Cranfield Large Scale CO_2 Injection-- Monitoring 3.5 Million Tons

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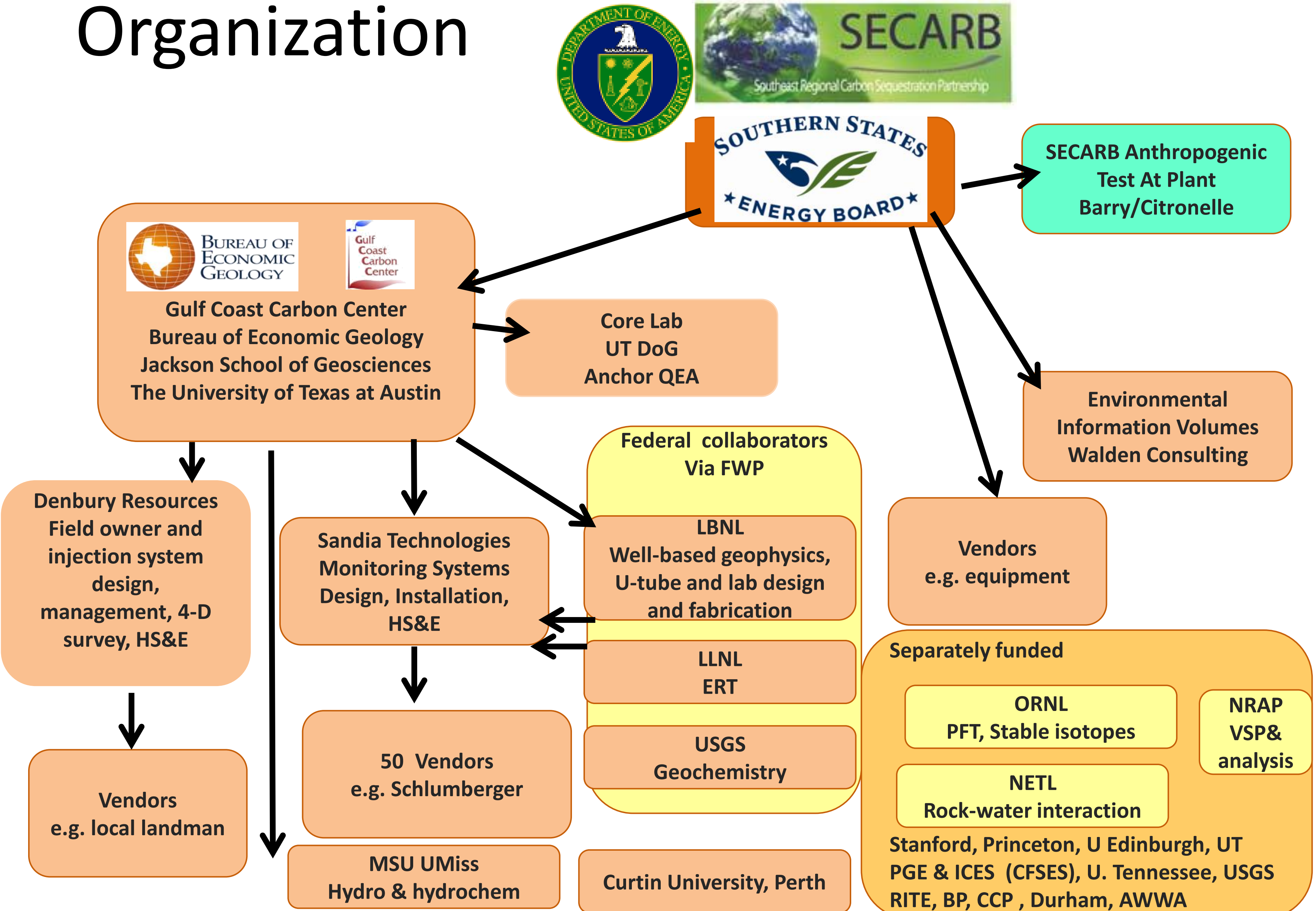
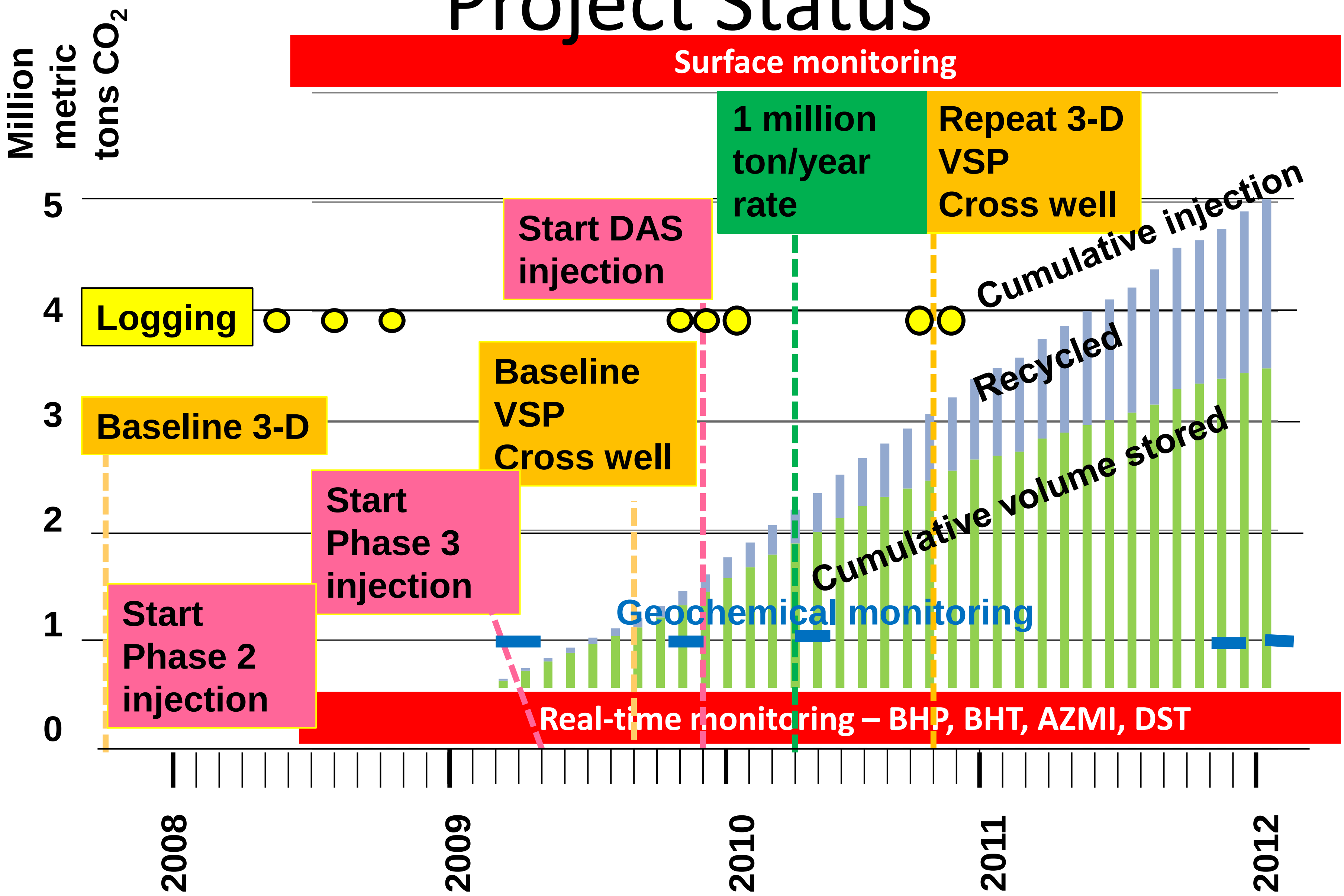
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CCUS : U.S. Department of Energy
National Energy Technology Laboratory
August 23, 2012
Pittsburgh, Pennsylvania

Organization



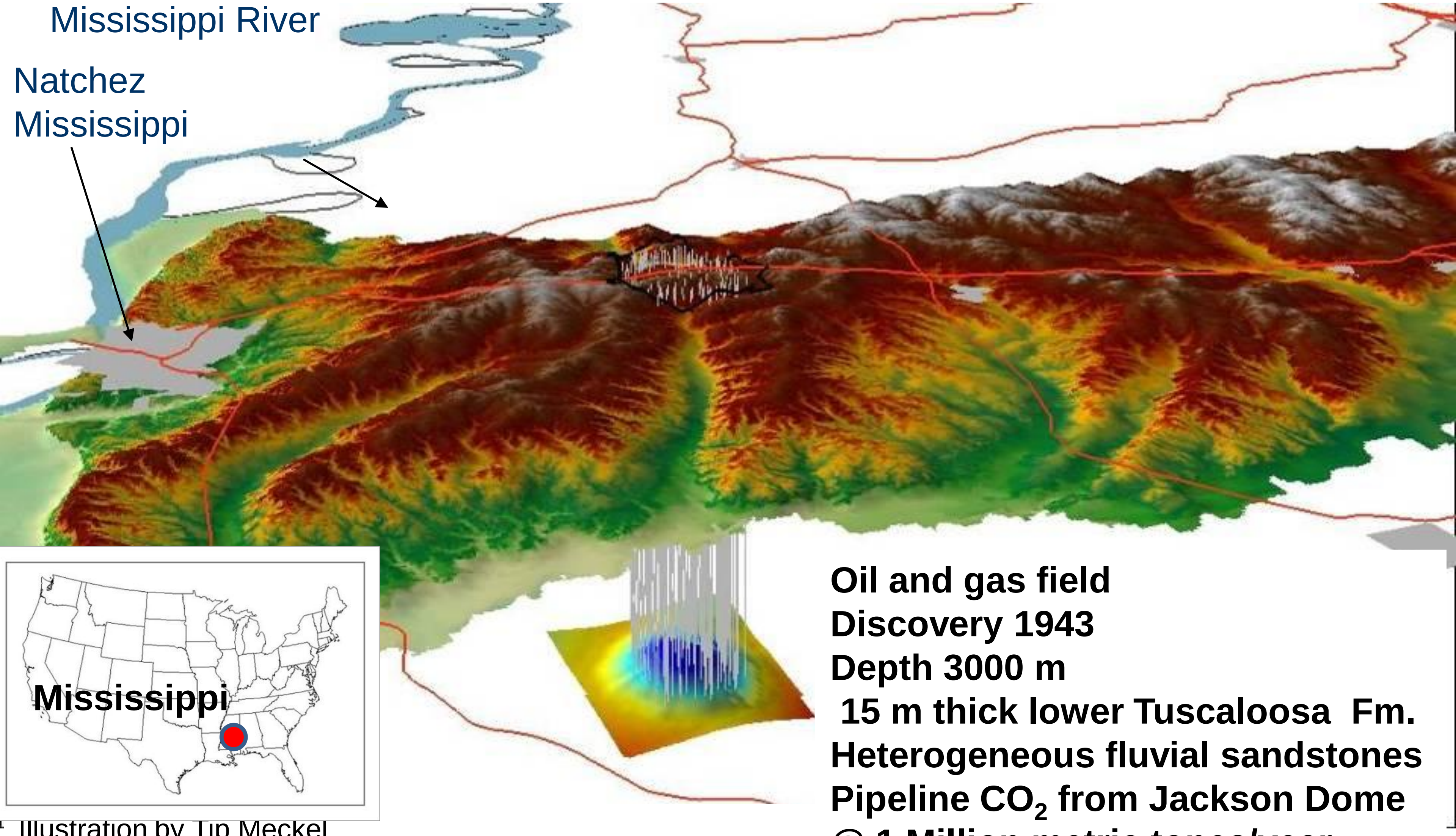
Project Status



Research-based Cranfield Monitoring Plan

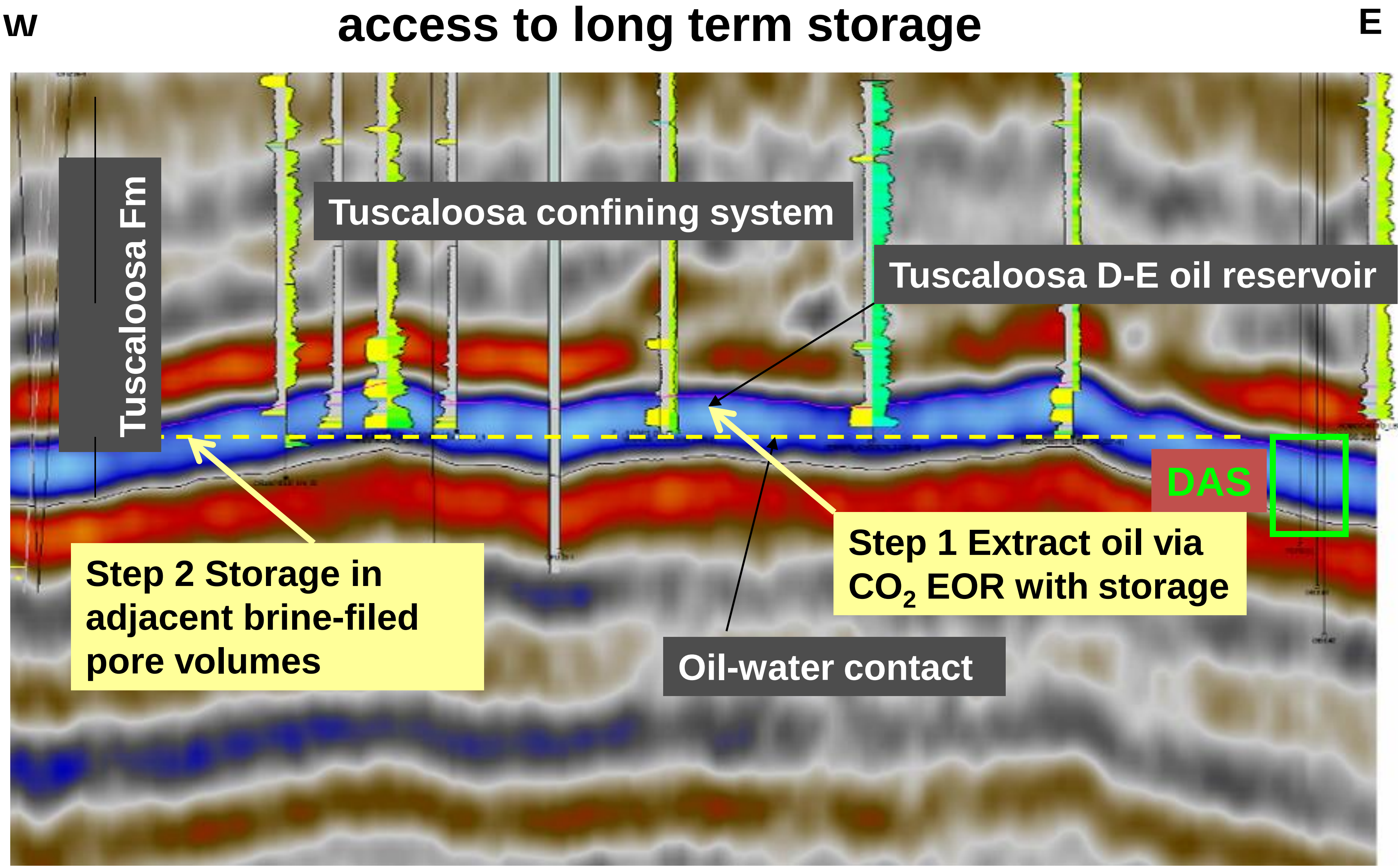
- Research-based: not regulatory- or risk-based
  - Scoped, designed, and budgeted 2006, prior to regulation
  - Operator holds risk
- Designed to respond to DOE programmatic questions
  - Lessons learned are derived products not processes to be duplicated

Cranfield Geologic Setting



Oil and gas field
Discovery 1943
Depth 3000 m
15 m thick lower Tuscaloosa Fm.
Heterogeneous fluvial sandstones
Pipeline CO_2 from Jackson Dome
@ 1 Million metric tones/year

Stacked Storage: Use in early stages (Now!) provides access to long term storage



Seismic line from 3-D survey, Cranfield reservoir, Mississippi interpretation Tip Meckel BEG

Regional Carbon Sequestration Program goal: Improve prediction of storage capacities

Existing data on reservoir volumetrics

Production history
37,590,000 Stock tank barrels oil
672,472,000 MSCU gas
(Chevron, 1966)

7,754 acres x 90 ft net pay x 25.5% porosity
(Chevron, 1966)

X E [pore volume occupancy (storage efficiency)] = Storage capacity

injection rate – limited by pressure response?

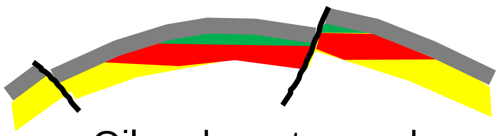
Measure saturation during multiphase plume evolution

Increase predictive capabilities by validating numerical models

Observation: pore volume occupancy was rate and dependent: not a single number

Regional Carbon Sequestration Partnership program goal: **Evaluate protocols** to demonstrate that CO_2 is retained

High confidence in storage permanence through characterization



Oil and gas trapped over geologic time

Material Risk of failing to retain

Uncertainty and risk assessment → Semi-quantitative assessment via Certification Framework

Research Questions

- P&A well performance in retention?
- Limited analogy between injected and natural fluid retention
- Off structure migration?
- Response to pressure elevation?

Selected assessment approach

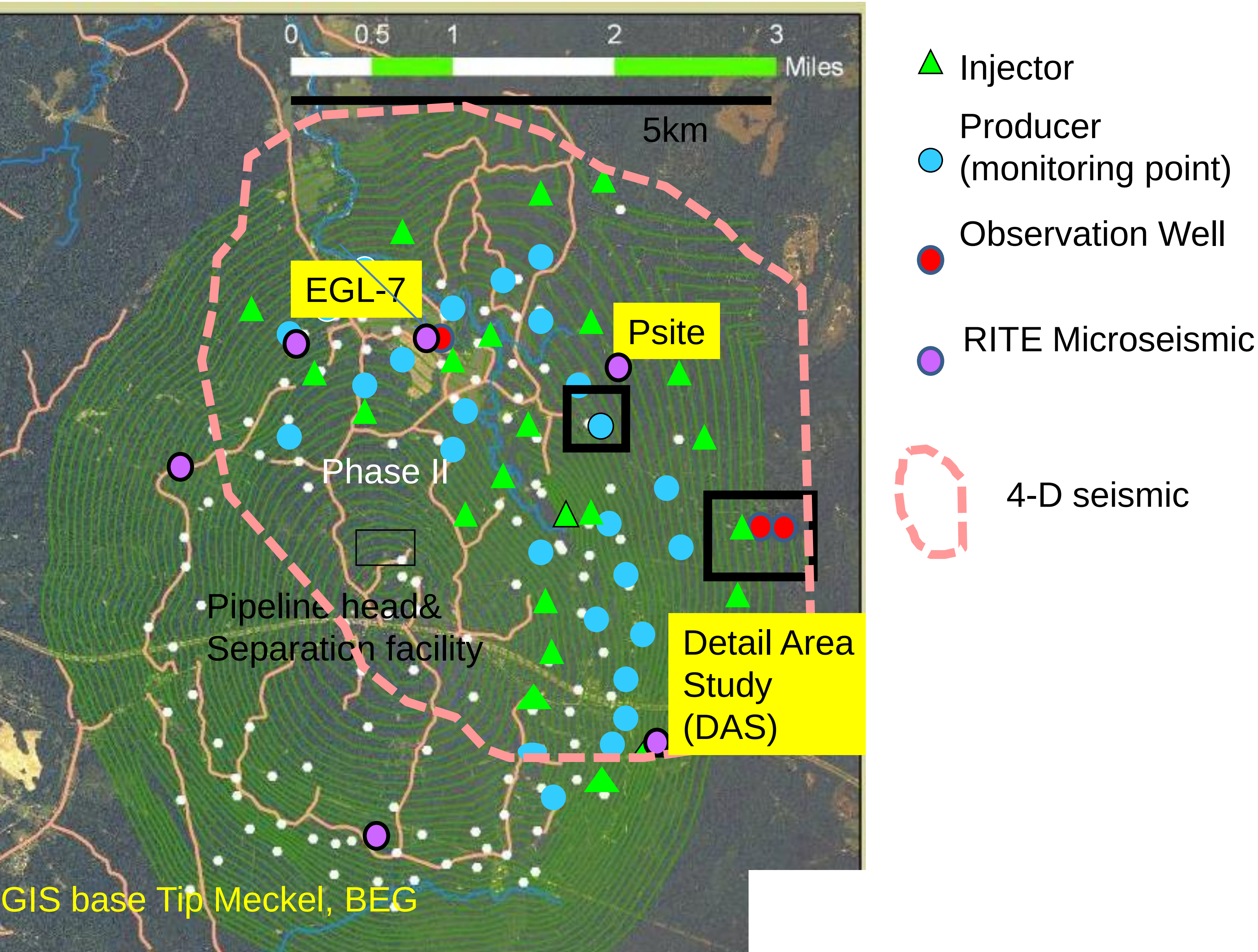
shallow

- Well-pad vadose gas
- Ground water chem.
- AZMI pressure
- 4-D Seismic
- 4-D VSP
- IZ pressure
- Microseismic

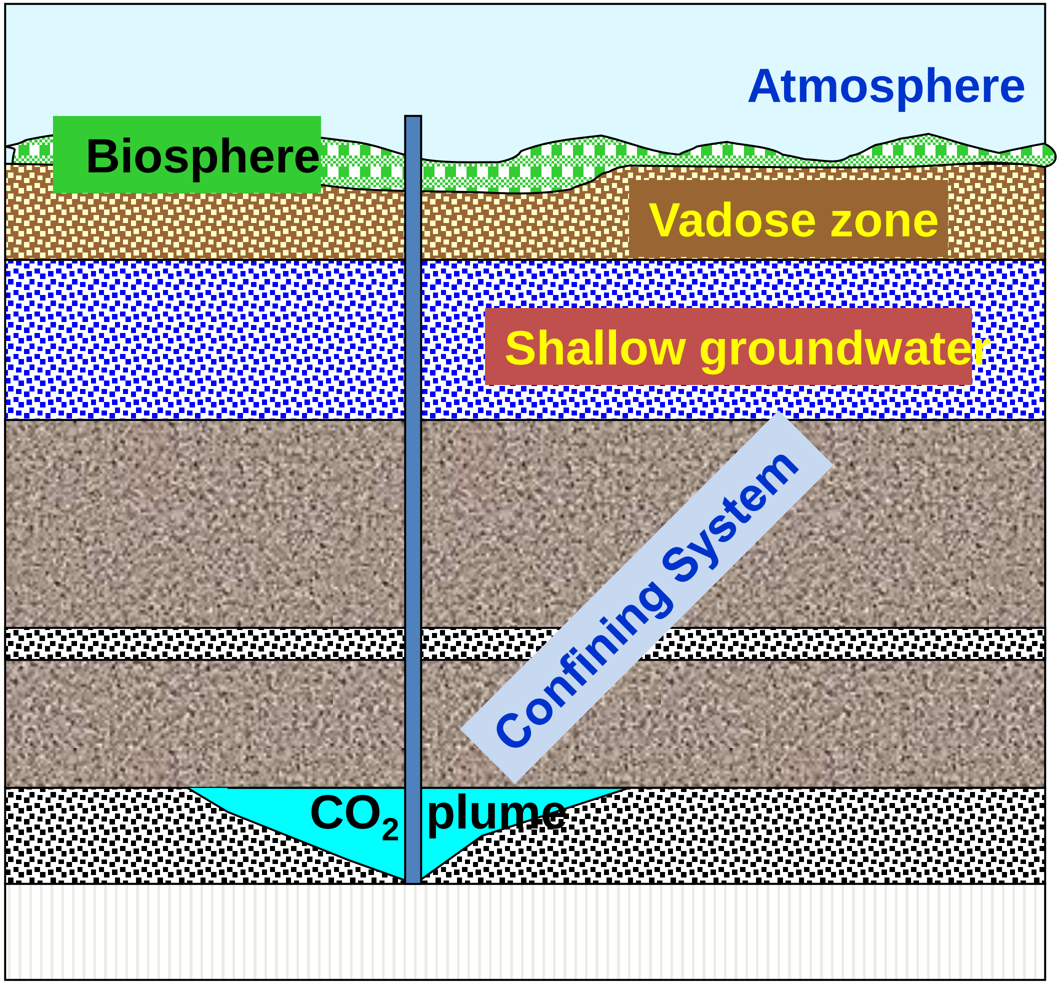
deep

Protocol Sensitivity & reliability

Monitoring layout



Monitoring Innovations

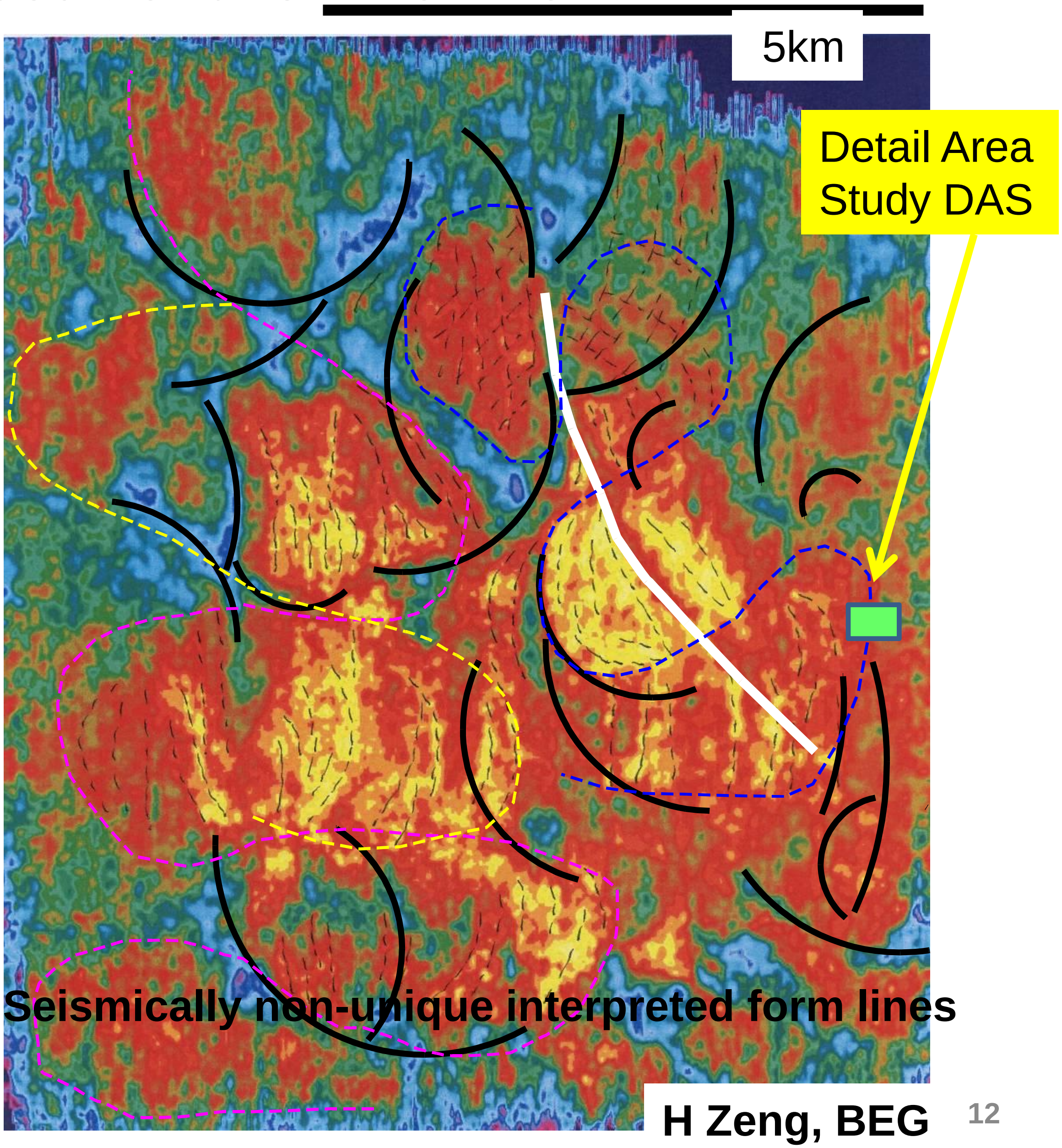


- Process-based vadose zone-gas method
- *In situ* rock-water-CO_2 interaction test.
- Contaminated site approaches
- Pressure in above-zone monitoring interval
- Stacked storage demonstration
- Cross-well ERT at depth
- Bore hole gravity
- Methane exsolution
- RITE microseismic

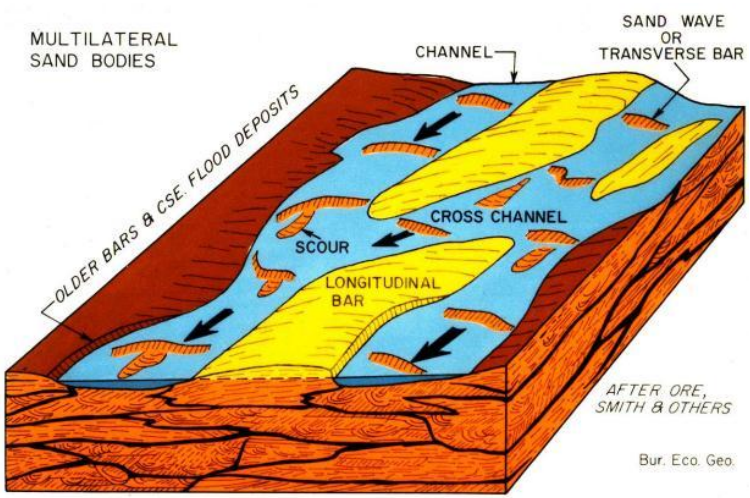
Monitoring Design

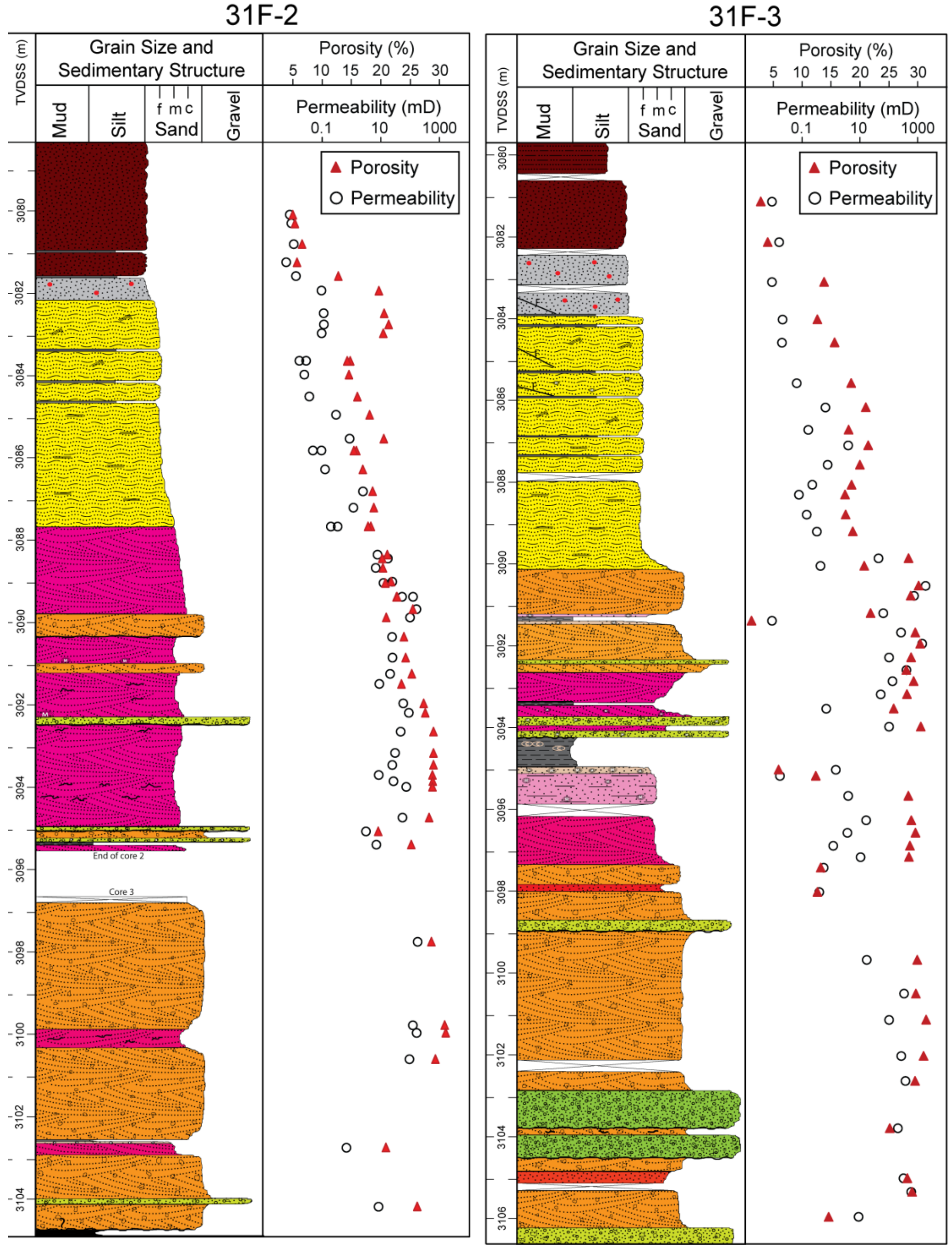
Area tested	Whole plume	Focus study
Atmosphere	Not tested	Not tested
Soil gas	Active and P&A well pads	"P site" methodology assessment
Groundwater	Monitoring well at each injector	EGL-7 UM test well, Push-pull test
Shallow production	Not tested	Not tested
AZMI	Not tested	DAS pressure and EGL 7 pressure + fluids
Geo-mechanics	RITE micro seismic study	GMT(failed)
Injection zone	Geochemistry breakthrough	DAS multi-well multi tool array

Lower Tuscaloosa sand and conglomerate fluvial depositional environment



Fluvial Facies concept



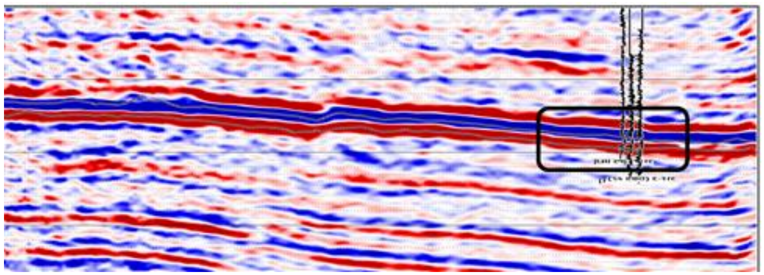


30-m apart

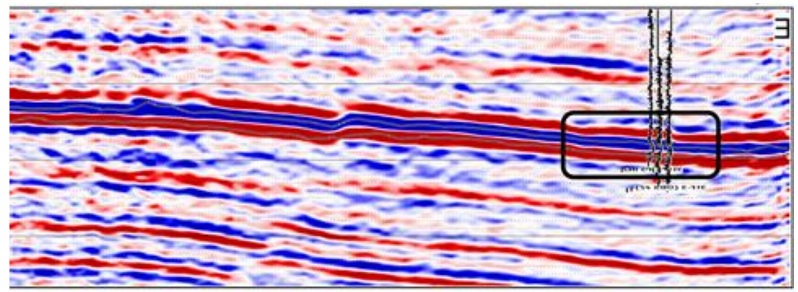
M. Kordi , BEG

Time lapse seismic analysis

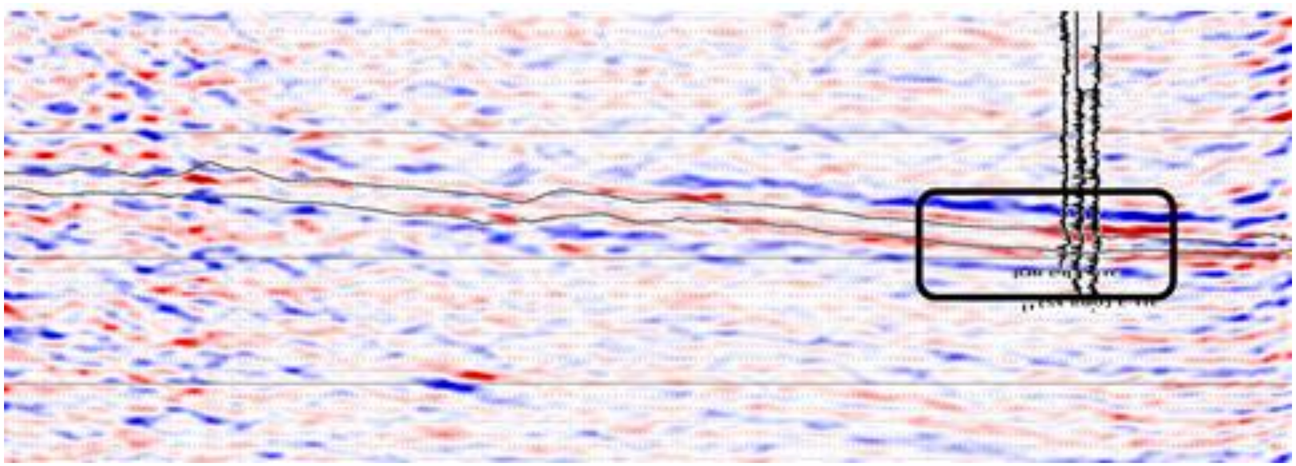
2007 Pre-injection **DAS**



2010 1 year of injection about 1/4 million metric tons this area **DAS**



Difference **DAS**



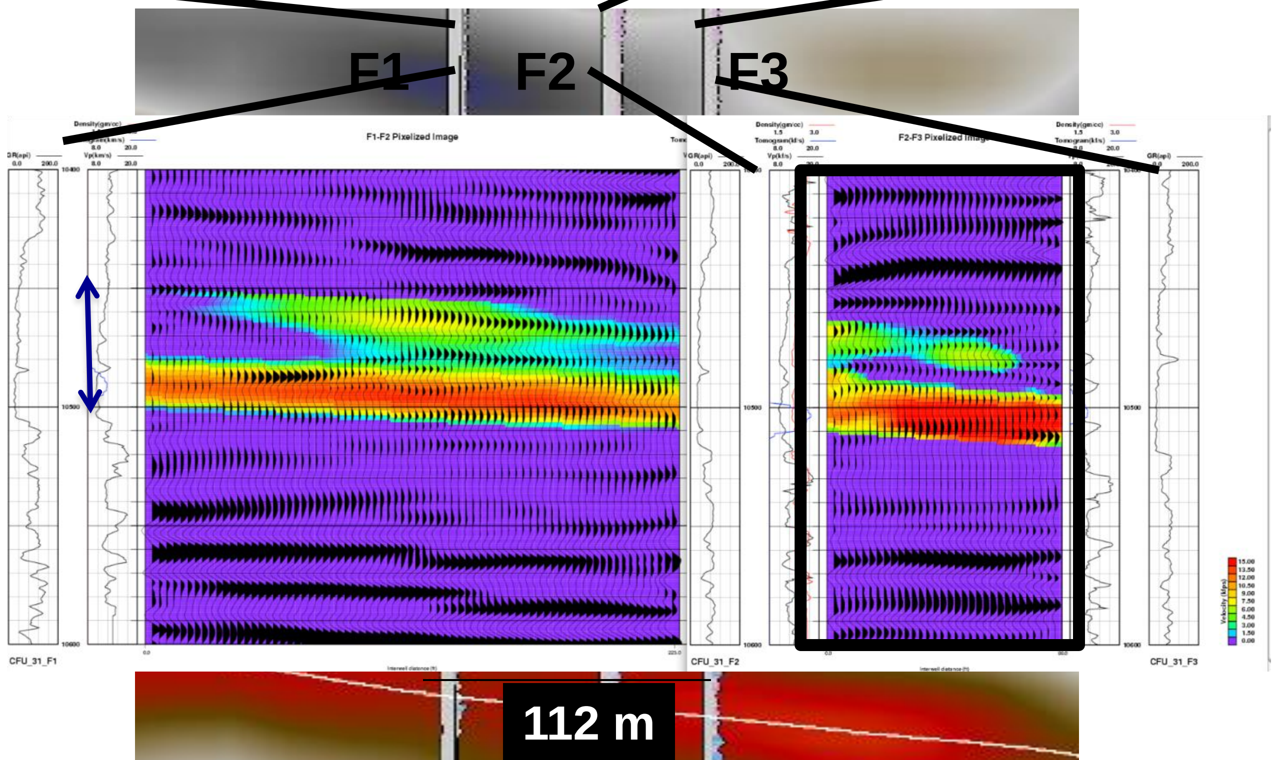
Rui Zhang, CFSES & UTIG

Detailed Area Study (DAS)

Closely spaced well array to examine flow in complex reservoir

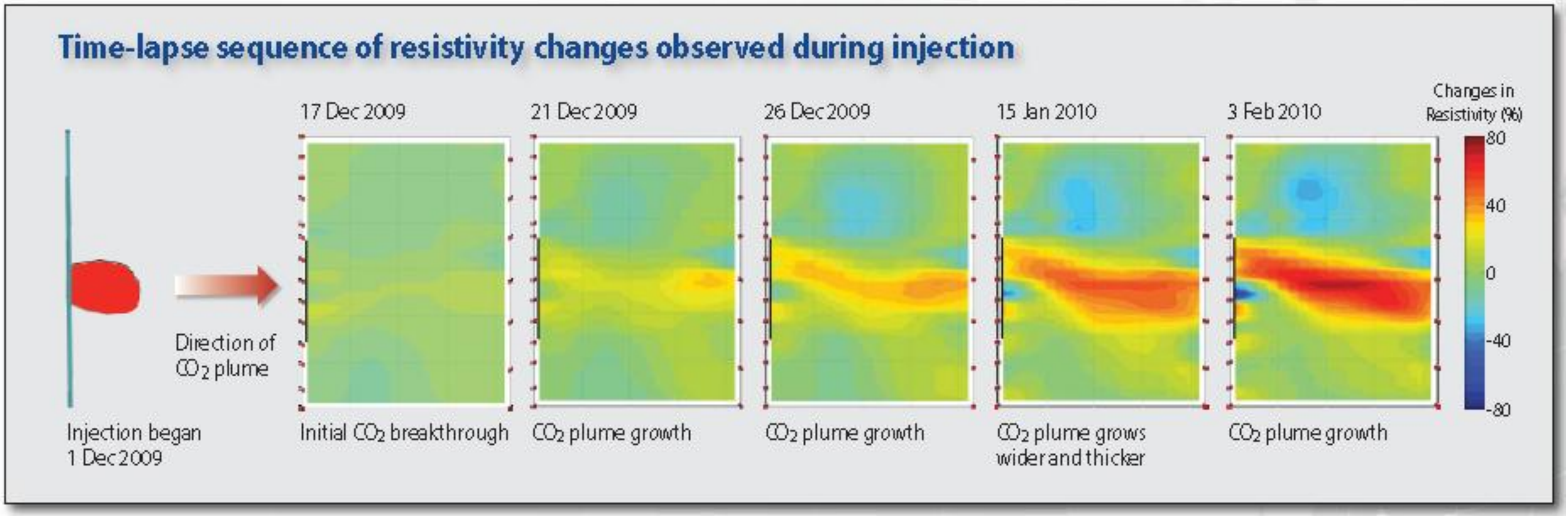
Tuscaloosa D-E reservoir

Petrel model Tip Meckel



LLNL Electrical Resistance Tomography- changes in response with saturation

F1 F2 F3



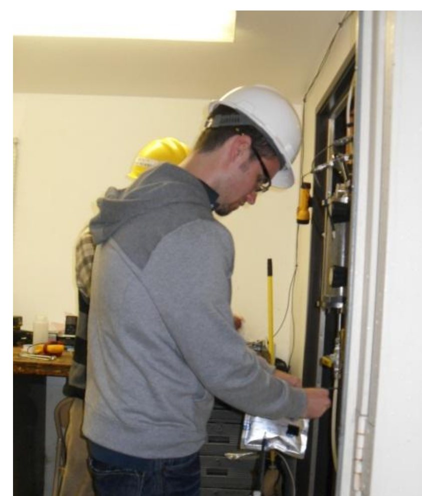
Lawrence Livermore National Laboratory

C. Carrigan, X Yang, LLNL
D. LaBrecque Multi-Phase Technologies

Fluid sampling via U-tube yields data on flow processes

- Small diameter sampler with N_2 drive brings fluids quickly and high frequency to surface with tracers intact
- High labor effort
- Unique data on fluid flow

Adding tracer



BUREAU OF ECONOMIC GEOLOGY

USGS science for a changing world

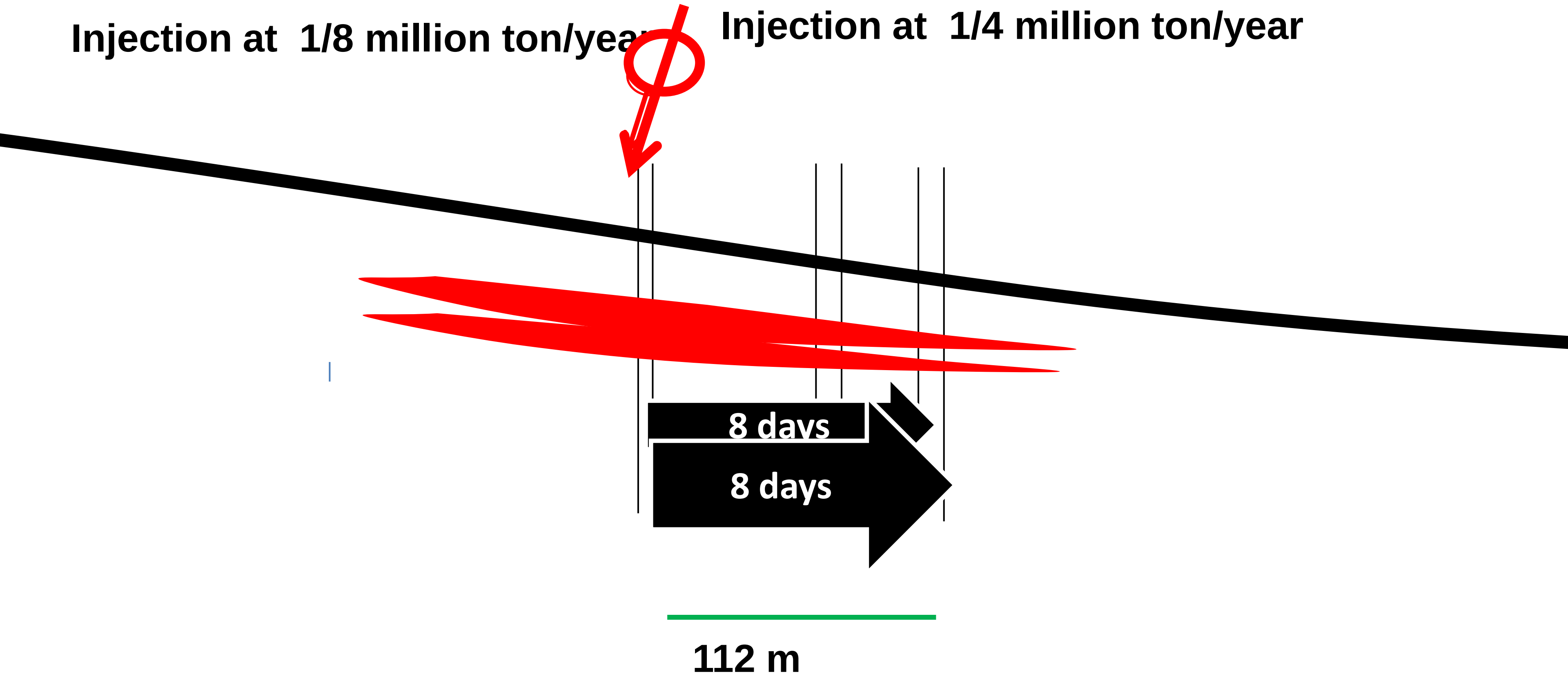
BERKELEY LAB

OAK RIDGE NATIONAL LABORATORY
Managed by UT-Battelle for the Department of Energy

UTDoG,

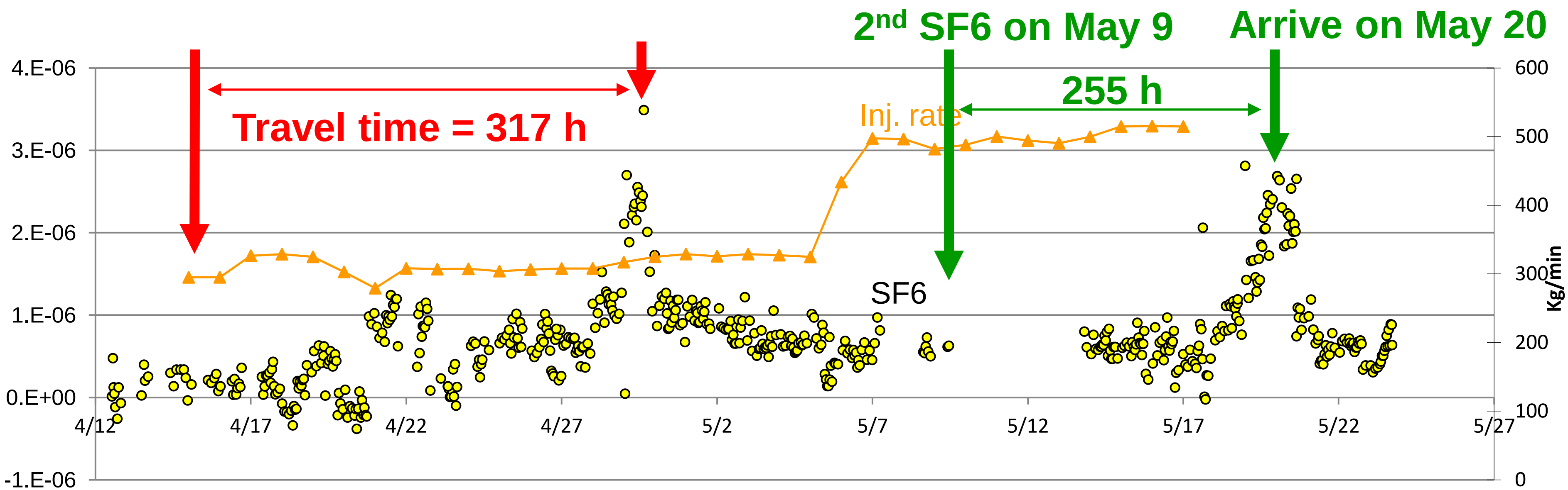
Gulf Coast Carbon Center

As injection rate increased, plume thickness increased

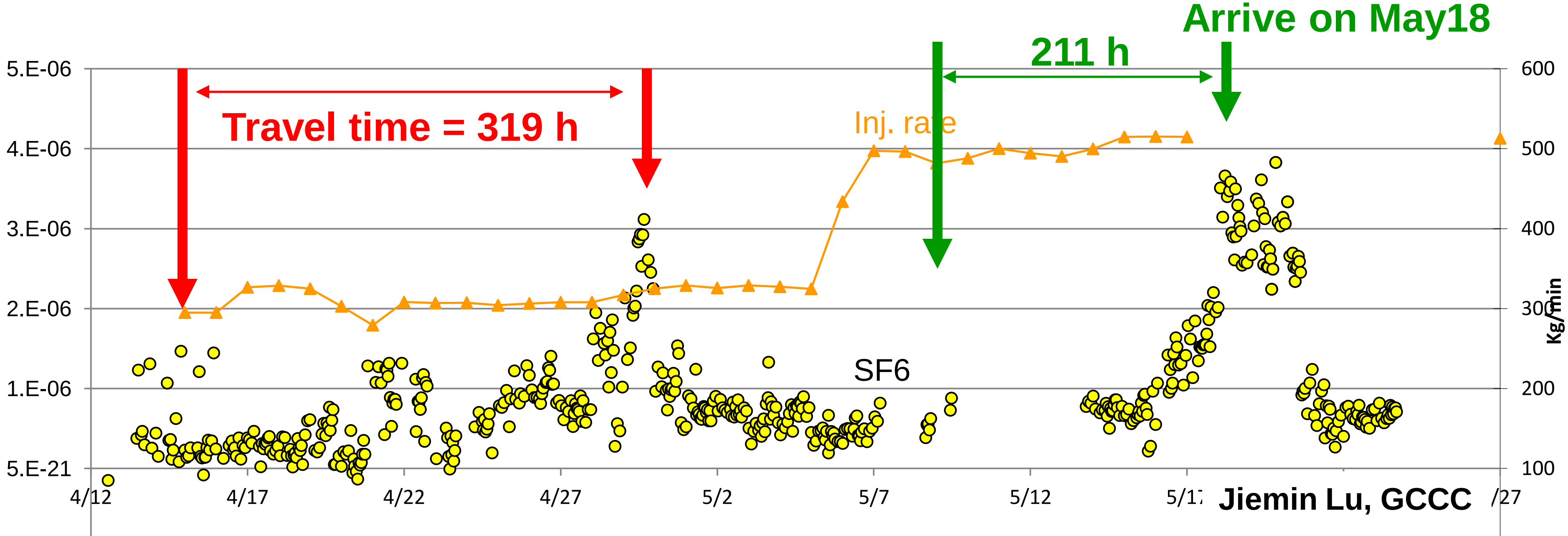


March-April 2010 tracer studies:
Jiemin Lu, Changbing Yang, GCCC
Tommy Phelps ORNL

CFU31F-2, 68 m away from injector SF6



CFU31F-3, 112 m away from injector SF6

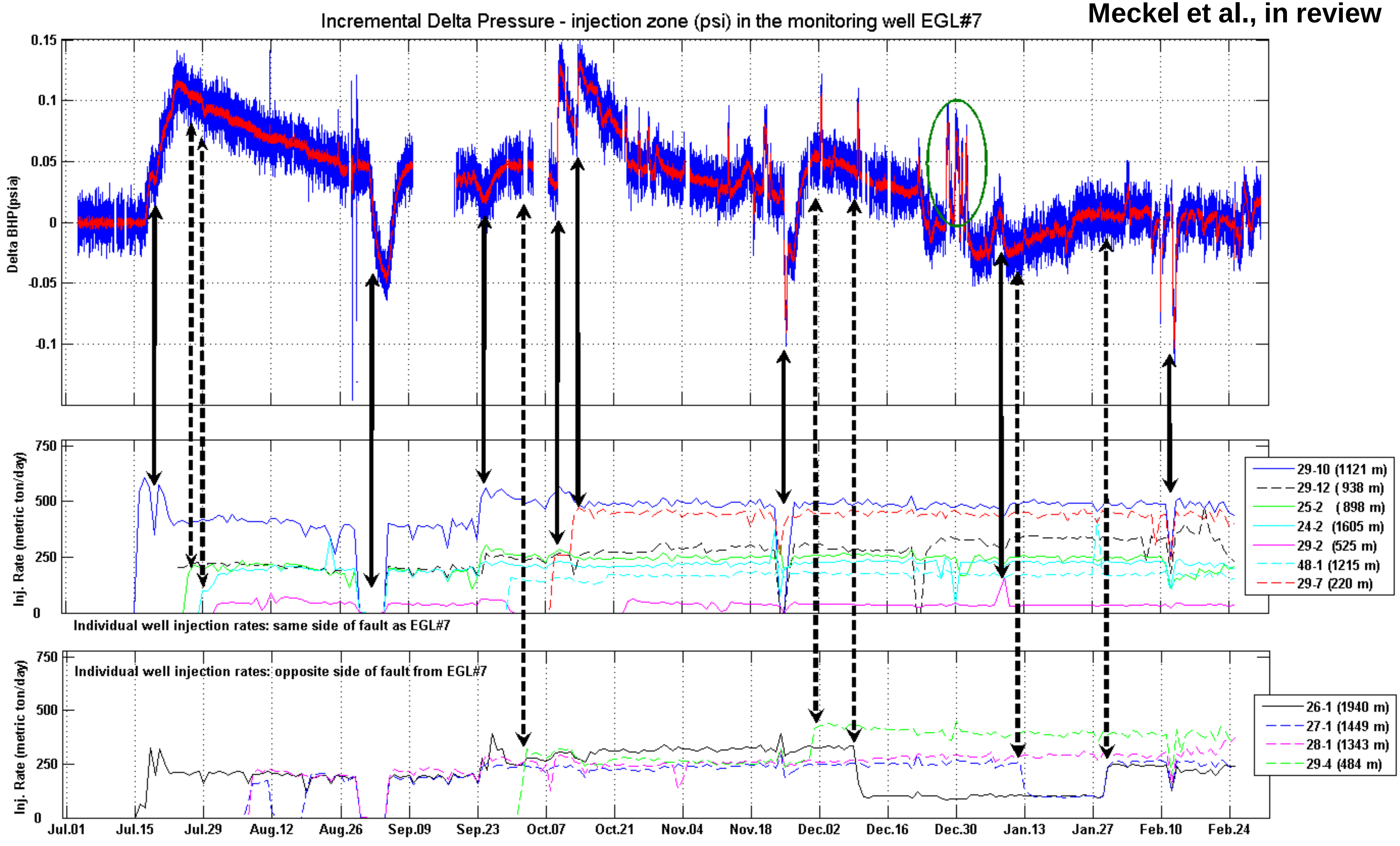


Jiemin Lu, GCCC

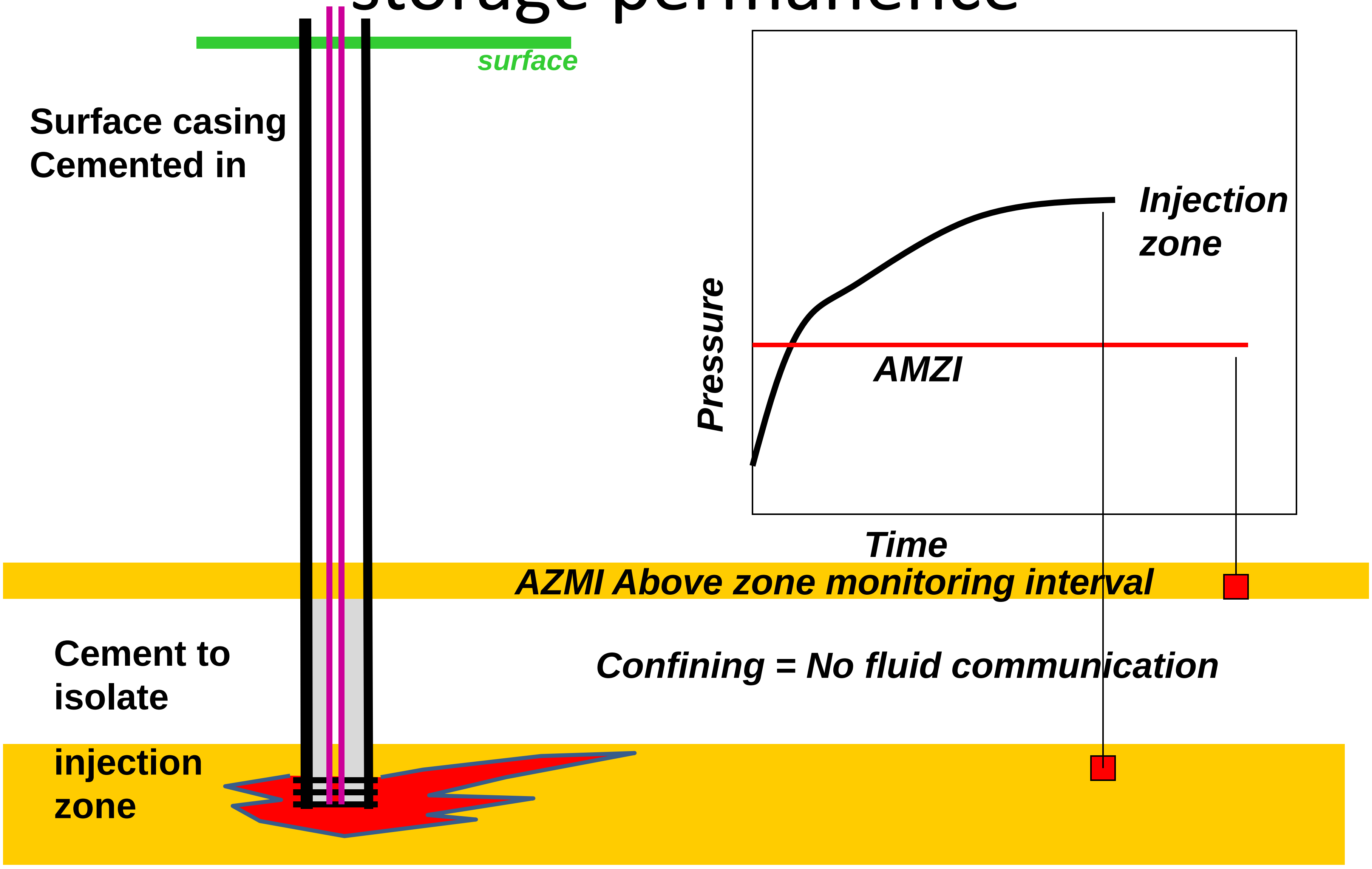
Continuous field data from dedicated monitoring well

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

Meckel et al., in review

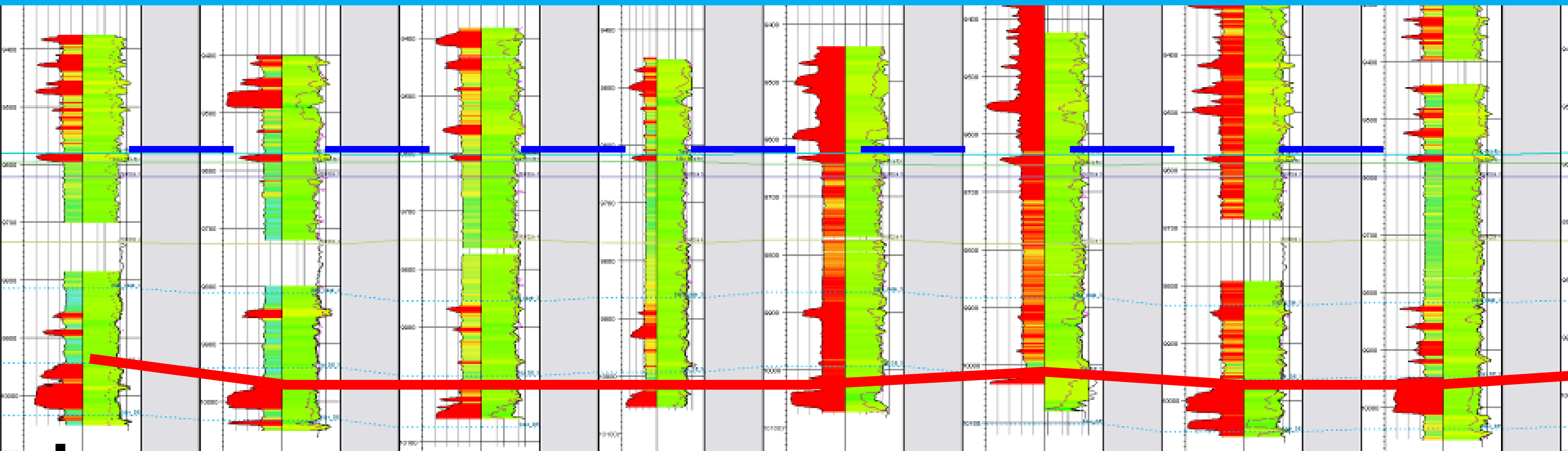


Using above AZMI pressure to assess storage permanence



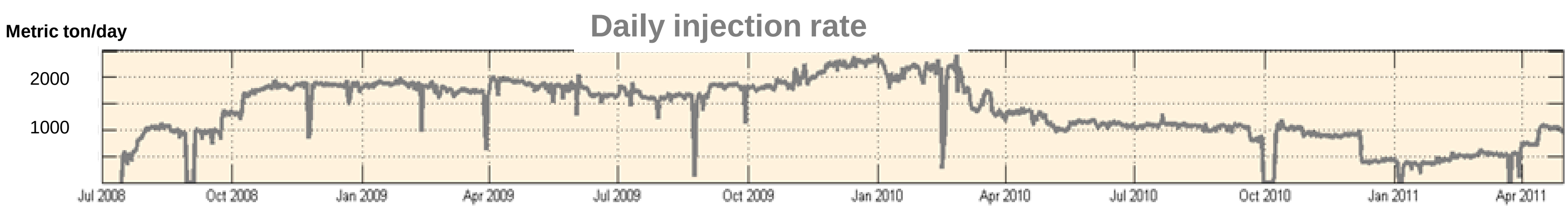
Pressure Monitoring

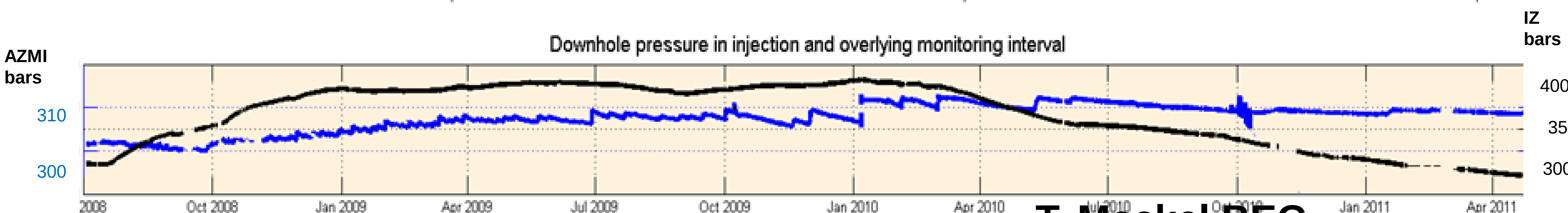
Above-Zone Monitoring Interval (AZMI) – leakage detection



30 m

Within Injection Zone (IZ) reservoir management





T. Meckel BEG

Groundwater monitoring strategy

Characterize shallow groundwater geochemistry

Identify a set of geochemical parameters for detecting CO_2 leakage

Test and validation

Numerical modeling

Lab experiments

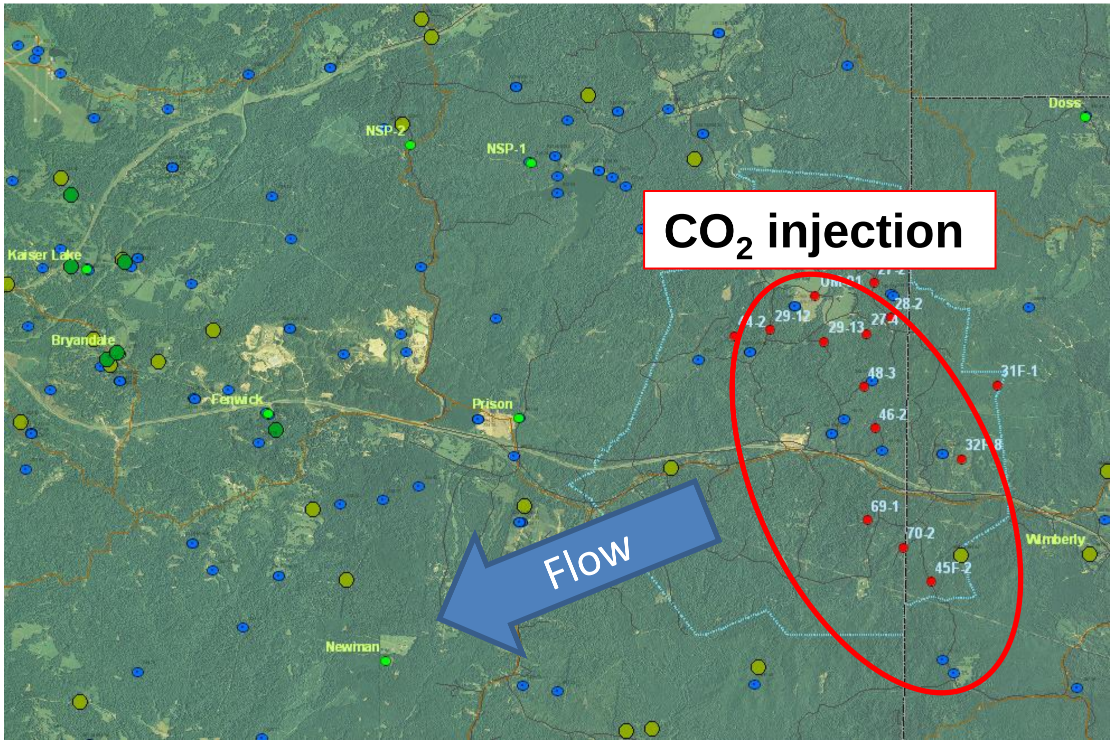
Field experiments (Push-pull tests)

Application

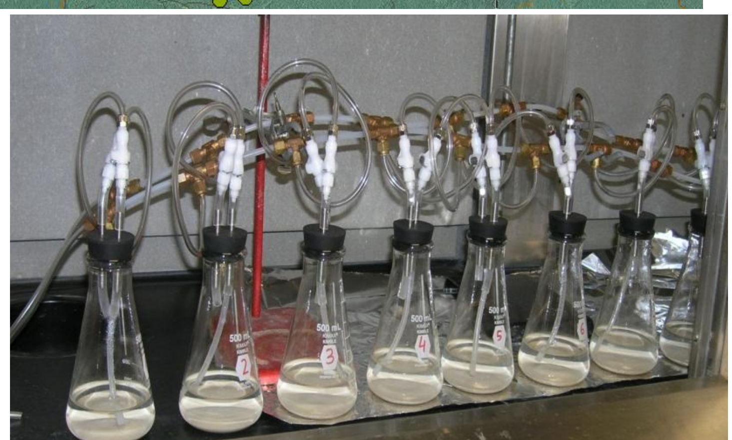
Groundwater chemistry monitoring for detecting CO_2 leakage

Changbing Yang BEG

Groundwater Monitoring

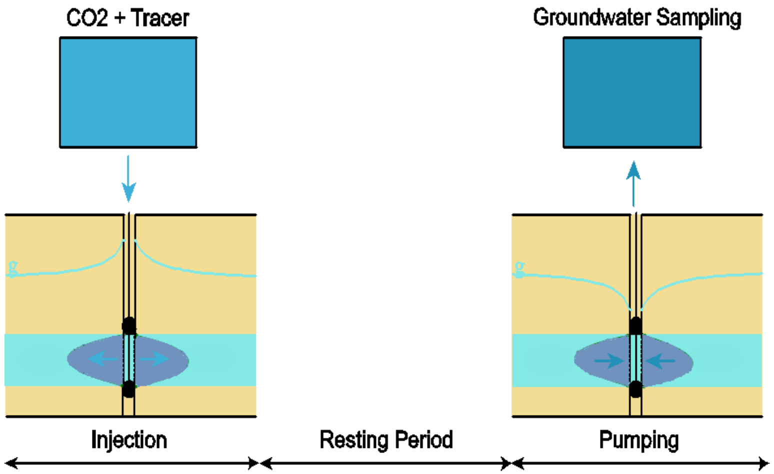


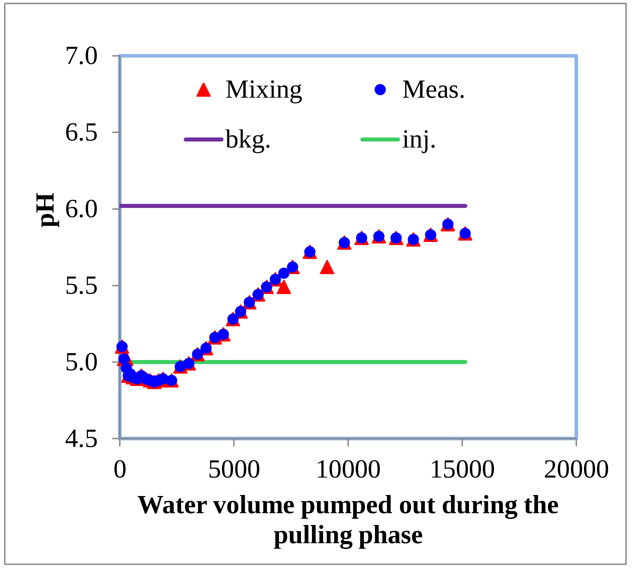
- Each injection well has a 200-300 ft deep groundwater well
- Quarterly geochemical monitoring by University of Mississippi,& Mississippi State
- Sensitivity studies: lab to field

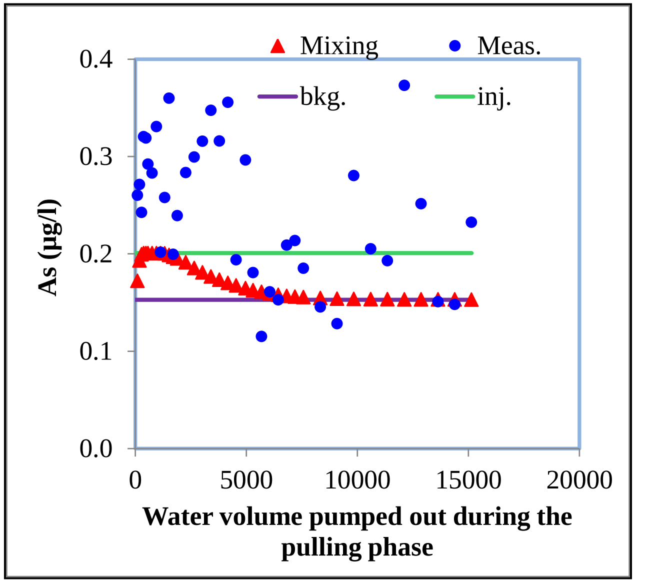


Changbing Yang, BEG

Using a push-pull field test to validate models under *insitu* redox conditions

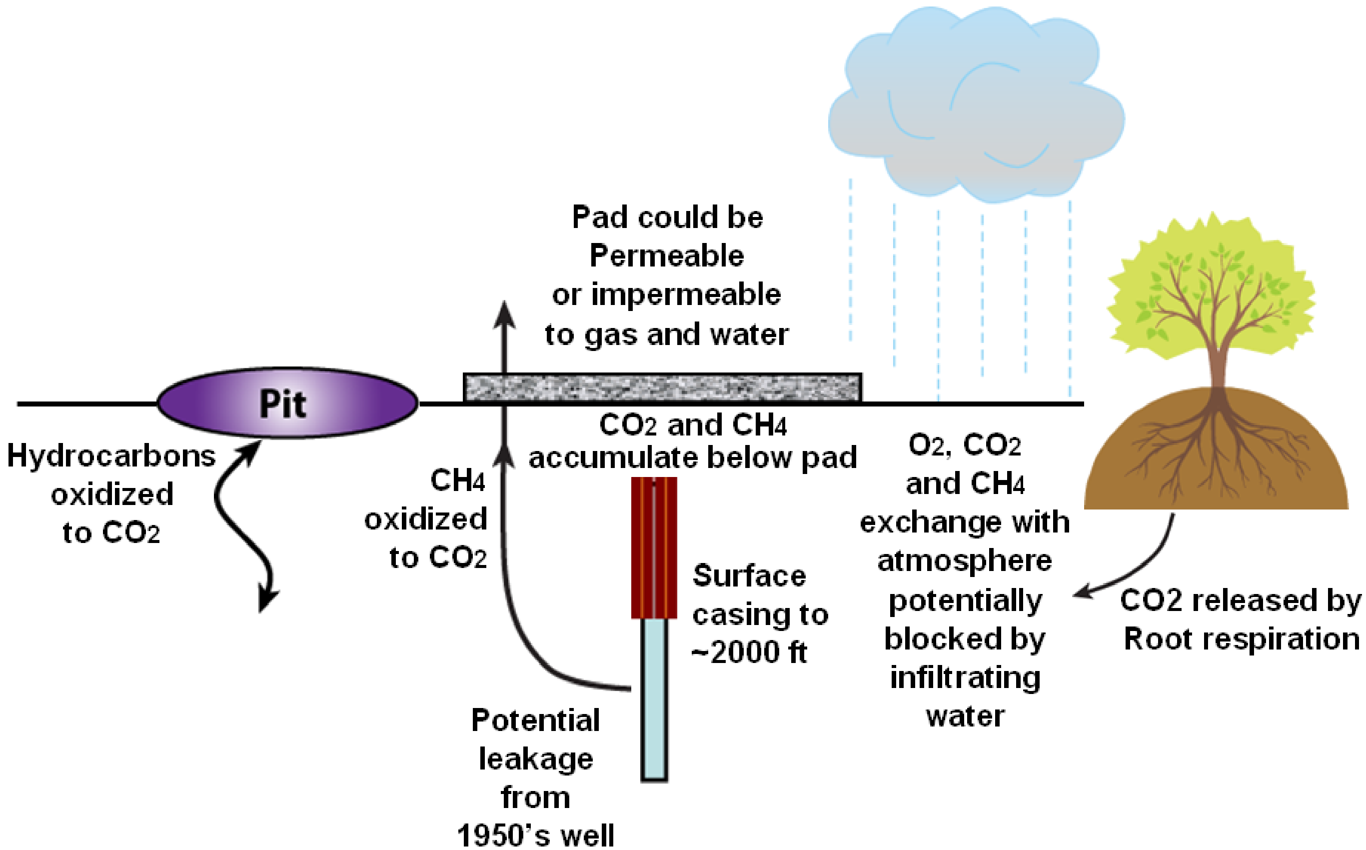






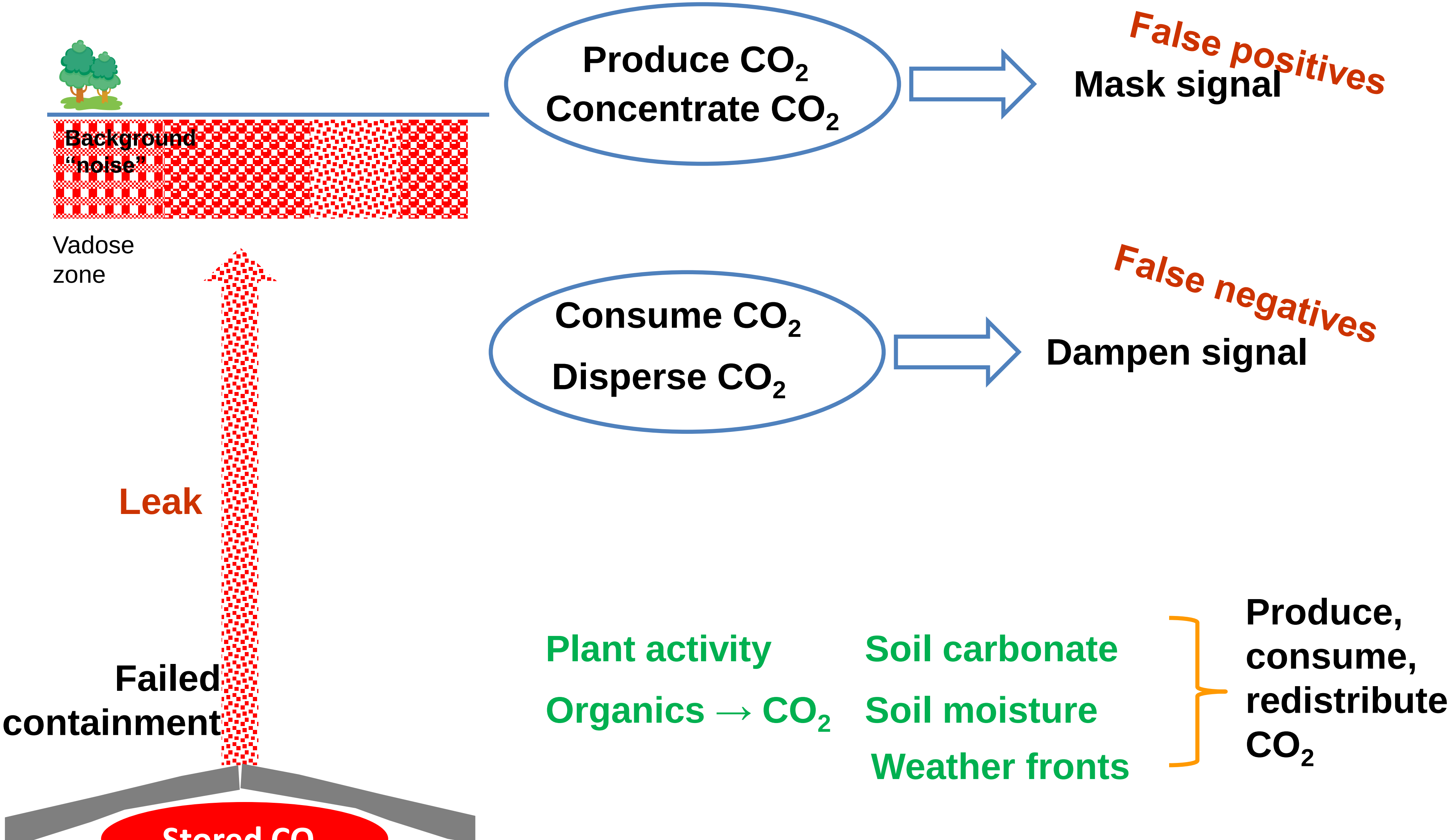
Changbing Yang, BEG (AWWA)

Vadose Zone Monitoring via Process Accounting



Katherine Romanak BEG

Challenges to Near-Surface Monitoring



Katherine Romanak BEG

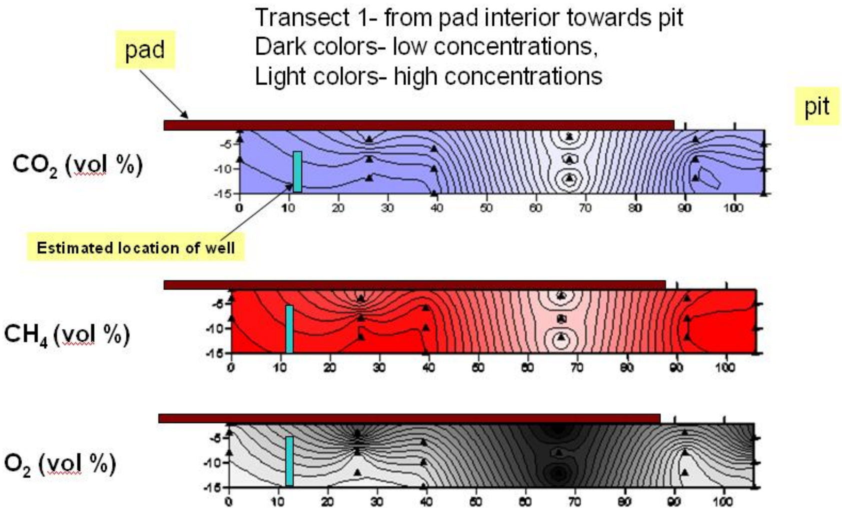
Soil gas composition - Unique leakage signal

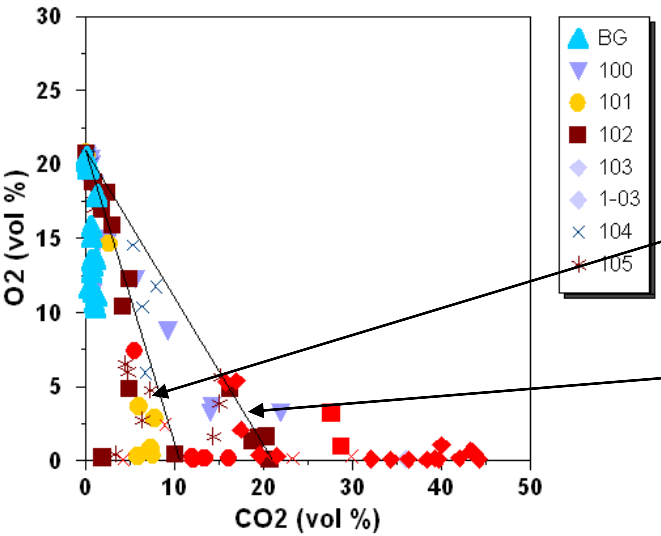
$CH_4 \le$ 34 vol. %

N_2 42-85%

O_2 2- 21%

$CO_2 \le$ 45 vol. %





Methane oxidation

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

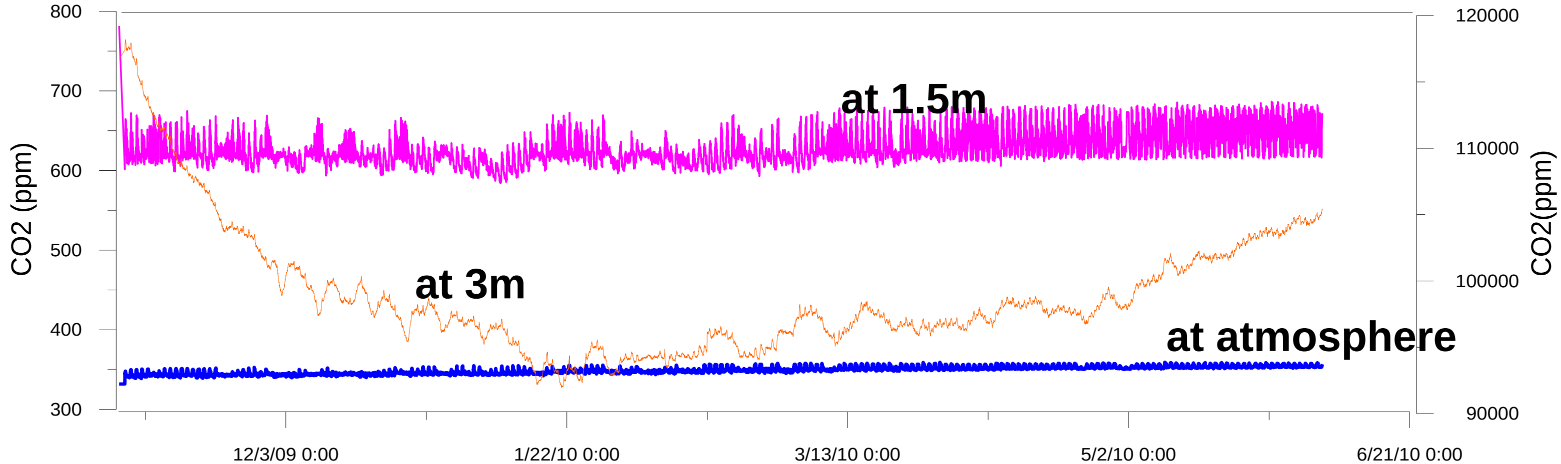
Org. oxidation

$CH_2O + 2O_2 \rightarrow CO_2 + H_2O$

Katherine Romanak BEG

CO_2 concentrations at different depths

CO_2 concentration alone may not reliable indicator for leakage detection



- **CO_2 concentrations show variations in depth, average CO_2 conc. ~350 ppm in the atmosphere, ~630 ppm at depth of 1.5 m below surface show, and ~99000 ppm at depth of 3 m over the observation time period**

Katherine Romanak Changbing Yang

Remaining Activities

- Knowledge sharing
  - Technical and public and policy
- Analysis of data collected
  - Joint/comparative inversions
  - NRAP
  - SIM-SEQ
  - Basic Energy Sciences – EFRC's
- Continued data collection
  - Report volumes injected and pressure response
  - Continue groundwater and soil gas observation
  - EGL7 deconstruction (DOE-Schlumberger Carbon Services)
- RITE microseismic array – collect microseismic data
- Use of DAS obs. well for DOE-LBNL CO_2 geothermal test
- Support for CCUS concept

Conclusions

- Stacked Storage Demonstrated
- Project objectives attained
  - Long term monitoring continues
- Innovative techniques for permanence assessment:
  - AZMI pressure
  - Groundwater testing to determine sensitivity
  - Fixed gas soil gas method
- Capacity is rate dependent

Gulf Coast Carbon Center (GCCC)

Gulf Coast Carbon Center

Bureau of Economic Geology

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U of Mississippi
SECARB
UT-PGE
UT Chem-E
CFSES- BES
UT- CIEEP
UT- DoGS
BEG- CEE
JSG – EER
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KINDER MORGAN
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Luminant
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BG GROUP
EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work
China Petroleum Co. Taiwan

STORE sequestration training, outreach, research & education

THE UNIVERSITY OF TEXAS AT AUSTIN JACKSON SCHOOL OF GEOSCIENCES

Bibliography

Please see www.gulfcoastcarbon.org "bookshelf"

Special volume of International Journal of Greenhouse Gas Control on Cranfield.