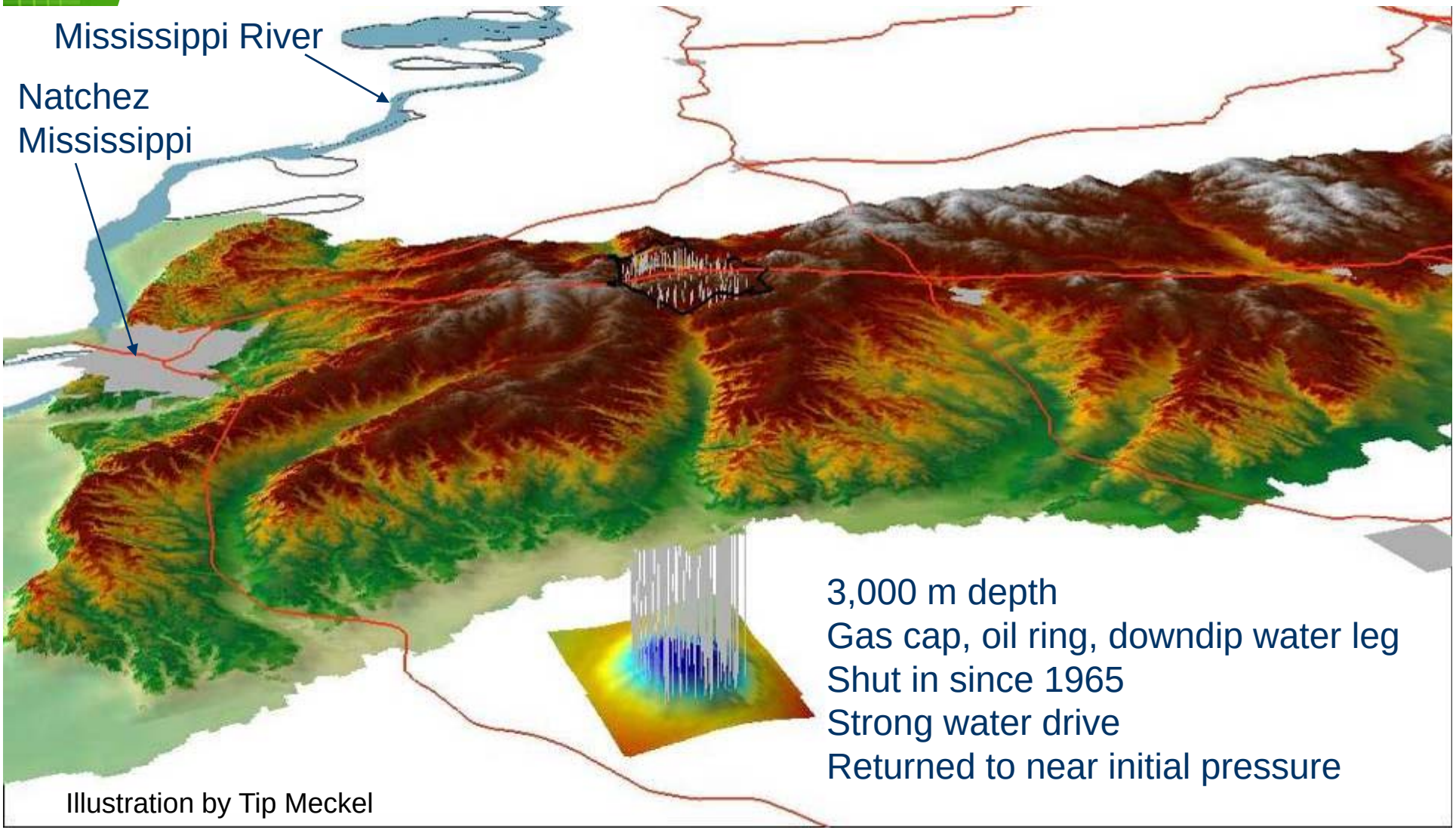
Update on Results of SECARB Test of Monitoring Large Volume Injection at Cranfield



Cranfield "Early" Field Test Collaboration

Denbury Onshore LLC

Sandia Technologies, 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
Stuart Coleman
Yihua Cai
Hamid Lashgari

BEG staff

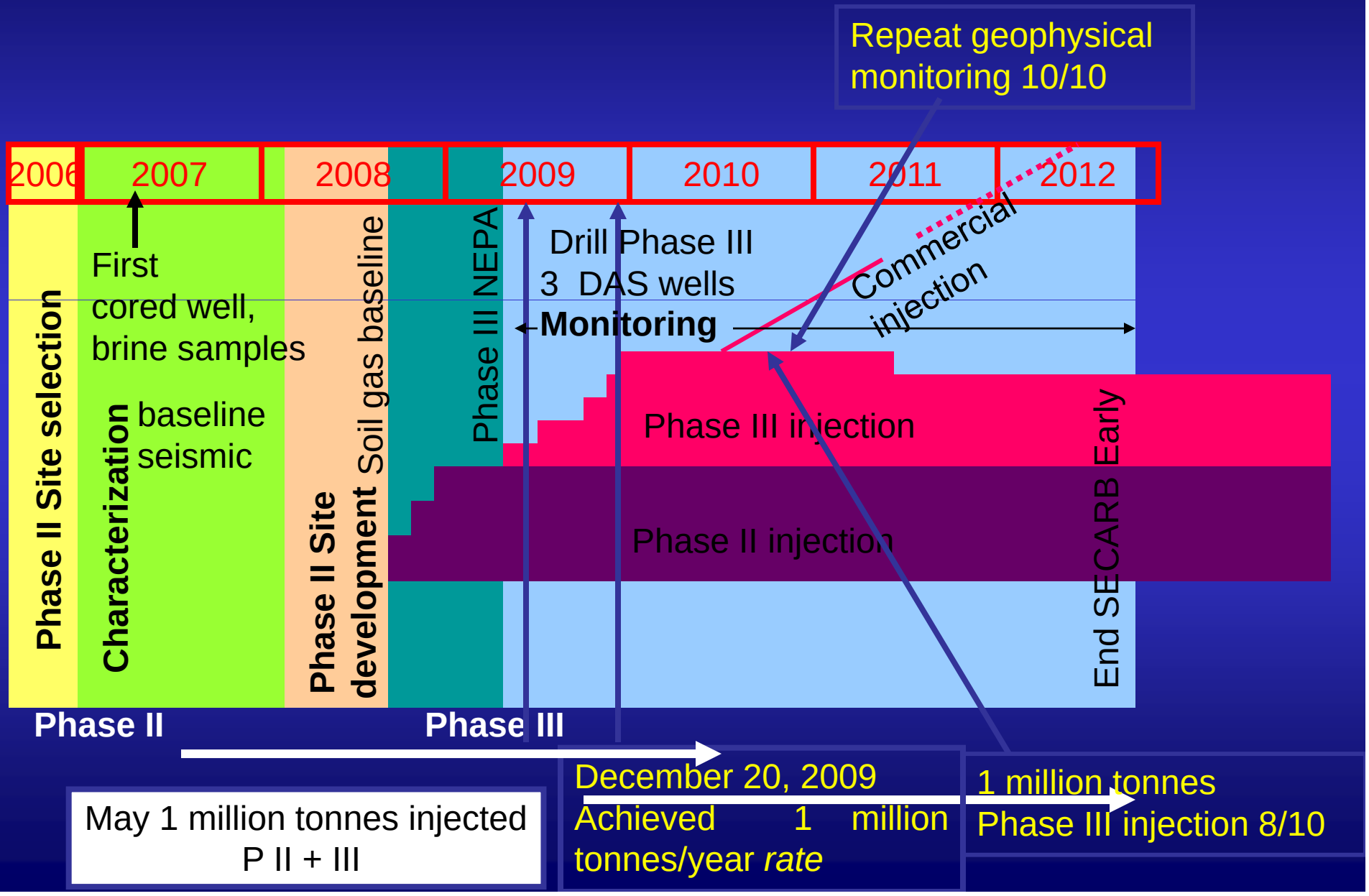
Tongwei Zhang
Jeff Paine
Bob Reedy
Robert Reed
Kitty Millikan

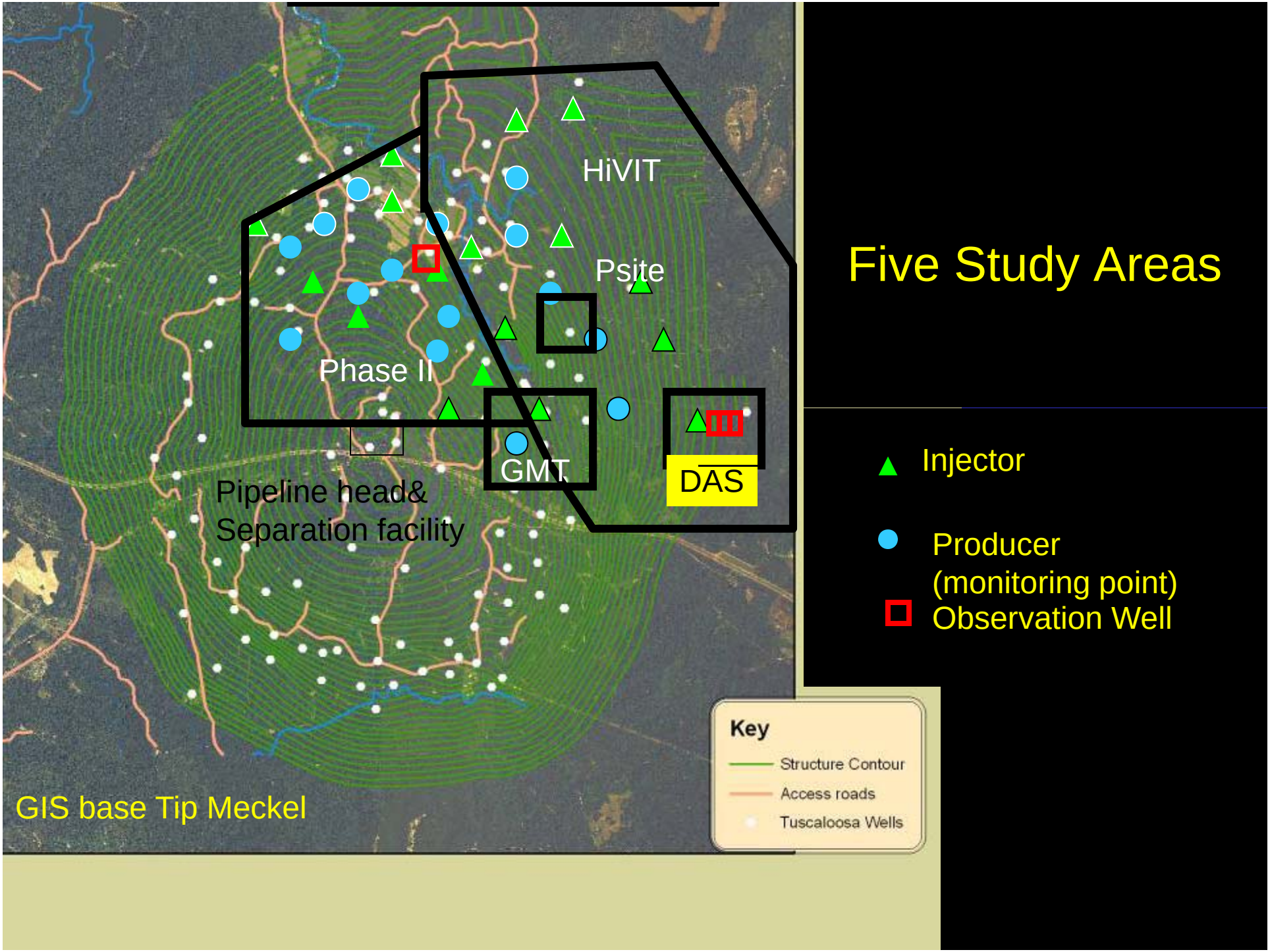
Gulf Coast Carbon Center Industrial Associates

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 CO2 dissolution
- Export to commercial EOR/sequestration projects

Cranfield Progress



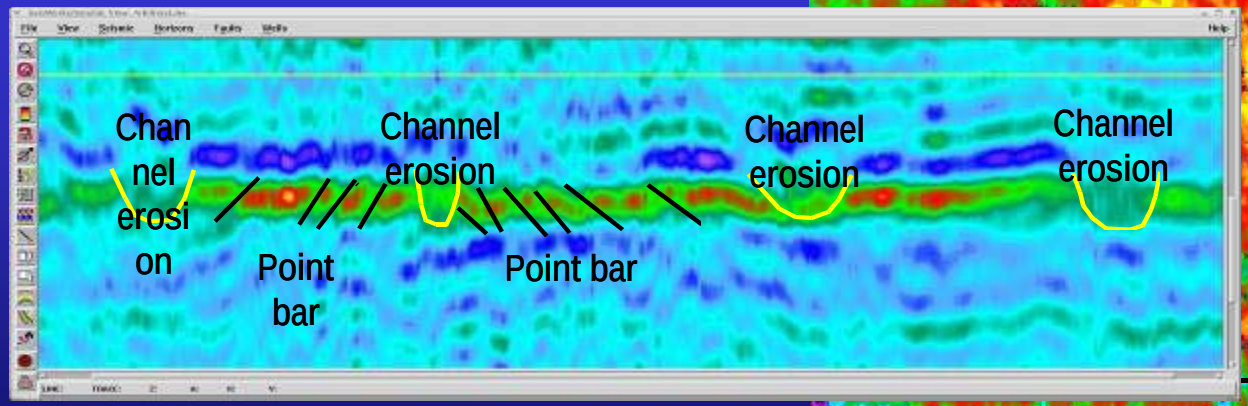


Five Study Areas

- Injector
- Producer (monitoring point)
- Observation Well

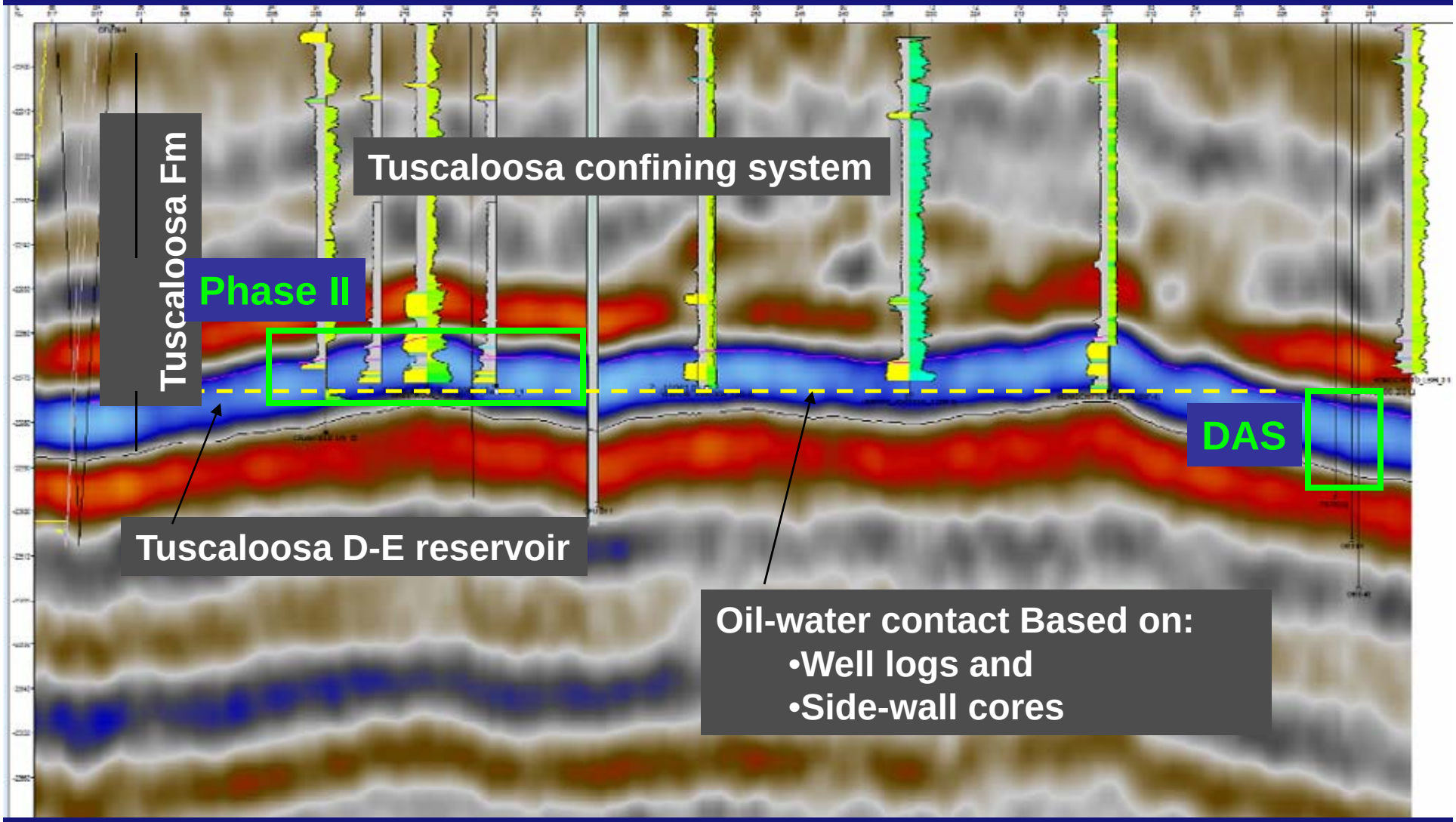
Reservoir Heterogeneity from Surface 3D Seismic

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



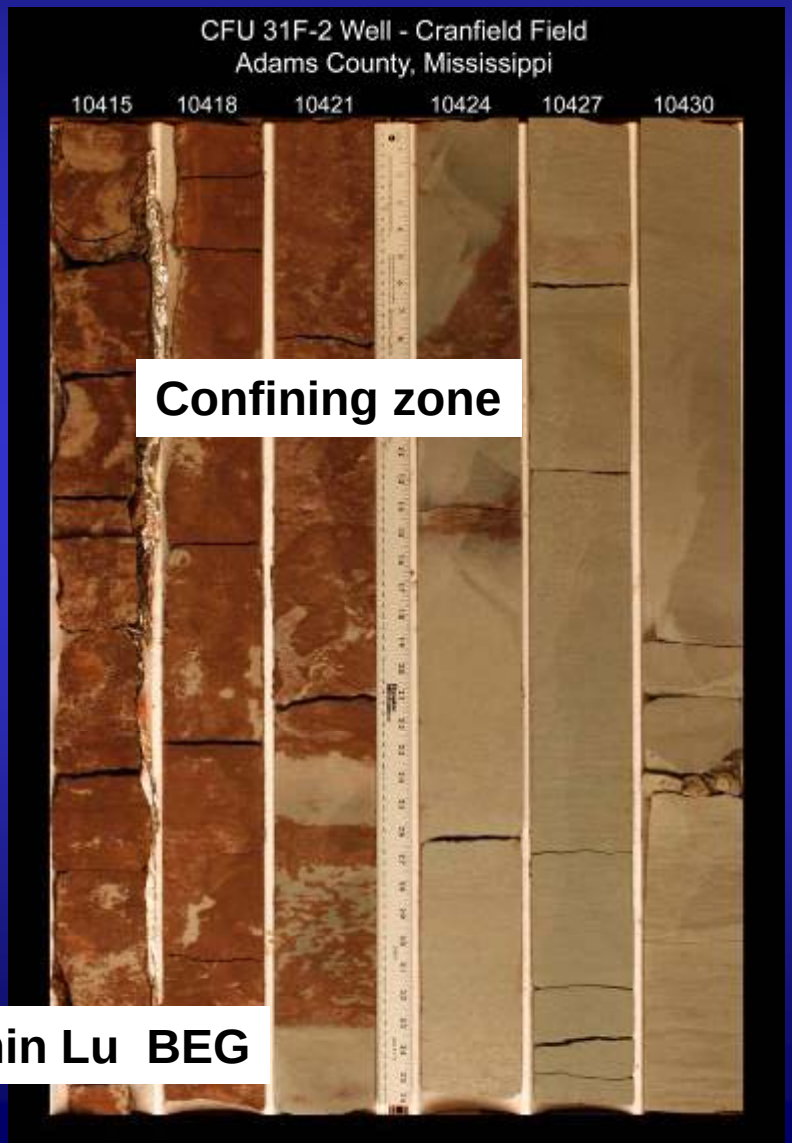
Denbury 3-D survey interpretation Hongliu Zeng, BEG

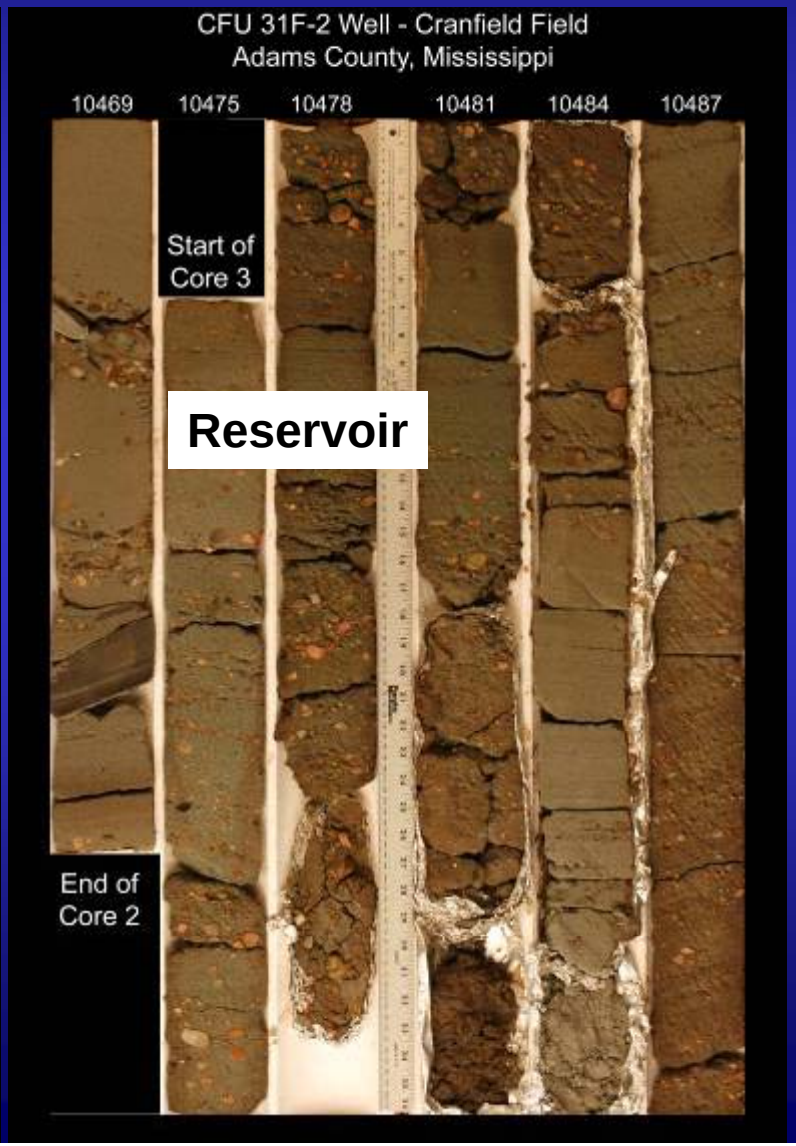
Reservoir Characterization



3D Denbury - interpretation Tip Meckel BEG

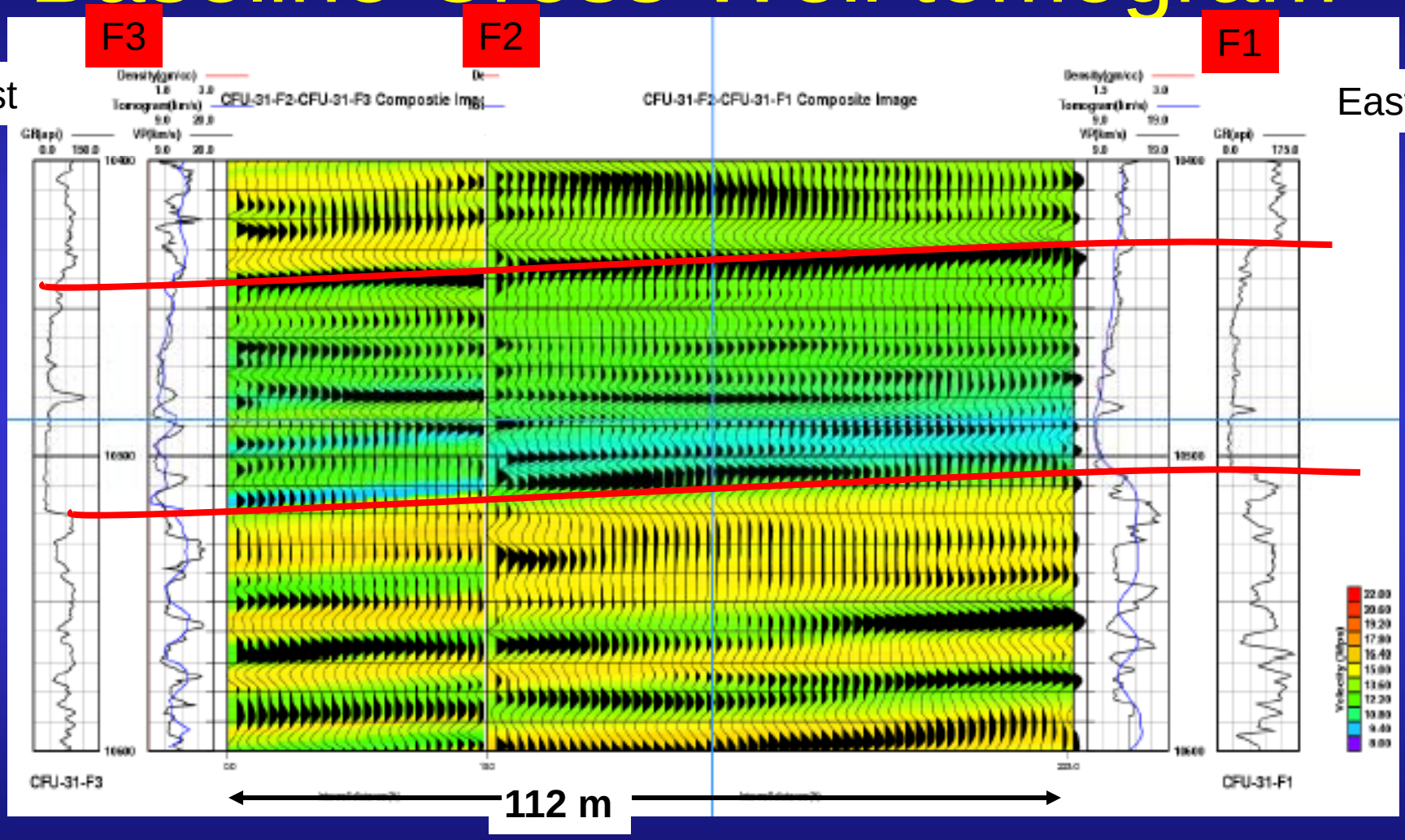
Upward fining fluvial sandstone and conglomerates of the lower Tuscaloosa Fm





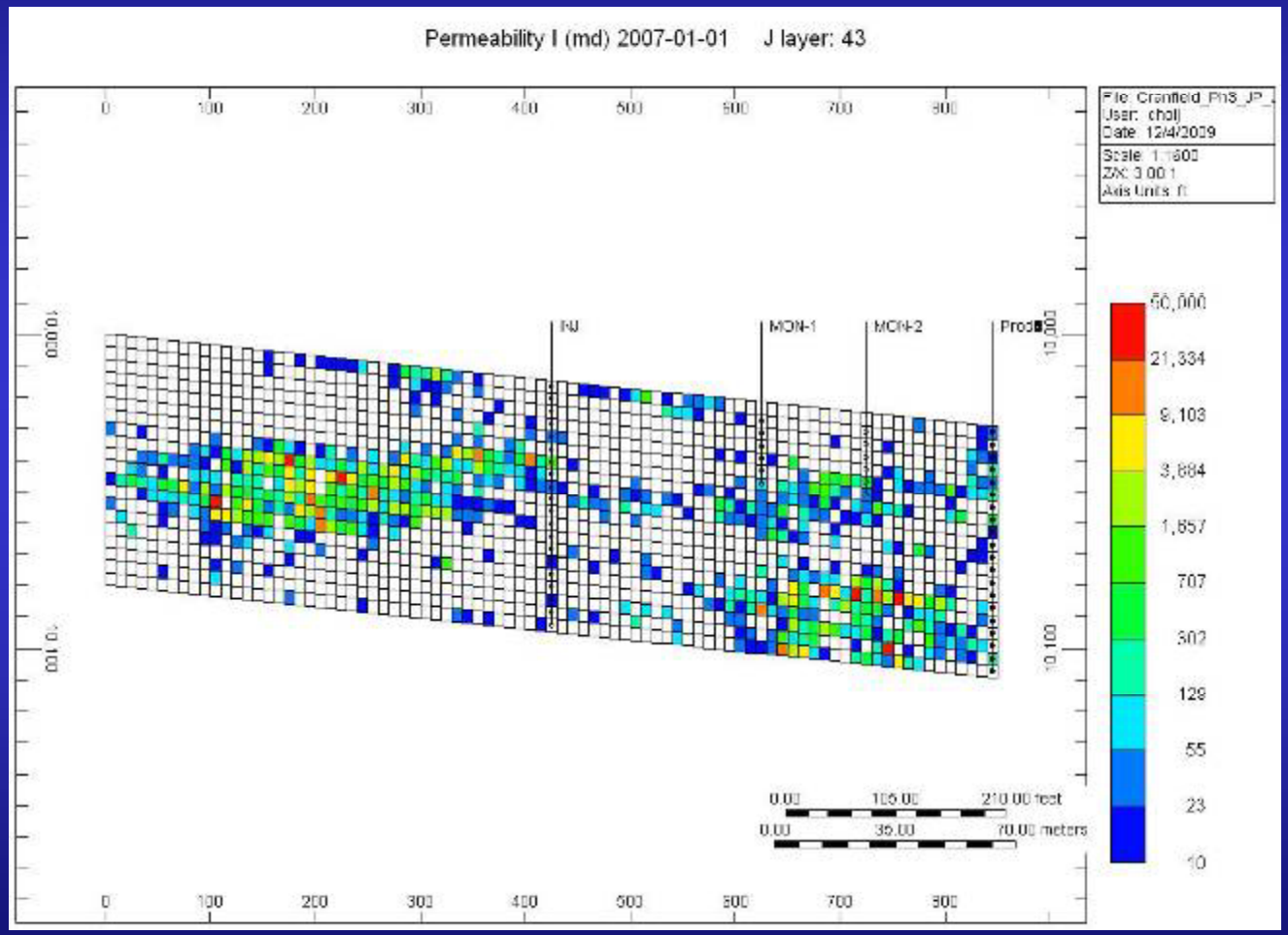
Jiemin Lu BEG

Baseline Cross Well tomogram



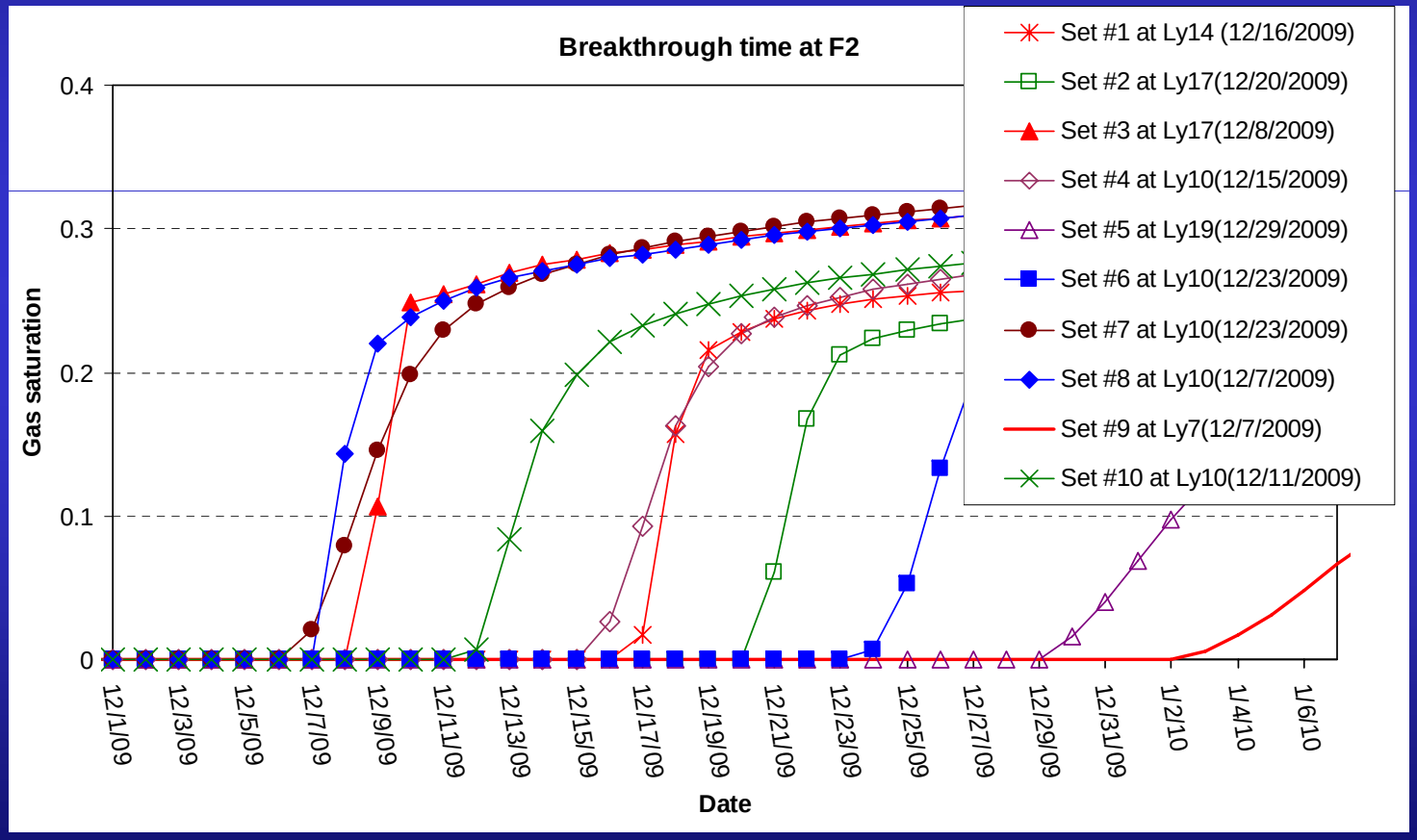
Z-Seis & Tom Daley Jonathan Franklin in review at LBNL

Probabilistic Realization Permeability



Jong-Won Choi and J.P. Nicot BEG

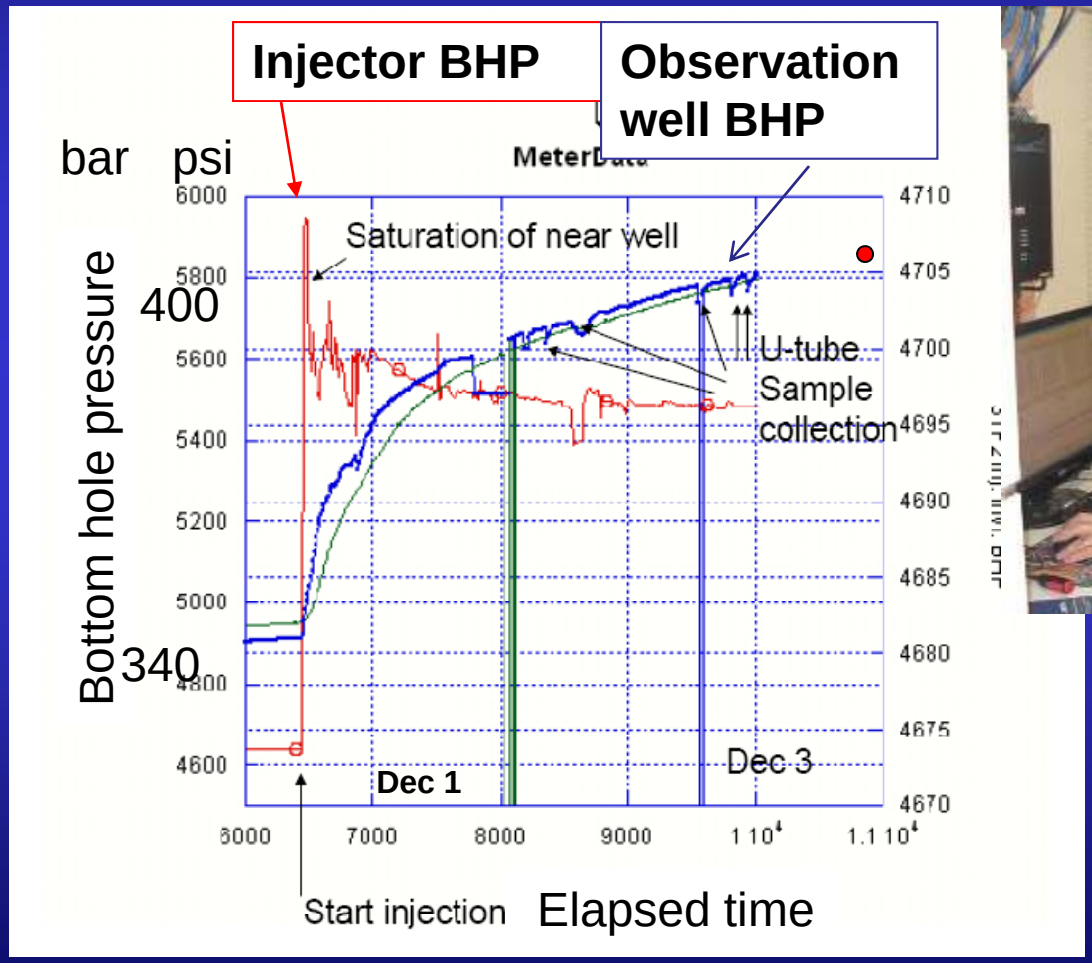
First Breakthrough (time) Predictions F2 Well (for each of 10 permeability fields)



Jong-won Choi and JP Nicot BEG

Start injection at DAS Dec 1, 2009

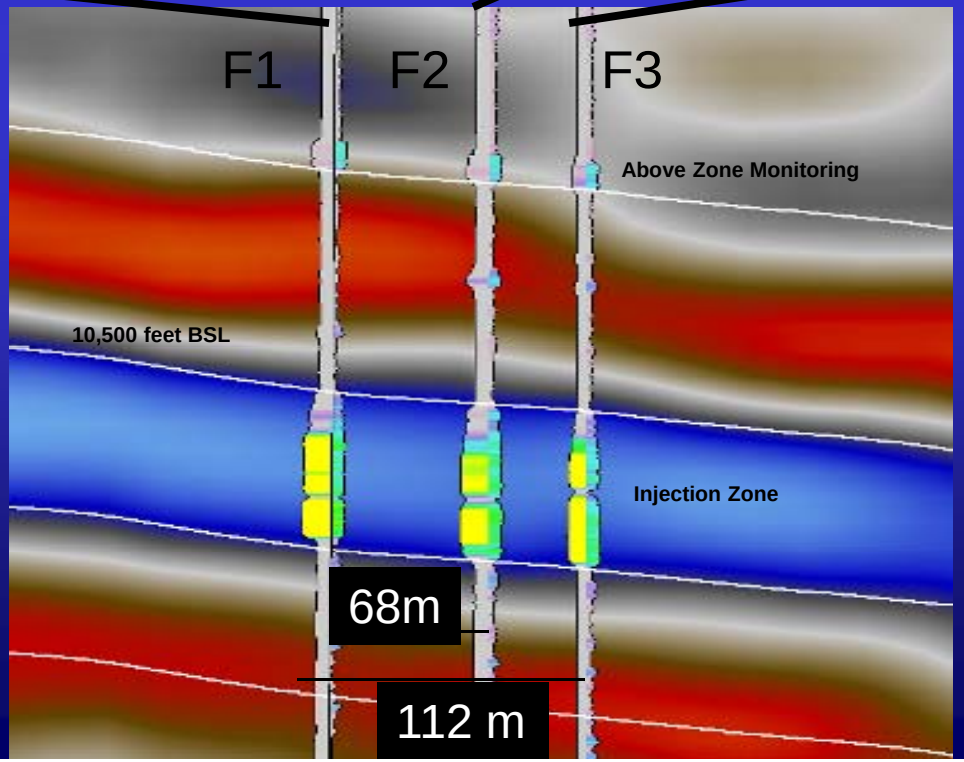
175 kg/min step up to 520 kg/min



It's all about pressure

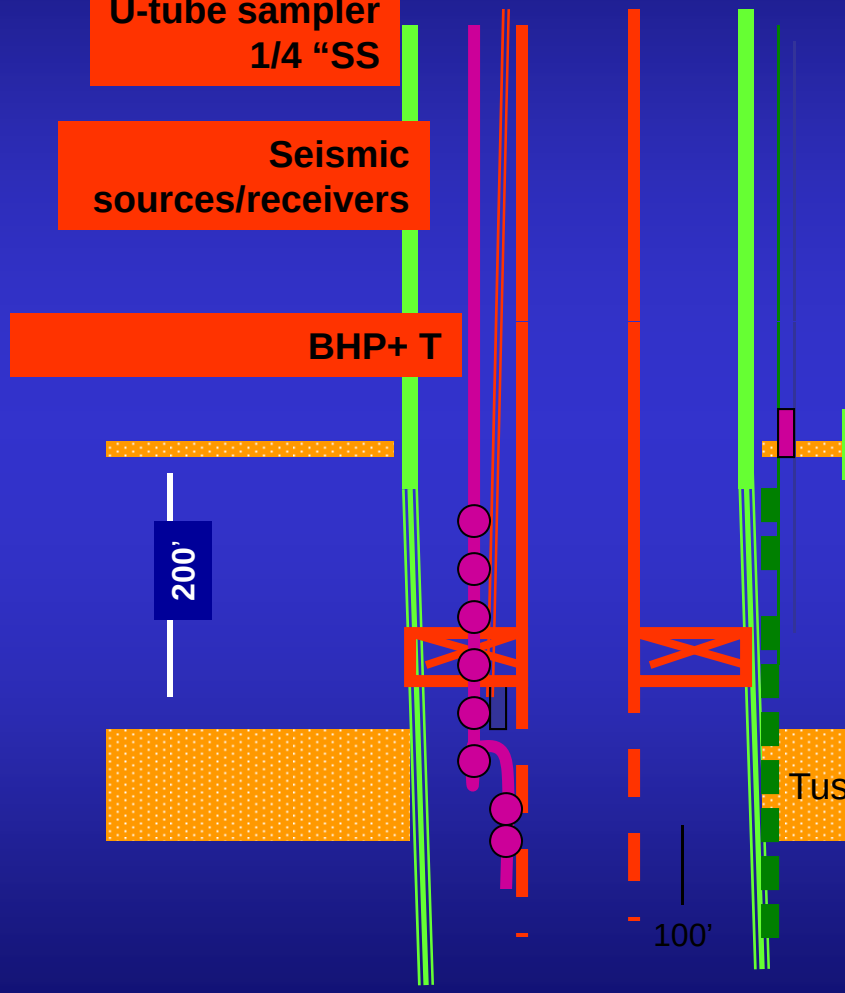
DAS Monitoring

Closely spaced well array to examine flow in complex reservoir



Petrel model Tip Meckel

Phase III Research Observation Wells' Construction



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

Casing-conveyed pressure sensor

ERT – 14 & 7 electrodes

Fiberglass non-conductive casing

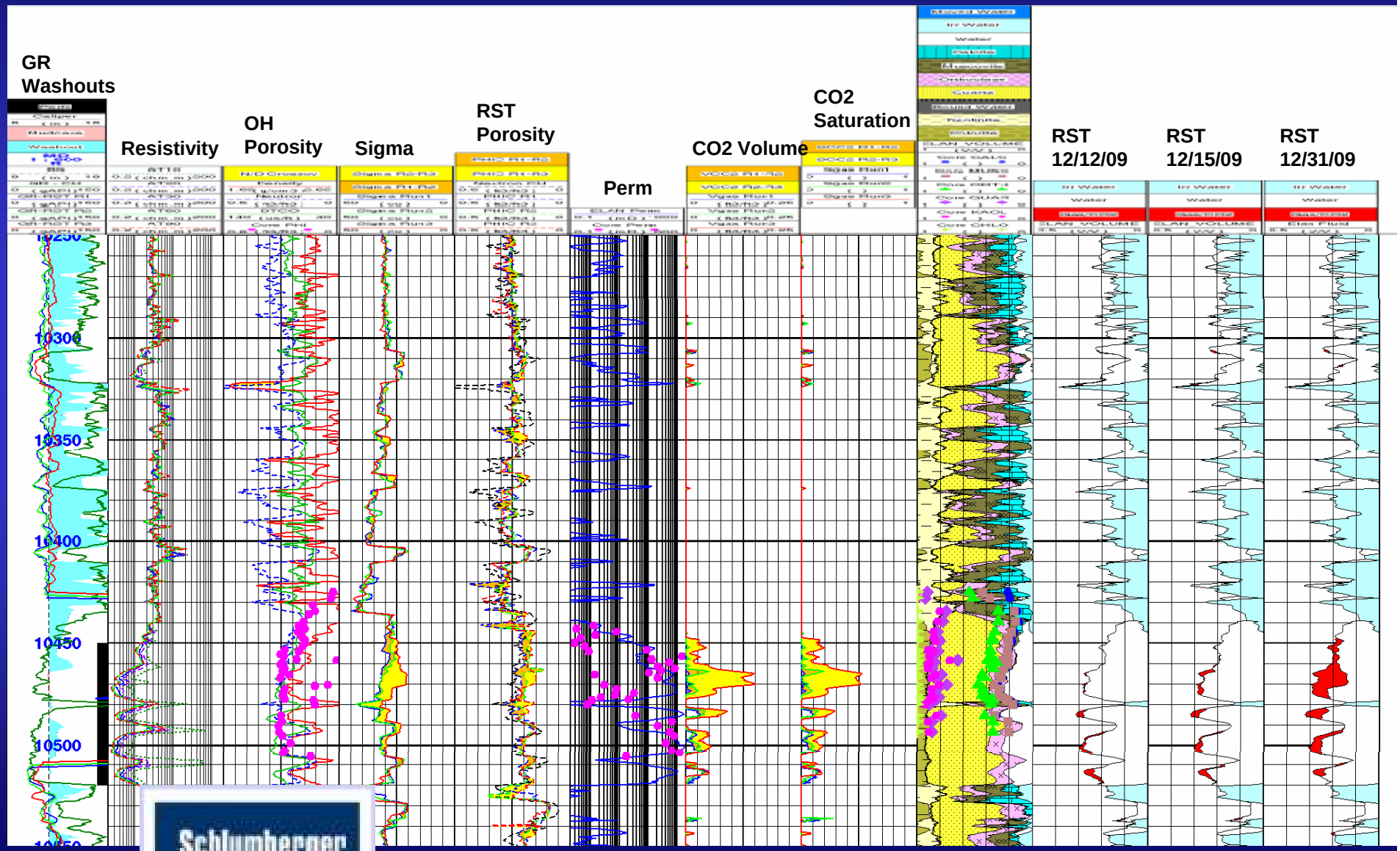
Distributed temperature and heater loop

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

Measuring CO_2 Distribution in Reservoir

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

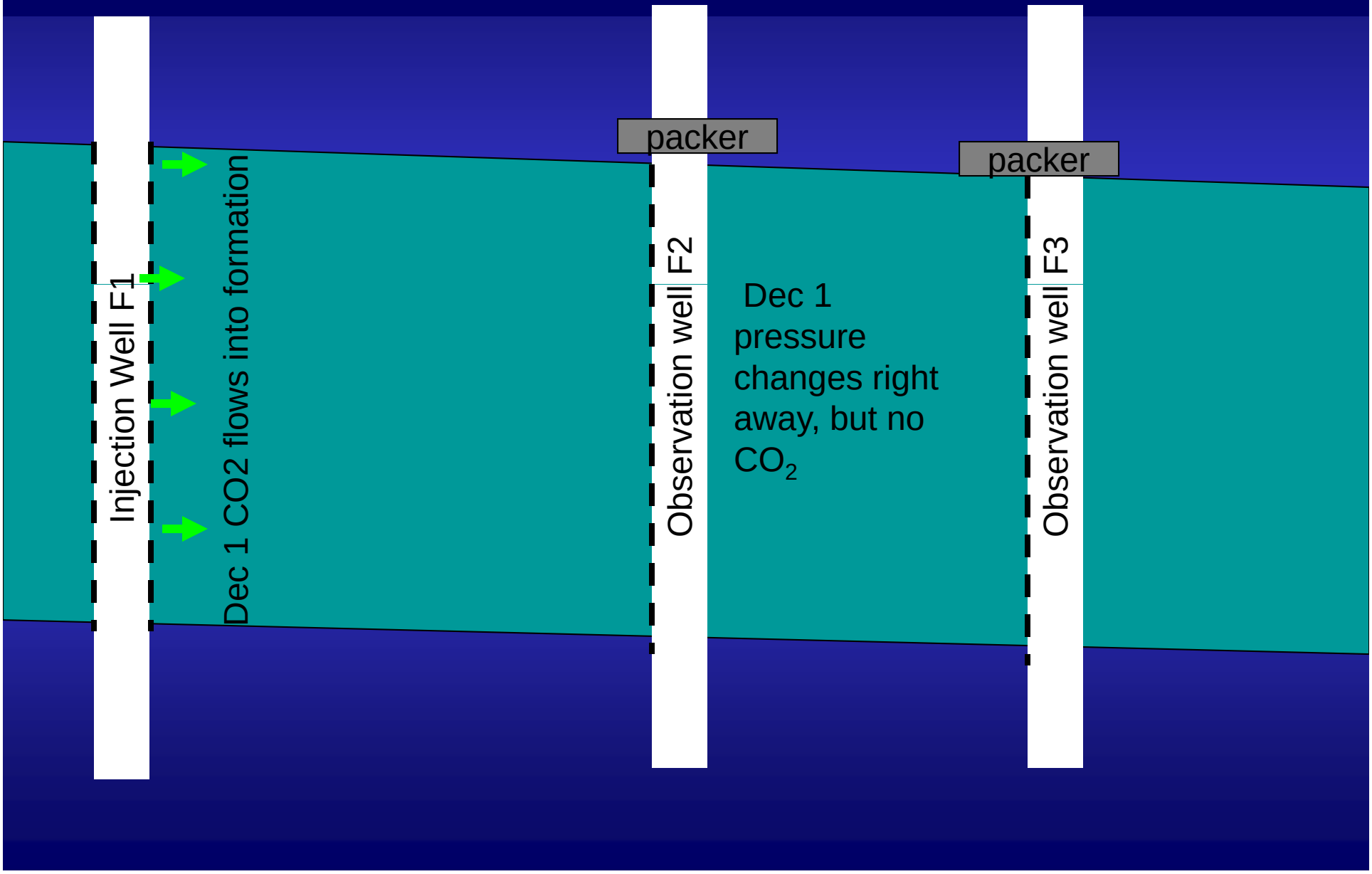
Wireline Formation Evaluation (ELAN – RST)
CFU 31 – **F3**

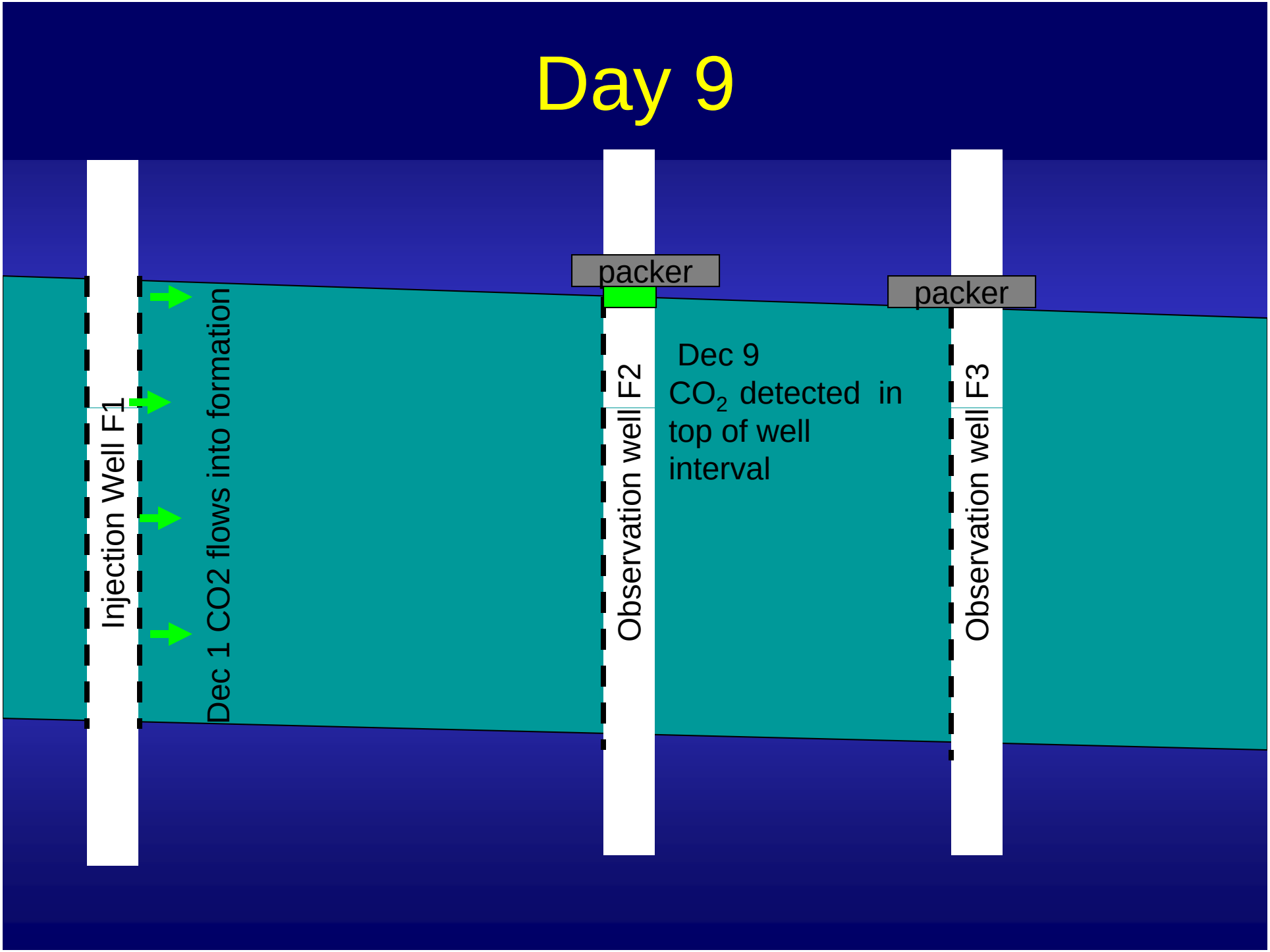


Schlumberger

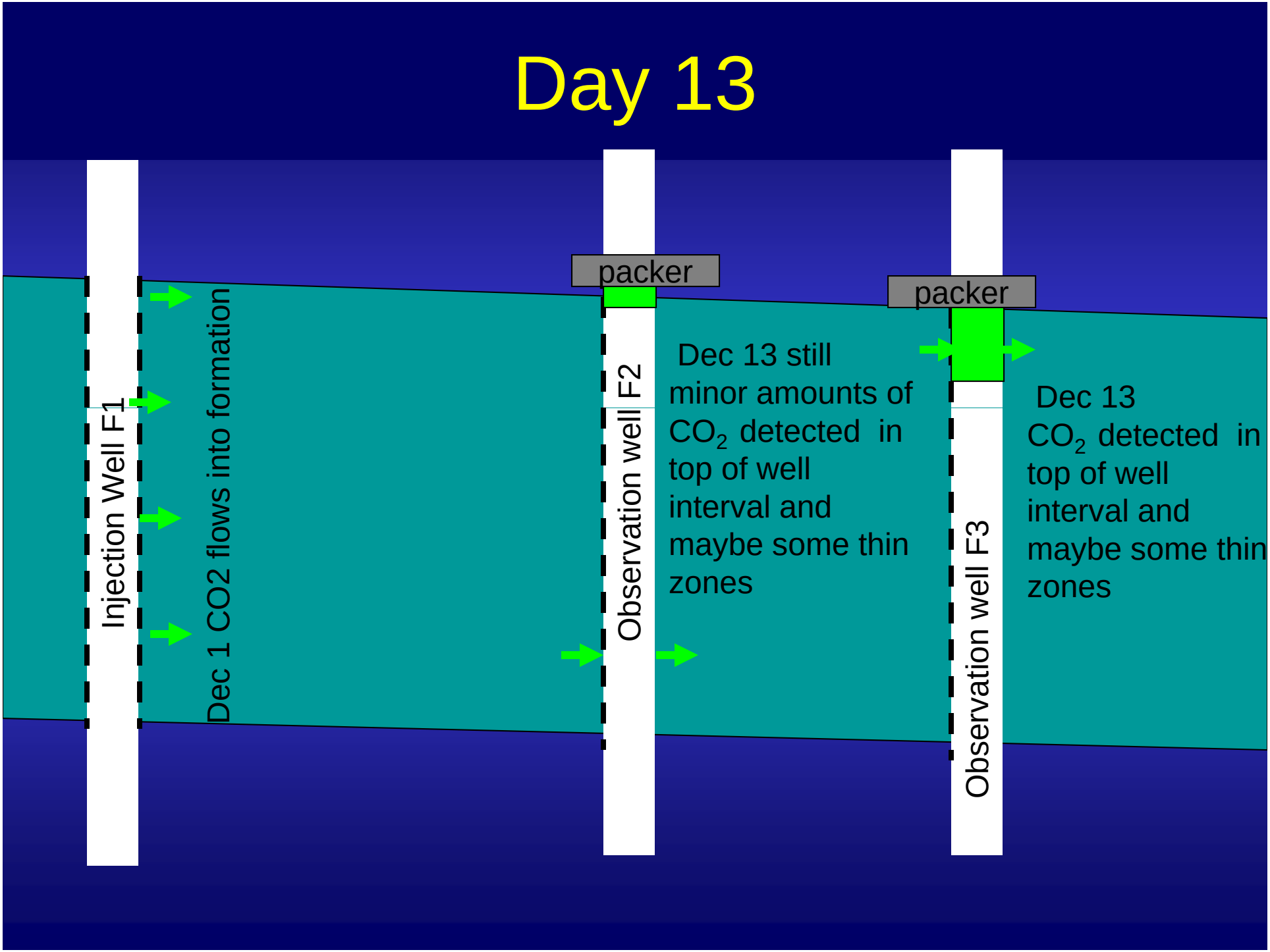
Bob Butch

What happened at the wells?

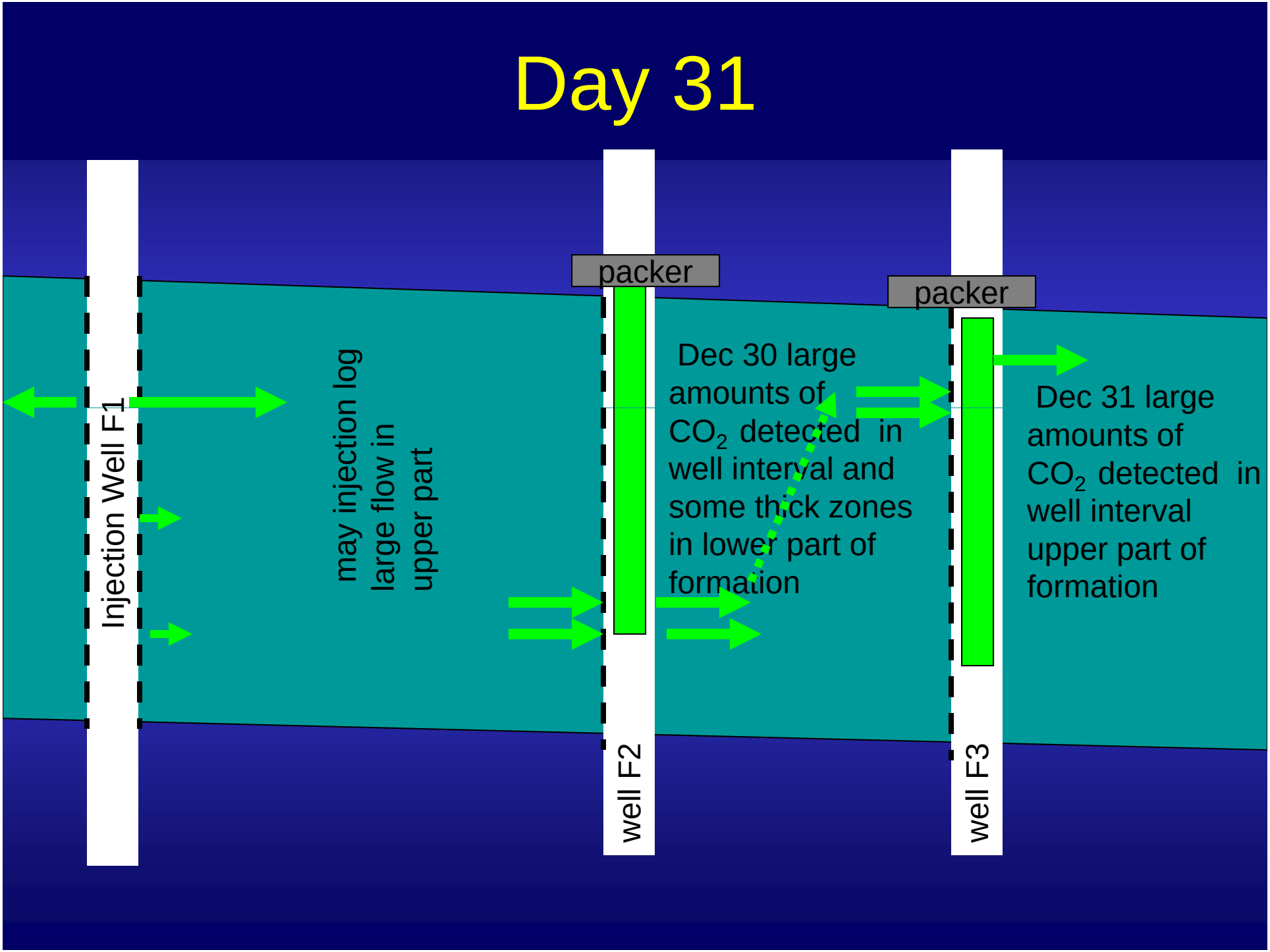



Day 9
packer
packer
Injection Well F1
Dec 1 CO2 flows into formation
Observation well F2
Dec 9
CO_2 detected in top of well interval
Observation well F3

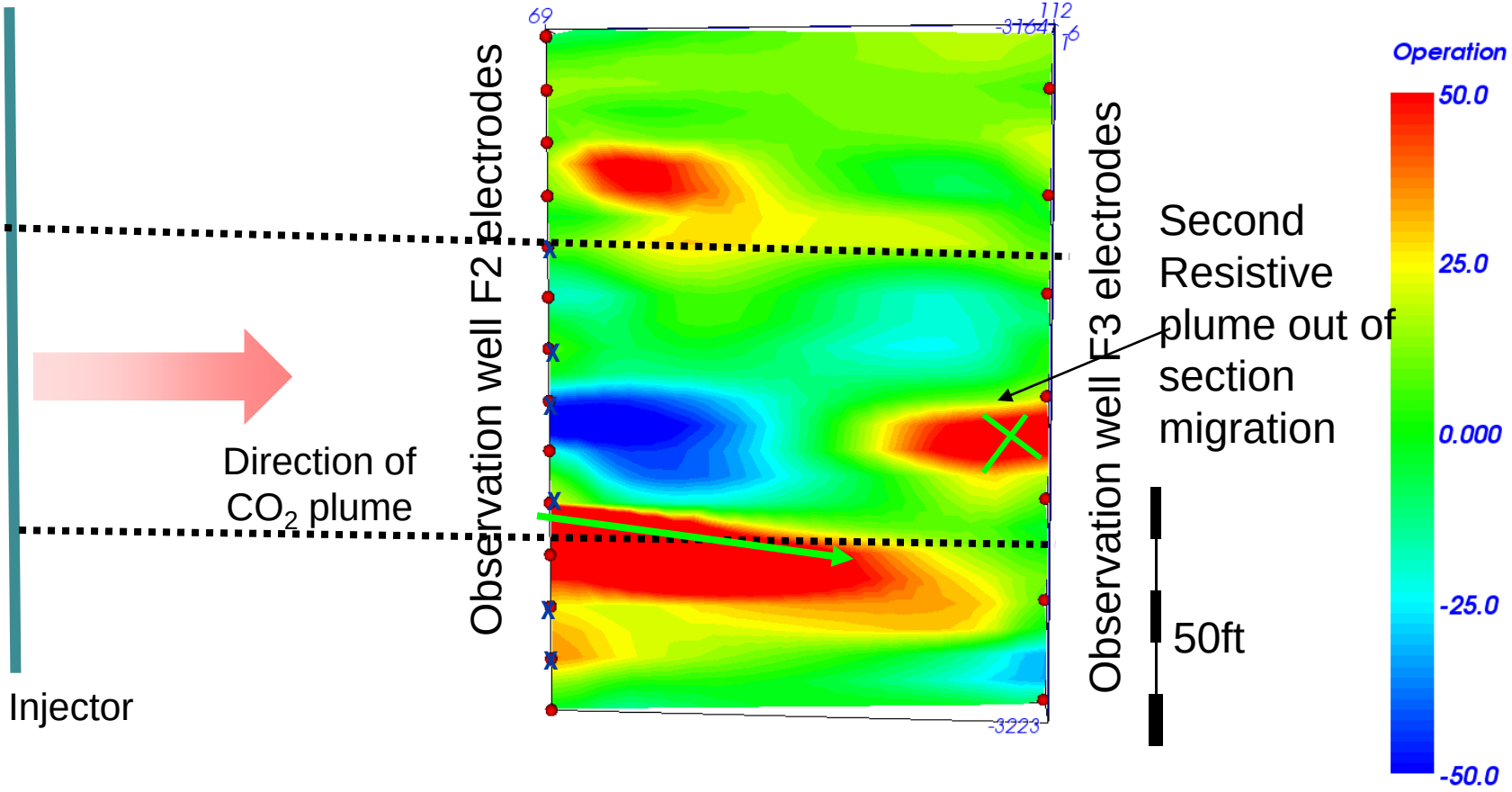
Day 13


Injection Well F1
Dec 1 CO2 flows into formation
packer
Observation well F2
Dec 13 still minor amounts of CO_2 detected in top of well interval and maybe some thin zones
packer
Observation well F3
Dec 13 CO_2 detected in top of well interval and maybe some thin zones

Day 31


packer
packer
Injection Well F1
may injection log
large flow in
upper part
Dec 30 large
amounts of
CO_2 detected in
well interval and
some thick zones
in lower part of
formation
Dec 31 large
amounts of
CO_2 detected in
well interval
upper part of
formation
well F2
well F3

Cross Well ERT tells us how flow occurred

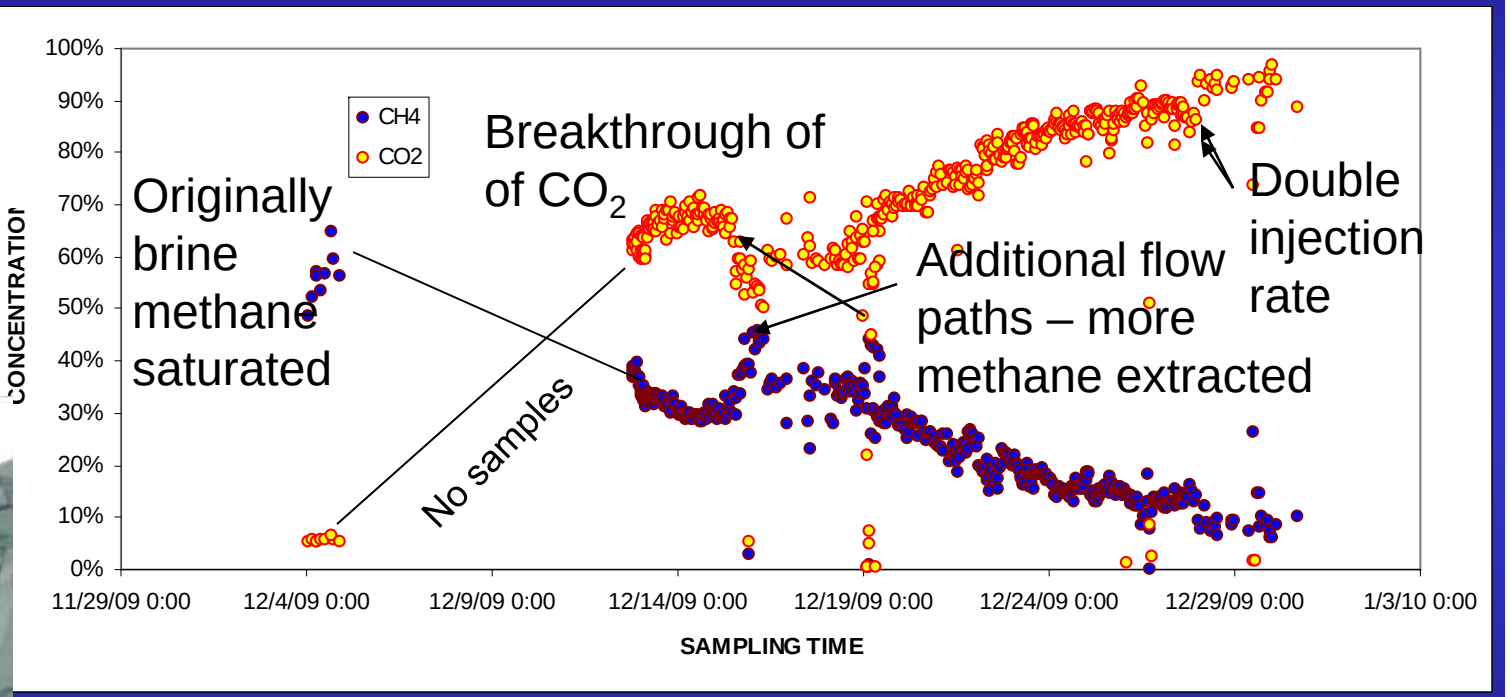


Resistive plume = CO2 in reservoir

Conductive plume= workover fluids?

Charles Carrigan, LLNL

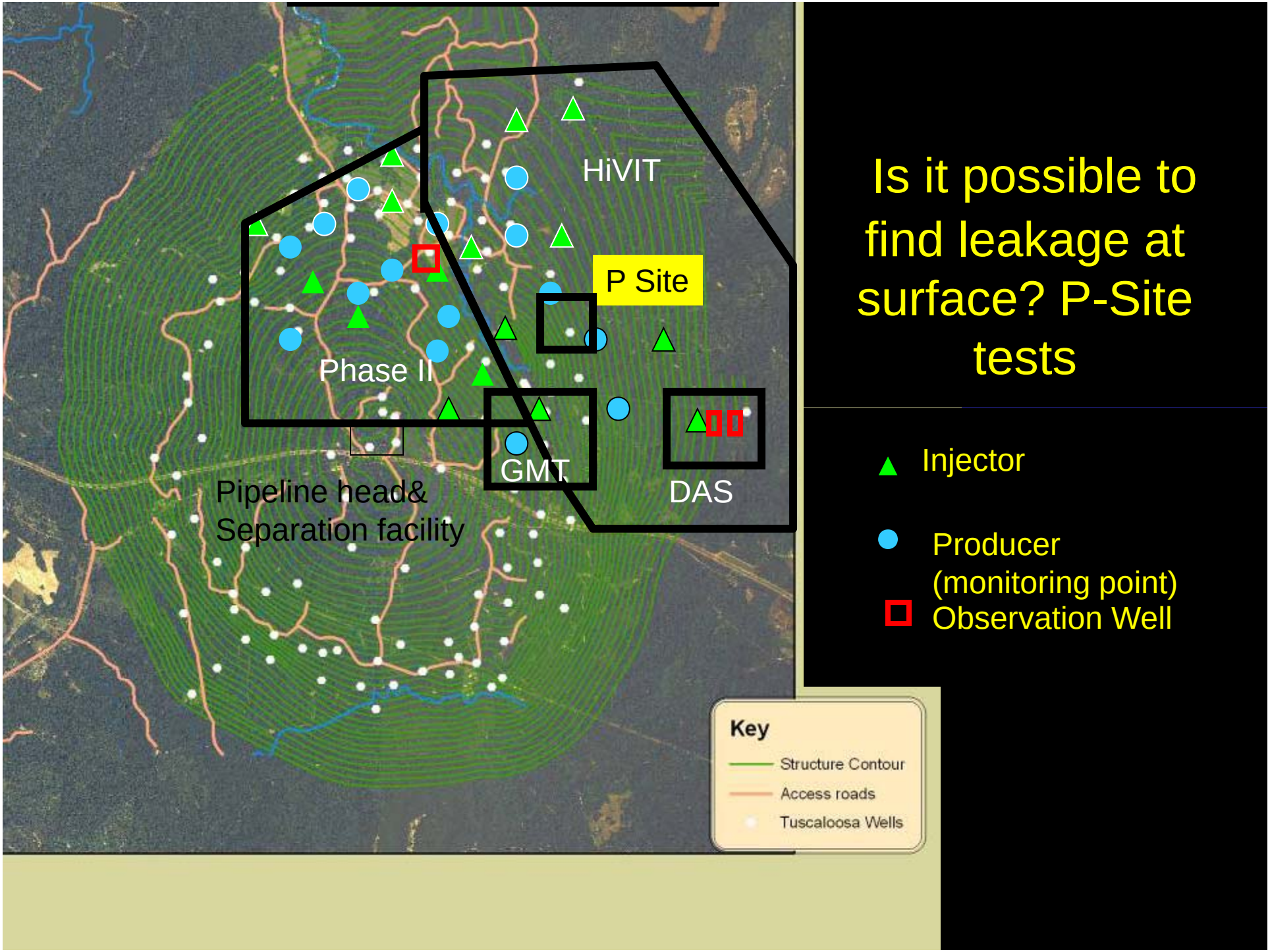
High frequency fluid sampling via U-tube yields data on flow processes



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

CO_2 dissolution into brine liberates dissolved CH_4

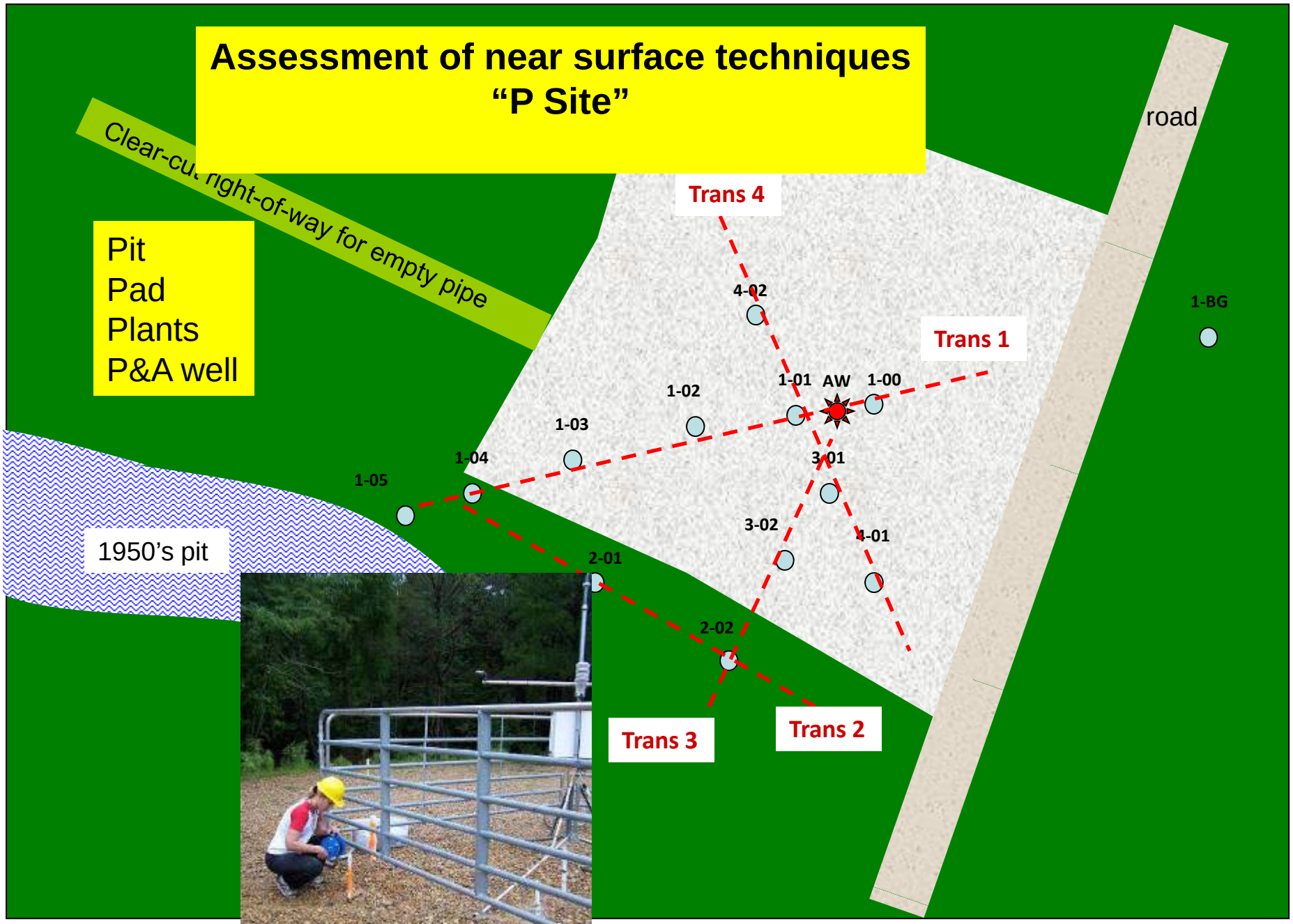
BEG, LBNL, USGS, ORNL, UTDoG,
data compiled by Changbing Yang BEG



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

- Injector
- Producer (monitoring point)
- Observation Well

Assessment of near surface techniques "P Site"



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
  - First US use of Electrical Resistance Tomography (ERT) for sequestration
  - Quantification of CO2 dissolution
- Export to commercial EOR/sequestration projects