

Summary of Current Regional Carbon Sequestration Partnership Activities, USA

December 9, 2010
CCS Technical Workshop

Kyoto, Japan

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Gulf Coast Carbon Center
Bureau of Economic Geology
The University of Texas at Austin



Outline

- Department of Energy & National Energy Technology Laboratory – Regional Carbon Sequestration Partnership Program (RCSP)
- Integrated Systems – Source to Sink
- Role of Enhanced Oil Recovery
- Pressure
- Onshore vs. Offshore

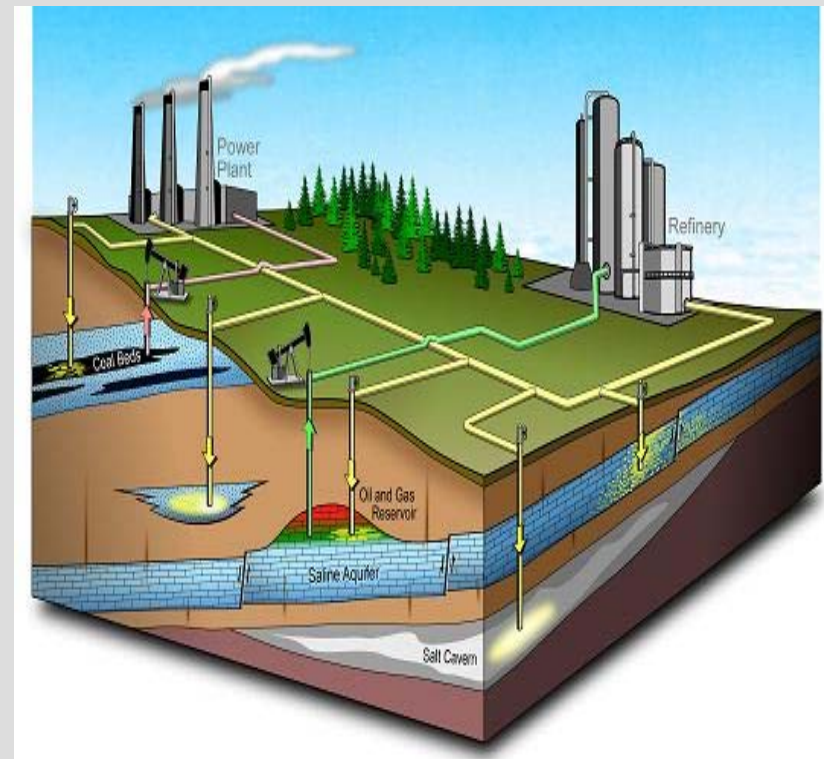
Carbon Sequestration Program Goals

RCSP

Develop Technology Options That...

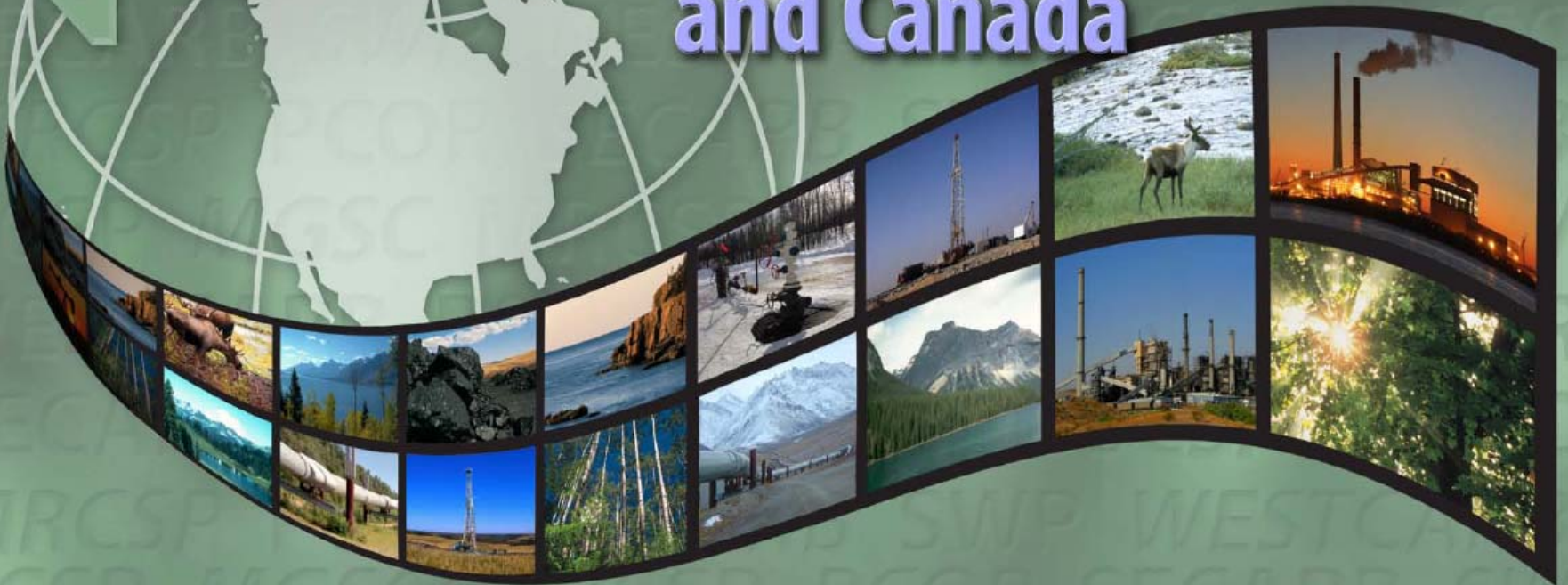
- Deliver technologies & best practices that provide Carbon Capture and Storage (CCS) with:

- 90% CO₂ capture at source
- 99% storage permanence
- < 10% increase in COE
 - Pre-combustion capture (IGCC)
- < 30% increase in COE
 - Post-combustion capture
 - Oxy-combustion



Third Edition

Carbon Sequestration **Atlas** of the United States and Canada

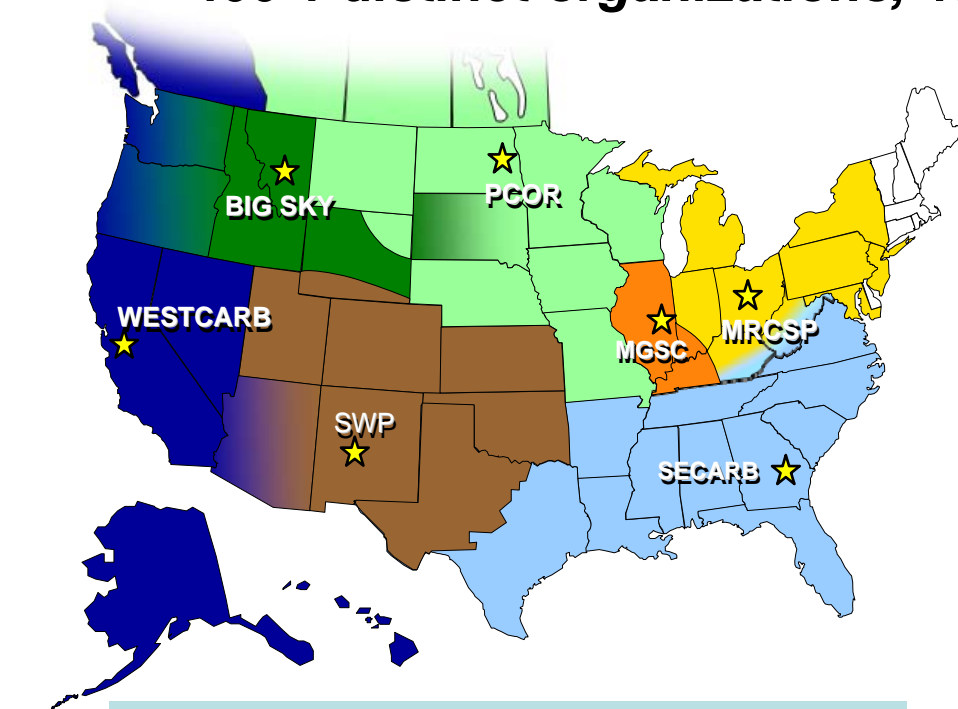


Regional Carbon Sequestration Partnerships

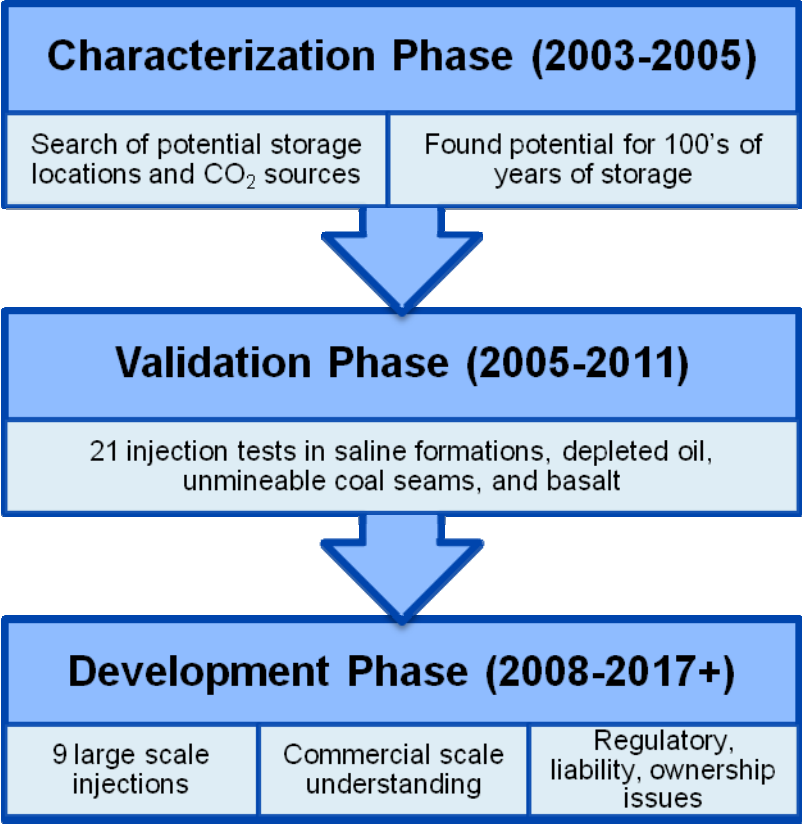
Innovation for Characterization to Large Scale Injection

Seven Regional Partnerships

400 + distinct organizations, 43 states, 4 Canadian Provinces

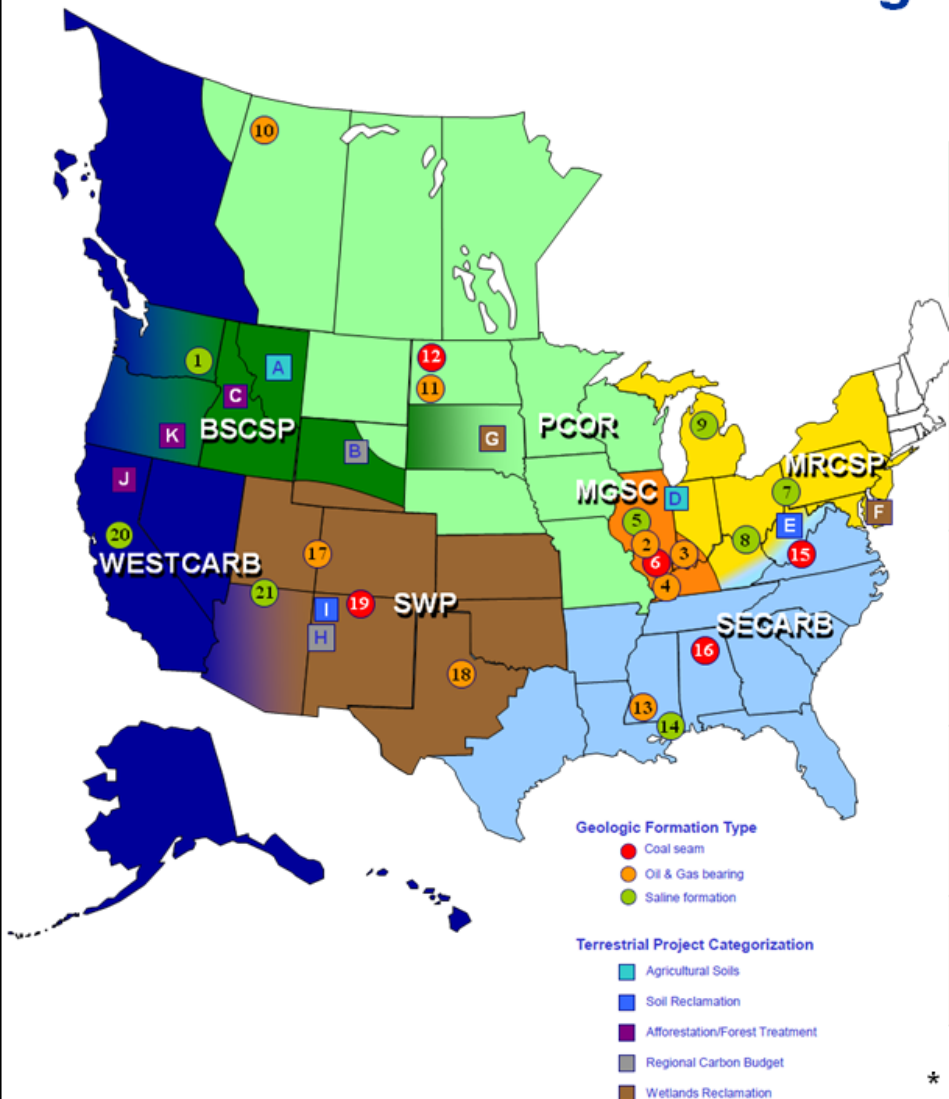


- Engage regional, state, and local governments
- Determine regional sequestration benefits
- Baseline region for sources and sinks
- Establish monitoring and verification protocols
- Address regulatory, environmental, and outreach issues
- Validate sequestration technology and infrastructure



RCSP Phase II: Validation Phase

Small-Scale Geologic and Terrestrial Tests

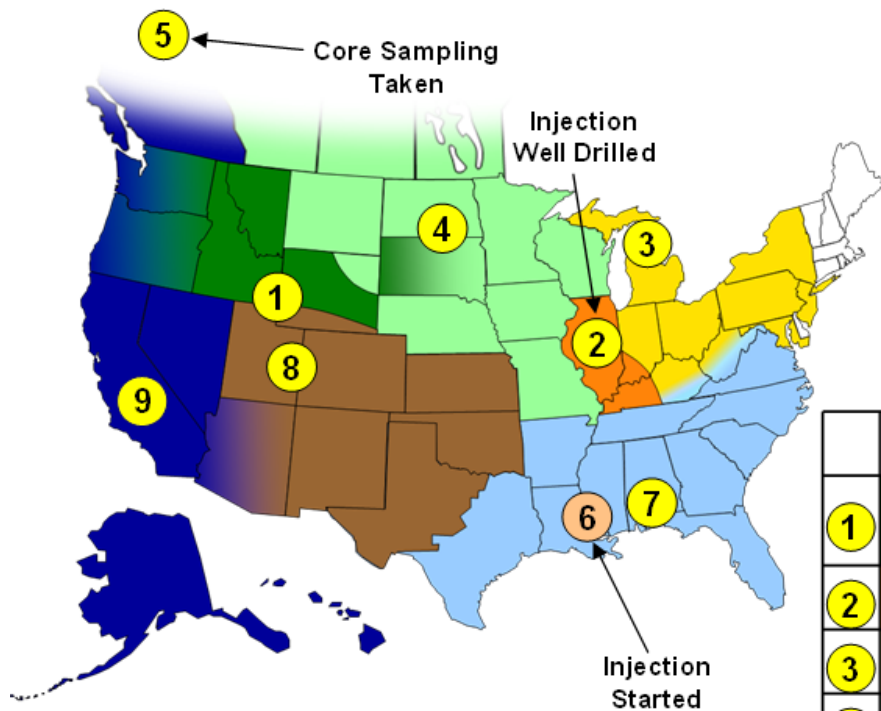


Injection Reservoirs (Total)	RCSPS	Deposition Environments Tested	Range CO ₂ (metric tons)
Saline Formations (7)*	MGSC* MRCSP SECARB WESTCARB	Shallow Shelf-Restricted Strandplain Braided Fluvial Near Shore Marine Delta Marine	0-60,000
Enhanced Oil Recovery-EOR (8)	MGSC PCOR SECARB SWP	Fluvial Marine Shelf Pinnacle Reef Shallow Shelf Open	50-630,000
Coalbed Methane-ECBM (5)	MGSC PCOR SECARB SWP	Coal	90-16,700
Basalt (1)	Big Sky	Basalt	1,000

* Includes Phase II Saline Test that evolved into Phase III Test

RCSP Phase III: Development Phase

Large-Scale Geologic Tests



- Injection Ongoing
- Injection Scheduled 2011/2015

Note: Some locations presented on map may differ from final injection location

- ✓ *Nine large-volume tests*
- ✓ *Injections scheduled 2011/2015*

	Partnership	Geologic Province	Type
①	Big Sky	Triassic Nugget Sandstone / Moxa Arch	Saline
②	MGSC	Deep Mt. Simon Sandstone	Saline
③	MRCSP	St. Peter Sandstone	Saline
④	PCOR	Williston Basin Carbonates	Oil Bearing
⑤		Devonian Age Carbonate Rock	Saline
⑥	SECARB	Lower Tuscaloosa Formation	Saline
⑦		Paluxy Formation	
⑧	SWP	Regional Jurassic & Older Formations	Saline
⑨	WESTCARB	Central Valley	Saline

CCS Best Practice Manuals

Critical Requirement For Significant Wide Scale Deployment

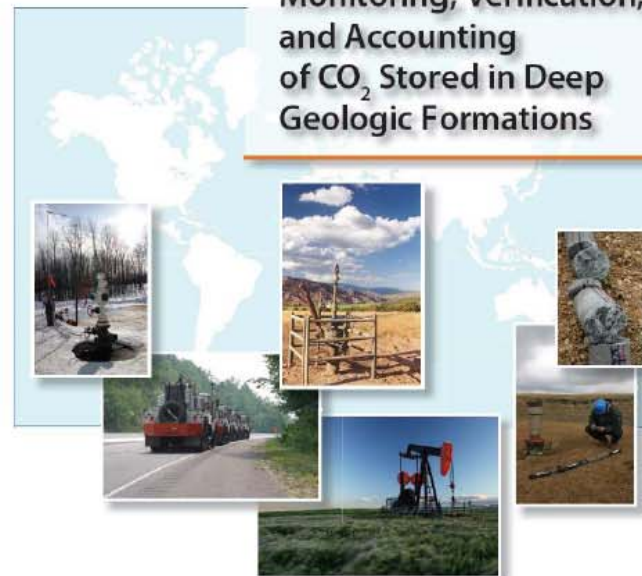
Capturing Lessons Learned

Best Practice Manual	Version 1 (Phase II)
Monitoring Verification and Accounting	2009
Site Characterization	2010
Simulation and Risk Assessment	2010
Well Construction and Closure	2010
Regulatory Compliance	2010
Public Education	2009
Terrestrial Sequestration Practices	2010



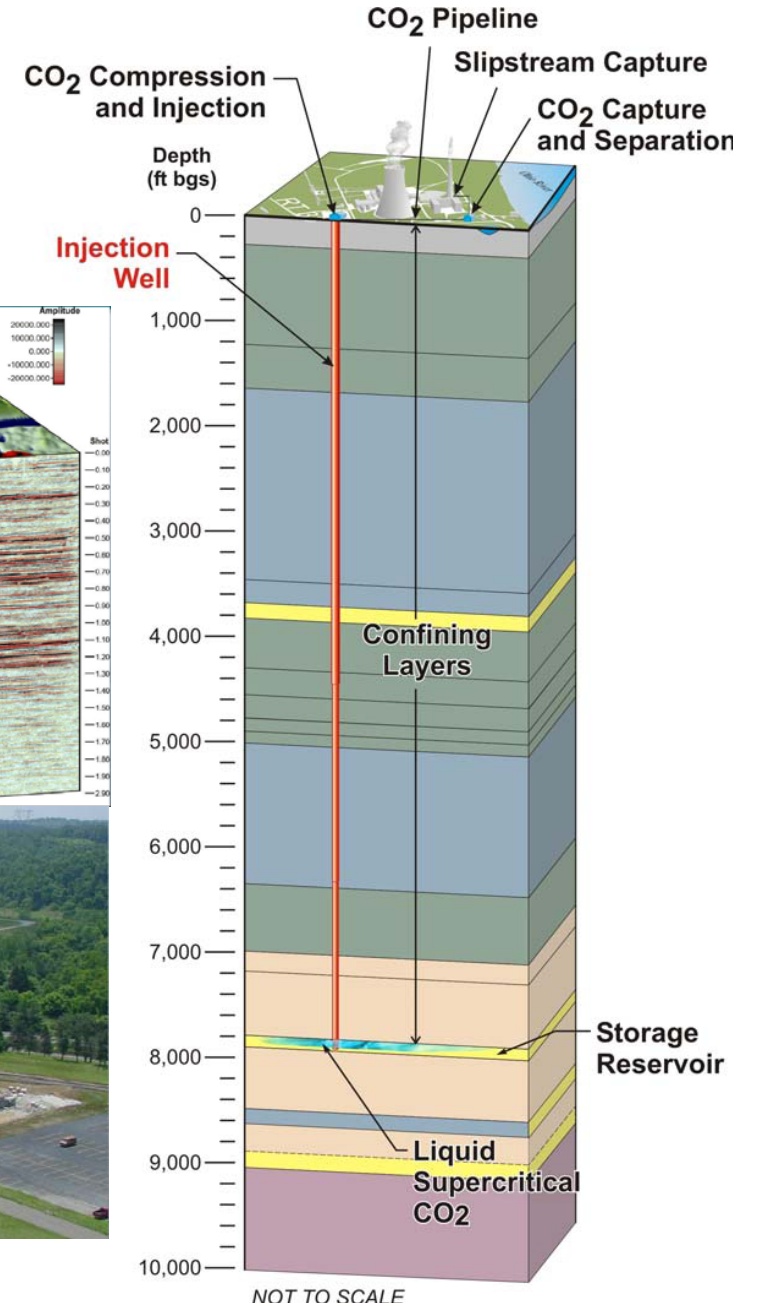
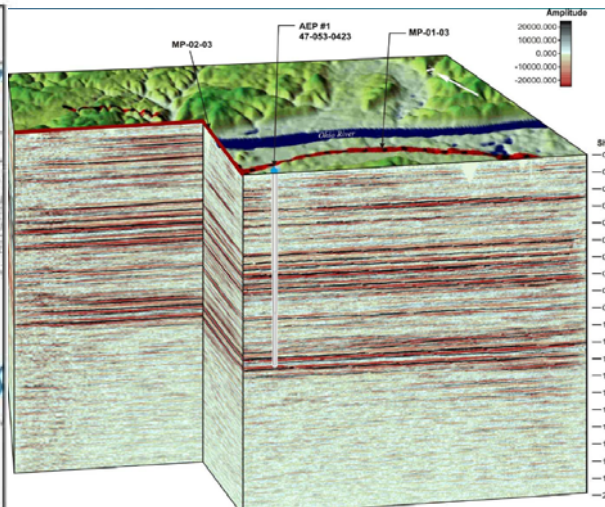
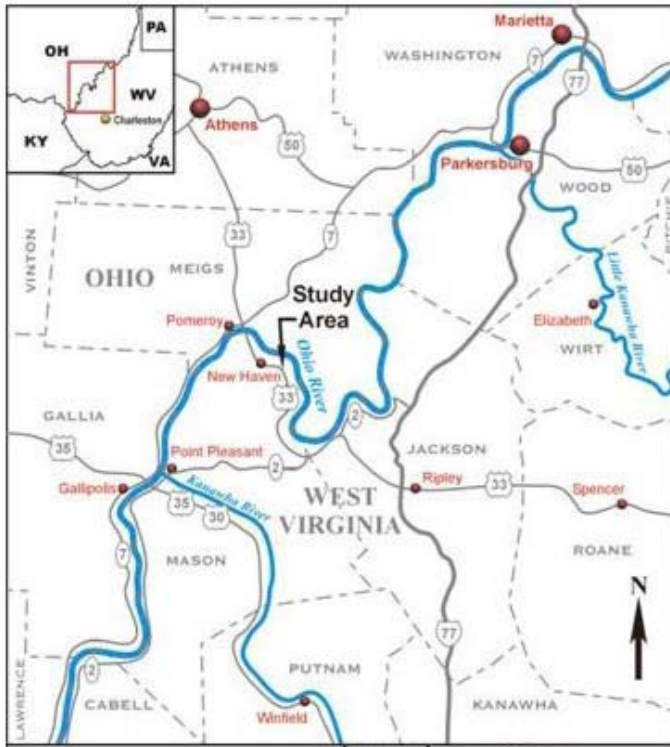
the ENERGY lab

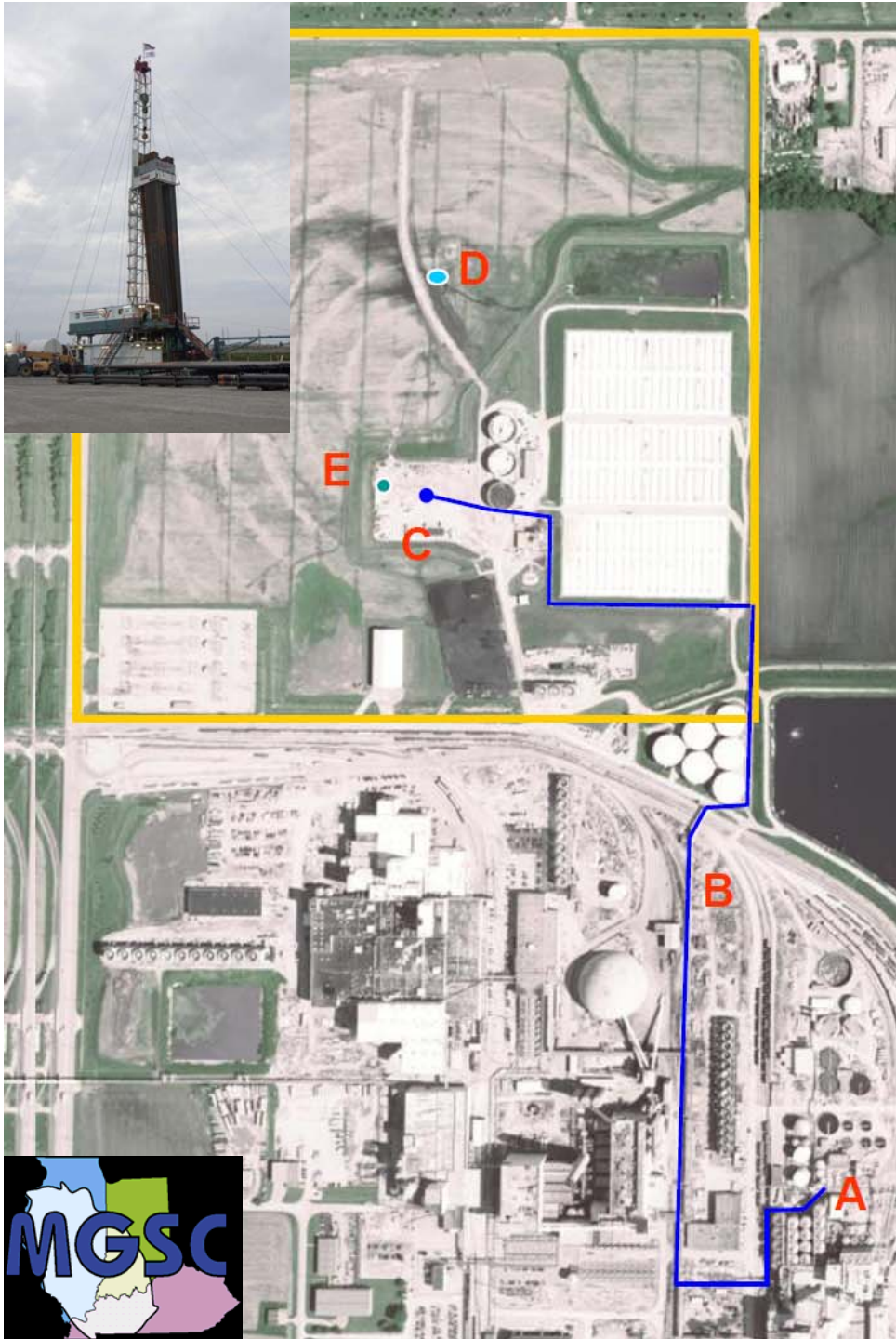
Monitoring, Verification,
and Accounting
of CO₂ Stored in Deep
Geologic Formations



AEP @ Mountaineer, WV

American Electric Power
 Post-combustion capture: chilled ammonia
 Operational 2015
 1.5 Mt/yr capture and storage





Illinois Basin- Decatur Test Site

Archer Daniels Midland (ADM)
Corn ethanol plant

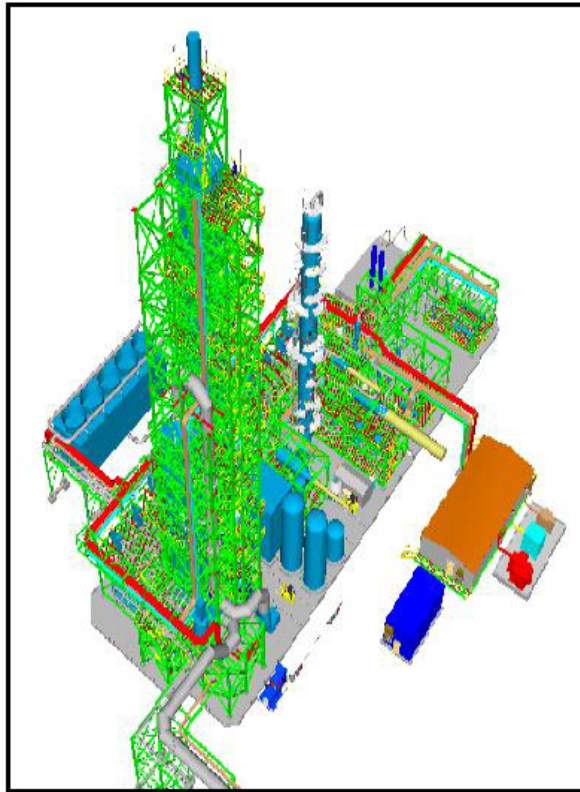
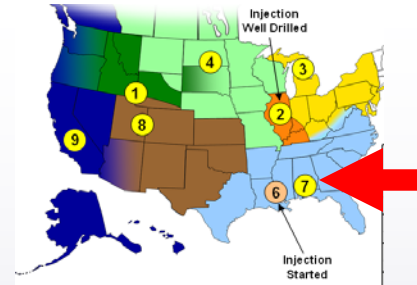
- **A** Dehydration/ compression facility location
- **B** Pipeline route
- **C** Injection well site
- **D** Verification well site
- **E** Geophone well

Quickbird Satellite Image: 9/16/2008



Southern Company, MS

CO₂ Capture Unit at Alabama Power's Plant Barry



- MHI advanced amine capture unit**
- 25 MW post combustion slip stream
- Compress CO₂ to 2000 psi

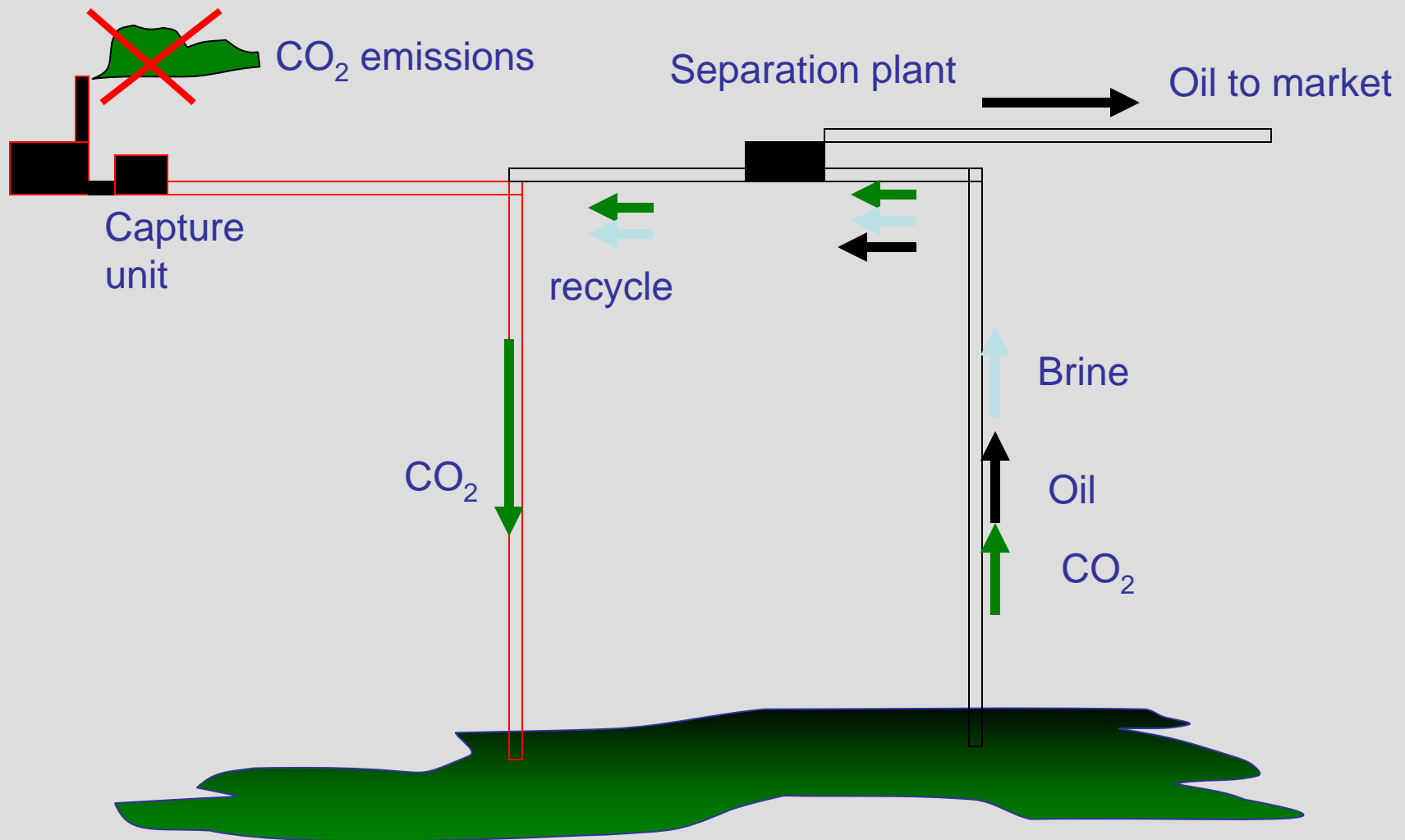
12-mile CO₂ pipeline constructed by Denbury Resources

CO₂ Injection at Denbury's Citronelle Field 2011-2013

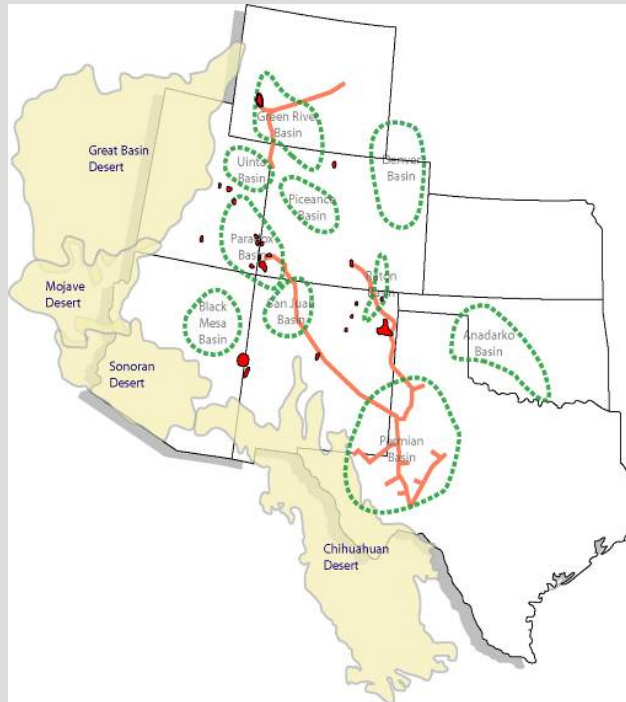
SECARB researchers will monitor injection and 3-years post injection



CO₂ use for Enhanced Oil Recovery (EOR) is Sequestration



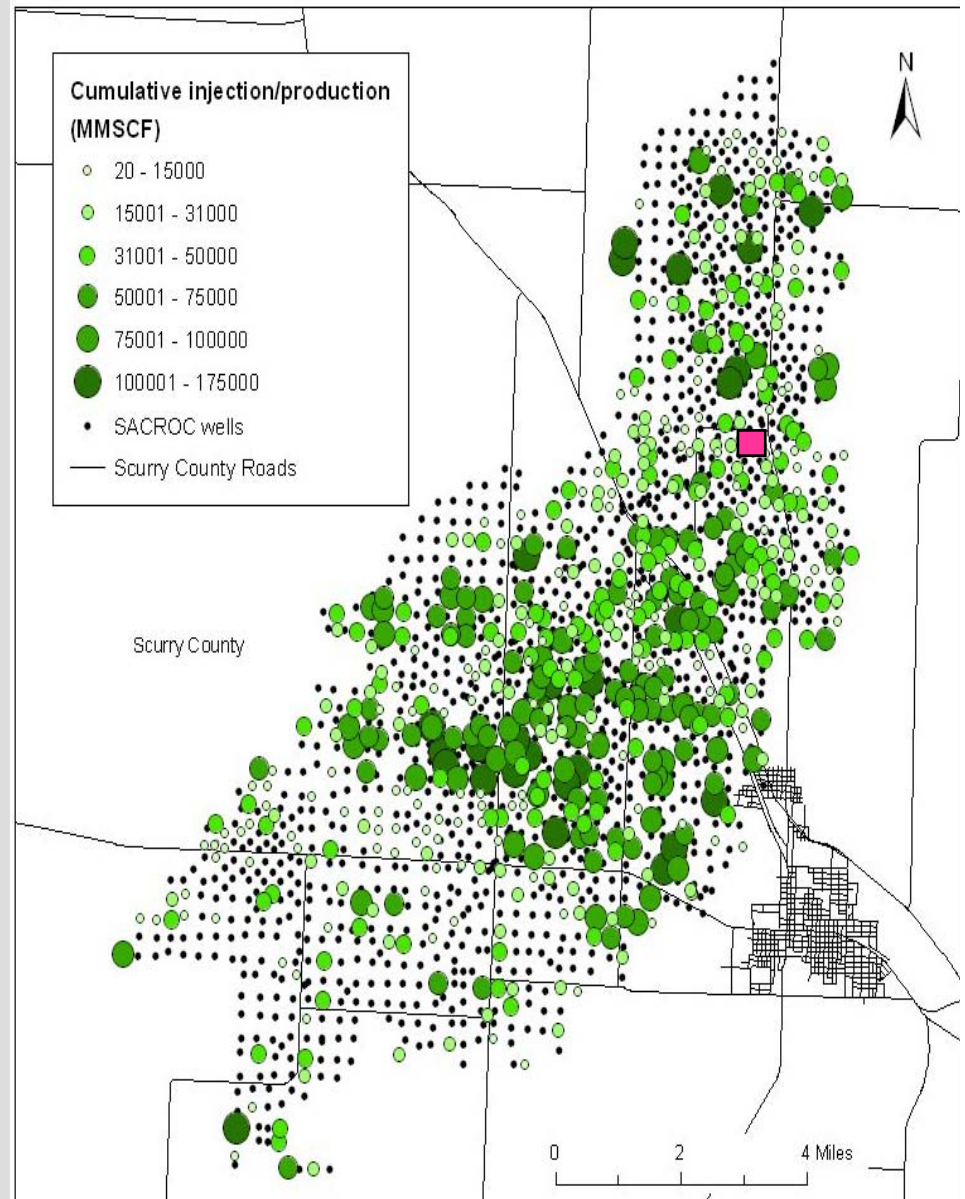
West Texas EOR



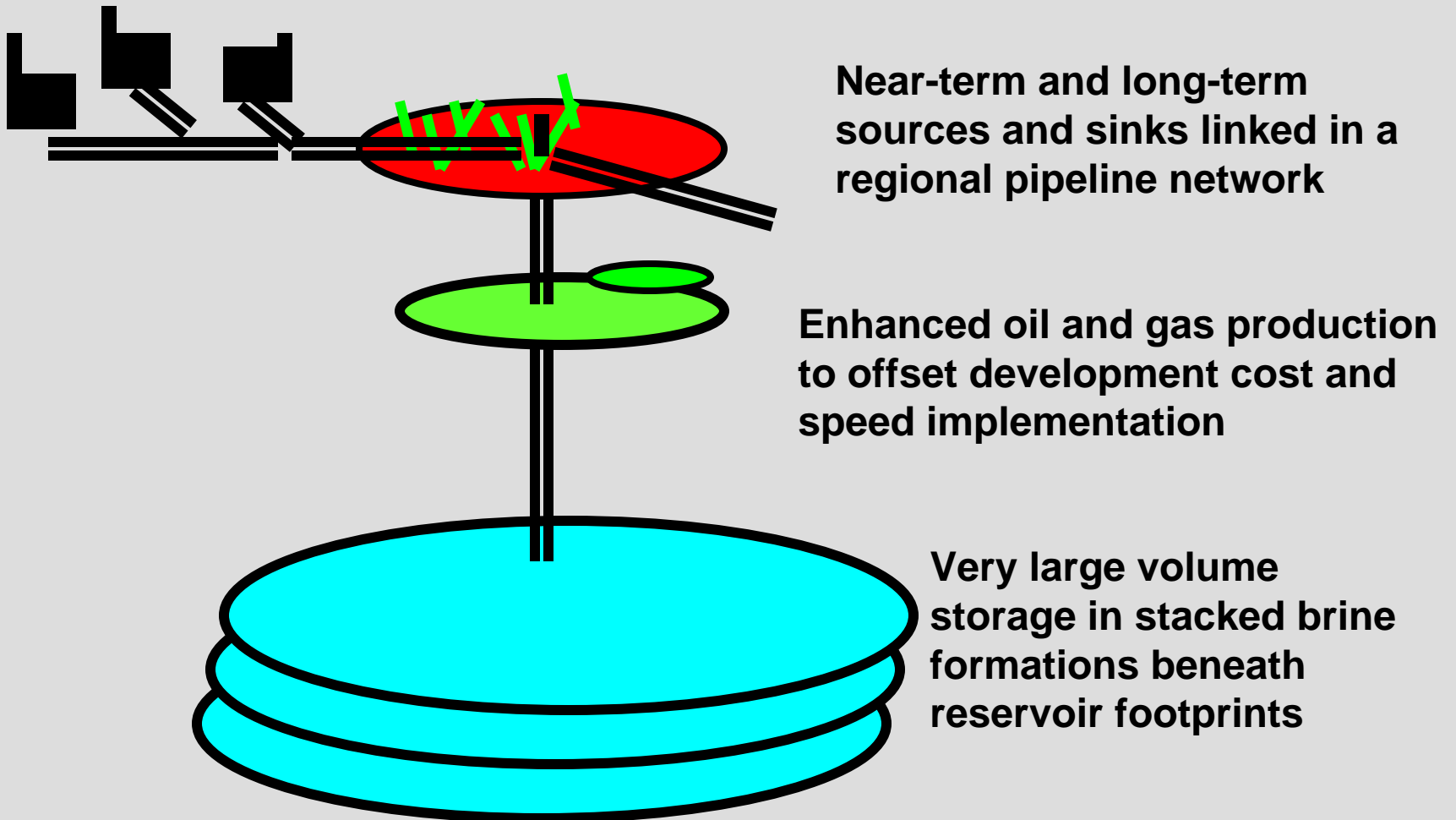
~150 million metric tons CO₂ injected for EOR since 1972 by various oil companies

~75 million metric tons CO₂ recovered through 2010

SWP + BEG researchers have documented no impact to overlying potable groundwater.

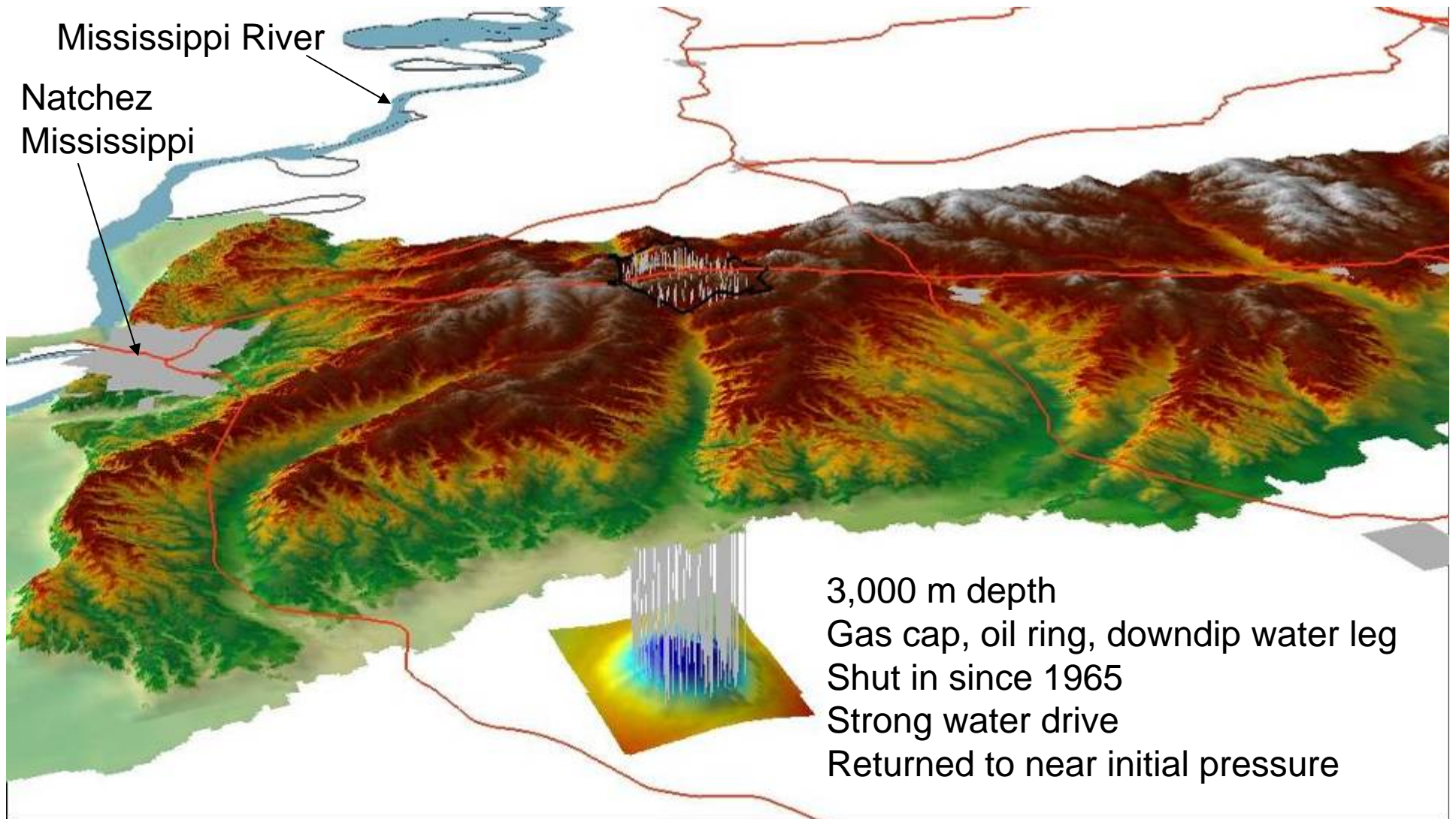


The Role of EOR: Stacked Storage Concept

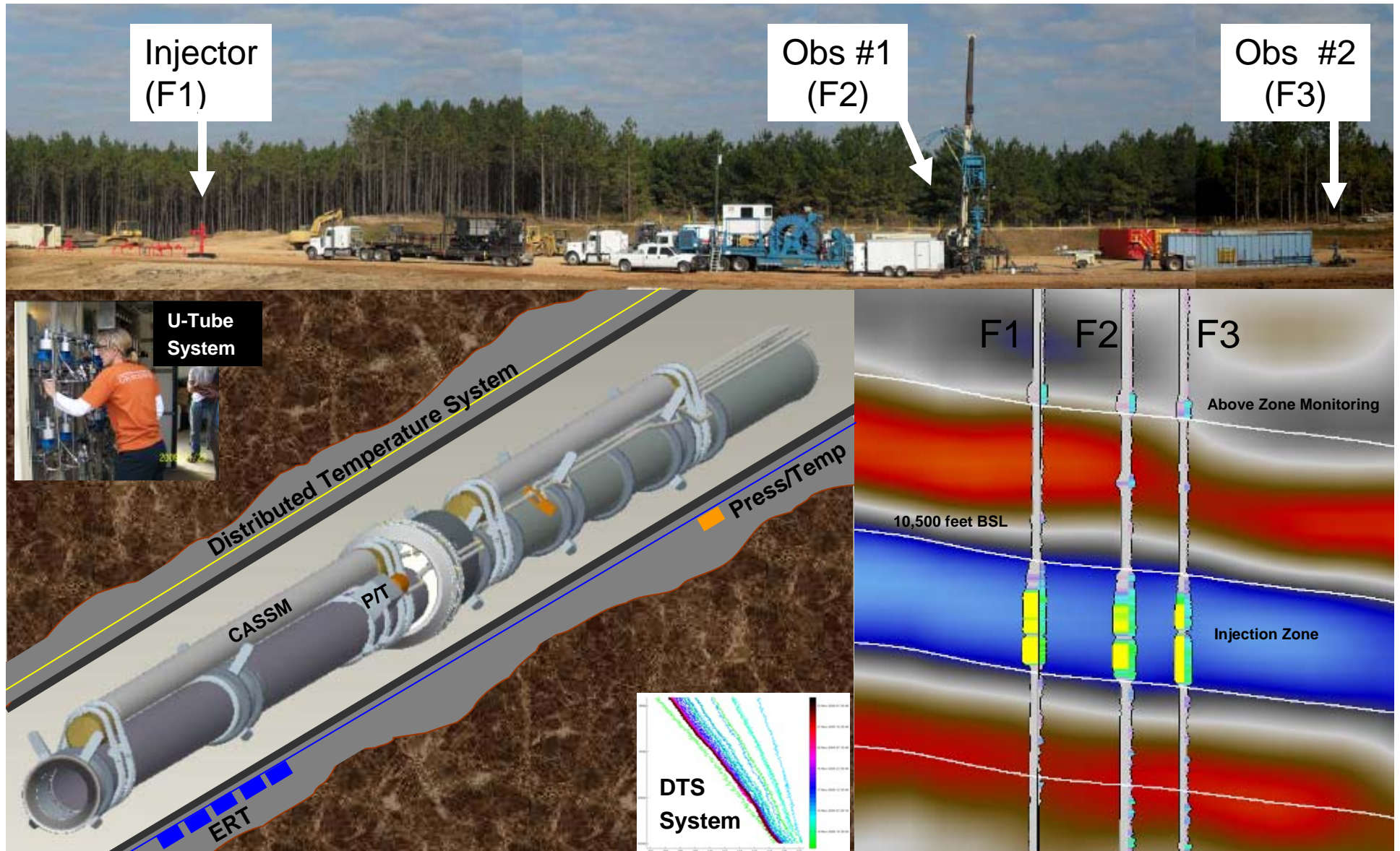


Cranfield, MS: SECARB Phase 3

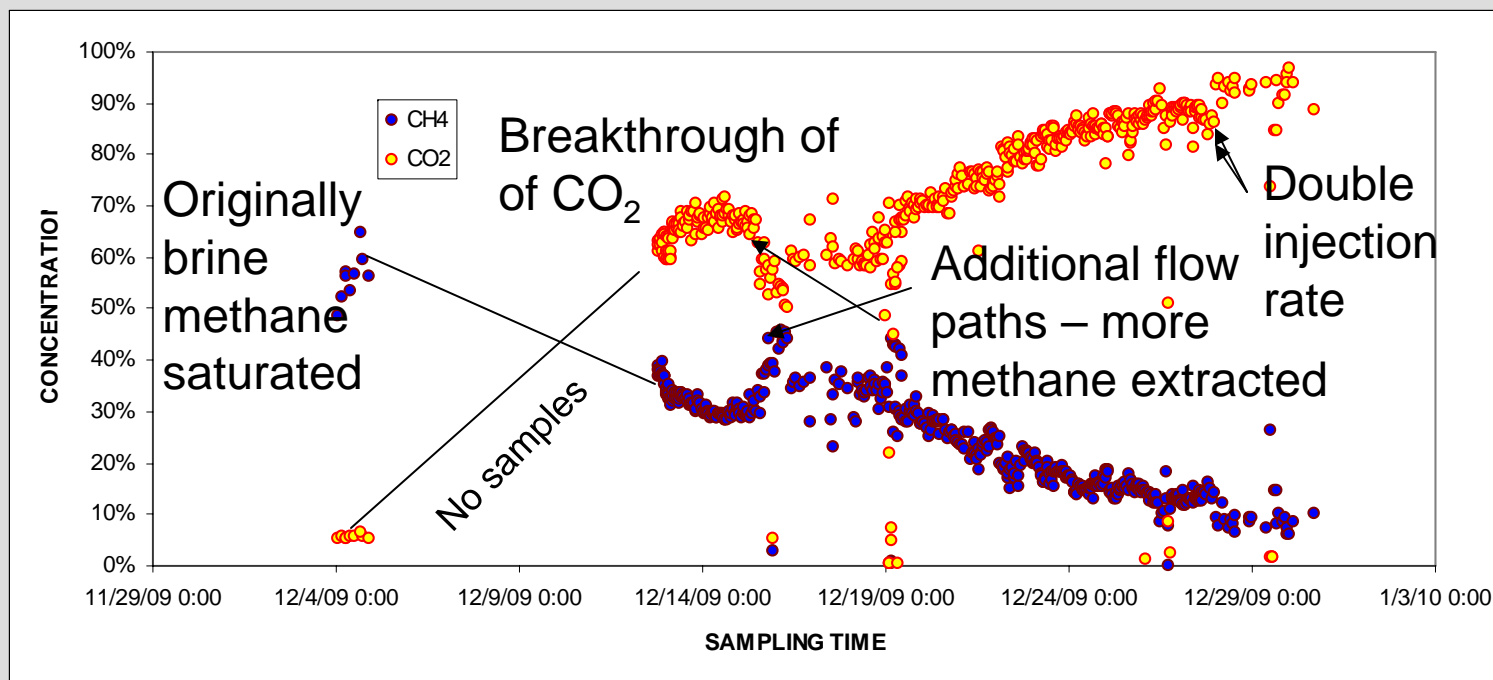
Example of stacked storage concept



Closely spaced injectors and observation wells in brine reservoir @ 3 km depth



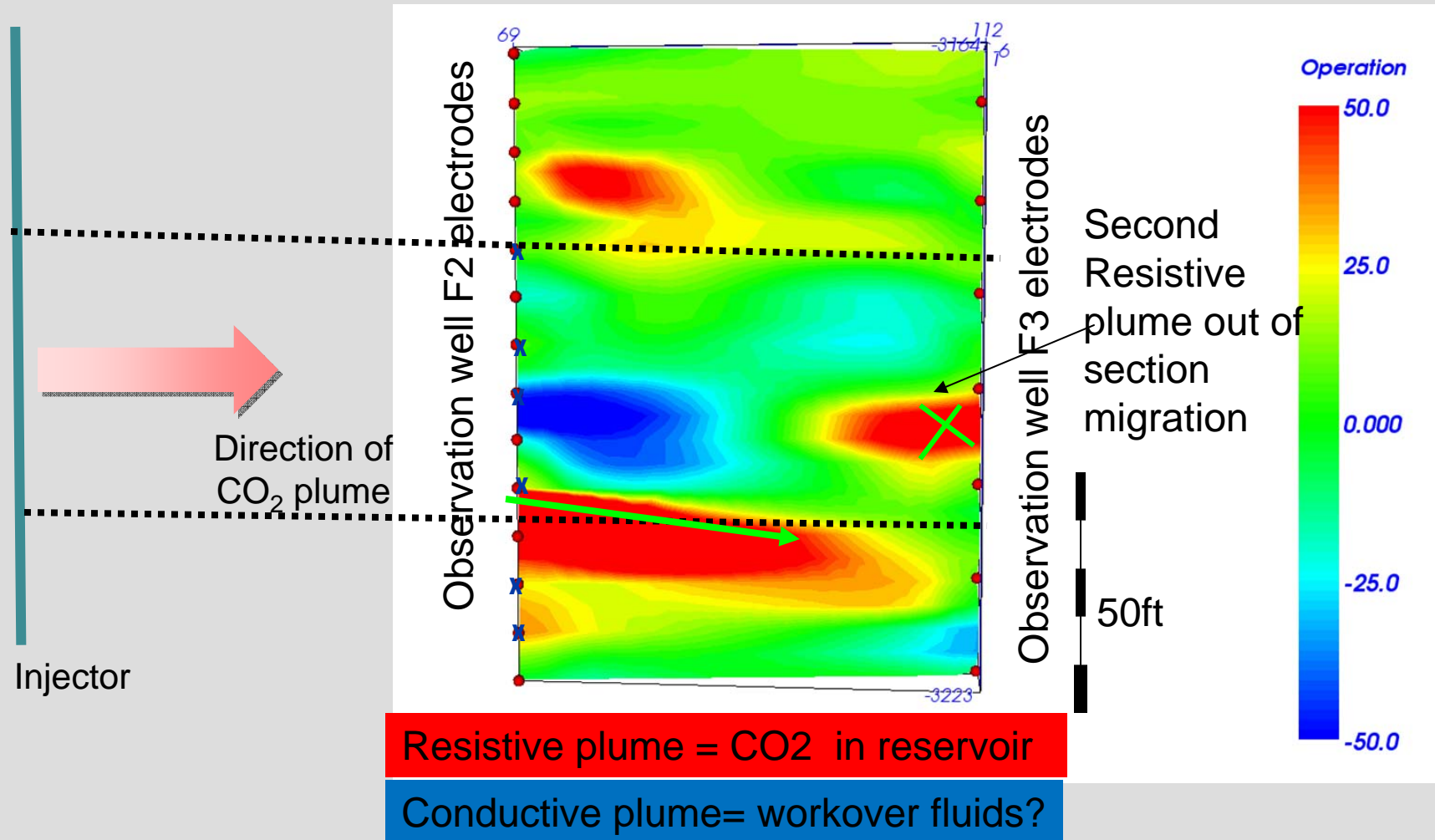
High frequency fluid sampling via U-tube yields data on flow processes



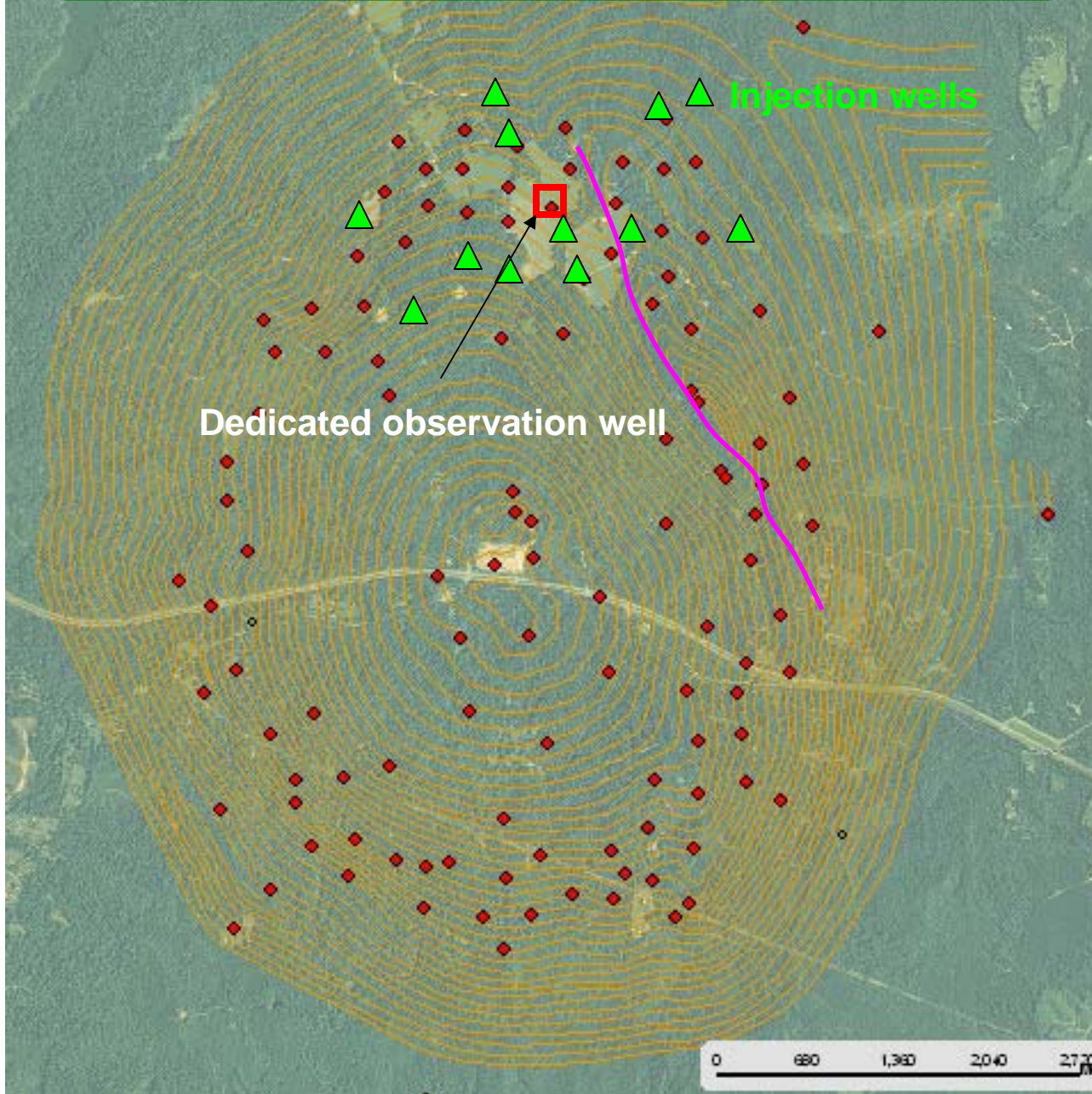
Small diameter sampler with N₂ drive brings fluids quickly to surface with tracers intact
CO₂ dissolution into brine liberates dissolved CH₄

BEG, LBNL, USGS, ORNL, UTDog,
data compiled by Changbing Yang BEG

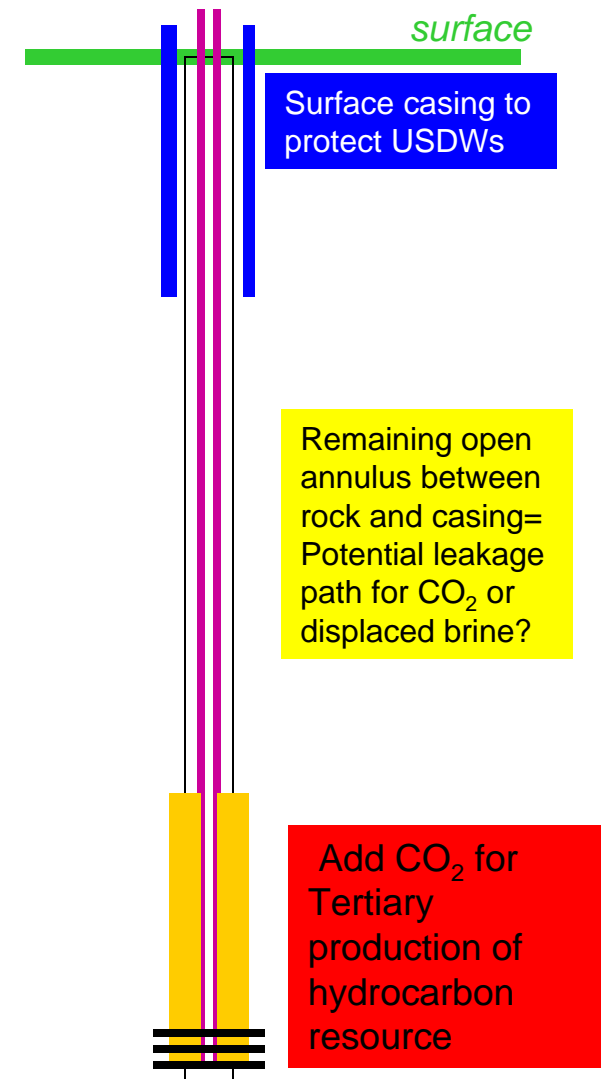
Cross Well Electrical Resistance Tomography: Flow dynamics at inter-well scale over months



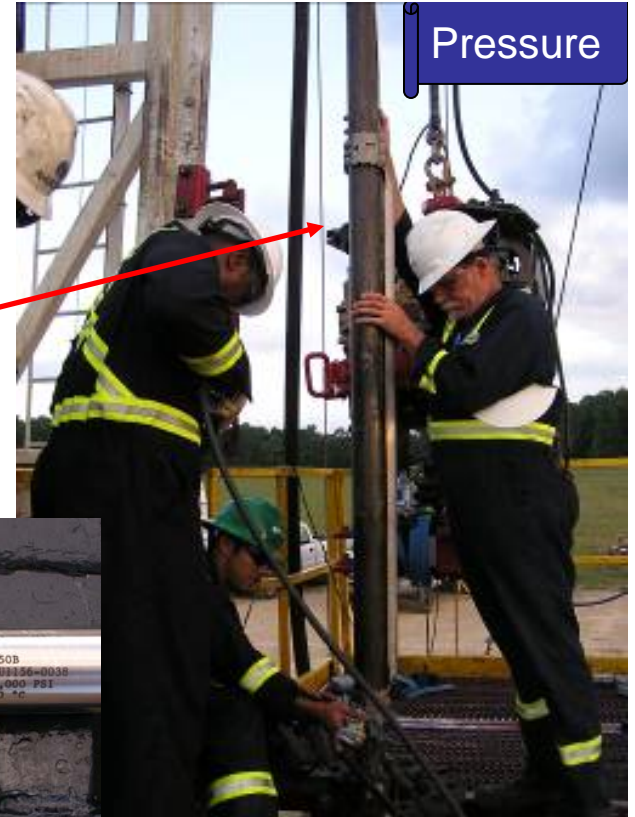
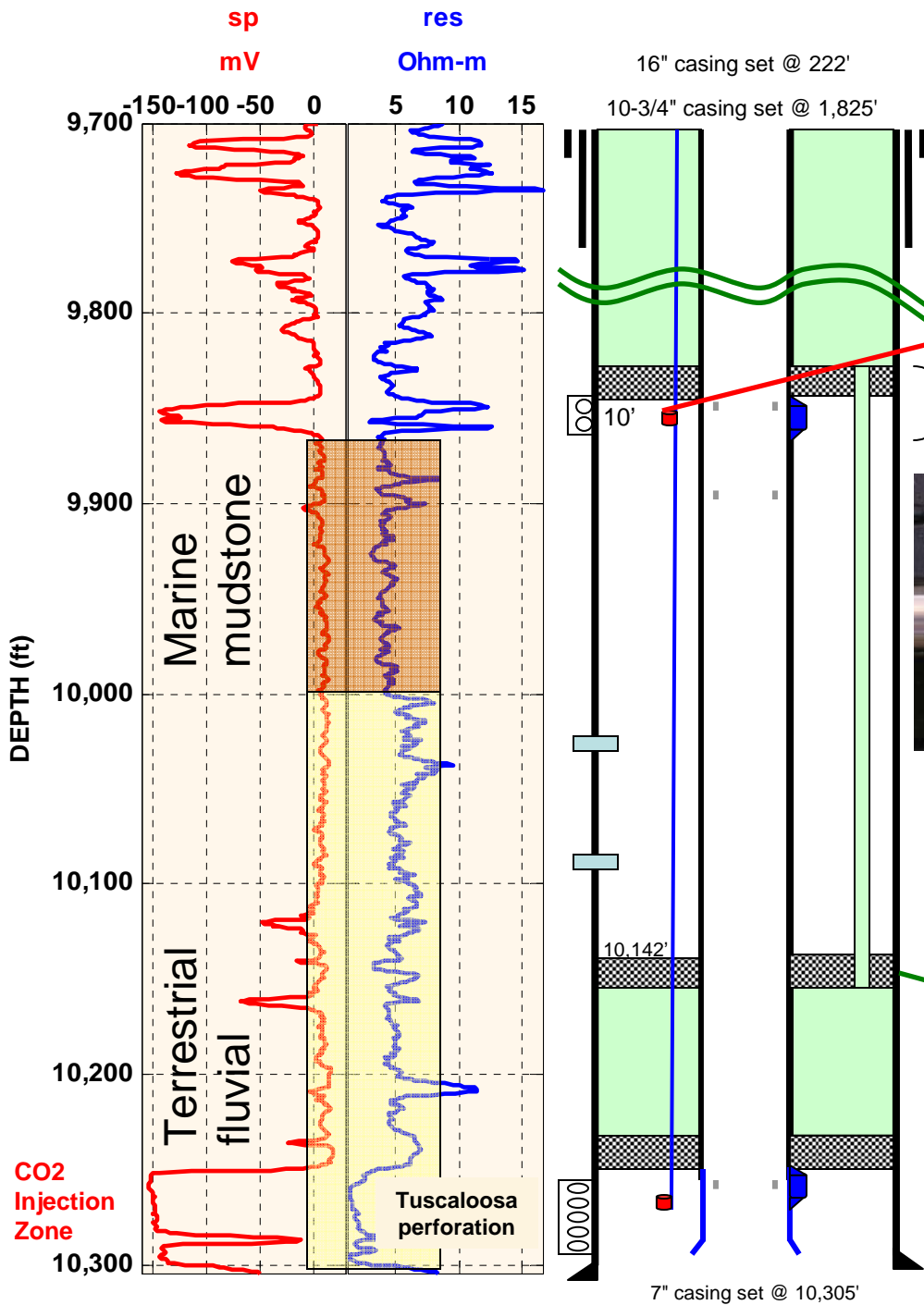
Pressure as Monitoring Tool: Cranfield, MS

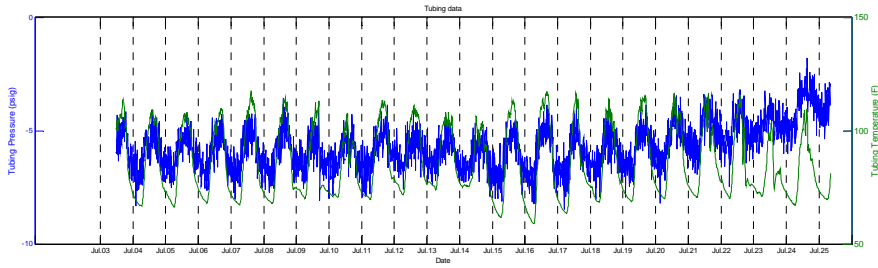


Problem: Many wells-
How Good is Cement?



Original development 1940's-60's





Stratosware - Sandia 2 > Ella G. Lees No. 7 - Windows Internet Explorer

http://aks-tech.stratosware.com/NewAlarms.aspx?MeterID=4226

Pressure

Welcome, ellagleez

Default Refresh: 10 Minutes

Sounds: None

en No Comms

SITELINE

SANDIA 2

Show STATS...

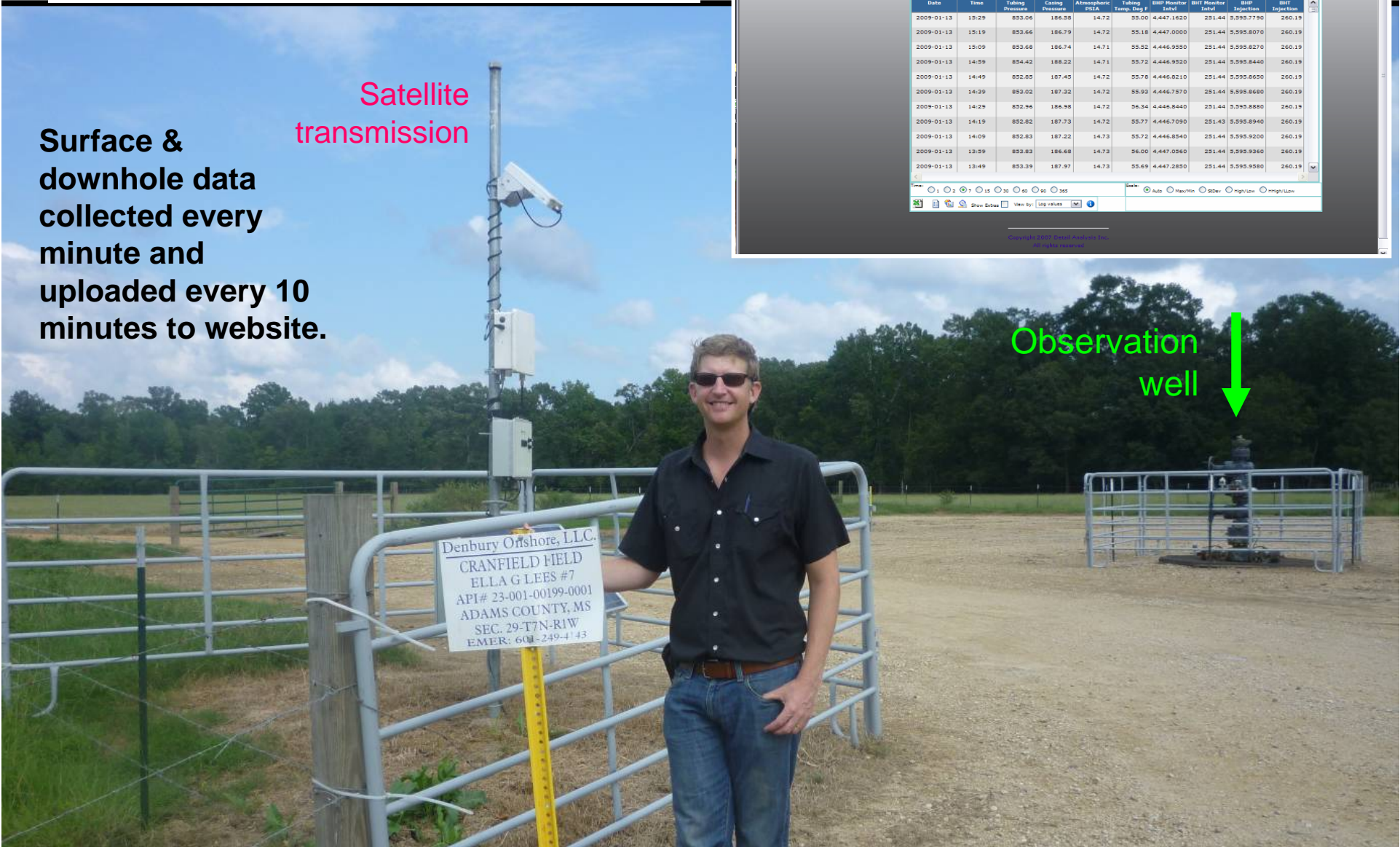
ELLA G. LEES No. 7

July 13, 2009 14:49 CST

Date	Time	Tubing Pressure	Casing Pressure	Atmospheric PSIA	Tubing Temp. Deg F	BHP Monitor Inlet	BHT Monitor Inlet	BHP Monitor Injection	BHT Monitor Injection
2009-01-13	15:29	853.06	186.58	14.72	55.00	4,447,1620	251.44	5,595,7750	260.19
2009-01-13	15:19	853.66	186.79	14.72	55.18	4,447,0000	251.44	5,595,8070	260.19
2009-01-13	15:09	853.68	186.74	14.71	55.52	4,446,9550	251.44	5,595,8270	260.19
2009-01-13	14:59	854.42	188.22	14.71	55.72	4,446,9520	251.44	5,595,8440	260.19
2009-01-13	14:49	852.85	187.45	14.72	55.78	4,446,9210	251.44	5,595,8650	260.19
2009-01-13	14:39	852.02	187.32	14.72	55.93	4,446,7570	251.44	5,595,8660	260.19
2009-01-13	14:29	852.96	186.98	14.72	56.34	4,446,8440	251.44	5,595,8880	260.19
2009-01-13	14:19	852.82	187.73	14.72	55.77	4,446,7090	251.43	5,595,8940	260.19
2009-01-13	14:09	852.83	187.22	14.73	55.72	4,446,8540	251.44	5,595,9200	260.19
2009-01-13	13:59	853.83	186.68	14.73	56.00	4,447,0560	251.44	5,595,9360	260.19
2009-01-13	13:49	853.39	187.97	14.73	55.69	4,447,2850	251.44	5,595,9580	260.19

Scale: auto max/min SDer night/low night/low

Copyright 2007 Data Analysis Inc. All rights reserved.

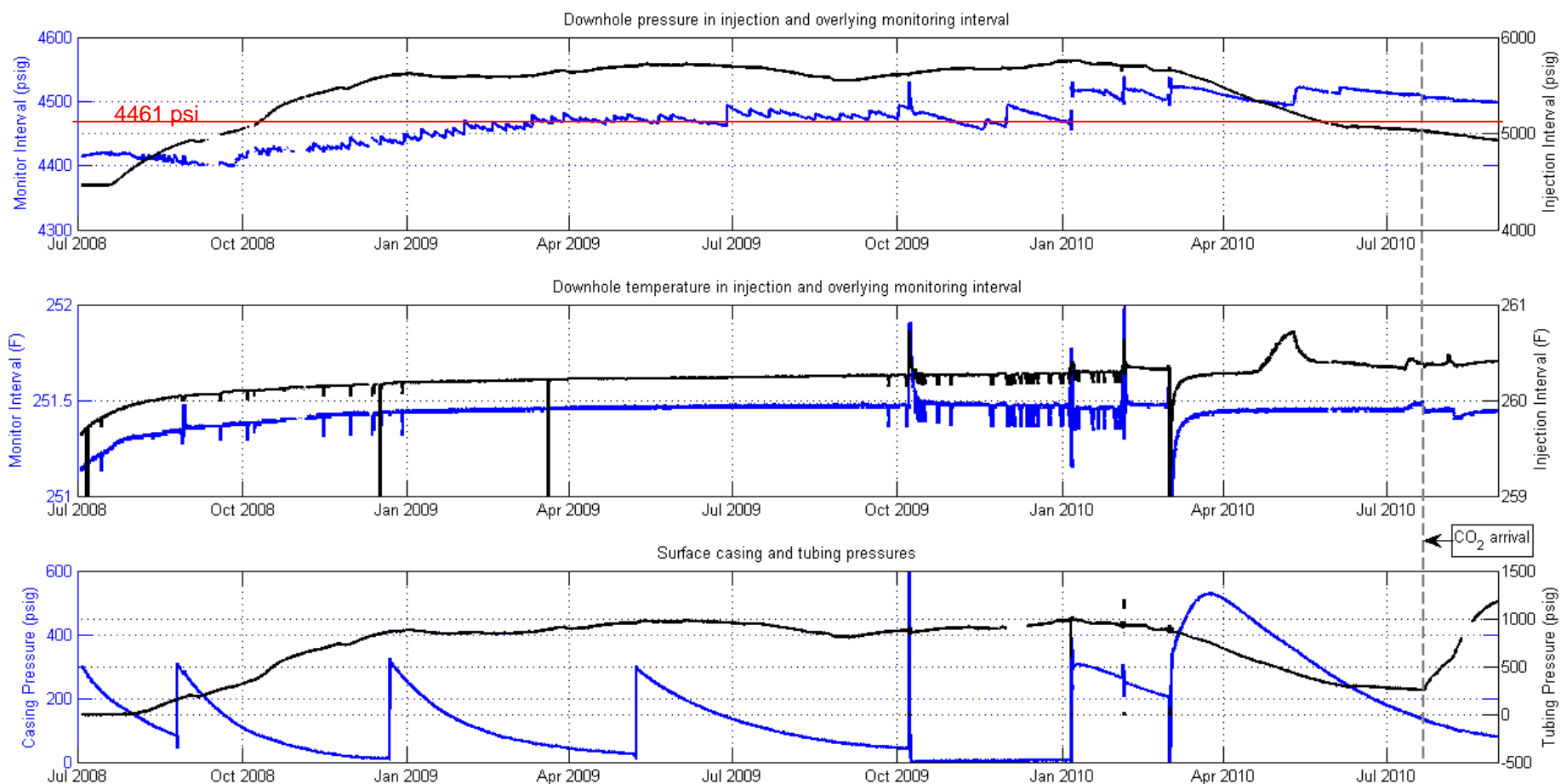


Continuous 2-year data series

Maximum sustained pressure differential >1,200 psi

Suggests old wells have reasonable integrity.

Some aspects of data difficult to interpret, but likely relate to complicated well completion.



Pressure & Boundary Conditions Influence Capacity

OPEN

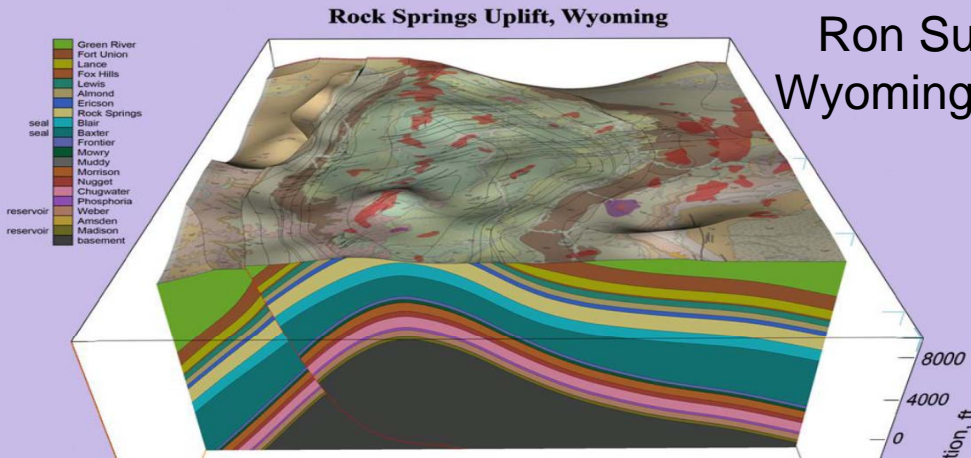


CLOSED

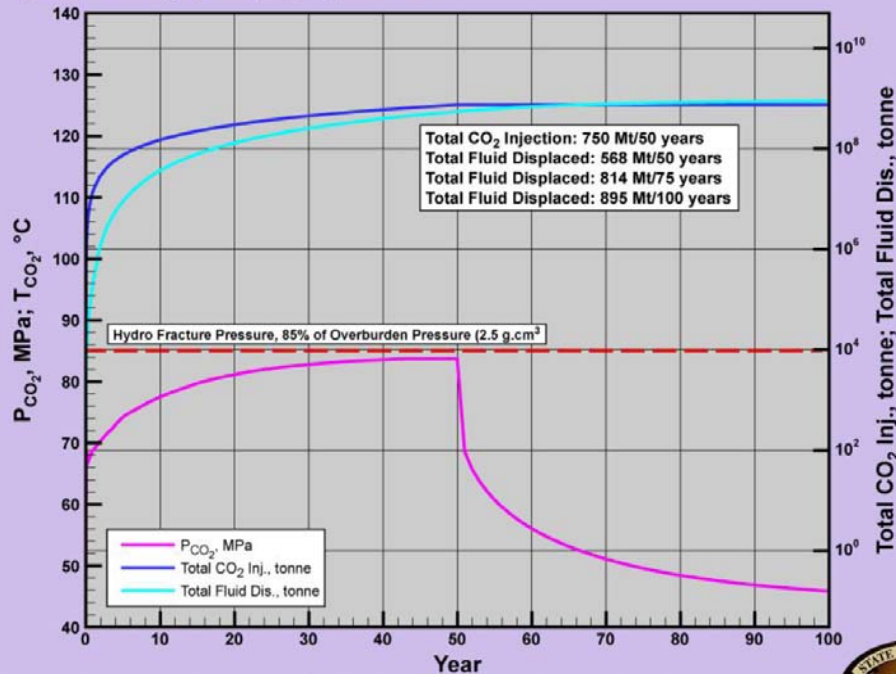


Pressure Mitigation (Fluid Withdrawal)

Ron Surdam,
Wyoming, USA



CO₂ Injection Simulation Results from FEHM for the Weber Sandstone, Rock Springs Uplift
Injection Interval 700 ft, Porosity 10%, Relative Permeability 1 md,
Injection Rate 8.8 kg/s, 15 Mt/year, 9 Injection Wells



Injected CO₂ will raise pressure and displace large volumes of brine – where will it go?

Extraction wells may be viable, but costs of re-injecting brine may be high.

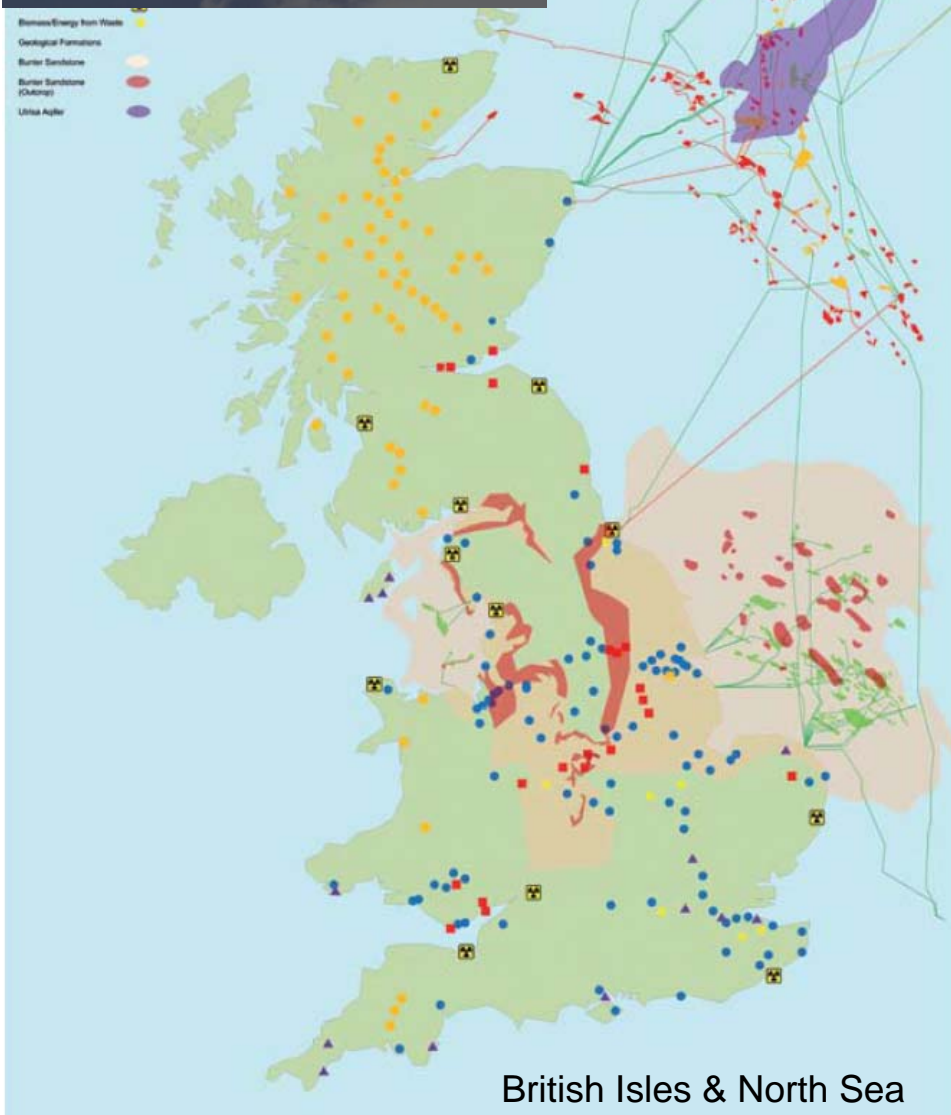
Potential to desalinate brine for economic use of water is being considered.

Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO₂ sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.



A CARBON CAPTURE AND STORAGE NETWORK FOR YORKSHIRE AND HUMBER

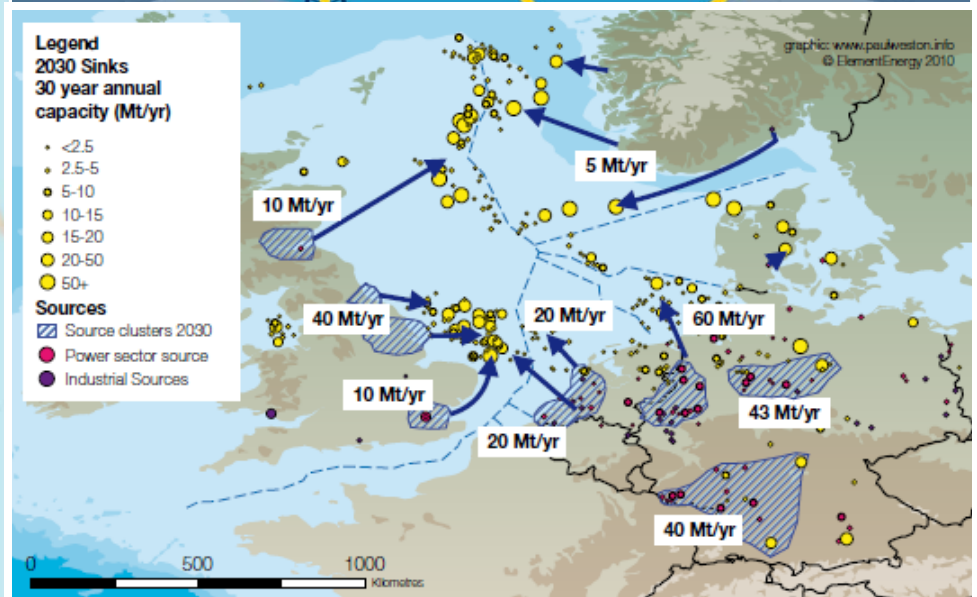
An introduction to understanding the transportation of CO₂ from Yorkshire and Humber emitters into offshore storage sites.



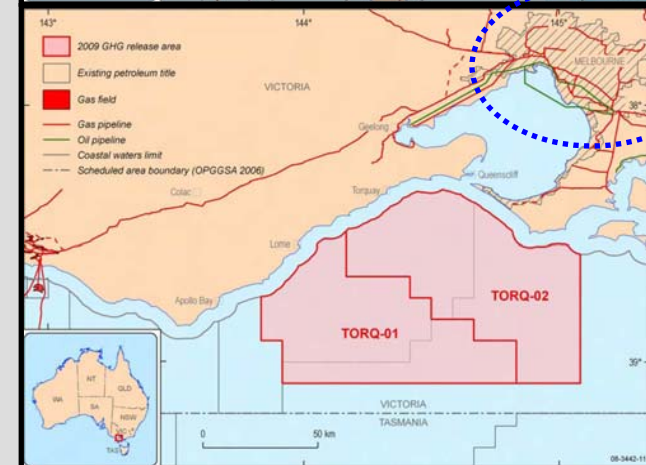
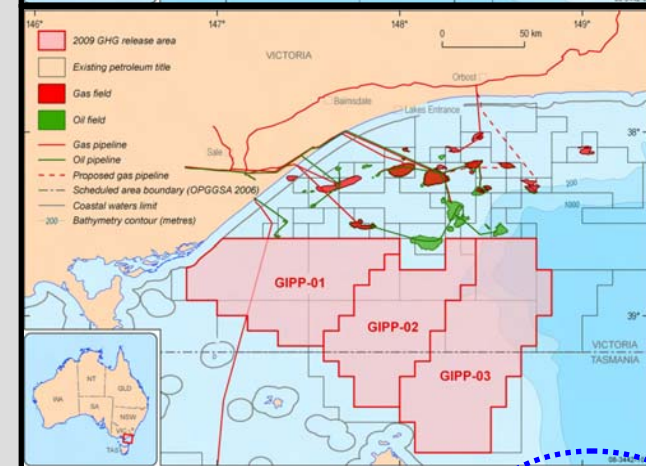
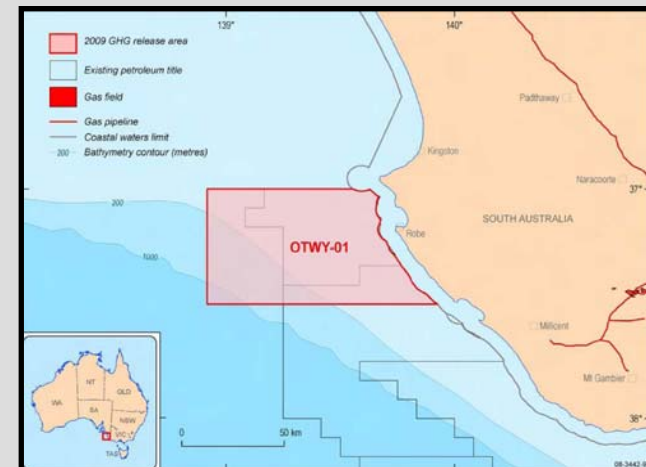
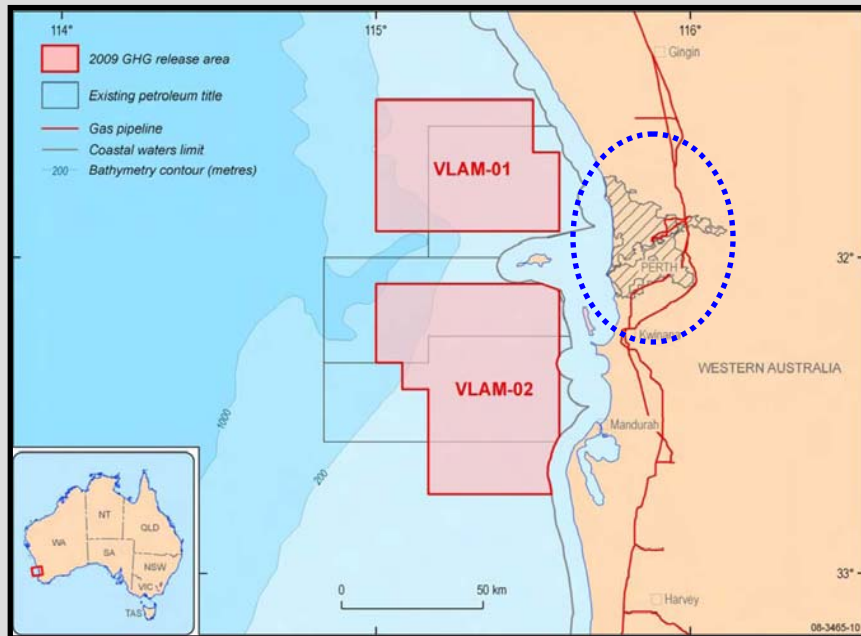
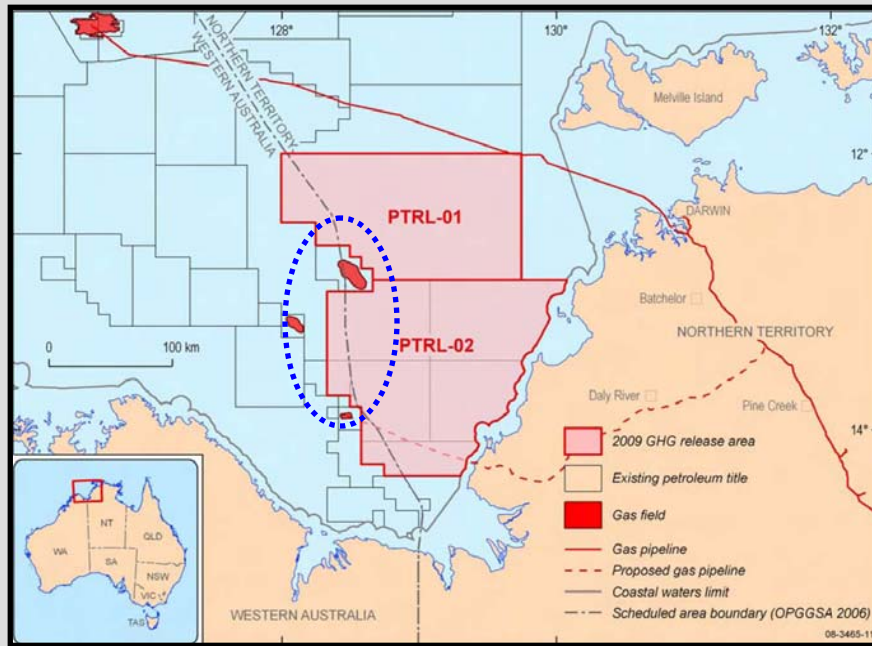
One North Sea

A study into North Sea cross-border CO₂ transport and storage

Illustration: Paul Weston 2010

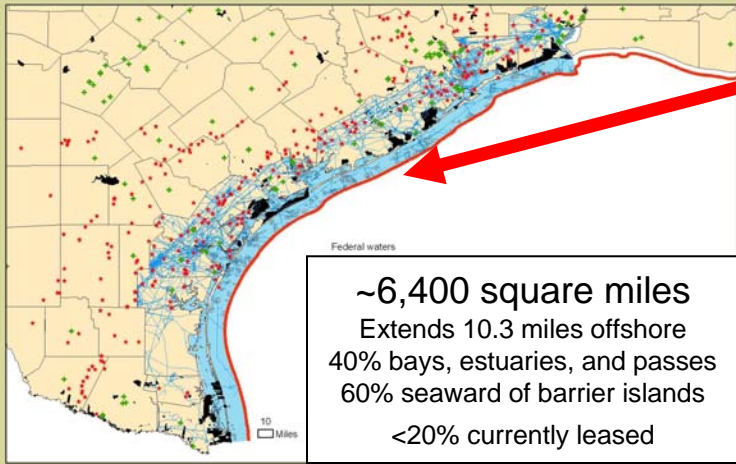


AUSTRALIA 2009 RELEASE OF OFFSHORE AREAS FOR GREENHOUSE GAS STORAGE ASSESSMENT

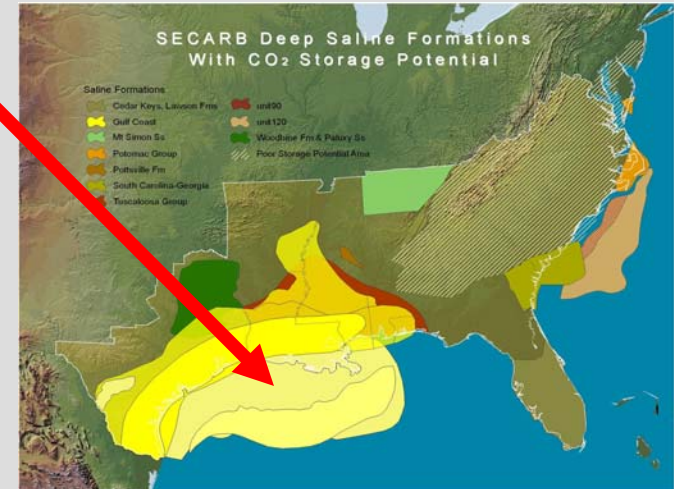


USA Offshore CCS Activities

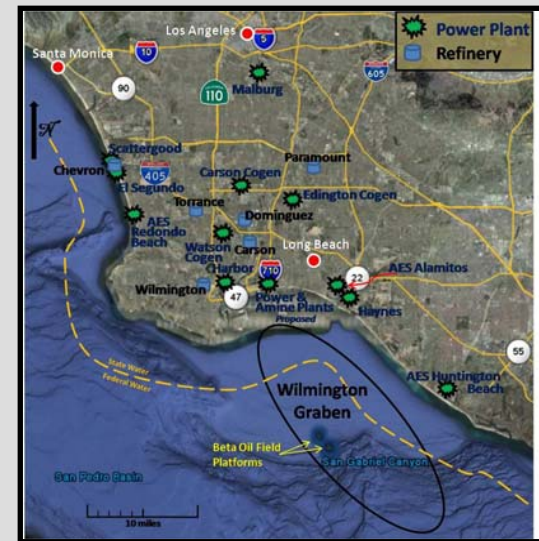
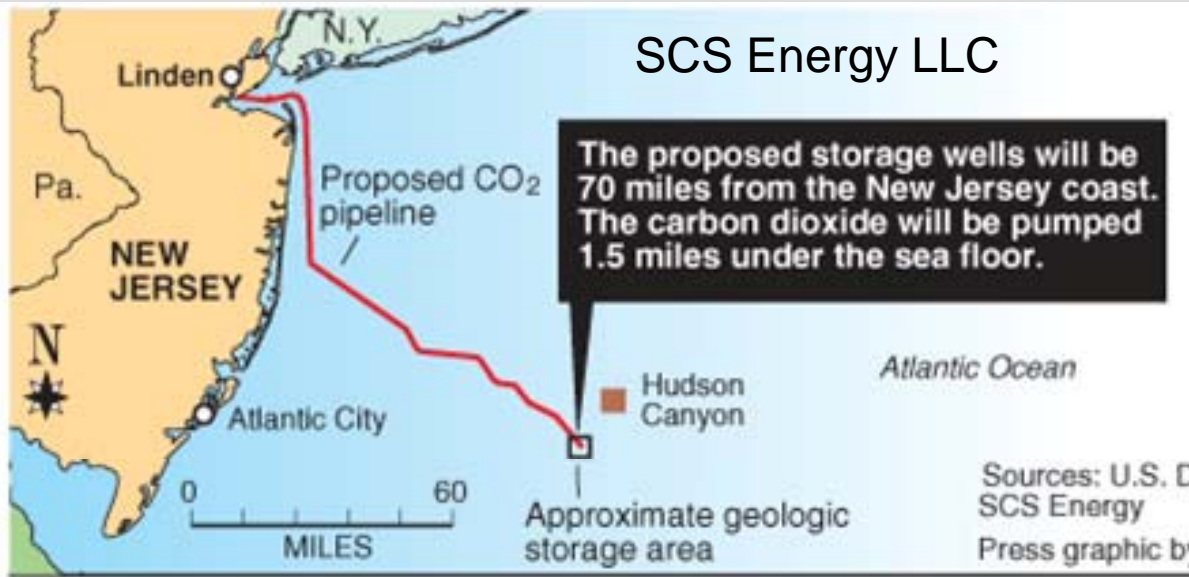
Offshore Texas, Gulf of Mexico
T. Meckel & R. Trevino, TX BEG



NETL 2010 Atlas of Capacity



SCS Energy LLC



Wilmington Graben, offshore LA
Mike Bruno, Terralog Tech.

Offshore Monitoring: RITE

Onshore vs. Offshore

Michimasa Magi: IEA Natural Releases Meeting, Maria Laach, Germany, Nov. 2010

2. Ocean Sequestration Project 2. Natural Analogue Study

Observation of Natural CO₂ Analogue Site

Dissolution Process
of CO₂ Droplets

Behavior
of Dissolved CO₂

CO₂ Leakage Process



Hatoma Knoll & Yonaguni Knol in Okinawa Trough
(FY2002)
CO₂ Leakage & CO₂ Droplets & Gas Analysis
ROV Hyper Dolphin by JAMSTEC



Hatoma Knoll in Okinawa Trough (FY2004-2005)
CO₂ Leakage & CO₂ Droplets & pH distribution
ROV Hakuyo2000 ()

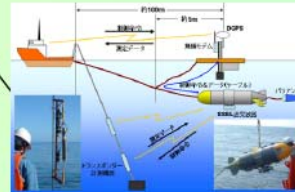


Wakamiko Caldera in Kagoshima Bay FY2007
CO₂ Leakage & pH distribution
R/V Hakuyo ()

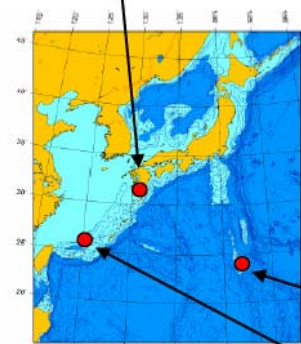
Wakamiko Caldera
in Kagoshima Bay FY2007
pH Distribution
AUV REMUS by CRIEPI



NW Eihuku SM in Mariana Arc
FY2006
pH Distribution
by CREPI



(KAGOSHIMA Bay)



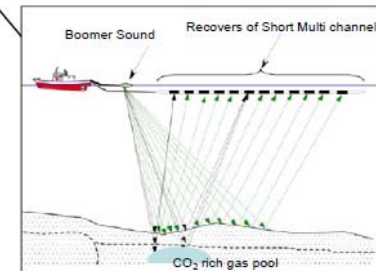
(MARIANA ARC)

(OKINAWA Trough)

Wakamiko Caldera in Kagoshima Bay
FY2008-2009
Sub-bottom Profiler & Side Scan Sonar



Wakamiko Caldera in Kagoshima Bay
and Other Site FY2010 - ?
Short multi-channel Profiler



Basin Fluid Histories and CO₂

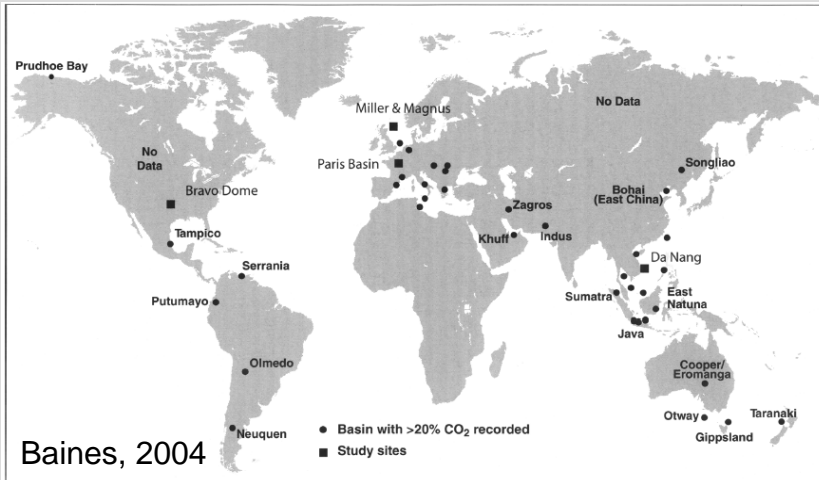


Fig. 1. Global distribution of high (>20%) CO₂-content basins. The sites discussed in this study are indicated.

CO₂ is common in many geological settings.

Understanding the historic ability of basins to naturally buffer CO₂ will greatly reduce uncertainties about long-term fate of injected CO₂.

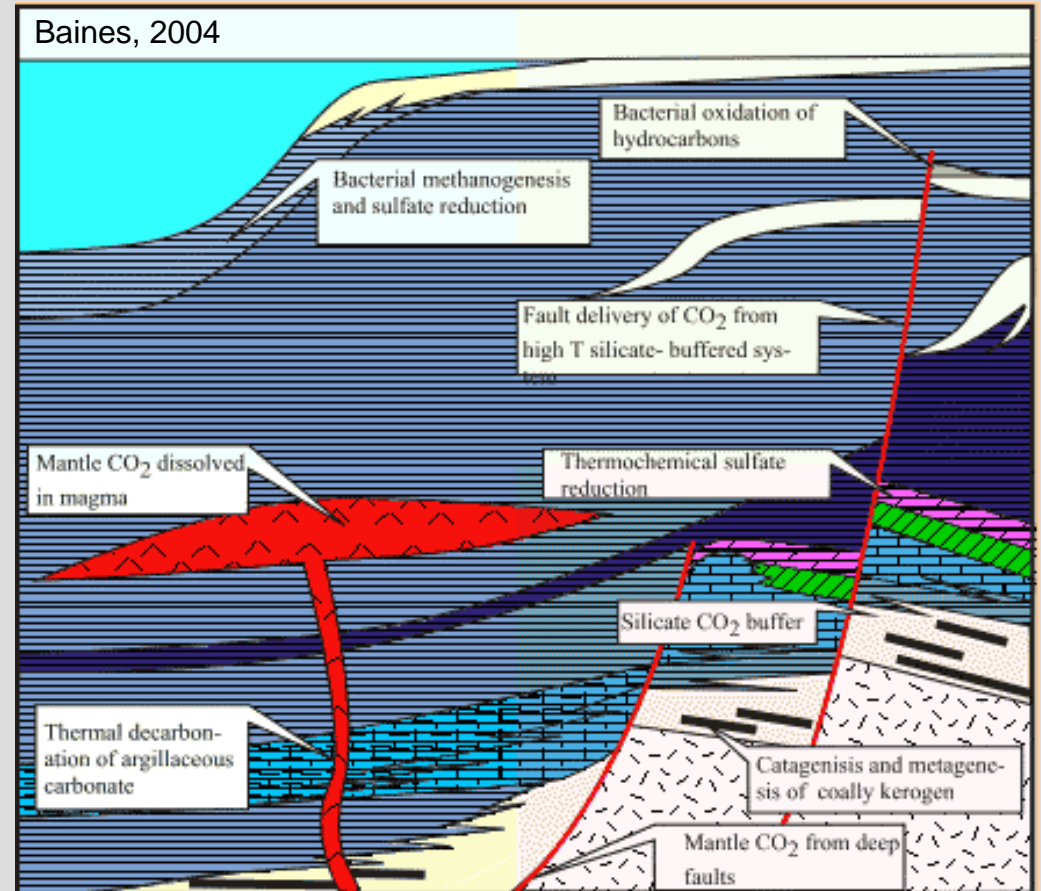


Figure courtesy of Alton Brown, used with permission

Figure 1: Sources of CO₂ in natural gas accumulations.

Global CO₂ Map

Each country is sized proportional to its annual CO₂ emissions.

Thank you to Japanese hosts, especially Ziqiu Xue.

I look forward to working on this important international issue with Japanese researchers.

