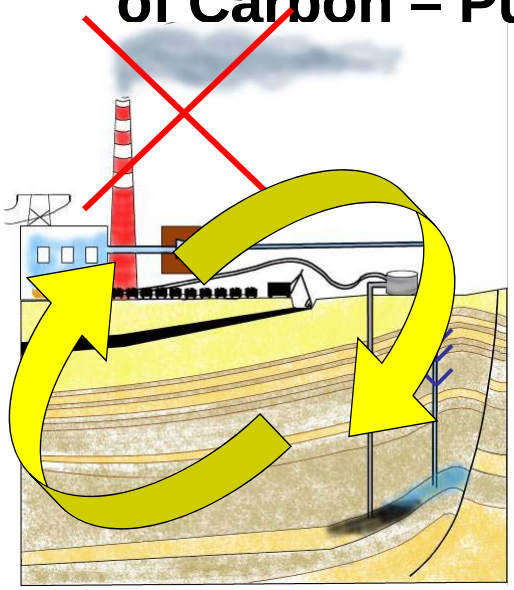
Testing Geologic Sequestration of Carbon – Put it back



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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Bureau of Economic Geology
Jackson School
University of Texas at Austin

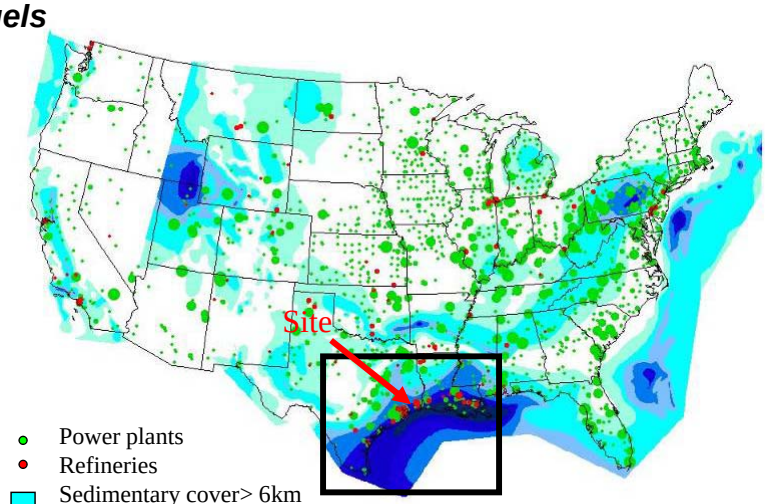
Gulf Coast Carbon Center

Problem and Possible Solution

Refineries and oilfield tubulars at the same location provide the experimental environment

Geologic Storage "Sequestration" of CO_2

Testing the feasibility of establishing a "closed loop" to limit atmospheric emissions of carbon from fossil fuels



Sources: USGS, IEA Source database

Frio Brine Pilot Research Team

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- **Lawrence Livermore National Lab:** Kevin Knauss, Jim Johnson
- **Alberta Research Council:** Bill Gunter, John Robinson, Bernice Kadatz
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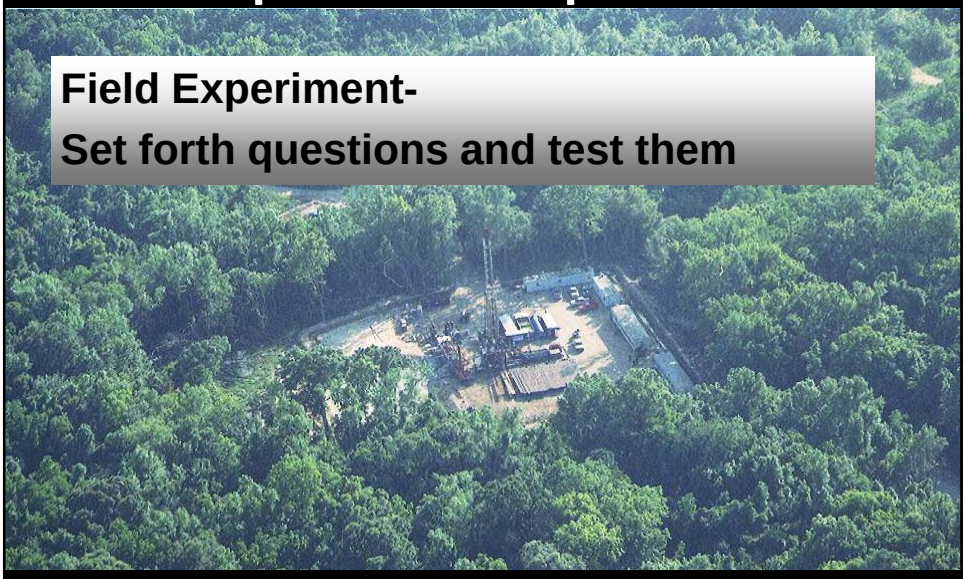
- **Sandia Technologies:** Dan Collins, "Spud" Miller, David Freeman; Phil Papadeas
- **BP:** Charles Christopher, Mike Chambers
- **SEQURE – National Energy Technology Lab:** Curt White, Rod Diehl, Grant Bromhall, Brian Stratizar, Art Wells
- **Paulsson Geophysical – Bjorn Paulsson**
- **University of West Virginia:** Henry Rausch
- **USGS:** Yousif Kharaka, Bill Evans, Evangelos Kakauros, Jim Thordsen
- **Praxair:** Glen Thompson, Joe Shine, Dan Dalton,
- **Australian CO2CRC (CSIRO):** Jim Underschultz, Kevin Dodds, Don Sherlock
- **Core Labs:** Paul Martin and others
- **MIT/ NBNL** Jonathan Ajo-Franklin

Frio Brine Pilot – First US sequestration experiment



Drilling experiment well to depths of 5,700 ft, South Liberty oilfield near Houston Texas

Experimental Questions

Can we measure the CO_2 "cloud" underground?

Can we predict where the CO_2 will move underground?

Is the CO_2 stored safely underground?

Monitoring

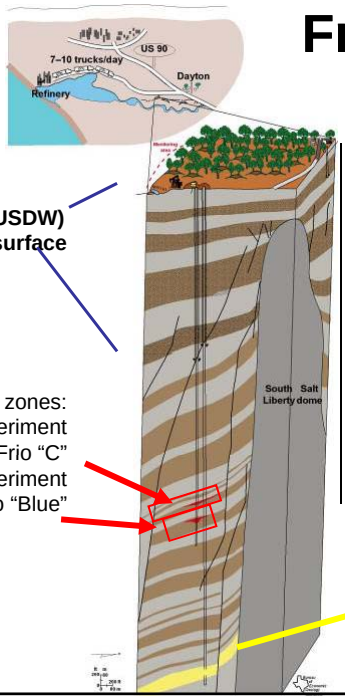
Verification

Modeling

Provide useful information to follow-up tests

Frio Brine Pilot Site

Food grade CO_2
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

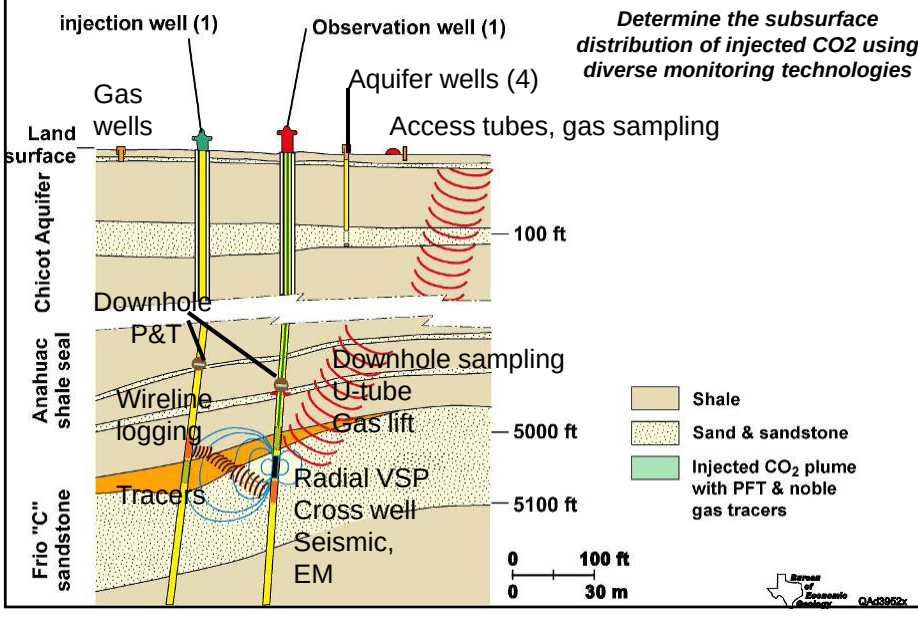
Steeply dipping- high permeability sandstone

Fluid is brine 100 ppt NaCl
100 -110 degrees F

Oil production

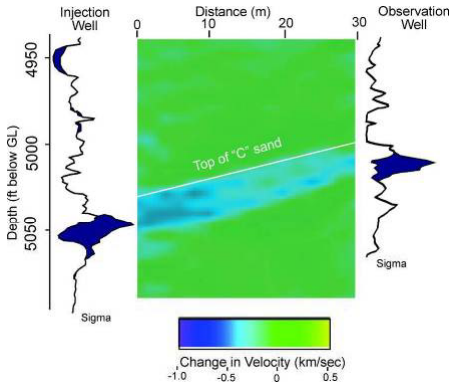
Monitoring- Can we measure the CO2 "cloud" underground?

Determine the subsurface distribution of injected CO2 using diverse monitoring technologies

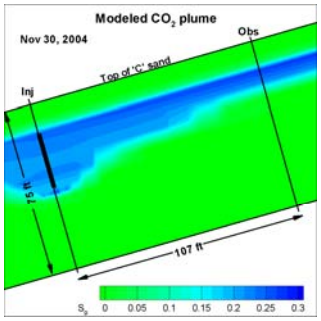


Yes, we can predict and measure where the CO_2 moves underground

Measured with cross-well tomography and wireline logs

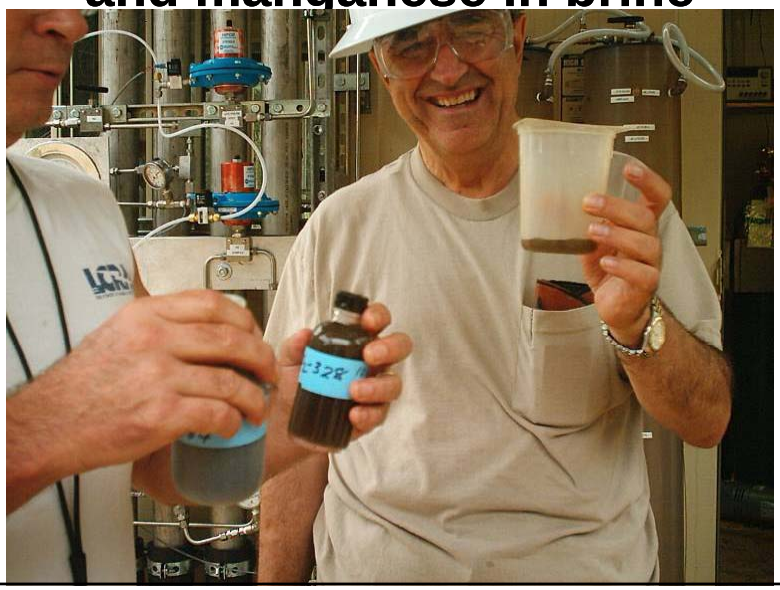


Predicted with computer model TOUGH2

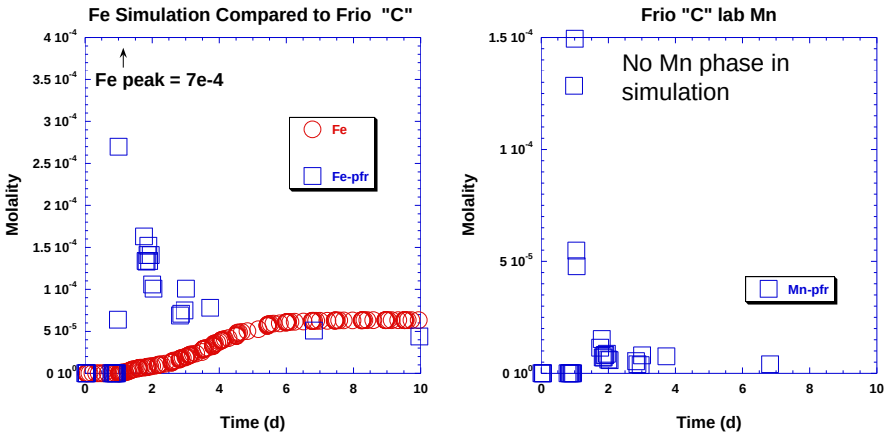


Tom Daley and Christine Doughty LBNL

Unexpected result – extra iron and manganese in brine

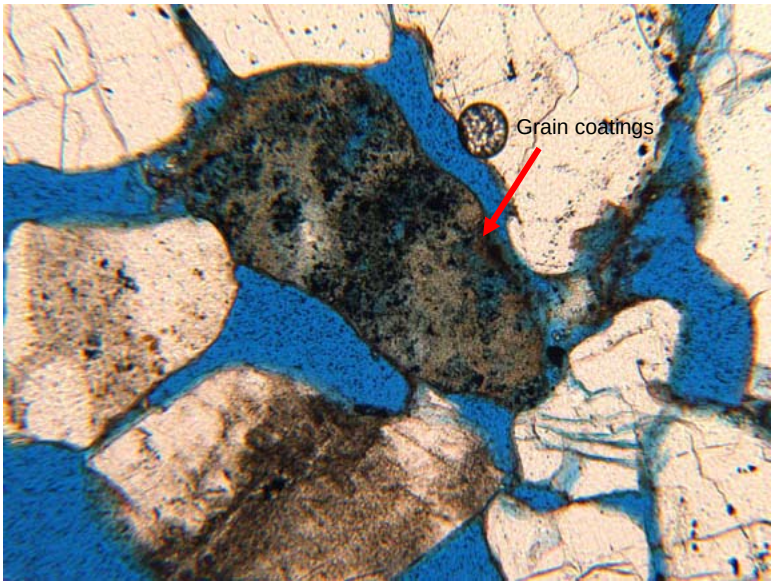


Geochemical Modeling vs. Measurement



Kevin Knauss, LLNL

Grain coatings – rust on sand is rinsed off – adds iron



Press version:

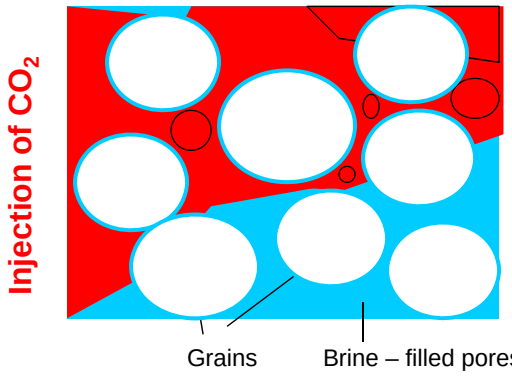
Potential leakage and toxicity problems with CO_2 sequestration… while sequestration to-date has been successful –there have been no detected leakages –the researchers conclude … that the chemistry of the process might prove problematic

Greenwire July 31, 2006

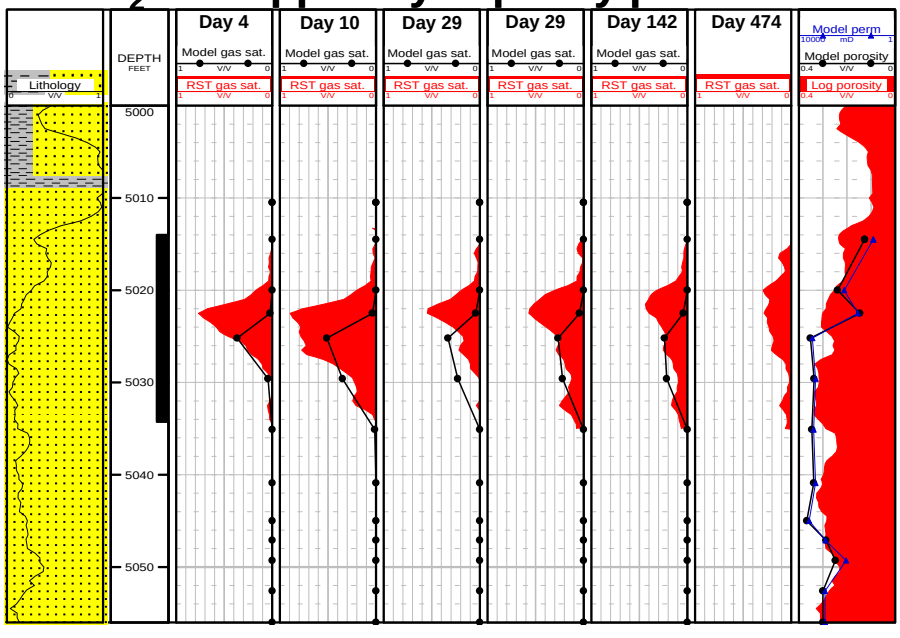
What can we say from this experiment about "Is CO2 safely Stored?"

- **Permanence of trapping – phase trapping limits movement of CO_2**
- **Wells are weak points – geochemical tracer and pressure tests show promise that flaws can be detected and wells remediated.**

Phase Trapping – the power of capillary pressure



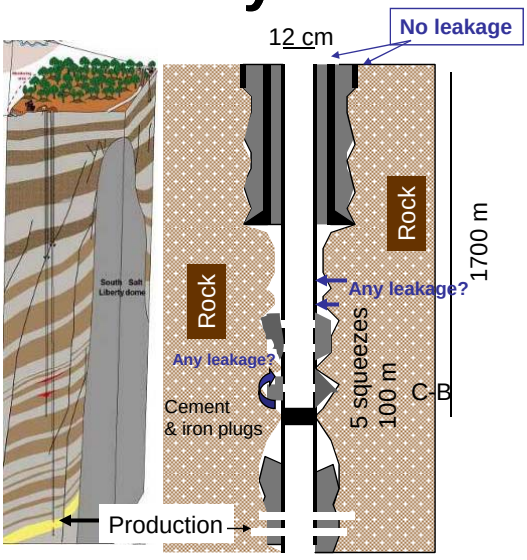
CO_2 is trapped by capillary processes



January 2006, attempting to produce the CO_2 back – no success CO_2 is underground but cannot be produced

Testing wells – likely flaws

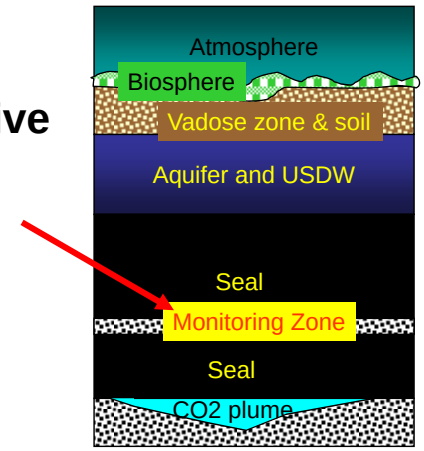
1952 oil production well was retrofit as an observation well



Well construction

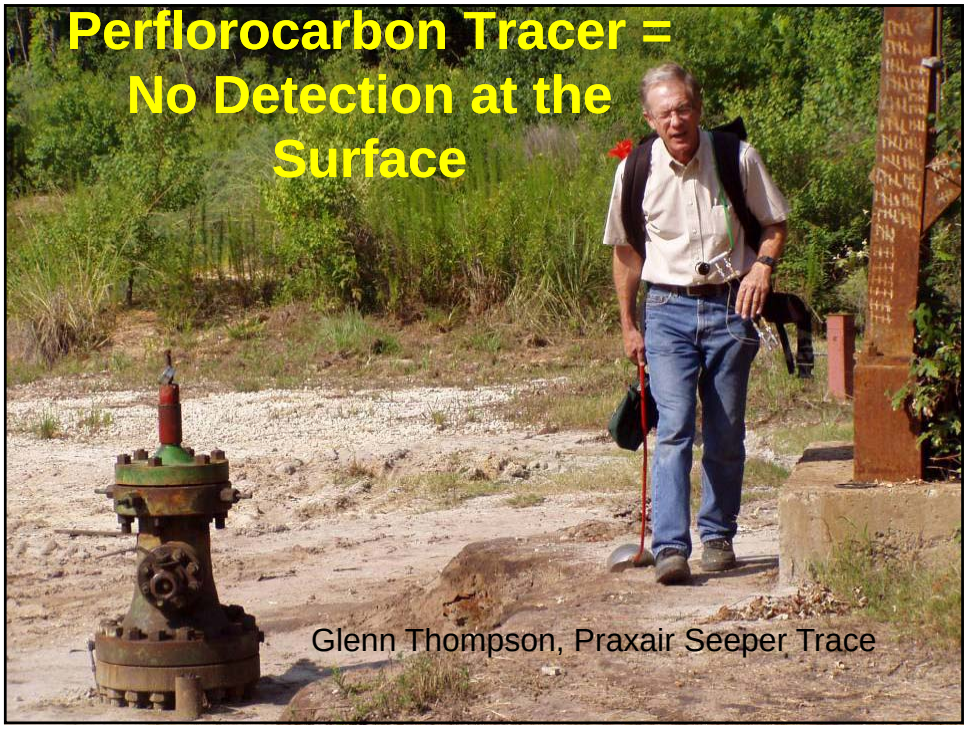
Subsurface Monitoring Above Injection Zone

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



Successful initial test of above zone monitoring

- Lower zone (C to B) detection of brine and/or CO_2 leakage within the injection zone – Tracer detection, elevated iron and dissolved inorganic carbon. No free CO_2 detected during wireline logging program
- No tracer detection at surface.
- Results from intermediate points pending (G. Bromhal, NETL).
- Follow-up program underway at Cranfield Mississippi


Perflorocarbon Tracer = No Detection at the Surface
Glenn Thompson, Praxair Seeper Trace


Seeper Trace equipment
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Underground Solutions
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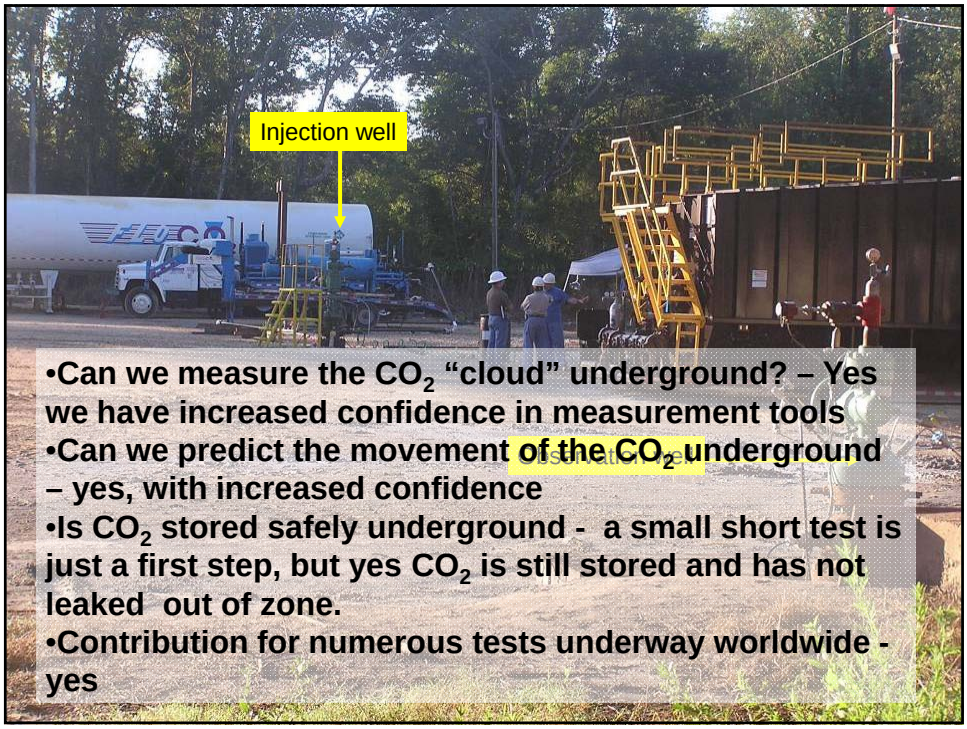
• Cathodic Protection
• Directional Drilling
• Environmental Services
Portable lab
Portable GC
Reusable sorbants



- Can we measure the CO_2 "cloud" underground? – Yes we have increased confidence in measurement tools
- Can we predict the movement of the CO_2 underground – yes, with increased confidence
- Is CO_2 stored safely underground - a small short test is just a first step, but yes CO_2 is still stored and has not leaked out of zone.
- Contribution for numerous tests underway worldwide - yes