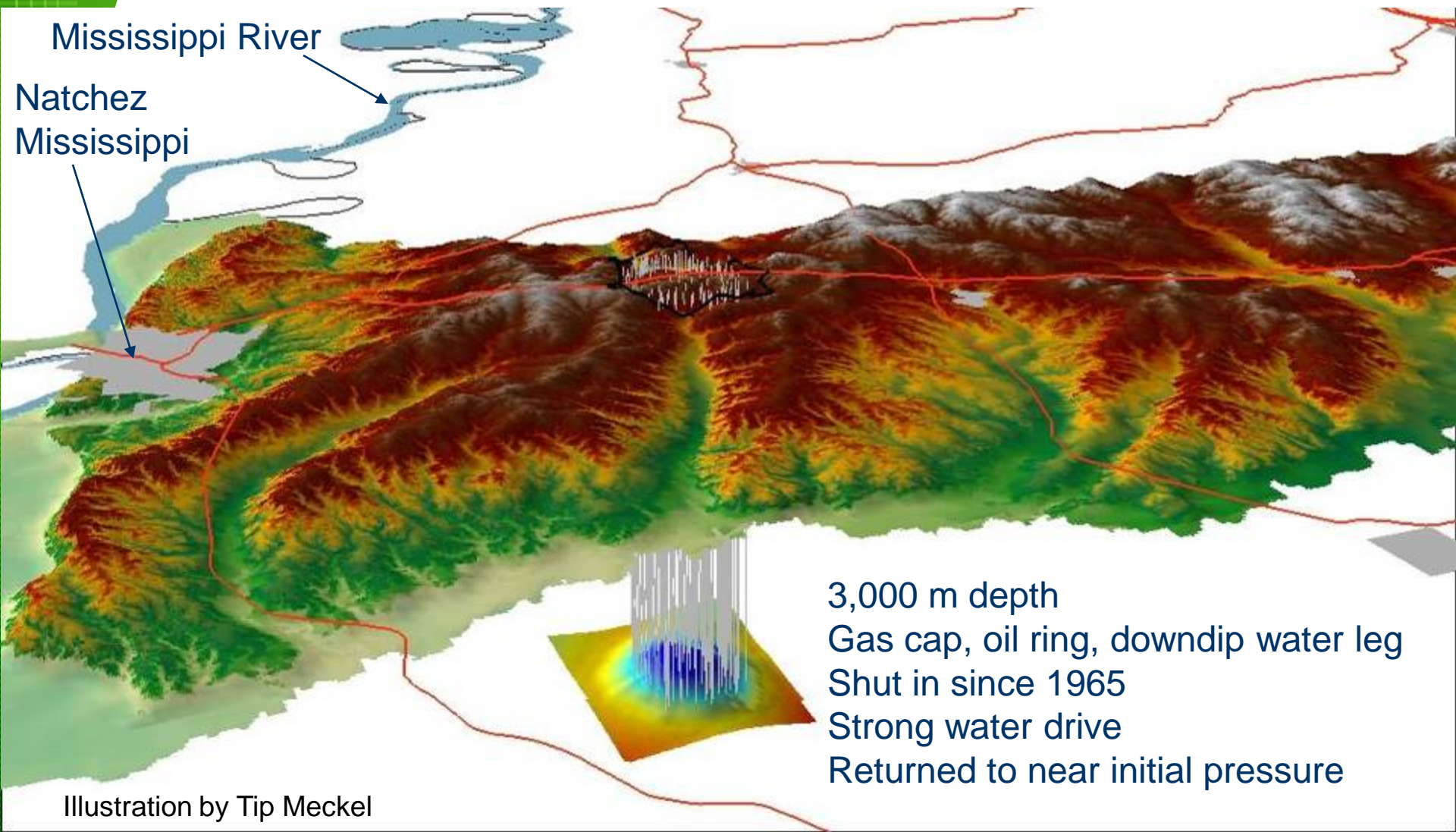


# Update on Results of SECARB Test of Monitoring Large Volume Injection at Cranfield



# Cranfield "Early" Field Test Collaboration



Sandia Technologies, LLC



Denbury Onshore LLC

LBNL  
LLBL  
USGS  
ORNL  
NETL

Schlumberger

Carbon Services

QEA

BP

U Mississippi

Miss State

UTPGE

UT DoG

University Tennessee

Princeton

Stanford

University Edinburgh

## Gulf Coast Carbon Center Staff

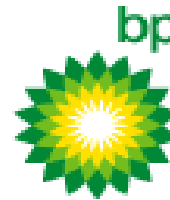
Susan Hovorka  
Ramon Trevino  
Tip Meckel  
Changbing Yang  
Jiemin Liu  
Katherine Romanak  
Rebecca Smyth  
Sigrid Clift  
Masoumeh Kordi  
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Hamid Lashgari

## BEG staff

Tongwei Zhang  
Jeff Paine  
Bob Reedy  
Robert Reed  
Kitty Millikan



# Gulf Coast Carbon Center Industrial Associates



Luminant



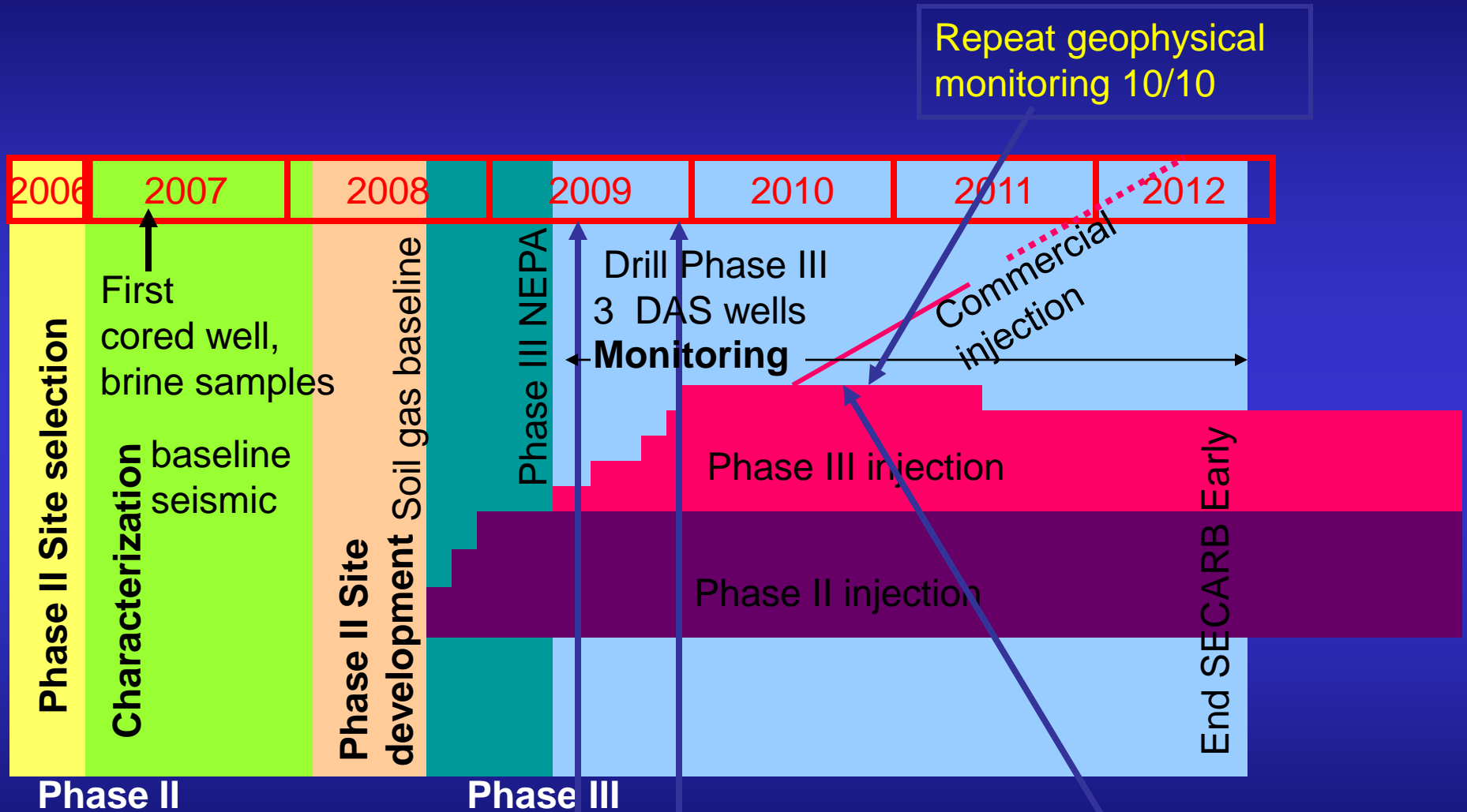
ExxonMobil



# Overview – Cranfield

- 1 million tonne/year rate achieved Dec 20, 2009
- 2 Million tonnes monitored since July 2008
- Rate to be maintained >15 months
- Monitored with standard and novel approaches
  - History match pressure response
  - Fluid flow measured/monitored – multiple tools / complex flow field
  - First US use of Electrical Resistance Tomography (ERT) for sequestration (deepest to-date worldwide)
  - Quantification of CO<sub>2</sub> dissolution
- Export to commercial EOR/sequestration projects

# Cranfield Progress



Repeat geophysical monitoring 10/10

Phase II

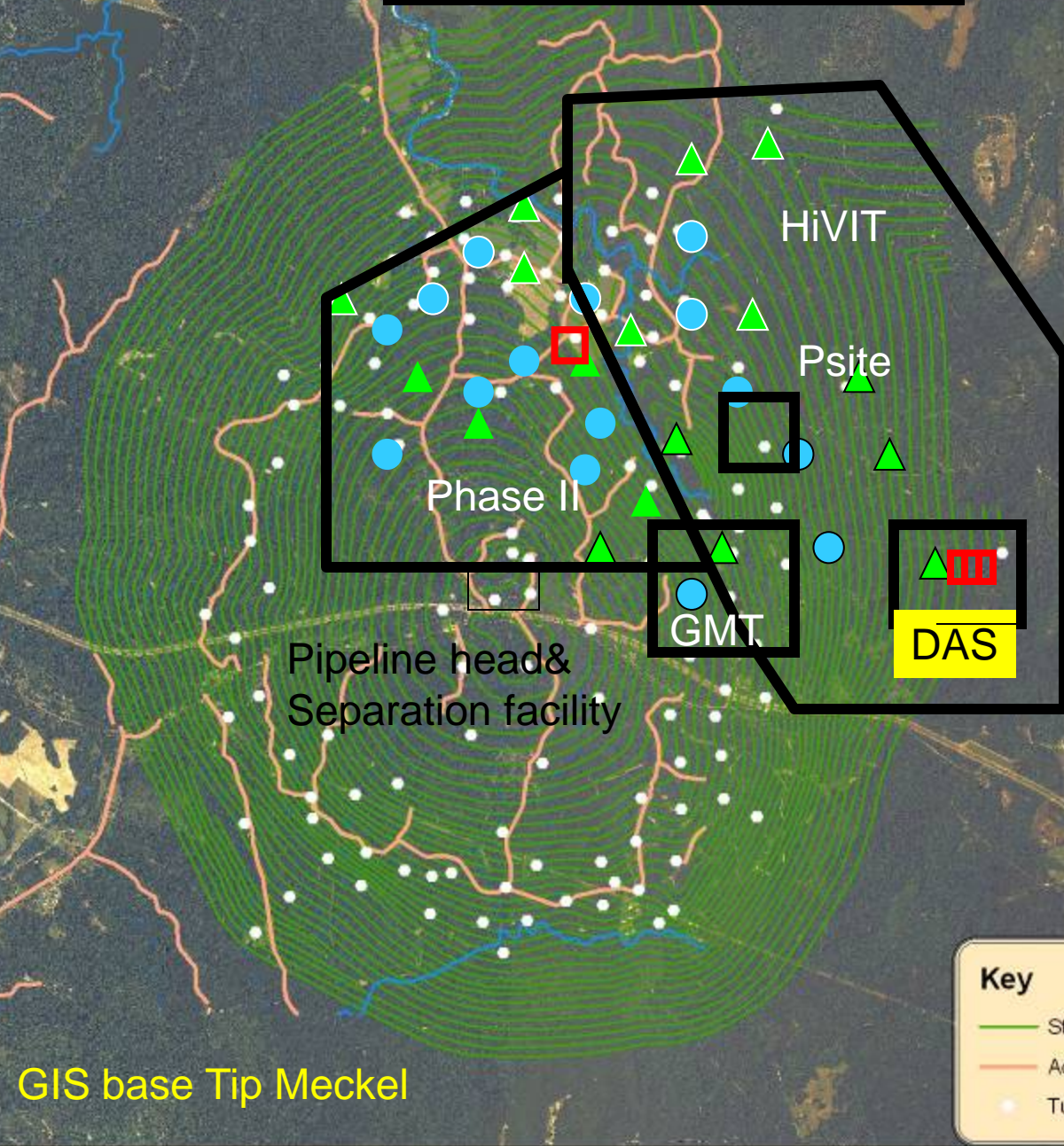
Phase III

May 1 million tonnes injected P II + III

December 20, 2009 Achieved 1 million tonnes/year rate

1 million tonnes Phase III injection 8/10

# Five Study Areas



- ▲ Injector
- Producer (monitoring point)
- ◻ Observation Well

## Key

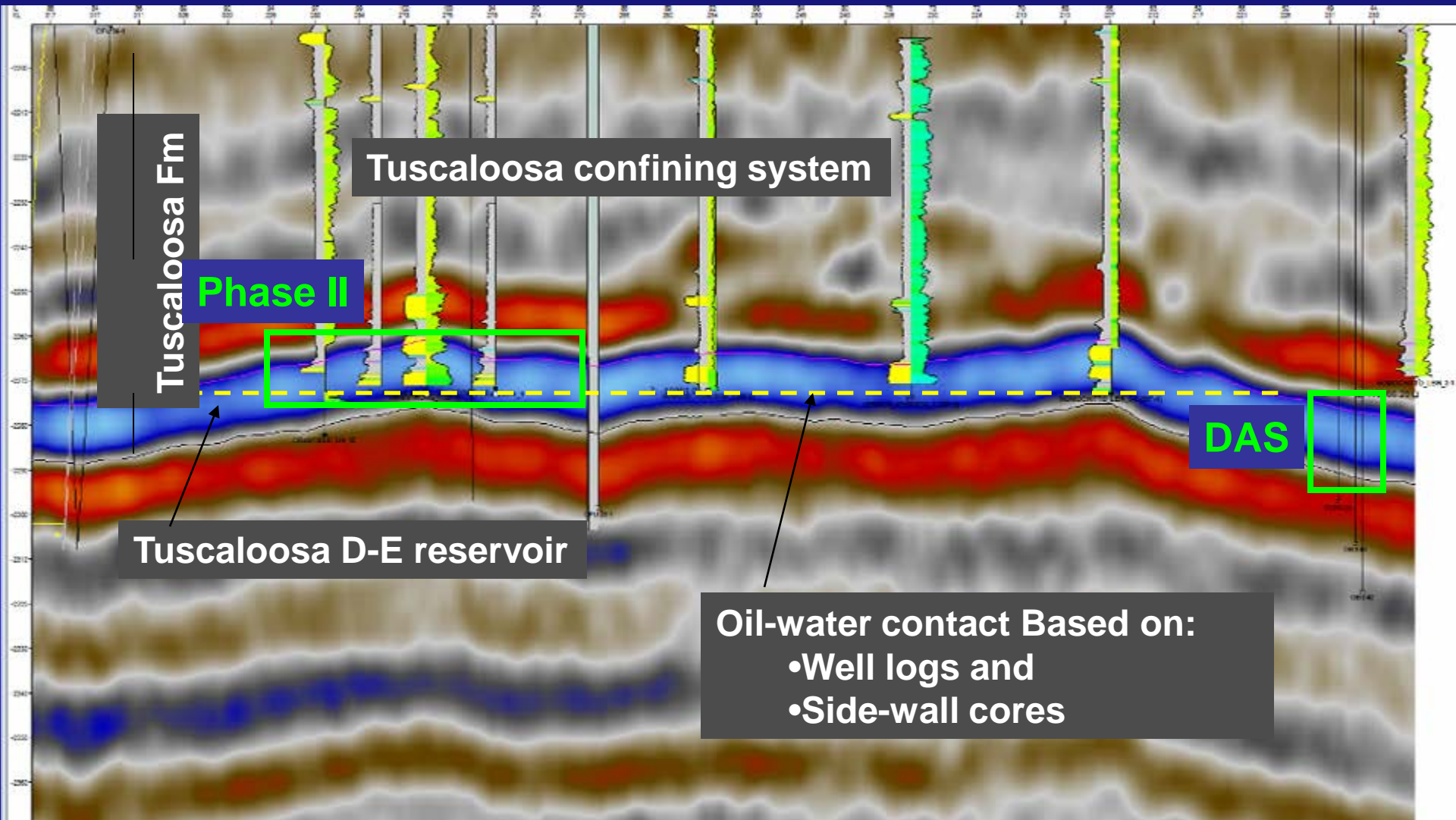
- Structure Contour
- Access roads
- Tuscaloosa Wells

GIS base Tip Meckel

# Reservoir Characterization

A

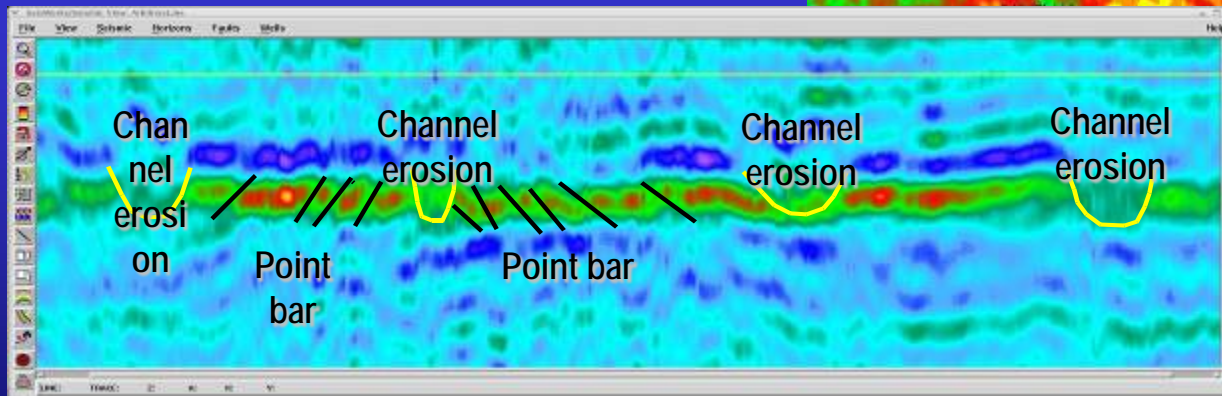
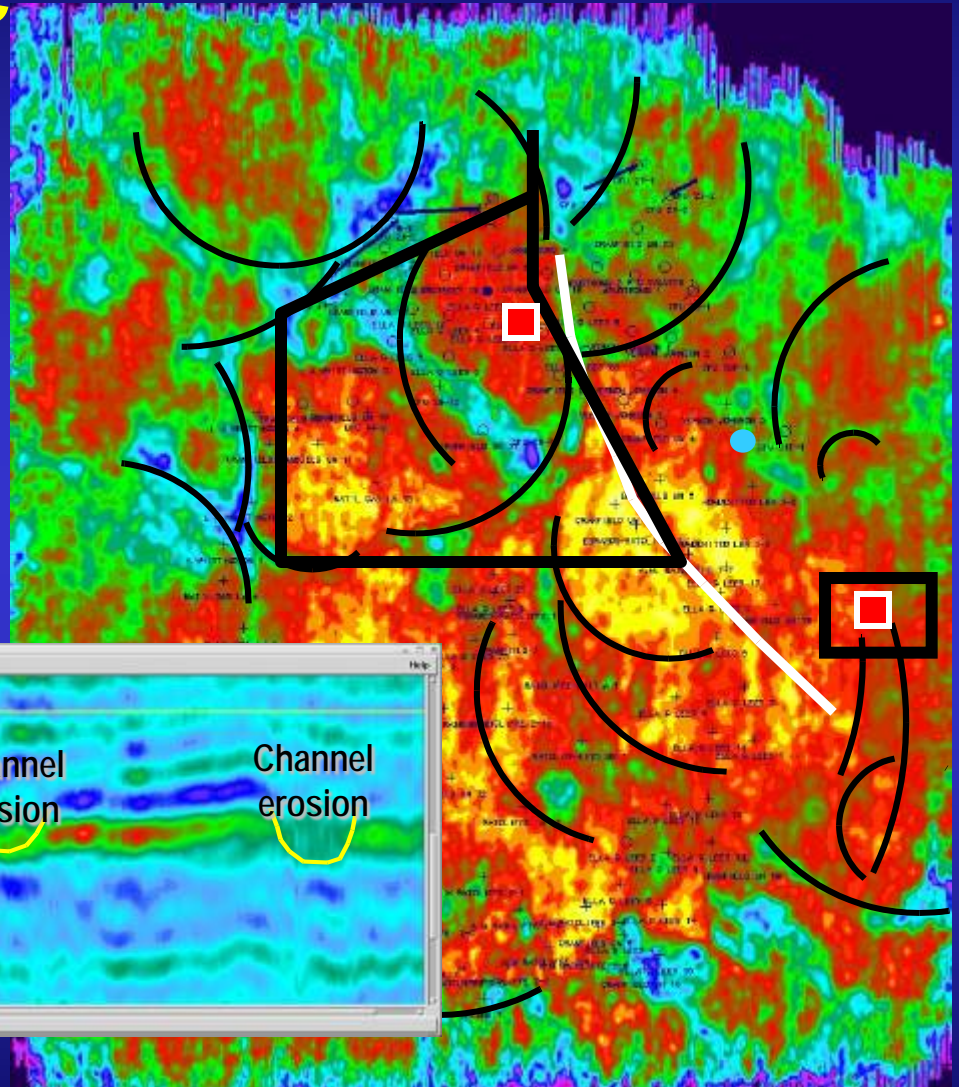
B



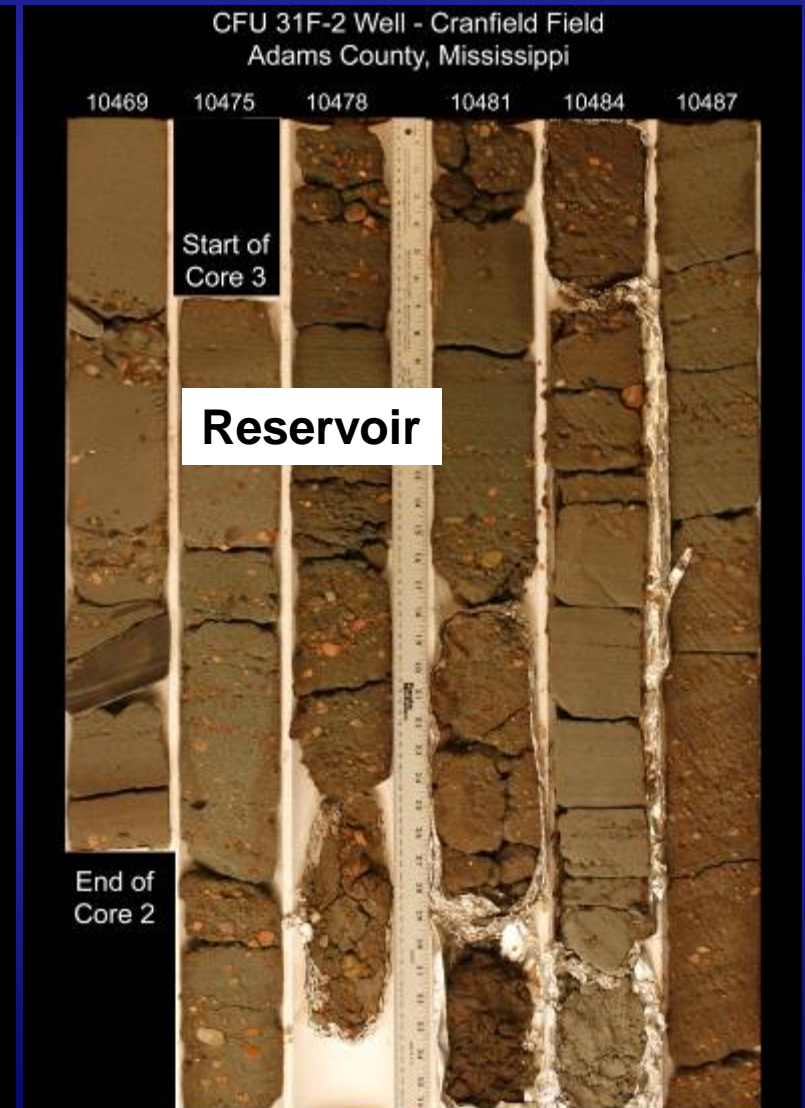
Oil-water contact Based on:  
• Well logs and  
• Side-wall cores

# Reservoir Heterogeneity from Surface 3D Seismic

- Stratal slicing for facies
- 90-degree phase
- AVF for thickness/fluid
- AVO for fluid/OWC



# Upward fining fluvial sandstone and conglomerates of the lower Tuscaloosa Fm





# Baseline Cross Well tomogram

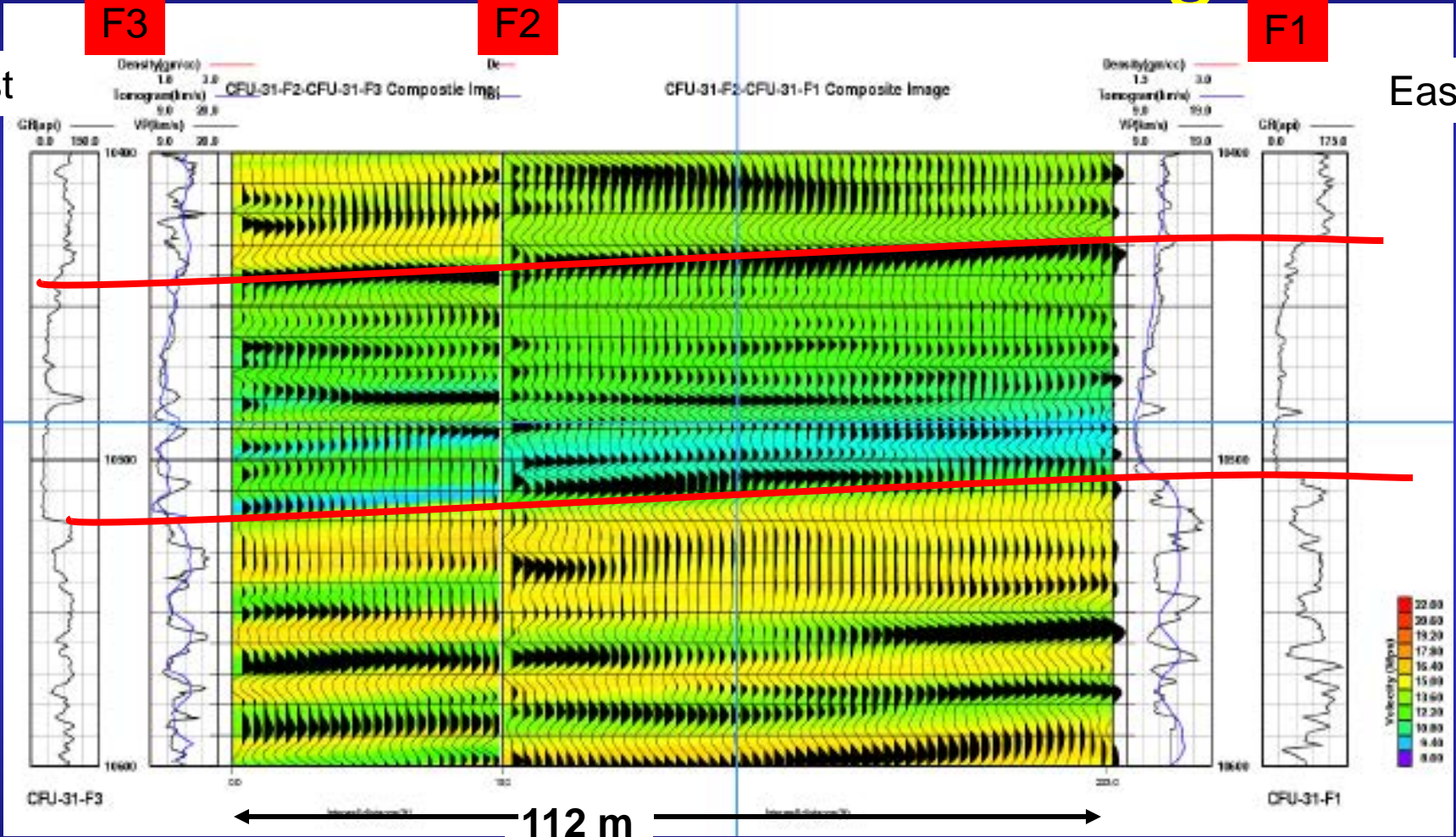
West

F3

F2

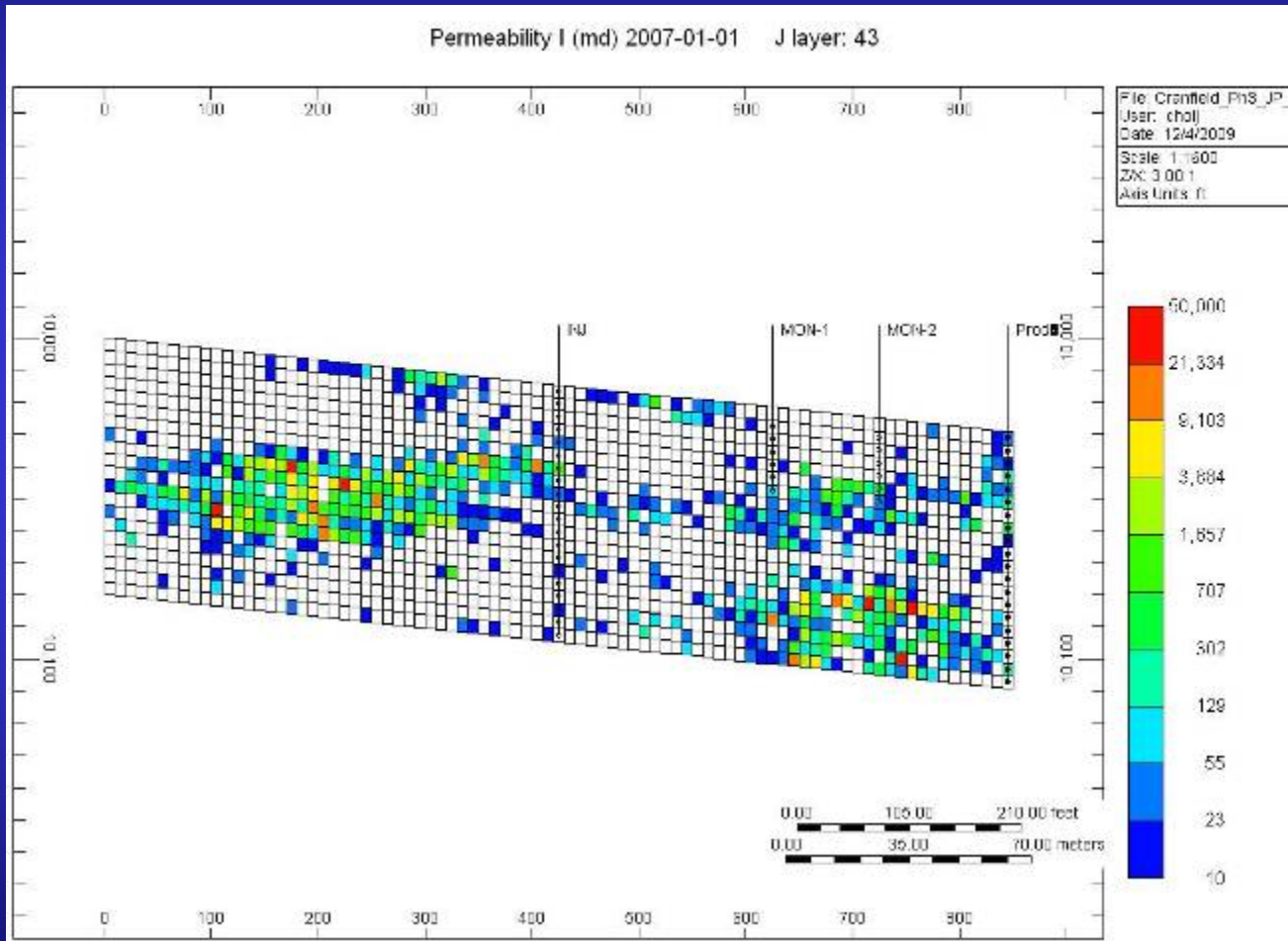
F1

East

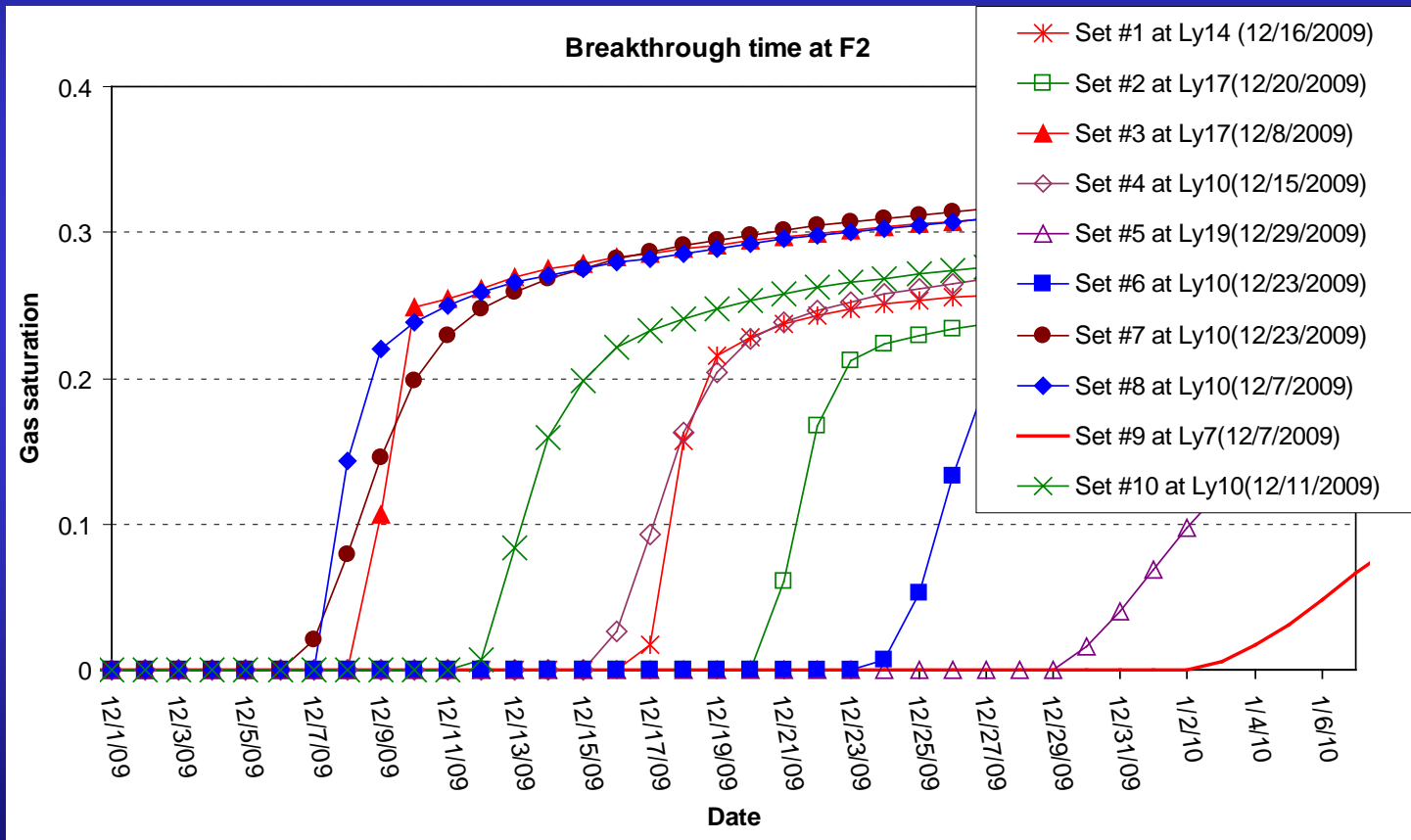


Z-Seis & Tom Daley Jonathan Franklin in review at LBNL

# Probabilistic Realization Permeability

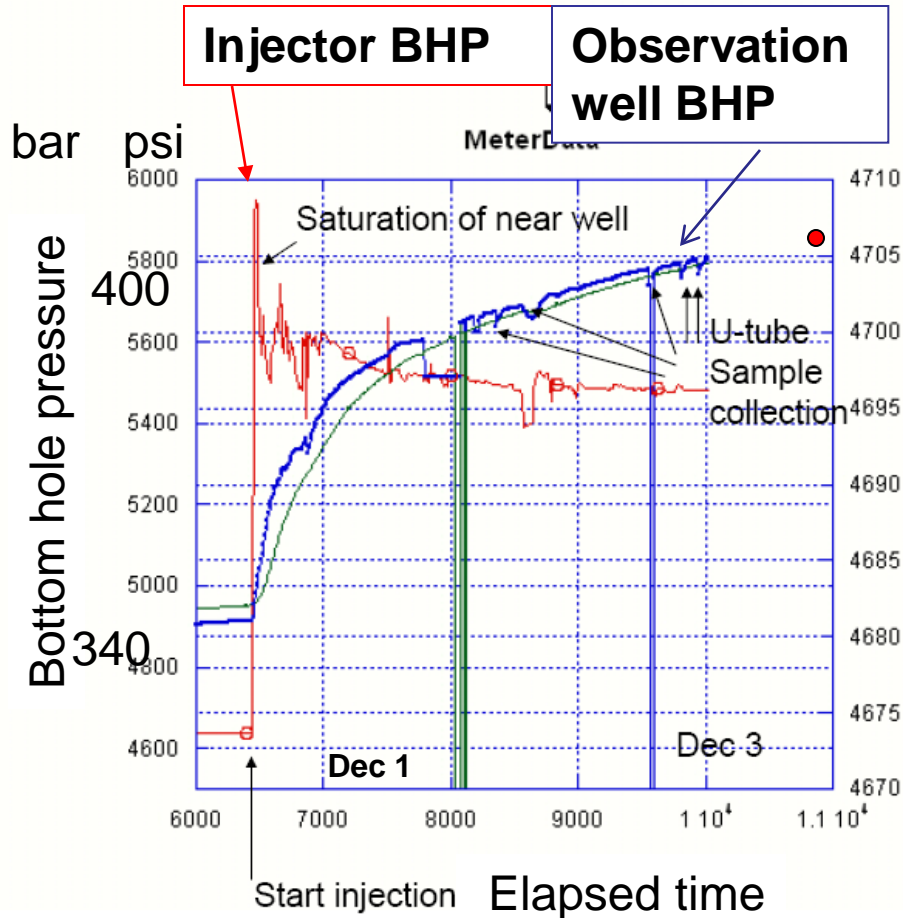


# First Breakthrough (time) Predictions F2 Well (for each of 10 permeability fields)



# Start injection at DAS Dec 1, 2009

175 kg/min step up to 520 kg/min



It's all about pressure

# DAS Monitoring

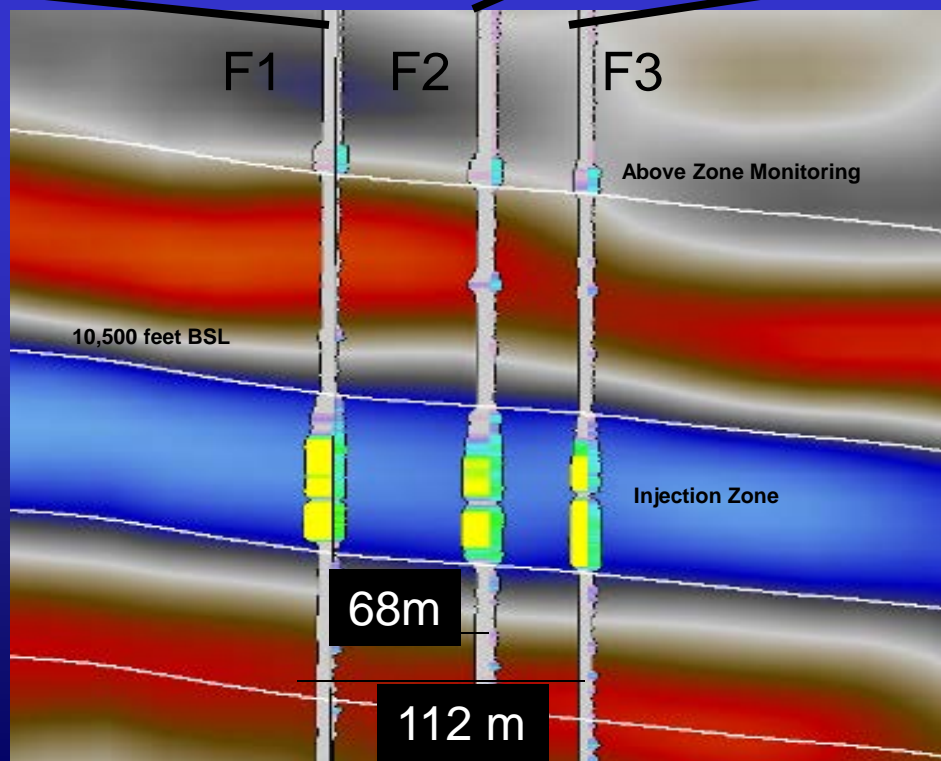
Injector  
CFU 31F1

Obs  
CFU 31 F2

Obs  
CFU 31 F3

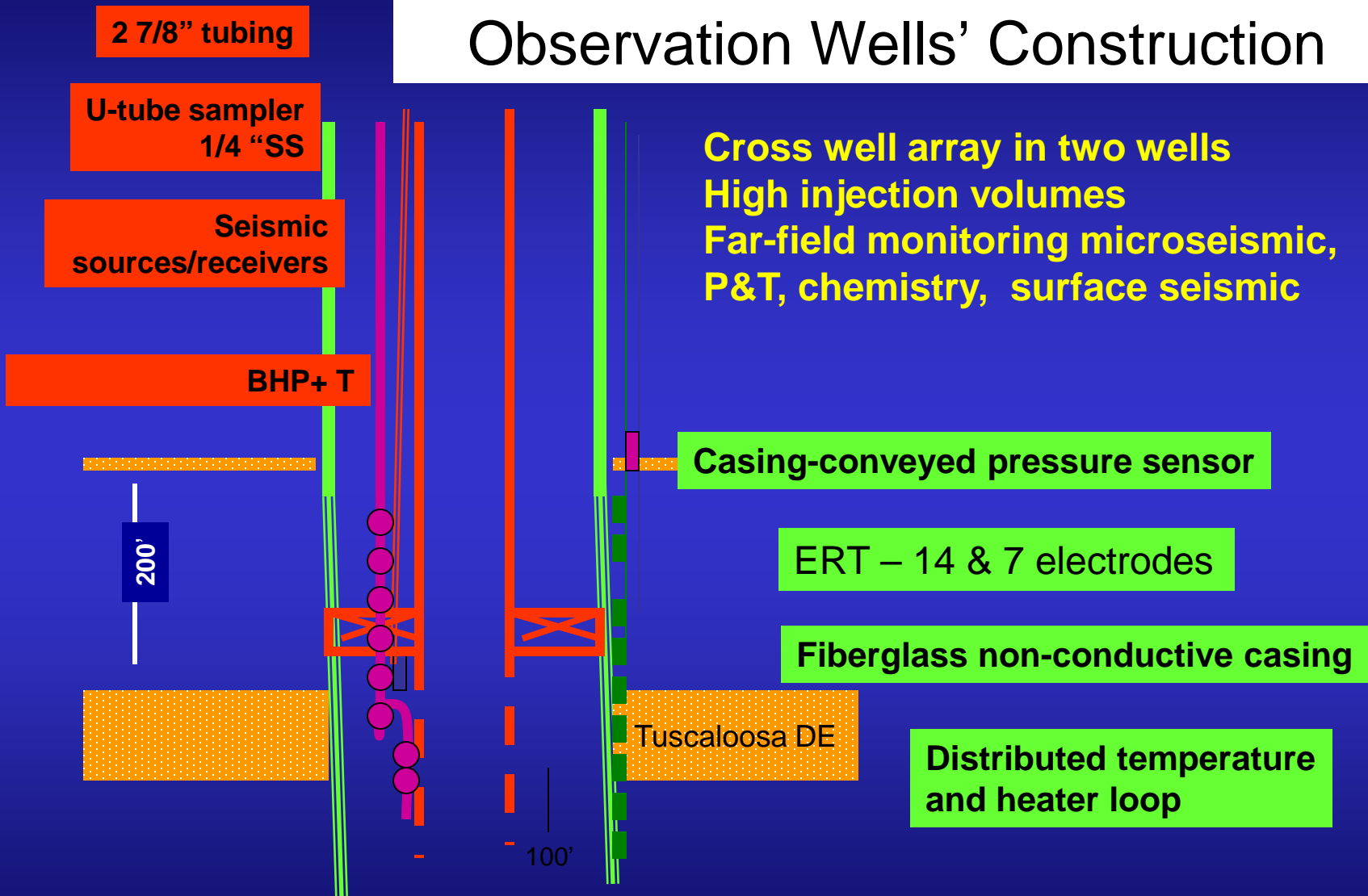


Closely spaced well  
array to examine  
flow in complex  
reservoir



Petrel model Tip Meckel

# Phase III Research Observation Wells' Construction



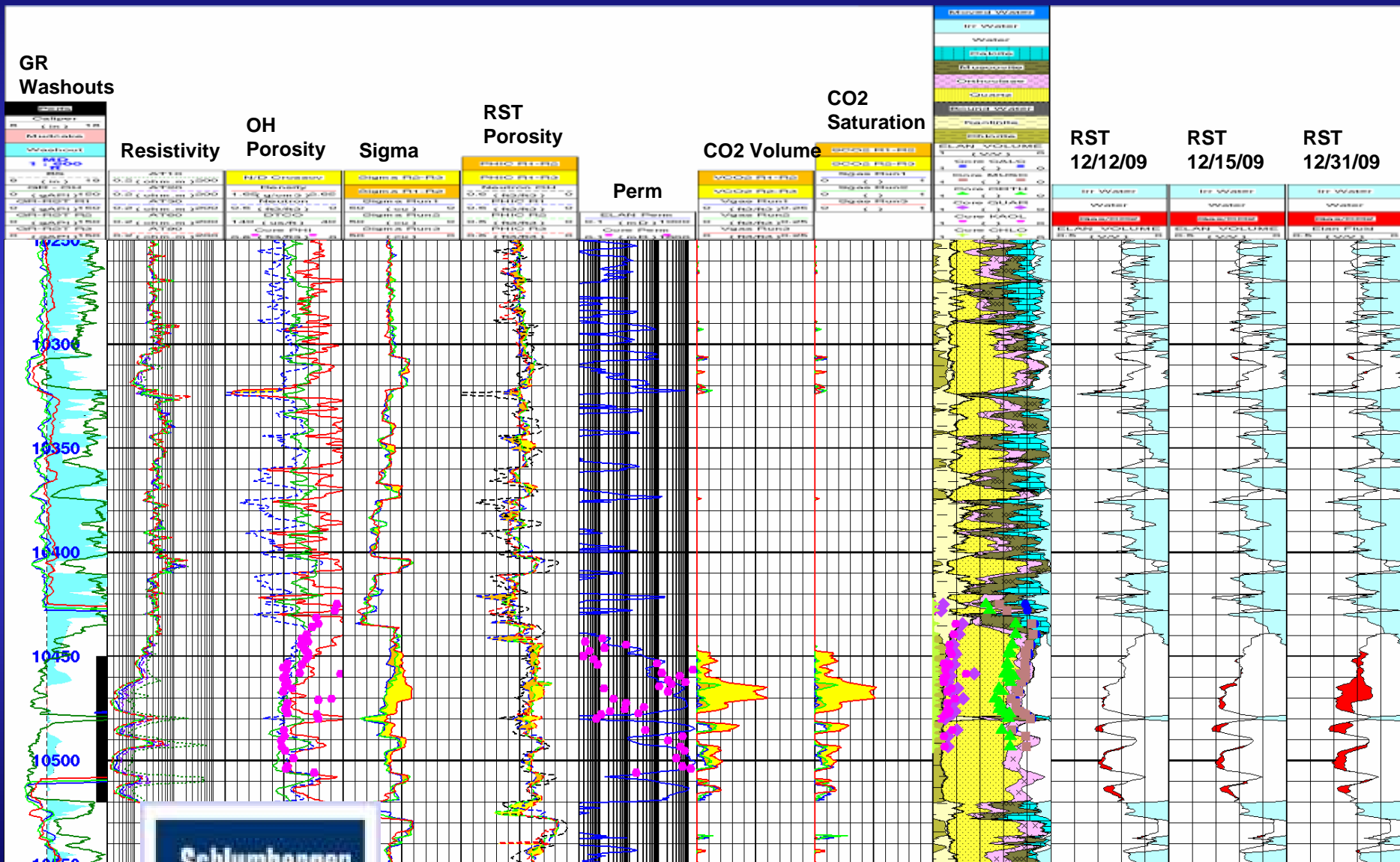
BEG, LBNL, LLNL, USGS, ORNL, Sandia Technologies LLC

# Measuring CO<sub>2</sub> Distribution in Reservoir

- Well-based methods
  - Wireline logs in time lapse – RST (Schlumberger)
  - Temperature
- Cross well methods
  - Time – lapse ERT
  - Time – lapse acoustic (seismic)

# Wireline Formation Evaluation (ELAN – RST)

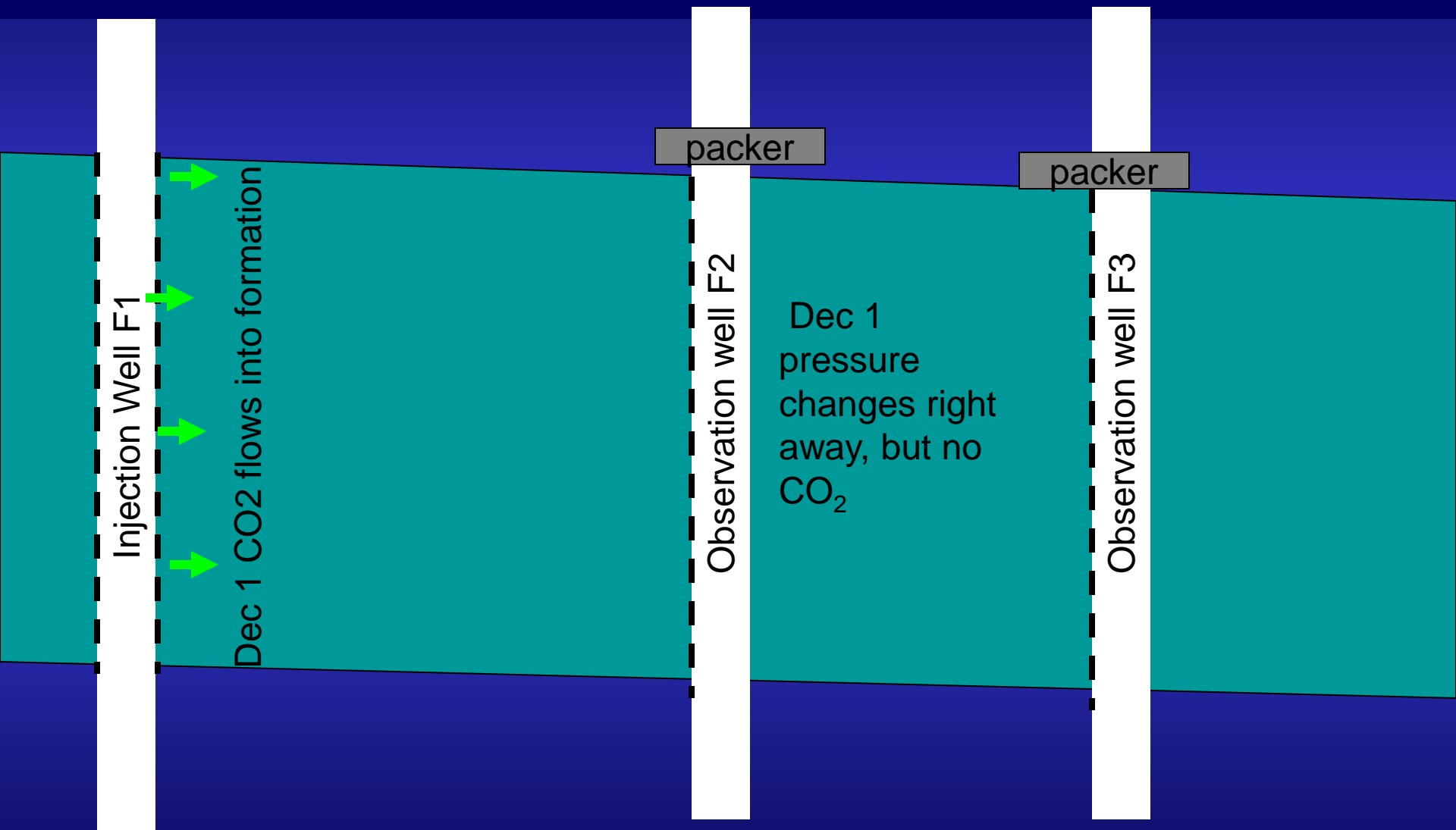
## CFU 31 – F3



Bob Butch



# What happened at the wells?



Injection Well F1

Dec 1 CO<sub>2</sub> flows into formation

packer

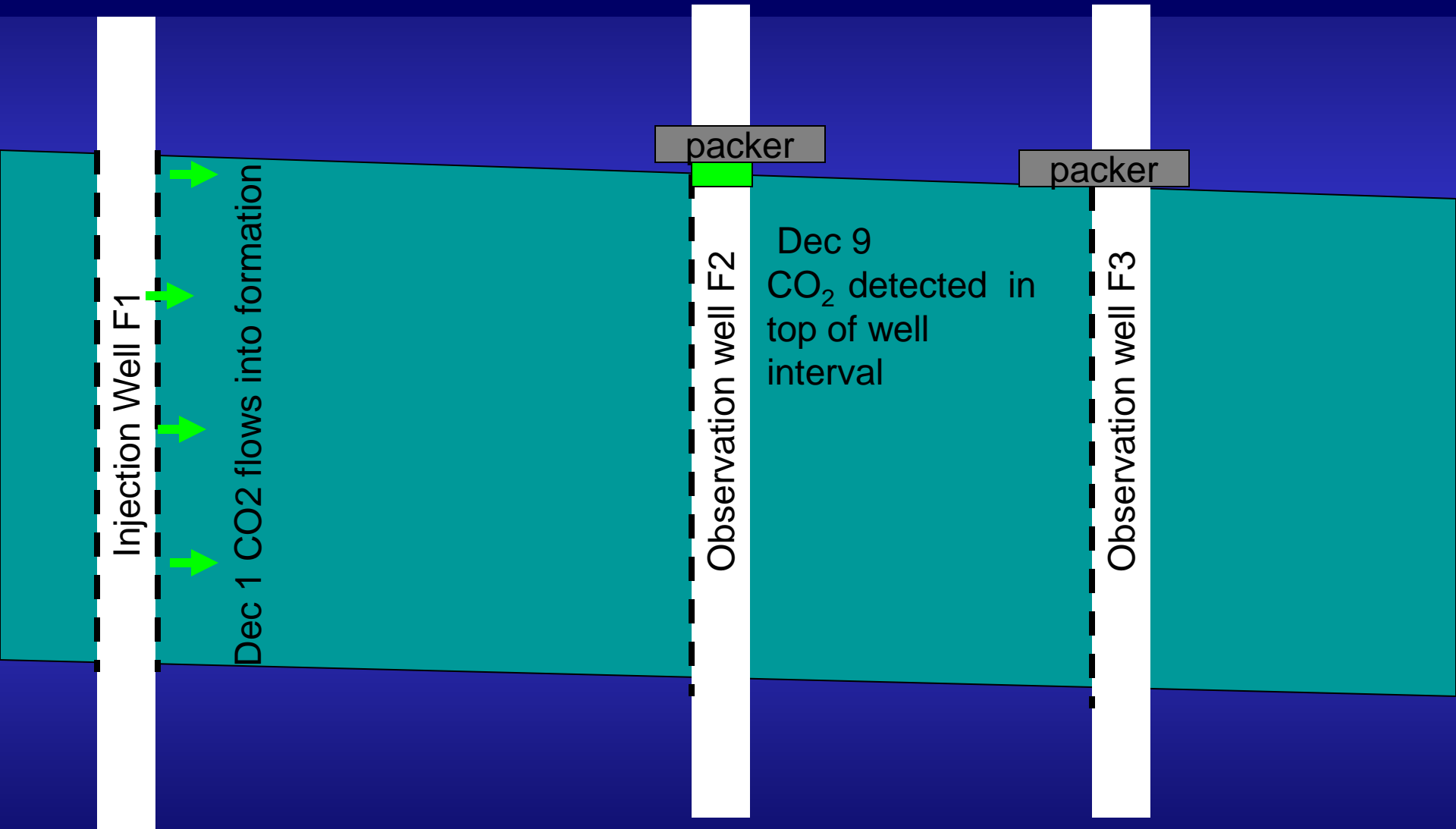
Observation well F2

Dec 1  
pressure  
changes right  
away, but no  
CO<sub>2</sub>

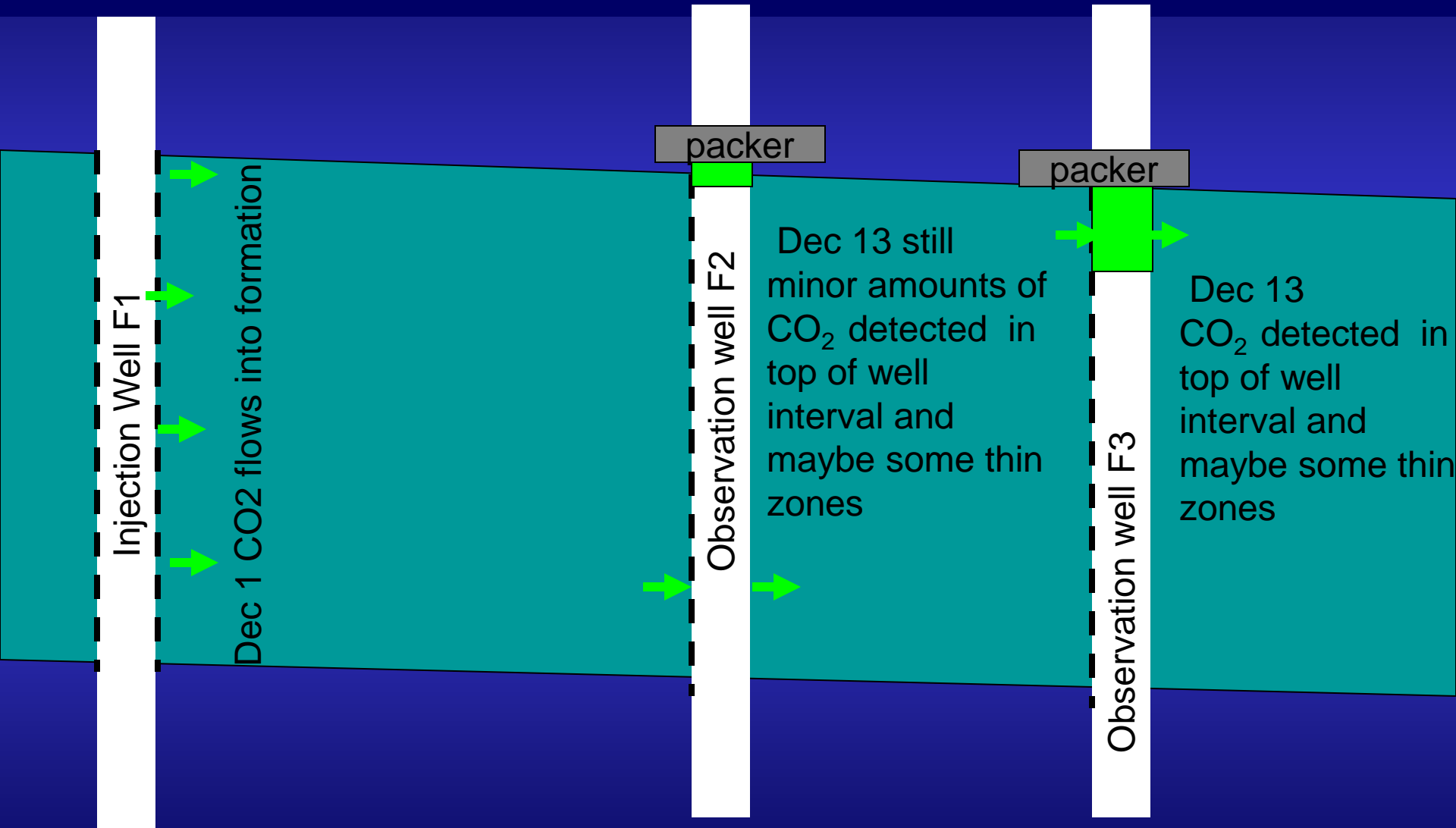
packer

Observation well F3

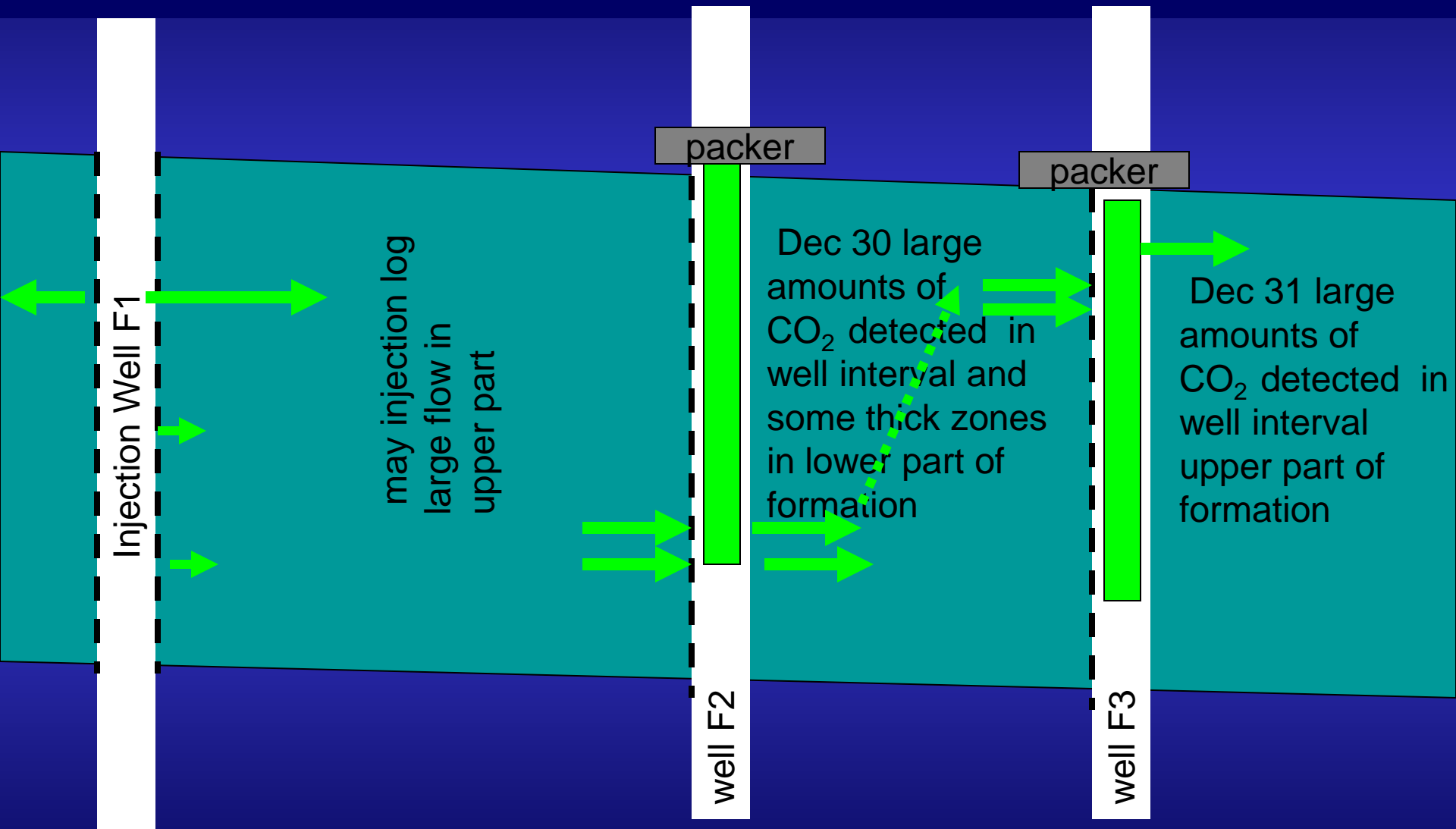
# Day 9



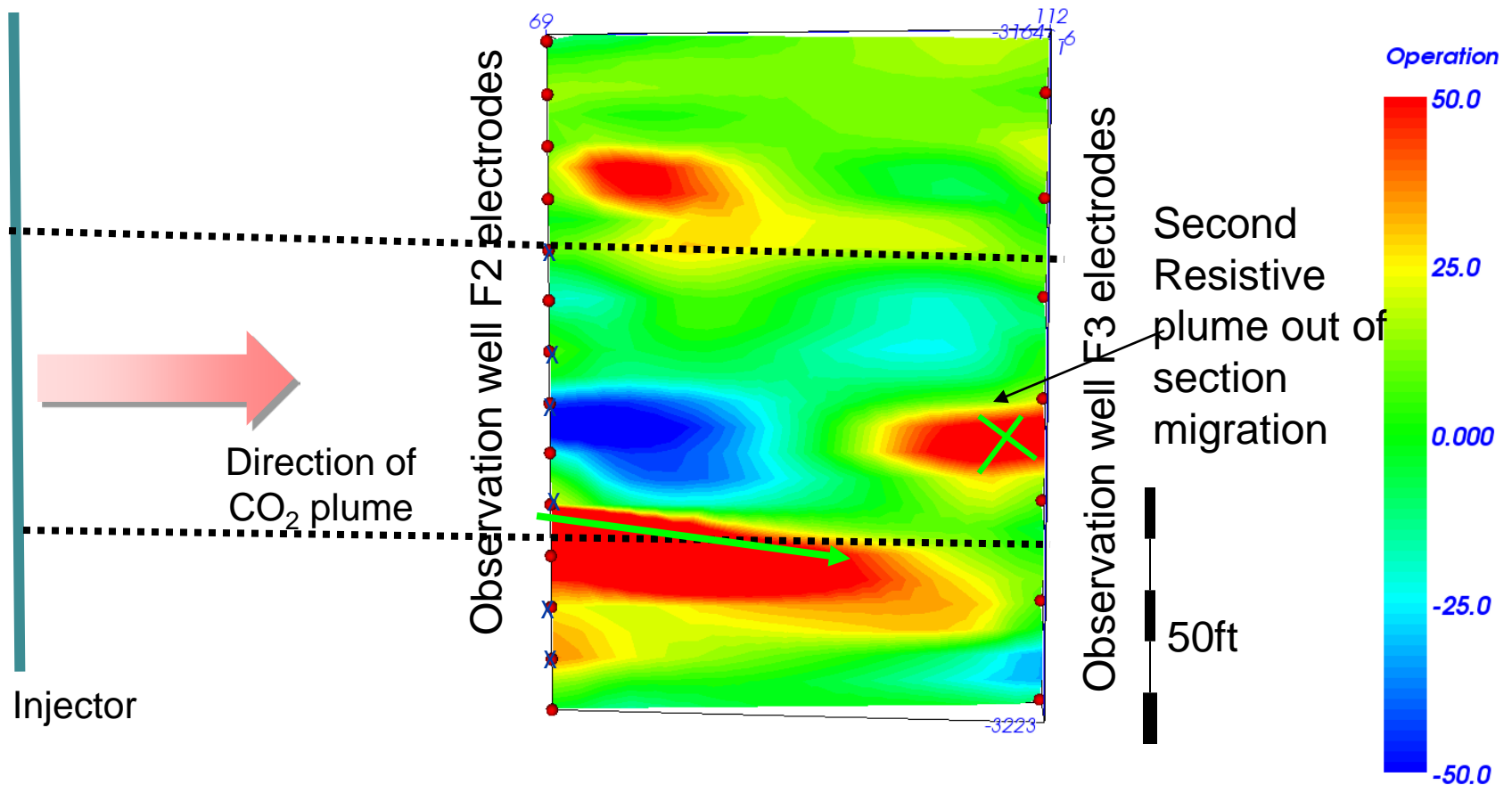
# Day 13



# Day 31

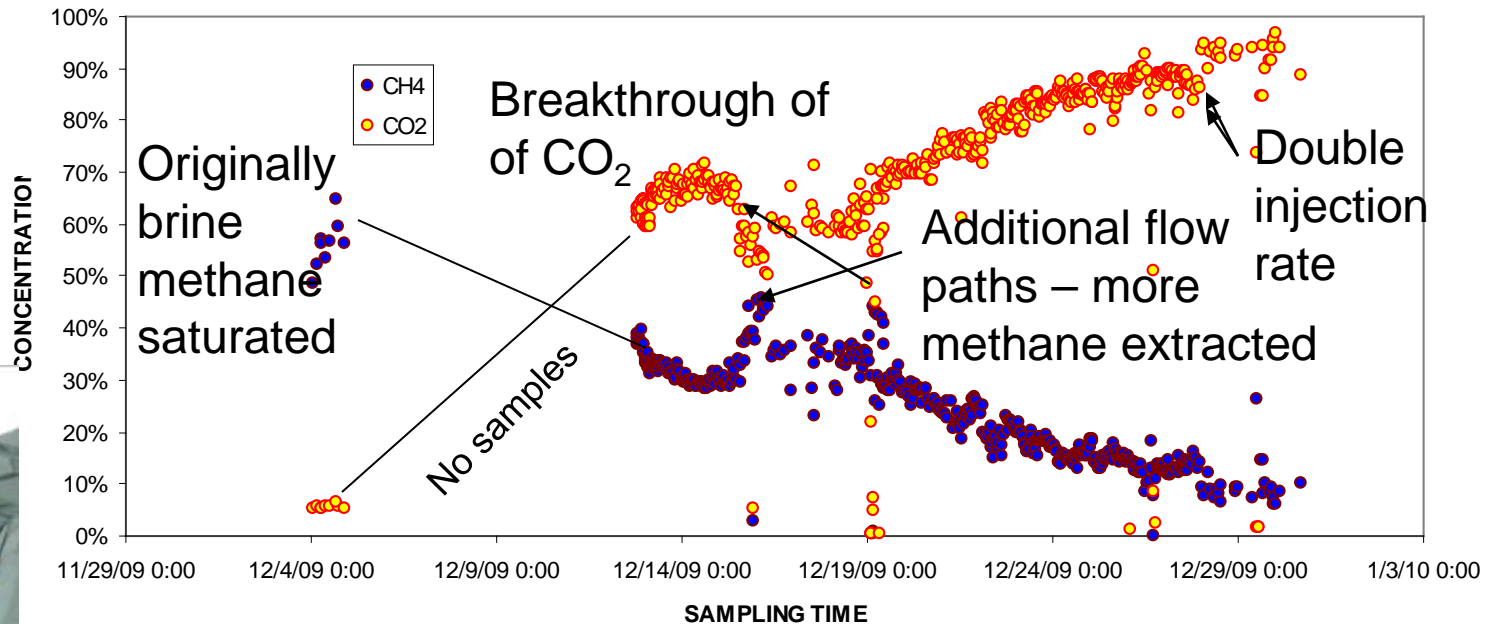


# Cross Well ERT tells us how flow occurred



Resistive plume = CO<sub>2</sub> in reservoir  
Conductive plume = workover fluids?

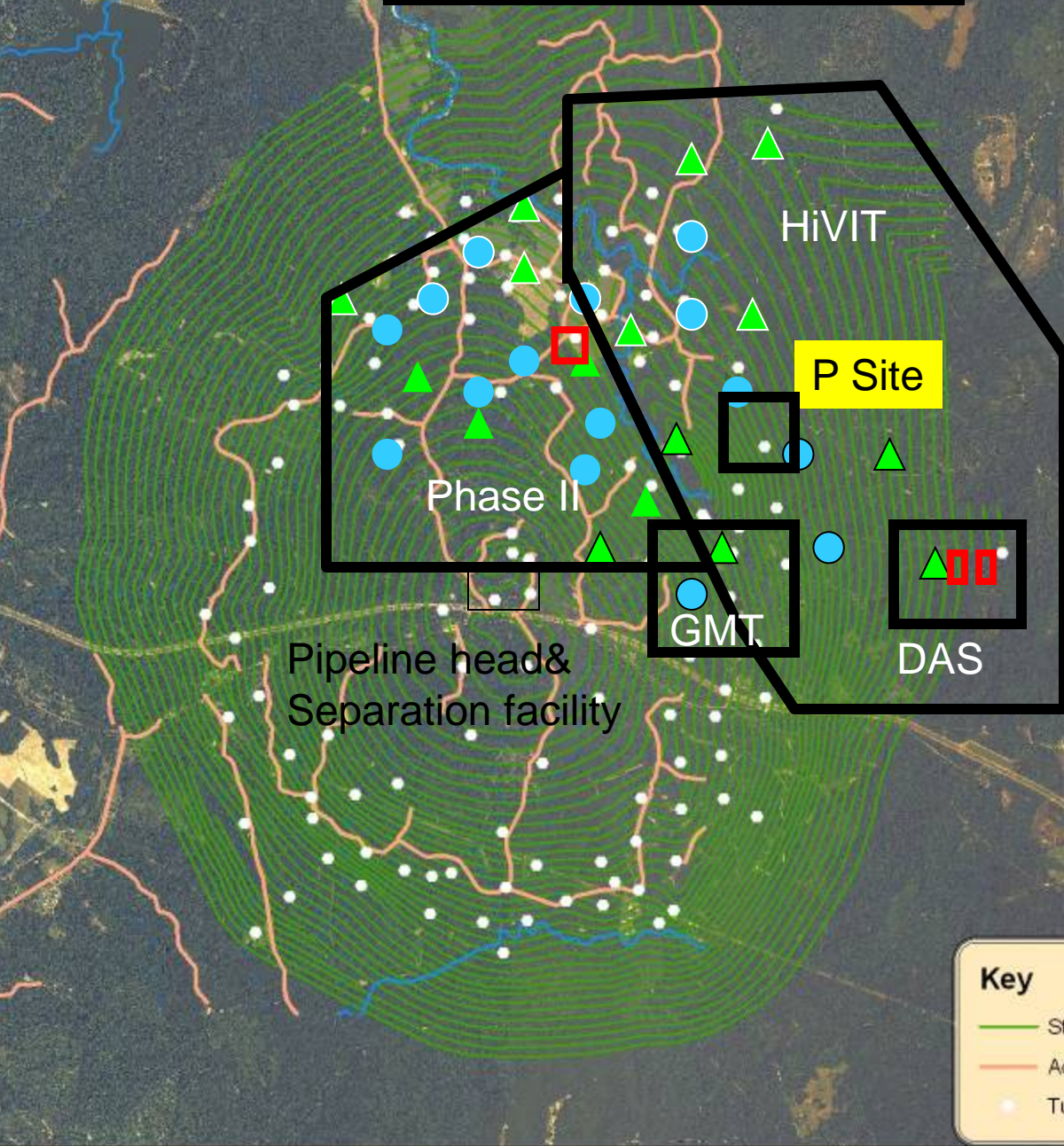
# High frequency fluid sampling via U-tube yields data on flow processes



Small diameter sampler with N<sub>2</sub> drive brings fluids quickly to surface with tracers intact

CO<sub>2</sub> dissolution into brine liberates dissolved CH<sub>4</sub>

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



Is it possible to find leakage at surface? P-Site tests

- ▲ Injector
- Producer (monitoring point)
- ◻ Observation Well

# Assessment of near surface techniques "P Site"

Clear-cut right-of-way for empty pipe

Pit  
Pad  
Plants  
P&A well

road

1-BG

Trans 1

Trans 4

4-02

1-02

1-01

AW

1-00

1-03

1-04

1-05

3-01

3-02

1-01

2-01

2-02

Trans 3

Trans 2

1950's pit





# Phase III Current Status

- Injection since April, 2009
- Injection through 23 wells cumulative volume of 1,067,339 metric tonnes
- Rates 0.8 to 1 million tonnes/year
- Currently Task 11: Repeat Geophysics
  - cross well seismic
  - VSP, AIT, acoustic logging, RST
  - repeat surface 3-D seismic

# Interim Conclusions (Cranfield)

- Phase III 1 million tonne/year rate achieved Dec 20, 2009, 2 Million tonnes monitored since July 2008
- Rate to be maintained >15 months
- Monitored with standard and novel approaches
  - History match pressure response
  - Fluid flow measured/monitored with multiple tools in complex flow field
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