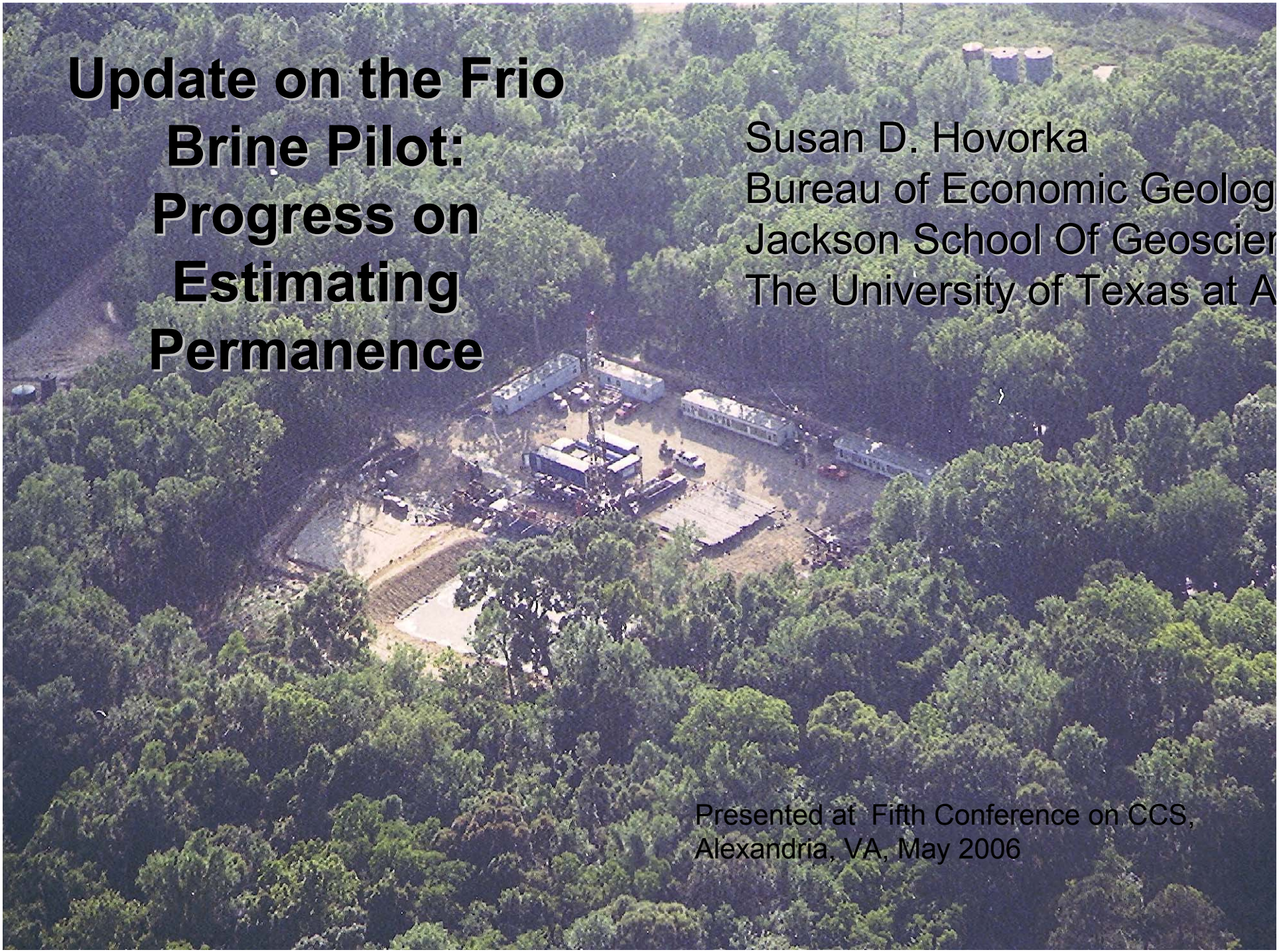


# Update on the Frio Brine Pilot: Progress on Estimating Permanence

Susan D. Hovorka
Bureau of Economic Geolog
Jackson School Of Geoscien
The University of Texas at A

Presented at Fifth Conference on CCS,
Alexandria, VA, May 2006

# Controls on Permanence

- Structural trapping
- Dissolution trapping
- Mineral trapping
- Phase trapping

# Frio Brine Pilot Research Team

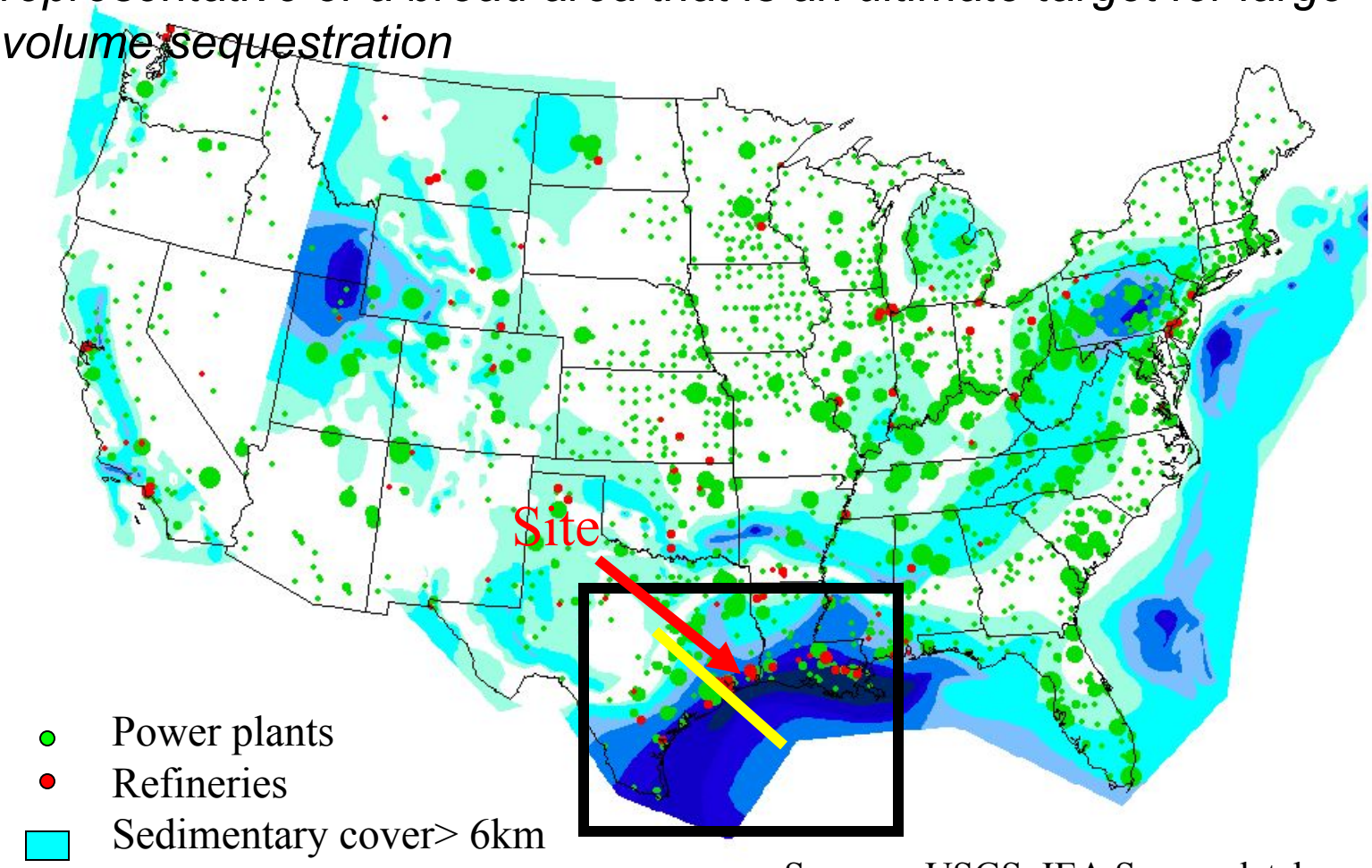
- Bureau of Economic Geology, Jackson School, The University of Texas at Austin: Susan Hovorka, Mark Holtz, Shinichi Sakurai, Seay Nance, Joseph Yeh, Paul Knox, Khaled Faoud, Jeff Paine
- Lawrence Berkeley National Lab, (Geo-Seq): Larry Myer, Tom Daley, Barry Freifeld, Rob Trautz, Christine Doughty, Sally Benson, Karsten Pruess, Curt Oldenburg, Jennifer Lewicki, Ernie Majer, Mike Hoversten, Mac Kennedy, Paul Cook
- Schlumberger: T. S. Ramakrishna, Nadja Mueller, Austin Boyd, Mike Wilt
- Oak Ridge National Lab: Dave Cole, Tommy Phelps, Scott McCallum, 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

Gulf Coast Carbon Center

NETL

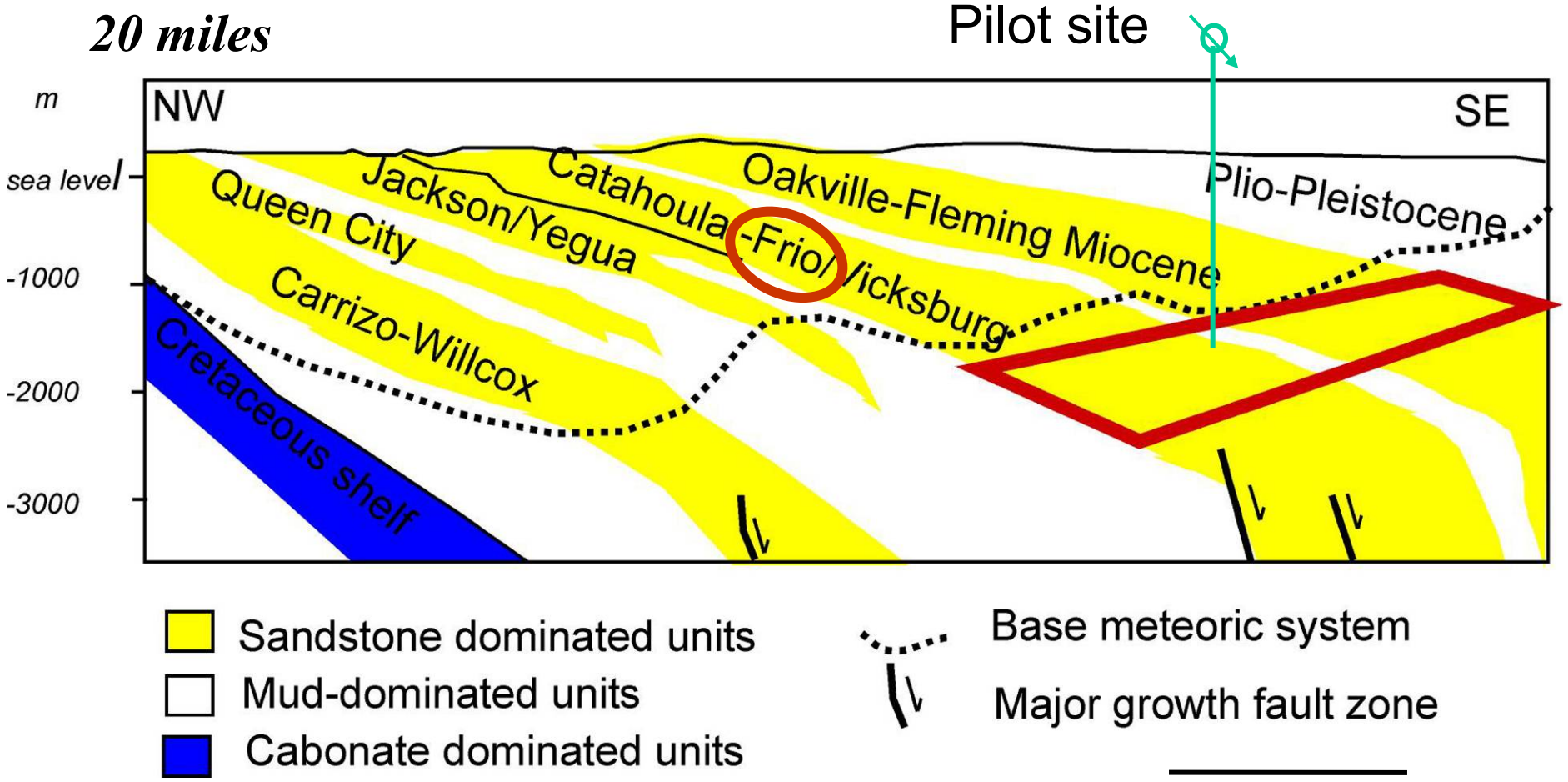
# Site Search

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



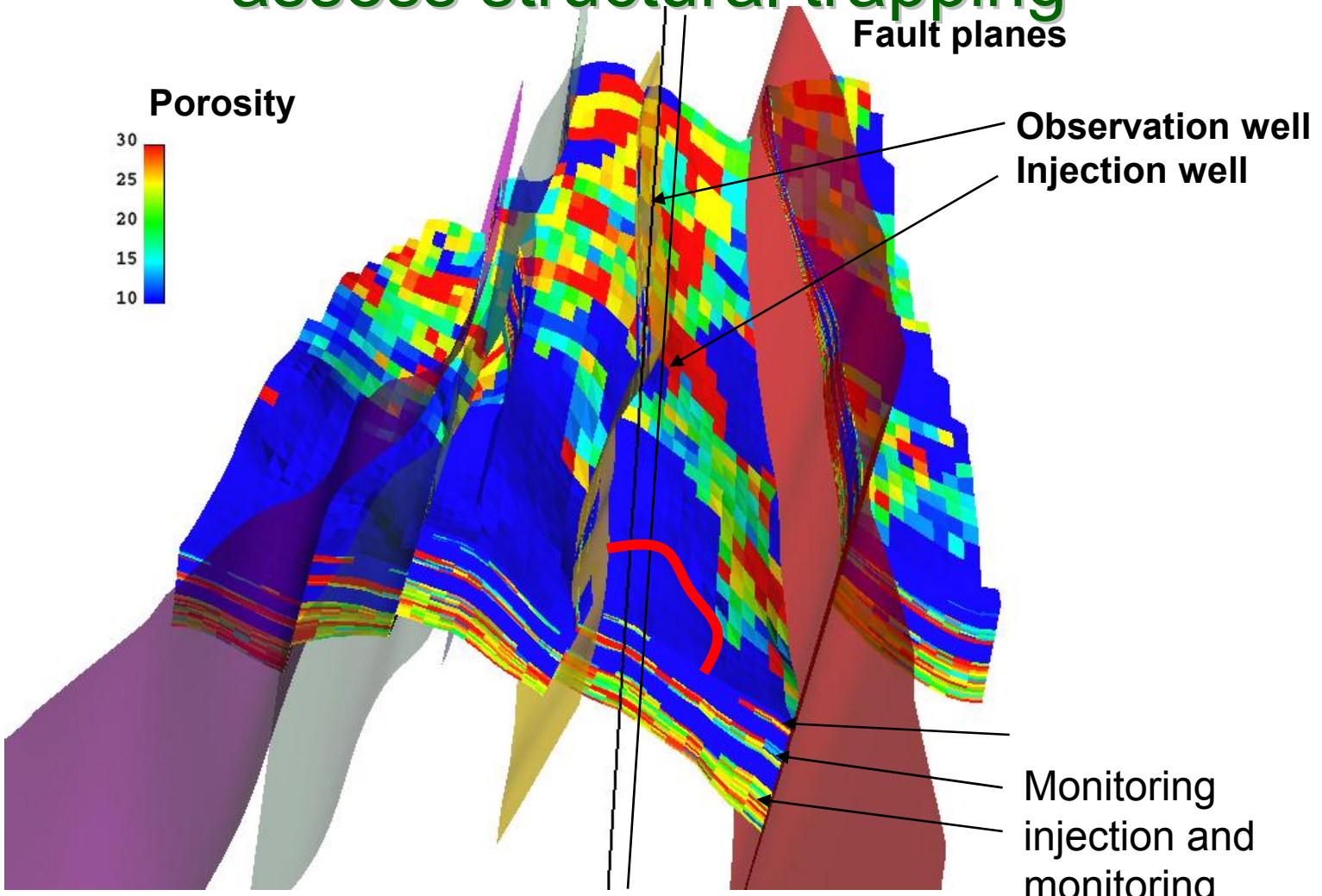

Sources: USGS, IEA Source database

# Regional Geologic Setting – Open Aquifer




Modified from Galloway and others, 1982

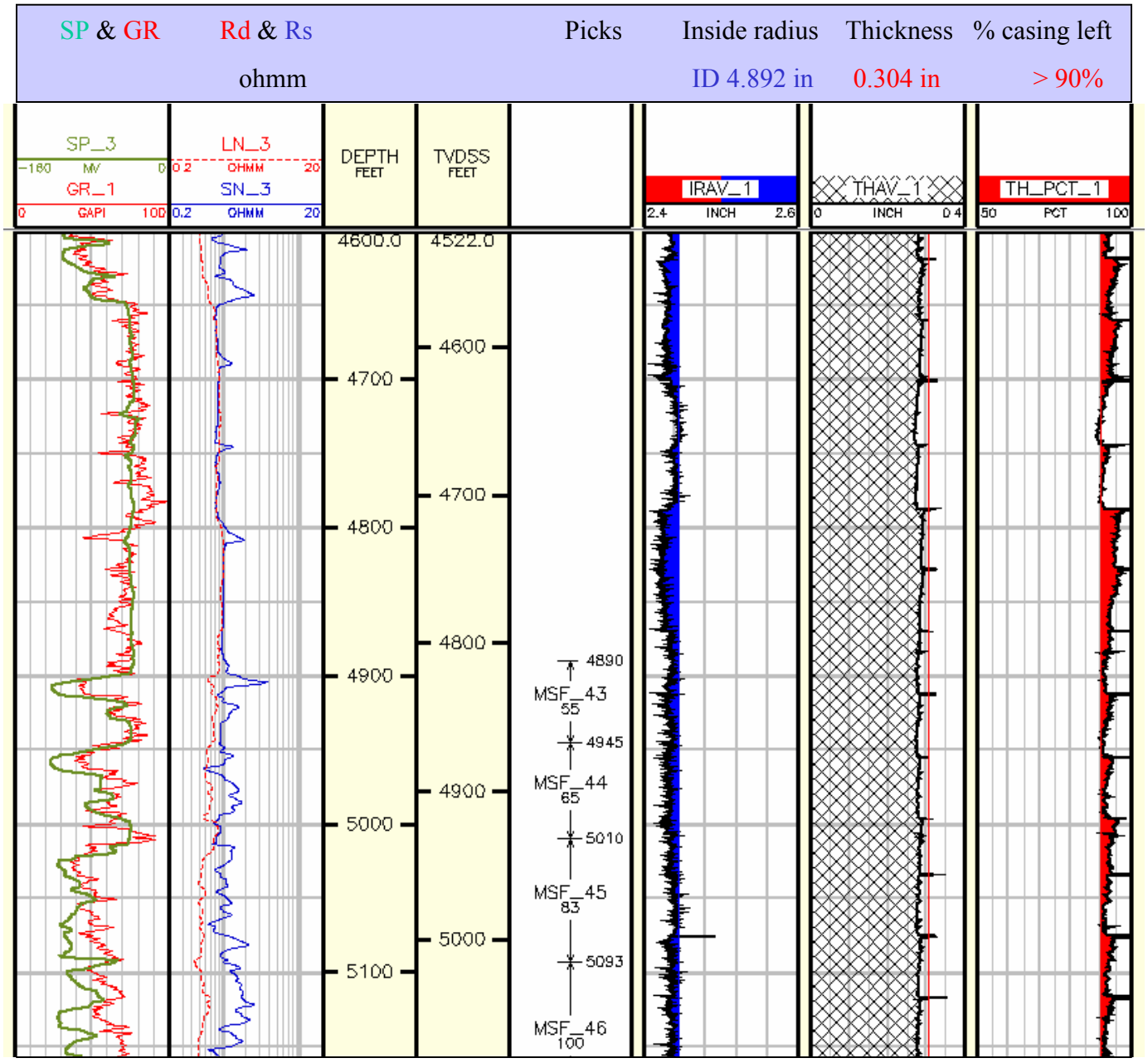
# Frio Test in a structural trap but did not assess structural trapping




Knox, Fouad, Yeh, BEG

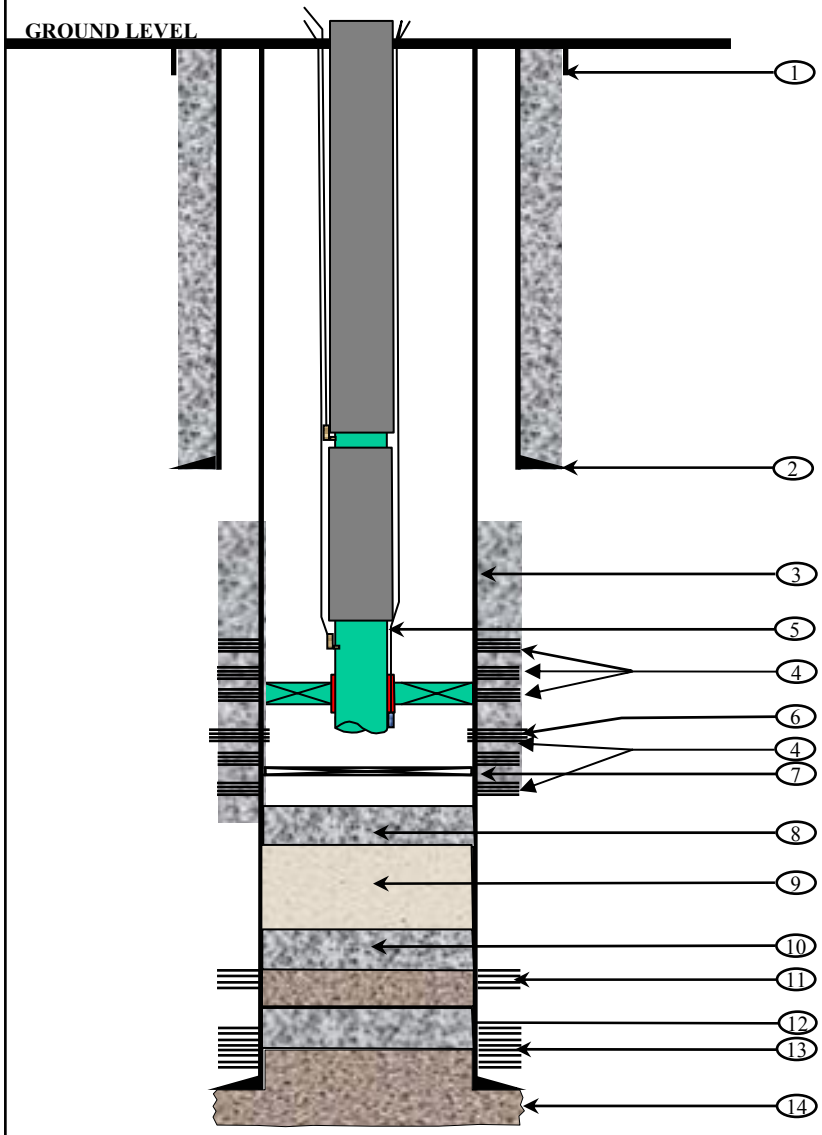
# Testing Remedial Cement on a 1950's well

# Casing Integrity



# Observation Well Schematic

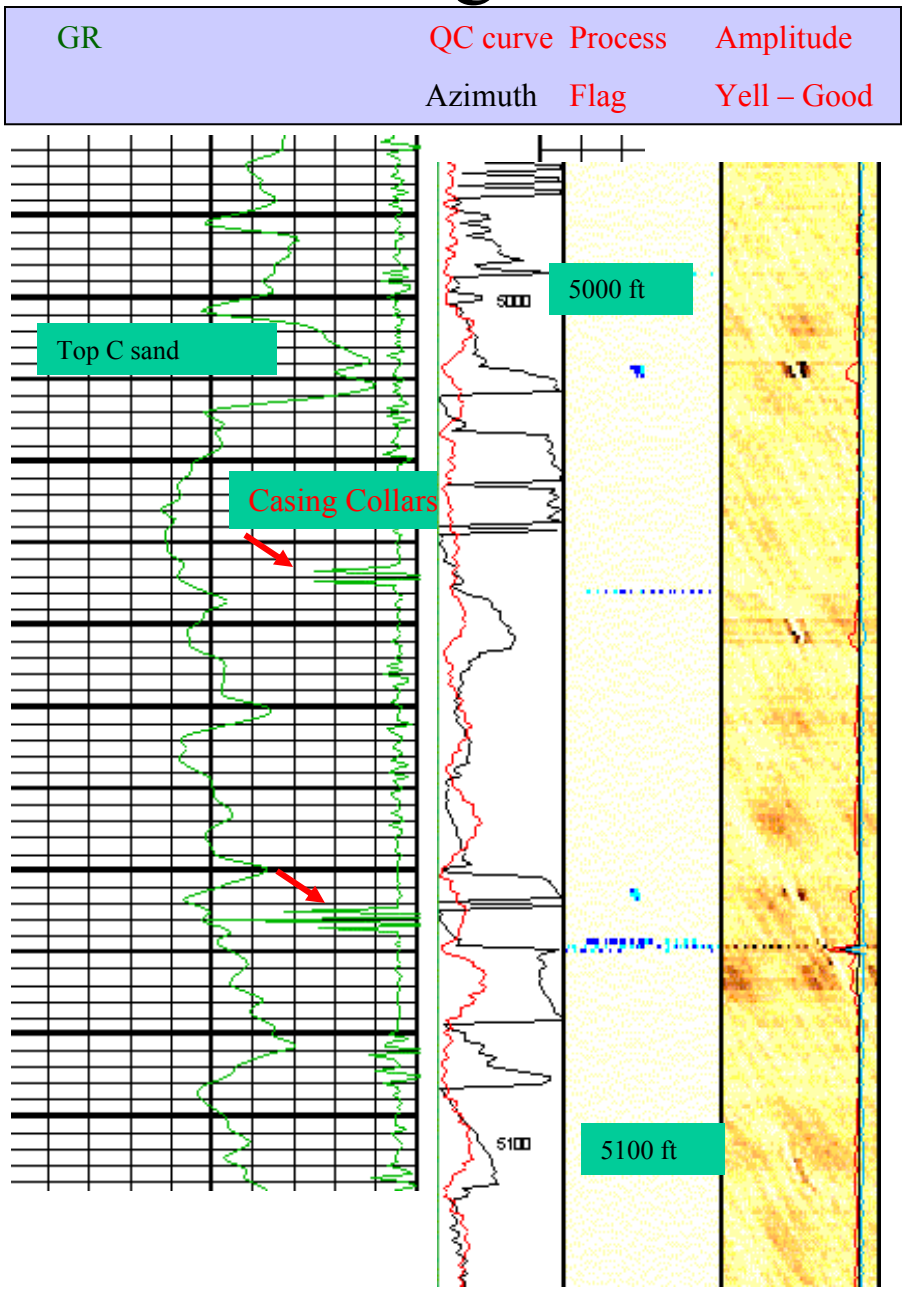
Sandia Technologies, LLC



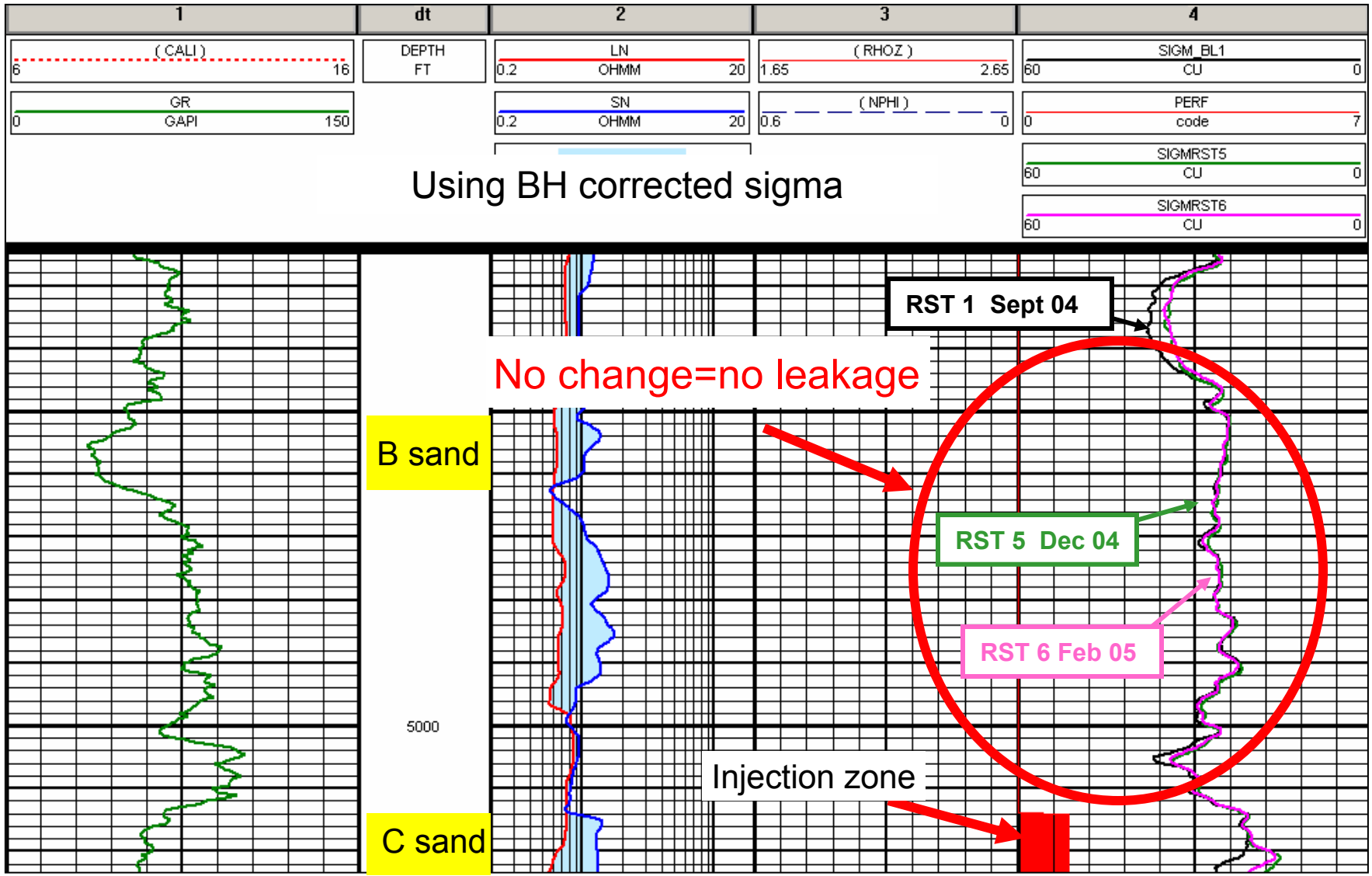

**COMPLETION DETAIL**

1. Conductor Pipe:
2. Surface Casing: 10-3/4" Set from surface to 2,040' (1952).
3. Protection Casing: 5-1/2" Set from surface to 8,964' (1952).
4. Tubing Sting: Surface to 4,971'
   - 2-7/8" tubing Surface to 1,516'
   - Gas Lift Sub, 2-3/8" pup joint, 1, 516' to 1,521'
   - 2-7/8" tubing, 1,521' to 4,948'
   - Pressure Gauge Sub, 2-3/8" pup joint 4,948' to 4,954'
   - Cross-Over Mandrel, 2" NU X 2-3/8", 4,954' to 4,960' (mandrel carries Sample Tube, Y and Check Valve, and Inflate Tube for Packer).
   - Inflatable Packer, Baker, w/3/8" pass-through SS line (sampler)
   - Inlet filter for Sample Tube
   - Wireline Re-entry Guide
5. Squeeze Perforations:
   - 4,831' to 4,835' and 4,882' to 4,885' (5/8/2004)
   - 4,932' to 4,935' and 4,998' to 5,002' (5/5/2004)
   - 5,040' to 5,044' and 5,023 to 5,025 (5/3/2004)
   - 5,102 to 5,106' and 5,054' to 5,057' (4/29/2004)
   - 5,189' to 5,192' and 5,110' to 5,113' (4/27/2004)
6. Production Perforations: 5,014' to 5,034' w/ 4 shots per foot, 90 degrees phasing, 6.5 gram HMX charges, .245" entry holes, and 20" penetration. (8//2004)
7. Cast Iron Bridge Plug: 5,180' (8//2004)
8. Cement Plug: 6,129' to 6,327' (8/01/2003). Class H, 23 sacks.
9. Drilling Mud Plug: 6,327' to 7,931' (8/01/2003). 10.6-ppg.
10. Cement Plug: 7,931' to 8,414'(7/31/2003). Class H, 57 sacks.
11. Abandoned Perforated: 8,489' to 8,501' (7/31/2003).
12. Plug Back Total Depth: 8,600'
13. Abandoned Perforation: 8,810' to 8,914'
14. Total Depth Drilled: 9,516'

# Cement Log

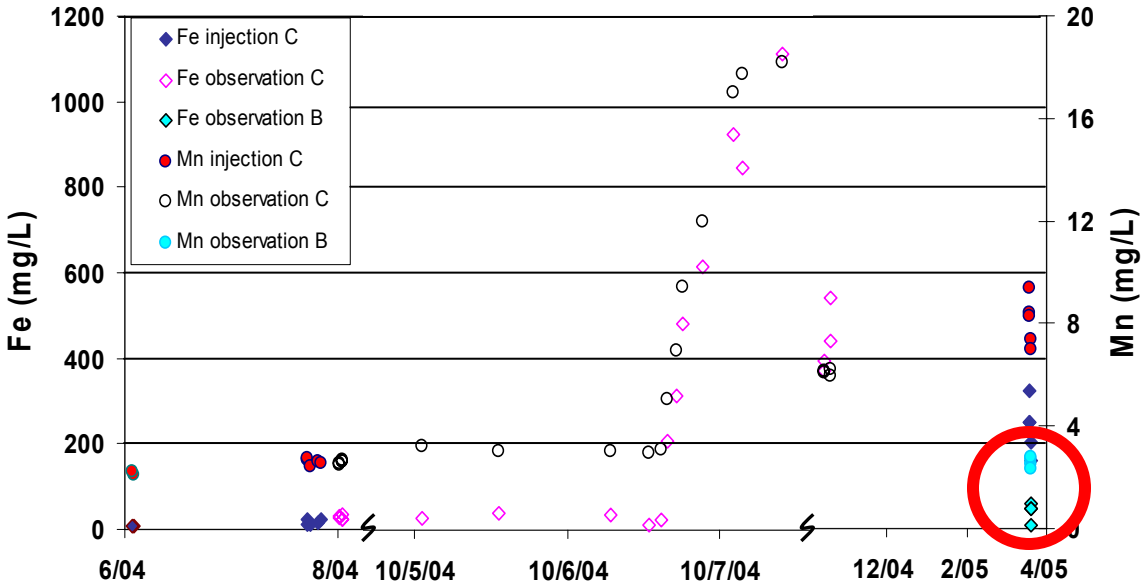

GR
QC curve
Process
Amplitude
Azimuth
Flag
Yell – Good
Top C sand
Casing Collars
5000 ft
5100 ft

# Evidence of upward leakage?
# From saturation logs: No



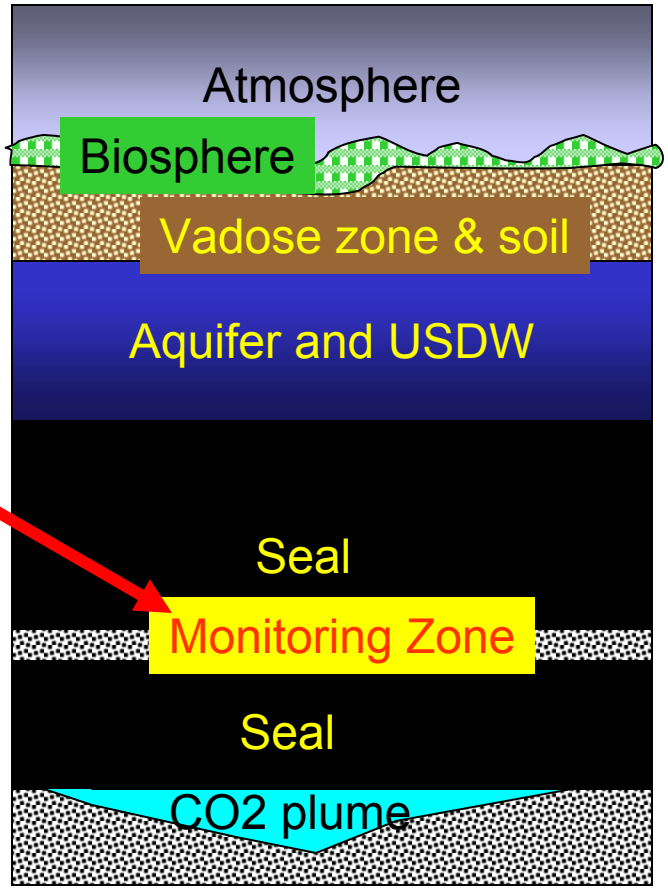
# Indicators of Leakage from “C” to “B”

- Sonic signal “bubbling”
- Tracer and geochemical change

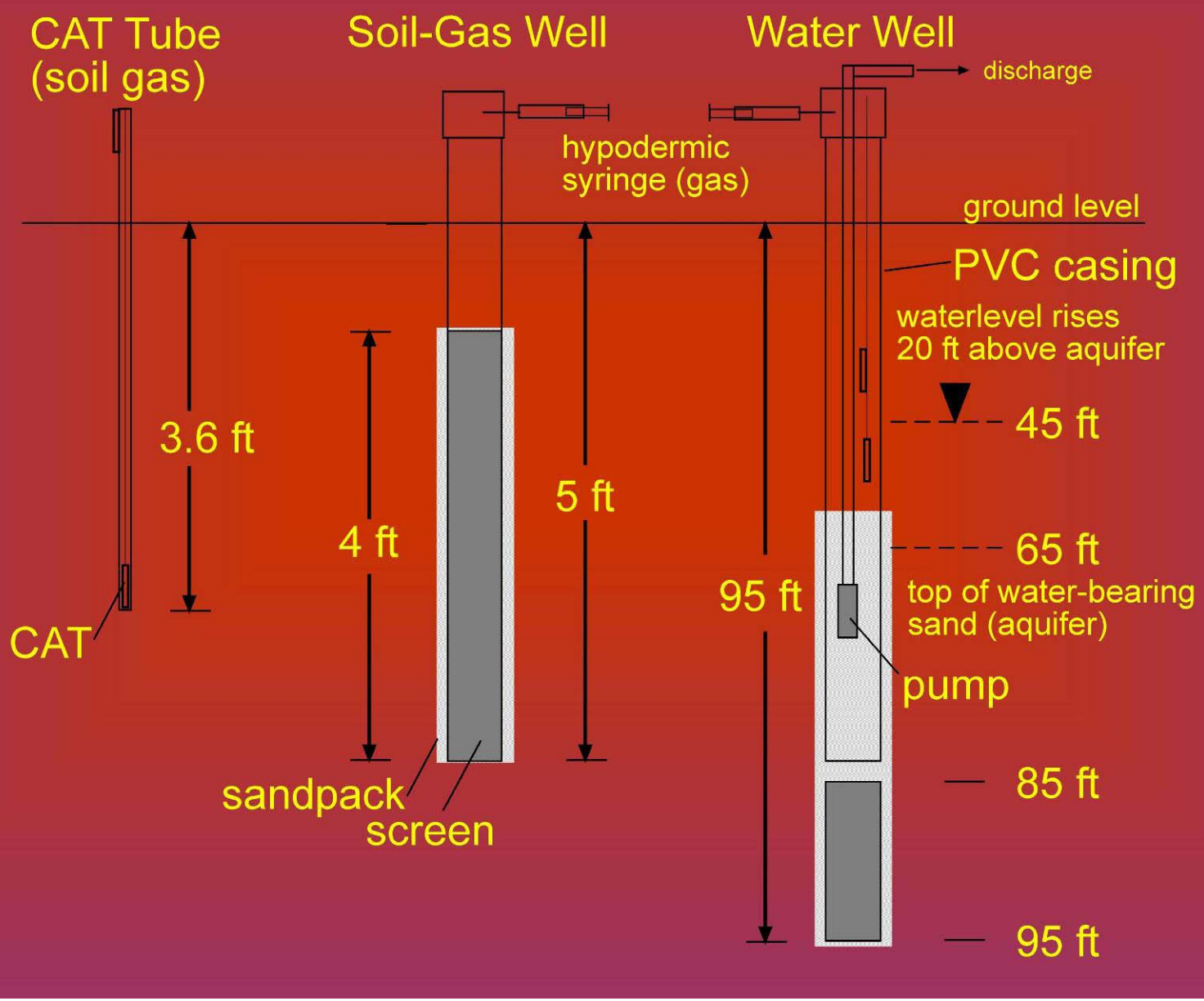


# Subsurface Monitoring Above Injection Zones

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



# Shallow Aquifer and Soil-gas Monitoring



# Surface Monitoring: No Clear Signal – repeat PFT survey

Gas well sampling

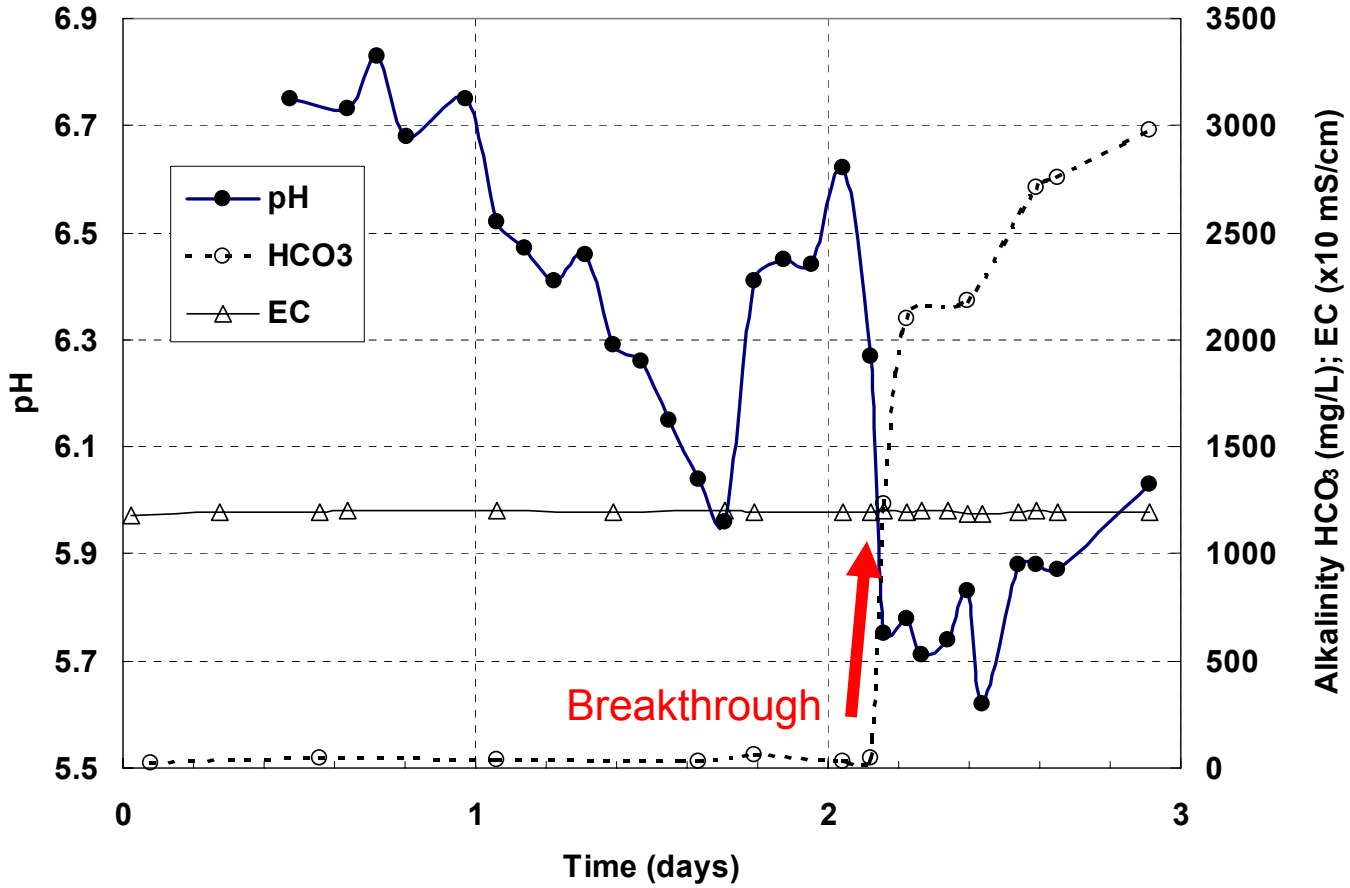
Water well sampling

Soil gas sampling

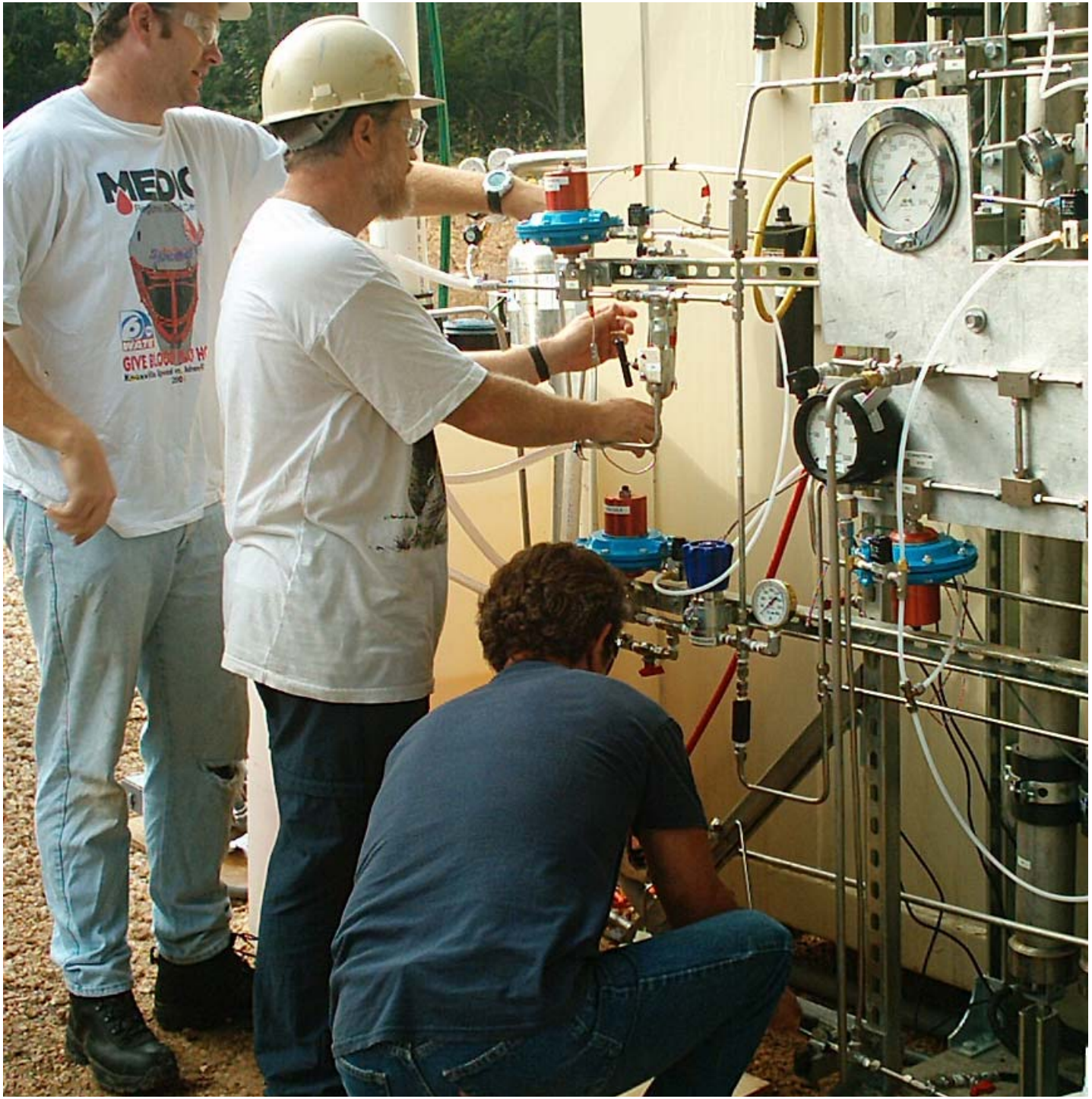

# Leakage at Surface?

- Tracers vented to surface as part of two-well design
- Successful detection not indicative of leaks
- Plan follow-on measurement

# Fluid chemistry: alkalinity and pH of brine from observation well during $CO_2$ Injection show rapid dissolution




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



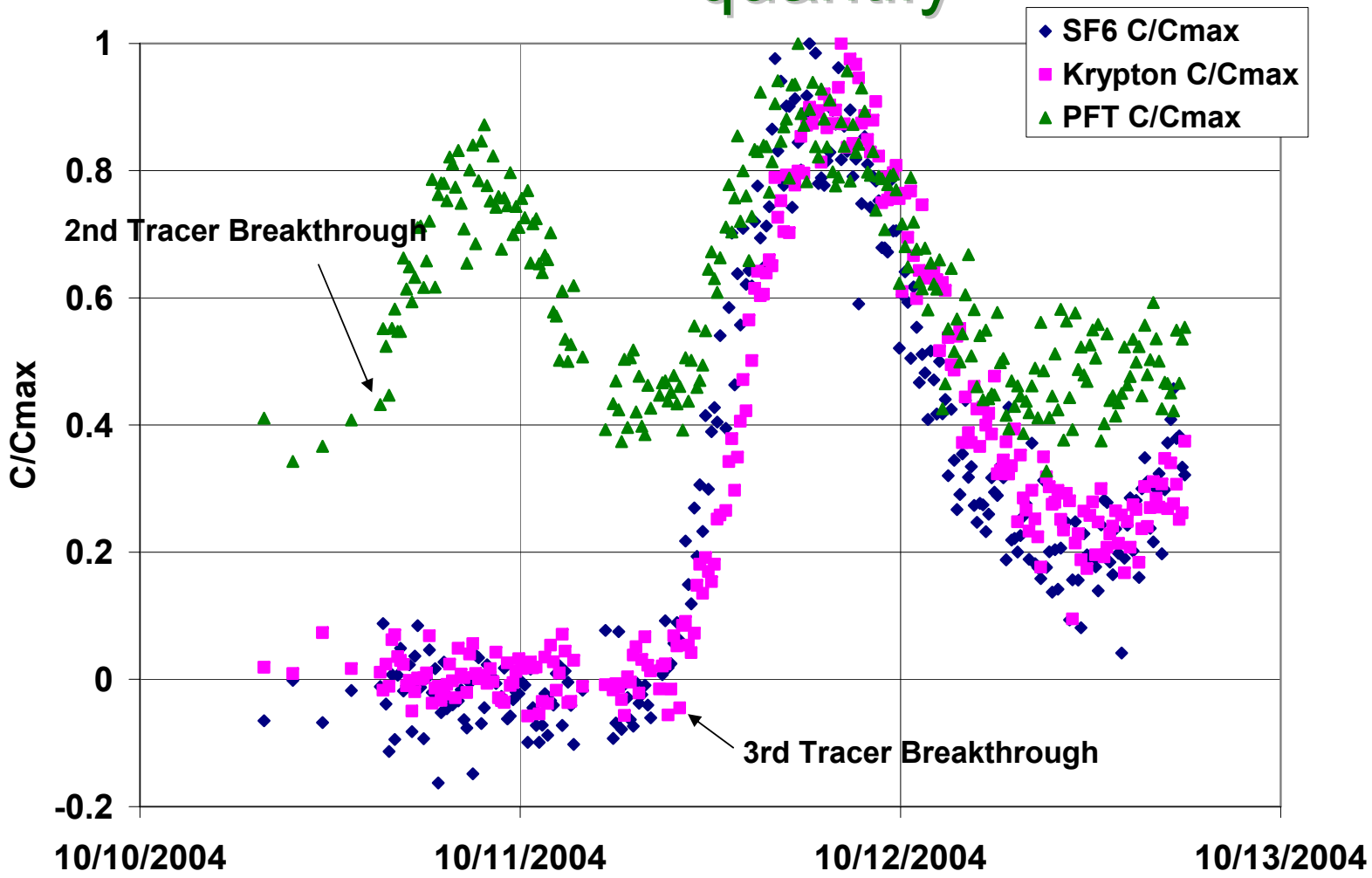

*New tool to do the job:*
*LBNL U-tube*

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

Tommy Phelps
Dave Ristenburg
Oak Ridge National Lab

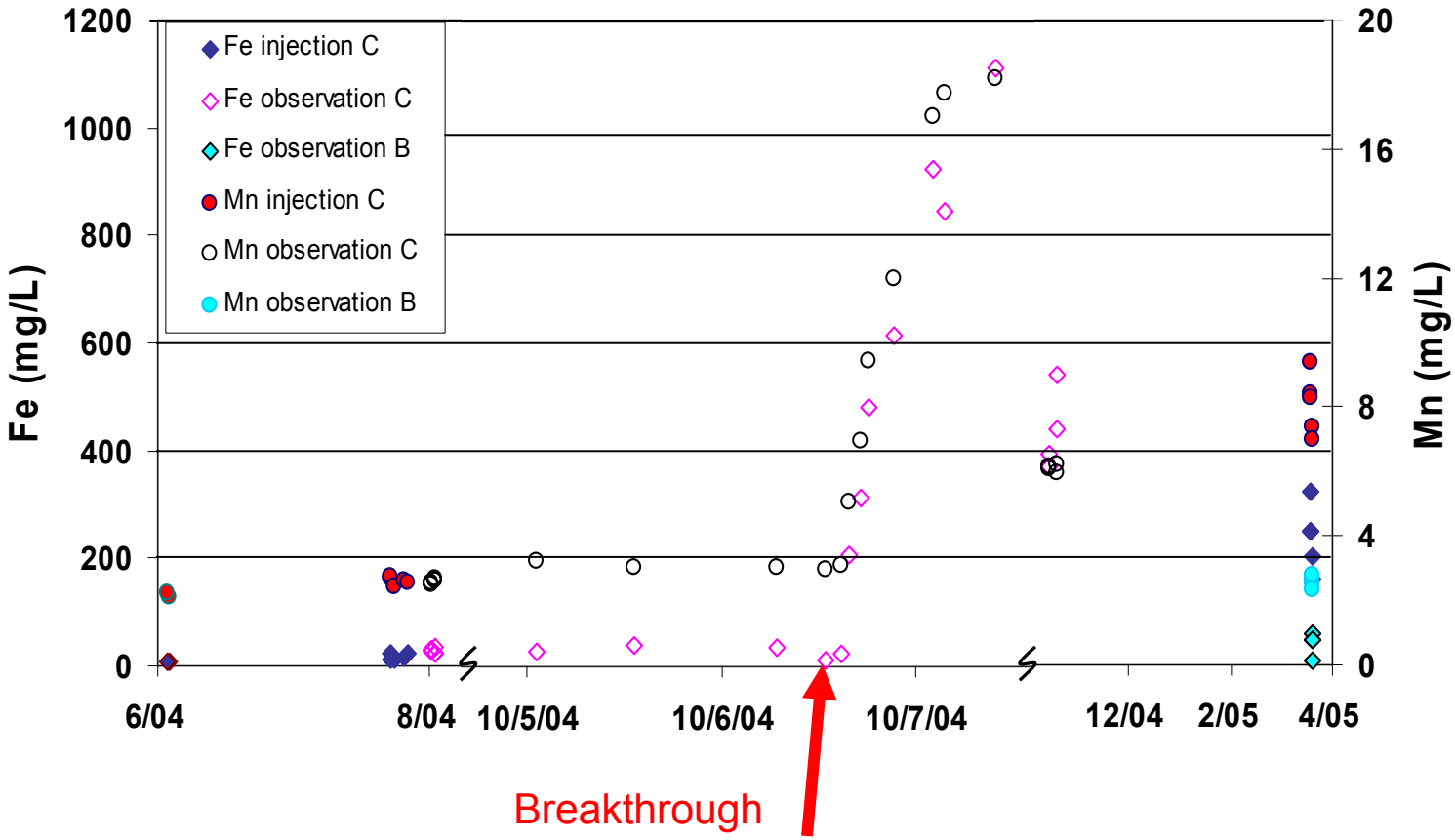
Seay Nance
BEG

# Tracer Breakthrough – significant dissolution – test again in Frio II to better quantify



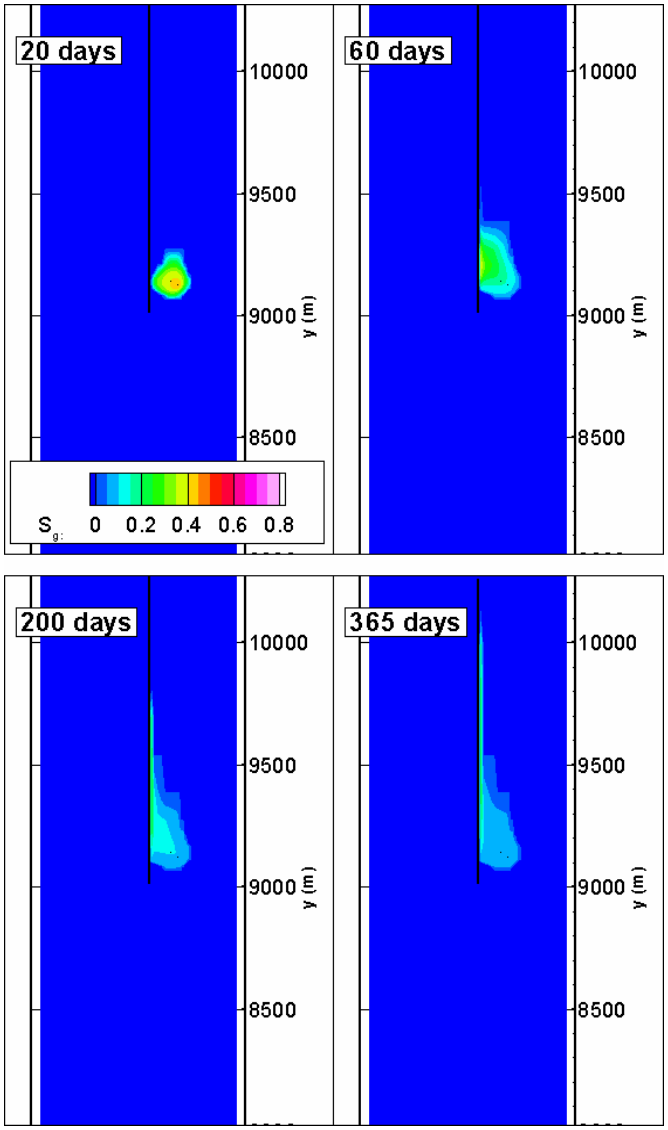

Barry Freifeld, LBNL; Tommy Phelps ORNL

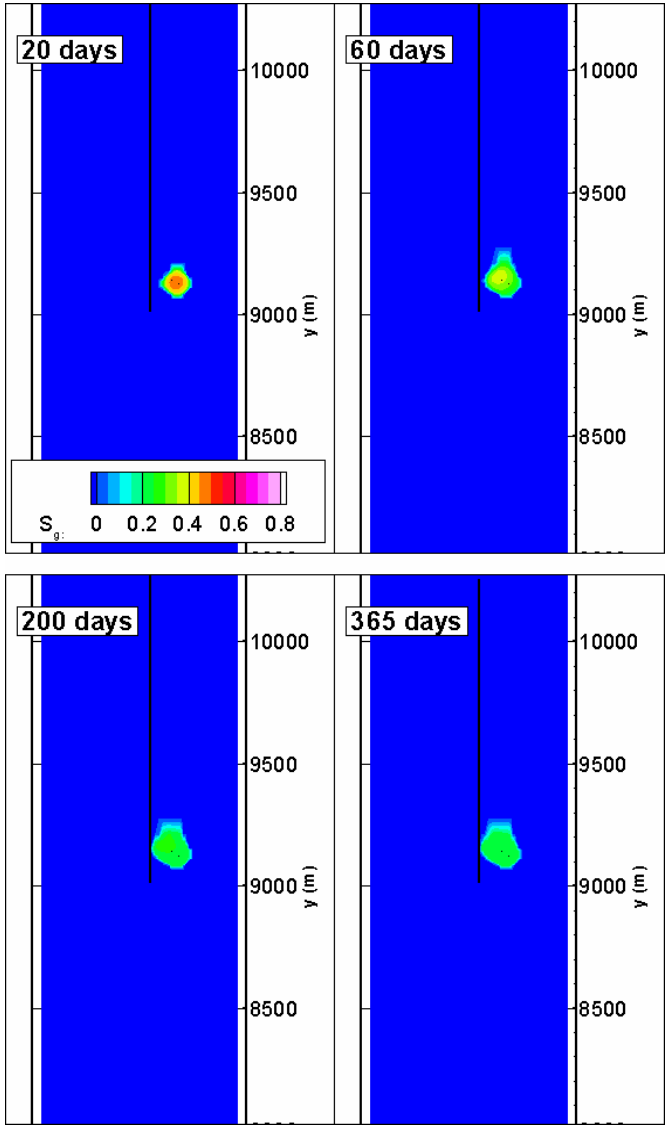
# Mobilization of Metals



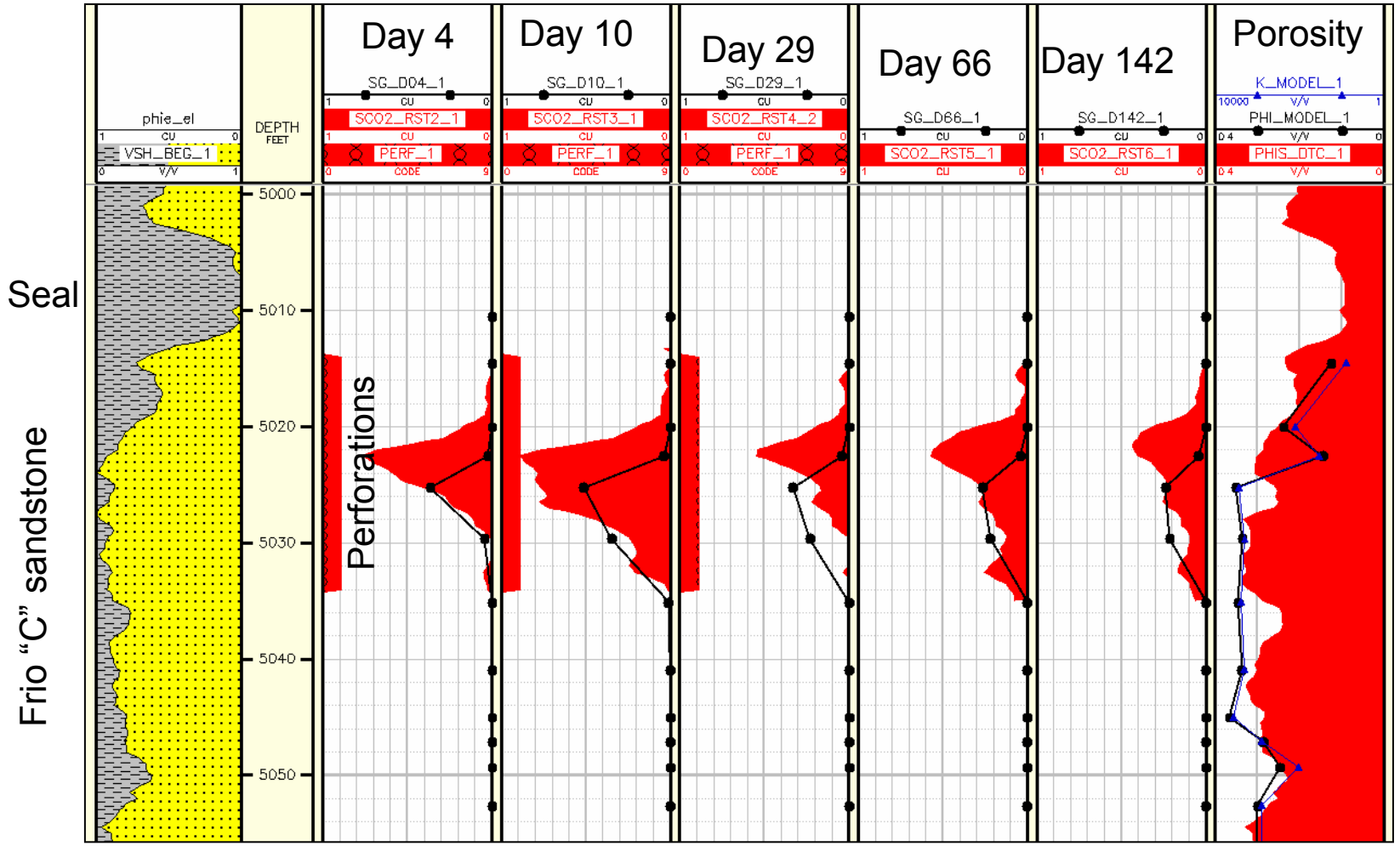

Y. Kharaka, USGS; H. S. Nance, BEG

# Phase trapping is significant in permanence



# Wireline logging observation well to measure changes in $CO_2$ saturation – match to model

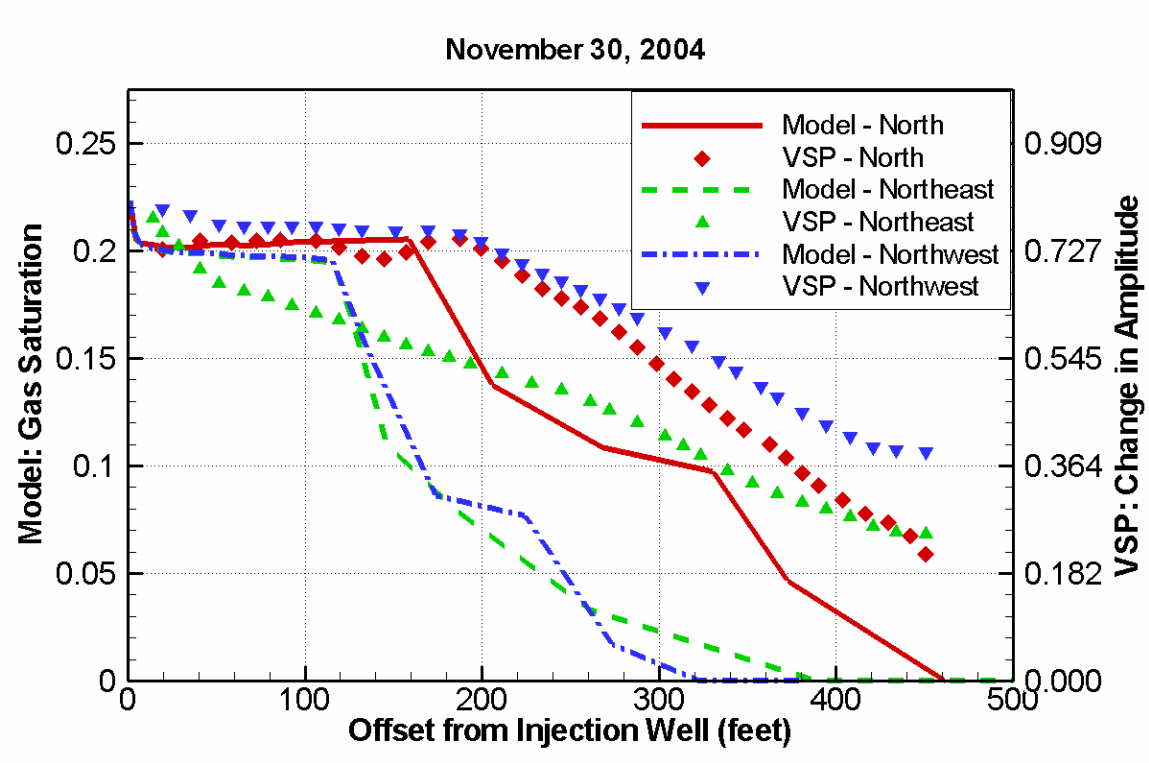



Shinichi Sakurai BEG and Schlumberger

# Production test -16 months after end injection

- 300 feet wellbore was filled with gas-phase $CO_2$, with atmospheric pressure at wellhead.
- Below 100 m, brine filled the well, and it failed to flow when the well was opened.
- Swabbing the well to produce brine decreased pressure about 14 bars in the injection zone and the well produced brine under weak $CO_2$ lift as $CO_2$ expanded in the formation.
- Water to gas was 13,600 to 1, and $CO_2$ was produced at an average of 0.17 tons/hour, but the rate did not decline during the one day production period.

# Plume Size Measured with VSP vs. modeled plume size – Not yet repeated




Tom Daley and Christine Doughty LBNL

# Frio 2 Plans

- Small injection - 400 tones
- Base of thick sandstone – test vertical migration
- U-tubes both wells, tracer program - test dissolution, plume evolution
- Optimized RST logging program- better quantified saturation
- Installed downhole seismic

# Conclusions

- Structural trapping not tested
- Field observations confirm well-leakage issue
- No interpretable results on surface environmental monitoring
- Dissolution of $CO_2$ into brine was rapid
- Phase trapping appears significant