Woodford Shale: Correlating Rock Properties in Outcrop and Core with Wireline Log Characteristics*

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Abstract

The Devonian-Mississippian (Frasnian-Tournaisian) Woodford Shale in the southern Midcontinent region was examined in core and outcrop to document changes in composition and the effects of these changes on wireline log responses. Outcrops examined include the McAlister Cemetery shale pit near Overbrook, OK on the Criner Hills Uplift, Interstate 35 outcrops on the north and south flanks of the Arbuckle Mountains, Wapanucka shale pit on the margin of the Tishomingo Anticline, Scratch Hill novaculite outcrop near Atoka, Oklahoma, in the frontal fault zone of the Ouachita, Mountains, and the Jane, Missouri, outcrop on the Ozark Uplift. Cores examined include the near-outcrop KGS-OGS Current #1 core from the Lawrence Uplift near Ada, Oklahoma. Wireline logs from nearby wells of various ages were compared to outcrop and core gamma-ray curves to increase confidence in correlations. In addition to gamma-ray curves, resistivity/microresistivity, spontaneous potential (SP), caliper, photoelectric index (PE) and porosity responses were examined. In the Ozark Region, the lack of nearby wireline logs prevented the calibration of outcropping Woodford (Chattanooga) Shale log curves. In some areas, correlation was achieved using the top of the Woodford Shale or a distinct highly radioactive subunit as datum. Correlation from the top down was necessitated by discrepancy in shale thickness, as it thins in intrafluves and lacks additional subunits that occur in paleovalleys. Properties of the Woodford Shale that affect log response were documented, including the relative percentage of chert, concentrations of U, Th and K, phosphate, carbonate cement, silt and clay. Of these, the percentage of silicified shale or "chert" was easiest to track and recognize on wireline logs. In vintage logs, cherty sections tended to coincide with negative deflection of the SP curve and permeability as indicated by positive separation of microresistivity curves. Modern logs exhibit changes in neutron porosity and PE measurements that may indicate chert-rich or clay-rich sections. In areas without bedded chert, increased silt content and phosphate also appear to impact neutron-porosity values.

Selected References

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Woodford Shale: Correlating Rock Properties in Outcrop and Core to Wireline Log Characteristics

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Problem: what we are trying to learn

Devonian-Mississippian (Frasnian, Famennian & Tournaisian) Woodford Shale, Woodford (Chattanooga) Shale and Arkansas Novaculite all contain organic-rich, dark shale and various amounts of chert, silt and phosphate.

Because the composition of the Woodford Shale changes, the log response should be affected.

Where composition affect brittleness, the resultant natural fractures enhance reservoir properties, increase fluid content and affects log signatures.

Objectives

Examine and describe the Woodford Shale in selected outcrops and cores and compare composition to well-log responses.

If a predictable response to any one or combination of constituents is established, resulting rock properties may be estimated from wireline logs with greater confidence.

Tasks

(1) Measure and describe outcrops and cores of the Devonian-Mississippian Woodford Shale and Arkansas Novaculite.

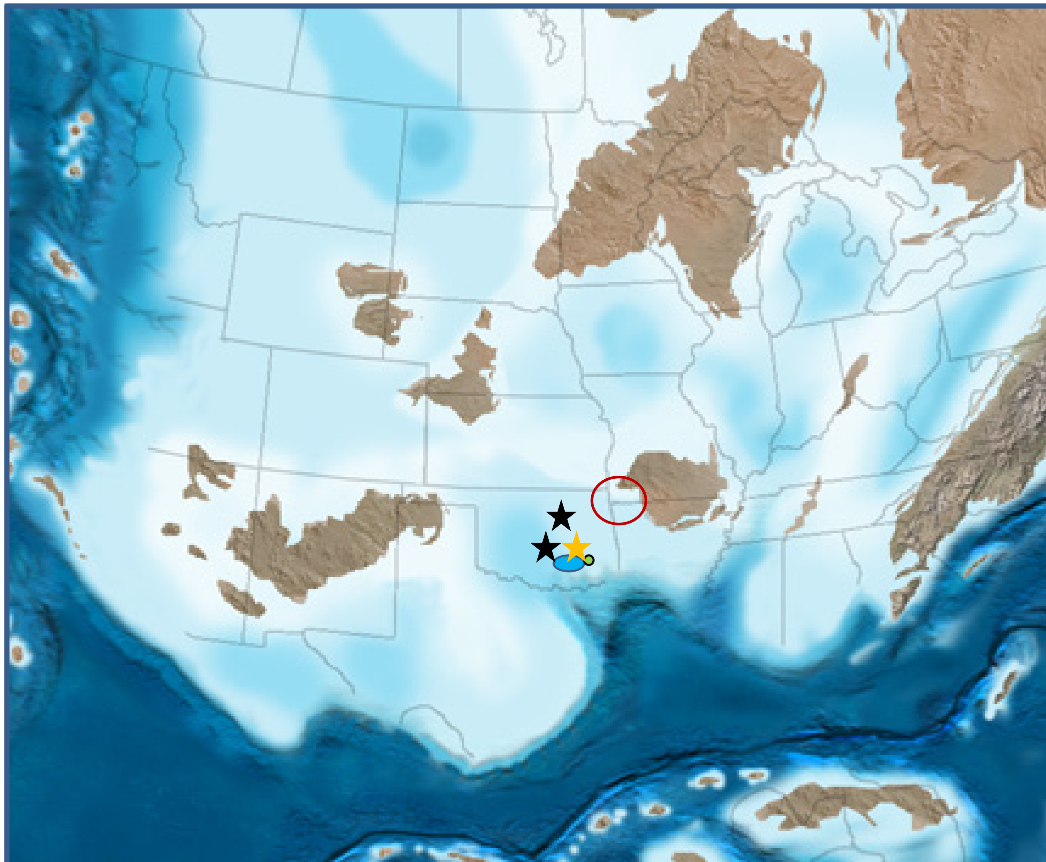
(2) Determine composition, organic content, and spectral gamma-ray signatures

(3) Plot composition and compare the impact of composition on log signatures of the Woodford in nearby wells

(4) Use these findings to develop criteria for predicting rock properties from wireline logs

Outline

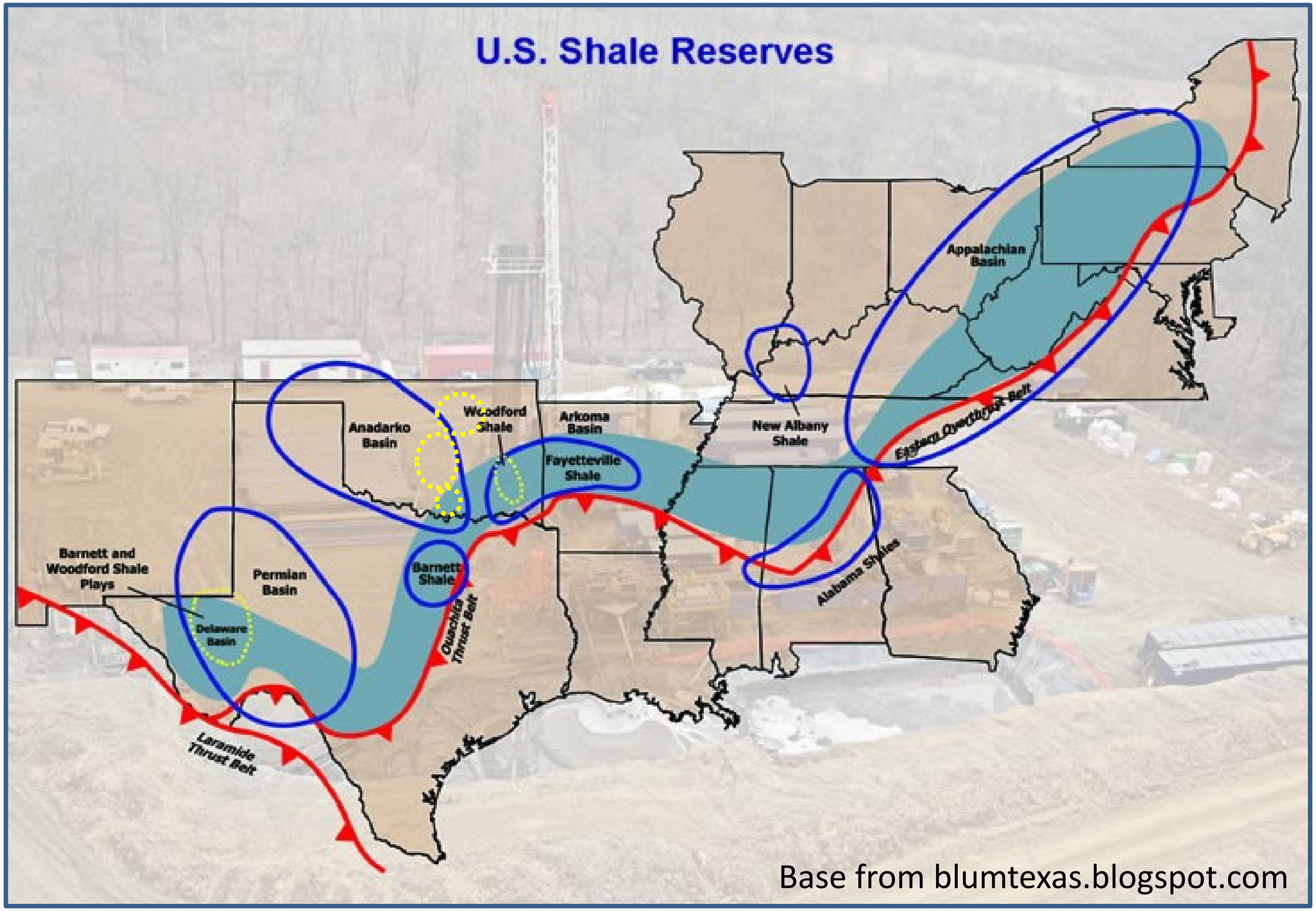
1. Introduction
2. Geologic Setting and Stratigraphy
3. Characterization of outcrops and cores
4. Comparison of outcrops and logs
5. Summary



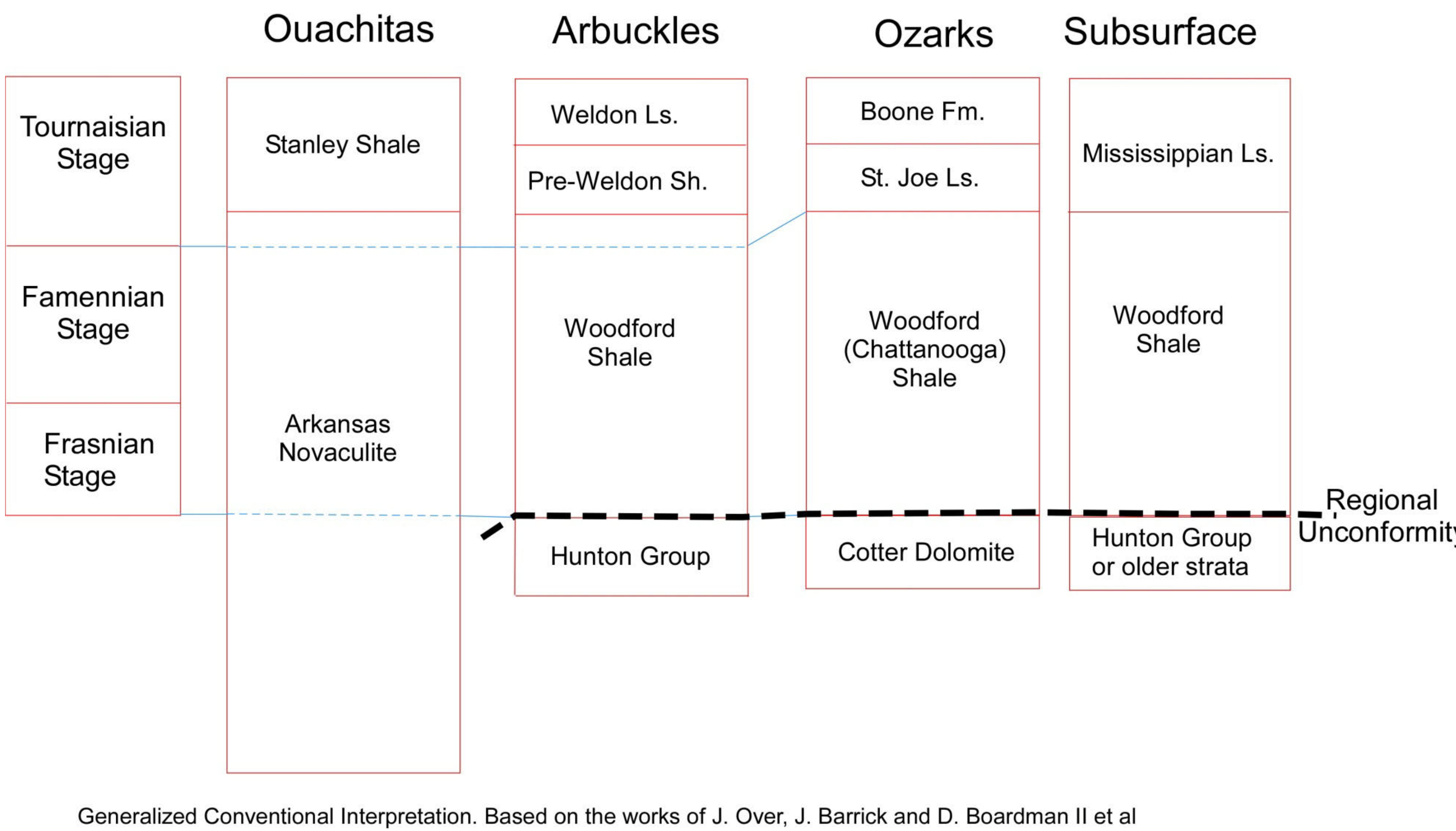
Map from R. Blakey – *cpgeosystems.com*

- Shelfward outcrops (Ozarks)
- Shelfward cores (Nemaha Ridge, Anadarko Shelf & Cherokee Platform)
- Basinward core – Current #1
- Basinward outcrops (Arbuckle Mountains, Criner and Tishomingo Uplifts)
- Basinward (Ouachita Trough) outcrops (Ouachita Frontal Fault Zone)

Late Devonian (360 mya) Paleogeography
Southern North America

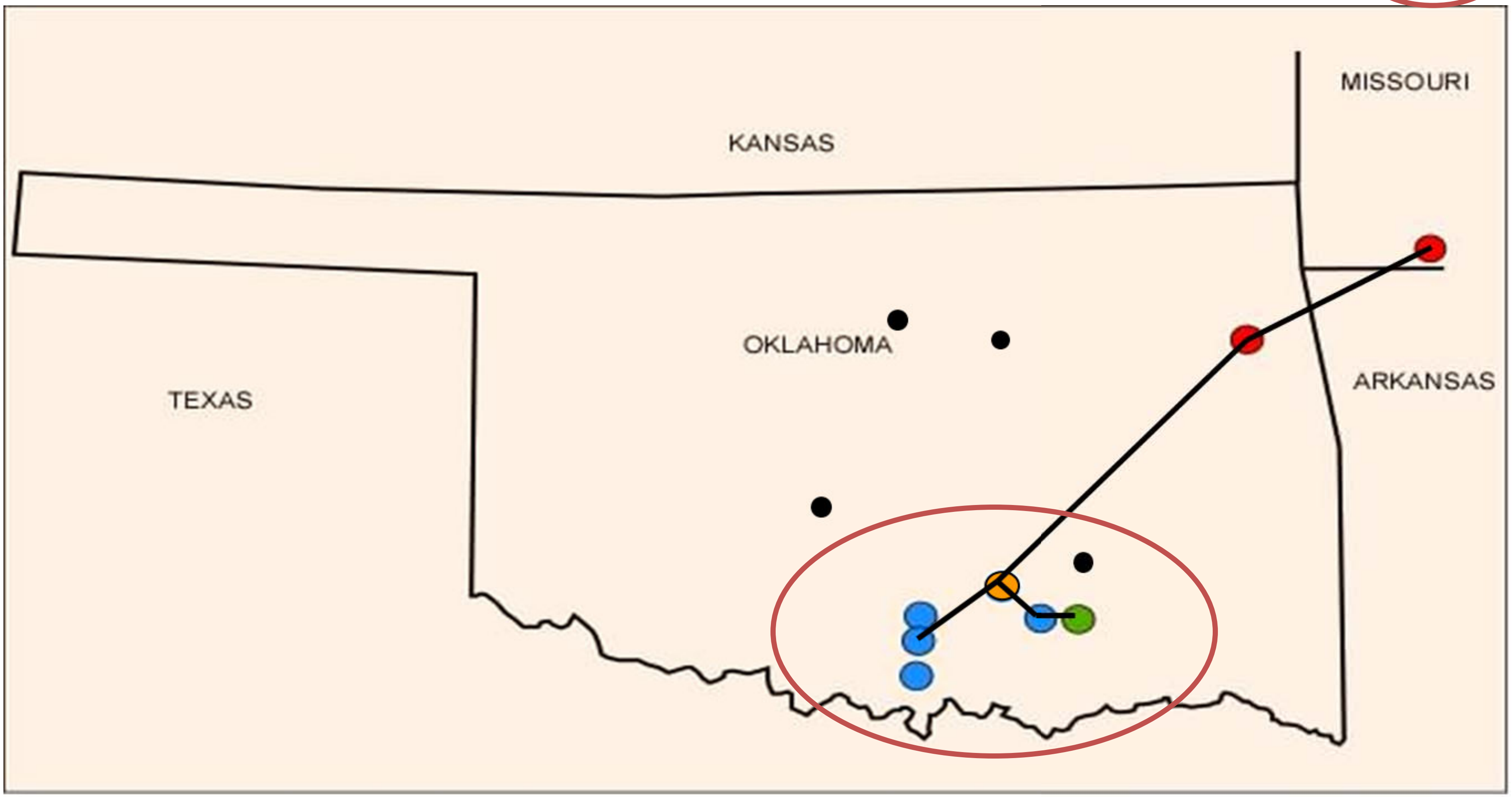


Woodford Shale Plays: Arkoma, Anadarko, Marietta-Ardmore and Permian Basins, and North-Central Oklahoma

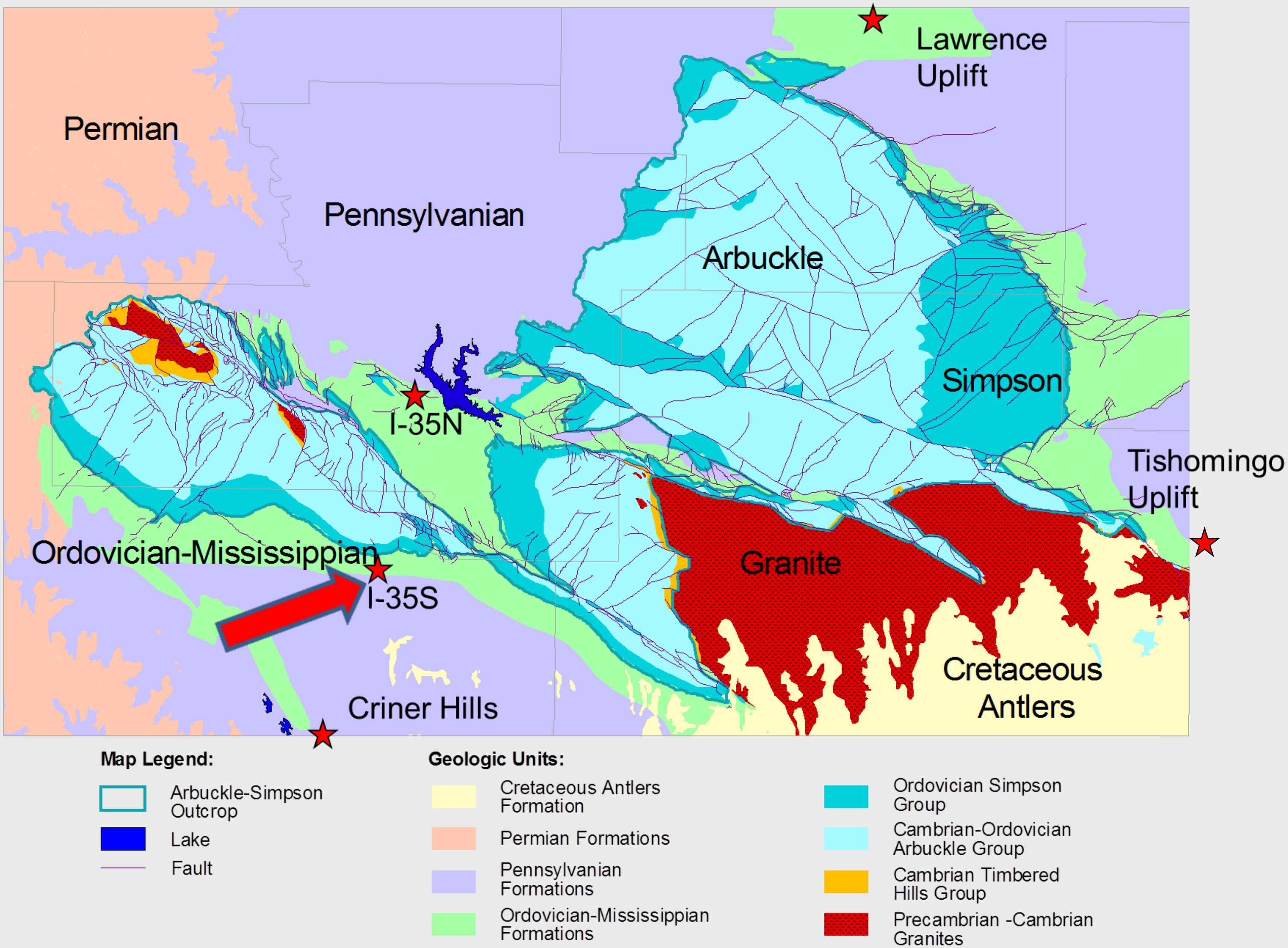


Generalized Regional Stratigraphy of the Woodford Shale

Locations of Outcrops and Cores Used in this Study



Southern Oklahoma: Woodford Shale –Current Core
Southern Oklahoma: Woodford - Arbuckle Mtns., Criner Hills, Tishomingo Uplift
Other cores
Ouachita Mtns. Frontal Fault Zone: Arkansas Novaculite
Ozark Region: Woodford (Chattanooga) Shale



Locations of outcrops and core from south-central Oklahoma

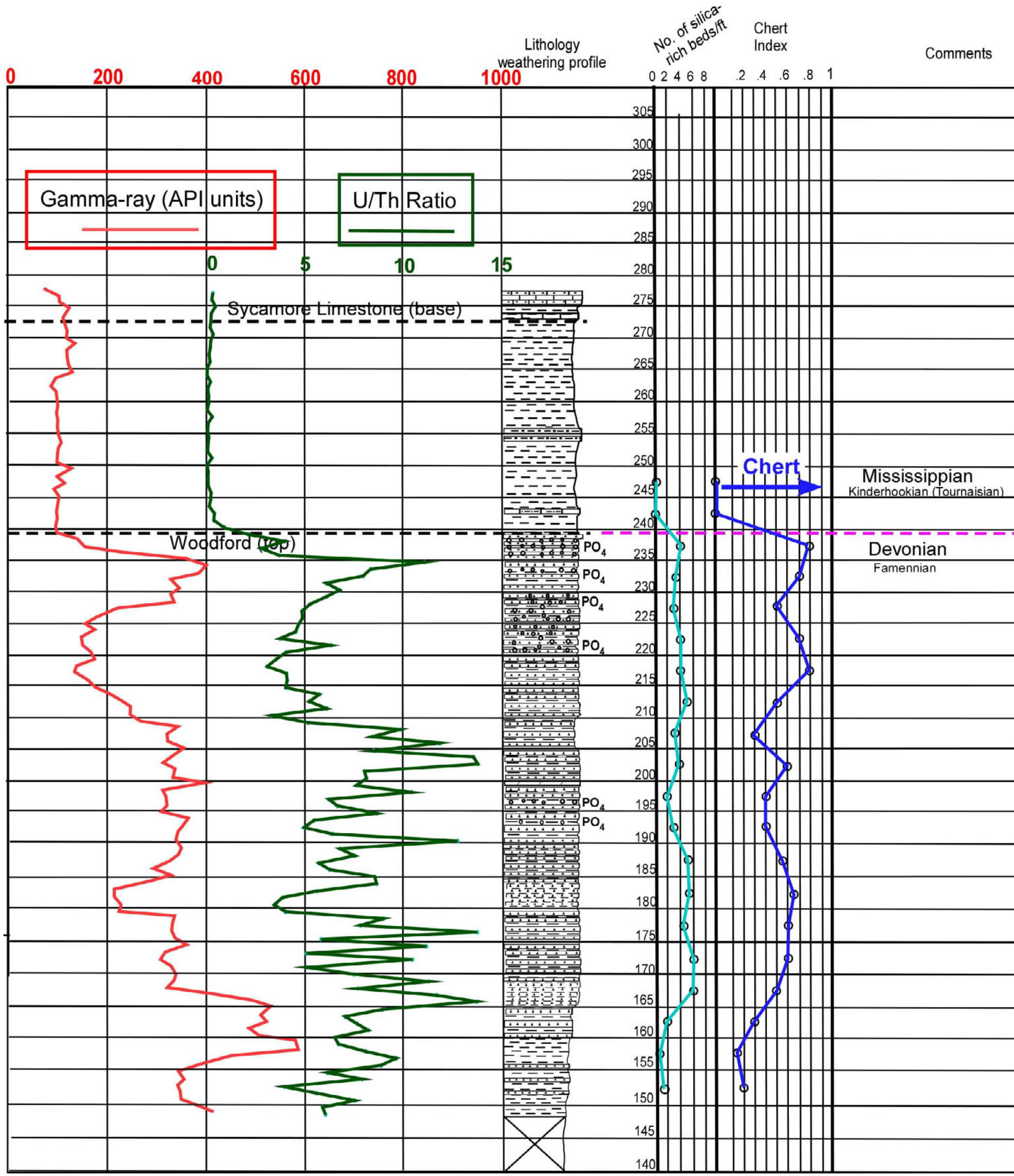
Characteristics:

- Chert-rich beds with spherical to flattened phosphate nodules
- Interbedded dark gray shale
- Abundant pyrite
- High TOC
- High Gamma-ray
- U/Th > 3.0 for dark shales
- Radiolarians abundant in cherts

Beds near the top of the Woodford, I-35 S, Arbuckle Mountains, OK

Southern Arbuckle Mountains I-35

Woodford Shale: Arbuckle Uplift, Southern Oklahoma

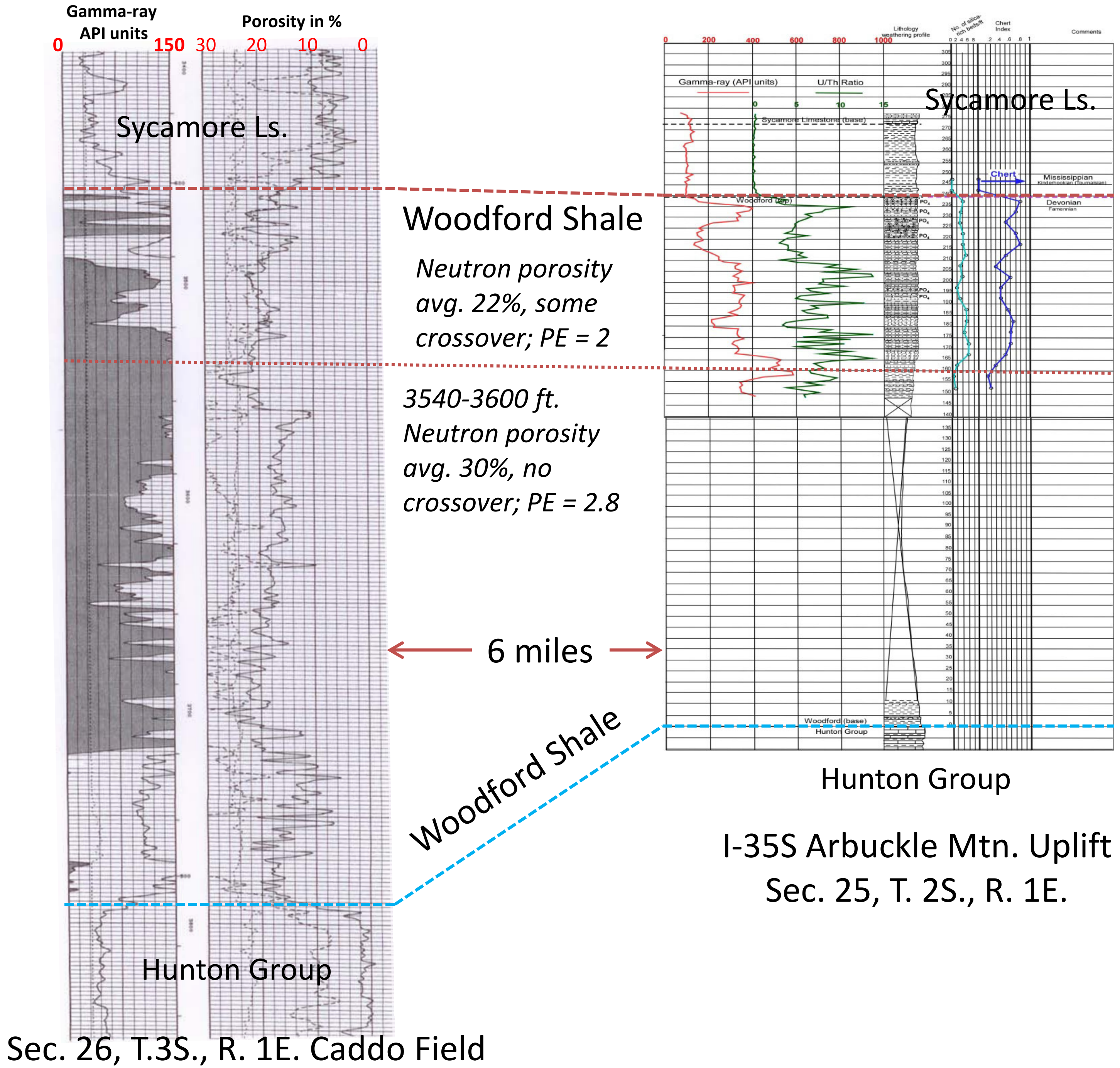


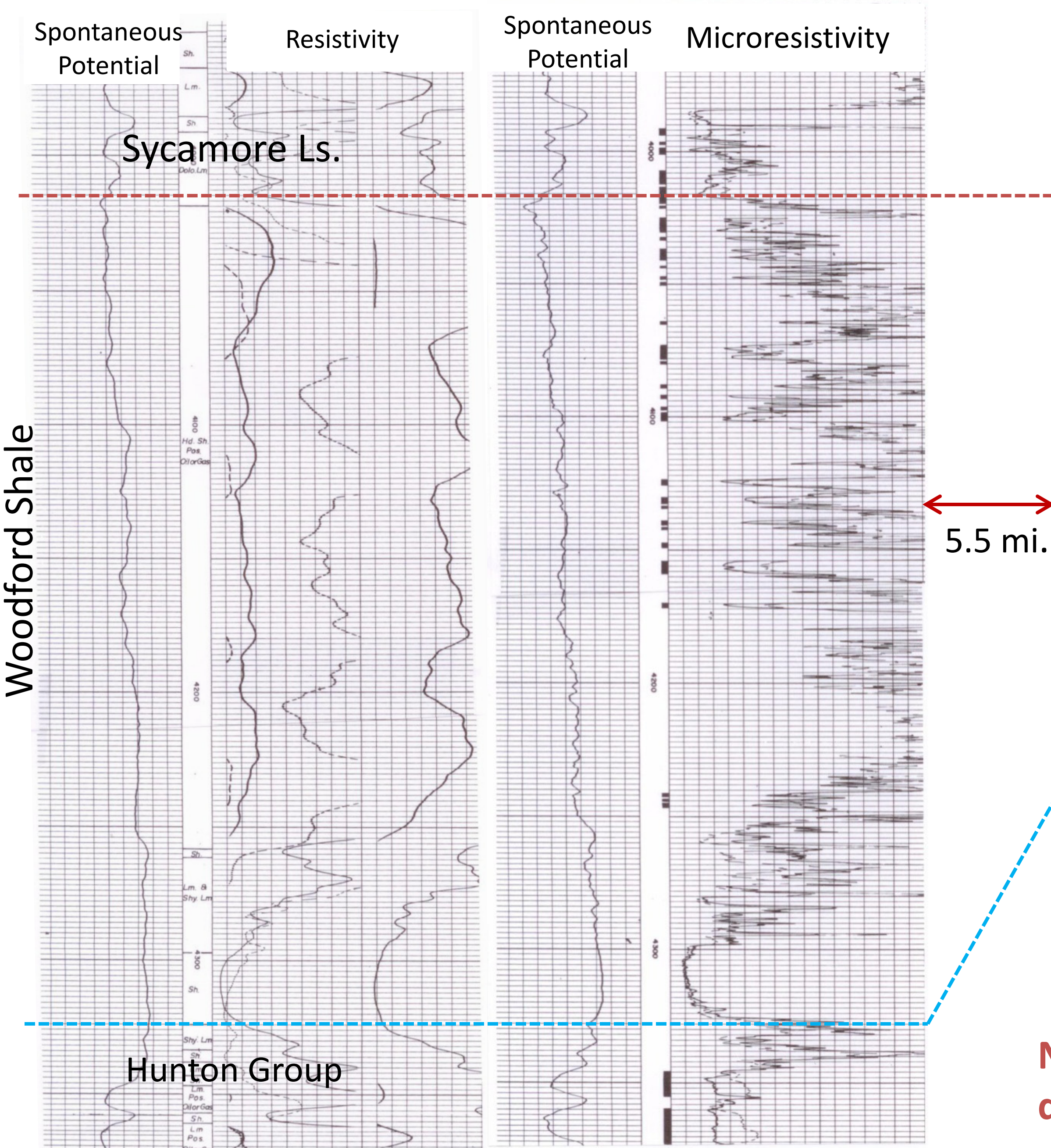
Lithologic section, total Gamma-ray, U/Th ratio and relative abundance of Chert in the upper Woodford Section, I-35S Arbuckle Uplift, Oklahoma

Chert and phosphate are absent above the Devonian/Mississippian contact.

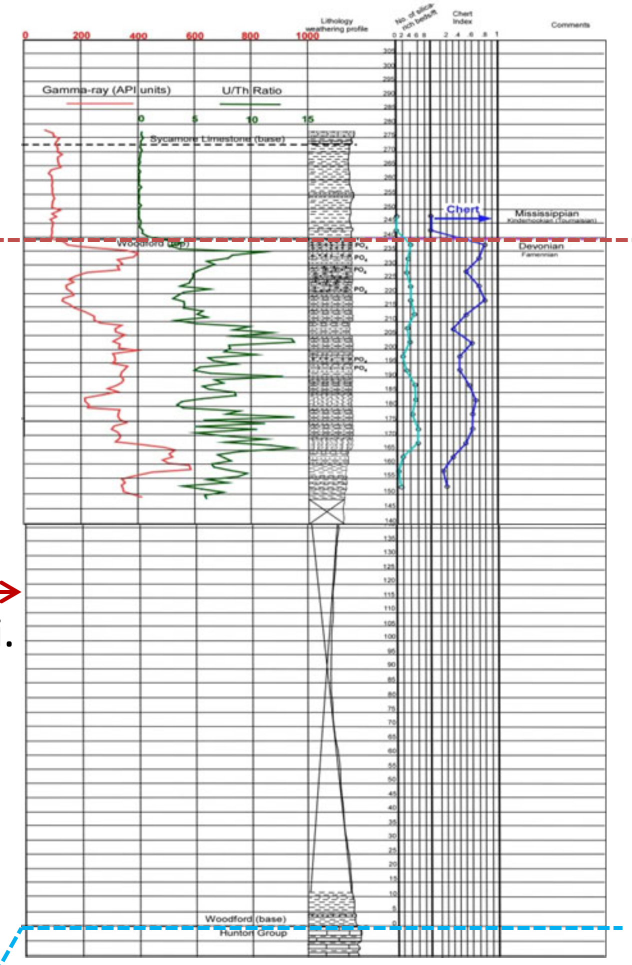
4 > U/Th < 14

Chert and phosphate are abundant below the Devonian/Mississippian contact.


Gamma-ray API units
0
150
Porosity in %
30
20
10
0
Sycamore Ls.
Woodford Shale
Neutron porosity avg. 22%, some crossover; PE = 2
3540-3600 ft. Neutron porosity avg. 30%, no crossover; PE = 2.8
6 miles
Woodford Shale
Hunton Group
Sec. 26, T.3S., R. 1E. Caddo Field
Gamma-ray (API units)
U/Th Ratio
Sycamore Ls.
Sycamore Limestone (base)
Woodford (top)
Chert
Mississippian
Devonian
Woodford (base)
Hunton Group
Hunton Group
I-35S Arbuckle Mtn. Uplift
Sec. 25, T. 2S., R. 1E.



Caddo Field: Sec. 23, T. 3S., R. 1E.
F/50 BO/1MMCF

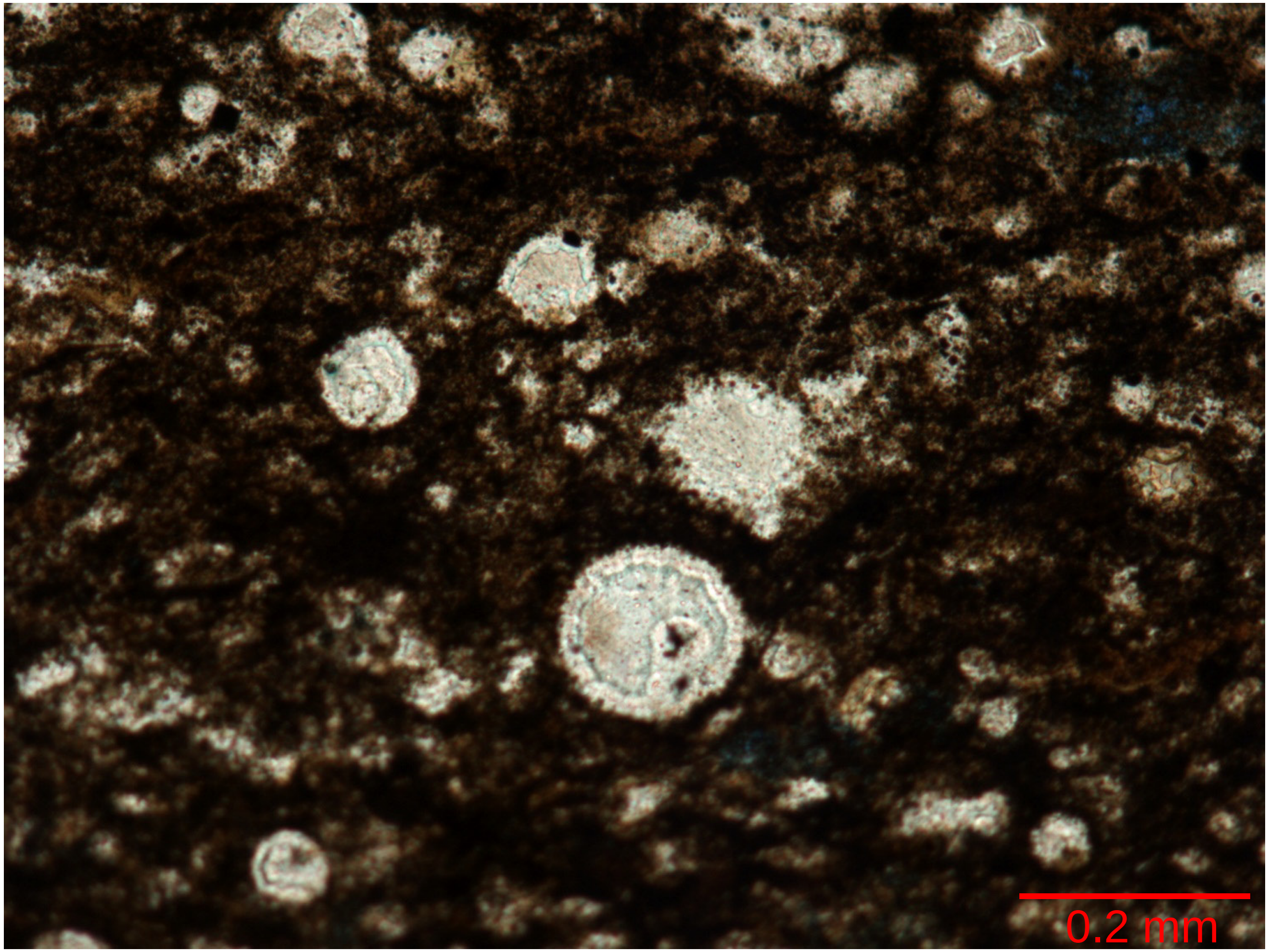


Hunton Group

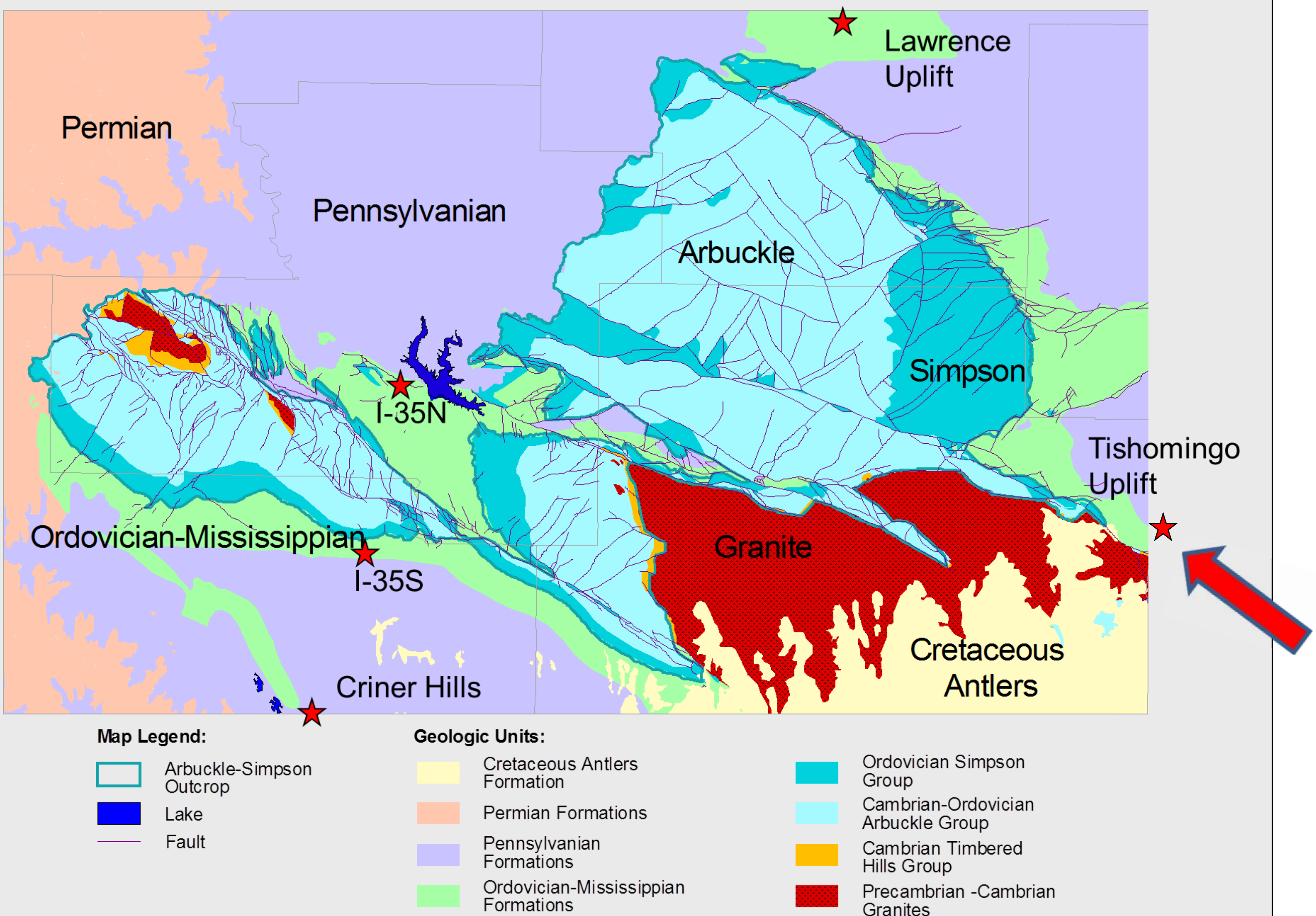
I-35S Arbuckle Mtn. Uplift
Sec. 25, T. 2S., R. 1E.

Notice subtle negative deflection of SP curve across permeable sections.

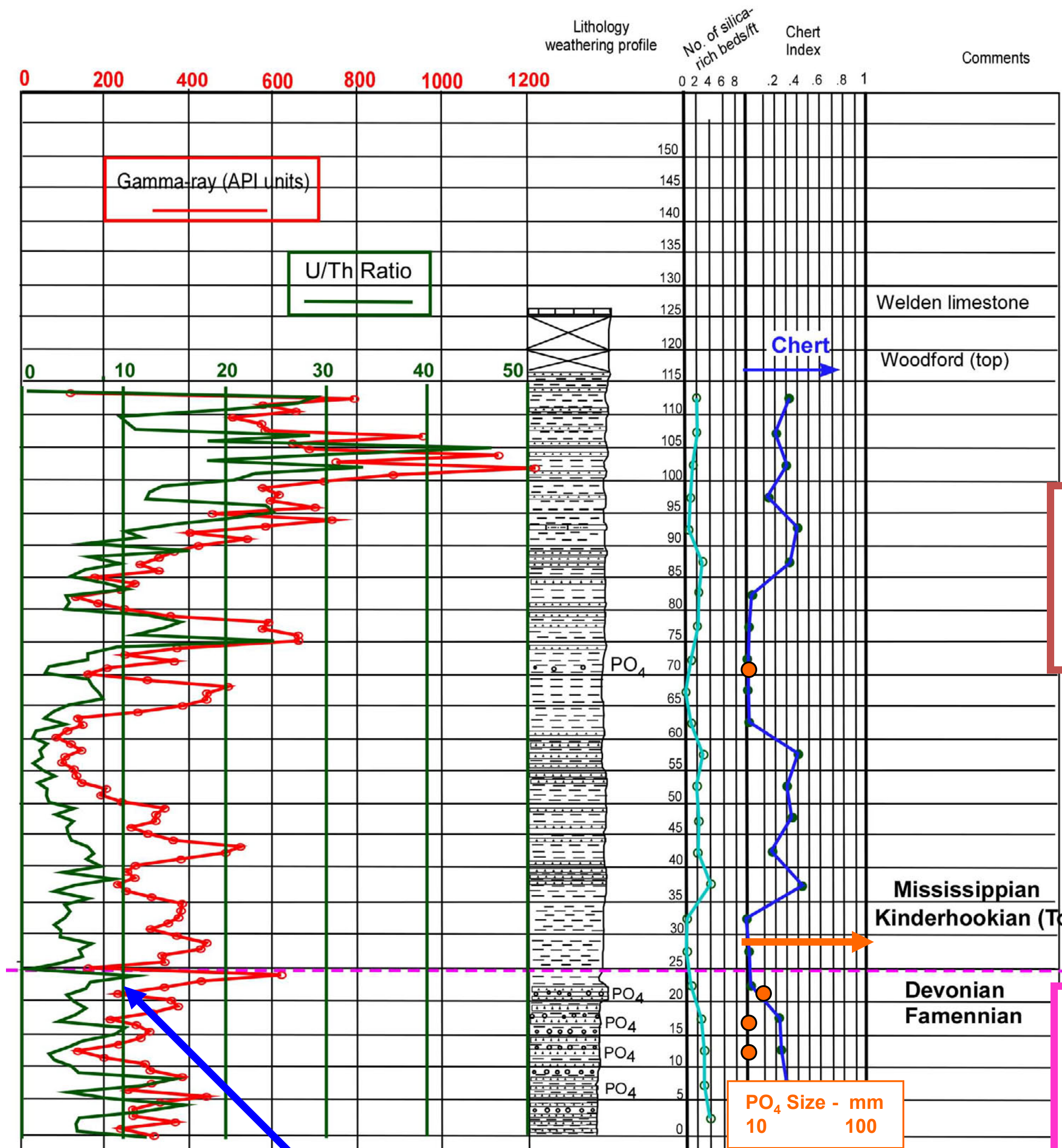
Radiolarians in Chert Bed, I-35S



Woodford Shale: Distal Shelf and Slope



Locations of outcrops and core from south-central Oklahoma



Lithologic section, total Gamma-ray, U/Th ratio and relative abundance of chert in the upper Woodford Section, Tishomingo Uplift, Oklahoma

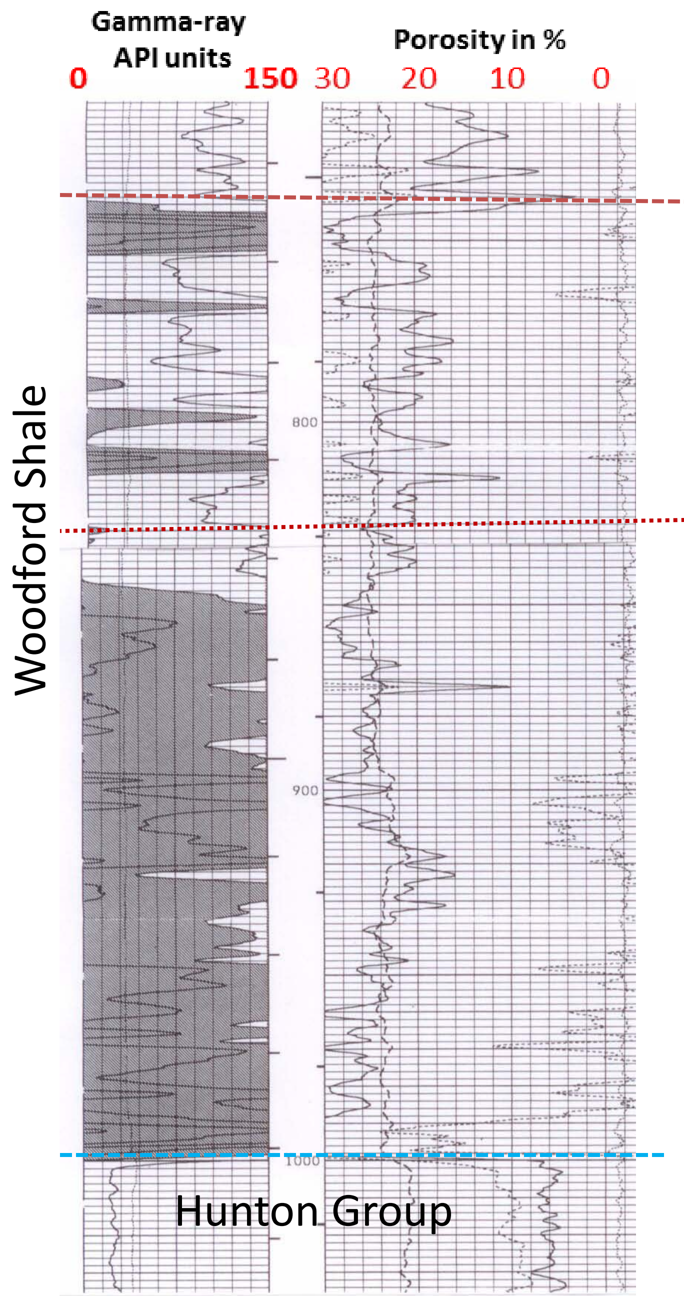
Chert and phosphate are absent for several meters above the Devonian/Mississippian contact.

4 > U/Th < 16*
*Excludes low & high values from Tournaisian interval

Chert and phosphate are abundant below the Devonian/ Mississippian contact.

Total gamma-ray plummets to 167 API units in grey transition zone between Devonian and Mississippian. U/Th concentration reverses and Th > U or U/Th < 1.0.

Tishomingo Uplift

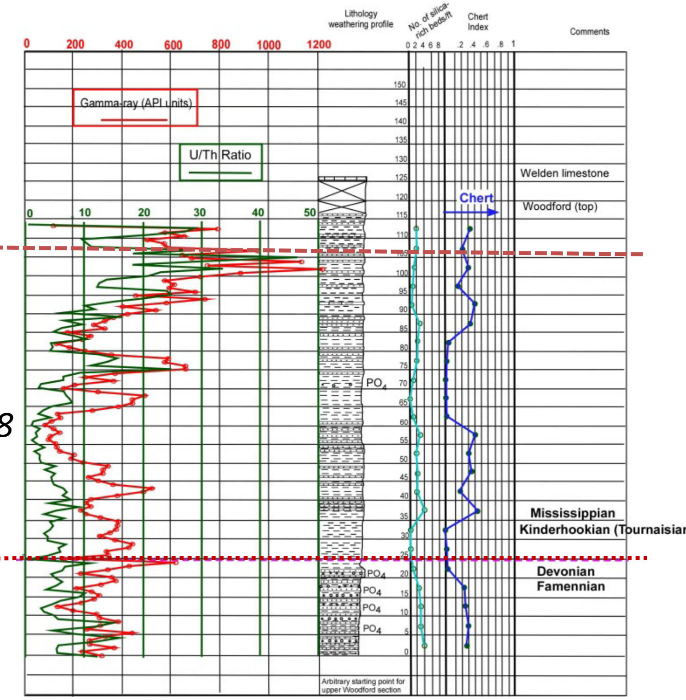


Sec. 17, T.2S., R.8E

Neutron porosity avg. 30%, PE = 2.8

Mississippian

Devonian

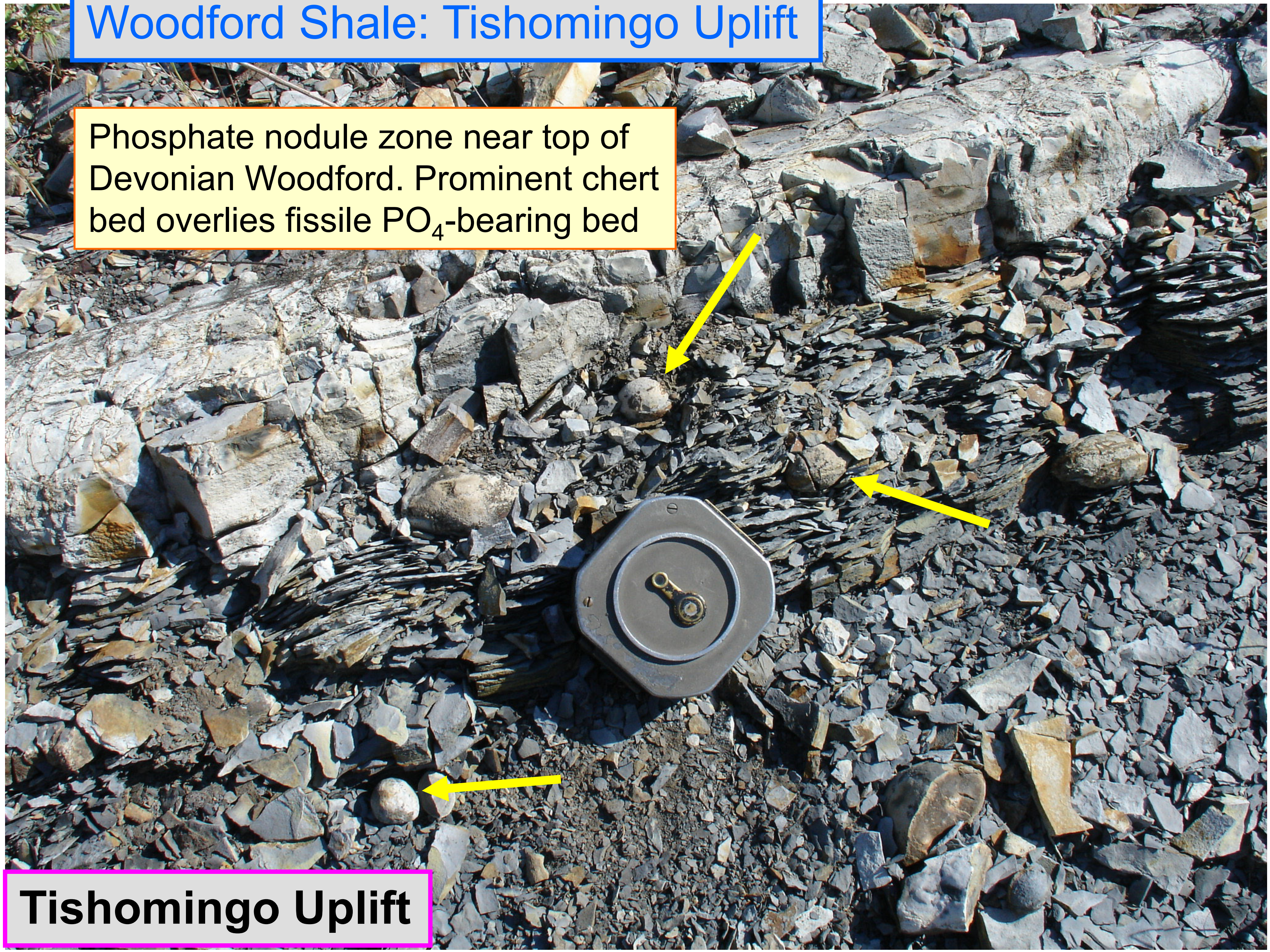


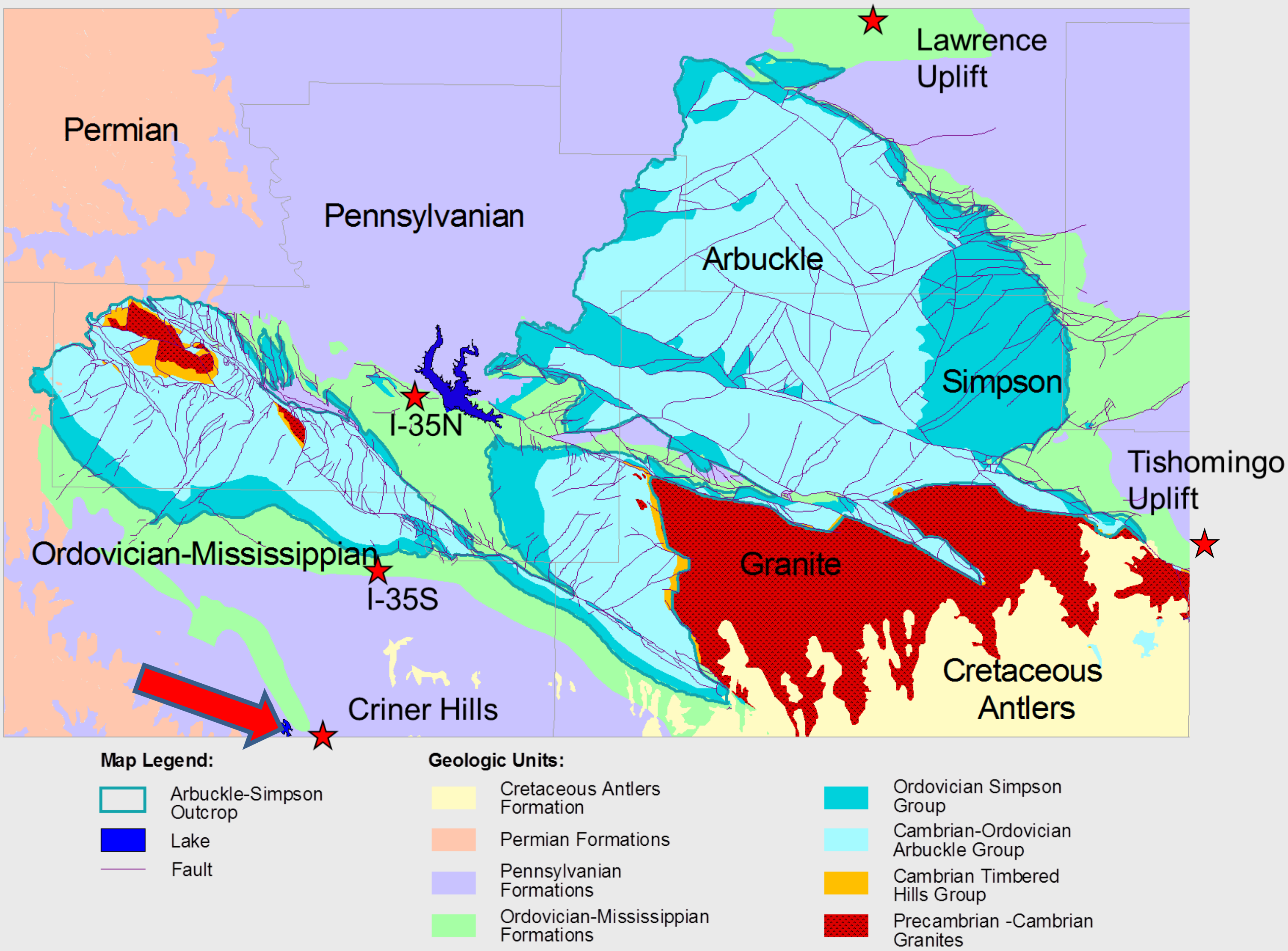
Sec. 26, T.2S., R.8E

Wapanucka Shale Pit

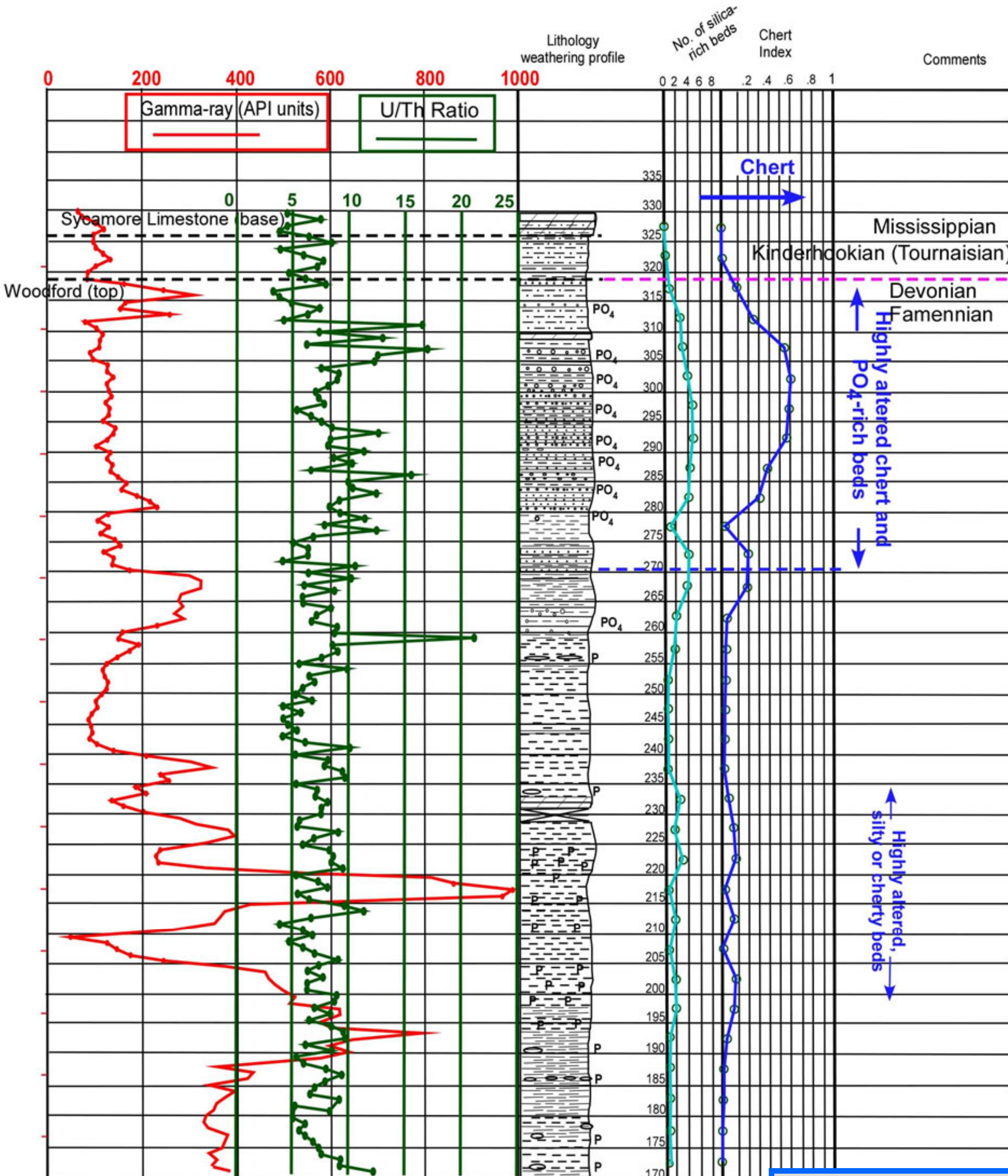
Neutron porosity continues to read >30% as chert in Mississippian Woodford Shale is not adequately abundant to reduce clay content and depress neutron log.

Woodford Shale: Tishomingo Uplift





Locations of outcrops and core from south-central Oklahoma

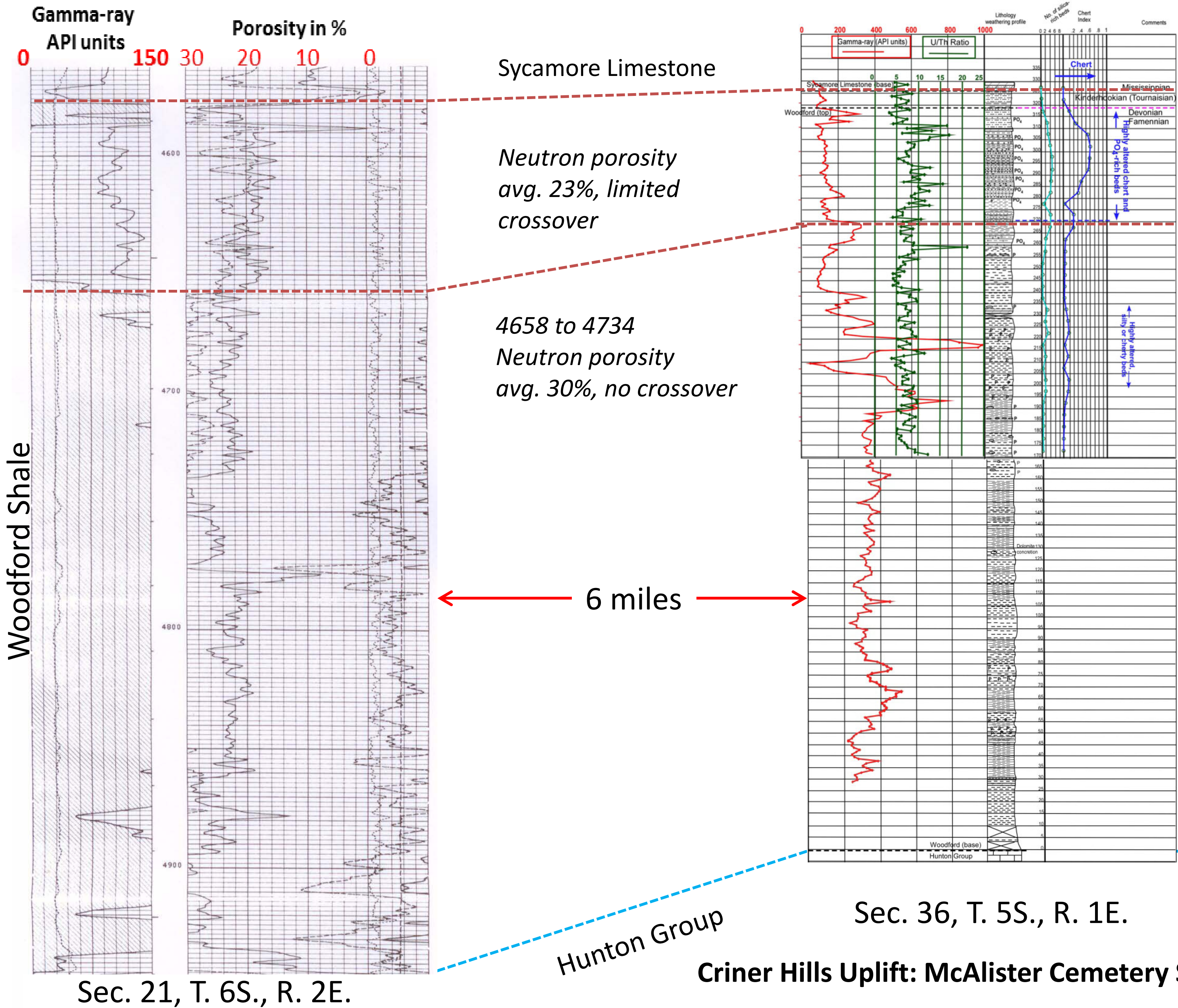


Lithologic section, total Gamma-ray, U/Th ratio and relative abundance of chert in the upper Woodford Section, McAlister Shale Pit Criner Hills Uplift, Oklahoma

4 > U/Th < 20*
*Excludes low & high values

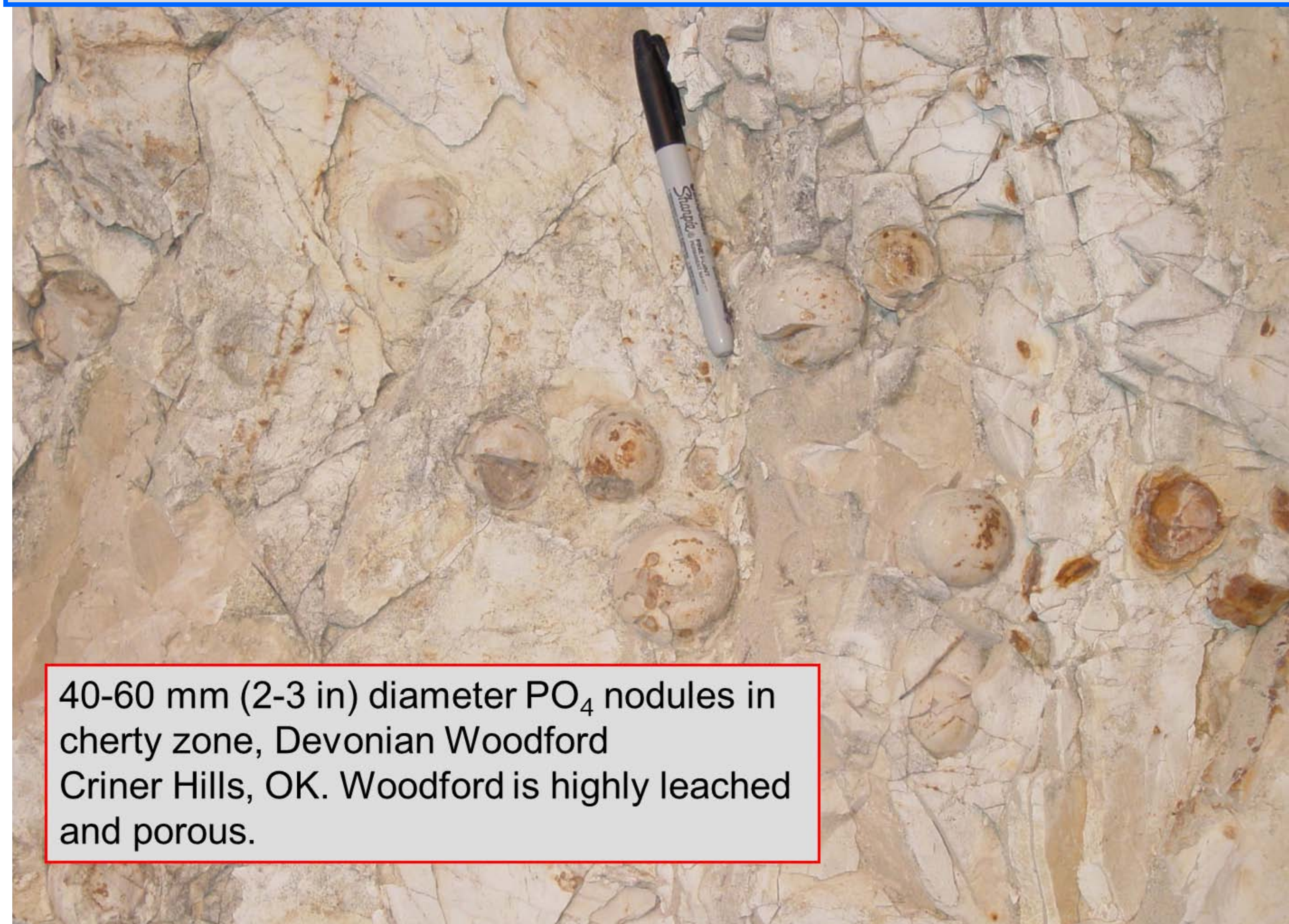
Chert and phosphate are abundant below the Devonian/ Mississippian contact.

Woodford Shale: Criner Hills Uplift



Criner Hills Uplift: McAlister Cemetery Shale Pit

Woodford Shale: Criner Hills Uplift: McAlister Cemetery Pit



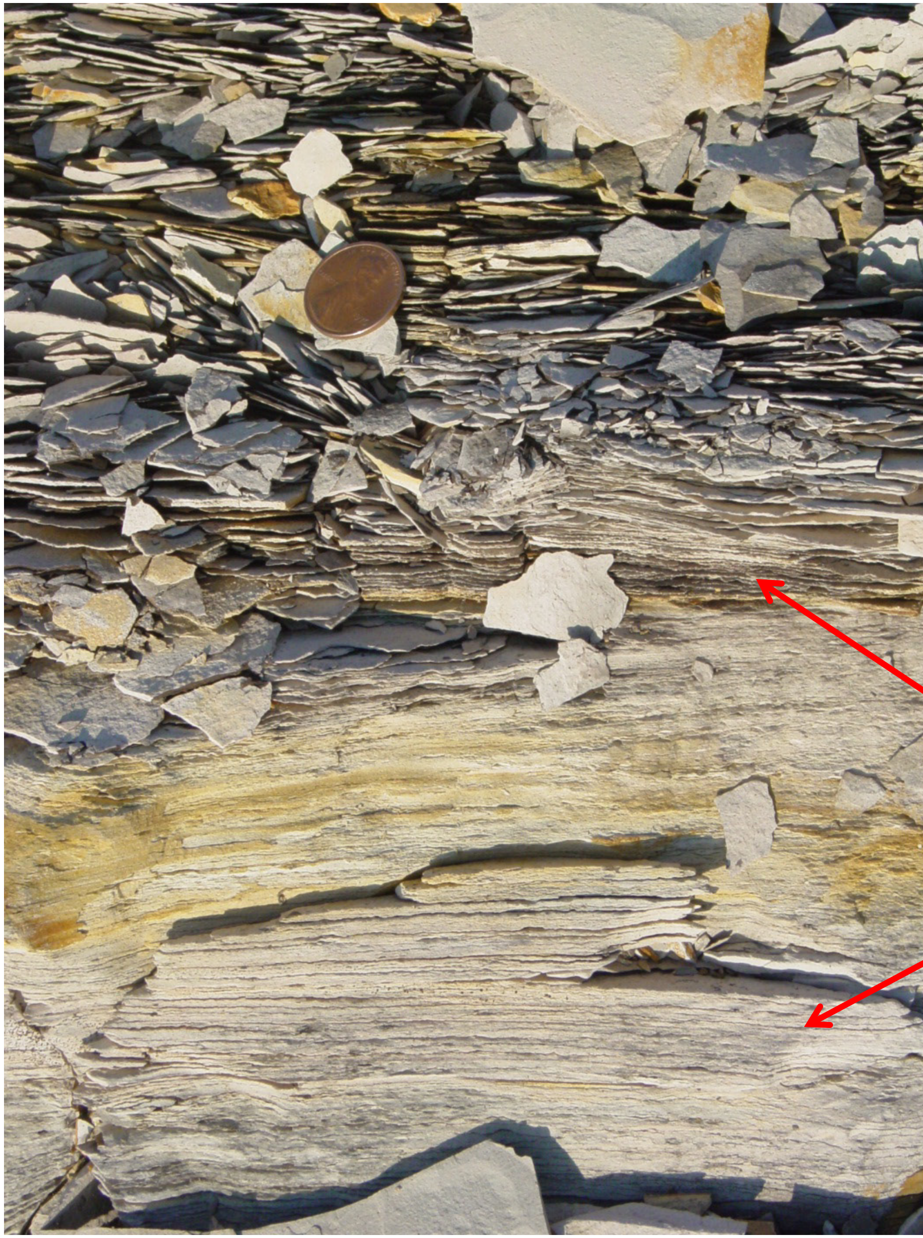
40-60 mm (2-3 in) diameter PO_4 nodules in cherty zone, Devonian Woodford Criner Hills, OK. Woodford is highly leached and porous.

Criner Hills Uplift McAlister Cemetery Shale Pit

Silica-rich “cherty” beds below the interval of large phosphate nodules. Alternating beds of chert and clay rich Woodford Shale.

Woodford Shale
McAlister Cemetery Shale Pit

Thinly bedded shale with areas cemented with carbonate or sulfide (pyrite)



Lower Section of the Woodford Shale
McAlister Cemetery Shale Pit

Thinly laminated siliceous shale that weathers to give the classic fissile character

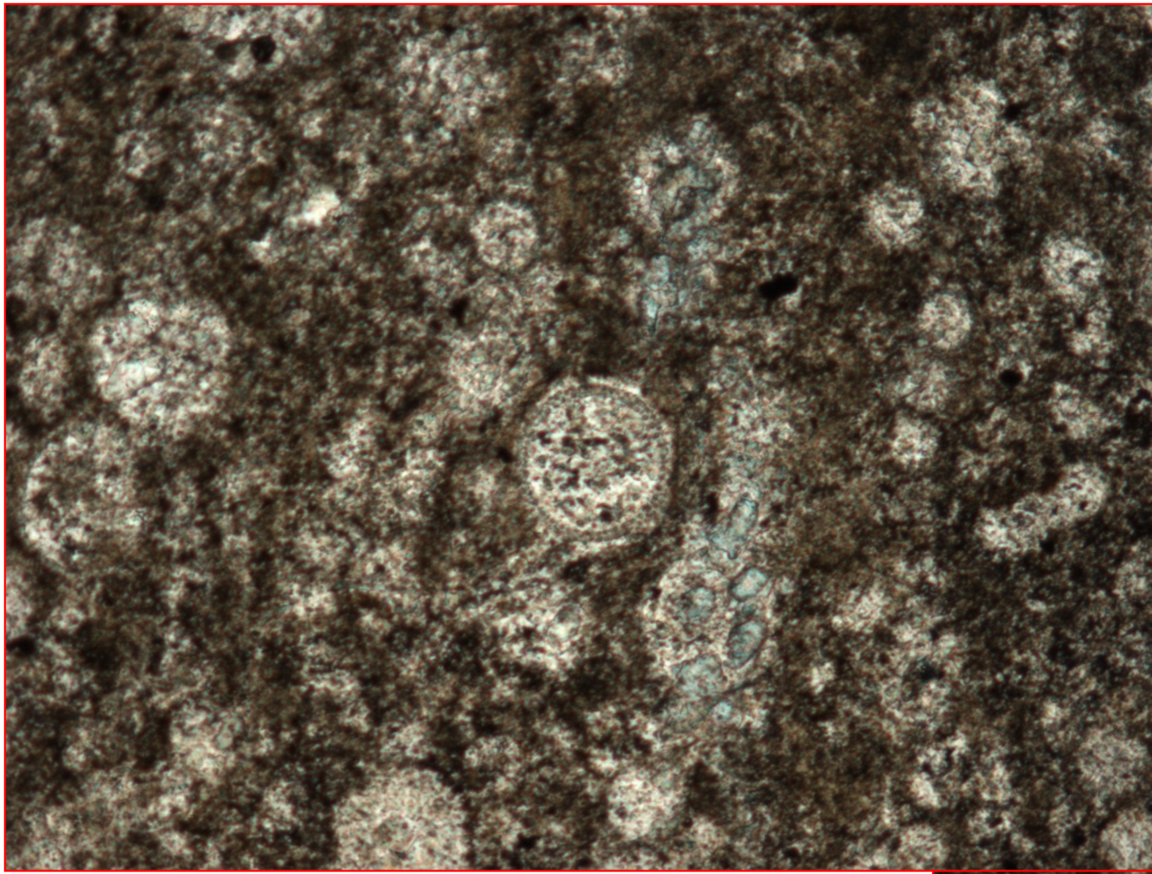
Woodford Shale
McAlister Cemetery Shale Pit

Solid oil residue in fractures in the middle section of the Woodford Shale

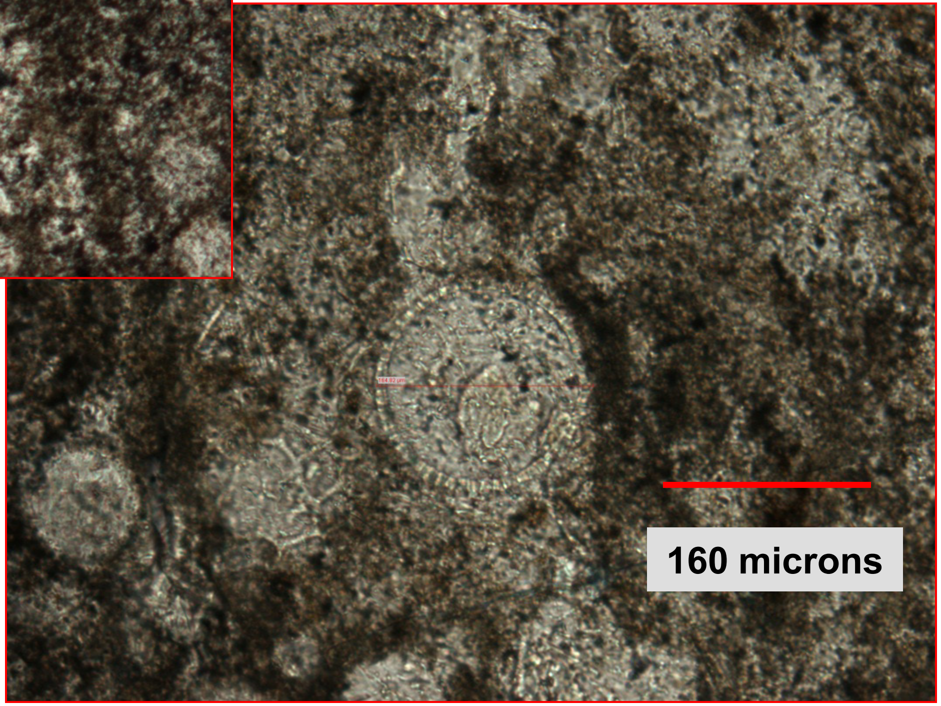
Criner Hills Uplift McAlister Cemetery Shale Pit

Large calcite concretion "bullion" excavated from the upper section of the Woodford Shale

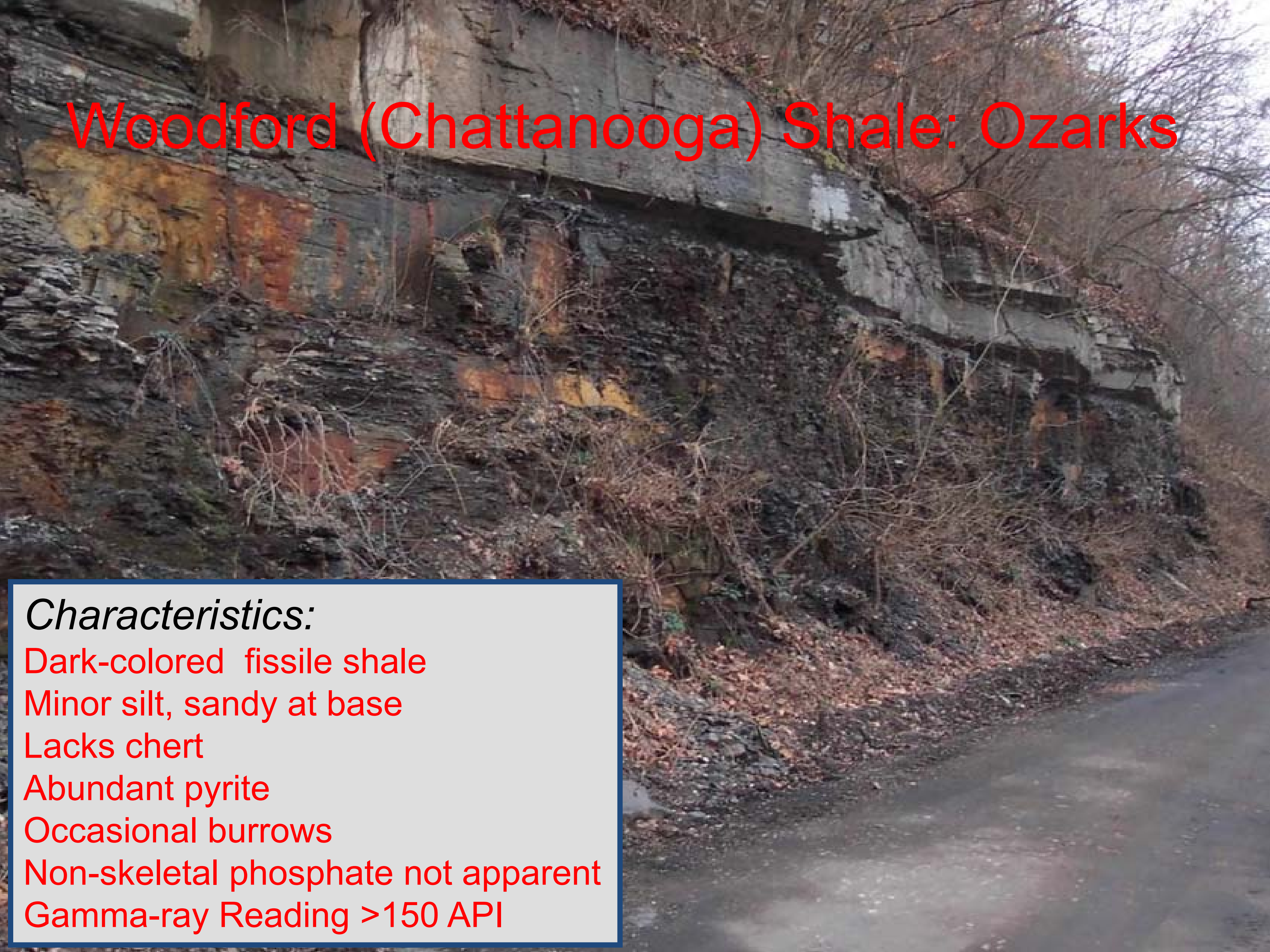
Criner Hills Uplift McAlister Cemetery Shale Pit



Radiolarian Tests Preserved in Carbonate Concretions



Woodford (Chattanooga) Shale: Ozarks

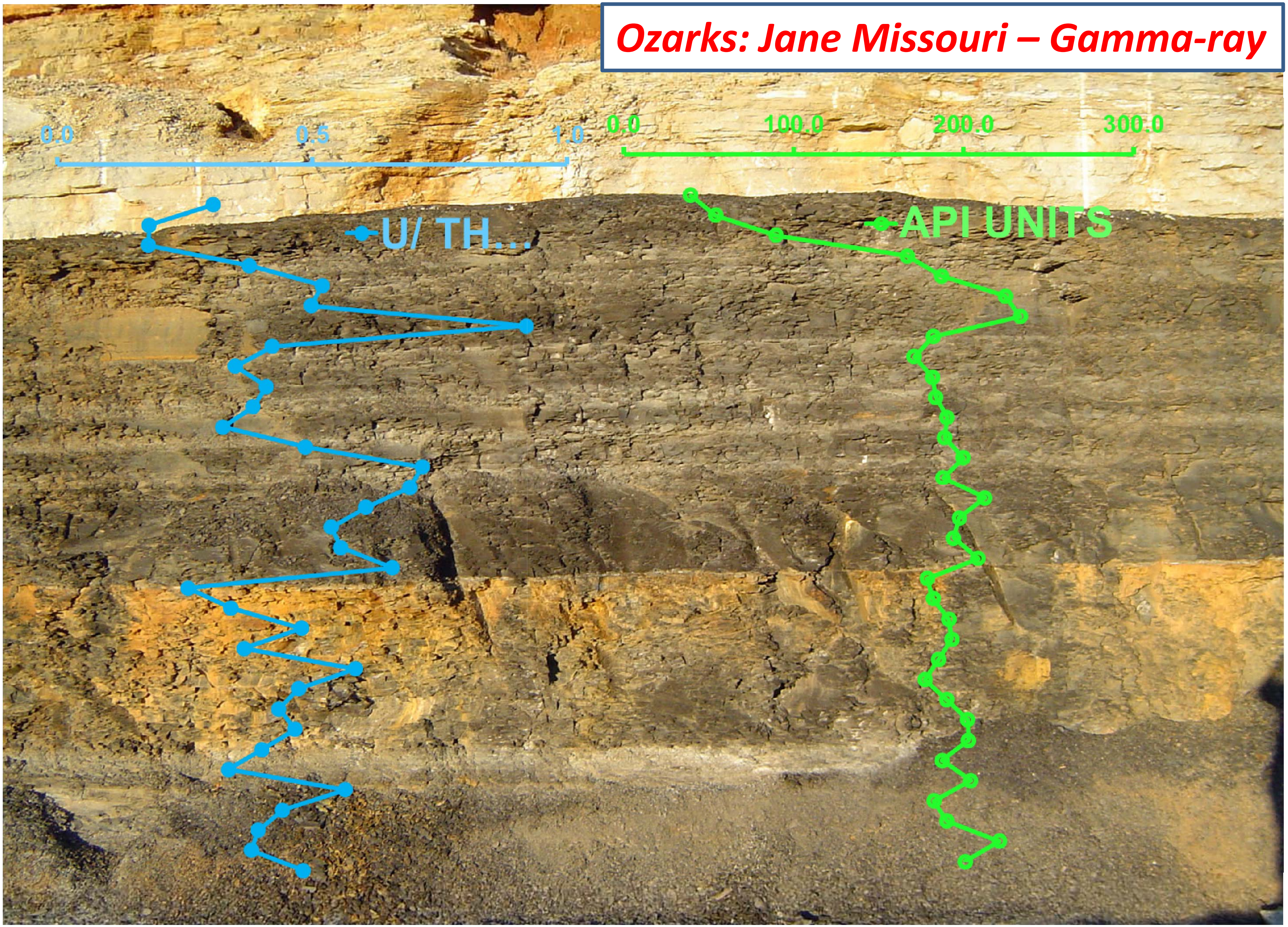


Characteristics:

Dark-colored fissile shale
Minor silt, sandy at base
Lacks chert
Abundant pyrite
Occasional burrows
Non-skeletal phosphate not apparent
Gamma-ray Reading >150 API

Woodford (Chattanooga) Shale: Ozarks

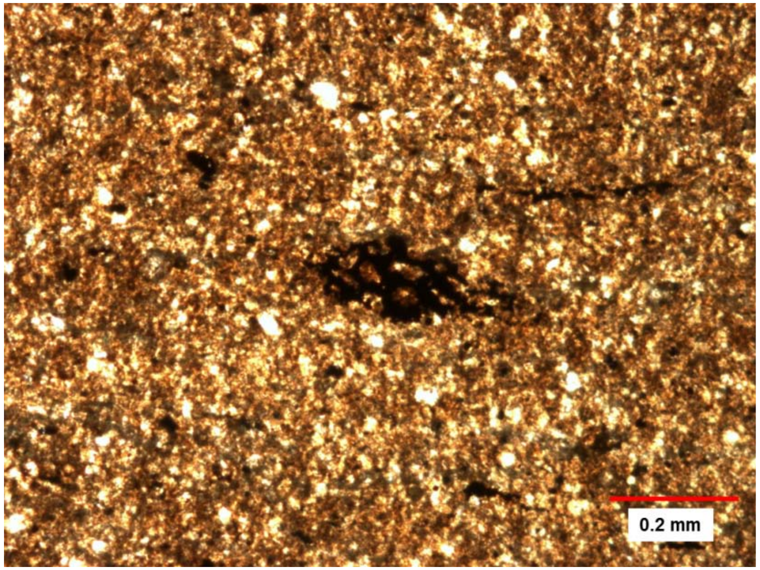
Jane Missouri: Mississippian Compton Limestone overlying Woodford (Chattanooga) Shale



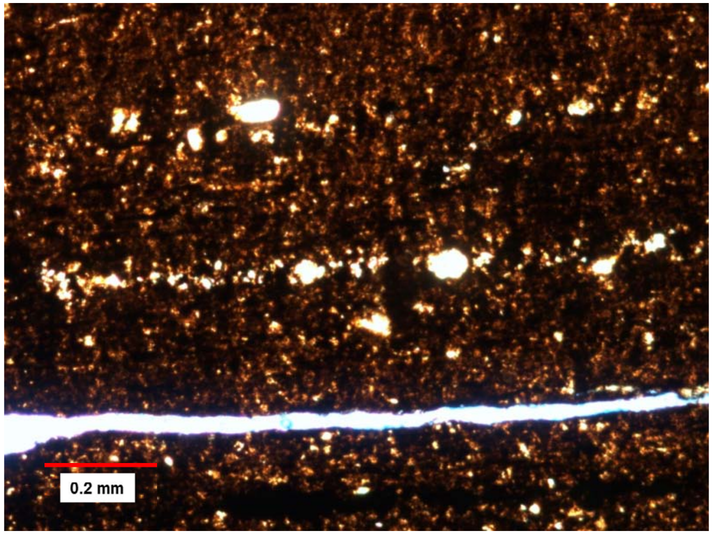
Ozarks: Jane Missouri – Gamma-ray
0.0
0.5
1.0
0.0
100.0
200.0
300.0
U/ TH...
API UNITS

Summary: Ozarks

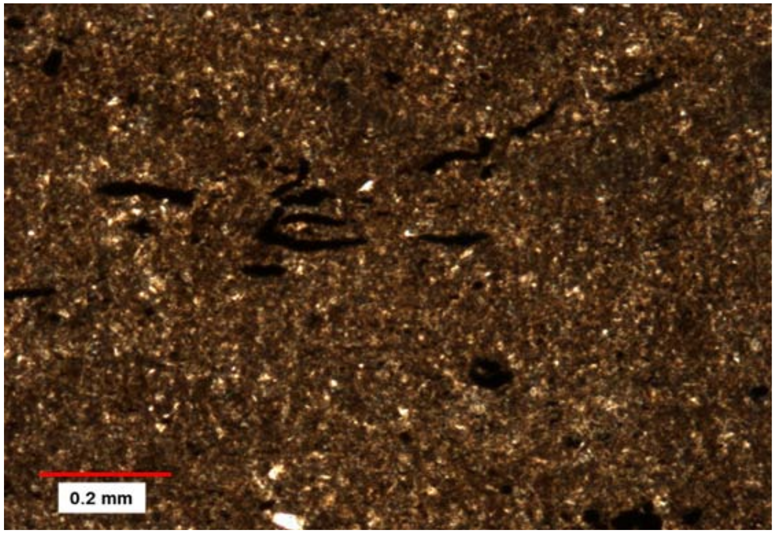
Characteristics:
Dark-colored fissile shale
Minor silt, sandy at base
Lacks chert
Abundant pyrite
Occasional burrows
Non-skeletal phosphate not apparent
High Gamma-ray Reading >150 API
U/Th ratio: 0 to 1.0



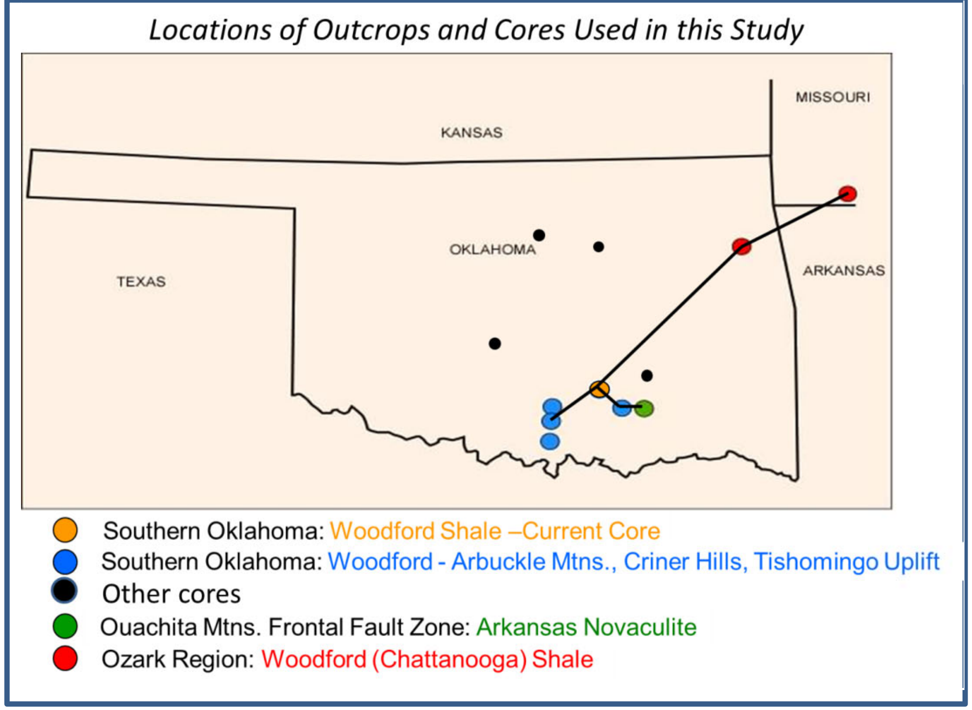
Pyritized bioclast (?), disseminated silt and dolomite. Plane-Polarized Light (PPL)

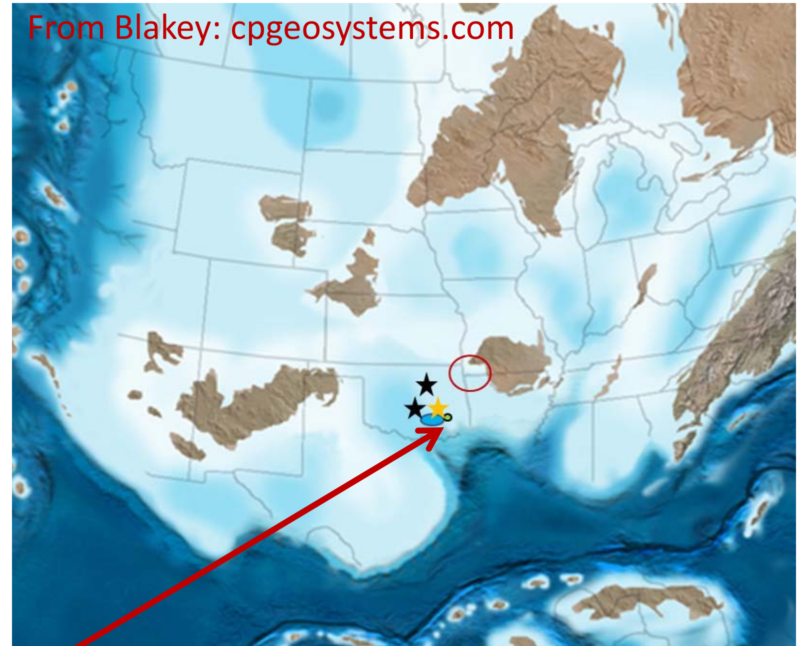


Bedded silt and occasional sand grains with pyrite and organics. PPL

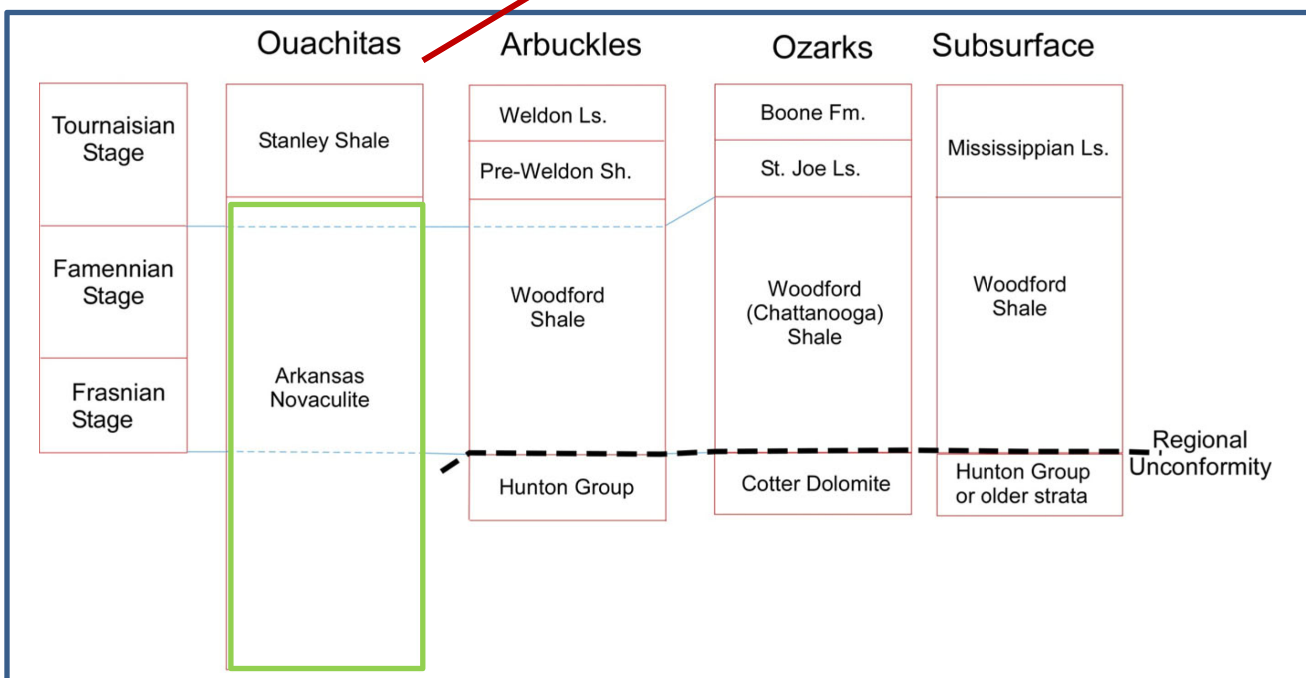


Random disseminated silt and with pyrite and organics. PPL

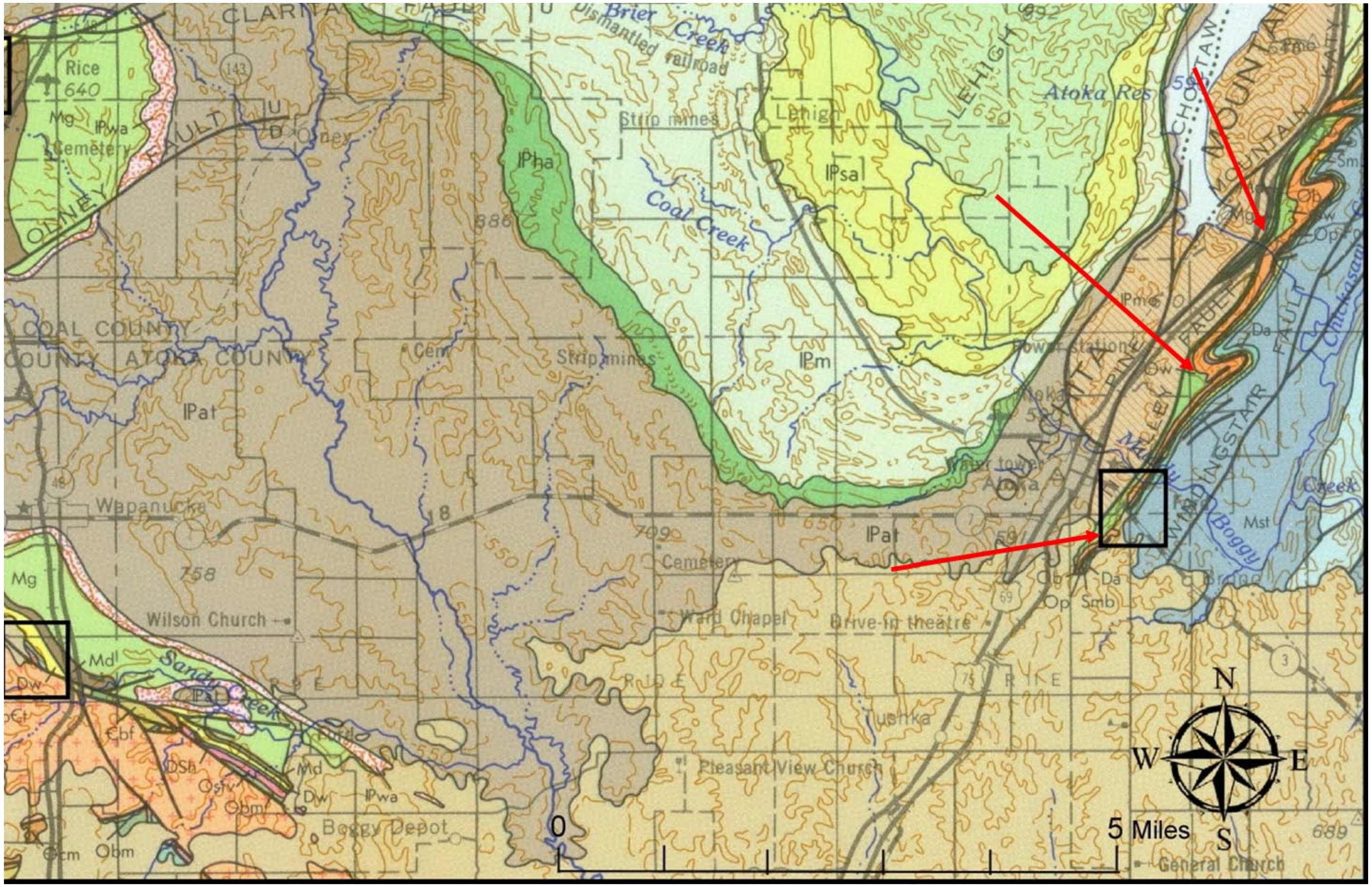




Ouachita Trough Deepest Setting?



Generalized Conventional Interpretation. Based on the works of J. Over, J. Barrick and D. Boardman II et al

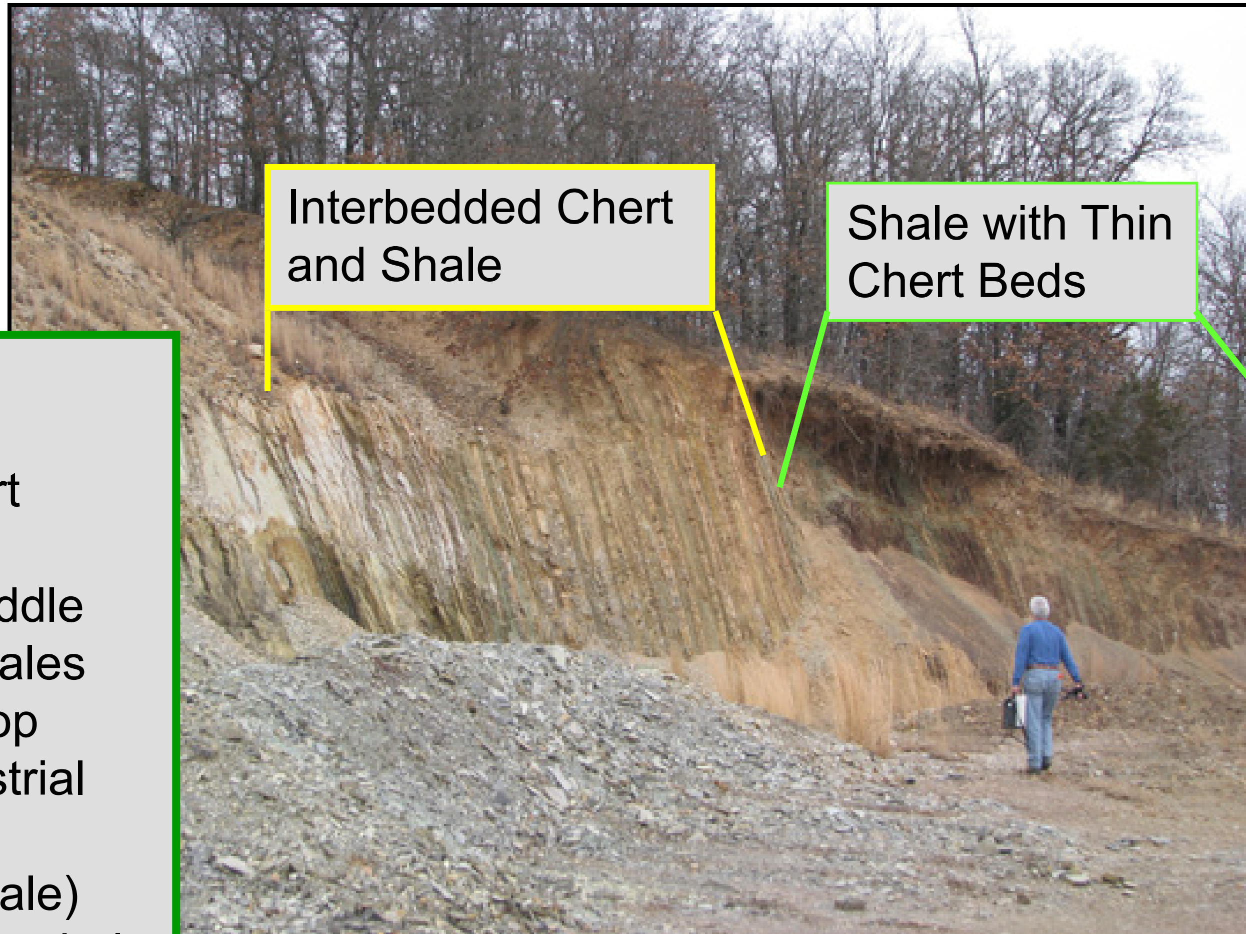


Arkansas Novaculite, Ouachita Mtns. Frontal-Fault Zone

Scratch Hill Section Atoka County, OK

Arkansas Novaculite: Ouachita Mtns: Frontal Fault Zone

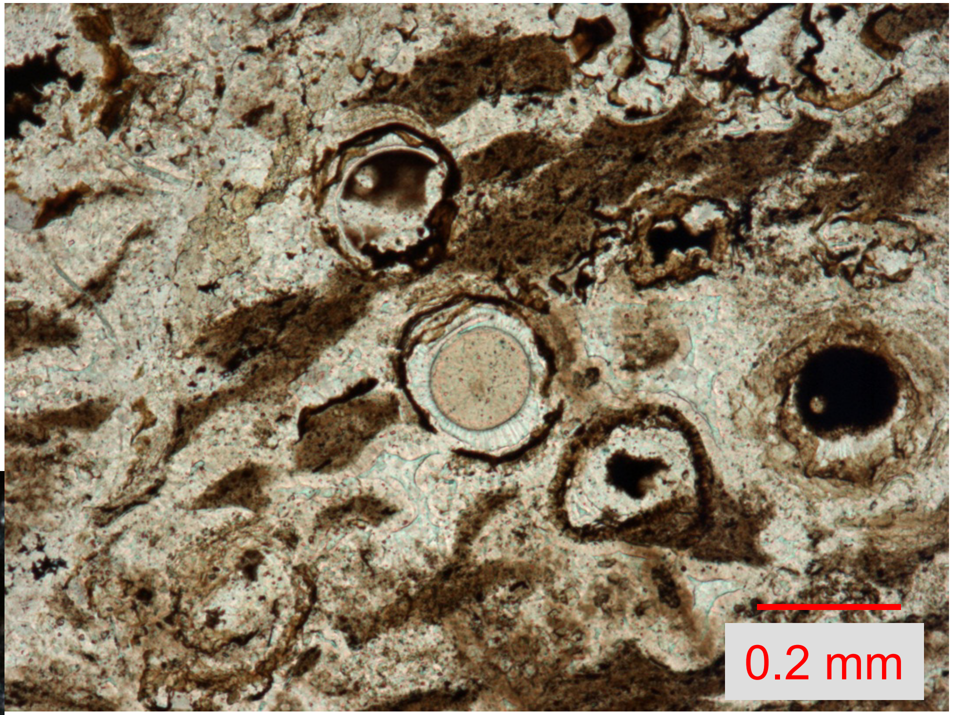
Arkansas Novaculite
Atoka, Oklahoma

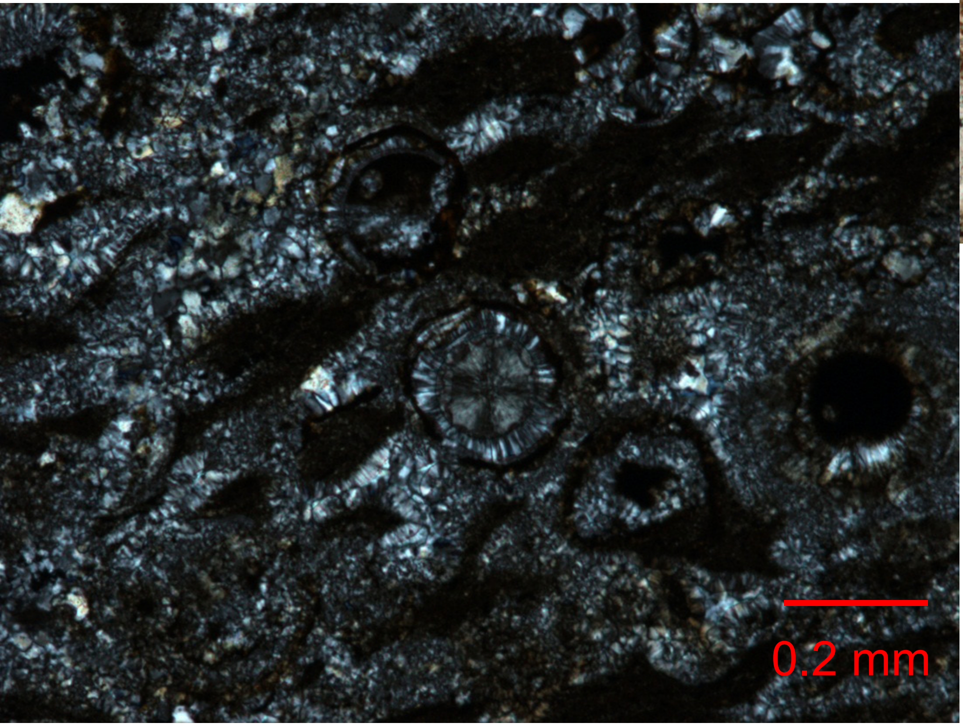


-Thick radiolarian-bearing chert beds a base
- Interbedded thinner chert and dark shale in middle
- Gray-green shales in middle
- Variegated red-green shales with thin cherts toward top
- U/Th < 0.5 (strong terrestrial influence)
- Phosphate rare (dark shale)
- Pyrite abundant in dk. gy. shale

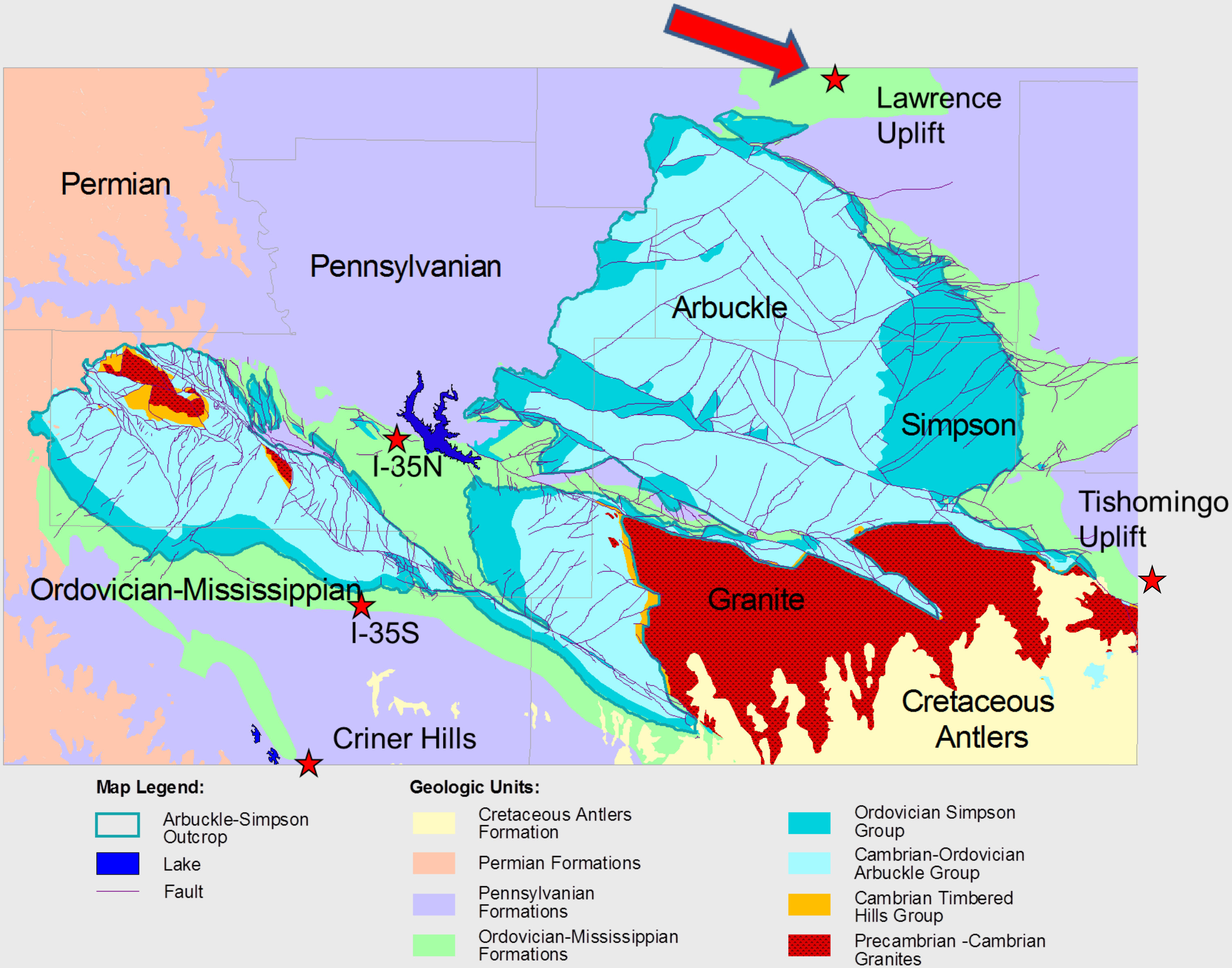
Arkansas Novaculite: Ouachita Mtns: Frontal Fault Zone

Ouachita Frontal Fault Zone



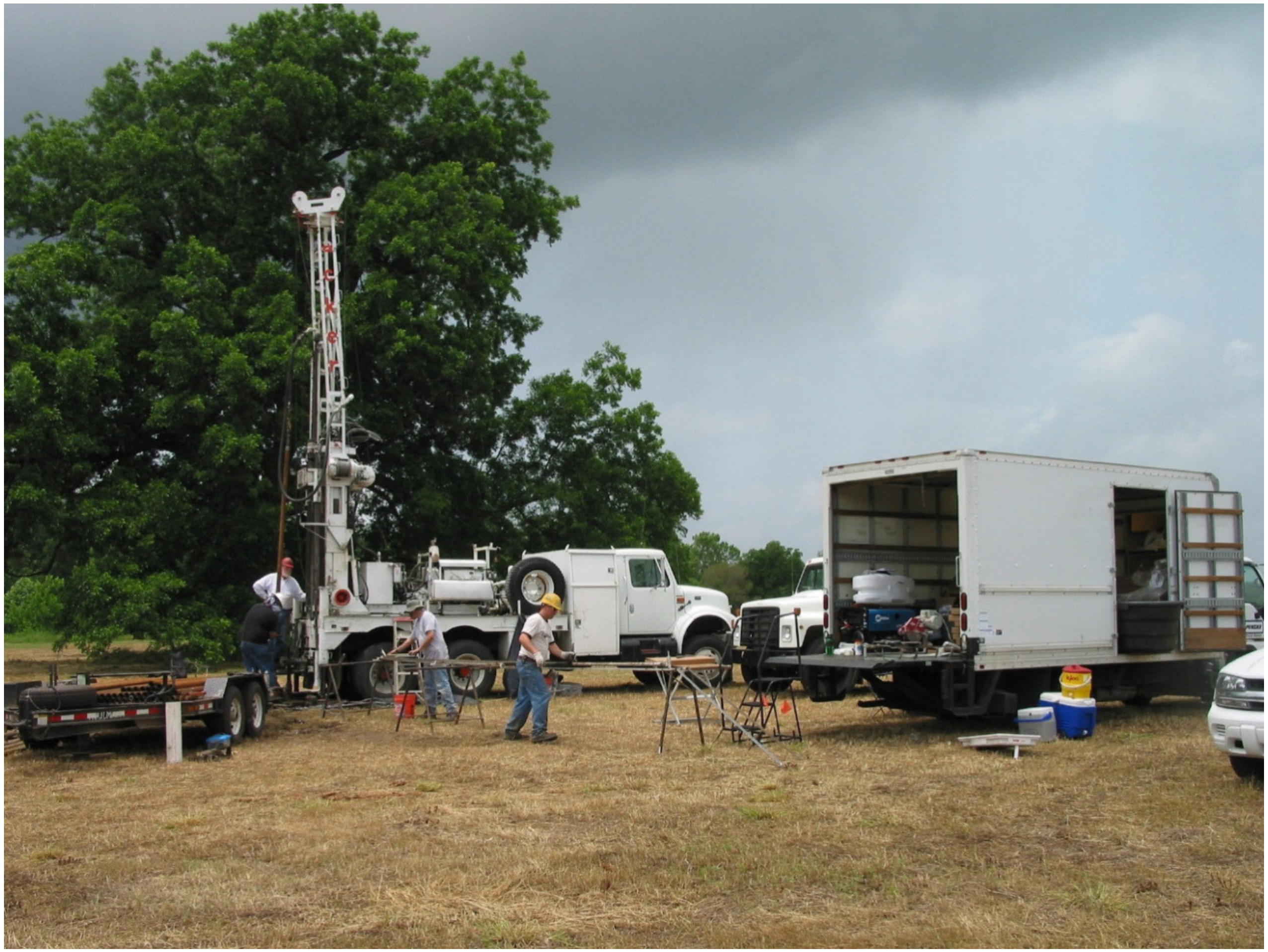


Radiolarian Tests in Chert Beds of the Arkansas Novaculite

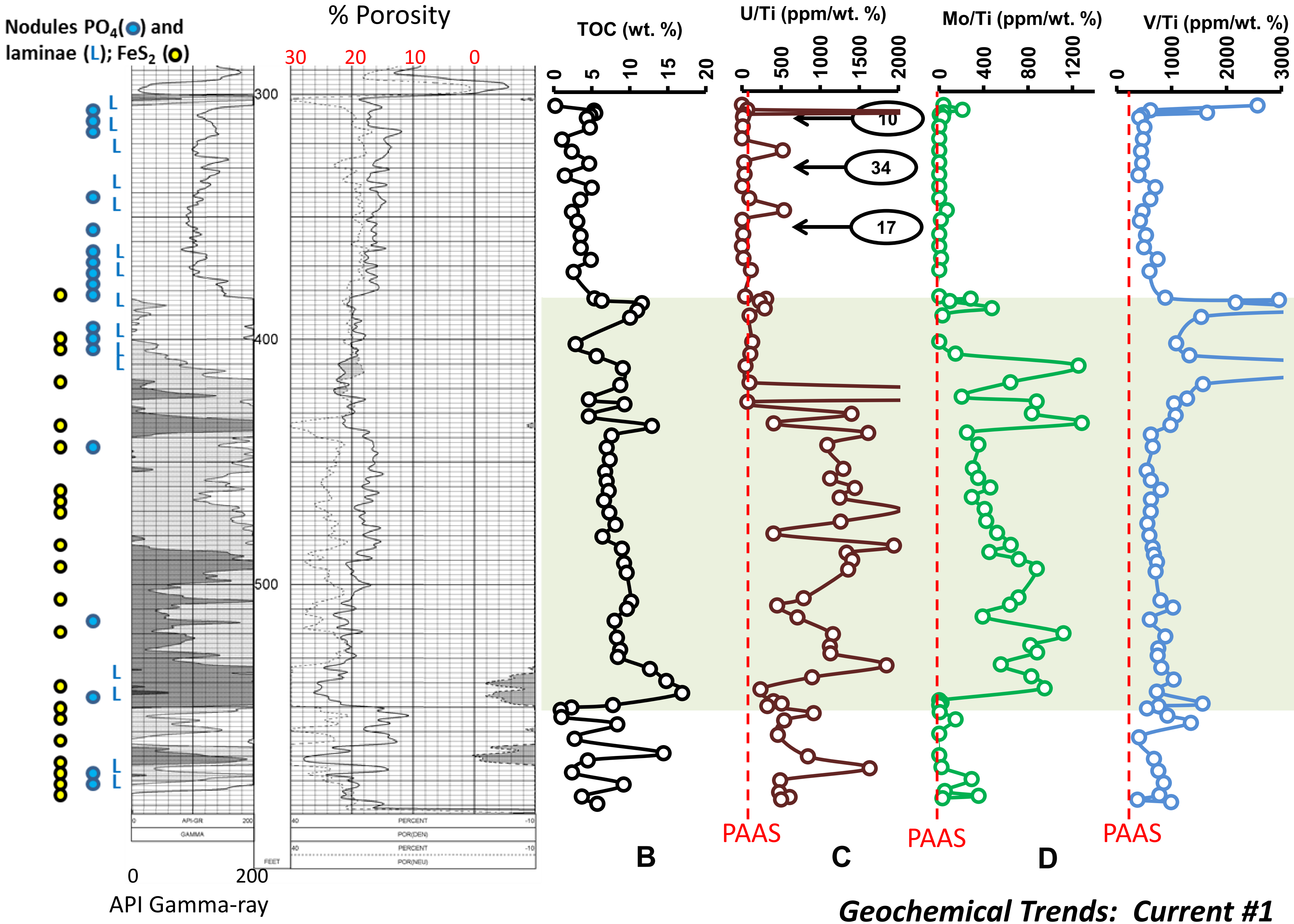


Locations of outcrops and core from south-central Oklahoma

KGS-OGS Current #1
NE/4 NE/4 NE/4 Sec. 26, T.3N., R.6E.



Woodford Shale: Lawrence Uplift, Southern Oklahoma



Geochemical Trends: Current #1

Woodford Shale: Lawrence Uplift

Burrows in silt and clay laminae indicating periods of oxygenation

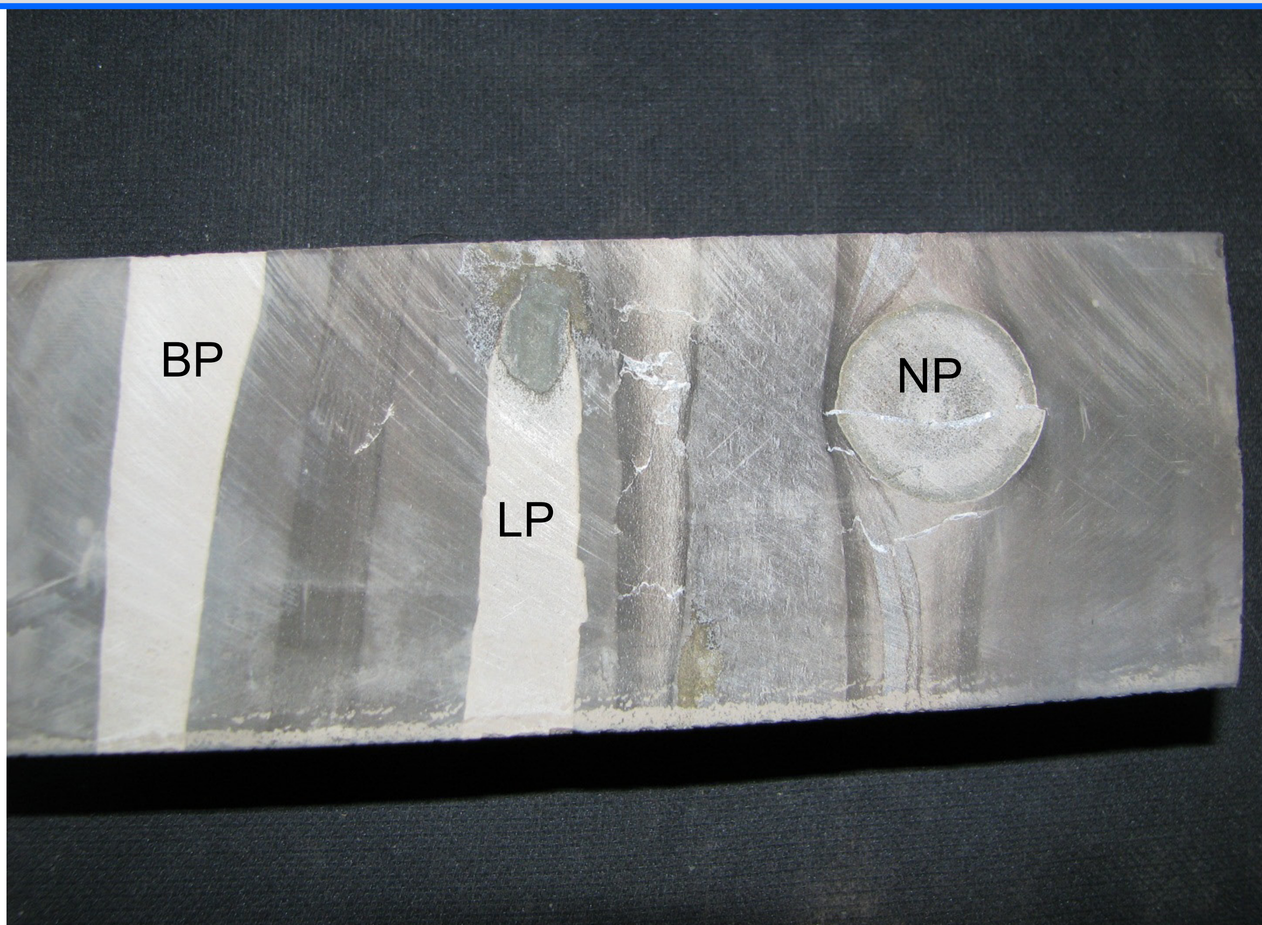
KGS-OGS Current #1

NE/4 NE/4 NE/4 Sec. 26, T.3N., R.6E.

Spherical and lenticular phosphate

Woodford Shale: Lawrence Uplift

- Dark Gray-Grayish Black Clay Shale
- Nodular (NP) and Bedded Phosphate (BP)
- Lenticular Bedded Phosphate (LP) and Laminar Phosphate



Summary

1. Arbuckle, Criner Hills and Wapanucka sections all contain evidence of silicification and chert
2. Chert positively impacts reservoir properties by increasing brittleness and propensity to fracture both naturally and artifically
3. Volume of chert in rock impacts wireline-log signatures with neutron and gamma-ray curve suppression with high volumes of chert
4. Nearby well logs to chert-rich outcrops contain evidence of microlog permeability and neutron-density curve crossover
5. In Caddo Field, vertical Woodford Shale well produced chertier facies
6. On Lawrence Upflift, Current #1 core lacks bedded chert, but increase in silt and phosphate cause reduction in clay and decrease in neutron porosity

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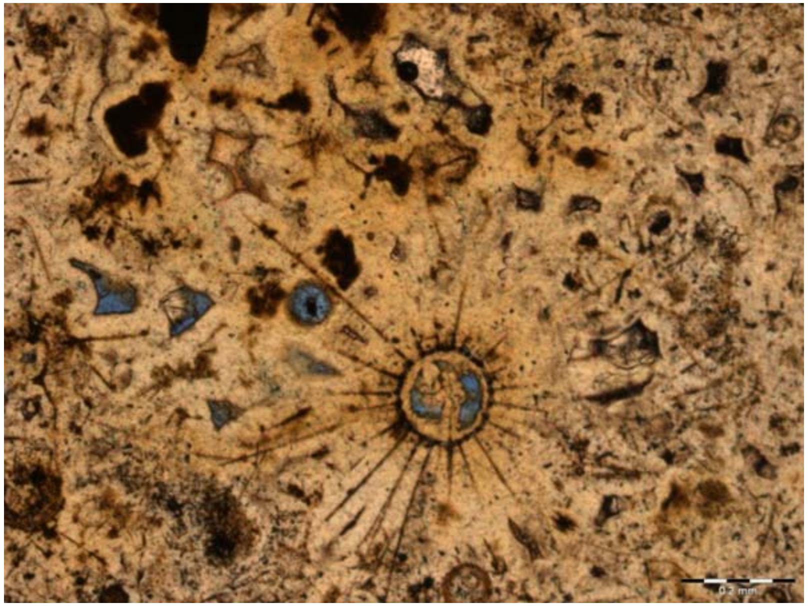
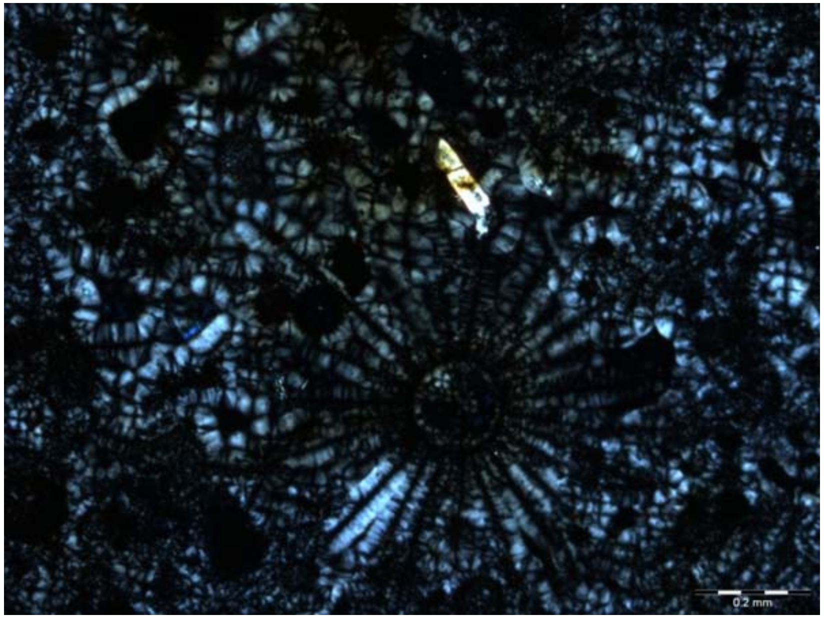


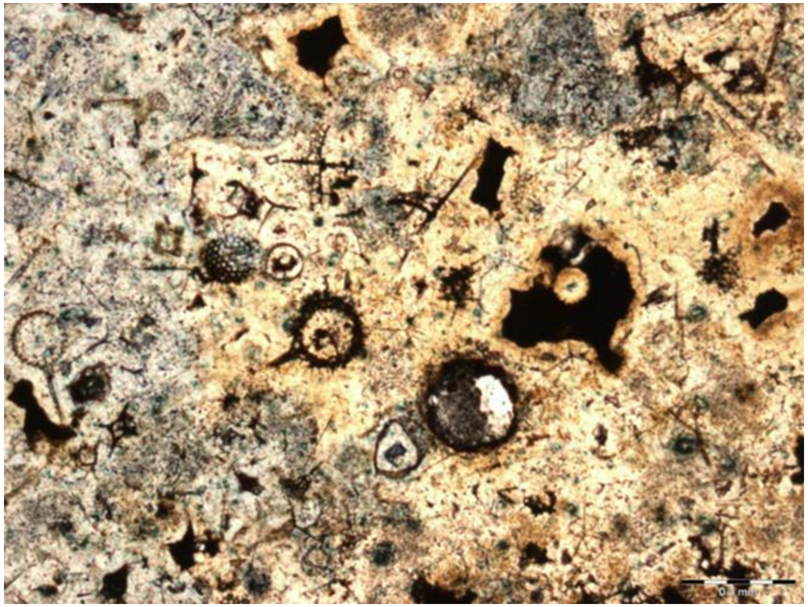
Plane-polarized light (PPL)

Thank You!

Assorted radiolarians:
Woodford Shale, southern Oklahoma



Cross-polarized light (CPL)



PPL