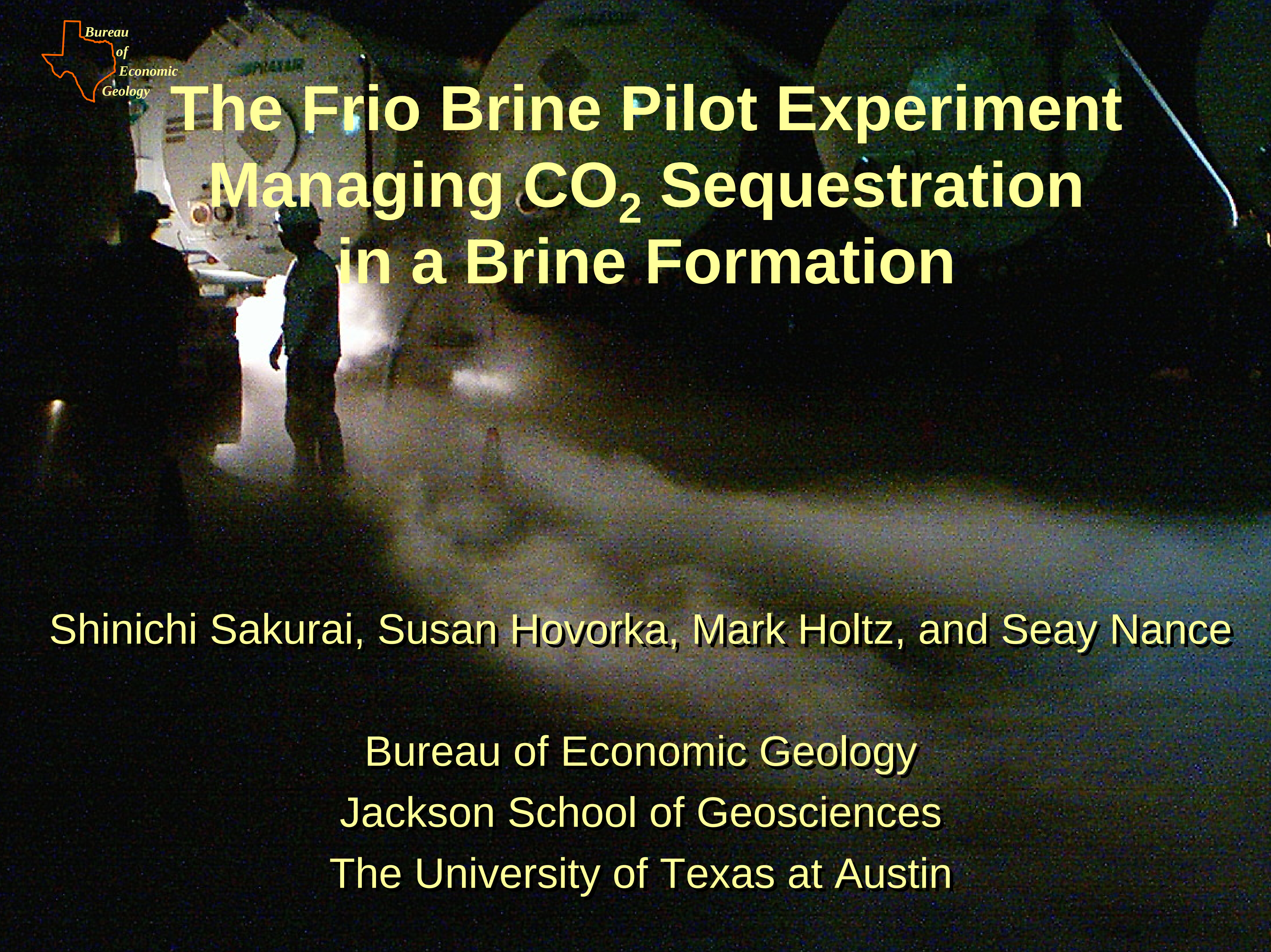
The Frio Brine Pilot Experiment: Managing CO_2 Sequestration in a Brine Formation

Shinichi Sakurai, S. Hovorka, M. Holtz, and S. Nance

Funded by the U.S. Department of Energy National Energy Technology Laboratory, the Frio Brine Pilot Experiment was begun in 2002. The increase in greenhouse gas emissions, such as carbon dioxide (CO_2), is thought to be a major cause of climate change. Sequestration of CO_2 in saline aquifers below and separate from fresh water is considered a promising method of reducing CO_2 emissions. The objectives of the experiment are to (1) demonstrate CO_2 can be injected into a brine formation safely; (2) measure subsurface distribution of injected CO_2; (3) test the validity of conceptual, hydrologic, and geochemical models, and (4) develop experience necessary for larger scale CO_2 injection experiments. The Bureau of Economic Geology (BEG) is the leading institution on the project and is collaborating with many national laboratories and private institutes. BEG reviewed many saline formations in the US to identify candidates for CO_2 storage. The Frio Formation was selected as a target that could serve a large part of the Gulf Coast and site was selected for a brine storage pilot experiment in the South Liberty field, Dayton, Texas. Most wells were drilled in the 1950's, and the fluvial sandstone of the upper Frio Formation in the Oligocene is our target, at a depth of 5,000 ft. An existing well was used as the observation well. A new injection well was drilled 100 ft away, and 30 ft downdip from the observation well. Conventional cores were cut, and analysis indicated 32 to 35 percent porosity and 2,500 md permeability. Detailed core description was valuable as better characterization resulted in design improvements. A bed bisecting the interval originally thought to be a significant barrier to flow is a sandy siltstone having a permeability of about 100 md. As a result, the upper part of the sandstone was perforated. Because of changes in porosity, permeability, and the perforation zone, input for the simulation model was updated and the model was rerun to estimate timing of CO_2 breakthrough and saturation changes. A pulsed neutron tool was selected as the primary wireline log for monitoring saturation changes, because of high formation water salinity, along with high porosity. Baseline logs were recorded as preinjection values. We started injection of CO_2 on October 4, 2004, and injected 1,600 tons of CO_2 for 10 days. Breakthrough of CO_2 to the observation well was observed on the third day by geochemical measurement of recovered fluids, including gas analysis and decreased pH value. Multiple capture logs were run to monitor saturation changes. The first log run after CO_2 breakthrough on the fourth day showed a significant decrease in sigma was recorded within the upper part of the porous section (6 ft) correlative with the injection interval. Postinjection logs were compared with baseline logs to determine CO_2 distribution as CO_2 migrated away from the injection point. The dipole acoustic tool was used to estimate saturation changes to improve geophysical data interpretation using VSP and crosswell tomography. Compared with the baseline log, wireline sonic log made 3 months later showed a weak and slower arrival of compressional wave over the perforated interval. Results from crosswell tomography data also showed changes in compressional velocity. Successful measurement of plume evolution documents an effective method to monitor CO_2 in reservoirs and document migration.



Bureau of Economic Geology

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Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

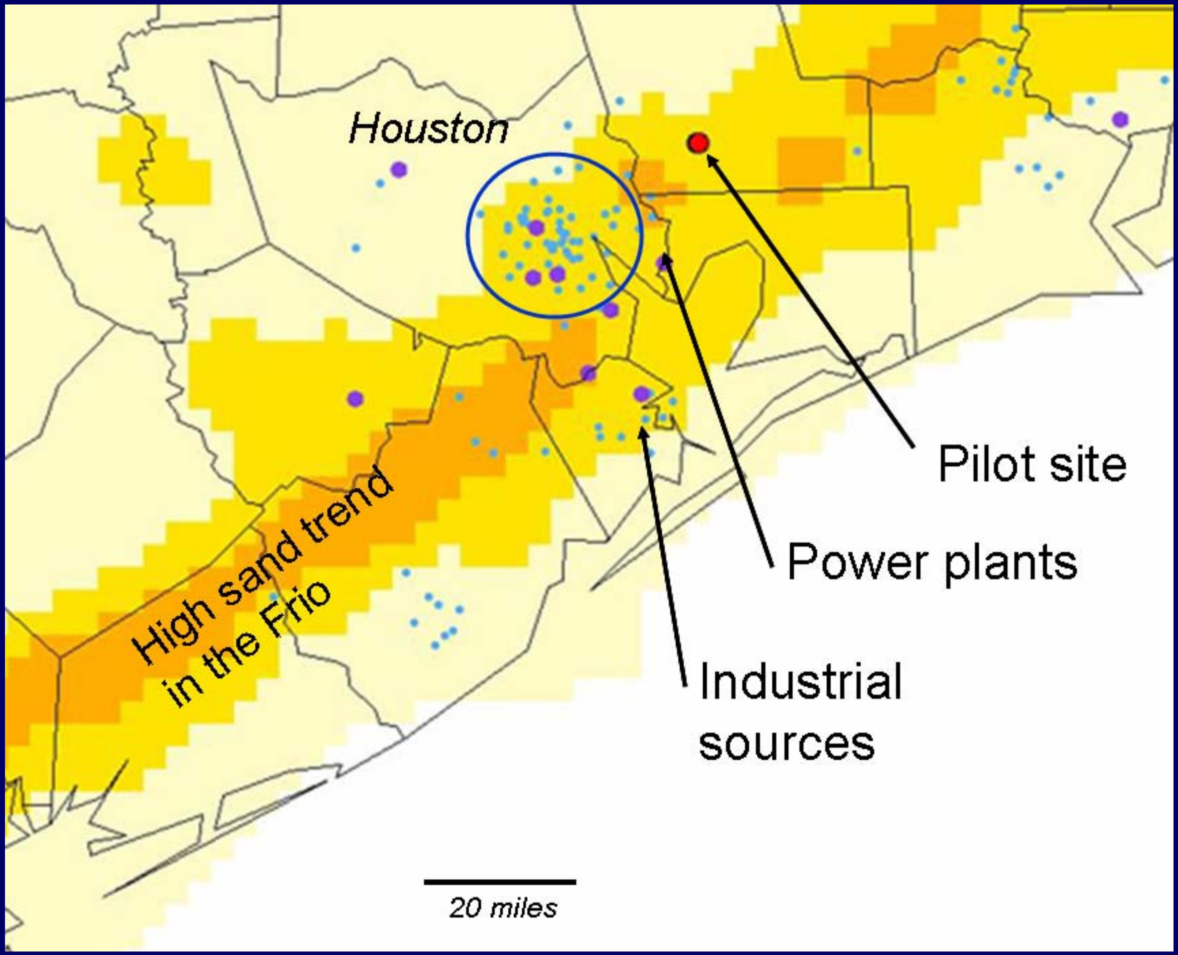
Outline

- Introduction
- New Injection Well
  - Core and Wireline Logs
- Monitoring of CO_2 Distribution
  - Monitoring by Cased-Hole Log
  - Tying to Geophysical Data

Objectives

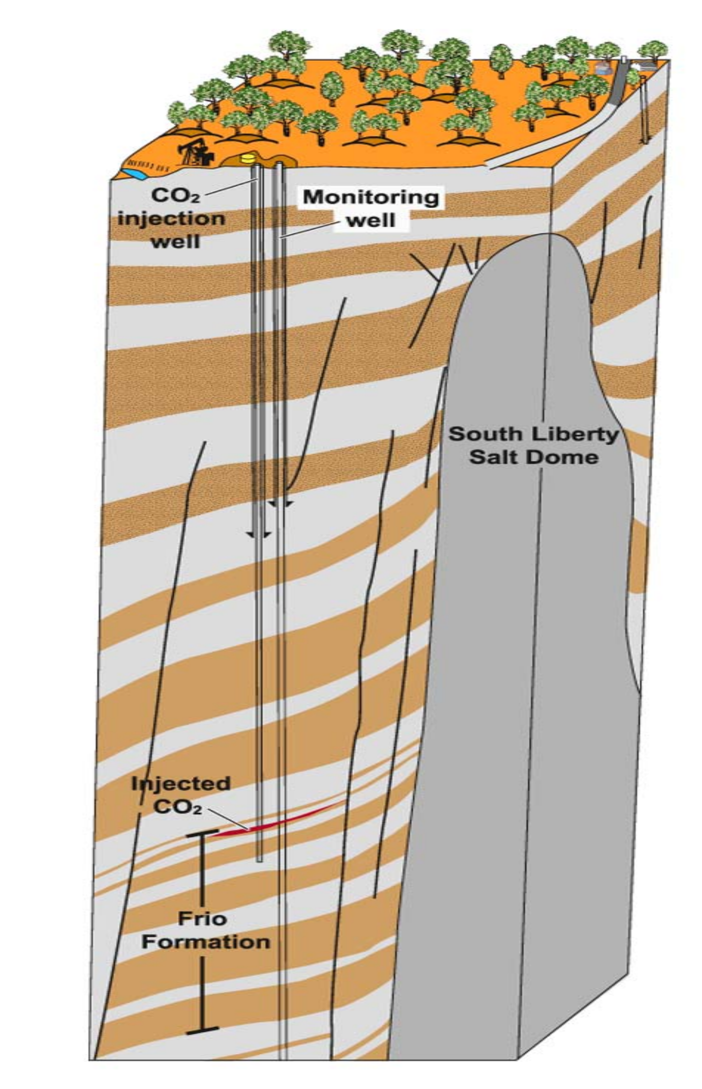
- Demonstrate CO_2 can be injected into a brine formation safely
- Measure subsurface distribution of injected CO_2
- Test the validity of conceptual, hydrologic, and geochemical models
- Develop experience necessary for larger scale CO_2 injection experiments

Frio Brine Pilot



- **Dayton, Texas, East of Houston**
- **South Liberty field**
  - **Discovered in 1925**
  - **Oil from Yegua sand (9,000 ft)**

Frio Brine Pilot



- Injection of CO_2 into Frio Sandstone (5,000 ft)

Frio Brine Pilot Research Team

- **Funded by U.S. DOE National Energy Technology Lab:**
- **Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin:**
- **Lawrence Berkeley National Lab (Geo-Seq):**
- **Oak Ridge National Lab:**
- **Lawrence Livermore National Lab:**
- **Alberta Research Council:**
- **Texas American Resources:**
- **Sandia Technologies:**
- **BP:**
- **Schlumberger:**
- **SEQUIRE – National Energy Technology Lab:**
- **University of West Virginia:**
- **USGS:**
- **Praxair:**
- **Australian CO2CRC (CSRIO):**
- **Core Labs:**

Gulf Coast Carbon Center

Frio Brine Pilot Research Team

- Funded by U.S. DOE National Energy Technology Lab: Karen Cohen/Charles Byrer
- Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin: Susan Hovorka, Mark Holtz, Shinichi Sakurai, Seay Nance, Joseph Yeh, Paul Knox, Khaled Fouad, 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 Major, Mike Hoversten, Mac Kennedy, Don Lippert
- 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
- Texas American Resources: Don Charbula, David Hargiss
- Sandia Technologies: Dan Collins, "Spud" Miller, David Freeman, Phil Papadeas
- BP: Charles Christopher, Mike Chambers
- Schlumberger: T. S. Ramakrishna, Nadja Muller, Austin Boyd, Mike Wilt
- SEQUIRE – National Energy Technology Lab: Curt White, Rod Diehl, Grant Bromhall, Brian Stratizar, Art Wells
- University of West Virginia: Henry Rausch
- USGS: Yousif Kharaka, Bill Evans, Evangelos Kakauros, Jim Thorsen
- Praxair: Joe Shine, Dan Dalton
- Australian CO2CRC (CSRIO): Kevin Dodds
- Core Labs: Paul Martin and others

Gulf Coast Carbon Center

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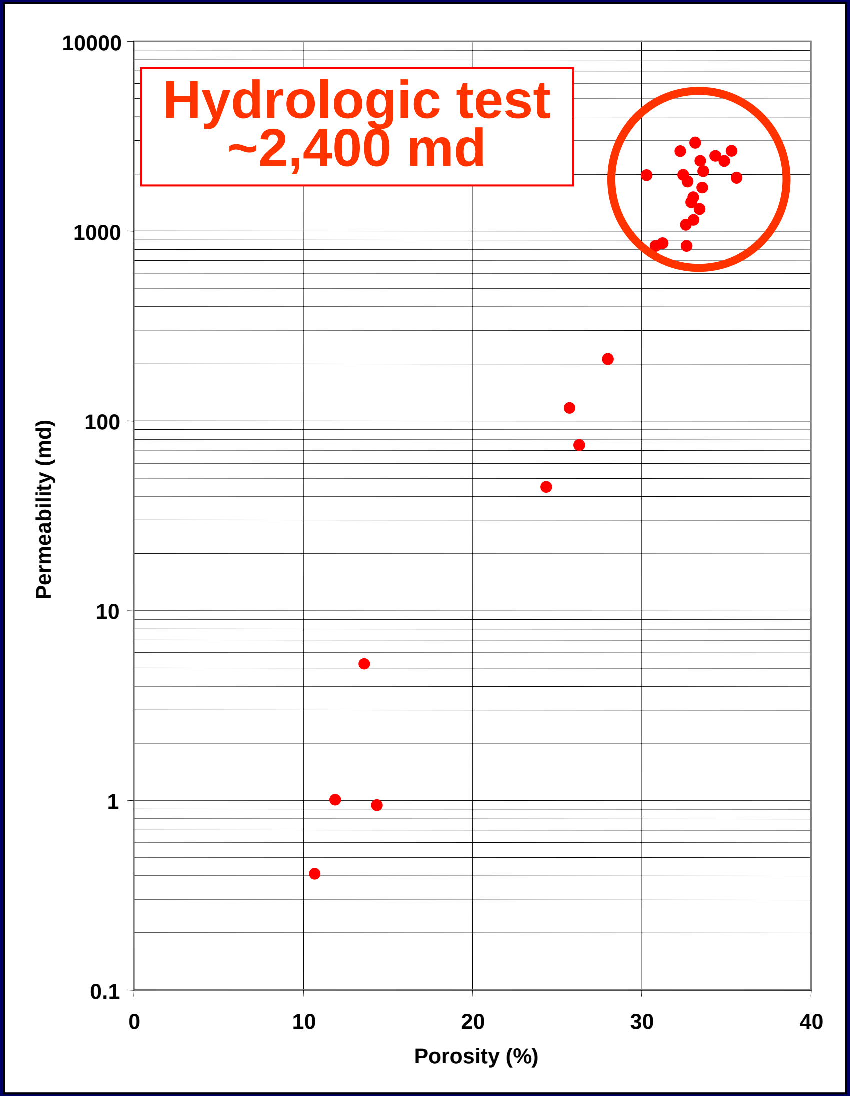
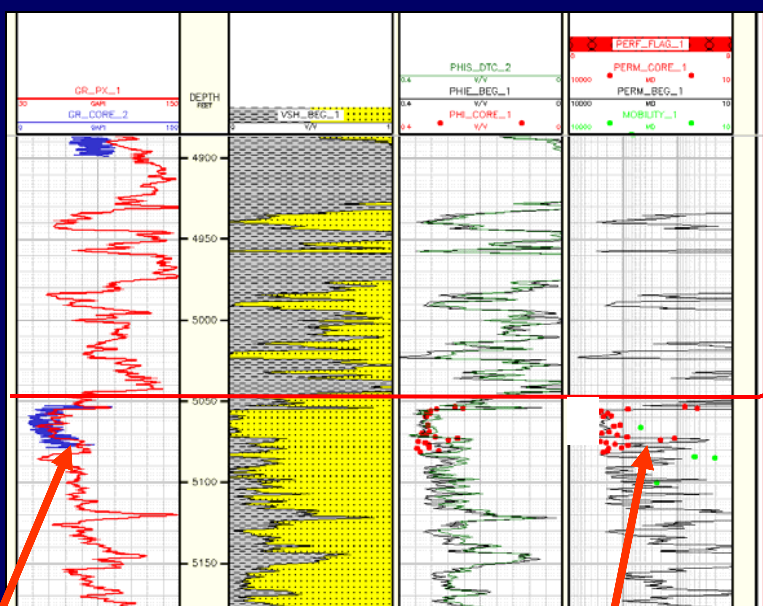
Core Analysis Results



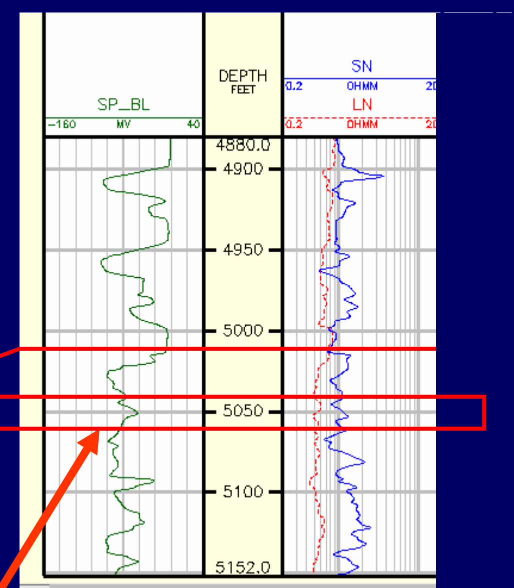
Conventional analysis made @ 1,800 psi

Core Description and Perforation Interval

Injection well



Observation well drilled in 1956



Mid C sand shale ?

Sandy silt K ~100 md

Mid C sand shale Perf. in Lower C sand

Not continuous shale

Change in perforation in Upper C sandstone

New Model

- Larger porosity and permeability
- Change in perforation intervals

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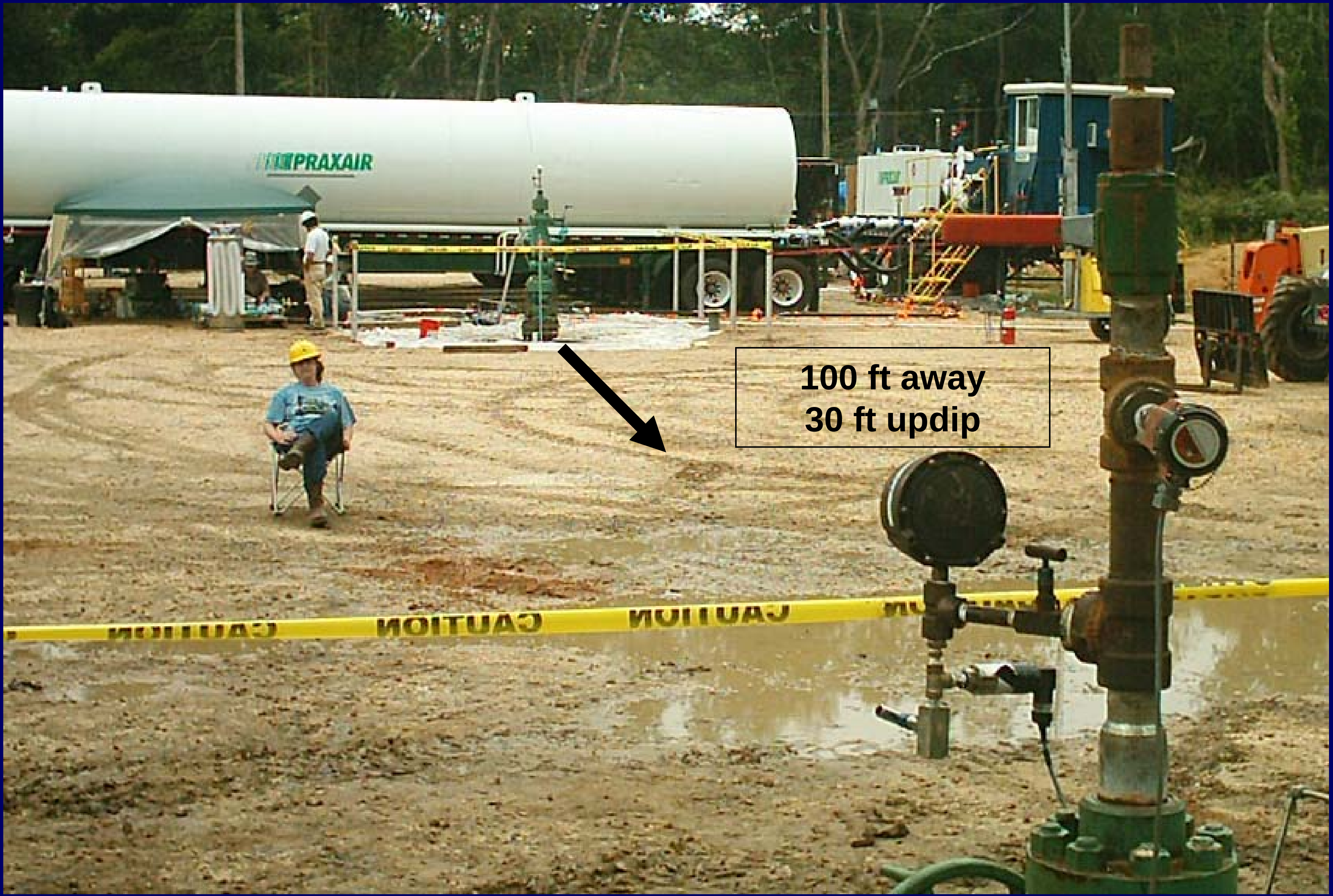
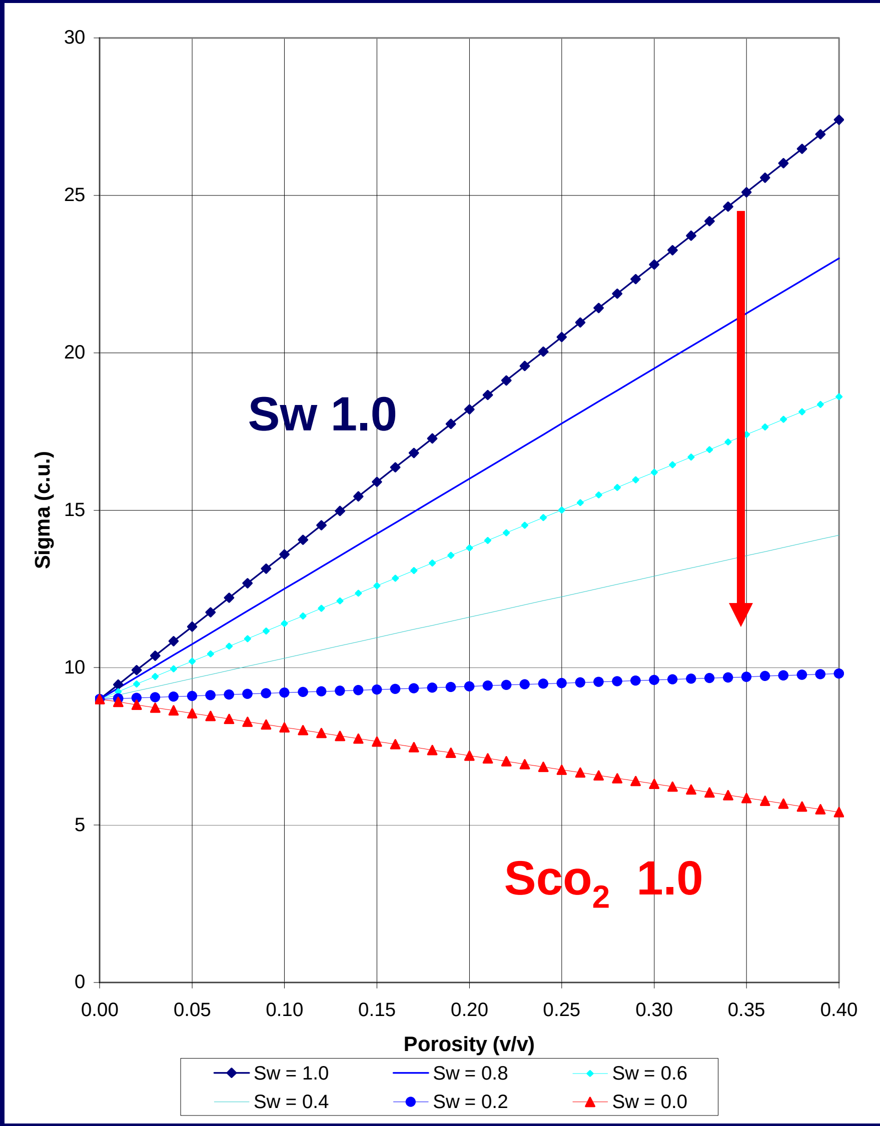
Monitoring of CO_2 Distribution



CO_2 Saturation from PNC
Pulsed Neutron Capture

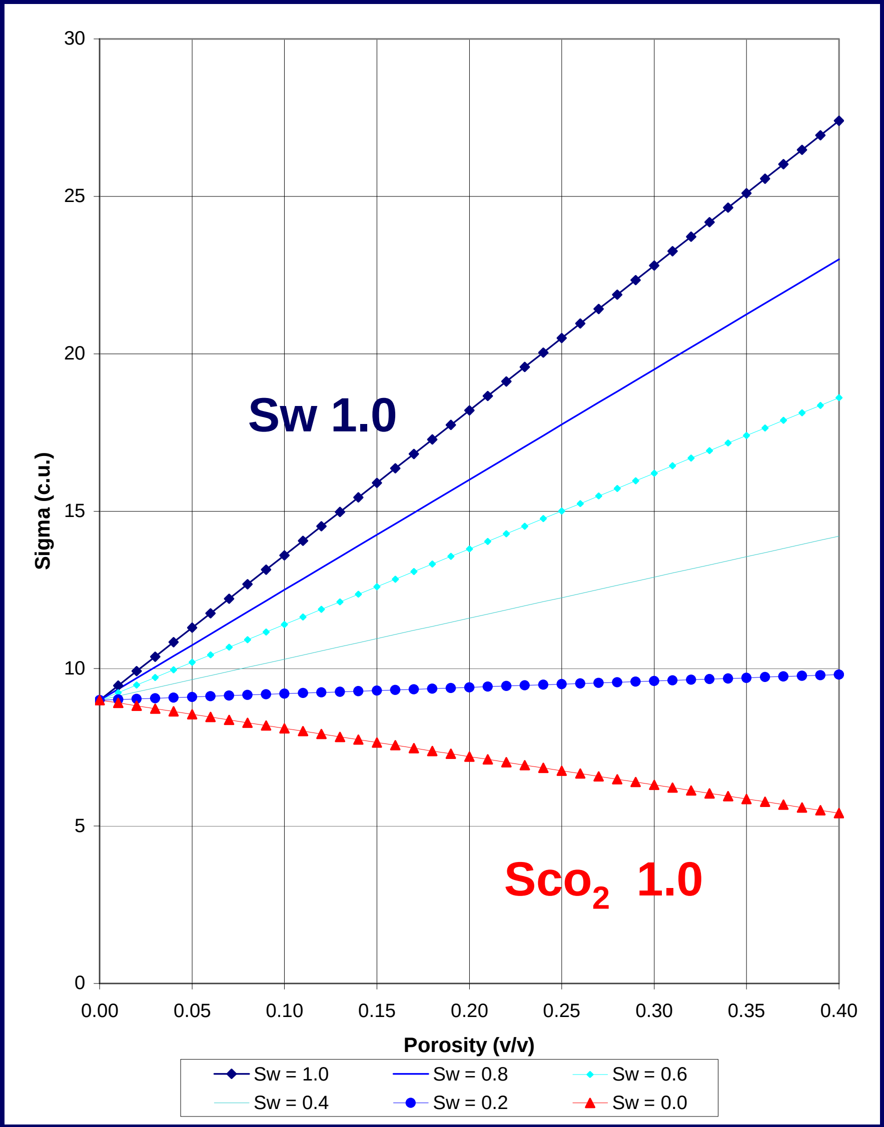


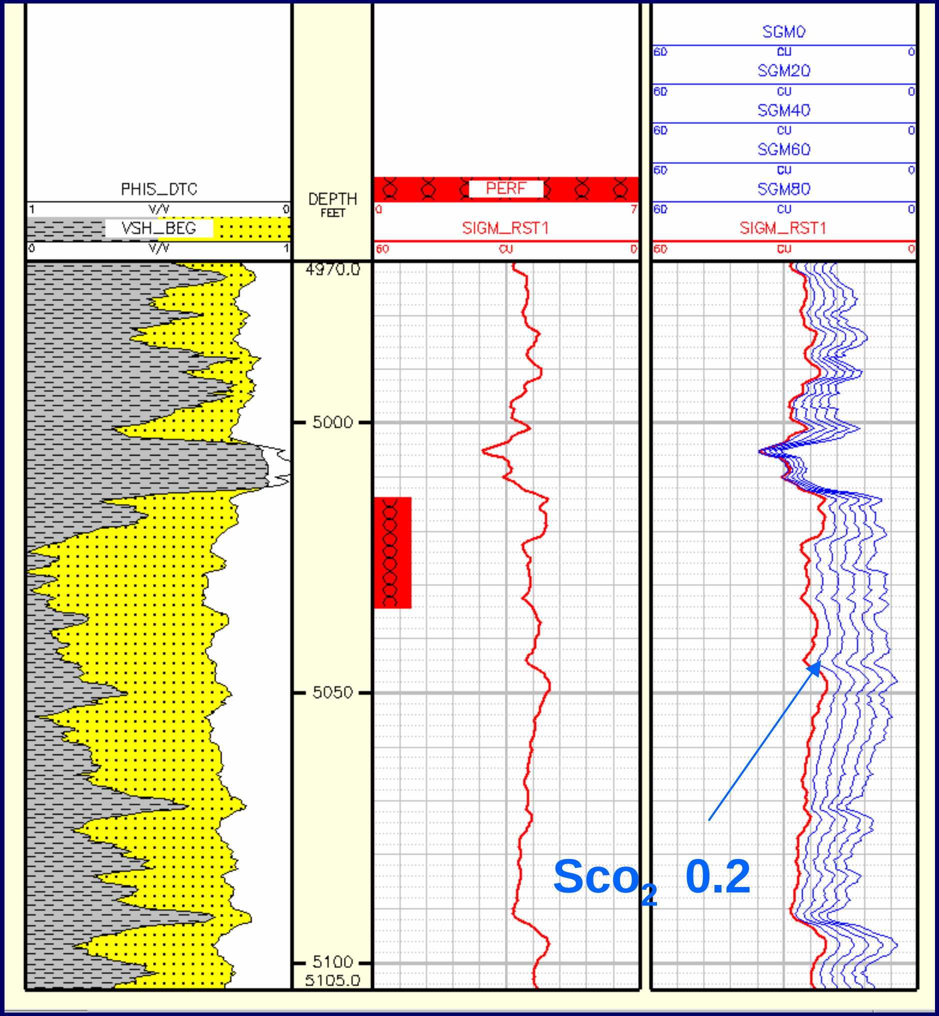
Large contrast of sigma between CO_2 (0.03 c.u.) and formation water of 93,000 ppm (55 c.u.)

High porosity of as much as 35%

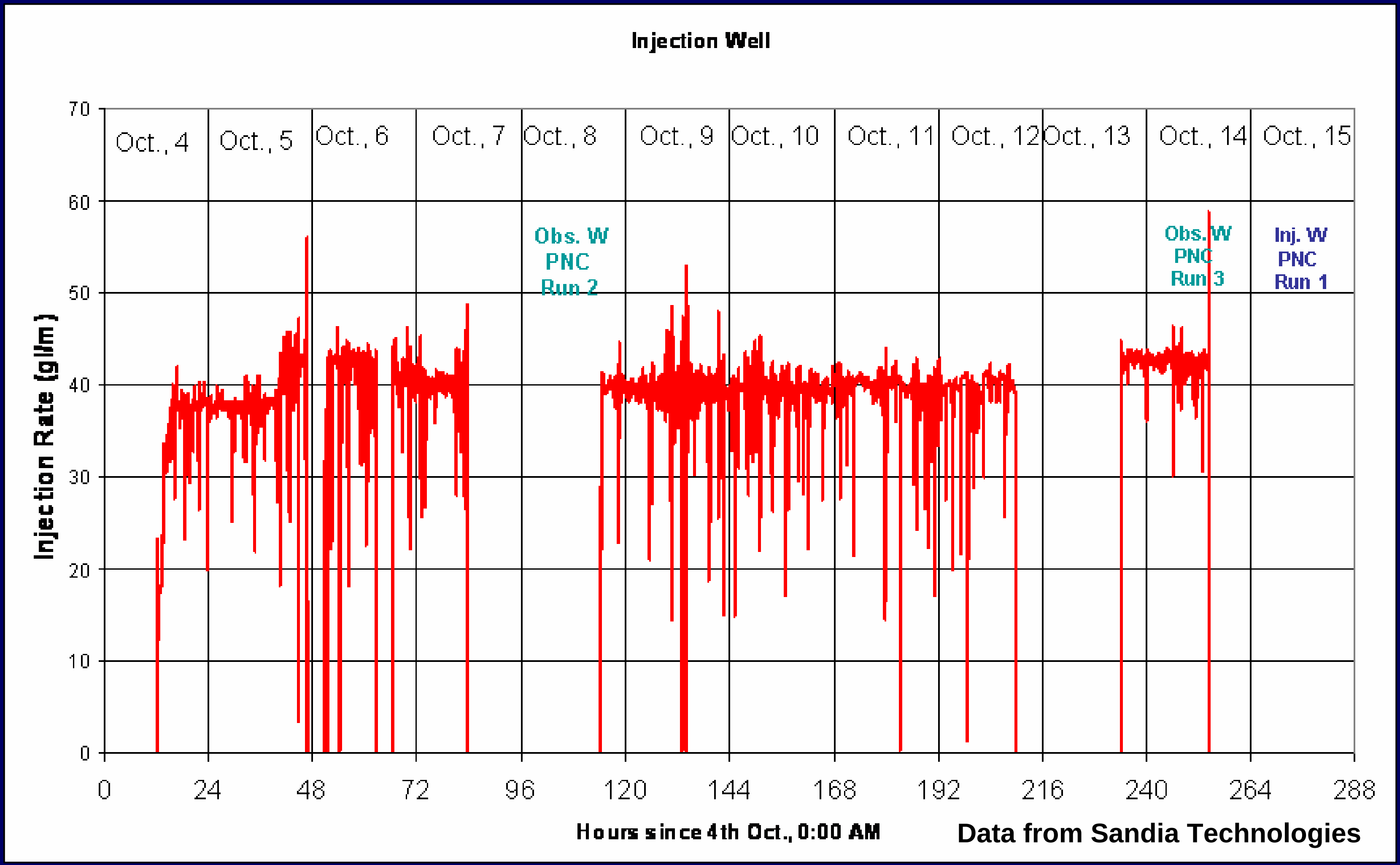
Can expect significant sigma changes

CO_2 Saturation from PNC



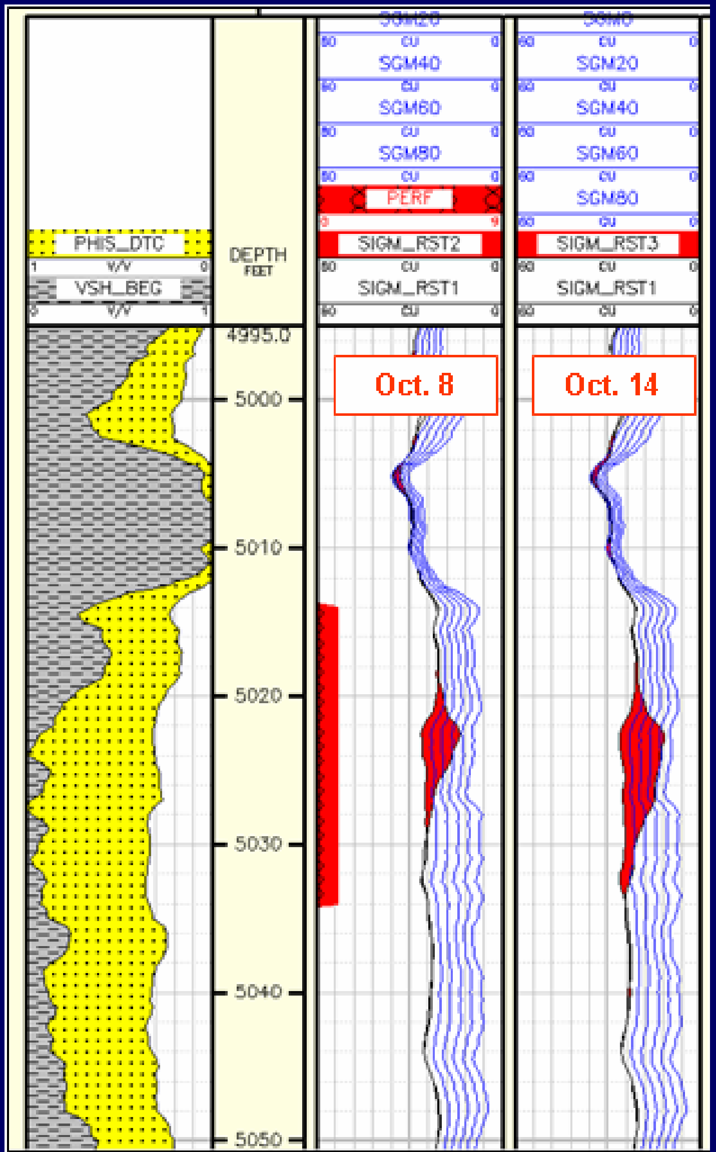


CO_2 Injection Rate



Injected 1,600 tonnes of CO_2

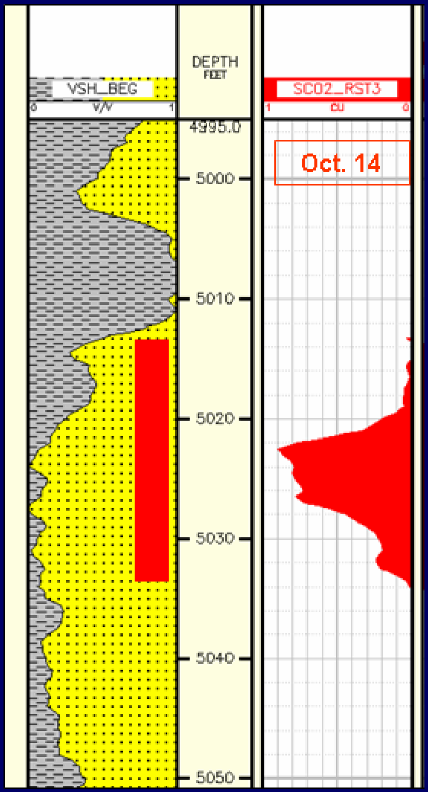
Change of thermal absorption cross section Observation Well



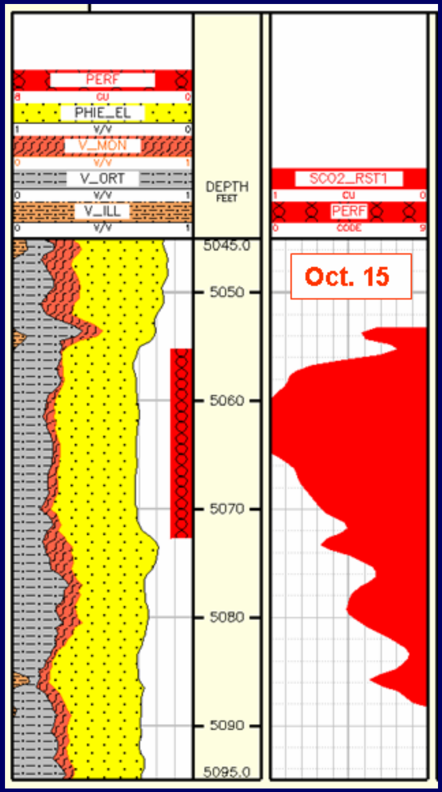
Change of CO_2 Saturation

* Saturation from PNC for end of injection

Observation well

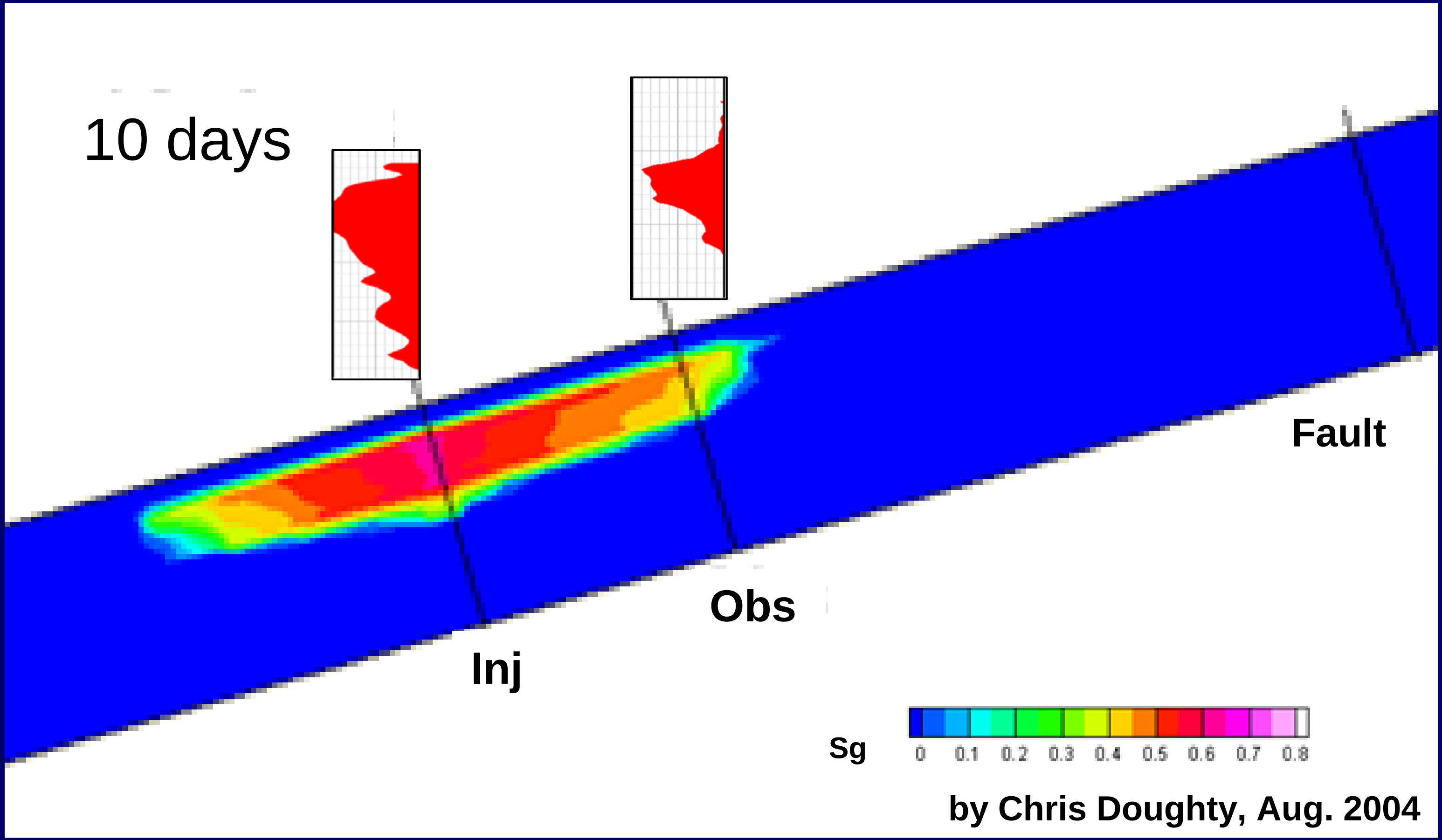


Injection well



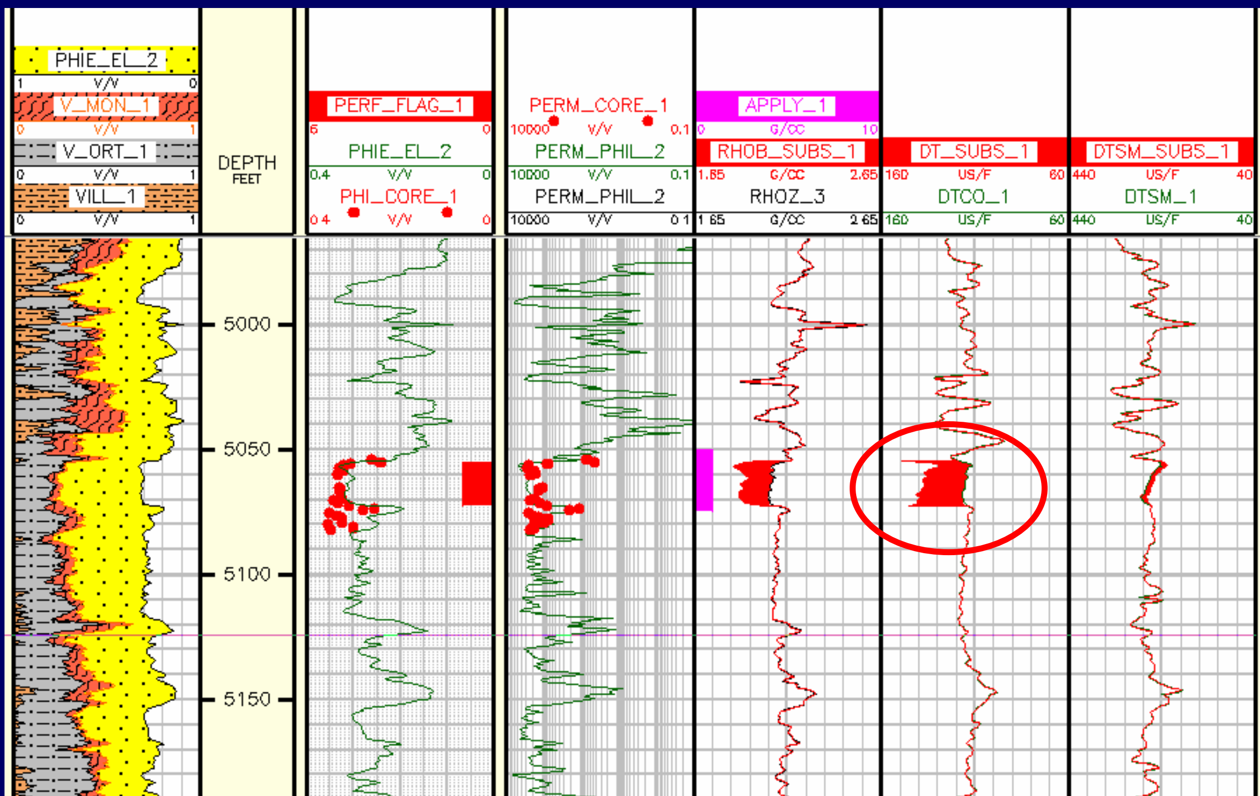
Comparison of CO_2 Saturation

PNC and Model Result



Change of Velocity with CO_2

Fluid Substitution



Assumed that CO_2 replaced formation brine in C sand

Expect lower density and slow velocity

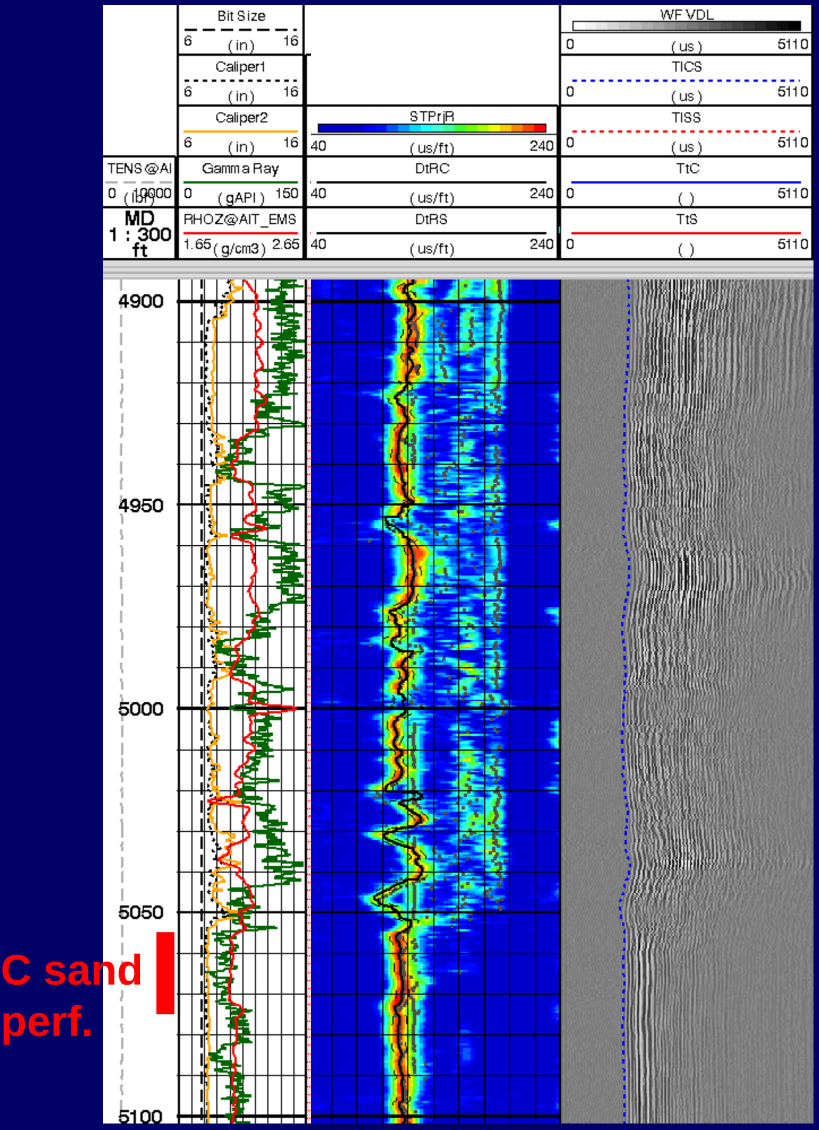
Dtco changed from

115 to 140 us/f or

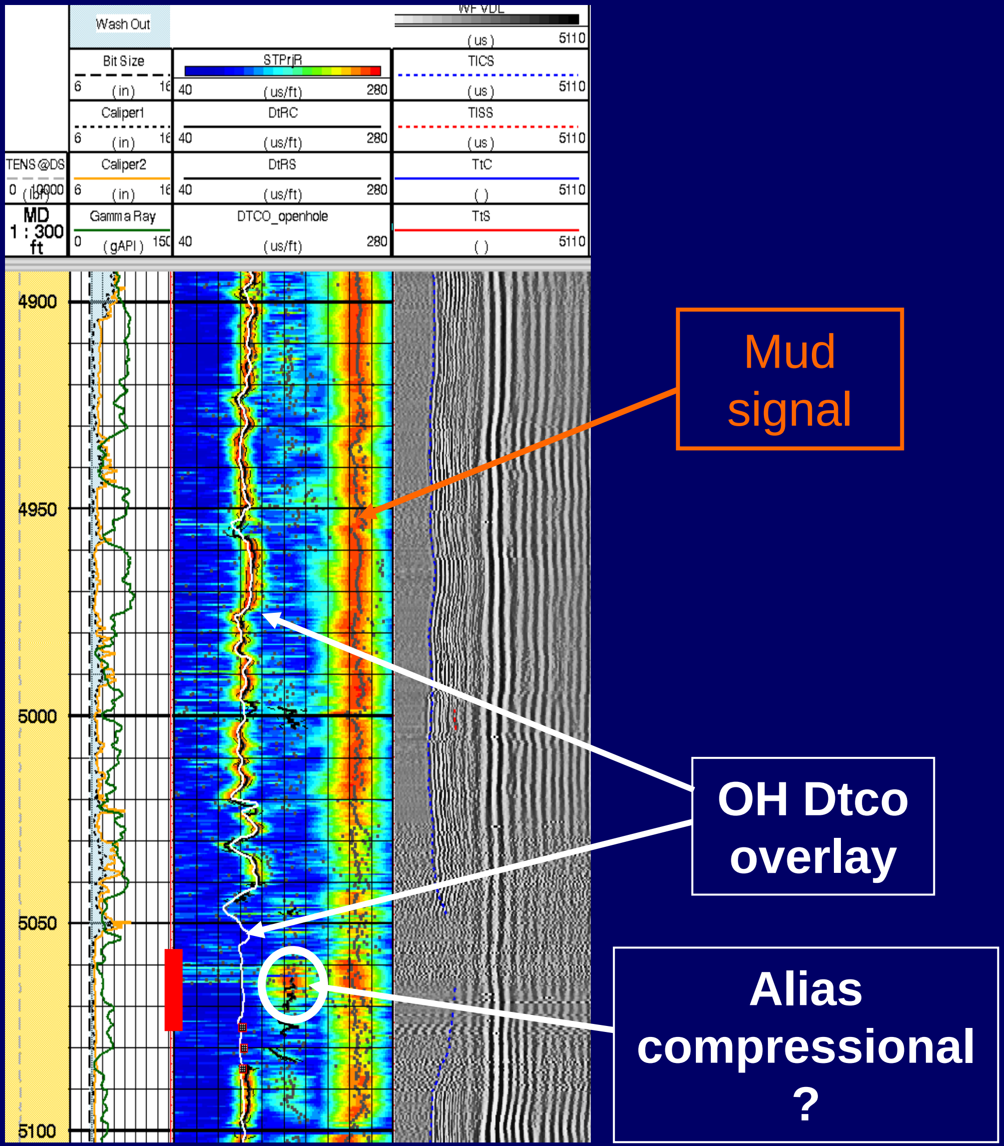
3.05 to 2.27 km/s

Sonic Transit Time Before and After Injection

Baseline open-hole log



Postinjection cased-hole log

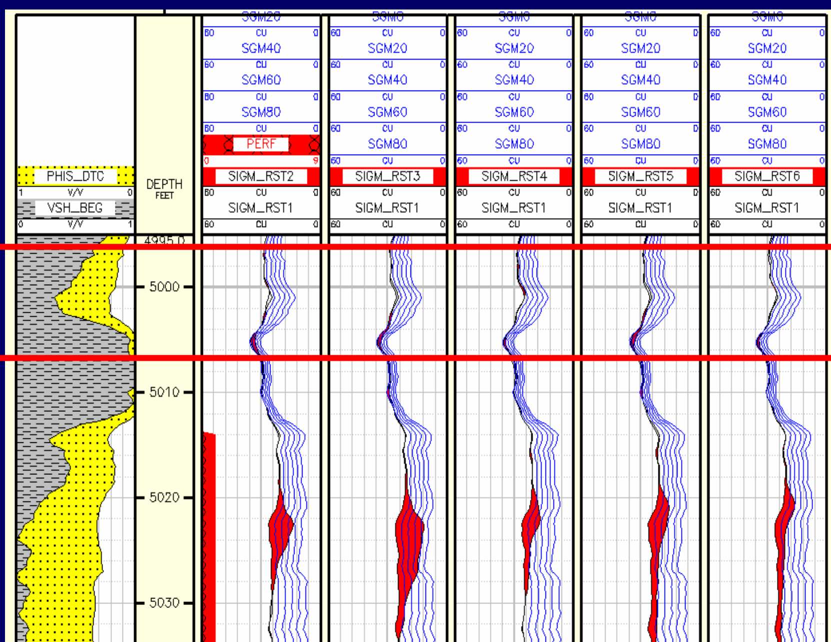


Velocity Change

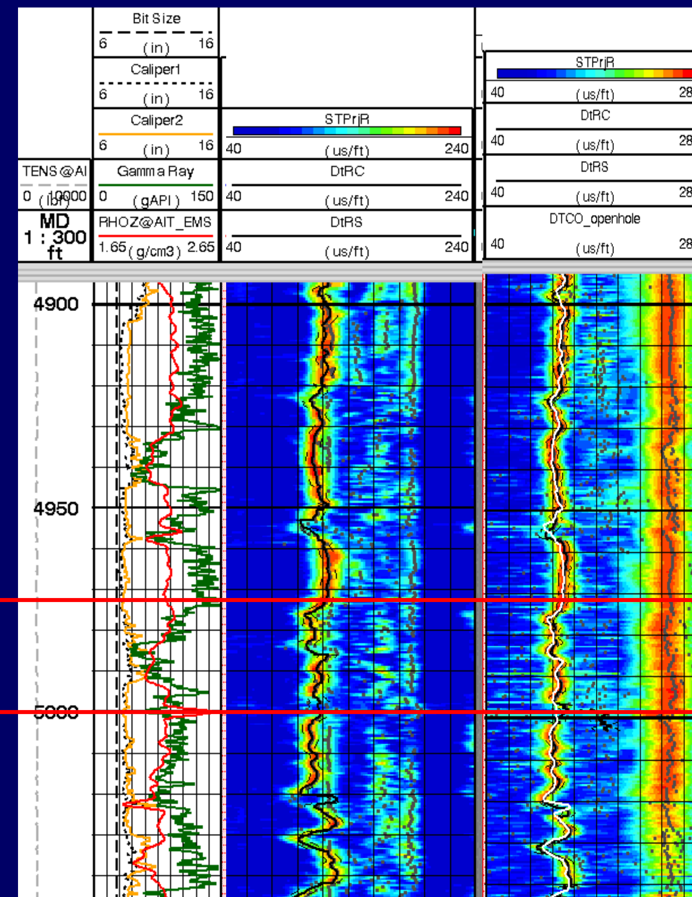
- See LBNL's results on VSP and crosswell tomography
- Will test new sonic tool on Phase II

CO_2 Migration up to B Sand

- Monitor log data to see migration of CO_2 to shallower interval



No change in sigma



No change in Dtco

CONCLUSIONS

- **Injected 1,600 tonnes of CO_2 safely into brine-filled formation**
  - **No leaks into shallow B sand**

- **PNC worked well for CO_2 saturation estimate**
  - **Large contrast of sigma and high porosity**

- **Reasonable agreement between CO_2 saturation from wireline logs and that predicted by simulation model**

- **Plan for Phase II (deeper sand) next year**
  - **No borehole changes**


Thank You