### Preliminary High-Resolution Stratigraphic Analysis of the Caney and Woodford Shales in a Continuous Shallow Corehole (KGS-OGS Current #1) from the Lawrence Uplift in Pontotoc County, Oklahoma

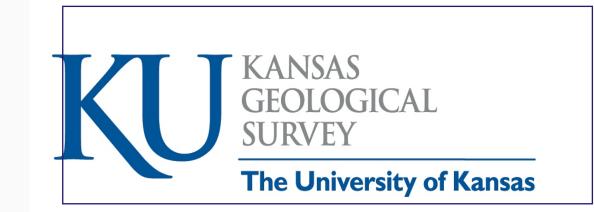
by W. Lynn WATNEY<sup>1</sup>, Darwin R. BOARDMAN<sup>2</sup>, Neil H. SUNESON<sup>3</sup>, Jim PUCKETTE<sup>2</sup>, Thomas L. THOMPSON⁴, John H. DOVETON¹, Evan K. FRANSEEN¹,¹a, John R. VICTORINE¹, Kenneth STALDER<sup>1</sup>, and Robert WALTON<sup>5</sup>

<sup>1</sup>Kansas Geological Survey, Lawrence, KS; <sup>1a</sup>University of Kansas, Lawrence

- <sup>2</sup>Oklahoma State University, Stillwater, OK; <sup>3</sup>Oklahoma Geological Survey, Norman, OK
- <sup>4</sup>Emeritus, Division of Geology and Land Survey, Missouri Department of Natural Resources, Rolla, MO
- <sup>5</sup>Cicaco, Camarillo, CA









#### KGS Open File #2009-5

Acknowledgement

Bob Walton of Cicaco, a company operating in the Ardmore Basin, Oklahoma is acknowledged for support of the KSG-OGS Current #1 corehole acquired in Pontotoc County, Oklahoma.

#### **Statement of Problem**

- Need for a basic scientific framework to augment resource appraisal of gas shales in order to place deposits in a global temporal and process framework. OProvide means to leverage successes to other shales in other basins.
- No global high-resolution stratigraphic or biostratigraphic model exists for the Upper Devonian to Lower Pennsylvanian succession.
- Complex mm- to dm- scale beds and bed sets of basinal, shale-dominated lithofacies have been variably related to global and regional processes, but their correlation is ill-defined.
- Strategic, continuous reference sections that are resolved stratigraphically, biostratigraphically, and geochemically in three dimensions are needed in Midcontinent basins to establish the systematics of temporal variations in lithofacies from basin to shelf. This is critical to establishing a sequence stratigraphic framework.
- Regional reference section must be tied to global stratotypes through chronostratigraphic methods to develop a robust, process-based understanding of strata and to allow results to be widely applicable to equivalent strata in other basins.
- The paleogeography for the Upper Devonian-Lower Pennsylvanian that defines the shelf- tobasin transitions surrounding the Arkoma Basin is highly generalized. Vastly improved resolution as needed to better assess resources and reconstruct the foreland basin framework and basement structures that have actively influenced sedimentation and paleooceanographic conditions.
- Shelf-to-basin detrital and biogenic silica distribution is poorly understood; refined spatial and temporal distribution is needed for these deposits that include the "Chat" or tripolite (microporous spiculitic-skeletal packstone-grainstone) deposits that accumulated along the shelf margin, and the gradation from non-siliceous to siliceous Woodford and the Arkansas Novaculite.
- In general, rock properties need to be placed in this spatial-temporal framework in order to optimize exploitation of associated remaining unconventional and conventional oil and gas
- The role of global, regional, and local controls on the distribution of organic-rich, phosphatic, and siliceous stratal successions needs to be determined before more refined global predictive models on resource distribution can be realized.
- From a global perspective, boundary stratotypes are being sought for key intervals that are being reexamined including Devonian-Carboniferous, Visean-Serpukhovian (Sand Branch, lower Favetteville and upper Barnett shales), Bashkirian-Moscovian (base of Atoka in Wapanucka).
- In general, the biostratigraphy in the type areas of the U.S. is based on shallow-water small forams and conodonts (e.g. Chesterian) and these species are different from those found in Russia and cannot be easily correlated.
- Systematic conodont biostratigraphy of the major gas-producing shales, including Fayetteville, Caney, and Barnett, is needed in conjunction with isotope chronology, chemostratigraphy, and sequence stratigraphy to establish global reference sections.

#### Research Team Expertise

- Collaborative investigation between KGS-KU, OGS, OSU, and SUNY-Stony Brook.
- Core expertise of participants includes sedimentology & stratigraphy (Franseen, Watney, Puckett, Suneson, Stalder), log petrophysical analysis (Doveton, Victorine), conodont biostratigraphy (Boardman, Thompson), organic and trace metal geochemistry (Anna Cruse, OSU, Stillwater; Dave Newell, KGS), and isotope geochronology (Troy Rasbury, Stony Brooke, NY).
- Insights from integrated approach would support strategic decision making toward development of unconventional oil and gas resources as well as address fundamental science questions.

#### **Coring Program**

The core described in this poster, the OGS-KGS Current #1, is part of a shallow, near-surface coring program that encompasses strategic sites targeting tripolitic chert shelf-margin lithofacies along the edges of the Arkoma Basin and the basinal shales in the greater Arkoma and Ft. Worth Basins (see map upper right). Intermediate slope locations are also included. Slimhole (3 1/2 inch) wireline coreholes are up to 2500 ft. in depth, and logged with a full-suite of geophysical tools including spectral gamma ray, neutron, density, fullwaveform sonic, resistivity, sonic imaging, spectral neutron, and magnetic susceptibility. The Current #1 corehole lacks the latter tool due to unavailability.

Cores are slabbed, photographed, and described by team to determine lithofacies, texture, color, and characteristics of bedding contacts, and establish preliminary sequence stratigraphy as reported in this poster. Cores are sampled every half-ft to 1 ft for paleo and geochemical analysis. Additional samples are taken for SEM and thin section study.

- Cores-log data provide the means to accomplish coordinated, precise sampling for a broad base of analytical
- Half of core is archived to preserve record and for sampling at later time.





New Core Rig for KGS Longvear-LF90D Hydraulic Diamond Core Drill

• Depth capacity of 900 m (2950 ft) NQ/NRQHP Hydraulic rod making and breaking

setup with 16,000 lb capacity mainline hoist

- Independent dual hydraulic mast raising cylinders Hydraulic mast dumping capability up to 2340 mm (92 in) • Hydraulic, telescopic, 6 m (20 ft) pull mast for ease of

#### Transect Southwestern Arkoma Basin: Four continuous wireline cores (Union Valley, Clarita, Wapanucka, Atoka) extending from Upper Devonian through Lower Pennsylvanian age strata would be acquired along a transect traversing the southwestern edge of the Arkoma Basin. Cores are located on three uplifted structural blocks on eastern flank of the Arbuckle Mountains. The core transect, extending southward from Current #1 acquired in June 2008, will sample Woodford Shale at increasingly greater paleo-water depths into the Ouachita foredeep. Strata represent a continuous succession of distal, deep basinal lithofacies of shales, siltstone, and minor limestones. The relatively shallow depth of burial in these gently dipping strata (3-7 degrees) will minimize diagenetic overprinting that affects conventional, more deeply buried basinal cores taken in producing oil and gas locations.

Geologic Map

0 25 50 75 100 150 200

Map of Anticipated Coring in Phases 2 and 3

#### Transect Northern Arkoma Basin and Northern Shelf

Margin: Eight cores are proposed along a transect that will extend from Muskogee, Oklahoma, to Batesville, Arkansas. Fayetteville and Chattanooga would be cored in a location where these shales merges into the Caney and Woodford shales, respectively. The Morrowan strata reflect the shallow to distal shelf conditions from east to west (sand rich to carbonate rich to basinal siliciclastics).

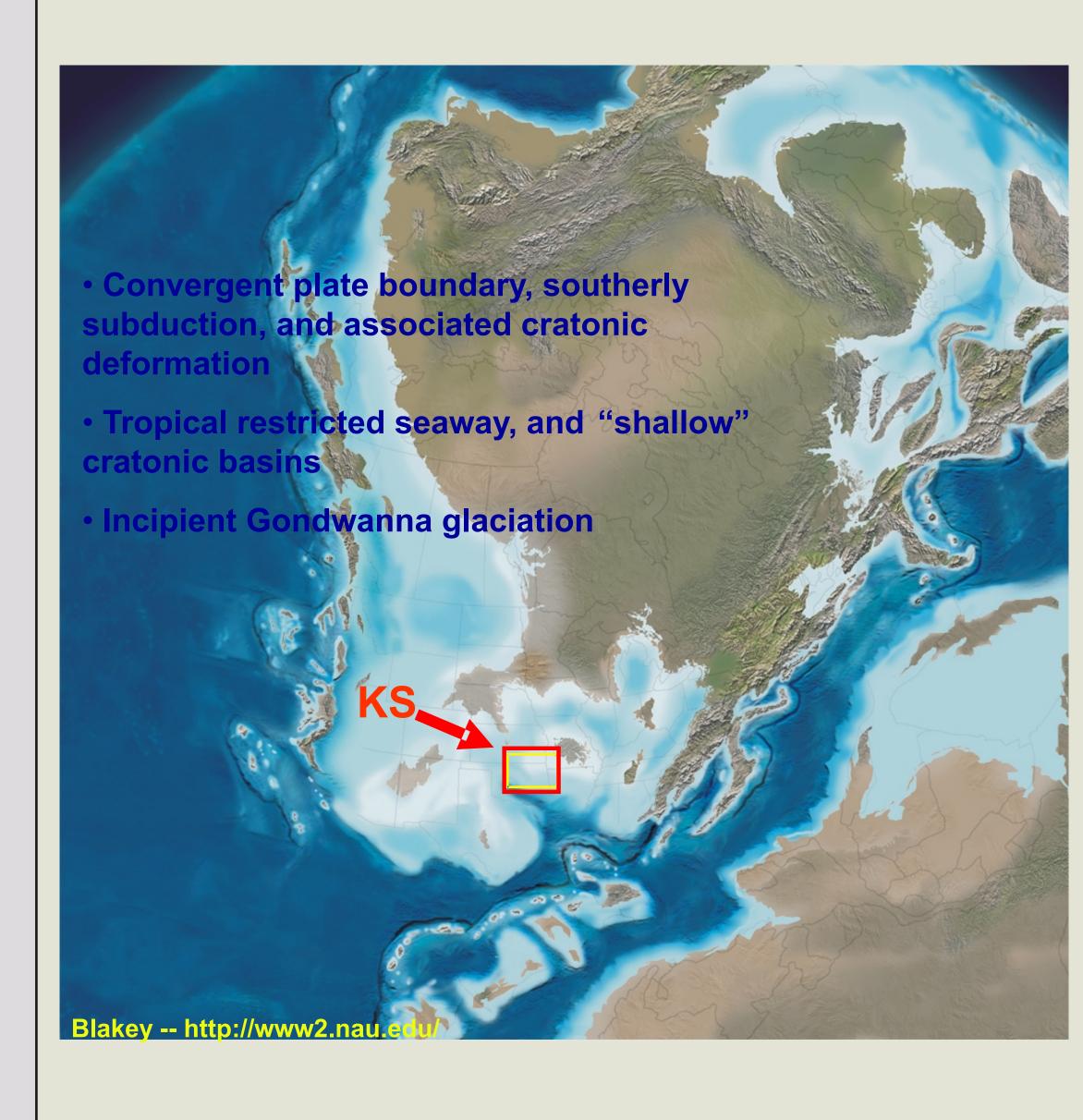
Two of the coreholes will be taken in Kansas providing additional control from 10 complete cores of tripolitic chert shelf margin lithofacies taken from the Tri-State District and from sampling of the Mississippian "Cowley Fm" and the Kinderhook and Chattanooga Shales.

Southern flanks of the Ft. Worth Basin: Closest surface exposure to the producing Barnett. Shallow cores that do exist are old unlogged (Houston Oil and Minerals).

#### Refined paleogeography and basin evolution sought in coring program for Late Devonian-Lowermost Pennsylvanian

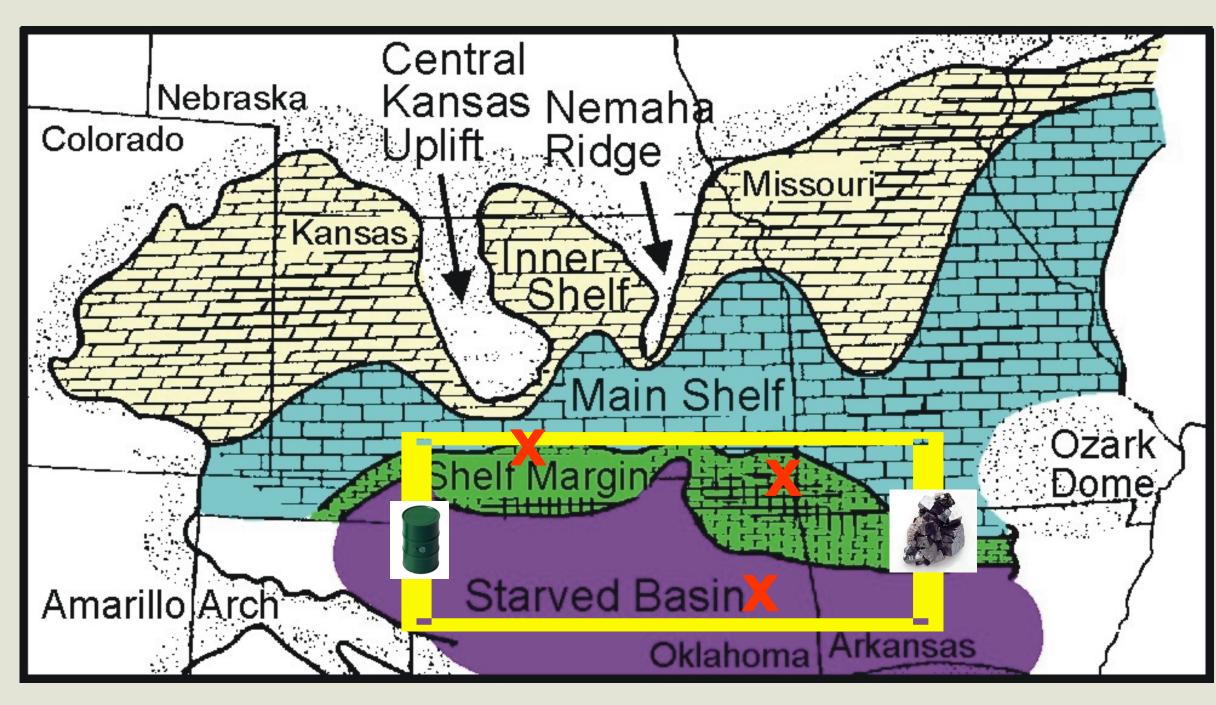
Areas of focus: Arkoma foreland basin and adjoining shelf margin along upper

- 1) Prolonged, notable subsidence along Arkoma Basin foredeep, proto Anadarko Basin, and sag basin near the Arbuckle aulacogen.
- ) Prevailing basin anoxia in foreland due to deep water, high subsidence, low elevated nutrient supply from possible upwelling and runoff from surrounding
- 1) Prominent, active basement faults including wrench and related regional fault systems that extend unto adjoining craton and influence sedimentation. 3) Later elevated thermal events related to burial with fluid flow along fault systems; localized magmatic activity, e.g., associated with Reelfoot Rift.
- B) Basinal fluid migration from foreland basin to shelf leading to deposits of Pb-Zn (MVT) and conventional oil and gas.
- 6) Tie to global processes



**U.S. Shale Reserves** 

#### Resolve stratal relationships between shelf margin and basin



Current study sites

Early Mississippian paleogeography Lane and DeKeyser (1980)

#### **Opportunity for Industry Participation**

Coring program and analyses are currently dependent on industry participation to acquire cores, log, slab and analyze the core.

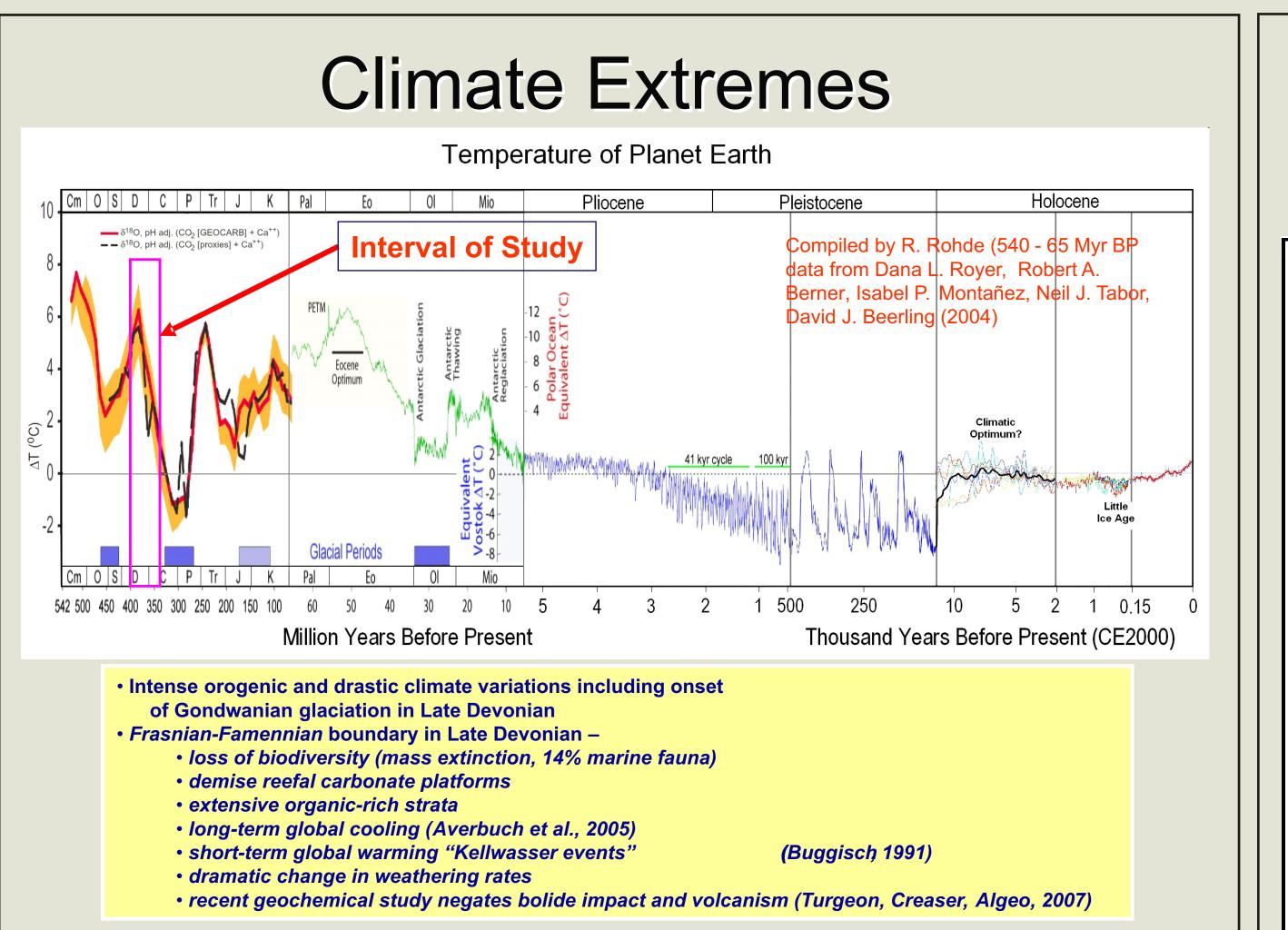
#### Tools and Methodology Applied to Cores

#### Critical elements addressed by the transects:

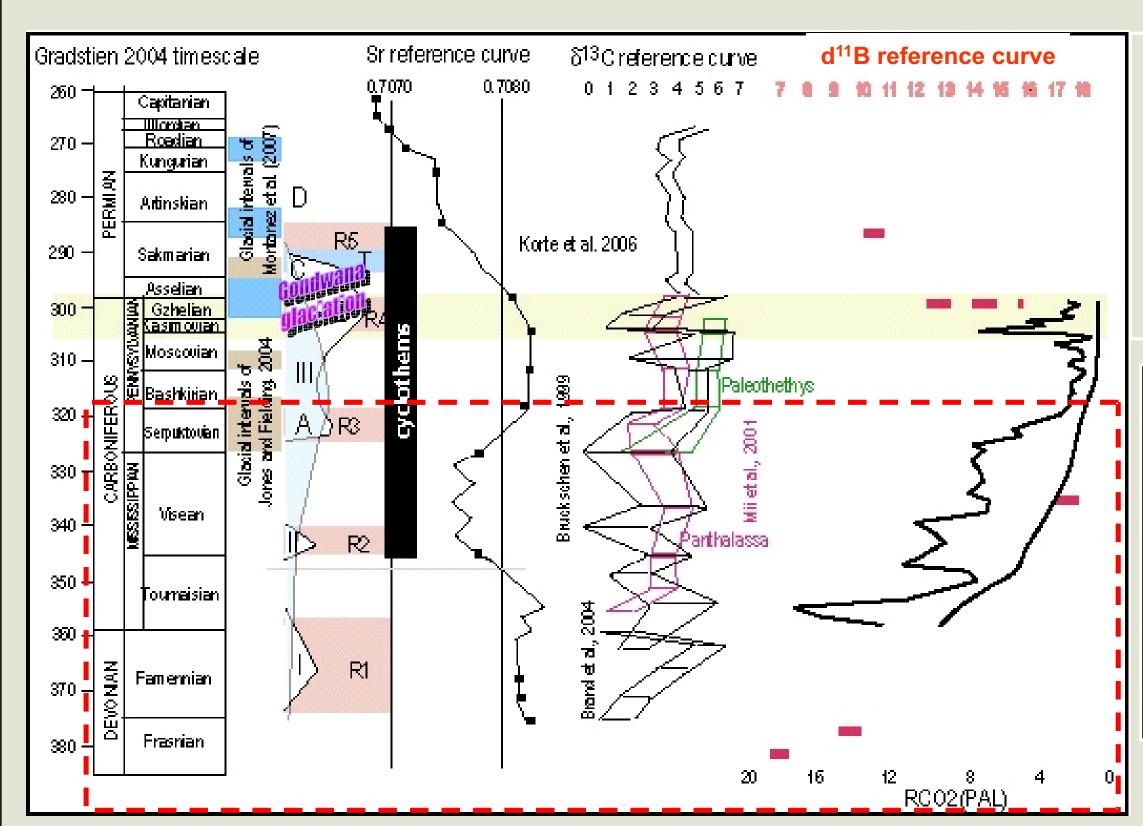
- ) coreholes provide a series of equivalent, continuous successions for biostratigraphic control that could serve as composite standards for global correlation using graphic correlation methods;
- 2) close and widely-spaced successions will provide the basis to establish and test isotope geochronology using Re-Os in high carbon (>3% TOC) shales and U-Pb in conodonts;
- 3) measure TOC, metals, including boron and strontium isotopes, and to establish geochemical cycles and evaluate as paleooceanographic proxies;
- 4) establish magnetostratigraphy calibrated to biostratigraphy as a global standard;
- 5) use oxygen isotopes from conodont elements to evaluate temporal changes in order to characterize the greenhouseto-icehouse transition;
- 6) cores and would be used to develop a sequence stratigraphy that is constrained by age and estimates of stratigraphic completeness based on accompanying analyses;
- 7) cyclostratigraphic analysis of cores using wavelet transforms would be used to evaluate the nature of cyclicity including Milankovitch and establish abrupt changes in stratal patterns;
- 8) establish a sea level curve and refine estimates by Ross and Ross (1987) and Johnson, Klapper, Sandberg (1995);
- 9) characterize detrital from biogenic quartz as it varies temporally and spatially, e.g., evaluate progressive southeastward increase in silica content in the southwestern Arkoma Basin core transect;
- 10) correlate a consistent suite of wireline logs obtained in each corehole with corresponding core attributes to refine interpretations and facilitate extending results to other wells and relate to other common rock properties such as mechanical and seismic properties; and
- 11) share precisely sampled material for use by industry participants to conduct additional proprietary tests.

#### Climate Extremes, Stable Isotope, and Climate Proxies

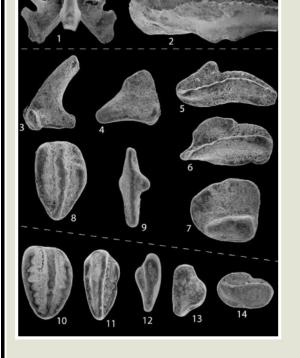
- \* Global cooling during Late Devonian and episode of abrupt anoxic events.
- \* Onset of Glaciation and Periods of High-Amplitude, High-Frequency Changes in Sea Level.



#### Stable Isotopes and Climate Proxies for the Late Paleozoic (compiled by T. Rasbury, 2008)



Including geochemica conodon

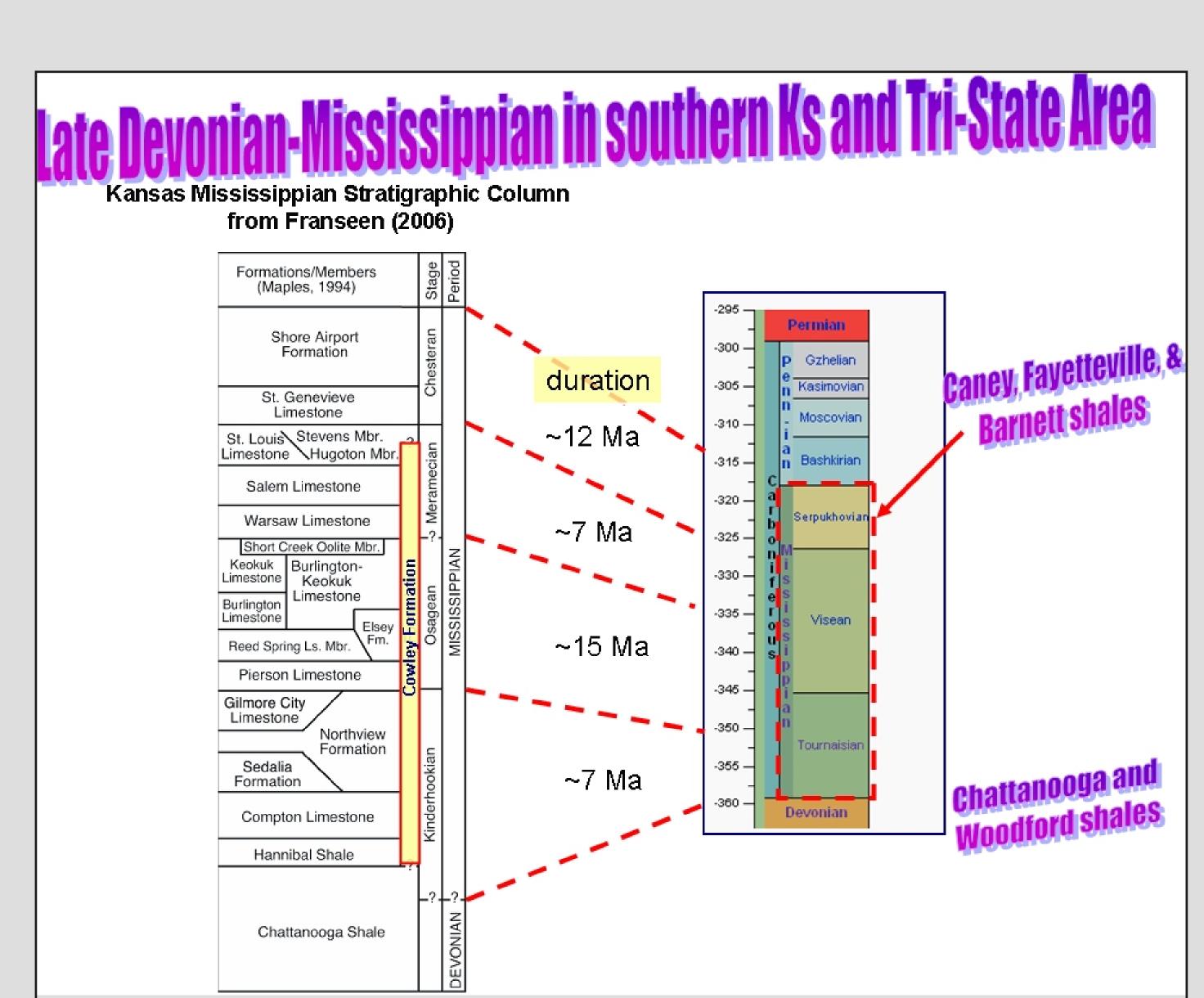


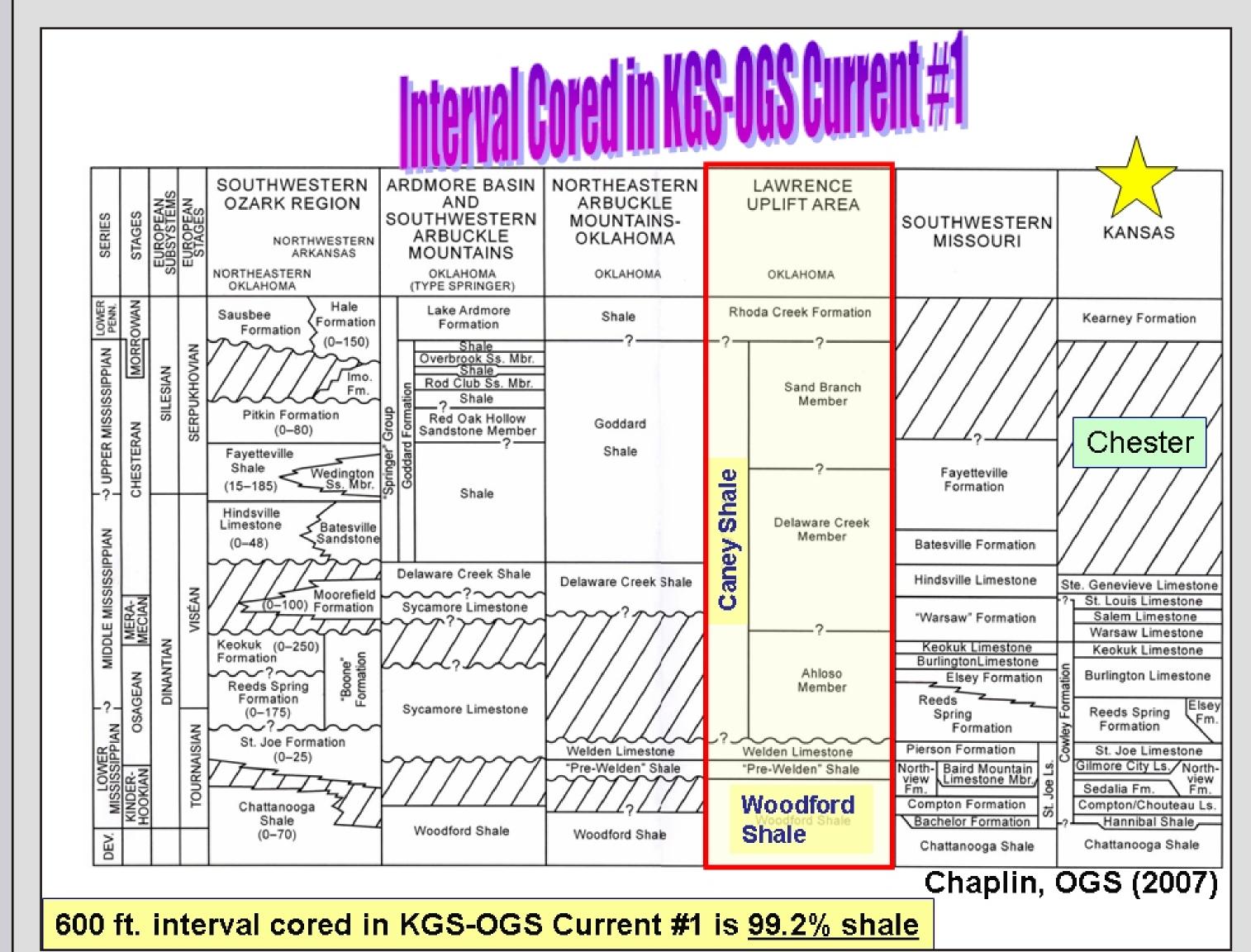
#### Stratigraphic Nomenclature and Preliminary Considerations About Depositional Sequences

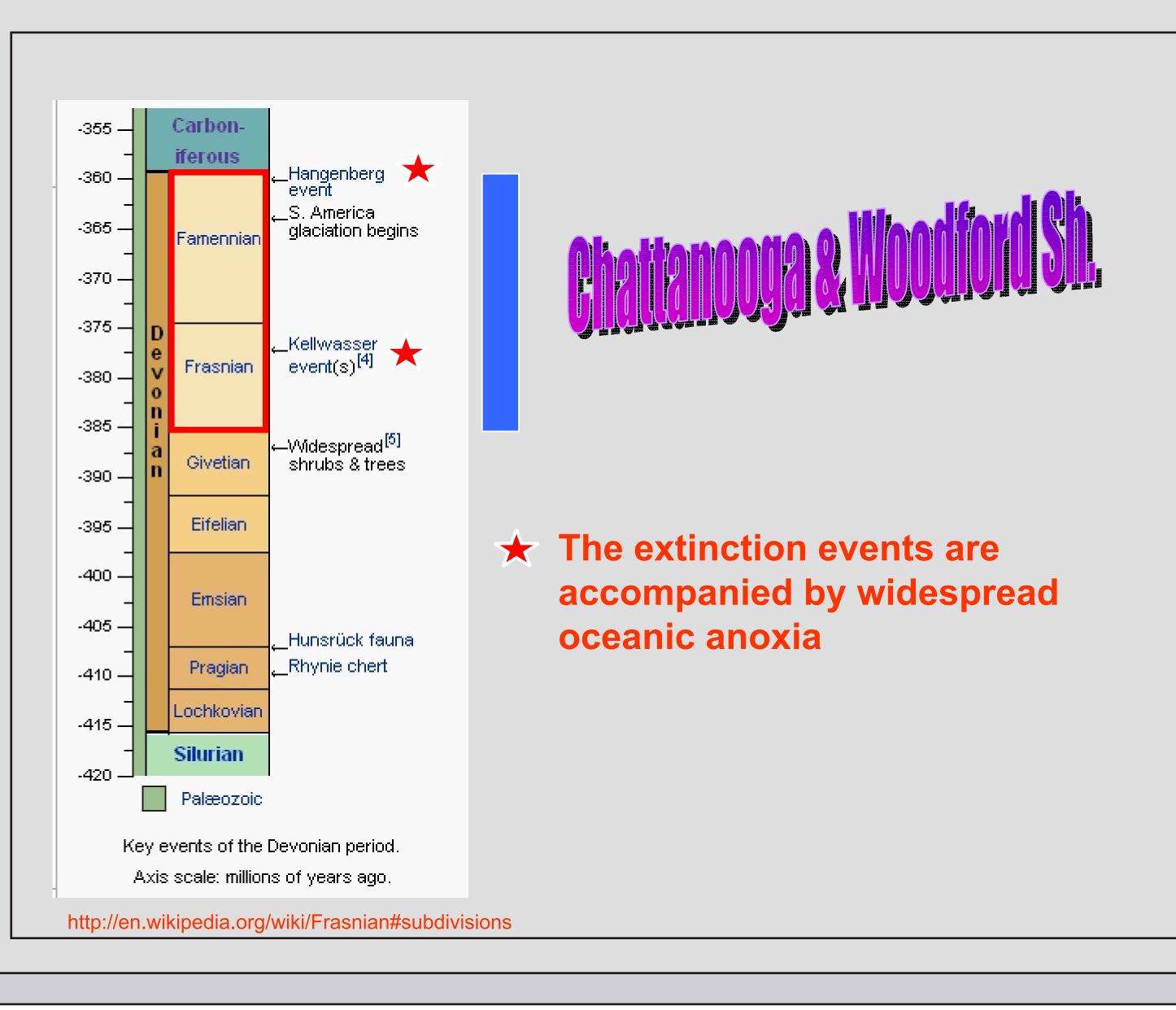
#### Stratigraphic Interval Under Investigation

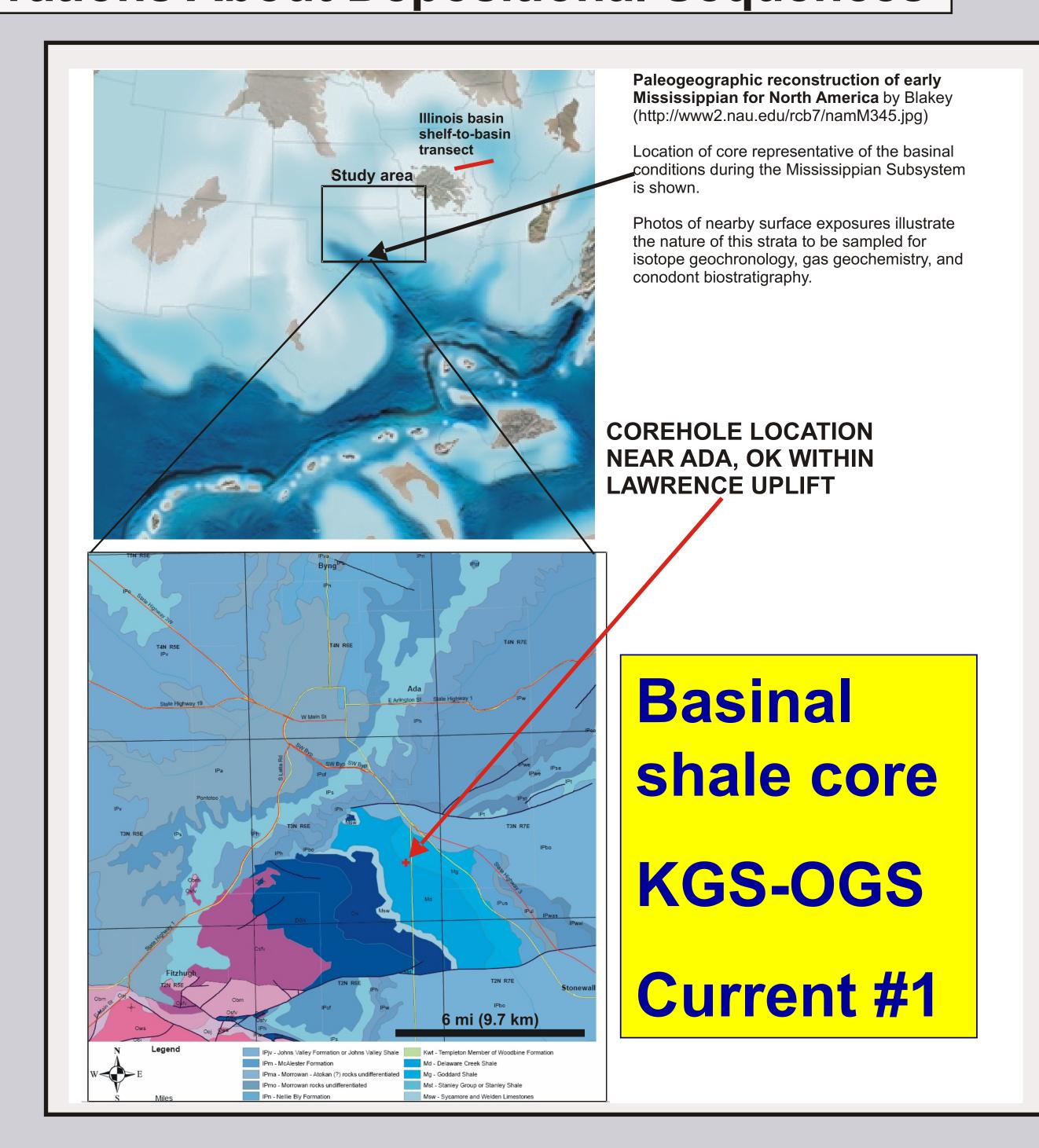
☐ Lack definitive correlations between shelf and basin.

☐ Lack of correlations and understanding stratal geometries along the shelf margin impede development of a robust sequence stratigraphic framework and related high-resolution paleogeography and resource characterization.









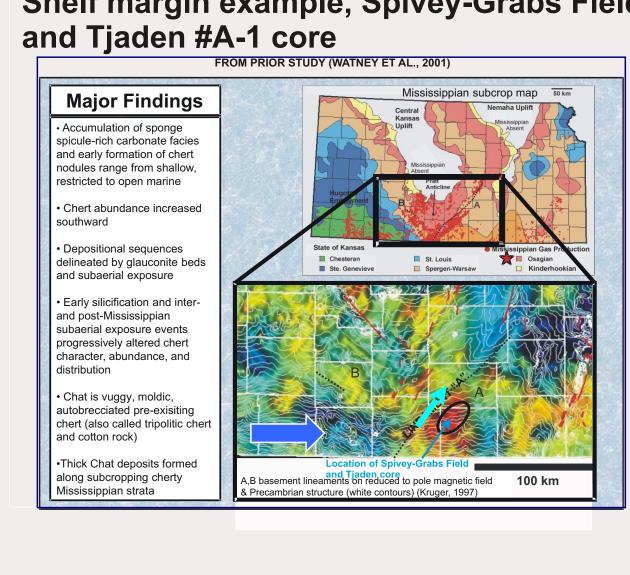
#### Findings of stratigraphic analysis along northern shelf margin bordering the Arkoma Basin:

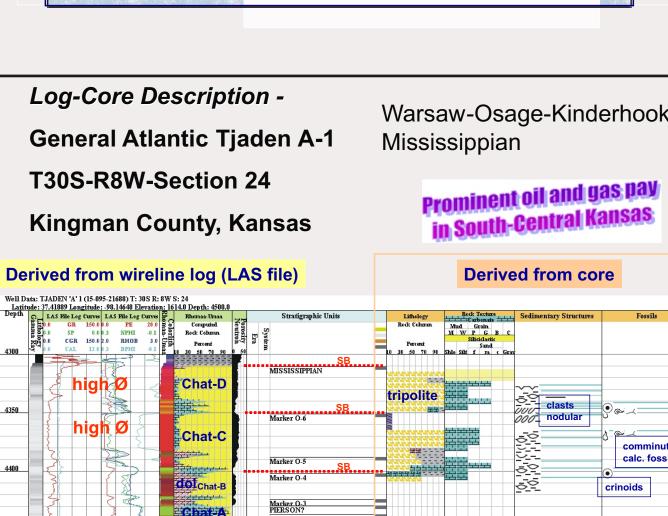
- Distal shelf margin T-R couplets of deeper-water dolomitic silty shale and carbonate lithofacies with scattered benthics with nodular chert and organic macerals ("Cowley Fm), and no subaerial exposure (typica of Upper Kinderhookian to Lower to Mid-Osagean
- Unconformity-bounded, subaerially exposed depositional sequences dominated by tripolitic chert O Total number of sequences >7.
- From southern Kansas bordering and southwestern Missouri bordering the Arkoma Basin, basinward increase in tripolite and dolomitic limestone lithofacies characteristic of the shelf margin.
- Conodont biostratigraphy indicates that chert is younger basinward and thus shelf margin is
- while chert-bearing successions are as old as Lower Osagean. ■ Basin-margin and slope lithofacies are probably represented by cherty dolomitic nodular chert and organic maceral-rich "Cowley" lithofacies.

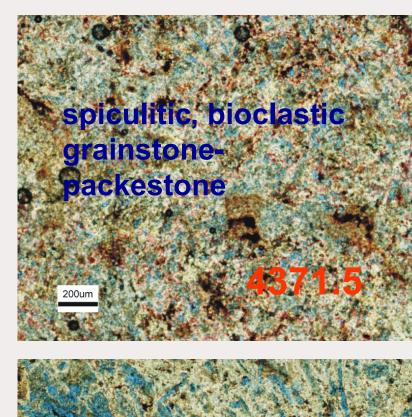
■ The most basinward sequences consisting of chert are Upper Osagean and Lower Meramecian in age,

- Northview Shale. Represents a major drowning of shelf and correspond with the advent of deeper basinal shale lithofacies. Chert-bearing cycles of shelf margin possibly equivalent to the phosphorite that occurs in the Pre-Weldon Limestone that overlies the Woodford Shale in the Current #1 corehole.
- Onlap/toplap? of microporous tripolite on east (landward) side of Tri-State MVT deposit is comparable to northern margin of tripolite in south-central Kansas. Loss of porous tripolite in updip direction corresponds to limits of hydrocarbon accumulation in south-central Kansas and MVT deposits in Tri-State area.
- Regional faulting during deposition appears to have influenced location of shelf margin and distribution of tripolite; faults possibly provided conduits for ore fluids and hydrocarbon migration out of the Arkoma

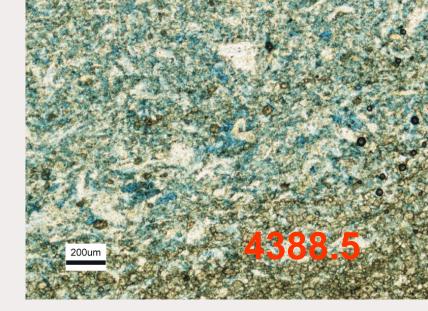
#### Shelf margin example, Spivey-Grabs Field





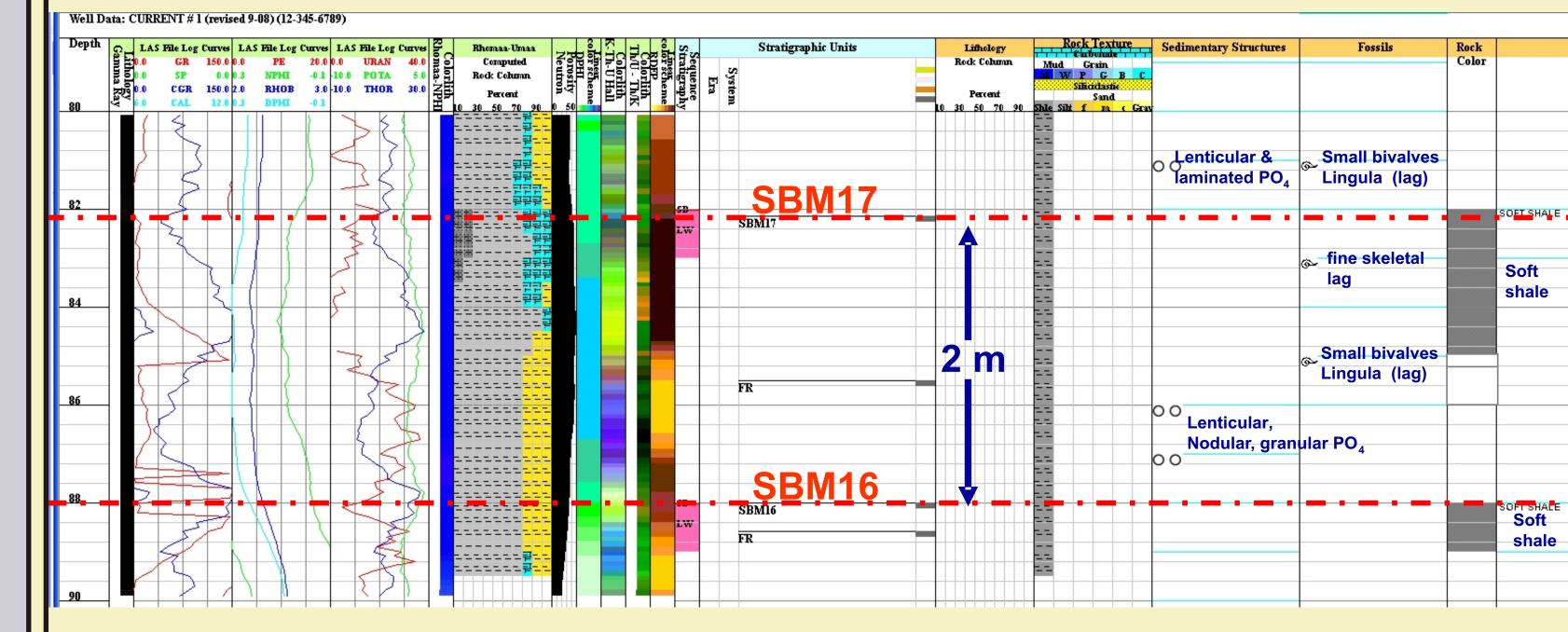






## Well Data: CHRRENT #1 (revised 9-08) (12-345-6789) Log-core Composite of Current #1 with Stratigraphic Nomenclature

#### Proposed Depositional Sequence for Upper Caney (Chesterian)



SB = sequence boundary -- abrupt upper surface overlying silty, bioturbated shale, or soft blocky mudstone, or green shales, some Th enriched; boundary is overlain by laminated, dark gray to black, often uranium-rich, phosphatic hard shale. FR = forced regression -- surface of abrupt shift in lithofacies; often silty shales overlying uranium-rich, commonly PO₄ or pyritic, laminated shales.

#### Depositional sequences in the basinal shales of the Upper Devonian and Mississippian (Lower Carboniferous) as described in Current #1 corehole.

■ Depositional sequences are defined in this deep-water setting as successions of genetically distinct strata that exhibit distinct patterns of sediment condensation and anoxic or euxinic conditions followed by regressive strata exhibiting dysoxic to oxygenated conditions. The condensed sections are generally characterized by a sharp base and consist of organic- and uranium-rich, phosphatic and pyritic dark gray shales. The condensed section is overlain by apparent regressive strata that often contain increased silt, sometimes indicating bottom transport, less organic matter, but often benthic fauna or traces in a green and gray shale. Thus, the regressive strata are inferred to have been deposited under dysoxic to oxic bottom conditions. Sharp facies dislocation occurs across a surface where the overlying strata contain characteristics that suggest abrupt regression (thus interpreted as forced regression). No subaerial exposure has yet been observed in the KGS-OGS Current #1. Yet, without subaerial exposure and the apparent conformable contacts between the sequences, the depositional sequences most closely resemble "Galloway-type" genetic sequences, delimited most prominently by the flooding surfaces at the base of the condensed sections.

#### Symbols used in core description:

SB = sequence boundary -- a sharp surface that separates silty, bioturbated shale, soft blocky mudstone, or green shales, some Th enriched that are interpreted as deep water from overlying laminated, dark gray to black, often uranium-rich, phosphatic hard shale that is interpreted as even deeper water.

 $FR = forced\ regression$  -- surface overlain by lithofacies indicative of abrupt regression, often more silty, particle lags, and sediment winnowing or reworking.

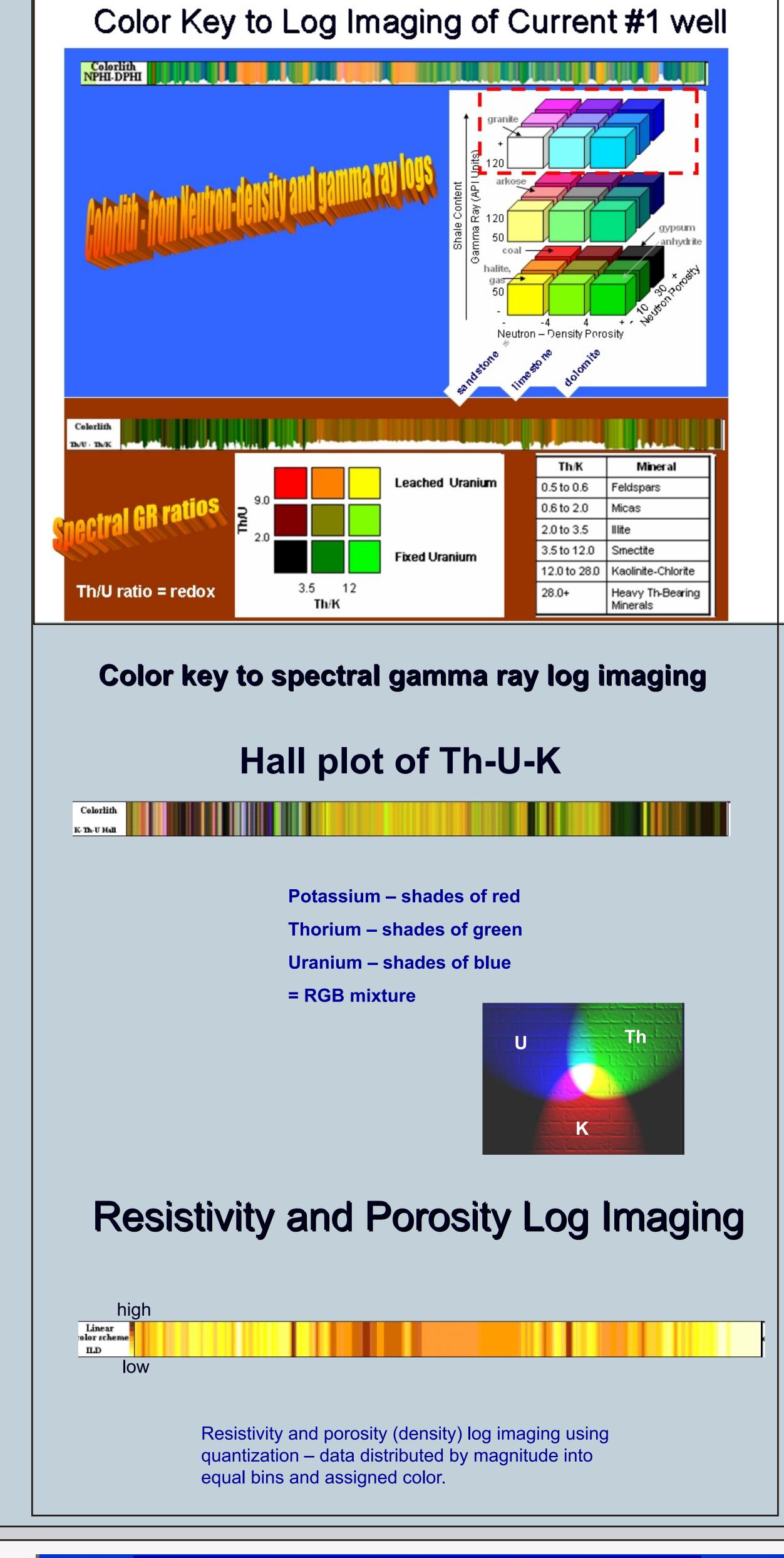
\_Five examples from Lower, Middle, Upper Woodford (Upper Devonian), pre Weldon Shale (Kinderhookian), Welden Limestone (Osagean), and Caney Shale (Meramecian through Chesterian) intervals are shown in Panel #3 to illustrate changes as well as similarities in composition of sequences. Changes in composition of these sequences probably reflect multiple processes include eustacy that will be addressed with continued analysis. (See Panel #3)

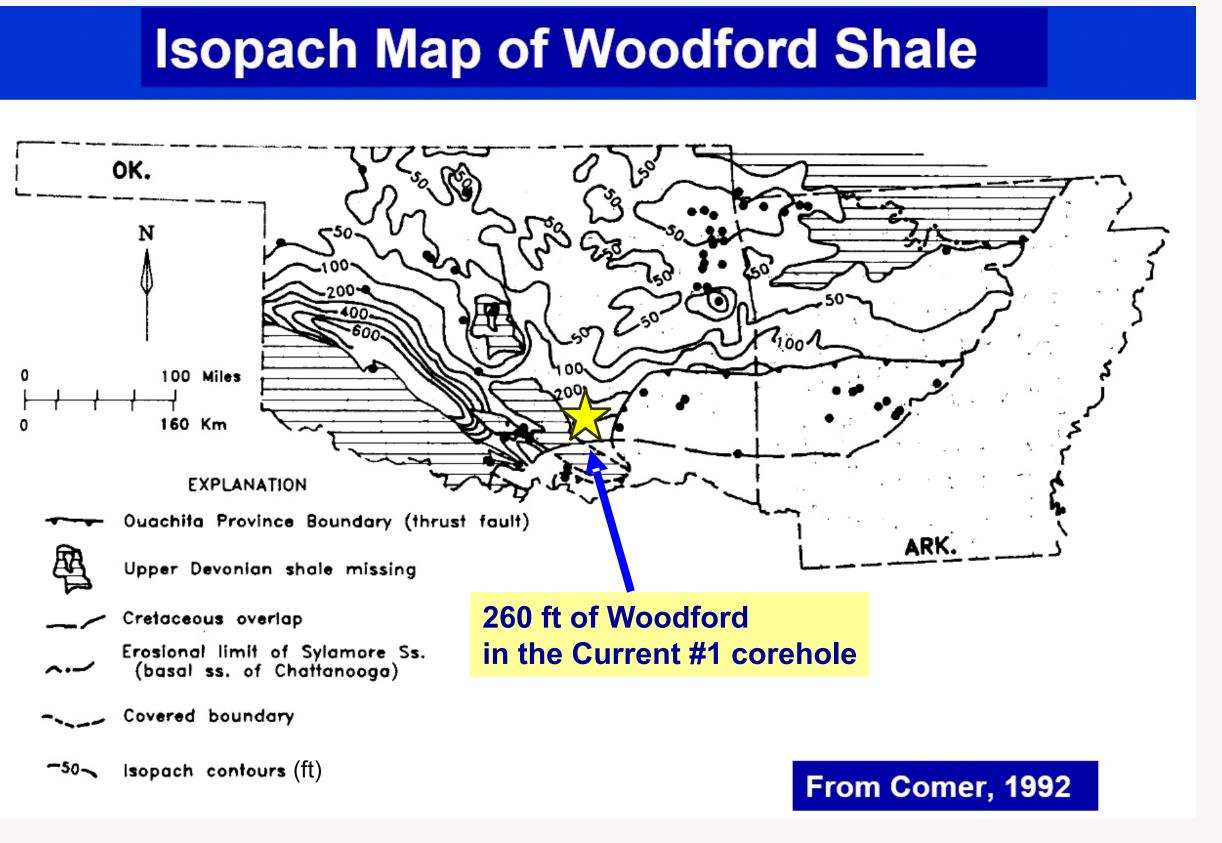
# Log-Core Description KGS-OGS Current #1 **Pontotoc County, Oklahoma** Gray intervals Top Middle Caney Sh. Top Lower Woodford Shale

#### Wireline Log and Core Integration **KGS-OGS Current #1**

#### Pontotoc County, OK

facilitated through the use of a web-enabled software being developed at the Kansas Geological Survey. Features of software include: 1) reading and parsing log data from U, and K values and Th/U and Th/K ratios, d) porosity and e) resistivity logs 3) growing list of tools to build core descriptions (stratigraphy, sedimentology, and soon biostratigraphy and geochemistry.



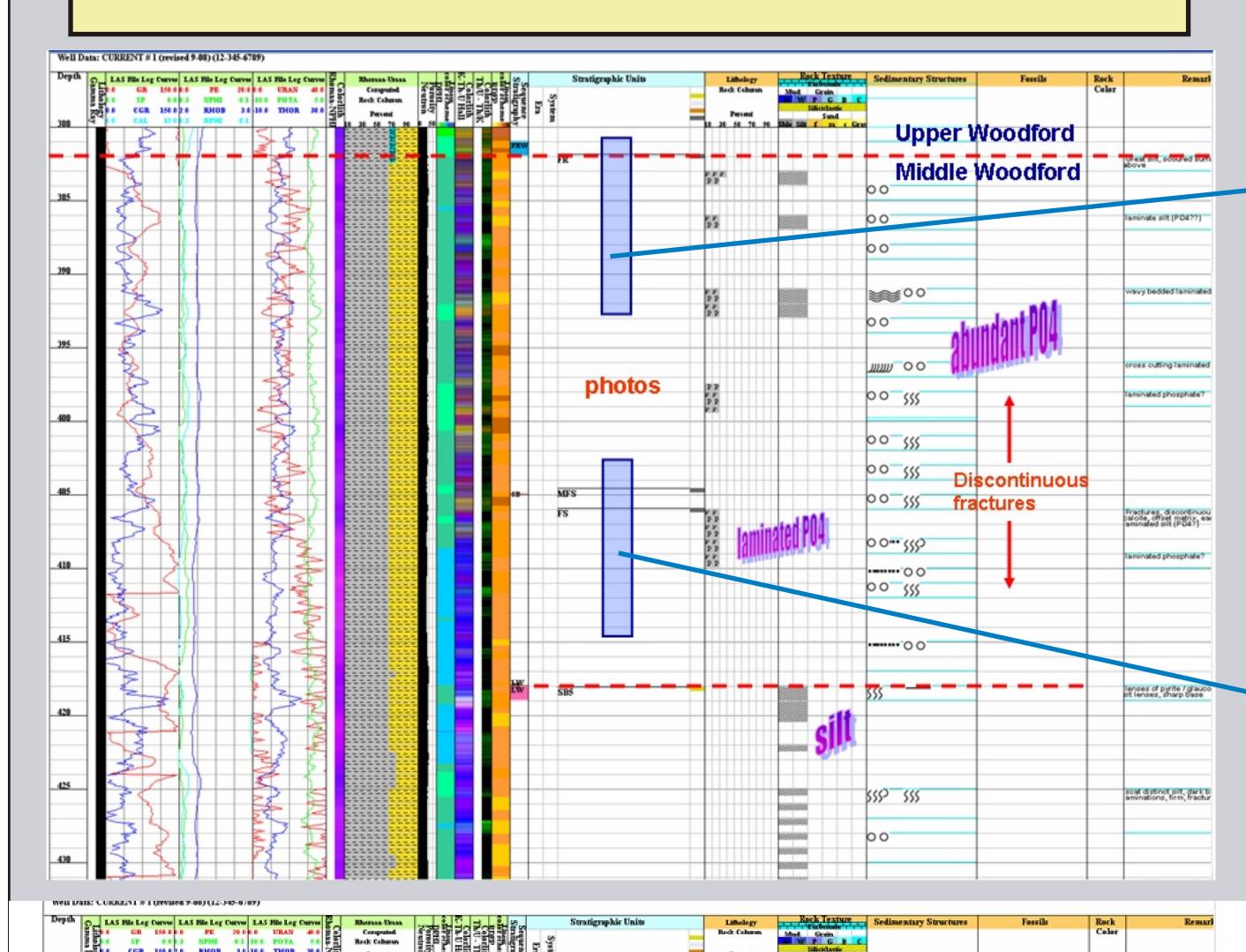


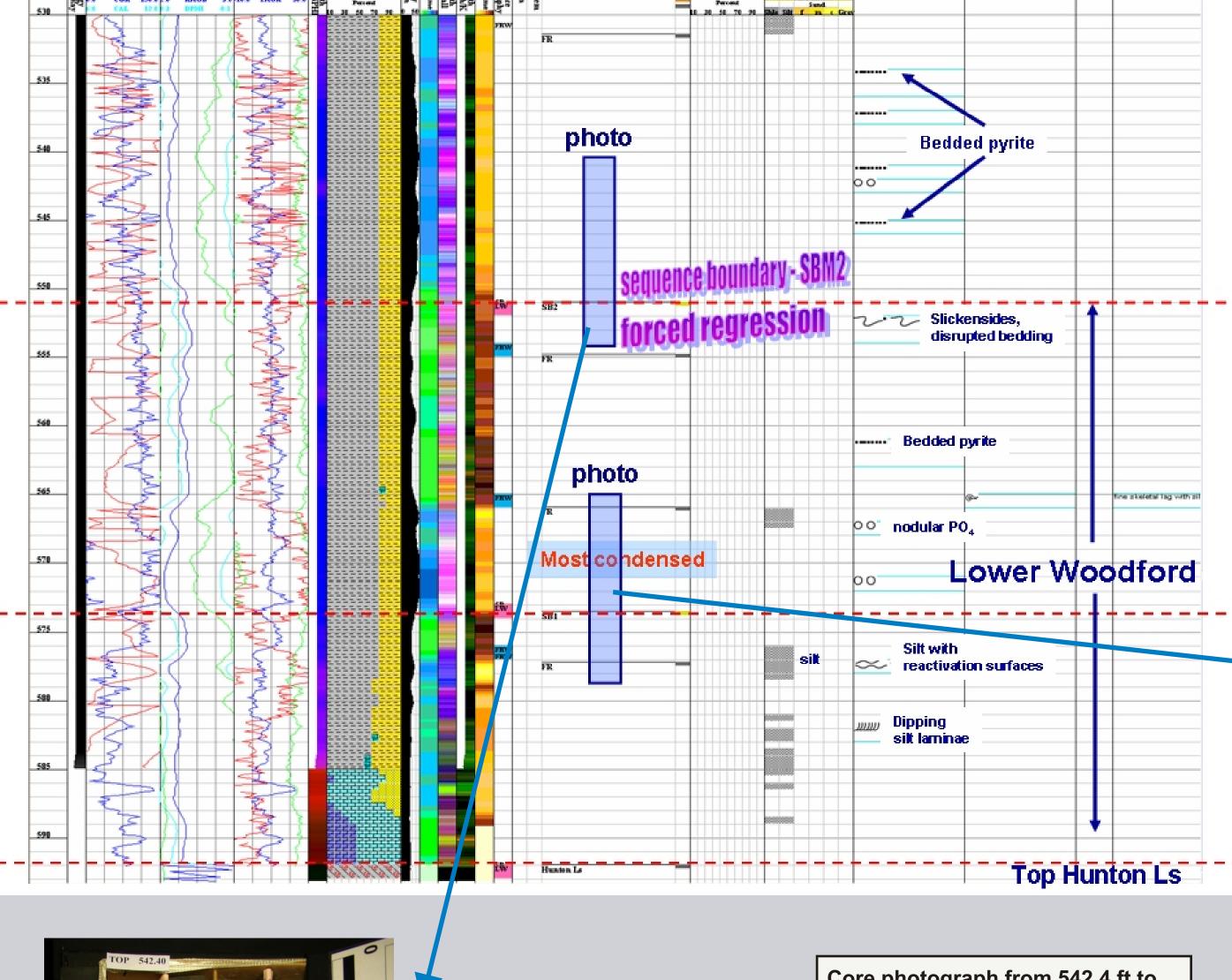
http://www.ogs.ou.edu/pdf/woodfordcardotttsop.pdf

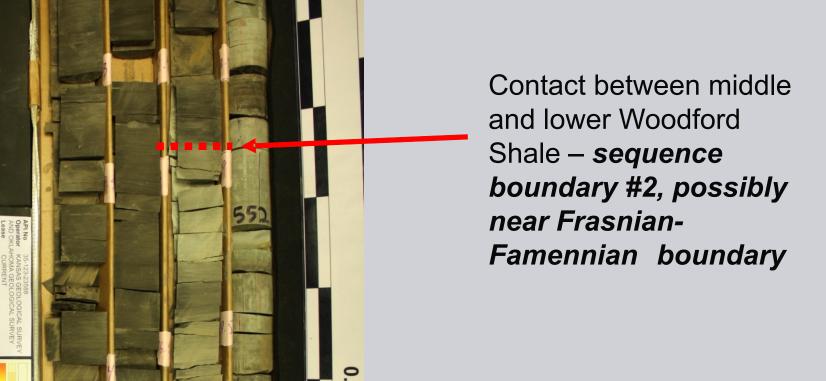
#### Preliminary Observations of Provisional Depositional Sequences in the KGS-OGS

#### **Woodford Shale:**

- SB2-SB1 (top of Lower Woodford) (551 to 574 ft): 23 ft thick with lower 10 ft composed of condensed section that is dark gray to black shale with pyrite and PO4 bands; condensed section has high U (40 ppm), low resistivity, low density (2.05 g/cc), nodular PO4 (see photo); two inferred surfaces of forced regression in upper portion of sequence between 551 and 566 ft that is composed of finely interbedded gray-green and brown clay and pyrite. Uranium moderate at ~20 ppm; high resistivity, higher density (2.2 to 2.3 g/cc).
- SB6-SB5 (top Middle Woodford Shale) (367-418 ft): 51 ft thick sequence with basal condensed dark gray shale, with PO4 nodules and laminae in "silt" intervals; high U at base (~40 ppm); moderate resistivity and density to silty disrupted gray dark gray shale with lower U (<10 ppm) and Th (5-10 ppm), slightly higher K (<5%) (see photos)
- SB7-SB6 (upper Woodford Shale) (311-366 ft): 55 ft thick sequence with generally low U (<10 ppm), higher K (4.5%), no Th contrasts, medium gray claystone with minor silt, scattered PO4 nodules, scattered bivalves in upper portion; forced regression near top at 323 ft overlain by abrupt increase in silt content.







Core photograph from 542.4 ft to 553.9 ft. – Sequence boundary (SB#2) separating the middle from the lower Woodford Shale. Greenish-gray shale below the sequence boundary is less well bedded with occasional slickensides. Above the sequence boundary is gray to black organic-ricl claystone layers of pyrite and phosphate laminae. Uranium concentration in this shale climbs to 70 ppm, while shale below the

sequence boundary has uranium concentrations from 10 to 30 ppm.

SEM image from 503.7 ft. - Siltstone along a surface interpreted as forced regression (FR). reactivation surfaces. Glauconite and phosphate silt-sized particles including clay and probably quartz silt. EDAX (energy dispersive X-ray) images of silicon (Si) and iron (Fe) confirm the characteristic of pyrite) and abundance of Si in 2μm EHT = 15.00 kV Signal A = SE2 Date :15 Oct 2008

Mag = 2.69 K X WD = 14 mm Photo No. = 160 Time :12:09:07 

380.9-392.6 ft – Photo of slabbed core at and below contact of upper

phosphate nodules at contact appearing as if winnowed by currents

and lenses

Silt layers =

403.8 to 415.3 ft - Middle Woodford Shale

surface (MFS) at 405.8 ft separates darker gra

First sequence boundary (SB #1) in Woodford Shale above the Hunton Ls.

**565.9 to 577.3 ft** – Sequence boundary (SB#1)

separates greenish-gray shale below from dark

contains lower uranium (~10 ppm) and above the

boundary contains much higher uranium (up to 50

ppm). This uranium-rich interval corresponds to

some of the most radiogenic shale in the core.

phosphate layers. Pyrite clusters lie on the

claystone with slickensides, and partially

laminated containing reactivation surfaces.

cemented) fractures (see photo above).

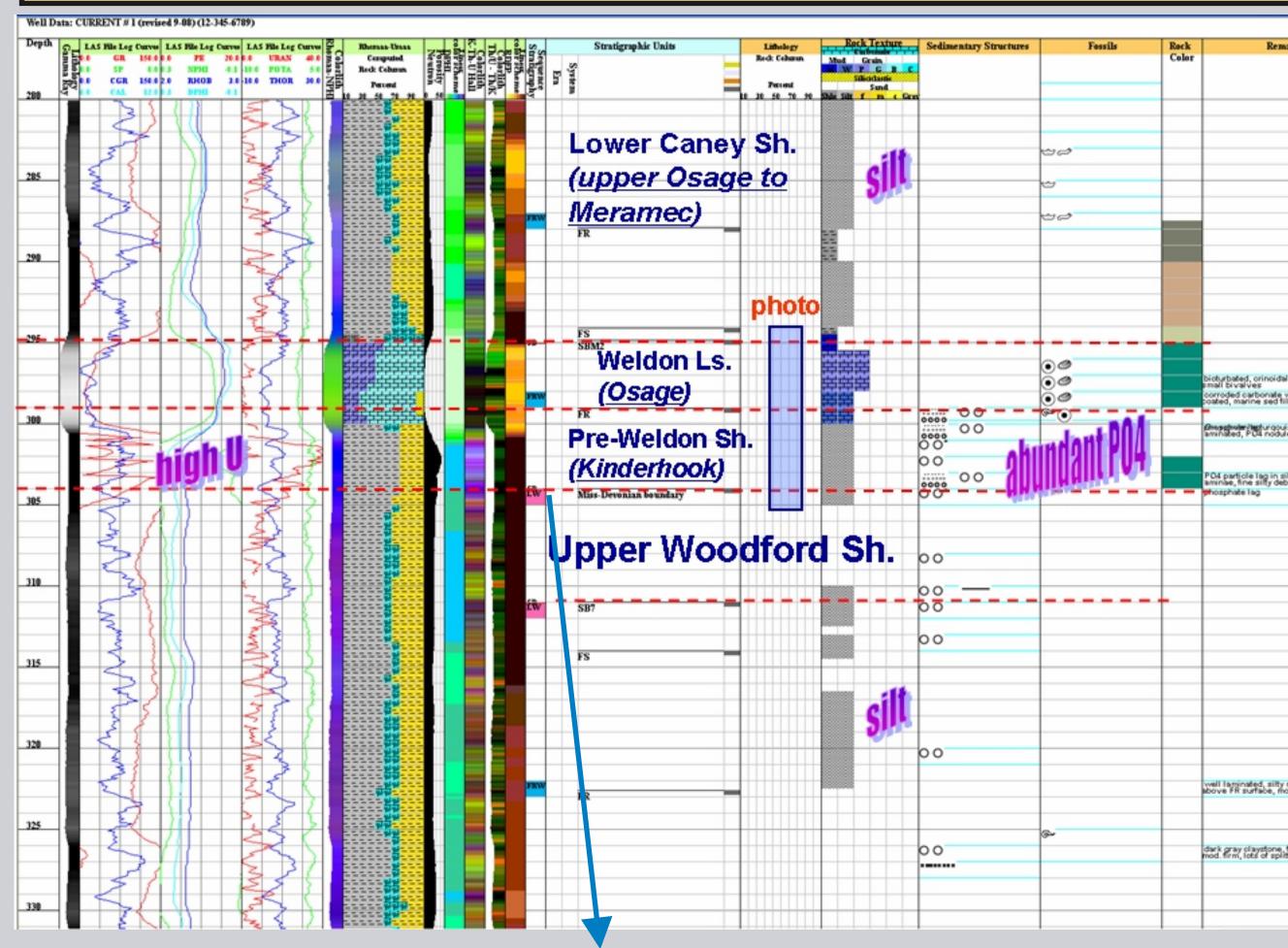
and middle Woodford Shale. Boxes are 3 ft long. Top of middle

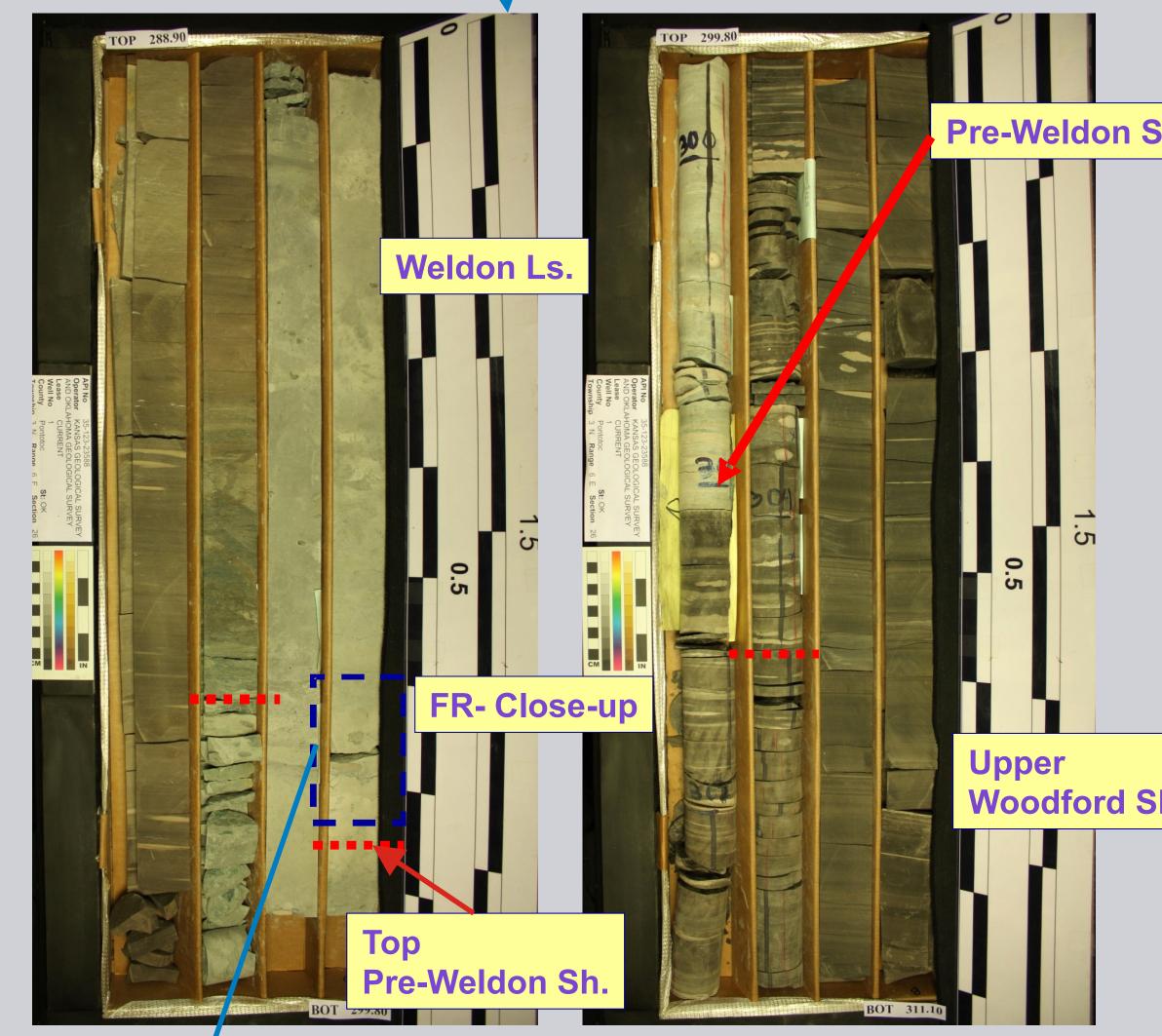
phosphate. Occasional phosphate with fine pyrite centers. Way

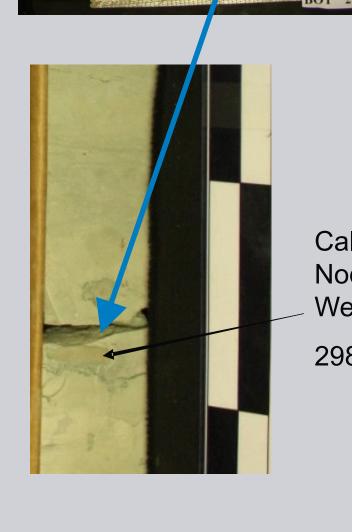
uranium from 20 ppm below to 5 ppm above the contact.

#### Pre-Weldon Shale and Weldon Limestone Mississippian and **Devonian boundary**

• SBM1 to SBM2 Kinderhookinan-Osagean (295-304 ft): 14 ft thick for 22 Ma long interval. This is likely a composite depositional sequence, i.e., comprised of multiple, higher-frequency sequences. The Pre-Weldon Shale is essentially a phosphorite consisting of medium gray to distinctive greenish gray (low OM) silty claystone with abundant PO4 including silt-sized, granular/sand size as lenses and nodules. Highest uranium in core in Pre-Weldon at 50 ppm. Maybe tied to upwelling and chert accumulation on shelf margin. Sharp base and top. Weldon Limestone is gray green wackestone to mudstone with crinoids and bioturbation with internal corroded surface (299.3 ft) with brown calcified PO4 nodule (no subaerial exposure). This presumed composite sequence representing considerable geologic time is exhibits deep water and likely upwelling conditions due to abundance of phosphate followed by substantial shallowing or greatly increased depth of photic zone. The interval is equivalent to much of the tripolitic chert lithofacies developed along the shelf margin.







288.9 to 311.1 ft – Lowermost Caney Shale, Weldon Limestone, pre-Weldon Shale, and Upper Woodford Shale -- Upper Woodford Shale (311.1 ft to 304.5 ft) Black to dark gray shale\_with silty zones containing thin layers of phosphate, pyrite and bivalve fragments. Also, interval of large cm-sized phosphate nodules. Top of interval has sharp Pre-Weldon Shale (304.5 to 301.2 ft) -- Medium dark gray grains. Phosphate nodule lag along sharp surfaces. Top of pre-Weldon Shale is phosphorite - packed phosphate nodules and smaller phosphate particules.

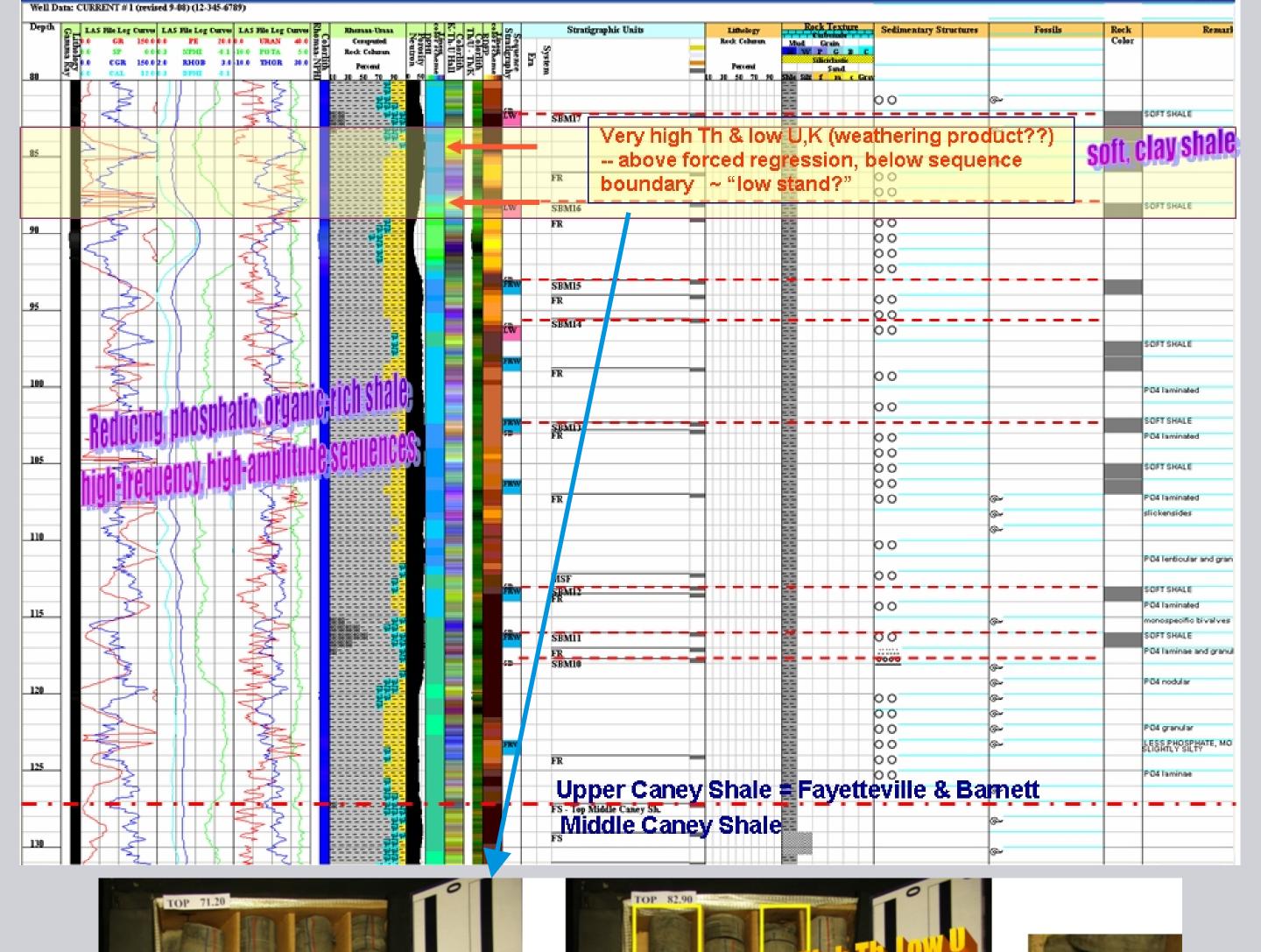
Sharp contact at 298 ft near base of the Weldon Limstone Light greenish gray micritic argillaceous limestone containing crinoids. Inches below is greenish shale containing corroded carbonate clasts that are coated by glauconite. Brown carbonate clasts along corroded surface with borings (?) at 298 ft contains nodules that physically resemble phosphate nodules below, but are calcareous. Carbonate above the contact is bioturbated crinoidal wackestone with small bioclastic debris.

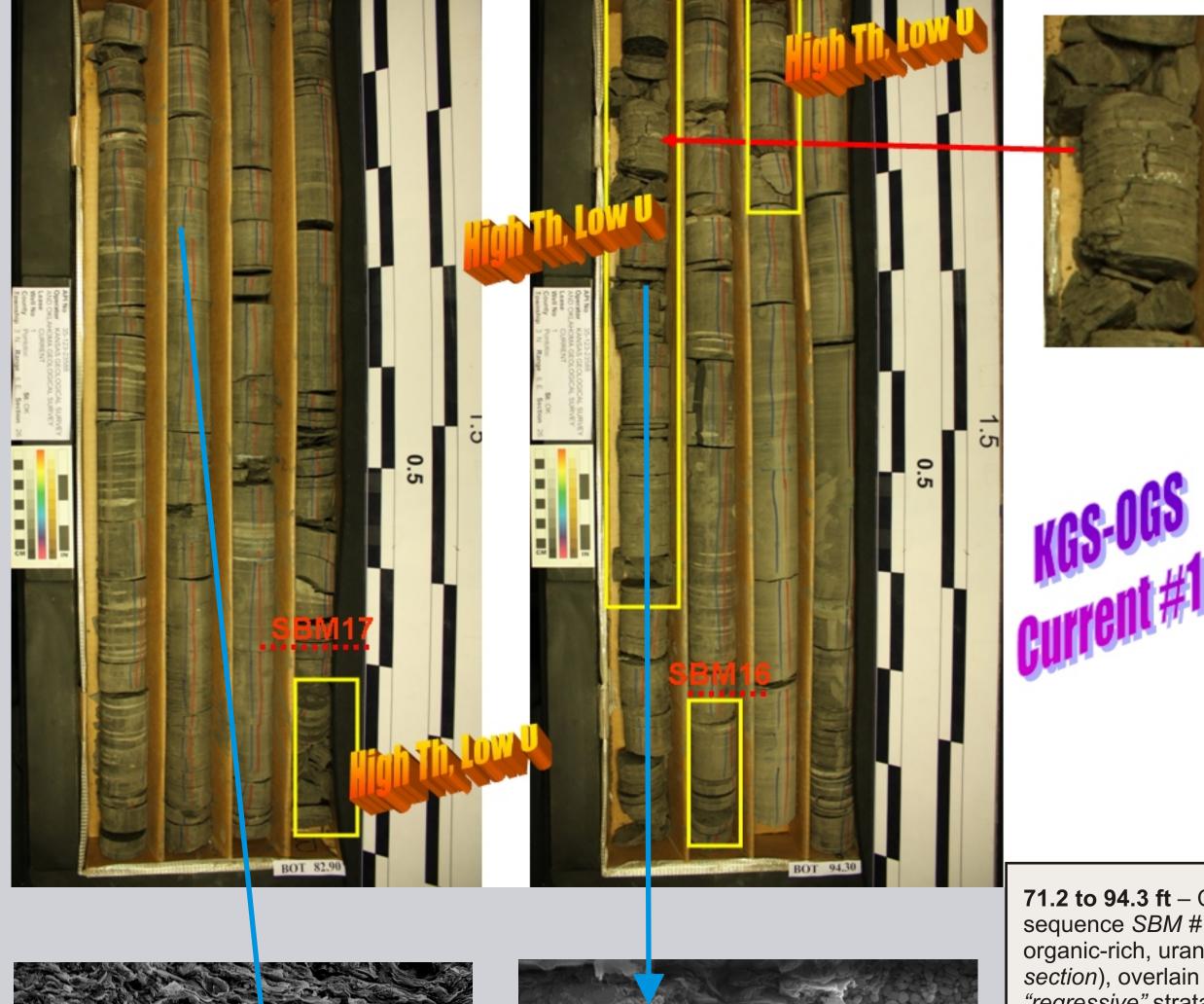
Uppermost Weldon Limestone (296.5 to 294.5 ft) --Increasing clay in light gray-green argillaceous lime mudstone with phosphate-coated lithoclasts that are increasingly dark to

Lowermost Caney Shale (294.5 to 288 ft) - Soft green-gray claystone at base with phosphate nodules and glauconite. Overlain by green and brown mottled silt to very fine sand with abundant glauconite. Overlain by brownish gray silty very fine grained sand with unidentified black grains, bioturbated, upwards to laminated argillaceous siltstone with scattered brachiopods, slightly micaceous with phosphate lenses. Overlain by darker gray-green argillaceous silt with dark horizontal burrows. Overlain by more continuous dark greenish gray silty shale, laminated and burrowed with

#### **Upper Caney Shale (Chesterian)**

• SBM17-SBM16 (82-88 ft): Soft blocky mudstone that is enriched in Th (25 ppm) and depleted in U (~0 ppm) overlying low Th (2 ppm) and high U (35 ppm) laminated, dark gray to black, phosphatic hard shale. Relationship is repeated more or less in other sequences in upper Caney Shale (roughly equivalent to the Barnett and Fayetteville Shales). Thorium enrichment appears to be associated with clay mineral lattice, proxy for Al? perhaps related to detrital material from intensely weathered land surface (wet/dry alternating tropical?)





10μm EHT = 15.00 kV Signal A = InLens Date :15 Oct 2008 2μm EHT = 15.00 kV Signal A = SE2 Date :15 υ Mag = 1.78 K X WD = 12 mm Photo No. = 157 Time :11:10:35 Mag = 5.17 K X WD = 9 mm Photo No. = 162 Time :12:α

11.2 to 94.3 ft – Core photos spanning depositional sequence SBM #17 that contains distinctive lower phosphatic section), overlain by soft thorium-rich shale, interpreted as the "rearessive" strata. This sequence is within a succession of high frequency, 2m-thick, depositional sequences that characterize the upper Caney Shale. This interval is bearing intervals of the Barnett and Fayetteville shales. **SEM image photographs** – **75.8 ft** within the lower

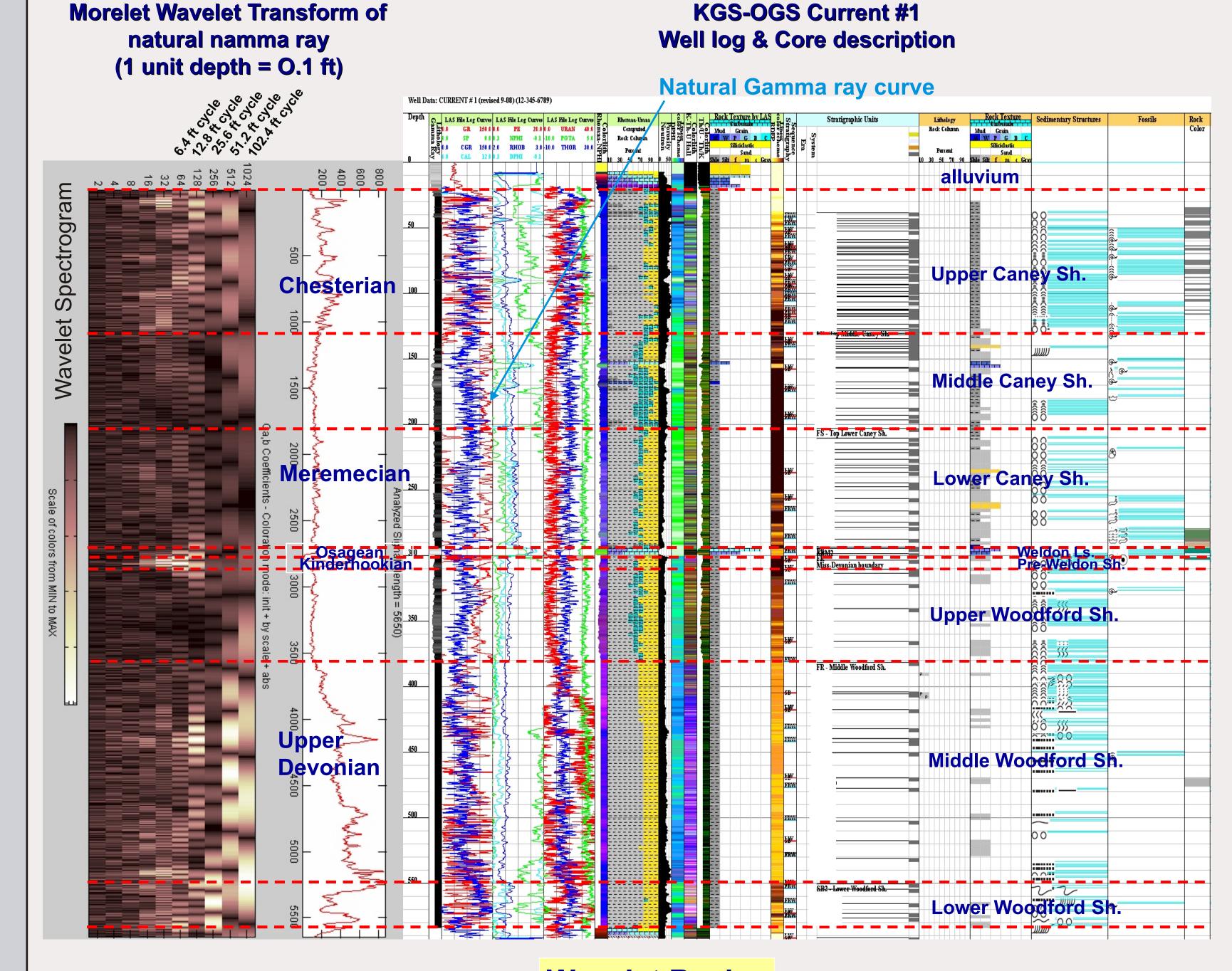
1μm EHT = 15.00 kV Signal A = SE2 Date :15 Oct 2008

Mag = 19.69 K X Δ/D = 9 mm Photo No. = 163 Time :13:01:56

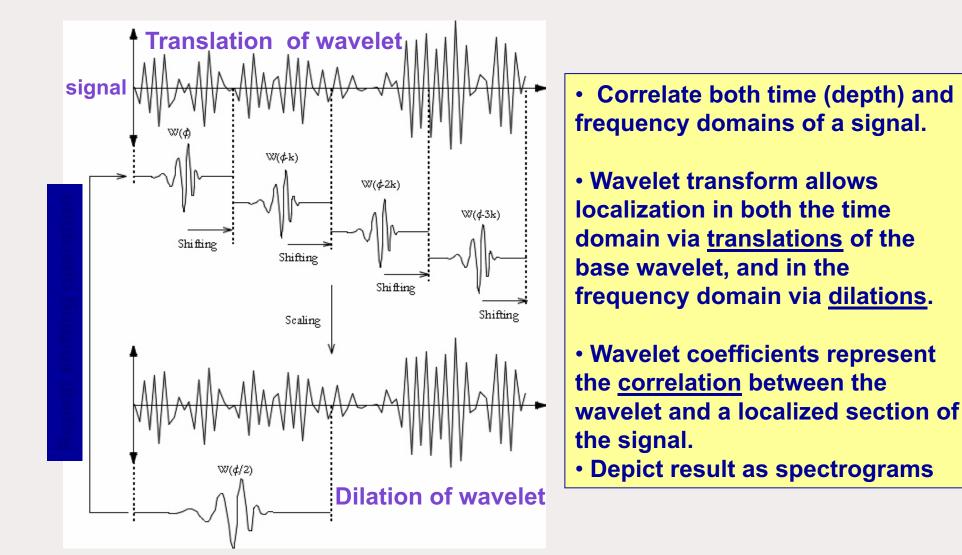
84.1 ft – Loose framework of small (~.2 to 0.5microns) fecal pellets in probably burrows. EDAX images to left show higher concentrations of carbon and lower silicon in pellets. Presence of infauna support oxygenation in the "regressive" portion of sequence.

#### Preliminary cyclostratigraphic analysis of the natural gamma ray log for the the Current #1 using wavelet transforms

Upper Caney Shale (Chesterian) exhibits a broad bandwidth cyclicity characteristic of the Pennsylvanian ranging from <6 ft- to around 12 ft-long periods. The presence of these high-frequency cycles correspond with unequivocal, long-term glacioeustacy of the upper Carboniferous.



#### **Wavelet Basics**



#### Summary:

- 1. Late Devonian- to Chesterian-age basinal shale-rich strata are increasingly important domestic unconventional oil and gas reservoirs.
- Extending resource development in the greater Anadarkao-Arkoma-Ft. Worth foreland basins from coreproducing areas requires an understanding of spatial variations of critical shale properties.
- . A classic interaction of major global and regional processes appears to be responsible for these new hydrocarbon resources including recurring basin anoxia, long- and short-term changes in eustacy, climate change, differential sedimentation and basin subsidence, spatial-temporal changes in fault system dynamics, and strong diagenetic
- 4. Stratigraphic analysis, namely establishing temporally distinct depositional sequences, is critical to mapping the distribution of favorable reservoir rocks. The preliminary analysis thereof for the KGS-OGS Current #1 corehole
- 5. Depositional sequence analysis once conducted on a regional level as proposed in an extended coring program from shelf-to-basin should provide the means to establish a high-resolution paleogeography.
- 6. Sequence stratigraphic interpretations and paleogeographic reconstructions substantiated with biostratigraphic, paleoecologic, geochemical, and chronostratigraphic information from strategic coring sites integrated with conventional analytical data about the resource (e.g., Rock Eval, gas desorption, rock properties) should help establish additional oil and gas resources.
- The extent of these unconventional oil and gas resources onto the surrounding shelf margins during episodes involving expanding anoxia and upwelling and increased organic productivity has yet to be delineated and is an outcome sought in this ongoing investigation.
- 8. Integration with global processes active in creating these oil and gas resources should aid in extending these results to other basins worldwide.
- 9. This approach to studying shale resources parallels those of modern characterization of conventional reservoirs

#### and, in fact, will aid in resolving long-standing correlations both regional and global.

#### REFERENCES CITED

Averbuch, O., Tribovillard, N., Devleeschouwer, X., Riquier, L., Mistiaen, B. and Van Vliet-Lanoe, B., 2005, Mountain building-enhanced continental weathering and organic carbon burial as major causes for climatic cooling at the Frasnian-Famennian boundary (c. 376 Ma)?: Terra Nova, v. 17, p. 25-34.

Buggisch, Werner, 1991, The global I Frasnian-Famennian Kellwasser Event: Geologische Rundschau, v. 80,

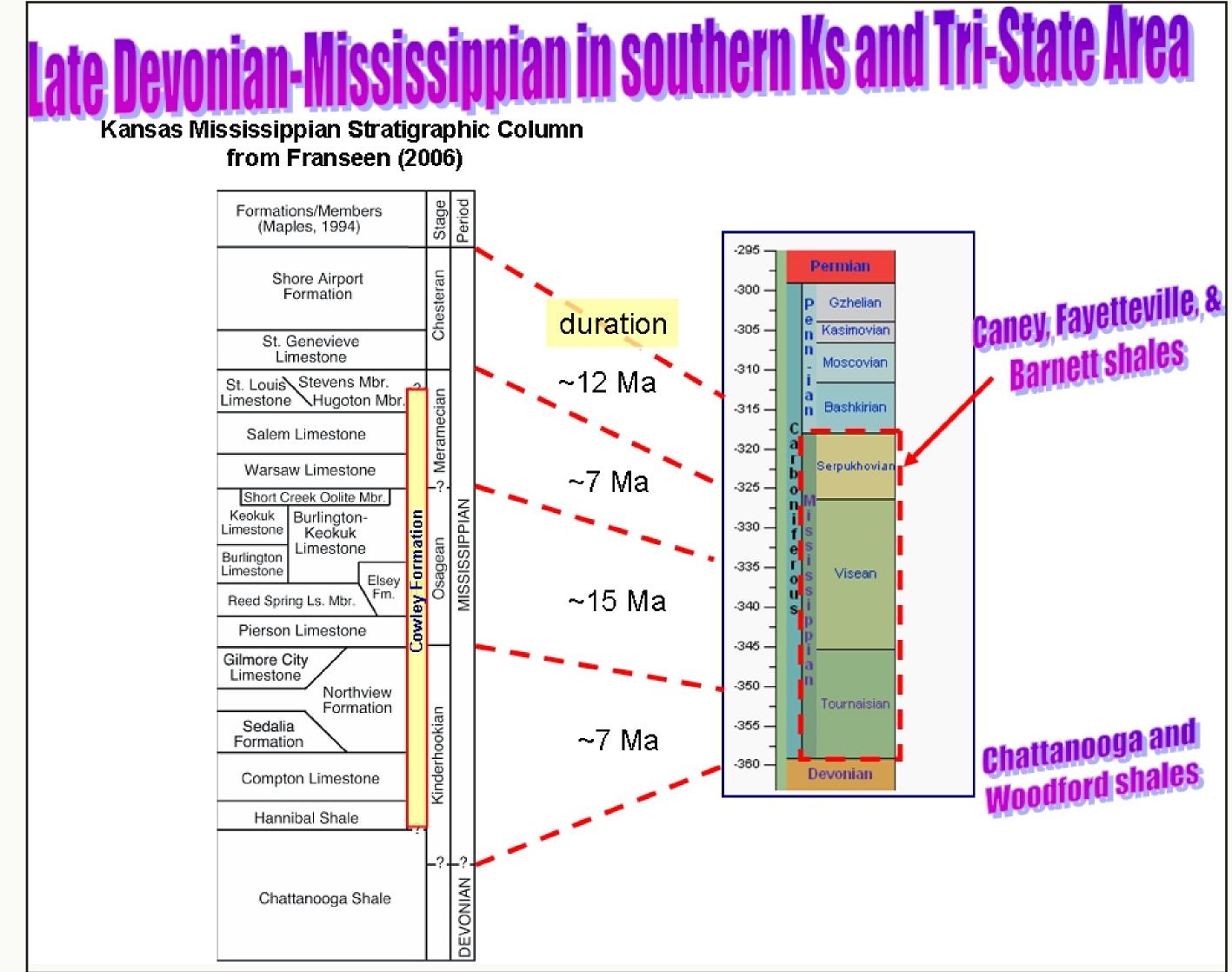
Johnson, J. G., Klapper, G. & Sandberg, C. A. 1985. Devonian eustatic fluctuations in Euramerica: Geological Society of America Bulletin, v. 96, p. 56787. Ross, C.A., and Ross, J.R.P., 1987. Late Paleozoic sea levels and depositional sequences. In: Timing and Depositional History of Eustatic Sequences: Constraints on Seismic Stratigraphy (edited by Ross, C.A., and Haman, D.), Special Publications - Cushman Foundation for Foraminiferal Research, v. 24: p. 137-149.

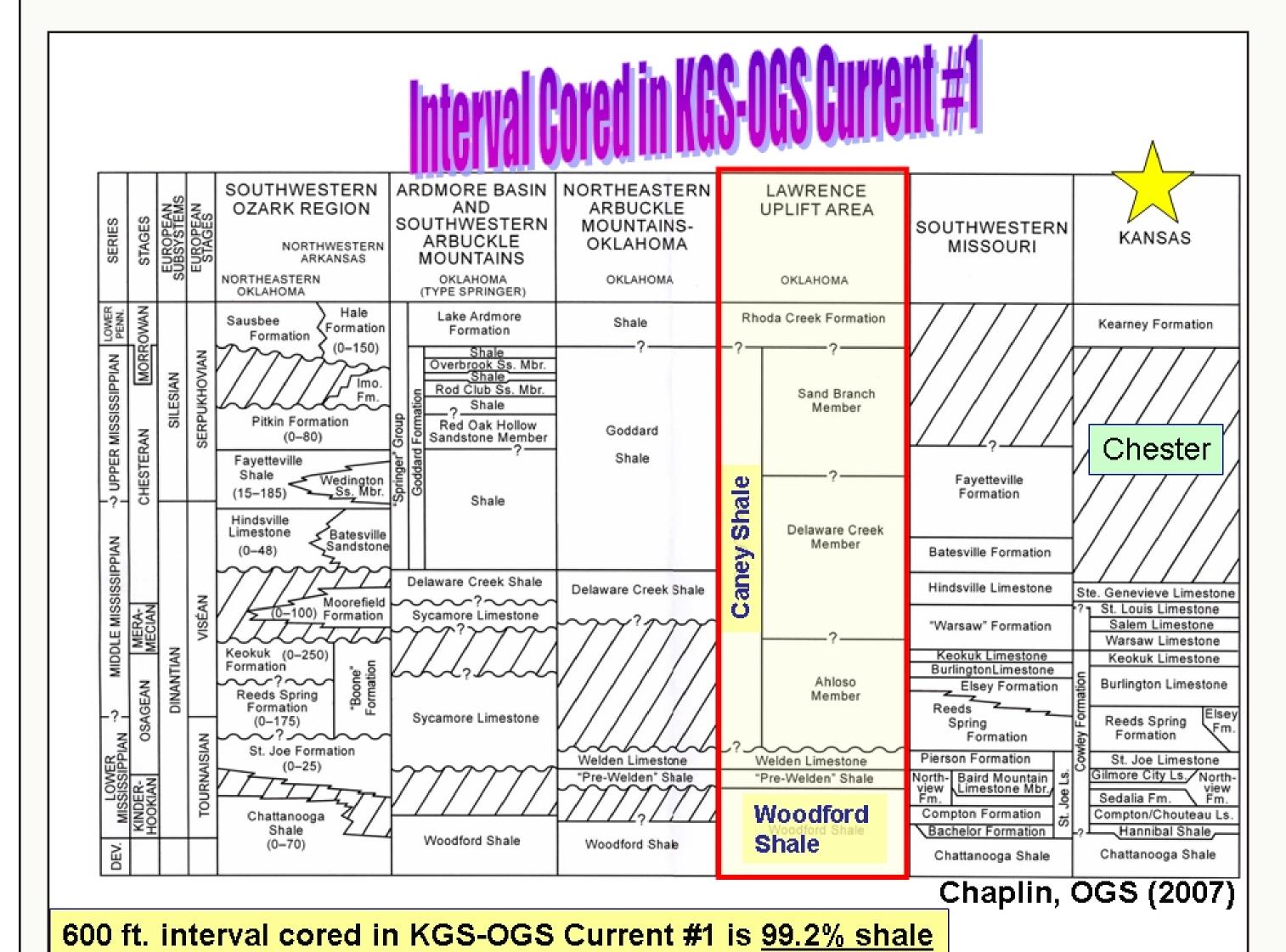
Turgeon, T.C., Creaser, R.A., Algeo, T.J., 2007, ReOs depositional ages and seawater Os estimates for the FrasnianFamennian boundary: Implications for weathering rates, land plant evolution, and extinction

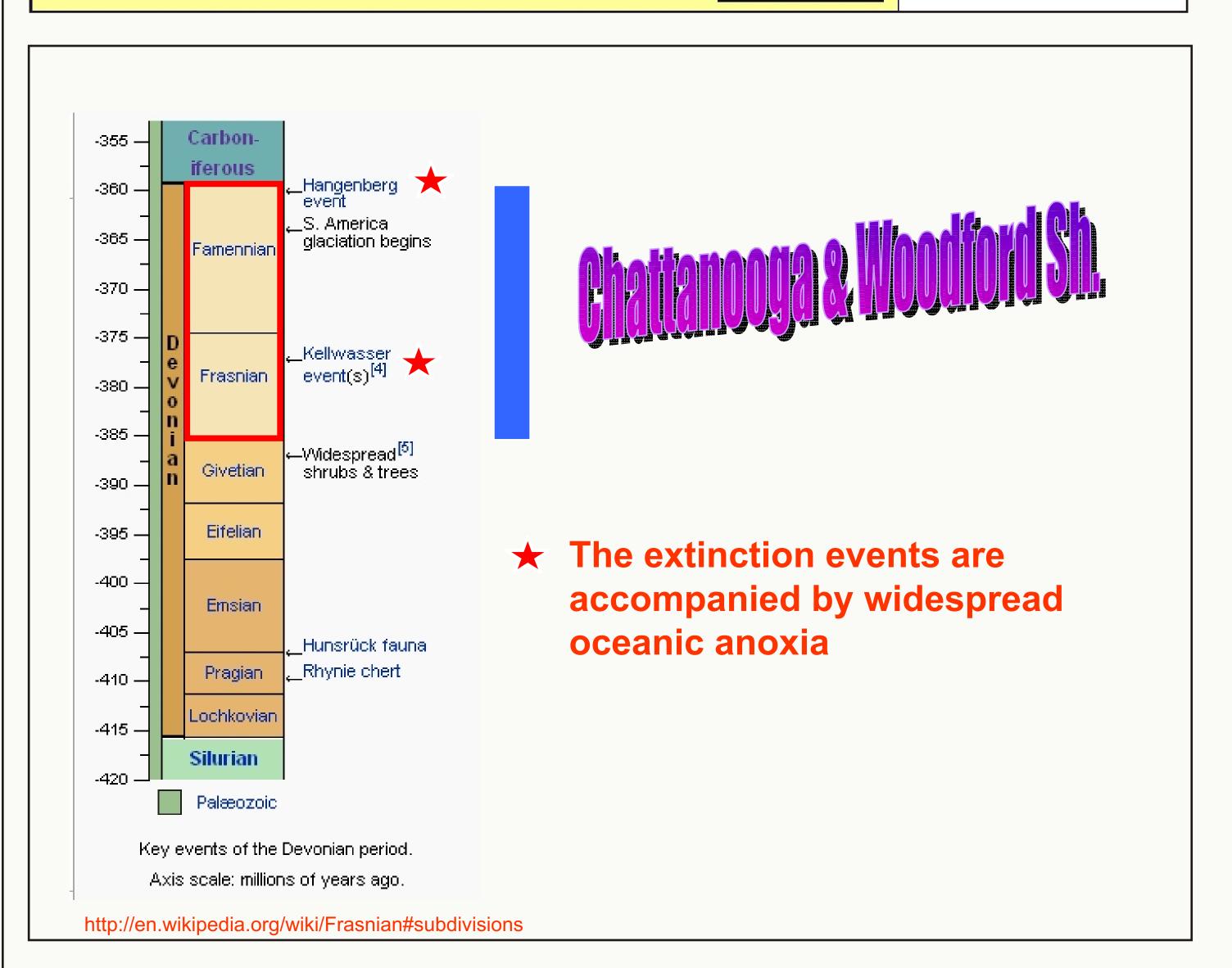
mechanisms: Earth and Planetary Science Letters, v. 261, p. 649-661.

Ongoing analysis of the KGS-OGS Current #1 corehole Current #1 corehole 10th degree Gamma Ray (total U+K+Th) **Total Miss-Upper Devonian interval (600 ft)**  thin sections and SEM Unit depth = 0.1 ft conodont biostratigraphy - taxonomy and abundance = sampling rate of chemostratigraphy (Sr,/carbon, boron)₩ · XRF and wet chemistry for metal

# Stratigraphic Interval Under Investigation Lack definitive correlations between shelf and basin. Lack of correlations and understanding stratal geometries along the shelf margin impede development of a robust sequence stratigraphic framework and related high-resolution paleogeography and resource characterization.

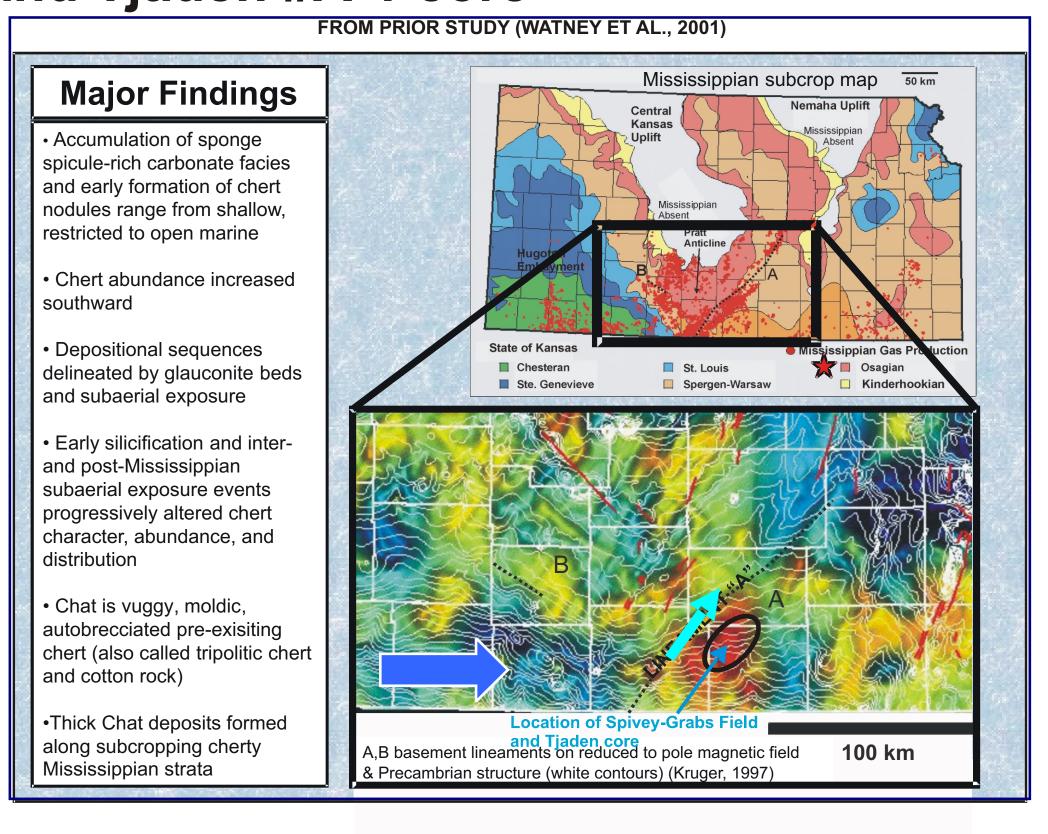


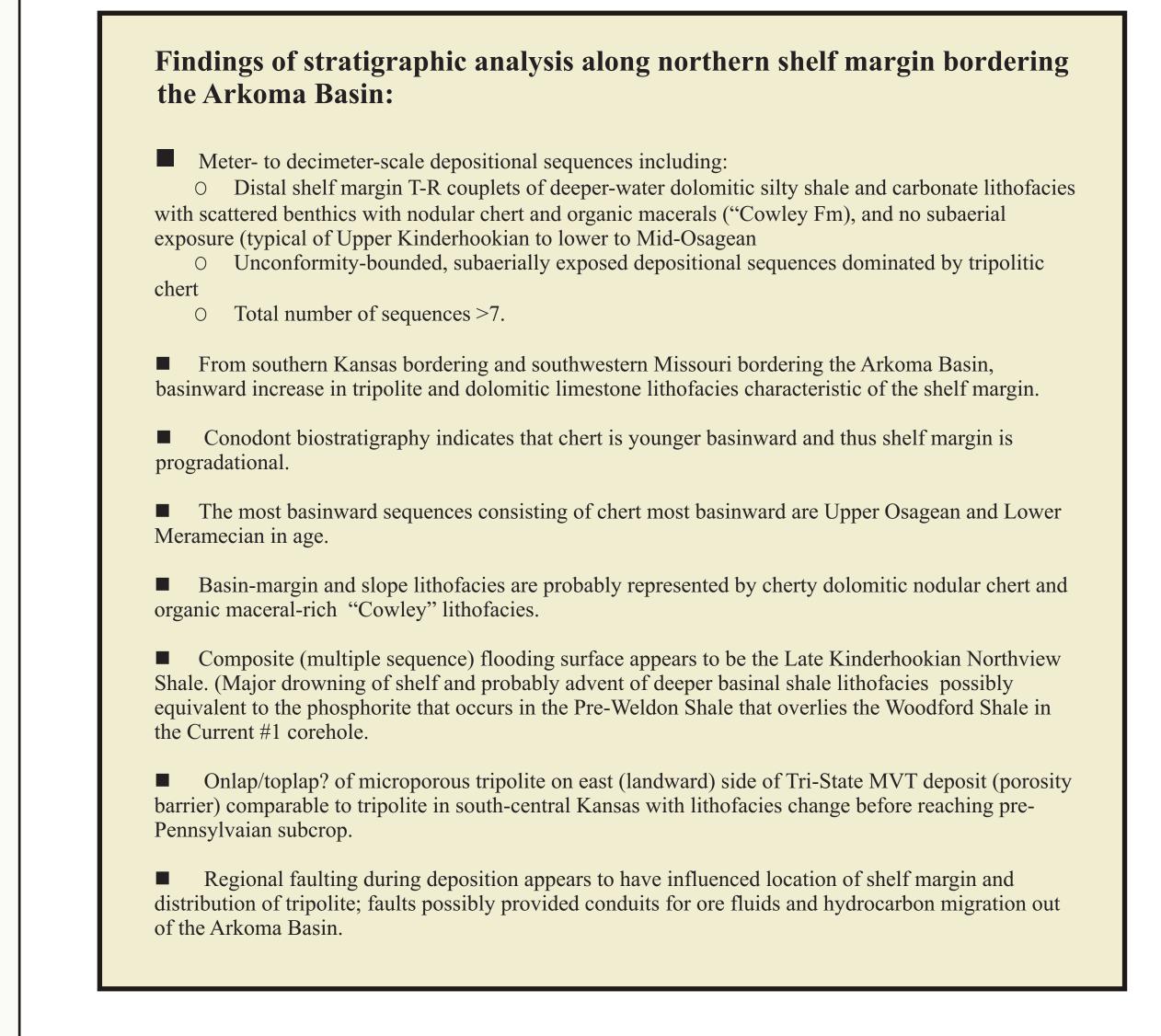


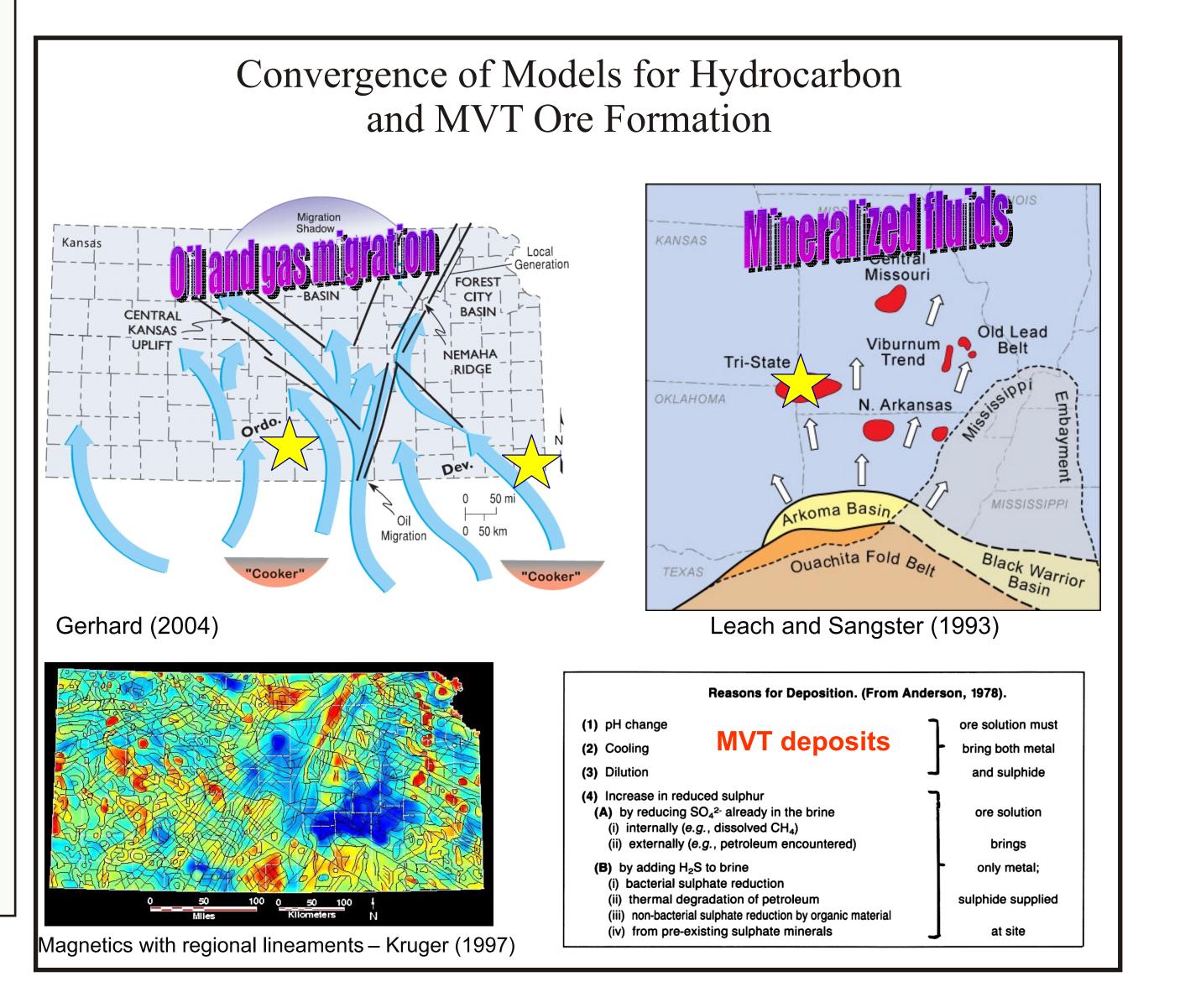


#### South Central Kansas Shelf Margin

#### Shelf margin example, Spivey-Grabs Field and Tjaden #A-1 core







#### Depositional sequences in tripolitic chert shelf margin lithofacies – northern shelf margin of Arkoma Basin, southern Kansas and Tri-State region

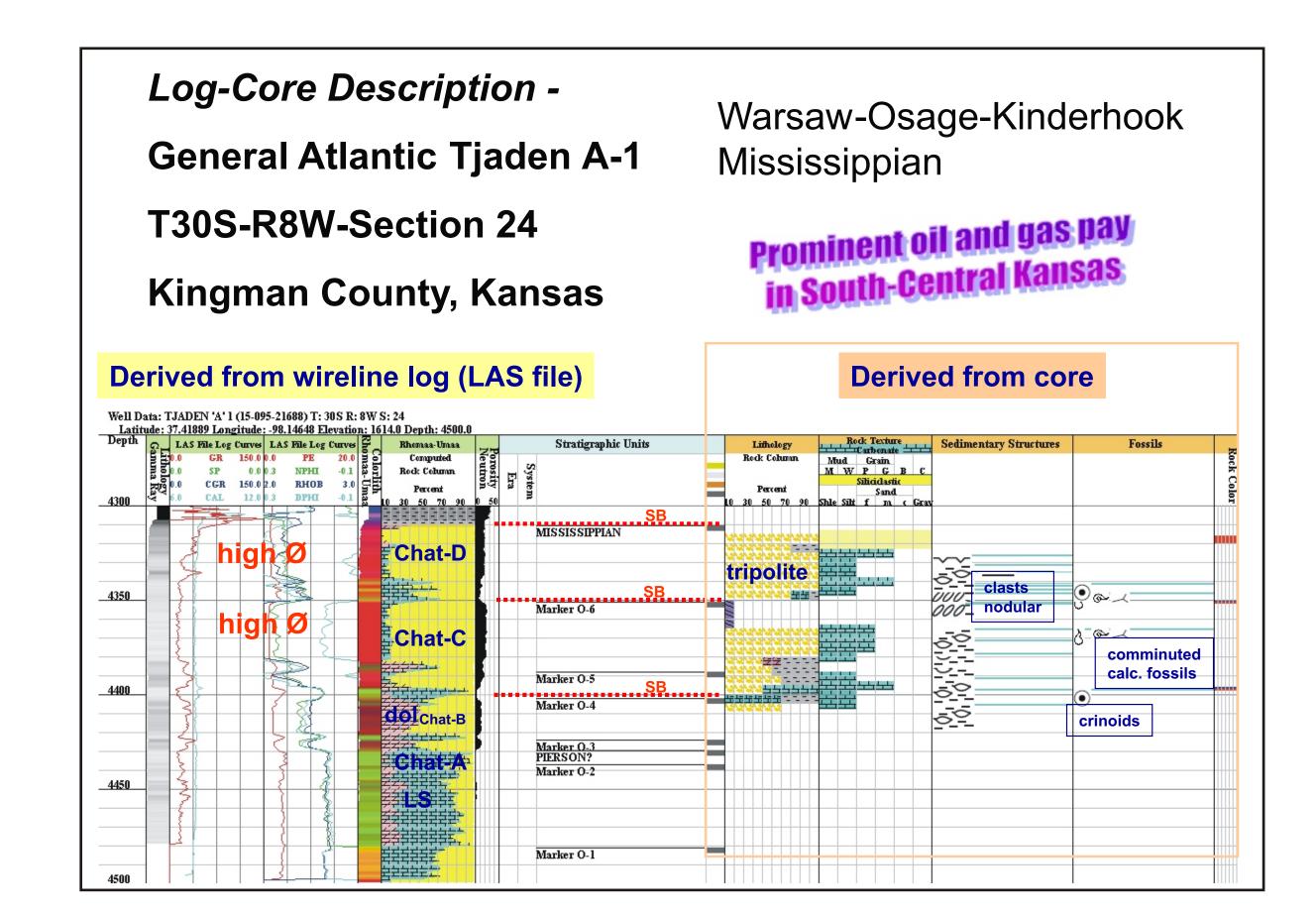
• Tjaden core in Barber County, south central Kansas (below)

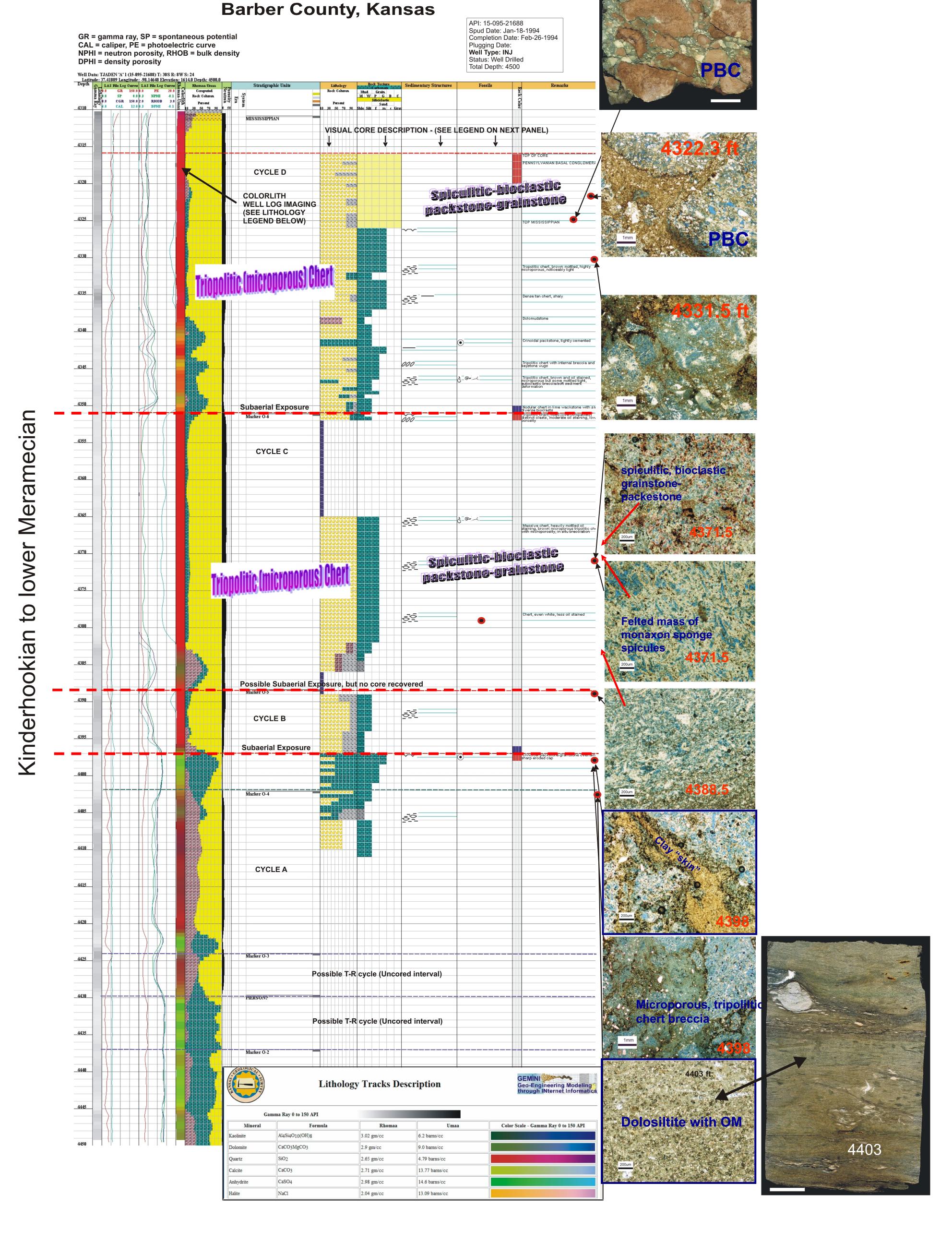
Log-Core Description -

T30S-R8W-Section 24

General Atlantic Tjaden A-1

• Series of complete Devonian-Mississipppian coreholes in Cherokee County, adjoining Tri-State Pb-Zn deposits (cross section to right)





#### Tri-State Area (KS-MO-OK) Shelf Margin

