Project 09123-18
Characterization of Potential Sites for Near Miscible CO_2 Applications to Improve Oil Recovery in Arbuckle Reservoirs

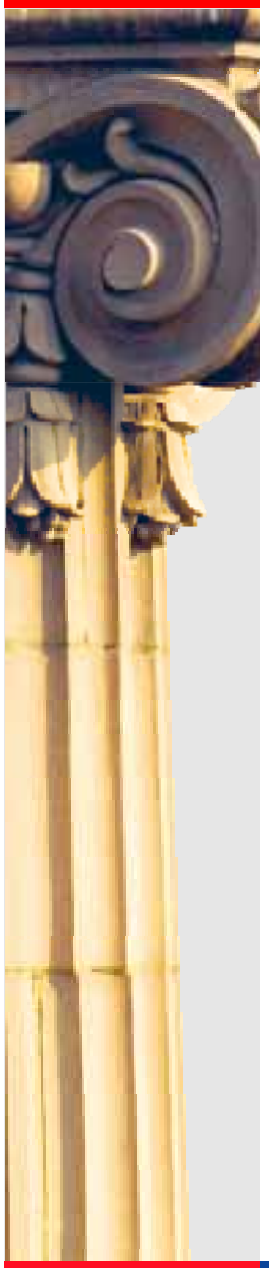
Golden, CO.

November 30, 2011

Jyun-Syung Tsau

TECHNOLOGICAL KEYS TO UNLOCKING ADDITIONAL RESERVES

RPSEA ONSHORE PRODUCTION CONFERENCE



Project Statement

- Arbuckle represents a significant resource for CO_2-IOR
- Near miscible CO_2 flooding may be applicable to thousands of mature oilfields in Kansas
- Ultimate oil recovery depends on the degree of reservoir heterogeneity, proper design and implementation of CO_2 injection
- Uncertainty of reservoir properties places a challenge for CO_2 application

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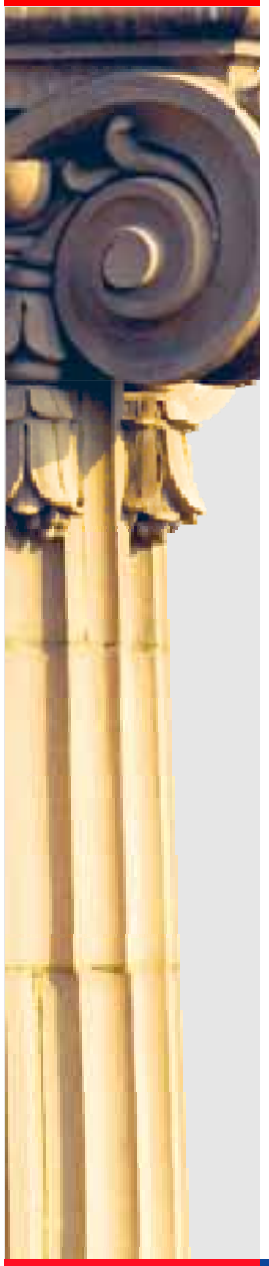

Objective

- Improve reservoir description by geologic and engineering approach
- Develop a field demonstration plan for CO_2 application

Project Team

- **TORP**
  - Mark Ballard
  - Jenn-Tai Liang
  - Kourosh Reza Maleki (GRA)
  - Jyun-Syung Tsau
  - Paul Willhite
- **Kansas Geology Survey**
  - Evan Franseen
- **Small Producer**
  - Carmen Schmitt
  - Francis Hitschmann

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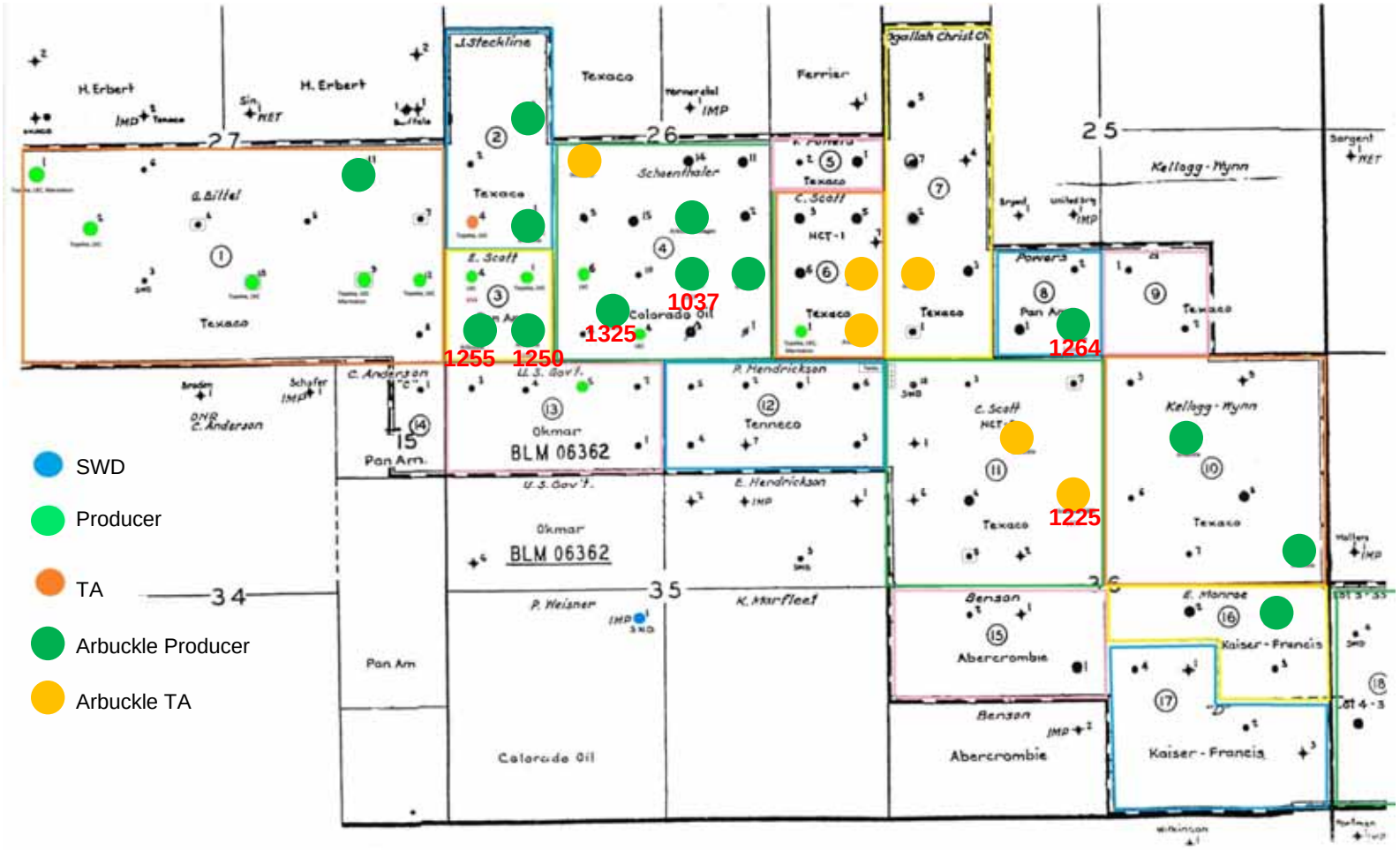
Ogallah Unit

Average Shut in pressure ~ 1226 psi (Near Miscible)



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Geological Model

Well Data

- 121 wells
  - Micro logs,
  - GR & Resistivity
  - Geological reports
- 1 well
  - Micro log
  - GR & Resistivity
  - Neutron
  - Density

Preliminary model

- Utilize micro log data to estimate porosity

$$\frac{R_{xo}}{R_{mf}} = \emptyset^{-m}$$

- Correlate micro log porosity with neutron density log porosity and apply the correlation to other wells

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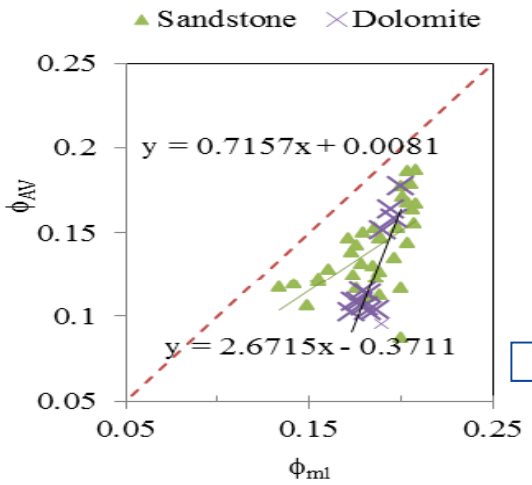
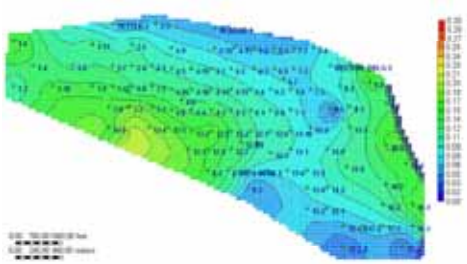
Reservoir model

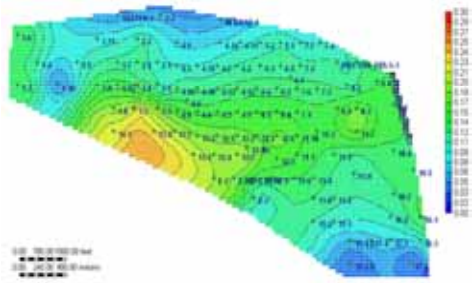


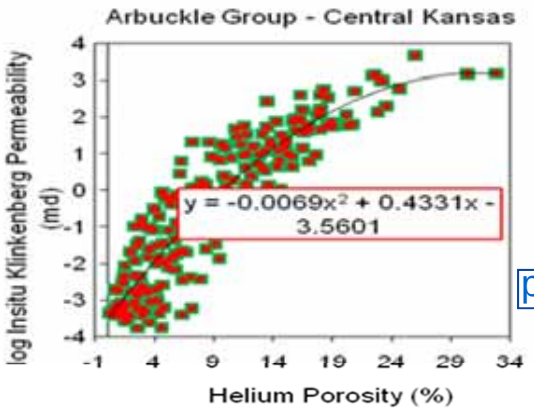
porosity

Arbuckle dolomite

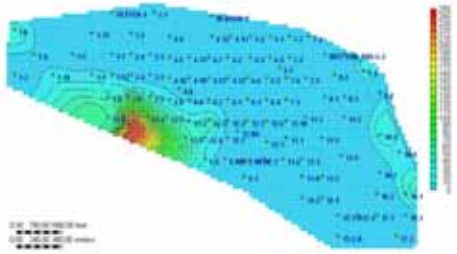


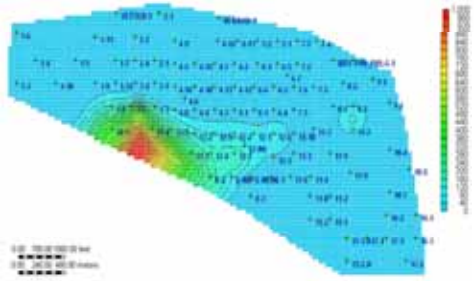
Reagan sandstone





permeability





(Byrnes, *et al.*, 1999)

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Geologic Characterization

Core Analysis

- 18 cored wells
- 408 samples
- Average 0.5 ft sampling interval
- Oil and water saturations
- Permeability and porosity

Revised model

- For cored wells
  - Convert *m* classifiers from core data with classifiers such as *rfn* (carbonate) and *FZI* (sandstone)
- For uncored wells
  - Identify electrofacies groups (similar to lithofacies) from well logs
  - Apply model-based clusters analysis to find relationship of log data to *m*

$$\frac{R_{xo}}{R_{mf}} = \emptyset^{-m}$$

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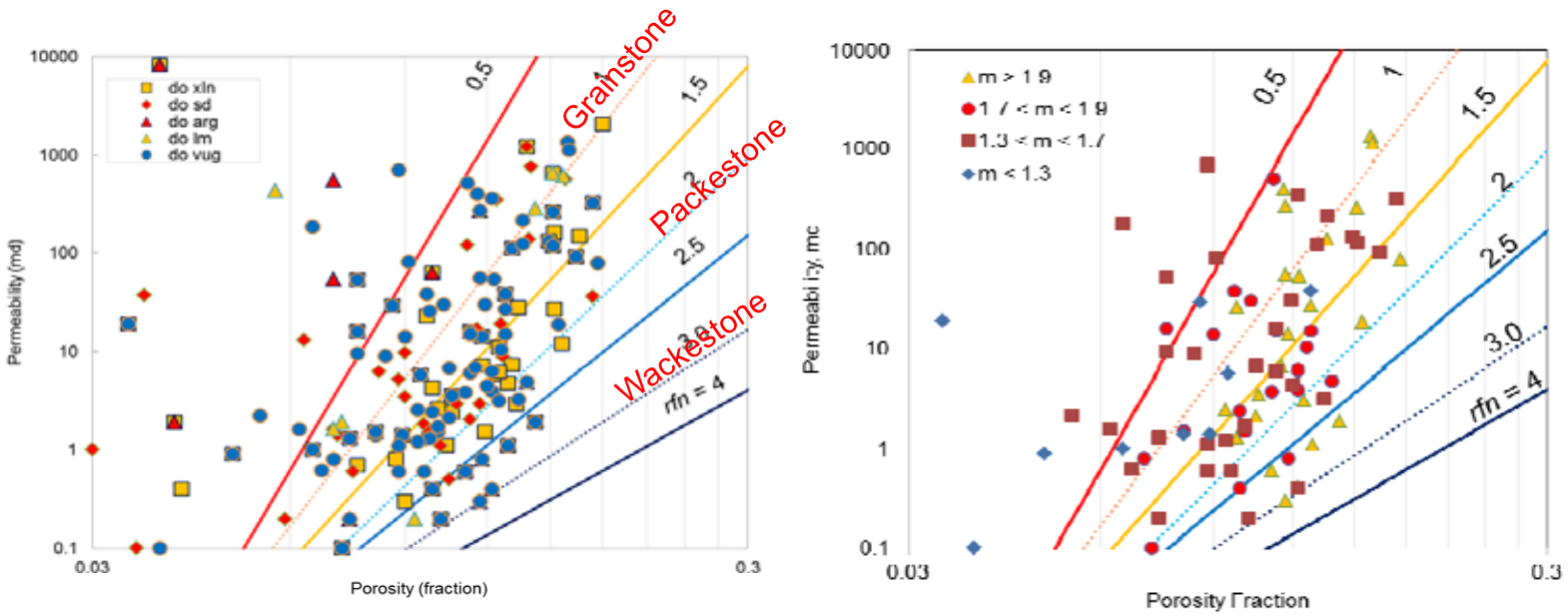
Carbonate (Rock fabric number)



- *Transform rock fabric number (rfn) to m classifier*

$$\log(k) = [A - B \times \log(rfn)] + [C - D \times \log(rfn) \times log\ (\emptyset)]$$

$$m = 0.4336 \log(rfn) + 1.6807$$

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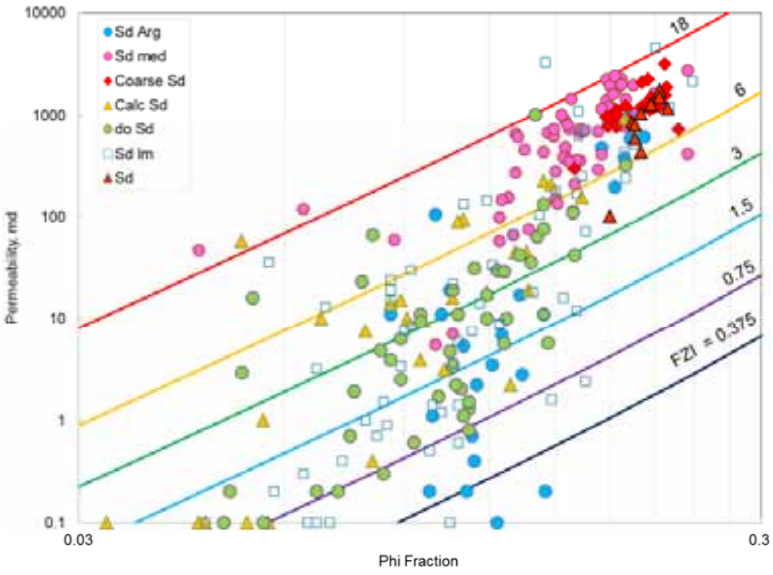
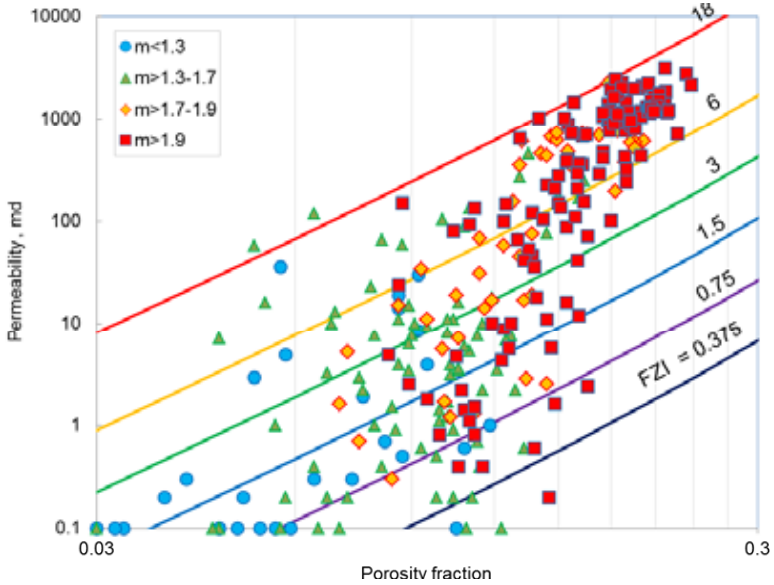
Sandstone (Flow zone indicator)

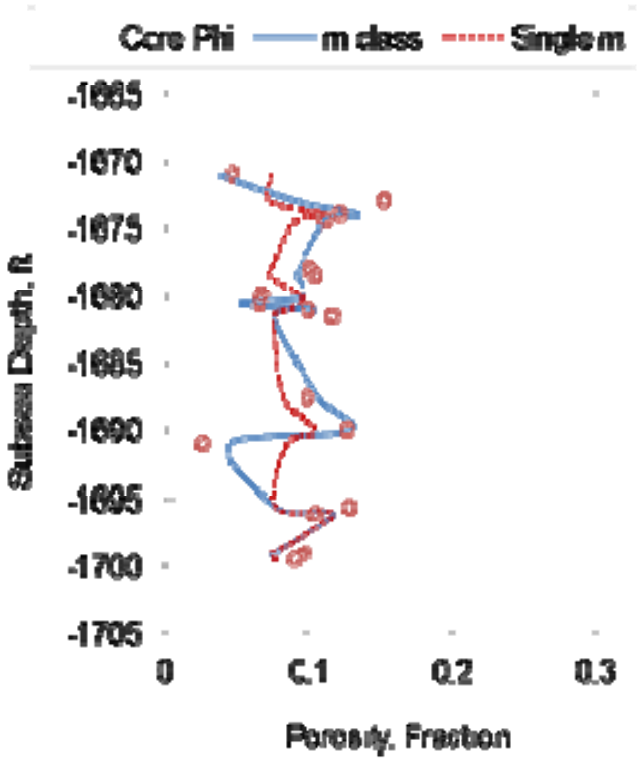


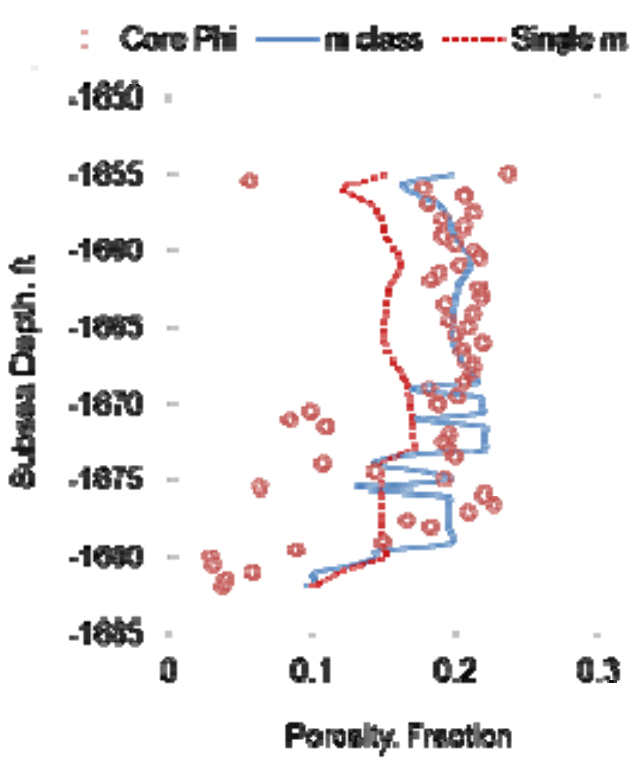


- *Transform Flow zone indicator (FZI) to m classifier*

$$FZI = 0.0341 \sqrt{K/\phi^2}\,(1-\phi)$$

$$m = 0.269 \log(FZI) + 1.607$$





$$\frac{R_{xo}}{R_{mf}} = \emptyset^{-m}$$

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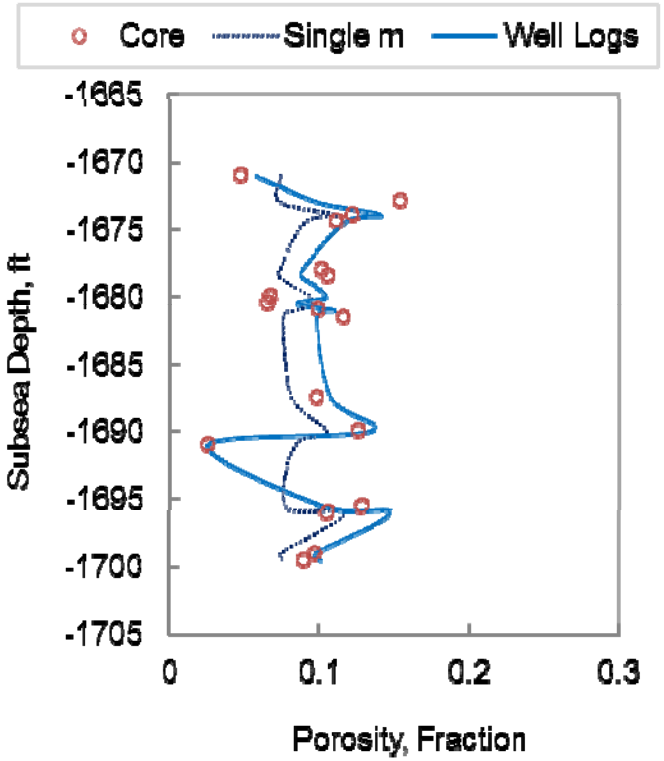

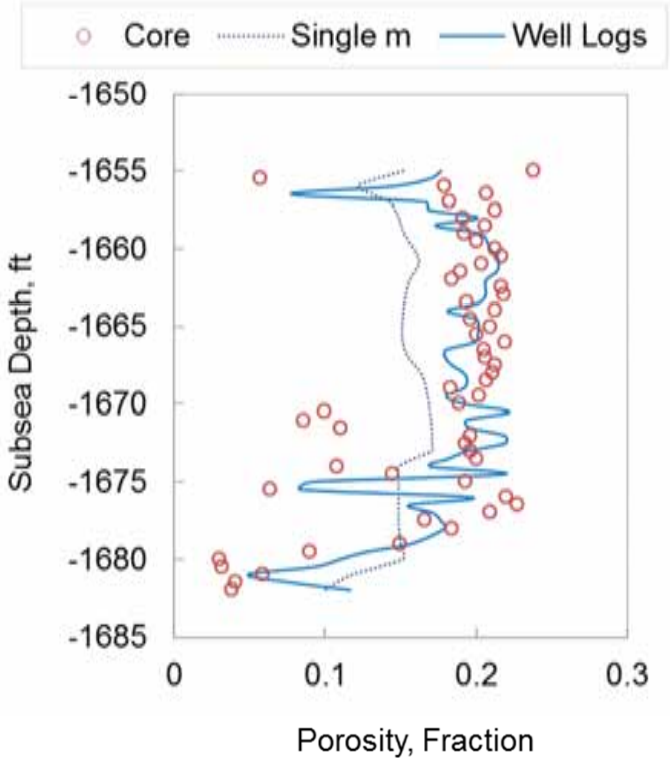

" Improved Predictions of Porosity from Microresistivity Logs in a Mature Field through Incorporation of Pore Typing," SPE paper 149506 presented in SPE Eastern Regional Meeting, Columbus, Ohio, August 17-19, 2011.

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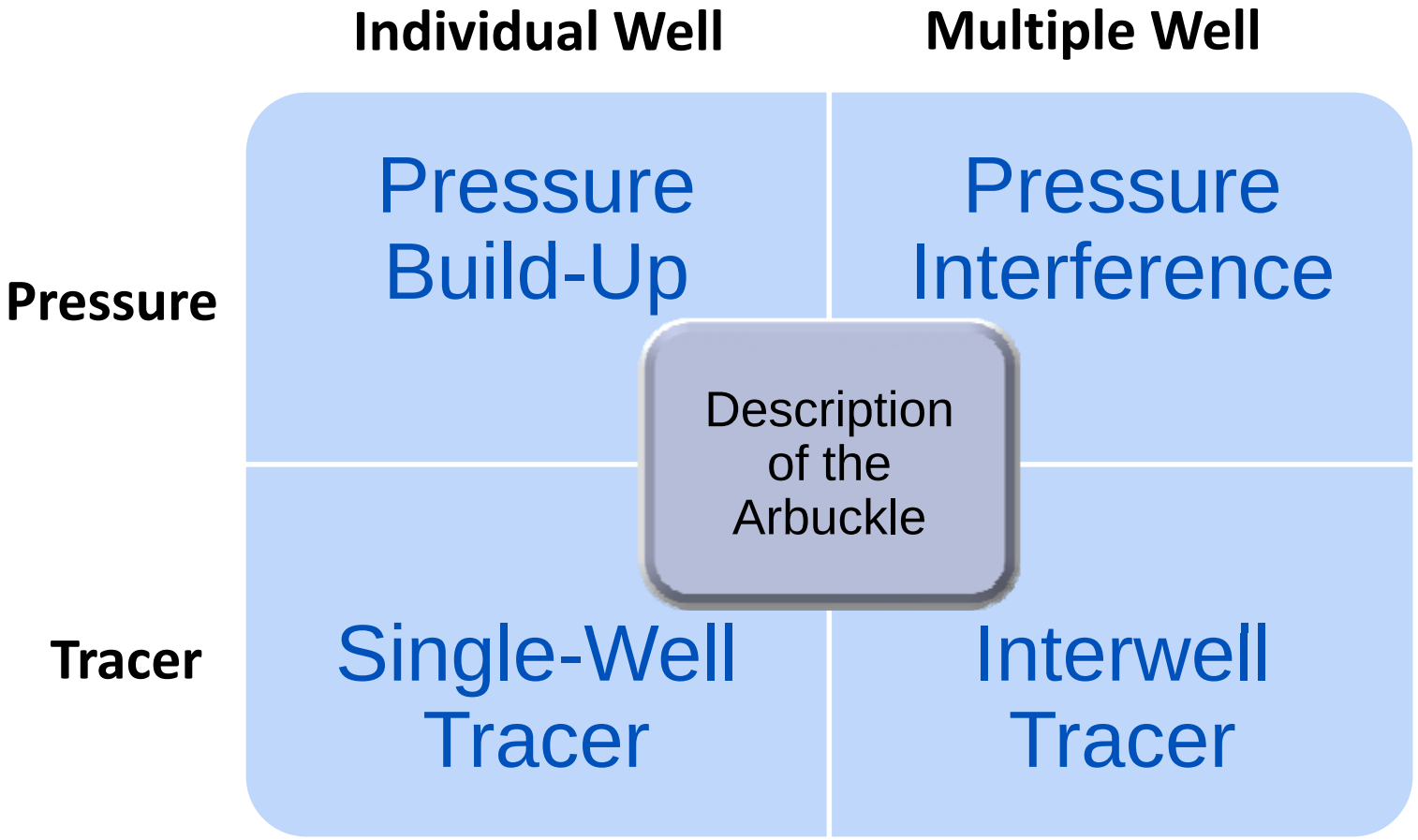
Engineering Characterization



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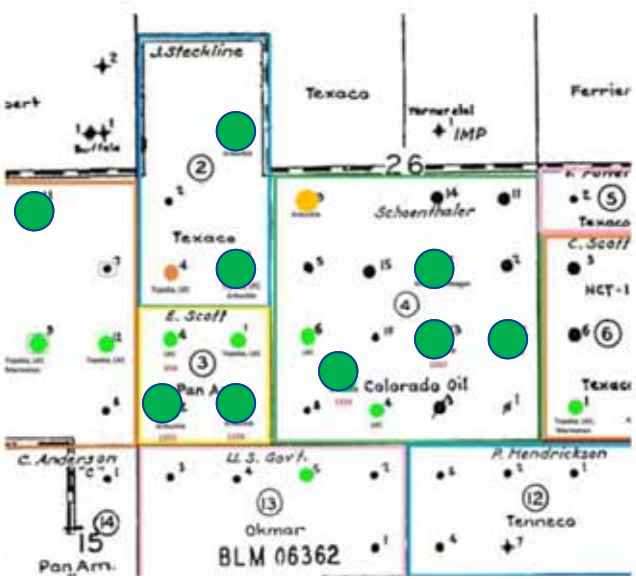
Pressure Build up



Procedure

- Select Arbuckle wells
- Connect Echometers or pressure gauge
- Shut-in wells
- Measure fluid levels or pressures

Determine

- Reservoir Pressure
- Flow Geometry

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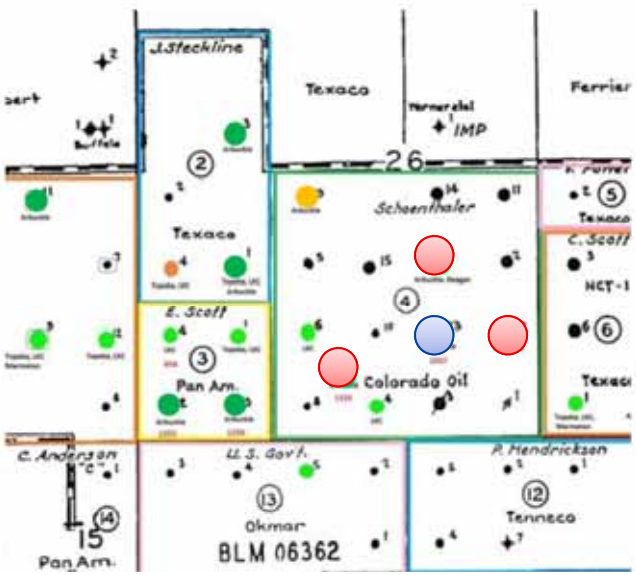
Pressure Interference



Procedure

- Remove rods from producers
- Run in surface-read pressure gauges
- Pump center well (pulse testing)
- Measure pressure response

Determine

- Flow Geometry
- Preferential Flow Paths
- Average or Bulk Permeability

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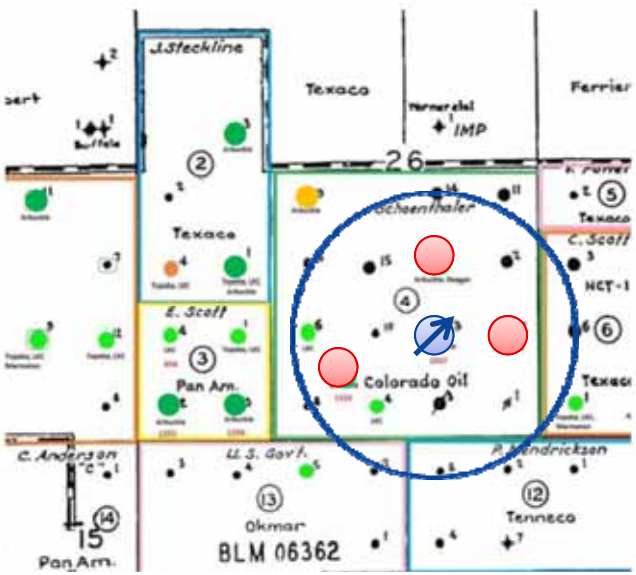
Interwell Tracer



Procedure

- Reverse equipment in center well
- Inject tracer into center well
- Produce the other wells
- Sample produced fluids
- watch for tracer

Determine

- Preferential flow paths
- Permeability variation or fracture existence

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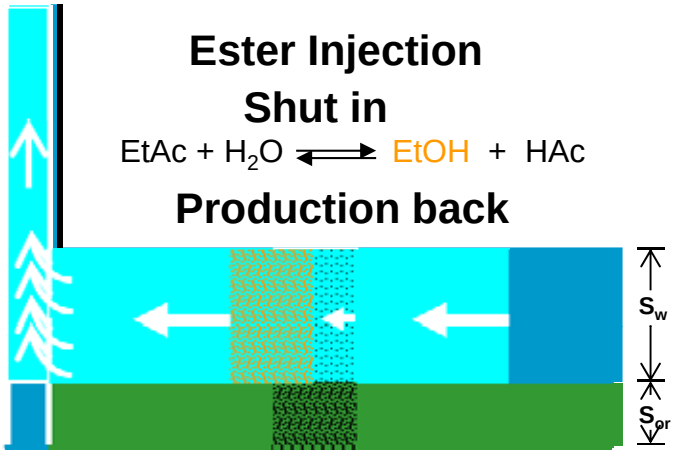
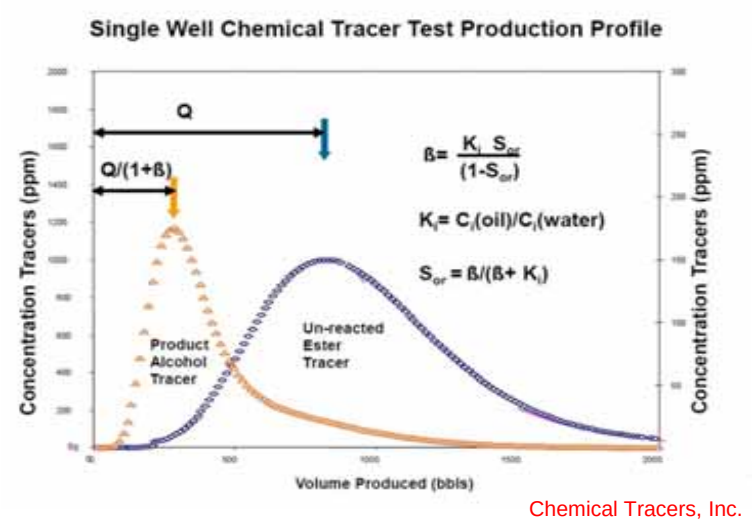
Single Well Tracer



Chemical Tracers, Inc.



Chemical Tracers, Inc.

Procedure

- Inject partitioning tracer into selected well
- Shut in well & allow hydrolysis reaction
- Produce the well
- Sample produced fluid & draw tracer curves

Determine

- Remaining oil saturation

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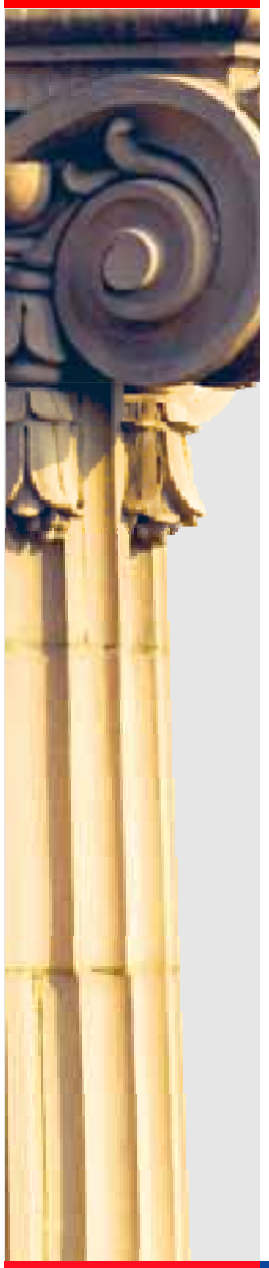

Pattern Design

- Update and revise the reservoir model.
- Conduct simulation to evaluate flooding pattern to maximize the recovery efficiency .
- Identify operational issues and concerns for future field demonstration test.

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CO_2 resources and oil fields in Kansas

Kansas Geological Survey

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Summary

- Current reservoir average pressure is suitable for CO_2 injection at near miscible condition, which is approximately at 1200 psi, 150 psi below MMP.
- An improved method was developed to estimate porosity from well logs, which will lead to a better reservoir description.
- All the proposed tests will aid the understanding of Arbuckle reservoir as well as the pattern design for a future field demonstration project.

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Acknowledgements

- ***Project Team***
  - Mark Ballard
  - Evan Franseen
  - Francis Hitschmann
  - Jenn-Tai Liang
  - Kourosh Reza Maleki (GRA)
  - Carmen Schmitt
  - Paul Willhite
- **Others**
  - Martha Cather
  - Bob Kiker
  - Chandra Nautiyal
  - Scott Ramskill
  - Jeremy Viscomi
  - Dana Wreath