Phase II

Stacked Storage @ Cranfield Completion Report

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Sandia Technologies LLC

Schlumberger Carbon Services

Gulf Coast Carbon Center

Other SECARB tests

SECARB coal seam tests
Geological Survey of Alabama
Virginia Tech

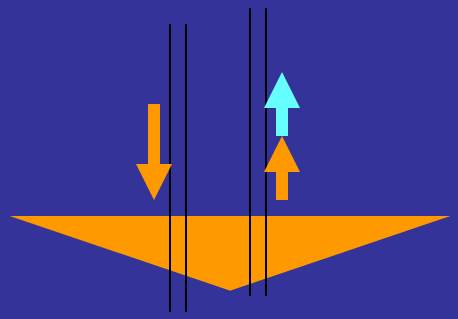
SECARB Power Plant tests
EPRI
Southern Co
ARI

Phase II Conclusions

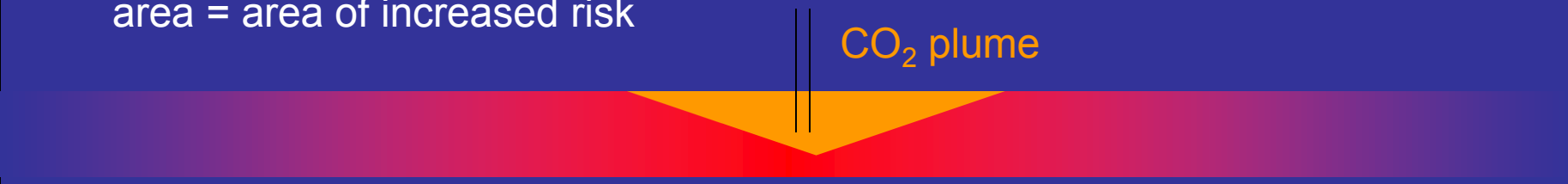
- 1 Million tons injected in EOR, 15 months, 11 injectors
- Pressure monitoring, a basic reservoir management tool, valuable in zone and above zone
  - Easier measurement and history match with pressure than with CO_2 saturation
- 1945 well completions performed better than expected – no large leakage detected
- Complications can be reduced next project
  - Simpler completions
  - Low cost single phase (brine only) monitoring

EOR and Sequestration-only have Different Footprints

In EOR, CO_2 injection is approximately balanced by oil, CO_2, and brine production so no pressure plume beyond the CO_2 injection area

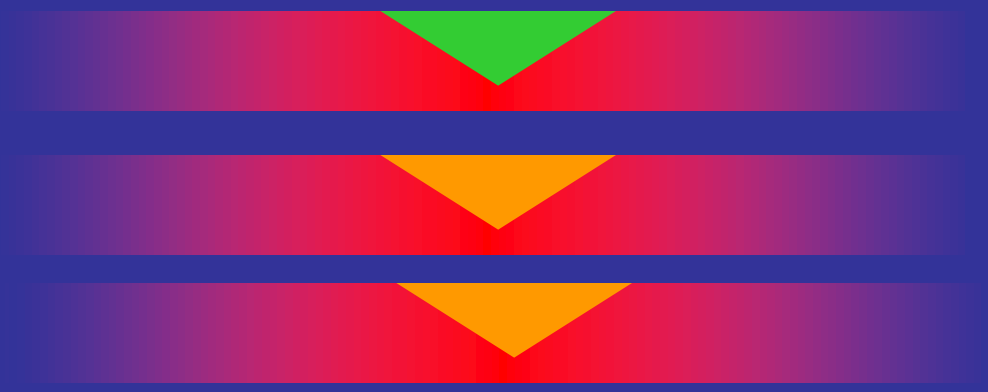


CO_2 injection (no production) pressure plume extends beyond the CO_2 injection area = area of increased risk



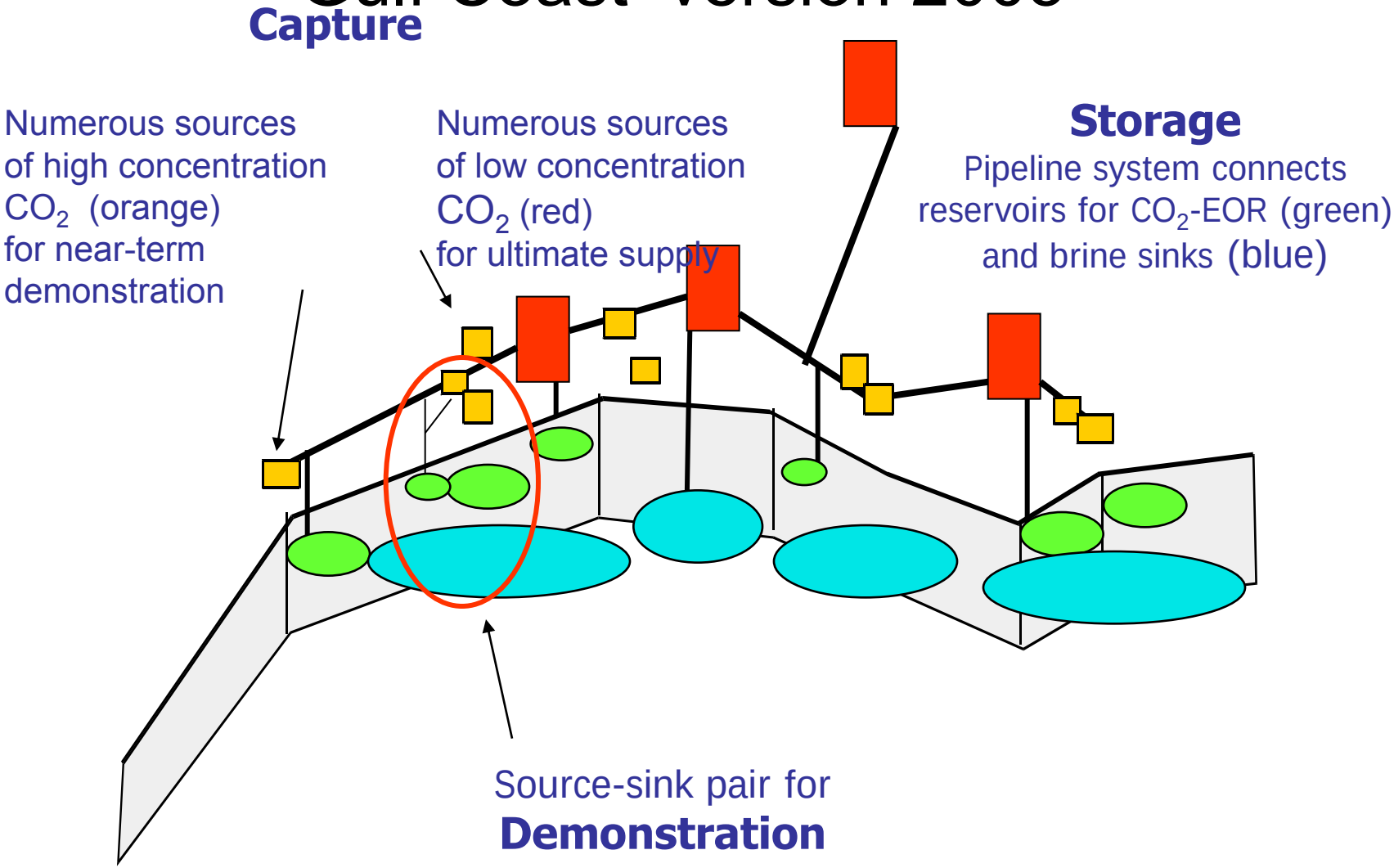
Elevated pressure

Stacked Storage

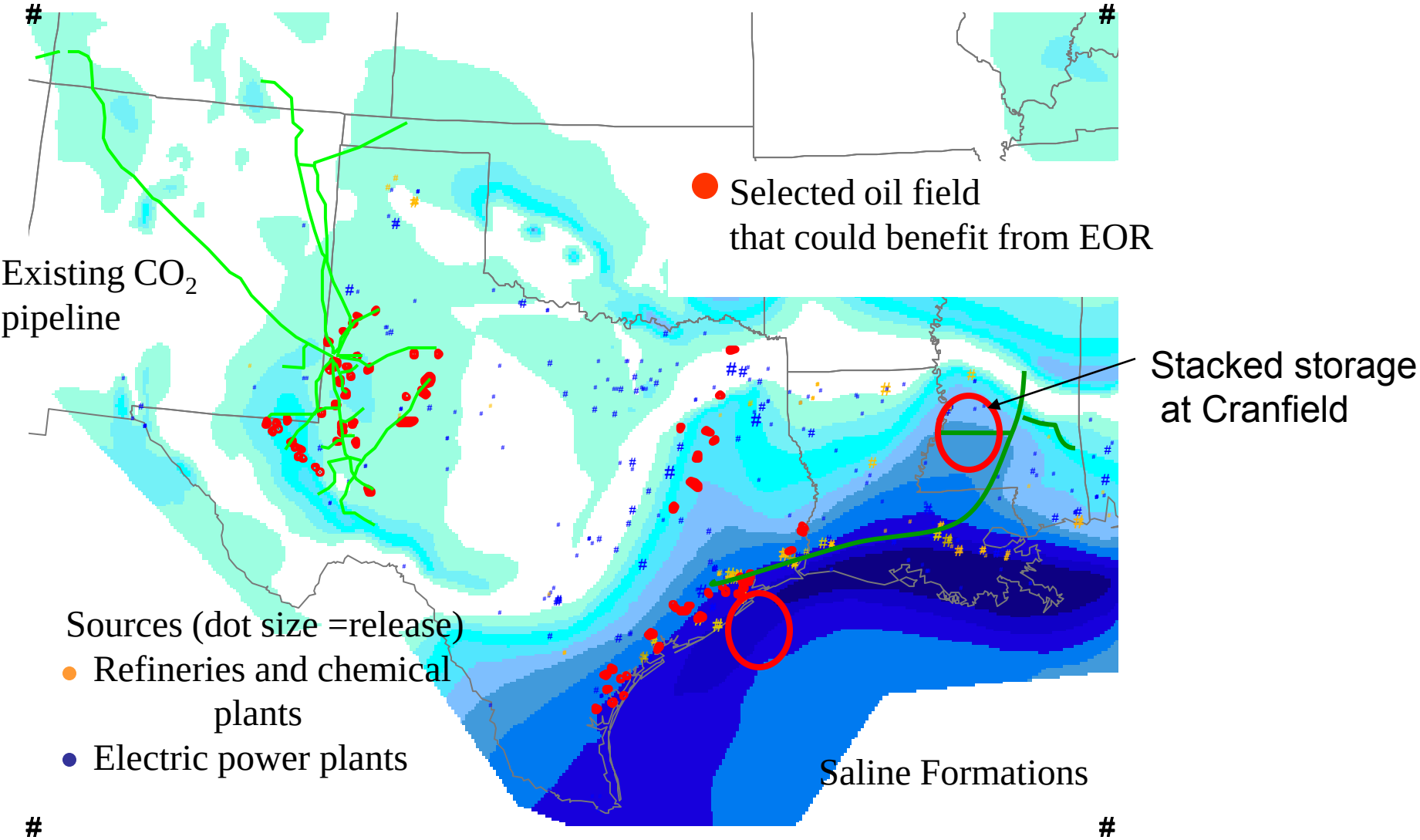


By developing multiple injection zones beneath the EOR zone, the footprint of the CO_2 and areas of elevated pressure can be minimized

Regional evolution of a CO_2 storage system Gulf Coast version 2005

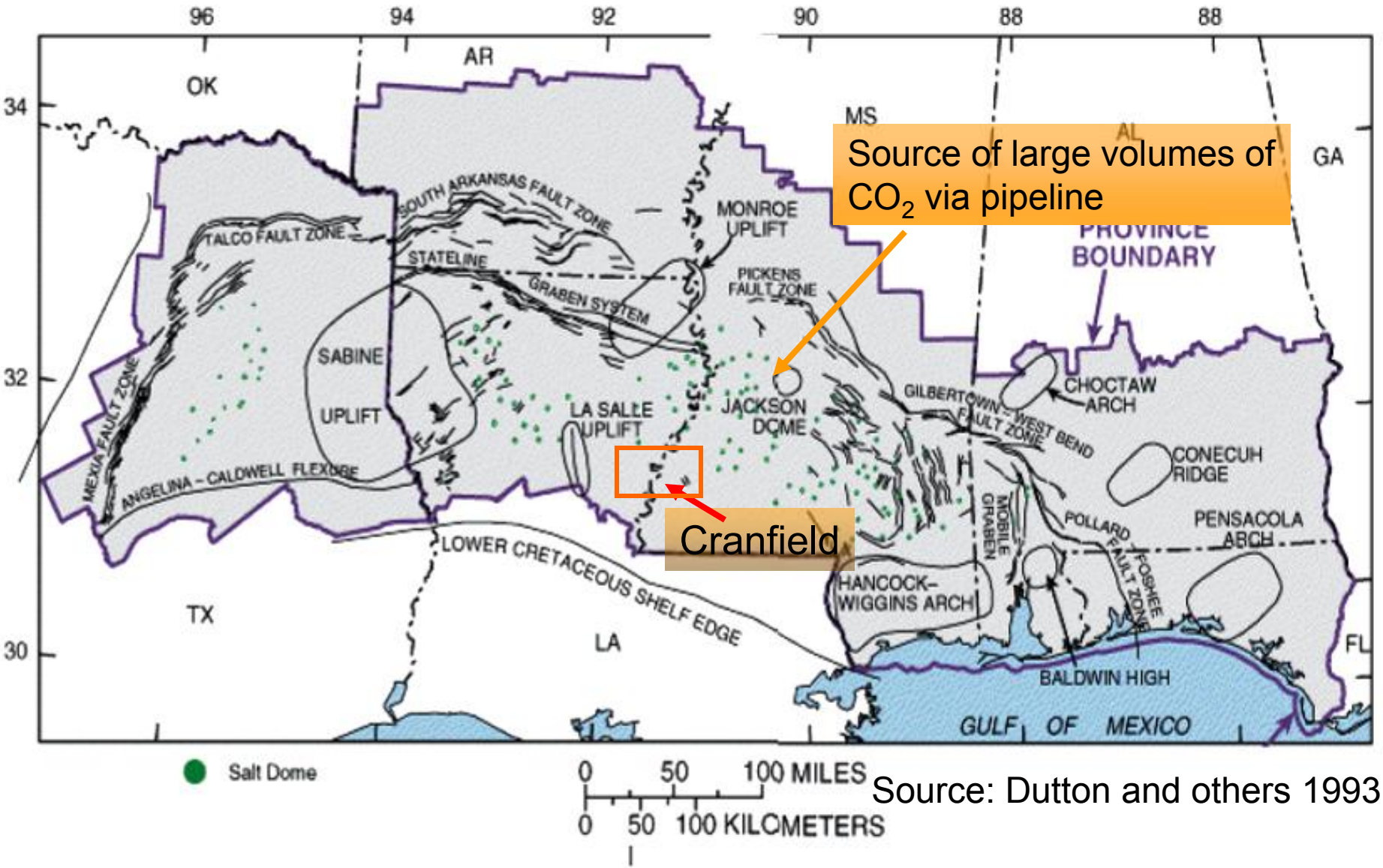


Stacked Storage via co-location of EOR and Saline Formations In the Gulf Coast



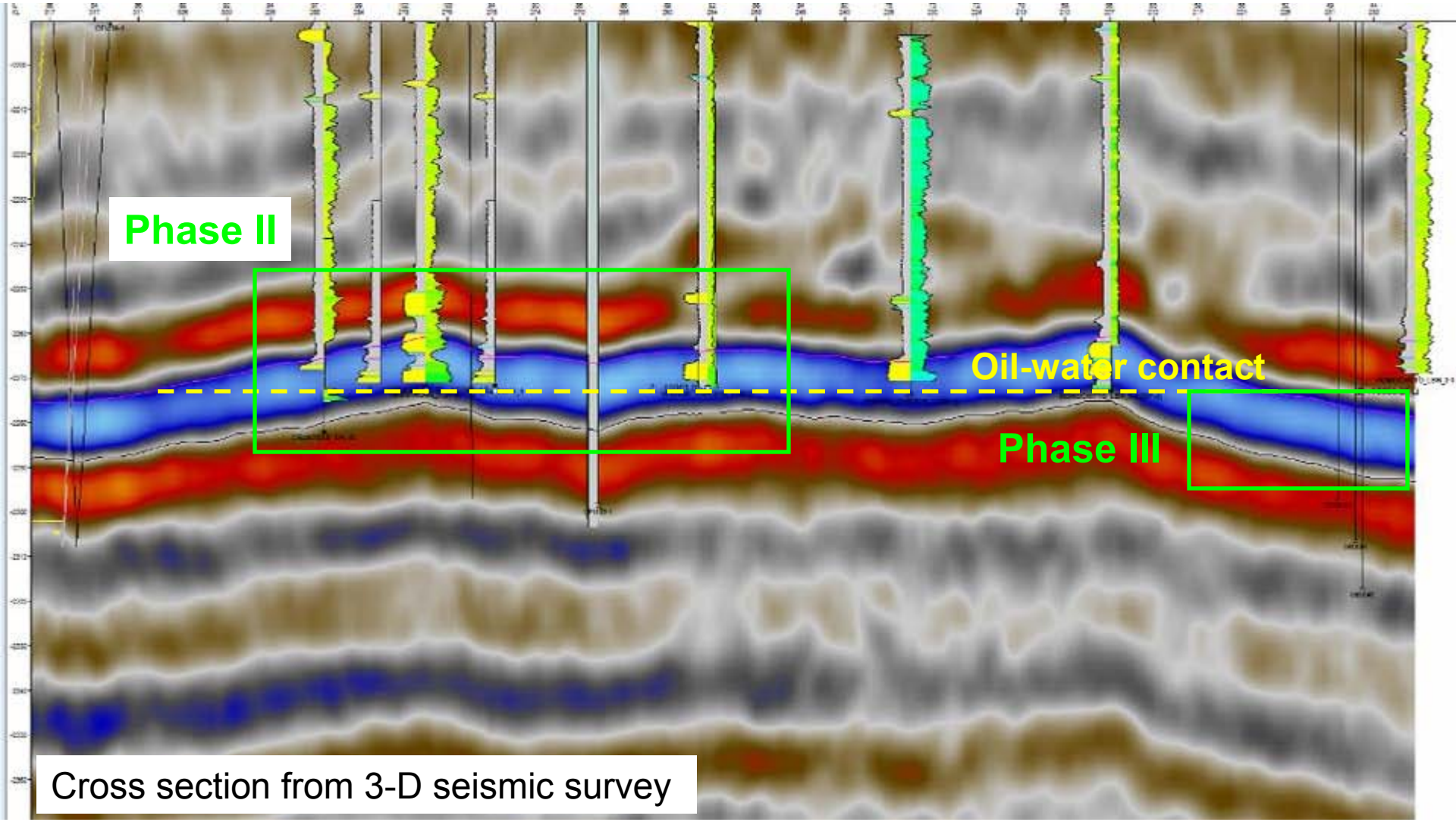
Anthropogenic CO_2 stationary source data from Hendriks and others, IEA Greenhouse Gas R&D Program, 2002).

Upper Cretaceous Tuscaloosa-Woodbine Trend – Cranfield in Mississippi Salt Basin



Source: Dutton and others 1993

W Stacked Reservoirs at Cranfield E



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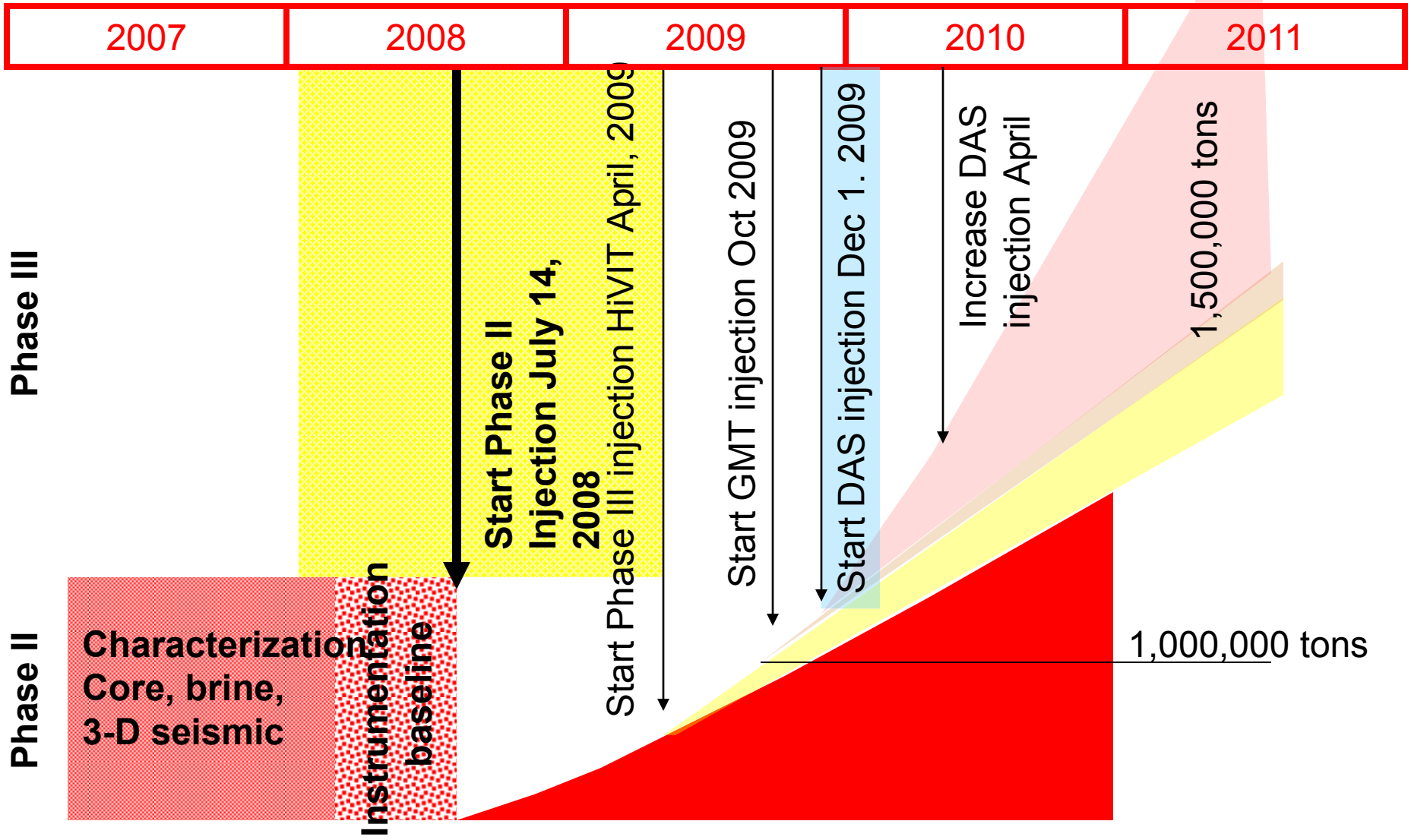
Scientific and Technical Objectives &Benefits

- **EOR**- Pressure based in-zone & above monitoring methods for area with many well penetrations
- Technique development for documenting EOR permanence

Injection Progress

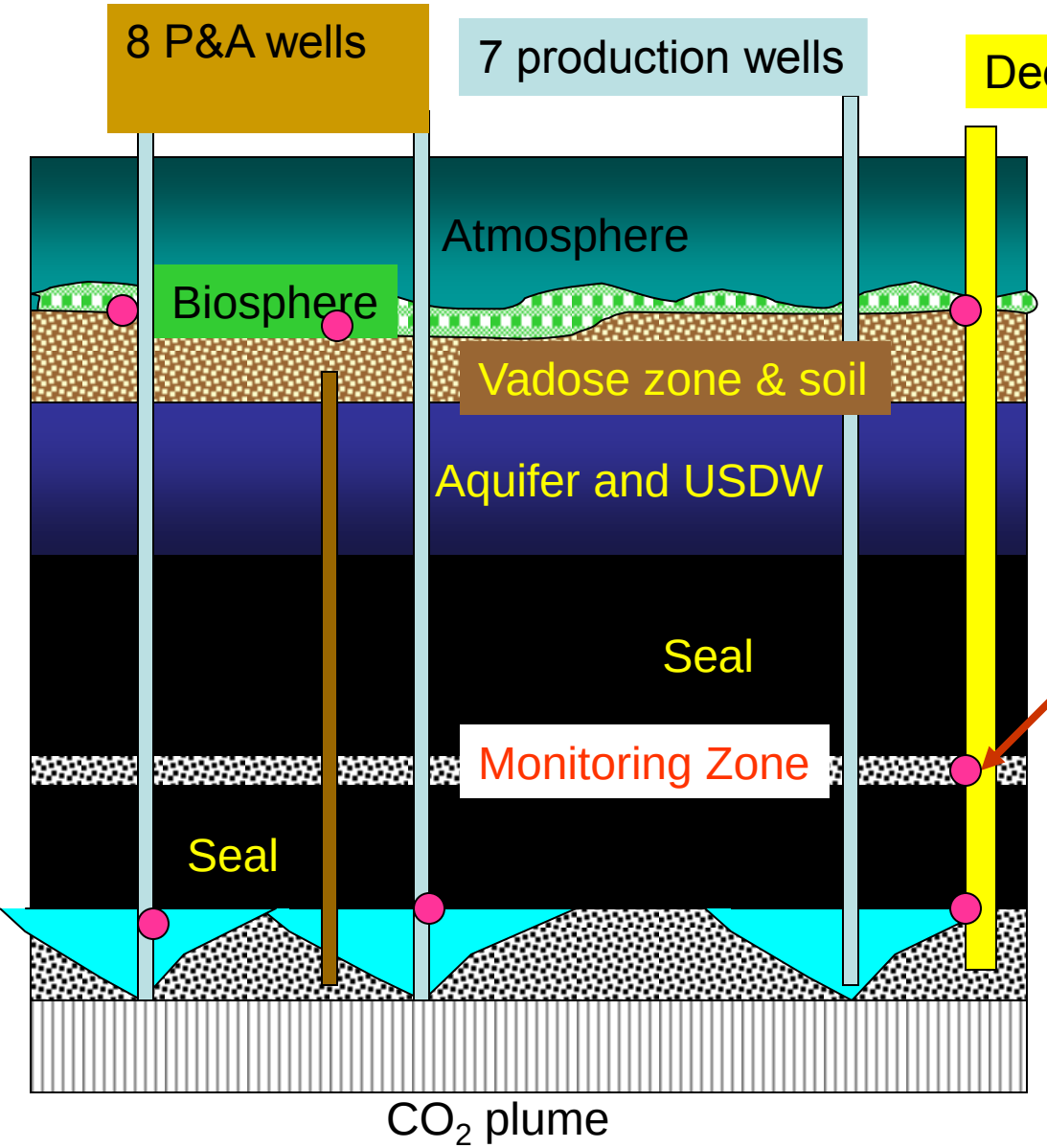


Phase II ecosystem program

Challenges to Monitoring EOR with Application to Cranfield

- Complex reservoir – complex fluids
  - -Oil, methane, brine
  - +No water flood at Cranfield and 40 years pressure recovery
- Complex flood – 11 wells injecting
  - + Increased gradually
  - + Initially production – reservoir lift
- Historic wells – no modern logs, poor casing condition, not deep enough for modern tools, cement only in zone.
- Surface monitoring complicated by past oilfield activities, historic oil spills and disturbed surface pits, well pads, roads. May be natural high background flux.

Phase II @ Cranfield Monitoring Locations



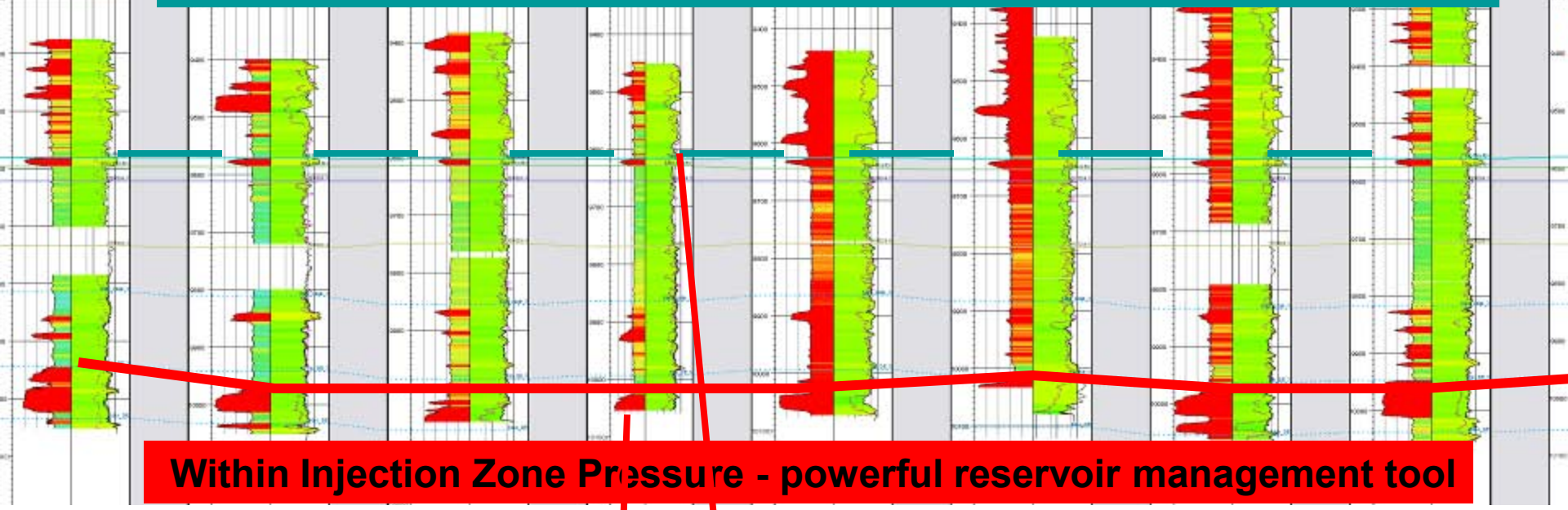
Focused monitoring at wells per risk assessment.
Soil gas baseline to look for methane
Repeat to look for above background CO_2, methane

Above injection monitoring zone continuous and real-time bottom-hole pressure and temperature at observation well.

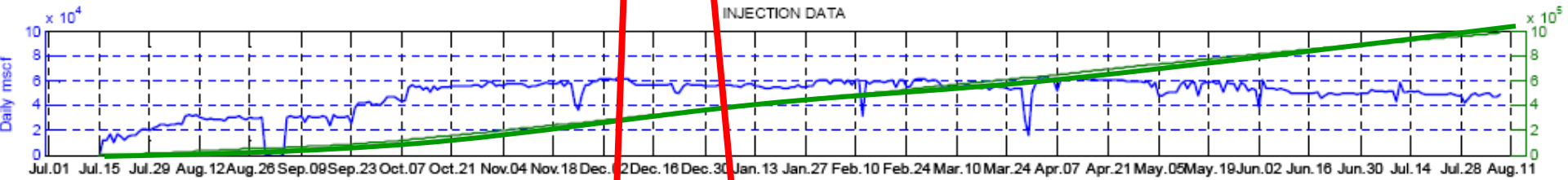
In reservoir -continuous and real-time bottom-hole pressure and temperature at observation well.
"Dip in" pressure at four wells and reservoir saturation logs at 3 wells.

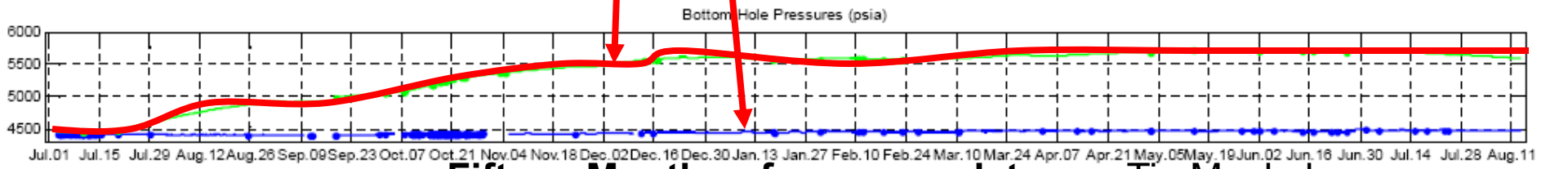
Pressure Monitoring EOR

Above-Zone Pressure Monitoring –powerful tool for leakage detection



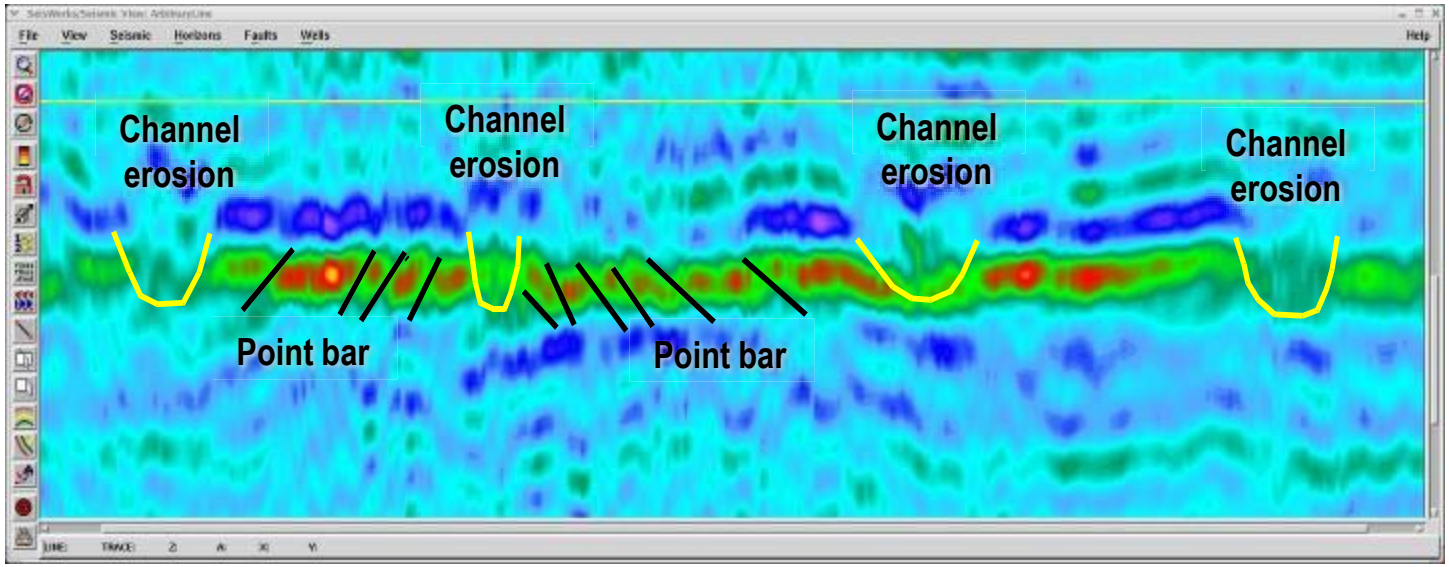
Within Injection Zone Pressure - powerful reservoir management tool

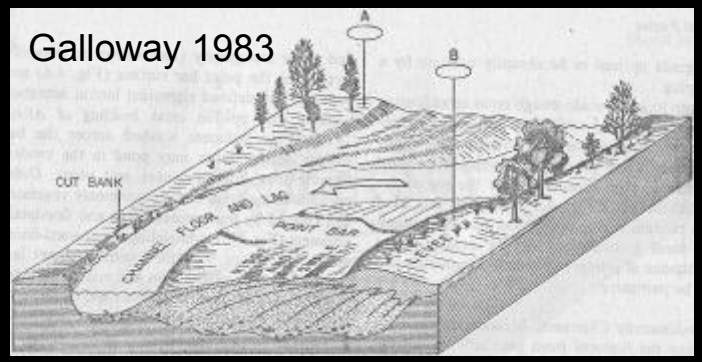




Fifteen Months of pressure data Tip Meckel

In-Zone Monitoring – fluid flow in a complex reservoir

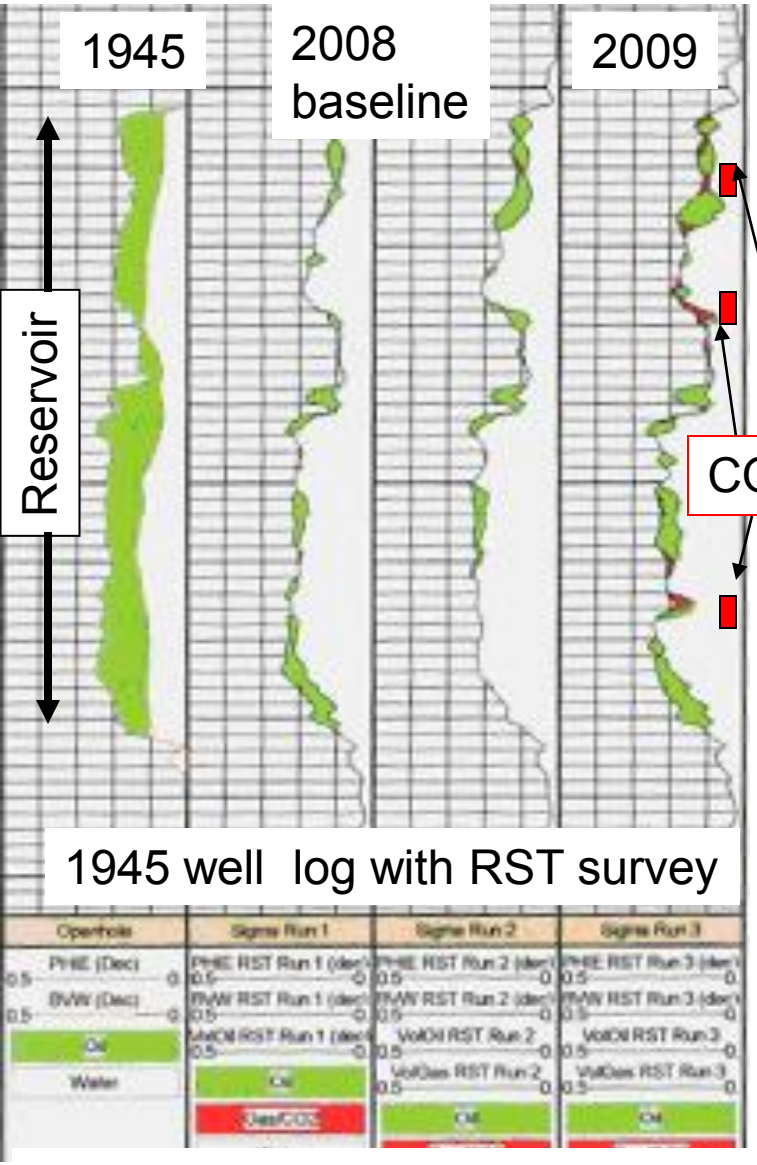




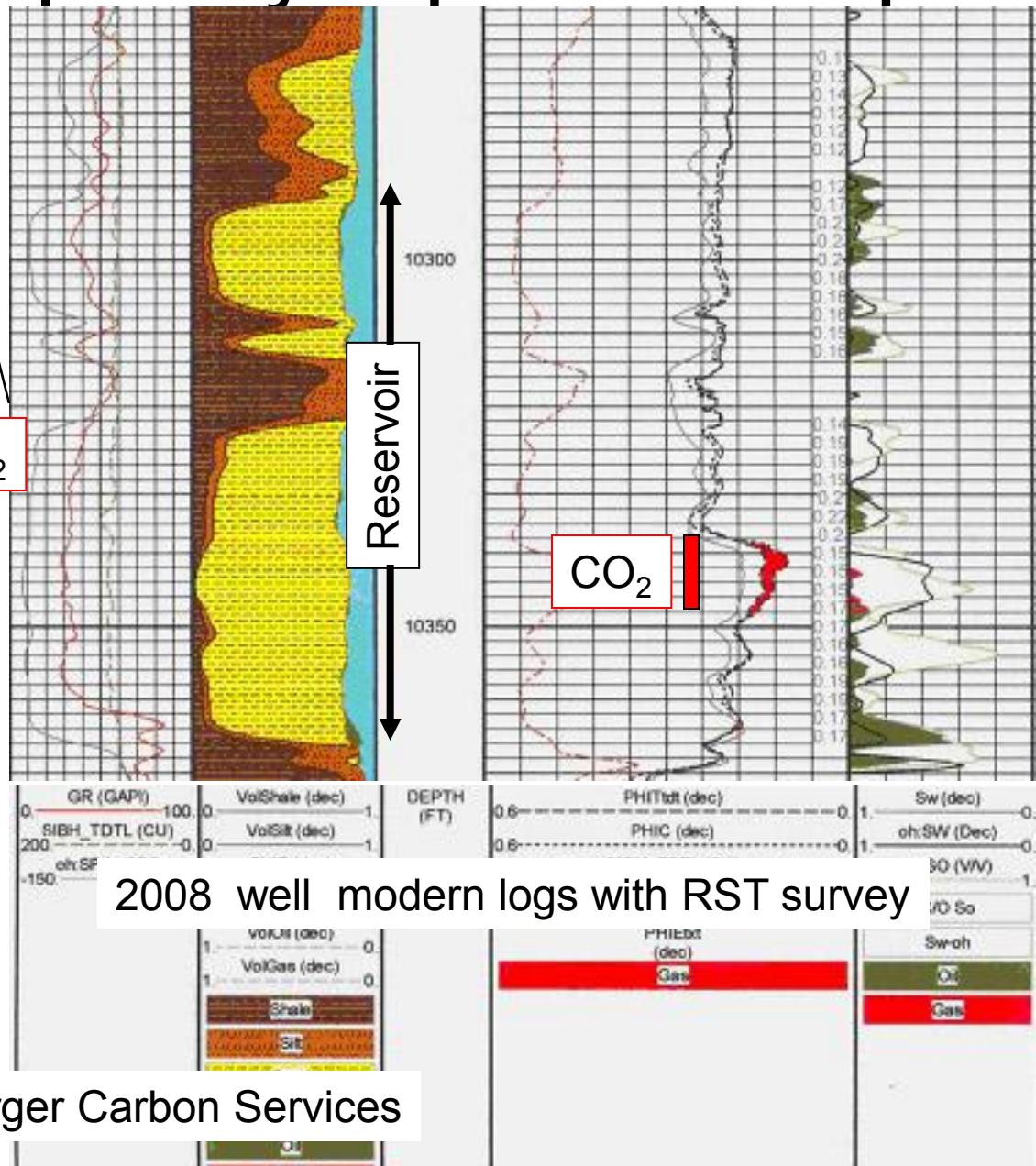
Meander fluvial model

Stratal slicing of 3-D volume
Hongliu Zeng

Reservoir Complexity = poor sweep



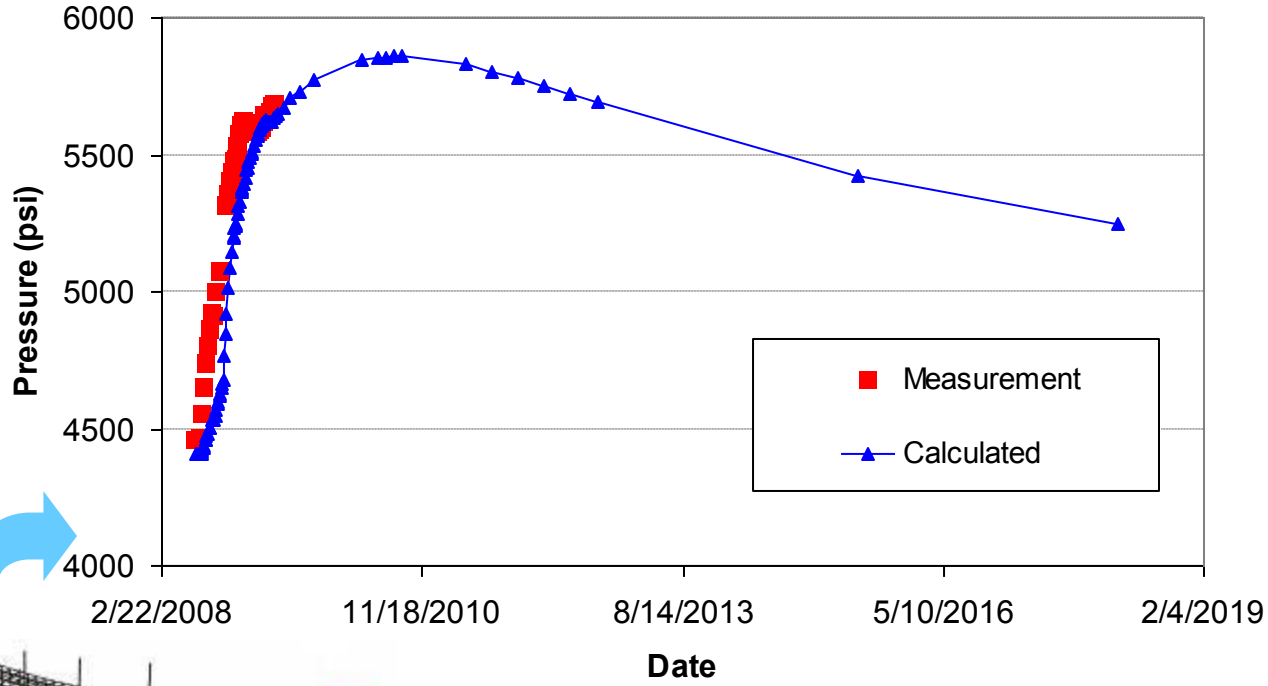
1945 well log with RST survey

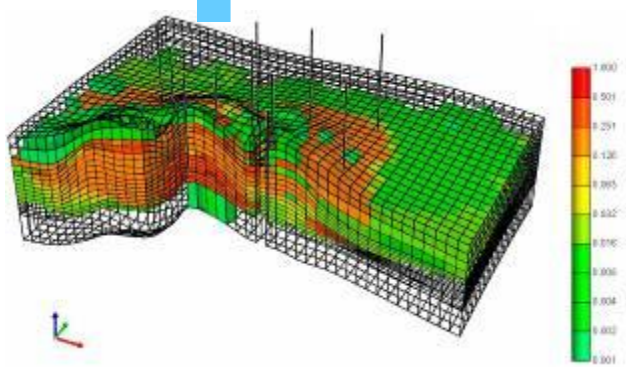


2008 well modern logs with RST survey

Interpretation Bob Butch Schlumberger Carbon Services

Model Match to pressure – measured in observation well to calculated with GEM

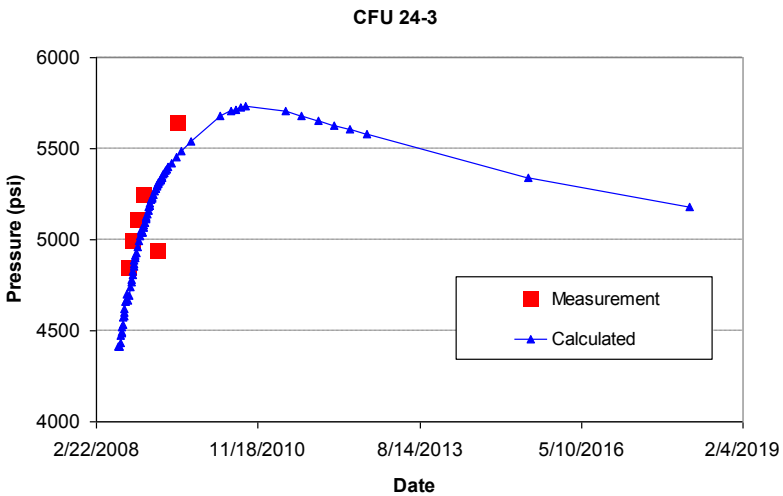


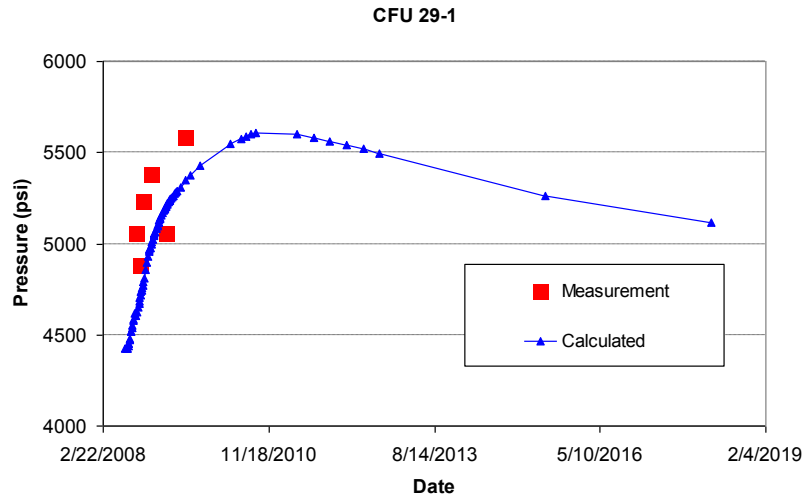


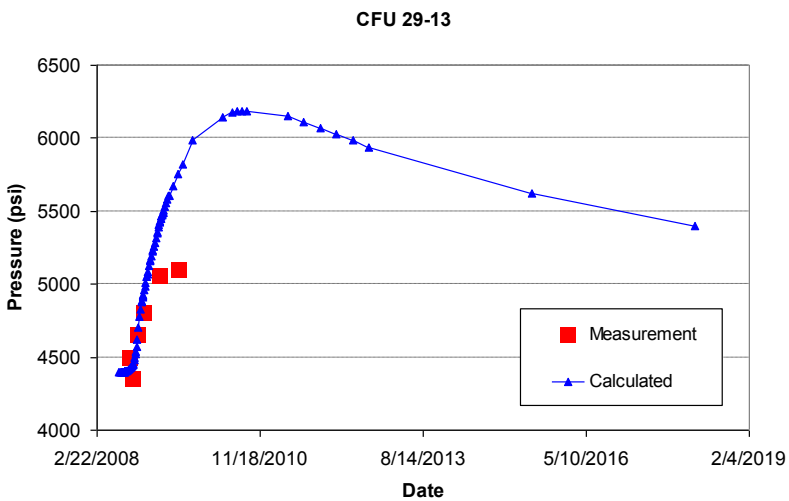
Flow model

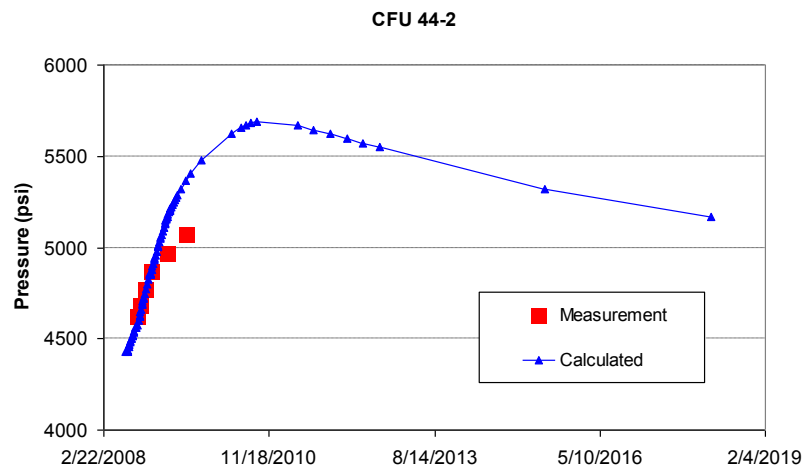
Jong-Wan Choi
JP Nicot

GEM Model Match – observed in producers to simulated pressure









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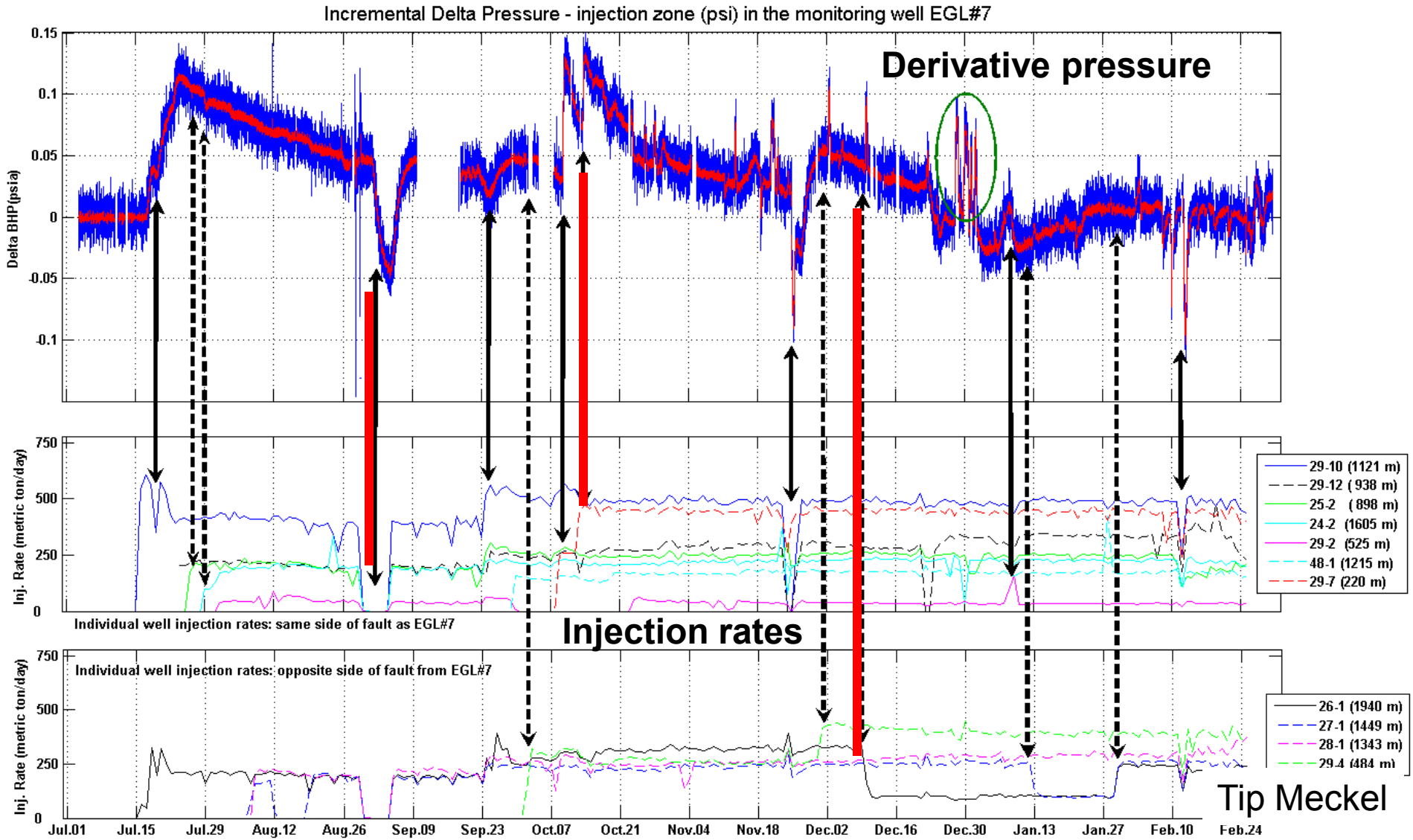
JP Nicot

Maximizing the Data Yield from Real Time Pressure Measurement



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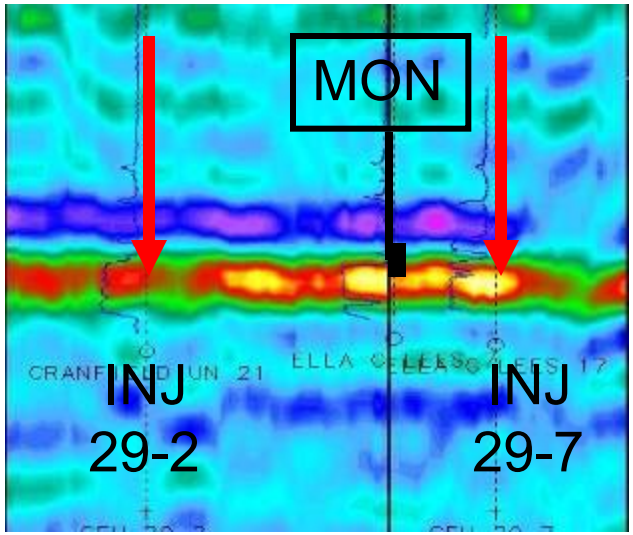
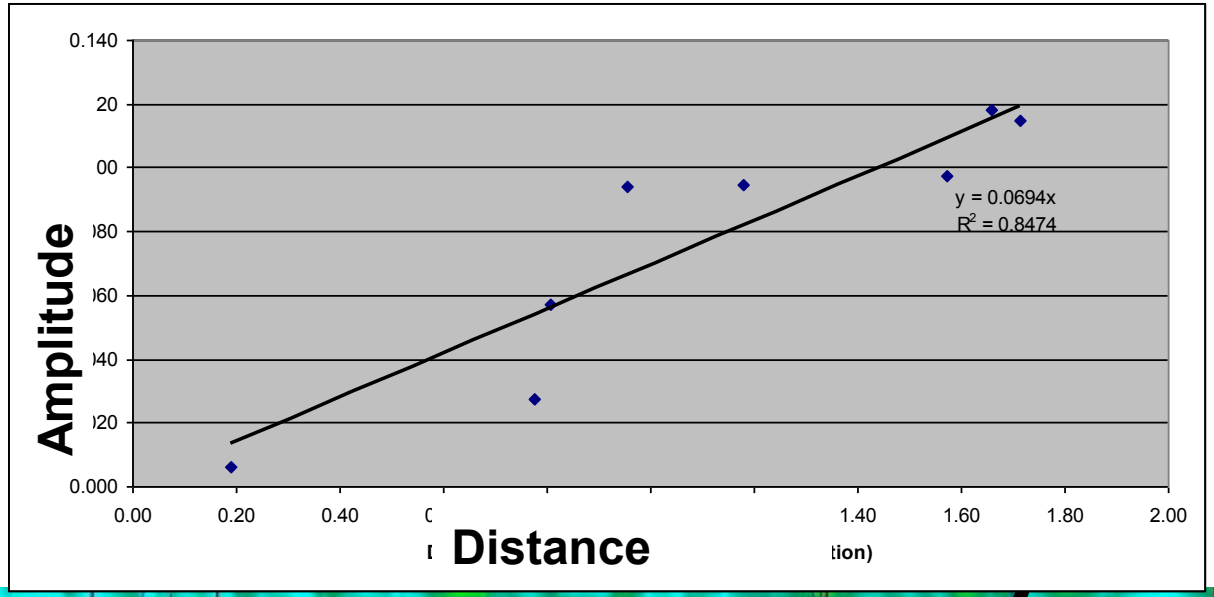
Documenting compartmentalization by matching predicted area of pressure increase to measured

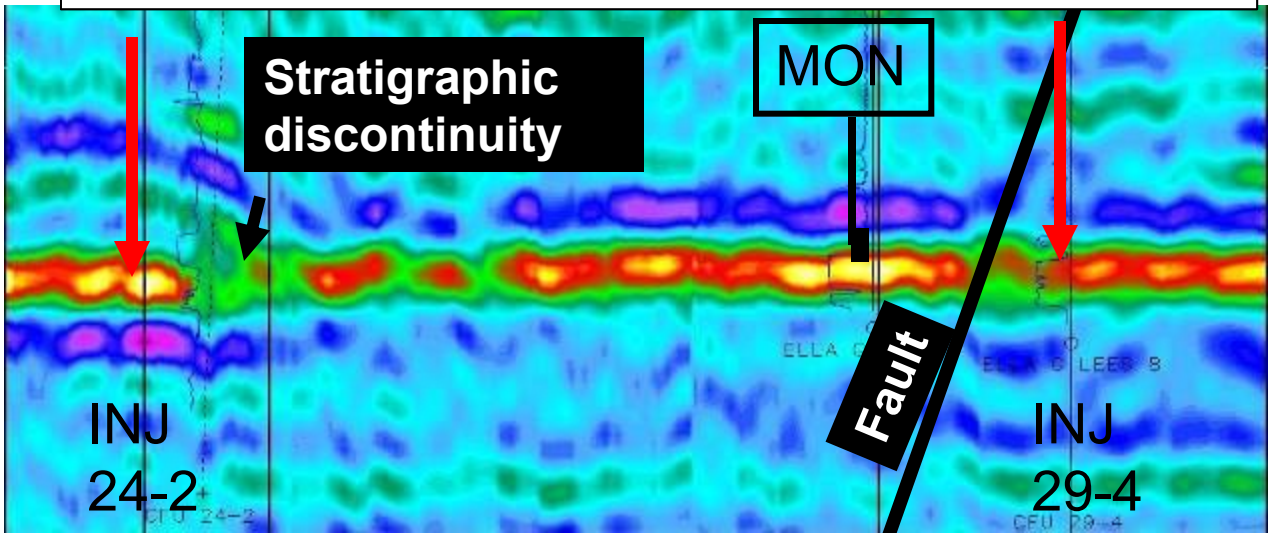
Predicted well connected



Observed well connected



Predicted poorly connected
= no pressure signal



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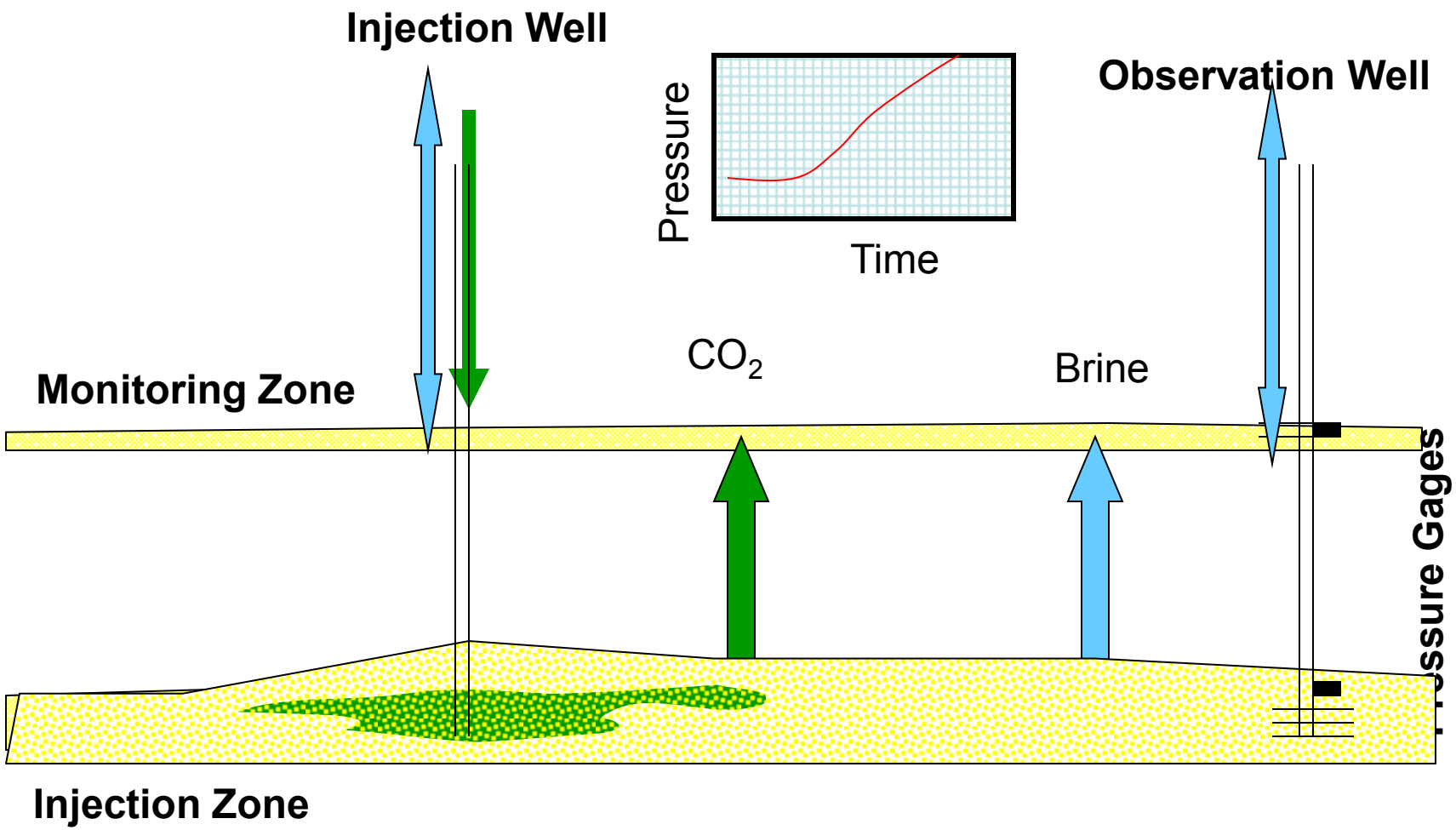
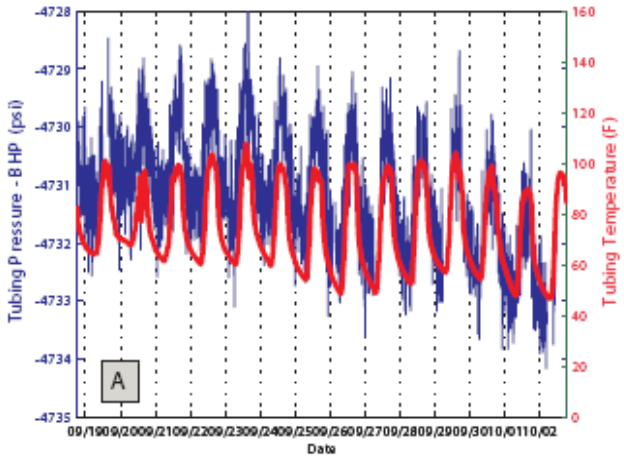
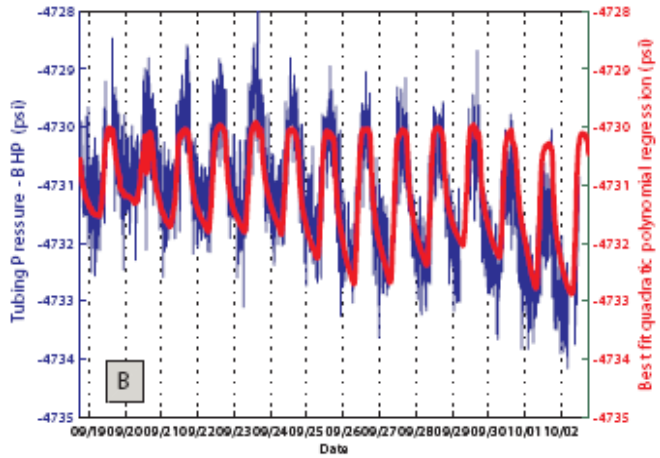
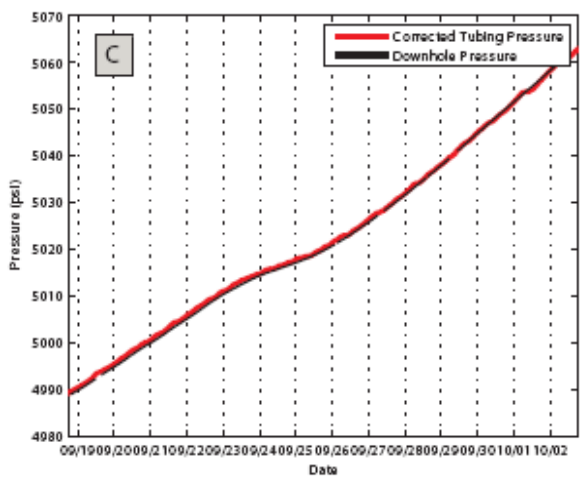
Sources of Noise and Uncertainty in Above-Zone Monitoring

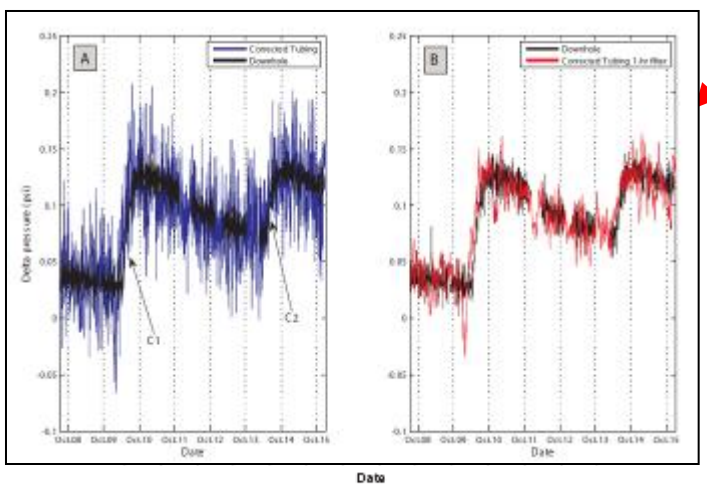


Comparison of processed surface tubing pressure sensitivity with downhole gauge









Tubing data corrected for Temperature and tubing fluids carries useful downhole information.

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Phase II Conclusions

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- www.gulfcoastcarbon.org