AAPG Woodford Shale Forum April 11, 2013

Woodford Shale: From Hydrocarbon Source Rock to Reservoir

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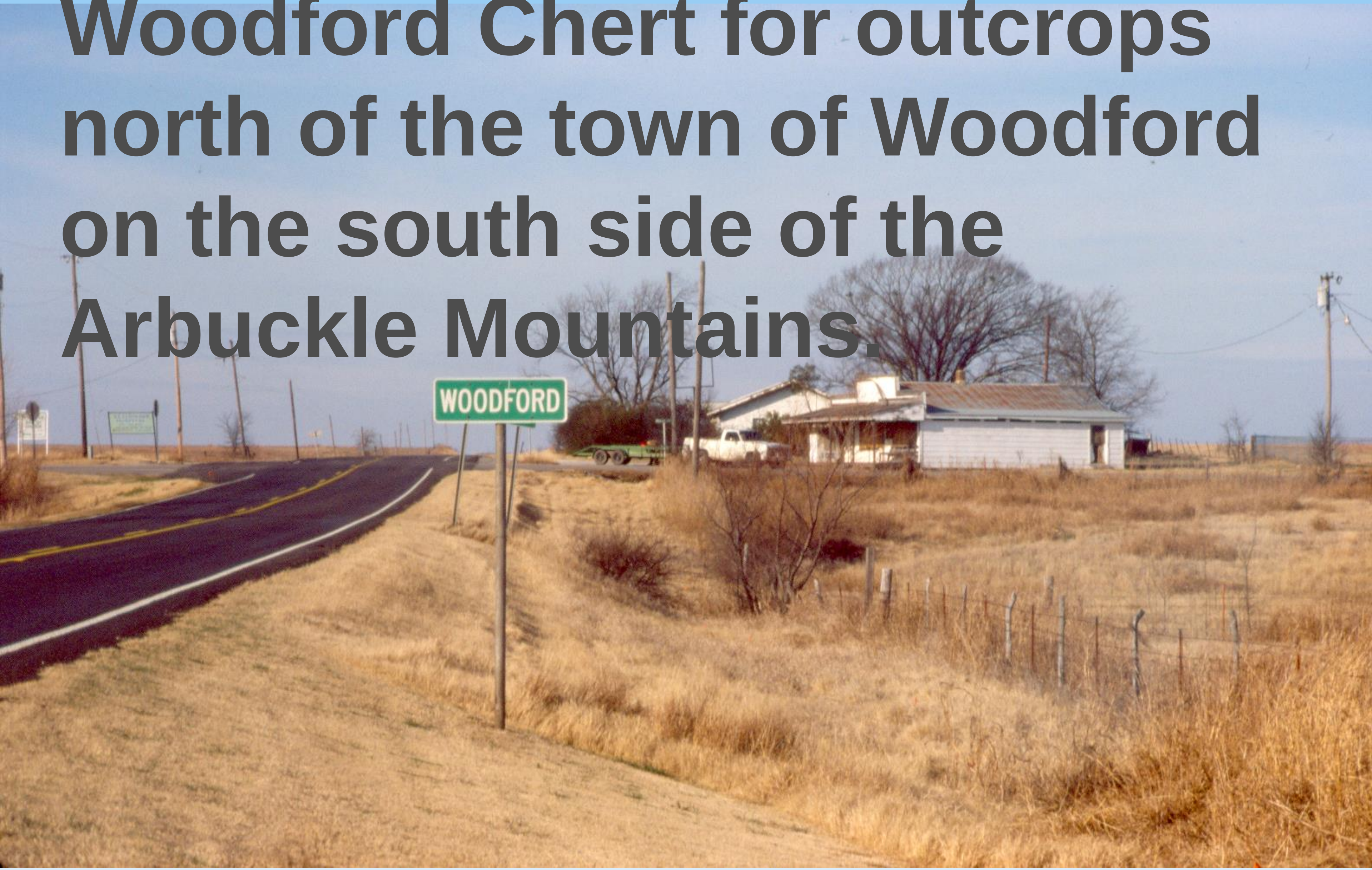
Oklahoma Geological Survey

Outline of Presentation

Woodford Shale:

- Terminology and distribution
- As a hydrocarbon source rock
- As a reservoir
- Hydrocarbon production

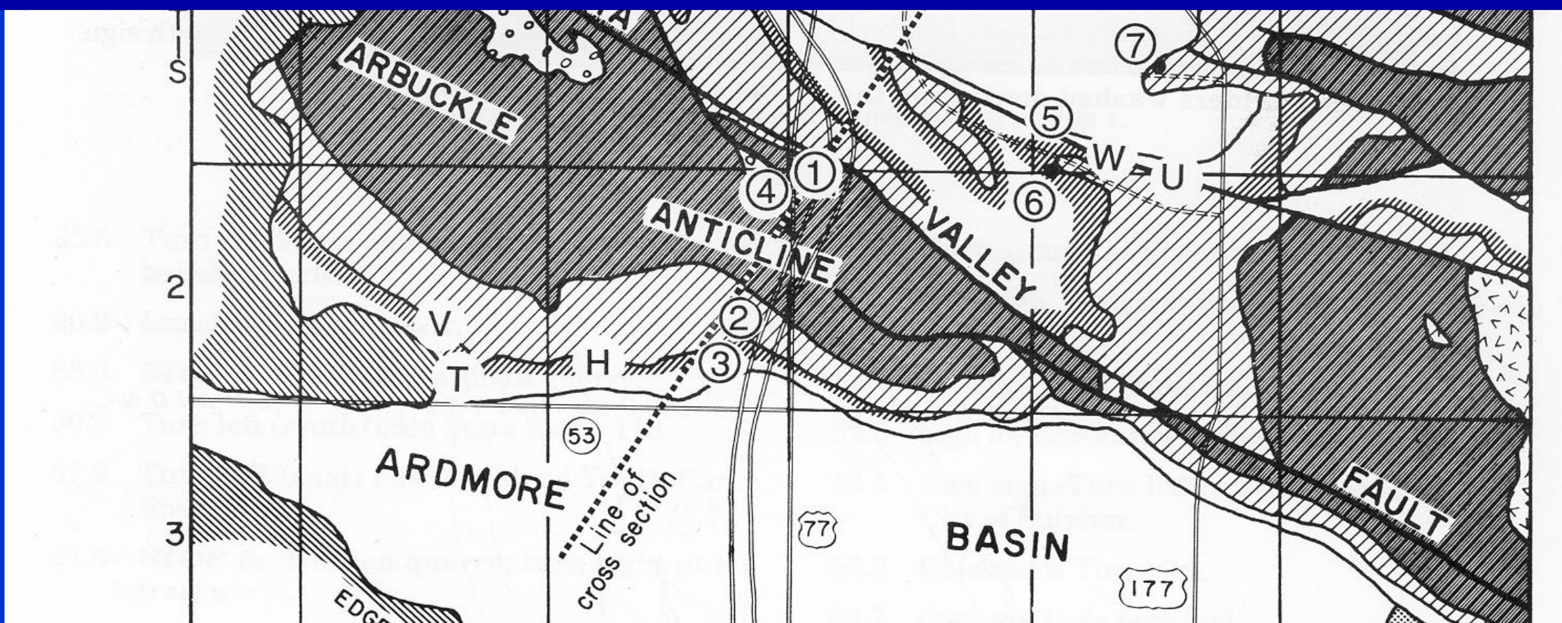
Taff (1902) introduced the name Woodford Chert for outcrops north of the town of Woodford on the south side of the Arbuckle Mountains.



WOODFORD CHERT: Taff (1902), Gould (1925), Wilmarth (1938), Dott (1952)

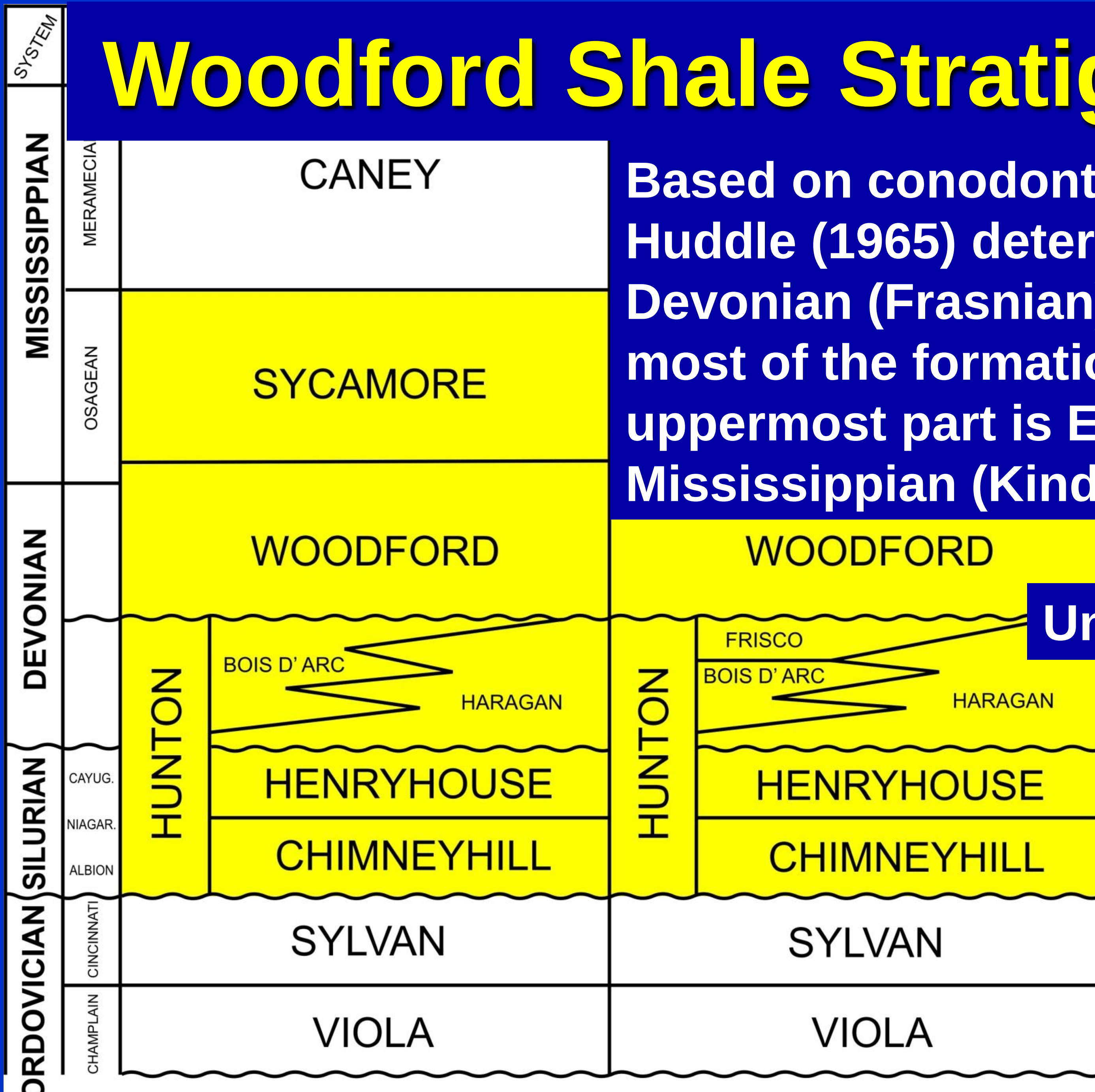
WOODFORD FORMATION: Morgan (1924), Amsden (1957-1963), Wilson (1958), O'Brien and Slatt (1990)

WOODFORD SHALE: Tarr (1955), Jordan (1957, 1959, 1962), Urban (1960), Hass & Huddle (1965), Amsden (1975, 1980)[preferred name in lexicons]

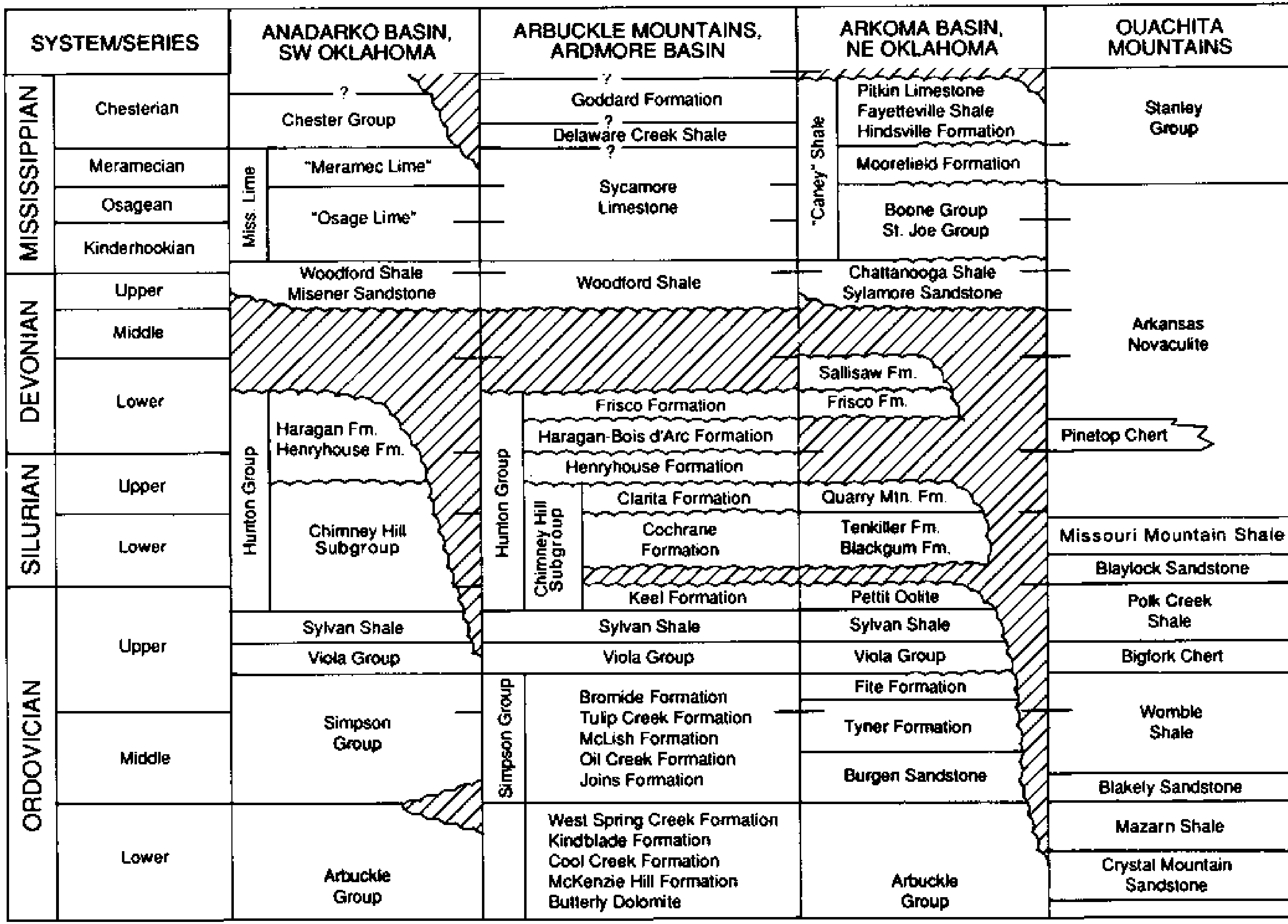


Woodford Shale Stratigraphy

Based on conodonts, Hass and Huddle (1965) determined a Late Devonian (Frasnian) age for most of the formation; uppermost part is Early Mississippian (Kinderhookian)

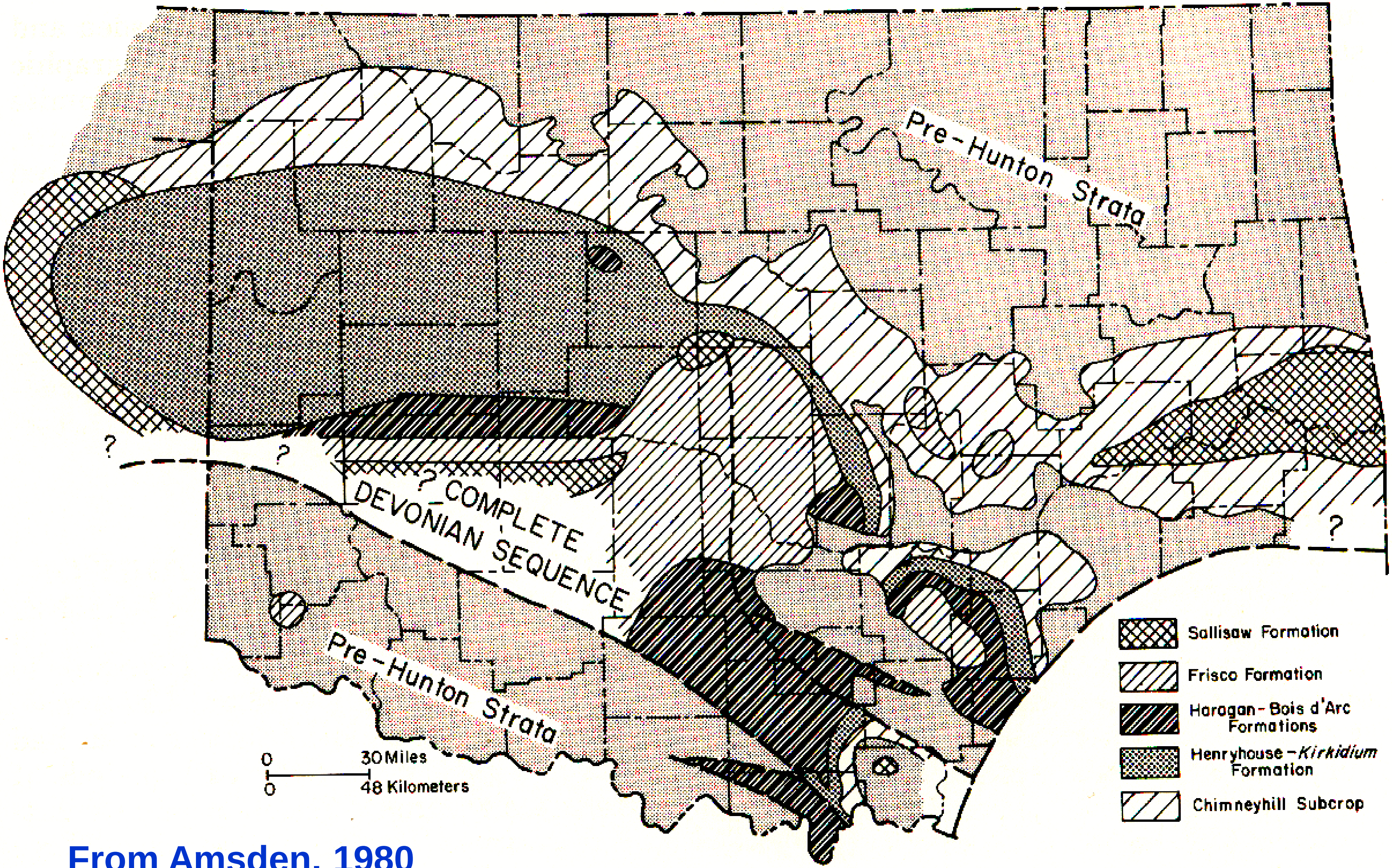


Unconformity



Modified from Johnson and Cardott, 1992

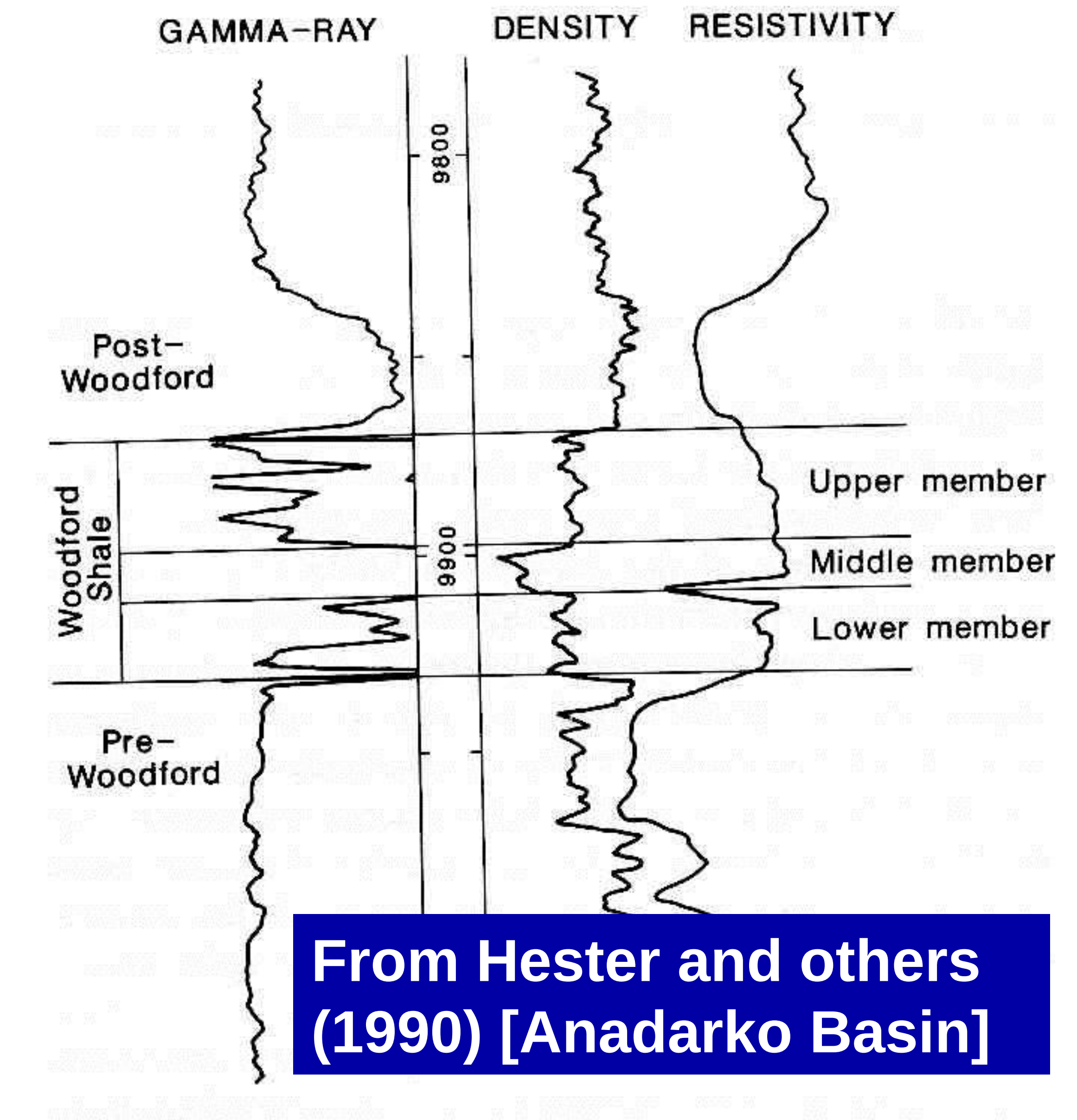
Pre-Woodford Geologic Map



From Amsden, 1980

Woodford Shale Members

Three informal members based on **palynomorphs** (Urban, 1960; Von Almen, 1970), **geochemistry** (Sullivan, 1985), **log signatures** (Hester and others, 1990; Lambert, 1993)

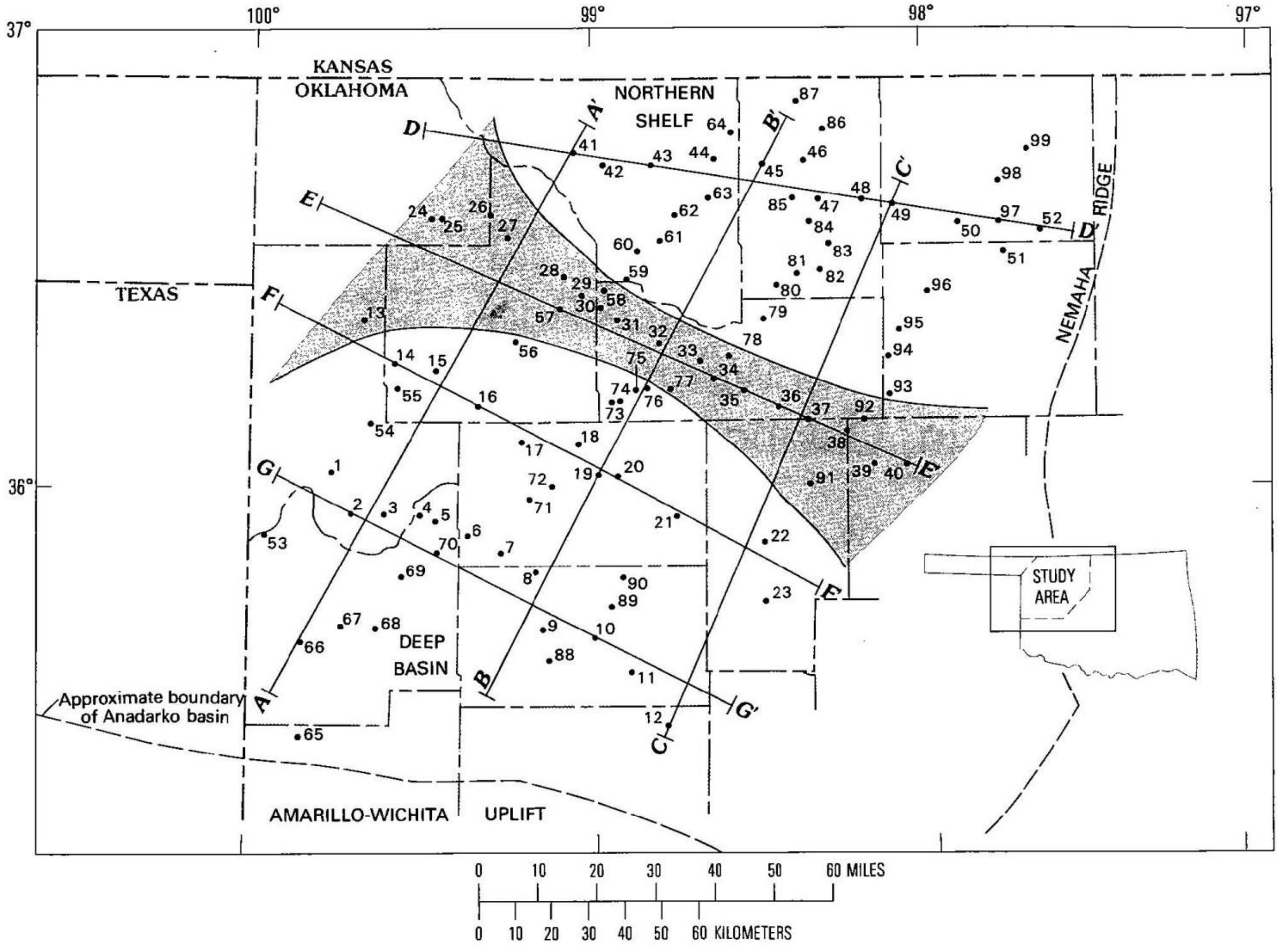


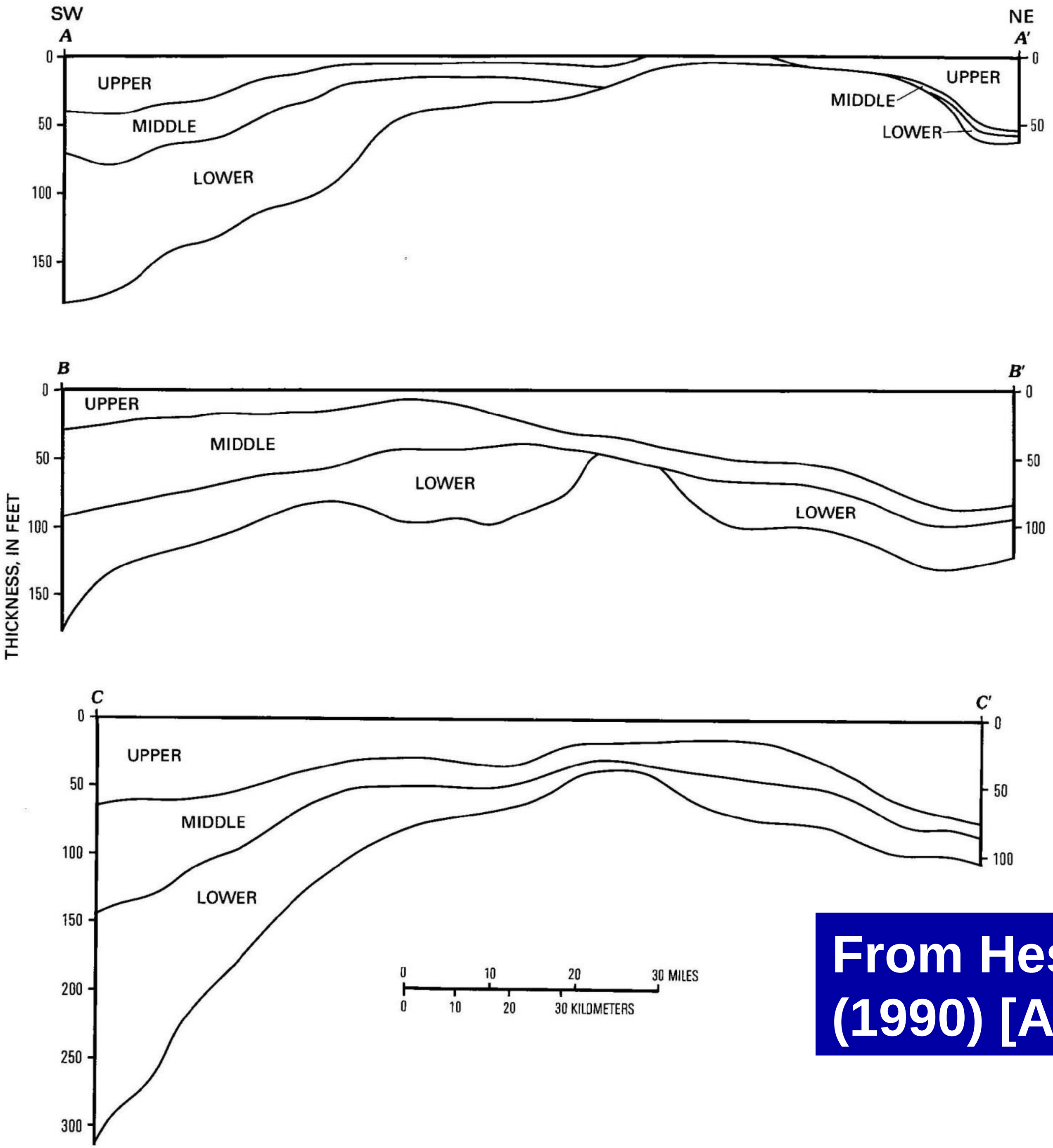
From Hester and others (1990) [Anadarko Basin]

Log-Derived Regional Source-Rock Characteristics of the Woodford Shale, Anadarko Basin, Oklahoma

By TIMOTHY C. HESTER, JAMES W. SCHMOKER,
and HOWARD L. SAHL

USGS Bulletin 1866-D





From Hester and others (1990) [Anadarko Basin]

Lithostratigraphy of the Woodford Shale, Anadarko Basin, West-Central Oklahoma*

Craig D. Caldwell[1]

Search and Discovery Article #50518 (2011)
Posted November 30, 2011

*Adapted from oral presentation at AAPG Mid-Continent Section meeting, Oklahoma City, Oklahoma, October 1-4, 2011

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Abstract

Since early 2008 over three-hundred horizontal Woodford Shale wells have been completed in the Anadarko basin, west-central Oklahoma, along a northwest-southeast trend approximately 100 miles (161 km) in length and 20 miles (32 km) wide. Shallowest production to date occurs at 10,500 ft (3,200 m), and deepest production occurs at 16,100 ft (4,900 m).

Seven mudrock lithofacies, defined mainly on the basis of percent TOC and variations in mineral content (primarily quartz, clay, and dolomite), make-up the fifteen stratigraphic units that comprise the Lower, Middle, and Upper Woodford in the geographic center of the play where the Woodford is 175 to 330 ft (53 to 100 m) thick. The basal-most units of the Woodford in this area are TOC-poor clayey mudrock (<2% TOC), recording the first transgression of the Woodford seas. The overlying Lower Woodford and the Middle Woodford are composed of 10 to 30 ft (3 to 9 m) intervals dominated by one of three lithologies: clayey mudrock (CM) (38% clay and 41% quartz), clayey siliceous mudrock (CSM) (27% clay and 55% quartz), and less common dolomitic clayey mudrock (DCM) (33% clay, 32% quartz, and 15% dolomite). These mudrock lithologies are organic-rich with TOC values averaging 5 to 6.5%. Clay is predominantly illite, and dolomite is commonly ferroan. Quartz is biogenic and detrital. The Upper Woodford in this area is predominately CSM and siliceous mudrock (SM) (14.5% clay and 75% quartz). CSM and SM units are characterized by density-neutron cross-over and are readily distinguishable on wireline logs. The more silica-rich mudrocks (CSM and SM) are likely dominated by biogenic silica, recording distal deposition in areas less affected by detrital influx.

Caldwell, 2011

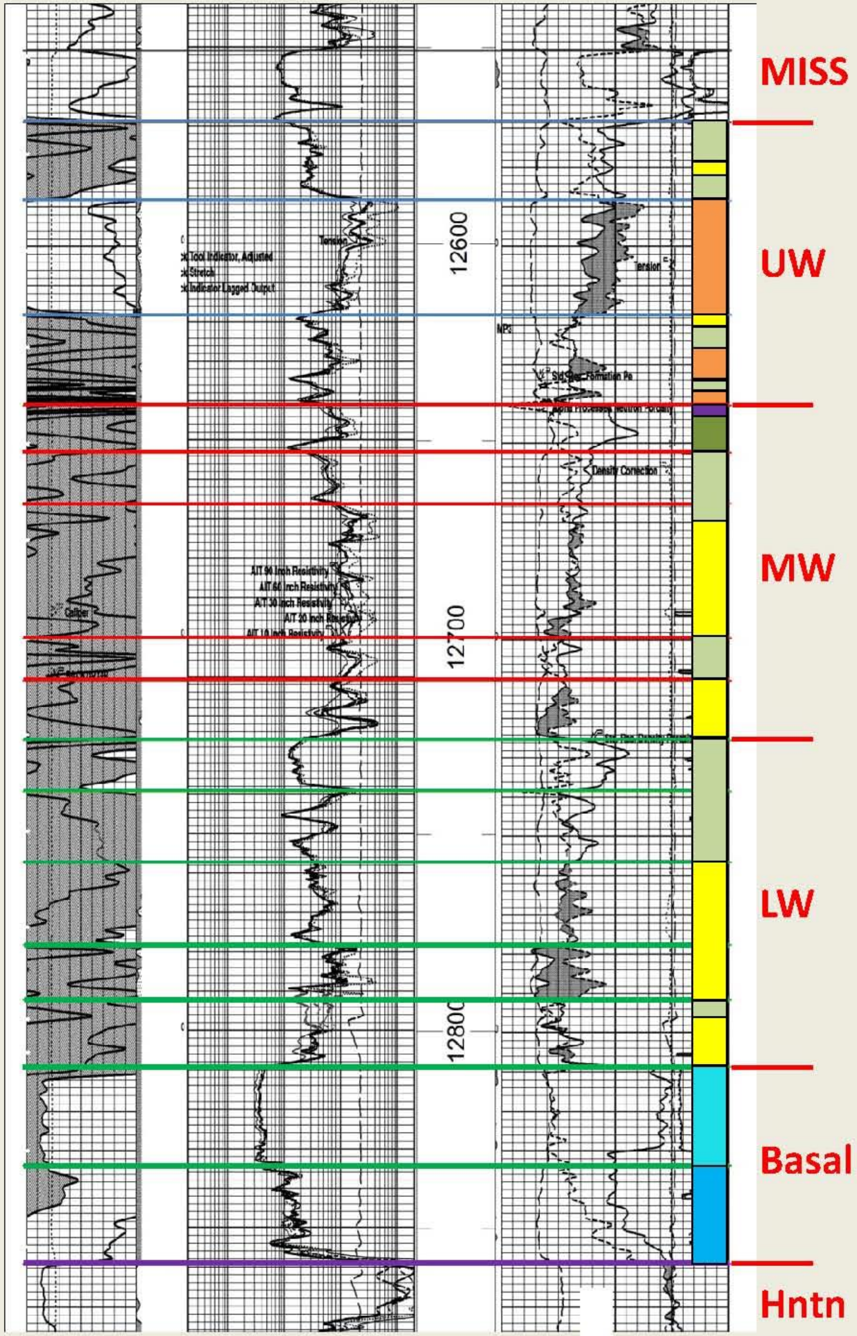
Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

Siliceous mudrock

Clayey, siliceous mudrock

Clayey mudrock

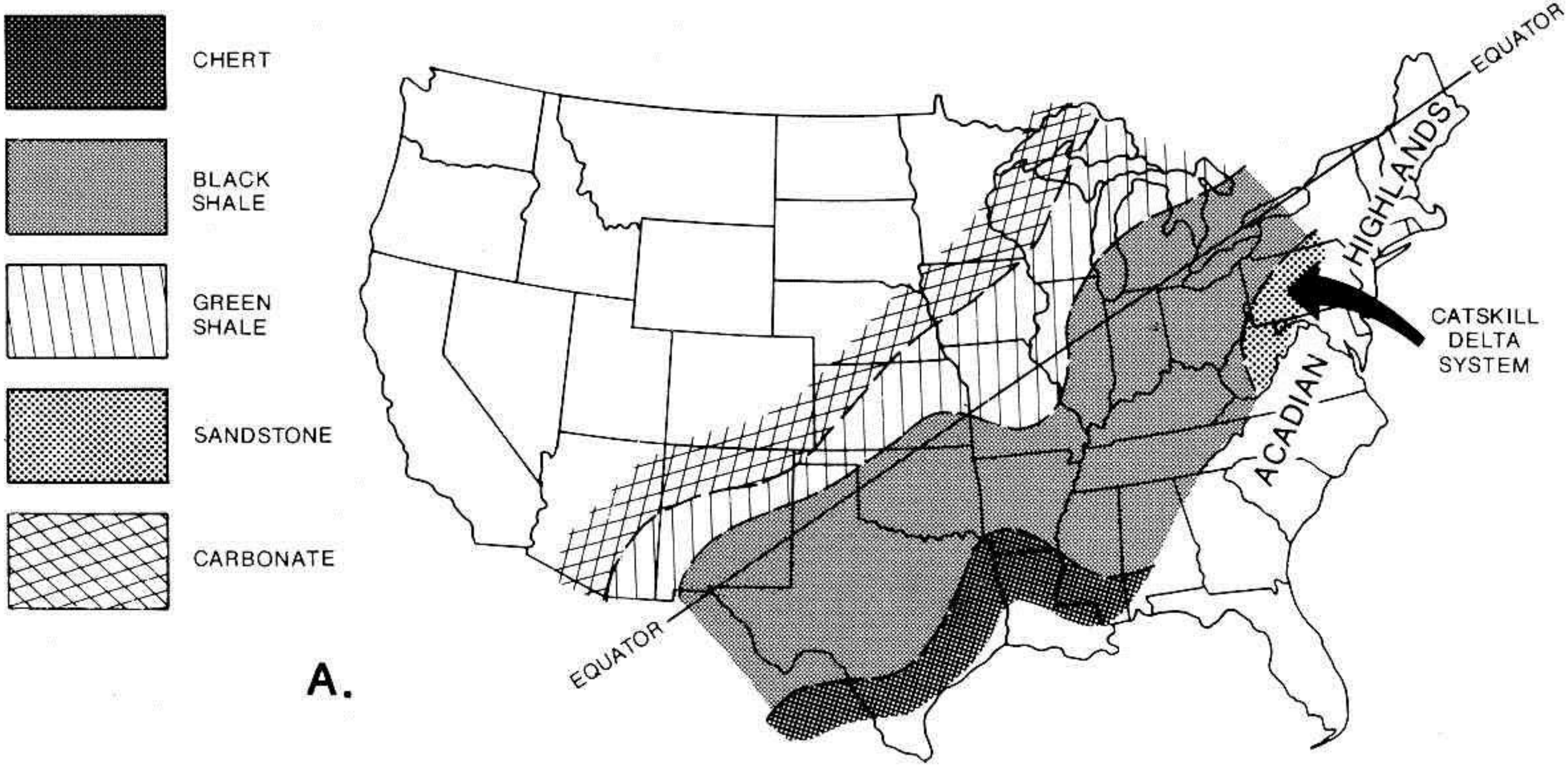
Organic-poor clayey mudrock



15 Stratigraphic Units Described by Caldwell, 2011

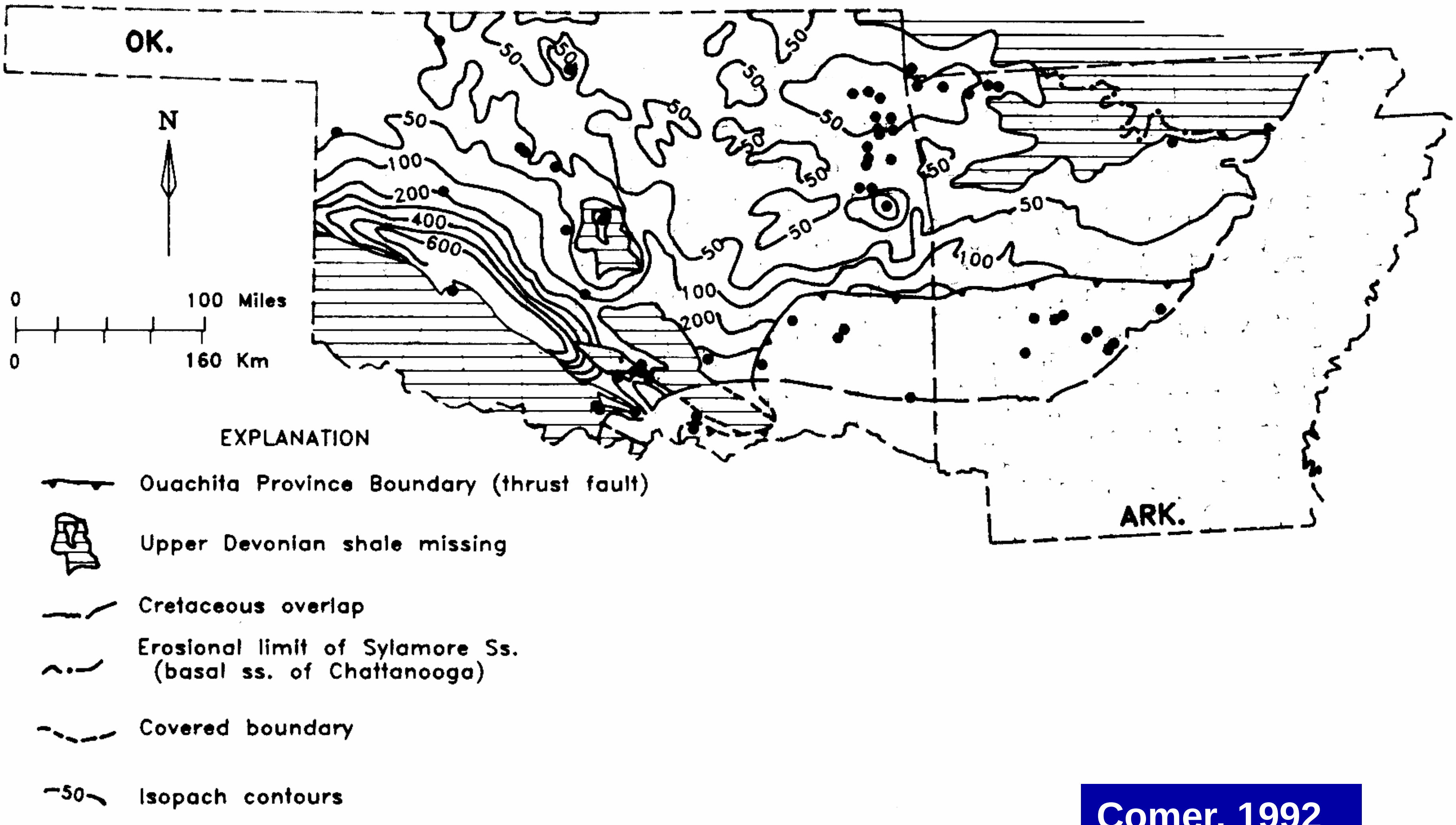
CIMAREX

Paleogeography and Facies Distribution in the Late Devonian



Kirkland and others, 1992

Isopach Map of Woodford Shale



Comer, 1992

Gas Shales

Gas shales are varieties of hydrocarbon source rocks (an important part of a petroleum system).

HYDROCARBON SOURCE ROCK CLASSIFICATION

Organic matter type refers to the kerogen or maceral type and can be lumped into gas generative (Type III), oil generative (Types I and II), or inert (Type IV).

Organic matter quantity is determined by the total organic carbon (TOC) content (weight percent, whole-rock basis).

Vitrinite reflectance (%Ro, oil immersion) is the most common thermal maturity indicator. Vitrinite is a maceral derived from the woody tissues of vascular plants. The oil window is considered to be from 0.5–1.35% Ro.

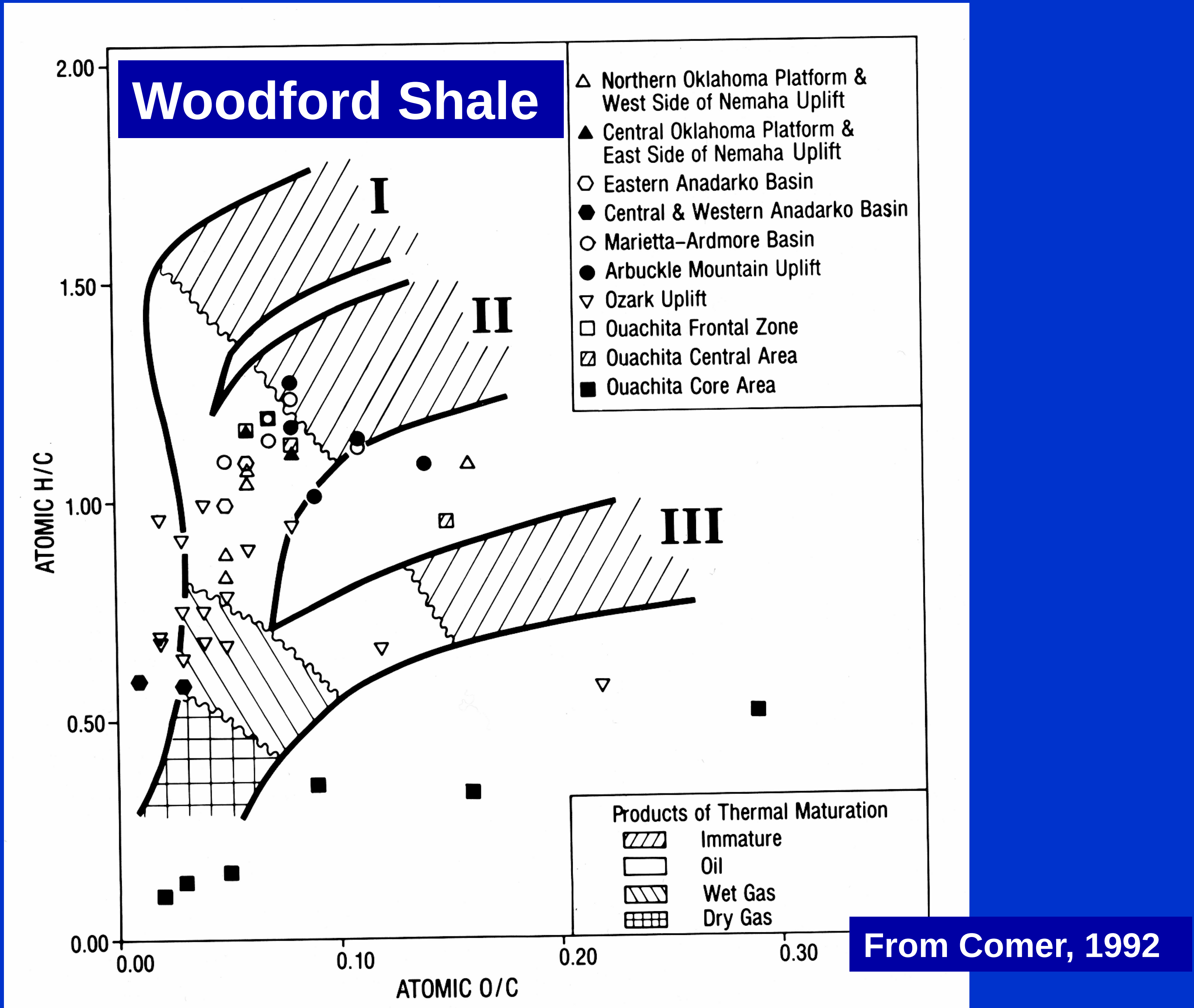
Woodford Shale as a Hydrocarbon Source Rock

- Type II Kerogen (oil generative organic matter)
- High total organic carbon (TOC)
- Contains vitrinite (vitrinite reflectance analysis) to determine thermal maturity

Hydrocarbon Source Rocks of Oklahoma

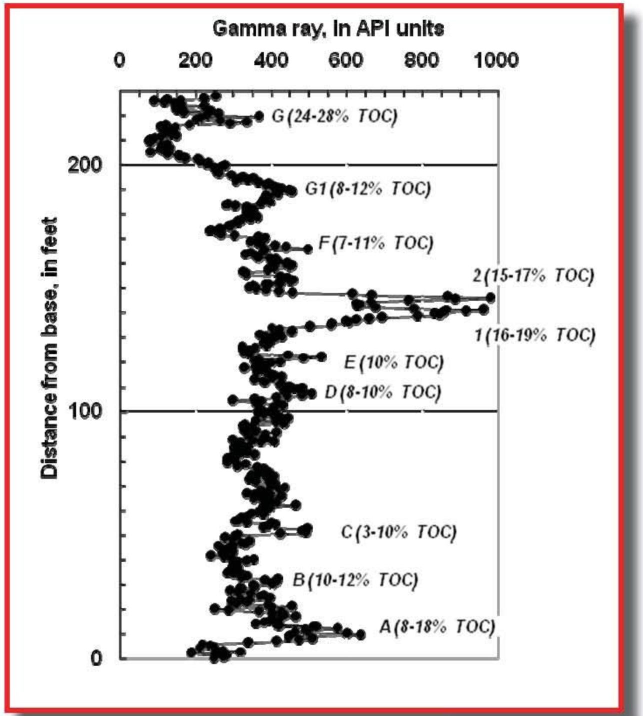
SYSTEM	PRODUCING INTERVAL	HYDROCARBON-SOURCE ROCK	KEROGEN TYPE	TOC %
PERMIAN	PERMIAN (UNDIFFERENTIATED)			
PENNSYLVANIAN	VIRGILIAN			
	DESMOINESIAN	UPPER AND MIDDLE PENNSYLVANIAN	II III	<1-25
	ATOKAN			
	MORROWAN	MORROWAN	III	0.5-3.4
MISSISSIPPIAN	SPRINGER FORMATION	SPRINGER FORMATION	III	
	PRE-CHESTER MISSISSIPPIAN (UNDIFFERENTIATED)	**Caney**	**II**	**1-8**
		WOODFORD SHALE	II III	<1-14
DEVONIAN	HUNTON GROUP			
SILURIAN				
ORDOVICIAN	SIMPSON GROUP	SYLVAN SIMPSON GROUP	II I II	<1-9
UPPER CAMBRIAN	ARBUCKLE GROUP			

Modified from Johnson and Cardott, 1992



Woodford Shale
2.00
1.50
1.00
0.50
0.00
ATOMIC H/C
0.00
0.10
0.20
0.30
ATOMIC O/C
I
II
III
Northern Oklahoma Platform & West Side of Nemaha Uplift
Central Oklahoma Platform & East Side of Nemaha Uplift
Eastern Anadarko Basin
Central & Western Anadarko Basin
Marietta-Ardmore Basin
Arbuckle Mountain Uplift
Ozark Uplift
Ouachita Frontal Zone
Ouachita Central Area
Ouachita Core Area
Products of Thermal Maturation
Immature
Oil
Wet Gas
Dry Gas
From Comer, 1992

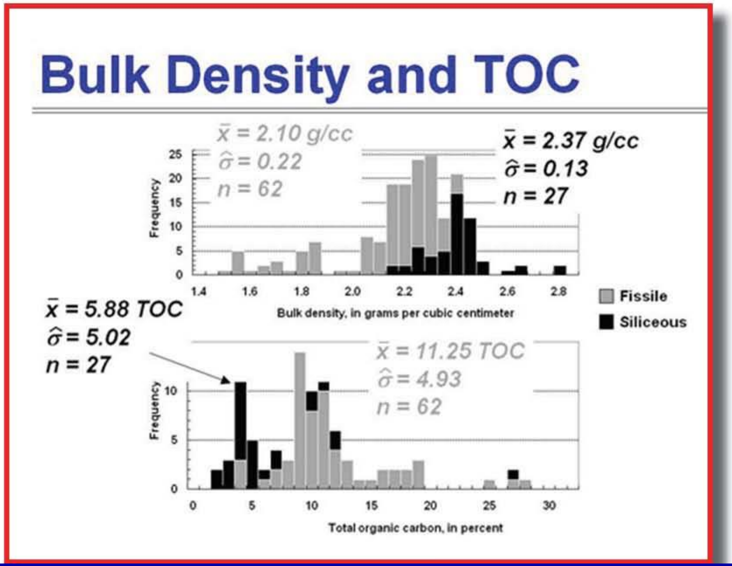
Gamma ray plotted full scale shows details



Range of total organic carbon (TOC) for the major gamma-ray markers at the Henry House Creek section. The TOC is highest at the base, top, and at major gamma-ray kicks #1 and #2. TOC and gamma-ray response are statistically associated but the relationship is not strong.

TOC is highest in fissile shale

Frequency distributions of bulk density and total organic carbon for the fissile and siliceous (cherty) beds at Henry House Creek. The fissile shale has lower bulk density and higher total organic carbon relative to the siliceous or chertier beds. The lower total organic carbon in the siliceous beds is probably a consequence of dilution from radiolarian sedimentation.



From Paxton and Cardott, 2008

Vitrinite is a coal maceral (organic) derived from the cell wall material or woody tissues of vascular plants (post Silurian)

Vitrinite Reflectance (%Ro) is a measurement of the percentage of light reflected off the vitrinite maceral at high (500X) magnification in oil immersion (average of many values)

For more information about vitrinite reflectance see AAPG Search and Discovery Article #40928

Introduction to Vitrinite Reflectance as a Thermal Maturity Indicator*

Brian J. Cardott[1]

Search and Discovery Article #40928 (2012)
Posted May 21, 2012

*Adapted from presentation at Tulsa Geological Society luncheon, May 8, 2012

[1]Oklahoma Geological Survey, Norman Oklahoma (bcardott@ou.edu)

Abstract

Thermal maturity is one of the most important parameters used in the evaluation of gas-shale and shale-oil plays. Vitrinite reflectance (VRo) is a commonly used thermal maturity indicator. Many operators use the vitrinite-reflectance value without knowing what it is or how it is derived. Conventional wisdom of the Barnett Shale gas play in the Fort Worth Basin indicates the highest gas rates occur at >1.4% VRo. Knowledge of the oil and condensate windows is essential for liquid hydrocarbon production. This presentation answers the questions: what is vitrinite; what is vitrinite reflectance; how is vitrinite reflectance measured; what are some sources of error; and how does one tell good data from bad data?

References

Abdelmalak, M.M., C. Aubourg, L. Geoffroy, and F. Laggoun-Défarge, 2012, A new oil-window indicator? The magnetic assemblage of claystones from the Baffin Bay volcanic margin (Greenland): AAPG Bulletin, v. 96, p. 205-215.

American Society for Testing and Materials (ASTM), 2011, Standard test method for microscopical determination of the reflectance of vitrinite dispersed in sedimentary rocks: West Conshohocken, PA, ASTM International, Annual book of ASTM standards: Petroleum products, lubricants, and fossil fuels; Gaseous fuels; coal and coke, sec. 5, v. 5.06, D7708-11, p. 823-830, doi: 10.1520/D7708-11, Web accessed 9 May 2012. http://www.astm.org/Standards/D7708.htm

American Society for Testing and Materials (ASTM), 1994, Standard test method for microscopical determination of the reflectance of vitrinite in a polished specimen of coal: Annual book of ASTM standards: gaseous fuels; coal and coke, sec. 5, v. 5.05, D 2798-91, p. 280-283.

Woodford Shale is the oldest rock in Oklahoma that contains wood (vitrinite) from the progymnosperm *Archaeopteris* (organ genus *Callixylon*)

Guidelines for the Barnett Shale (Based on Rock-Eval Pyrolysis)

VRo Values	Maturity
<0.55%	Immature
0.55-1.15%	Oil Window (peak oil at 0.90%VRo)
1.15-1.40%	Condensate–Wet-Gas Window
>1.40%	Dry-Gas Window

From Jarvie and others, 2005

Woodford Shale as a Reservoir Rock

- Biogenic Silica Rich (Brittle)
- Porous organic matter network

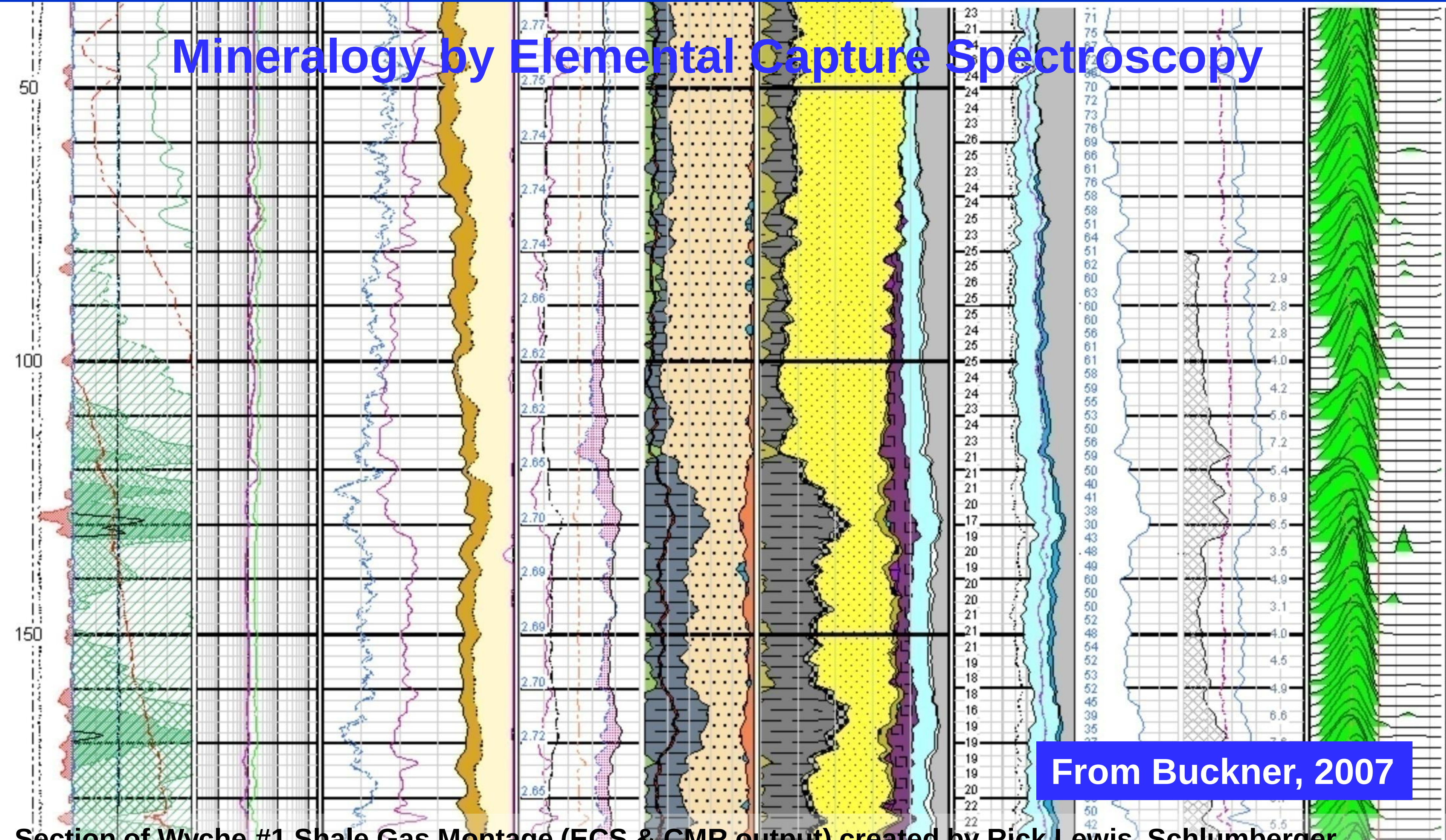
Woodford Mineralogy

[grab samples]	A	B	C	D	E
Quartz	63-68%	29-87%	30-60%	9-61%	27-53%
K-Feldspar	4%	0-2%	2-10%	2-42%	0-2%
Plagioclase	3%				1-4%
Calcite	10%		5-25%	0-7%	0-11%
Dolomite	6-9%	0-56%	0-5%	0-10%	0-6%
Pyrite	5-7%	0-1%	0-5%	2-30%	1-13%
Total Clays	12-14%				
Illite		8-35%	2-5%	7-53%	13-40%
Illite/Smectite			2-20%		
Kaolinite		1-7%	2-5%	0-2%	0-5%
Chlorite			2-5%	0-40%	0-5%

A. O'Brien & Slatt, 1990; B. Kirkland et al., 1992; C. Greiser, 2006;
D. Branch, 2007; E. Abousleiman et al., 2008

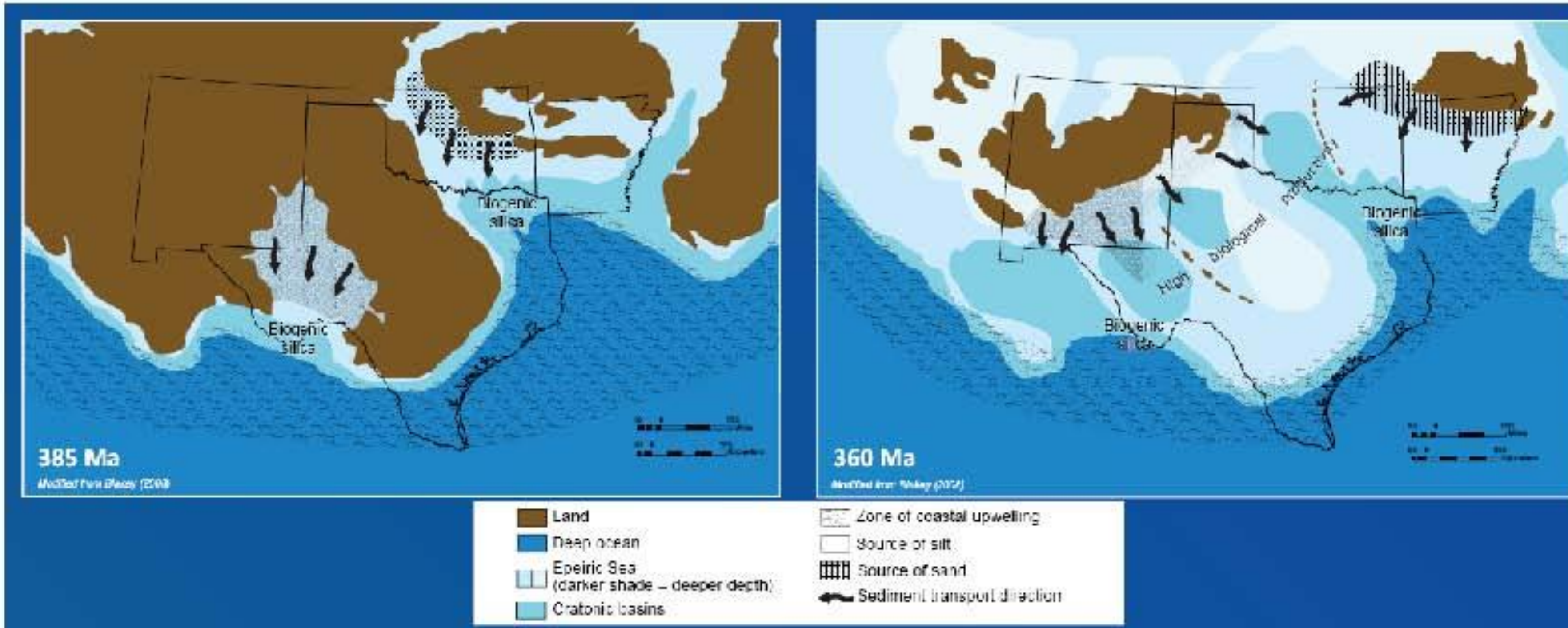
Example of ECS & CMR Log Data, Woodford Shale

- Higher silica content in upper portion of Woodford (above 120 ft)
- Very high porosity (unlike that found under reservoir conditions)



Section of Wyche #1 Shale Gas Montage (ECS & CMR output) created by Rick Lewis, Schlumberger

Extent of Biogenic Silica in the Woodford



Paleogeography of North America (Laurentia) at the beginning of the Late Devonian (Frasnian). Reconstructions show that Laurentia moved northward during this time and they place the Southern Midcontinent along the western or southwestern continental margin near 15° to 20° south latitude. Prior to the beginning of the Late Devonian epoch much of the Southern Midcontinent was subaerially exposed, and this extensively eroded and dissected landscape became a major regional unconformity surface. Worldwide Late Devonian marine transgression flooded the craton, creating an extensive epeiric sea that covered all but a few isolated areas during eustatic highstand. Thick accumulations of biogenic silica (Novaculite) document persistent coastal upwelling along the Late Devonian continental margin, while sand dispersed southward toward the subsiding Anadarko Basin from Ordovician sandstone exposures flanking the Ozark Uplift and silt dispersed southward from shoals and emergent parts of the Transcontinental Arch into the Delaware and Midland Basins.

Comer, 2008
AAPG Poster

“The primary mechanism of gas [& oil] production from shales is the fracture network in the reservoir. Gas residing in the very tight matrix system is forced to flow into the fracture network, first through chemical desorption and then through diffusion, to travel to the matrix/fracture interface.” (Biswas, 2011)

What is the potential for gas storage and diffusion within the organic network in shale?

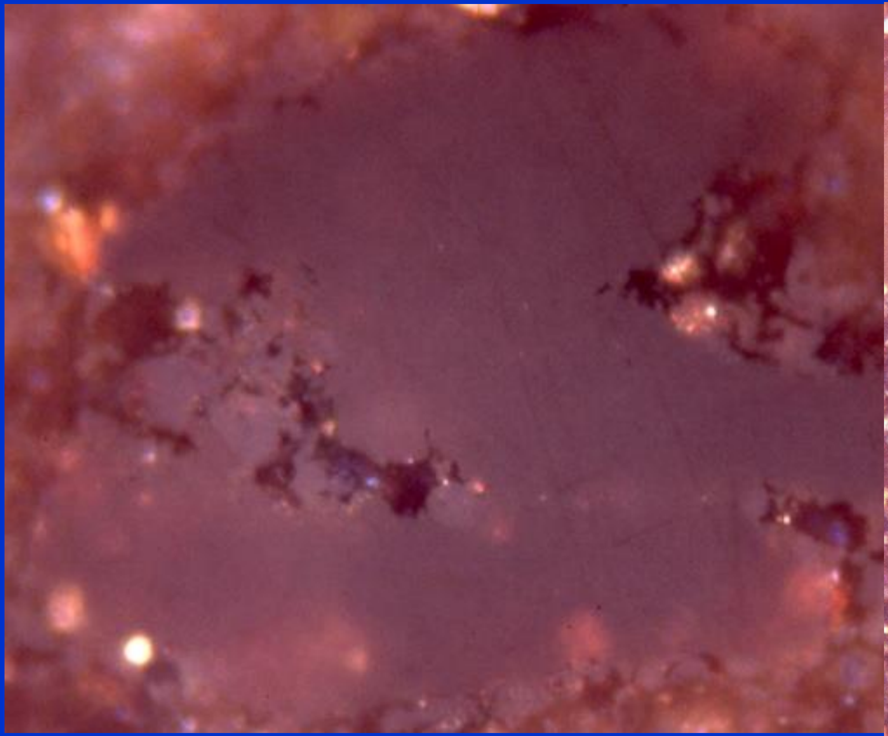
Genetic Bitumen Classification

- **Pre-Oil Solid Bitumen**: early-generation products of rich source rocks, probably extruded from their sources as a very viscous fluid, and migrated the minimum distance necessary to reach fractures and voids in the rock. [Kerogen → Bitumen → Oil]
- **Post-Oil Solid Bitumen**: products of the alteration of a once-liquid crude oil, generated and migrated from a conventional oil source rock, and subsequently degraded. [solid residue of primary oil migration]

Curiale (1986)

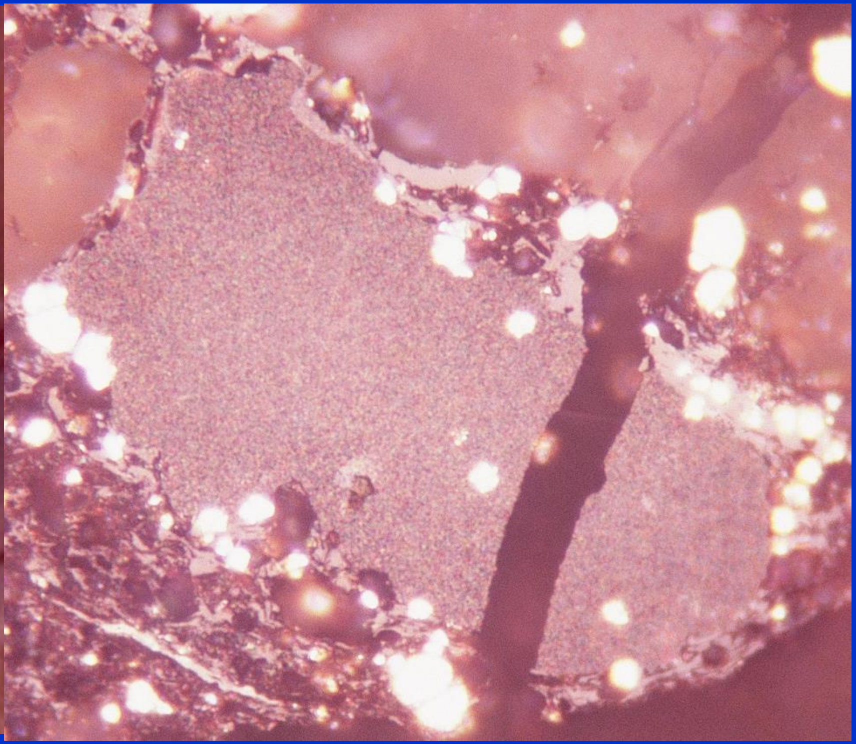
Two Common Pre-Oil Bitumen Optical Forms Based on Landis and Castaño (1994) [regression equation is based on homogenous form]

Homogenous form



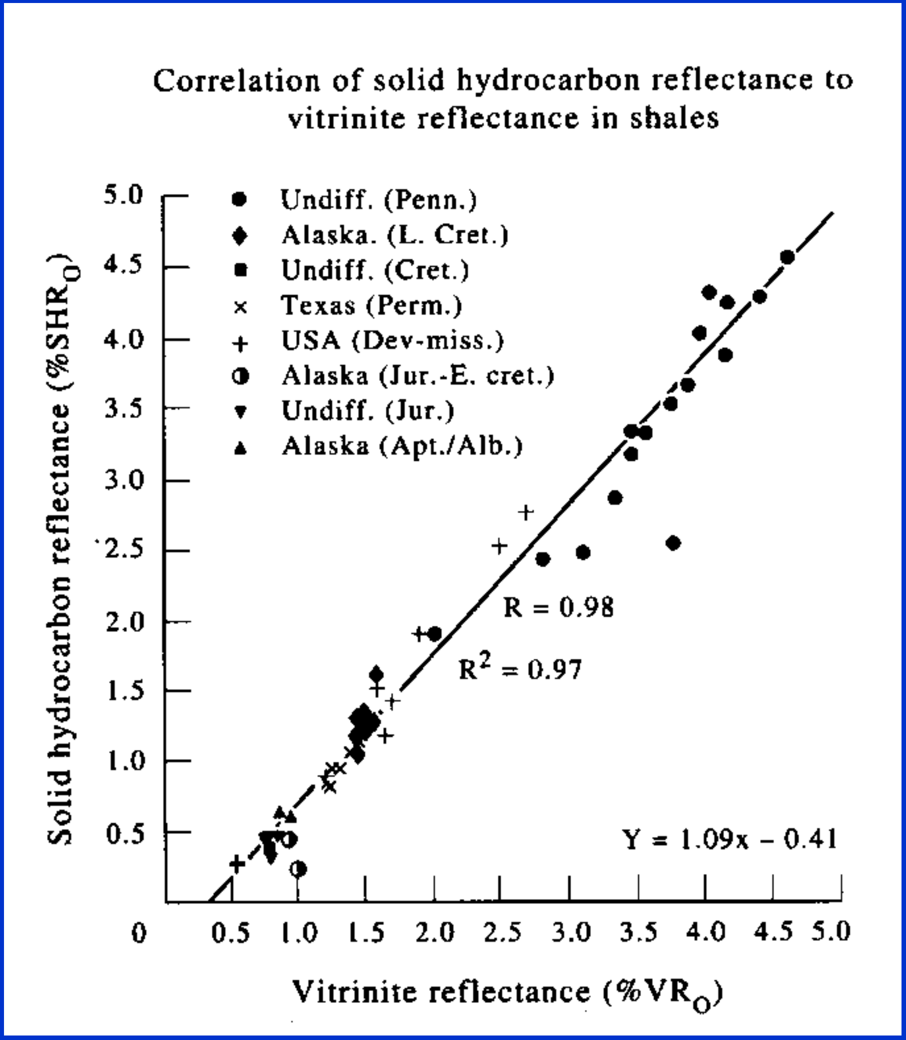
OPL 1333 500X

Granular form



OPL 1076 500X

Use of pre-oil solid bitumen as **thermal maturity indicator** following "solid hydrocarbon" reflectance to vitrinite reflectance equivalent regression equation of Landis and Castaño (1994)



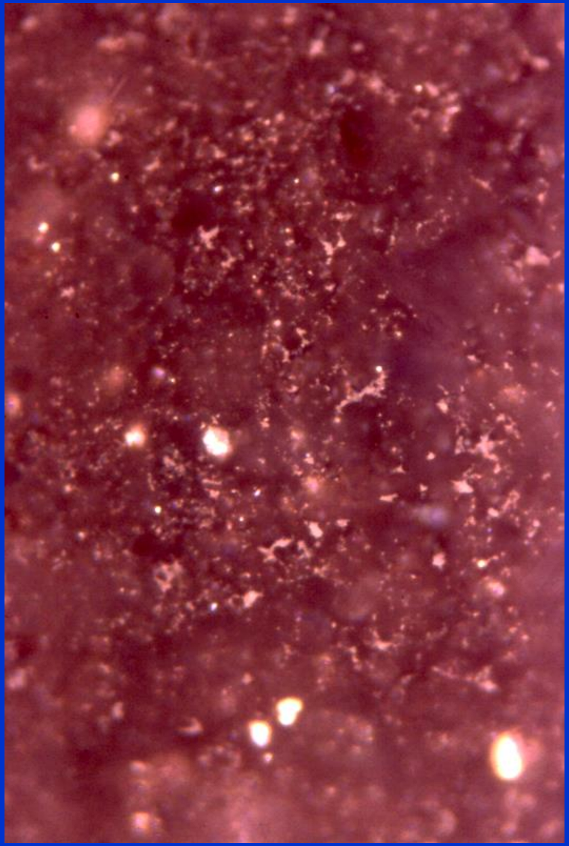
VRE = (BRo + 0.41)/1.09

Post-Oil Bitumen Network

Classification (@ 500X)

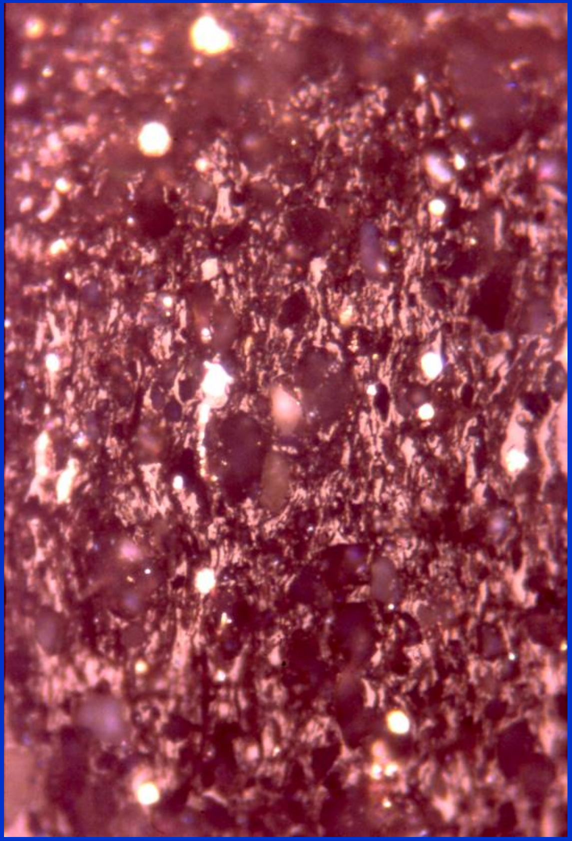
[primary oil migration]

Speckled



OPL 1368

Wispy



OPL 1372

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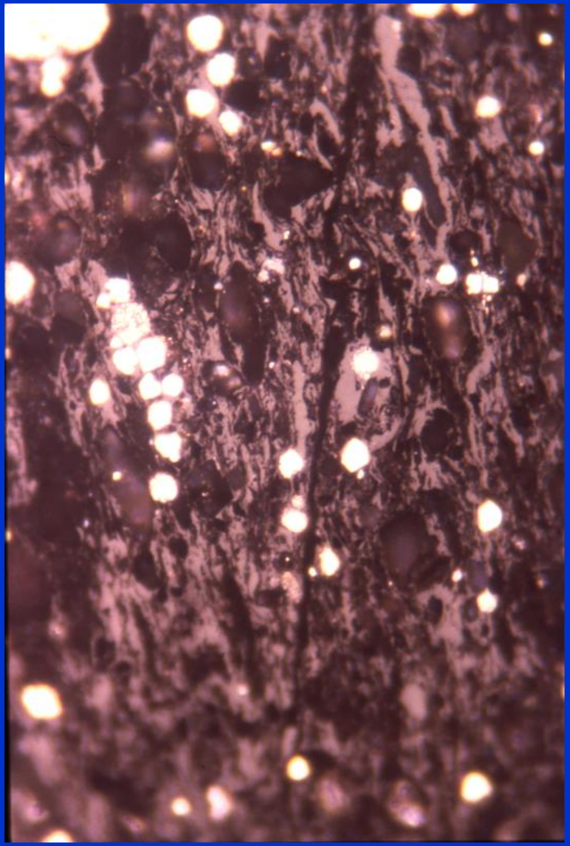

OPL 1366

Nanopores associated with "organic matter" using ion milling and SEM (from Loucks and others, 2009)

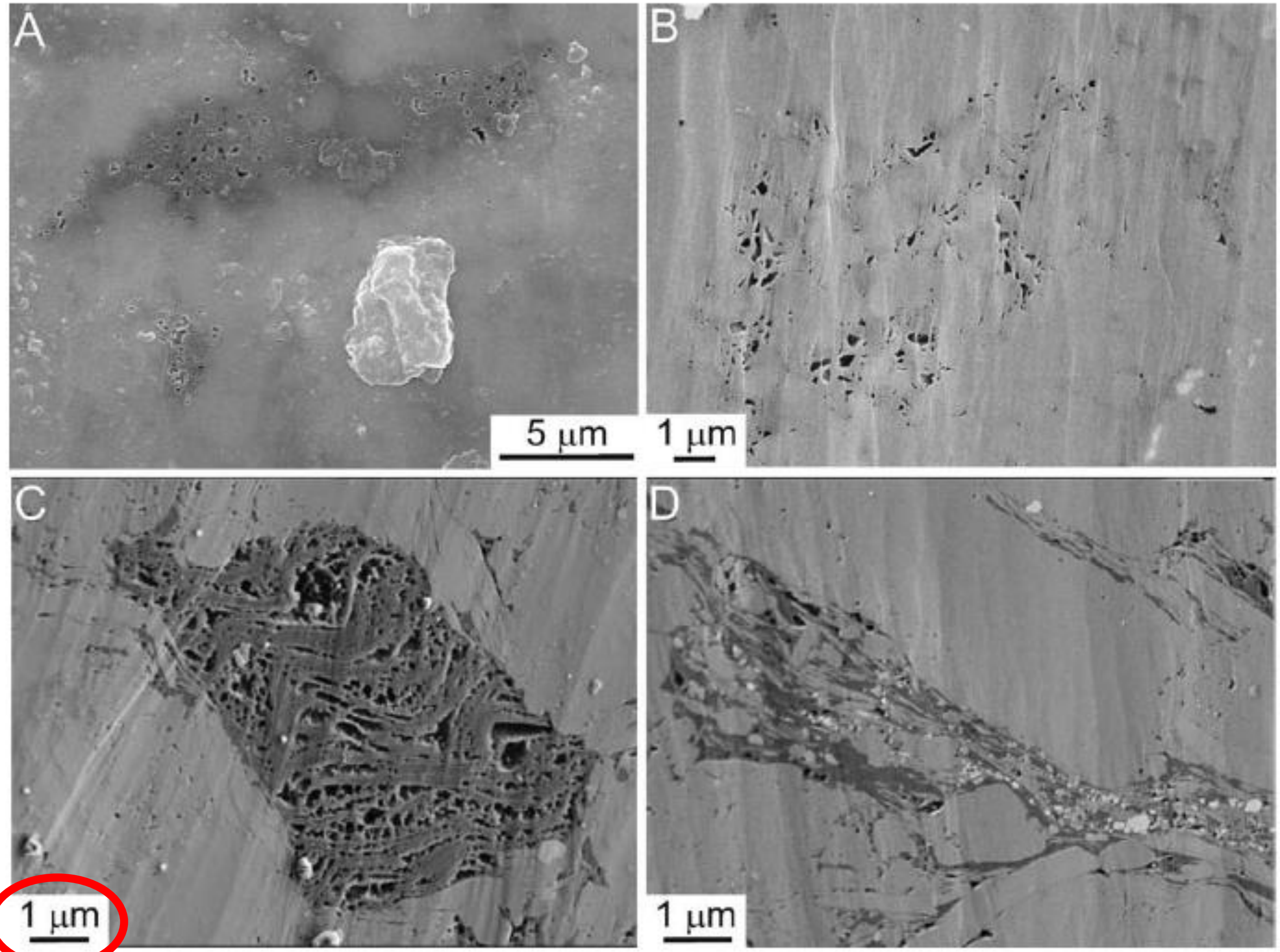

FIG. 5.—Nanopores associated with organic matter in the Barnett Shale. A) Elliptical to complexly rounded nanopores in an organic grain. Darker materials are organics. BSE image. Blakely #1, 2,167.4 m. B) Angular nanopores in a grain of organic matter. SE image. Blakely #1, 2,167.4 m. Accelerating voltage = 10 kV; working distance = 6 mm. C) Rectangular nanopores occurring in aligned convoluted structures. SE image. T.P. Sims #2, ~ 2,324 m. Accelerating voltage = 2 kV; working distance = 3 mm. D) Nanopores associated with disseminated organic matter. Carbon-rich grains are dark gray; nanopores are black. SE image. T.P. Sims #2, ~ 2,324 m. Accelerating voltage = 2 kV; working distance = 2 mm.

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Development of organic porosity in the Woodford Shale with increasing thermal maturity

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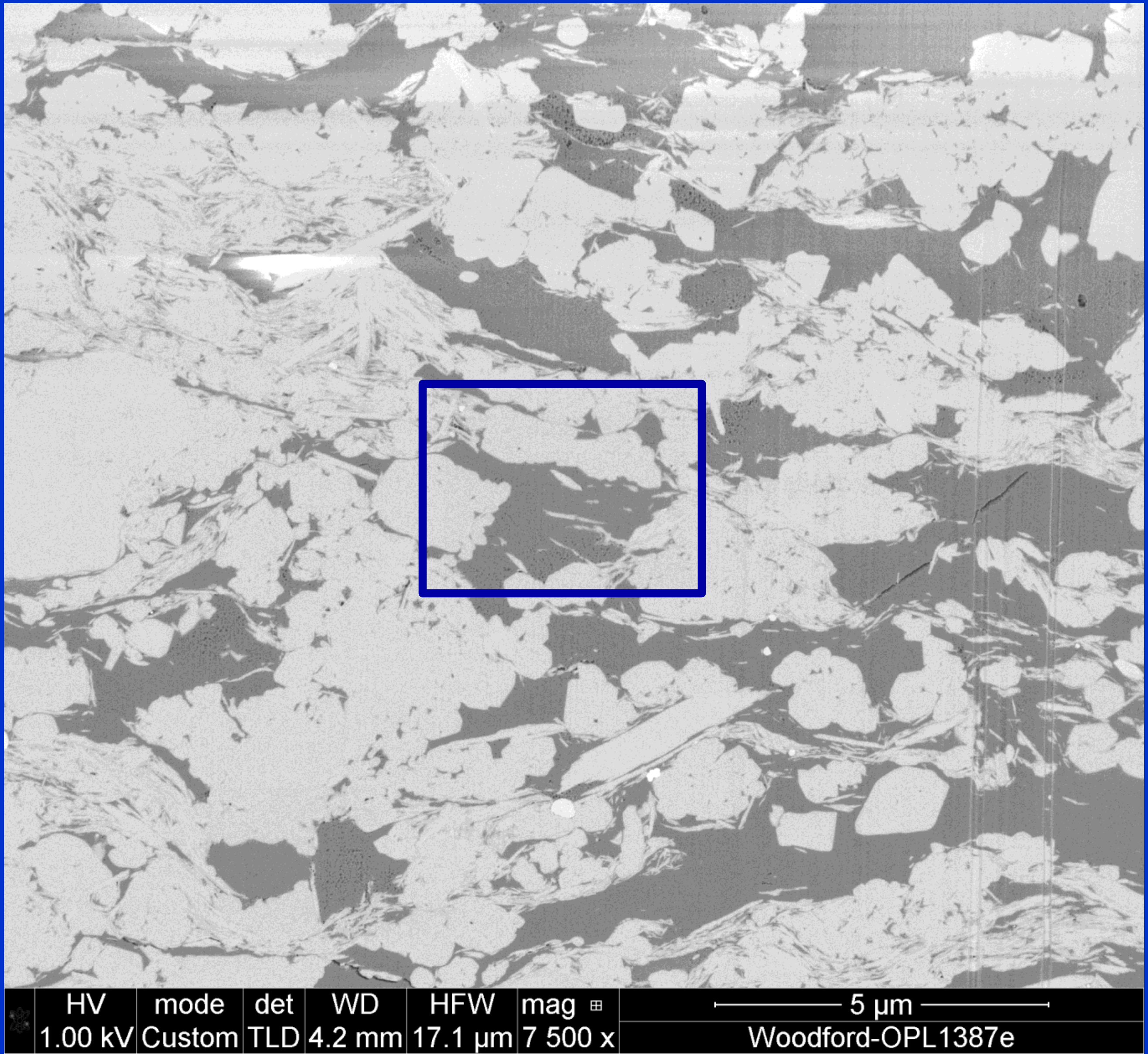
ABSTRACT

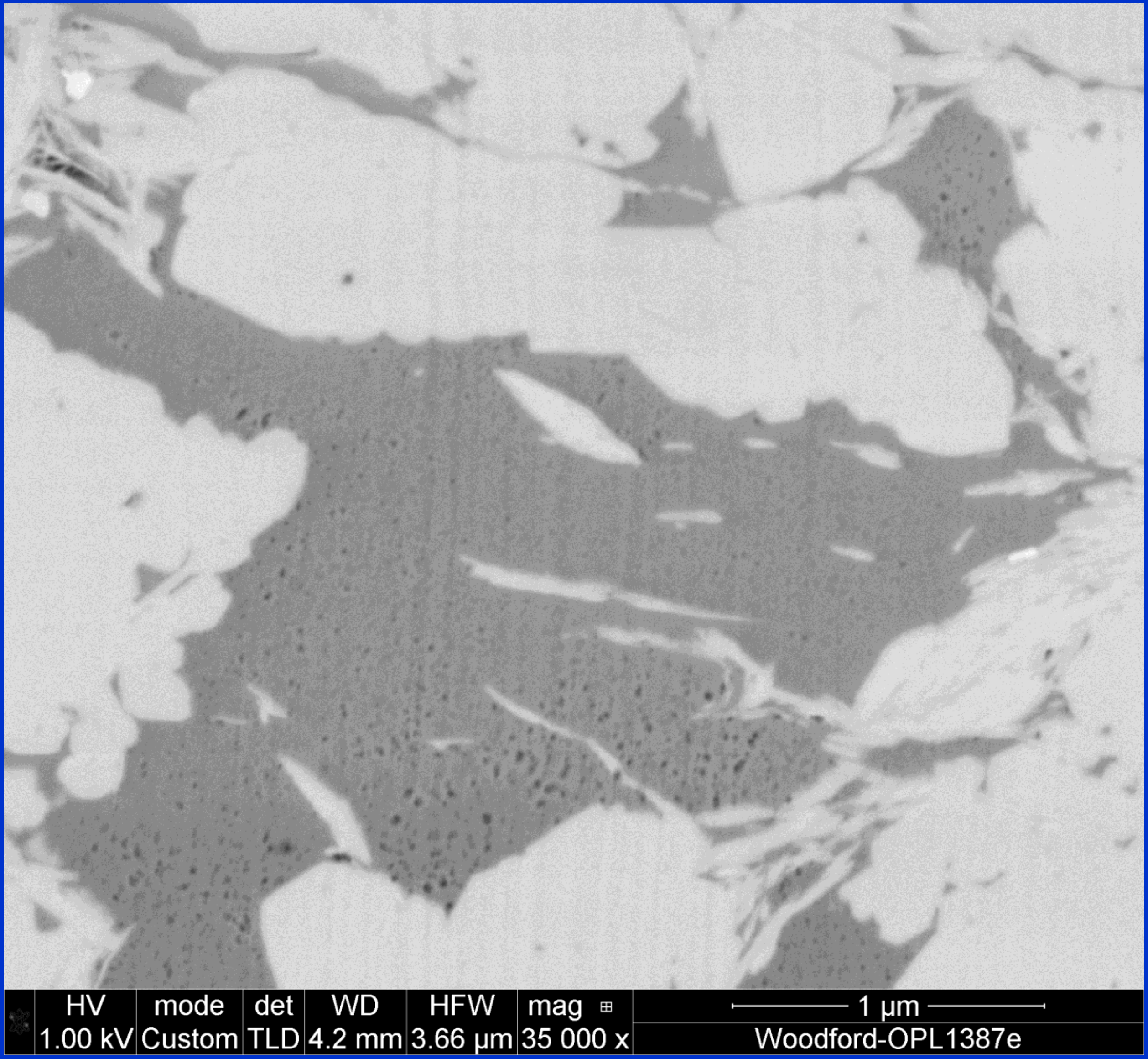
Using a combination of focused ion beam milling and scanning electron microscopy we describe the evolution of secondary organic porosity in eight Woodford Shale (Late Devonian–Early Mississippian) samples with mean random vitrinite reflectance values ranging from 0.51% Ro to 6.36% Ro. Organic porosity was observed to be absent in samples with vitrinite reflectance values of up to 0.90% Ro with the first appearance of secondary pores starting with the 1.23% Ro sample. Porosity in the organic matter was unexpectedly absent in a sample with a vitrinite reflectance of 2.00% Ro; however, organic pores were again found in samples with higher thermal maturities. Porosity, when present, did not appear to be uniformly distributed among the organic matter that was within less than a micron of each other suggesting important differences in composition of the organic matter. Thin regions of organic matter were observed between grains raising the possibility that small amounts of the deposited organic matter were compacted between grains to form thin layers and/or the structures are part of the secondary organic matter (interpreted to be post-oil bitumen) which was left behind as a residue during oil migration through the shale. Some regions of porous organic matter appeared to be grain protected whereas others did not which indicates that these non-protected porous organic regions may be stress supporting with porosity intact under in situ reservoir conditions. These observations suggest that thermal maturity alone is insufficient
shales, and other factors, such as organic matter composition, c

Curtis and others, 2012

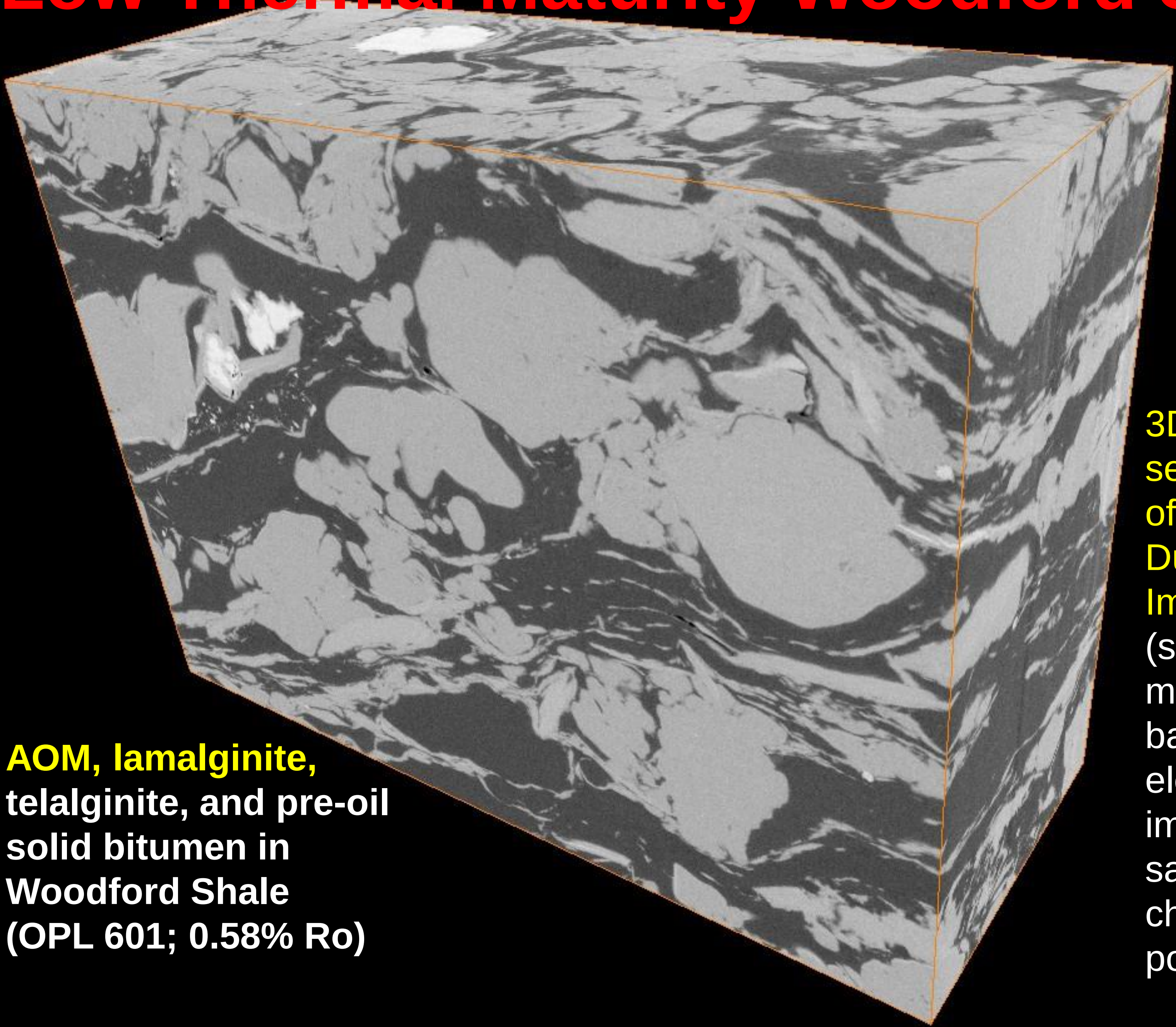
Focused Ion Beam (FIB) milling + SEM Backscatter Electron Imaging: Higher thermal maturity (1.4% Ro; OPL 1387) Woodford Shale core containing wispy post-oil bitumen network @ 500X



Higher magnification of previous slide showing nanoporosity in wispy post-oil bitumen network



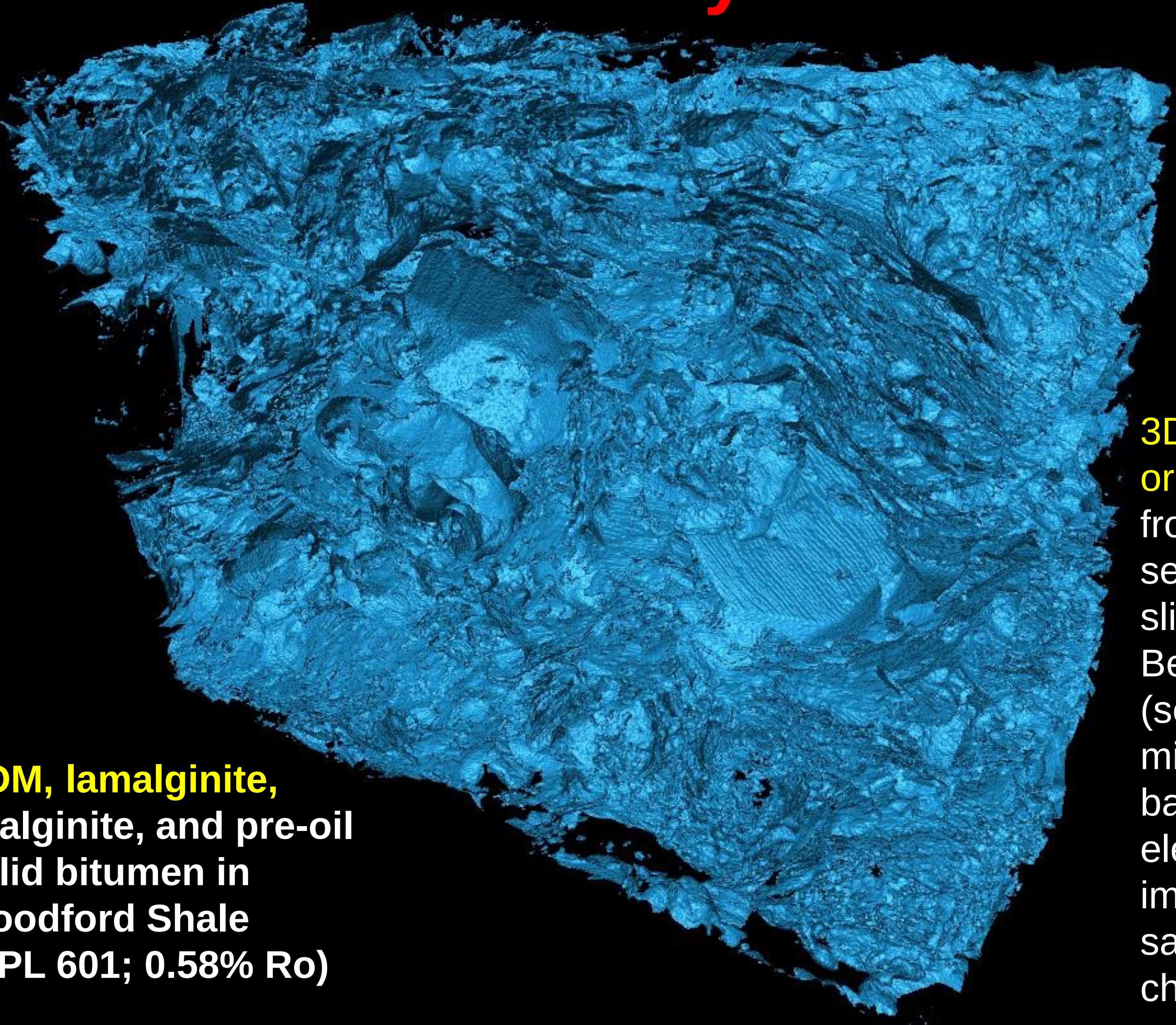
Low Thermal Maturity Woodford Shale



AOM, lamalginite, telalginite, and pre-oil solid bitumen in Woodford Shale (OPL 601; 0.58% Ro)

3D image from serial sectioning of 2D slices of Dual Beam Imaging (sequential ion-milling and backscatter electron imaging of a sample without changing its position)

Low Thermal Maturity Woodford Shale



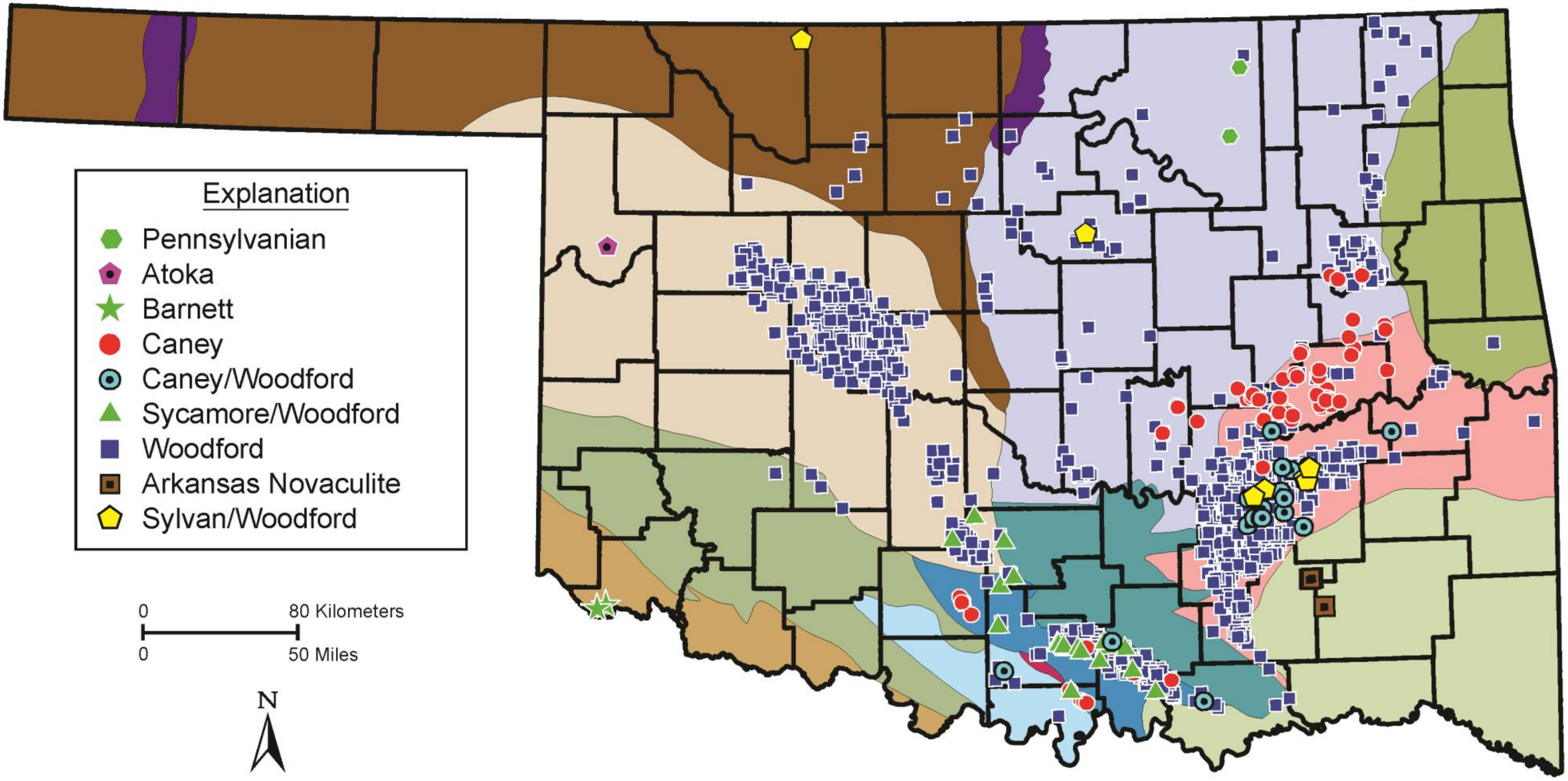
AOM, lamalginite, telalginite, and pre-oil solid bitumen in Woodford Shale (OPL 601; 0.58% Ro)

3D image of organic matter from serial sectioning of 2D slices of Dual Beam Imaging (sequential ion-milling and backscatter electron imaging of a sample without changing its position)

Woodford Production:

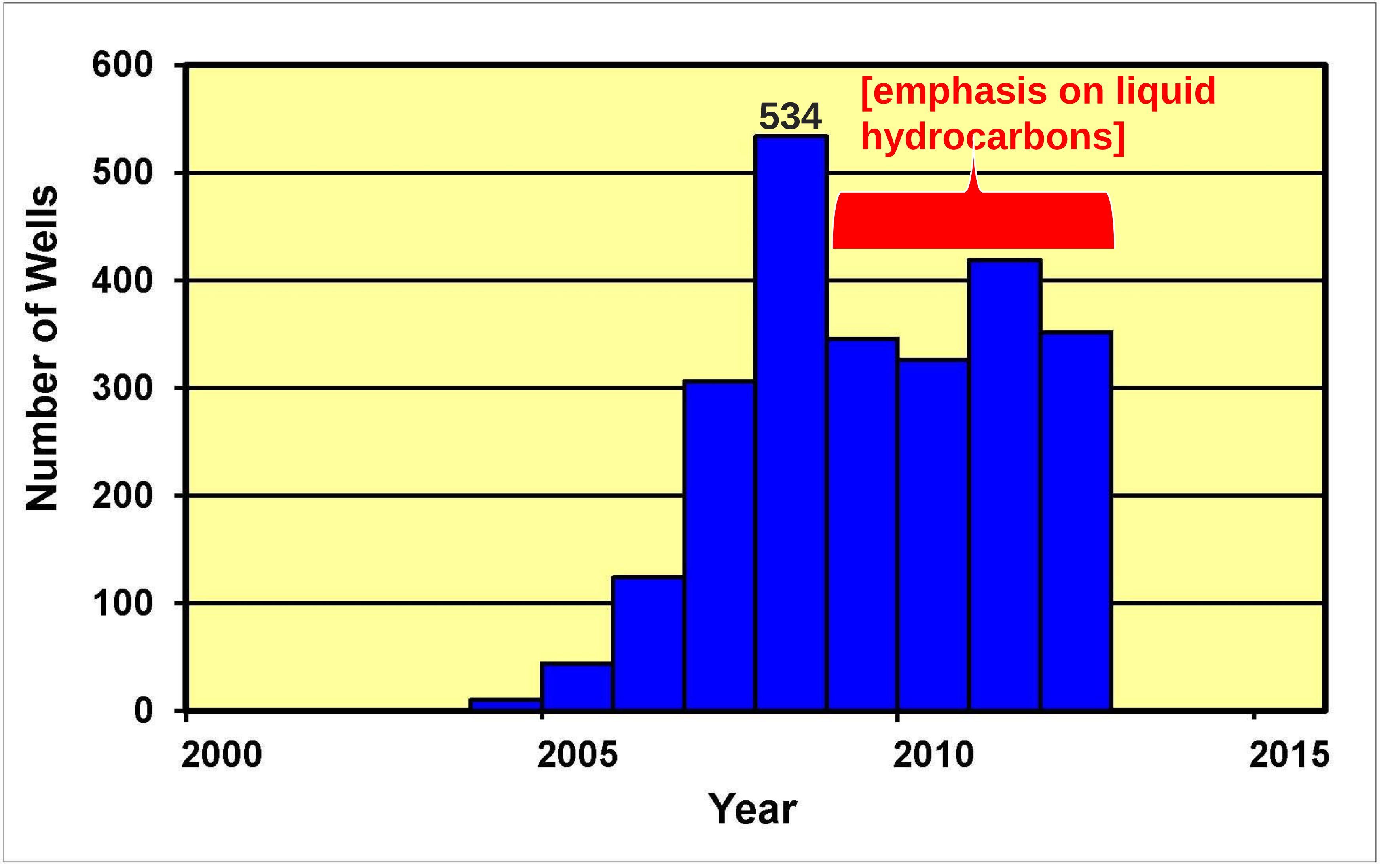
- Where are the Woodford Shale plays in Oklahoma?
- Why are the plays where they are?
- What types of hydrocarbons are produced?

Oklahoma Shale Gas/Oil Completions (1939-2012)

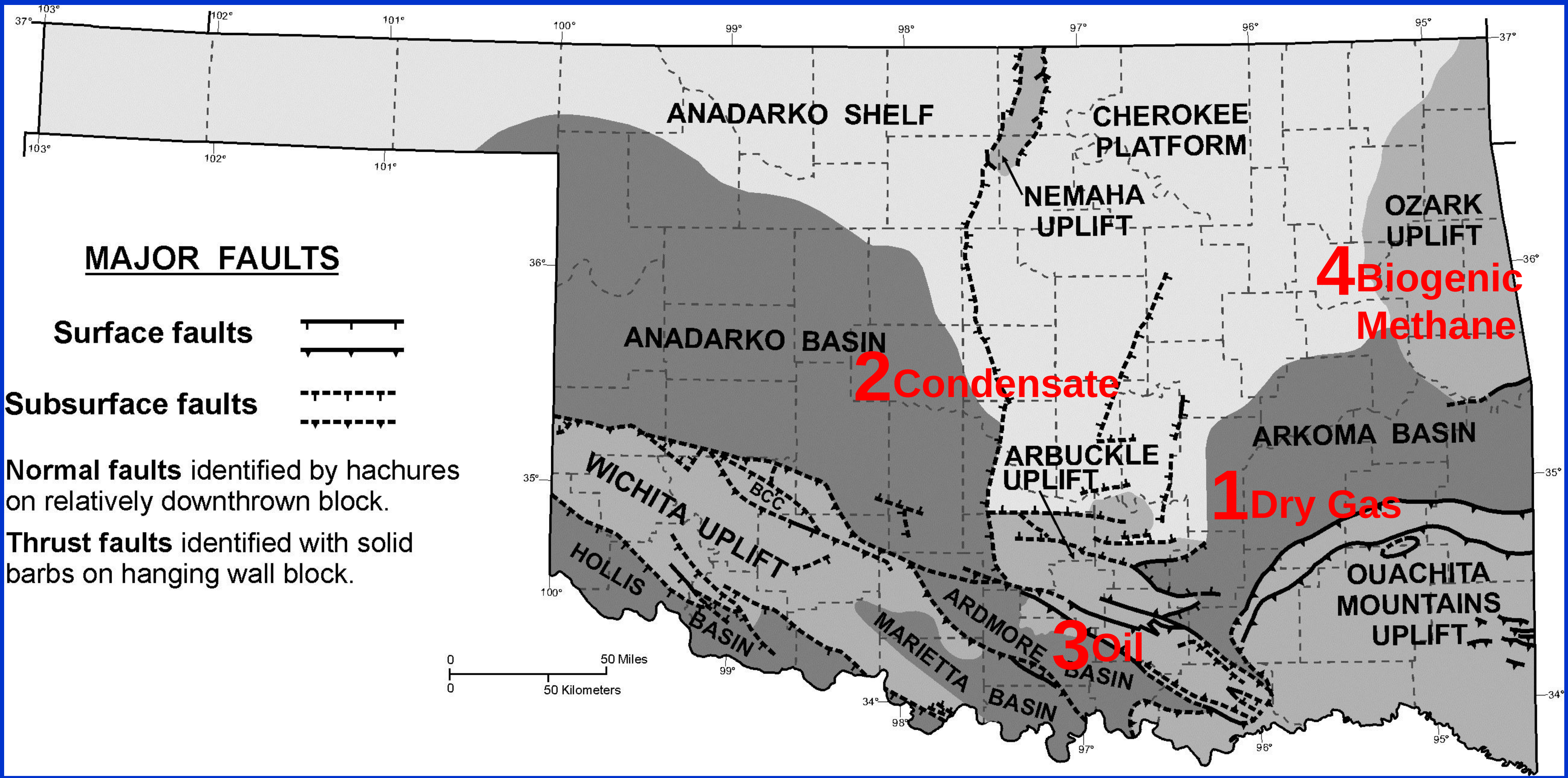


2,620 completions

Woodford Shale Completions (2004-2012)

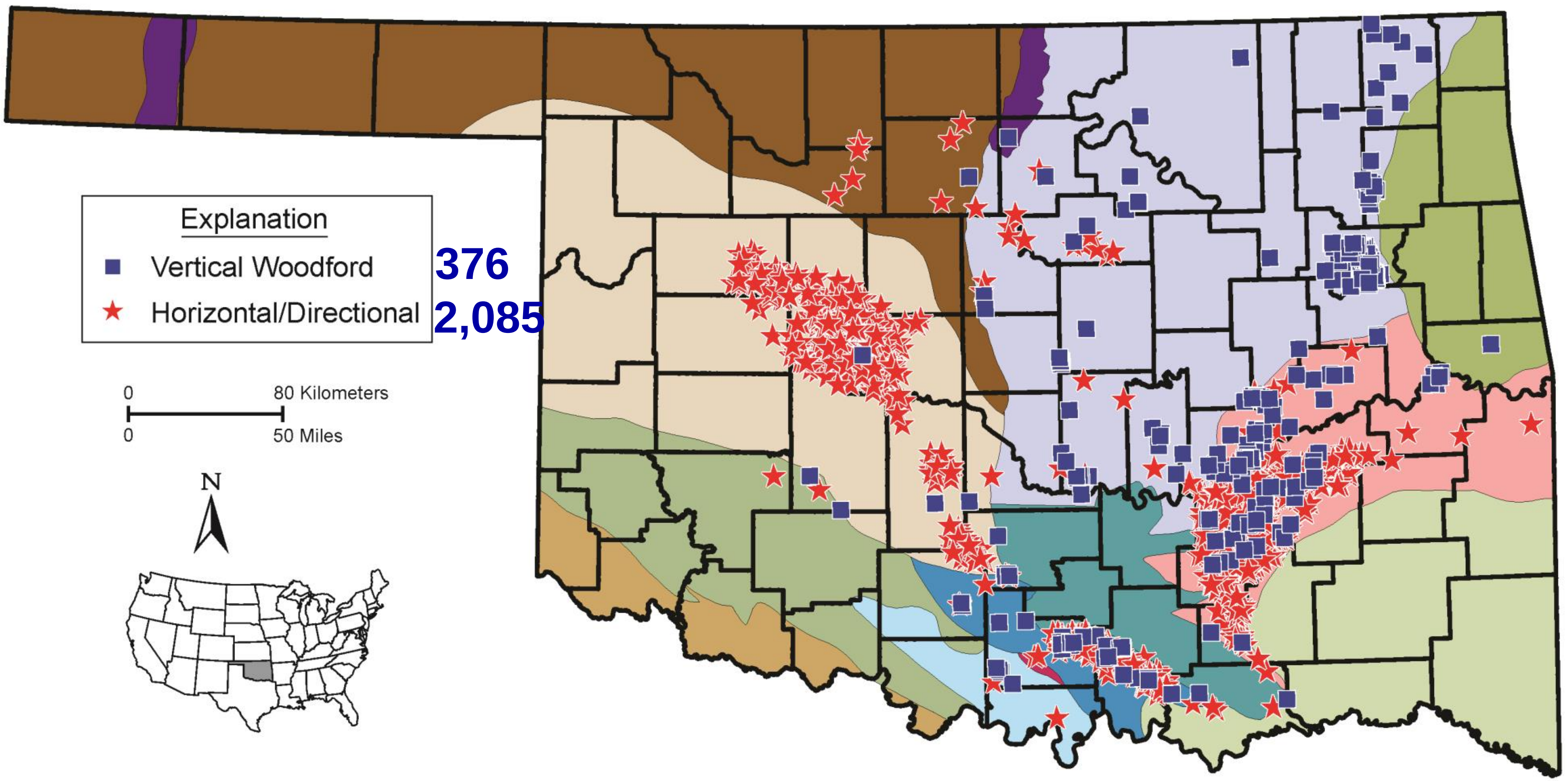


Woodford Shale Plays

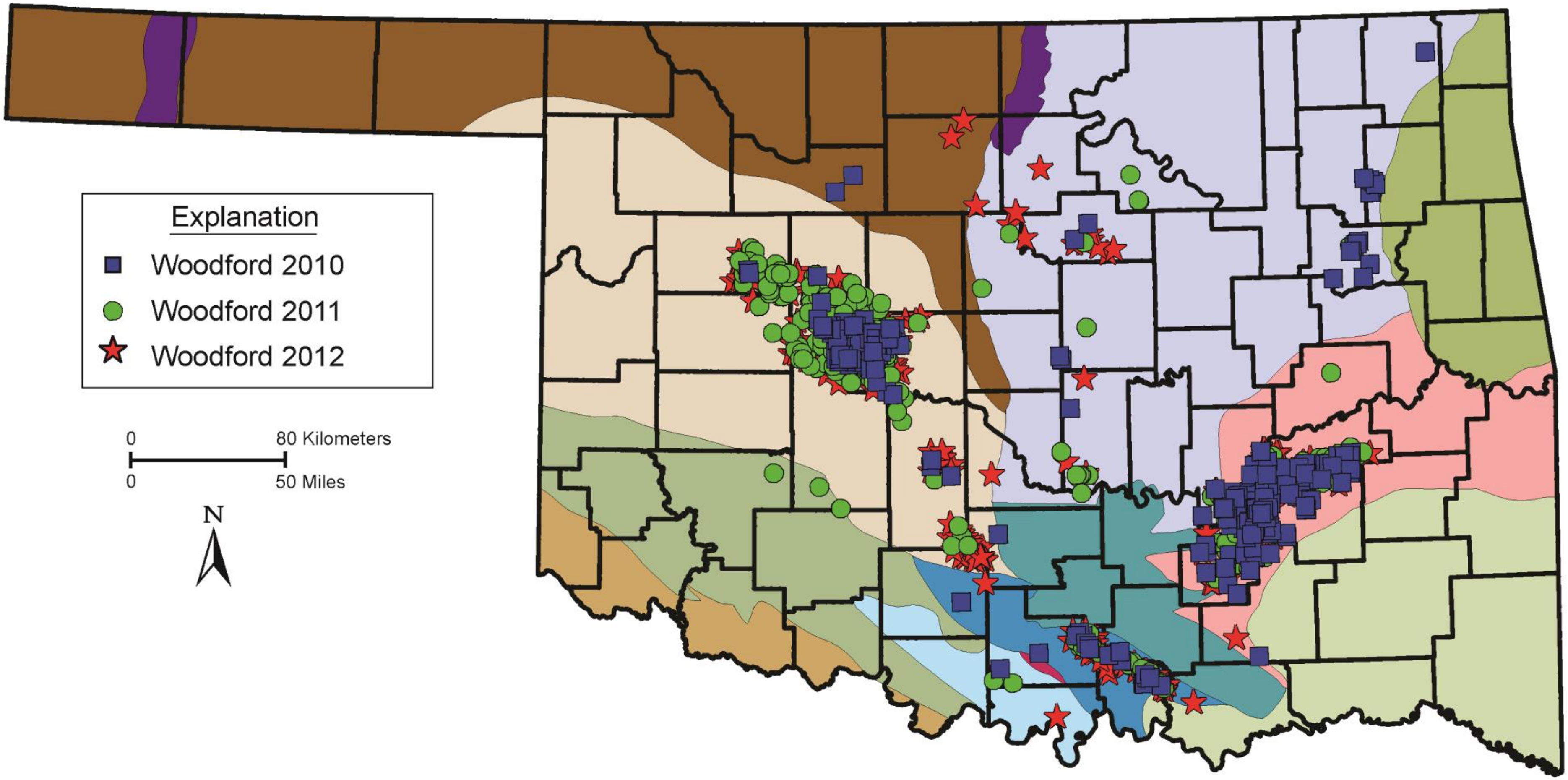


Geologic provinces from Northcutt and Campbell, 1995

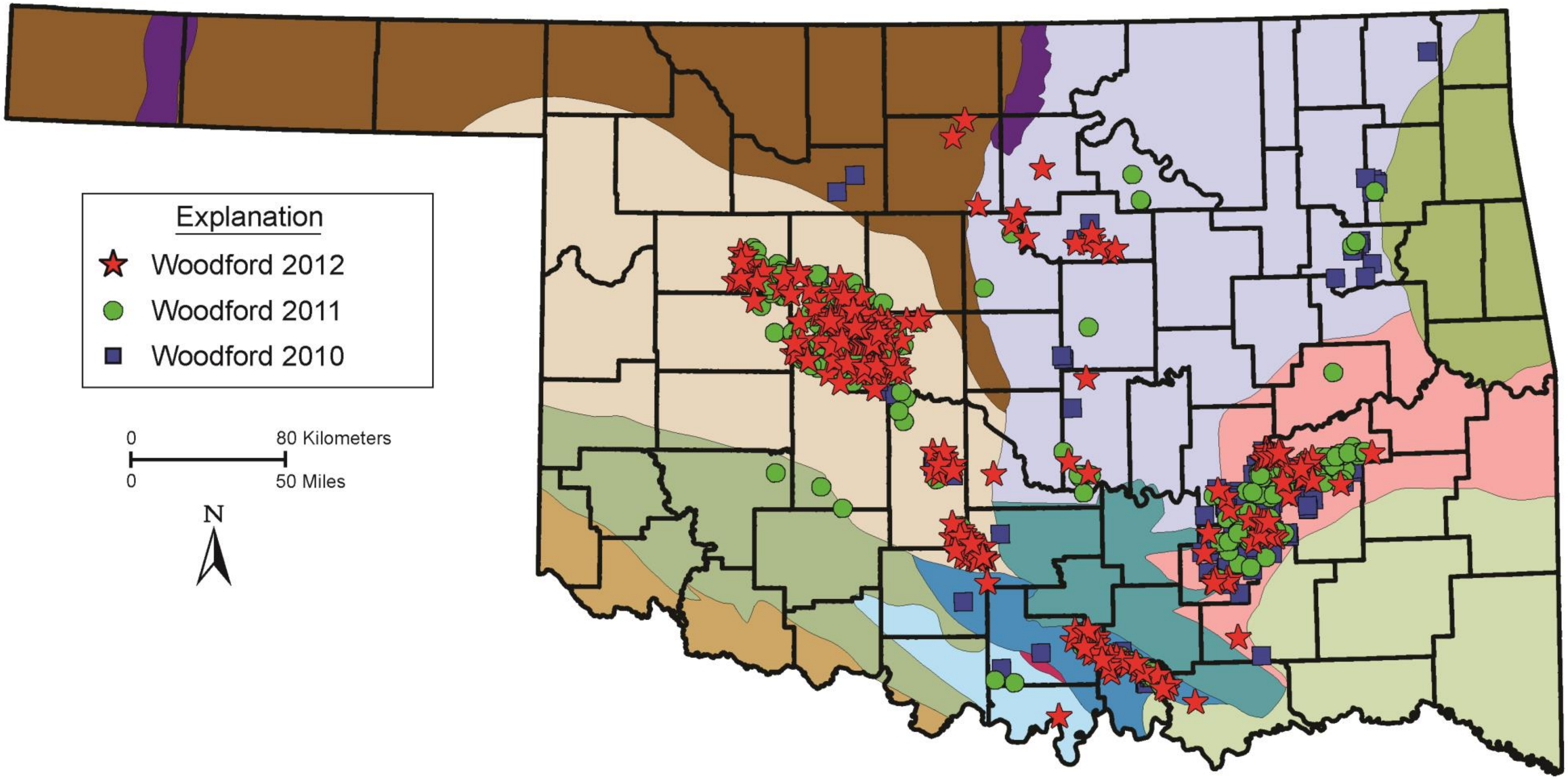
2,461 Woodford Shale Wells (2004-2012)



Woodford Shale Wells (2010-2012)

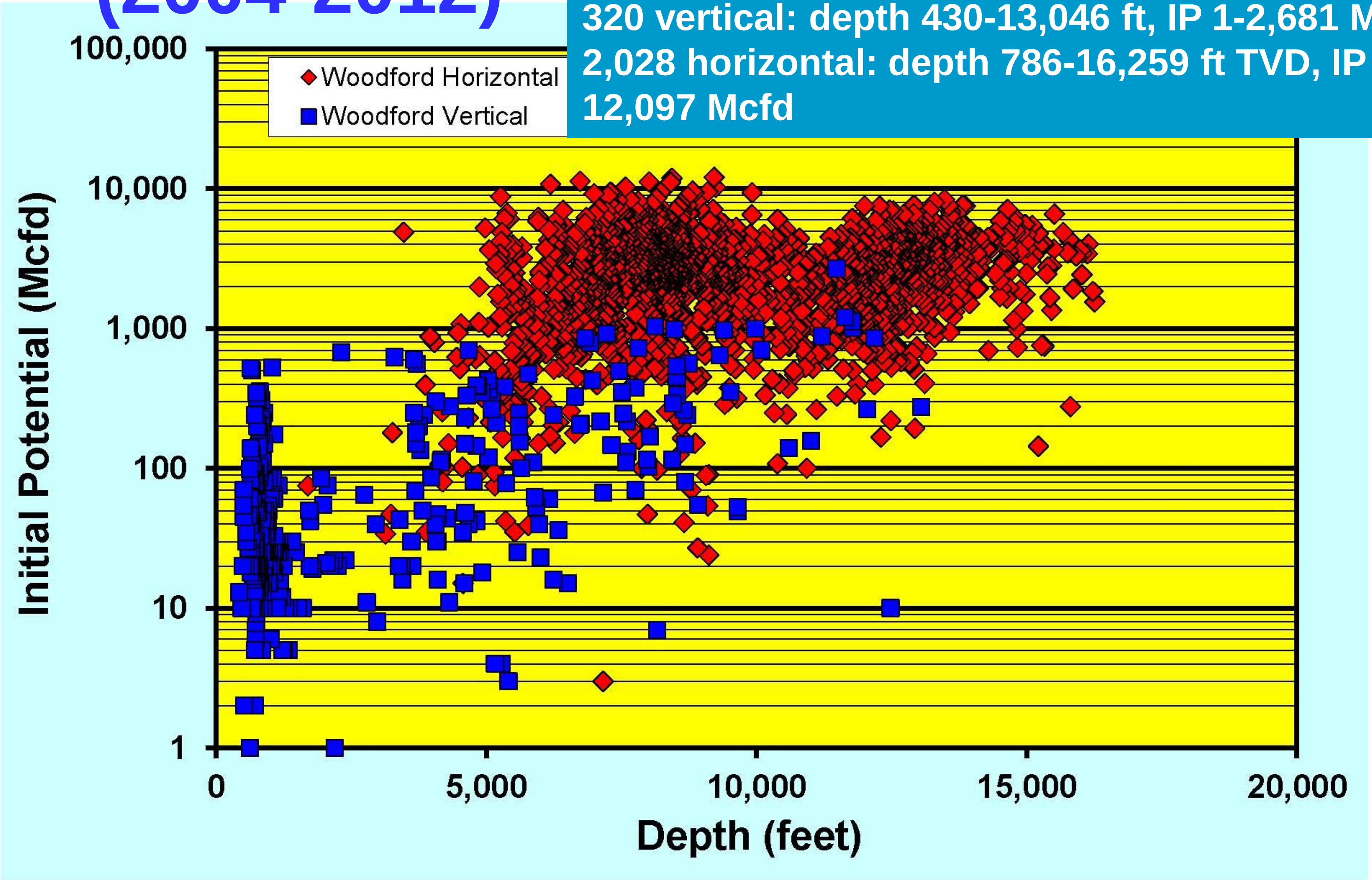


Woodford Shale Wells (2012-2010)

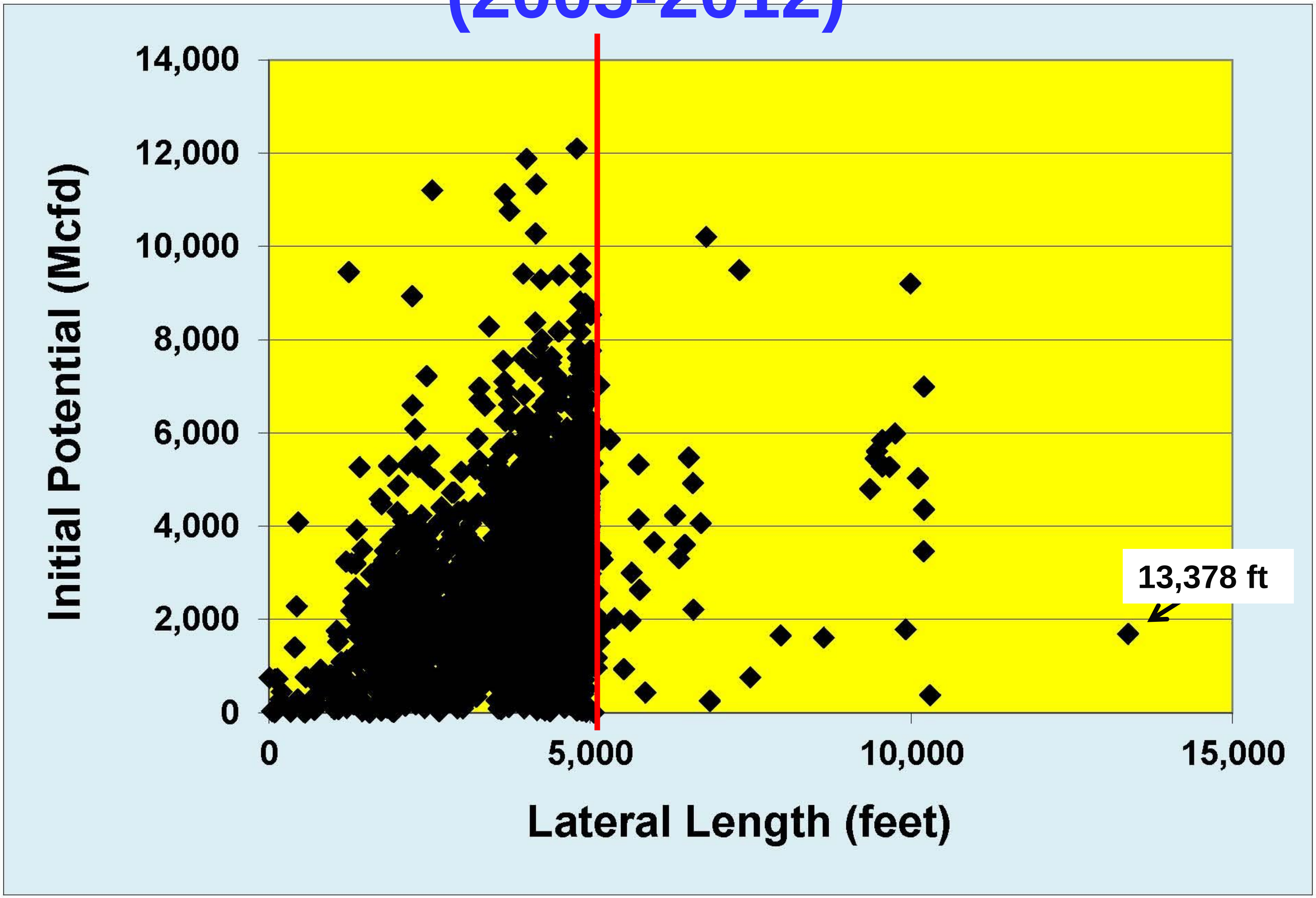


Woodford Shale IP Gas vs. Depth (2004-2012)

2,348 Woodford-only wells:
320 vertical: depth 430-13,046 ft, IP 1-2,681 Mcfd;
2,028 horizontal: depth 786-16,259 ft TVD, IP 3-12,097 Mcfd

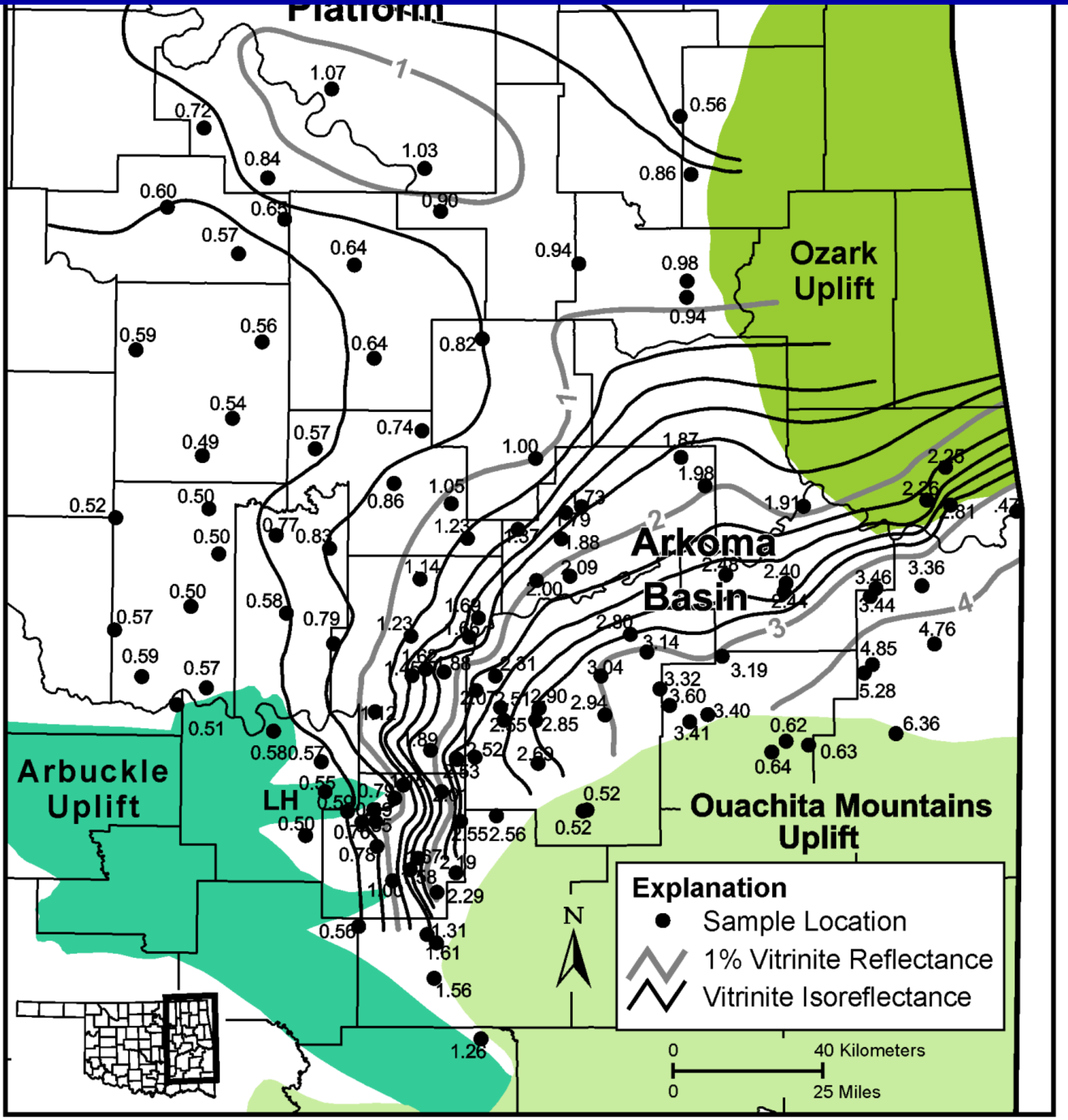


Woodford Shale Horizontal Well Laterals (2005-2012)



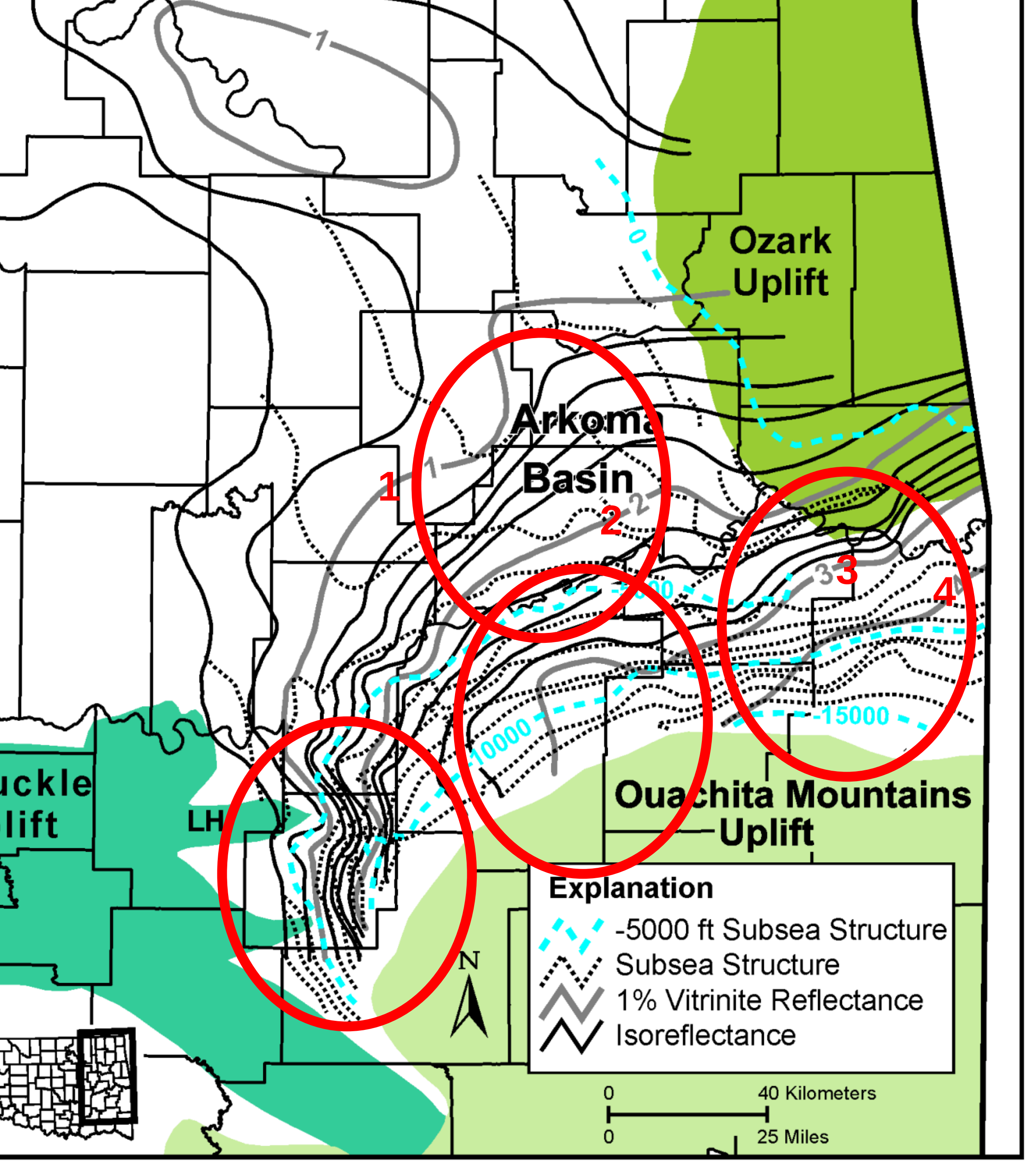
Emphasis of presentation will be on the importance of thermal maturity (by vitrinite reflectance) on the Woodford Shale oil and gas plays.

Isoreflectance Map of the Woodford Shale in Eastern Oklahoma (Updated November 2011)



Distribution of 117 Woodford Shale samples with vitrinite-reflectance data (n ≥20; whole-rock pellets)

Cardott, 2012



Woodford Shale Structure & Vitrinite Isoreflectance Map

Maps prepared by R. Vance Hall using Petra

Cardott, 2012

Most of the following maps are from an August 2011 presentation and have not been updated (published in 2012).

International Journal of Coal Geology 103 (2012) 109–119

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Thermal maturity of Woodford Shale gas and oil plays, Oklahoma, USA

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ABSTRACT

Being a hydrocarbon source rock and having a brittle (silica-rich) lithologic character makes the Woodford Shale (Late Devonian to Early Mississippian) an important oil and gas shale in Oklahoma. Since 2004, Woodford Shale plays have expanded from producing primarily thermogenic methane in one geologic province to producing thermogenic methane, condensate, oil and biogenic methane in four geologic provinces at thermal maturities from mature (>0.5% vitrinite reflectance, Ro) to post mature (2% to 3% Ro). Condensate is produced at a thermal maturity up to 1.67% Ro. Oil is produced from naturally-fractured, silica-rich shale. Biogenic methane is produced in shallow (<2000 ft, 610 m) reservoirs down dip from the outcrop in northeast Oklahoma.

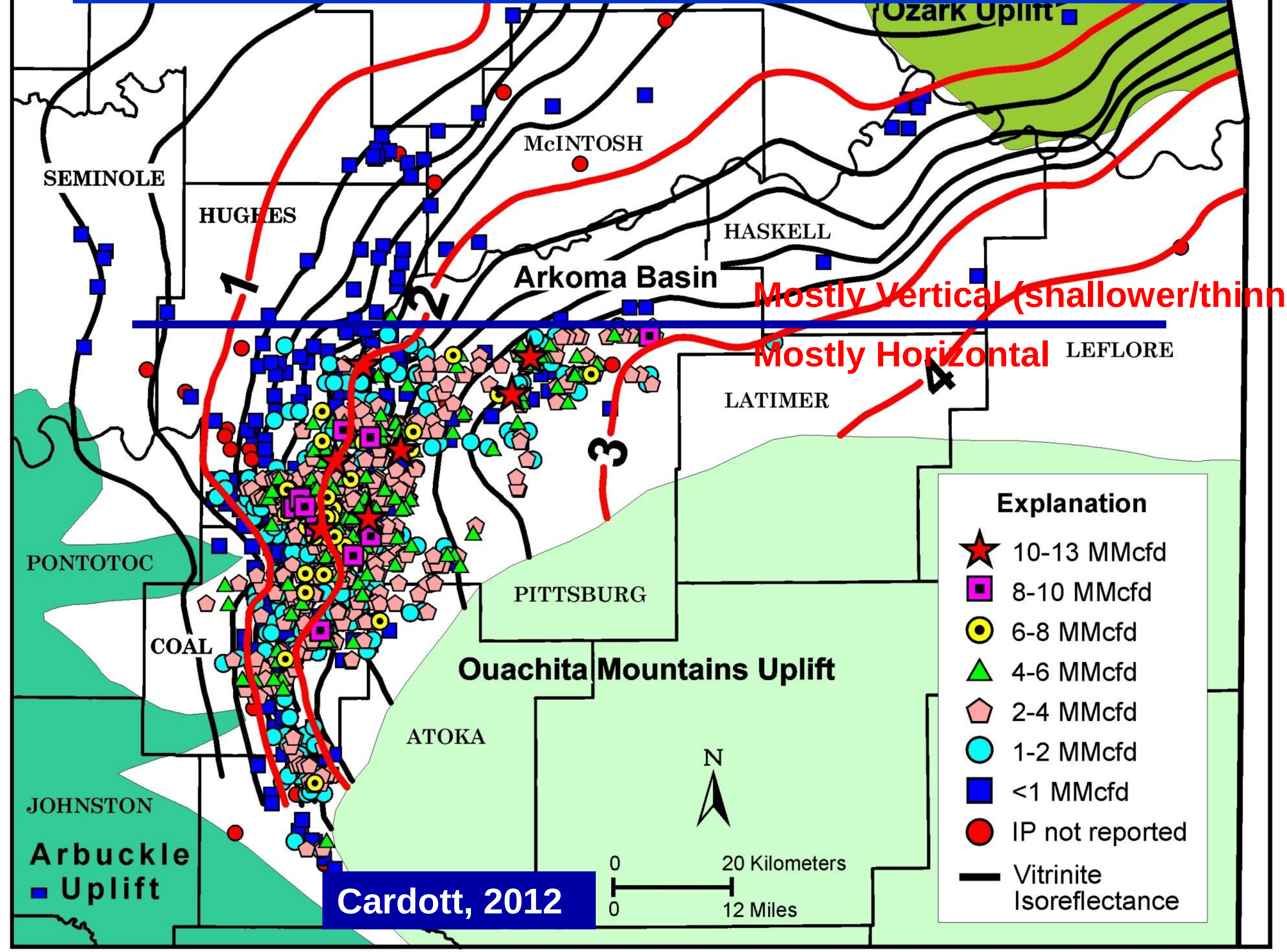
1. Introduction

The Woodford Shale (Late Devonian to Early Mississippian) is an important hydrocarbon source rock in Oklahoma (Comer and Hinch, 1987; Johnson and Cardott, 1992). It is a black to dark-gray, marine, carbona-

potential (e.g., high total organic carbon content with Type II kerogen), one advantage of the marine Woodford Shale as a gas shale is its quartz-rich composition, specifically rich in primarily from Radiolaria and sponge spicules Kuuskraa et al. (2011) indicated that marine shales (common deposi-

Cardott, 2012

Arkoma Basin Initial Potential



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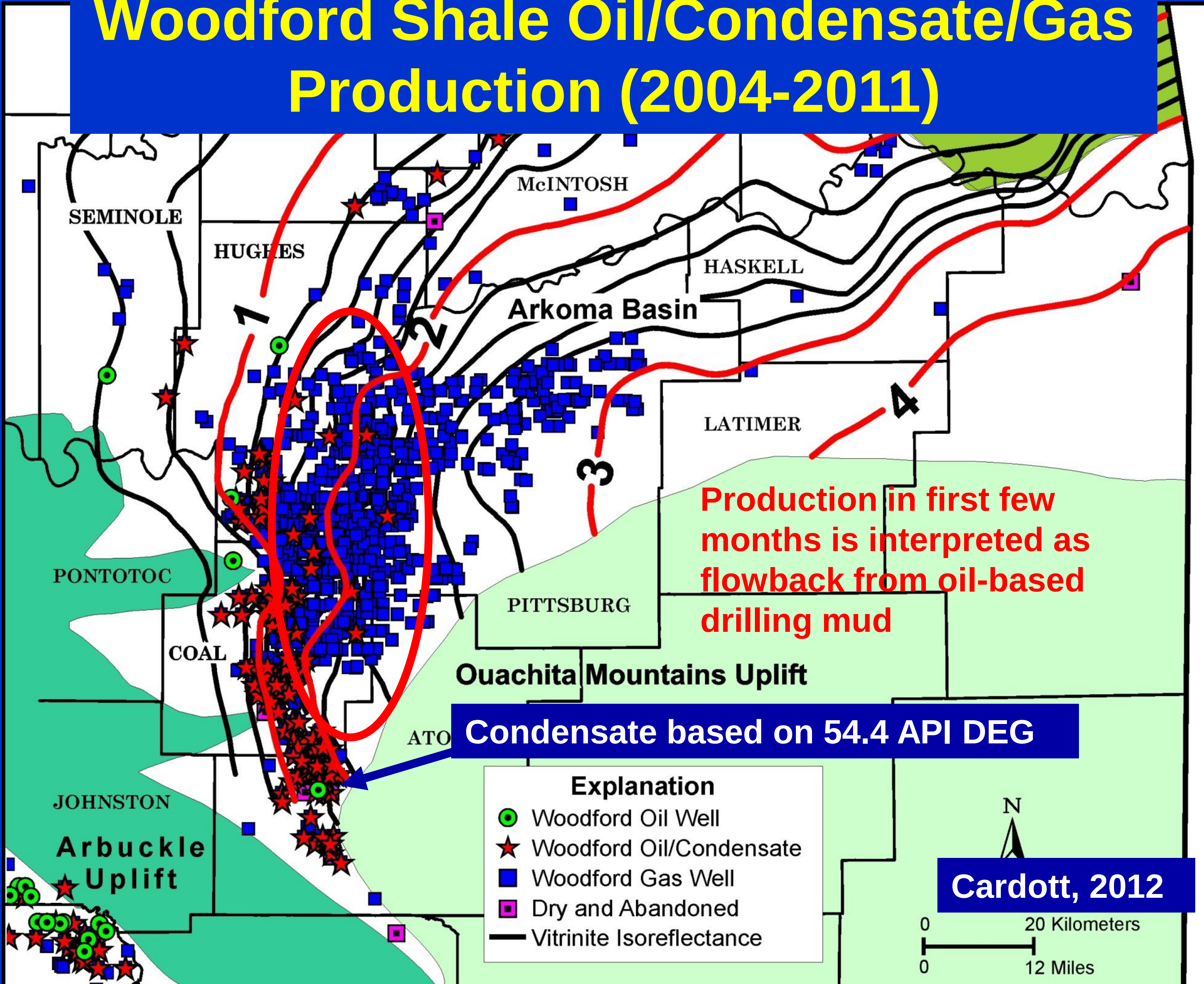
Woodford Oil/Condensate/Gas **Production** Caveat

- **Gas** production is reported by the Oklahoma Corporation Commission by **WELL**.

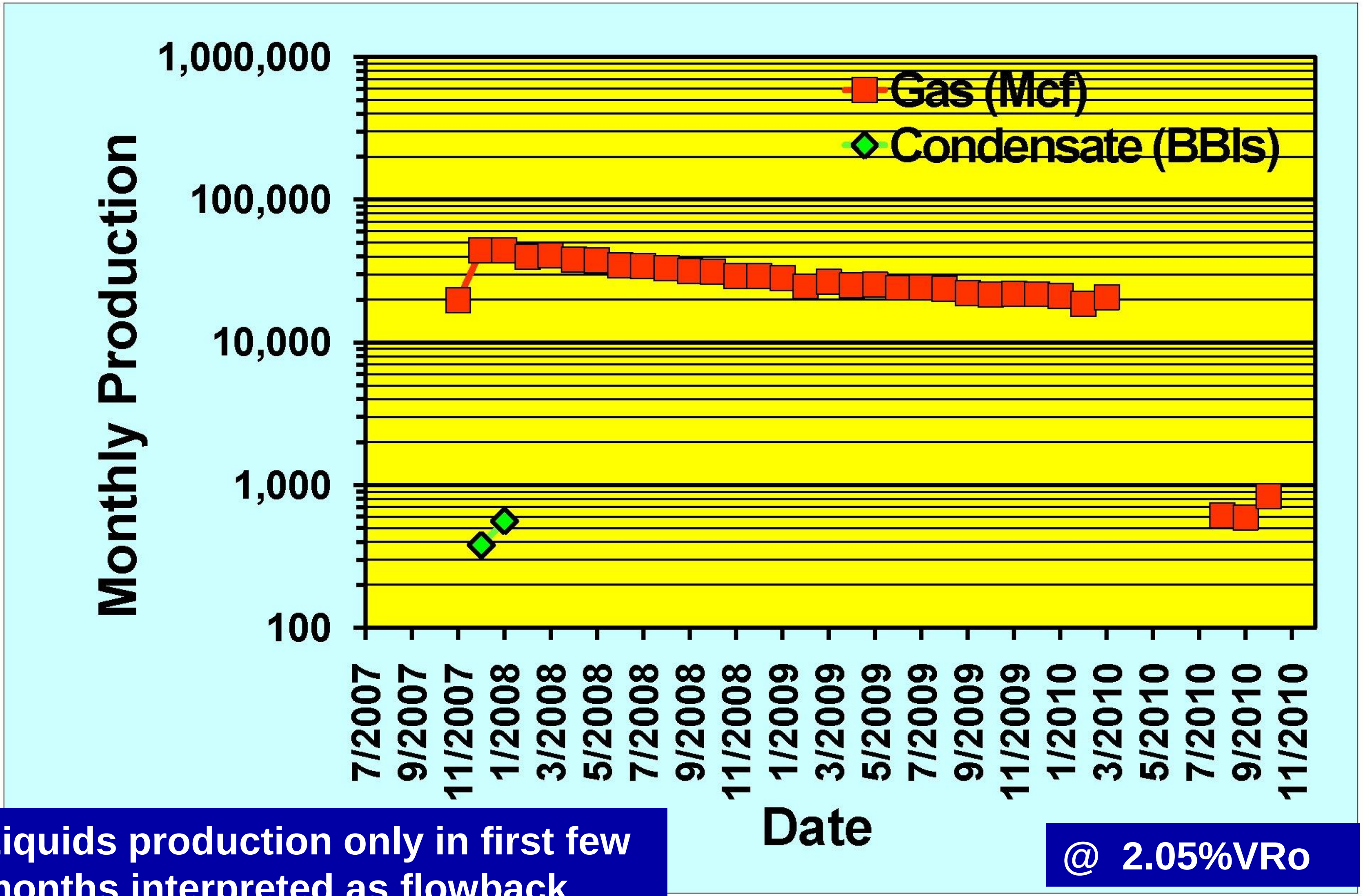
- **Oil/condensate** production is reported by the Oklahoma Tax Commission by **LEASE** [production by well is only on single-well leases]

Woodford Shale Oil/Condensate/Gas Production (2004-2011)



Cardott, 2012

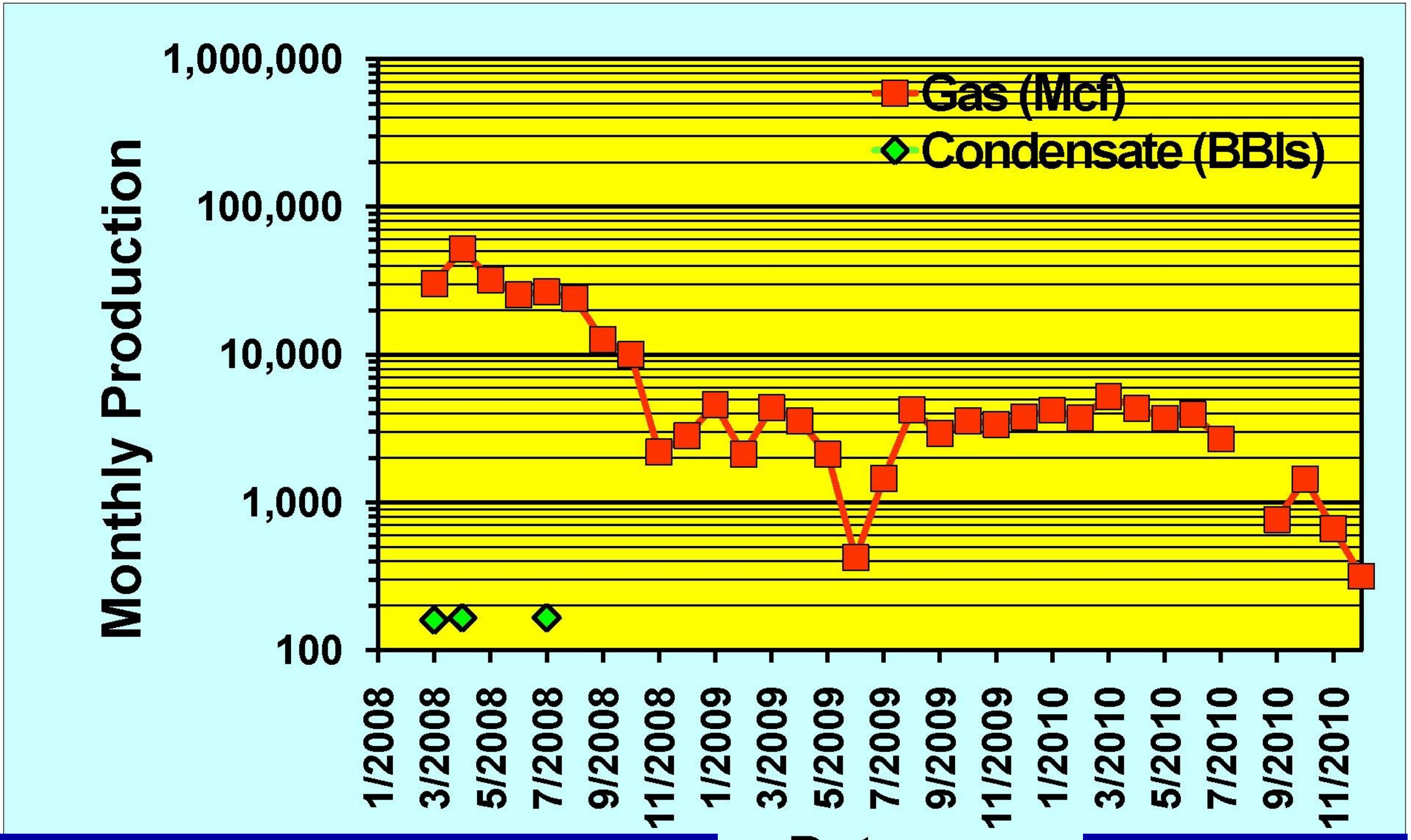
(1) Newfield 3H-36 Genevieve (36-6N-11E; Hughes Co.; IP 2,118 Mcfd)



Liquids production only in first few months interpreted as flowback

@ 2.05%VRo

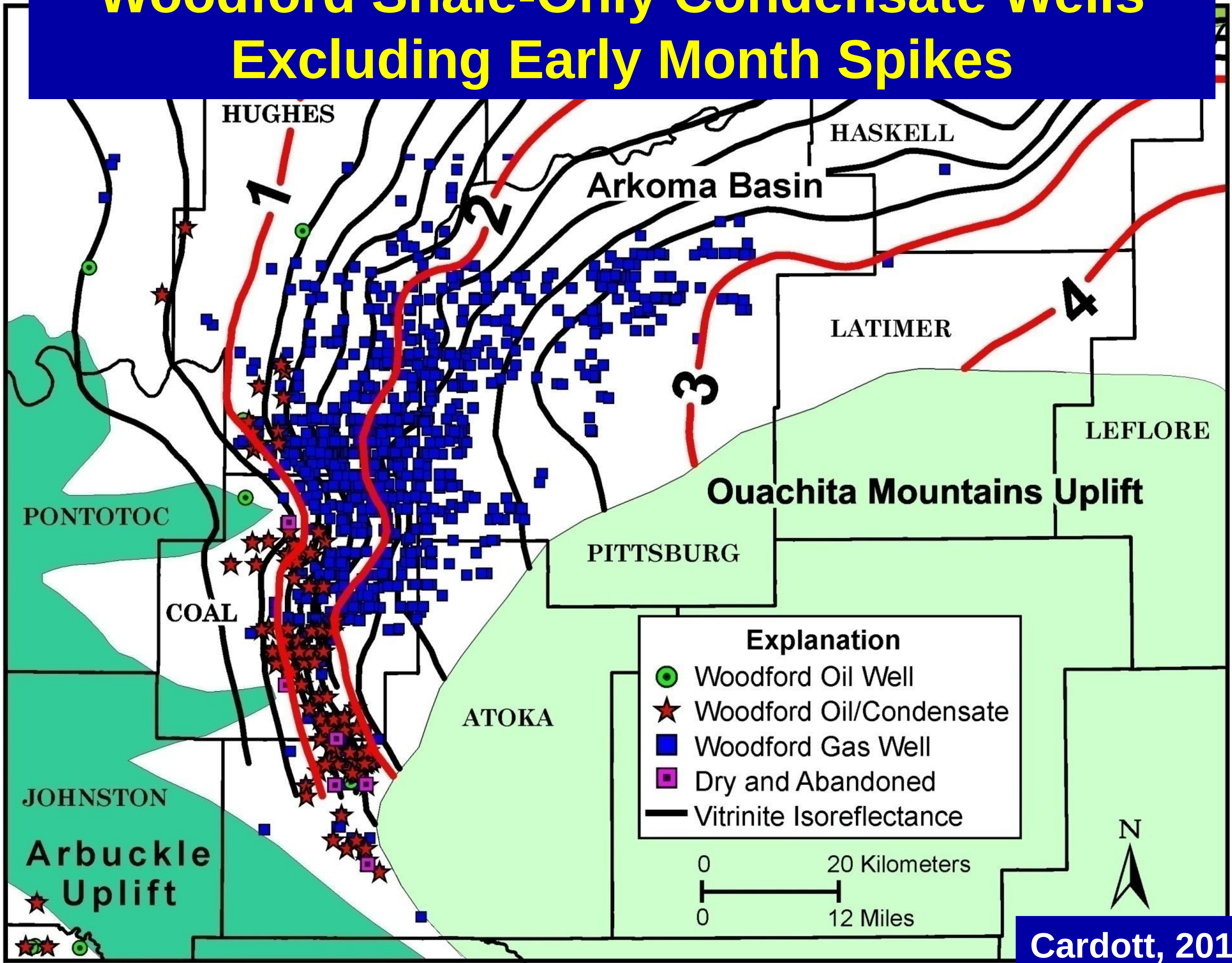
(2) Cimarex 3-34H Hall
(34-3N-11E; Coal Co.; IP 1,740 Mcfd)



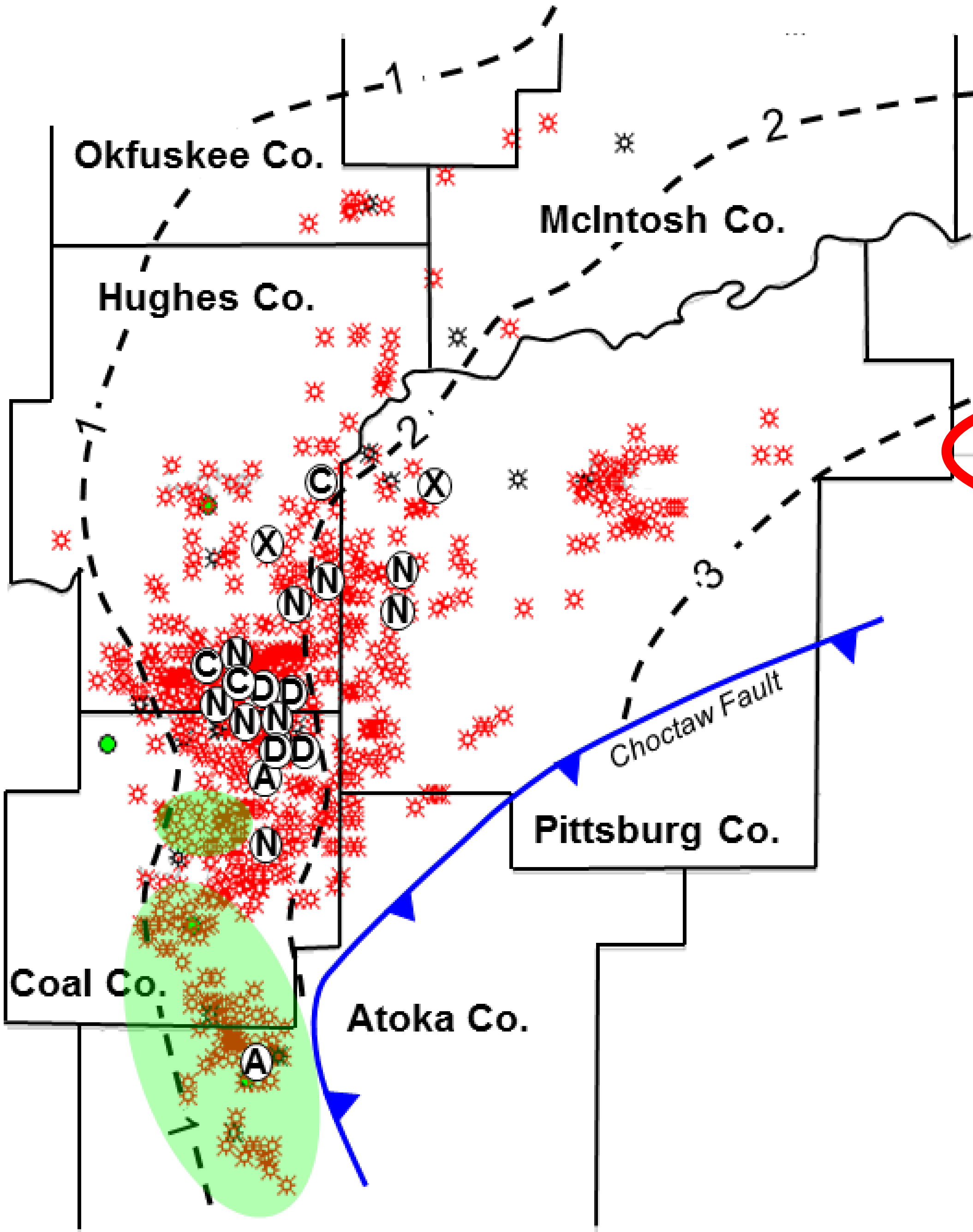
Intermittent liquids production in first few months interpreted as oil-based drilling mud flowback

@ 2.05%VRo

Woodford Shale-Only Condensate Wells Excluding Early Month Spikes



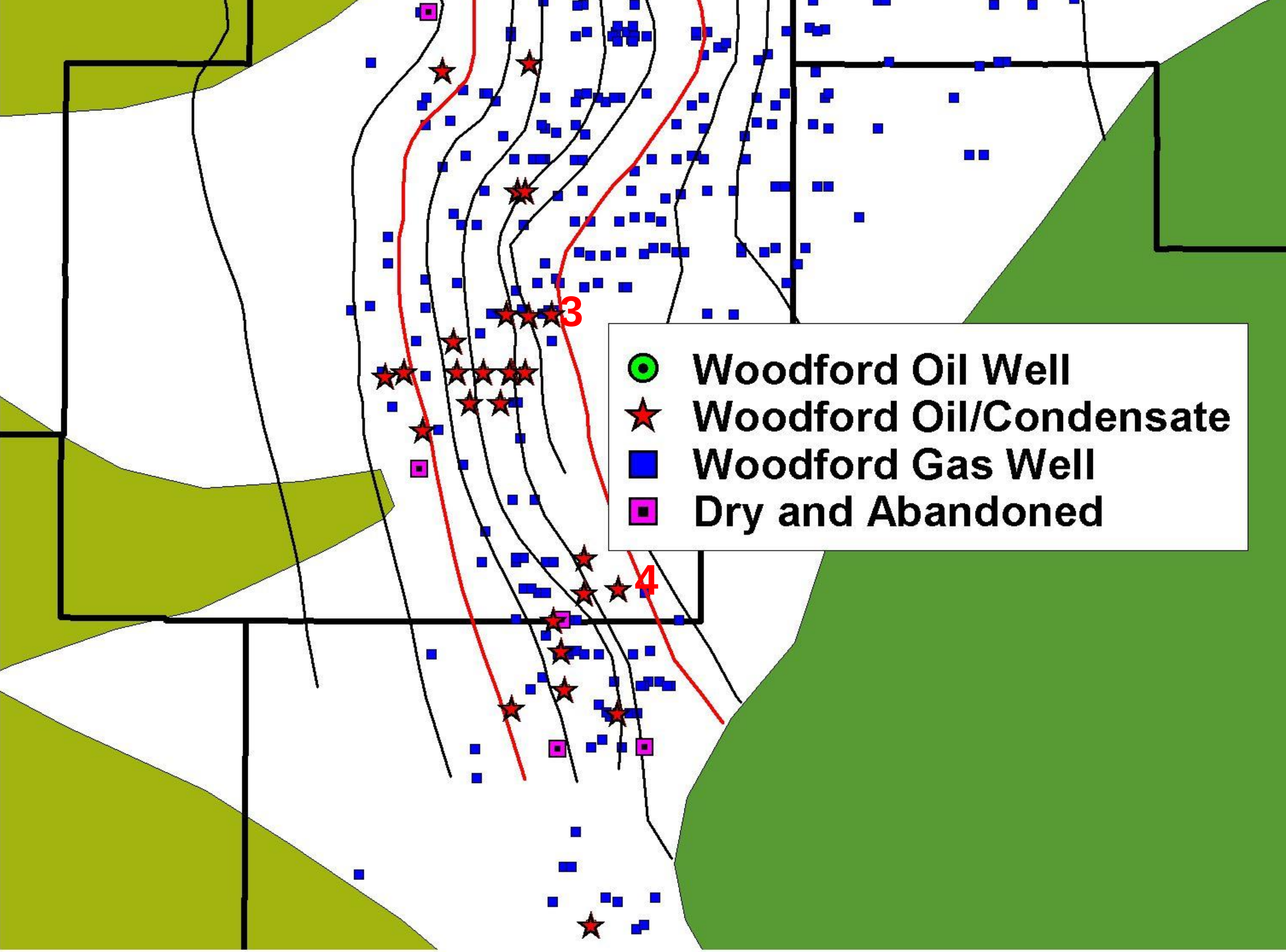
Cardott, 2012



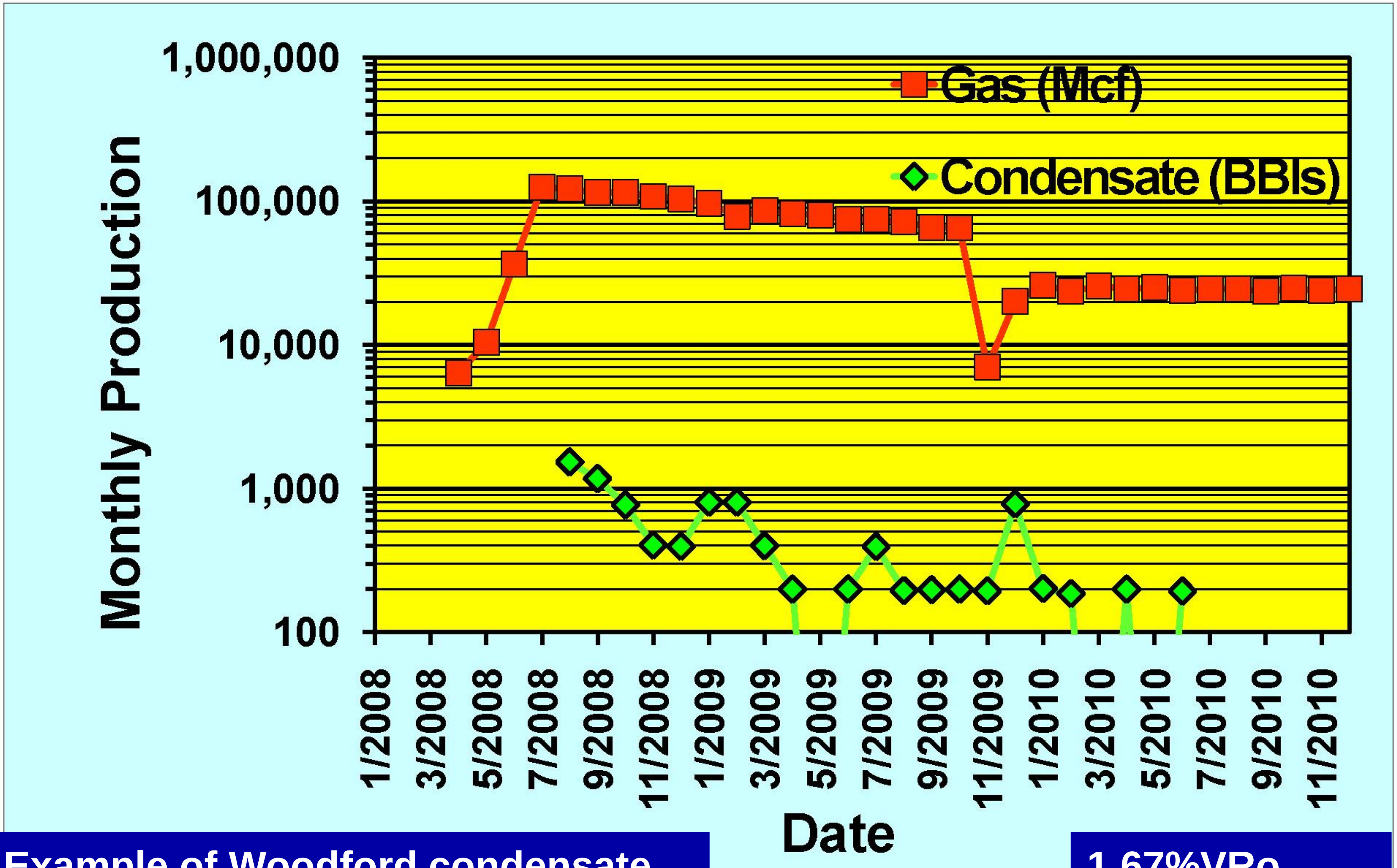
- Horizontal Woodford wells in the Arkoma Basin.
- Vitrinite reflectance (Ro).
- Condensate production (green-shaded areas).
- Location of 40 wells with highest initial production (IP). Operators affiliated with these wells are as follows:
A= Antero, C= Continental,
D= Devon, N= Newfield,
X= XTO.

Well data is from IHS Energy, 2009.
Reflectance data is modified from Cardott, 2008.

Andrews, 2009


3
4
Woodford Oil Well
Woodford Oil/Condensate
Woodford Gas Well
Dry and Abandoned

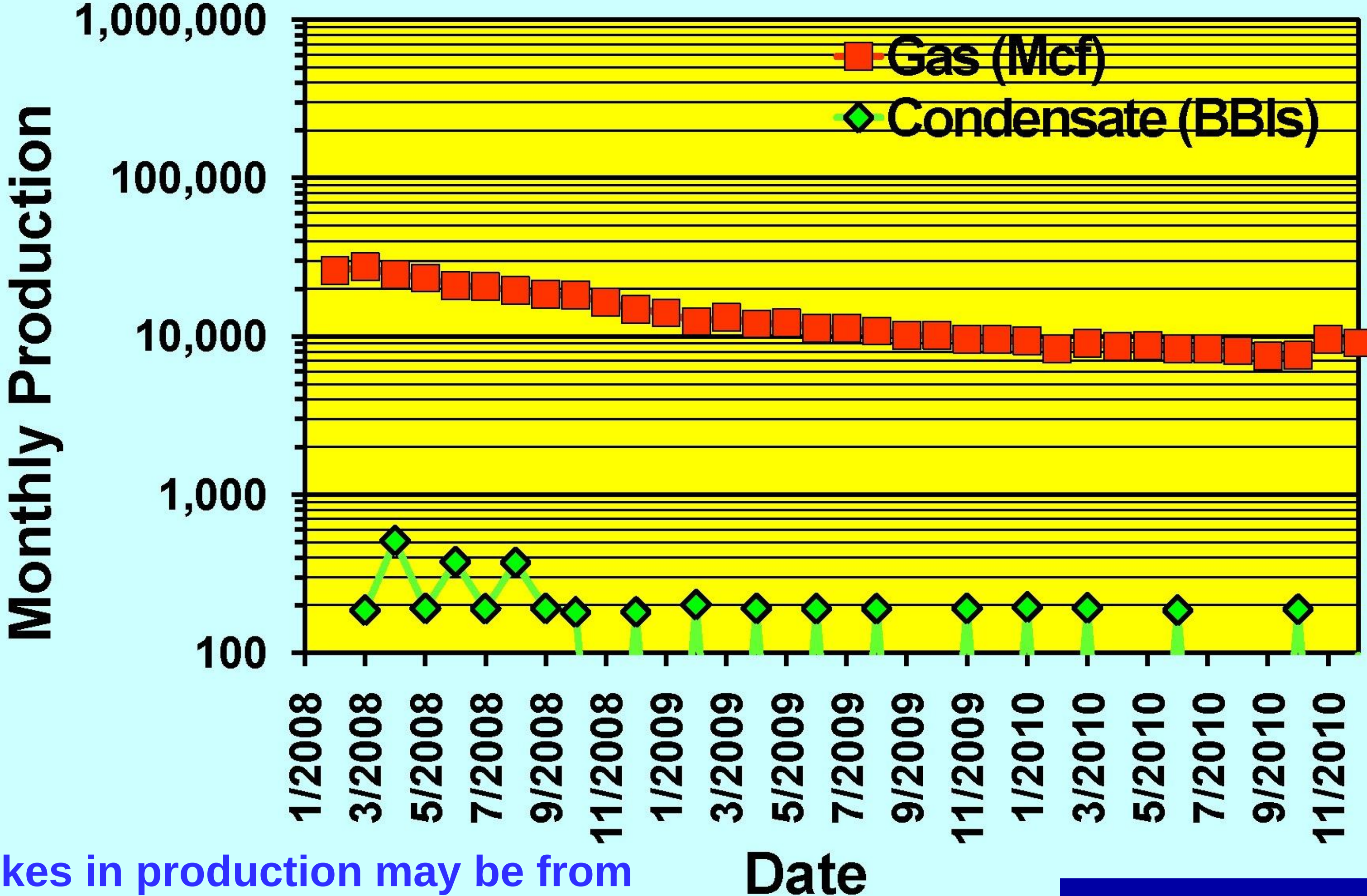
(3) St. Mary Land & Exploration 3-14 Marvin (14-1N-10E; Coal Co.; IP 3,125 Mcfd)



Example of Woodford condensate produced later in well's life

1.67%VRo

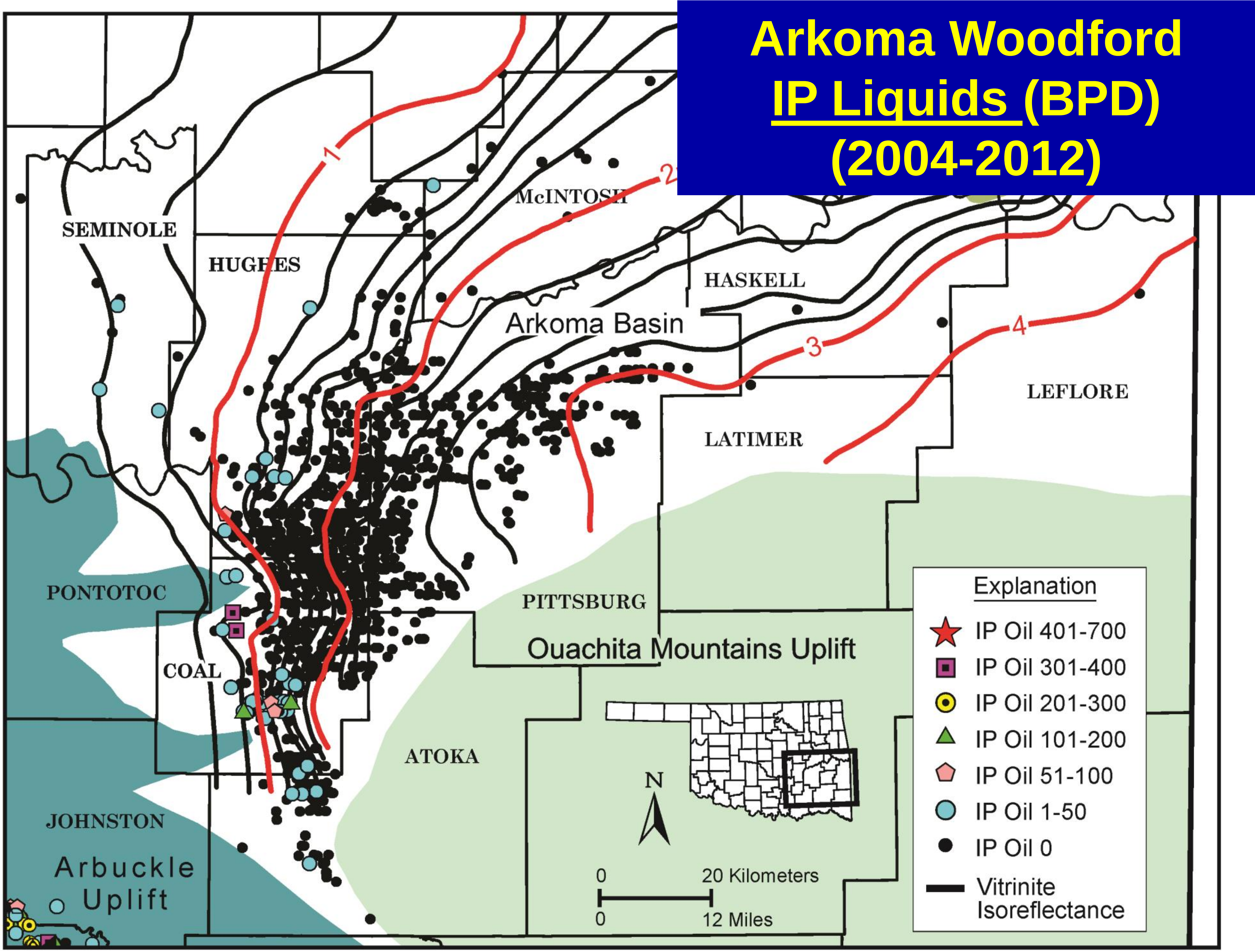
(4) Antero 30-1H Harris
(30-1S-11E; Coal Co.; IP 1,334 Mcfd)



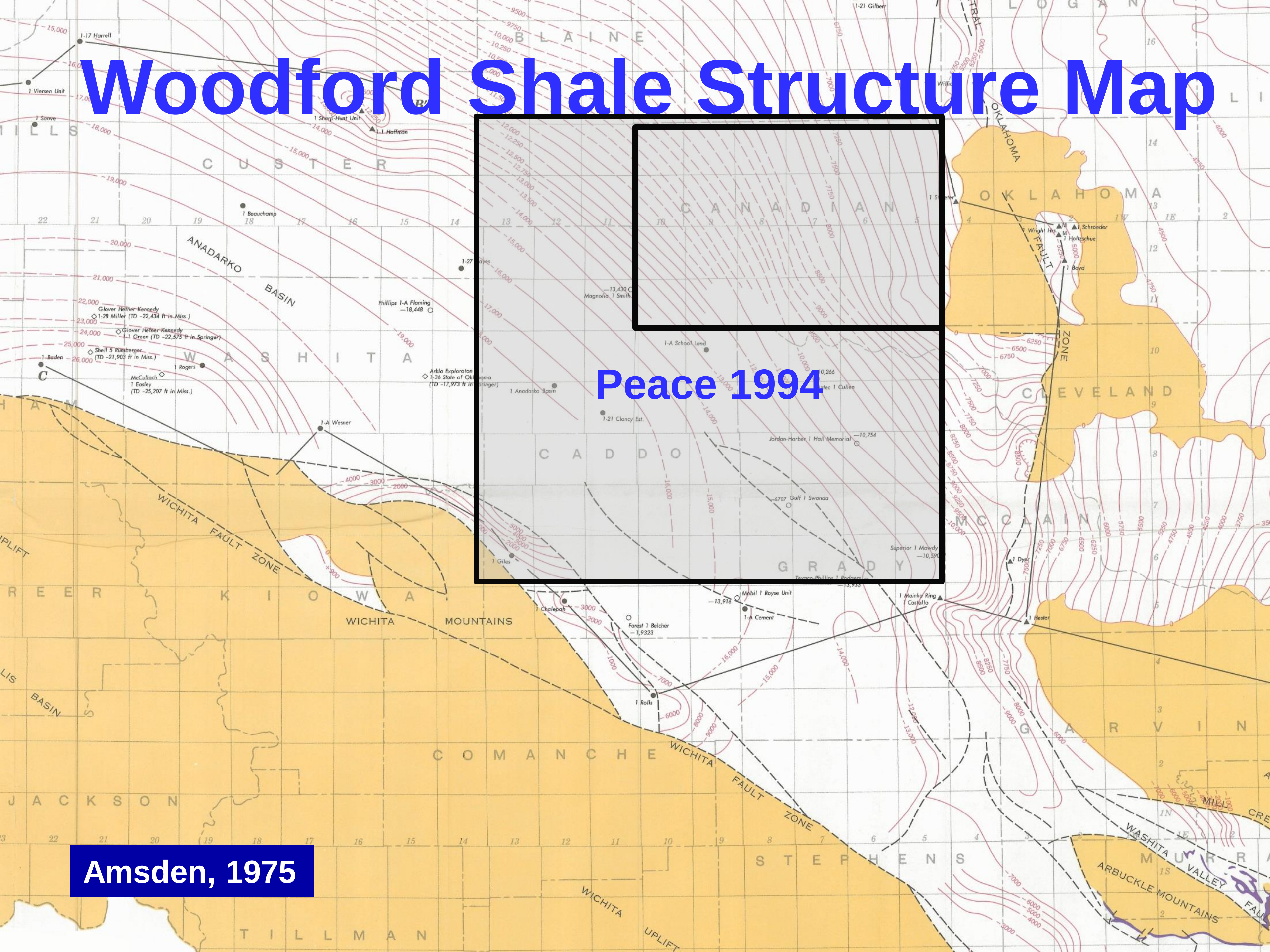
Spikes in production may be from intermittent trucking

@ 1.6%VRo

Arkoma Woodford IP Liquids (BPD) (2004-2012)

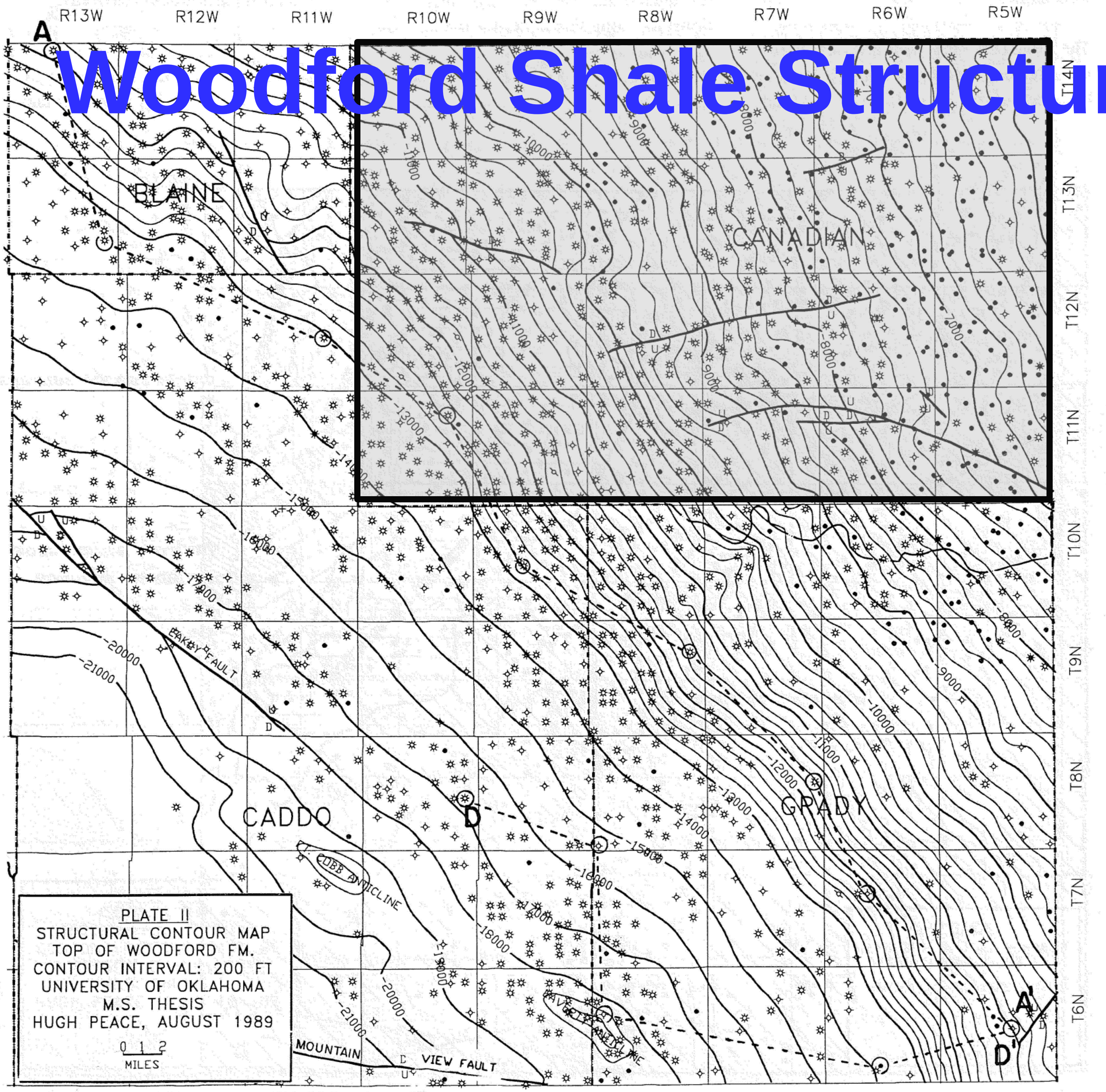


Woodford Shale Structure Map



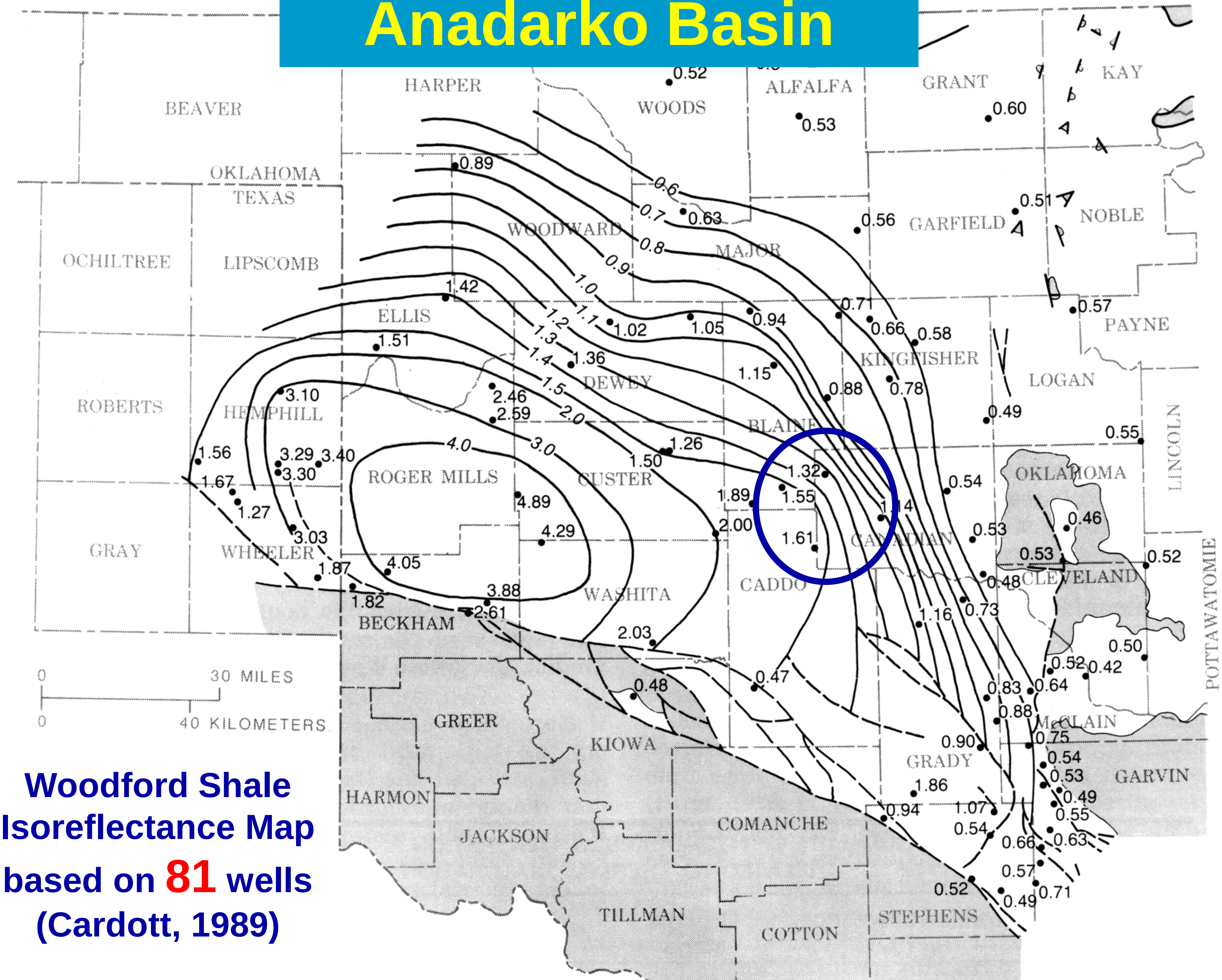
Amsden, 1975

Woodford Shale Structure Map



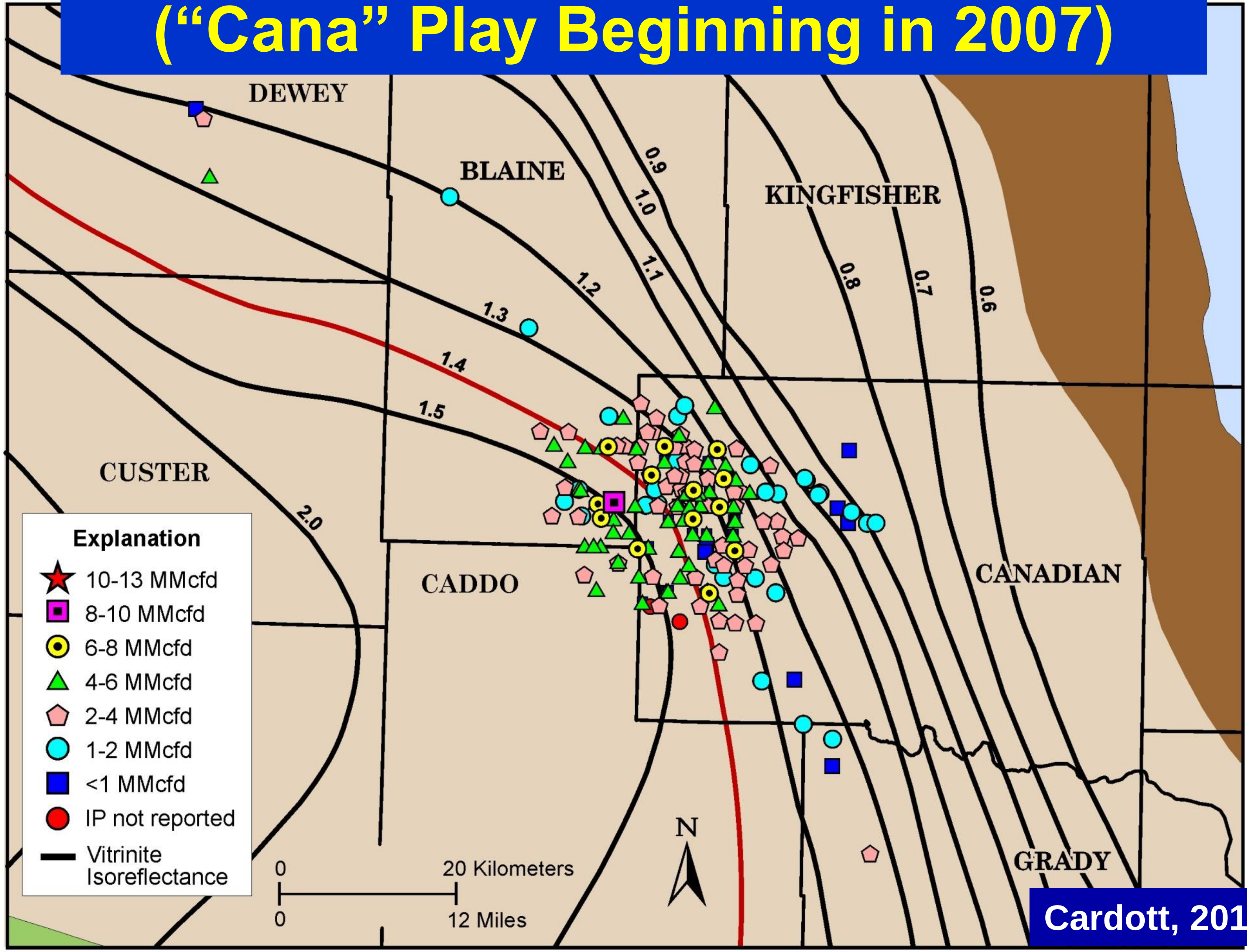
Peace, 1994

Anadarko Basin



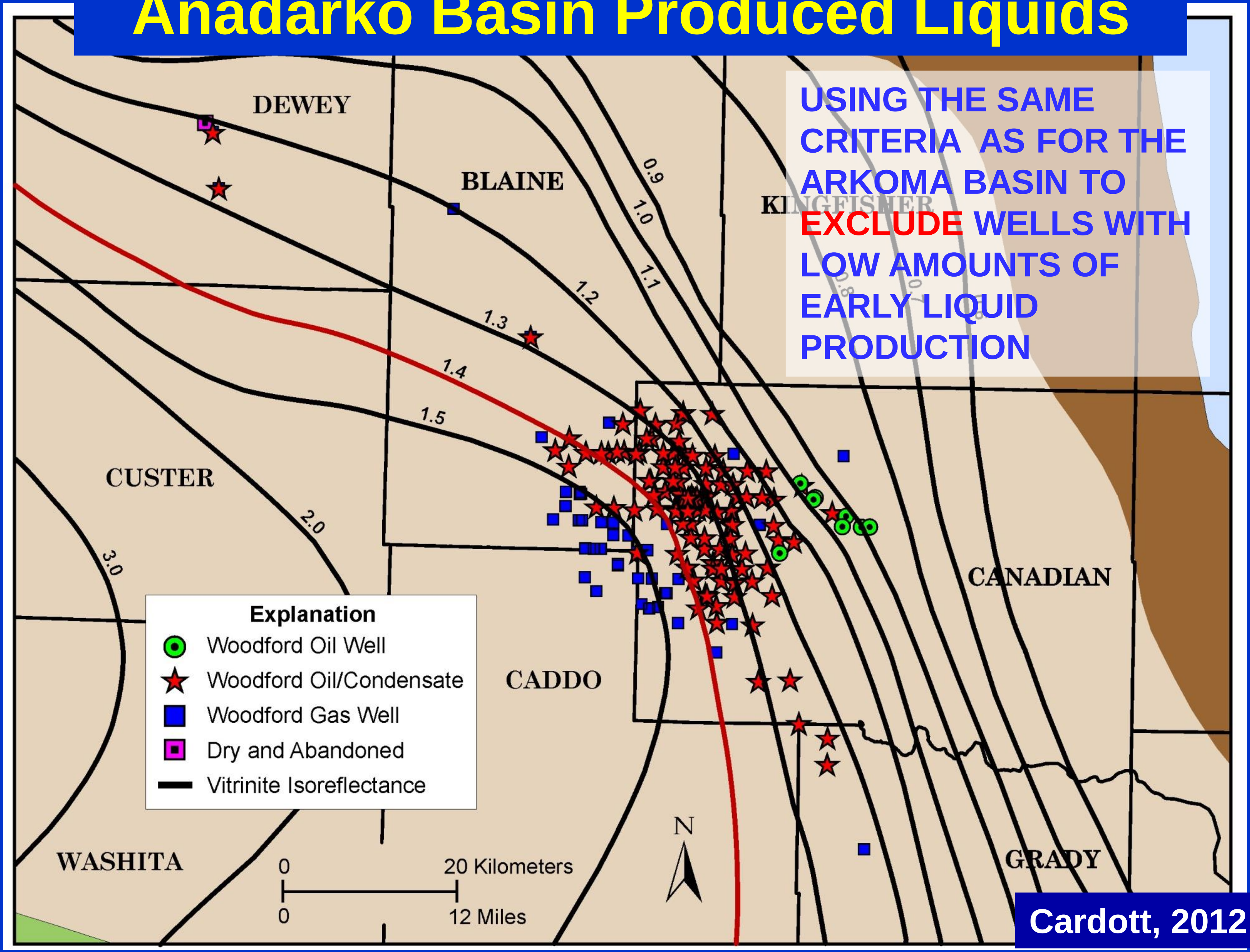
Woodford Shale Isoreflectance Map based on 81 wells (Cardott, 1989)

Anadarko Basin Initial Potential (“Cana” Play Beginning in 2007)



Cardott, 2012

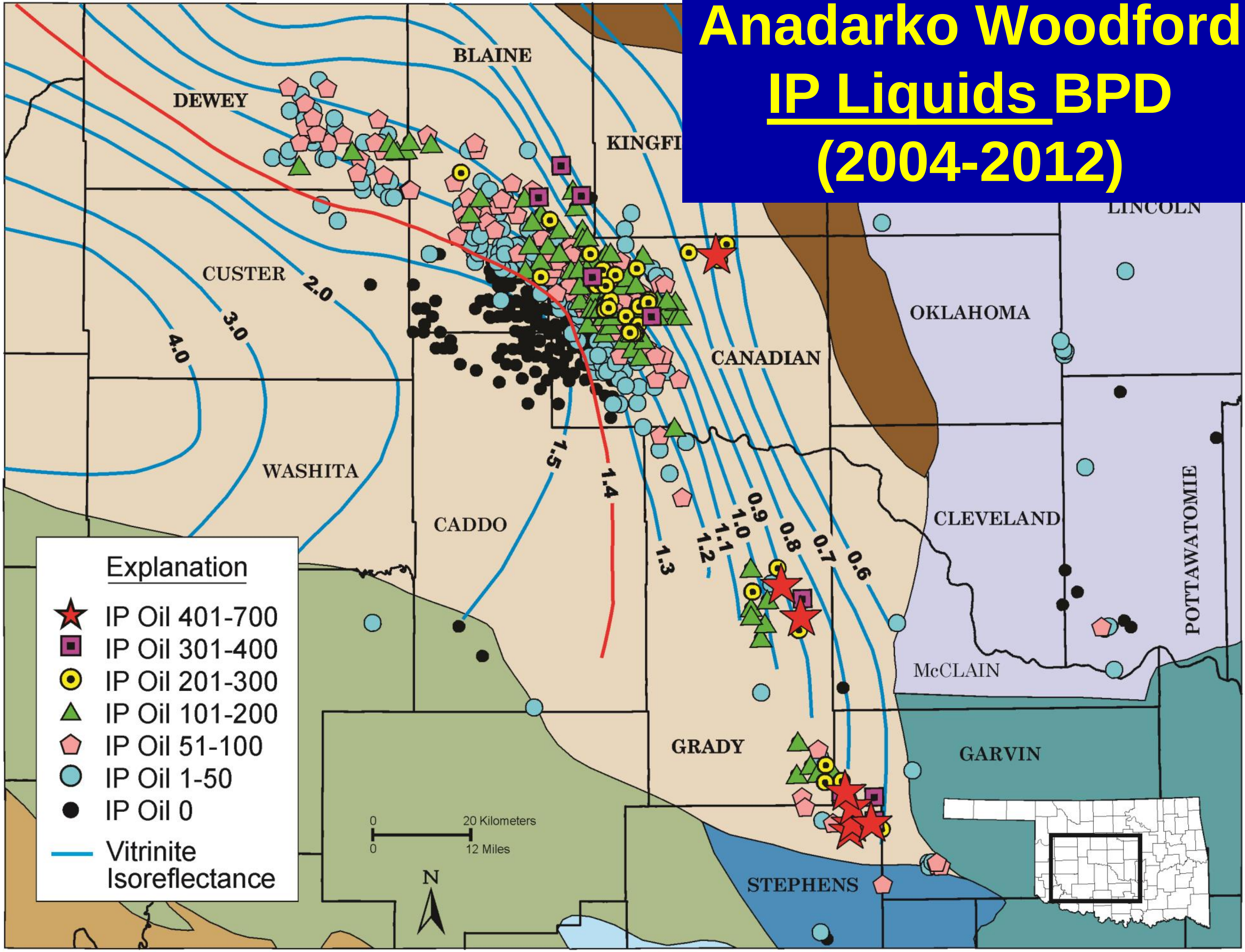
Anadarko Basin Produced Liquids



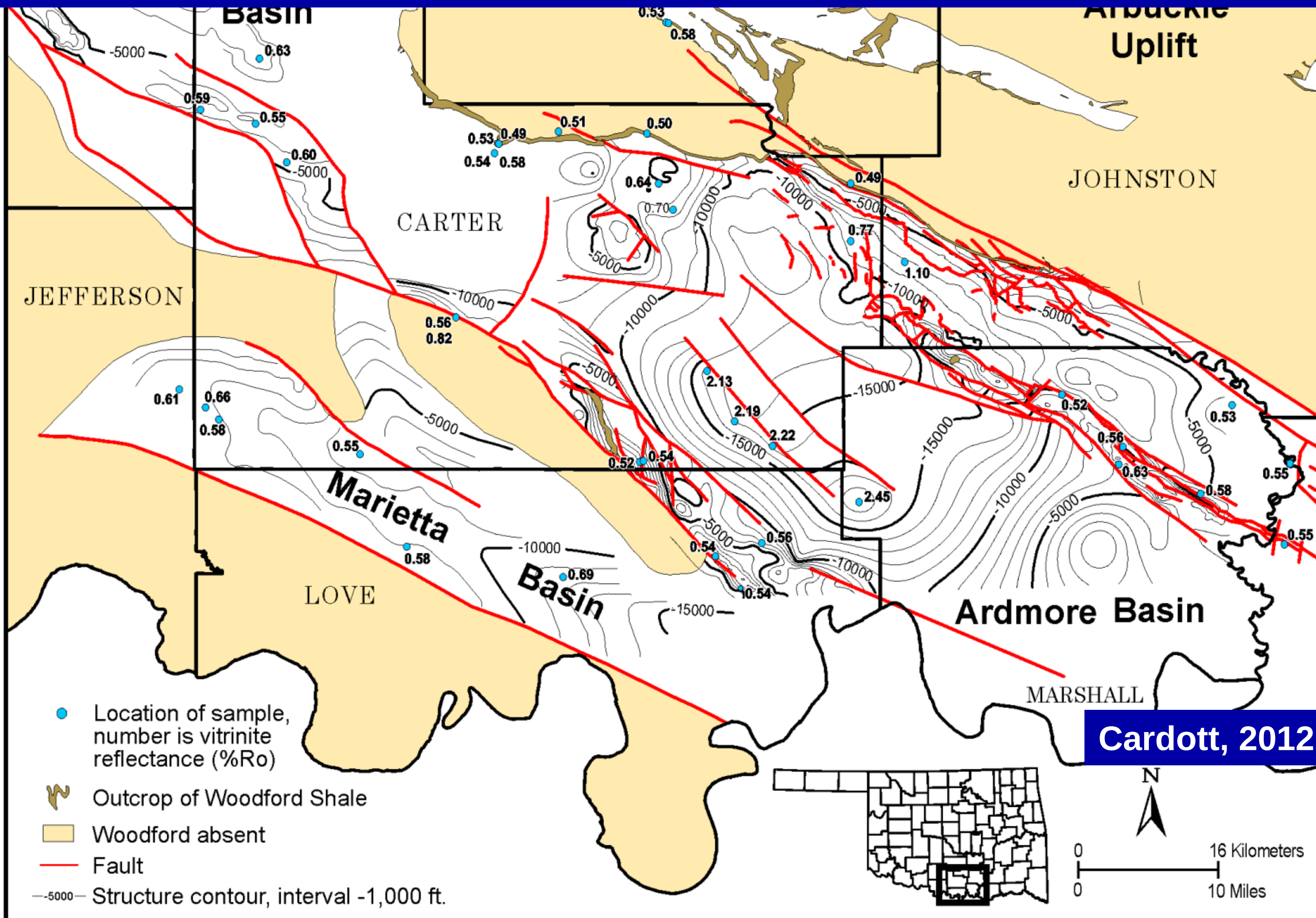
USING THE SAME CRITERIA AS FOR THE ARKOMA BASIN TO EXCLUDE WELLS WITH LOW AMOUNTS OF EARLY LIQUID PRODUCTION

Cardott, 2012

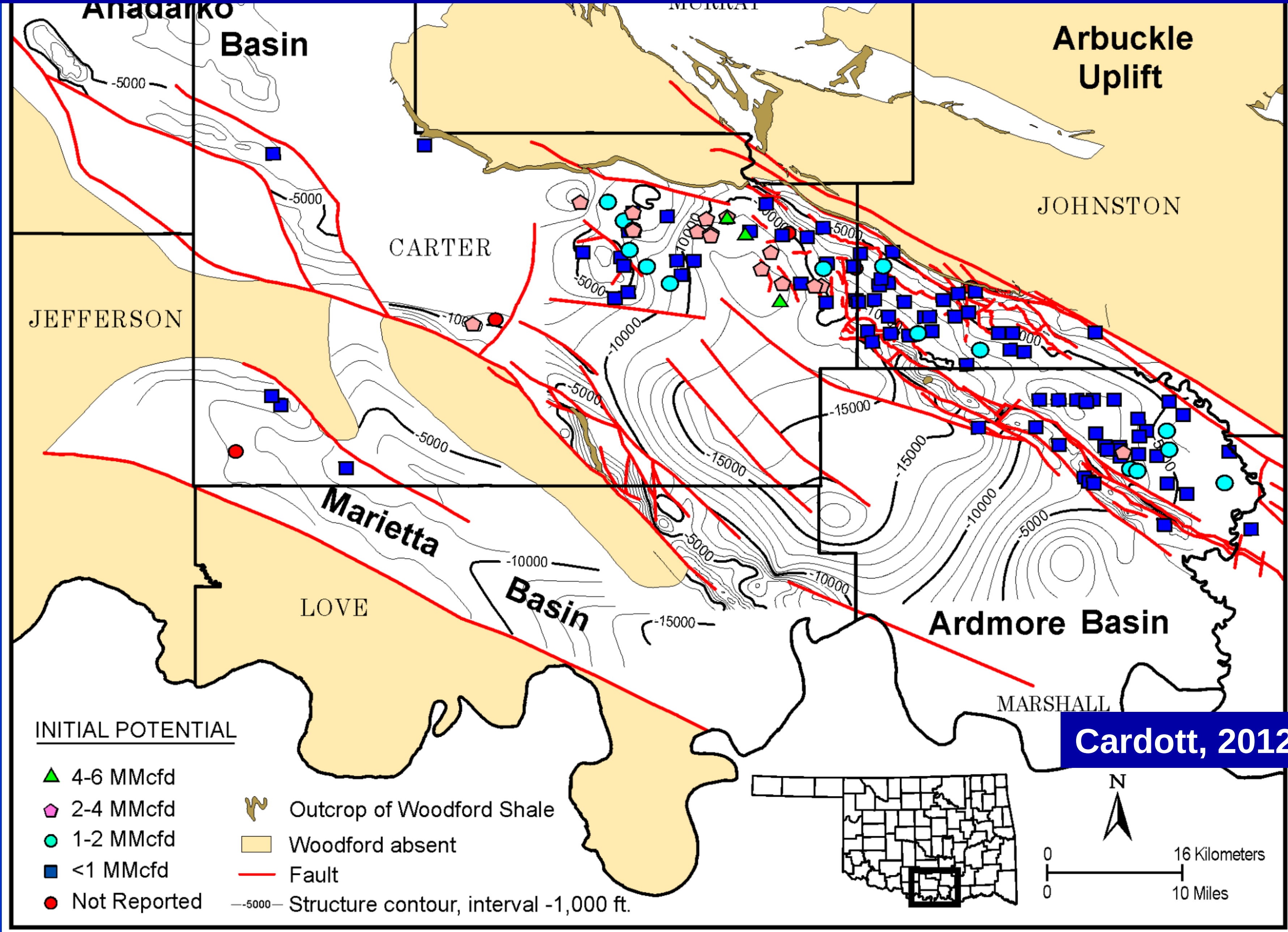
Anadarko Woodford **IP Liquids** BPD (2004-2012)



Woodford Shale VRo on Structure



Woodford Shale IPs on Structure



Cardott, 2012

Shale Oil Plays

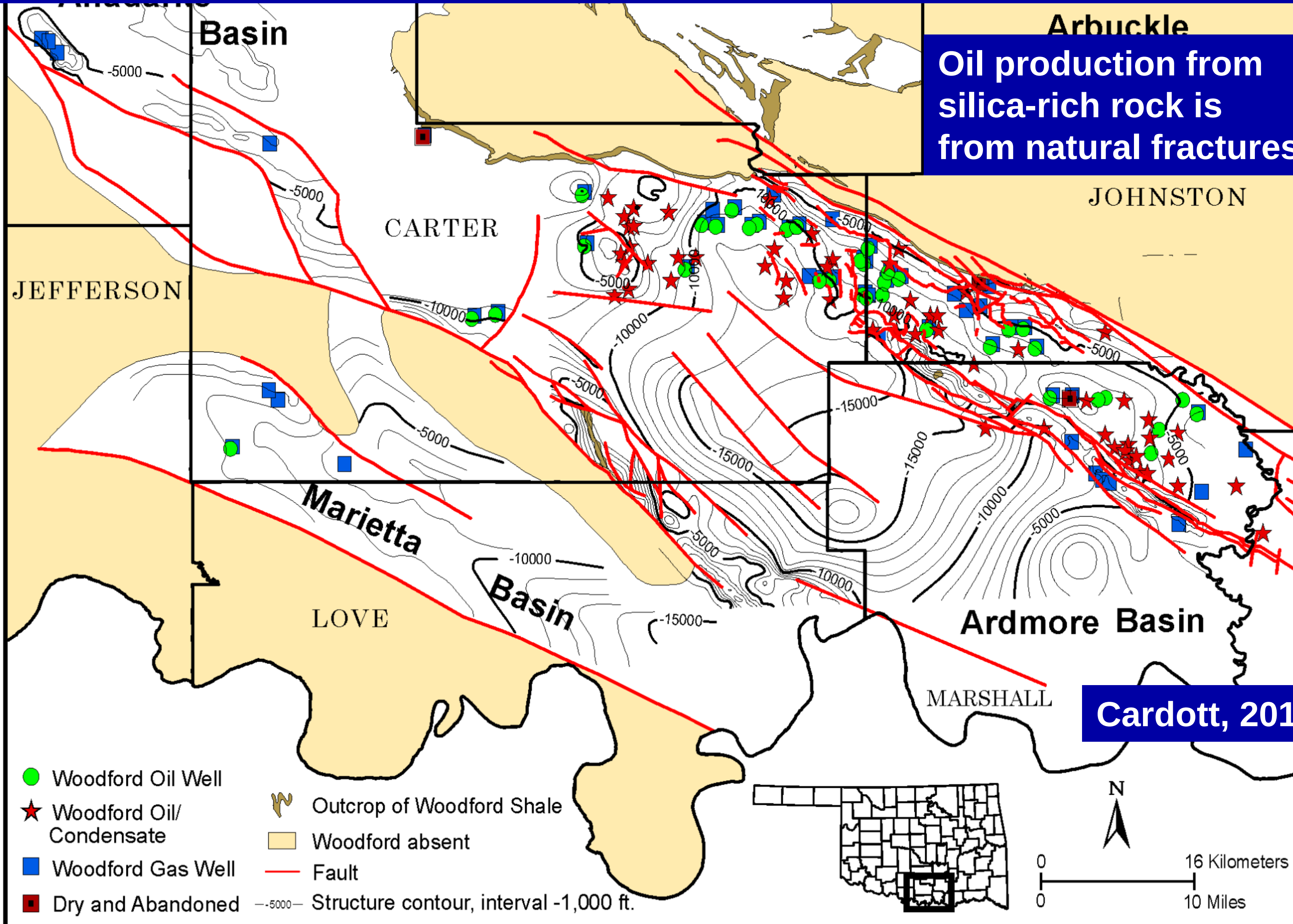
The Bakken Shale (Late Devonian-Early Mississippian; North Dakota & Montana) is the analog for shale oil plays. However, the reservoir of the Bakken is a permeable, non-shale middle member.

Other formations considered shale oil plays (mostly carbonates) are the Eagle Ford Shale (Late Cretaceous; Texas) and Niobrara Shale (Late Cretaceous; Rocky Mountains).

"The preferred rock type for a shale-oil play is a hybrid—that is, a formation with a good mix of non-shale lithologies, particularly carbonates"

(Darbonne, 2011)

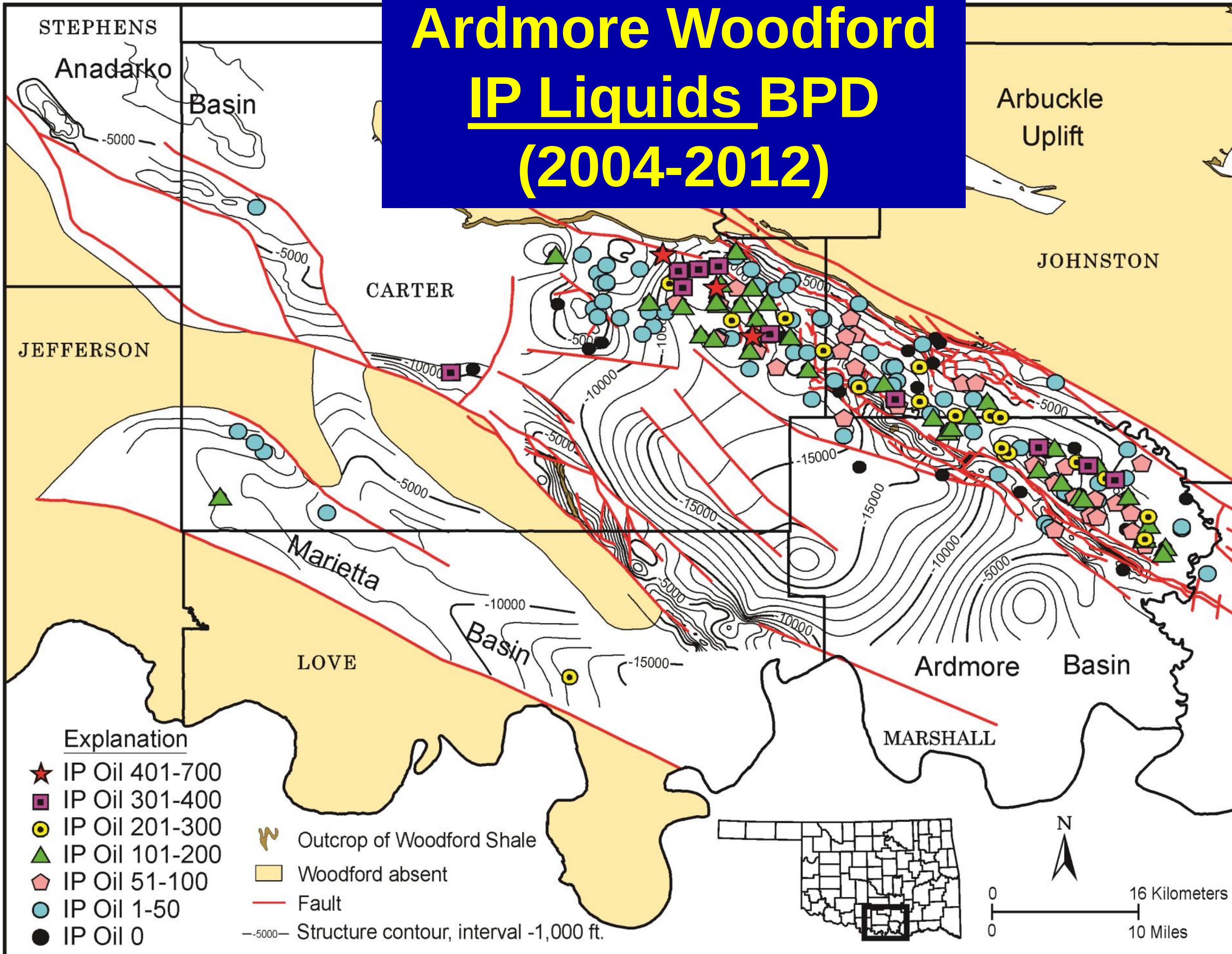
Woodford Production on Structure



Oil production from silica-rich rock is from natural fractures

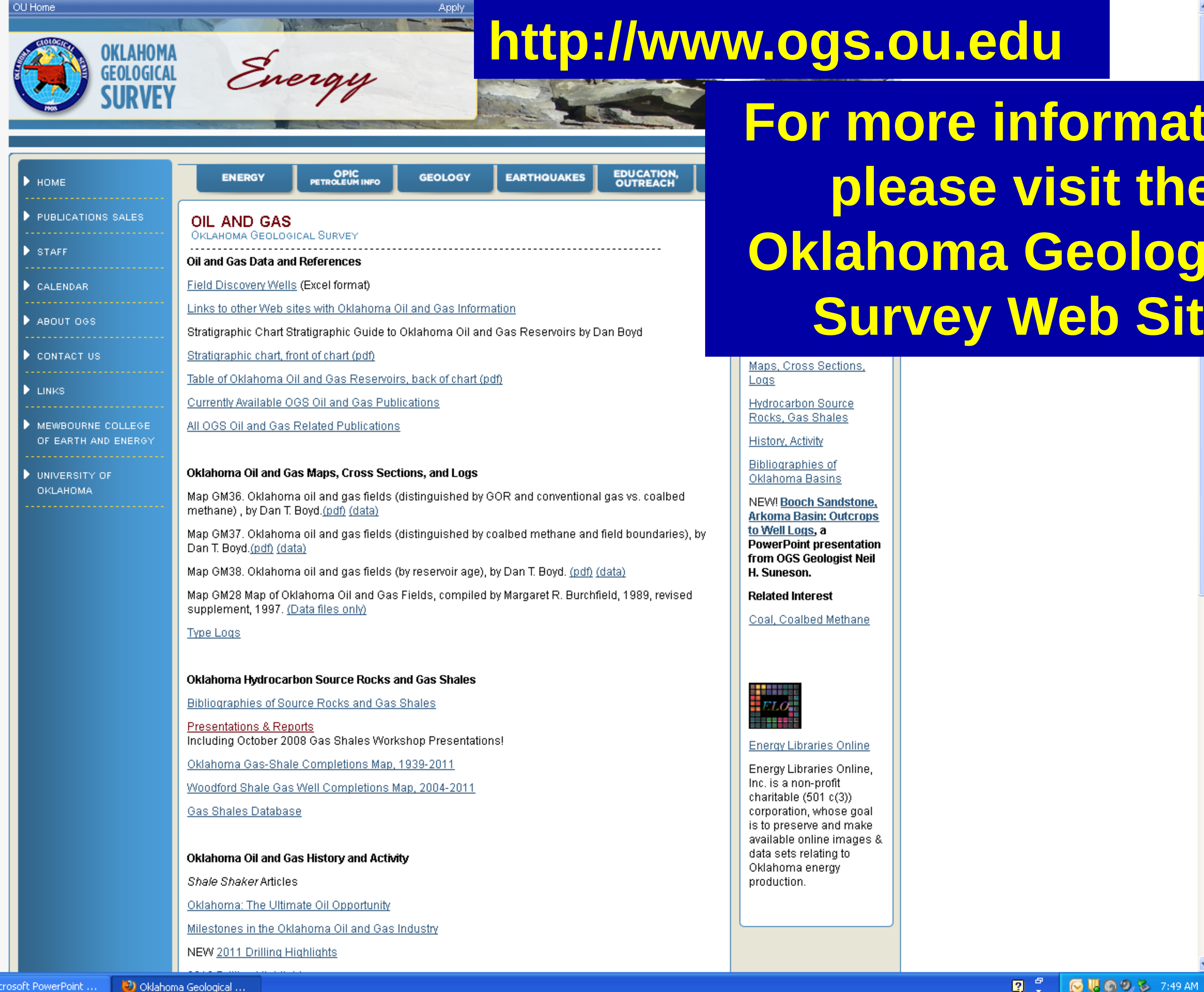
Cardott, 2012

Ardmore Woodford IP Liquids BPD (2004-2012)



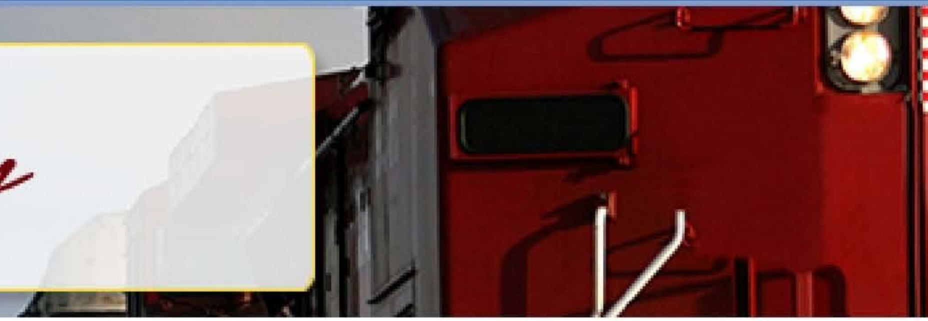
http://www.ogs.ou.edu

For more information, please visit the Oklahoma Geological Survey Web Site



OKLAHOMA GEOLOGICAL SURVEY

Energy



REFERENCES

BRIAN J. CARDOTT | OKLAHOMA GEOLOGICAL SURVEY

Bibliography of Caney Shale

Bibliography of Excello Shale

Bibliography of Woodford Shale

Bibliography of Woodford Shale Structure and Isopach Maps

Bibliography of Oklahoma Asphalt

Bibliography of Oklahoma Rock-Eval

Bibliography of Oklahoma Solid Hydrocarbons

Bibliography of Oklahoma Gas Shales

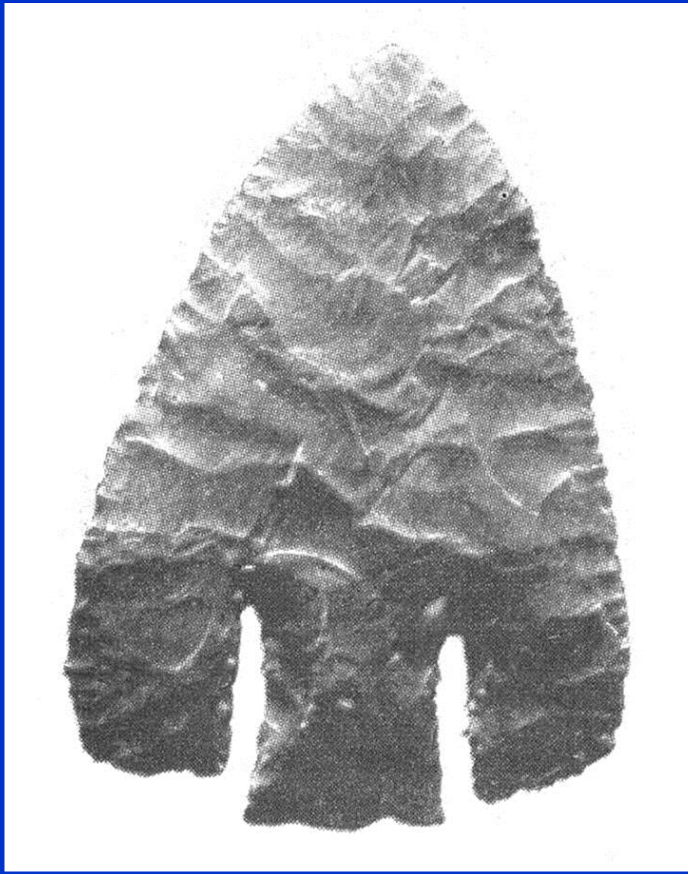
Bibliography of Oklahoma Hydrocarbon Source Rocks

updated 8/9/2012 cs

Record	API Number	Operator	Completion_Date	Well_Name	Field_Name	ectio	hip N	hip De	e Nu	Di	Qua	Qua	Qua	County	Formation/M	Depth	Ra
1993	35-063-24354	BP America Production Company	9/23/2011	3-14H Steinsick	Hill Top	14	5	N	11	E	NE	NW	NE	Hughes	Woodford	7357	735
1975	35-063-24373	Alta Natural Resources	9/9/2011	14-6H Brumby	Atwood S	14	5	N	9	E	SE	SW	SE	Hughes	Woodford	5272	527
1958	35-121-24476	BP America Production Company	9/7/2011	3-5H Powell	Ashland S	8	3	N	12	E	SW	NW	NE	Pittsburg	Woodford	8887	888
1976	35-121-24477	BP America Production Company	9/7/2011	4-5H Powell	Ashland S	8	3	N	12	E	SW	NW	NE	Pittsburg	Woodford	8912	891
1948	35-095-20552	XTO Energy	8/29/2011	1-5H Richardson	Aylesworth	8	6	S	7	E	NE	NW	NW	Marshall	Woodford	5723	572
1981	35-017-24142	QEP Energy	8/25/2011	3-30H Briscoe	Trend	30	13	N	10	W	SE	SE	SE	Canadian	Woodford	6	6
1991	35-029-21181	XTO Energy	8/24/2011	1-3H Hooe	Coalgate	10	1	N	11	E	NW	NE	NE	Coal	Woodford	1	1
1951	35-125-23701	West Star Operating	8/22/2011	1-12 Schoemann	Trousdale S	12	6	N	2	E	NE	SW	SE	e	Woodford	4423	46
1950	35-125-23692	West Star Operating	8/18/2011	2-7 West Star	Wanette	7	5	N	3	E	NW	SE	NW	e	Woodford	3865	38
1978	35-011-23270	Questar Exploration & Production	8/17/2011	1-13H Levi	Elm Grove	13	13	N	12	W	NE	NE	NW	Blaine	Woodford	0	0
1954	35-019-25483	XTO Energy	8/15/2011	1-24H Sampley	Berwyn	24	3	S	2	E	SE	SE	SE	Carter	Woodford	9	9
1995	35-121-24542	XTO Energy	8/15/2011	1-16H HR	Cabaniss NW	21	6	N	12	E	NW	NE	NE	Pittsburg	Woodford	7079	707
1945	35-121-24490	XTO Energy	8/14/2011	7-24H Morris	Pine Hollow S	24	5	N	12	E	NE	NW	NW	Pittsburg	Woodford	8521	852
1934	35-121-24481	BP America Production Company	8/12/2011	5-5H Powell	Ashland	5	3	N	12	E	SW	SW	SW	Pittsburg	Woodford	8856	885
1935	35-121-24450	BP America Production Company	8/12/2011	2-5H Powell	Ashland S	8	3	N	12	E	NE	NW	NE	Pittsburg	Woodford	9031	903
1994	35-121-24489	XTO Energy	8/3/2011	6-24H Morris	Pine Hollow S	24	5	N	12	E	NE	NW	NW	Pittsburg	Woodford	8519	851
1933	35-119-23870	Calyx Energy Limited Liability	8/2/2011	16-1H State WFD	Mehan	21	18	N	3	E	NE	NW	NW	Payne	Woodford	4305	430
1939	35-063-24374	XTO Energy	8/1/2011	3-23H Reeder	Legal N	14	4	N	11	E	SW	SW	SE	Hughes	Woodford	8403	840
1940	35-063-24375	XTO Energy	8/1/2011	4-23H Reeder	Legal N	14	4	N	11	E	SW	SW	SE	Hughes	Woodford	8428	842
1946	35-121-24546	Petroquest Energy	8/1/2011	1-29H Holman	Featherston	21	7	N	17	E	SW	SW	SW	Pittsburg	Woodford	8261	826
1947	35-121-24547	Petroquest Energy	8/1/2011	1-28H Lipska	Featherston	21	7	N	17	E	SW	SW	SW	Pittsburg	Woodford	8150	815
1942	35-121-24487	XTO Energy	7/30/2011	4-24H Morris	Pine Hollow S	24	5	N	12	E	NE	NW	NW	Pittsburg	Woodford	8483	848
1938	35-019-25513	XTO Energy	7/28/2011	1-12H Wiggins	Baum N	13	4	S	3	E	NW	NW	NW	Carter	Woodford	0	0
1931	35-011-23355	Marathon Oil	7/27/2011	2-30H Schwarz BIA	Trend	30	15	N	10	W	SW	SW	SE	Blaine	Woodford	1	1
1937	35-019-25499	XTO Energy	7/22/2011	1-36H McCarty	unnamed	36	3	S	2	E	SW	SW	SW	Carter	Woodford	9	9
1941	35-063-24371	XTO Energy	7/22/2011	1-23H Durham	Ashland N	23	4	N	11	E	SE	SE	SE	Hughes	Woodford	8369	836
1943	35-121-24488	XTO Energy	7/22/2011	5-24H Morris	Pine Hollow S	24	5	N	12	E	NE	NW	NW	Pittsburg	Woodford	8556	855
1971	35-017-24174	Cimarex Energy	7/16/2011	1-29H Stroh	Trend	32	13	N	9	W	NE	NE	NE	Canadian	Woodford	7	7
1989	35-017-24257	Devon Energy	7/14/2011	1-32H Ricker	Trend	5	13	N	9	W	NE	NE	NW	Canadian	Woodford	9	9
1909	35-029-21151	BP America Production Company	7/8/2011	5-27H Walkup	Ashland	27	3	N	11	E	NW	NE	NE	Coal	Woodford	8590	859
1944	35-011-23357	Devon Energy	7/8/2011	1-21H Neely	Trend	21	14	N	11	W	SW	SW	SW	Blaine	Woodford	3	3
1967	35-015-23154	Devon Energy	7/8/2011	1-19H Canyon	Bridgeport	19	12	N	11	W	SE	SW	SW	Caddo	Woodford	1	1
1920	35-095-20553	Range Production Company	7/6/2011	1-8H Jolly Roger XS	Madill	17	5	S	6	E	NE	NE	NW	Marshall	Woodford	8606	860
1932	35-011-23351	QEP Energy	7/6/2011	1-17H Cooper	Greenfield N	20	15	N	11	W	NE	NE	NE	Blaine	Woodford	4	4
1982	35-121-24465	Newfield Exploration	7/4/2011	6H-31Cunningham	Ashland	6	3	N	12	E	SE	NW	NW	Pittsburg	Woodford	8606	860
1957	35-117-23424	Mt. Dora Energy	7/3/2011	1-17 Wingo	Maramec	17	20	N	6	E	SE	NE	SW	Pawnee	Woodford	3442	344
1898	35-029-21148	BP America Production Company	7/1/2011	3-27H Walkup	Ashland	27	3	N	11	E	SE	SE	SW	Coal	Woodford	8370	837
1924	35-017-24224	Marathon Oil	7/1/2011	1-6H Base BIA	Trend	6	14	N	10	W	NE	NE	NE	Canadian	Woodford	1	1
1965	35-011-23327	Devon Energy	6/30/2011	1-29H Pinkerton	Fay E	29	15	N	12	W	NE	NE	NE	Blaine	Woodford	6	6
1917	35-121-24549	Petroquest Energy	6/27/2011	1-13H McAfee	Scipio NW	13	7	N	12	E	SW	SE	SE	Pittsburg	Woodford	5270	527
1969	35-017-24263	Devon Energy	6/25/2011	1-17H Annie May	Trend	17	12	N	9	W	SE	SE	SW	Canadian	Woodford	7	7
1899	35-029-21150	BP America Production Company	6/23/2011	4-27H Walkup	Ashland	27	3	N	11	E	SW	SW	SE	Coal	Woodford	8480	848

2,768 records

THANK YOU



Typical Calf Creek point of Woodford chert found in Haskell County, Oklahoma (Norman Transcript, March 11, 2007, p. E1)