CO_2 Storage, Monitoring, Verification and Accounting

Vanessa Nuñez-Lopez

CO_2 for EOR as CCUS: Texas-Norway Symposium
Houston, Texas
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Bureau of Economic Geology

The University of Texas at Austin
John A. & Katherine G. Jackson School of Geosciences

Gulf Coast Carbon Center

Monitoring goals for carbon storage

Show that:

- Storage capacity and injectivity are sufficient
- CO_2 will be contained in the target formation
- Know aerial extent of the plume elevated pressure effects compatible with other uses
- Advance warning to allow mitigation if needed
- Public acceptance provide confidence in safe operation

Who requires an MMV plan?

In the US:

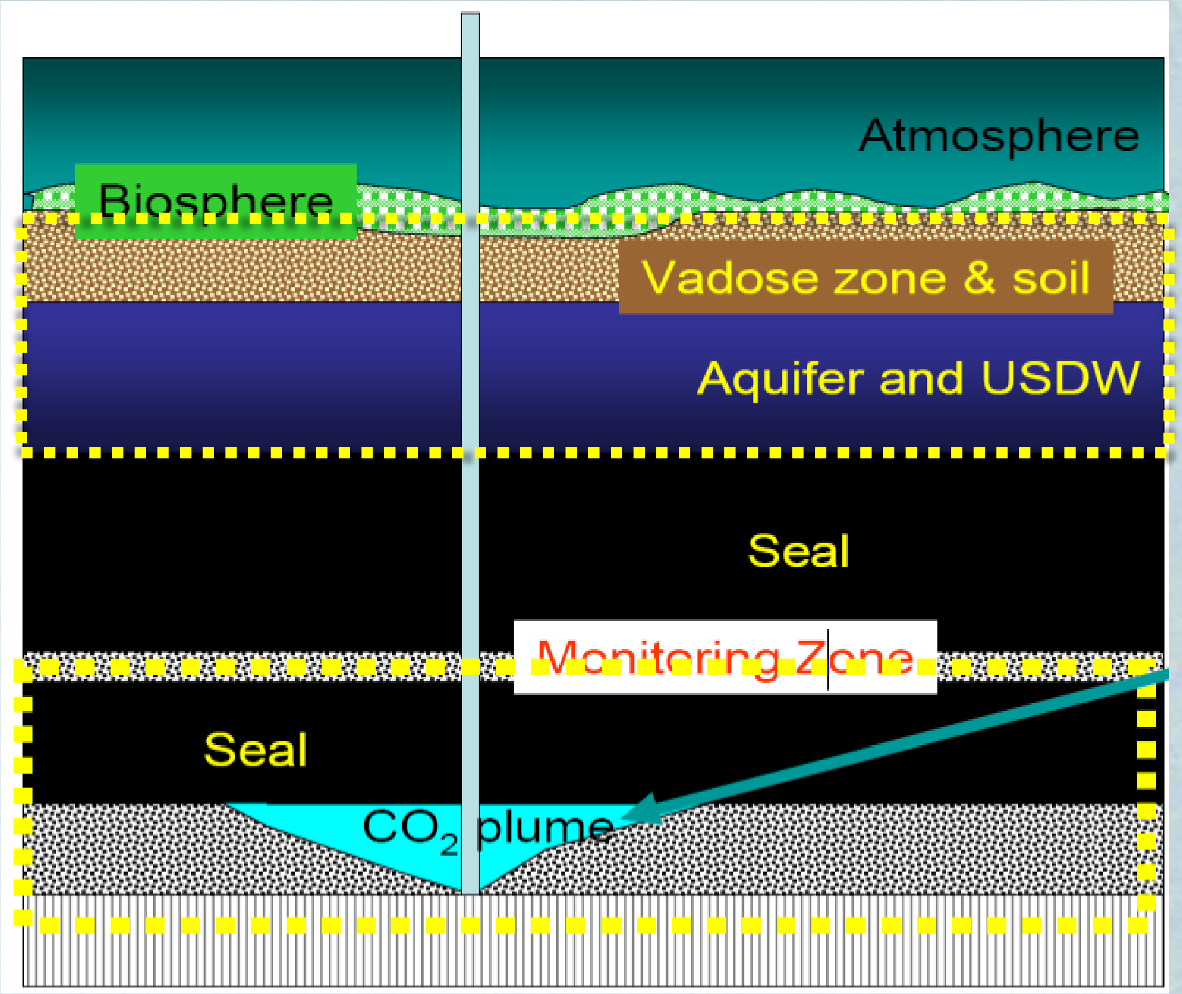
- The Federal GHG accounting regulations (under the Safe Drinking Water Act and the Clean Air Act)
- The U.S. Environmental Protection Agency (EPA) and the Underground Injection Control (UIC) program.

In the European Directive (2009/31/EC):

- Article 13: “Member States shall ensure that the operator carries out monitoring of the injection facilities, the storage complex (including where possible the CO2 plume), and where appropriate the surrounding environment…”

In Australia: *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth)

Where do we monitor?



Too complex

Dynamic

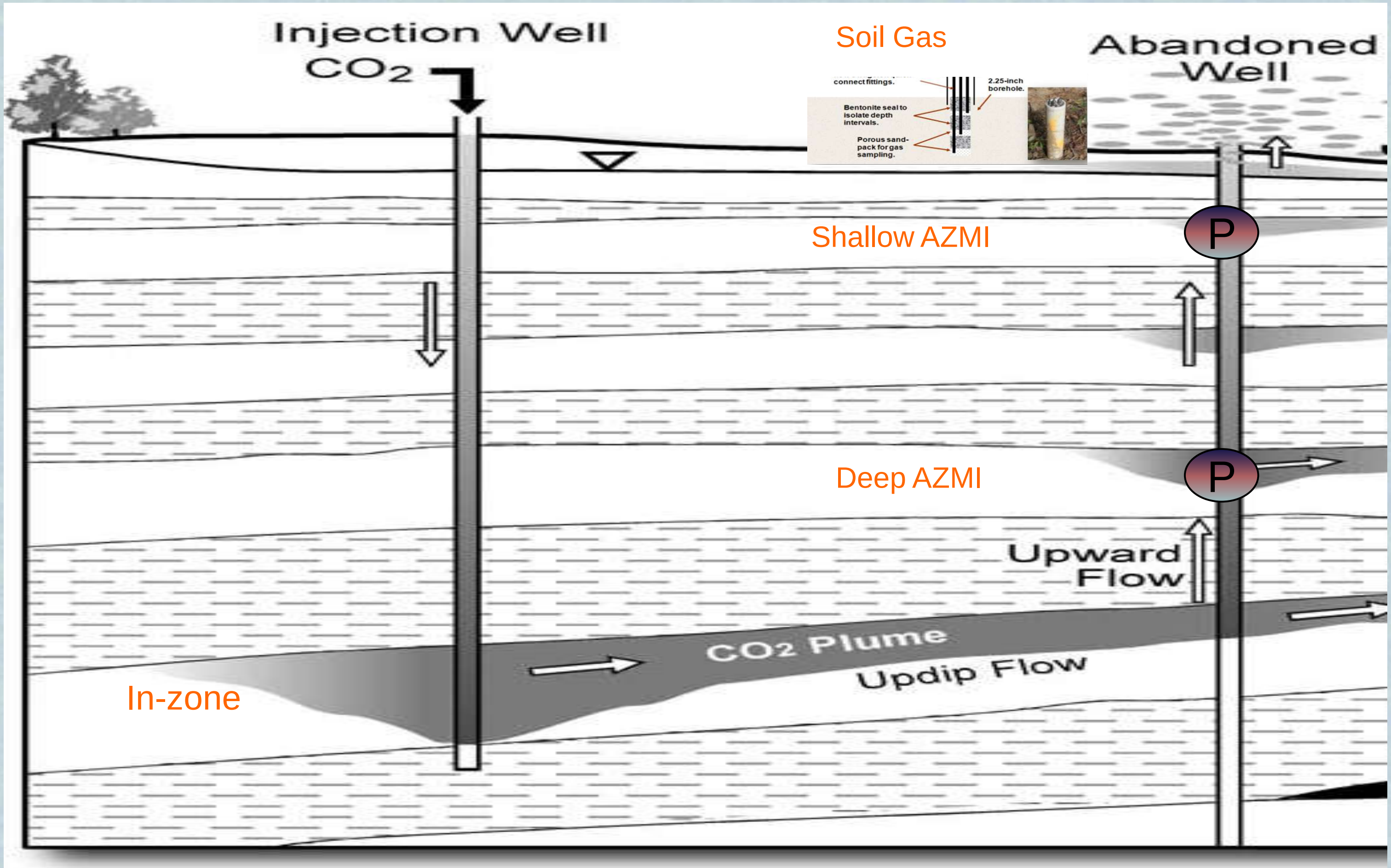
Stable
first
indicator

Standard oil
field
technologies

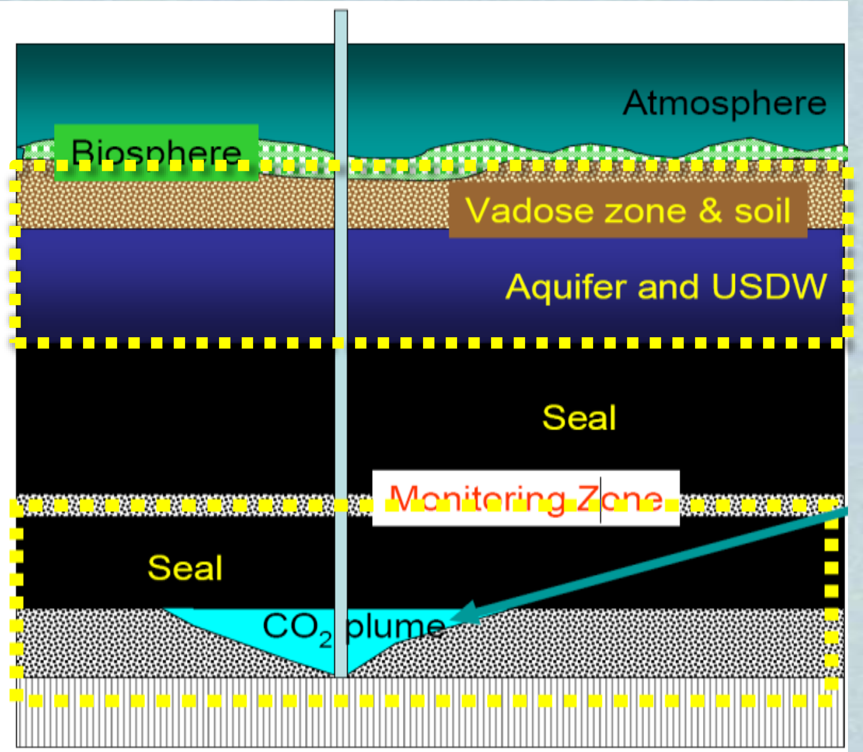
Geophysical monitoring methods

- Seismic Surveys: 2D, 3D, time-lapse 3D (4D)
- Vertical Seismic Profiles (VSP)
- Cross Well Seismic
- Well Logging
- Electrical Resistance Tomography (ERT)
- Others

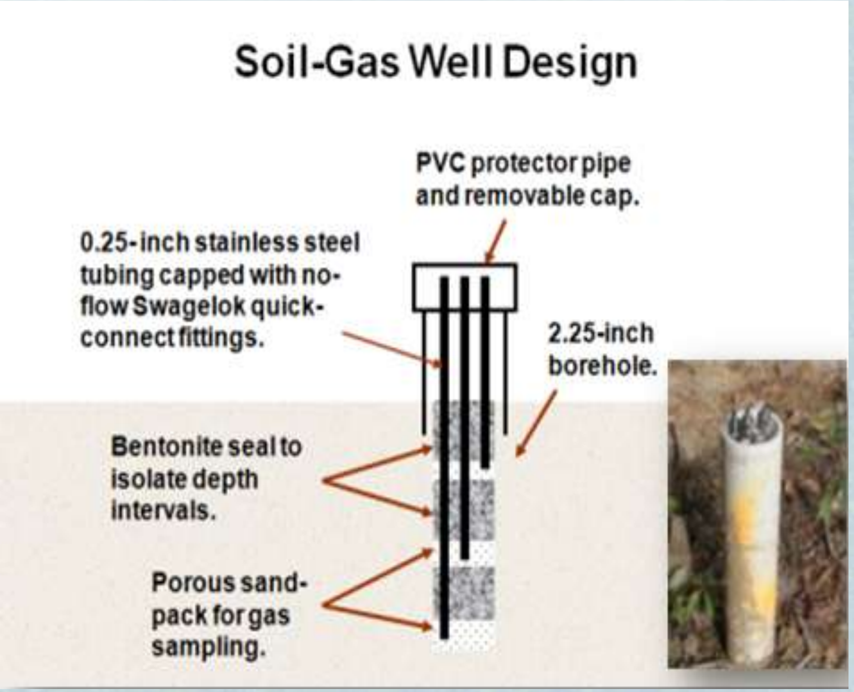
Pressure Monitoring



Groundwater and vadose zone monitoring



Characterization of groundwater before CO2 injection begins, followed by annual sampling.



Soil-gas monitoring

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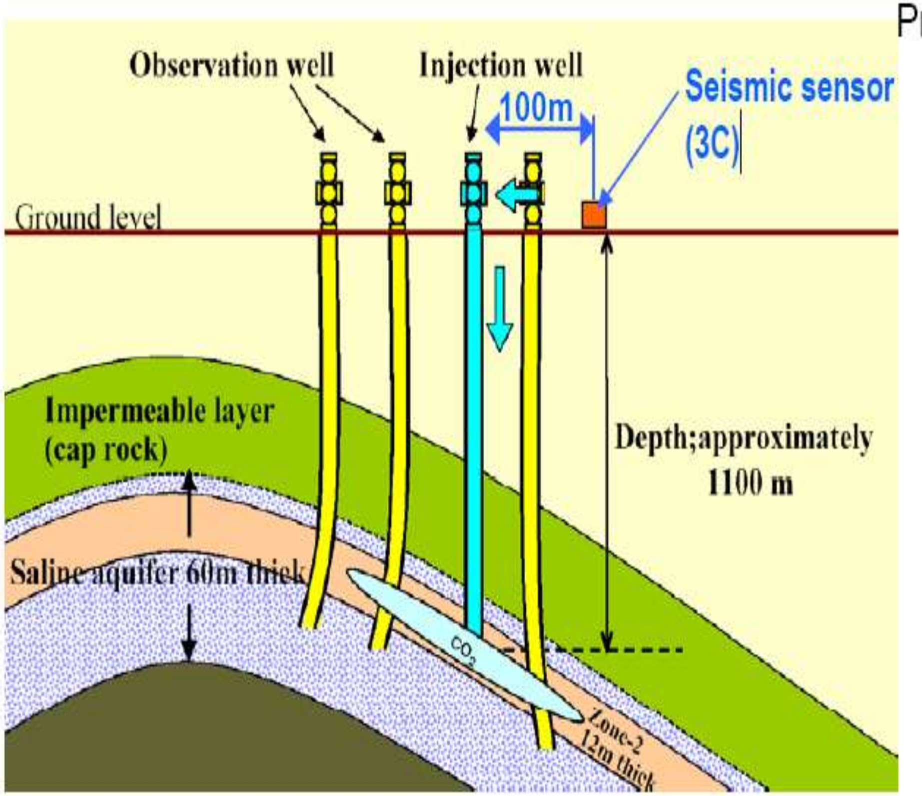
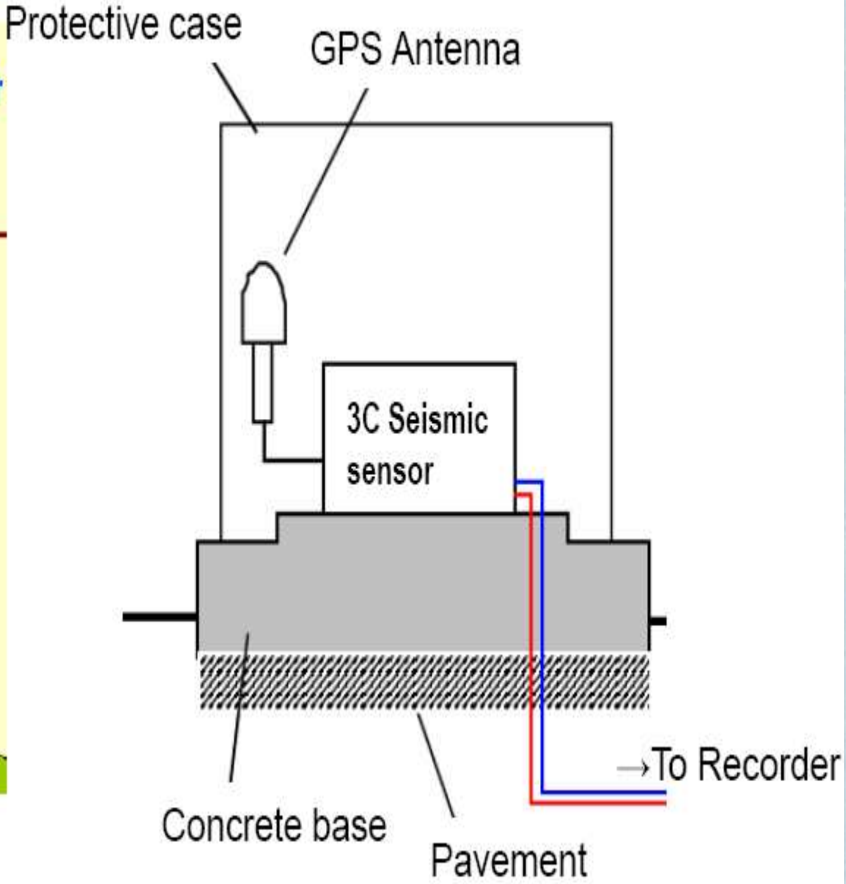
Surface deformation: space geodesy (GPS/InSAR)

- **Principle**: increased reservoir pressure from CO_2 injection may lead to measurable uplift; short term leakage may lead to subsidence.
- GPS (point positions, high temporal resolution) and InSAR (high spatial resolution, low temporal resolution) could provide a good combination for long term monitoring of sequestration sites.
- InSAR demonstrated for CCS at InSalah, Algeria (dry).
- InSAR not yet demonstrated for CCS in humid, vegetated areas.

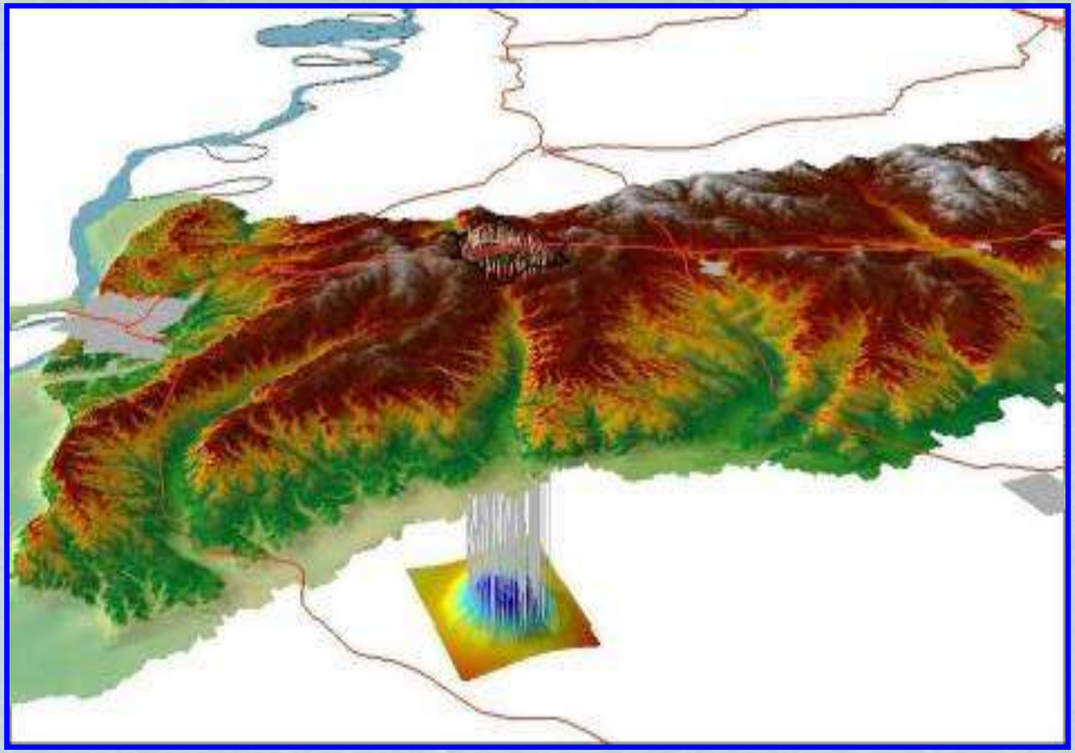
Microseismic: passive seismic monitoring





From RITE: Nagaoka Site

SECARB Phase III at Cranfield, Mississippi



Special Section dedicated to Cranfield in the October issue of the International Journal of Greenhouse Gas Control

http://www.sciencedirect.com/science/journal/17505836/18?utm_source=2013_10_22_Cranfield_Special_Issue_News_Flash&utm_campaign=GCCC-News-Flash_2013_10_28_CranfieldIssue&utm_medium=email

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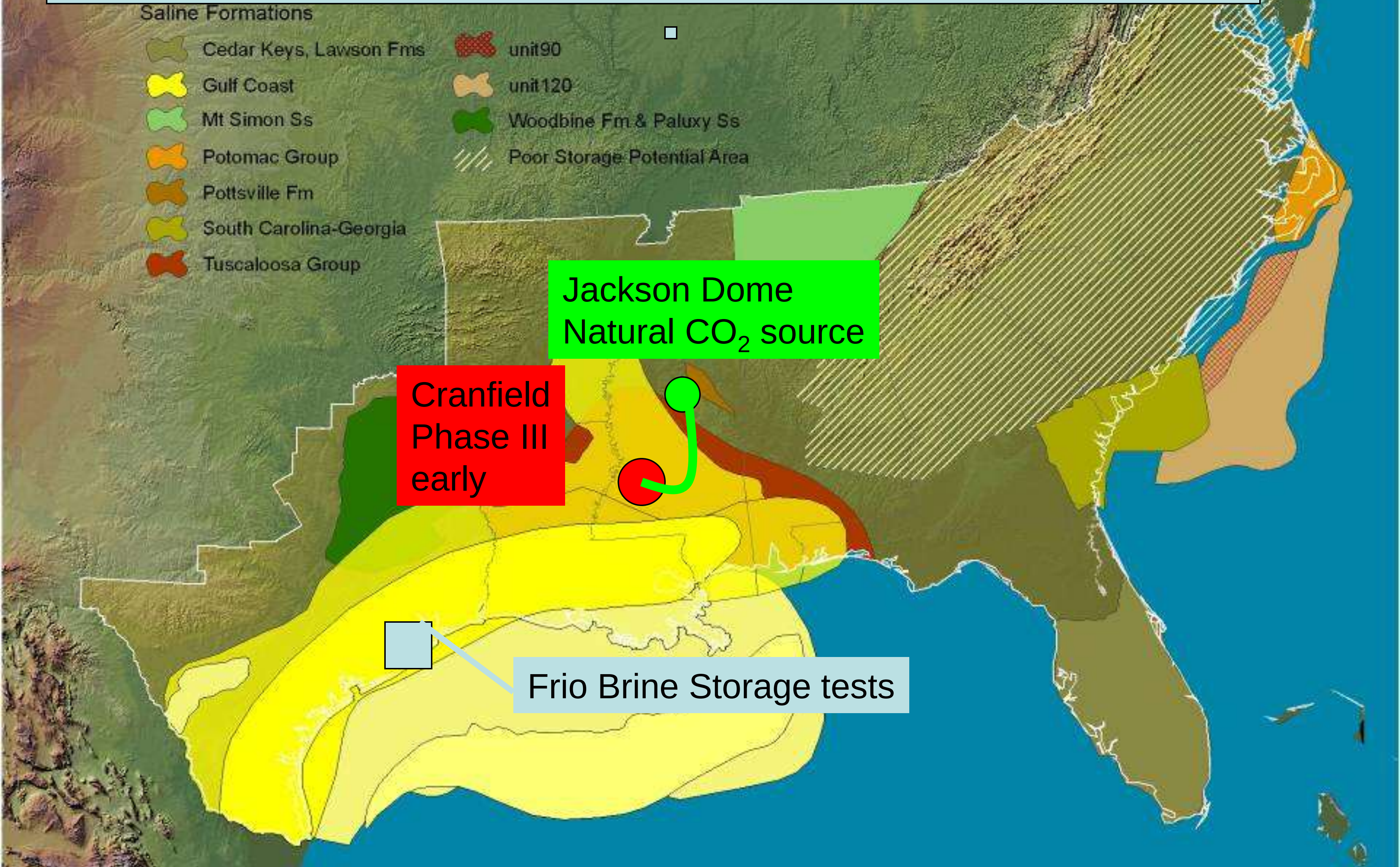
SECARB Test Site Location



Cranfield: goals and objectives

RCSP program goals:

- Predict storage capacities within +/- 30%
- Evaluate protocols to demonstrate that it is probable that 99% of CO_2 is retained

SECARB Cranfield "Early Test" goals:

- Obtain early results for the RCSP program
- Provide early information to policy makers

SECARB Cranfield "Early Test" technical objectives:

- Effective environmental assurance
- Predicting and monitoring the extent of CO_2 plume migration in the injection interval
- Predicting and monitoring the magnitude and extent of pressure increase

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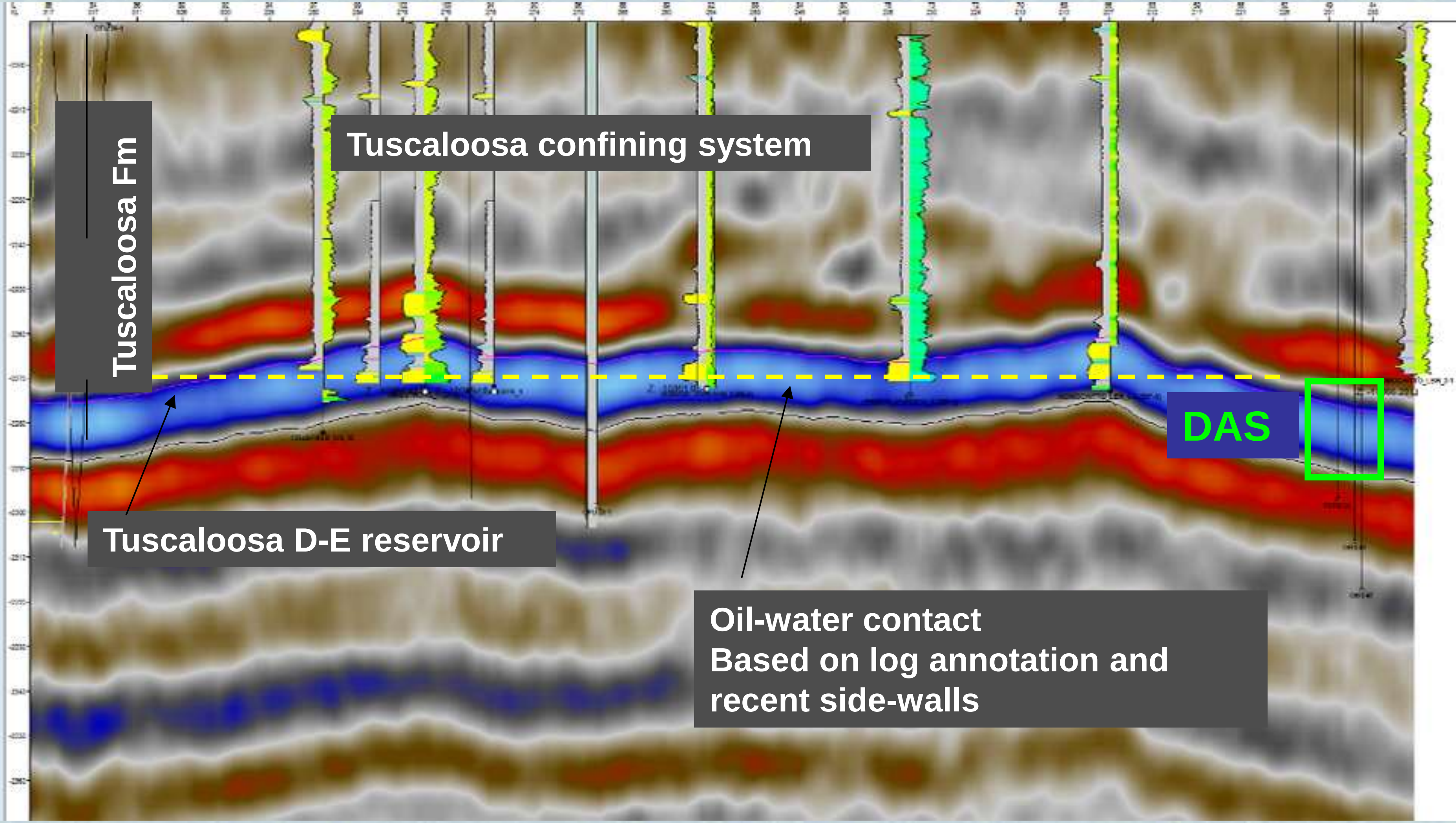
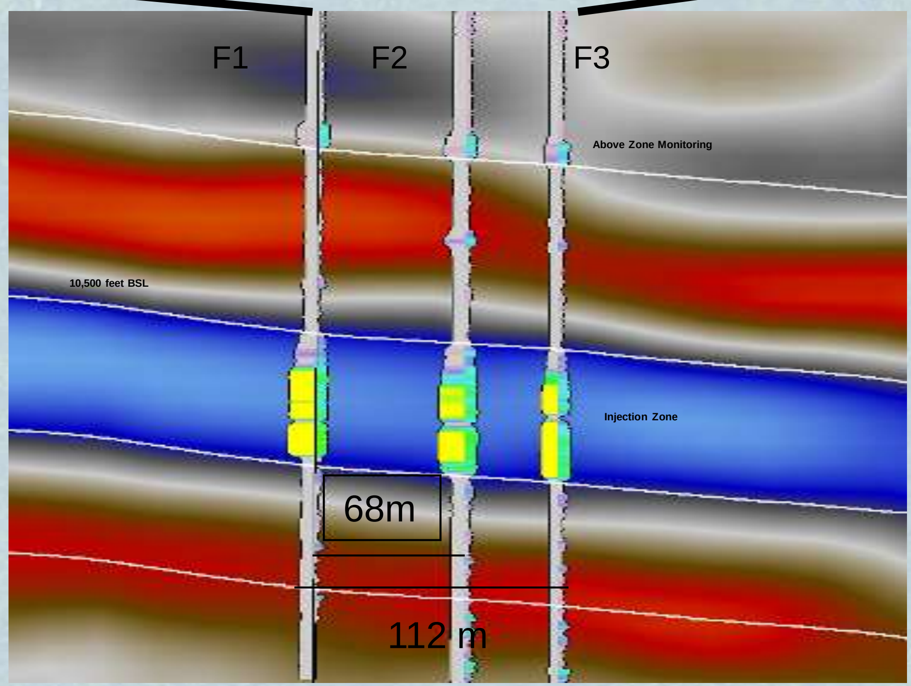
Cranfield: geological location



Cranfield: detailed area of study (DAS)

Closely spaced well array to examine flow in complex reservoir



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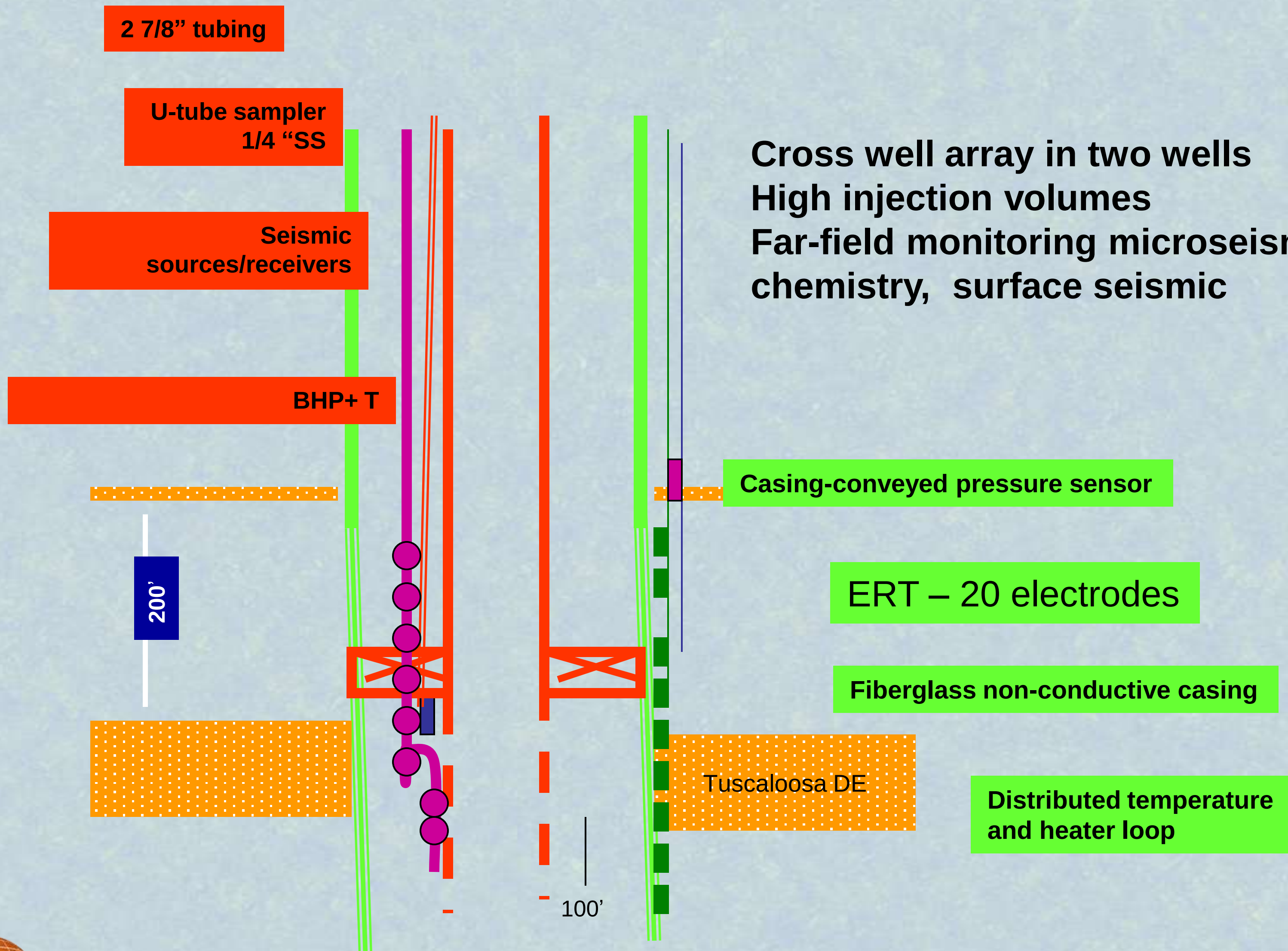
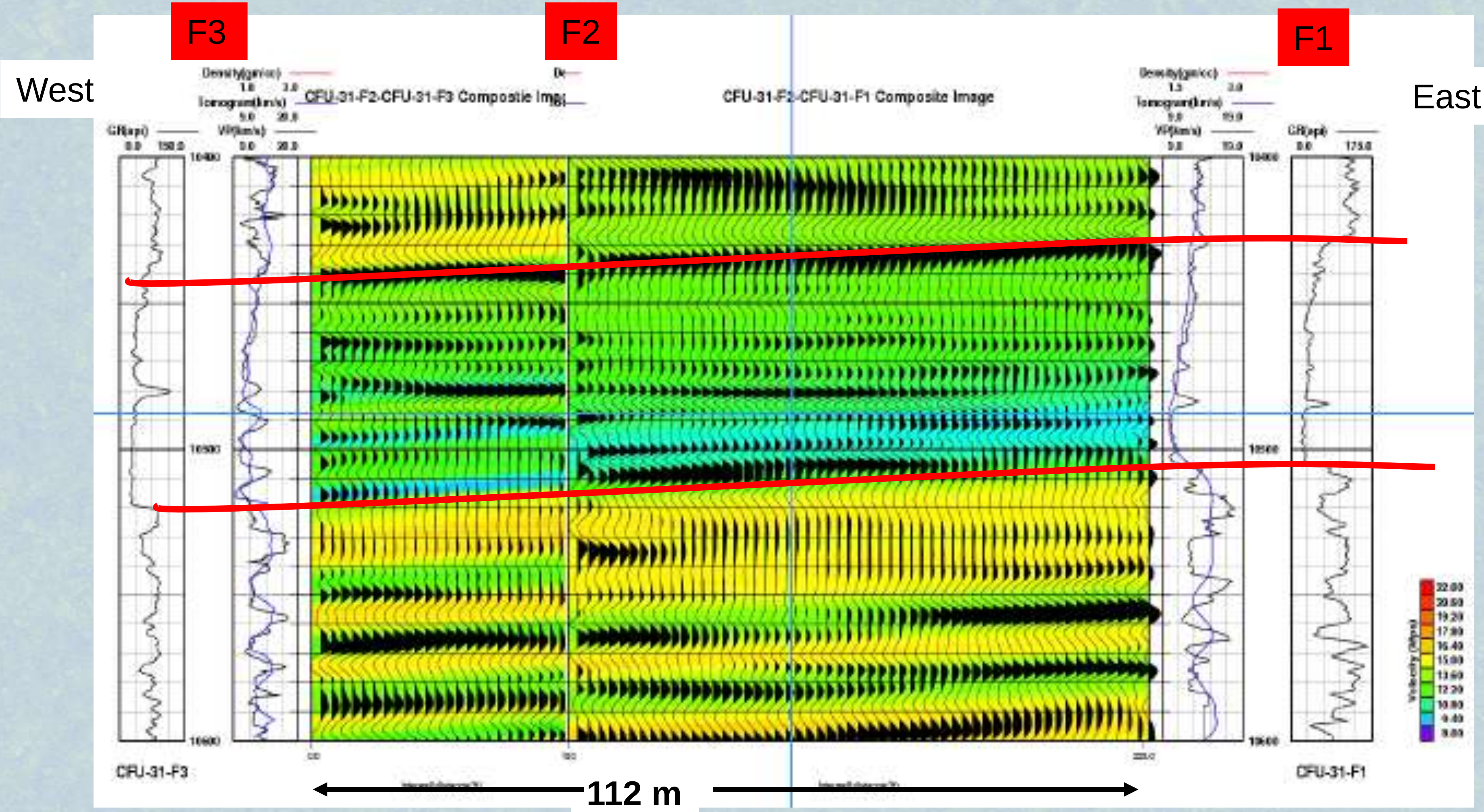
Cranfield: DAS observation well construction

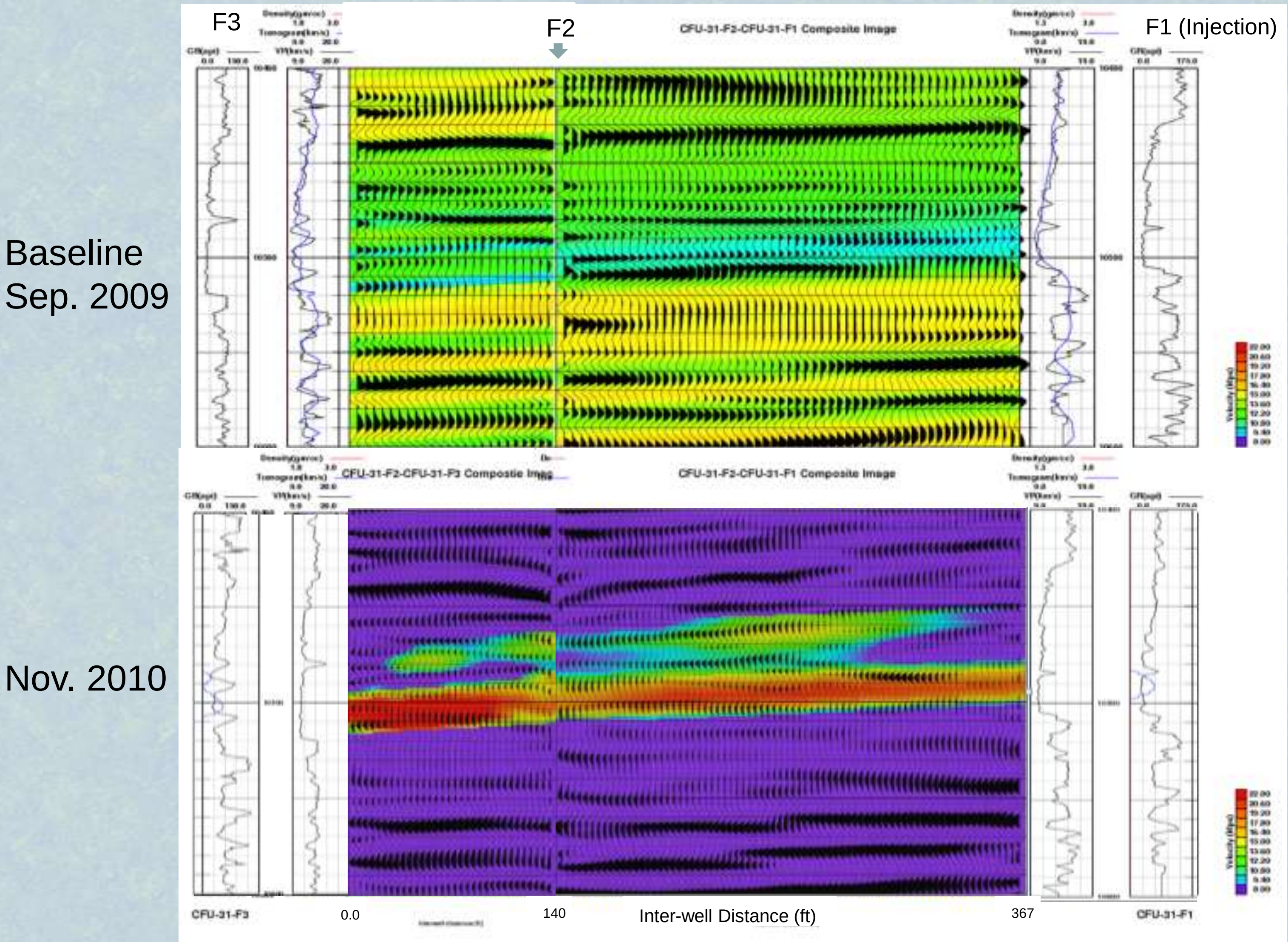
Cross well array in two wells
High injection volumes
Far-field monitoring microseismic, P&T, chemistry, surface seismic



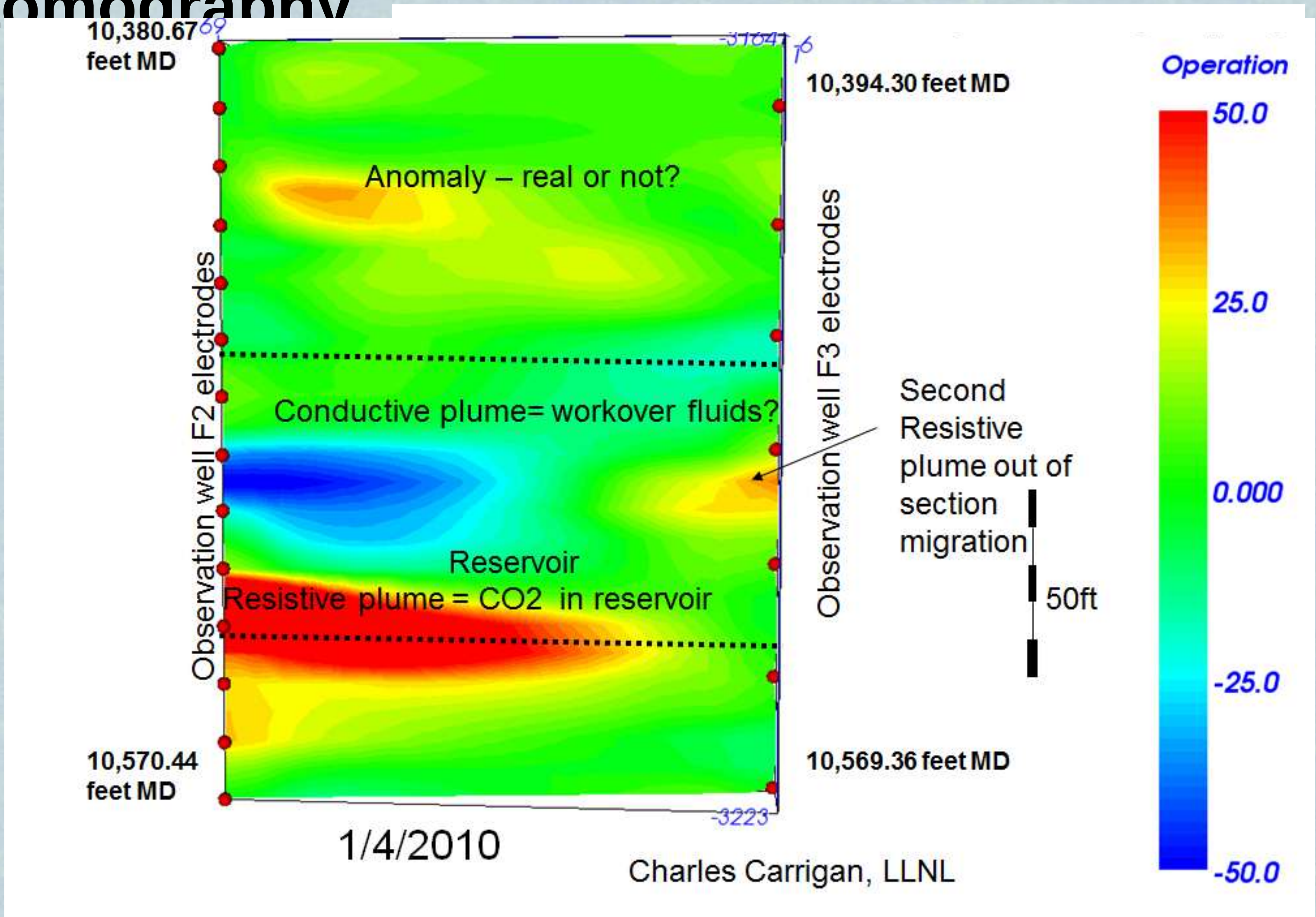
Cranfield: baseline cross-well tomogram



Cranfield: cross-well z-seis profile



Cranfield: electrical resistivity tomography



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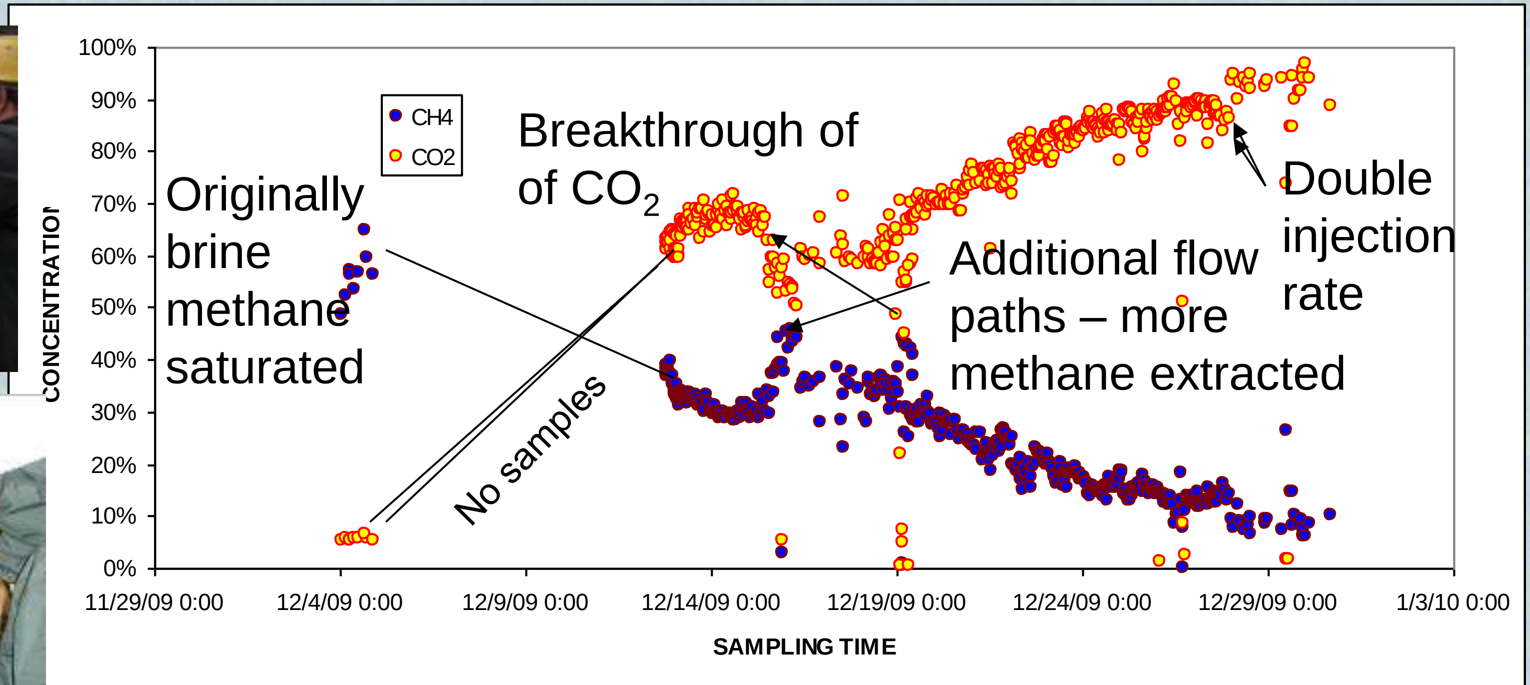
High frequency fluid sampling via U-tube yields data on flow processes



Small diameter sampler with N_2 drive brings fluids quickly to surface with tracers intact

CO_2 dissolution into brine liberates dissolved CH_4

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

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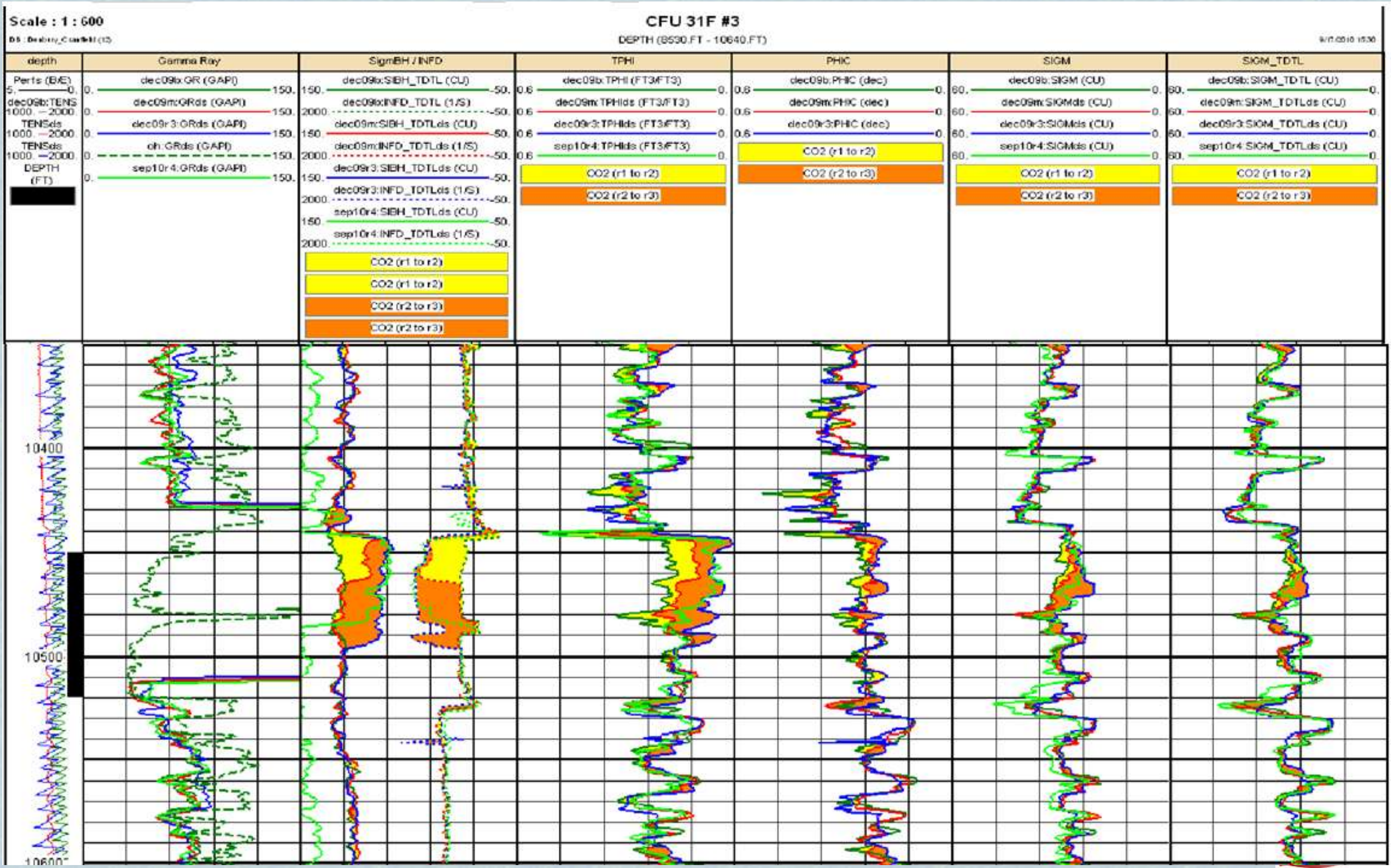
Wireline Logging
Reservoir Saturation Tool (RST)



Cranfield: conclusions

- More than 4.5 Million tons of injected CO_2 have been monitored
- CO_2 has been effectively retained in the injection zone, even in area of 1943-1944 wells
- Flow and pressure elevation was predicted within the range of uncertainty
- CO_2 moved in preferential paths along fluvial channels. A number of successfully deployed imaging tools support this channel-dominated flow theory.
- CO_2 moved downdip, indicating buoyancy forces were not flow dominating at the interwell scale of the experiment.
- BEG's risk-targeted monitoring program was designed to build confidence in carbon geologic storage.
- It is hoped that learnings based on success and weakness of this project will be relevant at future sites

Transitioning from research monitoring to commercial EOR monitoring

Research Monitoring

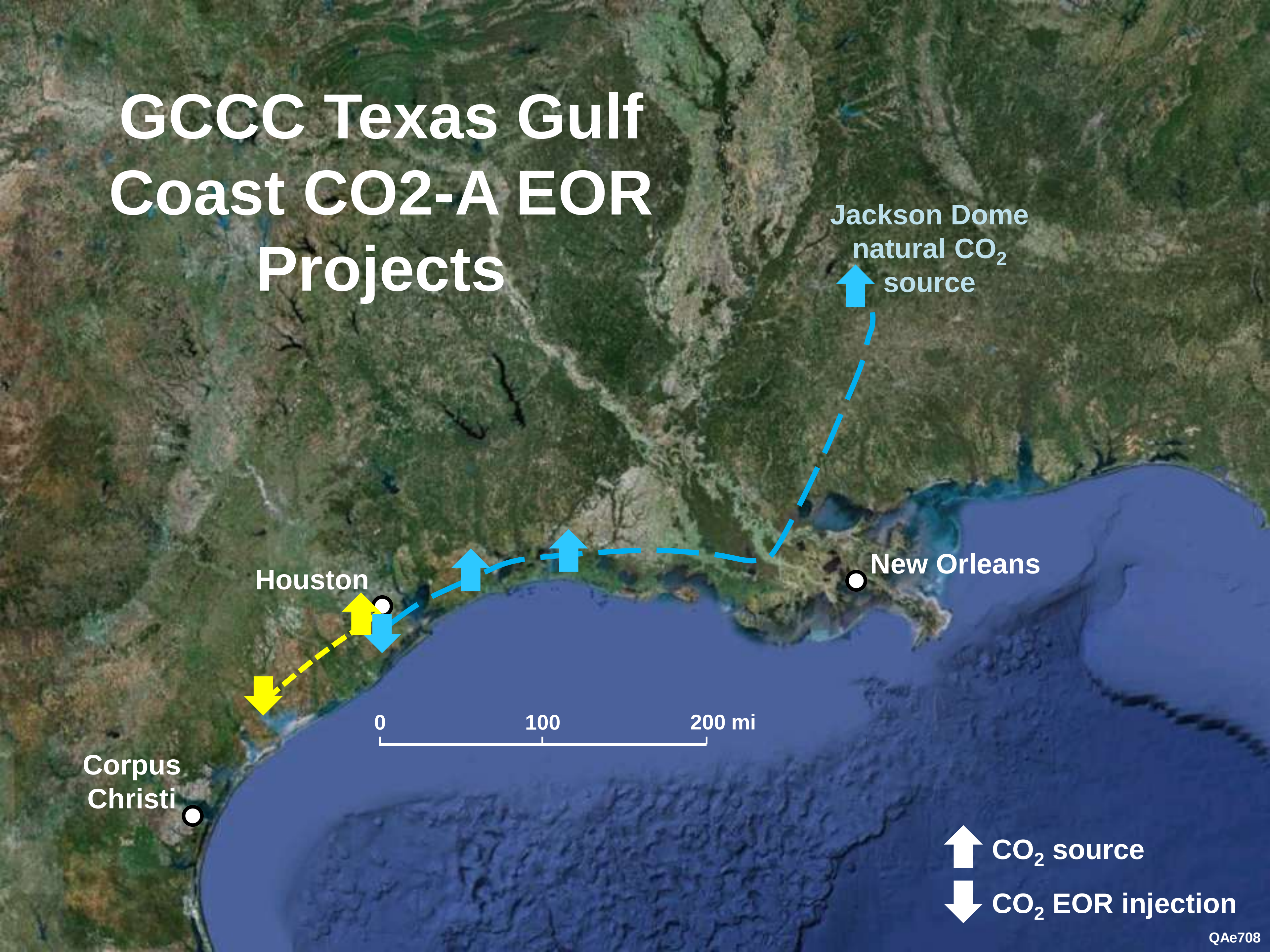
Tests-

- 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
  - monitoring observations that are *reasonably close* to model predictions
  - any non-compliance explained.
  - no unacceptable consequences result from injection
- Diminishing of monitoring frequency through the life of the project
  - eventually stopped, allowing the project to be closed.


GCCC Texas Gulf Coast CO2-A EOR Projects
Jackson Dome natural CO_2 source
Houston
New Orleans
Corpus Christi
0
100
200 mi
CO_2 source
CO_2 EOR injection
QAe708

General conclusions

- Diverse tools are available to determine if a site is performing correctly. Most of these tools have been extensively tested in similar settings and have been or are now being tested at CO_2 sequestration sites.
- The optimal tool combination for mature projects need to be site-specific.
- In-zone reservoir fluid pressure is a well-known measure of reservoir response and provides data that test the correctness of reservoir models.
- There is value in high-frequency pressure data that document short term transients in the rate of pressure change, which are not visible in low-frequency measurements
- Time lapse measurements of CO_2 saturation show complexities that are not included in traditional model matching.
- Groundwater monitoring for a geologic storage site should draw upon classic contaminated-site protocols.

Questions?