THE UNIVERSITY OF TEXAS AT AUSTIN

WHAT STARTS HERE CHANGES THE WORLD

SECARB Early Test Retrospective

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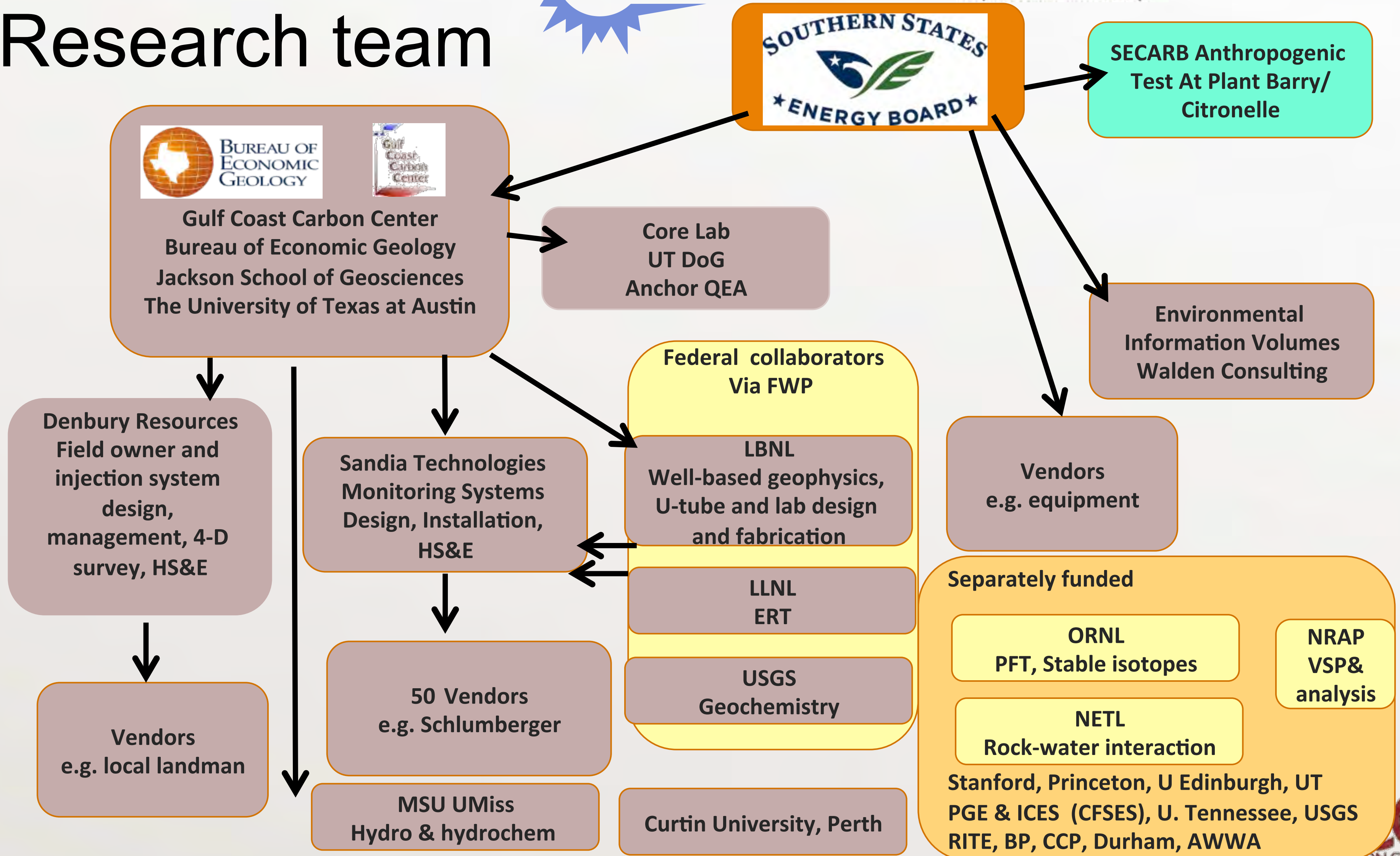
Jackson School of Geosciences

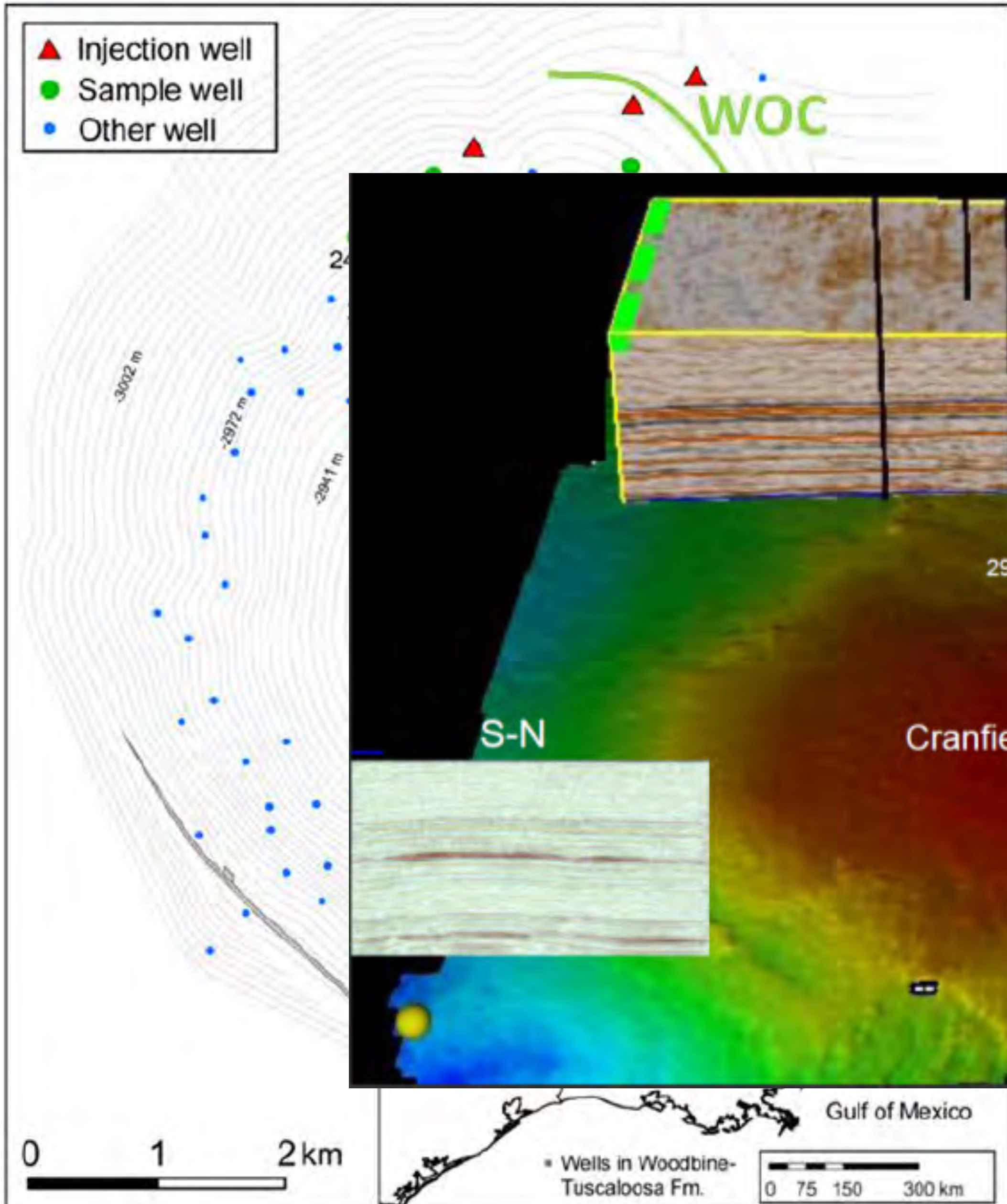
GCCC Gulf Coast Carbon Center

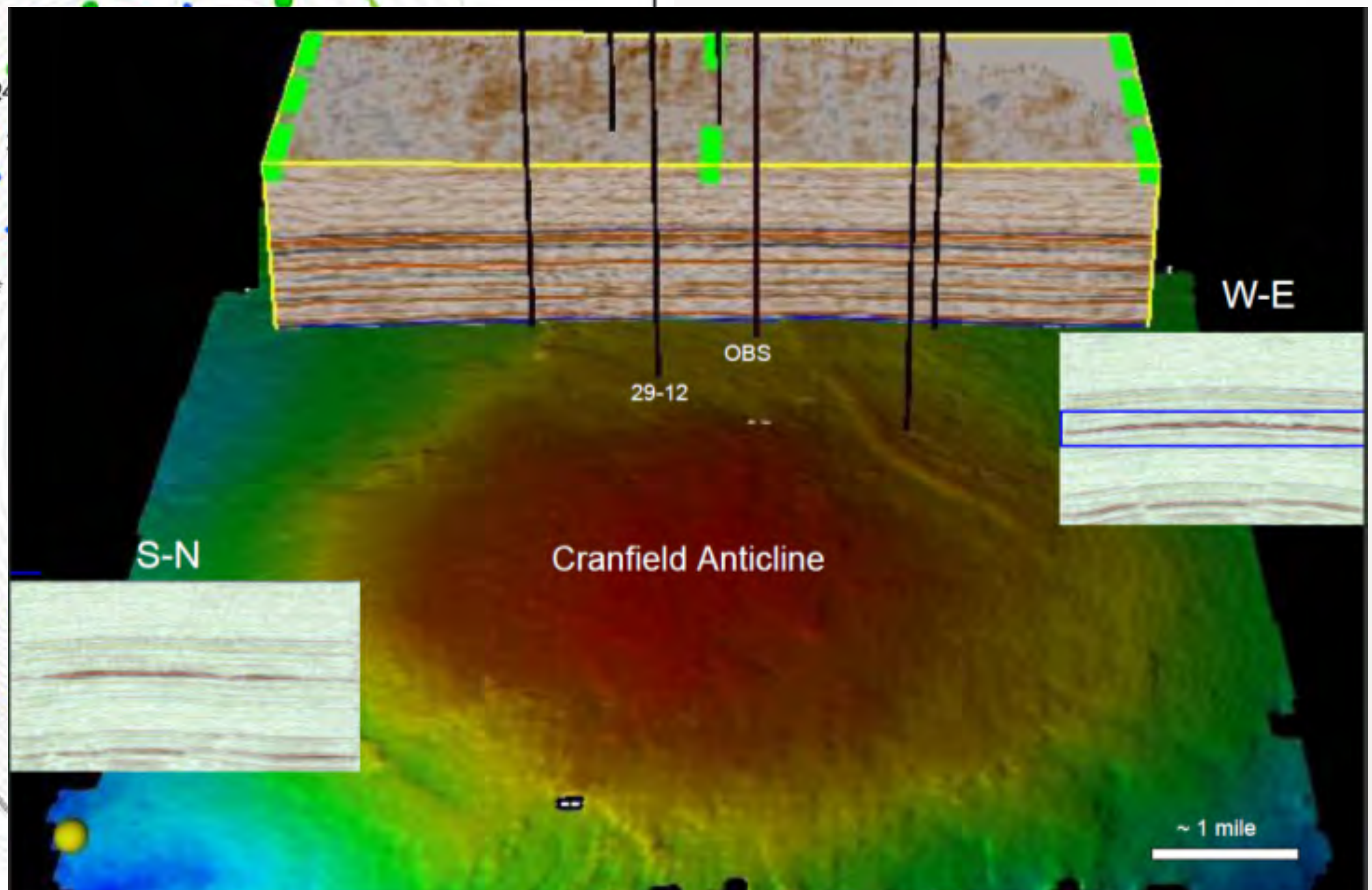
Early Test Research team

NETL

SECARB
Southeast Regional Carbon Sequestration Partnership




Injection well
Sample well
Other well
WOC
-3002 m
-2972 m
-2941 m
0
1
2 km
Gulf of Mexico
Wells in Woodbine-Tuscaloosa Fm.
0 75 150 300 km

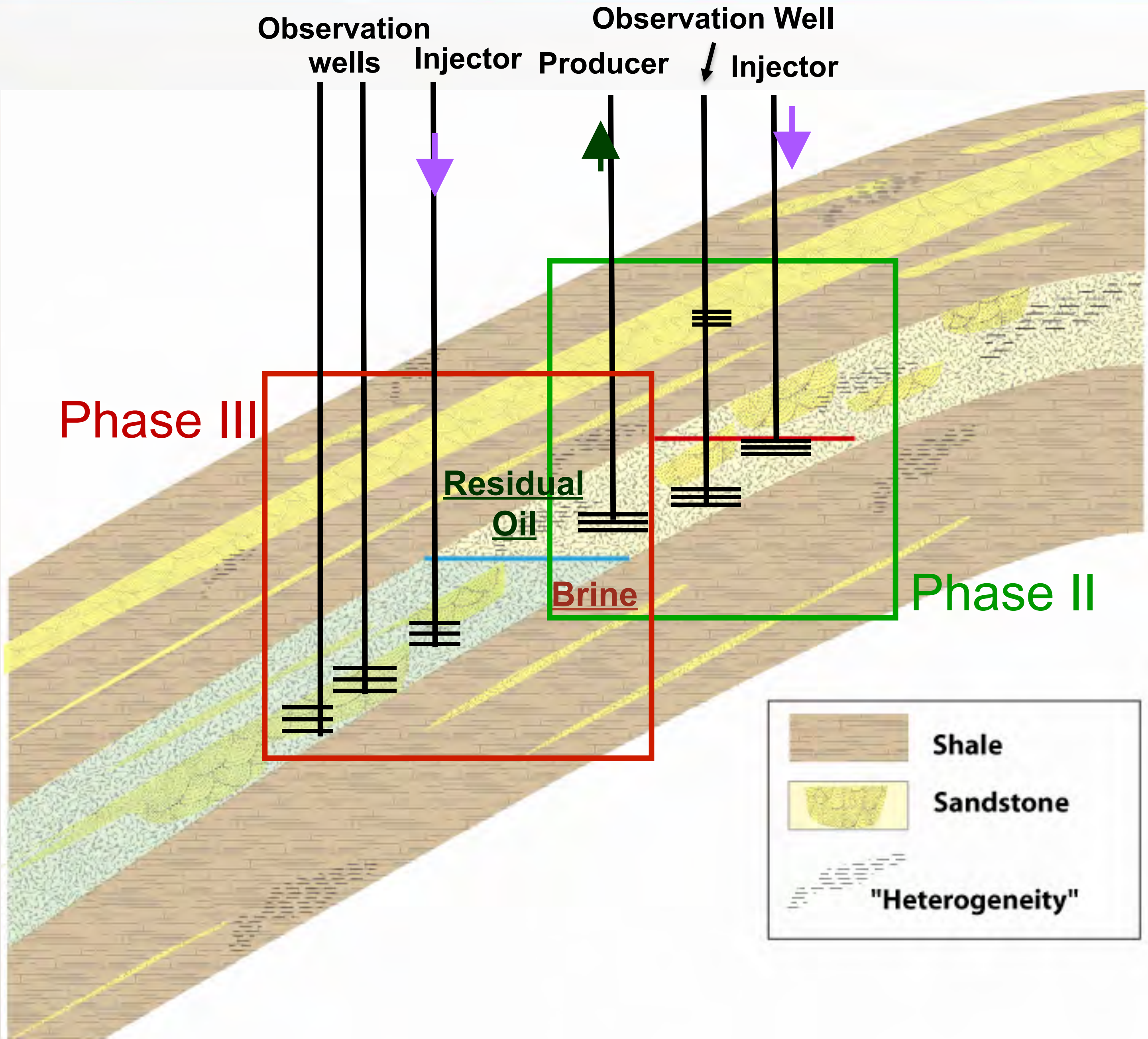

W-E
OBS
29-12
S-N
Cranfield Anticline
~ 1 mile

Overview

- > 1 Million metric tonne / yr injection
- Quick start up = "Early test" (bridge between pilot scale and SECARB's Plant Barry/Citronelle anthropogenic test)
- Of possible sites, Denbury's Cranfield field scheduled for 2008 CO_2 injection start was favorable:
  - Time to collect pre-injection data before injection
  - Build quickly to >1 MMT per year CO_2 injection rate (sufficient to assure project metrics met & *exceeded*)
  - Experienced operator in CO_2 EOR – low risk of permitting delay: ***early results for RCSP program***
  - Field abandoned (40 years); pressure recovered and equilibrated

Favorable Characteristics of Cranfield for SECARB Early test

- Follow-on between Phase II and Phase III
  - Phase II lower budget experiment, single monitoring well in EOR zone
  - Used Phase II as far-field and comparison point to Phase III
- Phase III planned in water leg downdip of oil zone
- Provided RCSP experience with CO2 EOR, (grew in importance)


Observation wells
Injector
Producer
Observation Well
Injector
Phase III
Residual Oil
Brine
Phase II
Shale
Sandstone
"Heterogeneity"

Less than-ideal characteristics

- CO_2 from Jackson Dome (not anthropogenic)
- Field commercial EOR
  - operational aspects not under project's control
  - some data proprietary
- Research purpose only
  - Designed prior to EPA or international regulations
- Relatively complex geology both deep & near surface
- Modeling reservoir's injection response complicated
  - by oil presence
  - injection and withdrawal complexities – ***managed…***

Simplified by:

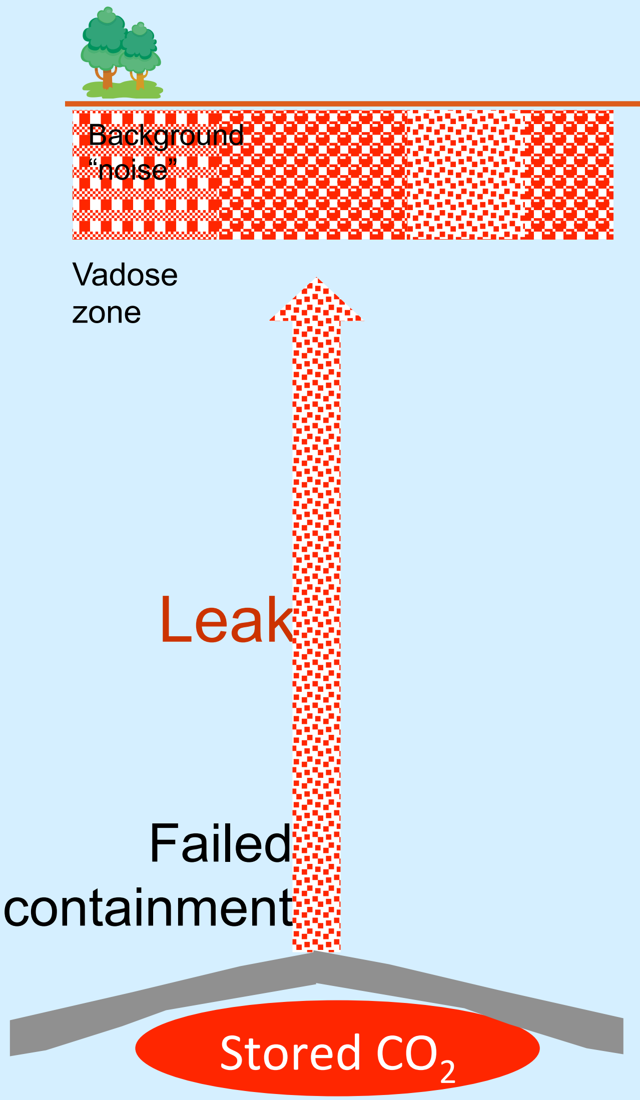
Focus on the DAS - ***brine only***

Early timing - ***production & recycle was minimal***

Developing the Experiment

- Year-long series of meetings (2007-2008)
  - designed plan
- Aligned general research objectives
  - well locations
  - selected team members
  - budget
- Designed detailed plans - major components
- Adapted to fast EOR field development
  - NEPA permitting (slow)
  - other timeline issues
    - equipment rental
    - procurement
    - cash flow (2009 “cash call”)

Project objectives



Produce CO_2
Concentrate CO_2 ⇒ Mask signal

False positives

Consume CO_2
Disperse CO_2 ⇒ Dampen signal

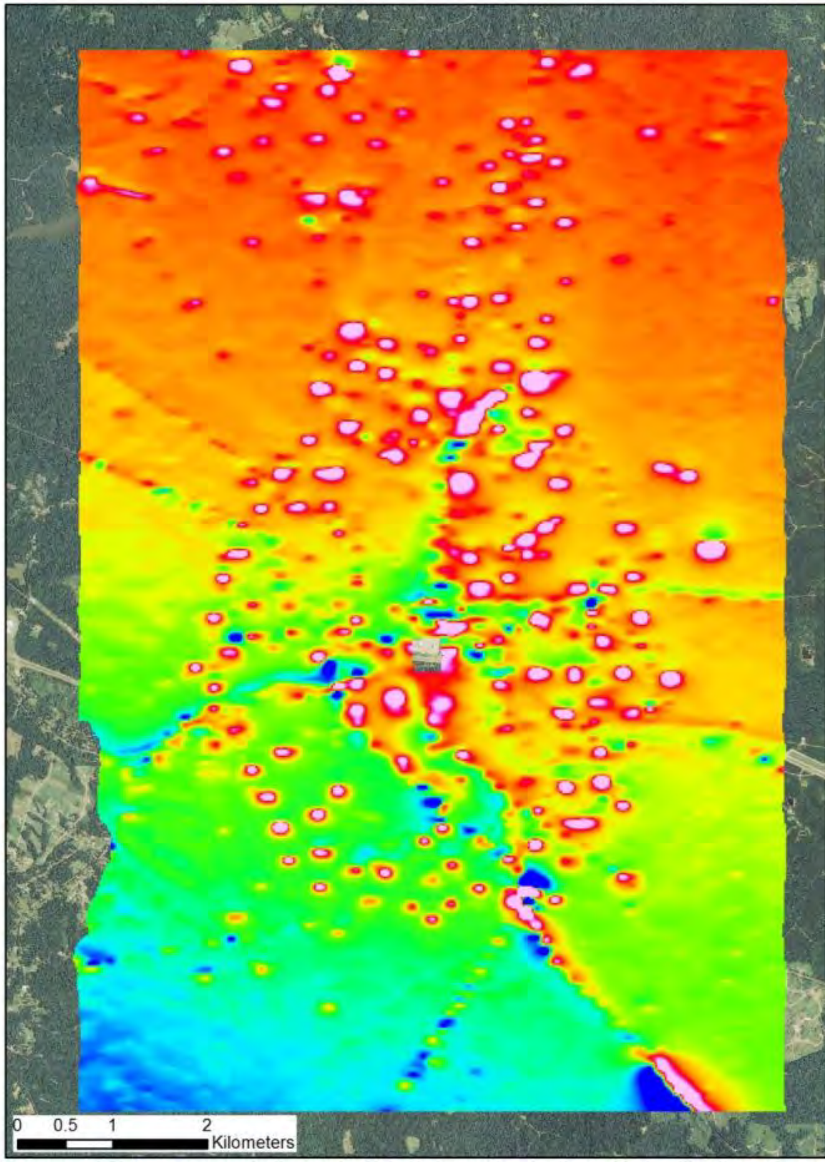
False negatives

Plant activity
Organics → CO_2
Soil carbonate
Soil moisture
Weather fronts

} Produce, consume, redistribute CO_2

Katherine Romanak BEG

Residual Magnetic Intensity - Cranfield, MS



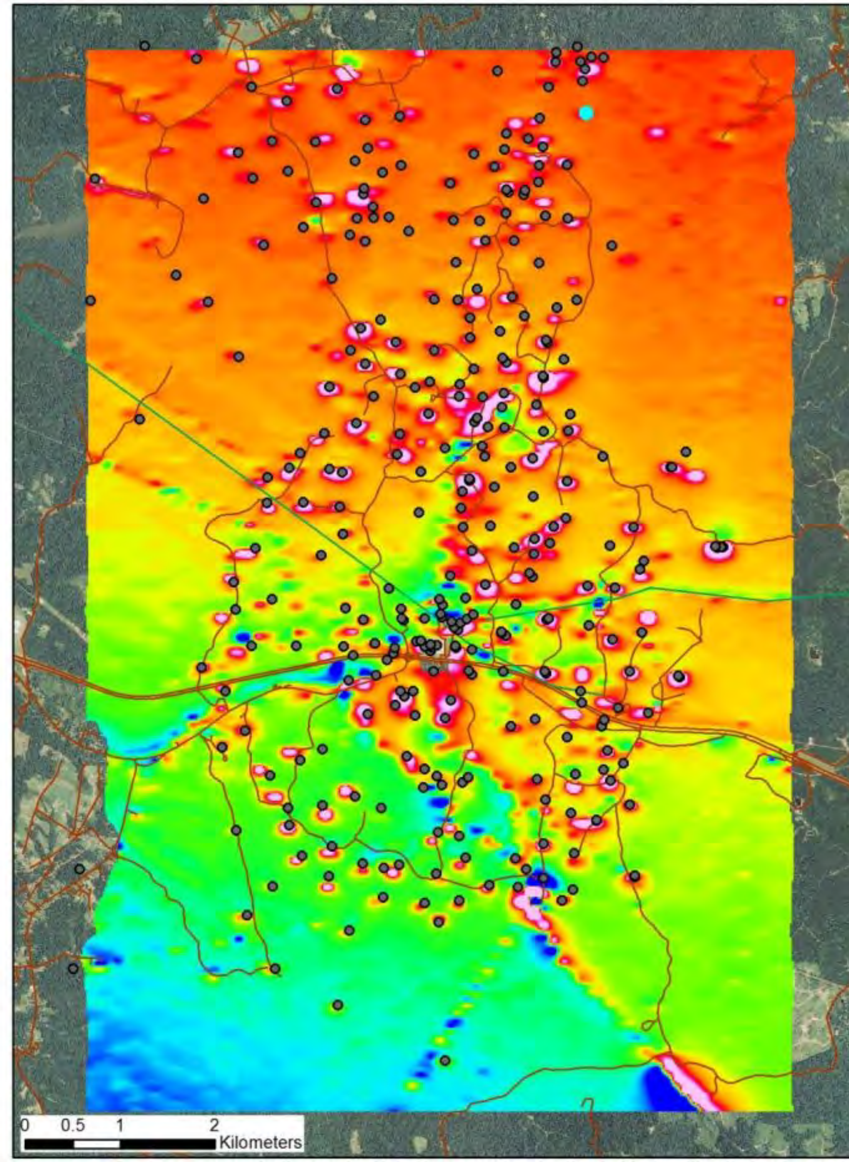
Legend

Residual Magnetic Intensity (nT)

High : 274.5

Low : -218.3

Residual Magnetic Intensity - Cranfield, MS



Legend

Wells

Pipelines

Roads

Residual Magnetic Intensity (nT)

High : 274.5

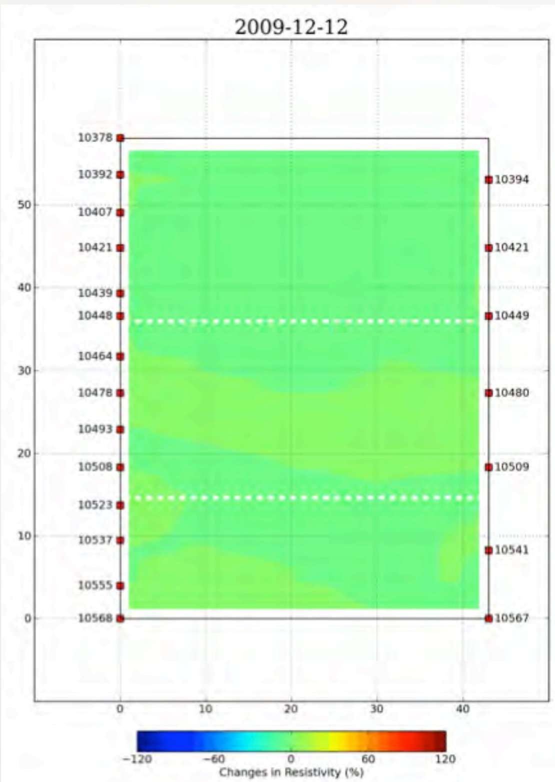
Low : -218.3

butions (2)

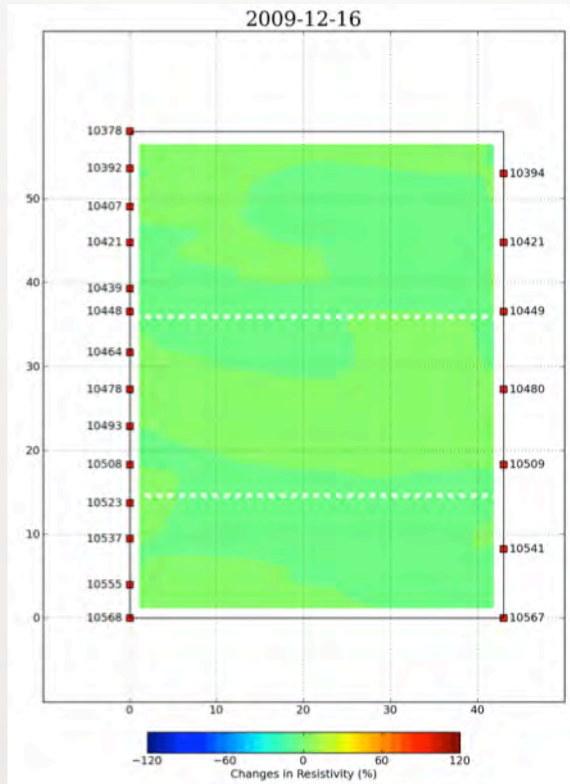
- Schlumberger Carbon Services
  - well logging
  - Cross well Seismic
  - AZMI fluid collection

- LBNL / NRAP
  - U-tube,
  - 3-D VSP
  - downhole fiber optic CASSM
- Oak Ridge NL
  - PFT and sampling
- University E
  - Noble gass
- Local lando
  - access
- Walden Co
  - NEPA

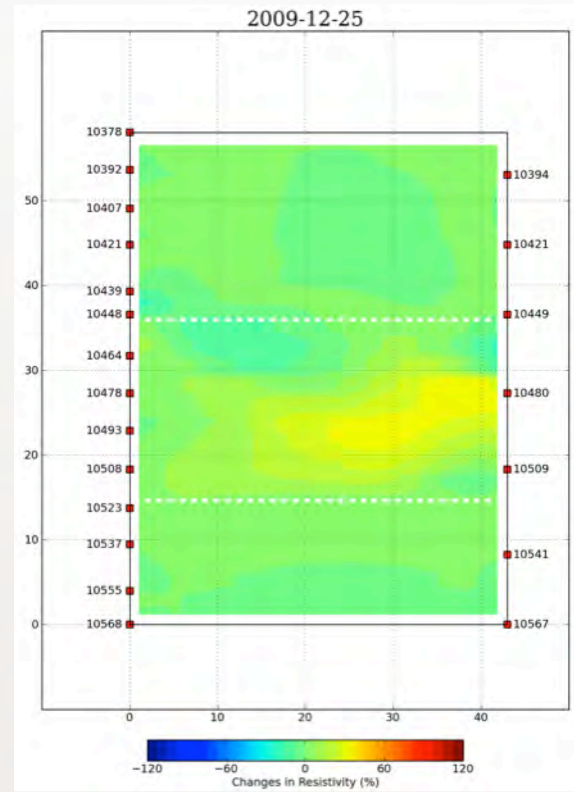
Time Lapse Resistivity Changes



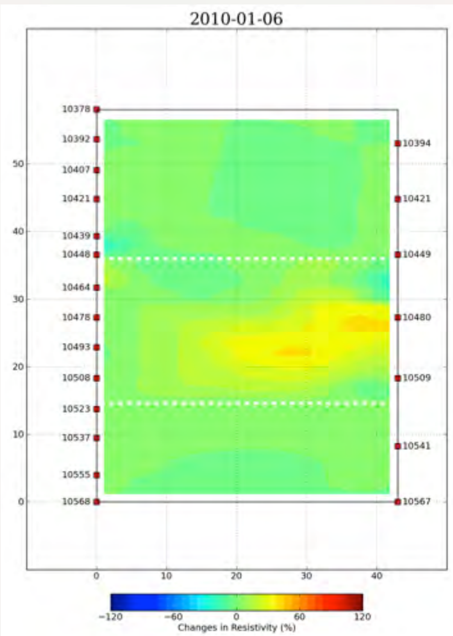
Initial CO_2 Breakthrough in F2

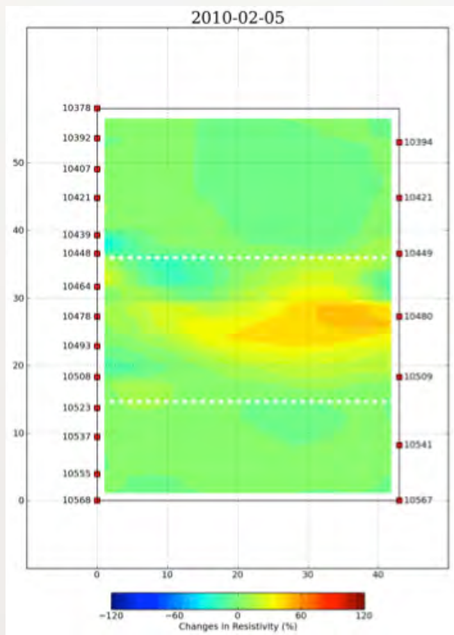


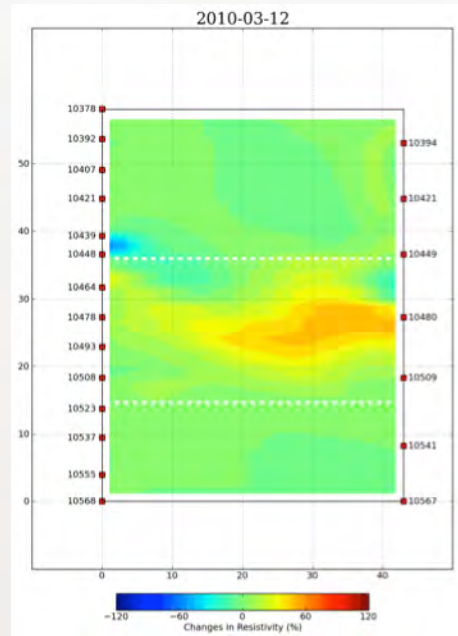
Initial CO_2 Breakthrough in F3

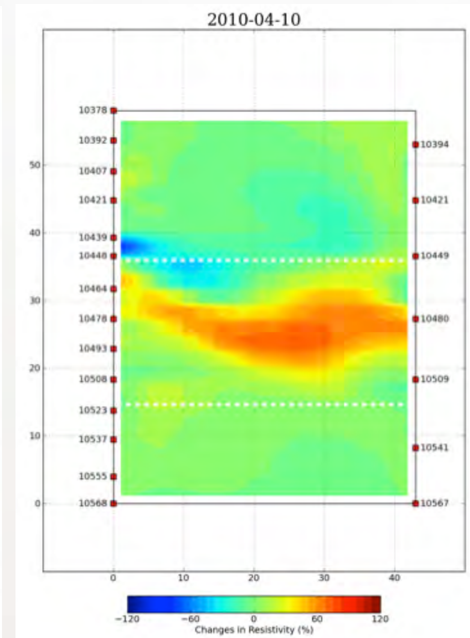


Time Lapse Resistivity Changes



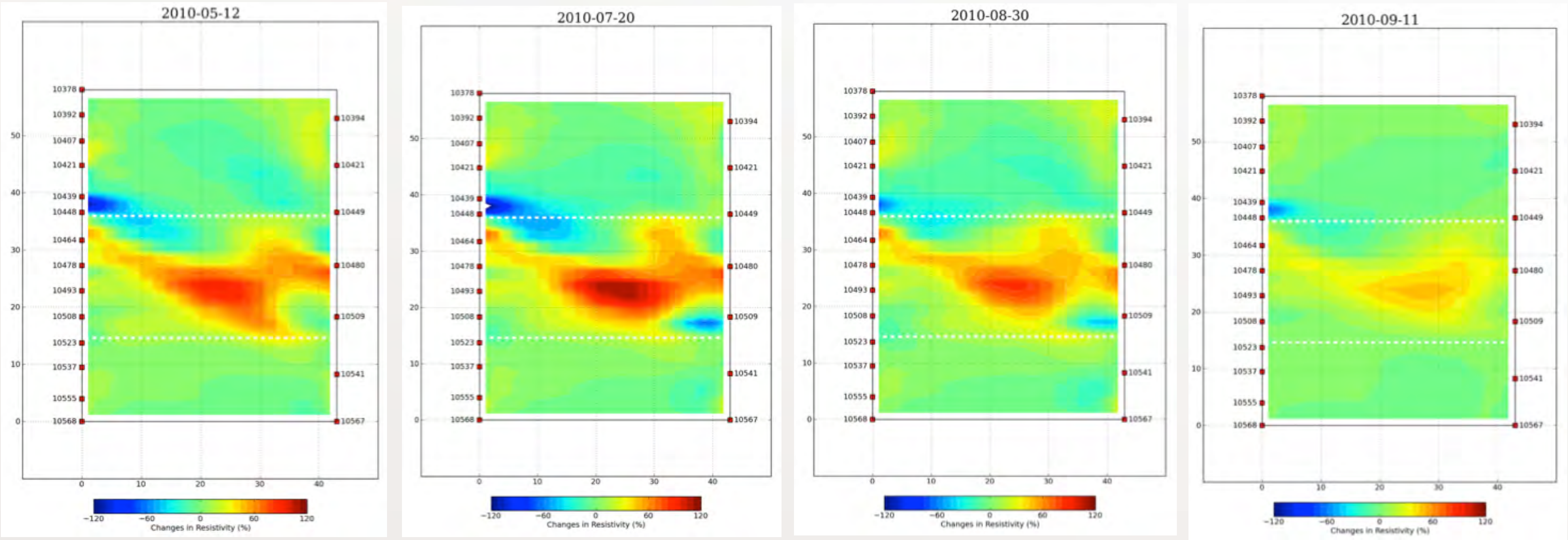






GCCC GULF COAST CARBON CENTER

Time Lapse Resistivity Changes



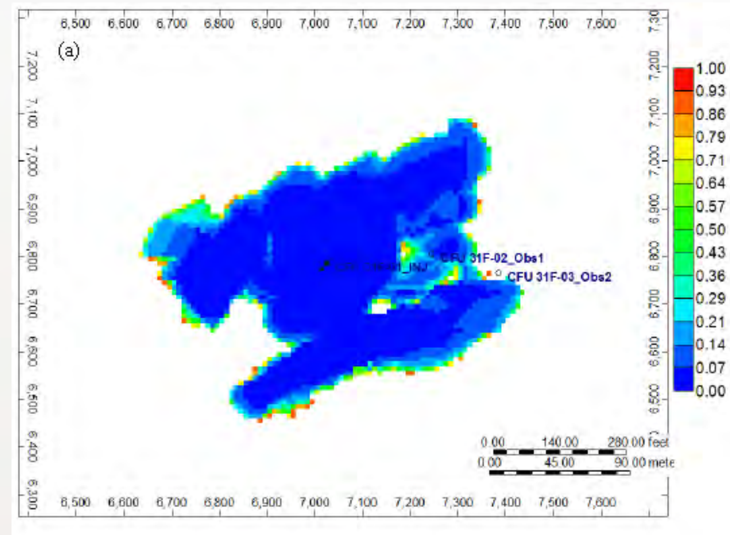
After Work-over in 9/2010

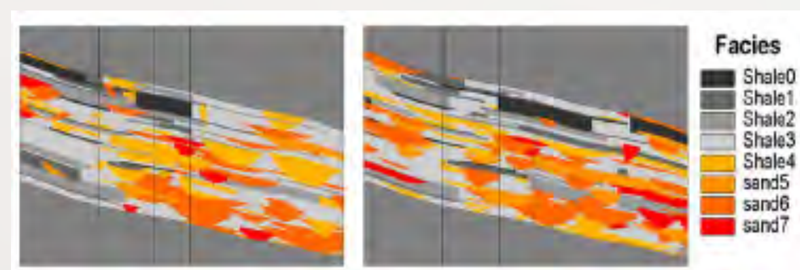
Contributions: Support Collaborators

- CFSES
  - rock samples for geomechanics
- NRAP
  - field site for 3D-VSP
- SIM SEQ
  - comparative modeling data set
- NETL
  - CO_2 EOR model data

Accomplishments

- Monitored CO_2 injection 2008 – 2015
- Injection through 23 wells, cumulative volume over 8 million metric tons
- First US test of ERT for GS (deepest)
- Time lapse plume imaging with cross well seismic, VSP, RST, & surface 3-D seismic
- RITE microseismic – none detected
- Groundwater sensitivity assessment (push-pull)
- Recognized by Carbon Sequestration Leadership Forum (CSLF) in 2010 for research contributions
- SIM-Seq inter-partnership model development test
- Knowledge sharing to Anthropogenic Test and other U.S./International CCS projects





"Early Test's" Major Contributions

- Large volume injection bridged RCSP to current & future anthropogenic sources
- Value of AZMI pressure monitoring in demonstrating reservoir fluid retention
- Probabilistic monitoring helps history-match fluid response to injection in a complex reservoir
- Process-based soil gas method developed and demonstrated for the first time
- Demonstrated utility and site-specific limitations of groundwater monitoring

Future (1)

- Model additional scenarios incorporating uncertainties
- Forward-model seismic response
- Compare Cranfield ERT to Ketzin
- Evaluate ERT for long-term viability (distinguish noise from signal)
- Determine time-dependent capacity through modeling
- Participate in ISO 265
- Further optimize process-based soil-gas method
- Further optimize groundwater uncertainties

Future (2)

- Technology transfer
  - Deployment of monitoring strategies developed at SECARB “Early” test as well as other RCSP and international CCUS sites
  - Support for maturation of monitoring for EOR as well as saline sites through international standards, best practices, critical reviews