SECARB Early Test at Cranfield Monitoring 4 Million Tons

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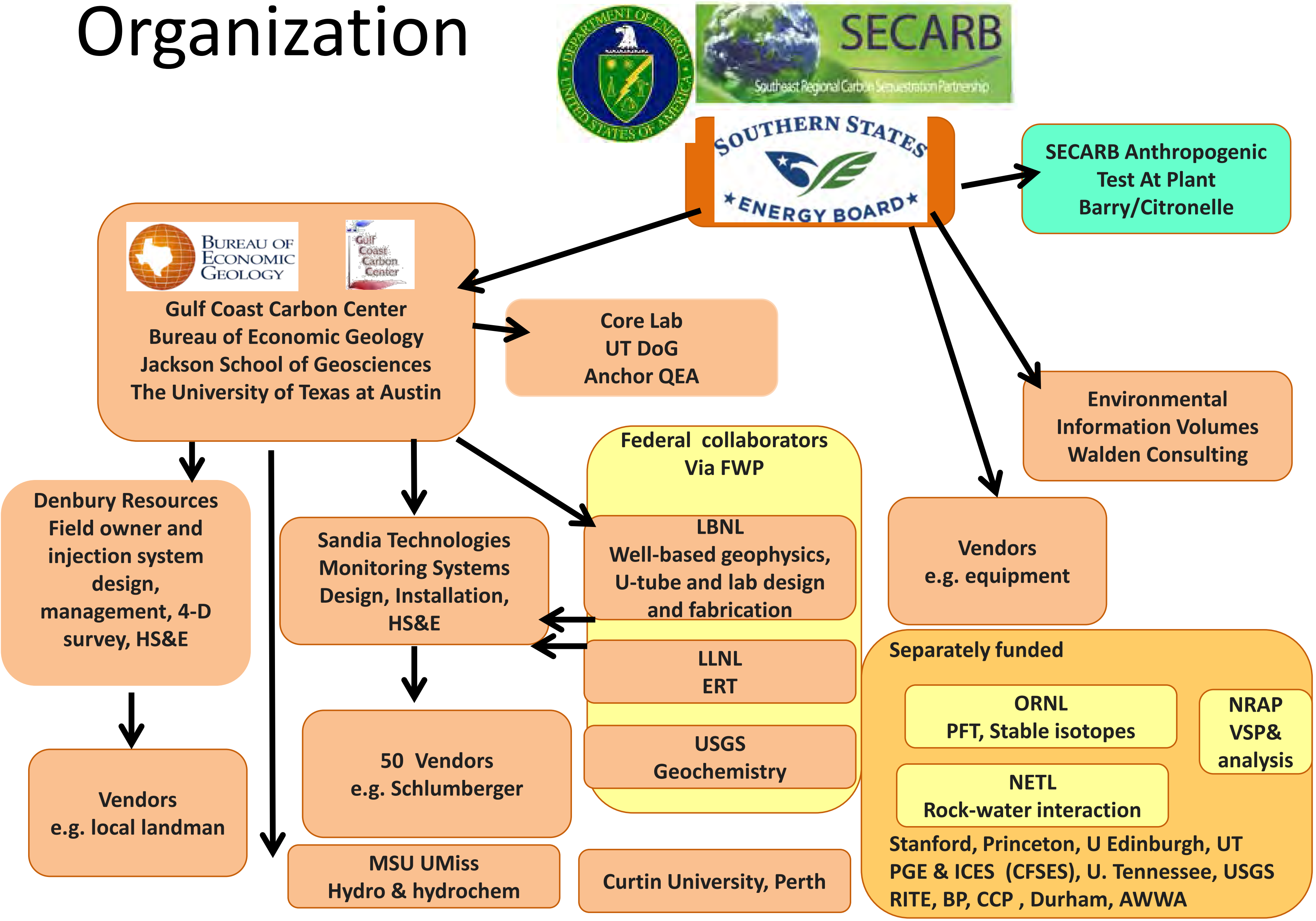
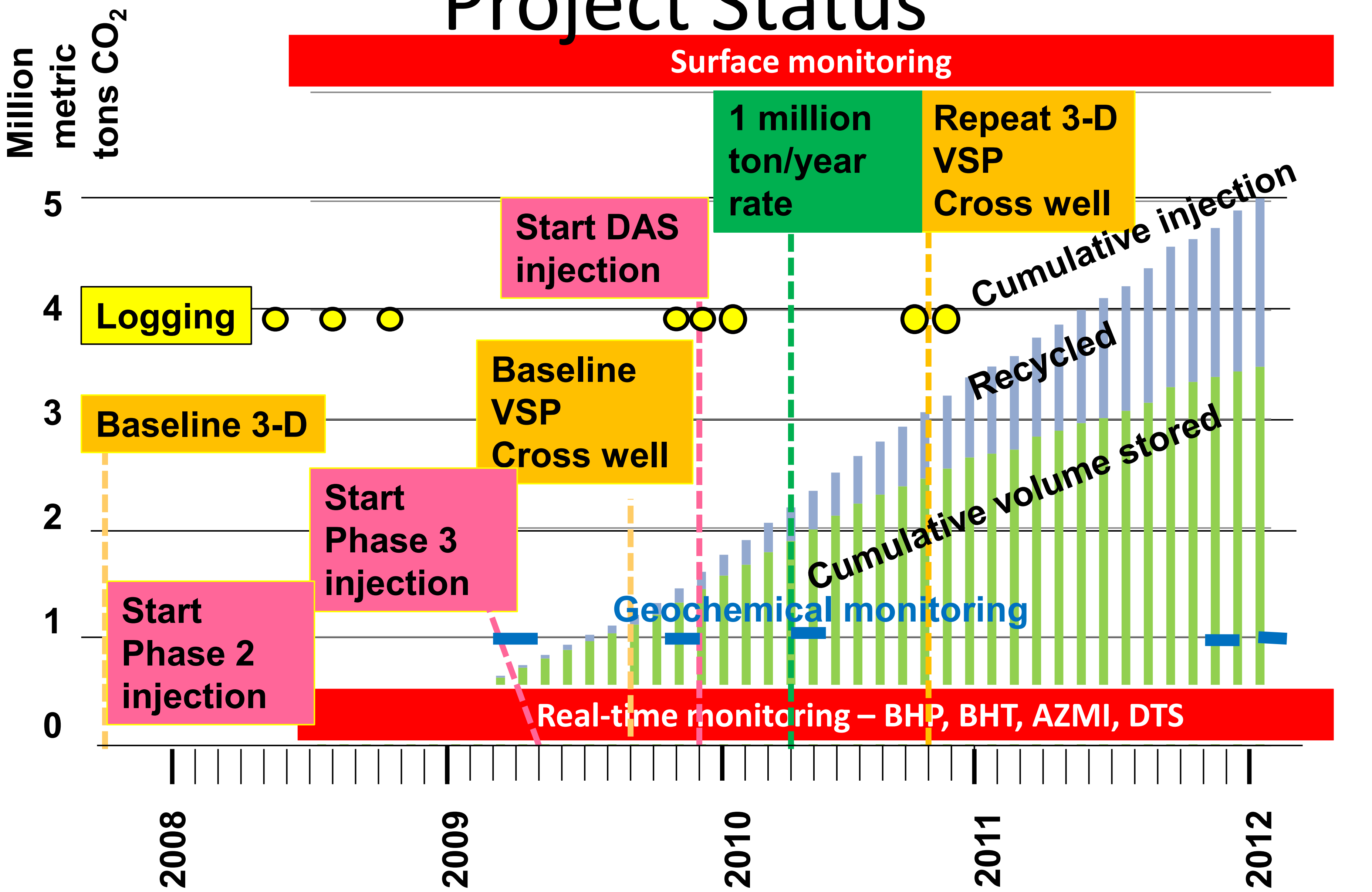
Jackson School of Geosciences
The University of Texas at Austin

CSLF CO2 Monitoring workshop, April 18, 2013

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

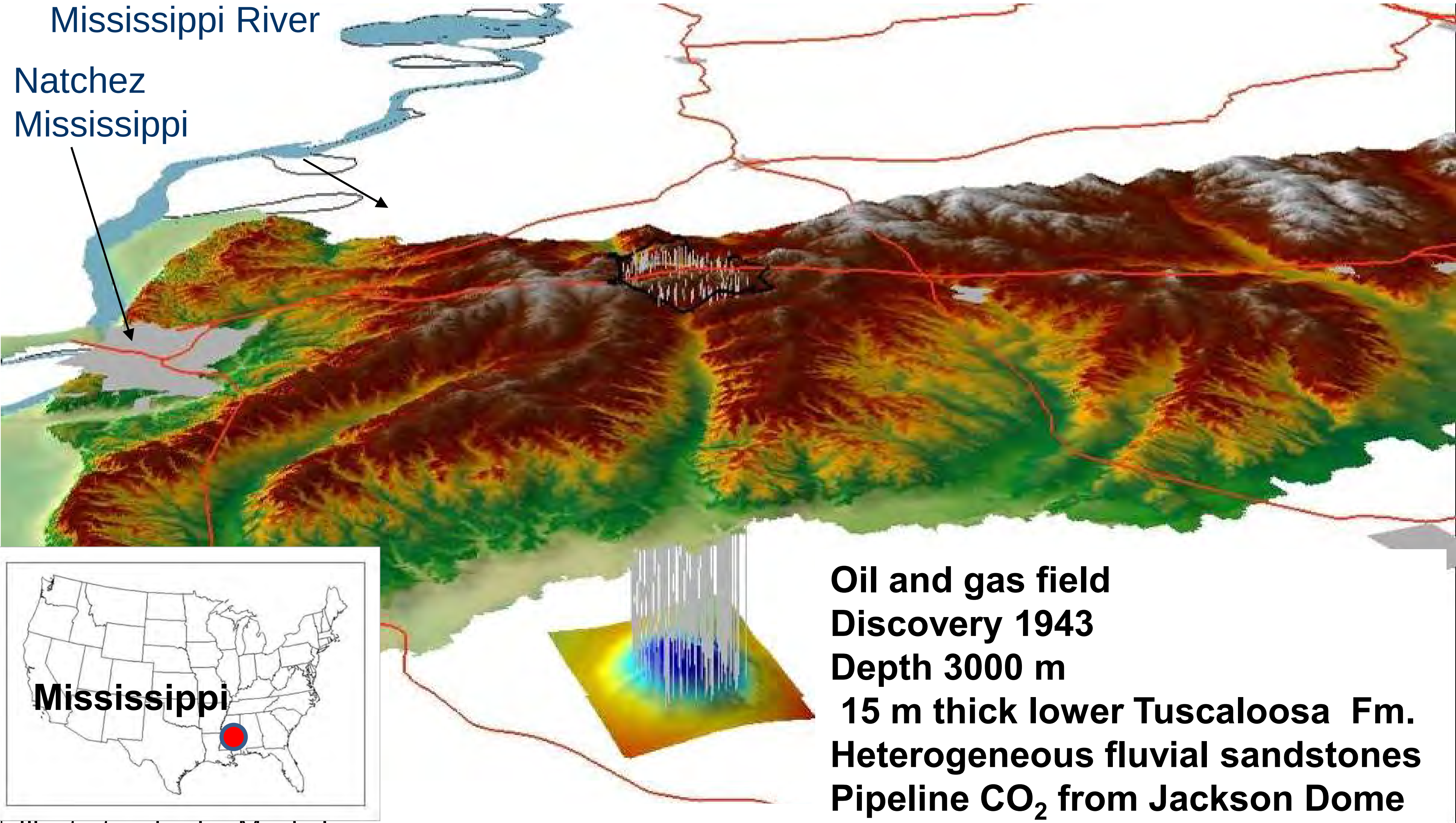
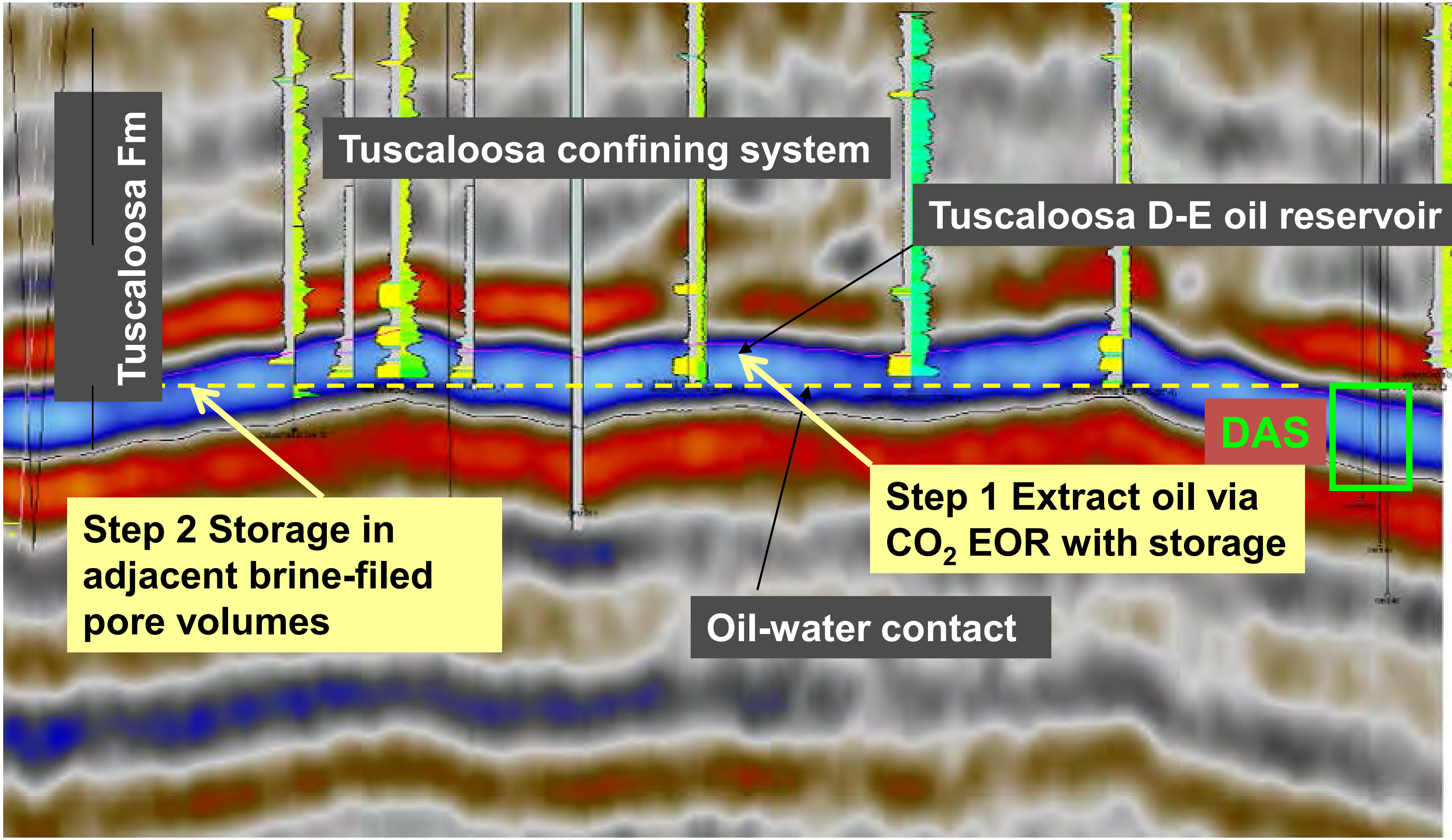


Illustration by Tip Meckel

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

W E



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?

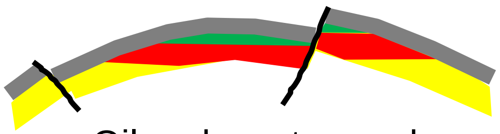
Measure saturation during multiphase plume evolution

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

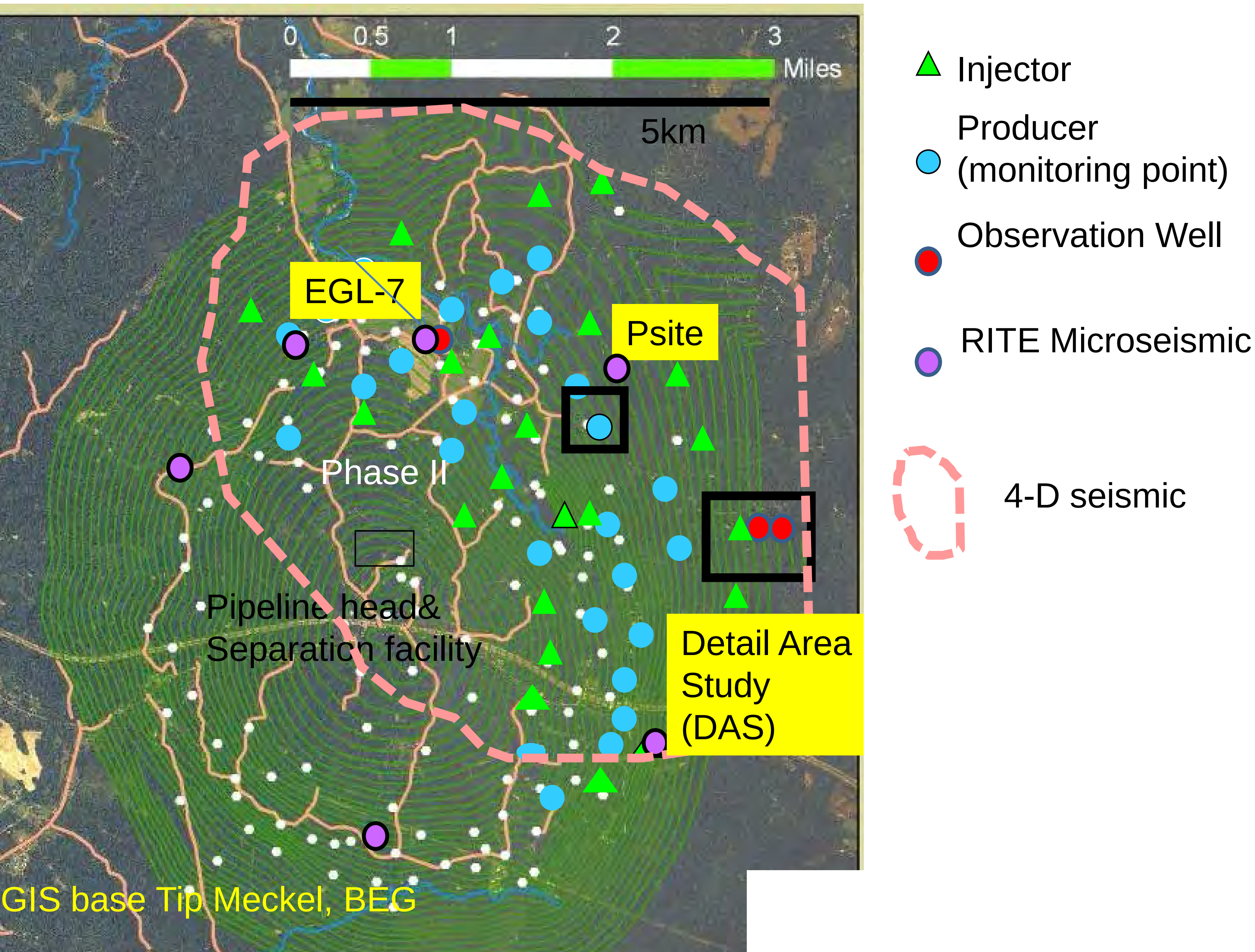
shallow

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

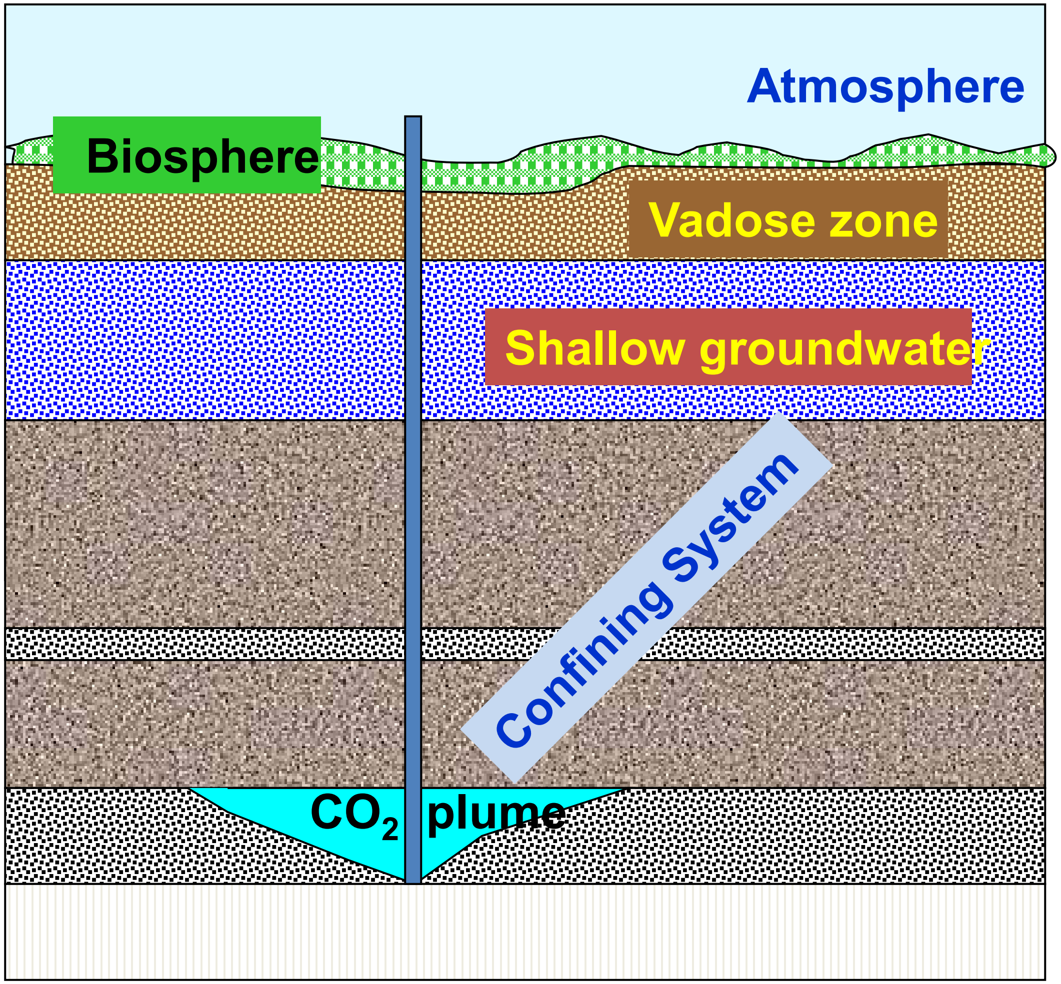
deep

Protocol Sensitivity & reliability

Monitoring layout



Monitoring Innovations

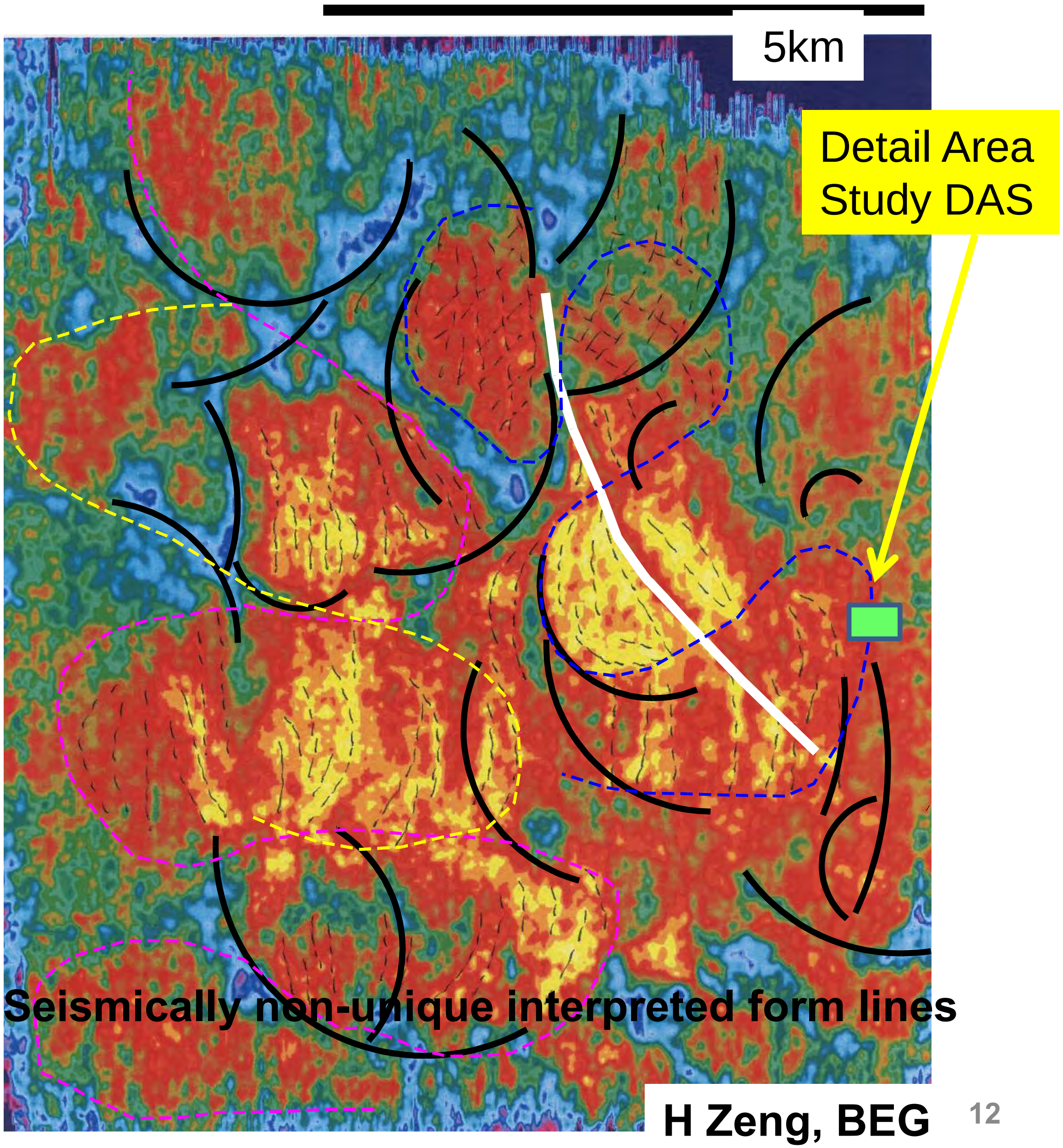


- Process-based vadose zone-gas method
- *In situ* rock-water-CO_2 interaction test.
- Contaminated site approaches
- Pressure in above-zone monitoring interval
- Stacked storage demonstration
- Cross-well ERT at depth
- Bore hole gravity
- Methane exsolution
- RITE microseismic

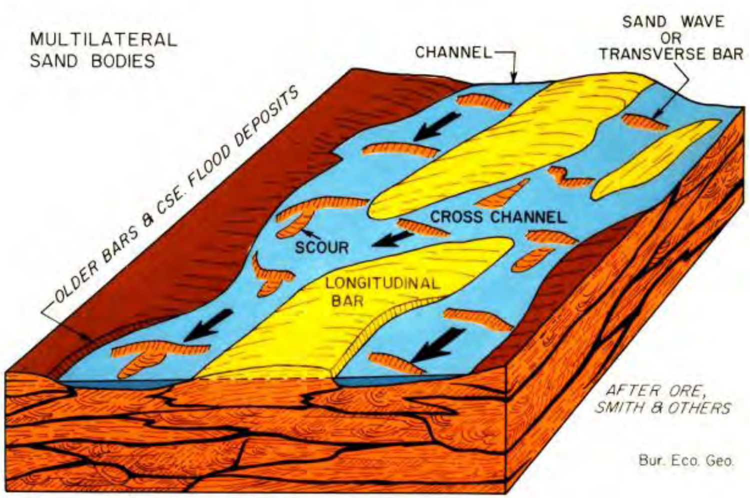
Monitoring Design

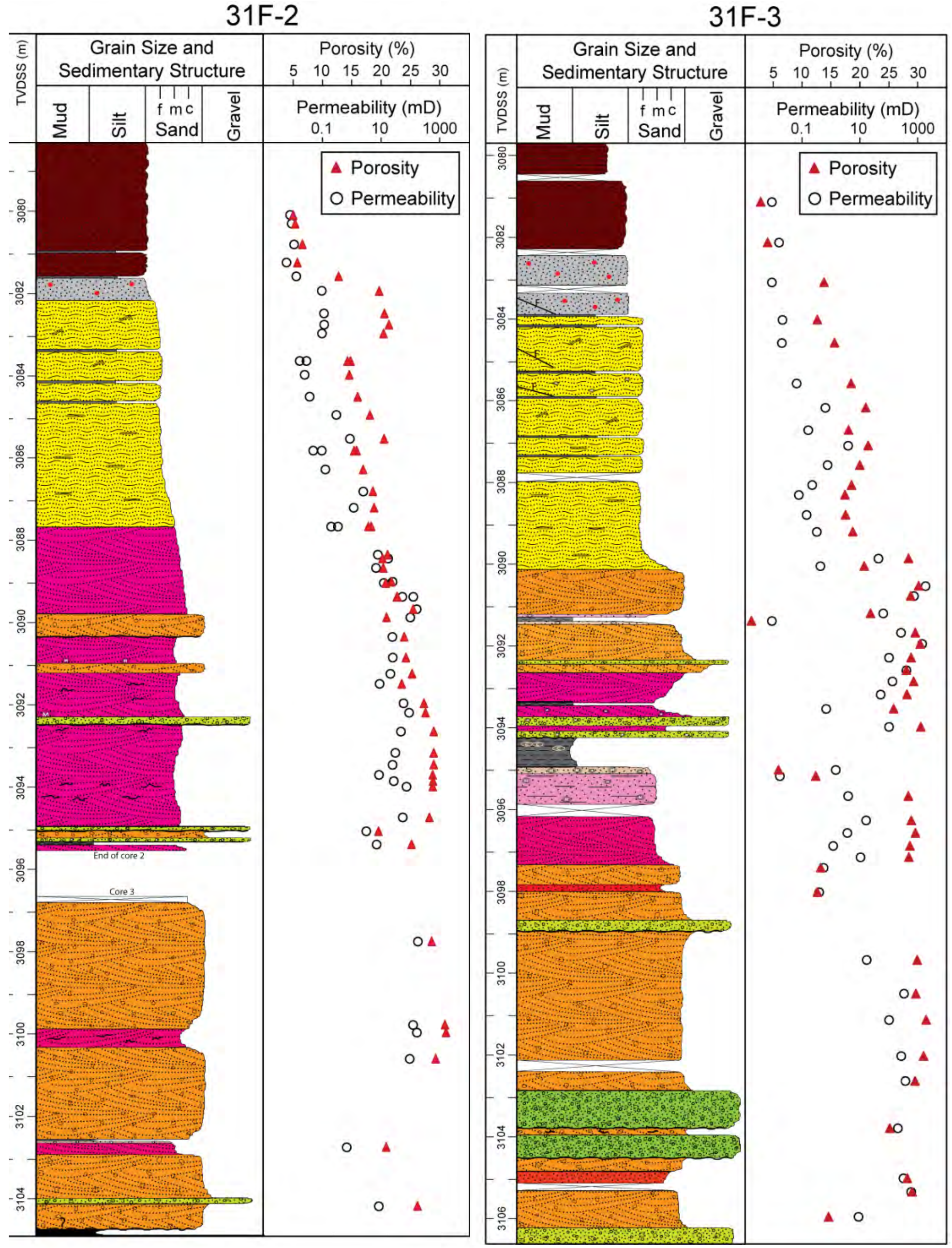
Area tested	Whole plume	Focus study
Atmosphere	Not tested	Not tested
Soil gas	Active and P&A well pads	"P site" methodology assessment
Groundwater	Monitoring well at each injector	EGL-7 UM test well, Push-pull test
Shallow production	Not tested	Not tested
AZMI	Not tested	DAS pressure and EGL 7 pressure + 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



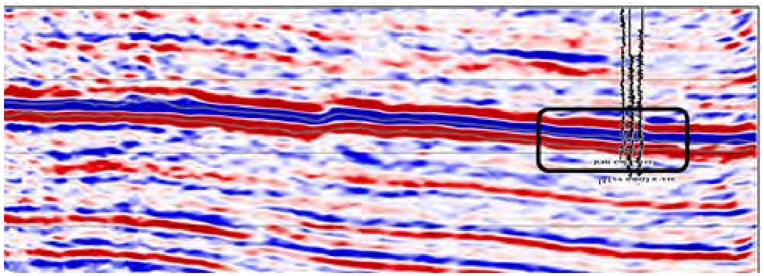


30-m apart

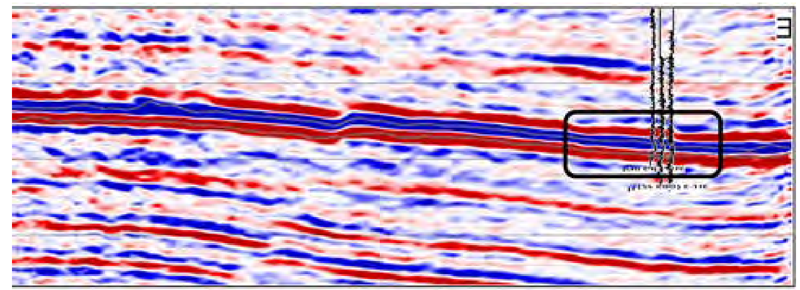
M. Kordi , BEG

Time lapse seismic analysis

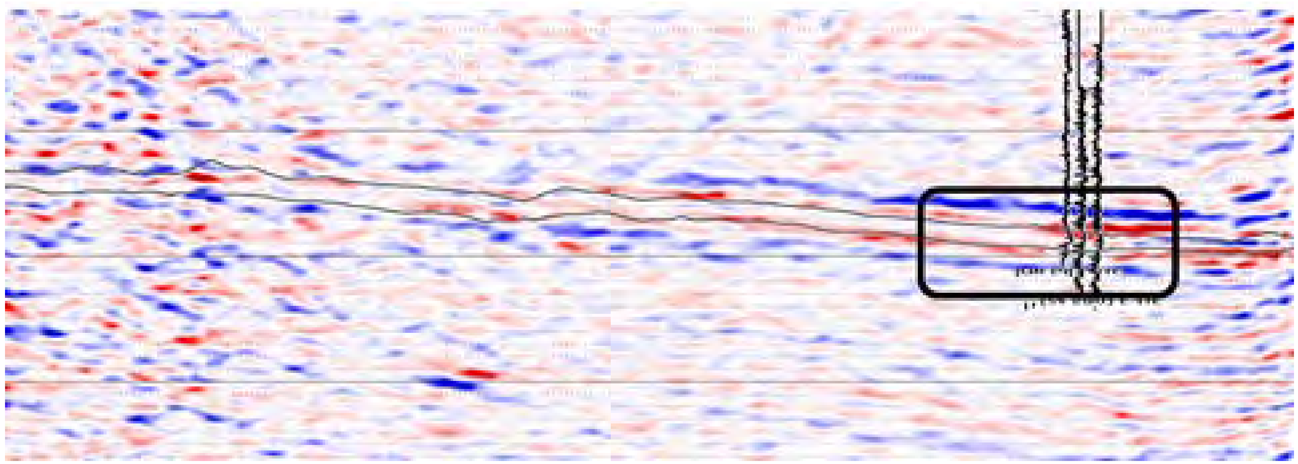
2007 Pre-injection **DAS**



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



Difference **DAS**



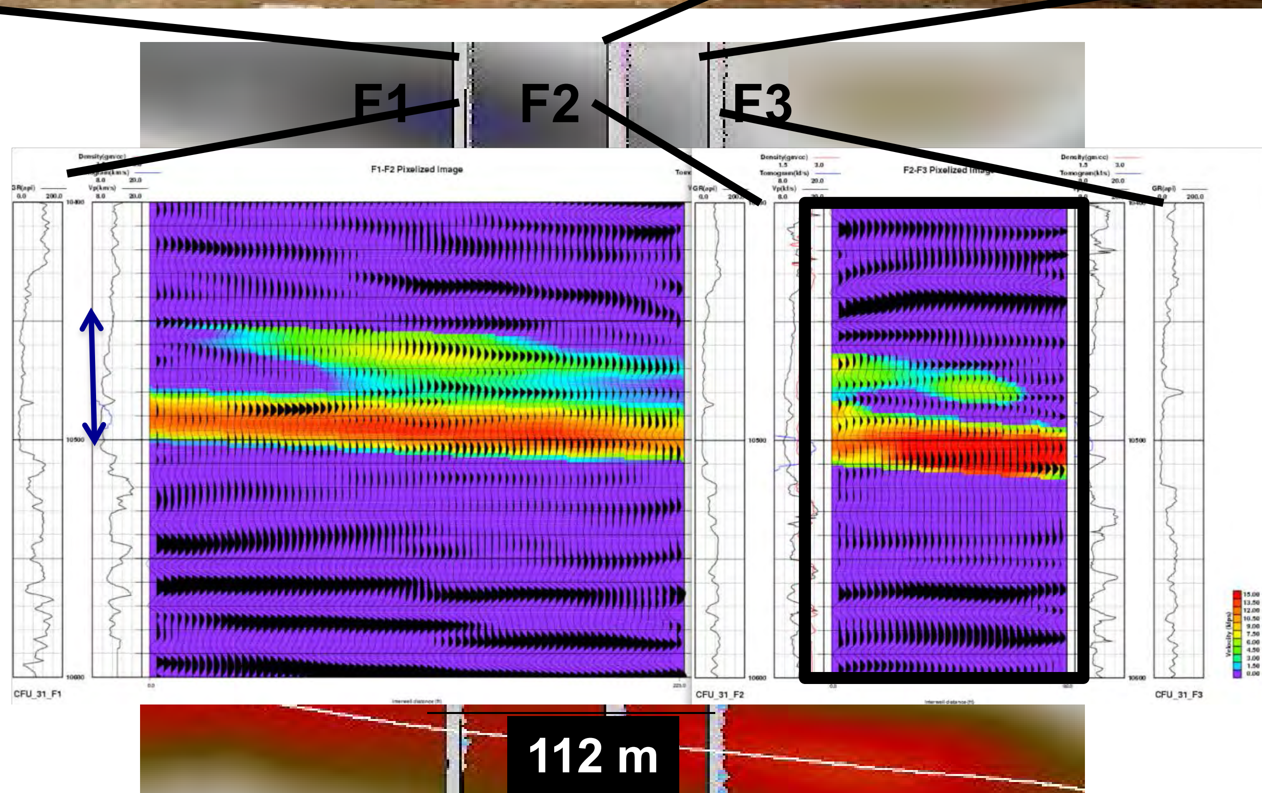
Rui Zhang, CFSES & UTIG

Detailed Area Study (DAS)

Closely spaced well array to examine flow in complex reservoir

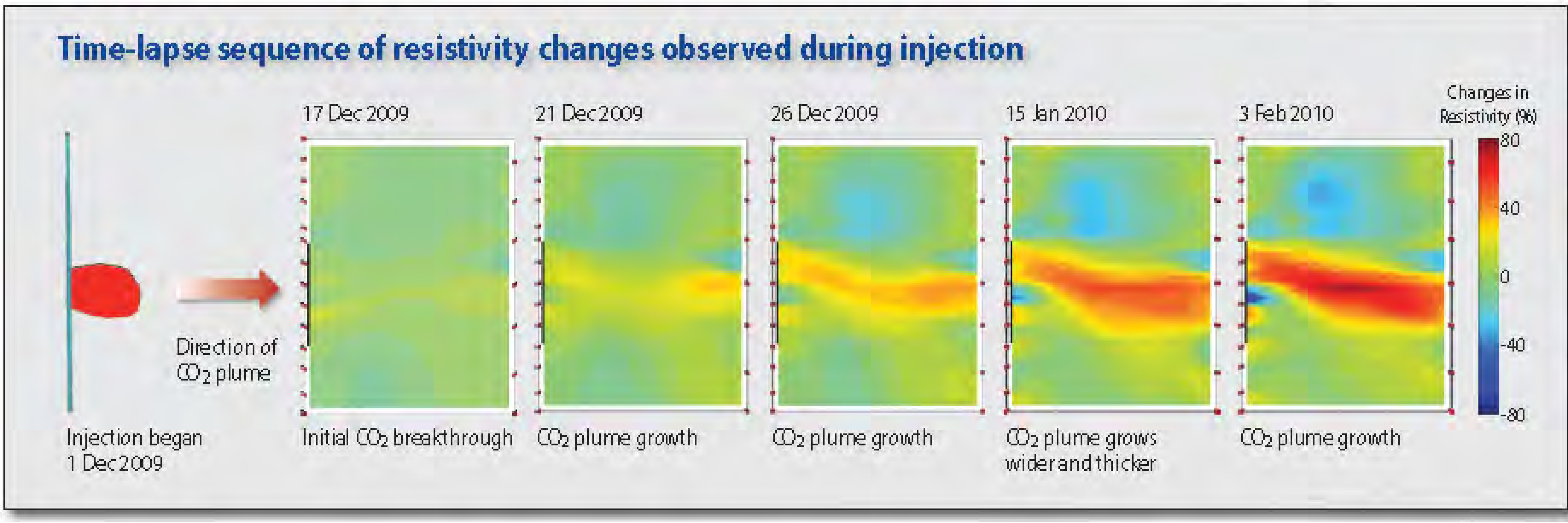
Tuscaloosa D-E reservoir

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

Adding tracer

- 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

Bureau of Economic Geology

USGS science for a changing world

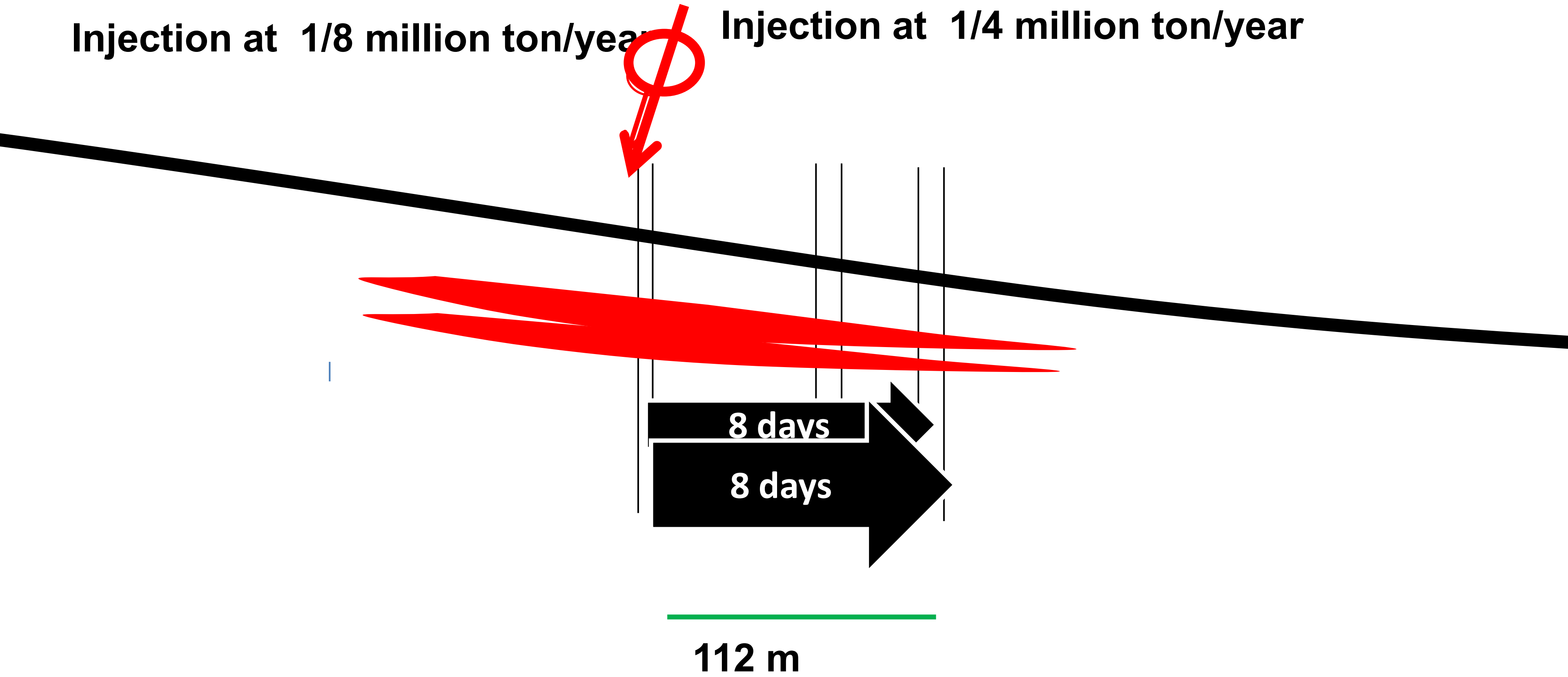
Berkeley Lab

Oak Ridge National Laboratory Managed by UT-Battelle for the Department of Energy

UTDoG,

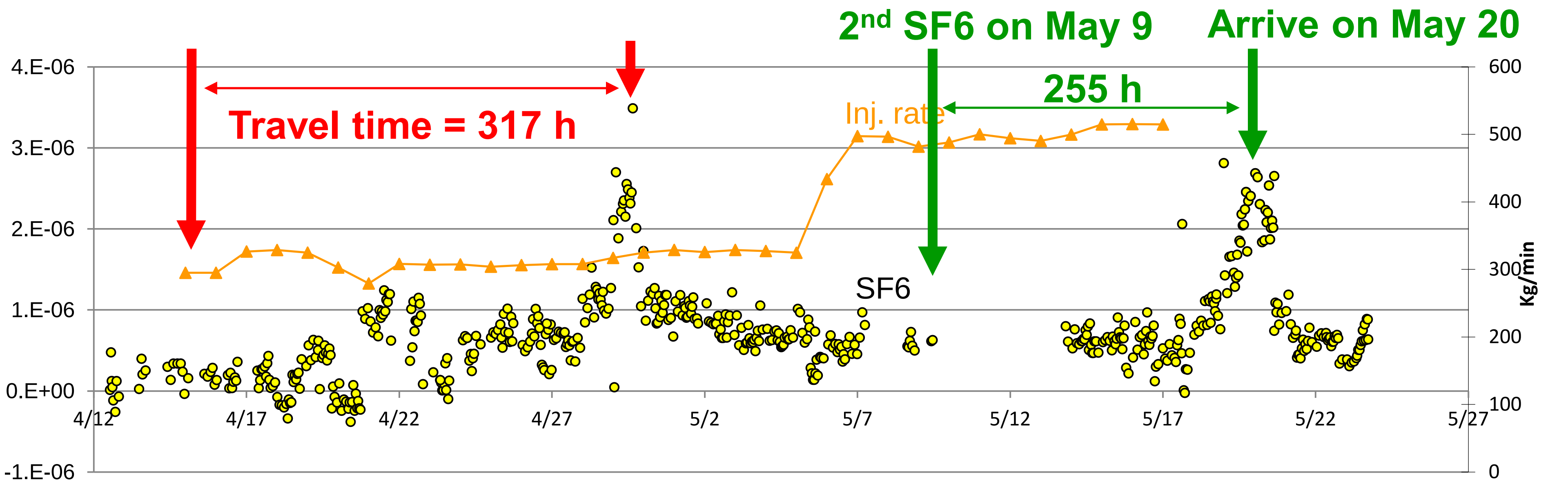
Gulf Coast Carbon Center

As injection rate increased, plume thickness increased

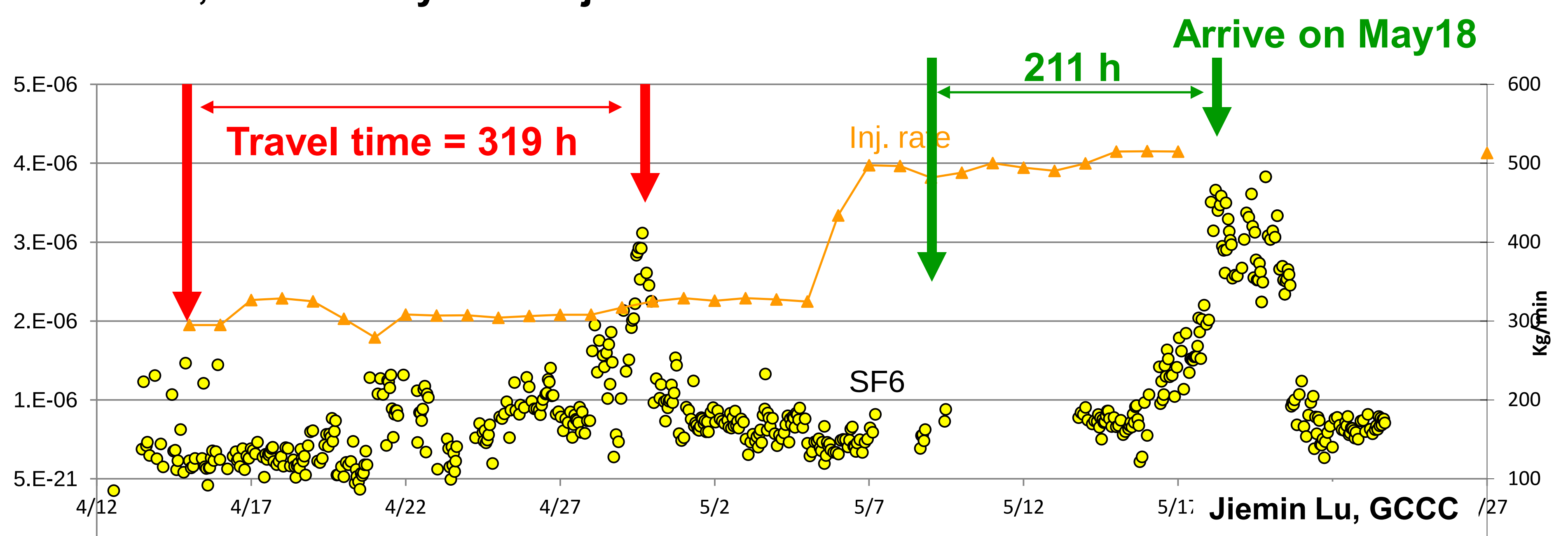


March-April 2010 tracer studies:
Jiemin Lu, Changbing Yang, GCCC
Tommy Phelps ORNL

CFU31F-2, 68 m away from injector SF6



CFU31F-3, 112 m away from injector SF6

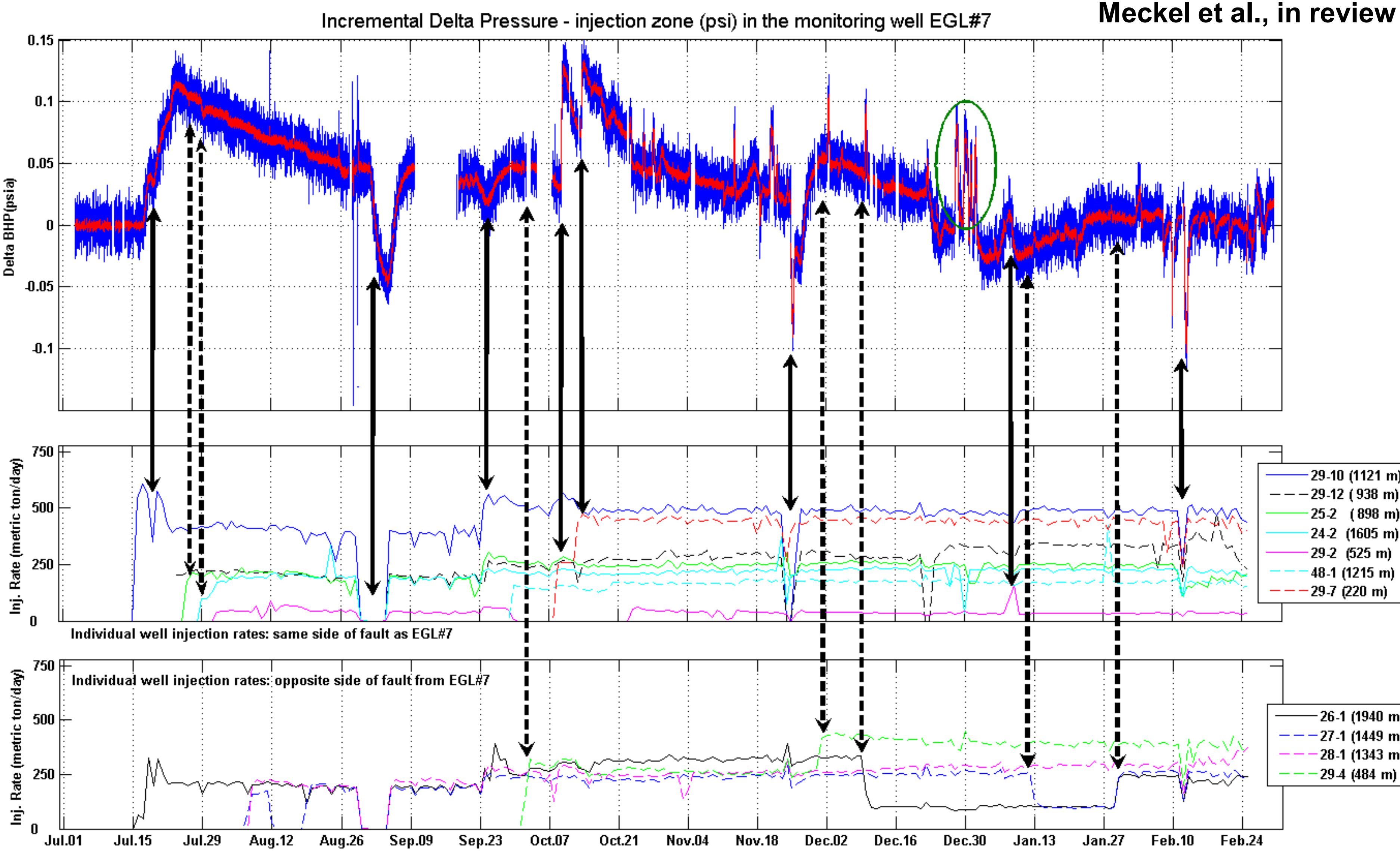


Jiemin Lu, GCCC

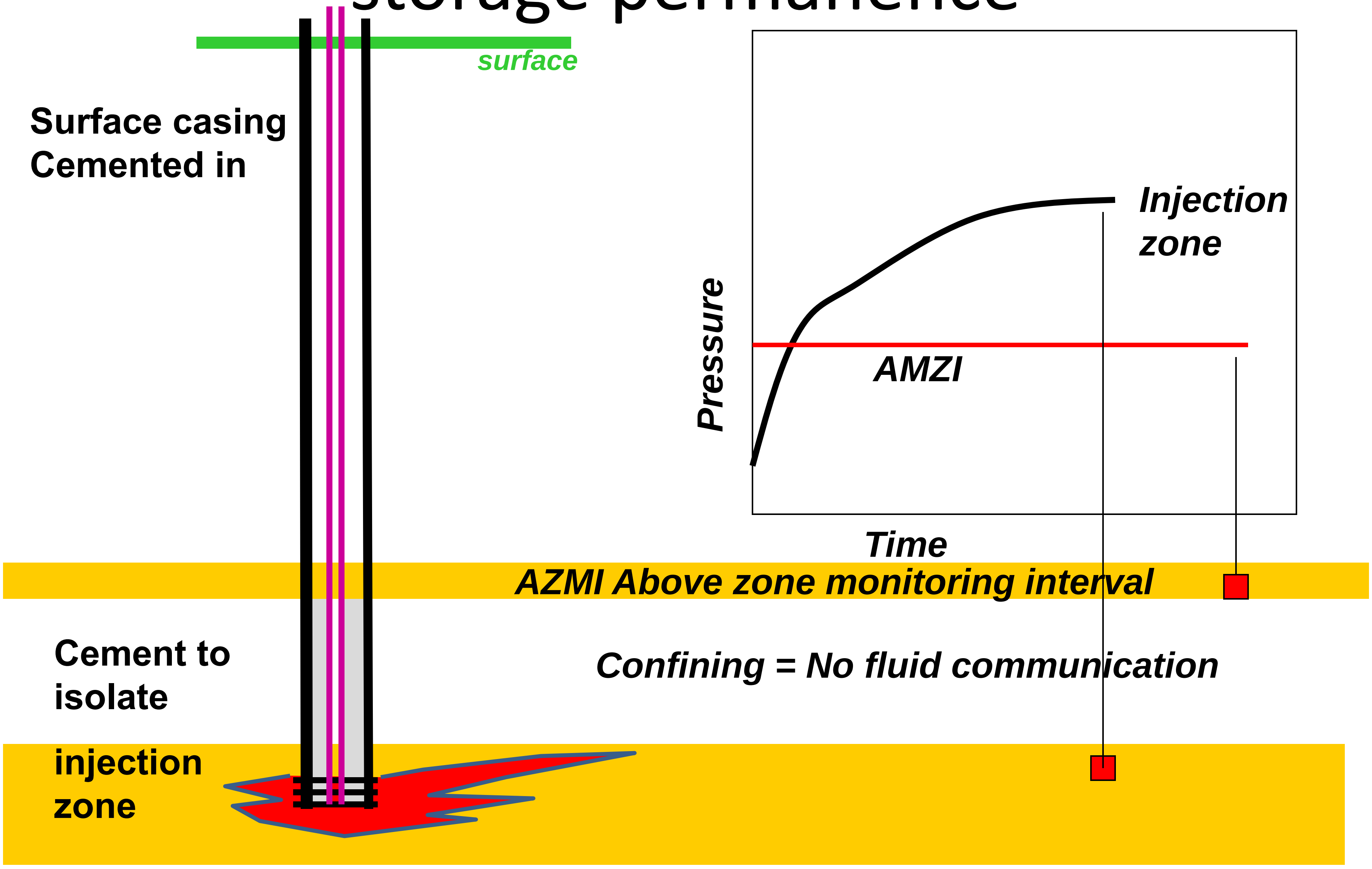
Continuous field data from dedicated monitoring well

- 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

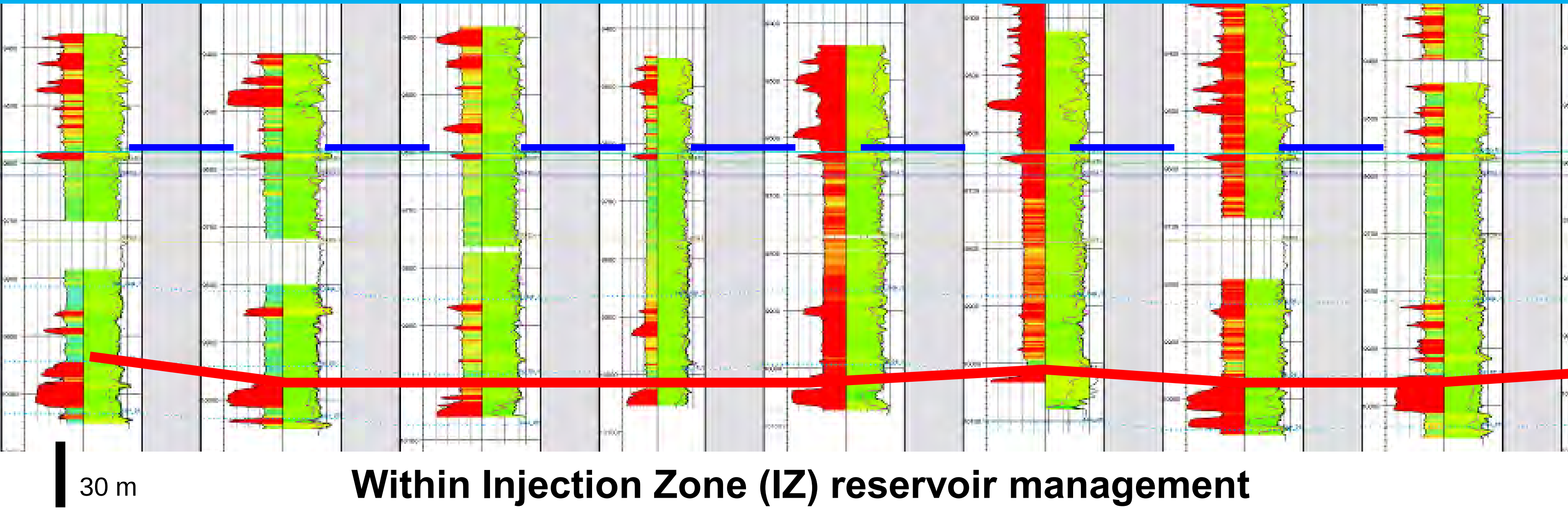


Using above AZMI pressure to assess storage permanence

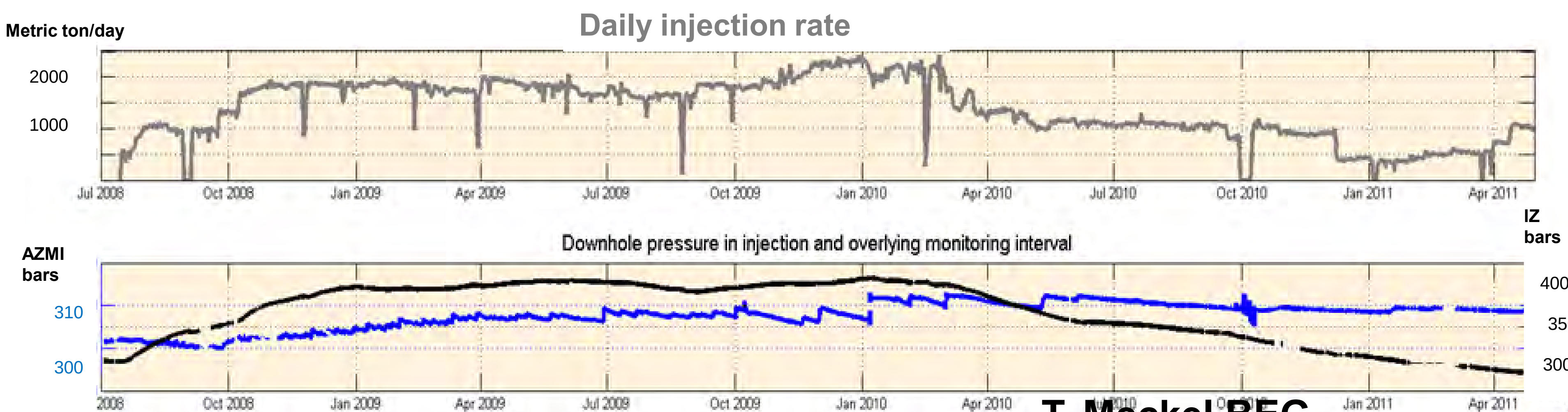


Pressure Monitoring

Above-Zone Monitoring Interval (AZMI) – leakage detection



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

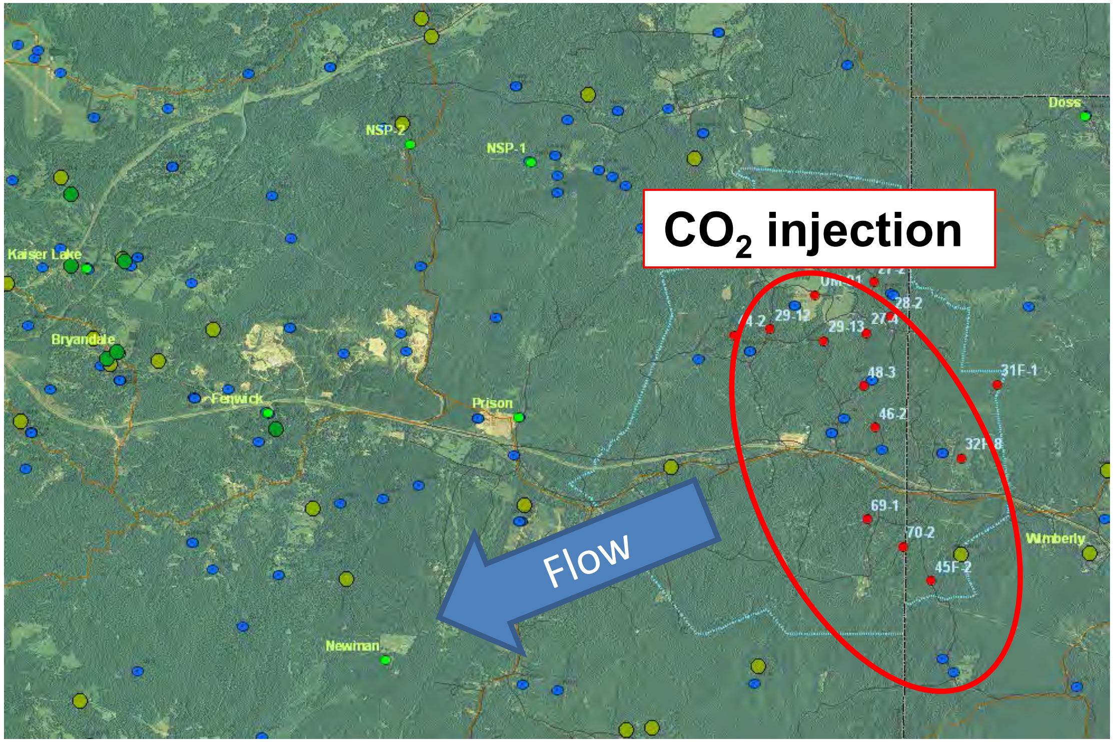
Field experiments (Push-pull tests)

Application

Groundwater chemistry monitoring for detecting CO_2 leakage

Changbing Yang BEG

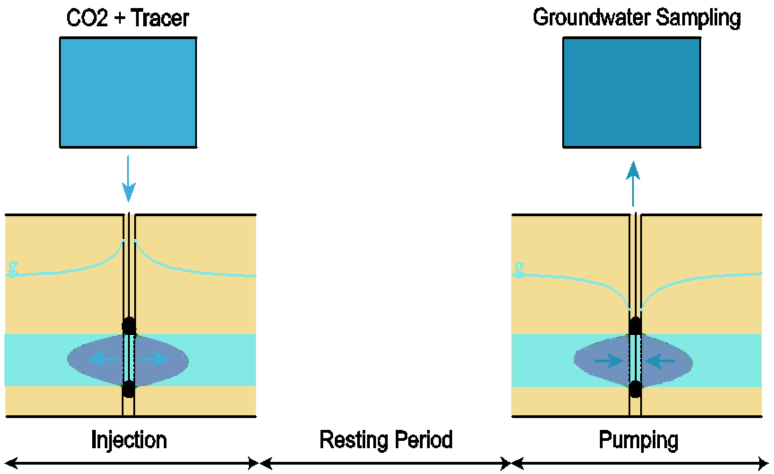
Groundwater Monitoring

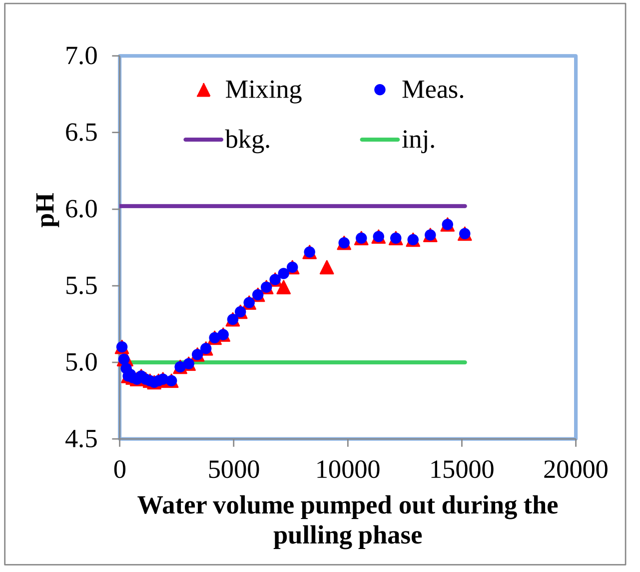


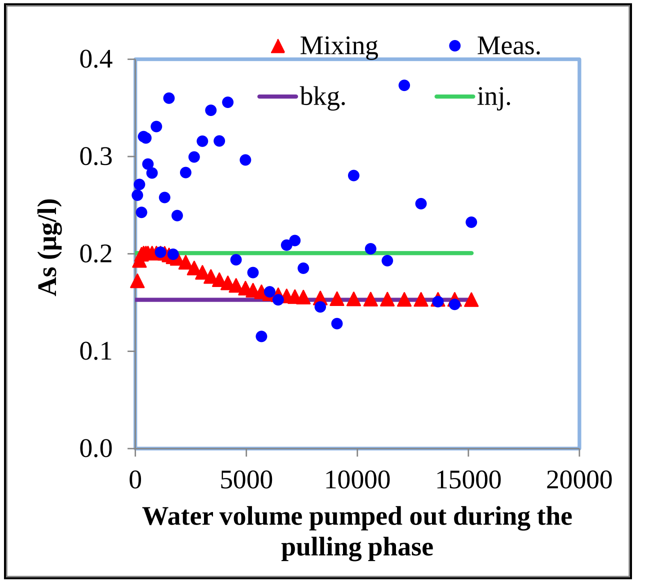
- Each injection well has a 200-300 ft deep groundwater well
- Quarterly geochemical monitoring by University of Mississippi,& Mississippi State
- Sensitivity studies: lab to field

Changbing Yang, BEG

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

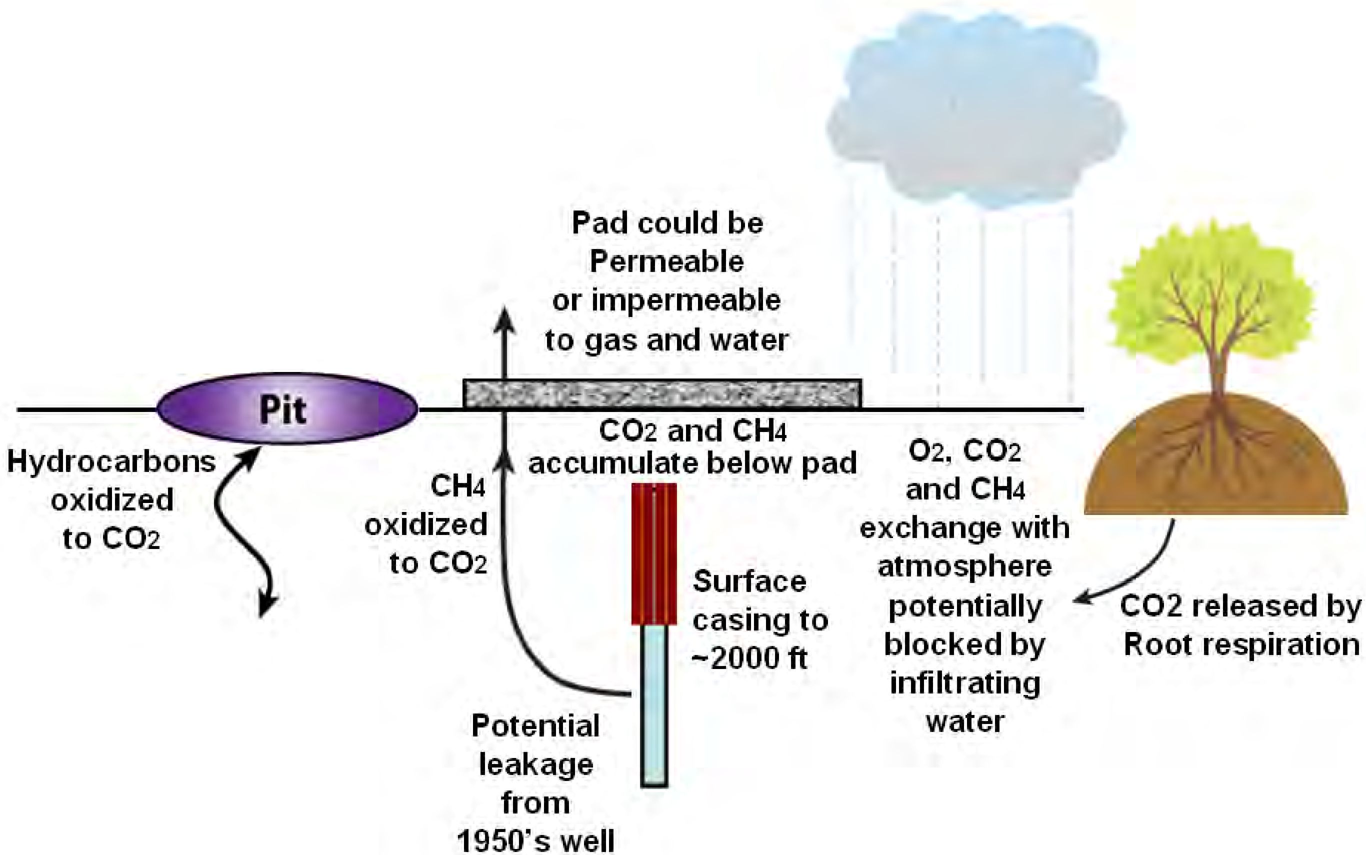






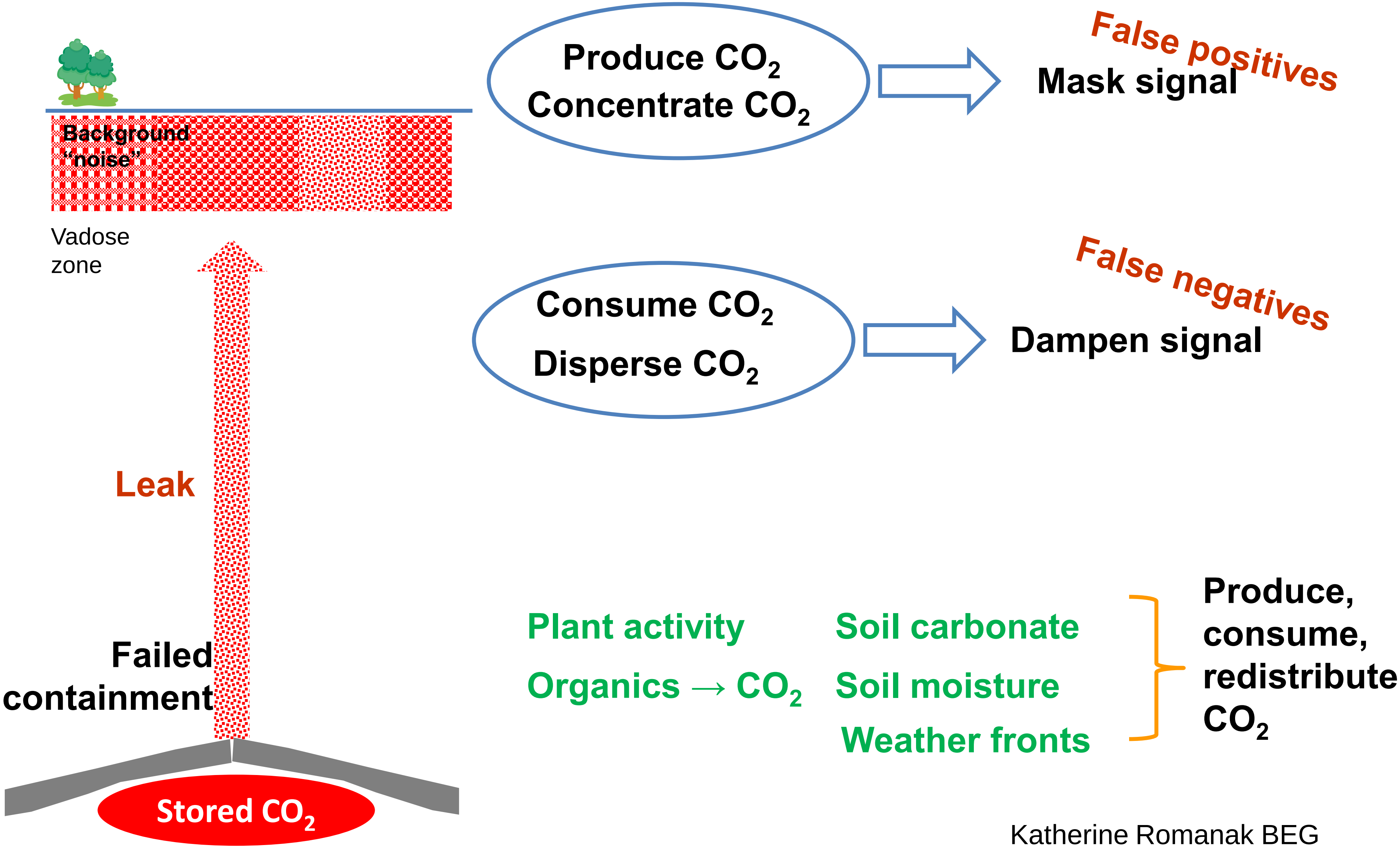
Changbing Yang, BEG (AWWA)

Vadose Zone Monitoring via Process Accounting



Katherine Romanak BEG

Challenges to Near-Surface Monitoring



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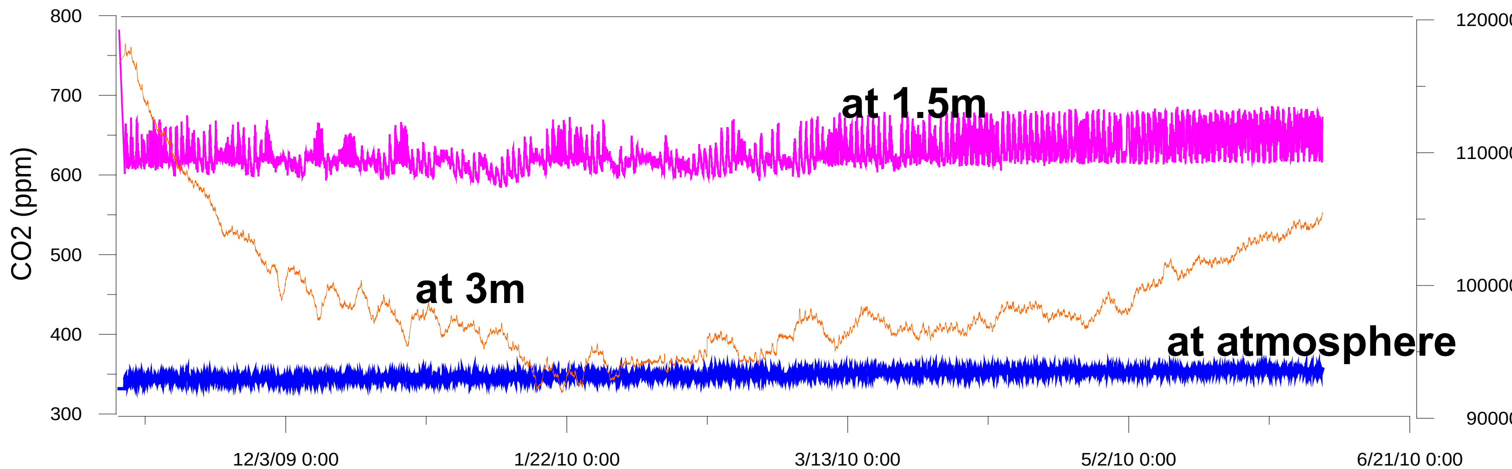
CO_2 concentrations at different depths

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

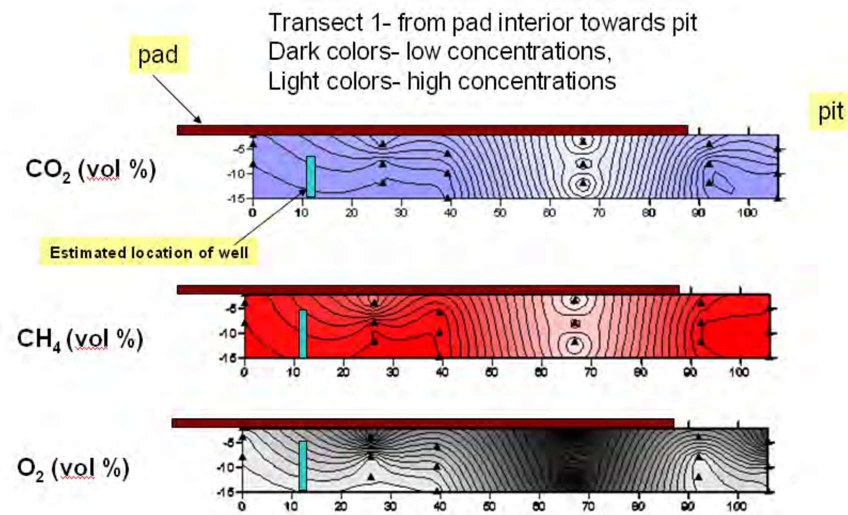
Soil gas composition - Unique leakage signal

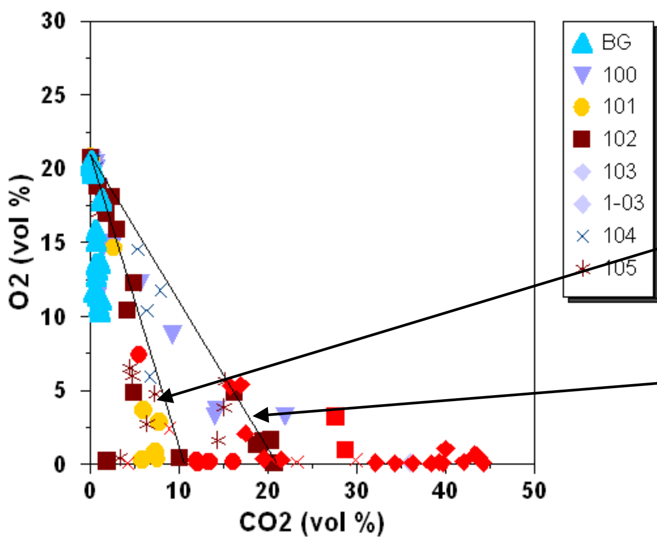
$CH_4 \leq 34$ vol. %

N_2 42-85%

O_2 2- 21%

$CO_2 \leq 45$ 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

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

Bibliography

Please see www.gulfcoastcarbon.org "bookshelf"

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

Gulf Coast Carbon Center

LBNL
LLNL
ORNL
NETL
SNL
Mississippi State U
U of Mississippi
SECARB
UT-PGE
UT Chem-E
CFSES- BES

UT- CIEEP
UT- DoGS
UT- LBJ school
BEG- CEE
JSG – EER
Univ. Edinburgh
Univ. Durham
RITE
CO2-CRC

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