Composition and Mechanical Properties of the Woodford Shale, Northern Oklahoma*

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Abstract

The Woodford Shale in southern Oklahoma is silica-rich as a result of radiolarian content and ranges from around 70 percent bedded chert for the Arkansas Novaculite to 10 to 50 percent for cherty Woodford in the Arkoma Basin and outcrops on the Arbuckle and Criner uplifts. Bedded cherts have higher natural fracture density, with fractures terminating in adjacent clay-rich beds. In contrast, the Woodford Shale in northern Oklahoma lacks bedded chert, but contains silica-rich bands that appear to nucleate on detrital-silt-rich laminae. Thin-section microscopy reveals that all detrital silt is not the same. Silt grains surrounded by clay result in relatively high silica content, as determined by x-ray, but silica bands did not develop. Silica cement is present where silt grains are in contact, increases at the expense of clay content, and alters wireline-log response and mechanical properties. Intervals with lower clay content exhibit higher resistivity and lower neutron porosity than clay-rich intervals. Silica cement, augmented by carbonate cement and sulfides, imparts competence and brittleness to the Woodford Shale. Competence is evident in the smooth outer core surface in cemented intervals that resisted erosion during coring. In contrast, clay-rich intervals are eroded, especially parallel to bedding, generating a rougher outer core surface. Cemented intervals are brittle, generating a propensity to fracture naturally and propagate fractures during hydraulic stimulation.

References Cited

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Foltz, K., 2015, Petrographic and petrophysical characterization of the Woodford Shale, northern shelf, Anadarko, Basin, Oklahoma: Unpublished M.S. thesis, Oklahoma State University, 129 p.

Northcutt, R.A., and J.A. Campbell, 1996, Geological provinces of Oklahoma: Oklahoma City Geological Society Shale Shaker, v. 46/5, p. 99-103.

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Oklahoma State University

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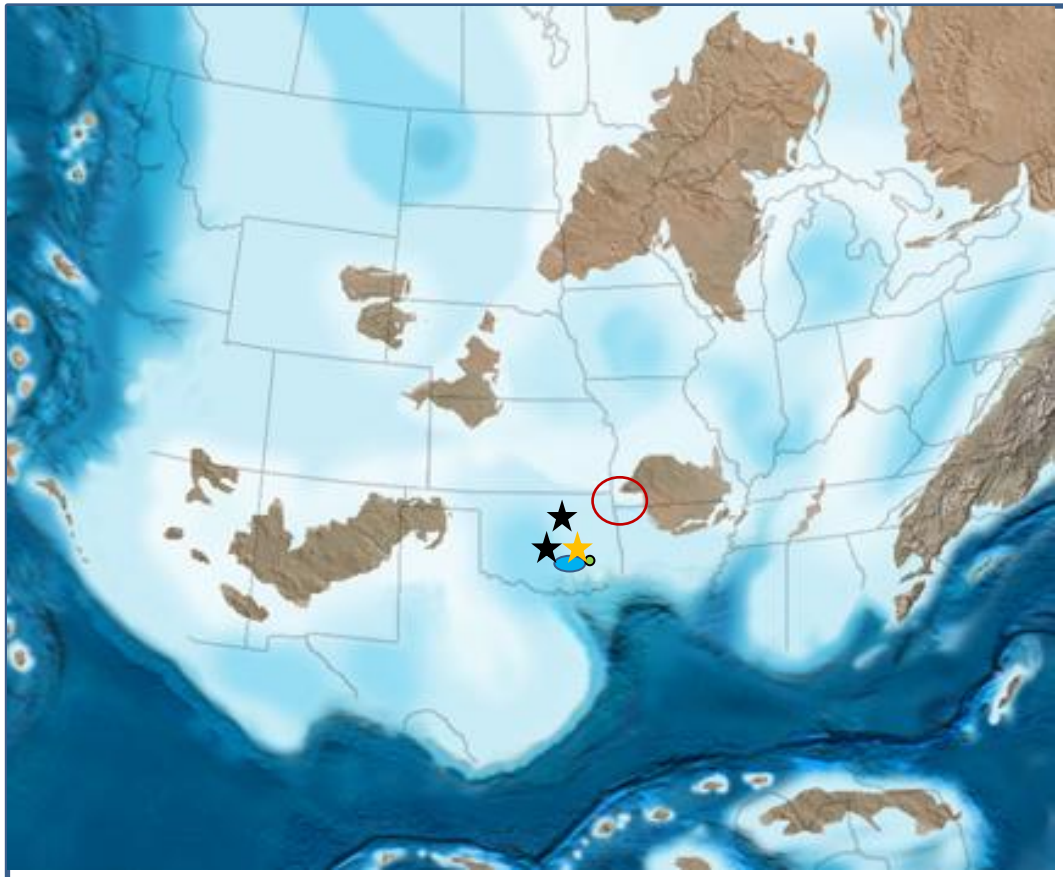
Objectives

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.

Why: who cares?

Where composition affects brittleness, natural fractures are more abundant and enhance reservoir properties, the ability to hydraulically fracture is increased, fluid volume increases and wells are more productive.



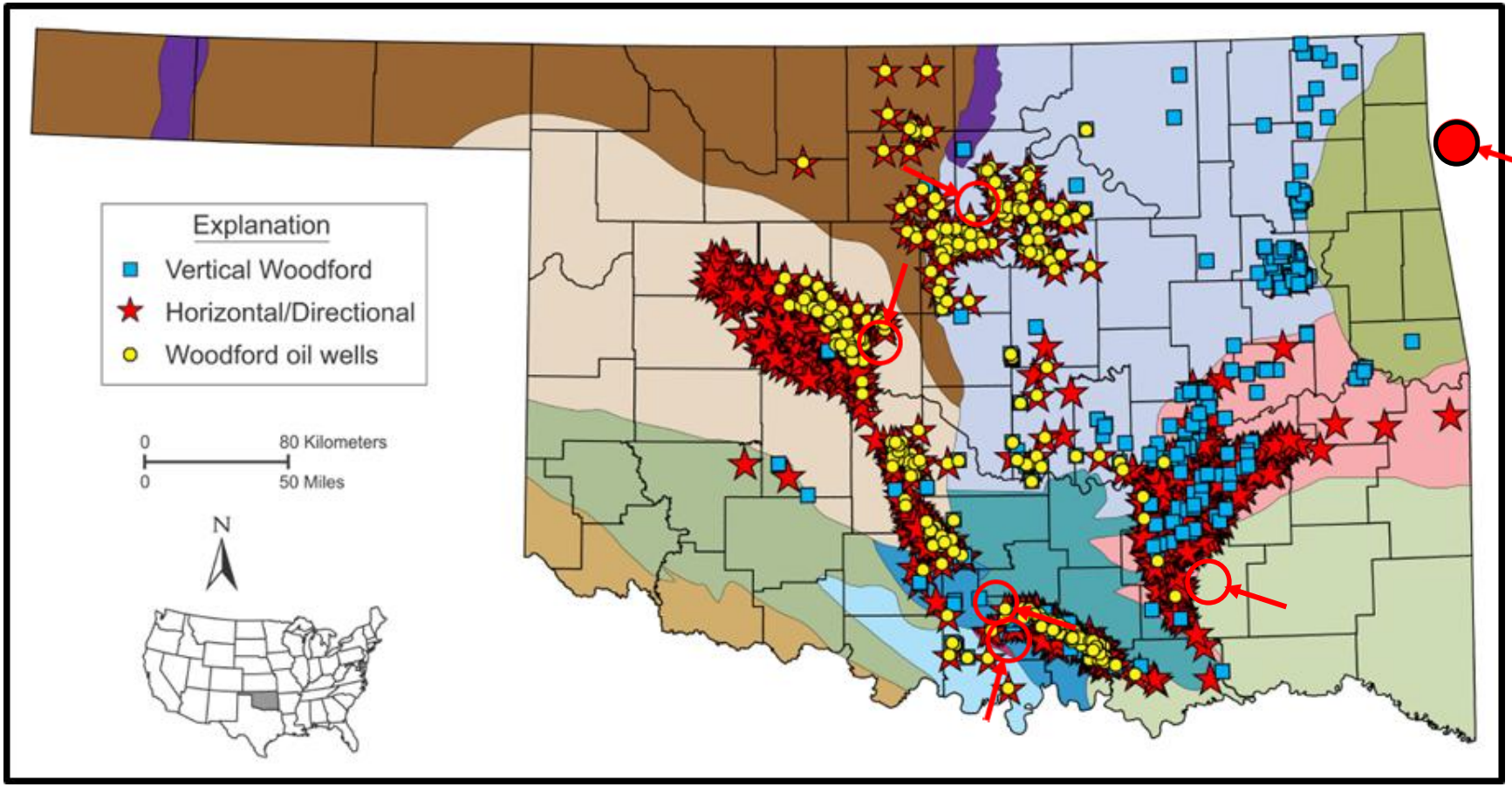
Map from CP Geosystems (2014)

DEPOSITIONAL SETTING

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

Late Devonian (360 mya) Paleogeography
Southern North America

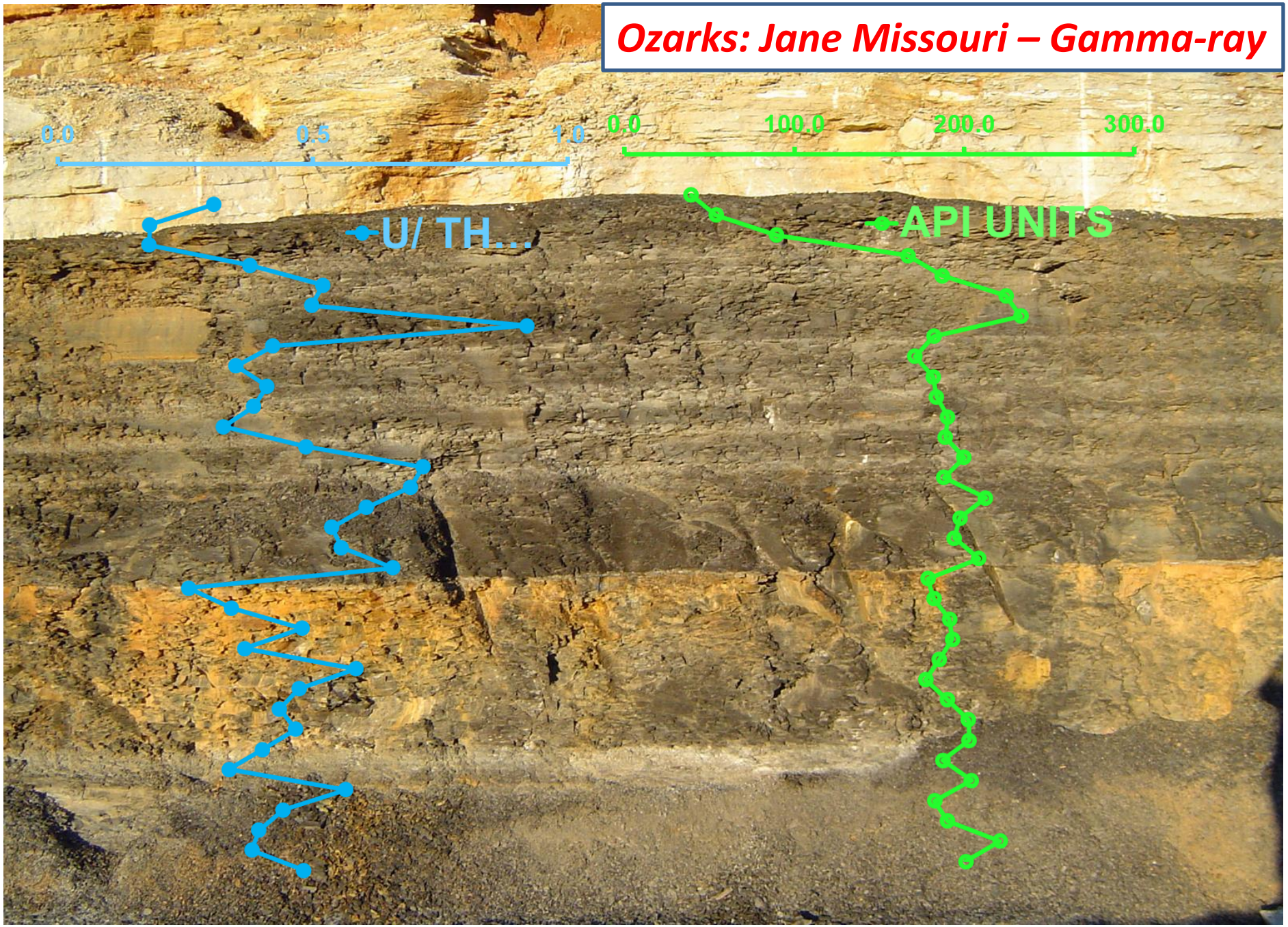
Status of Woodford Production



Map showing the major Woodford Shale plays and the major geologic provinces of Oklahoma. The Cherokee Platform is designated by the periwinkle color. Note that there are few oil wells in the basinal Woodford Shale plays when compared to the Cherokee Platform (modified from Cardott, 2014 and Northcutt and Campbell, 1996).

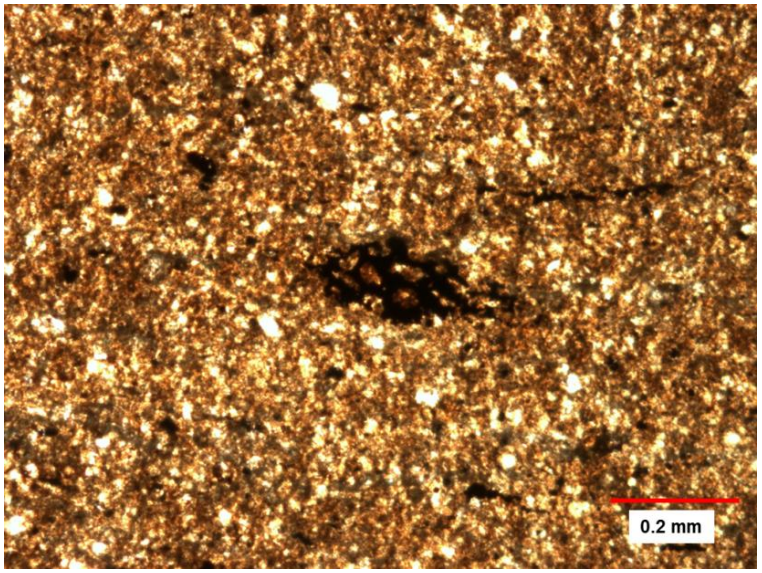
Woodford (Chattanooga) Shale: Ozarks

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

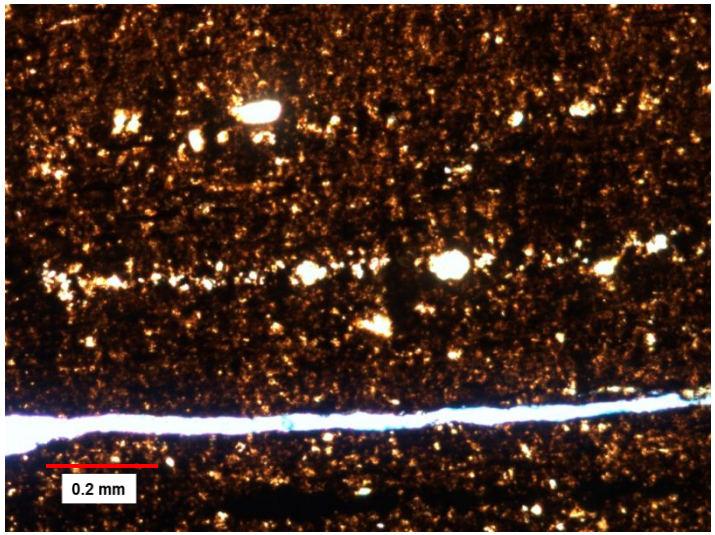

Ozarks: Jane Missouri – Gamma-ray
0.0
0.5
1.0
U/ TH...
0.0
100.0
200.0
300.0
API UNITS

Summary: Ozarks

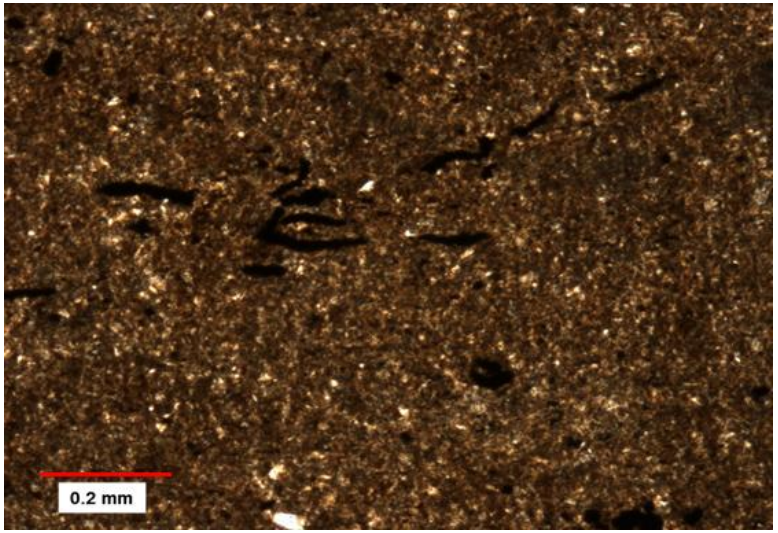
Characteristics:
Dark-colored fissile shale
Silty, sandy at base
Lacks chert
Abundant pyrite
Burrowed with current features
Non-skeletal phosphate not apparent
High Gamma-ray Reading >150 API
U/Th ratio: 0 to 1.0



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

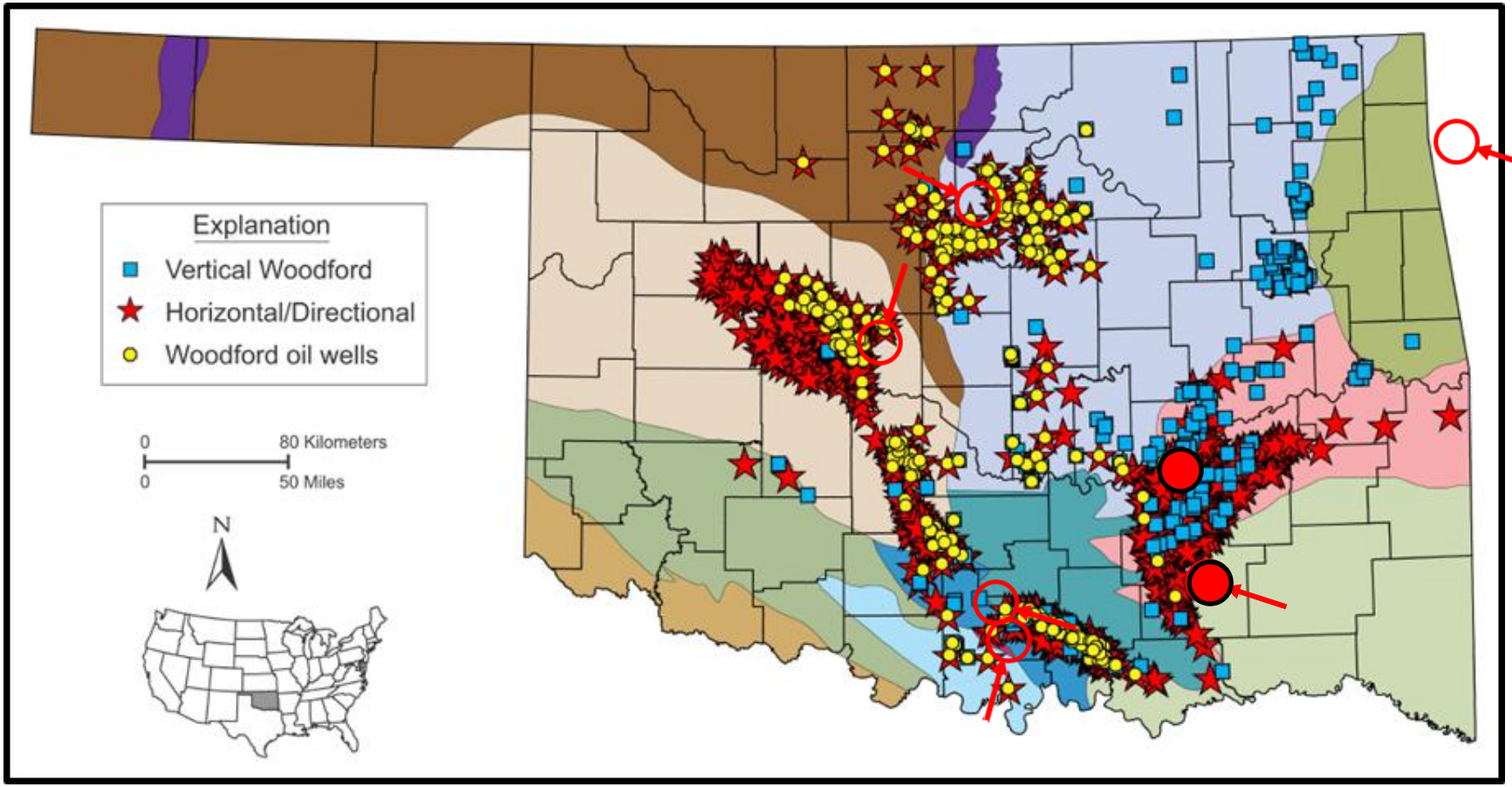


Bedded silt and occasional sand grains with pyrite and organics. PPL



Random disseminated silt and with pyrite and organics. PPL

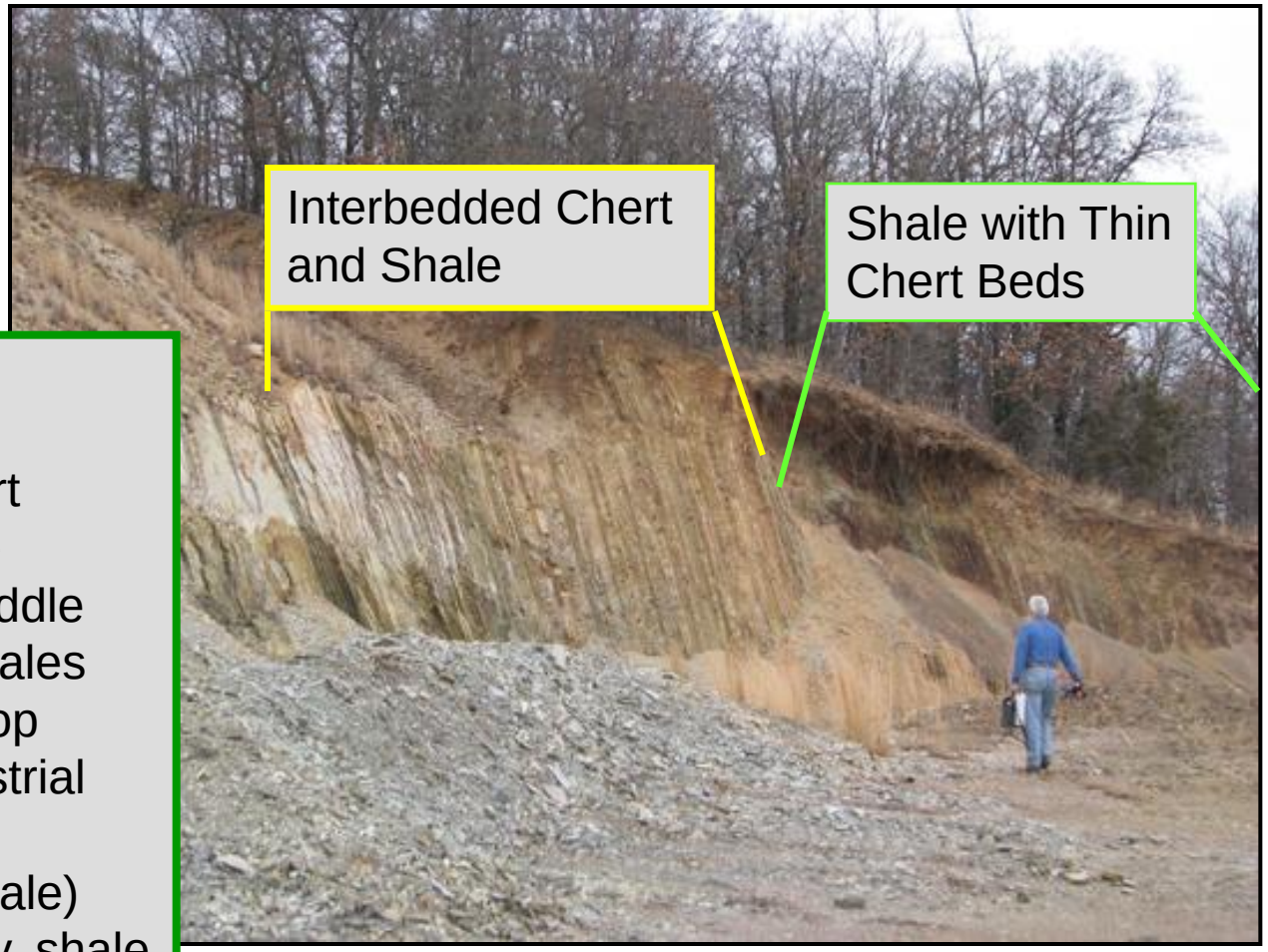
Status of Woodford Production



Map showing the major Woodford Shale plays and the major geologic provinces of Oklahoma. The Cherokee Platform is designated by the periwinkle color. Note that there are few oil wells in the basinal Woodford Shale plays when compared to the Cherokee Platform (modified from Cardott, 2014 and Northcutt and Campbell, 1996).

Arkansas Novaculite: Ouachita Mtns: Frontal Fault Zone Proximal to Basin Axis

Arkansas Novaculite
Atoka, Oklahoma

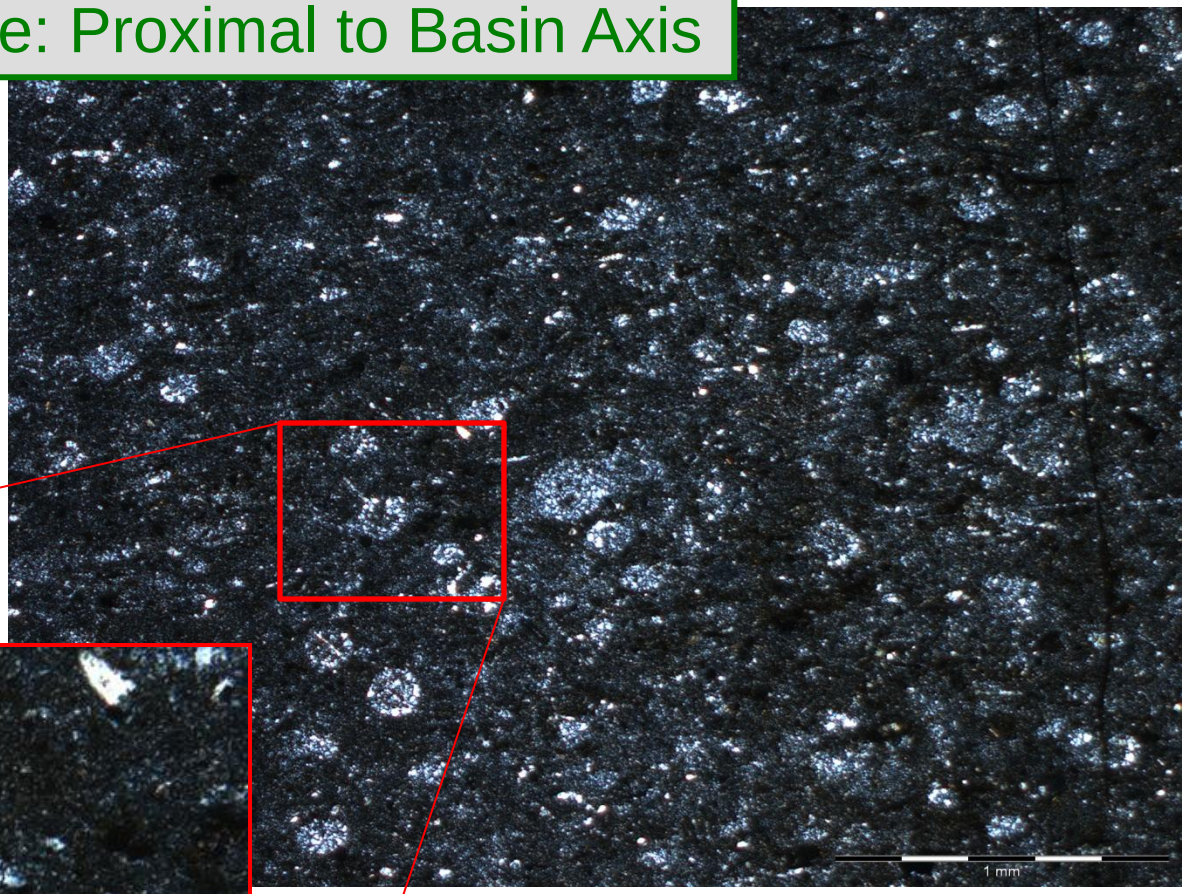


-Thick radiolarian-bearing chert beds at base
- Interbedded thinner chert and dark shale in middle
- Gray-green shales in middle
- Variegated red-green shales with thin cherts toward top
- U/Th < 0.5 (strong terrestrial influence)
- Phosphate rare (dark shale)
- Pyrite abundant in dk. gy. shale

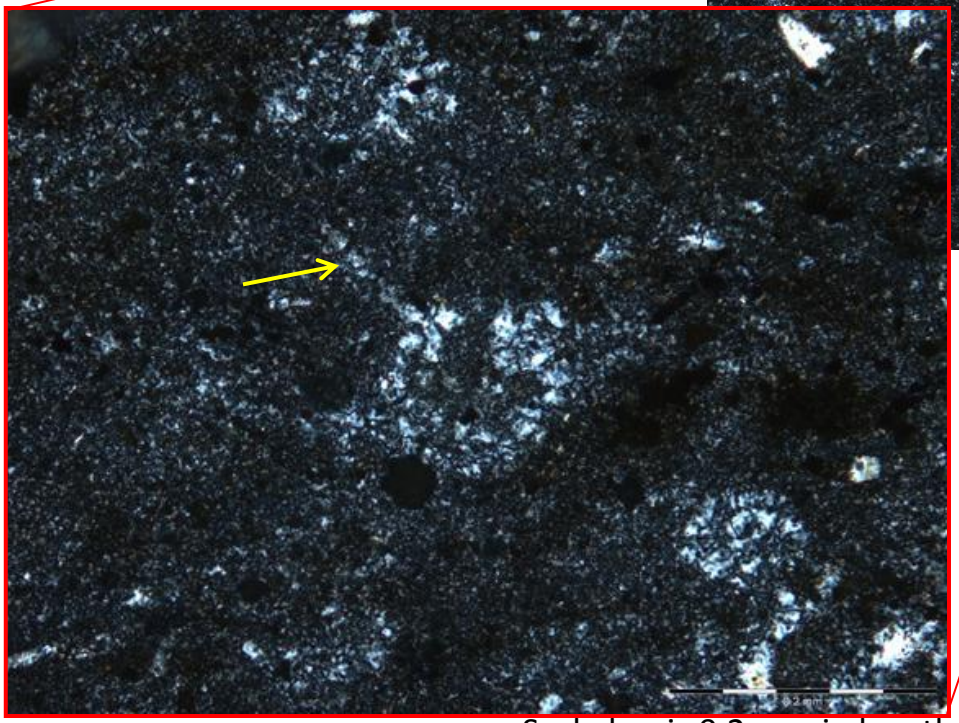
Arkansas Novaculite: Proximal to Basin Axis

Scratch Hill Outcrop
Atoka Co., Oklahoma

Radiolarian Tests in Chert Beds of the Arkansas Novaculite



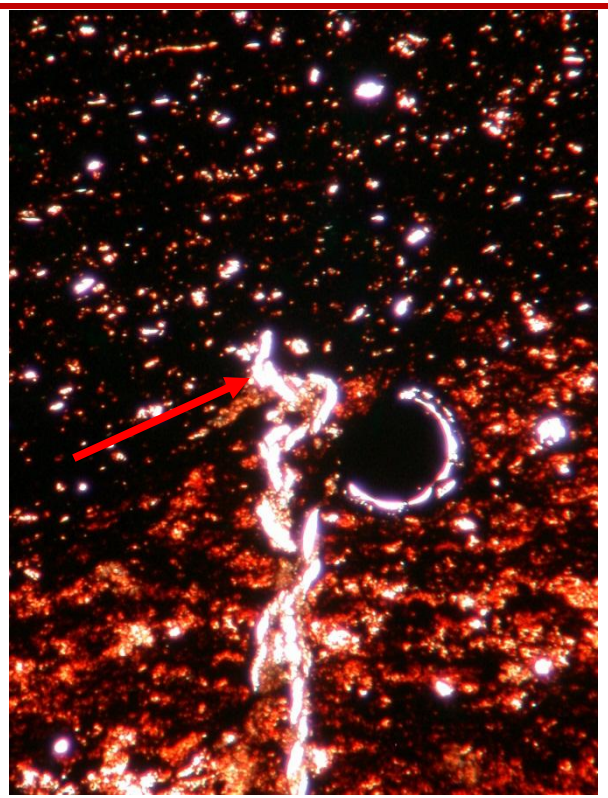
Scale bar is 1.0 mm in length



Scale bar is 0.2 mm in length

Concentration of radiolarians in the Arkansas Novaculite. Enlarged inset shows detail of radiolarian with spine. Both images are cross-polarized light.

Woodford Gas Area: Arkoma Basin, Hughes County, OK

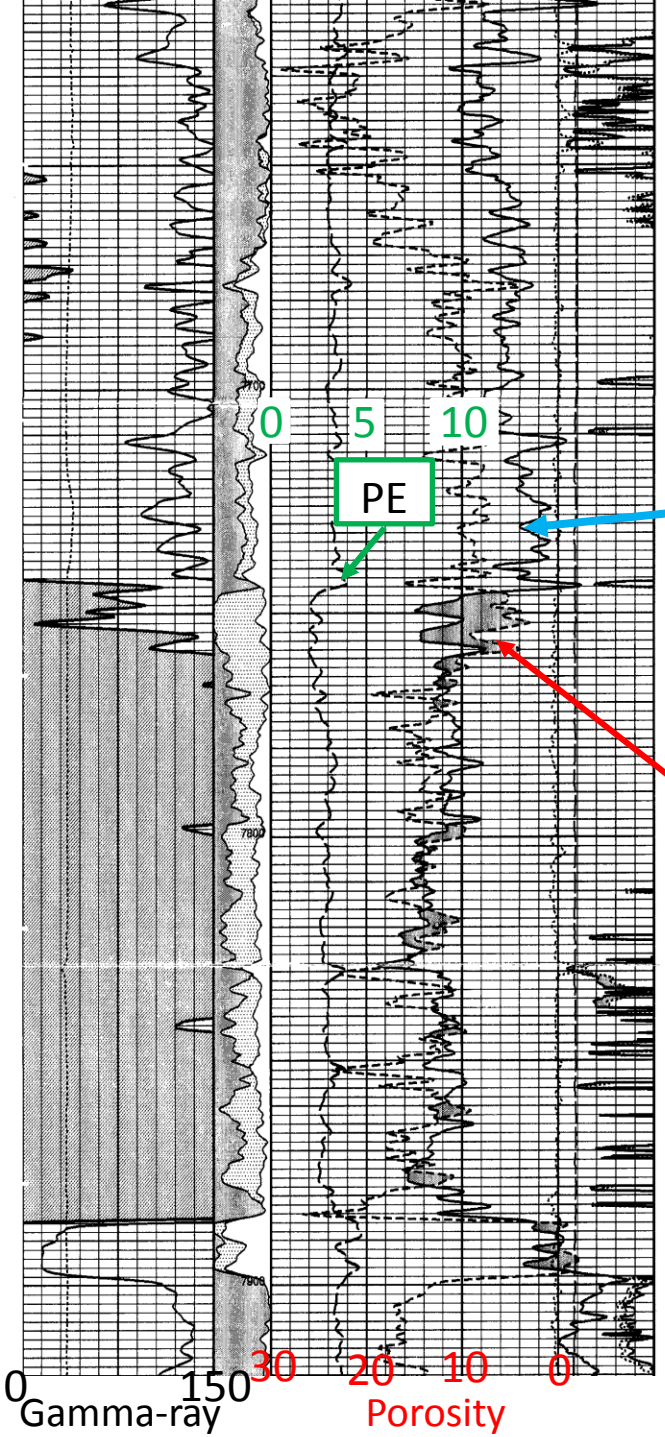


Narrow cemented fracture (arrow) (width 0.01-0.02 mm) that terminates in darker, clay-rich zone above silica-rich band. Depth 7825.5 feet.

Numerous near-vertical fractures in lighter-colored, silica-rich zone. Fractures terminate in the dark-colored, adjacent laminated zones. Depth 7826 feet.

Woodford Shale Proximal to Basin Axis

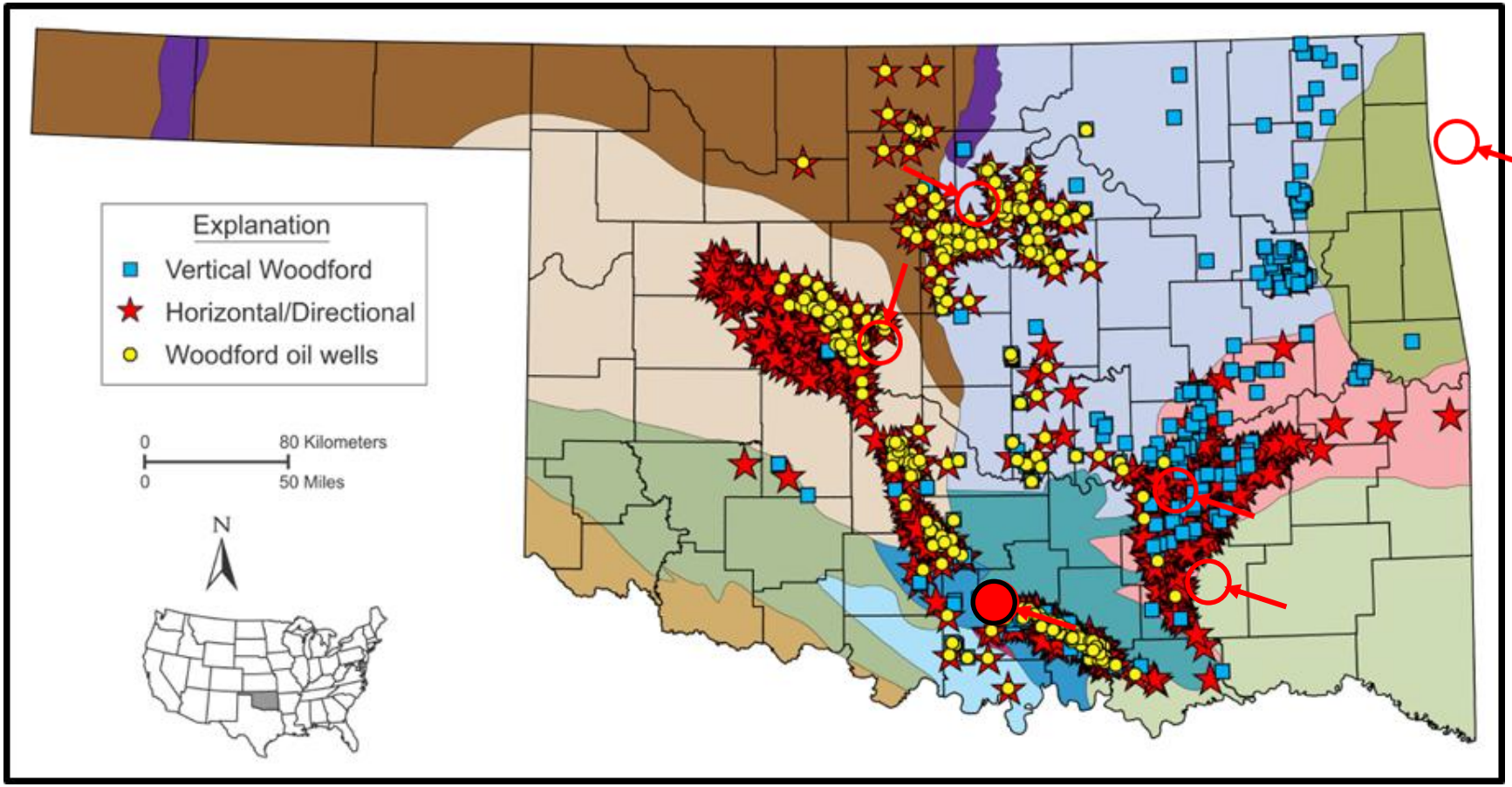
Woodford Gas Area: Arkoma Basin, Hughes County, OK



Neutron-density crossover with PE values approaching 2.0 in silica-rich zones

Gamma-ray, caliper, PE, and neutron-density porosity curves across the Woodford Shale and parts of adjacent strata, Newfield Exploration, Poe 1-29, Hughes County, OK.

Status of Woodford Production



Woodford Shale Proximal to Basin Axis

Map showing the major Woodford Shale plays and the major geologic provinces of Oklahoma. The Cherokee Platform is designated by the periwinkle color. Note that there are few oil wells in the basinal Woodford Shale plays when compared to the Cherokee Platform (modified from Cardott, 2014 and Northcutt and Campbell, 1996).

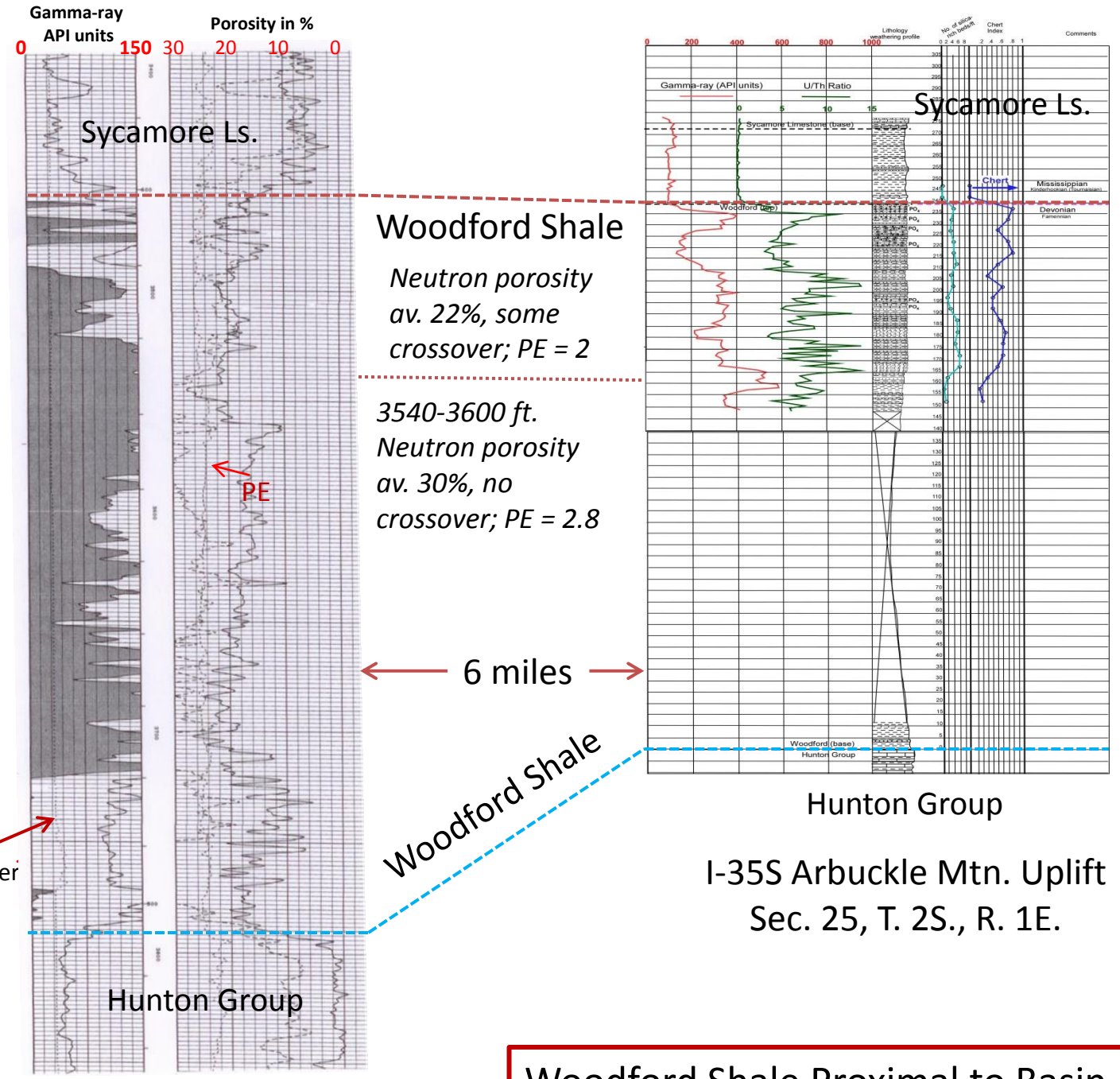
Characteristics:

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

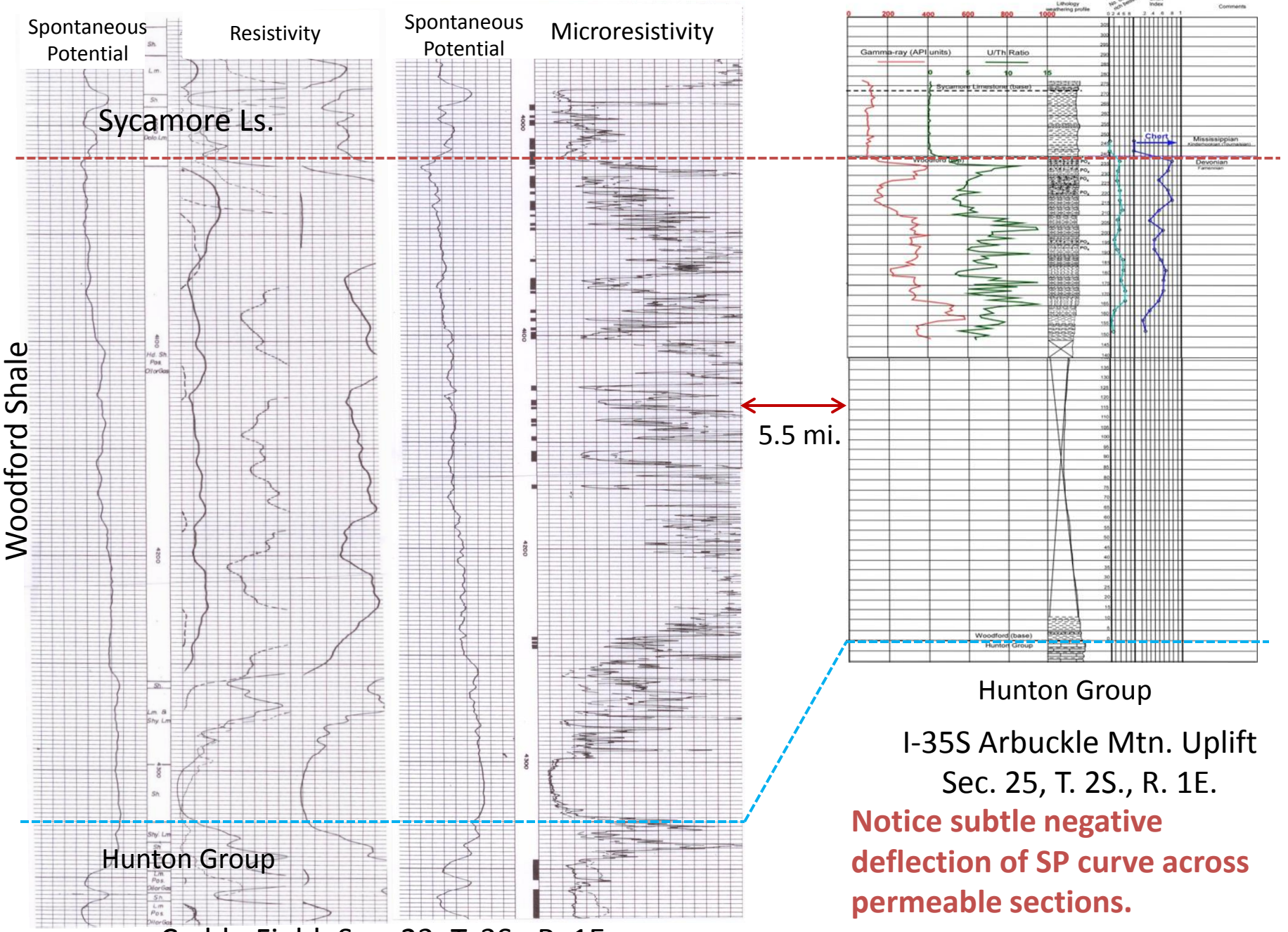
Beds near the top of the Woodford, I-35 S, Arbuckle Mountains, OK

Southern Arbuckle Mountains
I-35

Woodford Shale Proximal to Basin Axis



Woodford Shale Proximal to Basin Axis

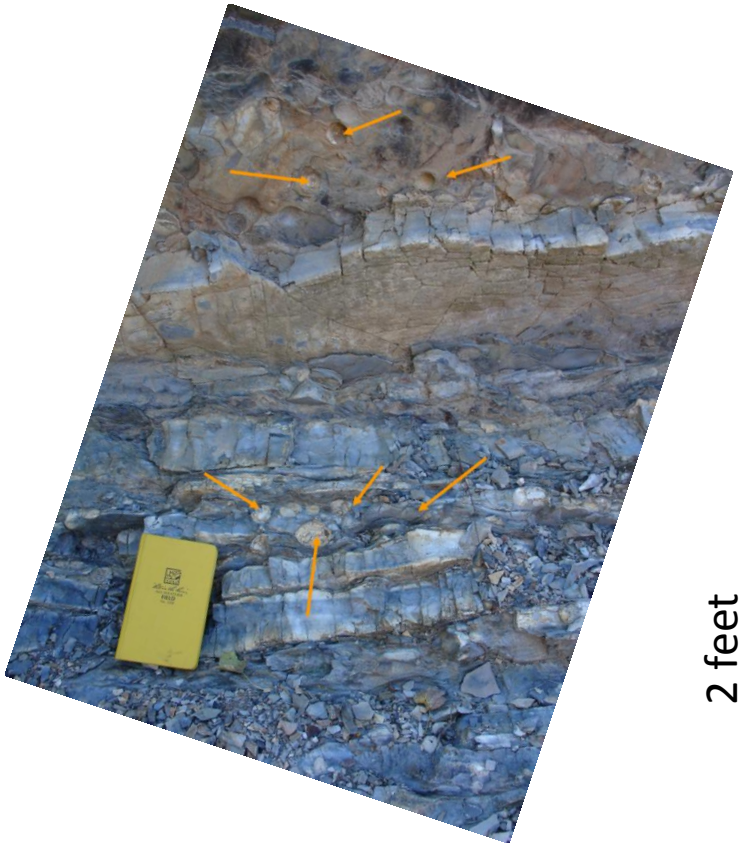


I-35S Arbuckle Mtn. Uplift
Sec. 25, T. 2S., R. 1E.

Notice subtle negative deflection of SP curve across permeable sections.

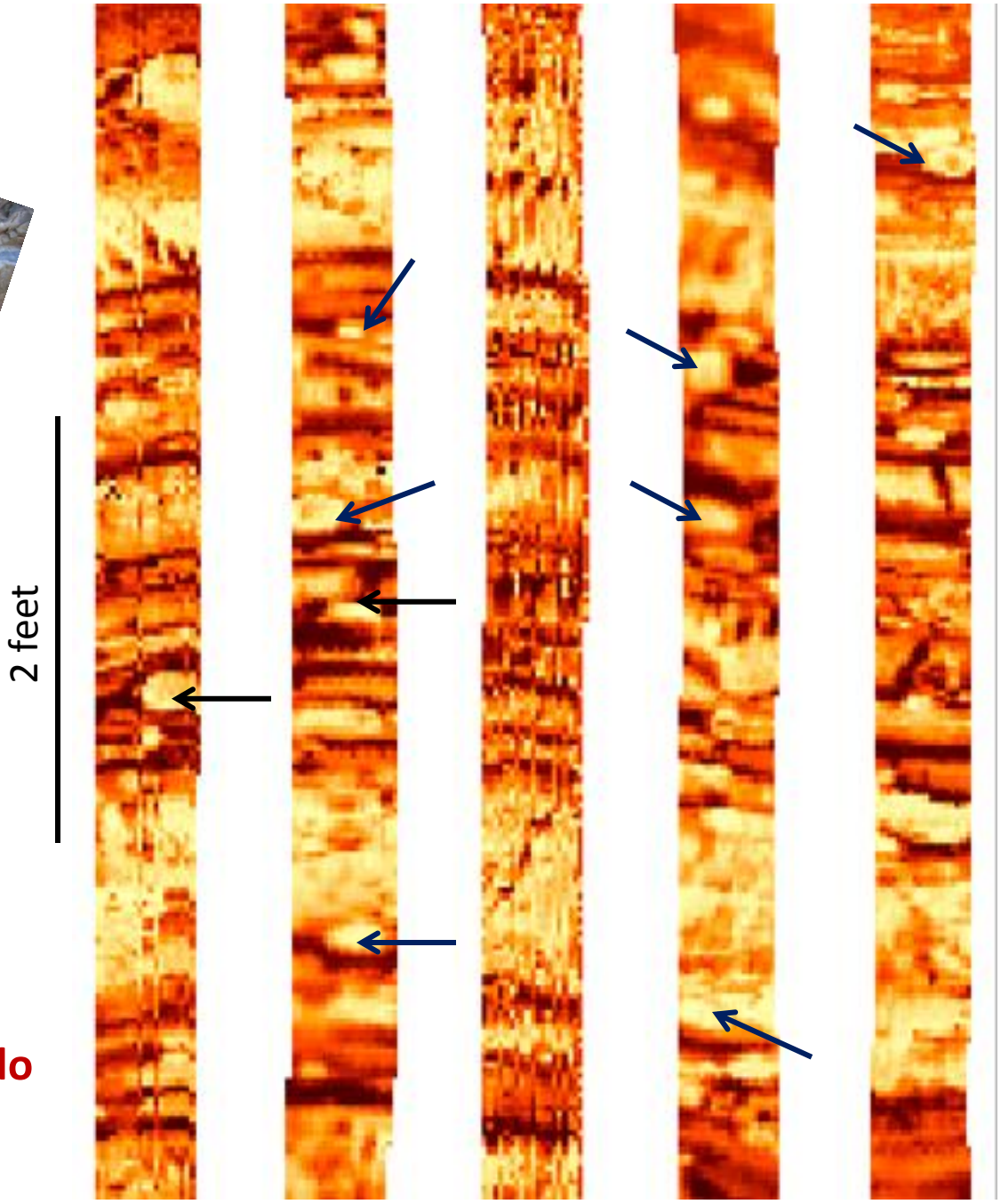
Caddo Field: Sec. 23, T. 3S., R. 1E.
F/50 BO/1MMCF

Woodford Shale Proximal to Basin Axis

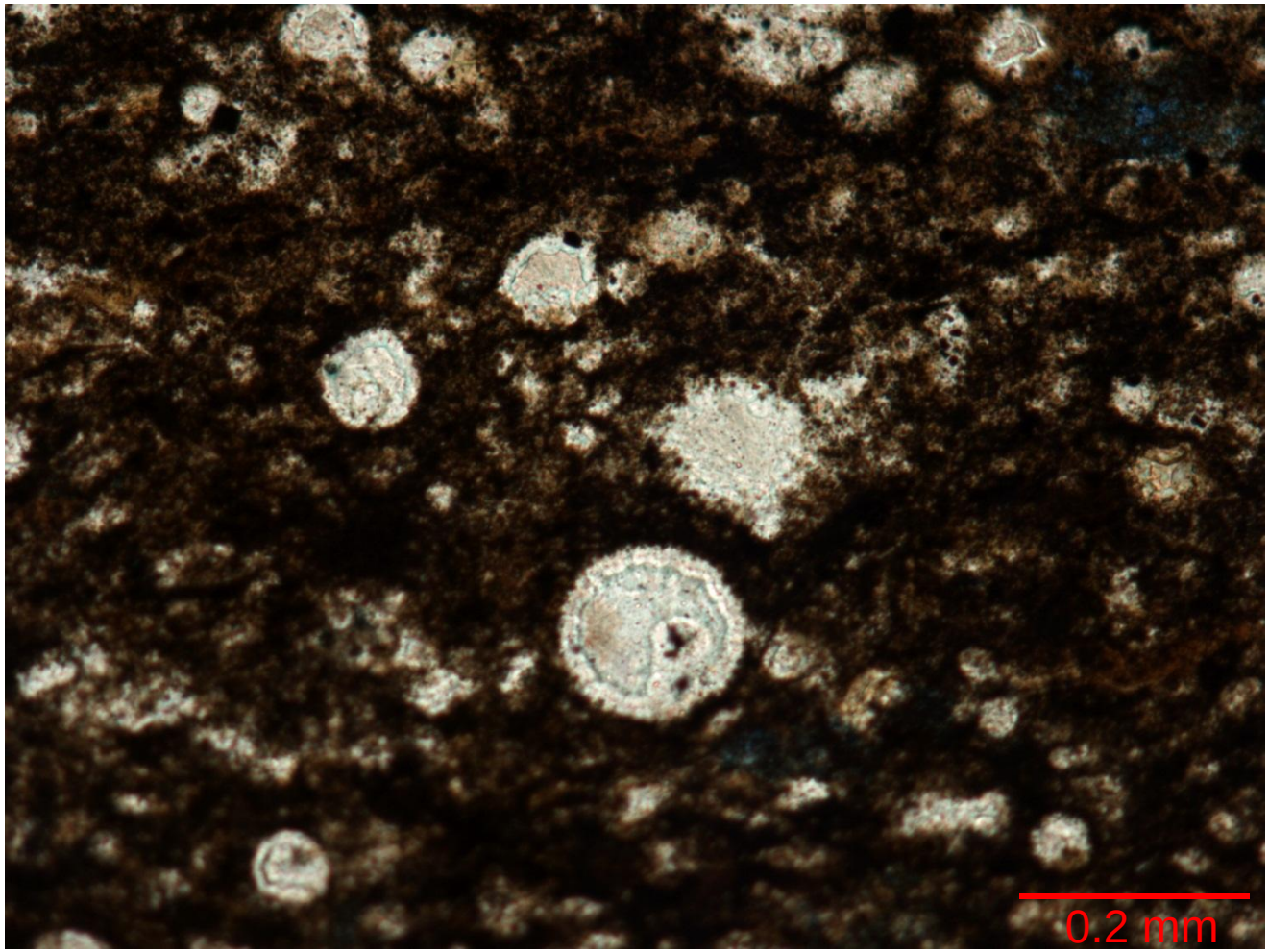


I-35S Arbuckle Uplift
Section 25, T.2S.,R.1E.

Outcrop Photograph Scaled to Imaging Log from Caddo Field to Illustrate Bedding and PO_4 Nodules (arrows)

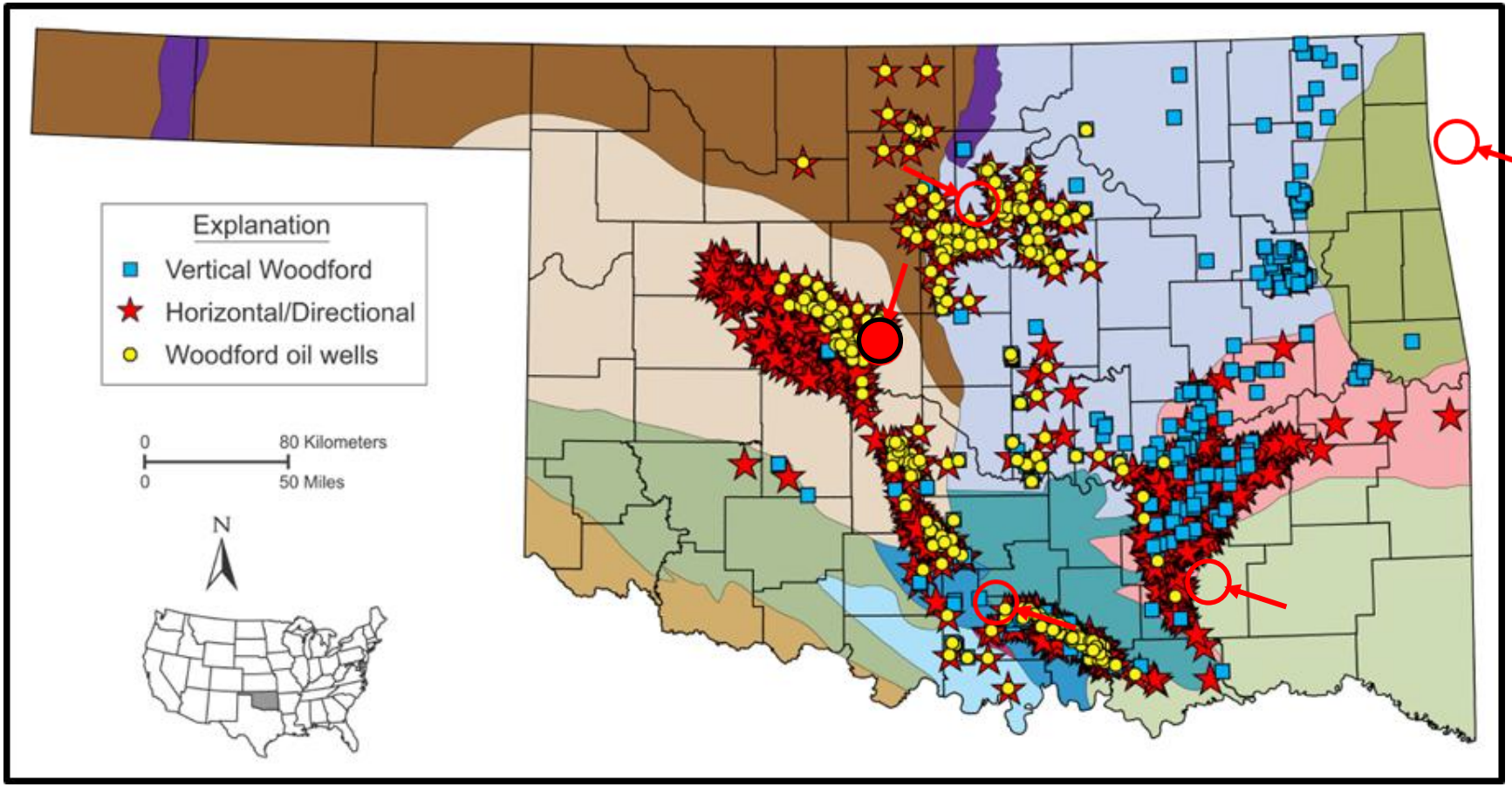


Radiolarians provide silica, I-35S



Woodford Shale Proximal to Basin Axis

Woodford Shale: Shelf Setting



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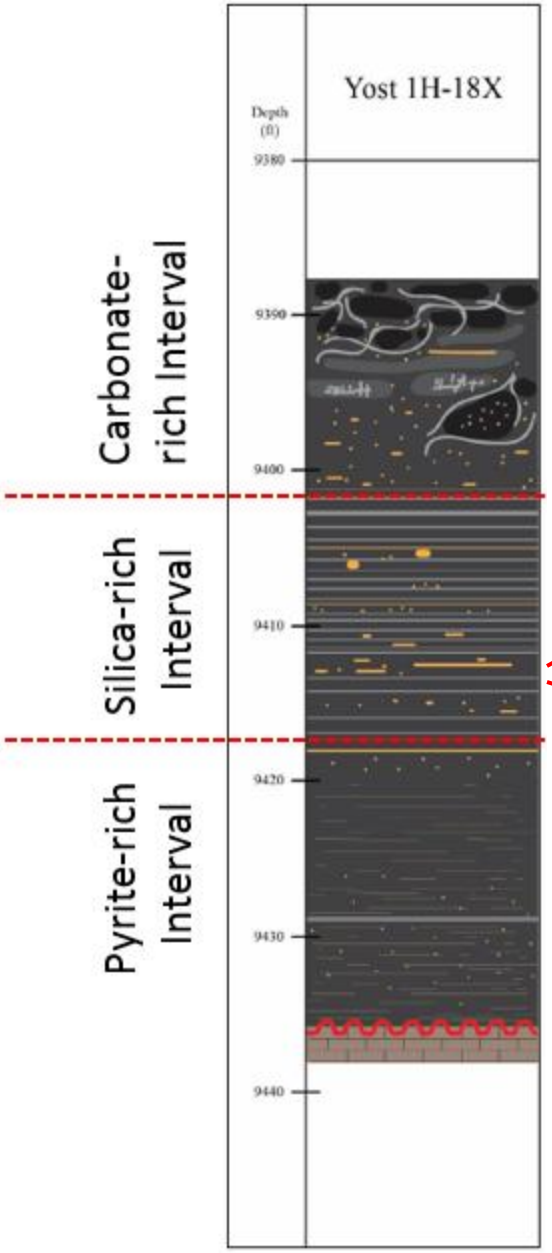
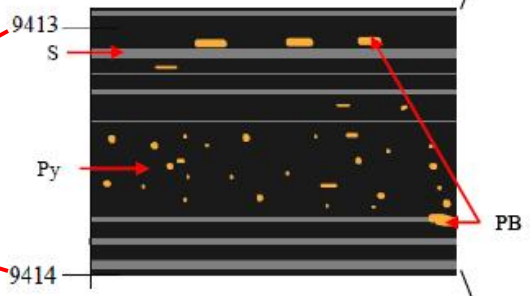
Woodford Shale: Shelf Setting

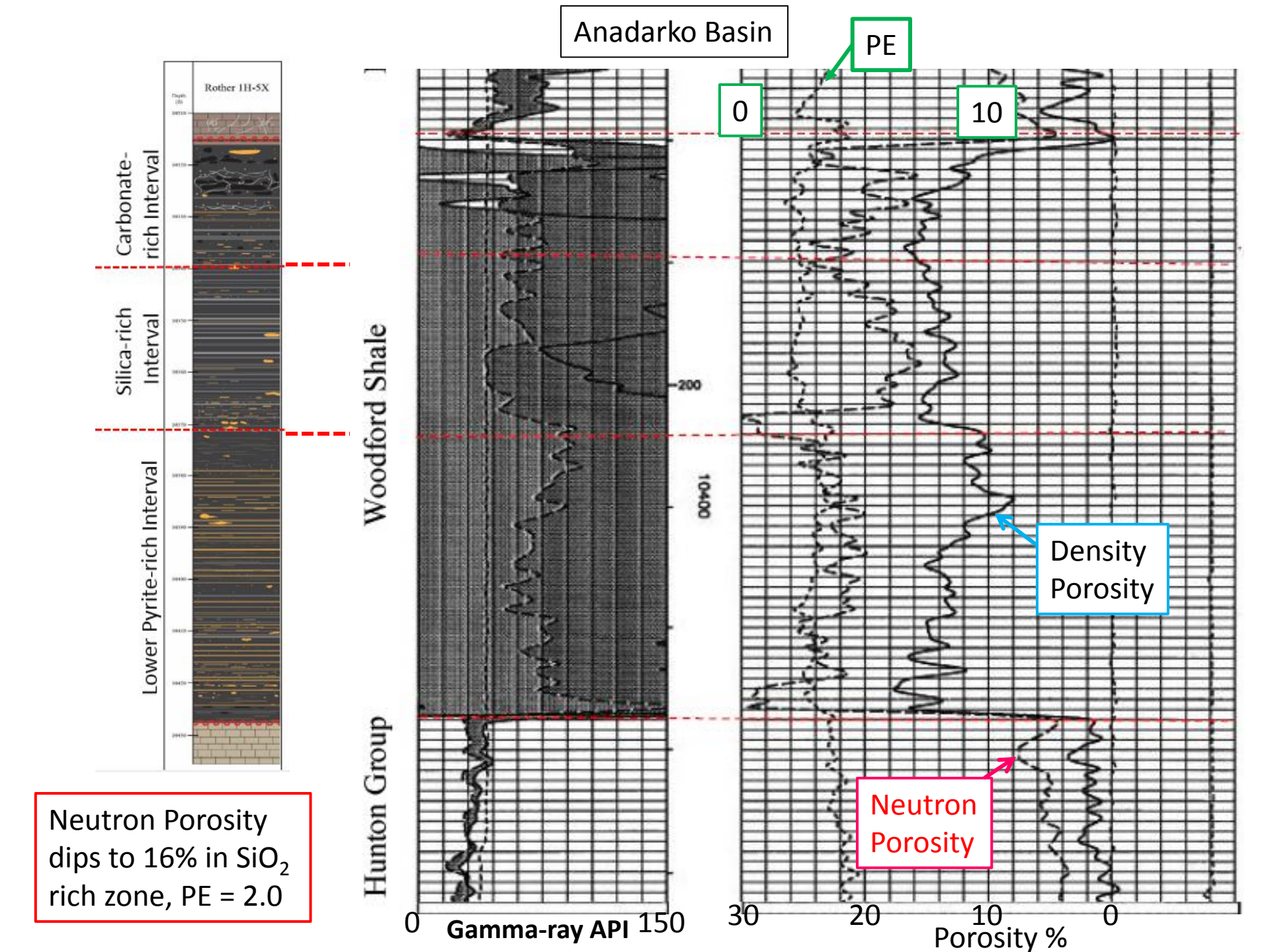
Anadarko Basin

Silica-cemented bands (S) with pyritized burrow (PB) and scattered pyrite (py) of the silica-rich (SR) interval. Calcite-filled fractures (F) are evident.

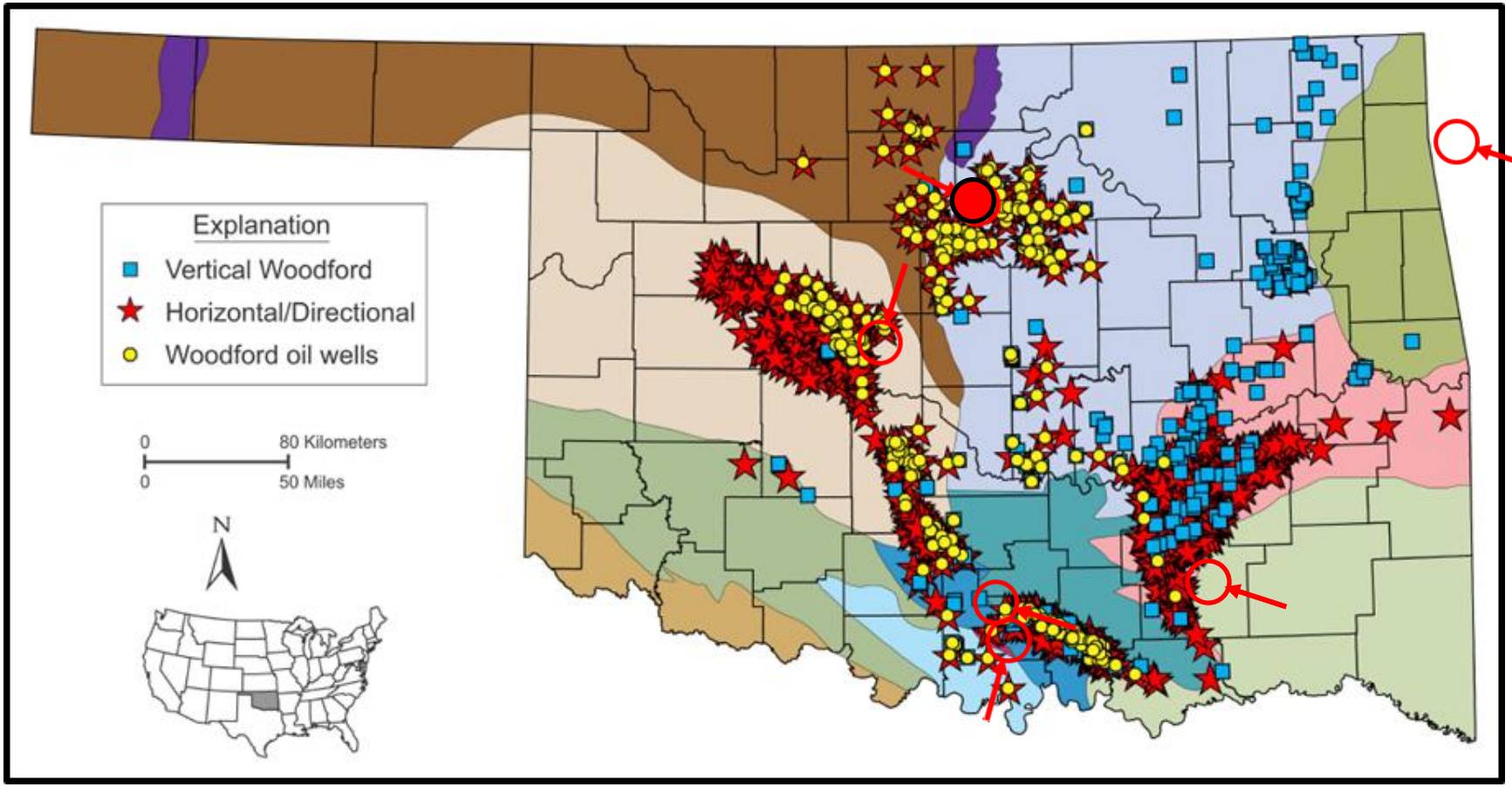


Foltz (2015)




Anadarko Basin
PE
0
10
Rother 1H-5X
Carbonate-rich Interval
Silica-rich Interval
Lower Pyrite-rich Interval
Woodford Shale
Hunton Group
200
10400
Density Porosity
Neutron Porosity
0
Gamma-ray API
150
30
20
10
0
Porosity %
Neutron Porosity dips to 16% in SiO_2 rich zone, PE = 2.0

Woodford Shale: Shelf Setting



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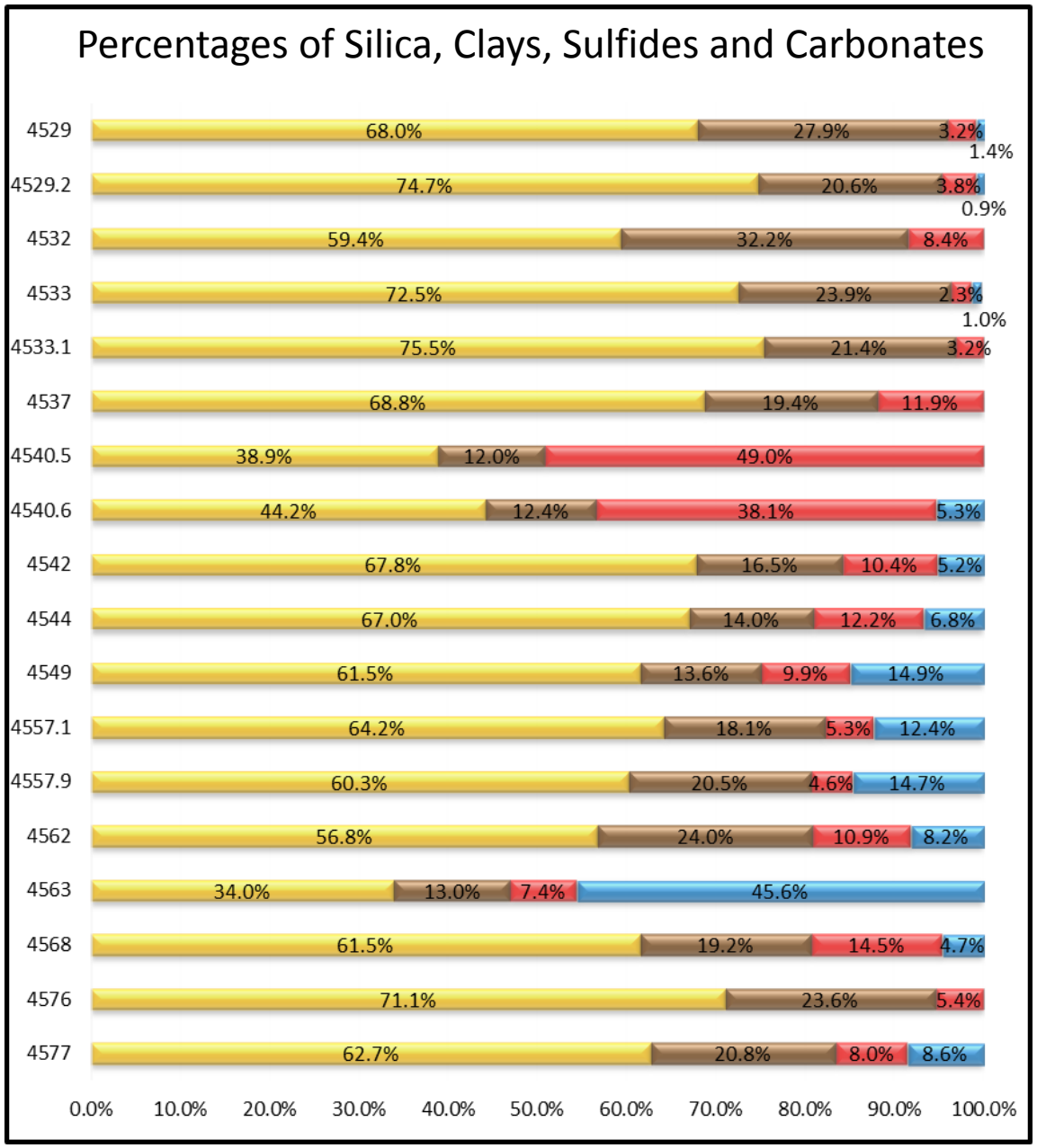


X-ray Results

Total Silica

Total Clays

Total Sulfides

Total Carbonates

Northern Oklahoma
Payne and Noble Counties

Woodford Shale: Shelf Setting

Woodford Shale: Shelf Setting

After Snider (2014)

Smooth Surface: Cemented Interval

Outer surface of core is smooth and uneroded. Rock competence a result of silica and carbonate cement. No silica bands are evident.

X-ray analysis indicates 62% SiO_2 14% clay, 10% sulfides and 14% carbonates

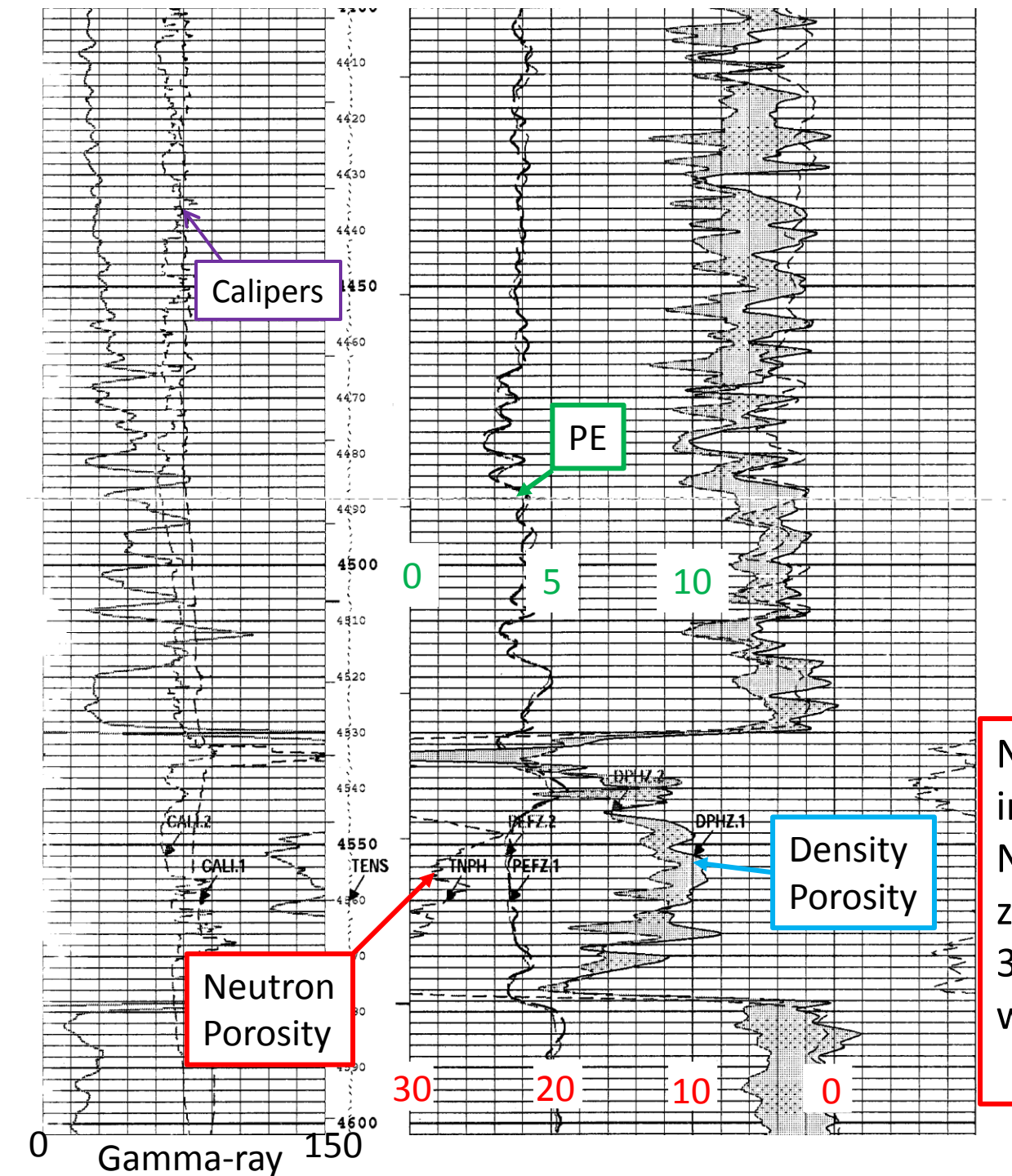
Woodford Shale: Shelf Setting

Eroded outer surface of core generated during coring. Rock is less Competent as a result of higher clay content.

Eroded Surface: Core from Clay-rich Interval

X-ray analysis indicates 59% SiO_2 32% clay, 8% sulfides and <1% carbonates

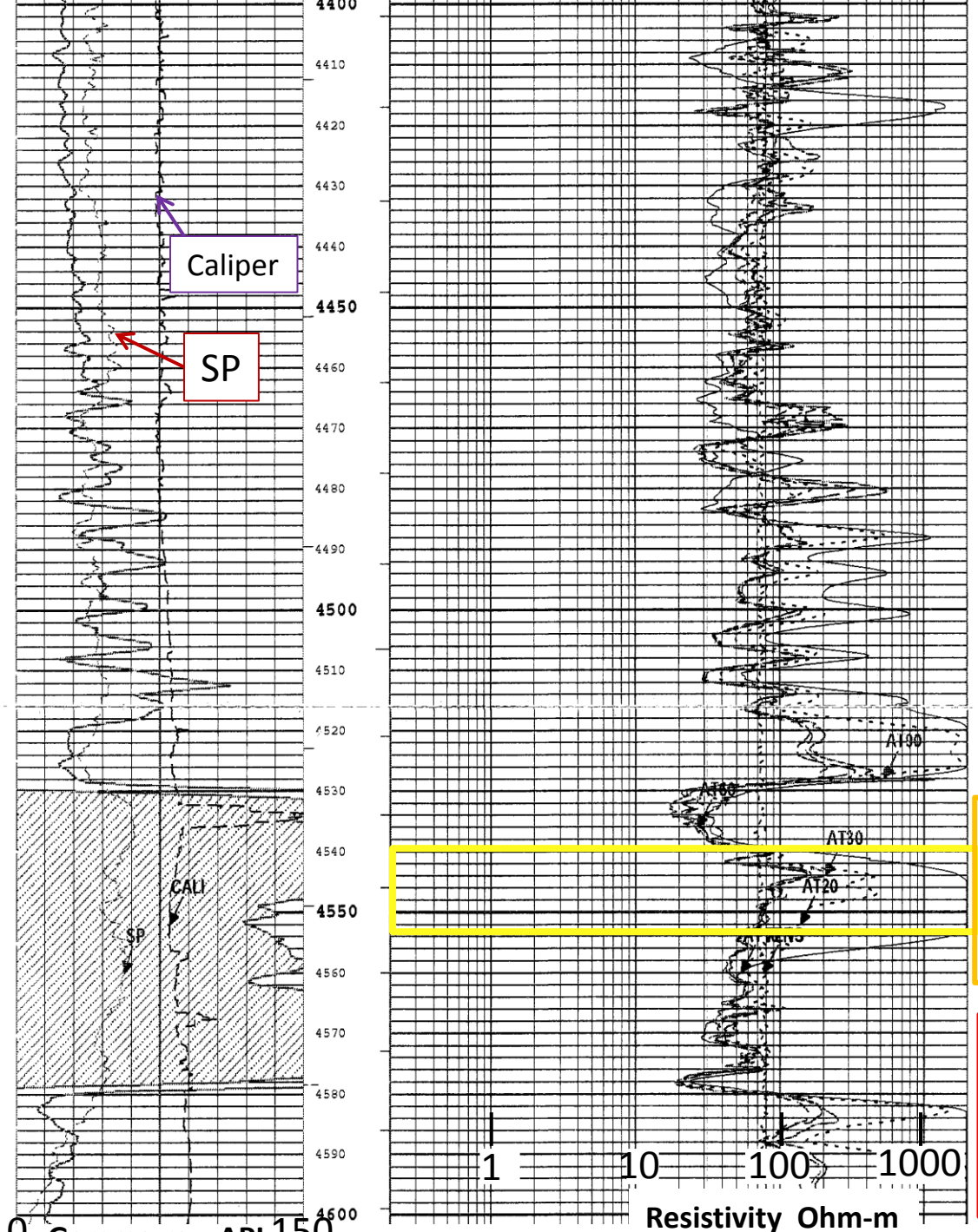
After Snider (2014)



Woodford Shale: Shelf Setting

Gamma-ray, caliper, PE, and neutron-density porosity curves across the Woodford Shale and parts of adjacent strata, Noble County, OK.

Neutron porosity decreases in cemented zone to <24%. Neutron porosity in clay-rich zone >30%. PE ranges from 3.0 to 4.0 except at 4540 feet, which has 38 to 49% sulfides.



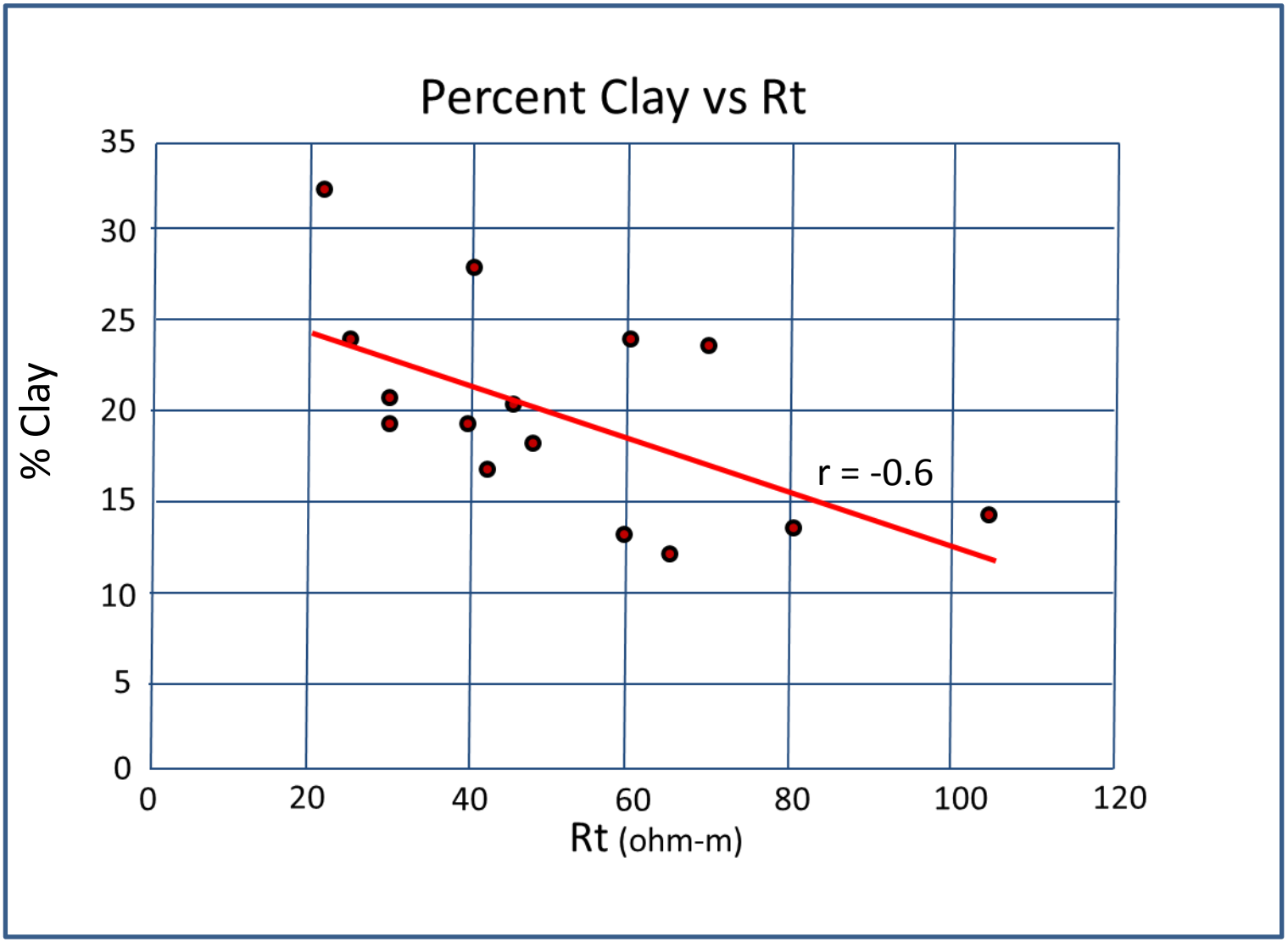
Woodford Shale: Shelf Setting

Gamma-ray, spontaneous-potential, caliper and resistivity curves across the Woodford Shale and parts of adjacent strata, Noble County, OK.

Resistivity values are >70 ohm-m across cemented zone with a maximum peak >100 ohm-m.

Increase in resistivity and decrease in neutron porosity is mappable.

Woodford Shale: Shelf Setting



Negative relationship between percentage of clay and resistivity

Summary

1. Southern Oklahoma: proximal to basin axis and upwelling all contain evidence of silicification and chert sourced by radiolarian tests

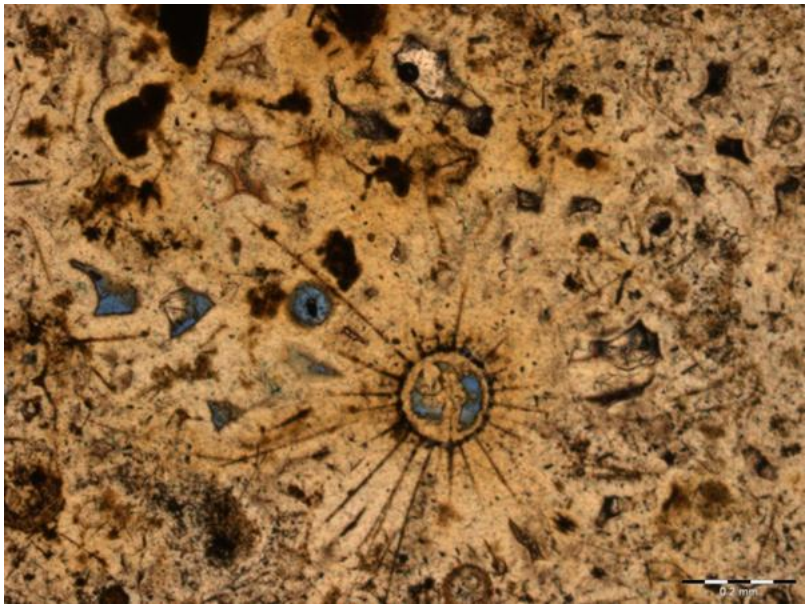
2. Chert positively impacts reservoir properties by increasing brittleness and propensity to fracture both naturally and artificially

3. Volume of chert impacts wireline-log signatures with neutron and gamma-ray curve suppression with high volumes of chert

4. In the Anadarko Basin shelf setting, radiolarian-sourced silica is manifested as cm-scale silica bands that when abundant, reduce neutron porosity

5. In northern Oklahoma chert or silica bands are not apparent, but increased silica, carbonate or sulfide cements reduce clay content, which in turn is manifested in rock competence and increased resistivity and corresponding decreased neutron porosity

6. Competent rock can be fracture stimulated and is mappable!

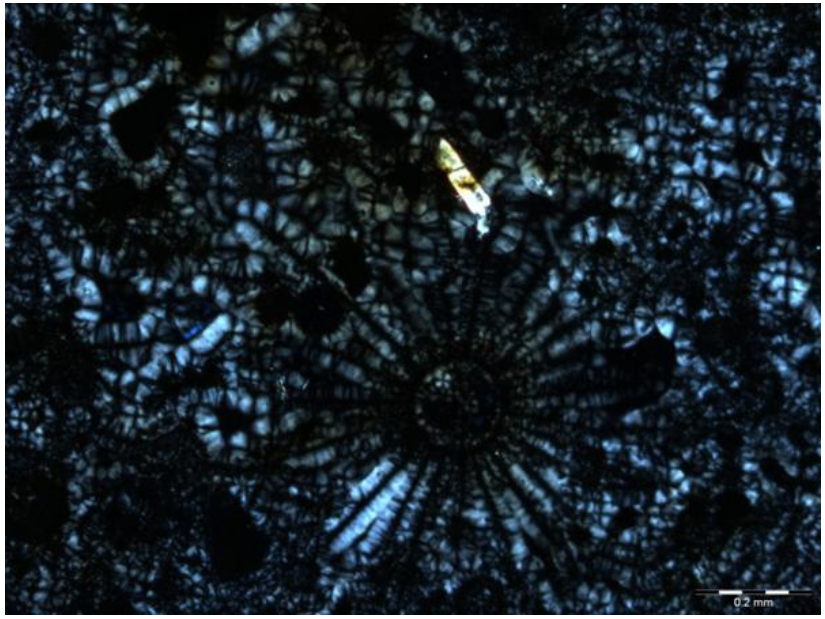


Plane-polarized light (PPL)

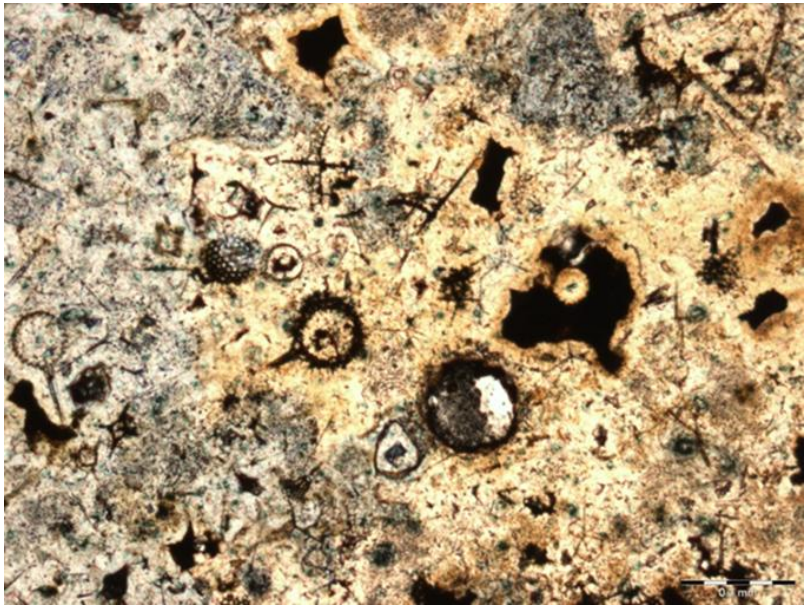
Thank You!

RPSEA- Research Partnership to Secure Energy for America
Newfield Exploration
Devon Energy
Cimarex Energy
AAPG
HighMount Exploration & Production
Boone Pickens School of Geology - OSU

Assorted radiolarians:
Woodford Shale, southern Oklahoma



Cross-polarized light (CPL)



PPL

Selected References

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