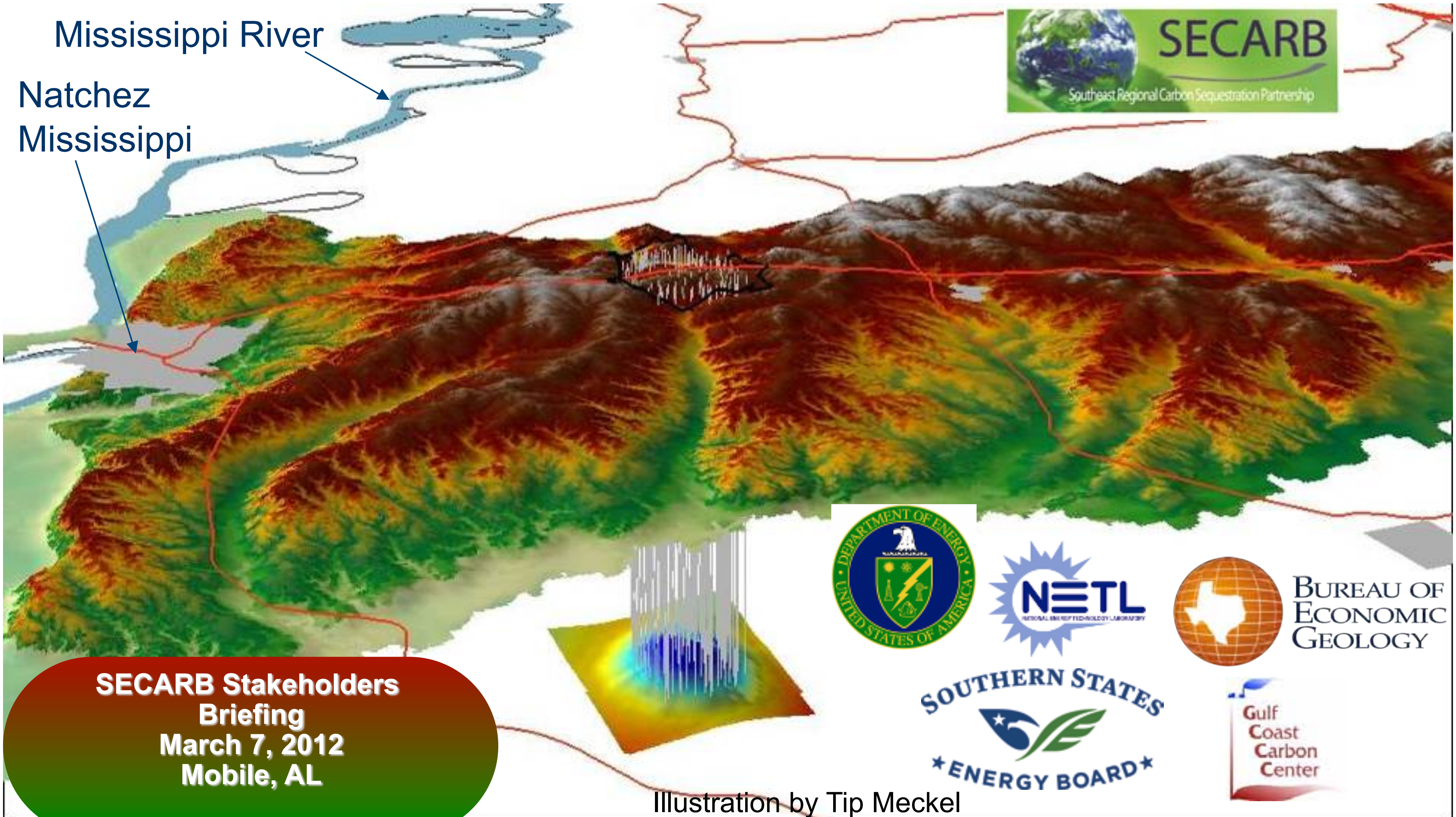
Progress Update SECARB " Early" Test Monitoring 3.5 Million Tons at Cranfield



SECARB Stakeholders Briefing
March 7, 2012
Mobile, AL

Illustration by Tip Meckel

SECARB Southeast Regional Carbon Sequestration Partnership

Bureau of Economic Geology

Southern States Energy Board

Gulf Coast Carbon Center

Panel Overview

- Overview and updates – Susan Hovorka
  - Organization, design, status
  - Update – Modeling and pressure response
  - Update – geochemistry in reservoir and AZMI
  - Technical and public knowledge-sharing
  - Future opportunities - CCUS
- Update on Geophysics and lab activities– Tom Daley
- Update on near surface monitoring – Katherine Romanak

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Funding agency

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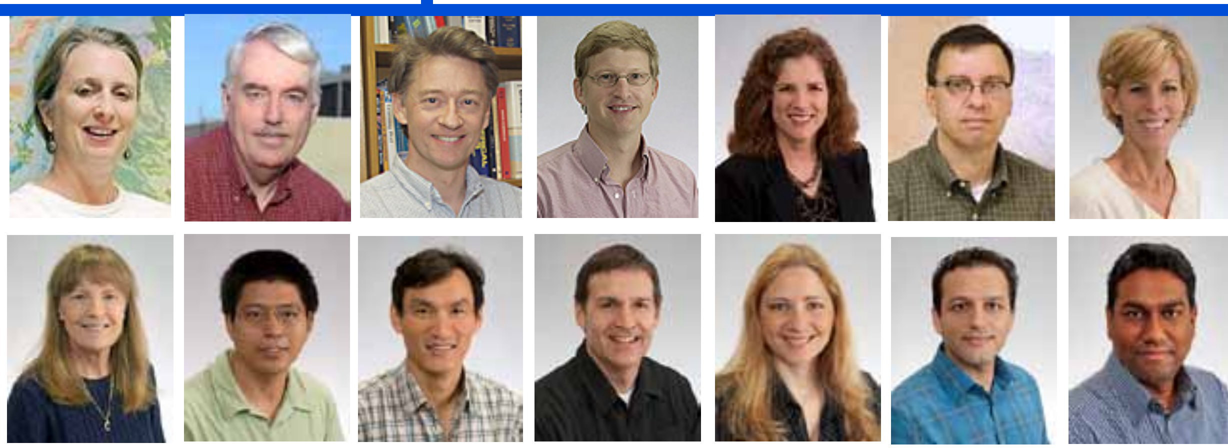
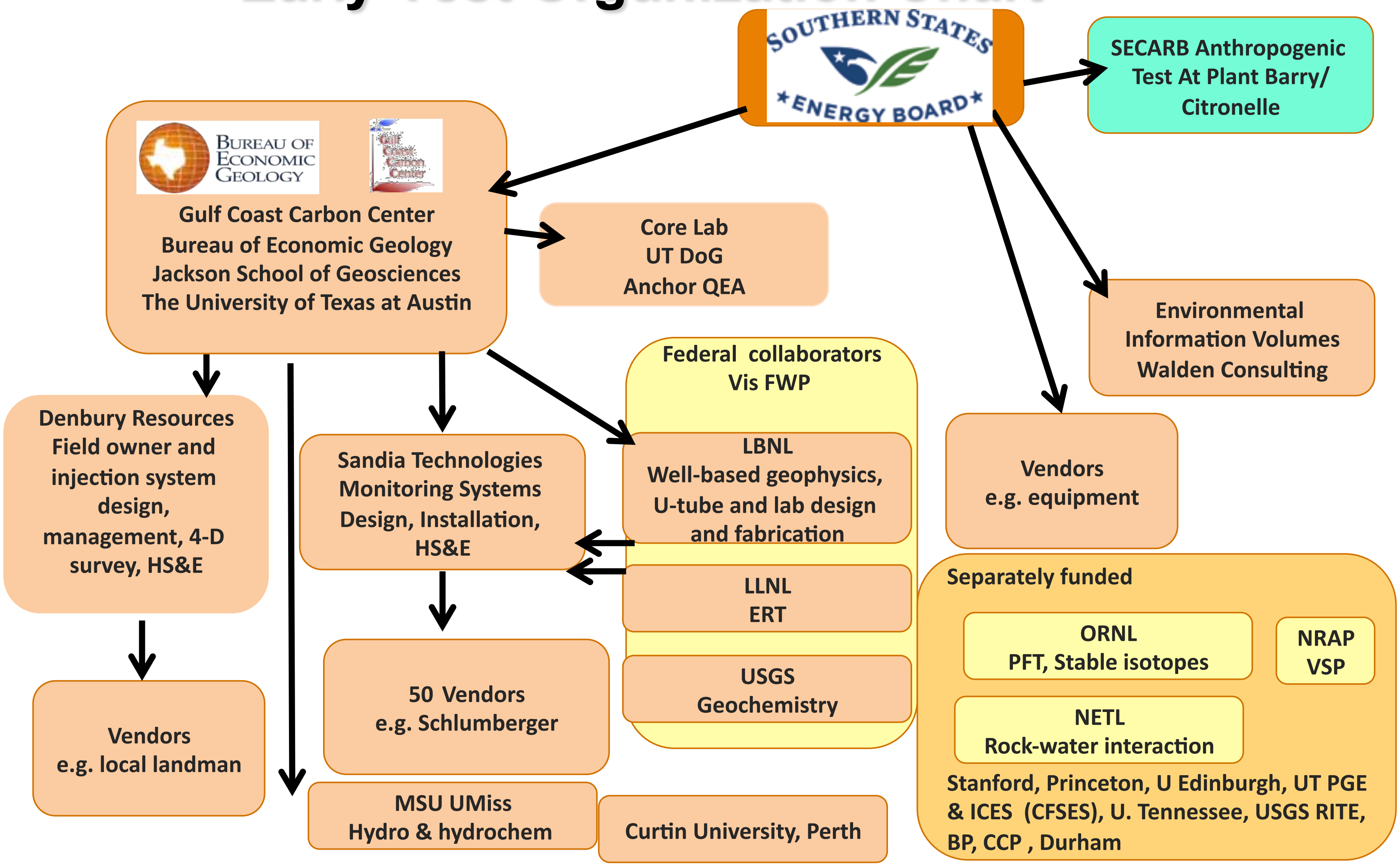
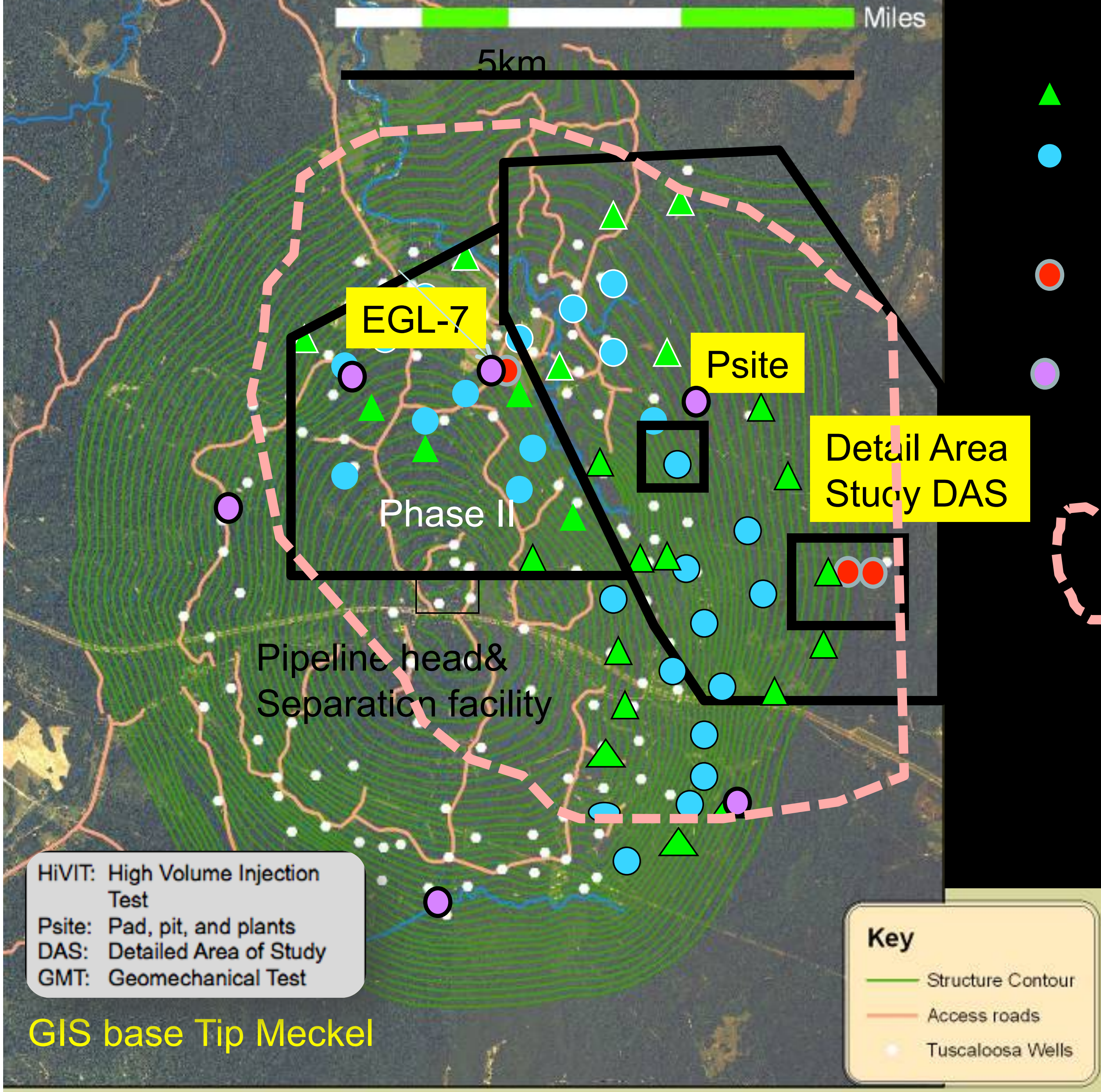


Early Test Organization Chart





Injector

Producer (monitoring point)

Observation Well

RITE Microseismic

4-D seismic

Bureau of Economic Geology

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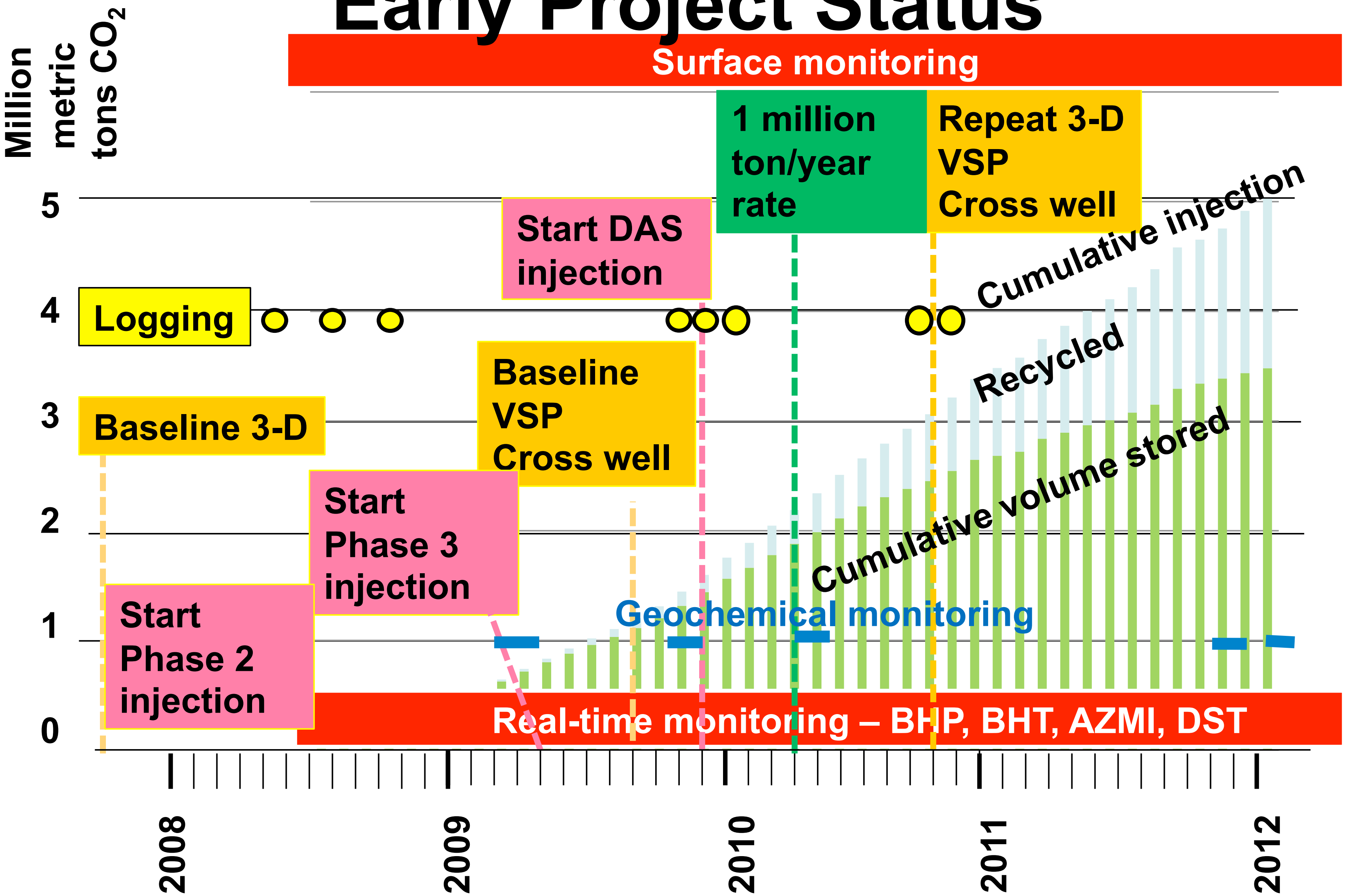
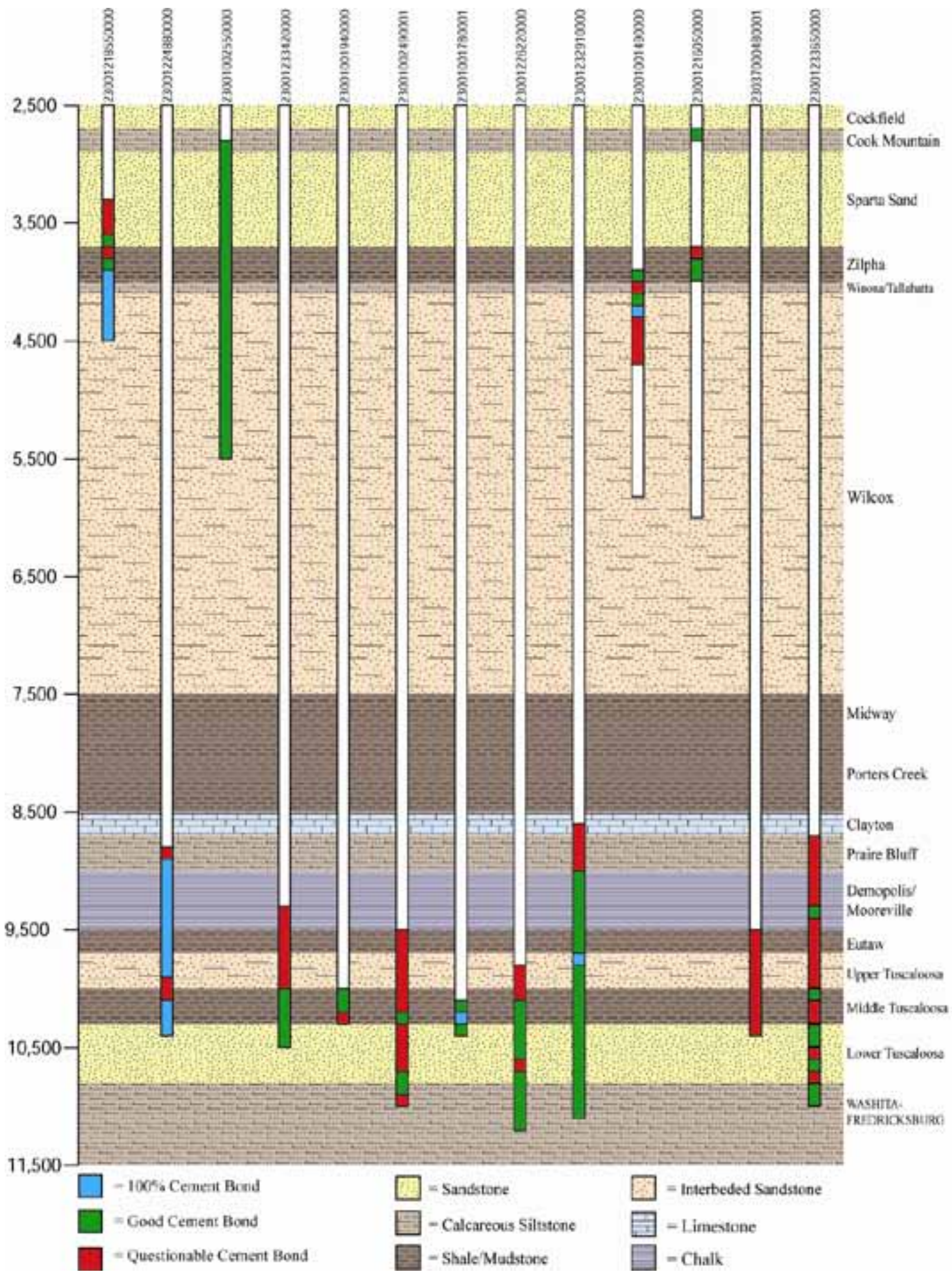
Early Project Status



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.

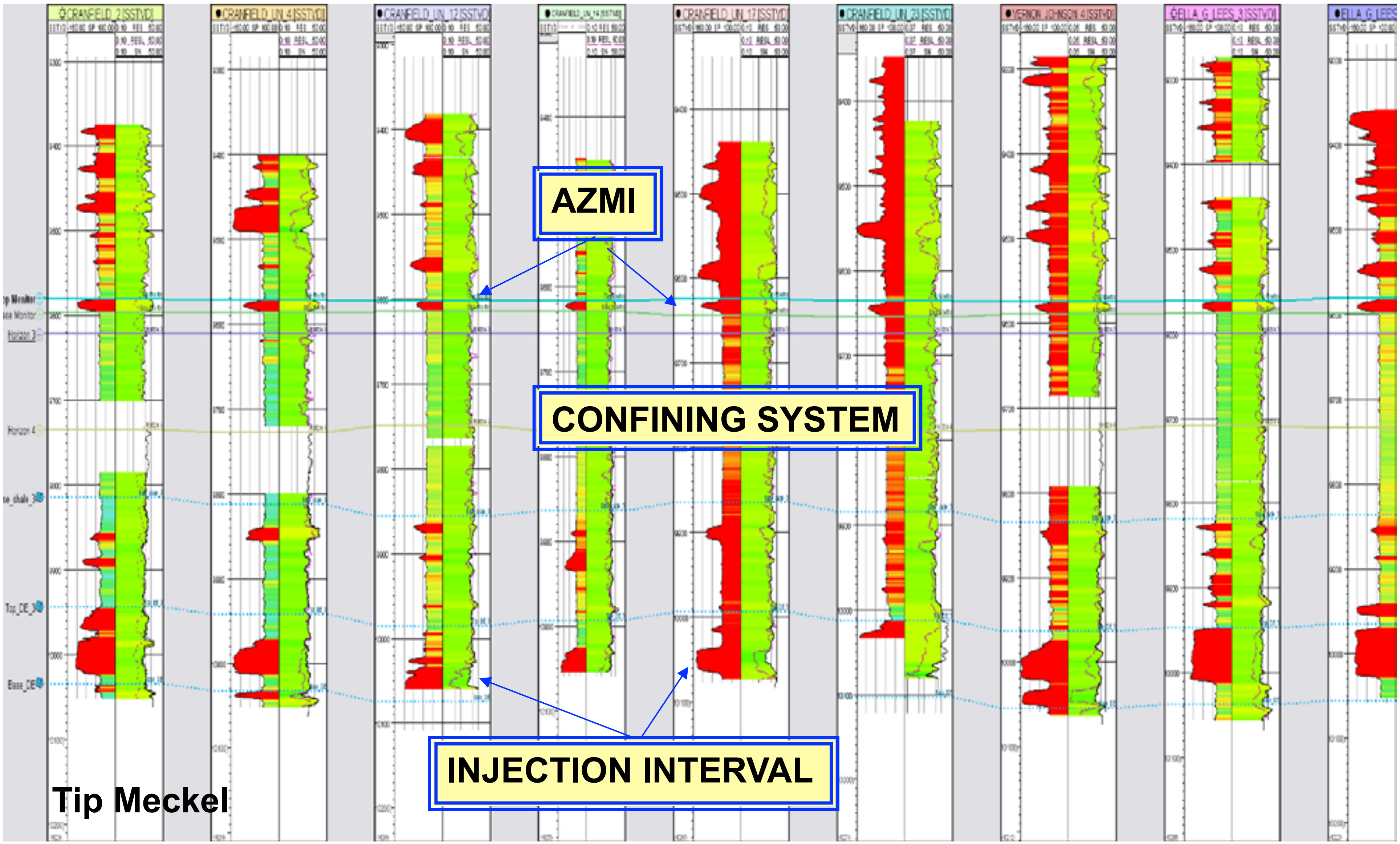
- Assessment of leakage risk.
  - Well performance is highest uncertainty and focus of monitoring research
- Conformance of flood in the injection zone
  - Pressure
  - Plume confined by 4-way closure.
    - Uncertainty – amount of radial flow (down dip/out of pattern)
- Measure changes above the injection 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

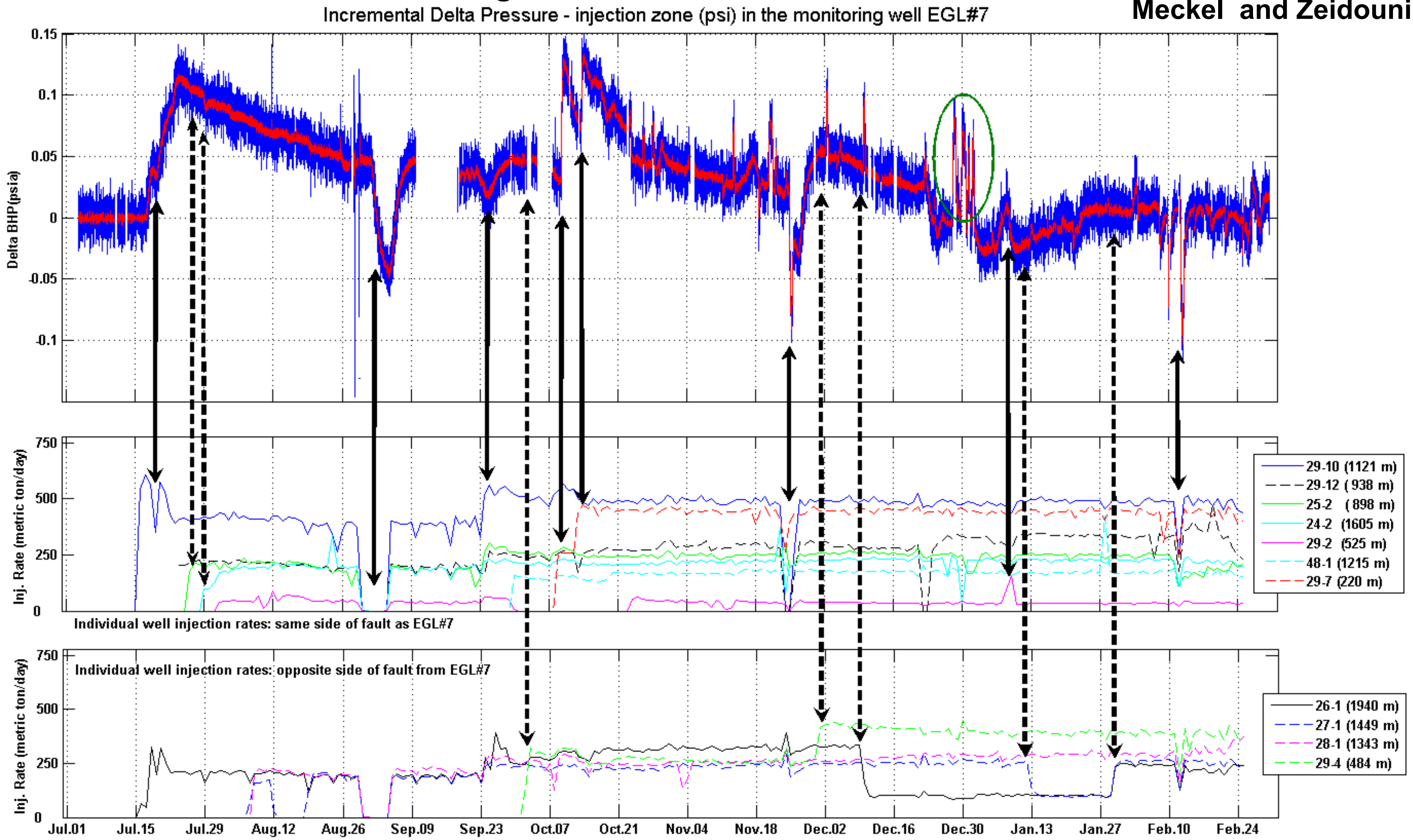
In-zone and AZMI pressure monitoring



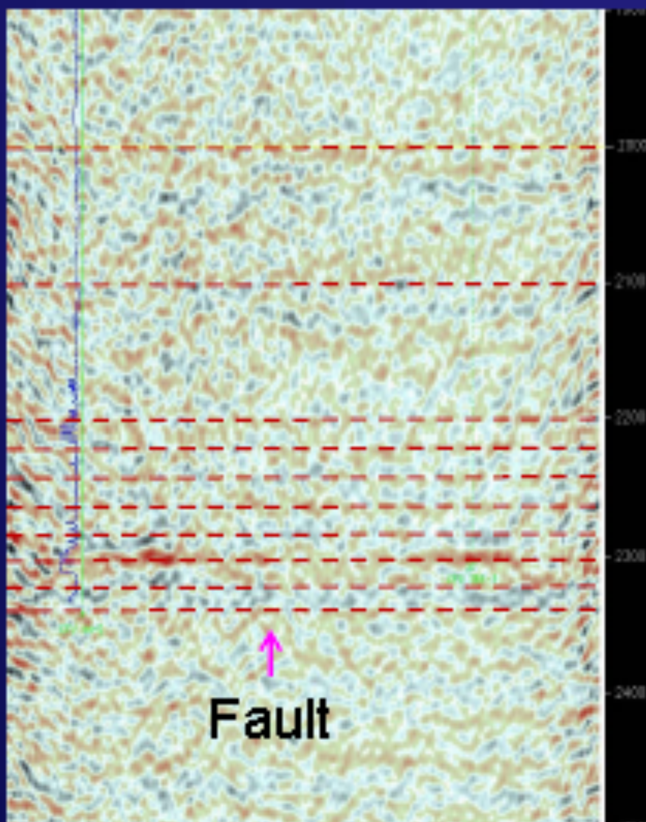
In Zone Continuous pressure data from dedicated monitoring well

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

Meckel and Zeidouni

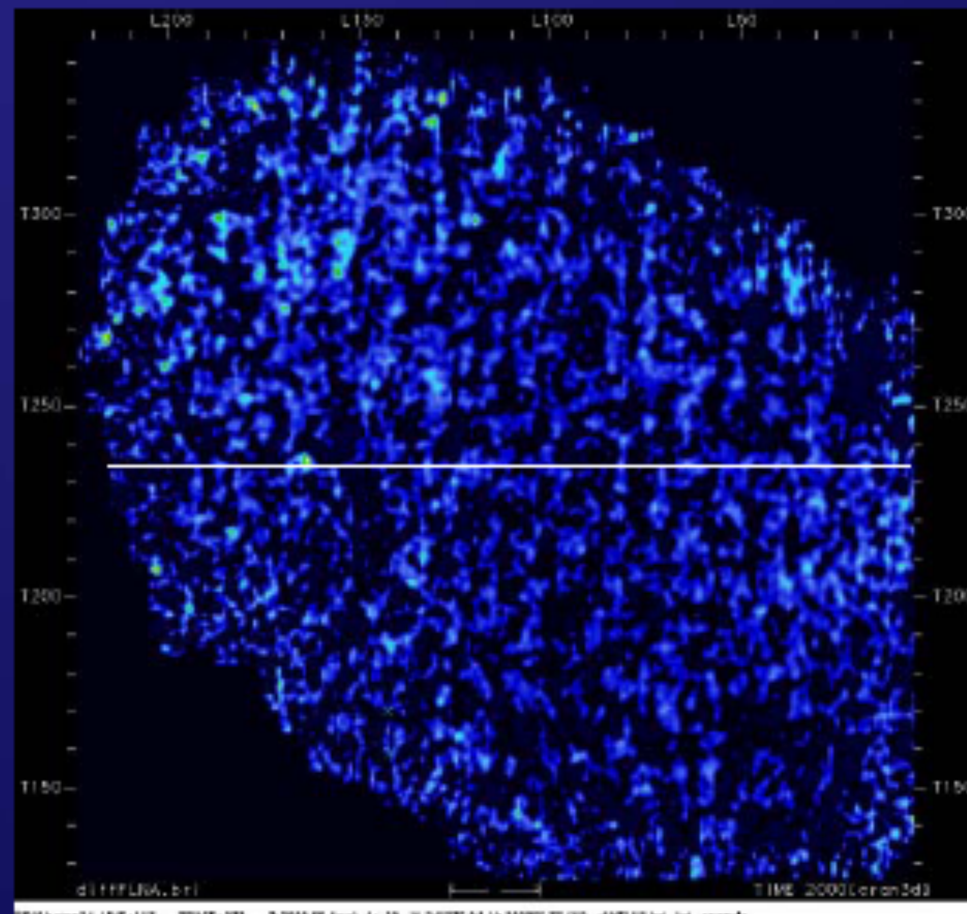


Stratal slices: there is no sign of leaking!

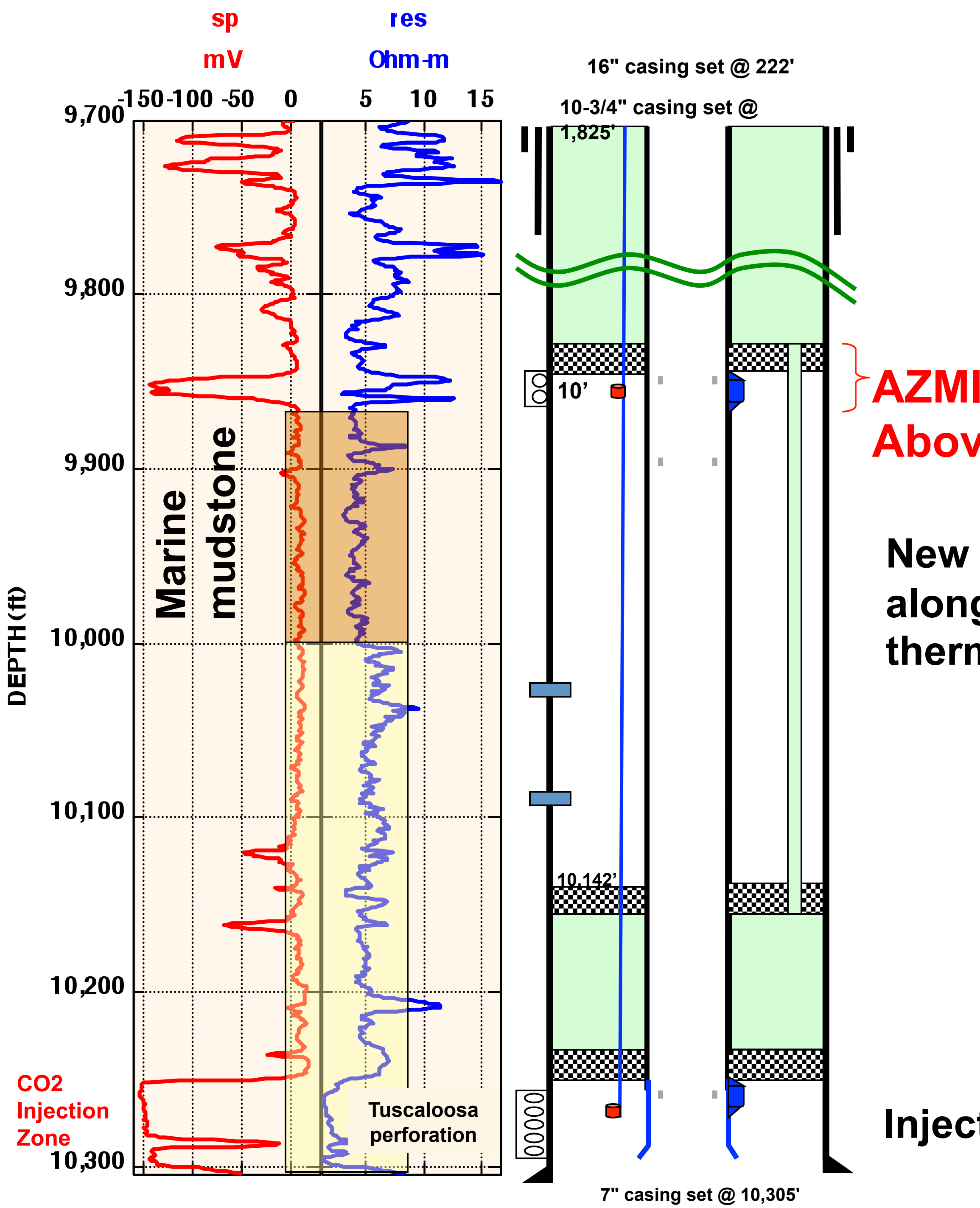


Cross-section flattened
Velocity difference

Velocity difference above zone



Initial result: Hongliu Zeng



Above Zone Monitoring Interval

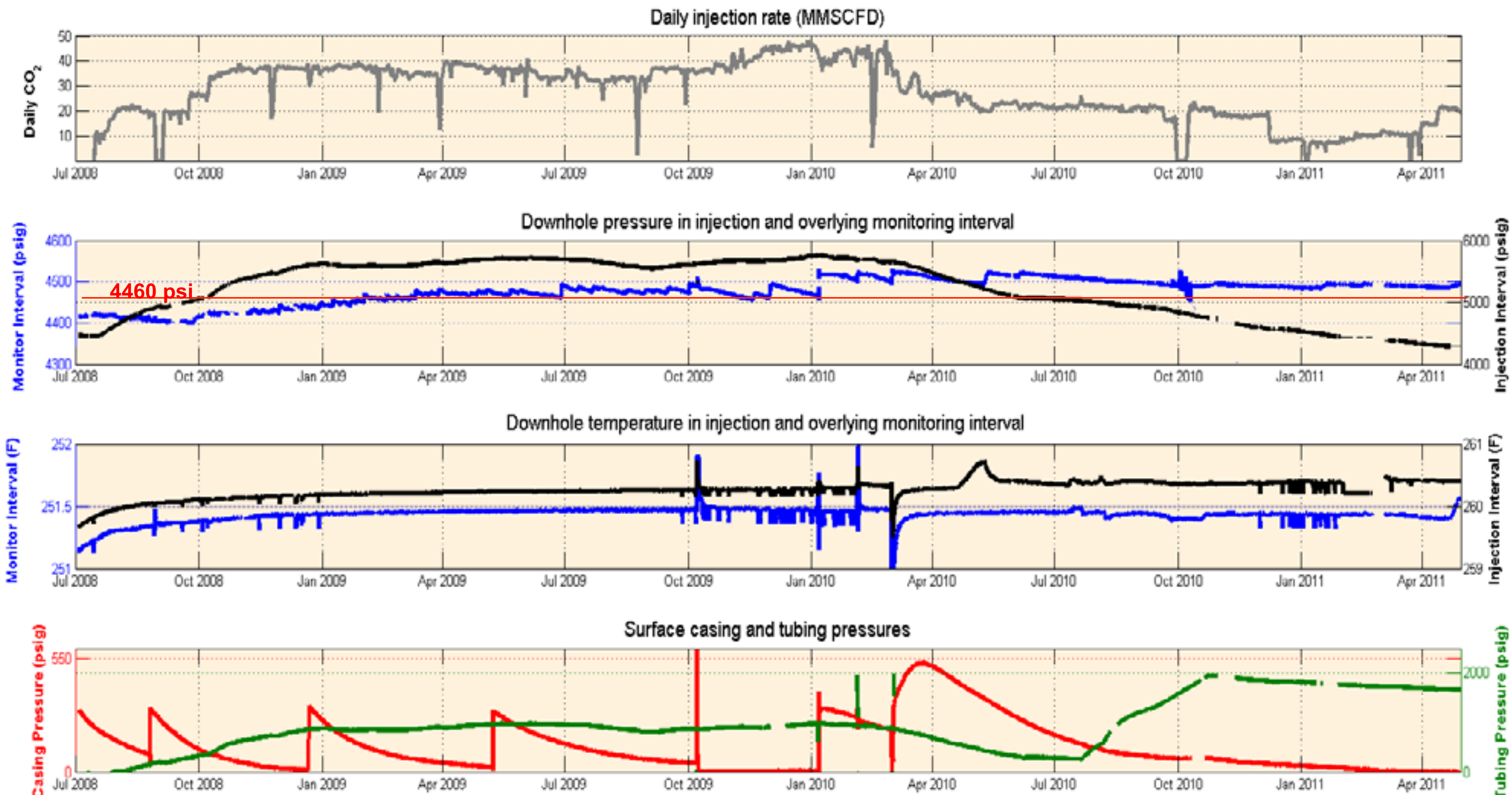
New analysis: Leakage not occurring along this well – integrated pressure-thermal analysis - Qing Tao UT PGE

Injection Zone

Tip Meckel

Continuous data series 3 years

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

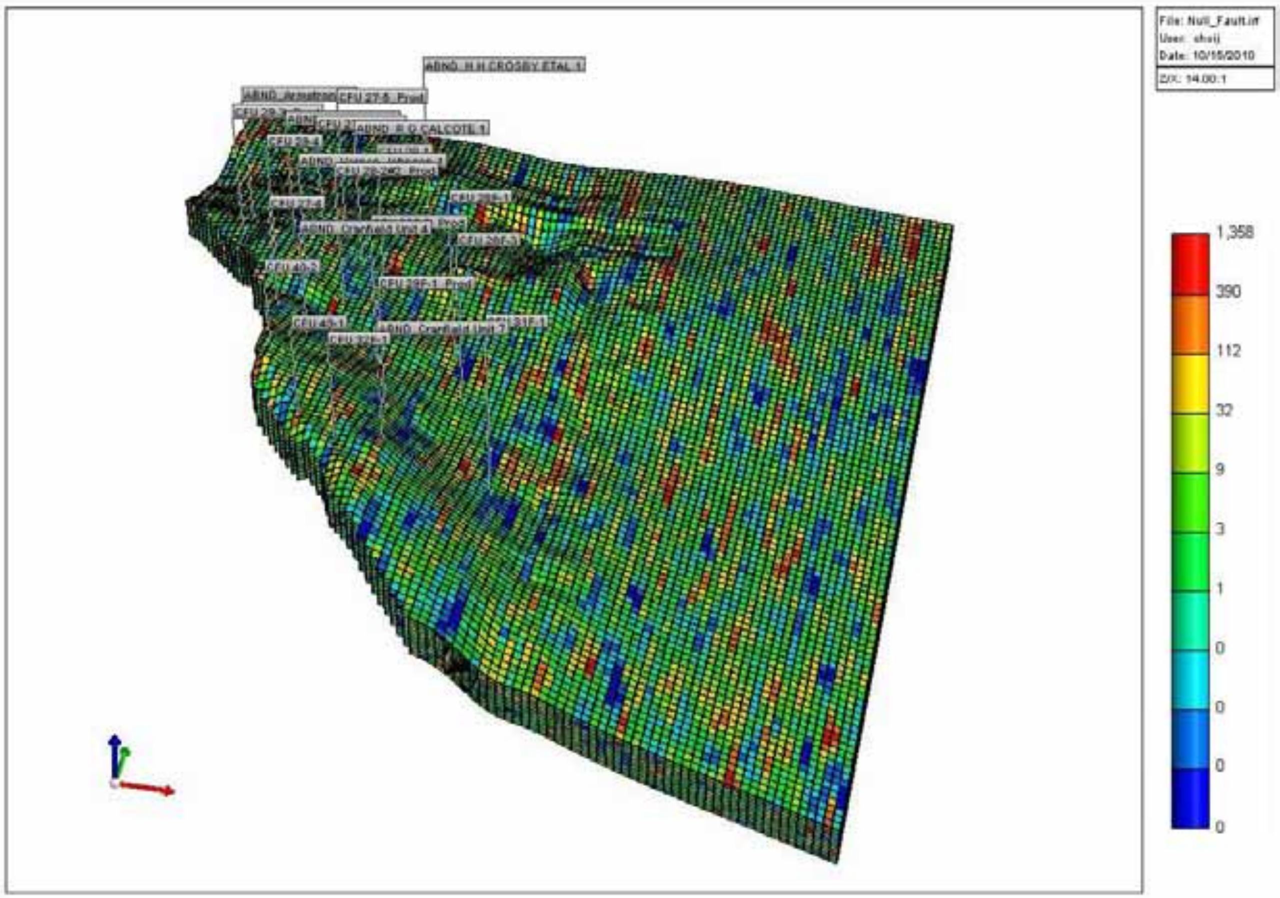


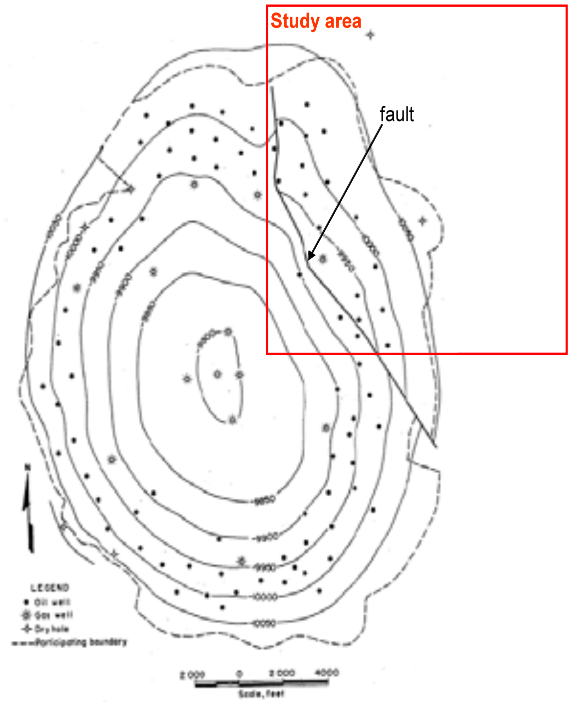
Tip Meckel

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 Simulation





Role of the mudrock during CO_2 injection

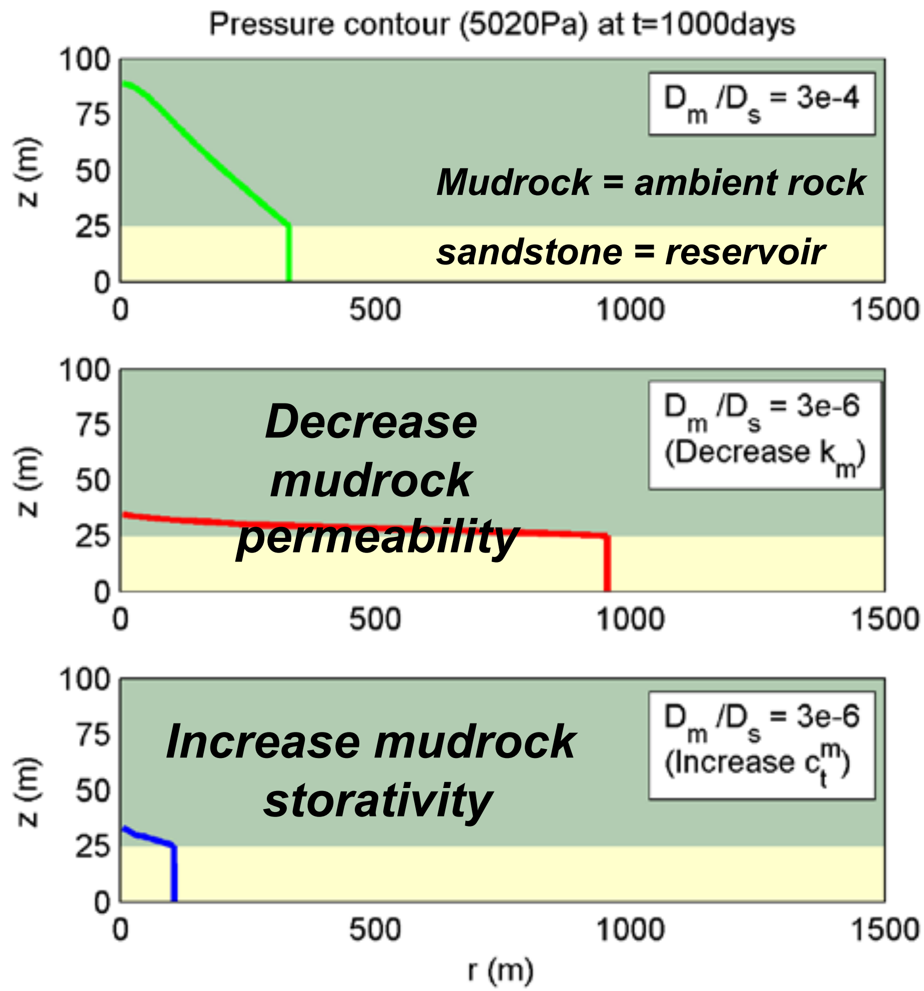
– Pressure propagation is governed by ratios of mudrock/ sandstone

permeability and storativity

– Permeable and compressible

surrounding rock reduces pressure propagation within a reservoir

♪

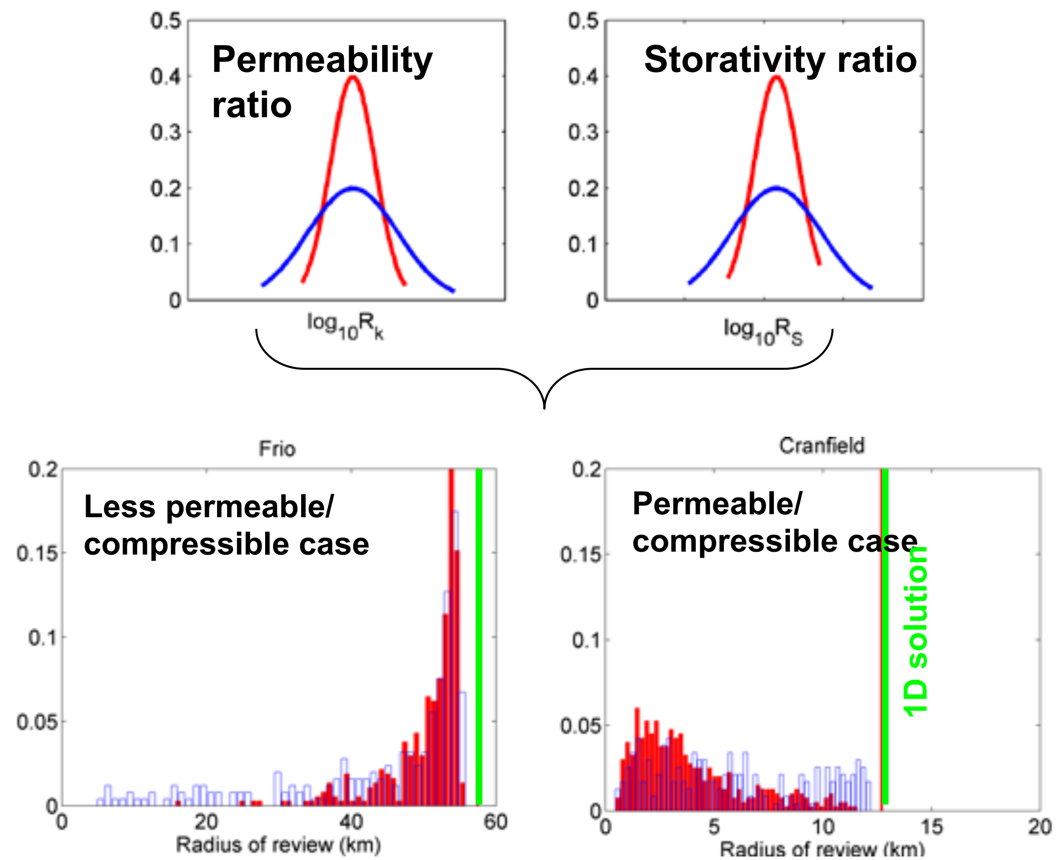


Kyungwon Chang UT DoGS

Continued…

- **Area of Review (Area of pressure increase):**
  - Compressible/ permeable mudrock may reduce the radius of review
  - The uncertainty in mudrock properties leads to large variance in radius of review

♪



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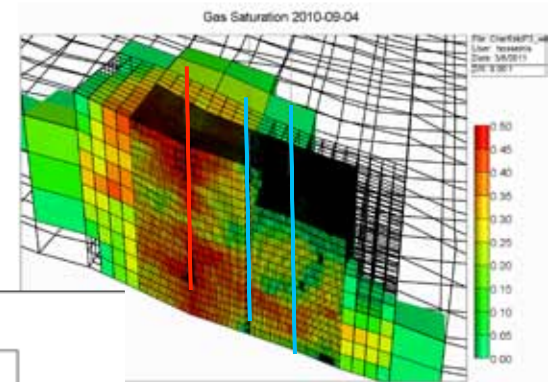
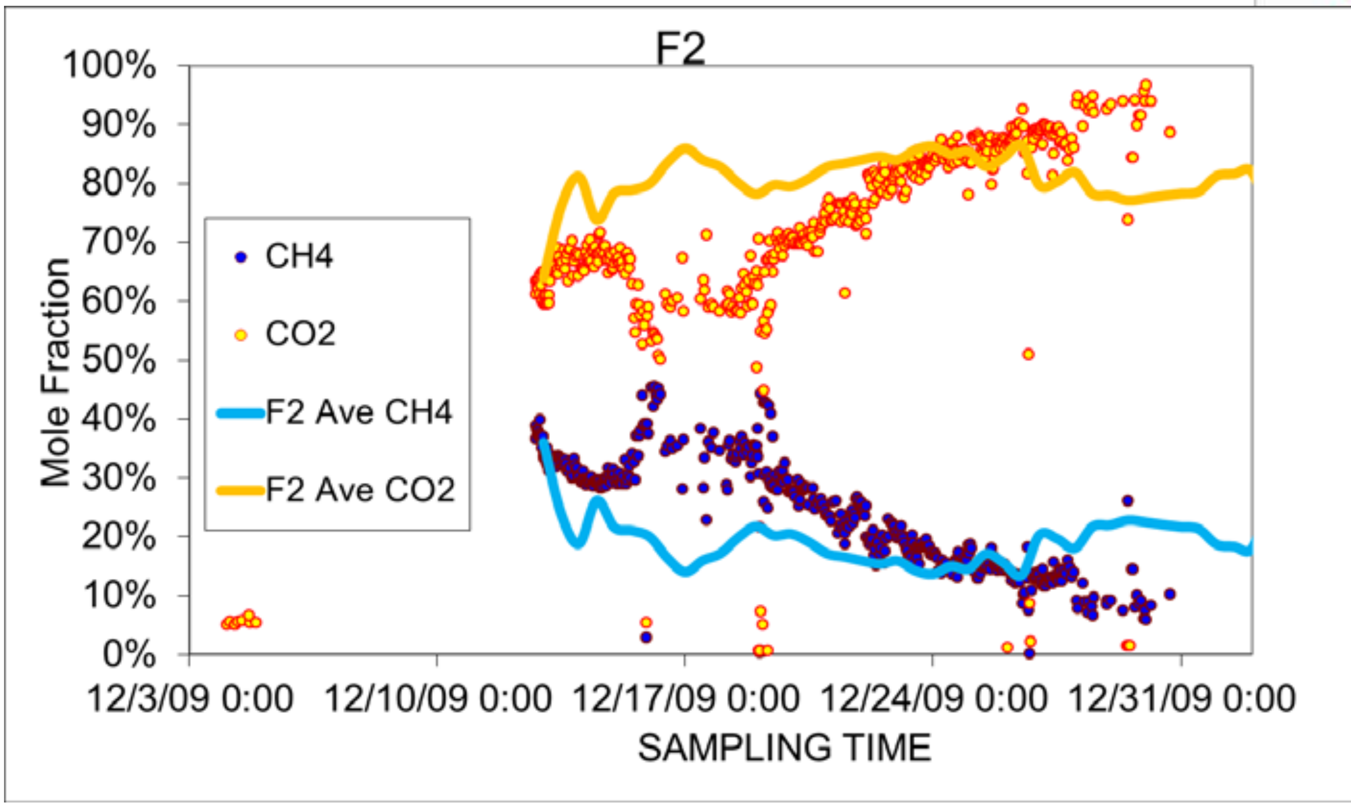
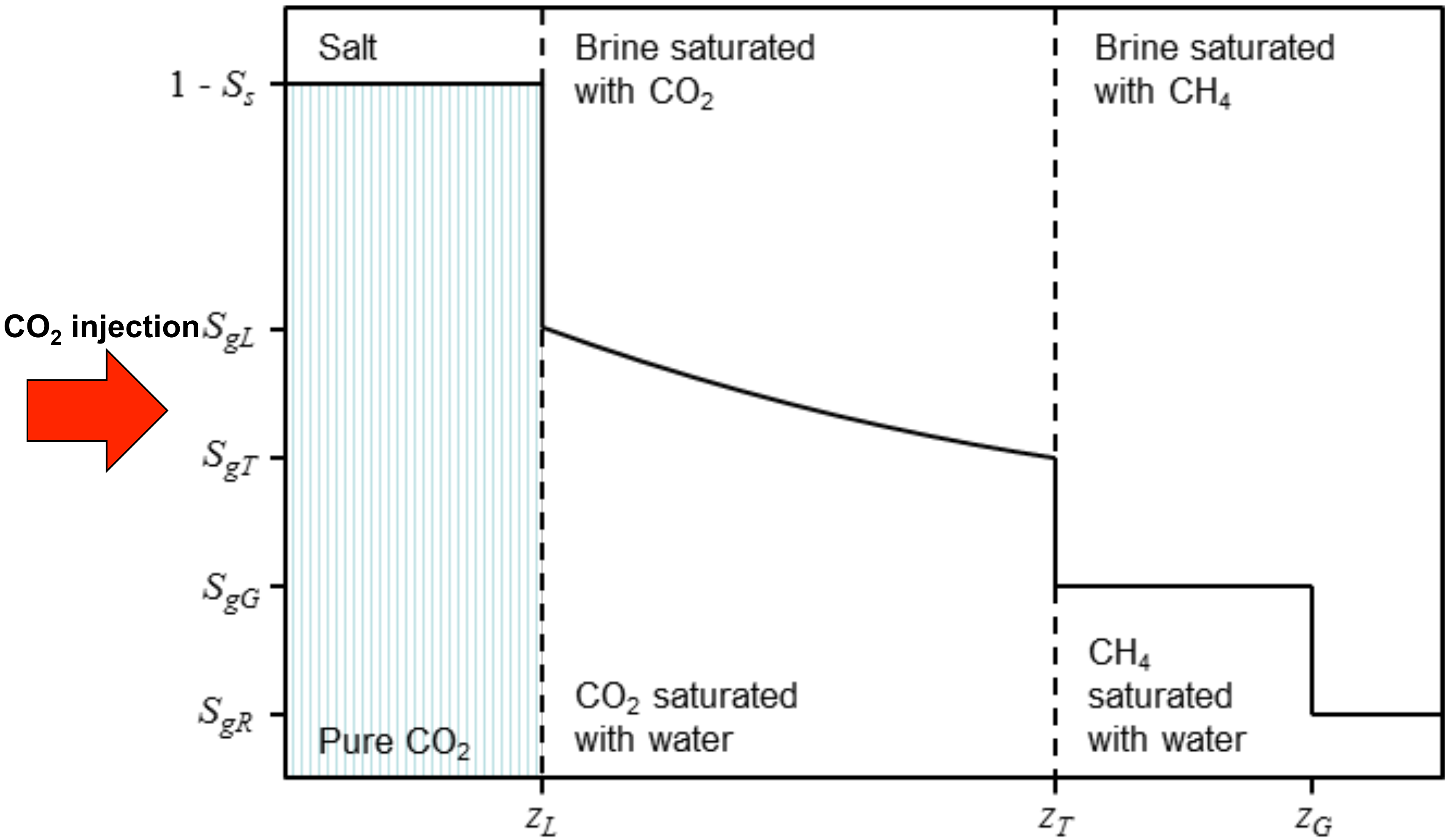
Residual methane effect on AOR and plume size





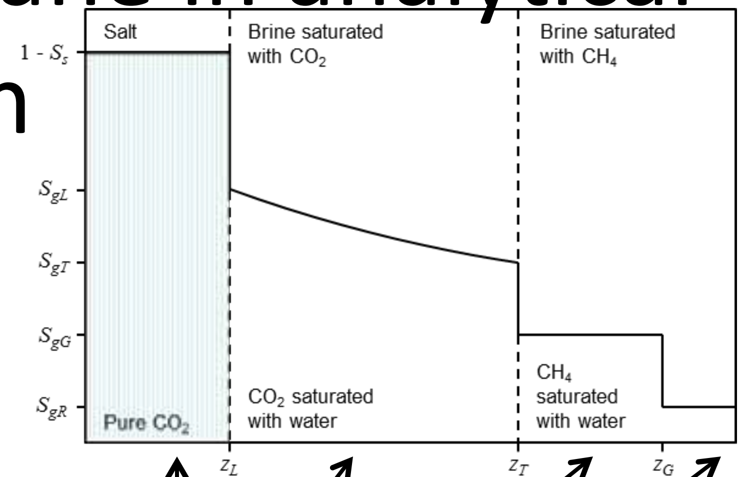
, U-tube-team; Seyyed Hosseini,

Significance of Methane Outgassing



Simon Matthias, Univ. Durham; Seyyed Hosseini, BEG

Effect of residual methane in analytical solution



- **Reduction of relative permeability**

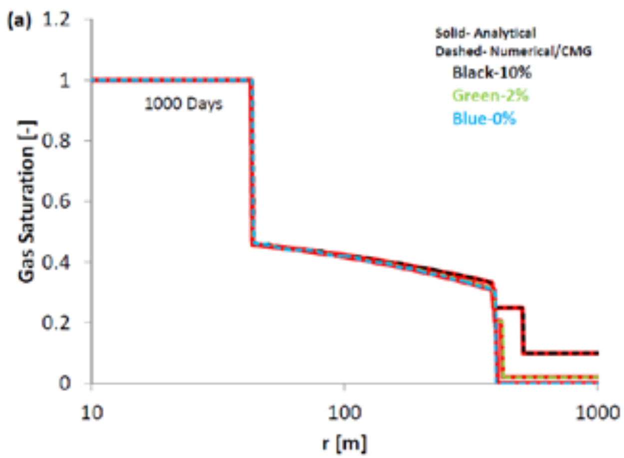
$$P - P_0 = \frac{M_0}{4\pi\rho_c H k}\begin{cases} \frac{\mu_c}{k_{rs}}\ln\left(\frac{z_T}{z}\right) + \mu_g q_{D2} F_3(z_T) + \mu_m q_{D3} F_2(z_L) + \frac{\mu_b q_{D3}}{k_{rb0}} F_1(z_G), & 0 \le z < z_T \\ \mu_g q_{D2} F_3(z) + \mu_m q_{D3} F_2(z_L) + \frac{\mu_b q_{D3}}{k_{rb0}} F_1(z_G), & z_T \le z \le z_L \\ \mu_m q_{D3} F_2(z) + \frac{\mu_b q_{D3}}{k_{rb0}} F_1(z_G), & z_L < z \le z_G \\ \frac{\mu_b q_{D3}}{k_{rb0}} F_1(z), & z > z_G \end{cases} \tag{49}$$

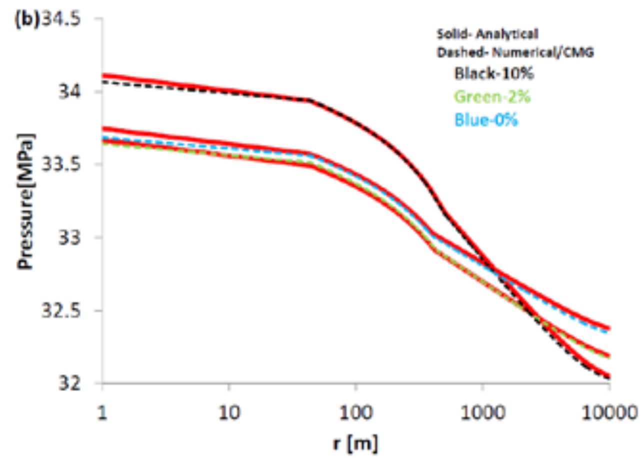
$$\alpha = \frac{M_0 \mu_b (c_r + (1 - S_{g3}) c_b + S_{g3} c_m)}{4\pi H \rho_c k}, \quad z_E = \frac{\pi\phi\rho_c H r_E^2}{M_0 t} \tag{53}$$

- **Increase of compressibility**

Simon Matthias, Univ. Durham;
Seyyed Hosseini, BEG

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

Knowledge Sharing

- UT Energy Forum
- UT Law School Continuing Education
- CSLF – Recognition of SECARB Early Test
- 10th Annual CCS conference (Pittsburg)
- IEA Monitoring network
- Trondheim CCS Conference
- Pew Center Accounting Framework
- Canadian Standards Association (CSA) carbon sequestration standards development
- CO2CARE – EU -post-closure research
- BIG CCS – Norwegian University Research program
- CCP Contingency Workshop
- EPA/LBNL Geologic Sequestration and Water workshop
- AEP Mountaineer – Geologic Expert Team
- Review EPA guidance documents
- UT CCS1
- STORE and SECARB-Ed training
- 29 Publications www.gulfcoastcarbon.org bookshelf
- Thesis and dissertations: 2 completed; 3underway

Future work

- Long-term monitoring- AZMI, groundwater, soil gas
- Complete cross- tool comparison
- Support other experiments
  - LBNL - CO_2 geothermal
  - RITE - microseismic
  - Schlumberger cement analysis
  - Univ. Edinburgh noble gas study
  - SIM-SEQ
- Possible CCUS activities

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

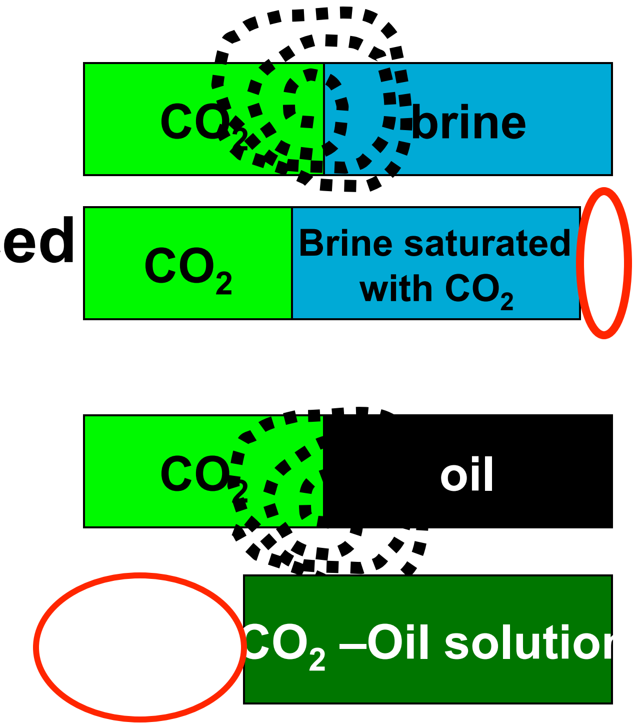
CCUS – EOR in brownfield

- 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

Role of Dissolution in Plume and Pressure Evolution CCS/CCUS

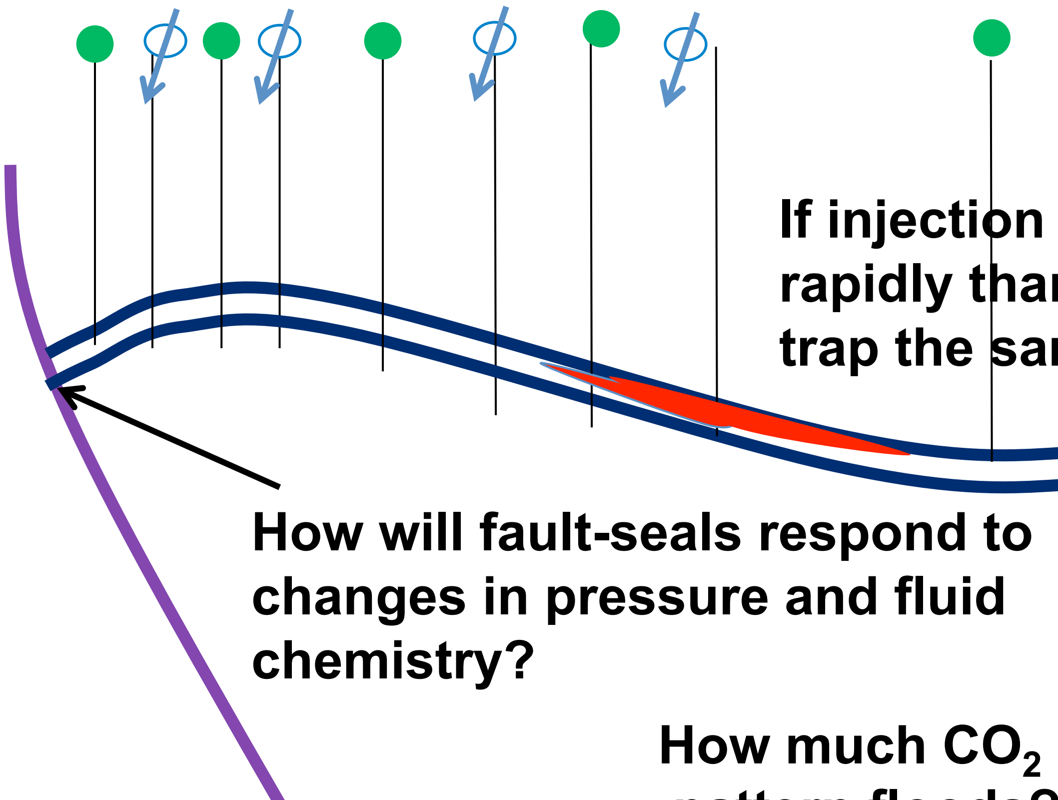
CO_2 injected into brine:
Minor dissolution: volume displaced 4% less than volume injected

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?