

Prototyping and testing a new volumetric curvature  
tool for modeling reservoir compartments  
and leakage pathways in the  
Arbuckle saline aquifer:  
*reducing uncertainty in CO<sub>2</sub> storage and permanence*

Project Number (DE-FE0004566)

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U.S. Department of Energy  
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Carbon Storage R&D Project Review Meeting  
Developing the Technologies and Building the  
Infrastructure for CO<sub>2</sub> Storage  
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# Presentation Outline

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- Benefits, objectives, overview
- Methods
- Background & location
- Technical status
- Accomplishments
- Summary

# Benefit to the Program

- Program goal addressed:

*Develop technologies that will support the industries' ability to predict CO<sub>2</sub> storage capacity in geologic formations to within  $\pm 30$  percent.*

- Program goal addressed:

*This project will confirm—via a horizontal test boring—whether fracture attributes derived from 3-D seismic PSDM Volumetric Curvature (VC) processing are real. If validated, a new fracture characterization tool could be used to predict CO<sub>2</sub> storage capacity and containment, especially within paleokarst reservoirs.*

# Goals and Objectives

Evaluate effectiveness of VC to identify the presence, extent, and impact of paleokarst heterogeneity on CO<sub>2</sub> sequestration within Arbuckle strata

– Develop technologies that demonstrate 99% storage permanence and estimate capacity within +30%.

- Predict **plume migration**...*within fractured paleokarst strata using seismic VC*
- Predict **storage capacity**...*within fractured paleokarst strata using seismic VC*
- Predict **seal integrity**...*within fractured paleokarst strata using seismic VC*

– Success criteria

- Merged & reprocessed PSTM volume reveals probable paleokarst (DP1)
- Within budget after landing horizontal test boring (DP2)
- VC-identified compartment boundaries confirmed by horizontal bore-hole (DP3)

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# Methods

- Merge, reprocess, interpret PSDM 3-D seismic
- PSTM & PSDM VC-processing (Geo-Texture)
  - Pre-processing: Raw, Basic PCA, Enhanced PCA, Robust PCA
  - Lateral wave-length resolutions: high (~50-ft), medium (~150-ft), long (~500-ft)
- Build pre-spud fault & geocellular property models
- Locate, permit, drill & log horizontal test boring
- Tool-push logging program using Compact Well Shuttle™
  - *Triple combo*
  - Full-wave sonic
  - Bore-hole micro-imager
- Formation evaluation & image interpretation
- Seismic inversion, variance & ant track
- Revise fault, facies & property models
- Simulate & history match

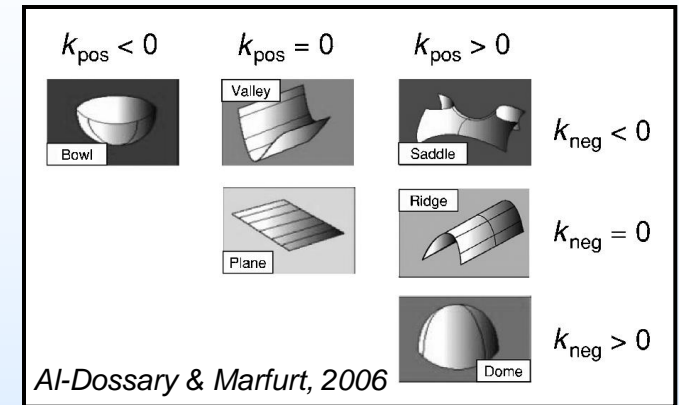
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# Background: Volumetric Curvature

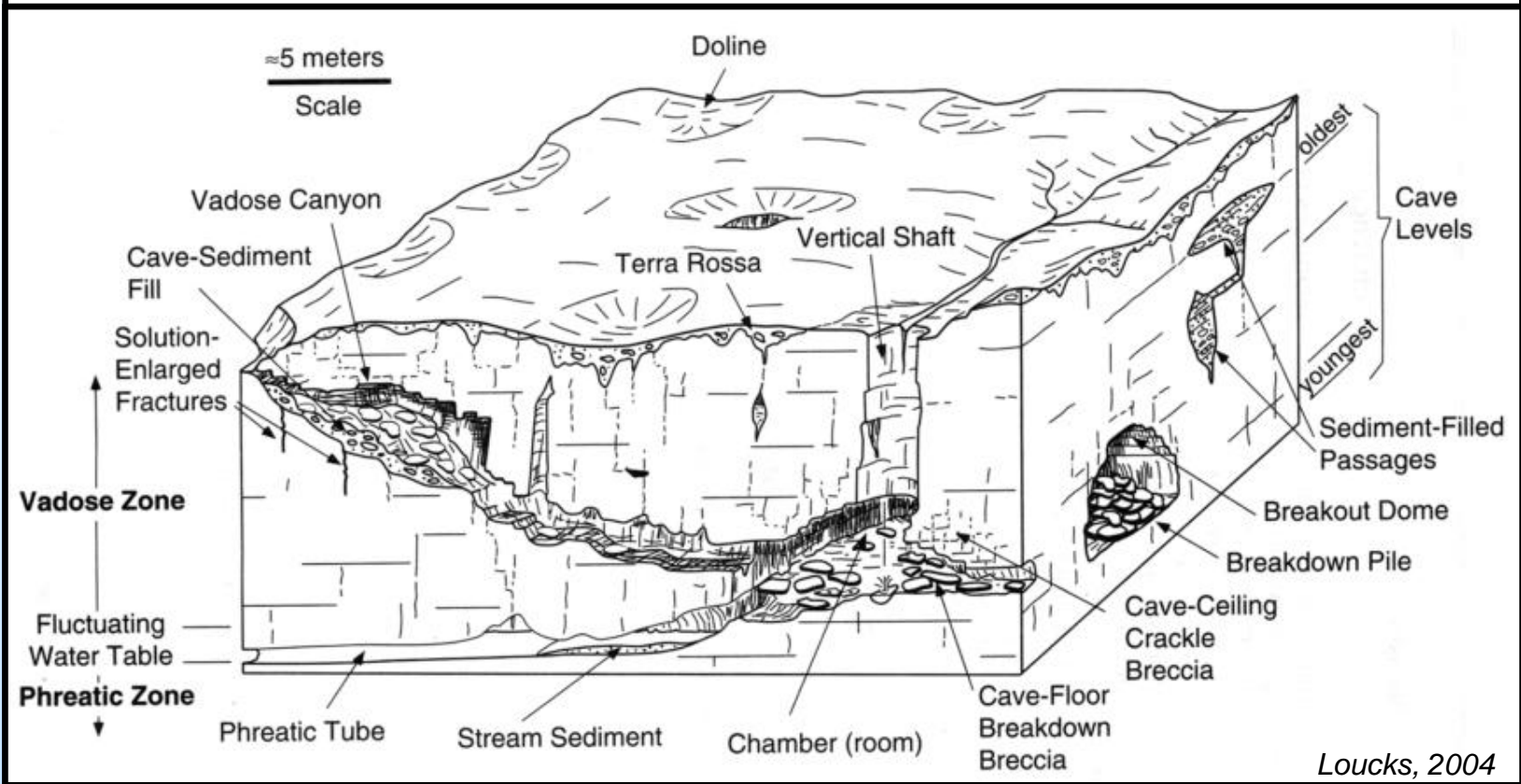
- A measure of reflector shape:
  - *Most-positive*: anticlinal bending
  - *Most-negative*: synclinal bending
- Measured at different wavelengths
- Horizon-independent
- Reveals fractures in complex zones where horizons are not track-able
- Curvature and rotation are mathematically independent of coherence and seismic amplitude



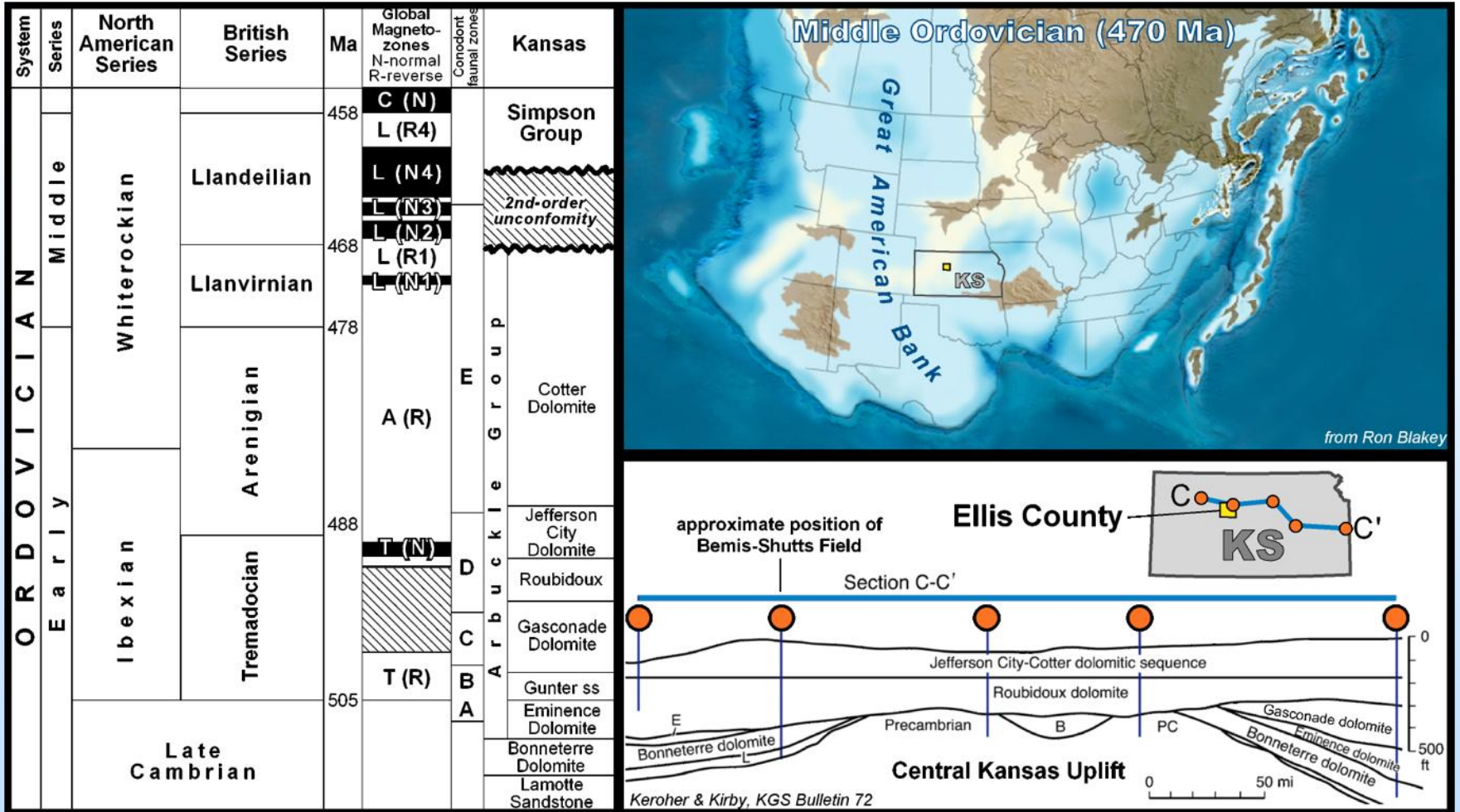


# Background: Paleokarst

VC utility can image faults, fractures, flexures, sags

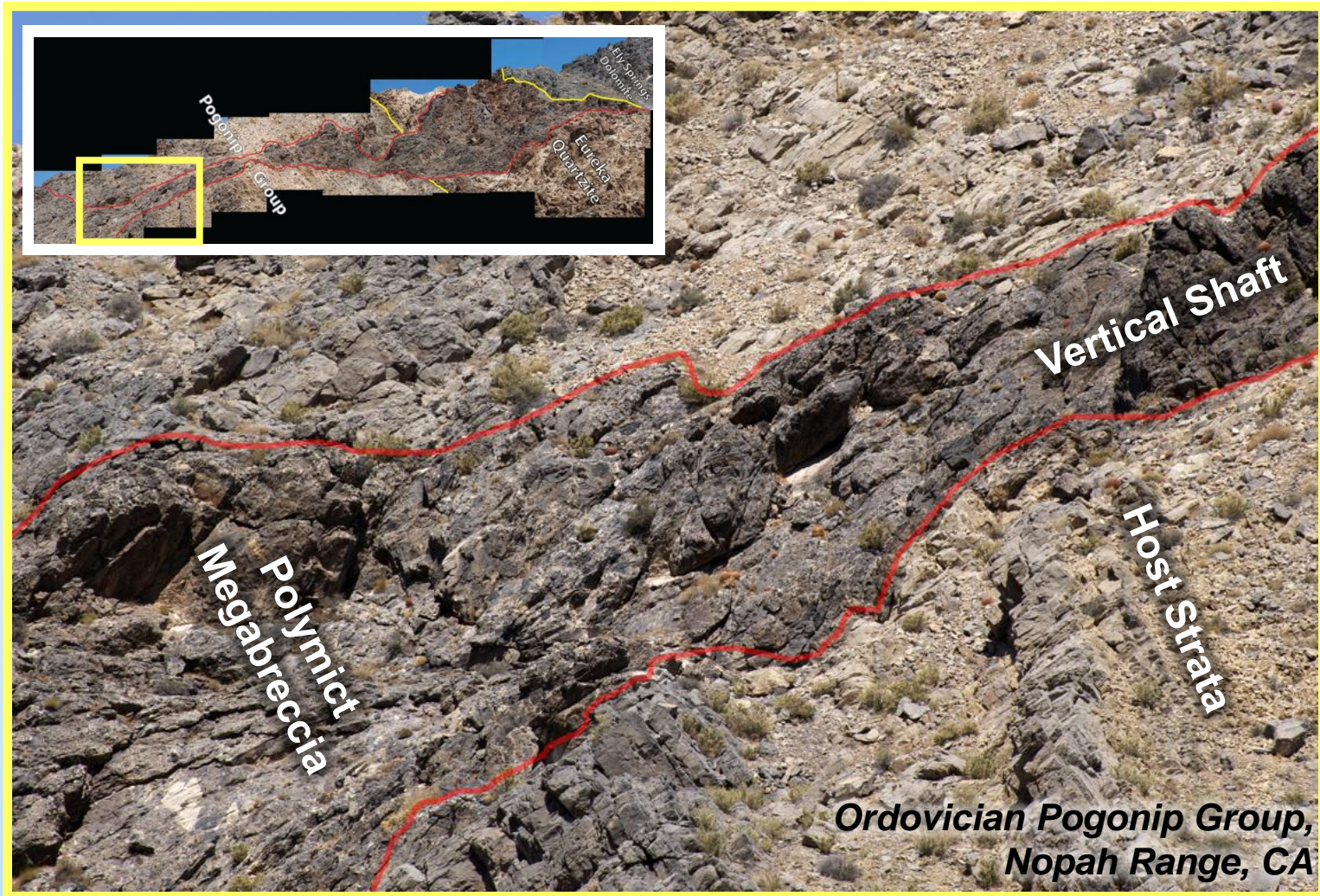


# Background: Arbuckle Group



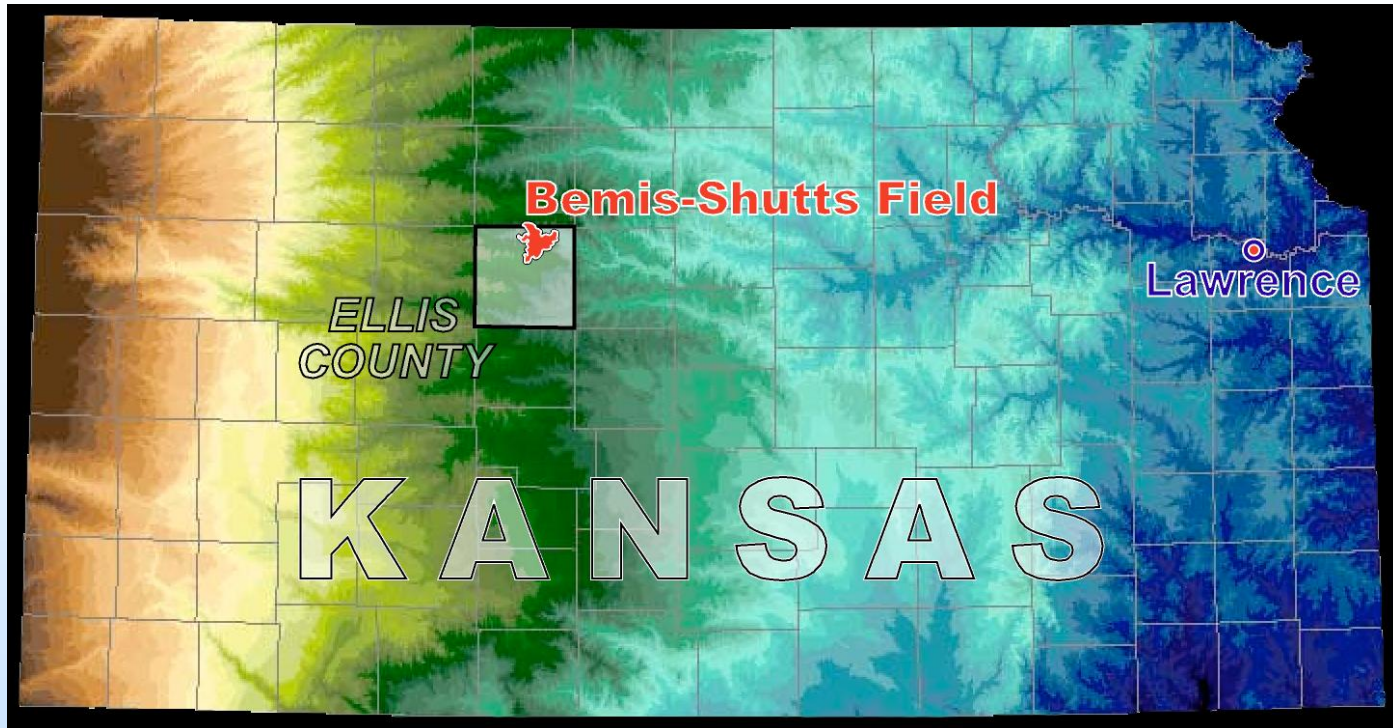


# Background: Paleokarst— Non-stratiform Reservoir Architecture



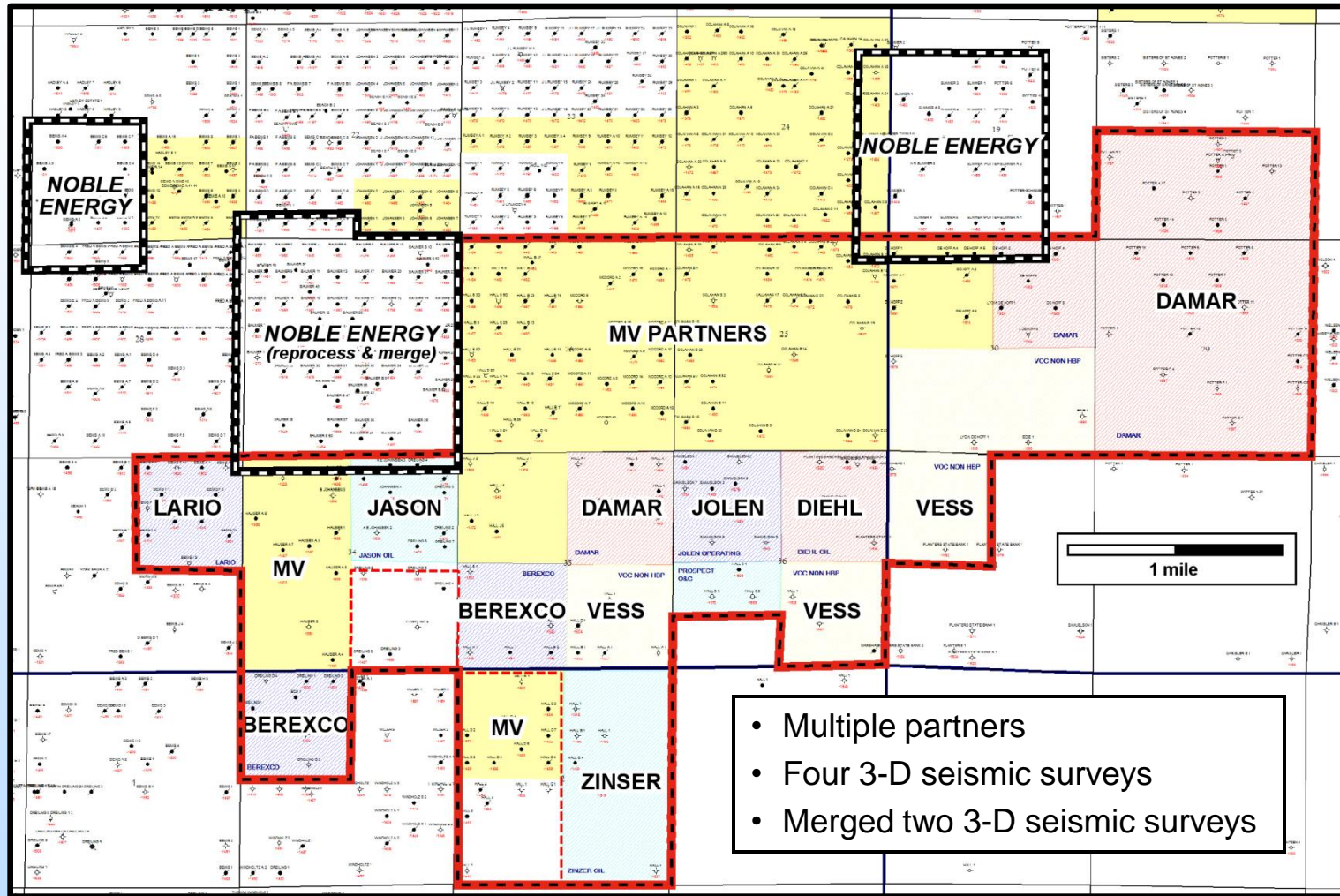


# Location: Bemis-Shutts Field



- Discovered 1928
- Arbuckle production—Ordovician paleokarst (Mississippian overprint)
- 615 open wells

# Location: southeast Bemis-Shutts



# Presentation Outline

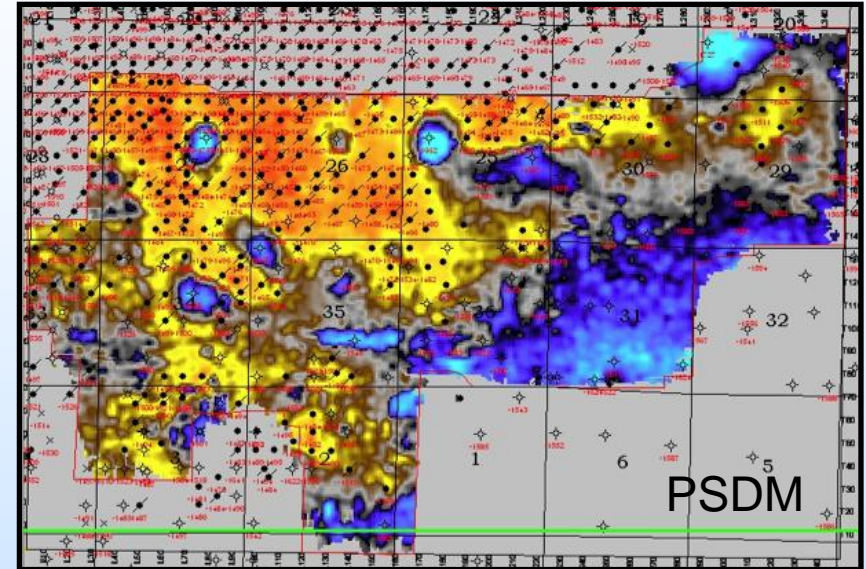
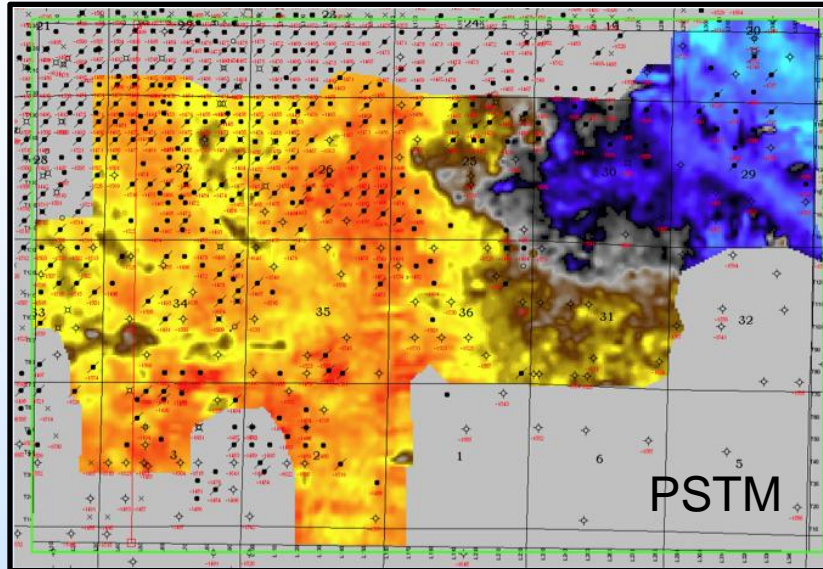
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- Recommendations
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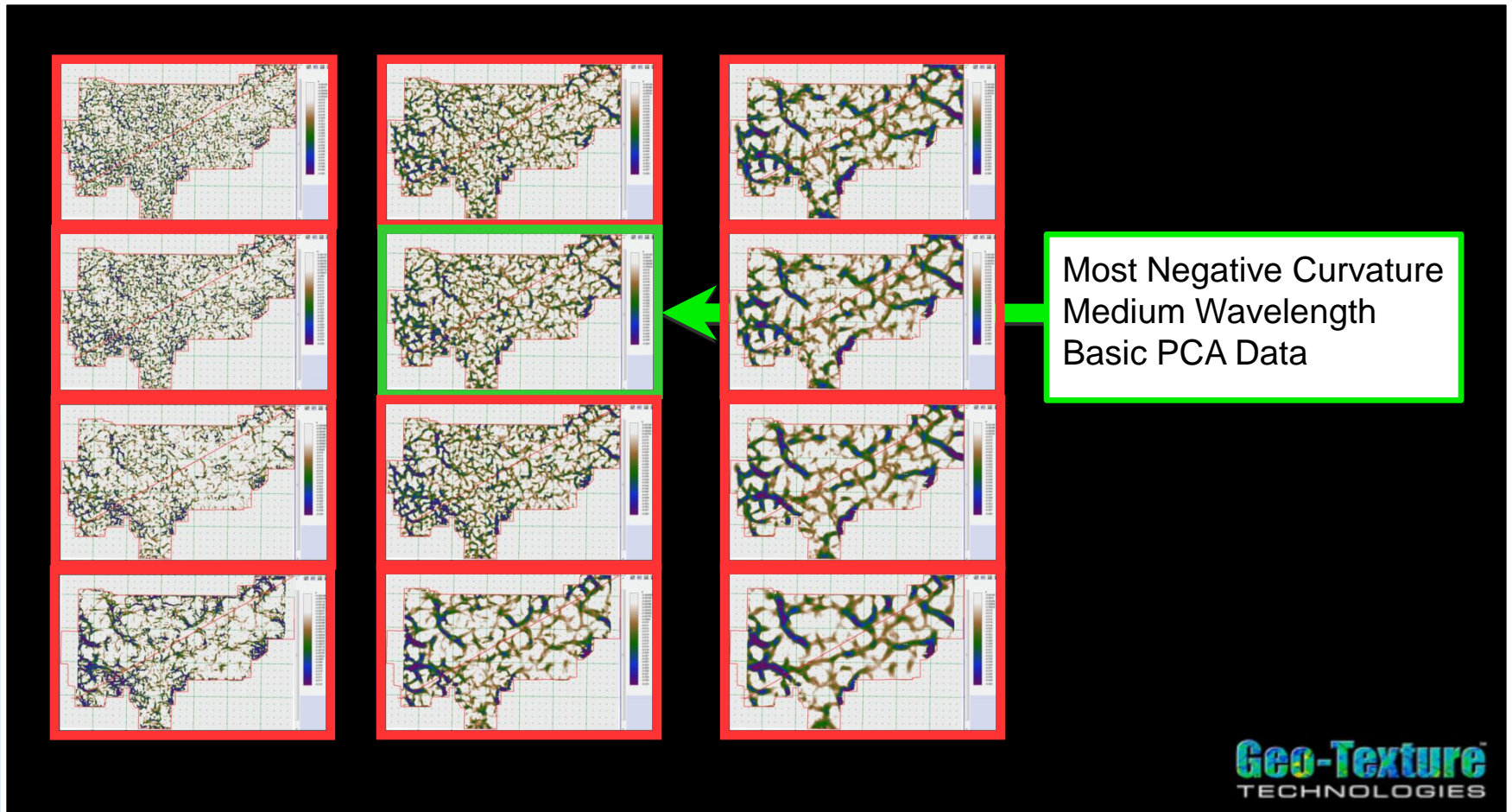
# PSTM–PSDM Comparison

Top Arbuckle surfaces showing paleokarst



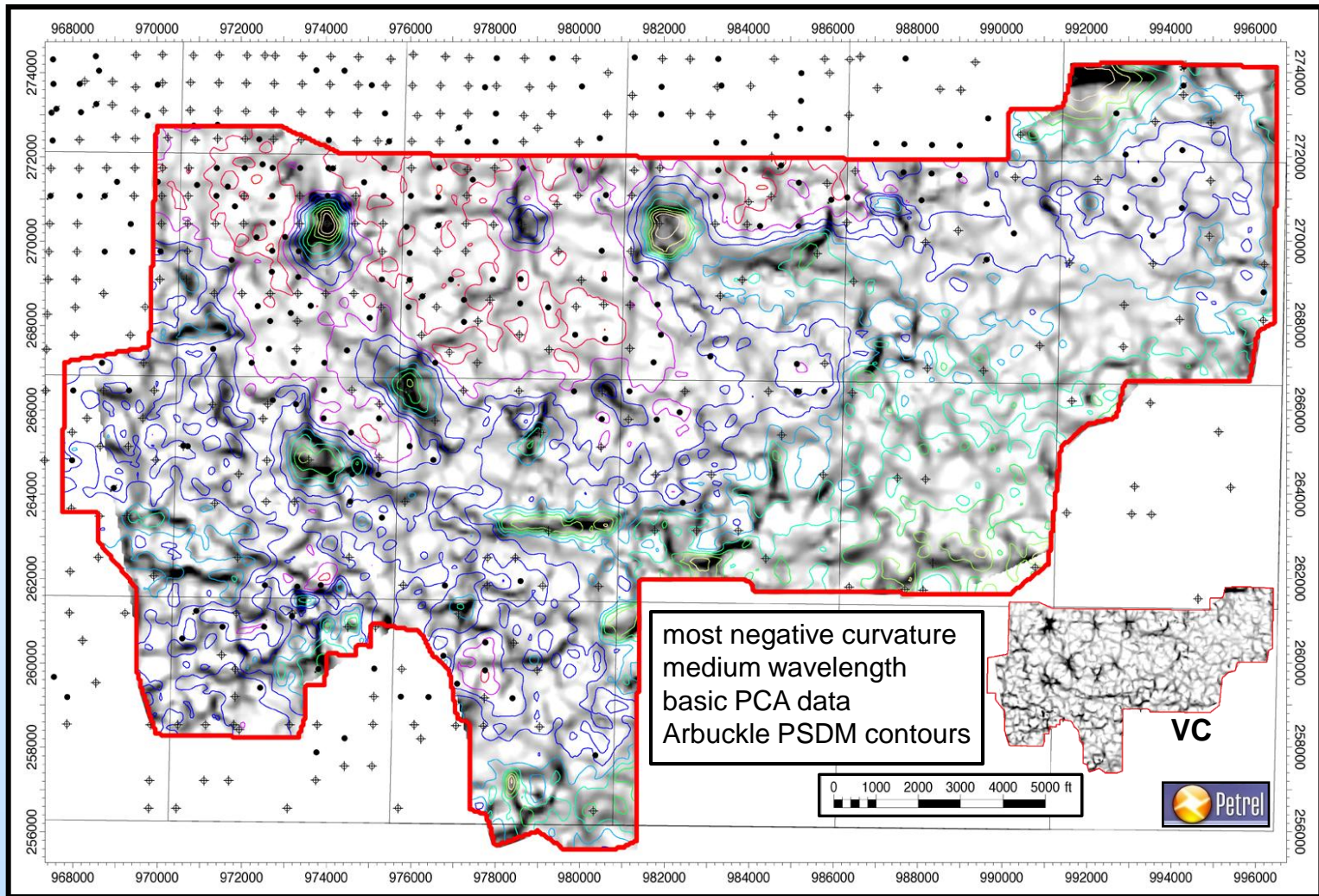
PSTM structure significantly different  
PSTM and PSDM *VC-attributes* are significantly different

# PSDM VC-Processing Results

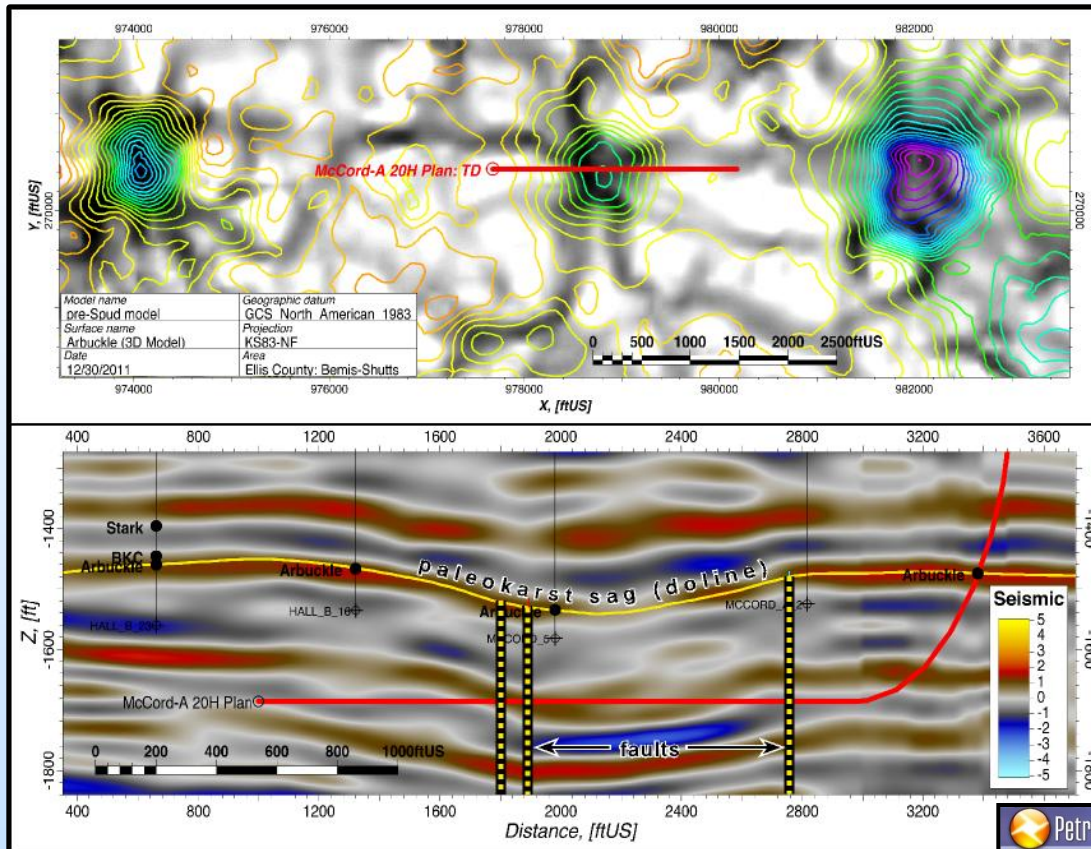




# Pre-spud VC-Attribute



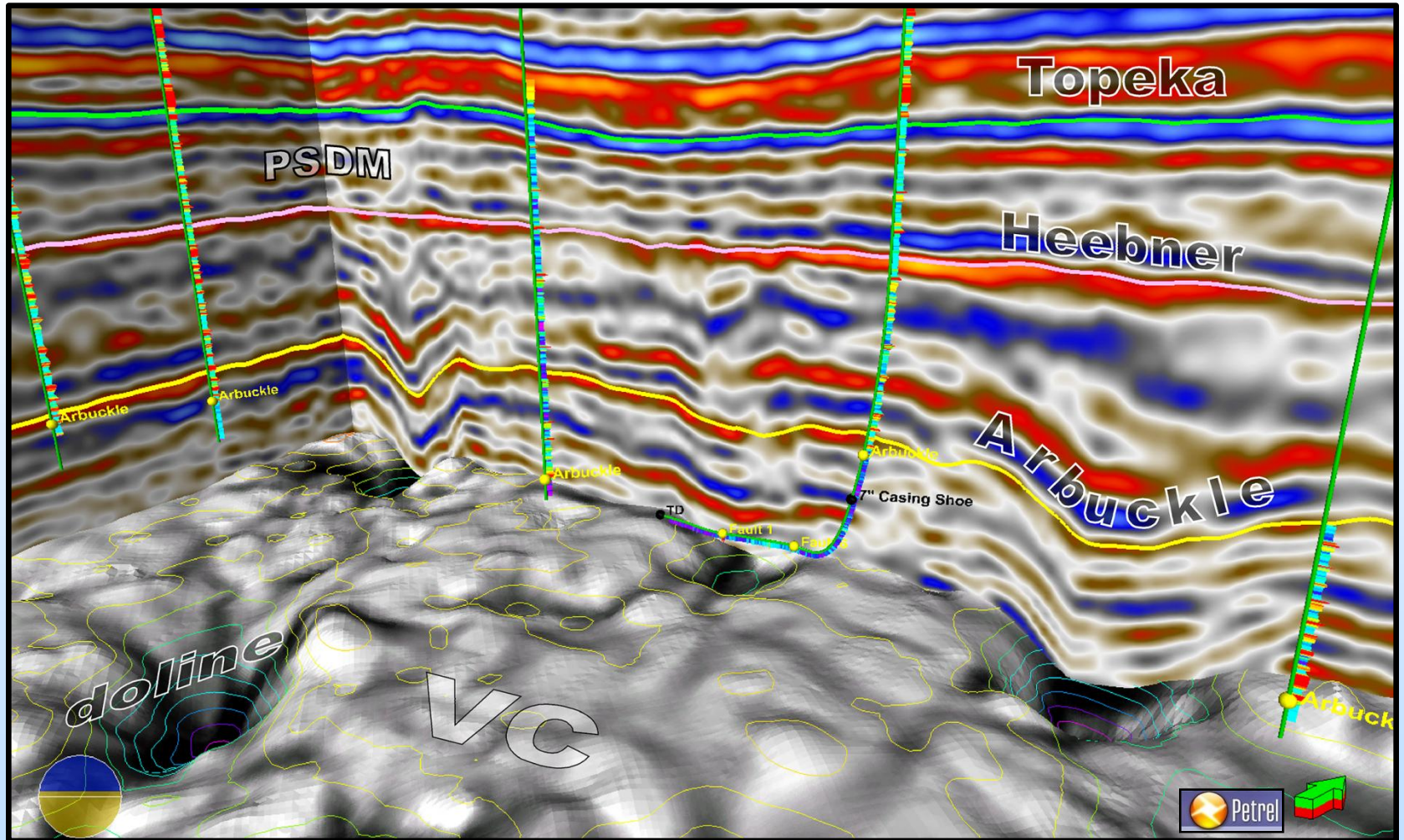
# Test Boring Plan



- Grass roots
- Set 7 inch casing
- Drill 6 1/8-inch hole to TD
- Land 400-ft below
- 1800-ft lateral in/out paleokarst
- Tool-push OH logs
  - Triple combo
  - Full-wave sonic
  - Image Log
- Set plug
- Drill stem test

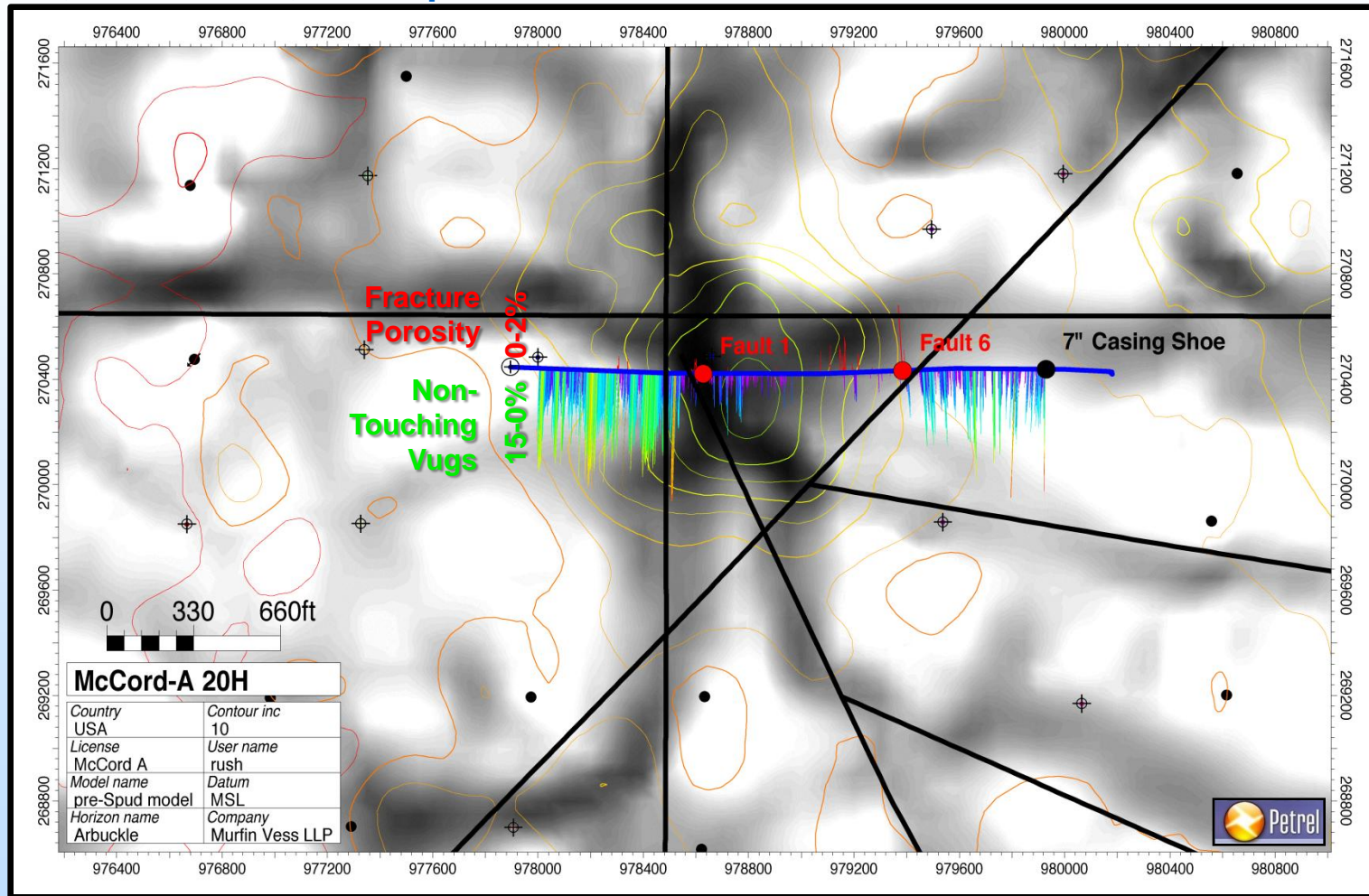


# Actual Test Boring



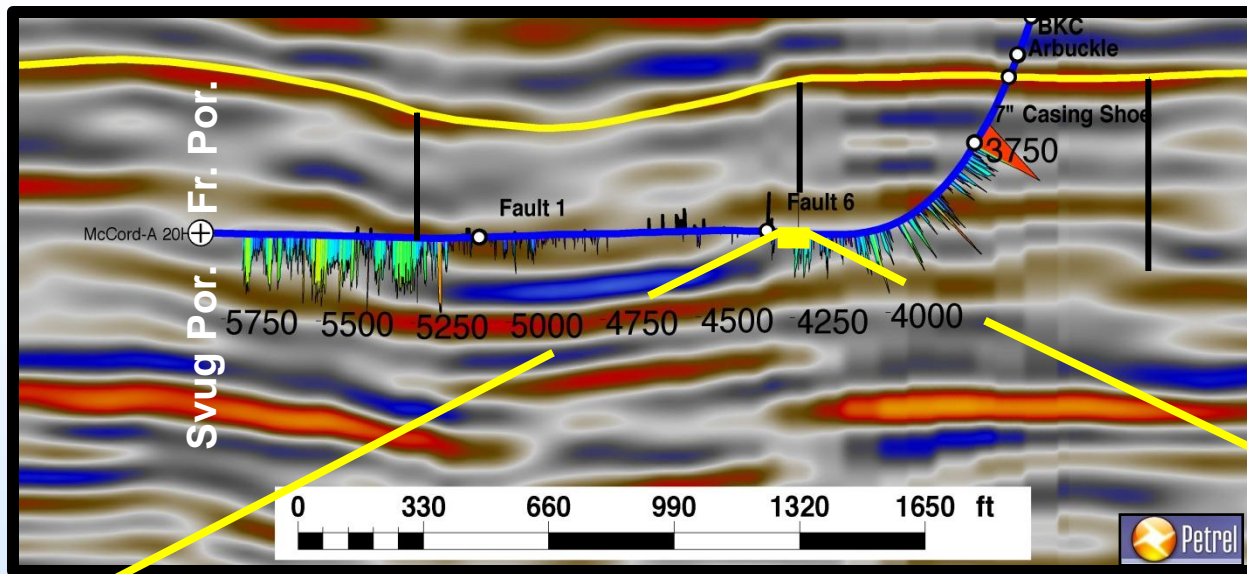
# Fracture & Non-touching Vug Porosity

## VC, fault model, and top Arbuckle contours

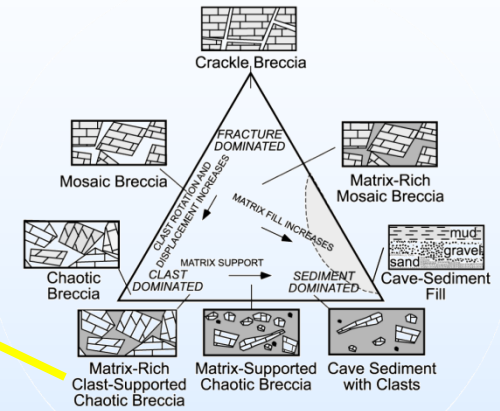




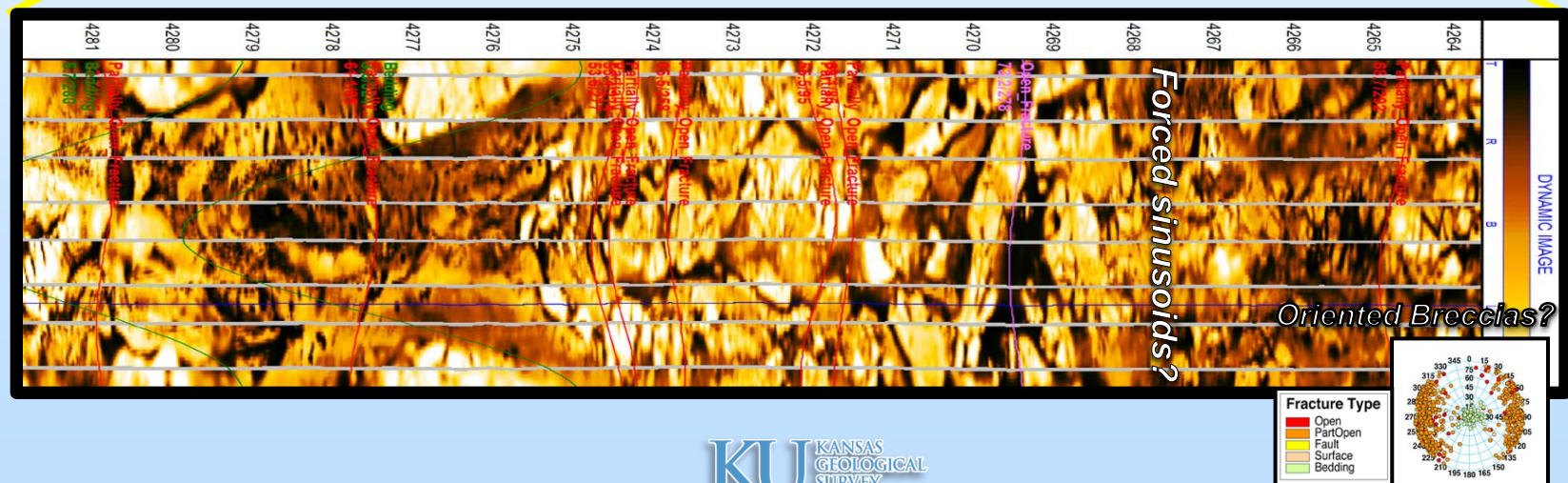
# Damage Zone Associated with Fault-Bounded Paleokarst



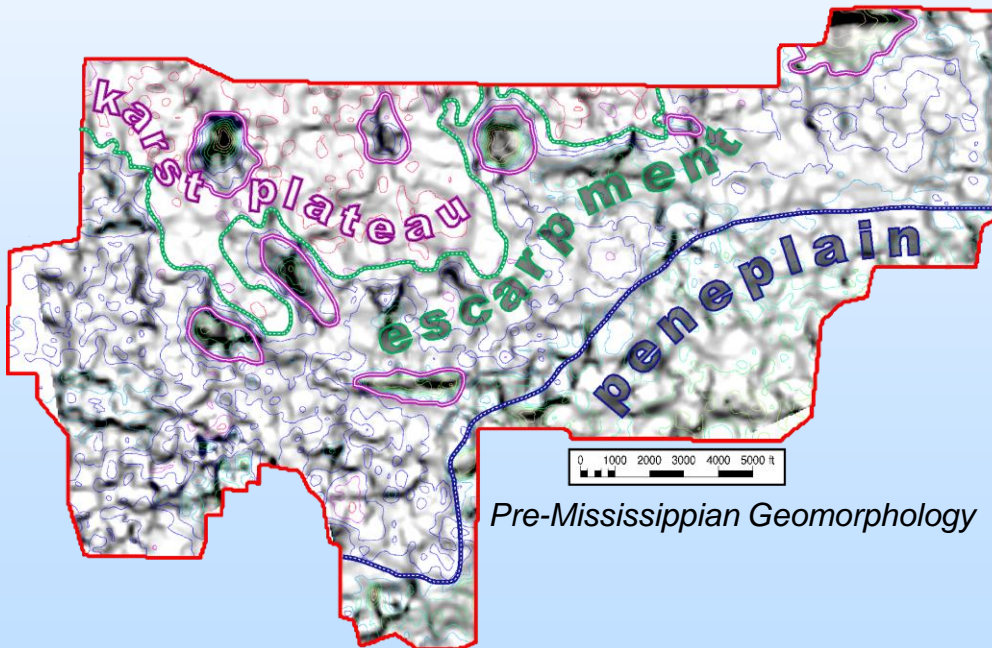
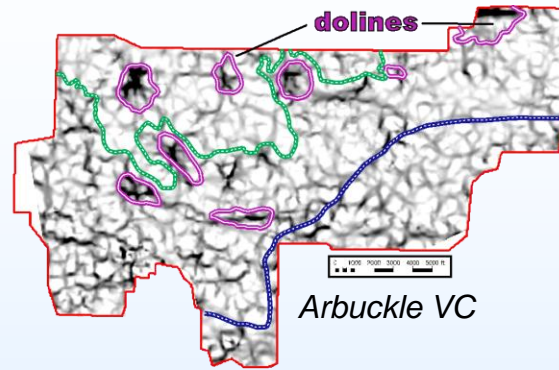
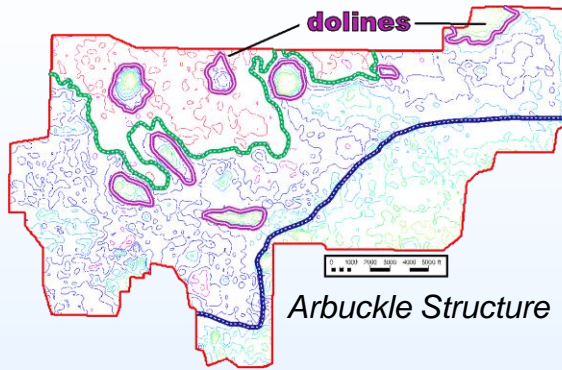
## Paleokarst Facies



Loucks, 2004



# Key Findings & Interpretations to Date



- Fault-bounded doline confirmed
- Dolines coincident with VC-identified radial lineaments
- Interior drainage
- Headward-eroding escarpment
- Disappearing streams/springs/fluvial plains
- Fracture system Ordovician-age
  - *does O-age reduce seal risk?*

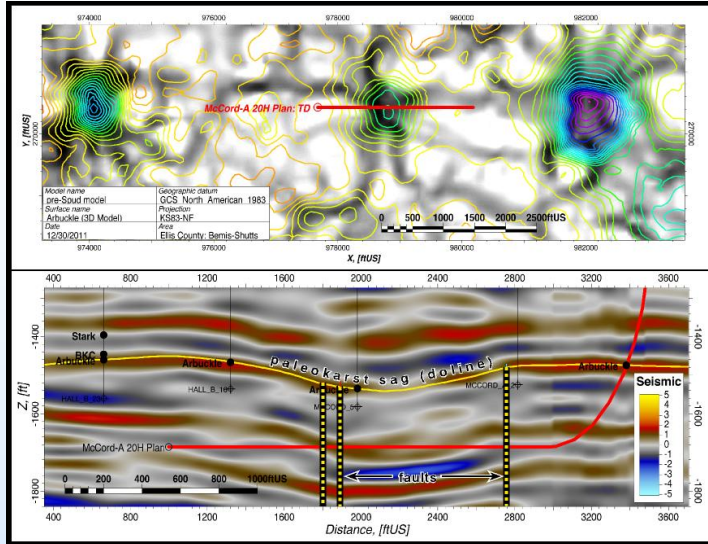
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# Accomplishments to Date



- Merged & reprocessed seismic
- LAS 3.0 format from scans
- Generated PSDM volume
- Processed PSTM/DM VC-volumes
- Generated pre-spud VC-attributes
- Generated fault & property models

- Drilled 1800-ft horizontal boring across VC-constrained doline
- Tool-pushed: 1) *triple combo*, 2) full-wave sonic, 3) micro-imager
- Completed formation evaluation
- Simulated & history matched pre-spud model
- Completed inversion and porosity probability cube



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# Summary

- Key Findings
  - Direct confirmation of VC-constrained, fault-bounded, paleo-doline
  - PSDM VC attribute significantly different than PSTM
  - VC requires PSDM 3D for complex structural settings
    - *Requires horizontal to reduce structural uncertainty?* ...policy question
  - History match was not a unique solution
- Lessons Learned
  - VC attribute(s) not a unique solution
  - Lost-in-hole tool insurance—cost prohibitive
- Future Plans
  - Revise models: fault, DFN, facies, property
  - Analyze uncertainty of flux between blocks
  - Simulate & history match new models

