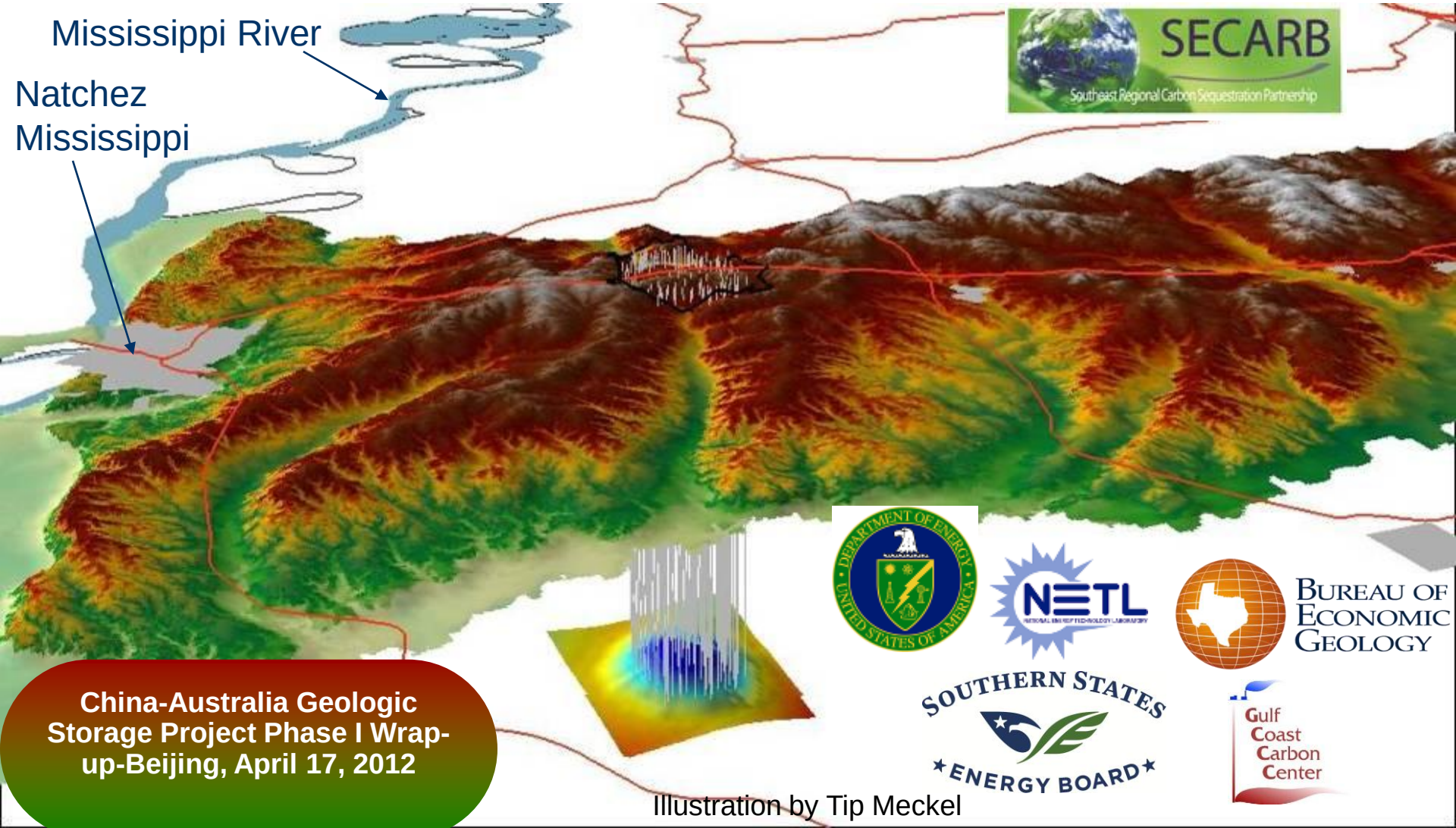
Progress Update SECARB " Early" Test Monitoring 3.5 Million Tons at Cranfield



China-Australia Geologic Storage Project Phase I Wrap-up-Beijing, April 17, 2012

Illustration by Tip Meckel

US CCS Program

US Department of Energy National Energy Technology Lab (NETL)

Core R&D

- Capture
- Storage
- MVA
- Risk etc.
- Training
- National Lab & university

Infrastructure

- Regional Carbon Sequestration Partnerships (7)
- NATCARB Atlas
- Industrial sourced projects (3)
- Clean coal projects (7)
- Charaterizationprojects (10)

US Environmental Protection Agency

Promulgation of rules
Risk studies

US Geological Survey

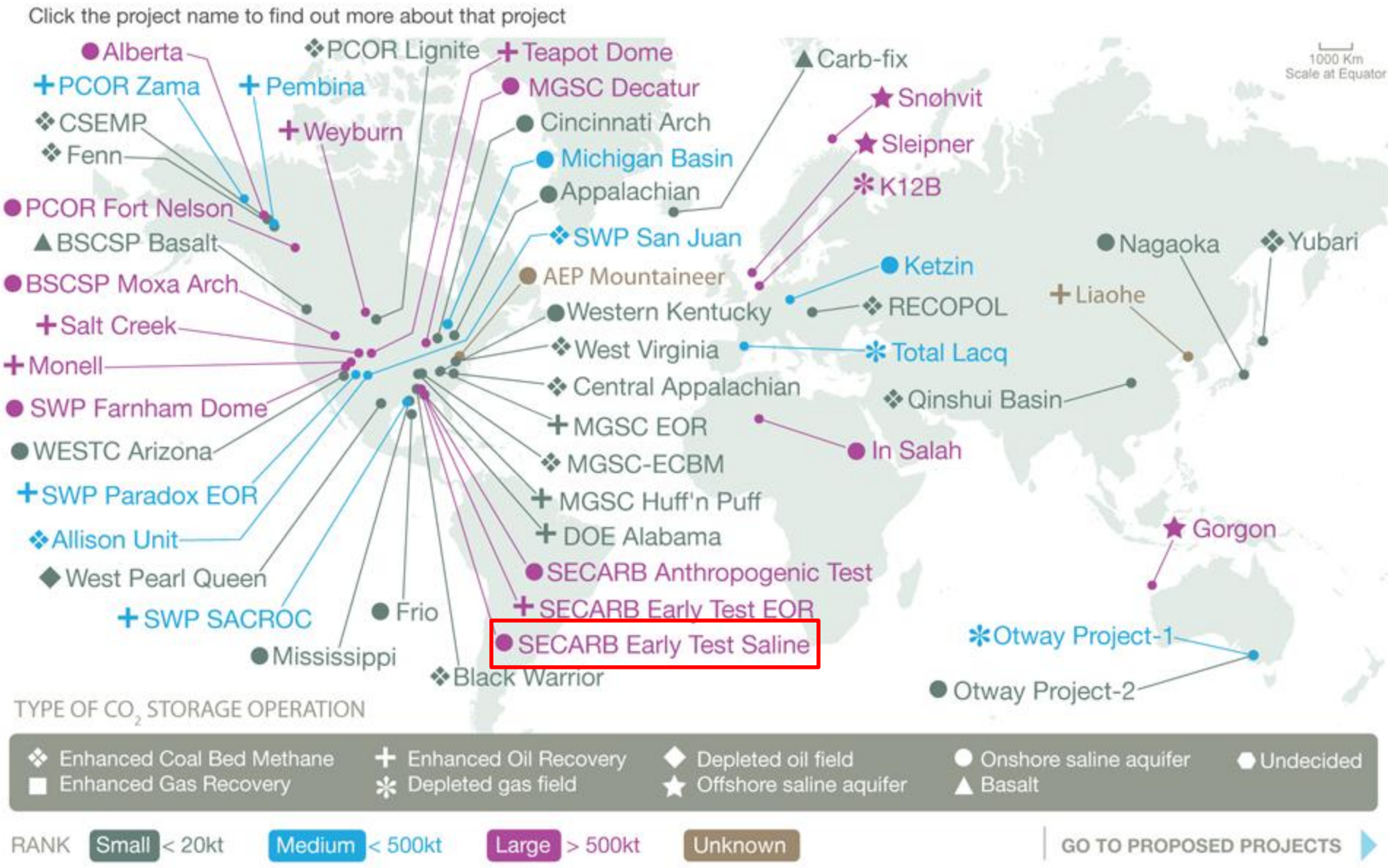
Capacity Assessment

Other groups

BOEM (offshore)
American Water-Works Association

excerpted from www.fe.doe.gov

CO2CRC World Project Inventory



http://www.co2crc.com.au/demo/worldprojects.html

Gulf Coast Carbon Center
Leveraged Project Inventory and Status

Name	Funded by	Field study	Whole system	Paper study	Characterization	Monitoring	Risk	Training	Status end 2010
SECARBII -Cranfield	NETL	X			X	X		X	Completed
SWP SACROC	NETL	X				X		X	Completed
SECARBIII -Cranfield	NETL	X			X	X	X	X	Injecting
Frio Brine Pilot I&II	NETL	X			X	X			Completed
SE Power -sinks	SSEB			X	X			X	Completed
LCRA -sinks	LCRA			X	X			X	Completed
EPA-training	EPA R- VI							X	Completed
STORE	NETL							X	Underway
SECARB-Ed	NETL							X	Underway
CFSES	DOE-BES			X					Underway
Offshore	NETL	X		X	X				Underway
Offshore	TX-GLO	X		X	X				Underway
EPA-Monitoring	EPA			X		X		X	Underway
CCP3-Monioting	CCP			X		X		X	Underway
CCP2-CF	CCP			X			X		Underway
CCP- CO2 specs	CCP			X					Underway
NRG-Parrish	NETL	X	X			X			Underway
Hastings -AP-LLC	NETL	X	X			X			Underway
Summit	Summit	X	X			X			Planning

Example this talk

Gulf Coast Carbon Center

Funding agency

NETL

SECARB

Southeast Regional Carbon Sequestration Partnership

Southern States Energy Board

Texas General Land Office

Research Collaborators

Denbury

Sandia Technologies, LLC

USGS science for a changing world

Oak Ridge National Laboratory

Managed by UT-Battelle for the Department of Energy

Schlumberger Carbon Services

Berkeley Lab

Lawrence Berkeley National Laboratory

Los Alamos National Laboratory EST. 1943

Lawrence Livermore National Laboratory

Univ. Mississippi
Miss State
Curtin University
Univ. Durham

Univ. Tennessee
Princeton Univ.
Stanford Univ.
Univ. Edinburgh

GCCC sponsors

bp

Chevron

Kinder Morgan

Schlumberger

NRG

BG Group

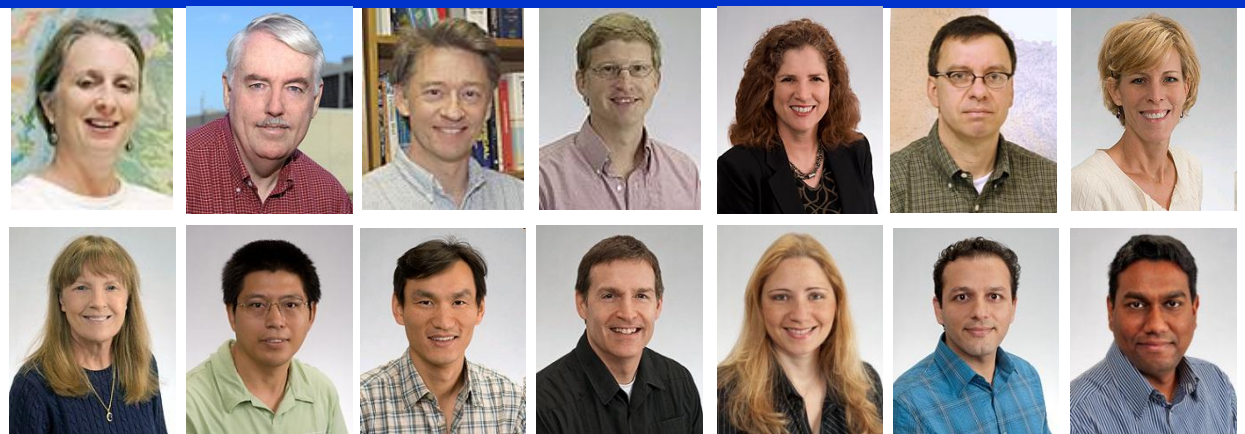
Luminant

ExxonMobil

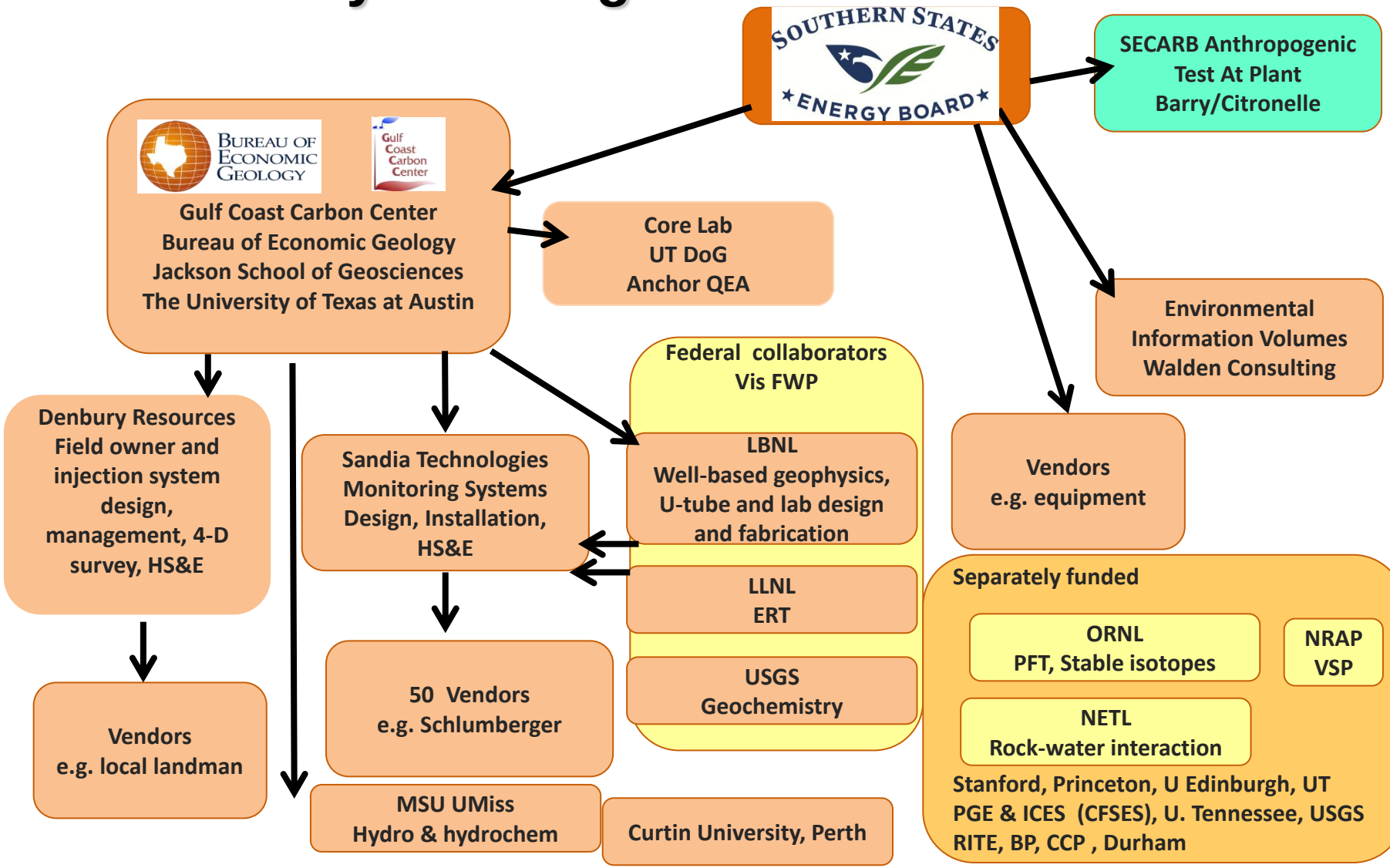
Saudi Aramco

EDF Environmental Defense Fund

STAFF



Early Test Organization Chart



Transition From… **To**

Research Monitoring

Tests-

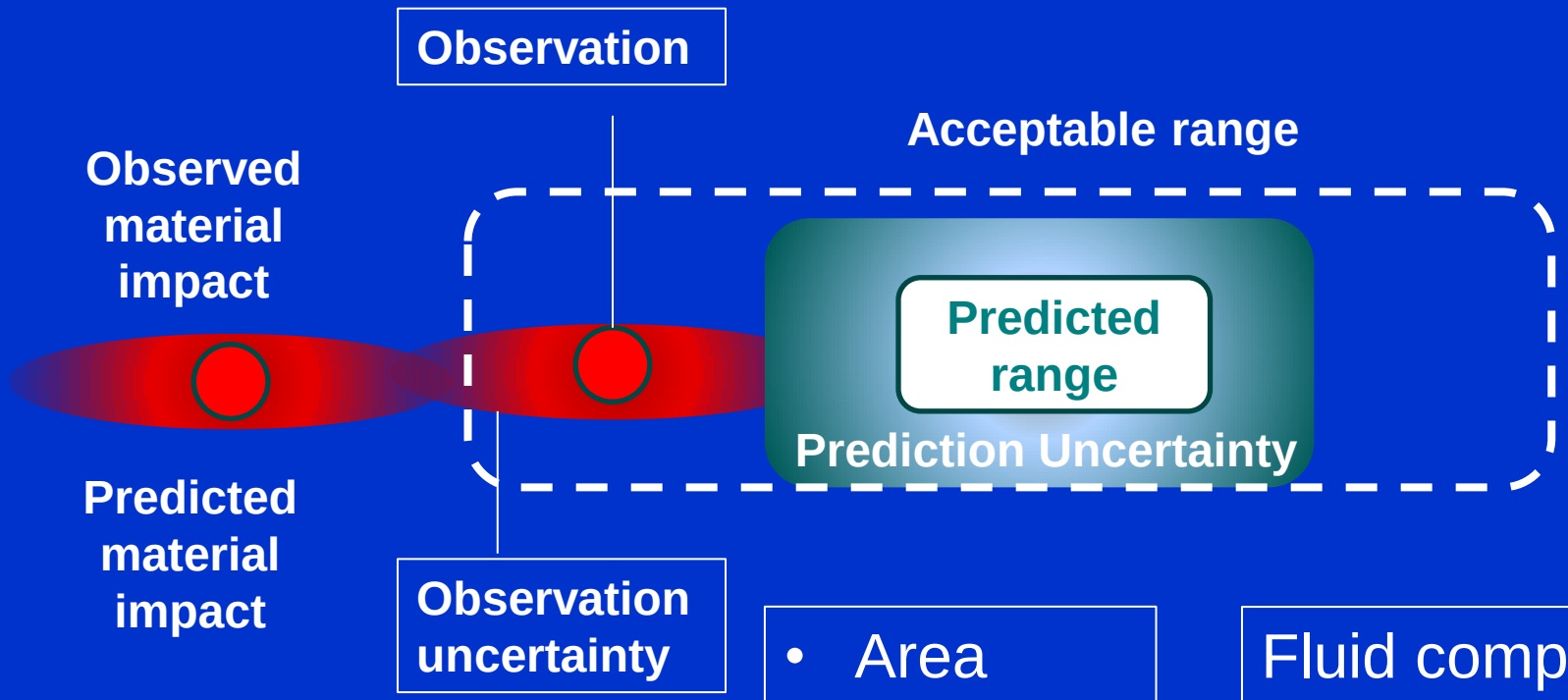
- Hypotheses about the nature of the perturbation created
  - compare response modeled to the response observed via monitoring.
- Performance and sensitivity of monitoring tools
  - sensitivity to the perturbation
  - conditions under which tool is useful,
  - reliability under field conditions.

Commercial Monitoring

Confirms -

- predictions of containment based on site characterization at the time of permitting are correct
- Confidence to continue injection is gained
  - monitoring observations that are *reasonably close* to model predictions
  - any non-compliance explained.
  - no unacceptable consequences result from injection
- Monitoring frequency could be diminished through the life of the project
  - eventually stopped, allowing the project to be closed.

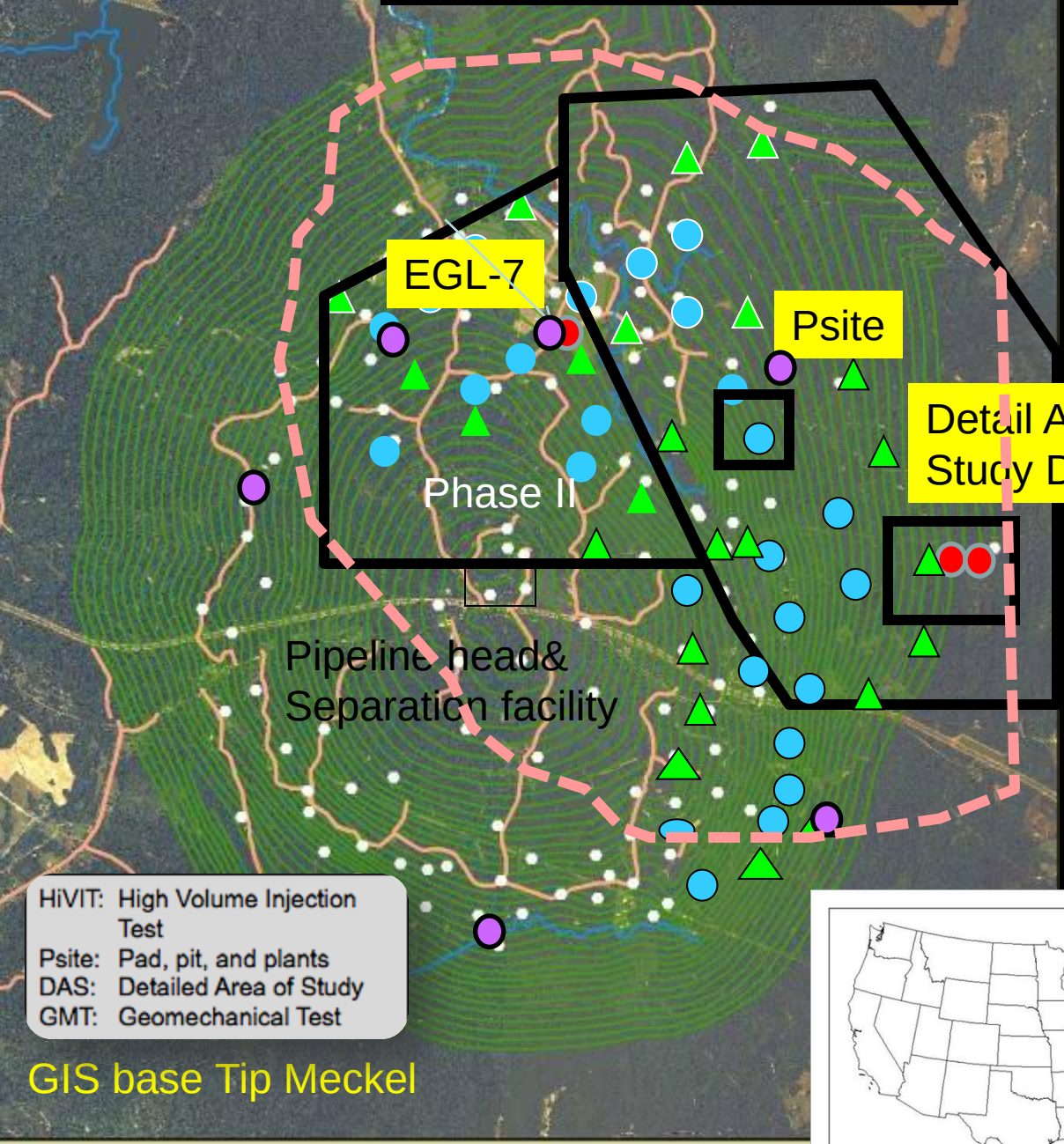
Commercial Monitoring Goal: Identify Unexpected Occurrences with Material Impact



- Area
- Magnitude
- Vector

of

Fluid composition
Pressure
Stress/Strain



Injector

Producer
(monitoring point)

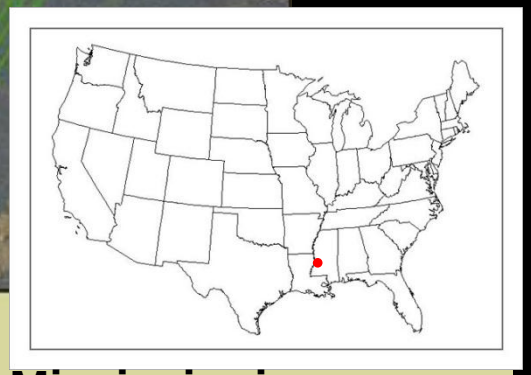
Observation Well

RITE Microseismic

4-D seismic

HiVIT: High Volume Injection Test
Psite: Pad, pit, and plants
DAS: Detailed Area of Study
GMT: Geomechanical Test

GIS base Tip Meckel

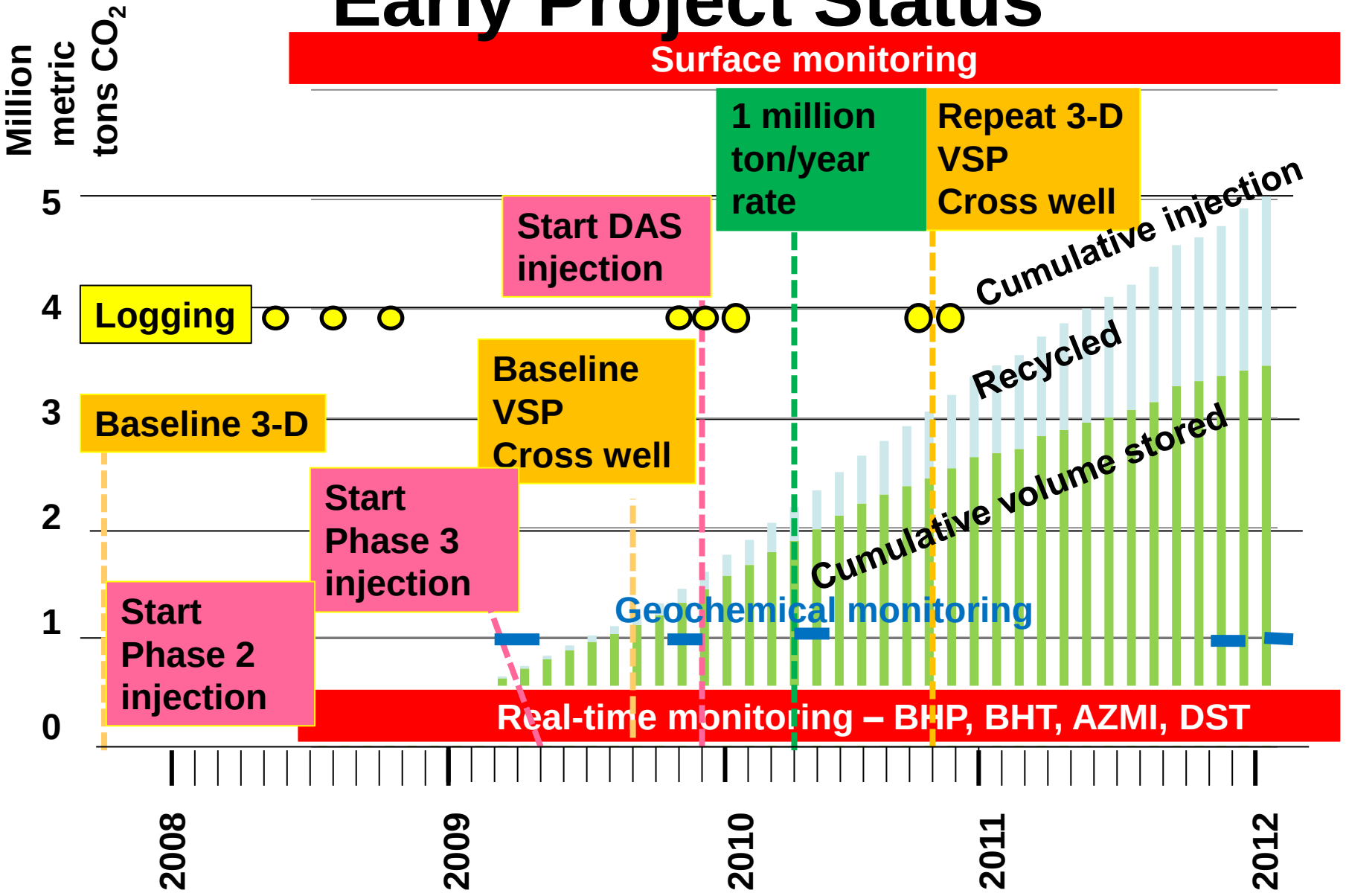


SECARB research program, Cranfield Mississippi

Bureau of Economic Geology

Gulf Coast Carbon Center

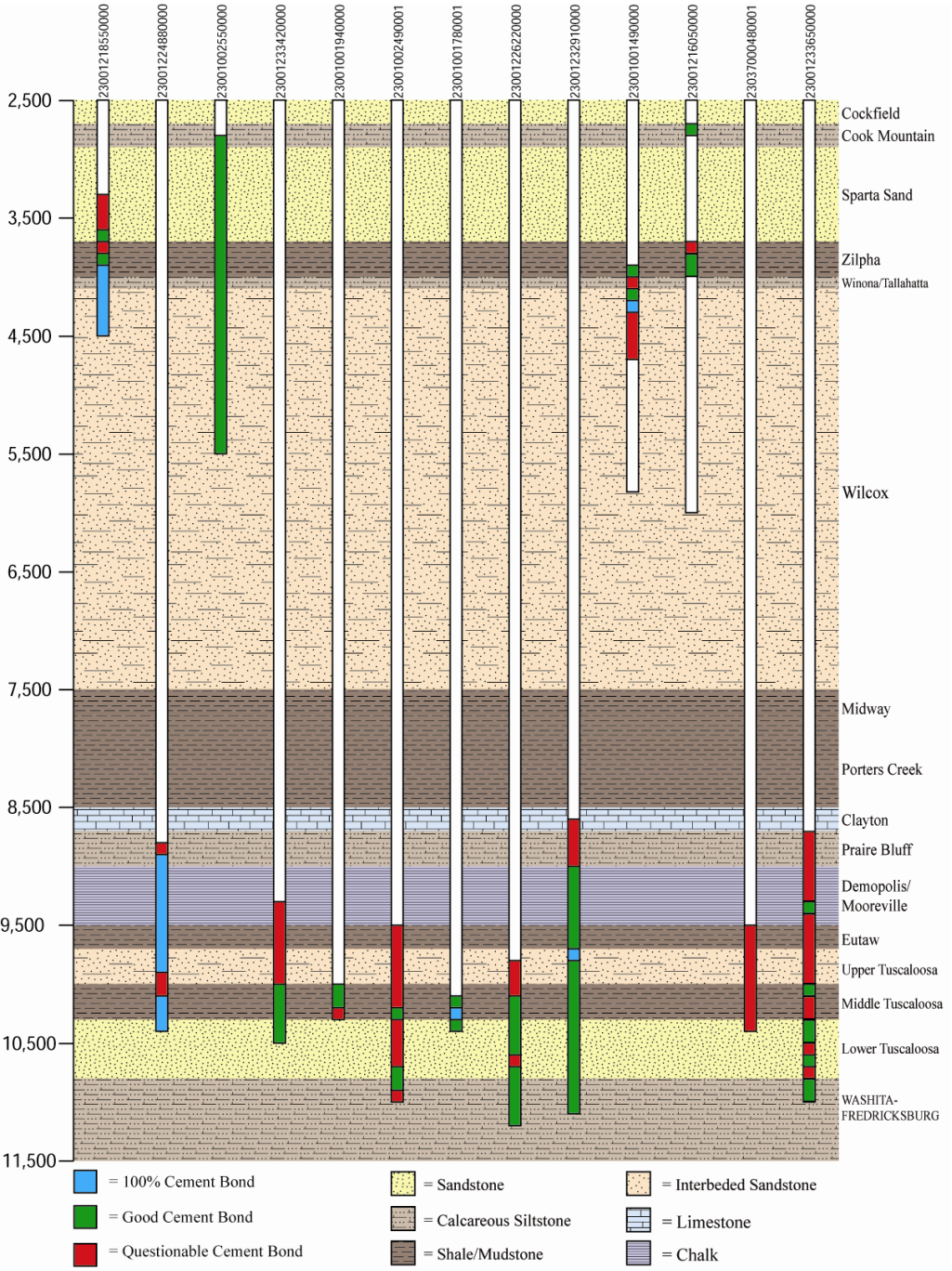
Early Project Status



RCSP program goal: Evaluate protocols to demonstrate that it is probable that 99% of CO_2 is retained

Permanence of geologic system well understood prior to test.

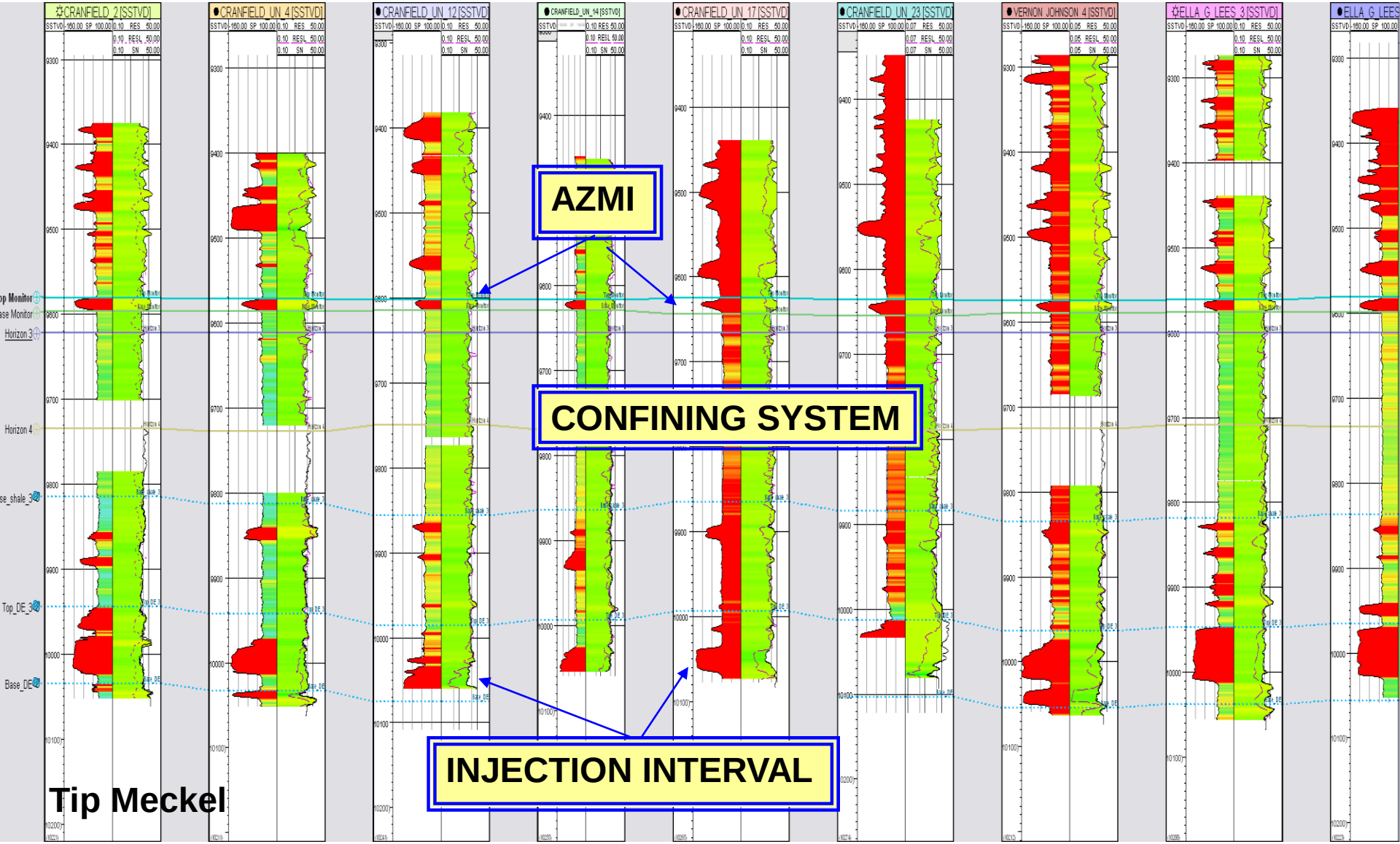
- Assessment of leakage risk.
  - Well performance is highest uncertainty and focus of monitoring research
- Conformance of flood in the injection zone
  - Pressure
  - Plume confined by 4-way closure.
    - Uncertainty – amount of radial flow (down dip/out of pattern)
- Measure changes above the injection zone
  - along well
  - above zone monitoring interval (AZMI)
  - Seismic response
  - at surface over long times



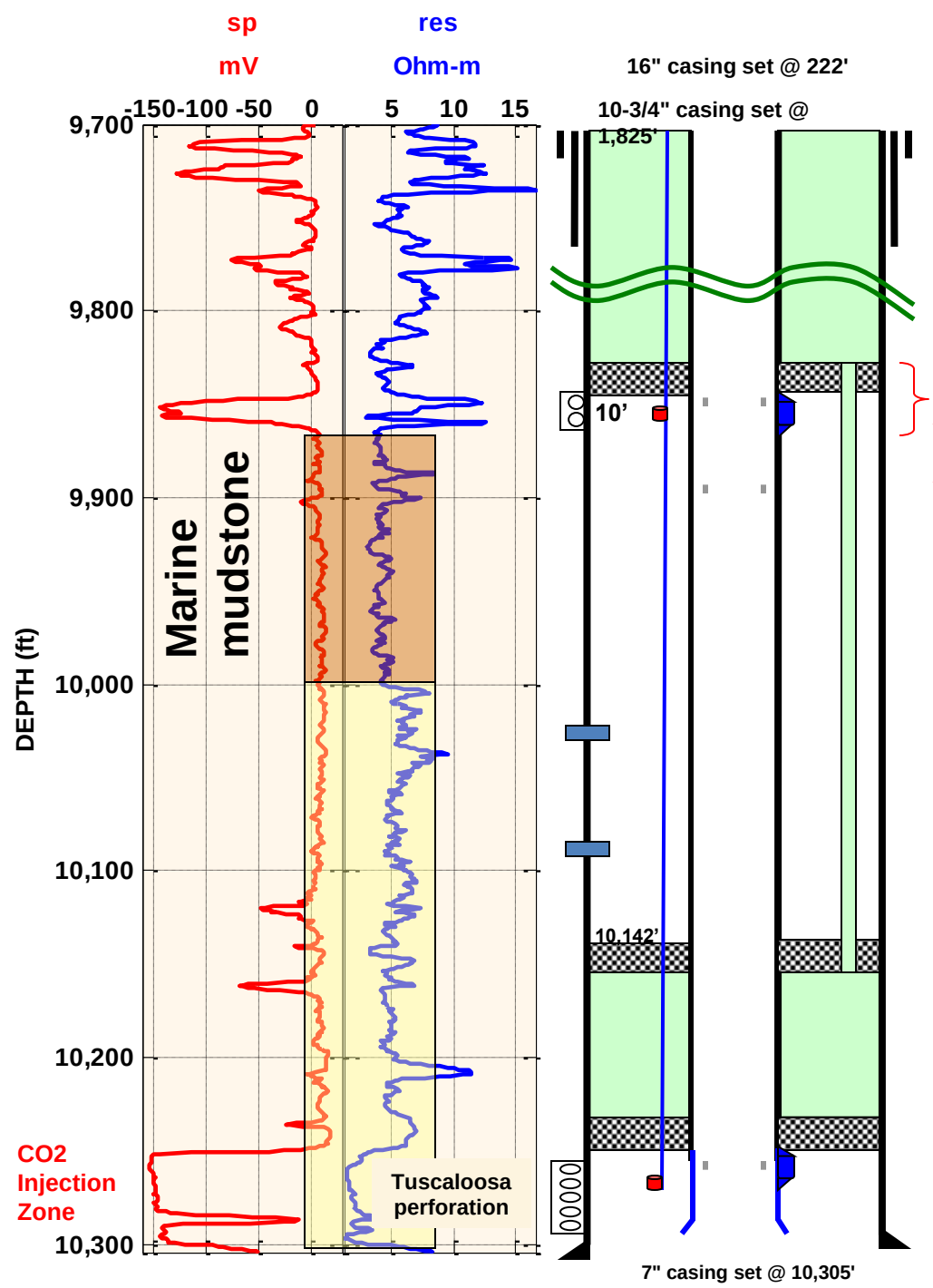
Evaluation of available Cement Bond Logs

Risk Assessment result – greatest leakage risk in unknown well rock-casing annulus bond

In-zone and AZMI pressure monitoring



Tip Meckel



AZMI
Above Zone Monitoring Interval

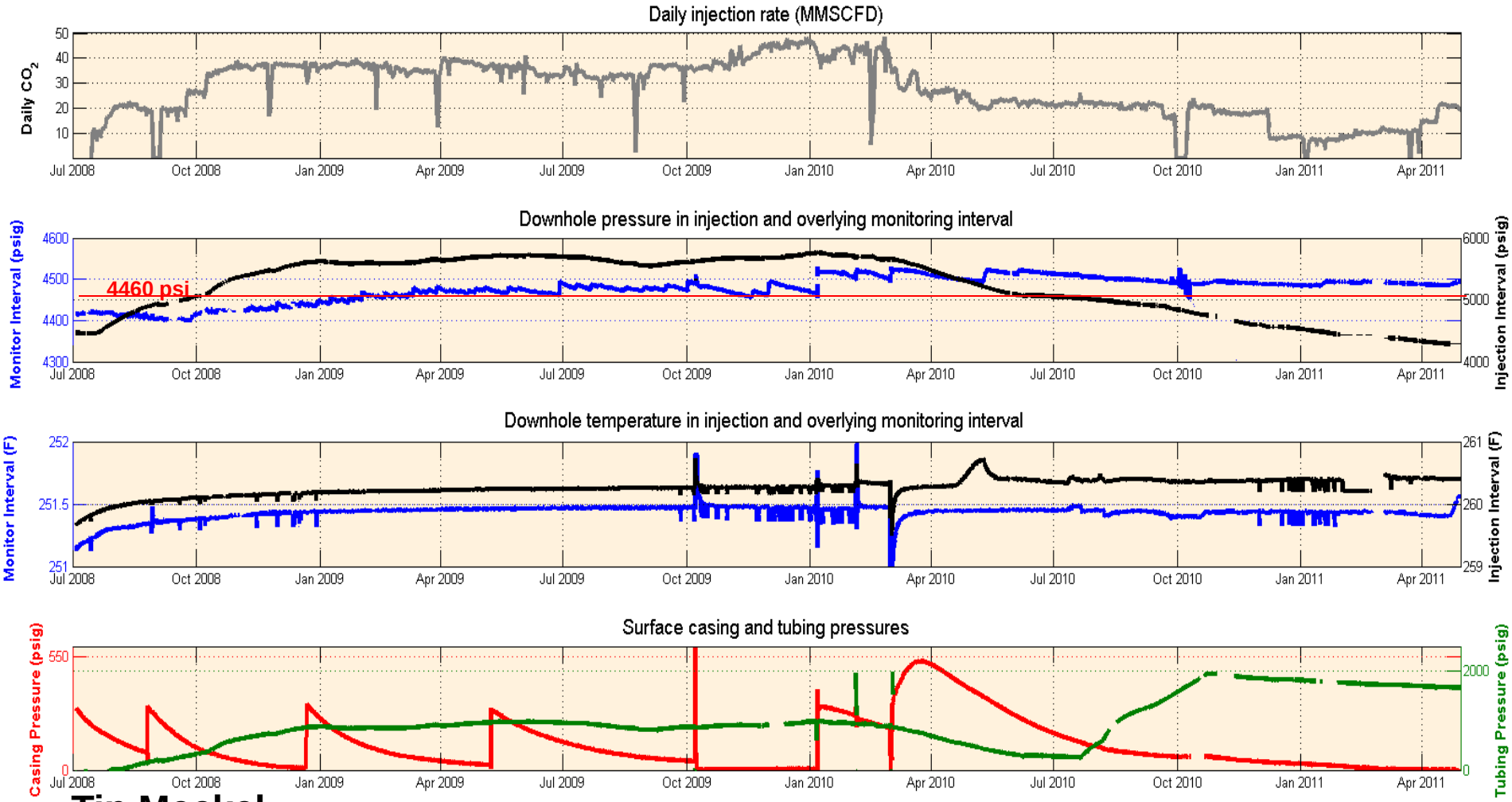
New analysis: Leakage not occurring along this well – integrated pressure-thermal analysis - Qing Tao UT PGE

Injection Zone

Tip Meckel

Continuous data series 3 years

Maximum sustained pressure differential ~1,200 psi / 80 bar / 8 MPa

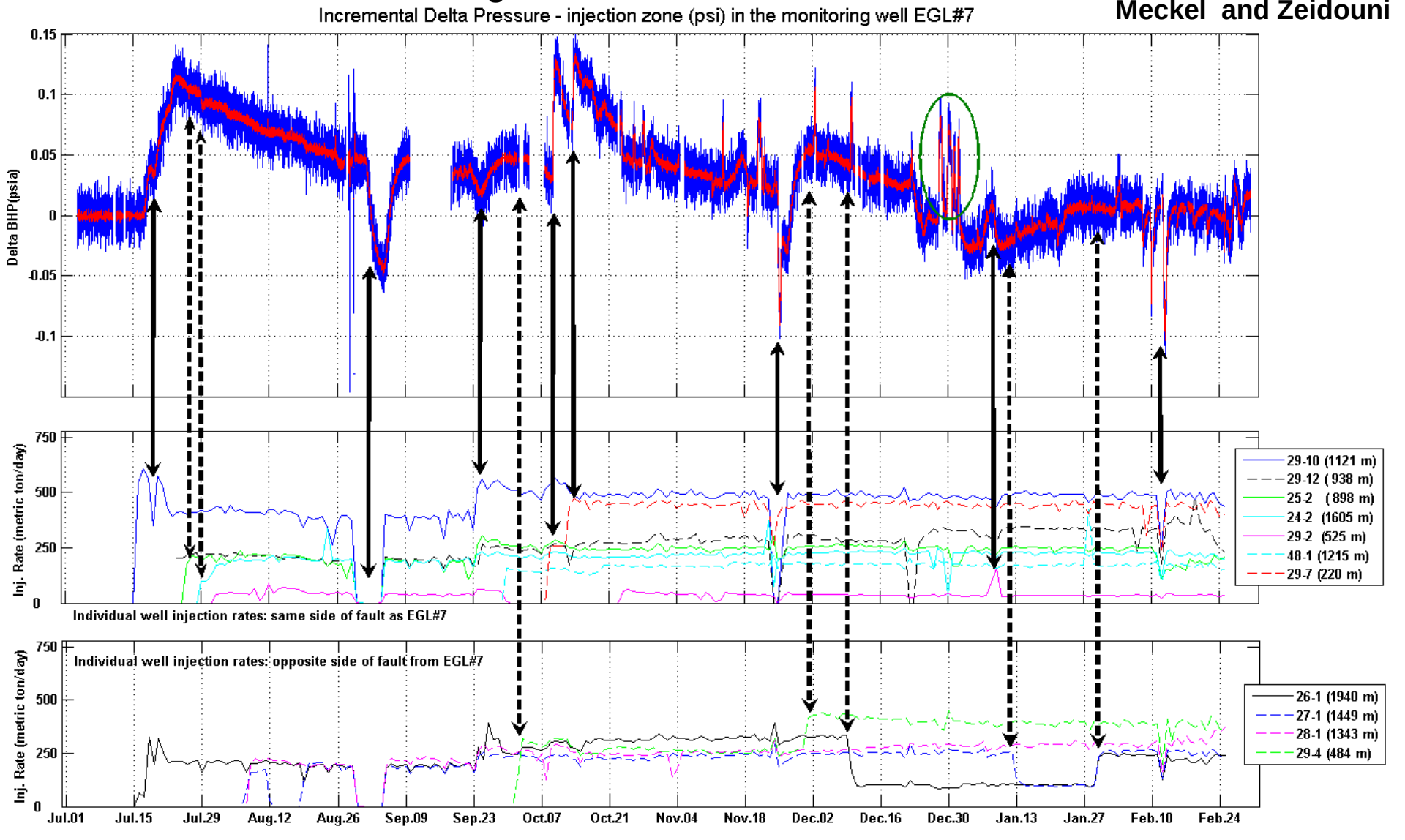


Tip Meckel

In Zone Continuous pressure data from dedicated monitoring well

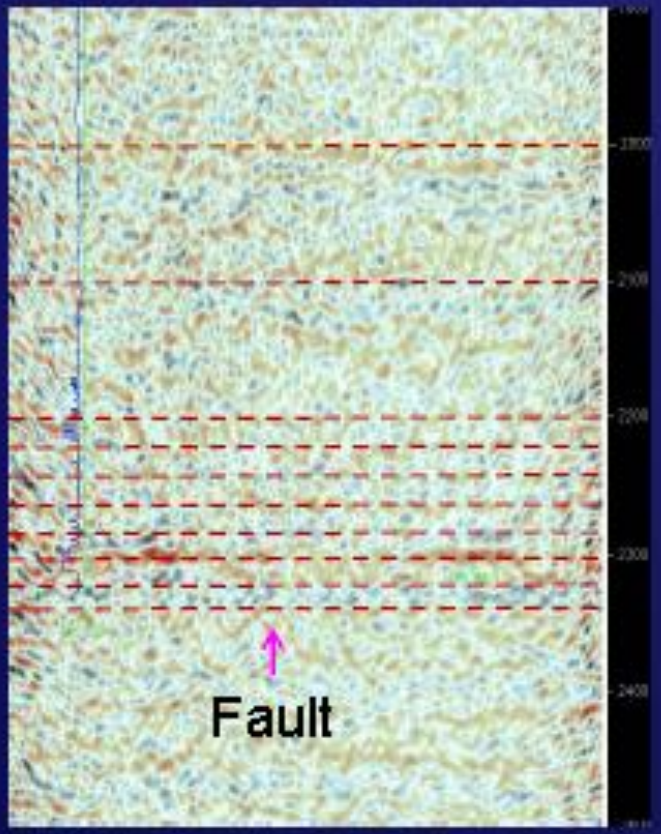
- Large perturbations obvious
- Even small perturbations observable (100's tons/day flux from 1 km)
- Fault observed to be sealing

Meckel and Zeidouni

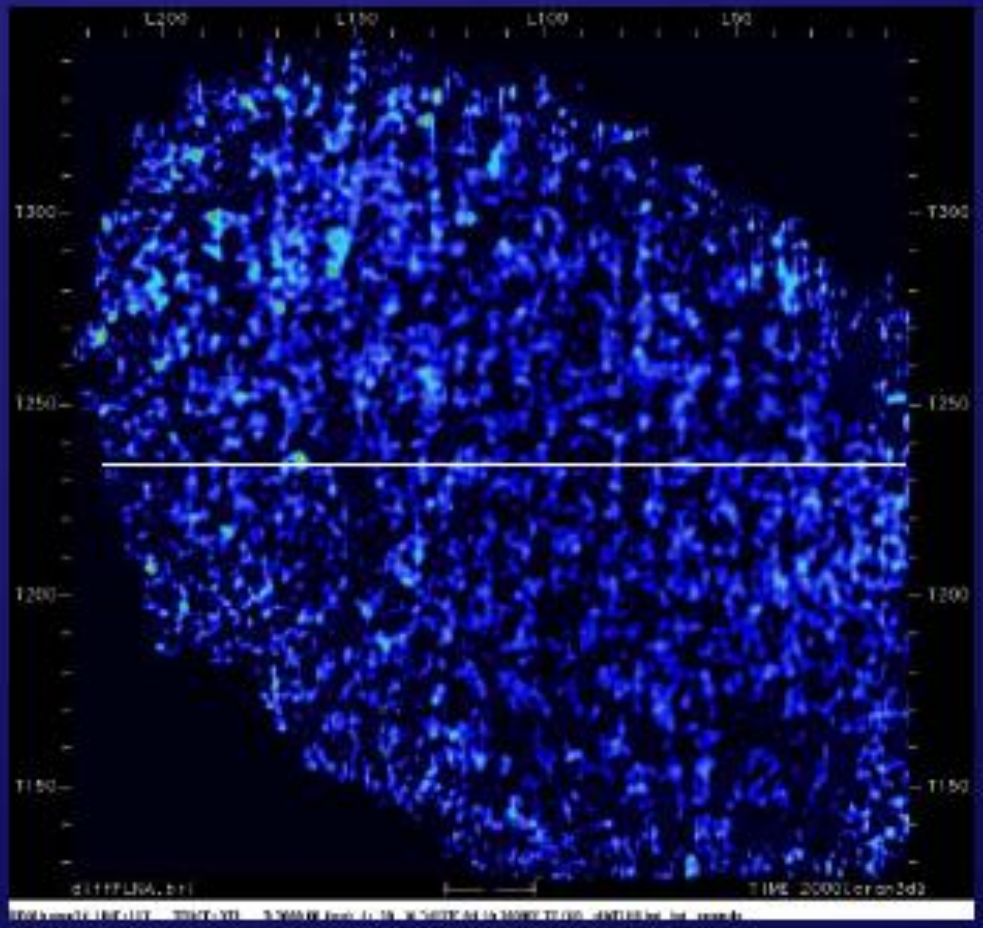


Stratal slices: there is no sign of leaking!

Velocity difference above zone



Cross-section flattened
Velocity difference



Initial result: Hongliu Zeng

Assessment of near surface Monitoring techniques “P Site”

Pit
Pad
Plants
1944 well

Pipe right-of-way

1950’s pit

Trans 4
Trans 1
Trans 2
Trans 3

4-02
1-BG
1-02
1-01
AW
1-00
1-03
1-04
3-01
1-05
3-02
4-01
2-01
2-02

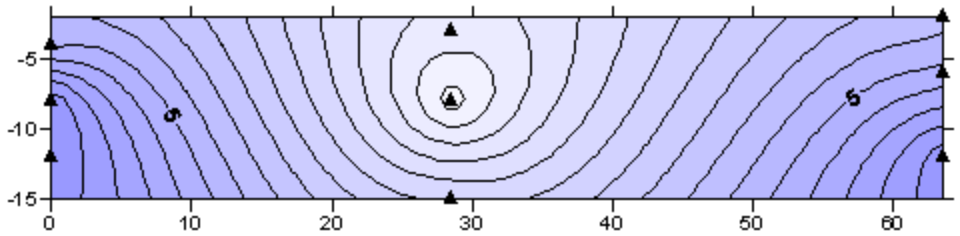
See poster by K. Romanak

Bureau of Economic Geology

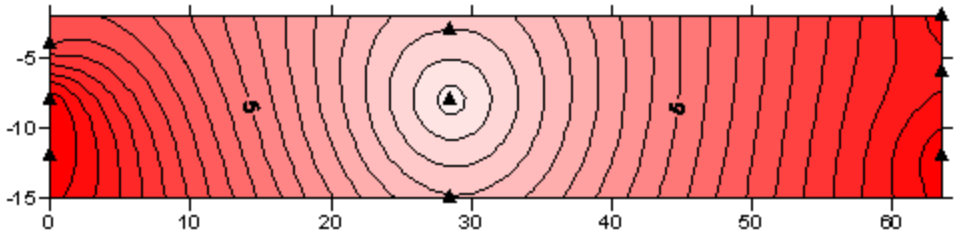
Gulf Coast Carbon Center

Preliminary Soil Gas Results – minor methane leakage at P site wellbore

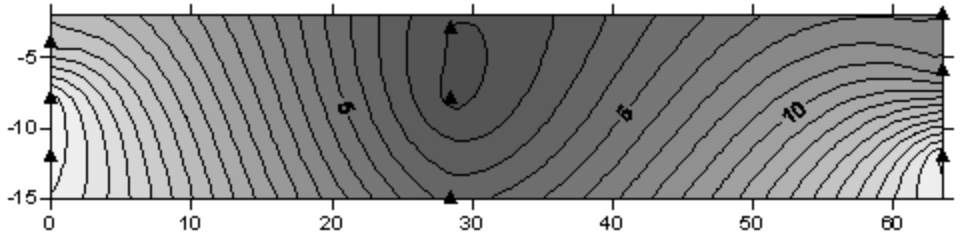
CO_2 (vol %)



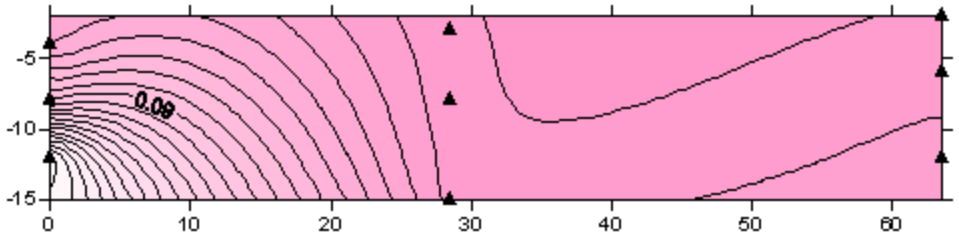
CH_4 (vol %)



O_2 (vol %)



Pressure (inches H_2O)



Gulf Coast Carbon Center

RCSP program goal:
Predict storage capacities within +/- 30%

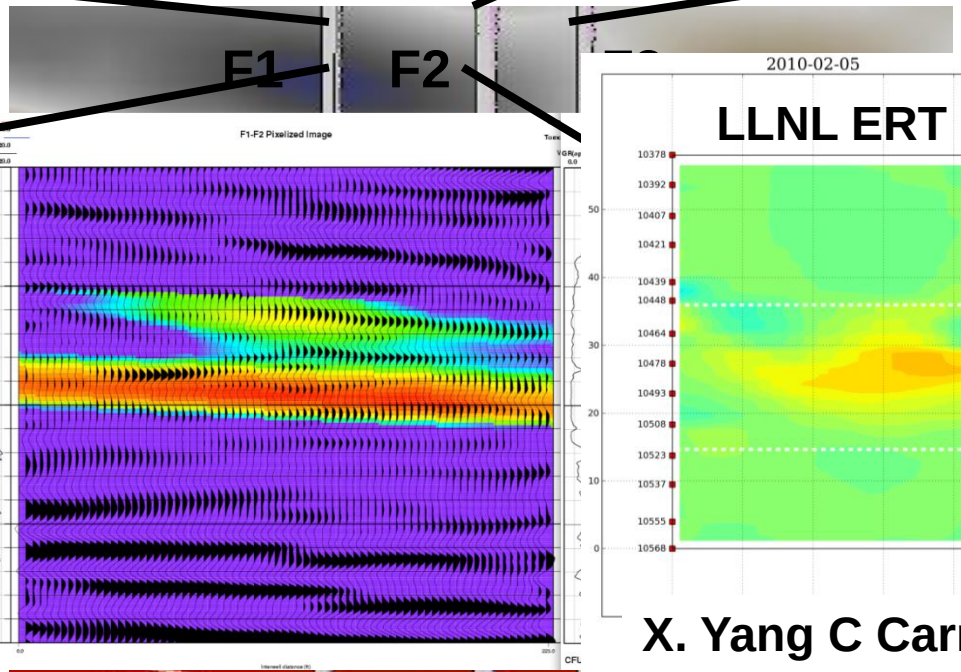
- Capacity and injectivity well known at project start.
  - Open boundary conditions predicted during characterization are demonstrated by good model match.
  - CO_2 moved radially from injectors at the scale of the test (density contrast did not dominate)
- Advance understanding of efficiency of pore-volume occupancy (E factor)
  - Measure saturation during multiphase plume evolution Increase predictive capabilities (underway through modeling)
  - The plume continued to thicken over time, increasing capacity

DAS Monitoring

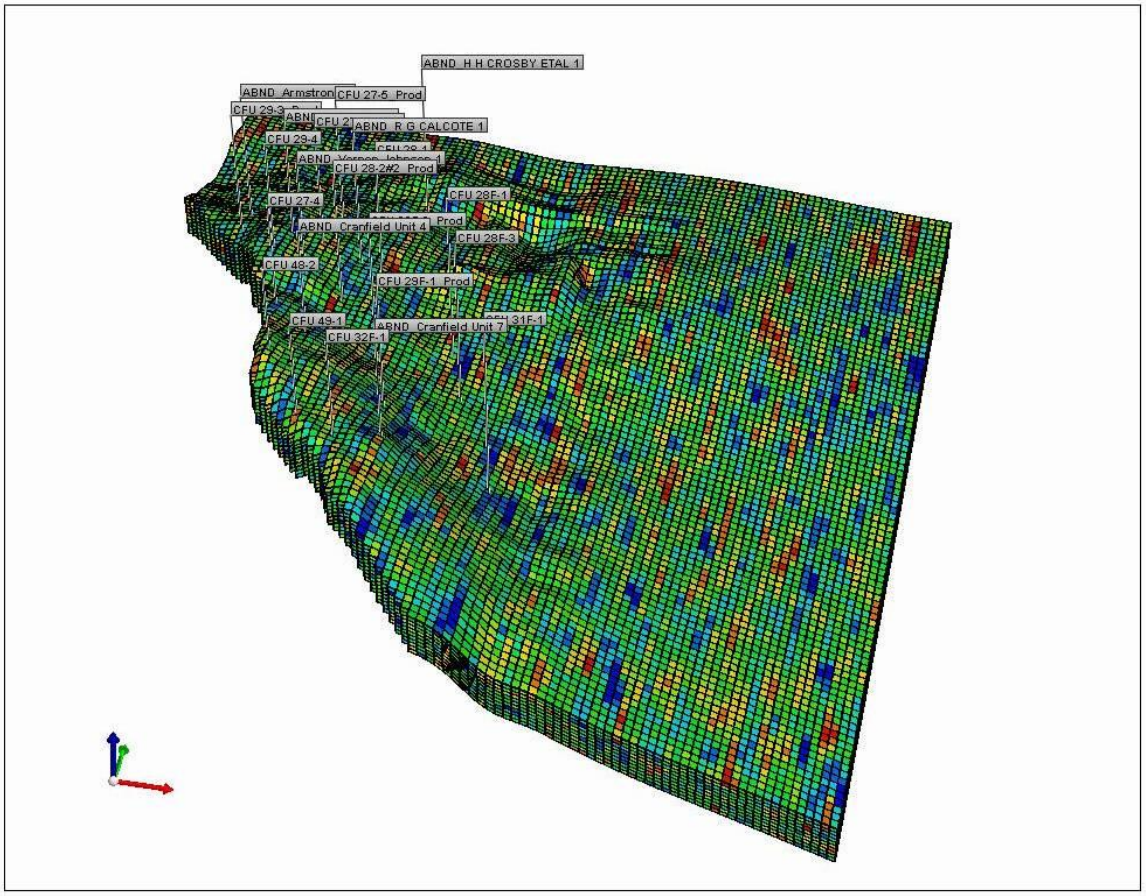
Closely spaced well array to examine flow in complex reservoir

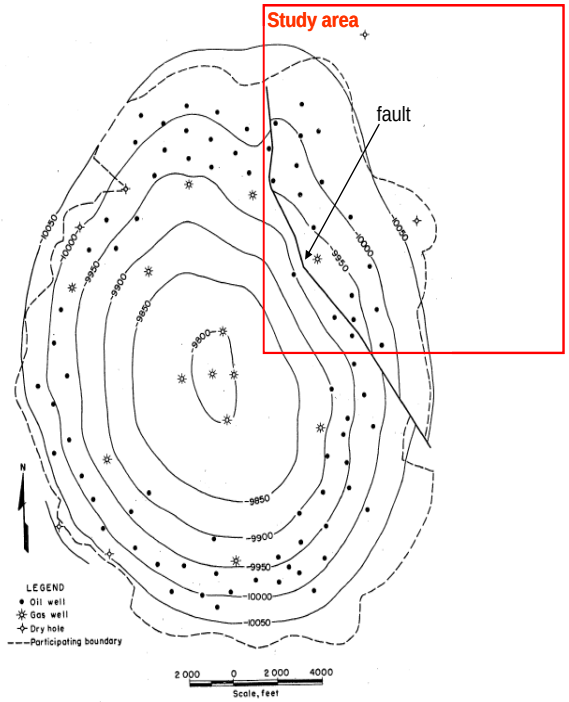
Tuscaloosa D-E reservoir

Petrel model Tip Meckel



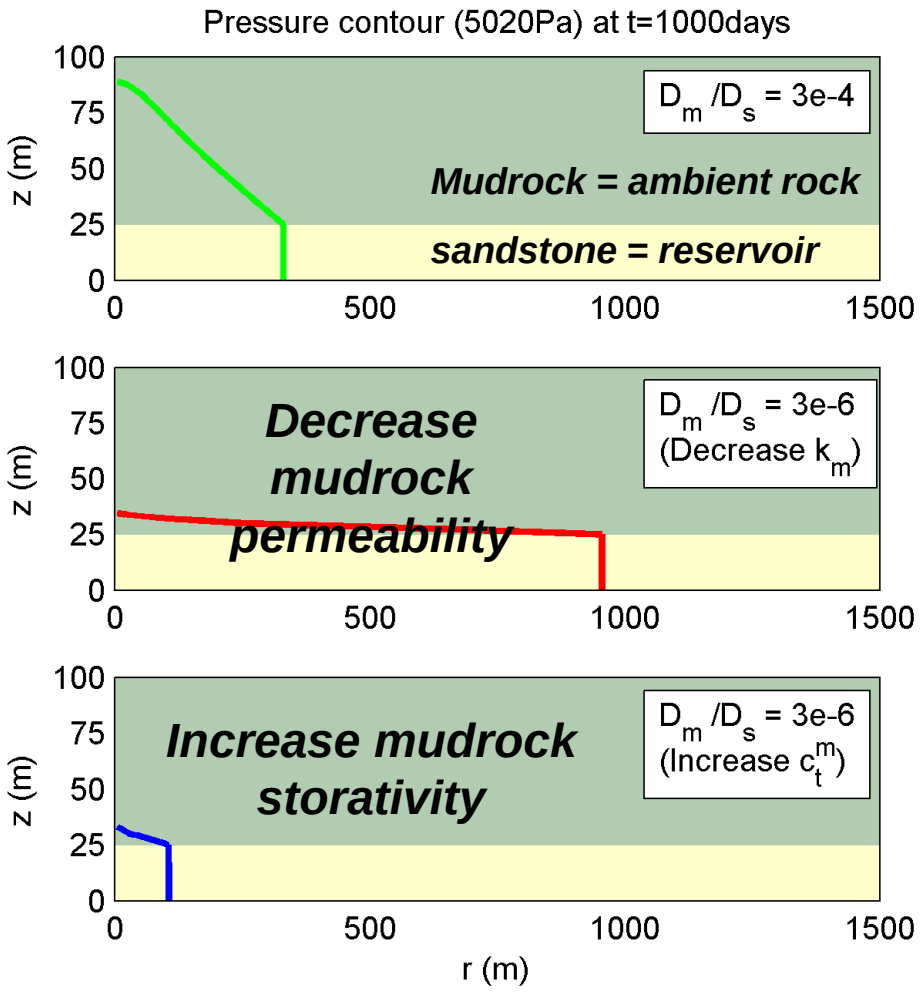
DAS Simulation



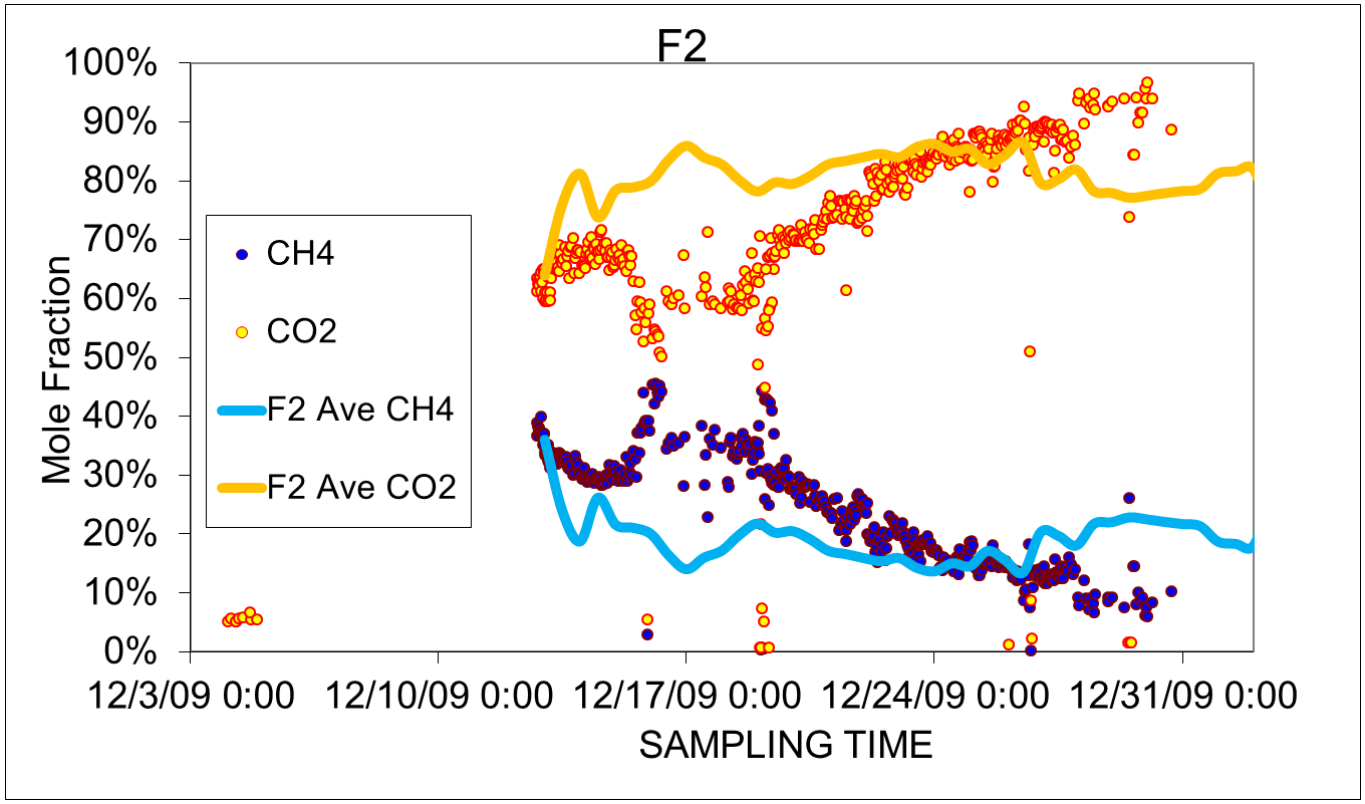


Role of the mudrock during CO_2 injection

- Pressure propagation is governed by ratios of mudrock/sandstone permeability and storativity
- Permeable and compressible surrounding rock reduces pressure propagation within a reservoir

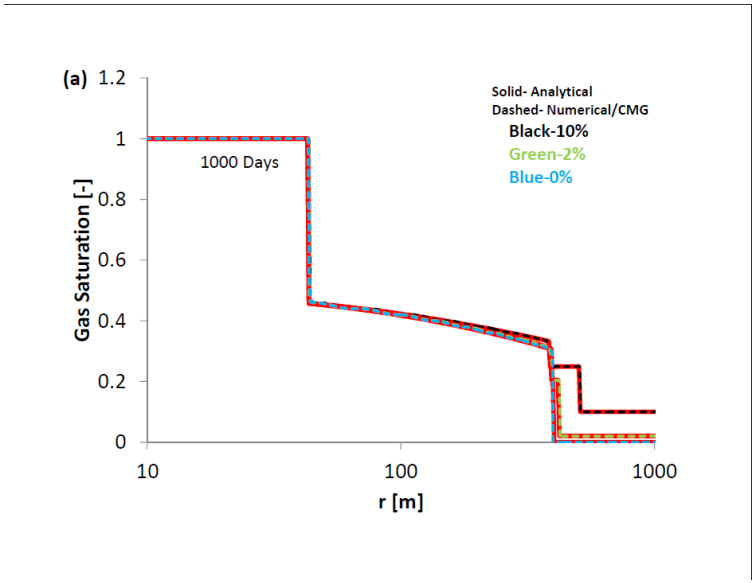


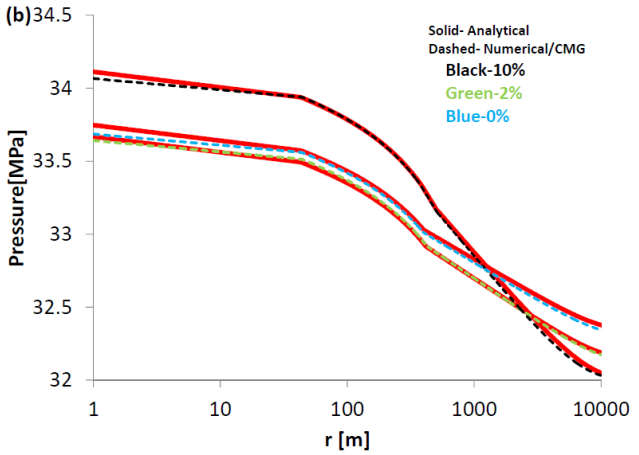
Residual methane effect on AOR and plume size



, U-tube-team; Seyyed Hosseini,

Sensitivity to initial residual gas amount





- At **higher** methane residual saturations it can:

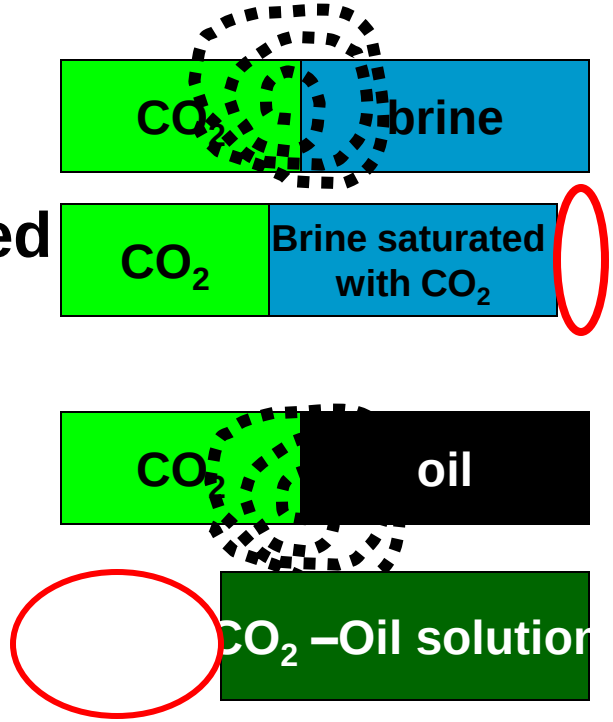
1. Reduce the injectivity
2. Reduce the far-field pressure
3. Increase the plume size by 30%

Simon Matthias, Univ. Durham; Seyyed Hosseini, BEG

Role of Dissolution in Plume and Pressure Evolution CCS/CCUS

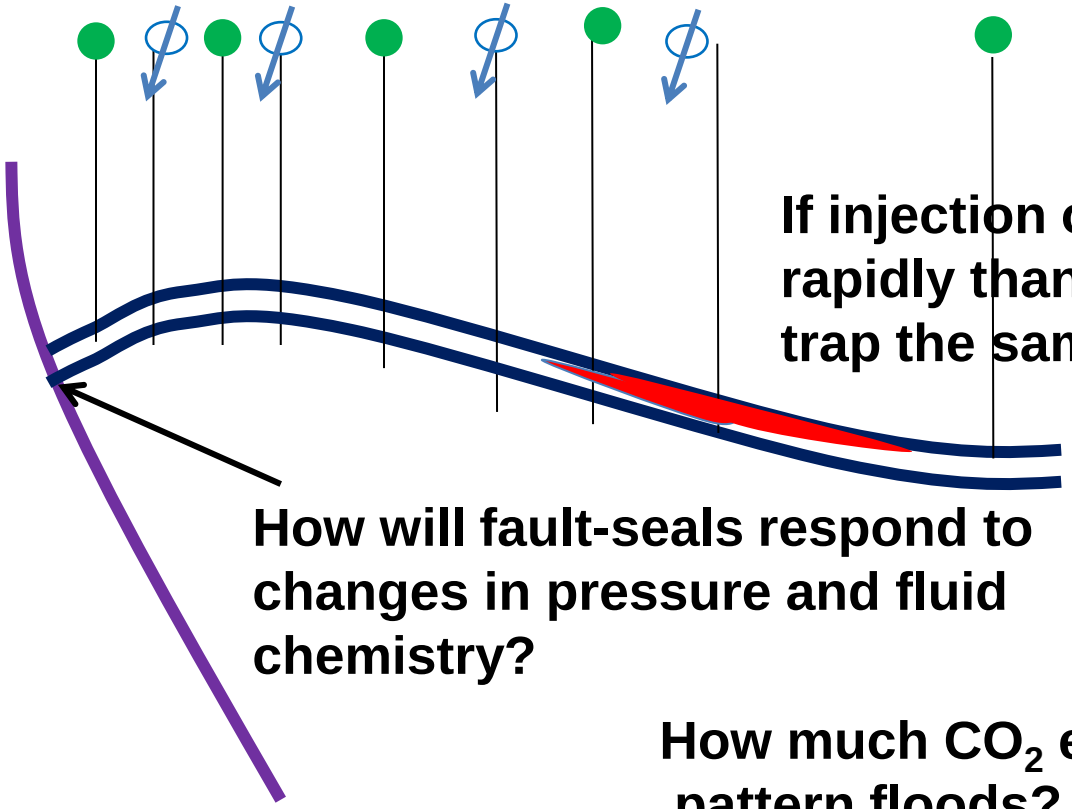
CO_2 injected into brine:
Minor dissolution: volume displaced
4% less than volume injected

CO_2 injected into oil:
Complete dissolution:
volume displaced
as much as 40% less than
volume injected



Less space occupied = enhanced security and lower pressure.

Is it always true that traps and seals that held oil will hold CO_2 ?



If injection occurs much more rapidly than charge, will it fill the trap the same way?

How will fault-seals respond to changes in pressure and fluid chemistry?

How much CO_2 escapes from pattern floods?

Document storage permanence

Storage only saline green field

- Prove-up capacity
- Prove-up confinement

- Simple fluid – low solubility

- Few wells
- Historical uses?
- Evolving regulatory and legal framework
- Unknown public acceptance

CCUS – EOR in brownfield

- Well-known capacity
- Well-demonstrated confinement
- Complex fluids, high solubility
- Many wells
- Complex history
  - Perturbation from past practices
- Mature regulatory and legal framework
- Good public acceptance

Thank You!