Testing Geologic Sequestration of Carbon – Put it back

Carbon extracted from coal or other fossil fuel…

Returned into the earth where it came from

An elegant solution - will it work?

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Jackson School
University of Texas at Austin
GCCC Field Tests for Monitoring and Verification Technologies - DOE-NETL and Industry Hosts

- Frio Test
  - Texas American Resources

- Cranfield SECARB
  - Phase II&III Denbury

- SACROC
  - Southwest Partnership
  - KinderMorgan
  - NM Tech –U Utah

Map showing locations such as Frio Test, Cranfield SECARB, SACROC, and other relevant areas with pipeline and CO2 in the Gulf Coast region.
Field Research Teams

**Frio Test**
Bureau of Economic Geology
Lawrence Berkeley National Lab
Schlumberger
Oak Ridge National Lab
Lawrence Livermore National Lab
Alberta Research Council
Texas American Resources
Sandia Technologies
BP
National Energy Technology Lab
Paulsson Geophysical
University of West Virginia
USGS
Praxair
Australian CO2CRC -CSIRO
Core Labs

**SACROC**
Bureau of Economic Geology
New Mexico Tech
University of Utah
University of Pittsburg
Kinder Morgan
Los Alamos National Labs
Sandia National Labs

**Cranfield**
Bureau of Economic Geology
University of Mississippi
Mississippi State University
Schlumberger Carbon Services
Sandia Technologies
Denbury Resources
Lawrence Berkeley National Lab
Lawrence Livermore National Lab
USGS
BP
Oak Ridge National Lab
Experimental Questions

- Can we measure the change resulting from putting CO₂ underground?
- Can we predict the change over time?
- Is the CO₂ stored safely underground?

Provide useful information to next tests and deployments
Food grade CO₂
Shipped by truck

Fresh water (USDW)
protected by surface casing

Injection zones:
First experiment
2004: Frio “C”
Second experiment
2006 Frio “Blue”

Depth 5034
and 5450 ft
Steeply dipping - high permeability sandstone

Fluid is brine 100 ppt NaCl
100 - 110 degrees F

Oil production
Injection well

Observation well

30 m
Understand what you inject into

Core slab

Rock slice “thin section” microscope view
Yes, we can predict and measure where the CO$_2$ moves underground

Measured with cross-well tomography and wireline logs

Predicted with computer model TOUGH2

Tom Daley and Christine Doughty  LBNL
Measurement at a Well:
Saturation logging (RST) Observation well to measure changes in CO₂ saturation – match to model

Shinichi Sakurai, Jeff Kane, Christine Doughty
Phase Trapping – the power of capillary pressure

![Diagram showing Phase Trapping](image)

- **Injection of CO₂**
- **Phase-trapped CO₂**
- **Grains**
- **Brine – filled pores**
January 2006, attempting to produce the CO$_2$ back – no success. CO$_2$ is underground but cannot be produced.
Chemical Changes During Injection

6.00 6.50 7.00
CO₂ detected

4.50 5.00 5.50
pH

3.00 3.50 4.00
inlinepH

0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00 90.00 100.00
Elapsed hours after injection

Analysis underway by USGS
Alkalinity, metals, DOC, DIC, VOC
Unexpected result – extra iron and manganese in brine
Geochemical Simulation vs. Lab data

Fe Simulation Compared to Frio "C"

Fe peak = 7e-4

Molality vs. Time (d)

Frio "C" lab Mn

No Mn phase in simulation

Molality vs. Time (d)

Kevin Knauss, LLNL
Grain coatings – early actors in geochemistry
Perflorocarbon Tracer = No Detection at the Surface

Praxair Seeper Trace
Cranfield test: Subsurface Monitoring Above Injection Zone

- Close to perturbation
- Quiescent relative to the surface
- High signal to noise ratio
Real-time Pressure monitoring at Cranfield

Satellite uplink

Surface & downhole data collected every minute and uploaded every 10 minutes to website.

Sandia Technologies, Pinnacle, BEG 2009
Continuous field data from dedicated monitoring well

CO2 Injection Data for Cranfield, MS

1,000,000

Continuous field data from dedicated monitoring well

500,000 metric tons injected around 15 Feb 2009

Daily Injection Rate (mcf)

Cumulative Injection

Data provided by Denbury

Continuous Pressure Data from EGL #7 Monitor Well

50,000 metric tons

50,000 metric tons

~1200 psi difference

Meckel, BEG 2009
SACROC- testing fresh water after 35 years large-scale injection

Smyth, BEG 2009
pH Along Transects Across SACROC field

Wells completed through Ogallala aquifer with TD in Dockum Santa Rosa Aquifer

Romanak, Yang, Smyth BEG 2009
What can we say from these tests about “Is CO$_2$ safely stored?”

- Permanence of trapping – phase trapping limits movement of CO$_2$
- Wells are weak points – but in two areas studied this year with many wells, no evidence that leakage has occurred
## Conclusions

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>Can we measure the change resulting from putting CO$_2$ underground?</td>
<td>Yes, the tools tested have worked better than expected, confidence is increased.</td>
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<tr>
<td>Can we predict the change over time?</td>
<td>Yes, numerical models have worked correctly, confidence is increased.</td>
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<tr>
<td>Is the CO$_2$ stored safely underground?</td>
<td>So far yes, becomes more rigorous as we test larger scale over longer periods.</td>
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<tr>
<td>Work so far has helped prepare for next larger, longer tests, which are underway</td>
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