"Wellington Field, Sumner County, Kansas as a calibration site for CO_2-EOR in Mississippian chert and dolomite reservoirs and deep saline aquifer CO_2 sequestration

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Dennis Hedke - **Hedke-Saenger Geoscience, Ltd., Wichita, KS**
Susan Nissen - **Geophysical Consultant, McLouth, KS**

David Koger - **Koger Remote Sensing, Ft. Worth, TX**
Ralph Baker - **Geological Consultant, Houston, TX**

John Lorenz & Scott Cooper - **Fracturestudies.com, Edgewood, NM**

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DOE Contract #FE0002056
and partner cost share

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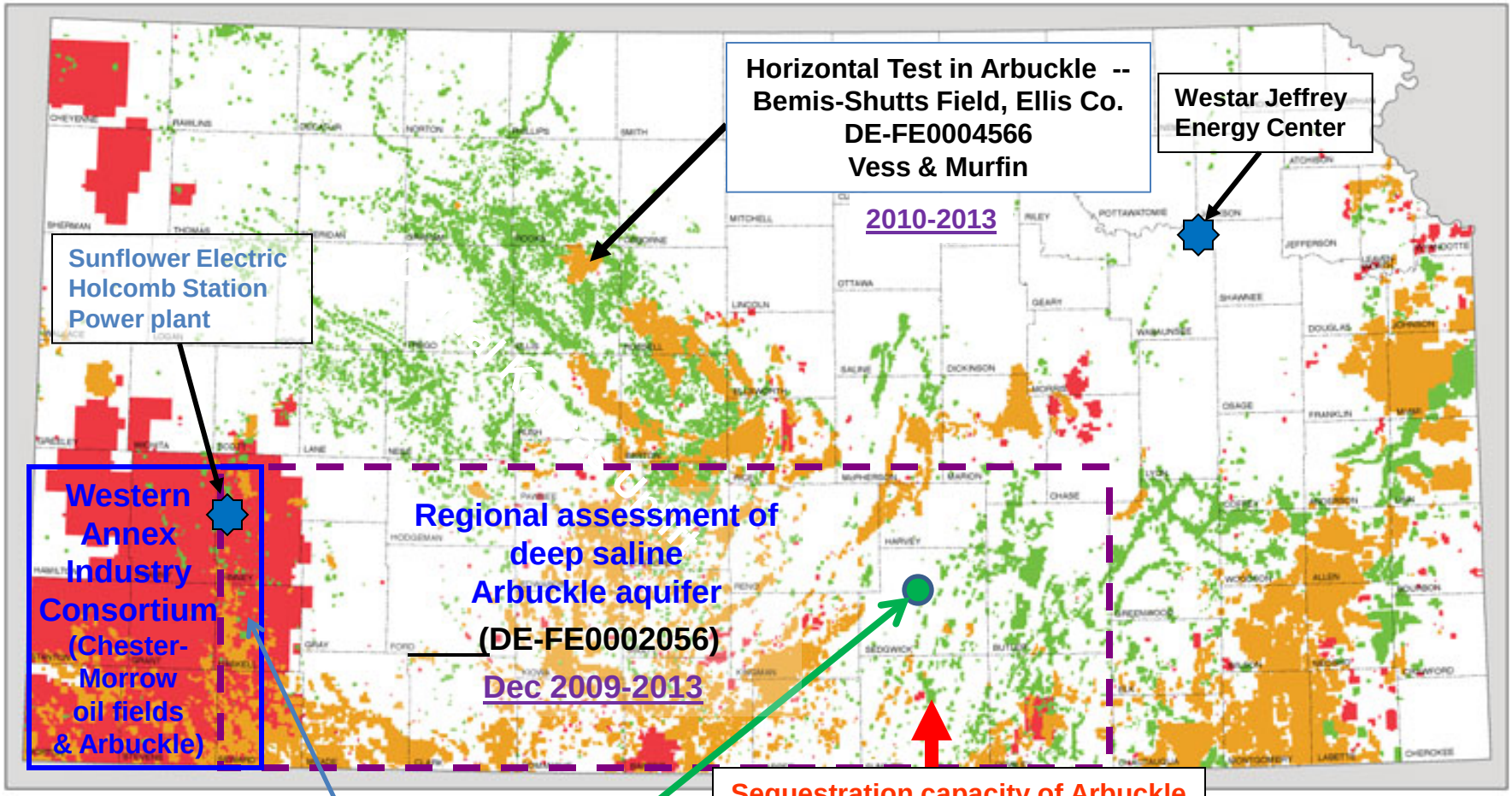
OIL AND GAS FIELDS OF KANSAS

2009

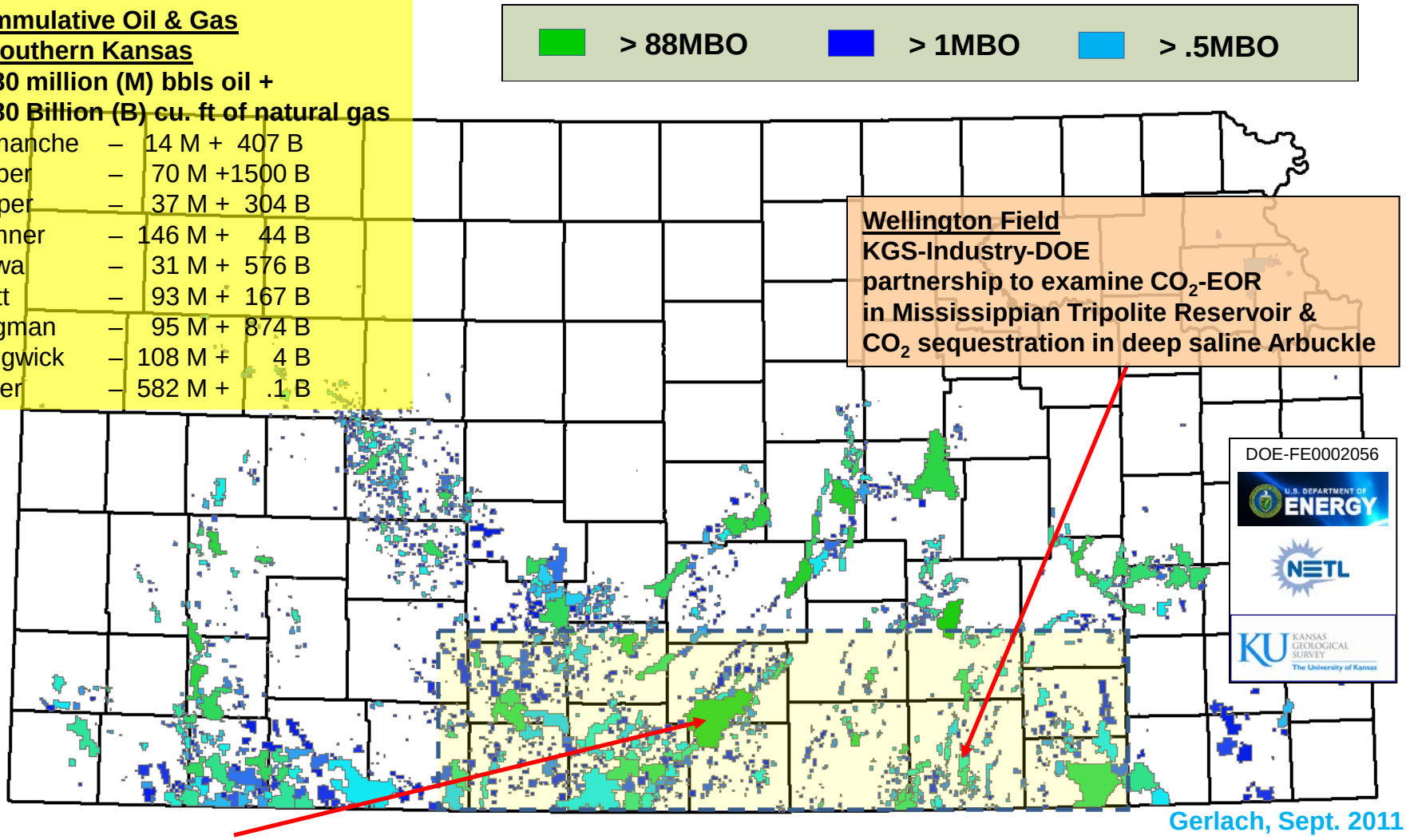


Mississippian Oil and Gas Fields in Kansas

Approximate outline of southern Kansas Mississippian Oil Play & cumulative oil and gas production (BOE)

Cummulative Oil & Gas in southern Kansas
1,180 million (M) bbls oil +
3,880 Billion (B) cu. ft of natural gas

Comanche	–	14 M +	407 B
Barber	–	70 M +	1500 B
Harper	–	37 M +	304 B
Sumner	–	146 M +	44 B
Kiowa	–	31 M +	576 B
Pratt	–	93 M +	167 B
Kingman	–	95 M +	874 B
Sedgwick	–	108 M +	4 B
Butler	–	582 M +	.1 B

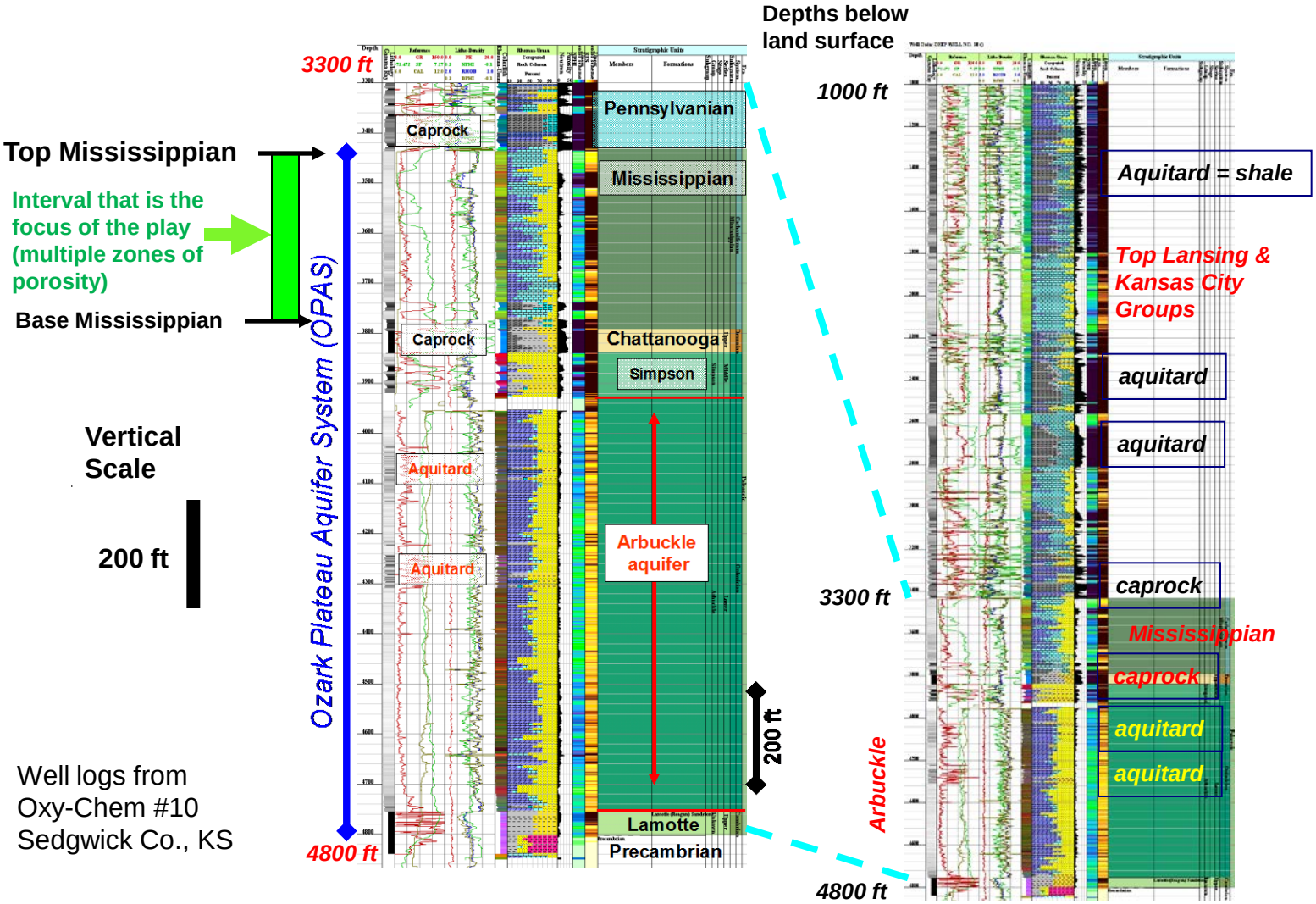


Gerlach, Sept. 2011

Spivey-Grabs Basil is the largest Mississippian oil field in Kansas with 69 MM BO & 841 BCFG
Produces from the tripolite and could benefit from horizontal drilling and, in later maturity, by CO_2-EOR

Ozark Plateau Aquifer System (OPAS) lies ~3500 feet below the surface in southern Kansas

Multiple Caprocks & Aquitards above the Mississippian – serve as <u>barriers to migration of fractures and fluids above the Mississippian</u>



Well logs from Oxy-Chem #10 Sedgwick Co., KS

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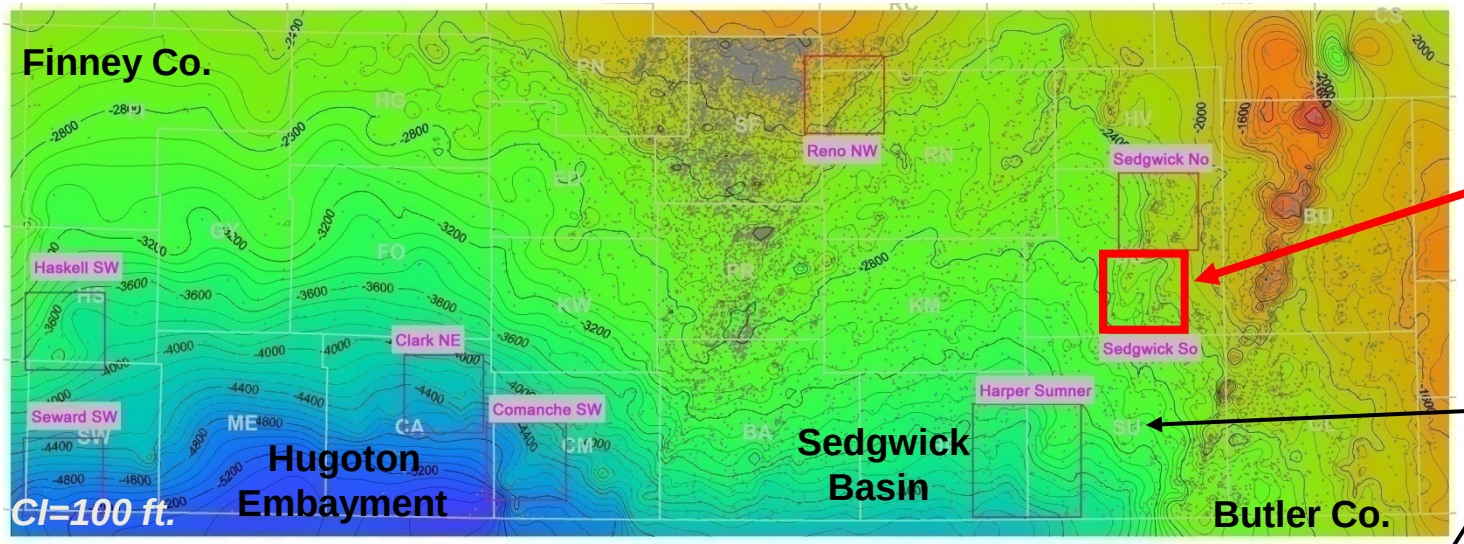
Regional Study – Structure, isopach, and property mapping to determine CO_2 sequestration capacity

Structure top of Arbuckle Group

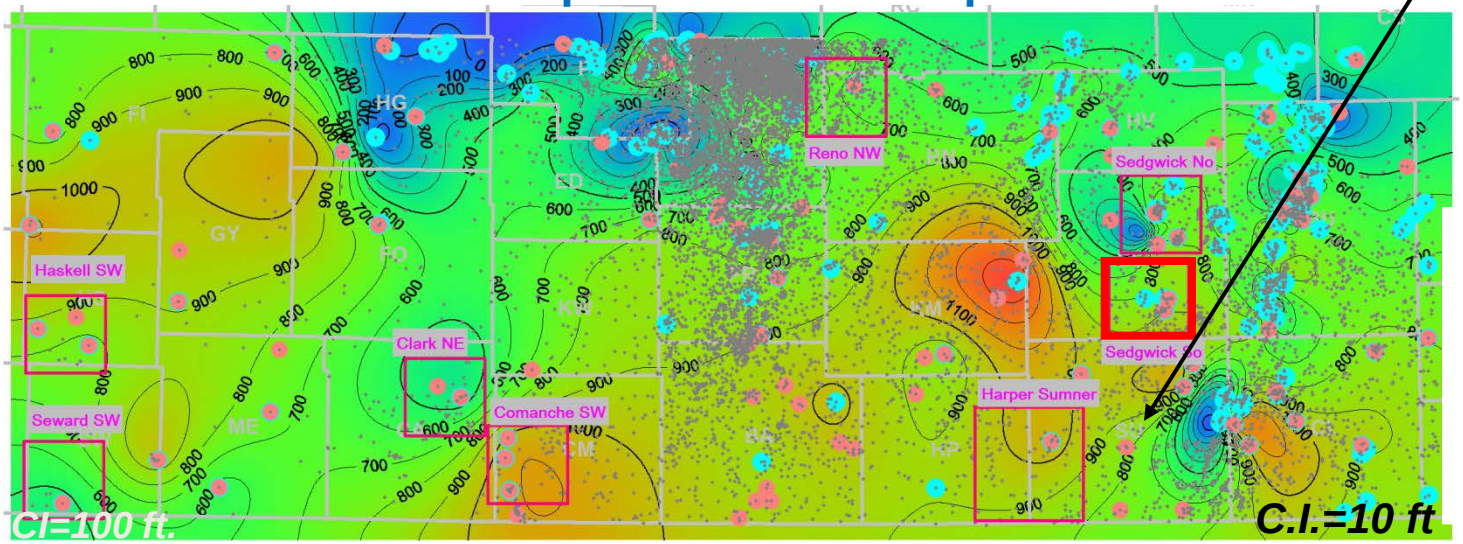


Initial Arbuckle modeling site southern Sedgwick County

Wellington Field

50 mi

Isopach Arbuckle Aquifer



Compartment Candidate

ARBK Penetrations

Super Type Well (91 wells)

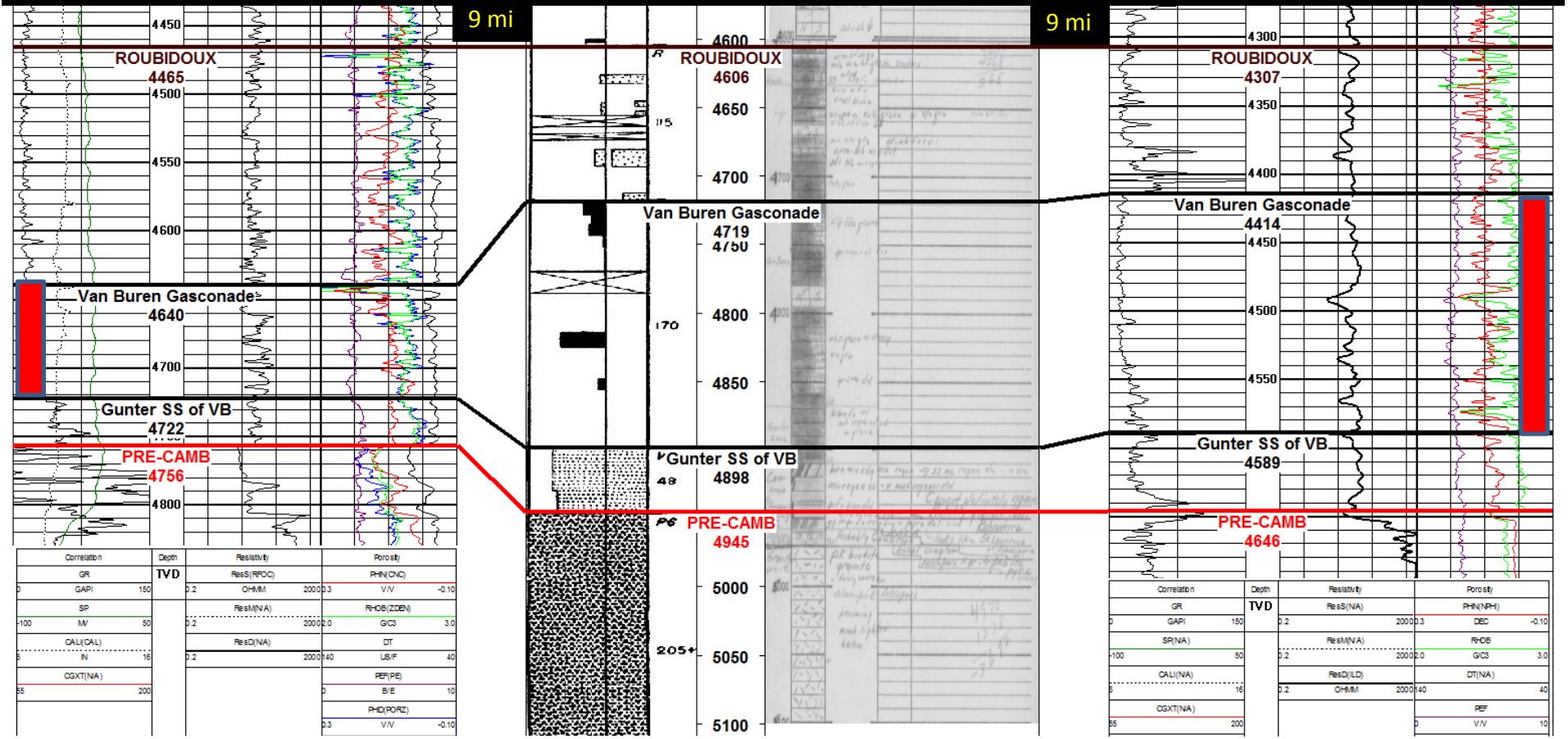
P-C Tests (292 wells)

Quantitative Characterization of Arbuckle in southern Kansas

Quantitative Reservoir Characteristics

Correlated to

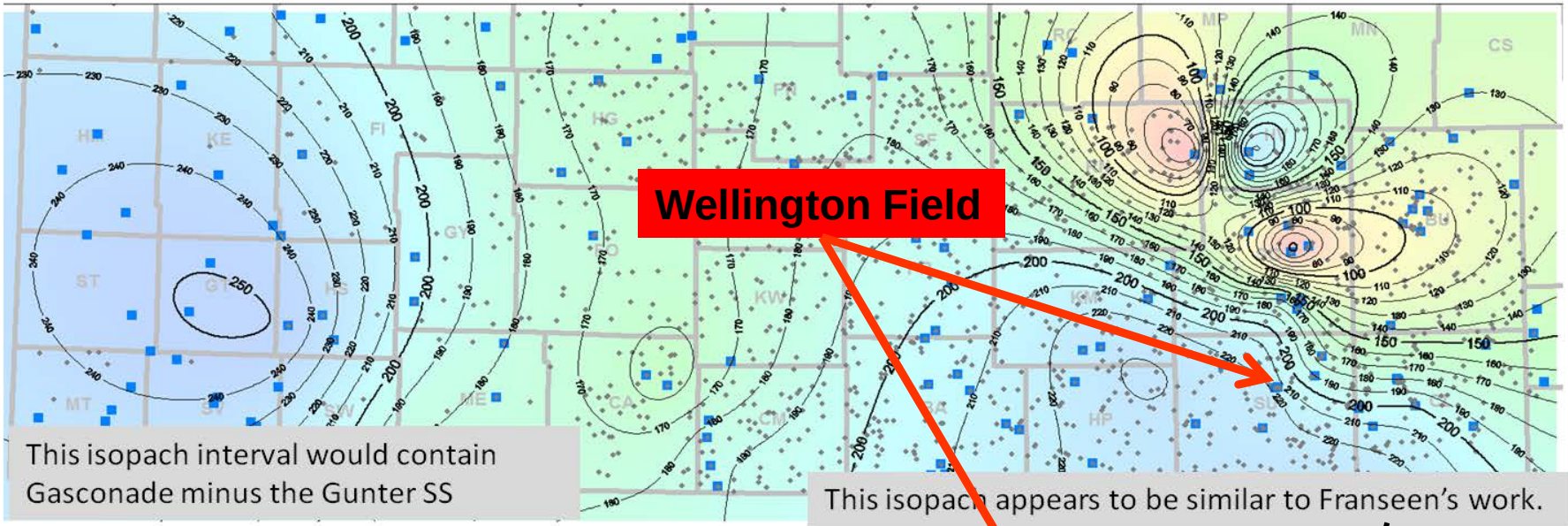
Internal Arbuckle Stratigraphy



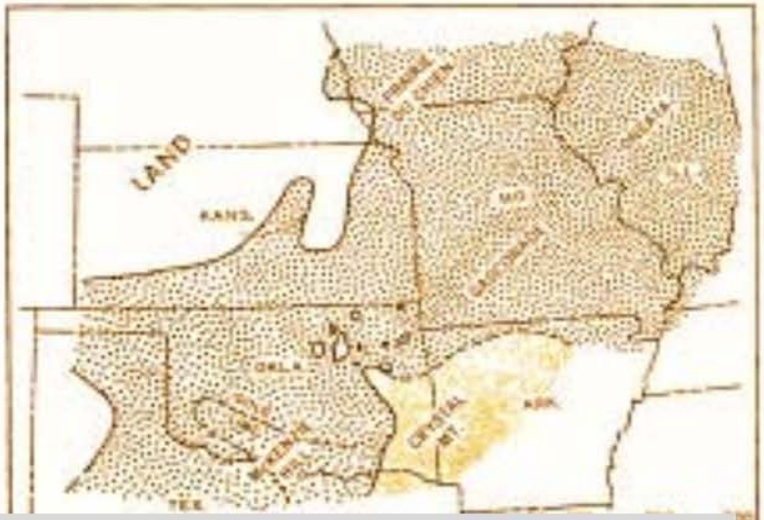
Example stratigraphic cross section of lower Arbuckle from top Roubidoux (datum) to basement including new and old well data (*insoluble residue logs, georeports, and modern suite of logs managed as LAS files*) – Gerlach et al.

Lower porous zone in Arbuckle at Wellington Field

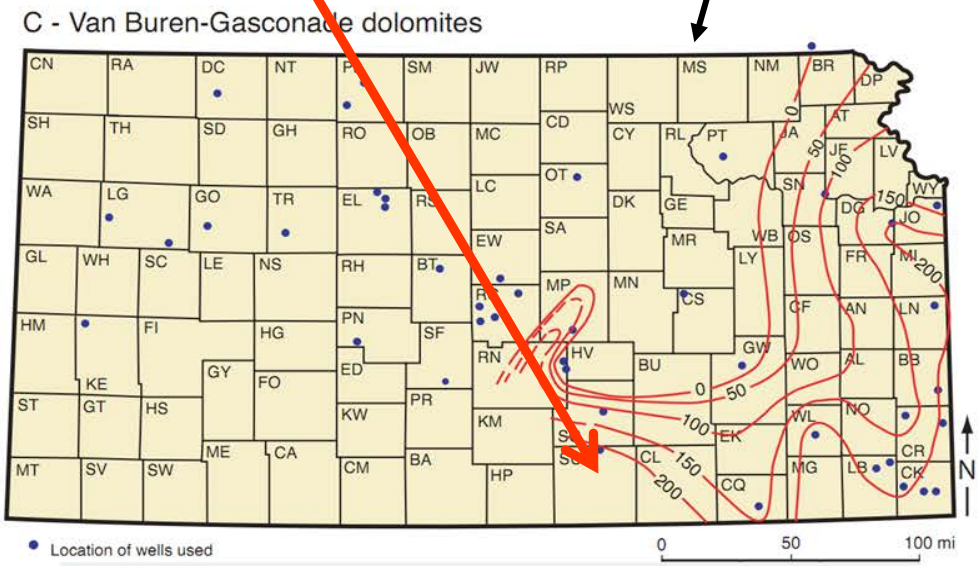
ISOPACH GASCONADE to GUNTER SS



Gerlach et al.

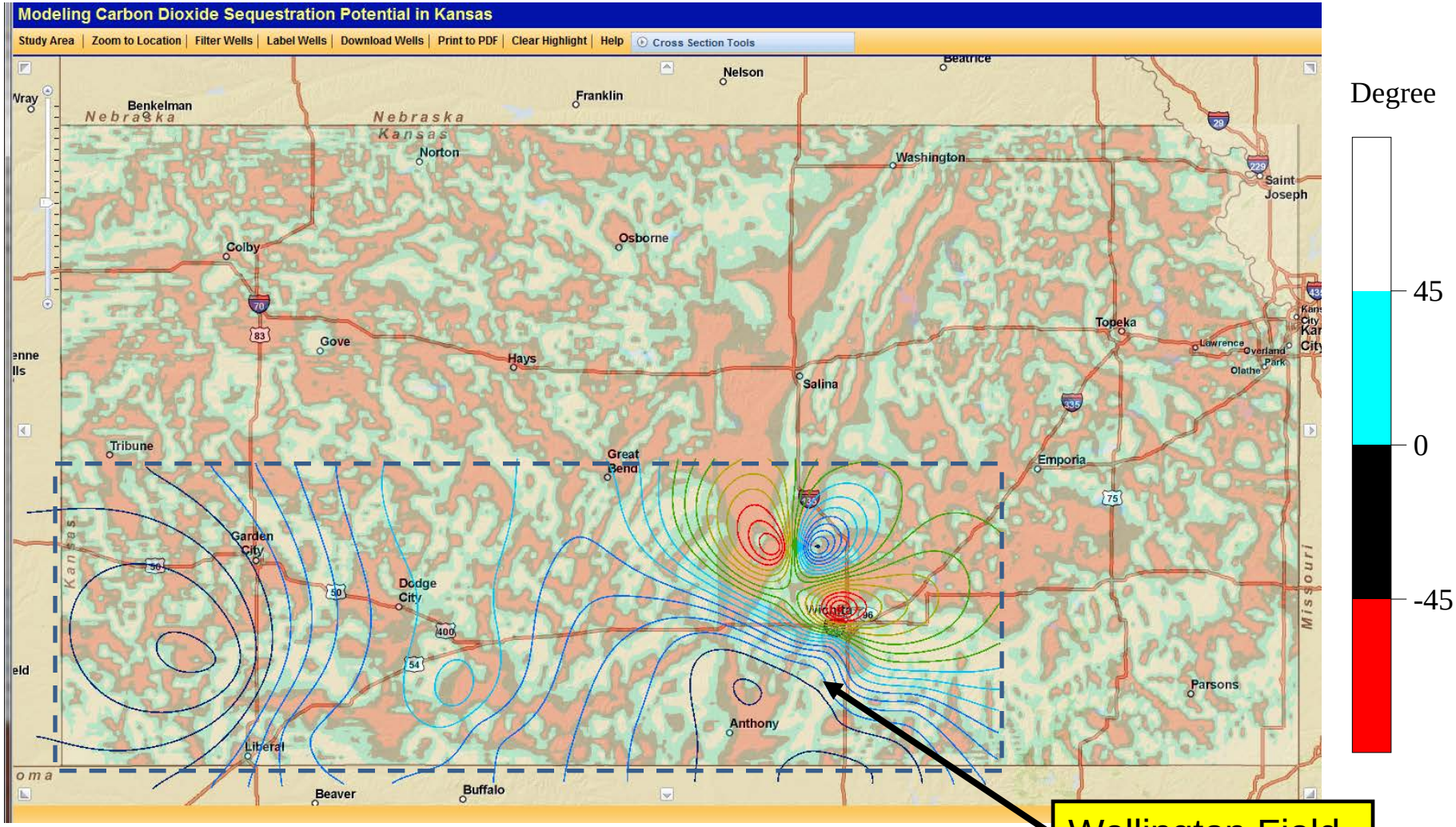


Early Ordovician (approx Gasconade time)
Paleogeography, Chenoweth, 68



Van Buren Gasconade Isopach, Franseen et al., 2004

Tilt angle map of the total magnetic field intensity overlain with isopach Gasconade to Gunter Sandstone interval



Wellington Field

isopach -> Red contour = <u>thin</u>, blue to purple = <u>thick</u>

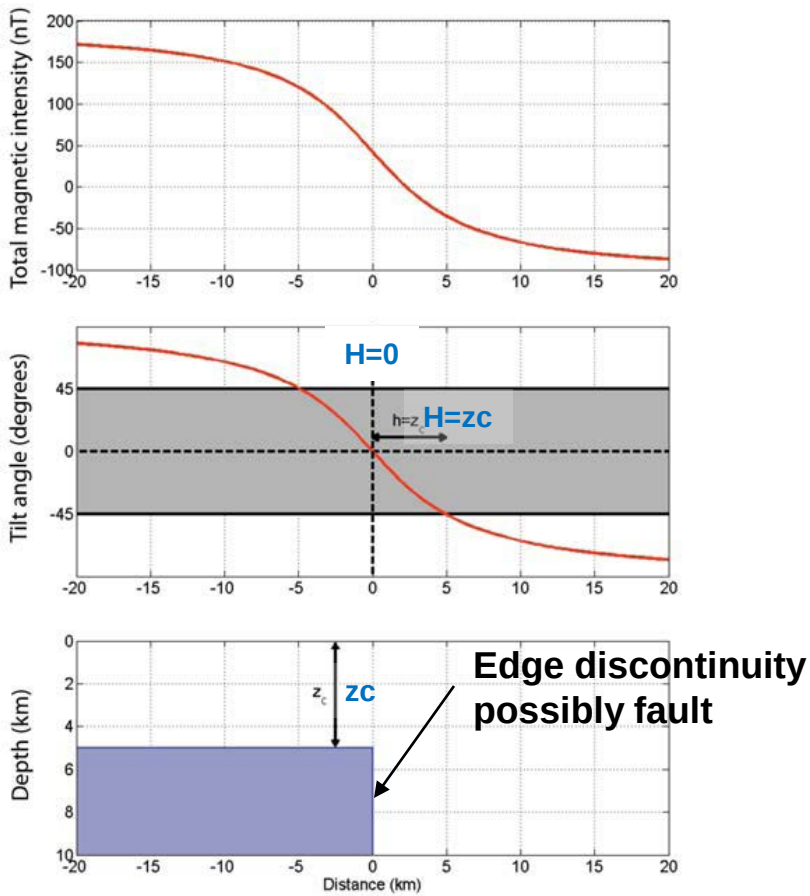
Snapshot from project's interactive mapper -- http://maps.kgs.ku.edu/co2/?pass=project

Illustration of tilt angle computation to locate discontinuities and ~depth to gravity and magnetic anomalies as an aid to identifying possible basement faults

(Xia, 2011)

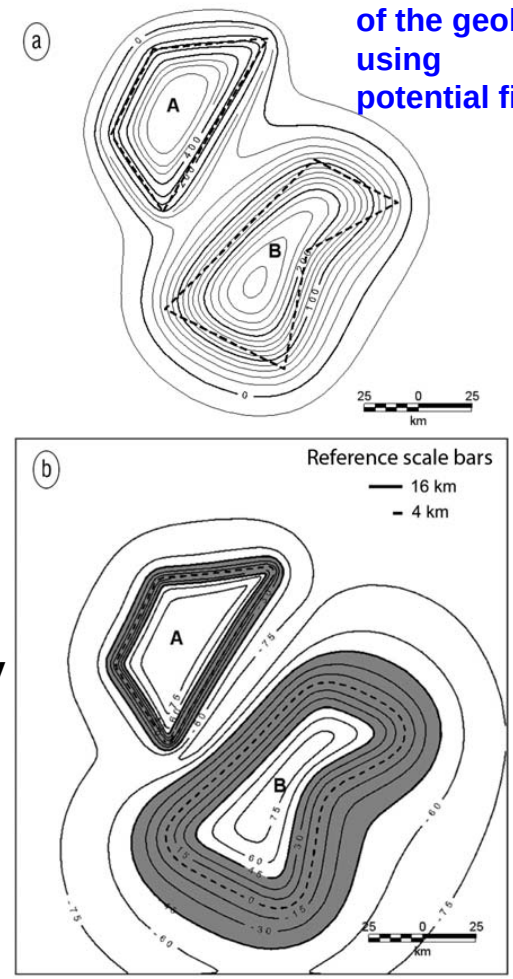
$$\theta = \tan^{-1}\left[\frac{\partial M}{\partial z} \Big/ \frac{\partial M}{\partial h}\right]$$

arctangent of the ratio of the 1st-order vertical derivative by the 1st-order horizontal derivative



Salem et al., 2007

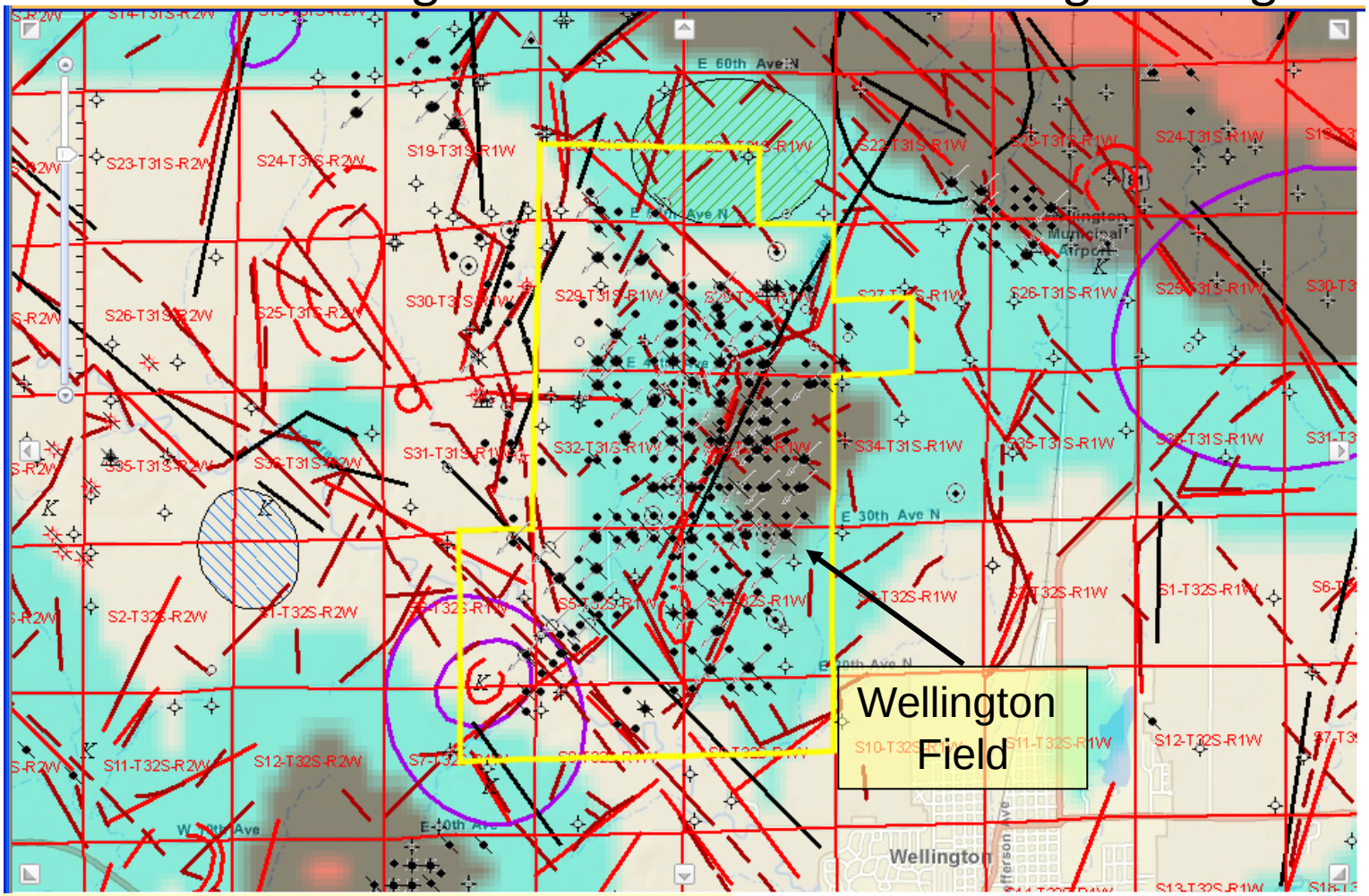
Geobody expression of the geobody using potential fields



Wellington Field Area

Landsat lineaments and gravity tilt angle map

Northeast trending surface lineament bisecting Wellington Field

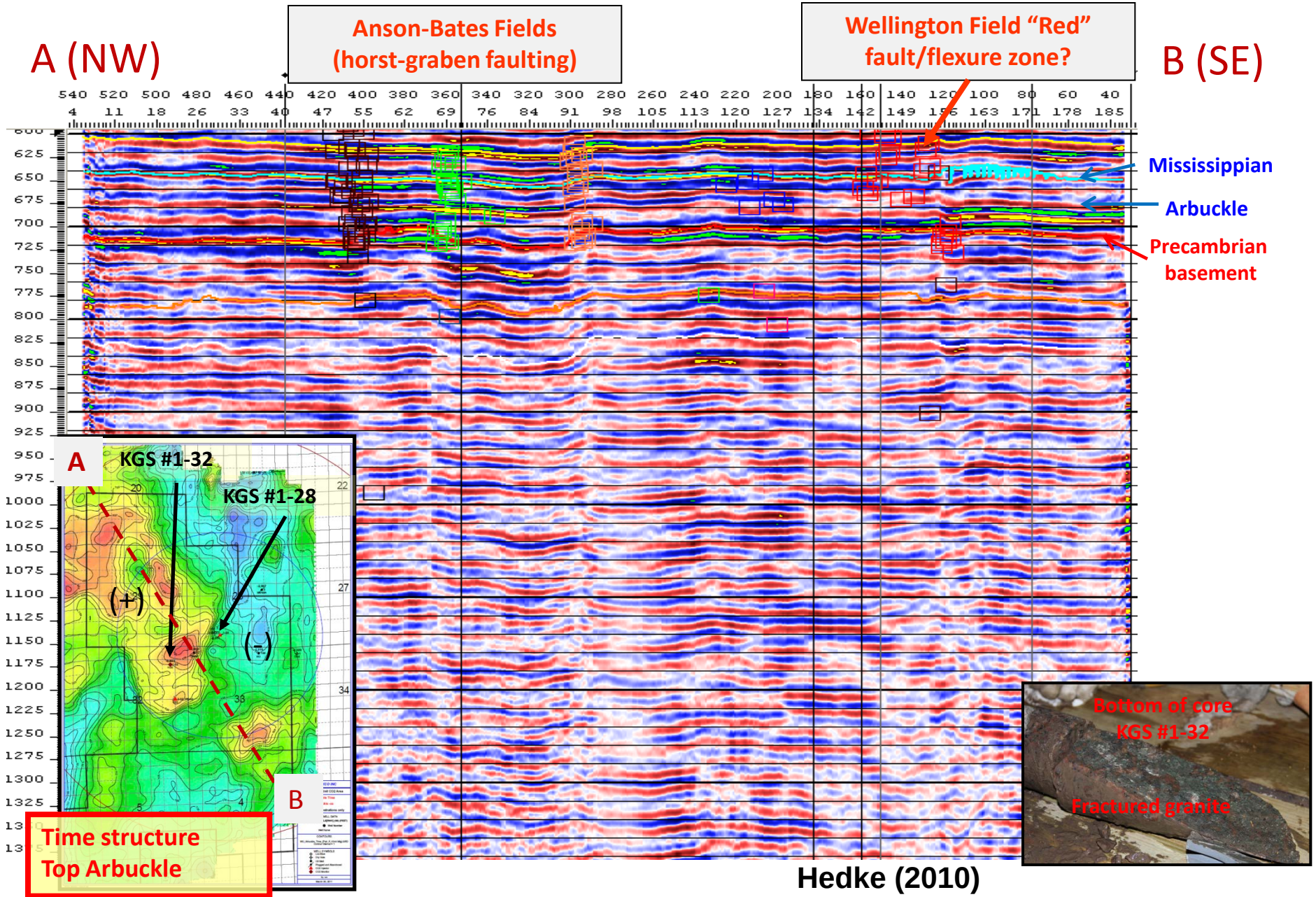


http://maps.kgs.ku.edu/co2/?pass=project

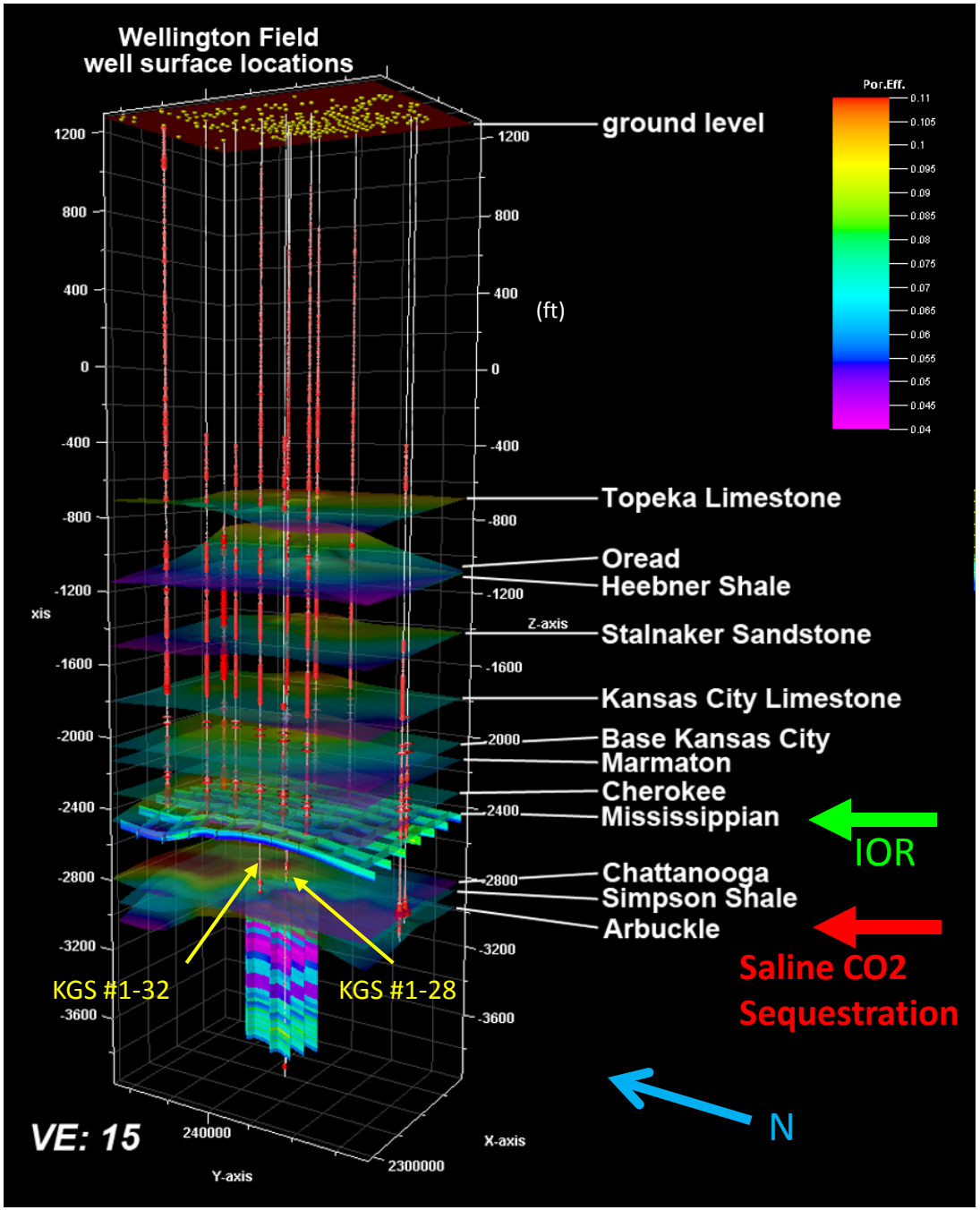
6 miles

Gravity Tilt Angle = arctangent of the ratio of the 1st-order vertical derivative by the 1st-order horizontal derivative of the Bouguer anomaly.

Paleozoic structures closely tied to basement faults deformation as flexure and later faulting (reactivation)



Hedke (2010)



Wellington Field

1) Mississippian tripolitic chert/dolomite reservoir
2) Arbuckle saline aquifer
3) Intervening caprocks

- New core and logs from KGS #1-32 and logs from #1-28 obtained in Jan-Feb. 2011
- Using to assess --
  - Integrity of caprocks
  - Porosity types, injectivity, and storage
  - Model potential for $C0_2$-EOR in Mississippian saline aquifer
  - Sequestration in Arbuckle

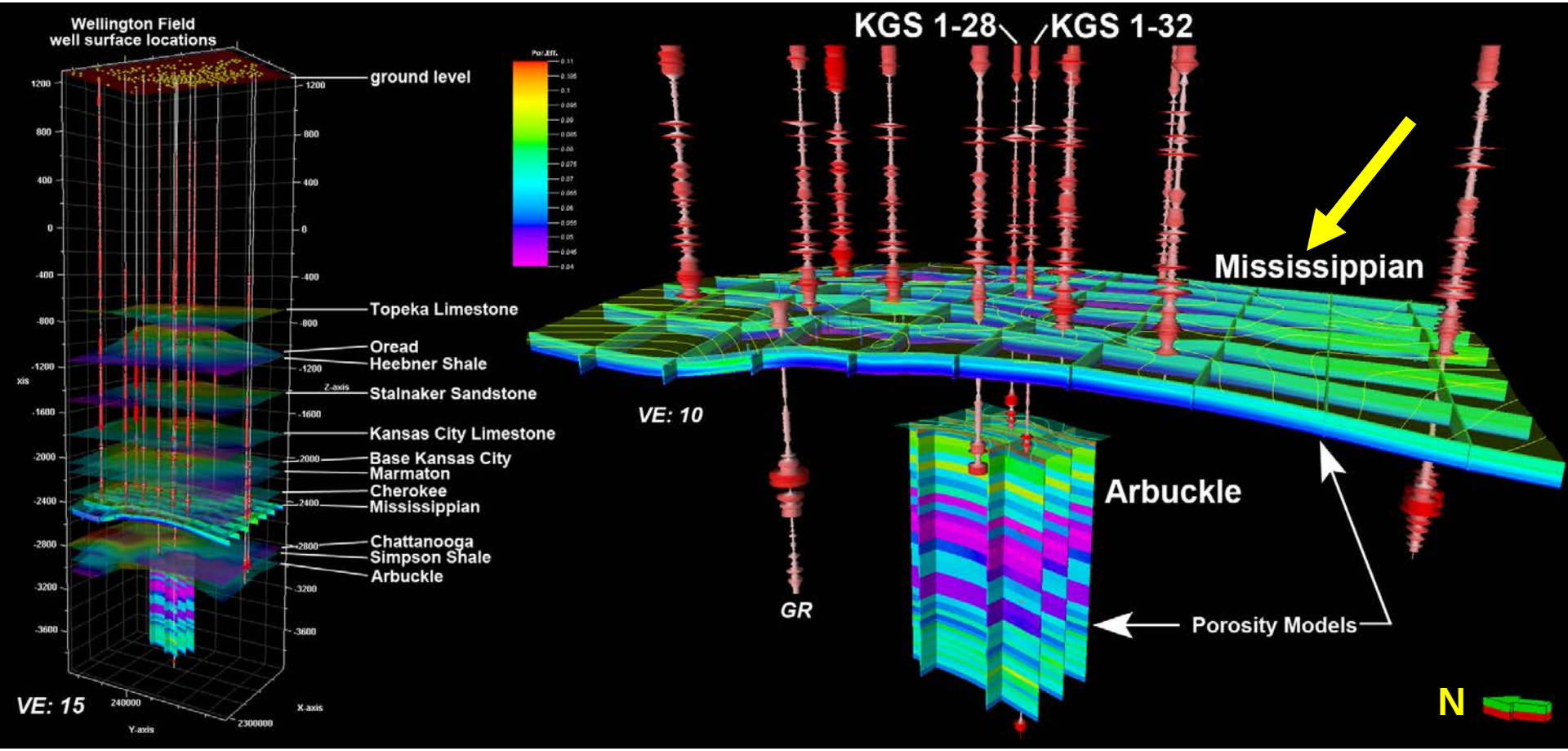
New Small Scale Field Test (70k tonnes CO_2) awarded by DOE 10-1-11

- Surface MVA -- LiDAR/InSAR, shallow groundwater and soil monitoring
- Mississippian reservoir - pressure, geochemistry, strategic 2D seismic
- Arbuckle - *in situ* cross hole tomography, U-tube plume sampling, CASM (continuous seismic imaging), cross hole seismic, repeat 3D seismic

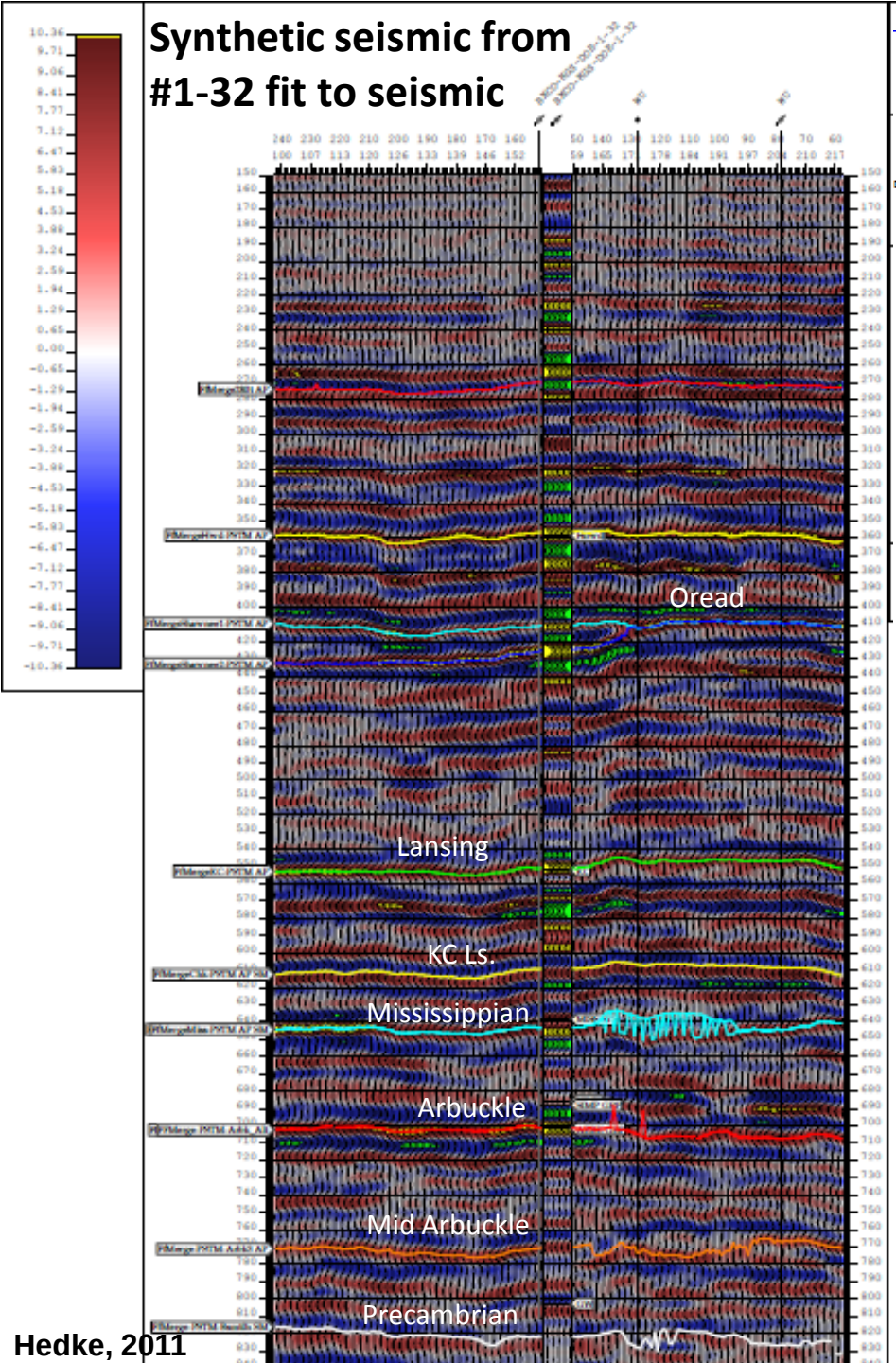
Wellington Field

Porosity Fence Diagram

Mississippian Tripolitic Chert Oil Reservoir & Arbuckle Saline Aquifer

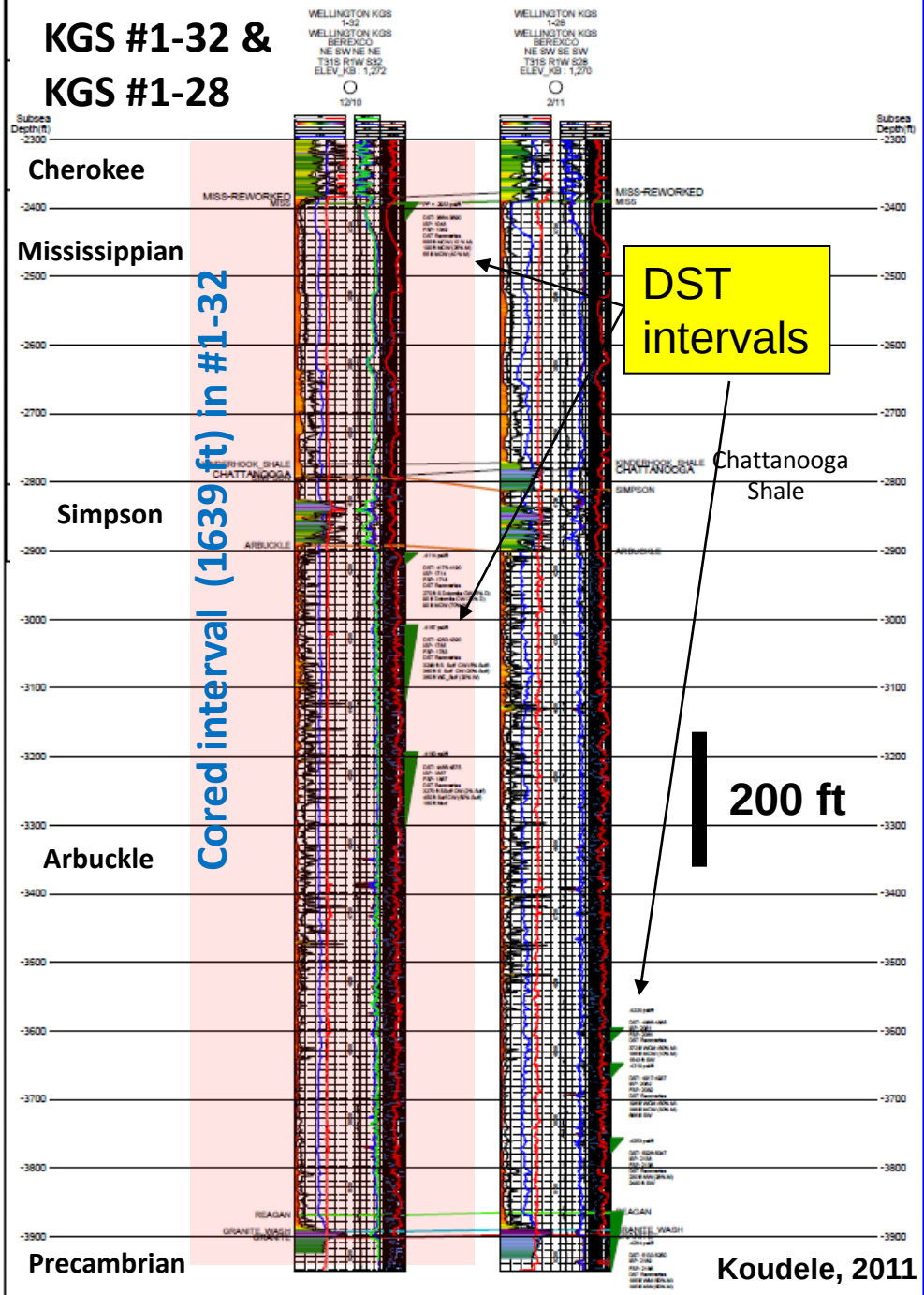


Synthetic seismic from #1-32 fit to seismic



Hedke, 2011

Structure X-section KGS #1-32 & KGS #1-28

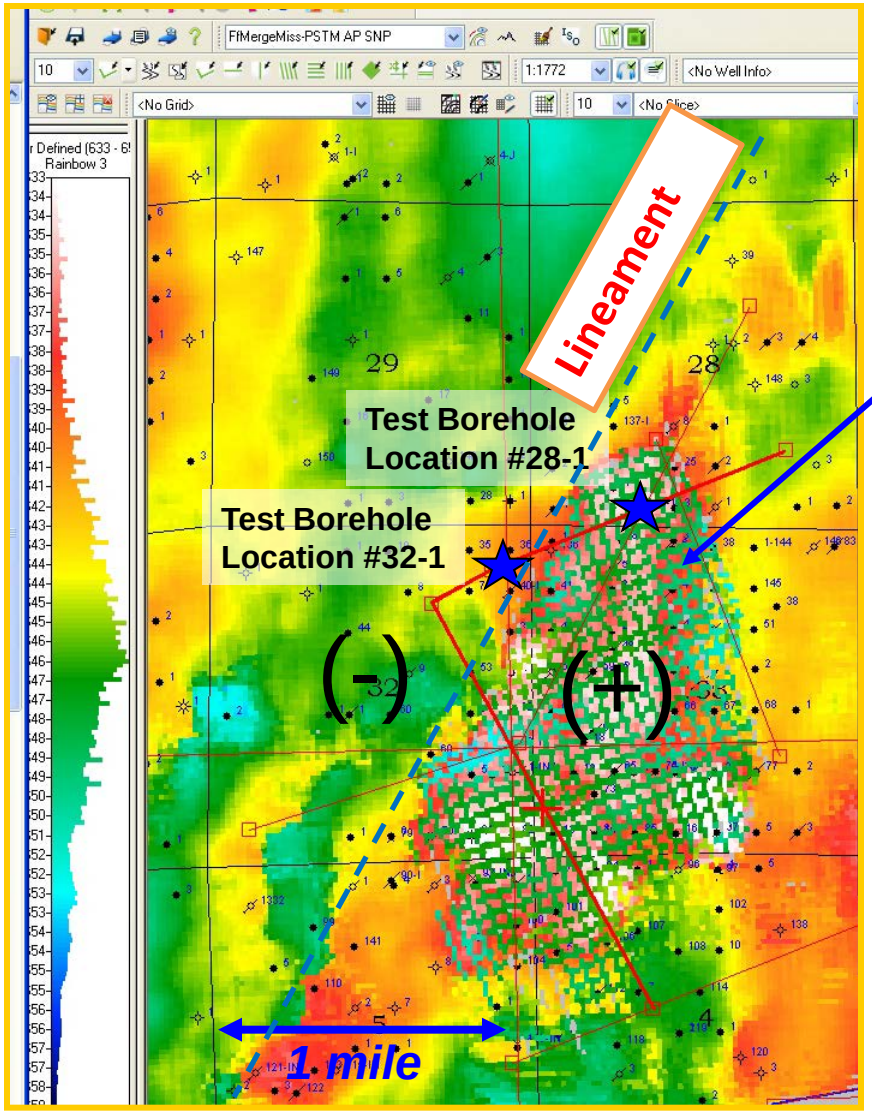


Koudele, 2011

Wellington Field

Initial P-Wave Interpretation of 3D Seismic with Location of Test Boreholes

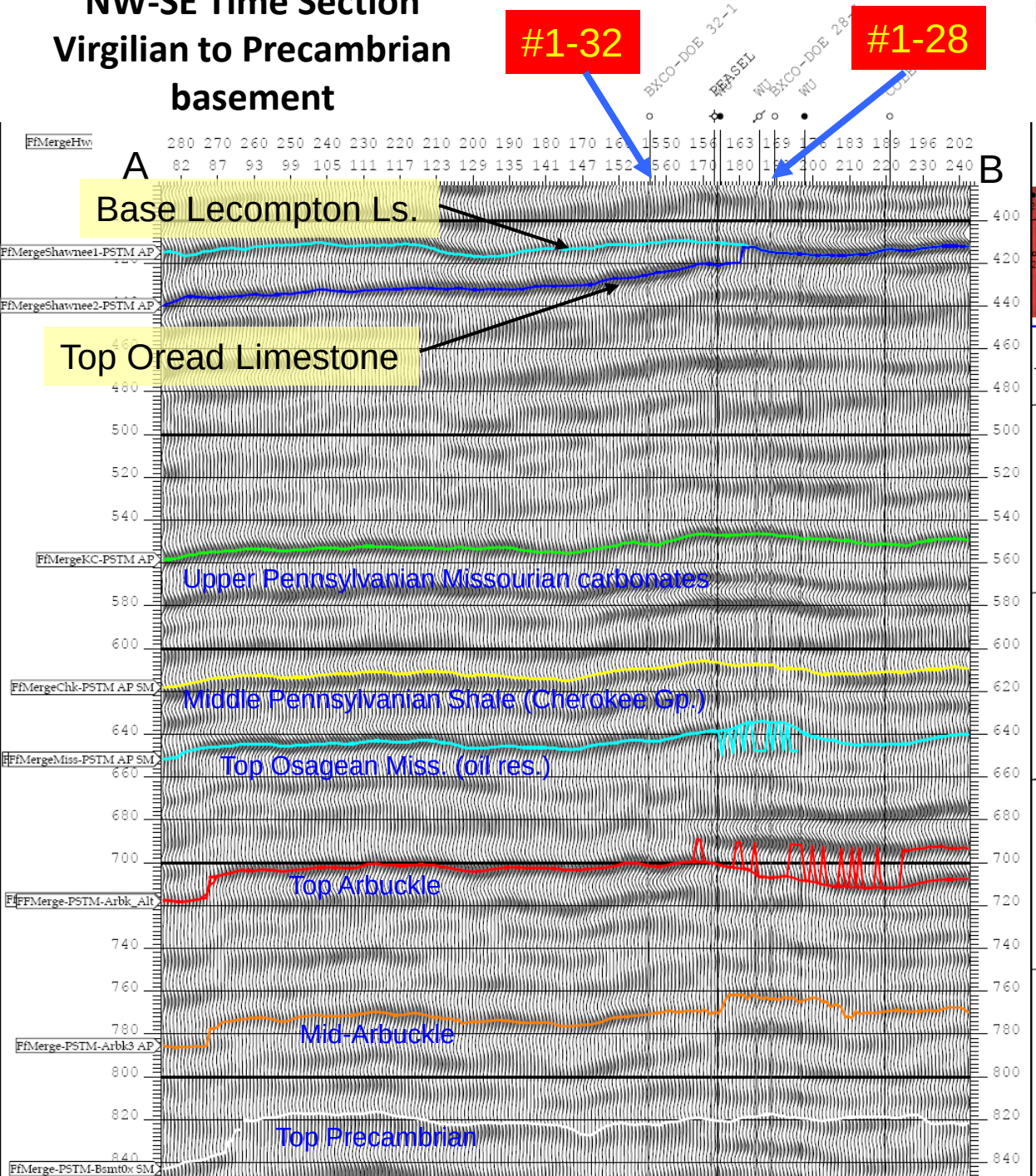
Mississippian time structure



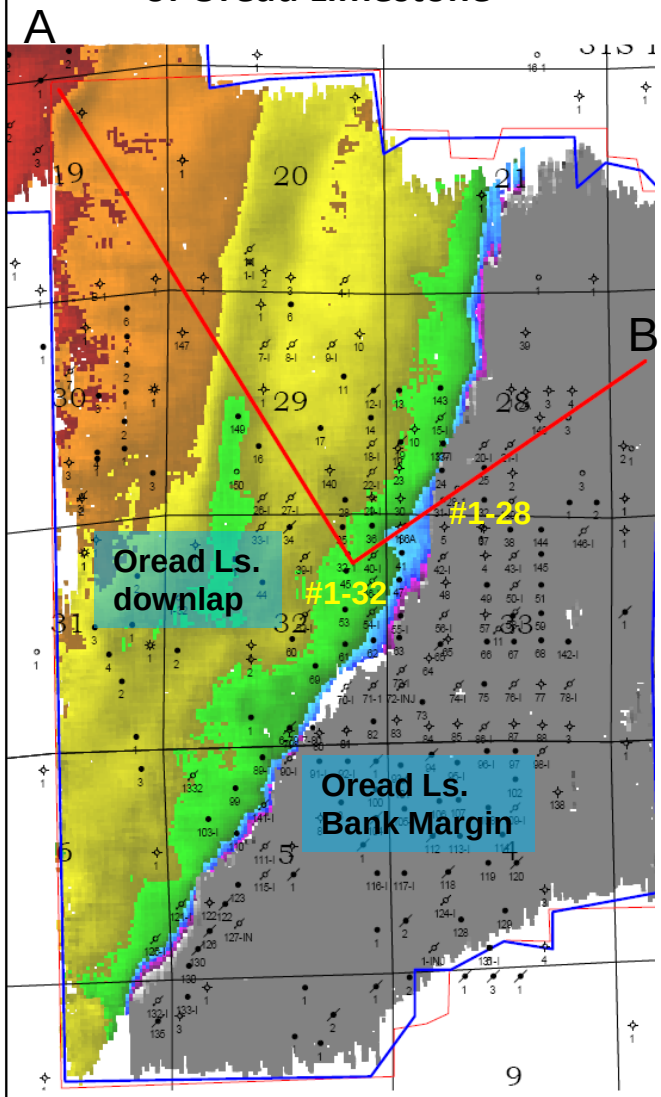
Area of Mississippian dual reflector identifying <u>buildup of uppermost tripolitic chert reservoir (exhumed topography?)</u>

Hedke (2010)

NW-SE Time Section Virgilian to Precambrian basement



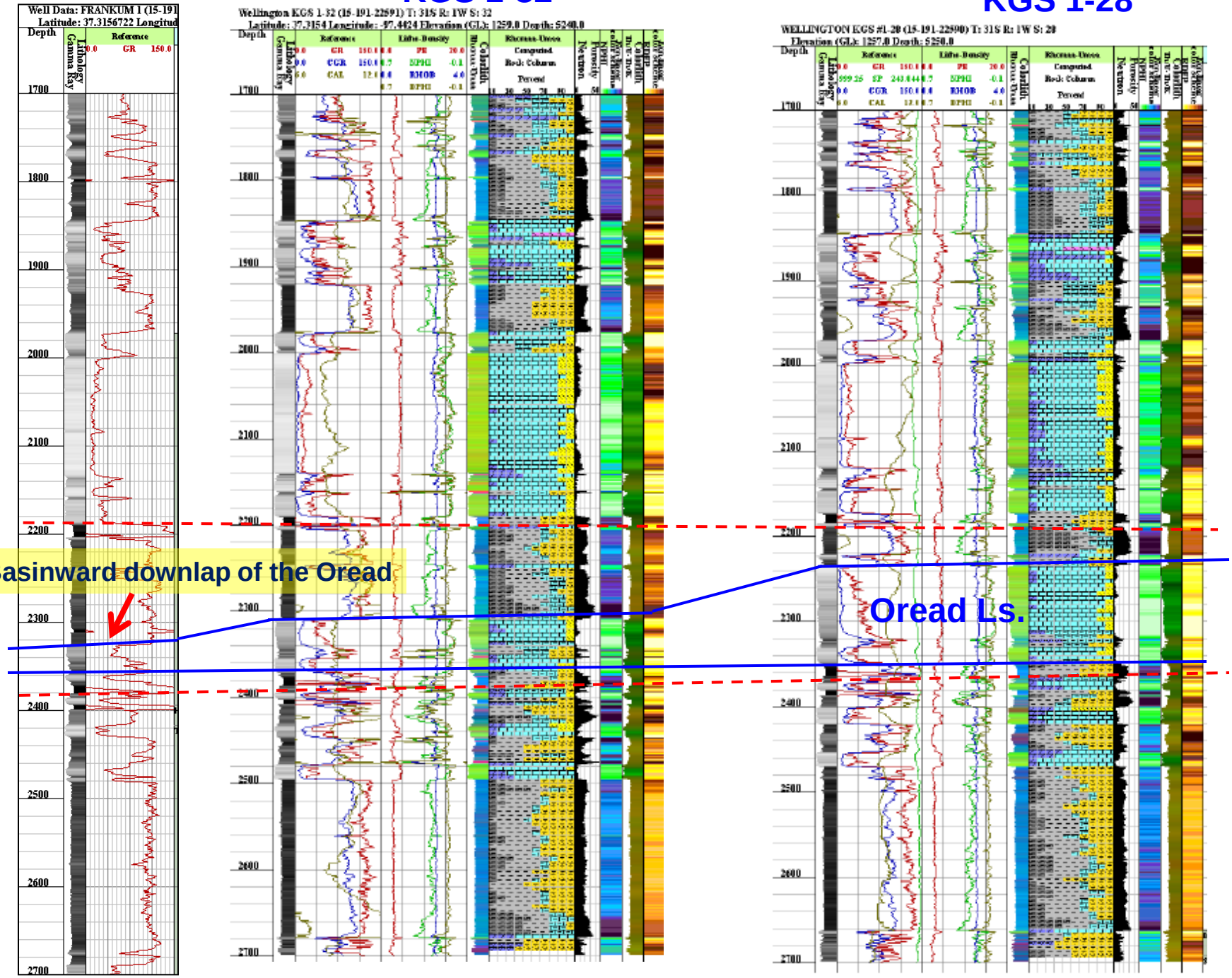
Index map, Isochron between base Lecompton Ls and top Oread ls. delimiting carbonate bank margin of Oread Limestone



Hedke, 2011

KGS 1-32

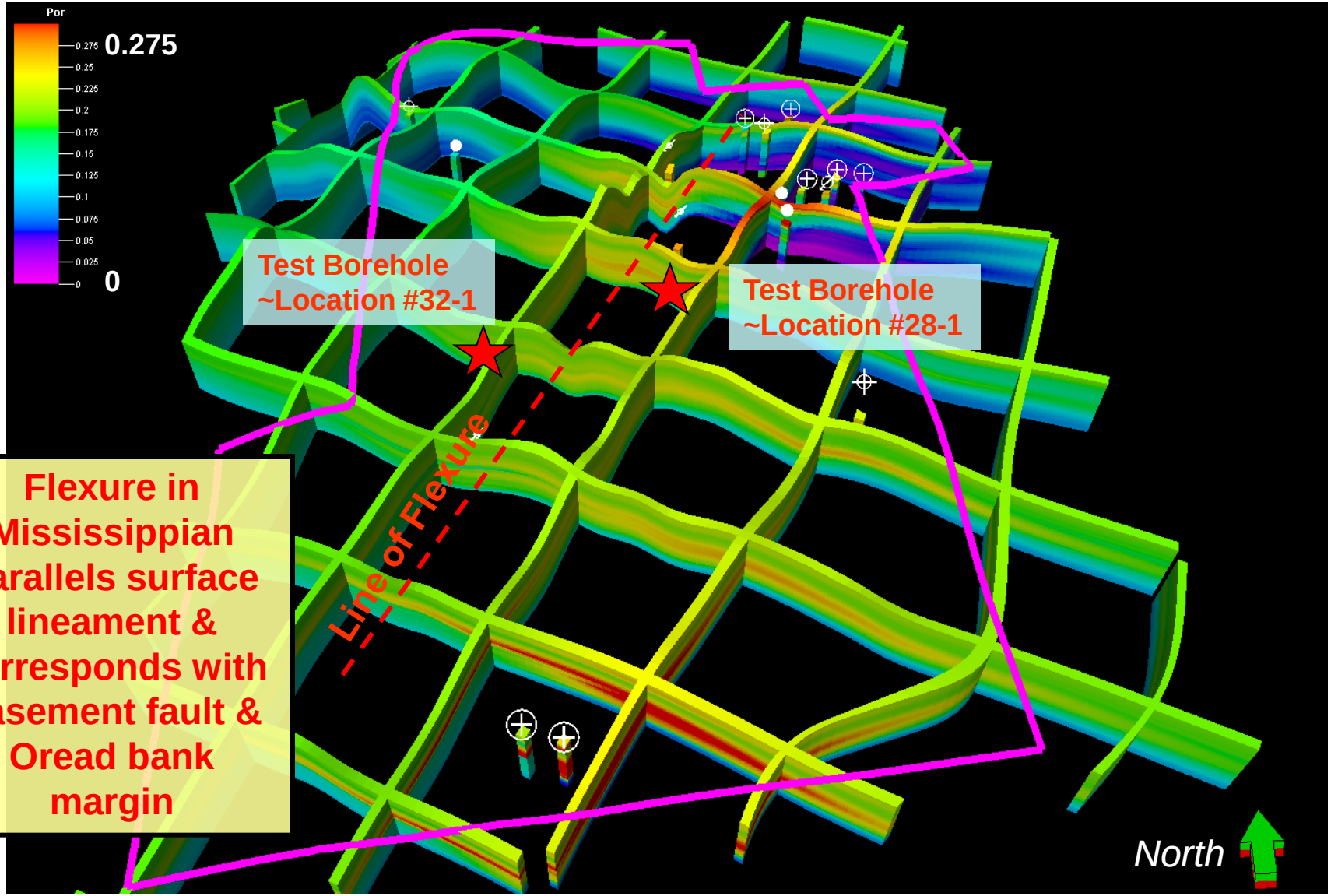
KGS 1-28



Wellington Field

Porosity Fence Diagram

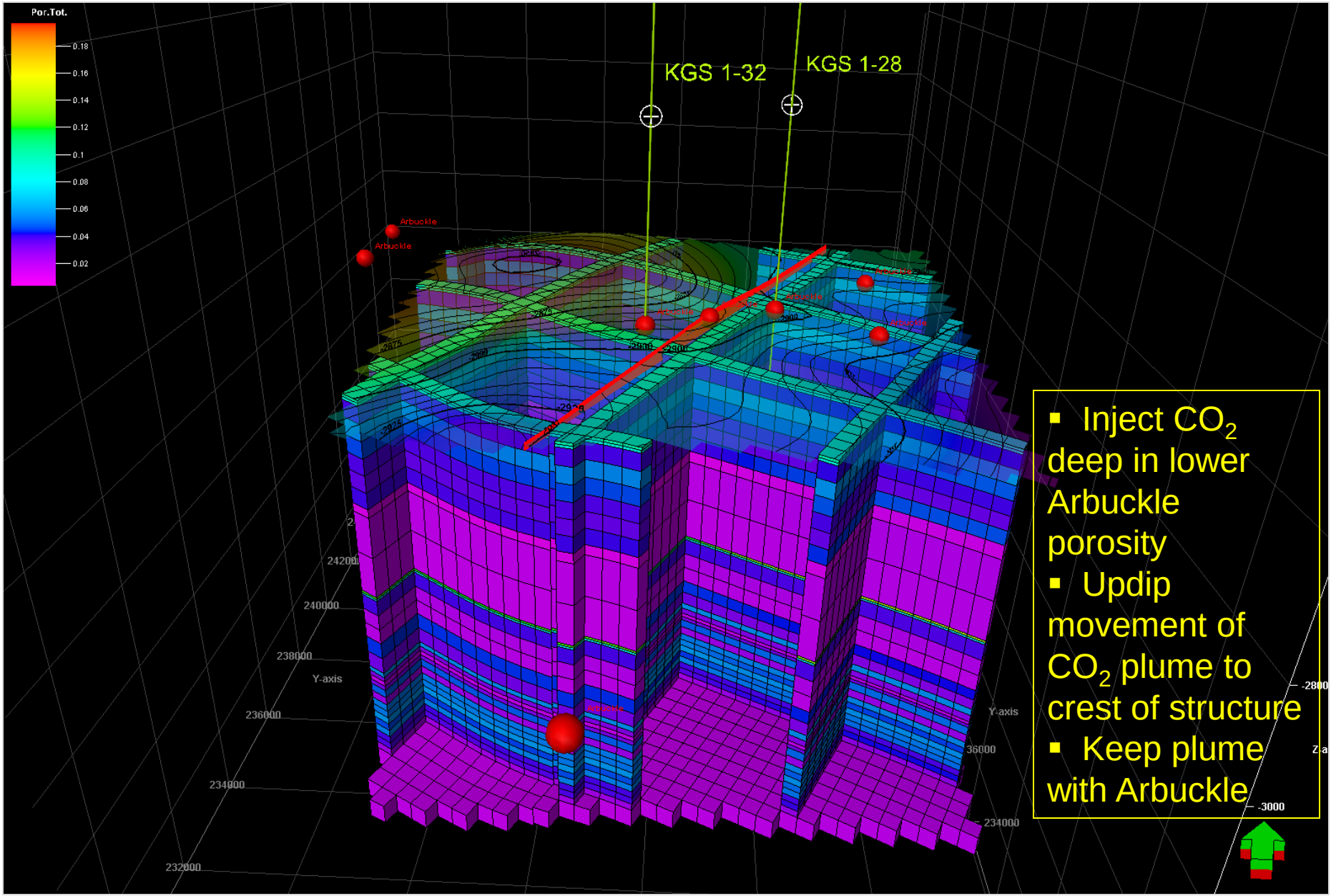
Mississippian Tripolitic Chert Oil Reservoir



Flexure in Mississippian parallels surface lineament & corresponds with basement fault & Oread bank margin

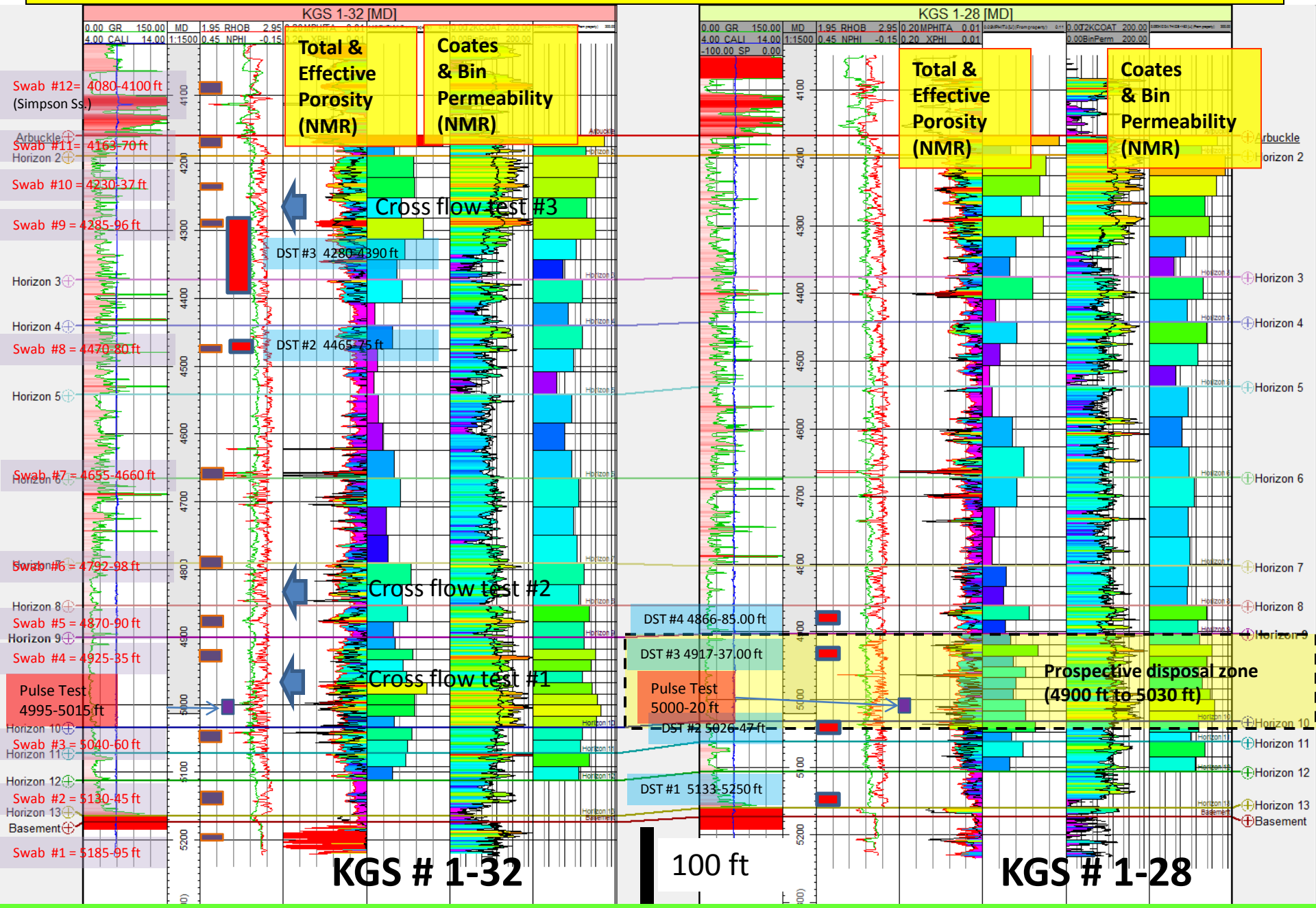
Initial geomodel of Arbuckle (porosity & structure)

Cored well (#1-32) & (#1-28), latter to be used to as CO_2 injector



- Inject CO_2 deep in lower Arbuckle porosity
- Updip movement of CO_2 plume to crest of structure
- Keep plume with Arbuckle

Step rate test and preliminary perforate & swab intervals in Arbuckle and Simpson Groups



Cross section (east to west) between KGS #1-28 and #1-32 in Wellington Field and upscaled hydrostratigraphic units in Arbuckle Group

ZONAL FRACTURES AND AUTOCLASTIC BRECCIAS IN THE POROUS INTERVALS OF THE ARBUCKLE

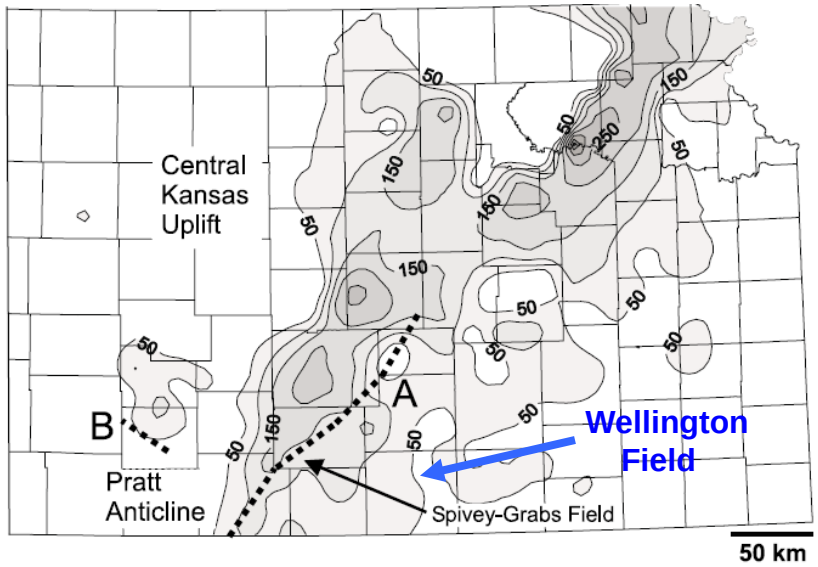
4593 ft

4556.2 ftt

4609 ft.

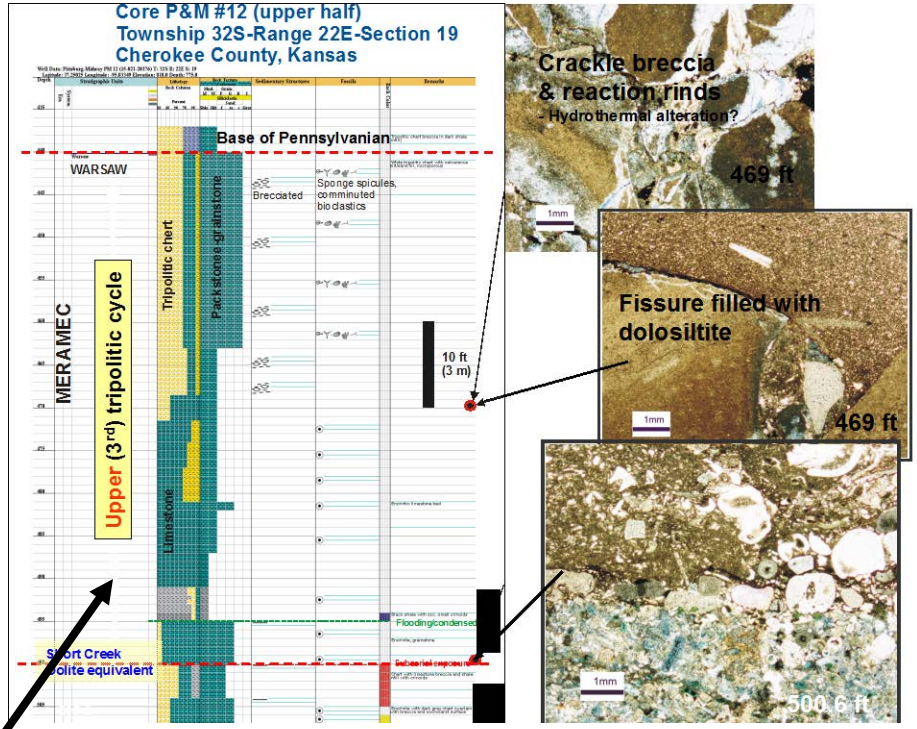
Mississippian

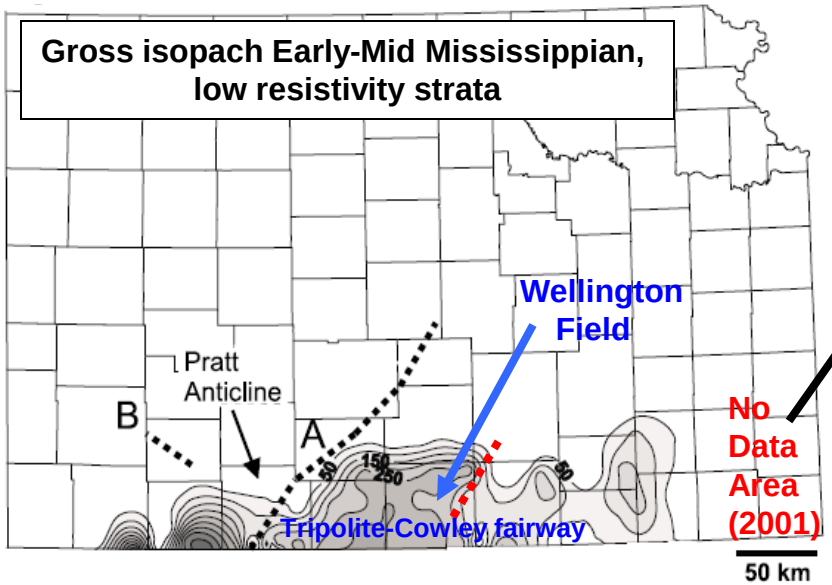
Gros Isopach Late Devonian- Early Mississippian Chattanooga Shale & Kinderhook Shale

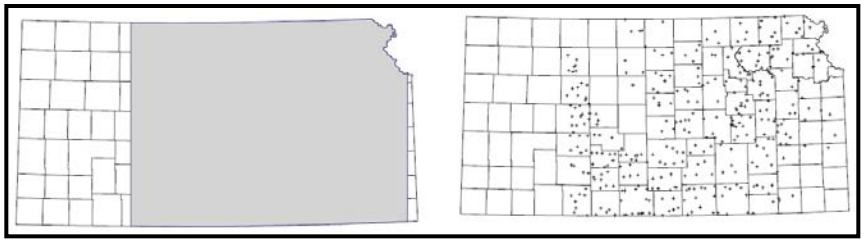


Watney, Guy, Byrnes (2001)

- **Late Devonian to Early Mississippian, NW-trending sag basin overlying Midcontinent Rift System**
- **During late Kinderhookian - abrupt change to shelf margin in southern Kansas, bordering early Anadarko and Arkoma basins**
- **Tripolitic chert cycles developed along shelf margin**

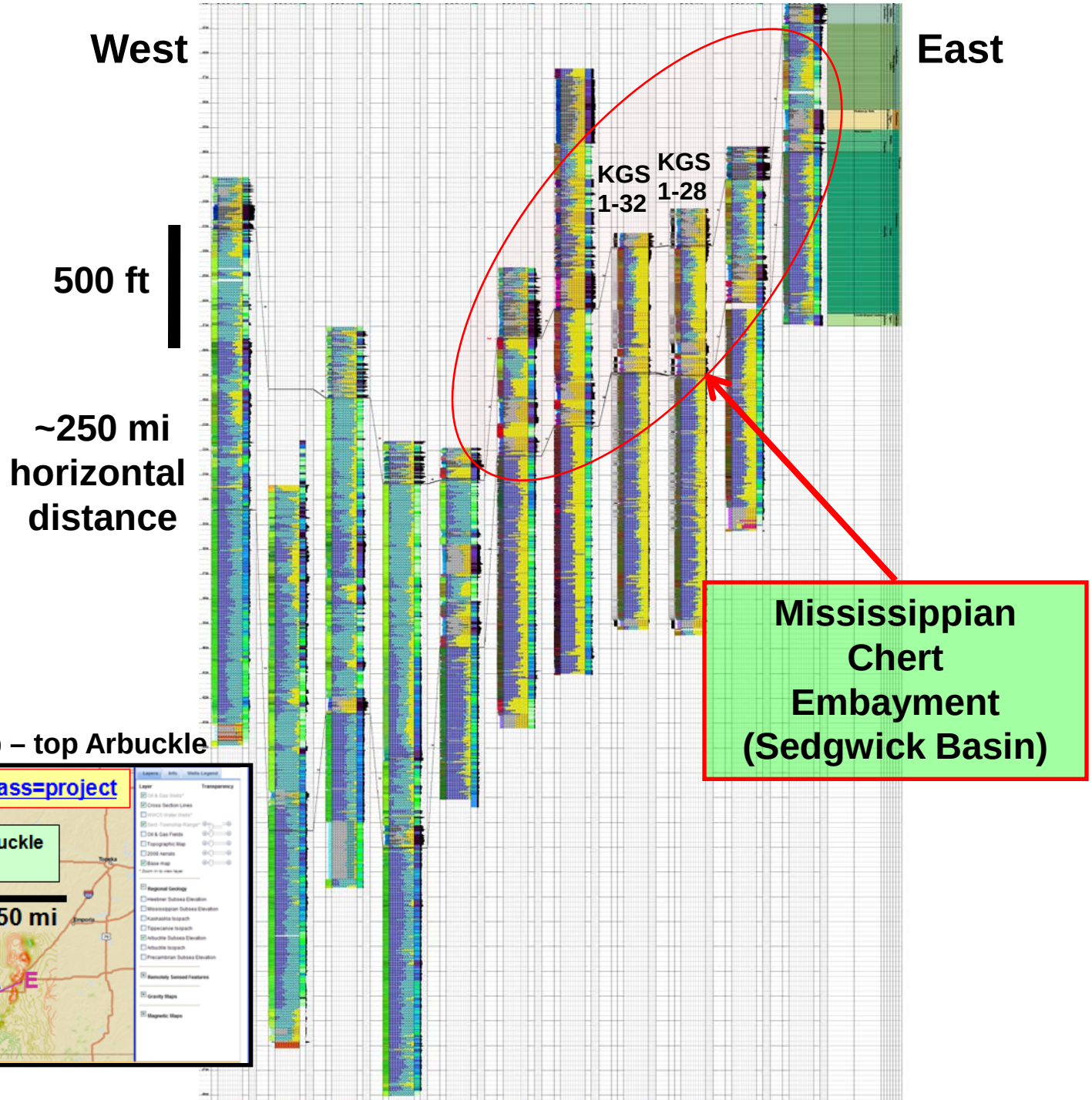




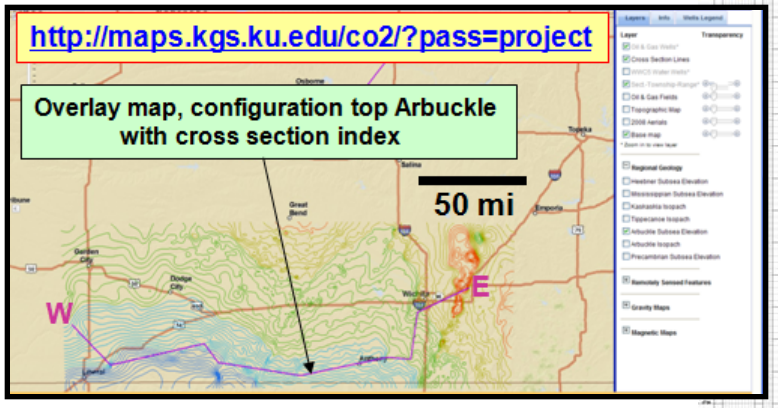


West-to-East Structural Cross Section with Log Derived Lithology

Delineate Mississippian Chert Embayment



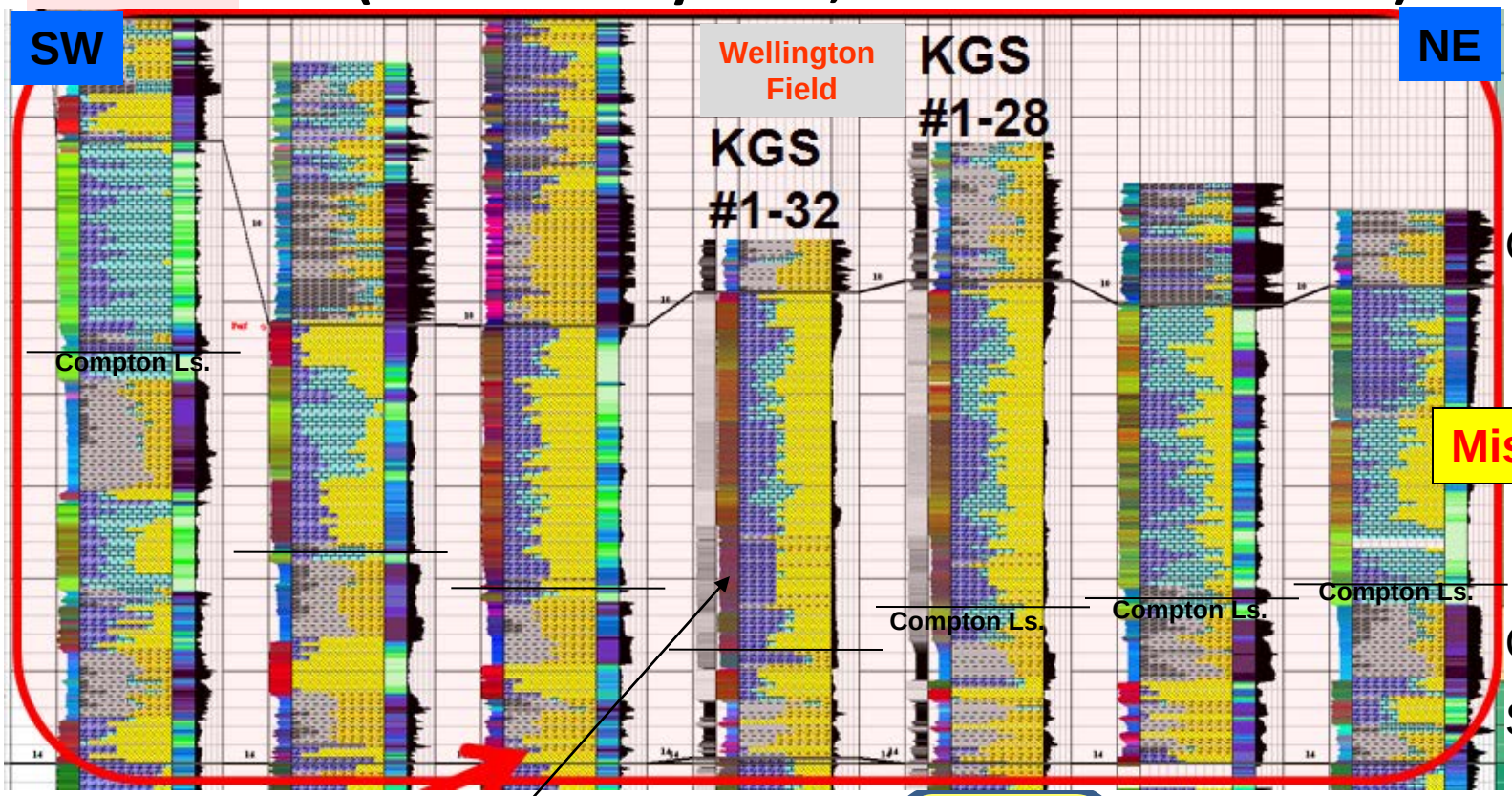
Cross section index map – top Arbuckle



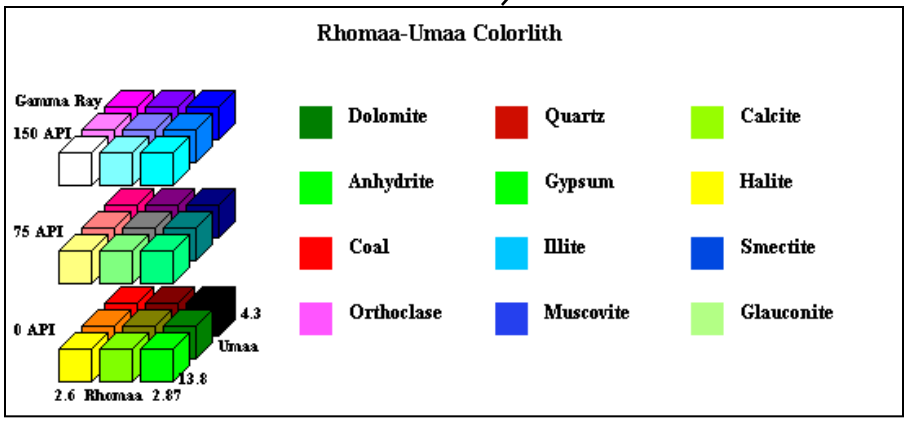
Lithologies Within the Mississippian Oil Play (Chert Embayment, South Central Kansas)

West side
Hartner Field
Barber Co.

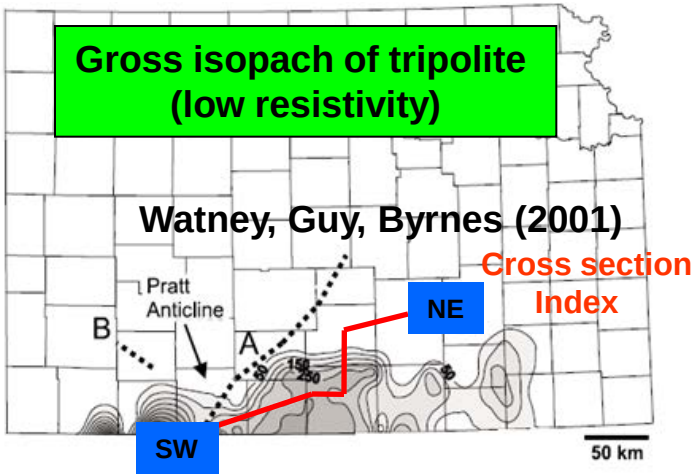
DOE-FE0002056



Datum: Top Arbuckle Group

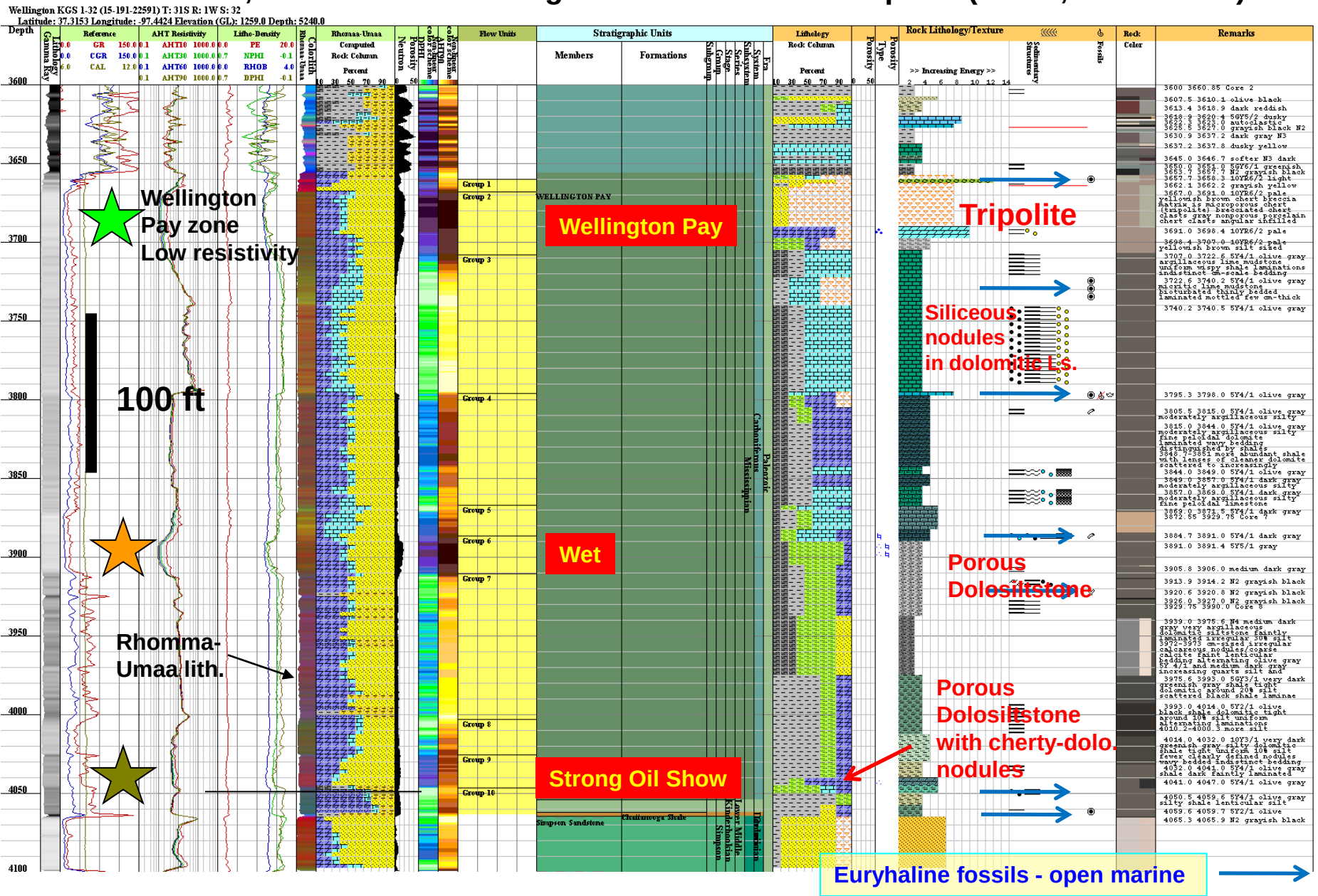


500 ft

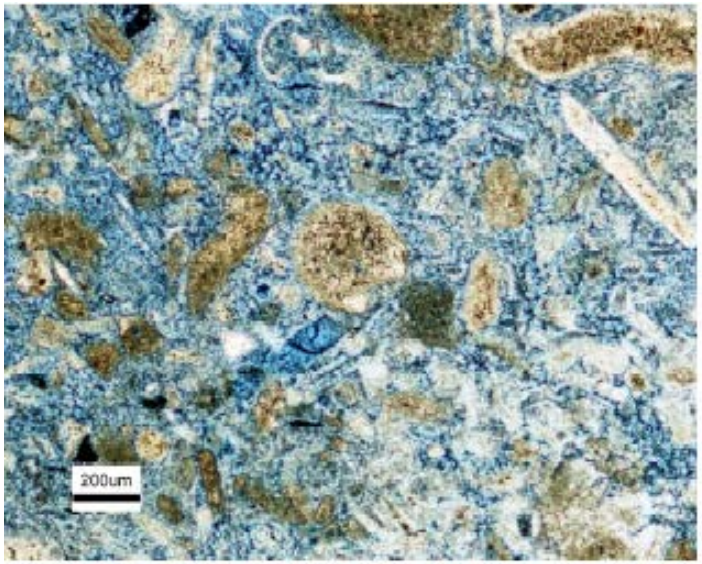


Mississippian (Osage-Kinderhook)

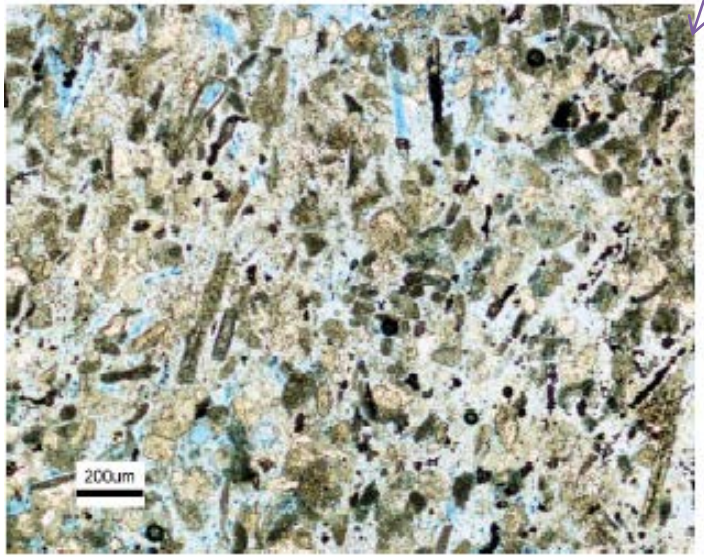
Cored Well, KGS #1-32 – Well log and initial core description (uncut, whole core)



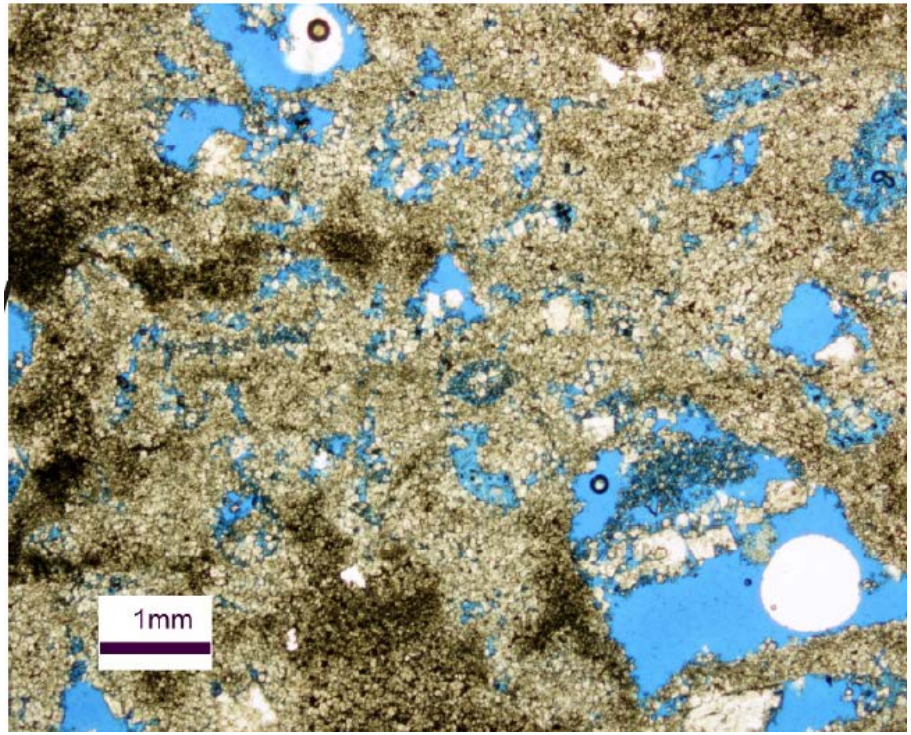
Reservoir-Quality Mississippian Lithologies
Osagean Tripolitic Chert and Dolosiltite
(P&M #12, Cherokee County, KS)



Photos of thin section/slice of reservoir quality rock showing blue epoxy-filled pores in tripolitic chert



Thin section - blue-epoxy filled pores in porous dolosiltite



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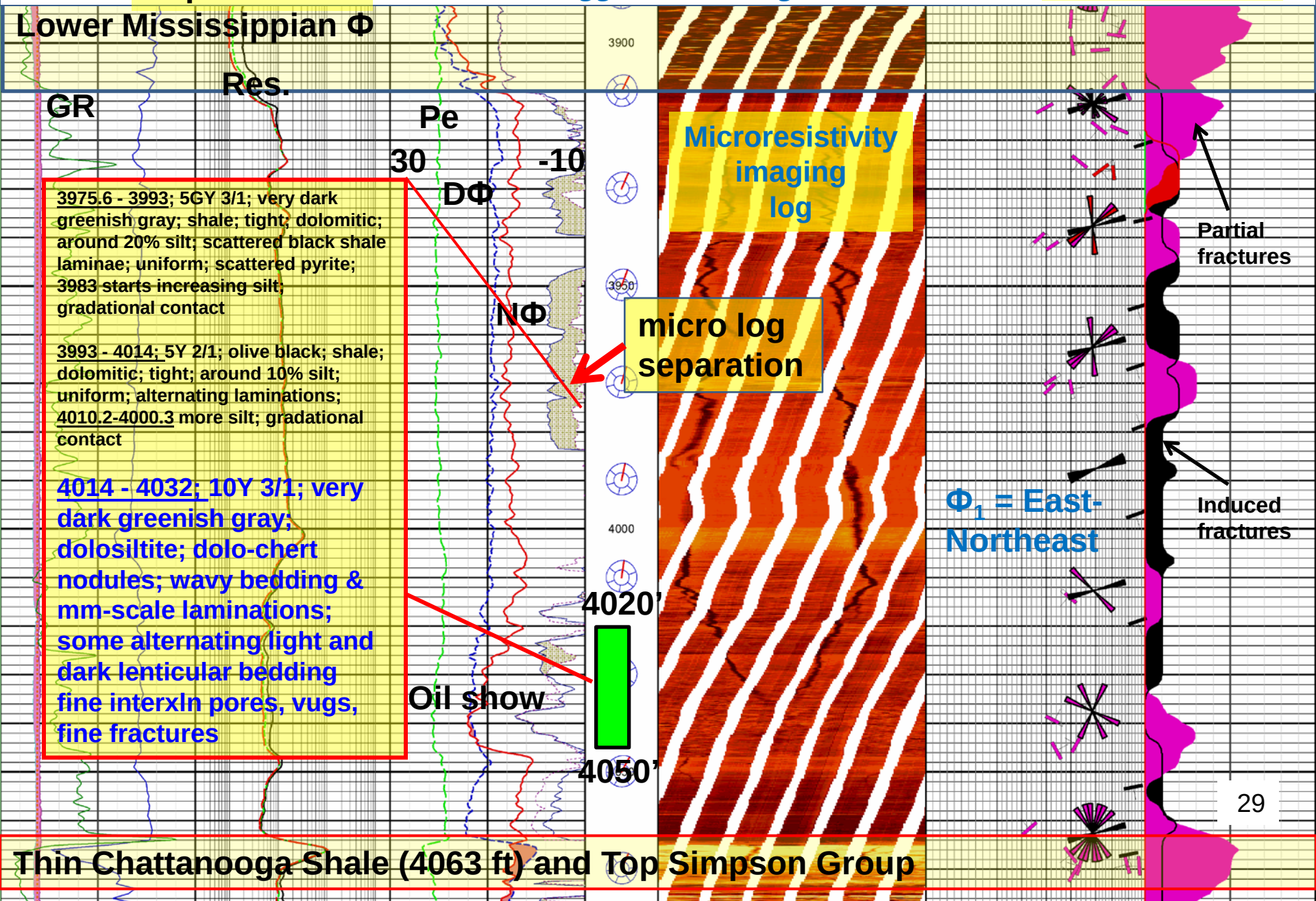
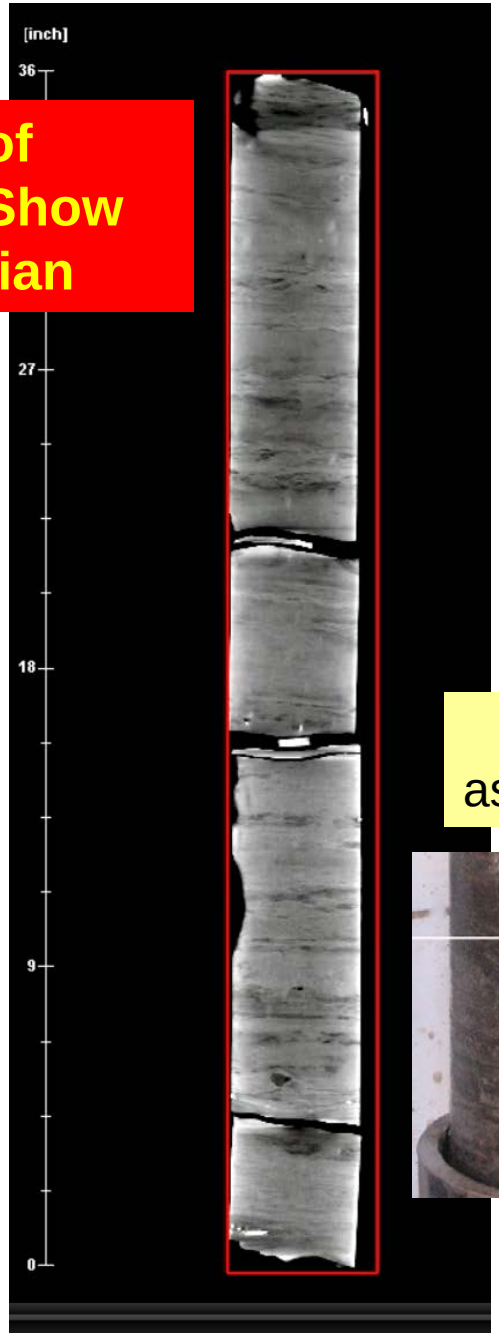
Lowermost Mississippian (Compton Ls.) Porosity/Oi Show Zone

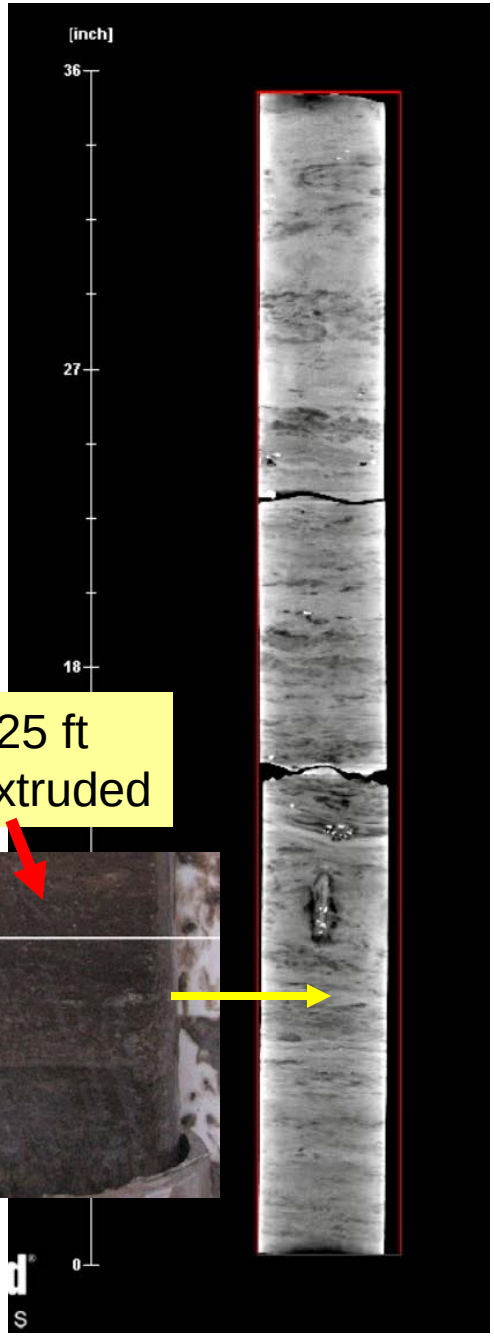


CT Scans of Lower Oil Show Mississippian

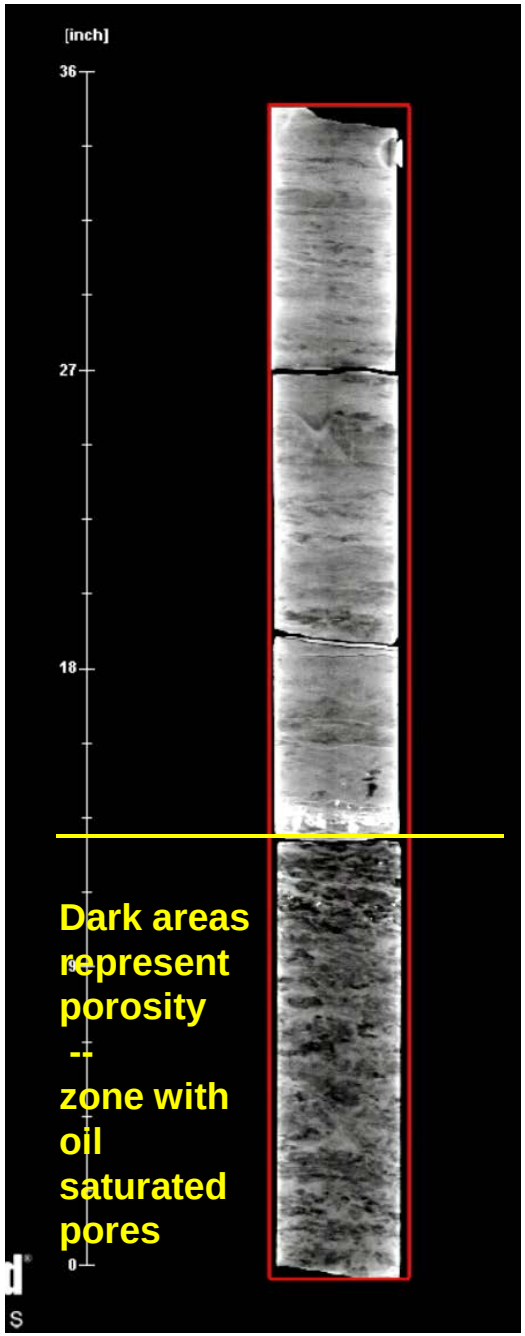
4020-4022.9 ft



4022.9-4025.85



4025.85-4028.8



4025 ft
as extruded

Dark areas represent porosity -- zone with oil saturated pores

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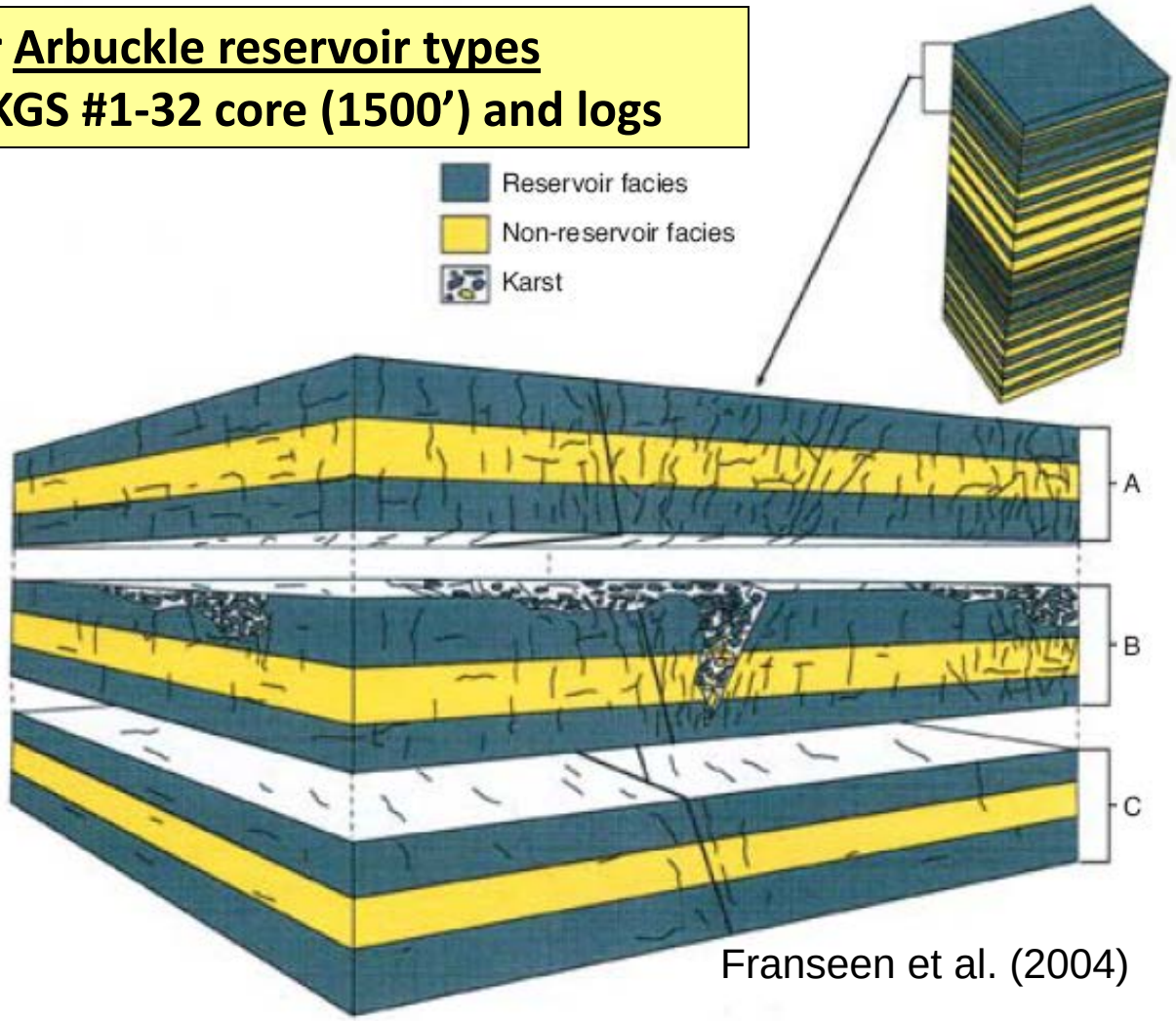
Prognosis -- Arbuckle appears to be a candidate for CO_2 saline aquifer sequestration

End-member Arbuckle reservoir types observed in KGS #1-32 core (1500') and logs



Franseen et al. (2004)

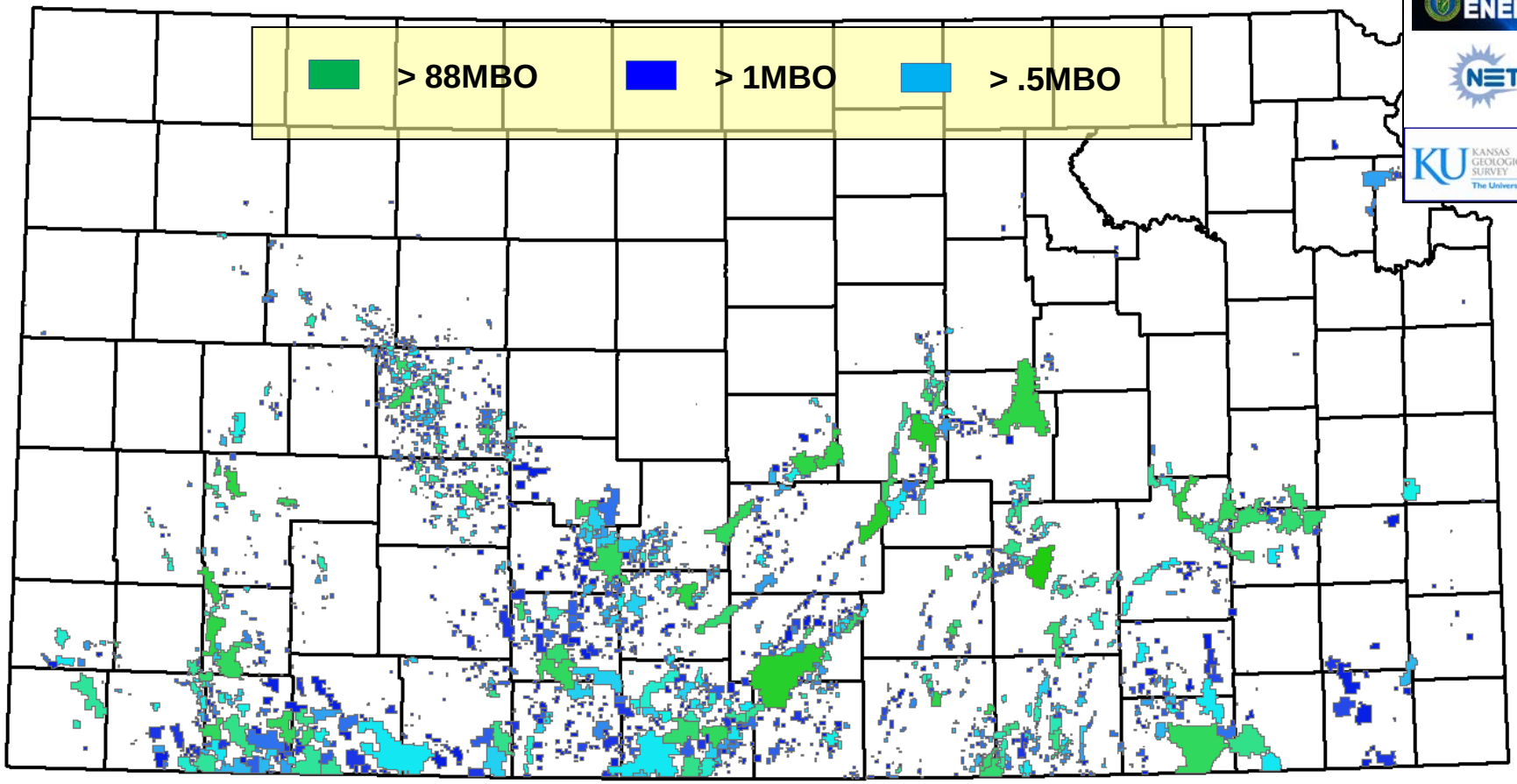
Discontinuous fracturing, karst overprinting, lithofacies control porosity & permeability in persistent stratal packages

Wellington Field and Regional Mapping

- *Mississippian tripolite reservoir is likely an excellent candidate for CO_2-EOR*
- *Succession of distinct, mappable porous stratigraphic packages below main tripolite reservoir*
- *Promising deep saline Arbuckle aquifer as an asset for anthropogenic CO2 sequestration*
- *Analogous Miss fields in southern Kansas with underlying thick Arbuckle*

Mississippian Oil and Gas Fields in Kansas

DOE-FE0002056



Gerlach, Sept. 2011

Acknowledgements & Disclaimer

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Paleozoic structures closely tied to basement faults deformation as faulting at depth and flexure above (reactivation)