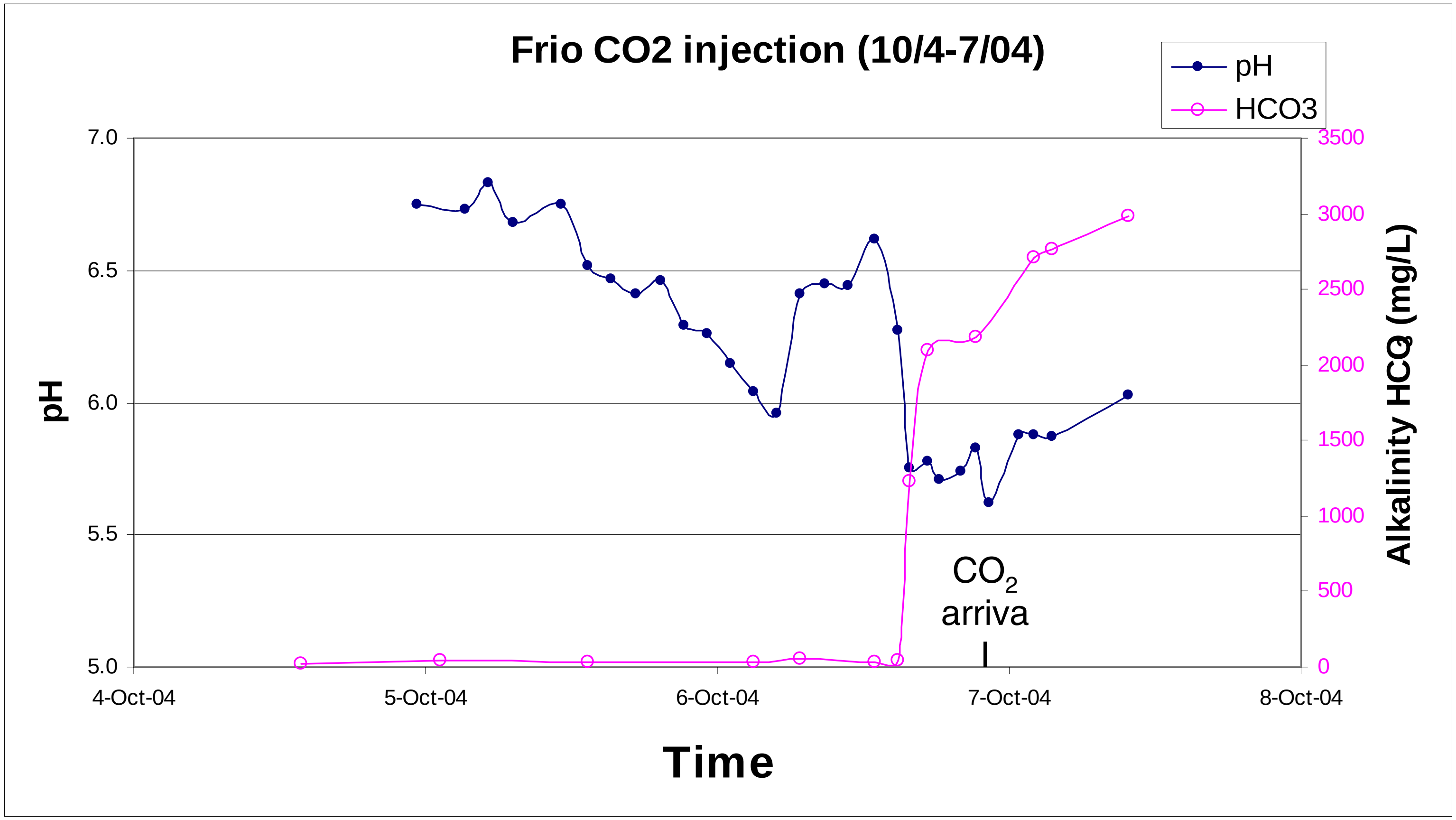
Closely spaced measurements in time and space



New tool to do the job:
LBNL U-tube

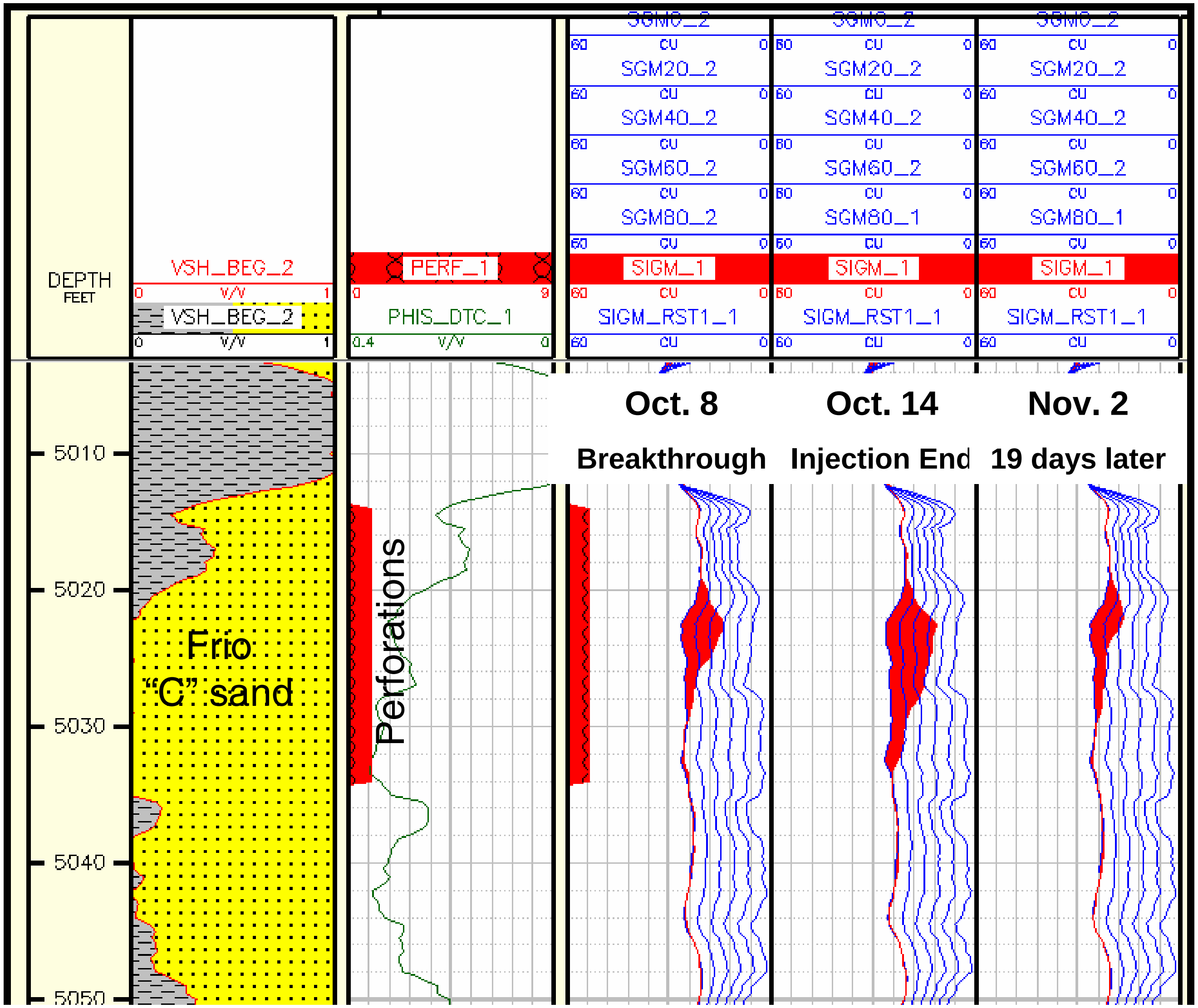
instrument to collect high frequency, high quality two-phase samples

Alkalinity and pH of Brine from Observation Well During CO_2 Injection



Y. Kharaka, USGS; H. S. Nance, BEG

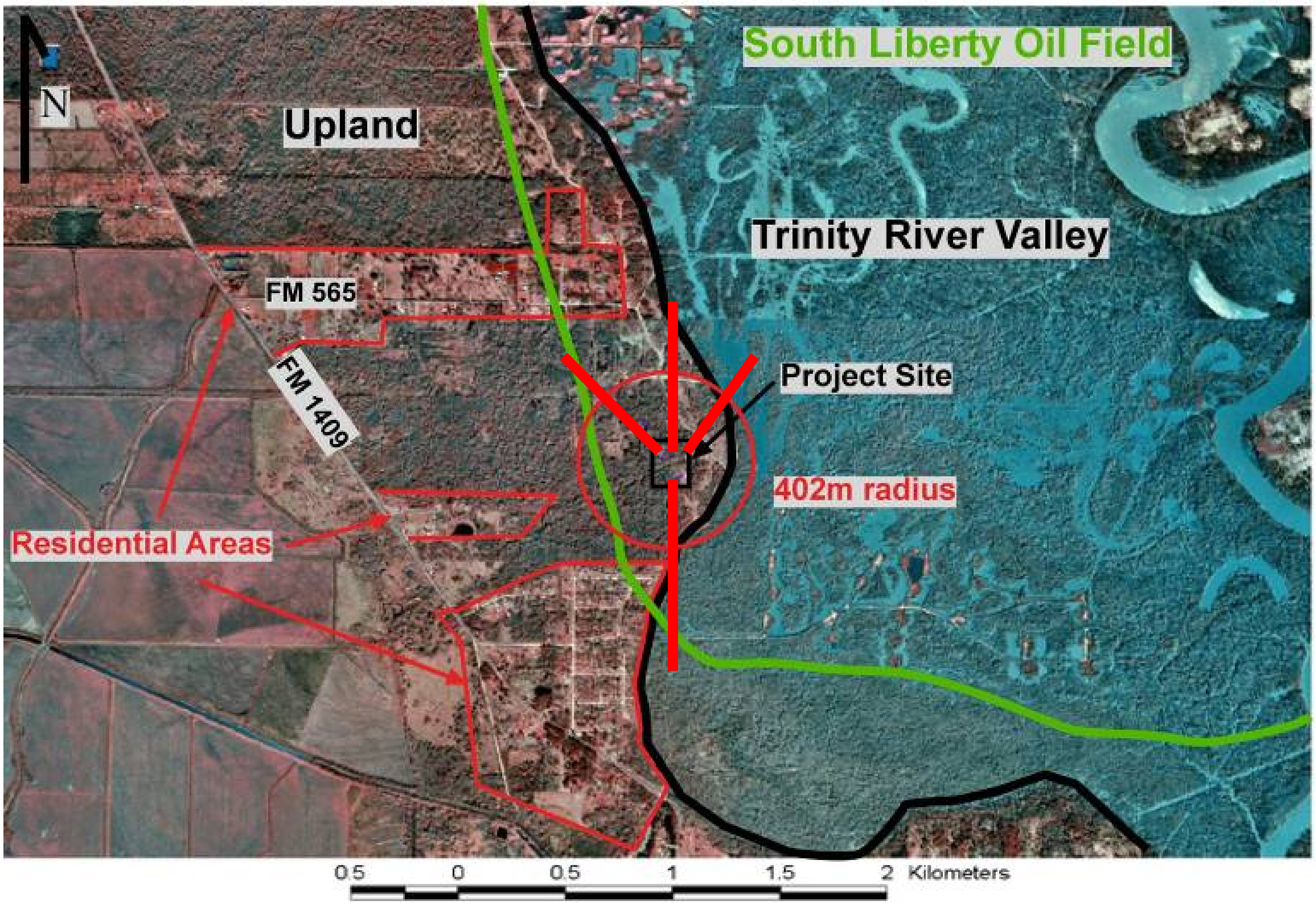
Wireline logging to measure changes in CO_2 saturation



Quantitative,
High resolution
Low cost

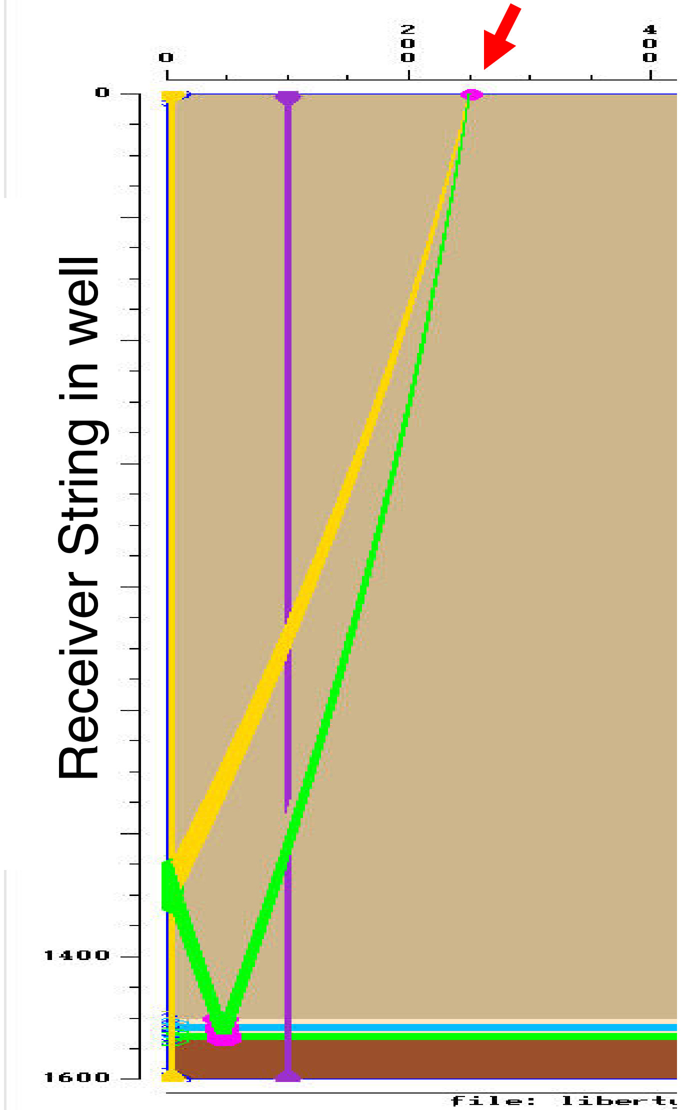
Change in sigma
Pulsed Neutron Log

Azimuthal Array of Vertical Seismic Profiles



Vertical Seismic Profiling

Explosive shothole at surface

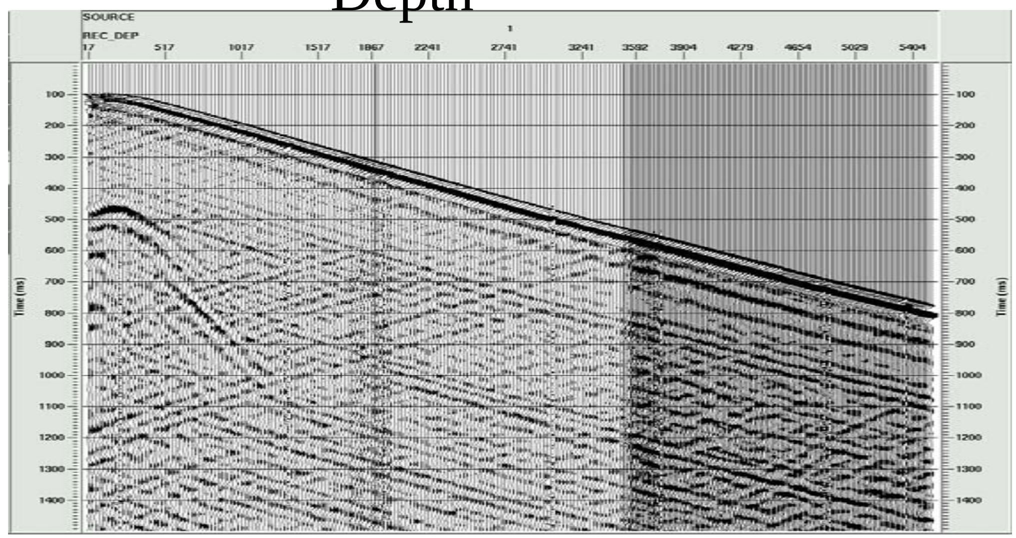


Receiver String in well

Raw Data Site 1

Depth →

Time ↓



Denser spacing in reservoir interval

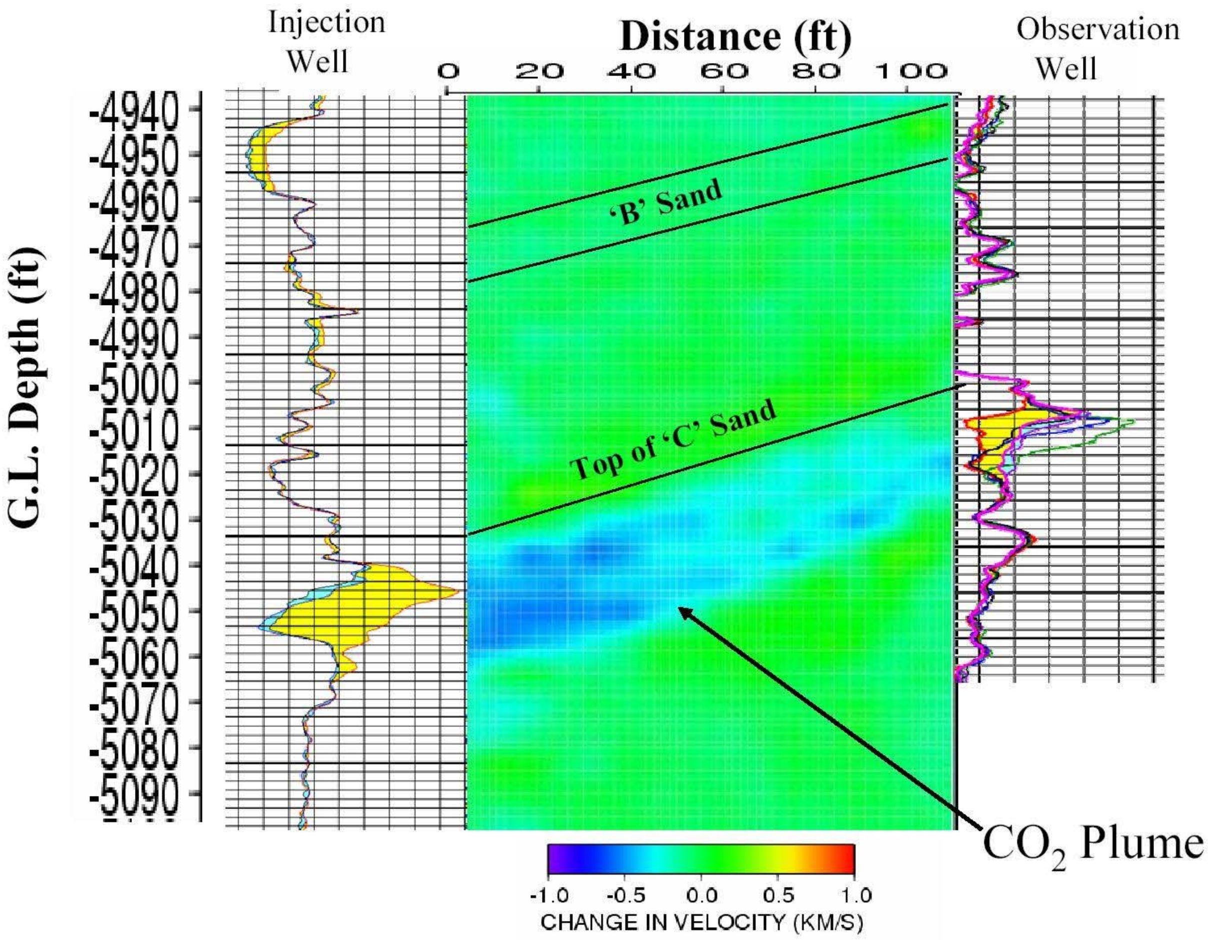
Tom Daley LBNL

VSP Imaged CO_2

Demonstrates the usefulness of the seismic techniques for leak detection

Site 1 (North, Up Dip)
Reflection Section Tom Daley

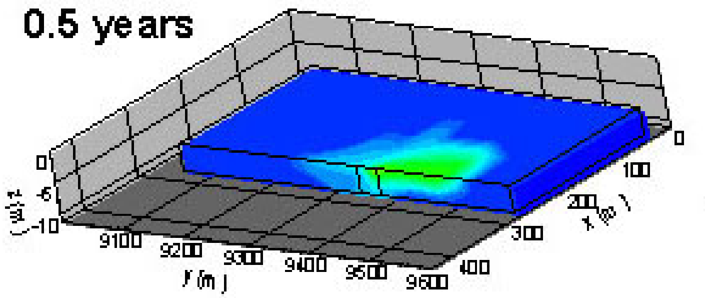
Measurement of CO_2 Distribution with Cross-well Time Lapse Seismic



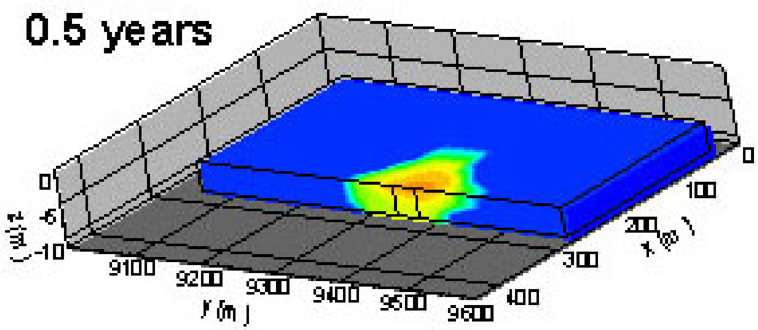
Tom Daley. LBNL

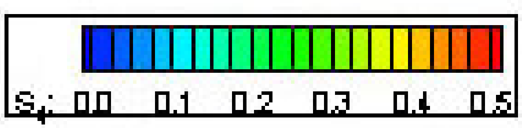
How Modeling and Monitoring Demonstrate Permanence

Residual gas saturation of 5%



Residual gas saturation of 30%





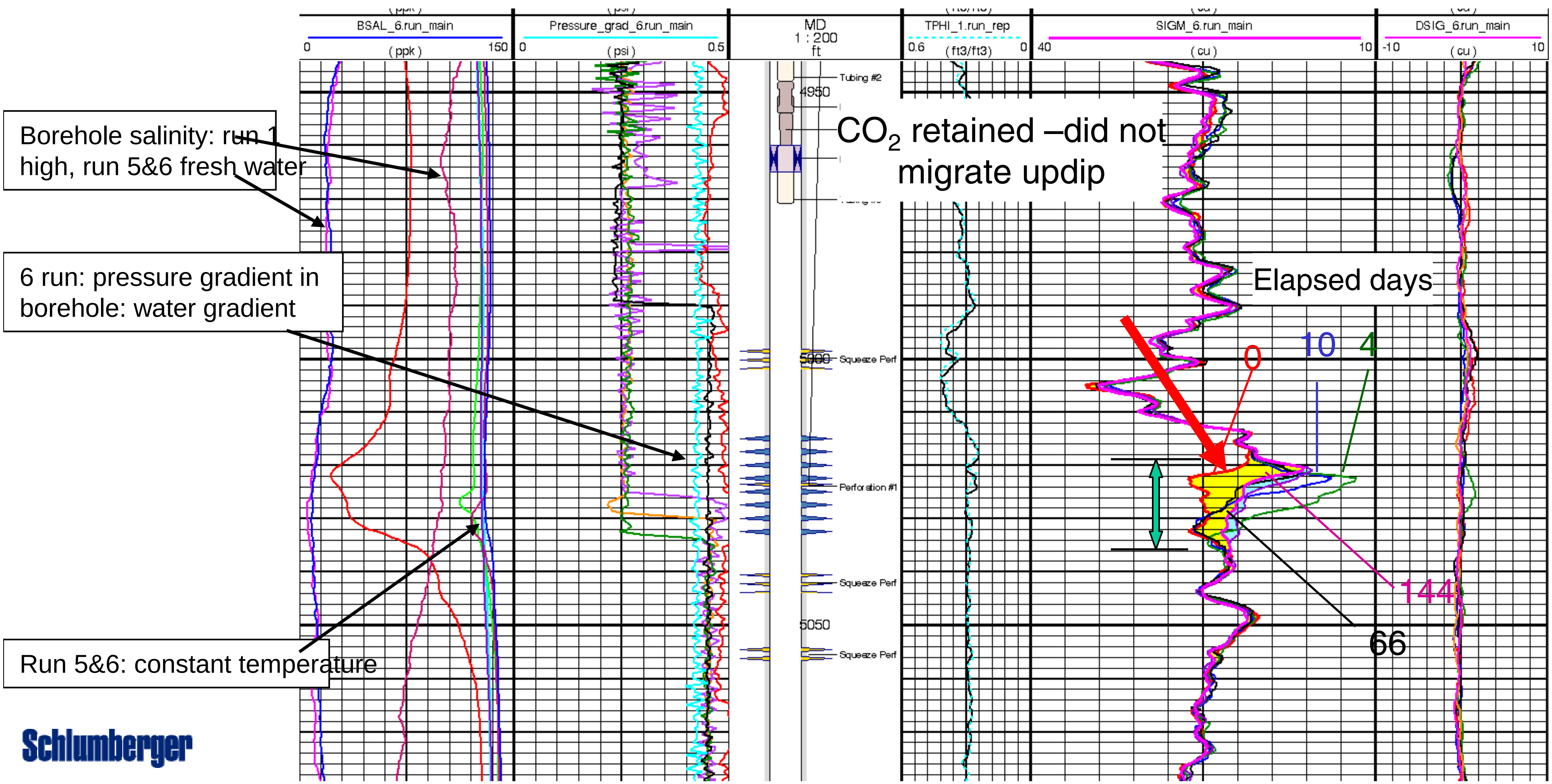
- Modeling has identified variables which appear to control CO_2 injection and post injection migration.
- Measurements made over a short time frame and small distance confirm the correct value for these variables
- Better conceptualized and calibrated models will now be used to develop larger scale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

TOUGH2 simulations
C. Doughty LBNL

Preliminary Saturation Log Interpretation 6-months post injection- Saturation remains high

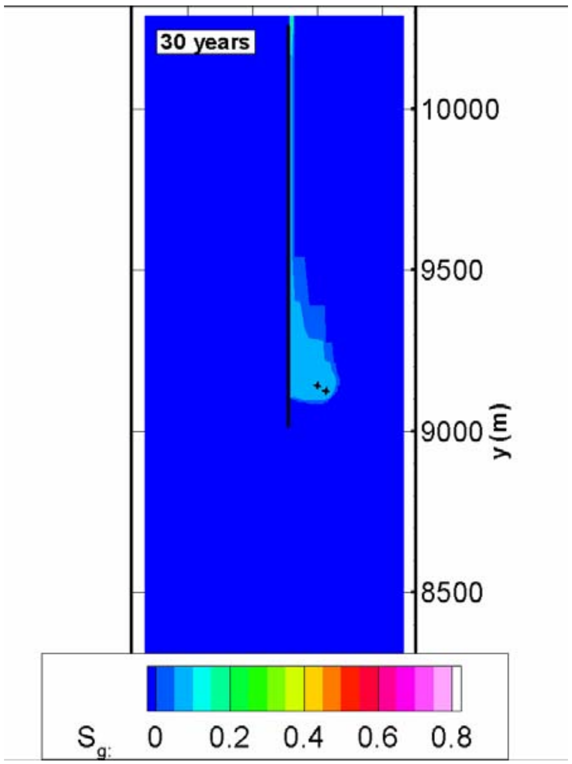
Borehole correction

Sigma

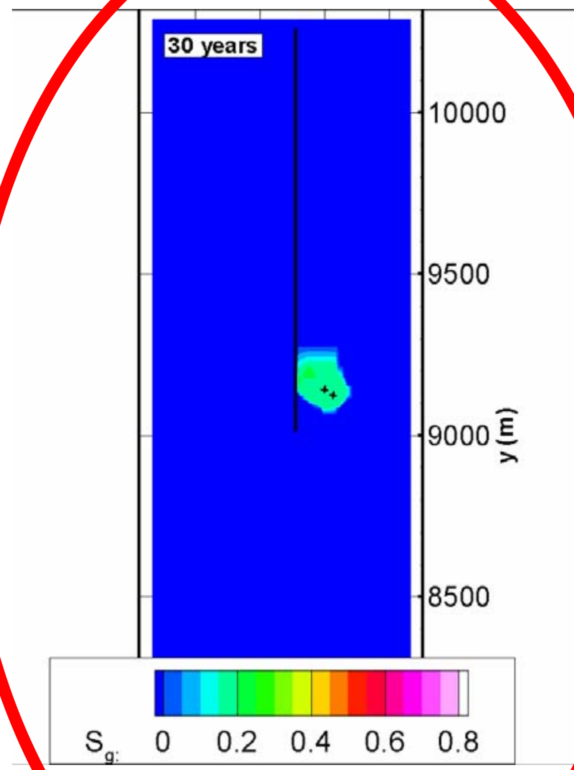


Schlumberger

Modeled Long-term Fate
30 years based on observed post-injection saturation

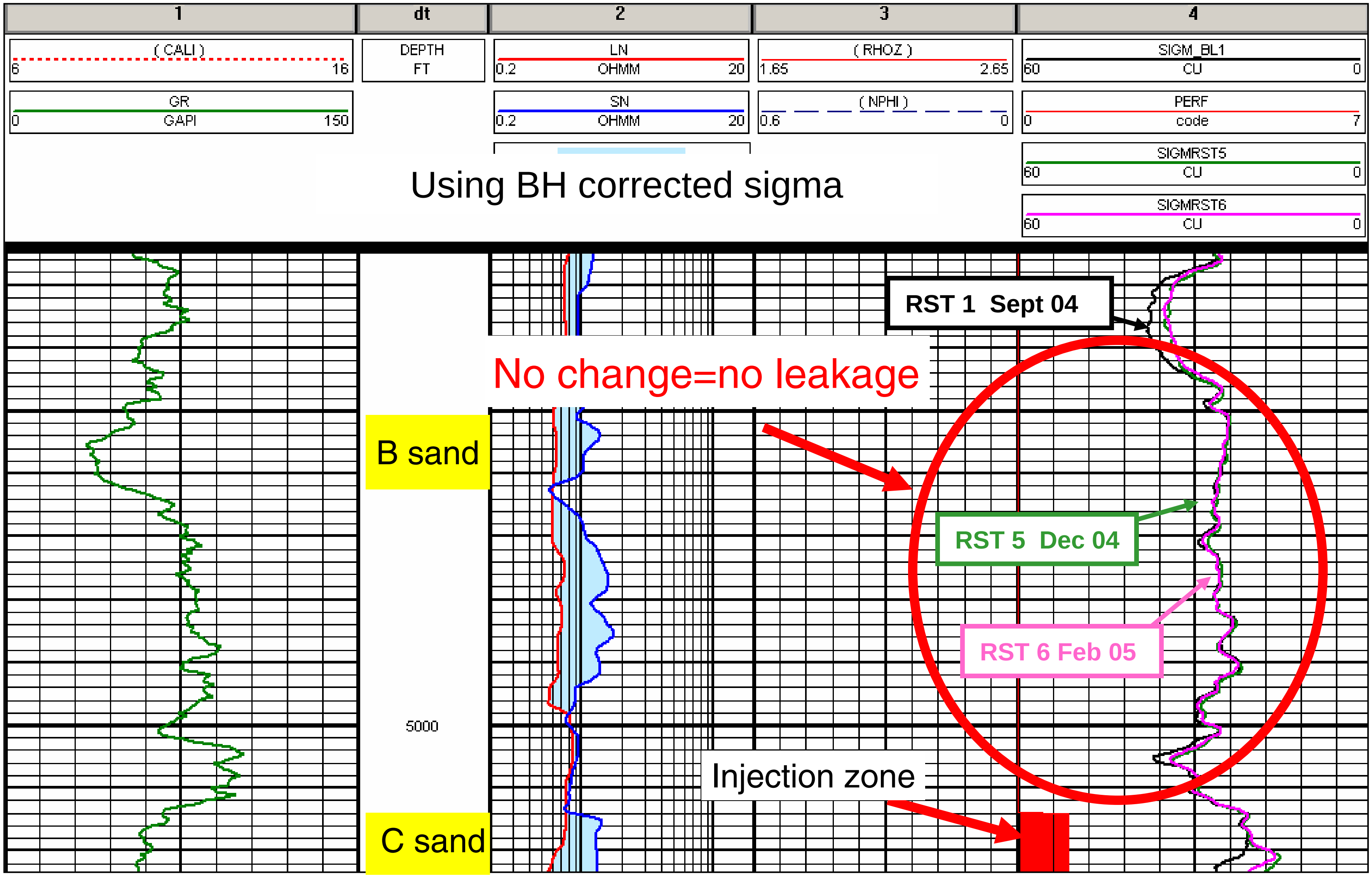


Minimal Phase trapping



Predicted significant phase trapping

Evidence of upward leakage? From saturation logs: No

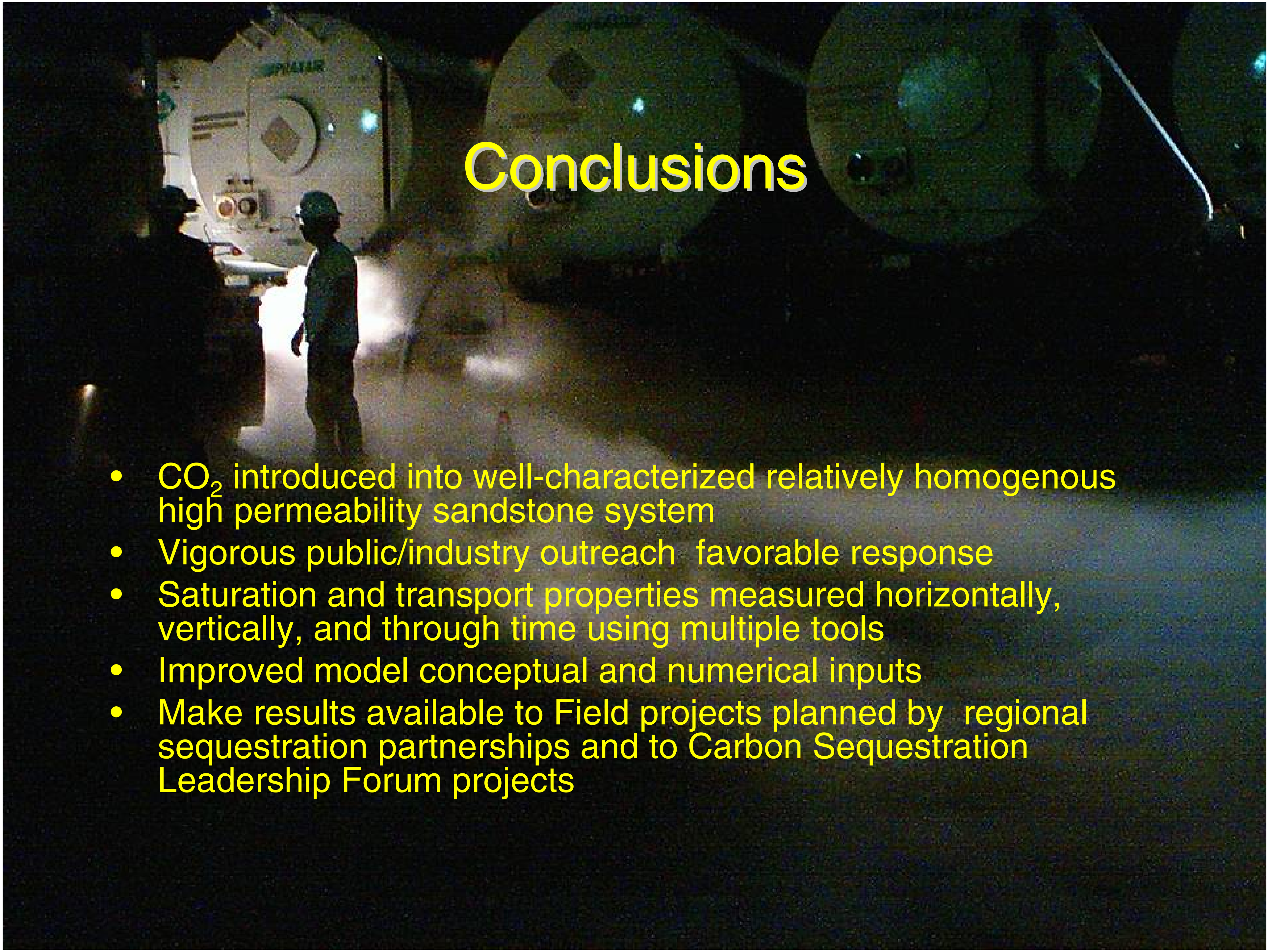


Surface Monitoring continues: results pending

Soil gas sampling

Gas well sampling

Water well sampling



Conclusions

- CO_2 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 Field projects planned by regional sequestration partnerships and to Carbon Sequestration Leadership Forum projects

More work needed: experiments not done at Frio

Experiment	why not done?
Large volume of CO_2	Risk, $
Interaction with faults premature	Risk, complex,
4-D survey	Problematic, $
Observation well array in zone	$
Tilt	Problematic, $
Microseismic array	Problematic,$
WAG	Interference
EOR	interference
EGR	interference
Streaming potential	$
Ecosystem impact survey	Problematic, $
Massive pre-project PR	Problematic
Legal/regulatory system test case	Problematic

Experiment	why not done?
During experiment pressure monitoring in overlying brine aquifers, fresh aquifers	Interference
Ecosystem CO2 flux towers	Problematic, $
Surface CO2 monitoring lasers	Problematic, $
Airborne/ satellite monitoring	Problematic
Dealing with dissolved methane	no plan
Exhaustive logging	Problematic, $
Other edgy down hole monitoring	
(e.g. non-conductive wells)	$
Long-term monitoring	problematic, $
Pipeline issues	premature
Complex gas injection	interference
Inject low, recover high	$
Well integrity, special cement	premature
Long-term geochemistry	$

Problematic = estimated to be unlikely to collect useful measurements at Frio scale, duration, site specific conditions
Interference = interferes with success of another experiment
$ = cost prohibitive in total project context. Might be used in a larger budget project