

Woodford Production History and Future Analysis

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Major Contributors to this presentation are Richard Andrews, Dan Boyd, and Brian Cardott who are geologists at the Oklahoma Geological Survey

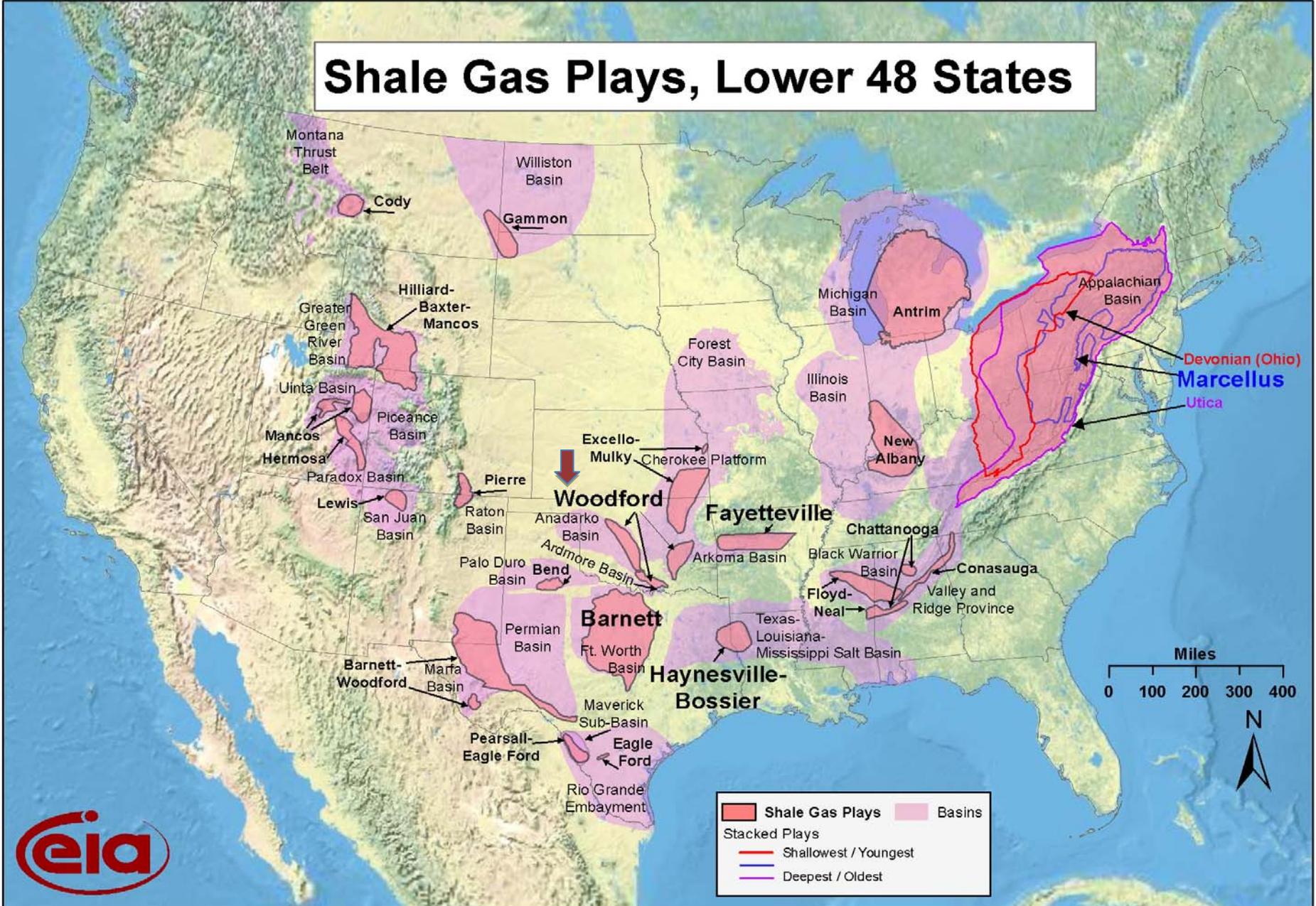


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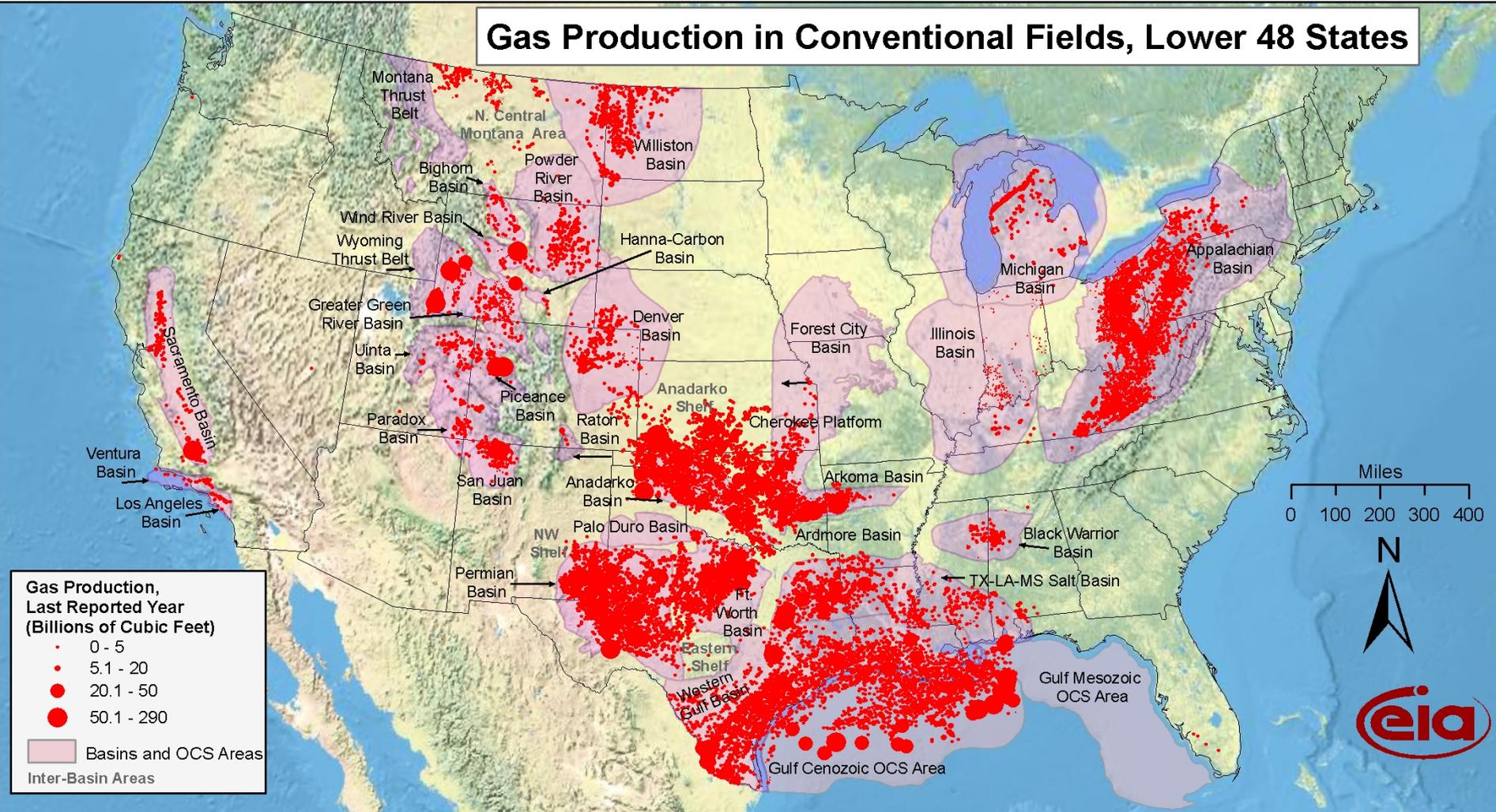
Shale Gas Plays, Lower 48 States



Source: Energy Information Administration based on data from various published studies.
 Updated: March 10, 2010



Gas Production in Conventional Fields, Lower 48 States

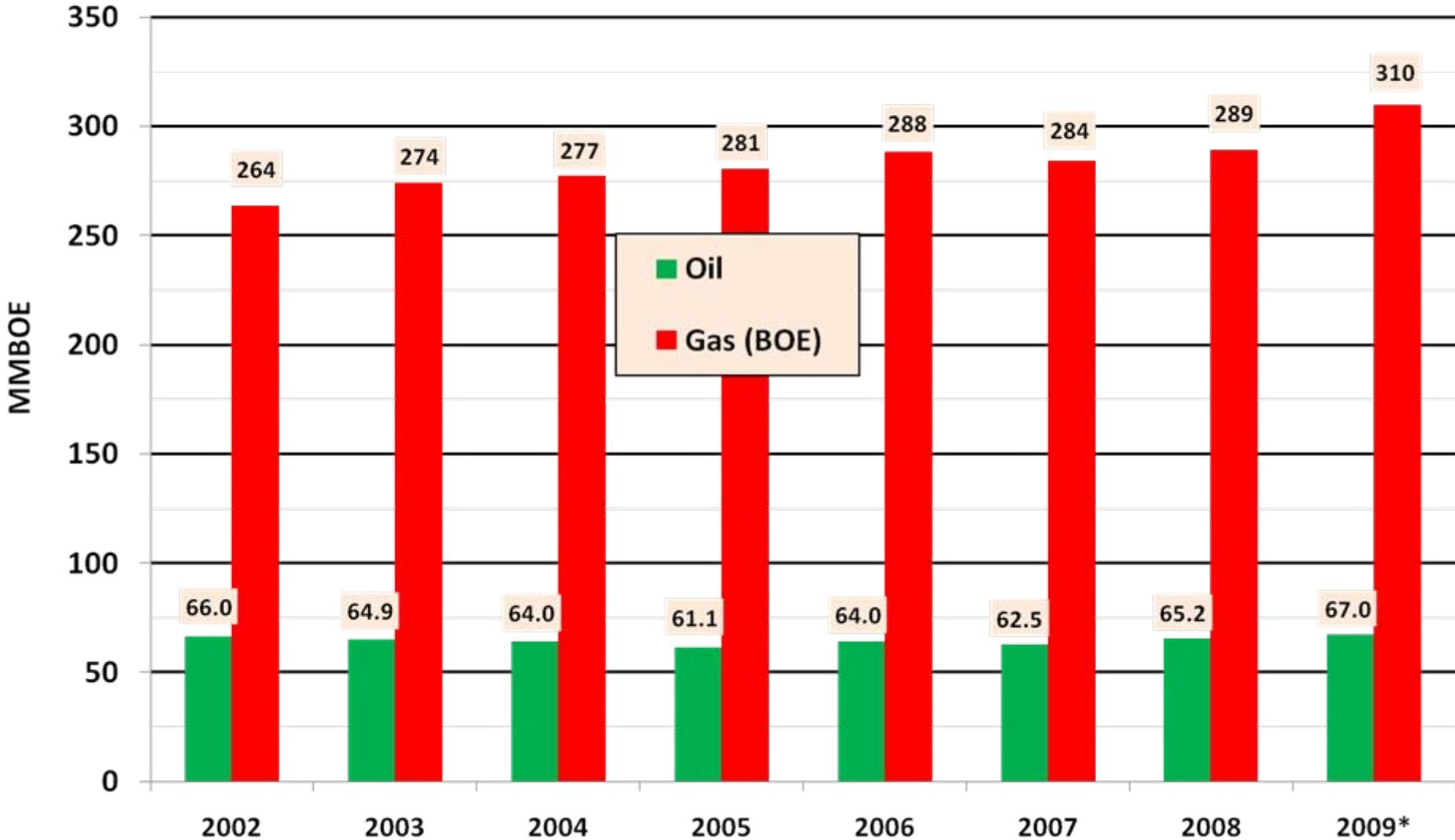


Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
 Updated: April 8, 2009

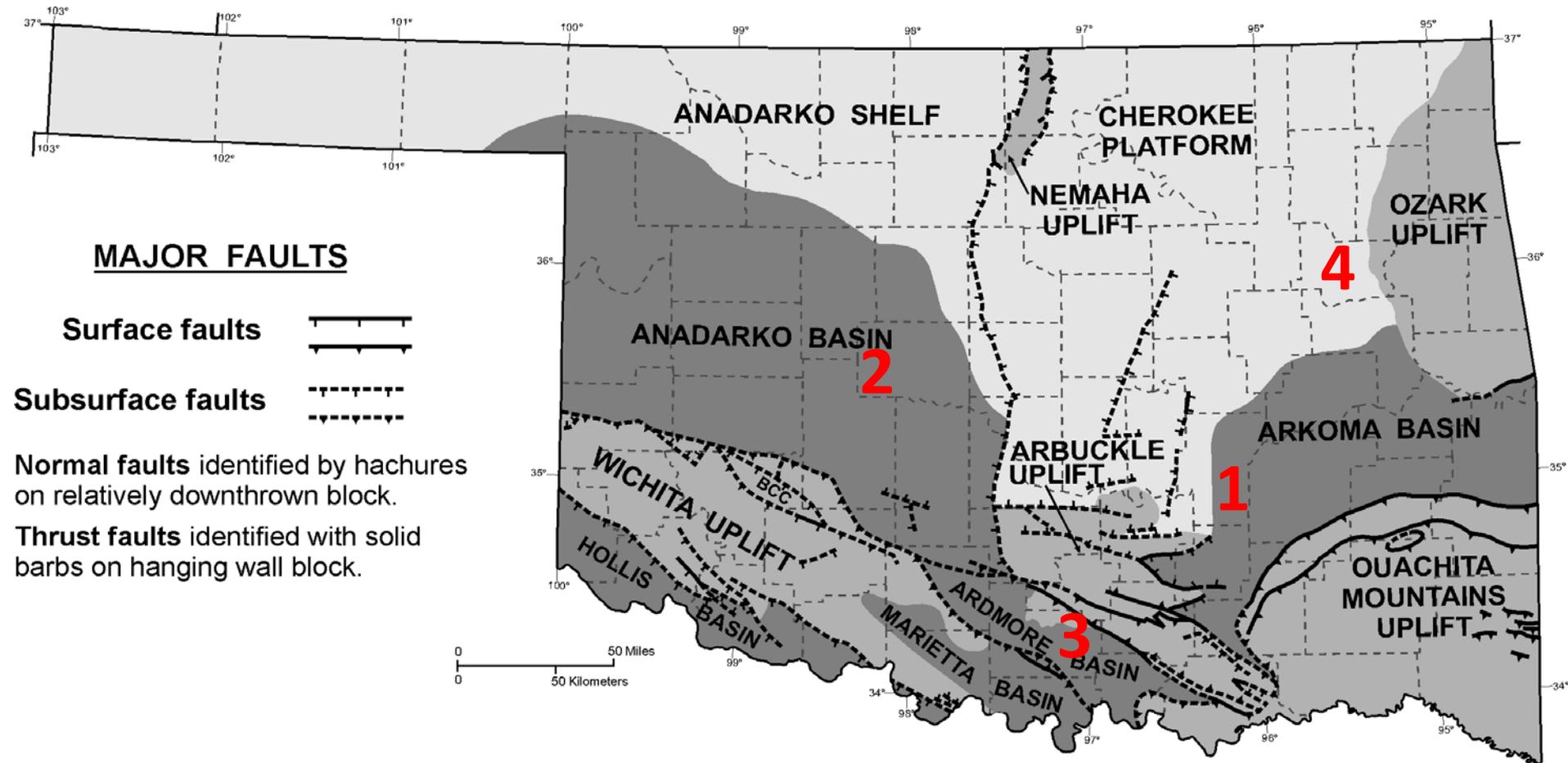


Oklahoma Oil and Gas Production

(In Million Barrel Equivalent)



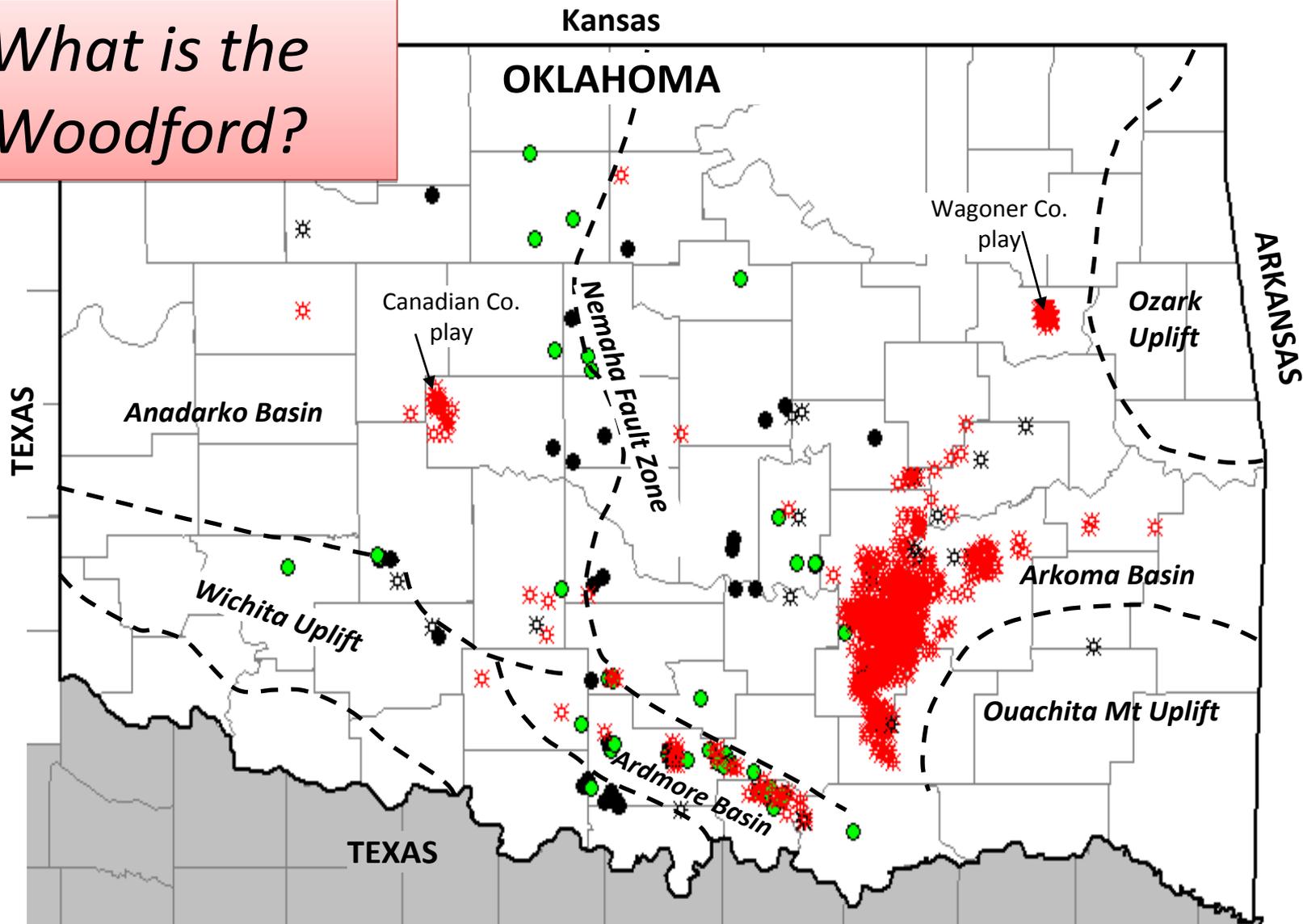
Woodford Gas-Shale Plays



There are 4 Woodford plays

Geologic provinces from
Northcutt and Campbell, 1995

What is the Woodford?



Woodford Shale well completions in Oklahoma (1934–2009). From IHS Energy, 2009.



Photo by Rick Andrews

**Woodford Shale in McAlester Cemetery Quarry
Natural Fractures Highlighted by the Presence of Asphalt**

Generalized stratigraphic chart showing the age relationship of gas shales in the southern midcontinent. Modified from Andrews (2003), Pollastro (2003) and Suneson (2008).

	Ft. Worth Basin Texas	Arkoma Basin Oklahoma	Arkoma Basin Arkansas
Pennsylvanian	Marble Falls Group (Morrowan)	Morrow Group (Cromwell) Springer	Hale Fm. (Ls & Ss)
		Springer (Goddard)	
Mississippian	Barnett Shale Chappel Ls	Caney Shale Sycamore/M ayes Ls	Pitkin Ls Fayetteville Shale Hindsville & Batesville Ls Keokuk and Reeds Spring Fms and St. Joe Group
		Woodford Shale	Chattanooga Shale
Devonian	Woodford Shale and Hunton Ls are absent		
Silurian		Hunton Limestone	St. Clair Ls Brassfield Ls

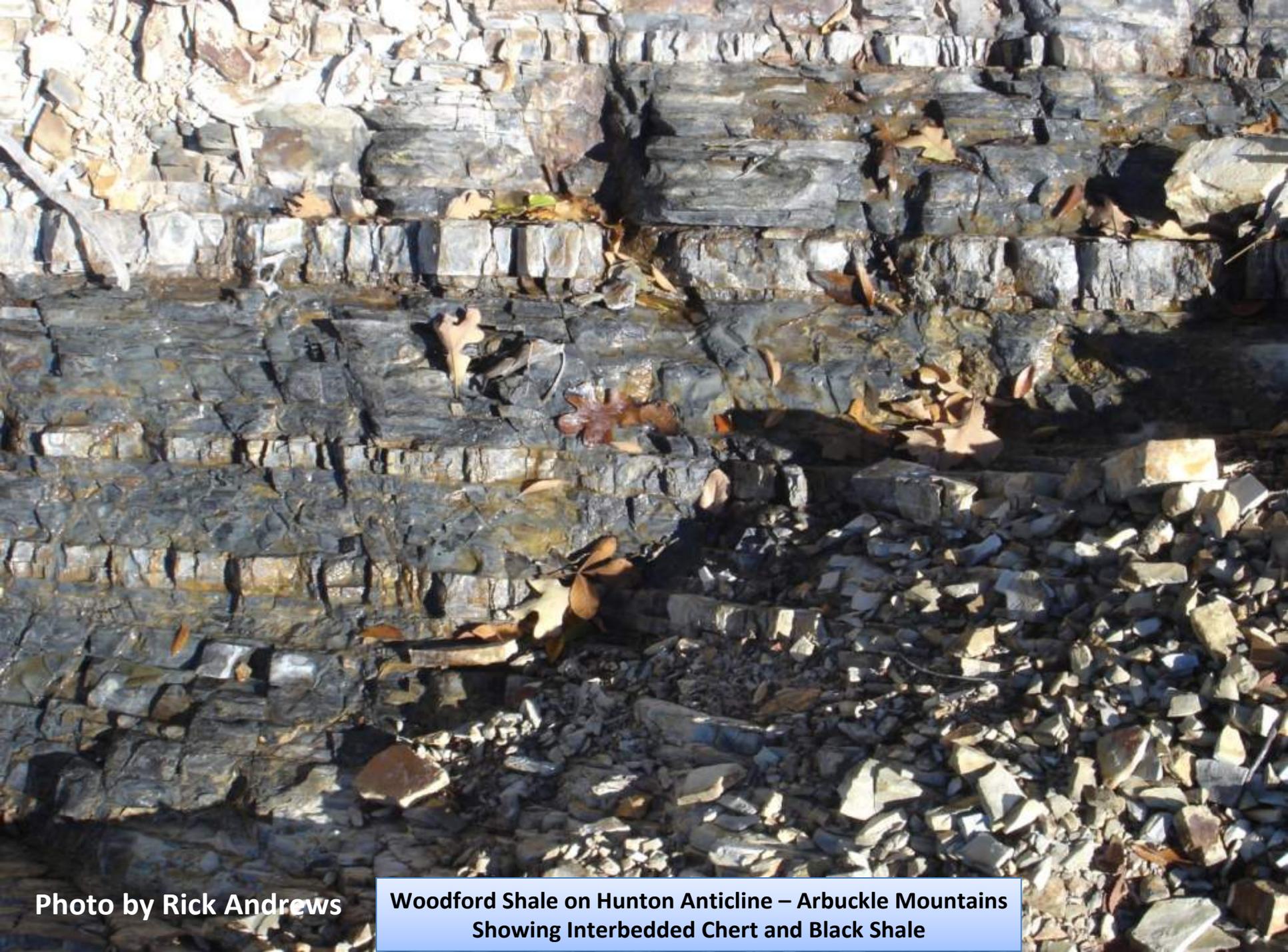


Photo by Rick Andrews

**Woodford Shale on Hunton Anticline – Arbuckle Mountains
Showing Interbedded Chert and Black Shale**

REPRESENTATIVE LOG

Newfield Exploration
 Ida Jane #1-32
 SW SW sec. 32,
 T. 6 N., R. 12 E.

Resistivity Ω -M

1 10 100 1K

GR & CAL

0 API 200 1 PE 10

Den, Neu

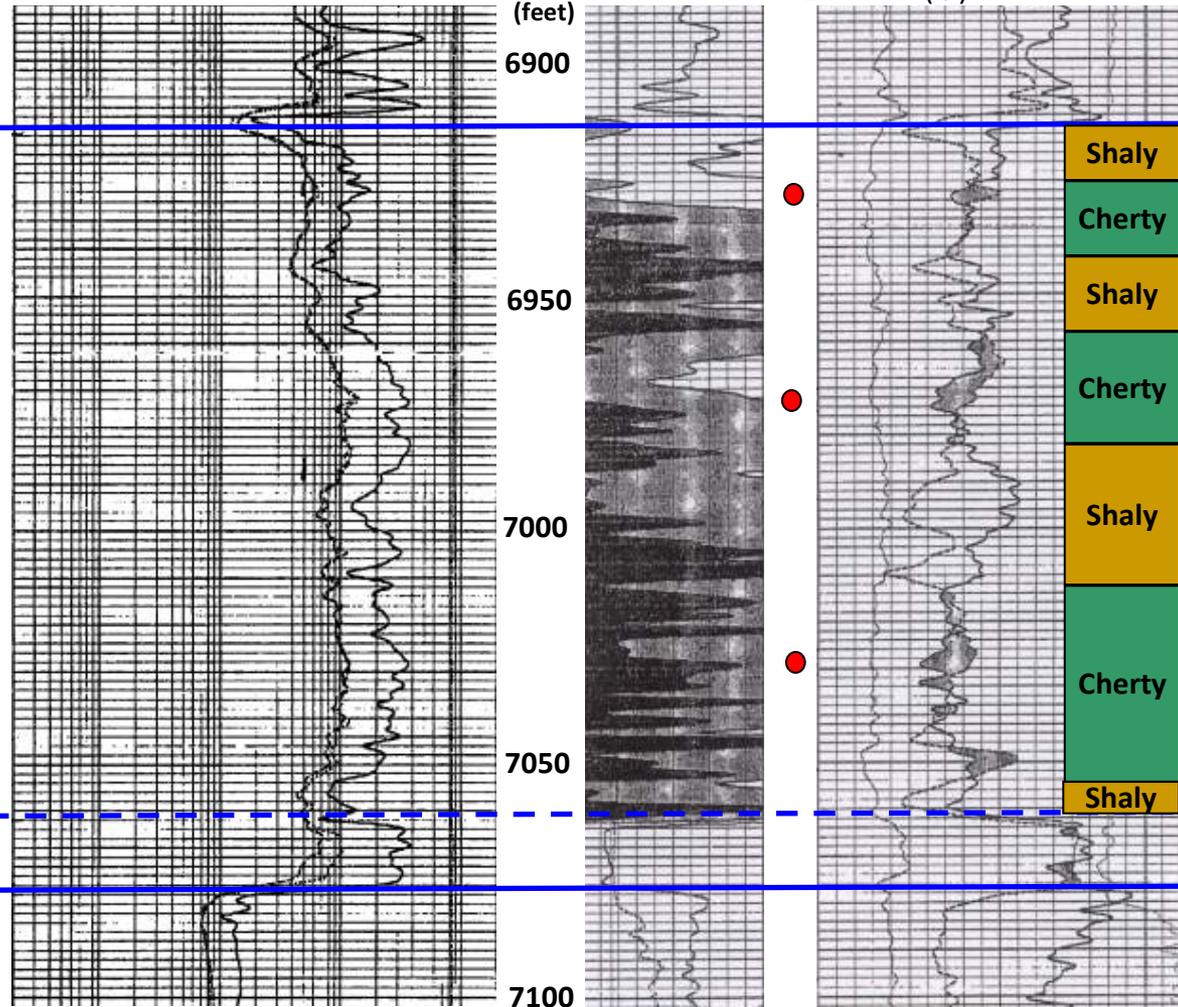
10

Depth (feet) 30 20 10 0 (Φ)

Sycamore (Mayes)

Woodford Shale

Woodford Shale



upper?

middle?

lower?

Hunton LS (eroded)

Sylvan Shale

● = Perforated intervals

Representative well log of the Woodford Shale showing typical log responses in a productive zone: caliper = CAL, gamma-ray = GR, Photoelectric = PE, Density porosity = Den, and Neutron porosity = Neu.



Photo by Dan Boyd

Woodford Shale on Hunton Anticline – Arbuckle Mountains
Showing Survey Geologists Rick Andrews & Neil Suneson

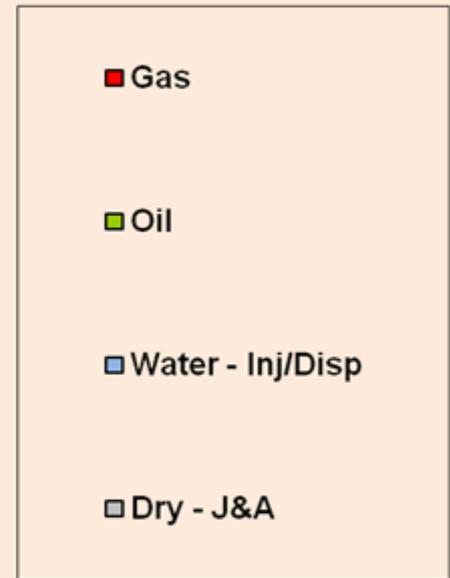
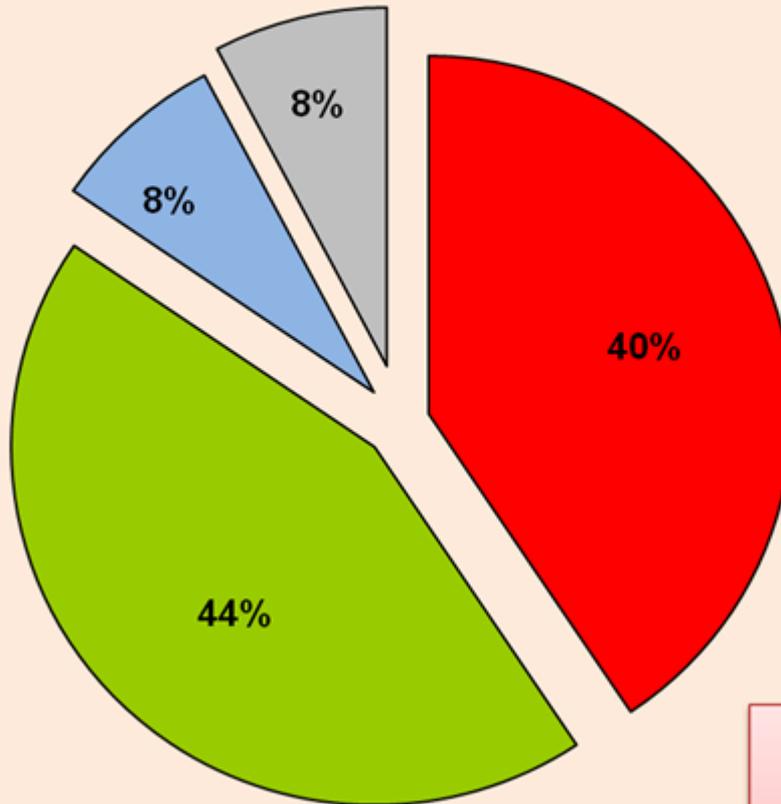


Oklahoma 2010 Well Completion Results

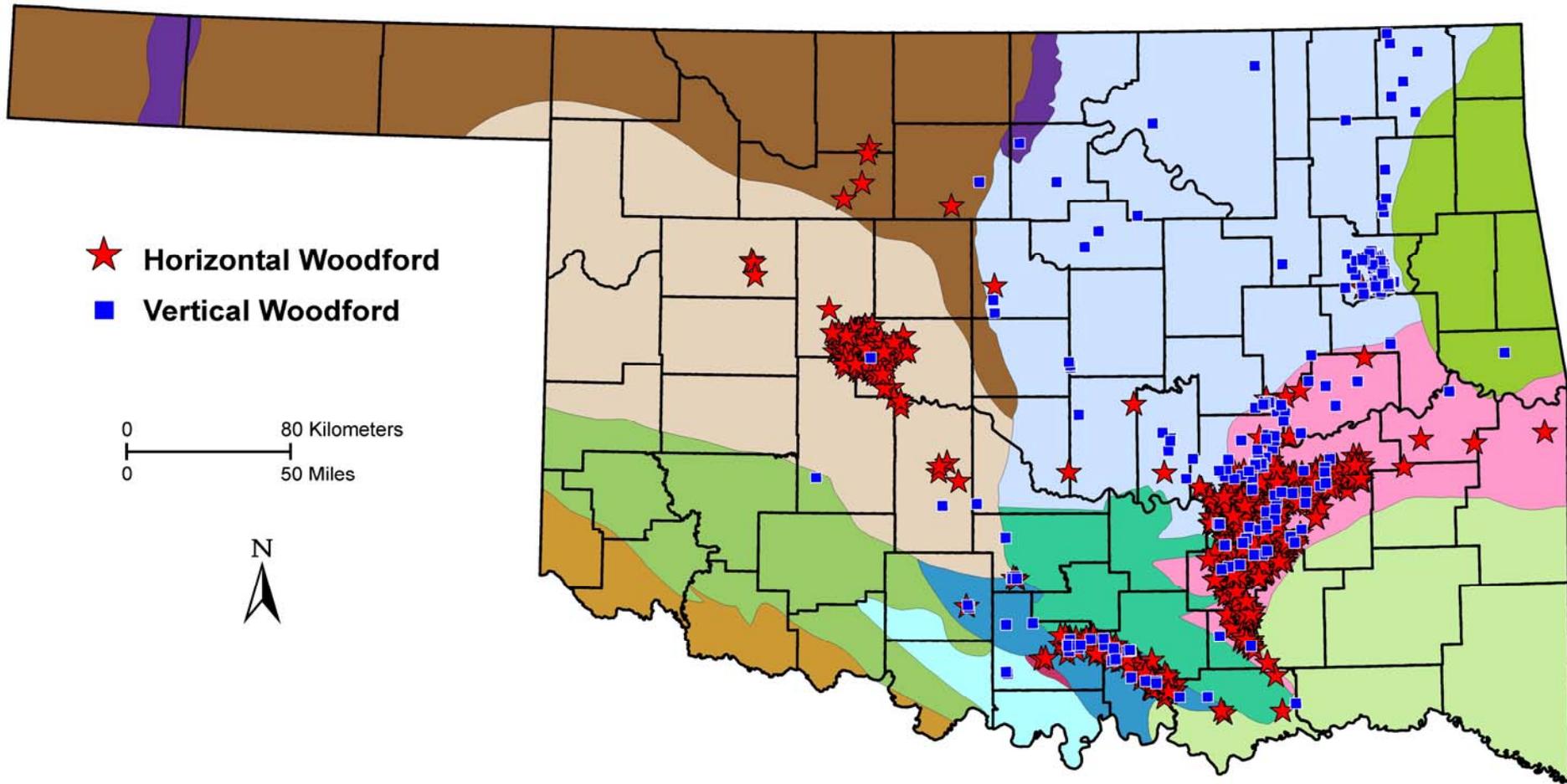
(Data from IHS Energy - registered through 1-1-2011)

An obvious point made by this chart is that the increase in oil prices has caused the number completions for oil to actually exceed the number for gas wells.

Thus, the liquids in portions of some of the Woodford plays are a factor in this development.

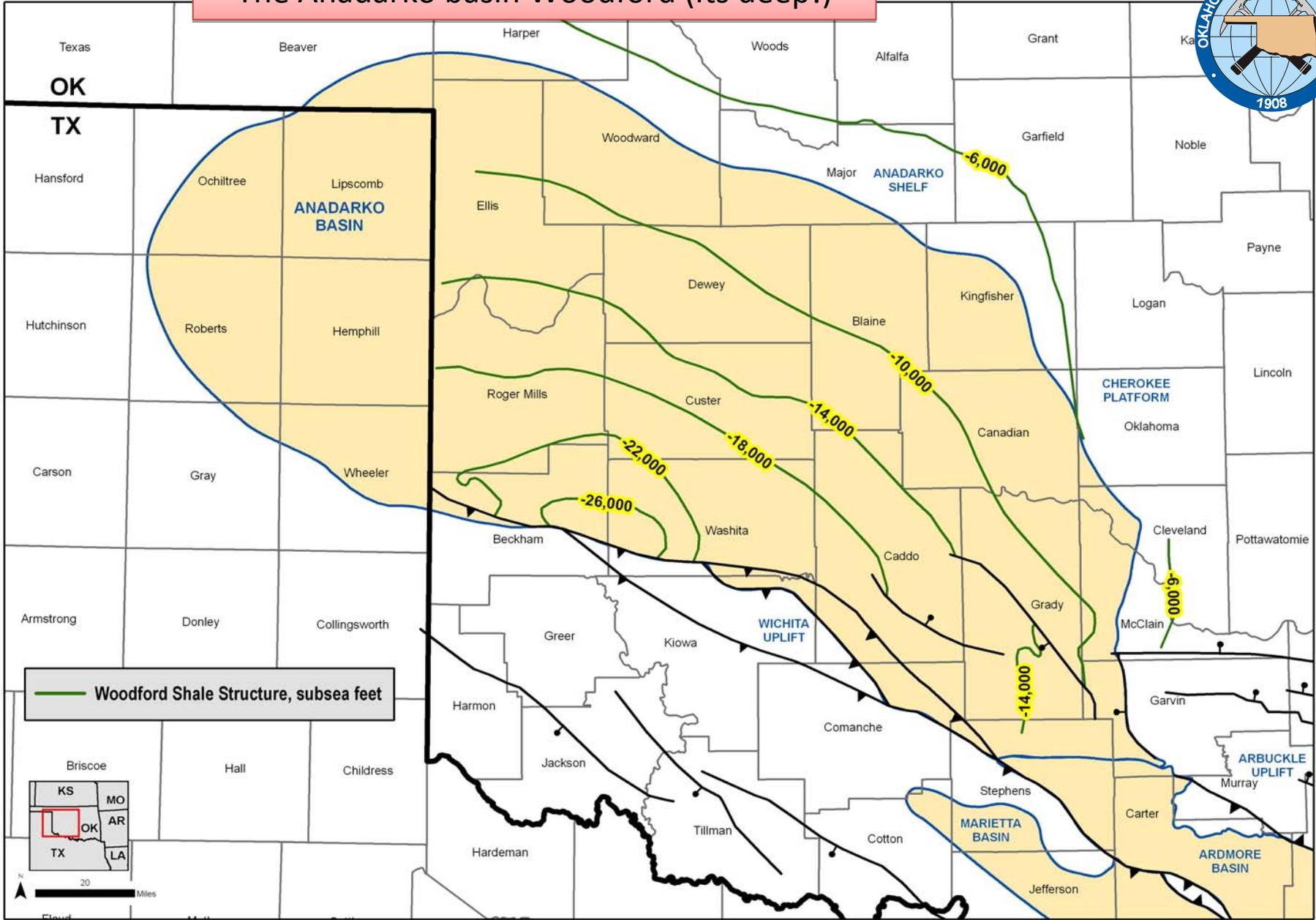


The relatively new development is that the Woodford is also producing a significant volume of liquids

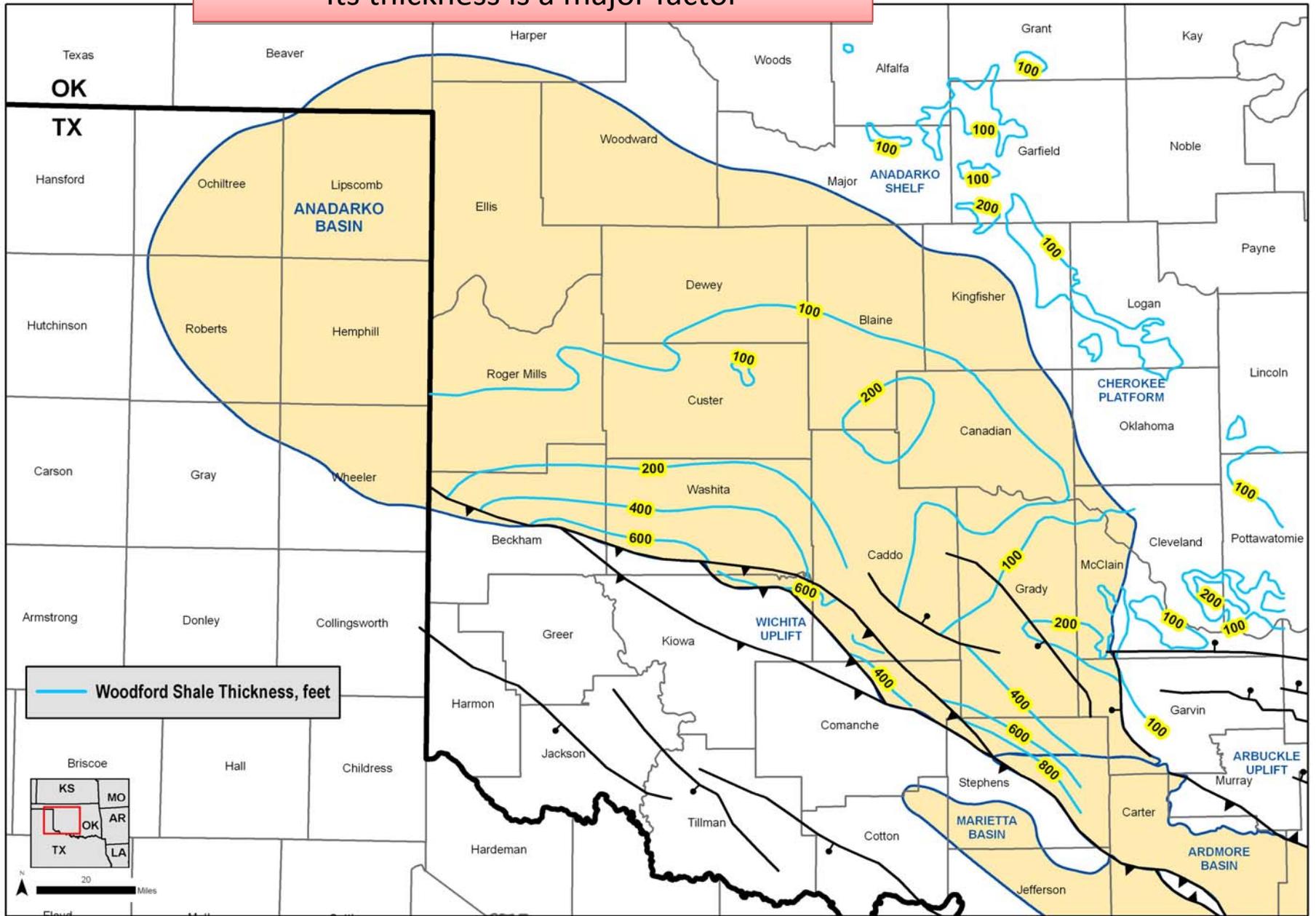


Map showing Woodford Shale-only well completions from 2004-2011 on a geologic provinces map of Oklahoma modified from Northcutt and Campbell (1998)

The Anadarko basin Woodford (Its deep!)

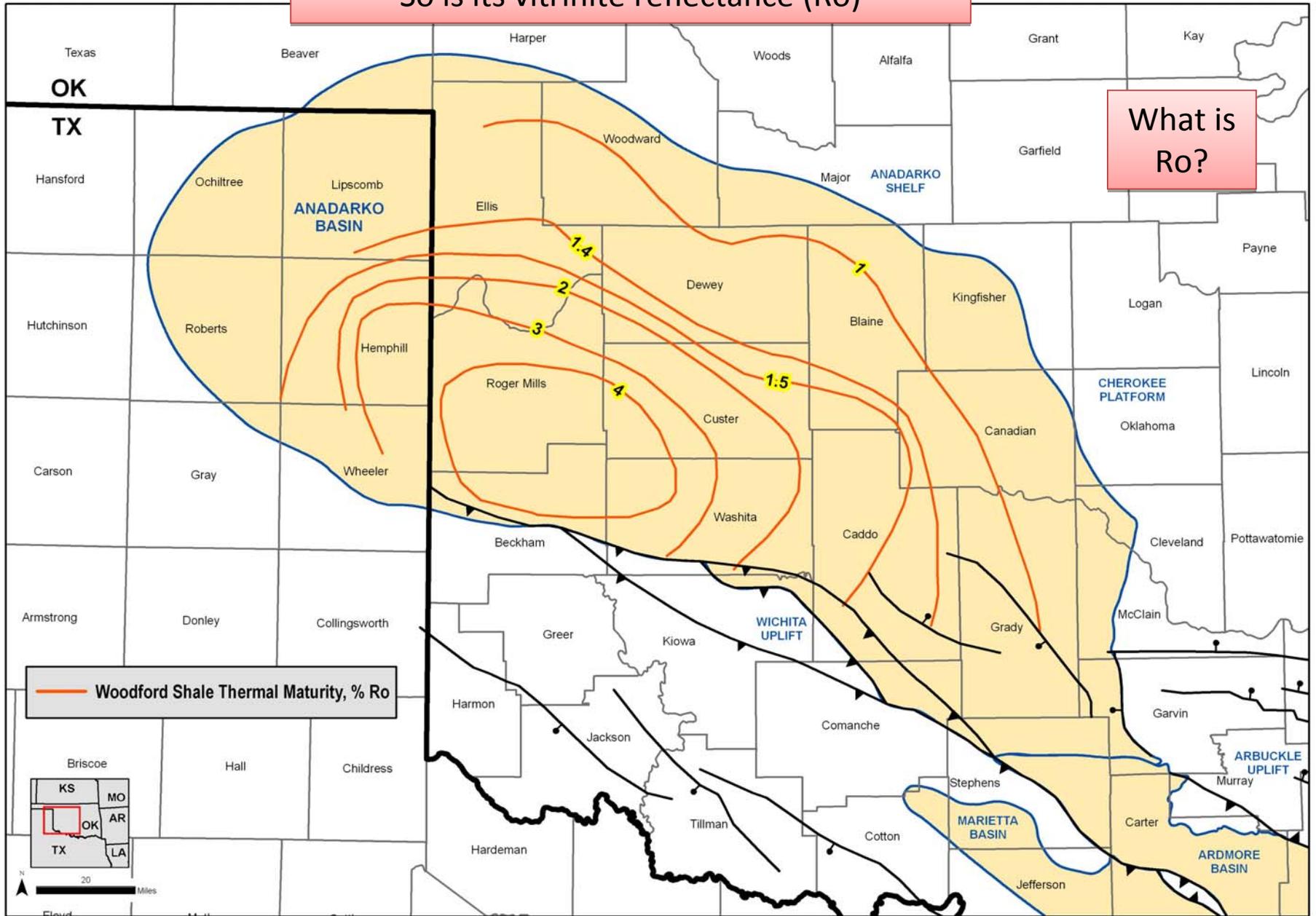


Its thickness is a major factor



So is its vitrinite reflectance (R_o)

What is R_o ?



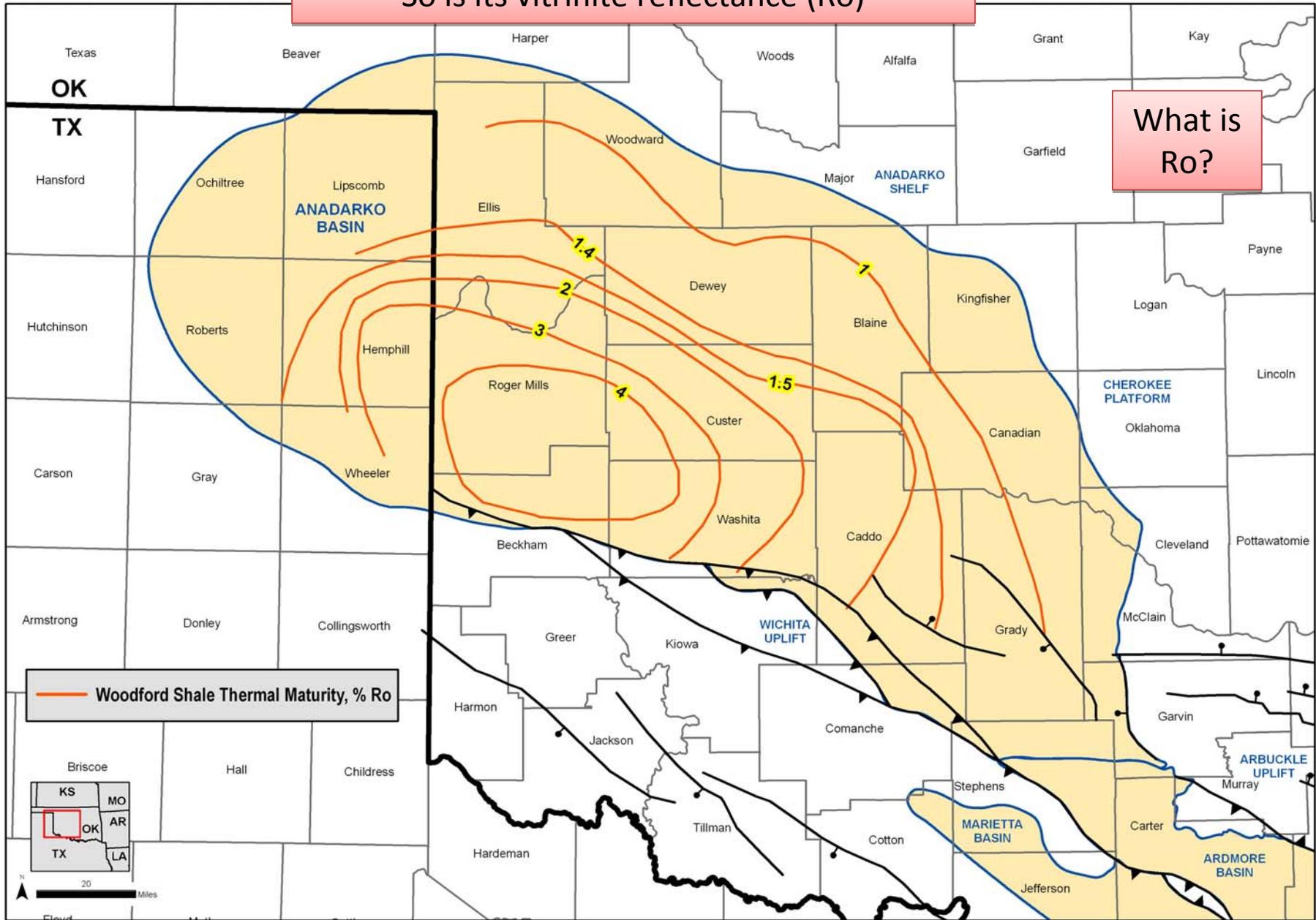
Vitrinite reflection measurements play a major role in the Woodford plays

The study of vitrinite reflectance is a key method for identifying the temperature history of sediments in sedimentary basins. The reflectance of vitrinite was first studied by coal explorationists attempting to diagnose the thermal maturity, or rank, of coal beds. More recently, its utility as a tool for the study of sedimentary organic matter metamorphism from kerogens to hydrocarbons has been increasingly exploited. The key attraction of vitrinite reflectance in this context is its sensitivity to temperature ranges that largely correspond to those of hydrocarbon generation (i.e. 60 to 120°C). This means that, with a suitable calibration, vitrinite reflectance can be used as an indicator of maturity in hydrocarbon source rocks. Generally, the onset of oil generation is correlated with a reflectance of 0.5-0.6% and the termination of oil generation with reflectance of 0.85-1.1%.



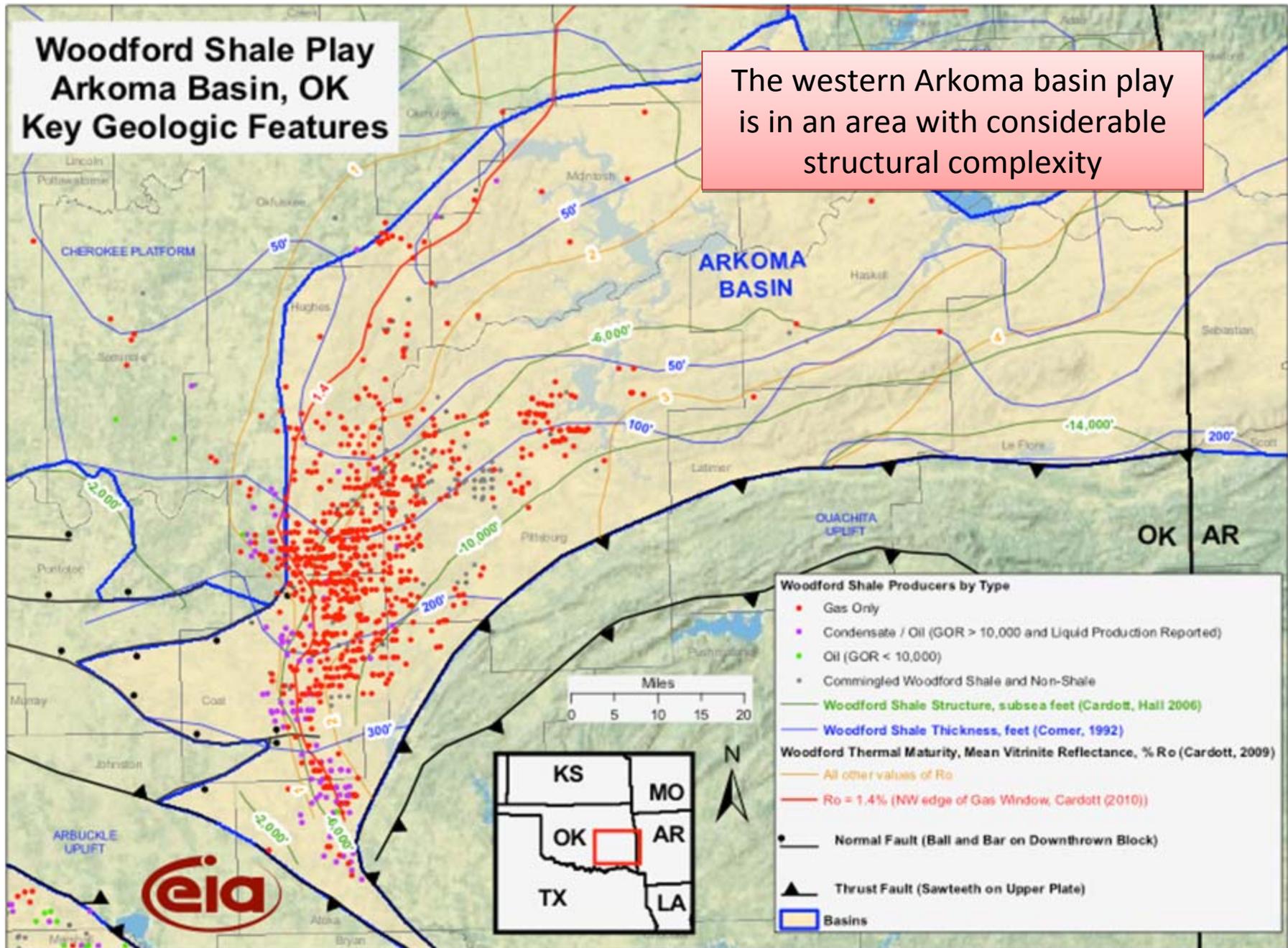
So is its vitrinite reflectance (R_o)

What is R_o ?

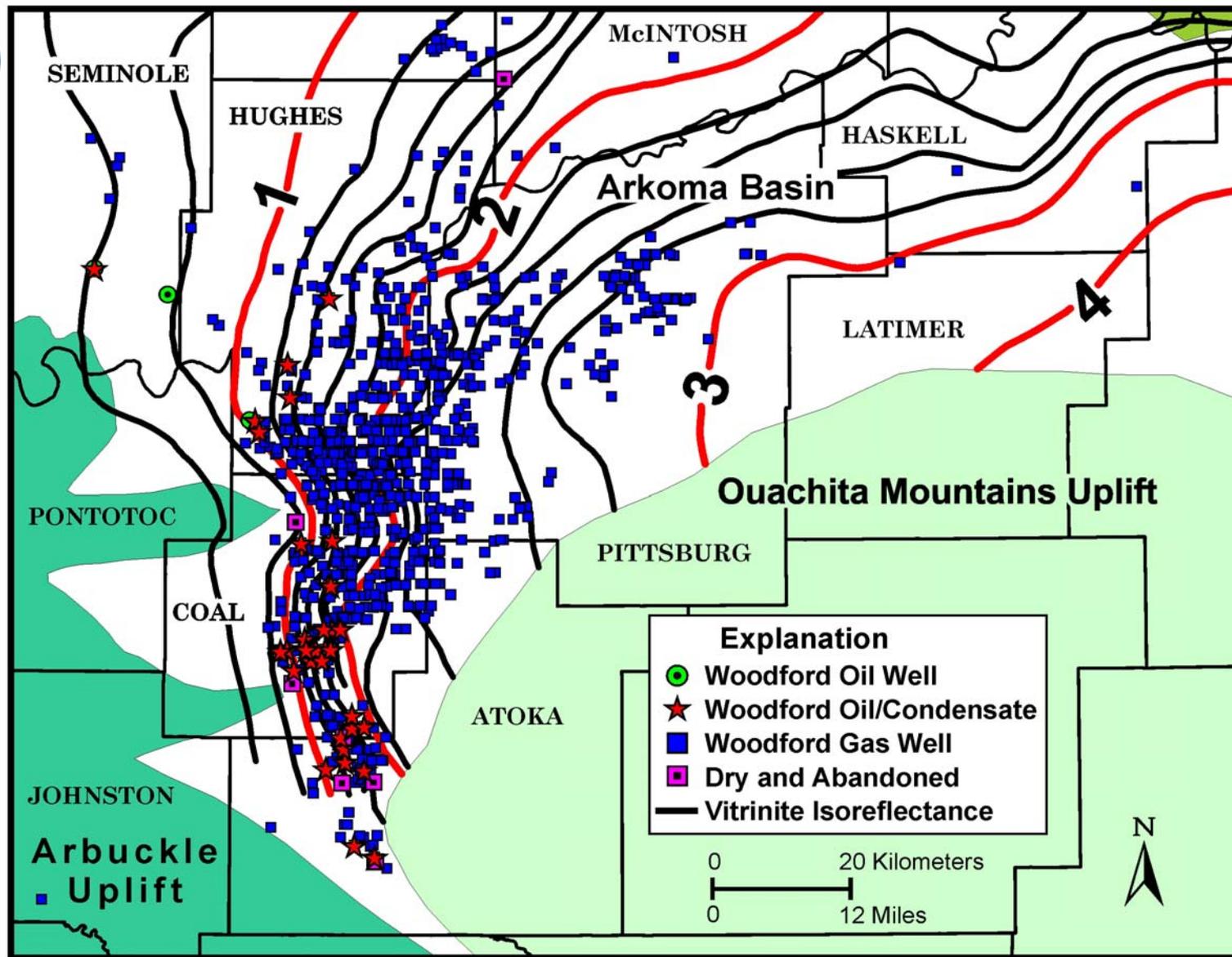


Woodford Shale Play Arkoma Basin, OK Key Geologic Features

The western Arkoma basin play is in an area with considerable structural complexity

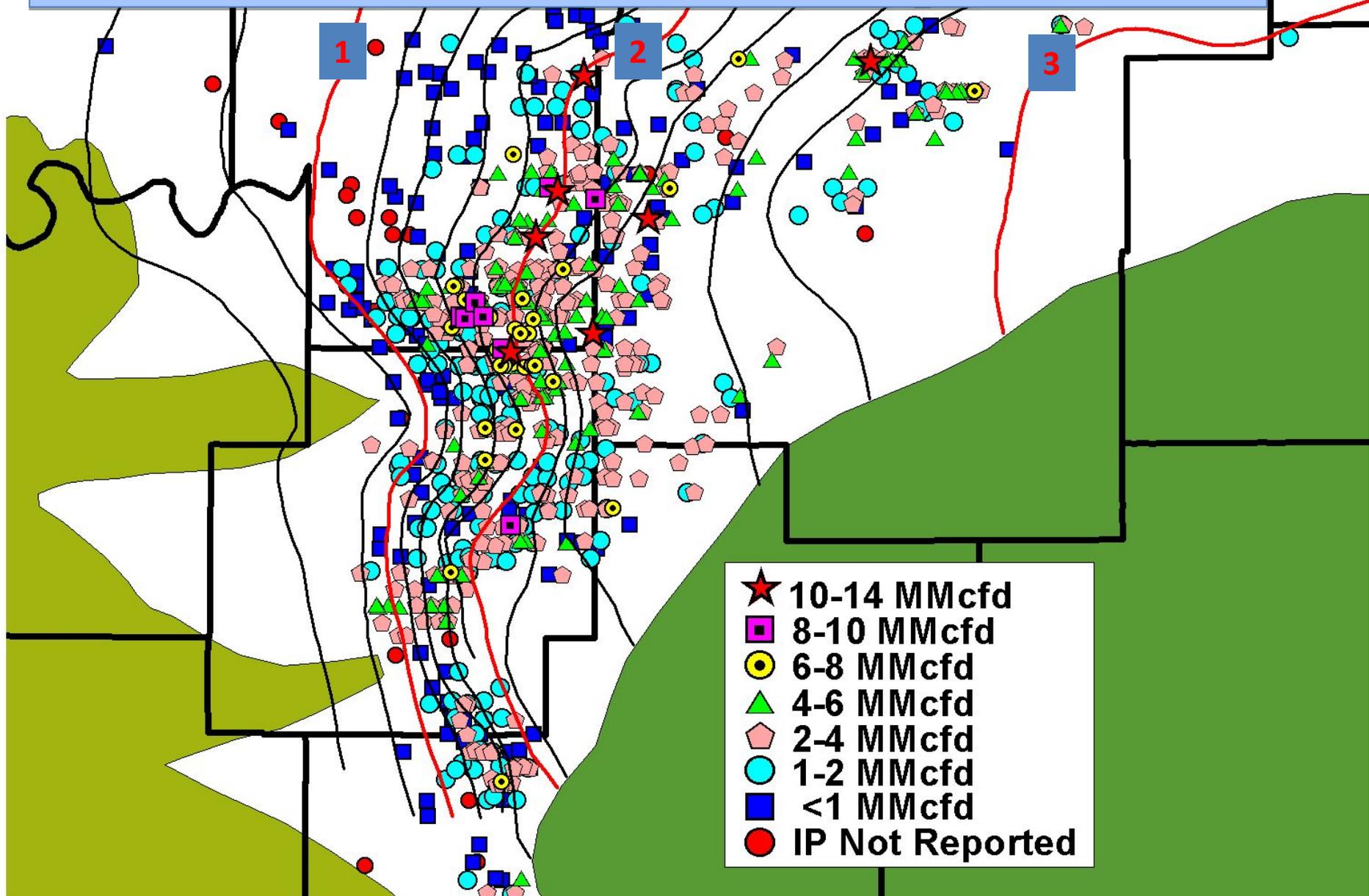


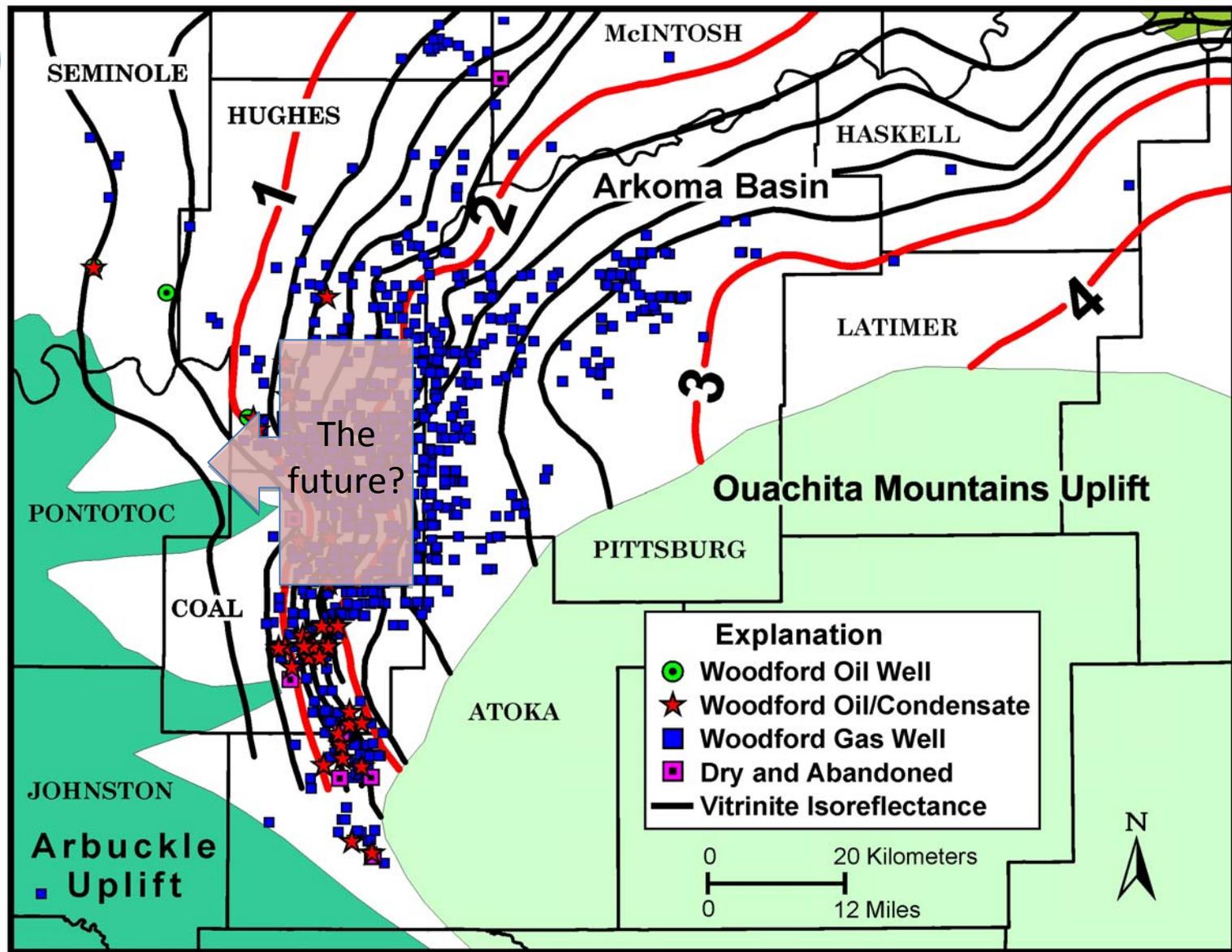
Source: Energy Information Administration based on well data from HPDI and B. Cardott (OK Geological Survey). Only wells producing from the Woodford Shale with first production after 1-1-2001 are shown. Basins and faults from Northcutt & Campbell (1995) and Cardott (2008). Updated: March 30, 2010



Map showing Woodford Shale dry gas and dry gas/condensate producing wells in the Arkoma Basin based on an unpublished vitrinite isorefectance map by Brian Cardott (numbers indicate %VRo; variable contour interval).

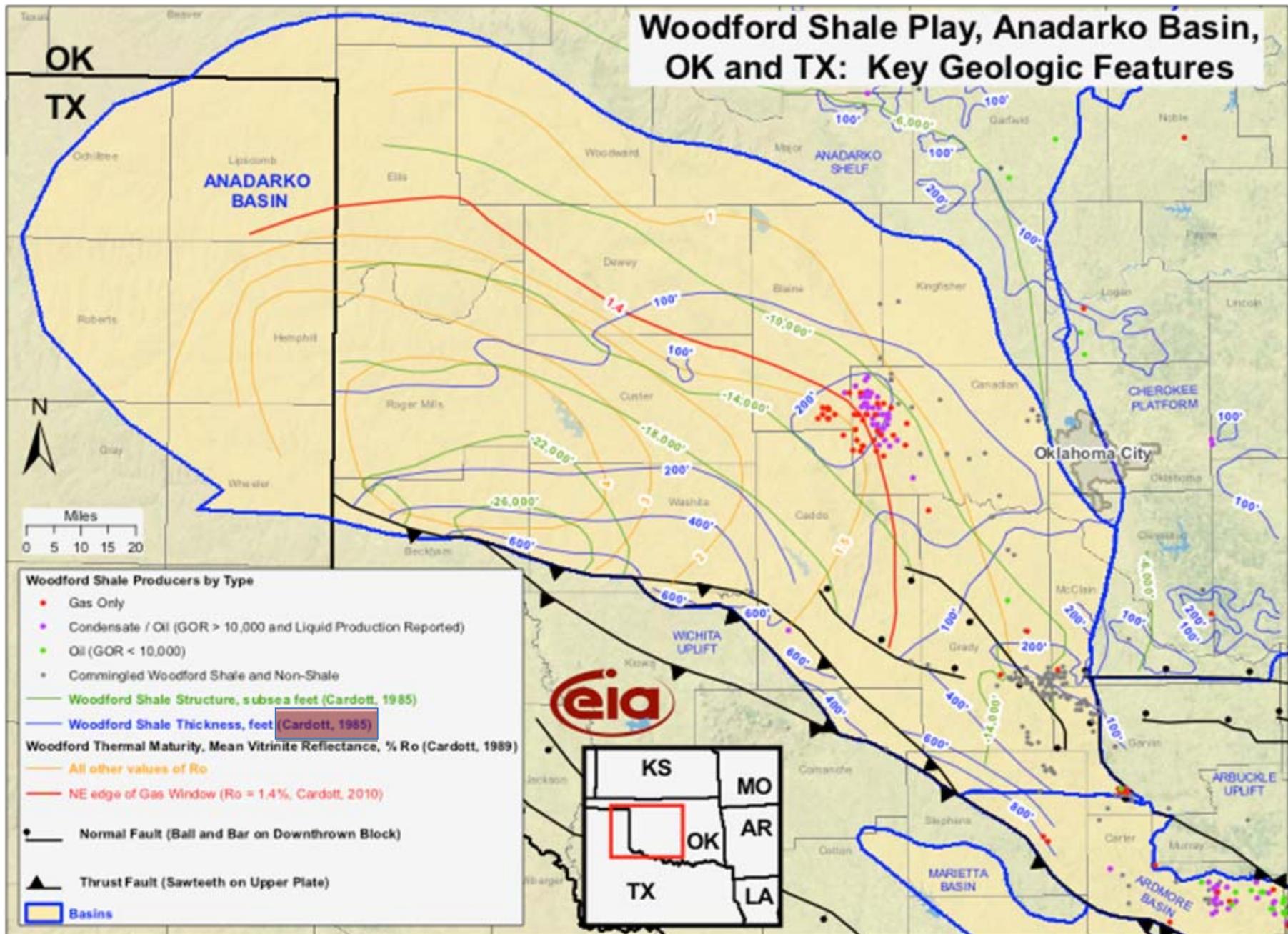
Woodford Shale Only -- Initial Production (IP) on Isoreflectance Map



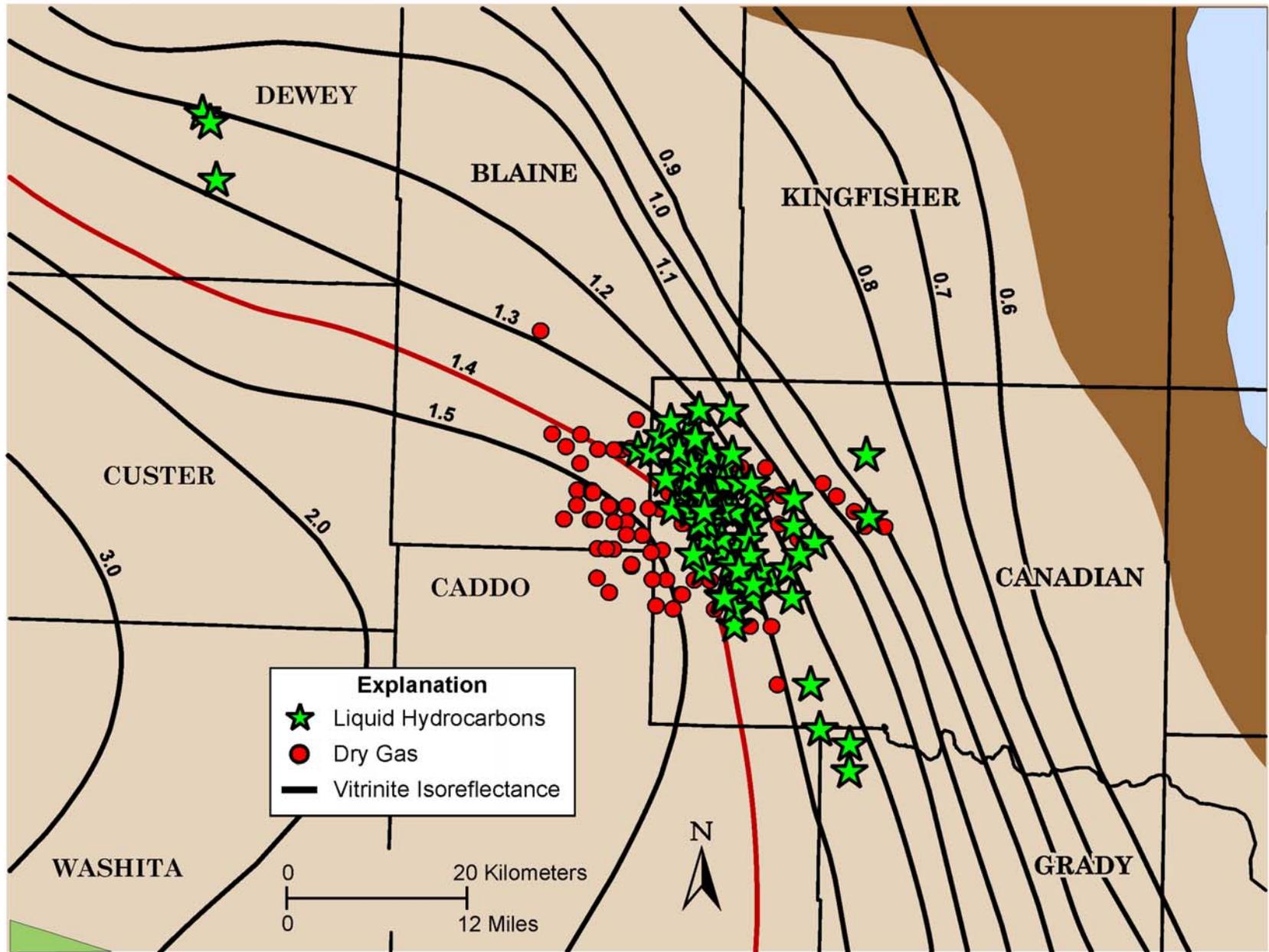


Map showing Woodford Shale dry gas and dry gas/condensate producing wells in the Arkoma Basin based on an unpublished vitrinite isorefectance map by Brian Cardott (numbers indicate %VRo; variable contour interval).

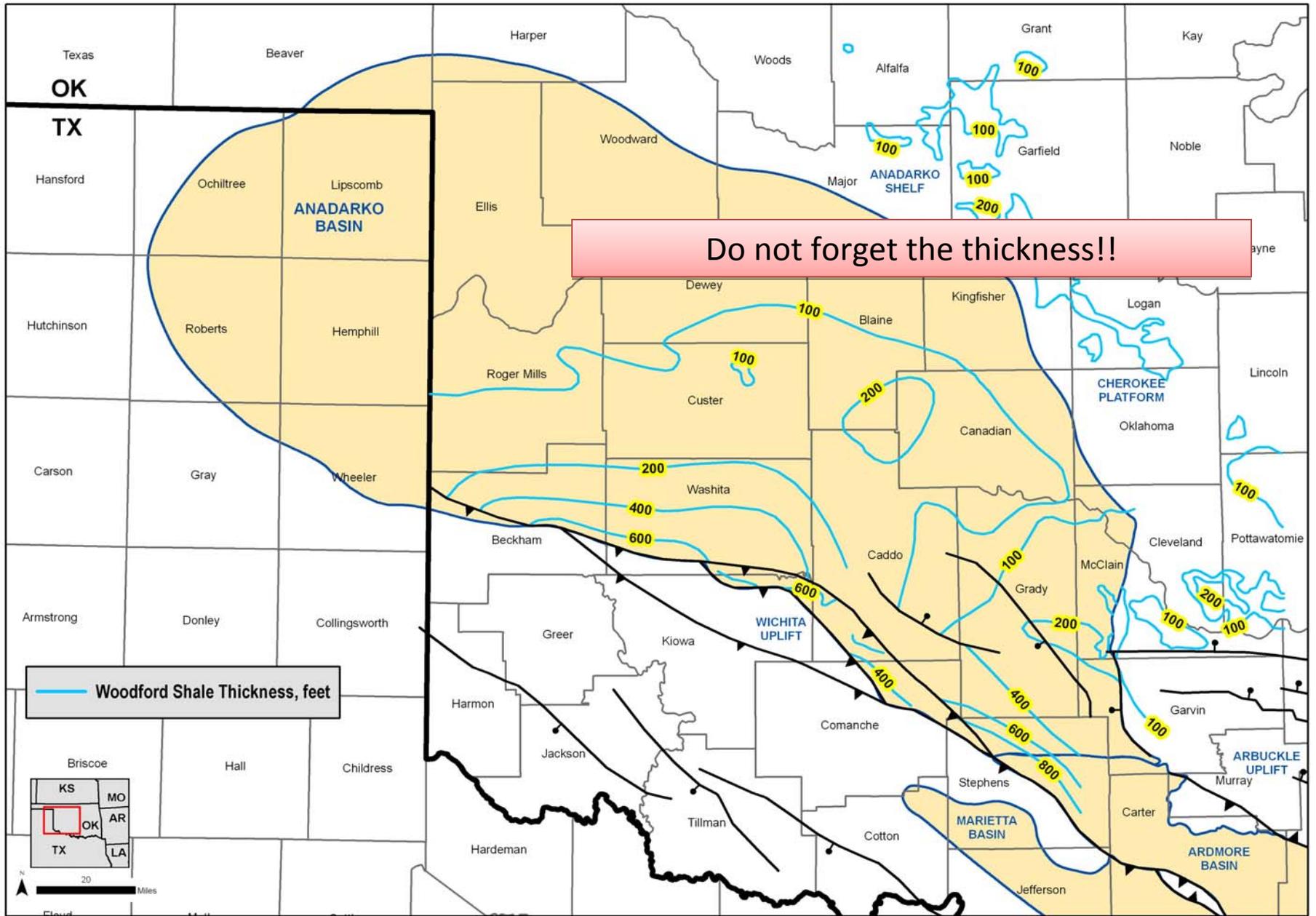
Woodford Shale Play, Anadarko Basin, OK and TX: Key Geologic Features

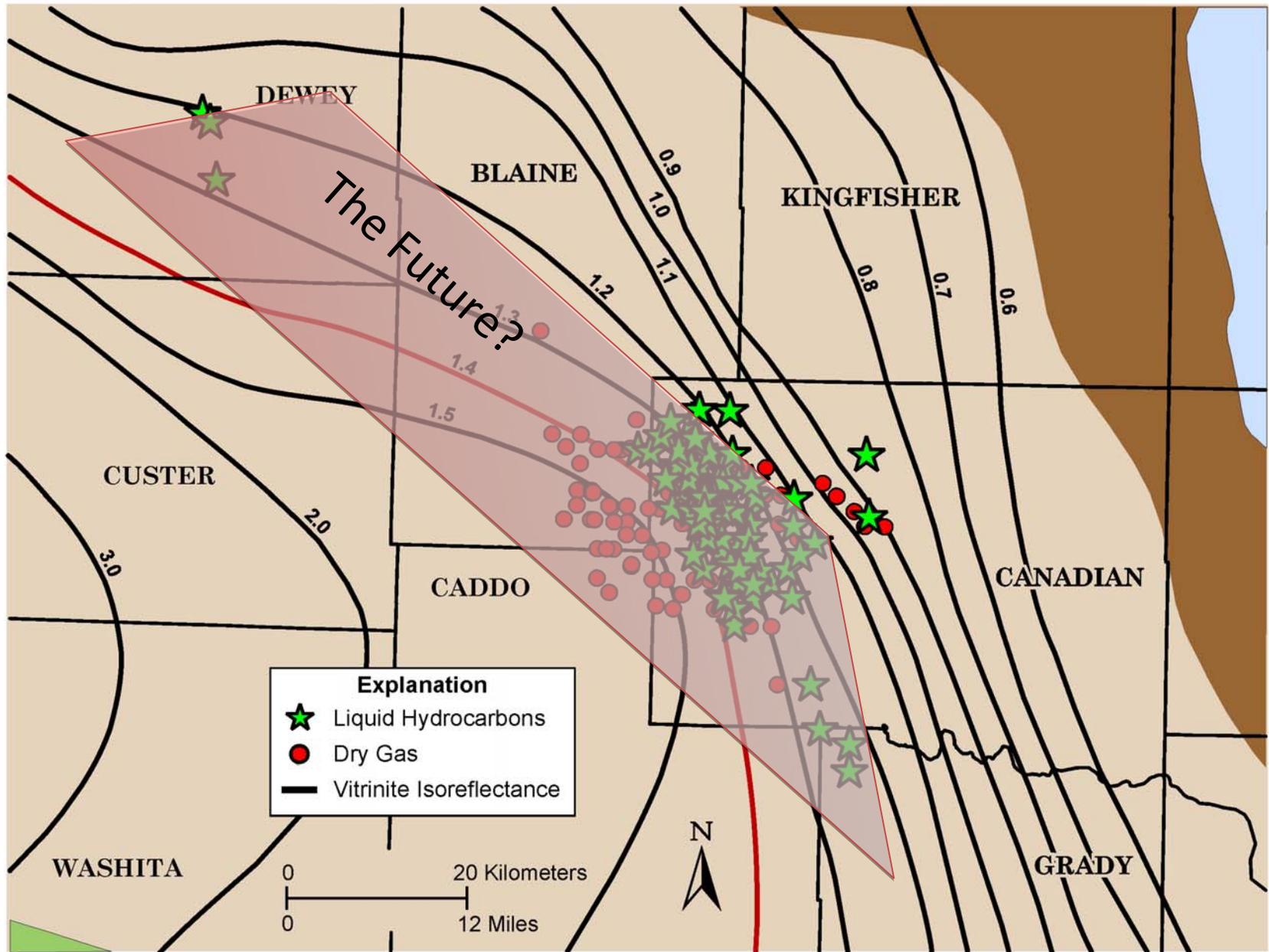


Source: Energy Information Administration based on well data from HPDI and B. Cardott (OK Geological Survey). Only wells producing from the Woodford Shale with first production after 1-1-2001 are shown. Basins and faults from Northcutt & Campbell (1995); Cardott (1985). Updated: March 30, 2010

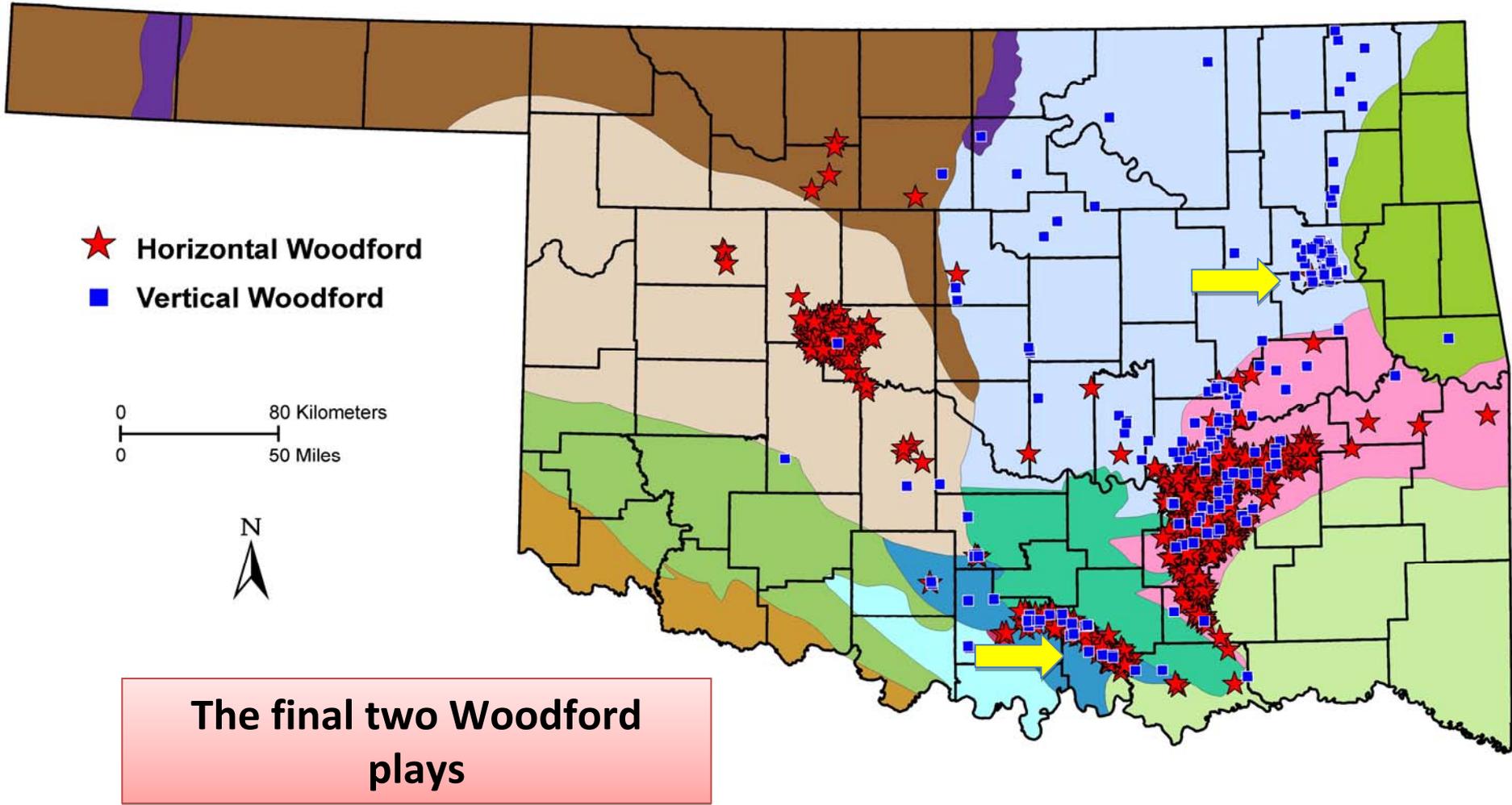


Map showing Woodford Shale dry gas and condensate wells in the Anadarko Basin on a vitrinite isorefectance map from Cardott (1989)





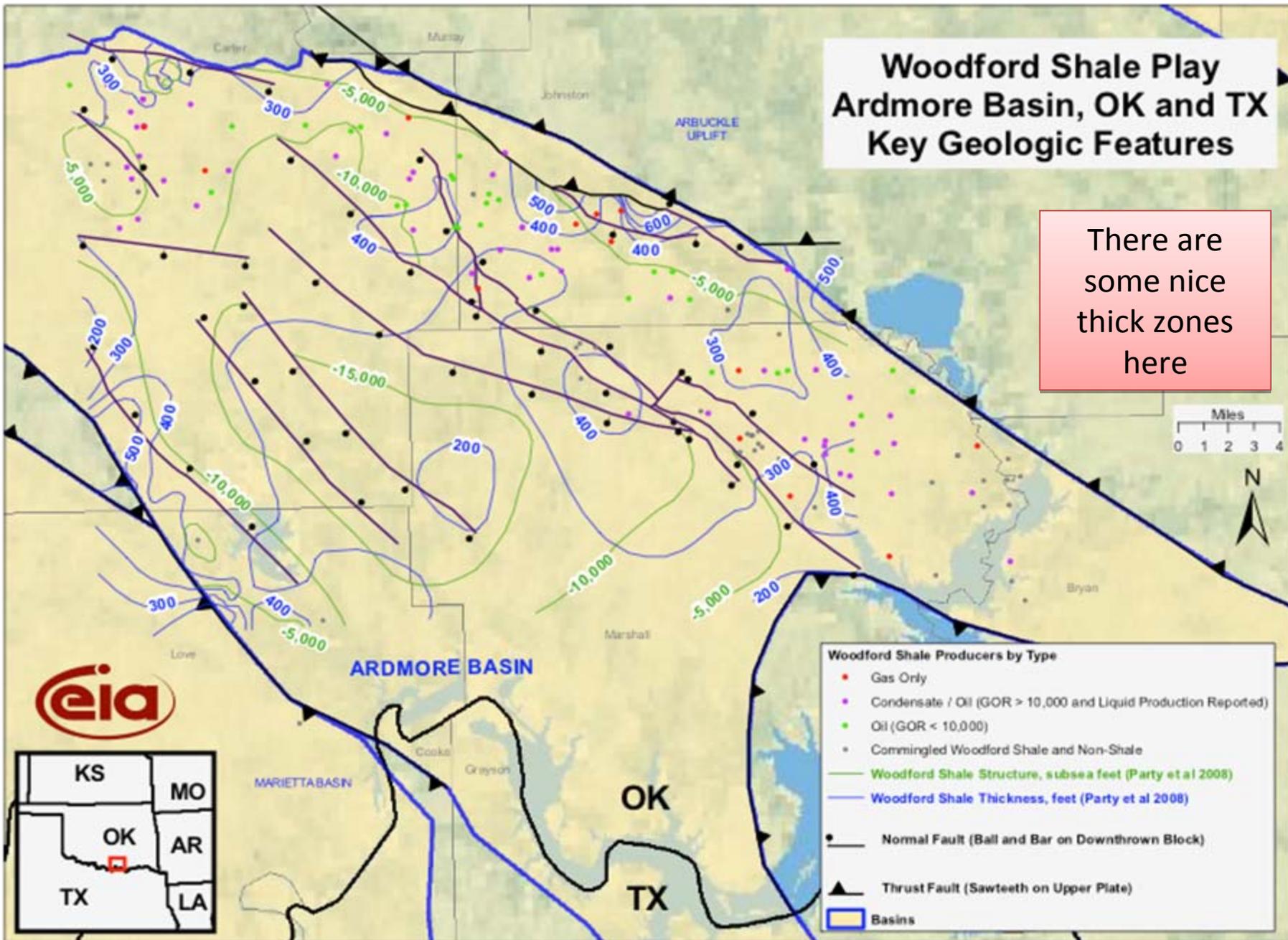
Map showing Woodford Shale dry gas and condensate wells in the Anadarko Basin on a vitrinite isorefectance map from Cardott (1989)



Map showing Woodford Shale-only well completions from 2004-2011 on a geologic provinces map of Oklahoma modified from Northcutt and Campbell (1998)

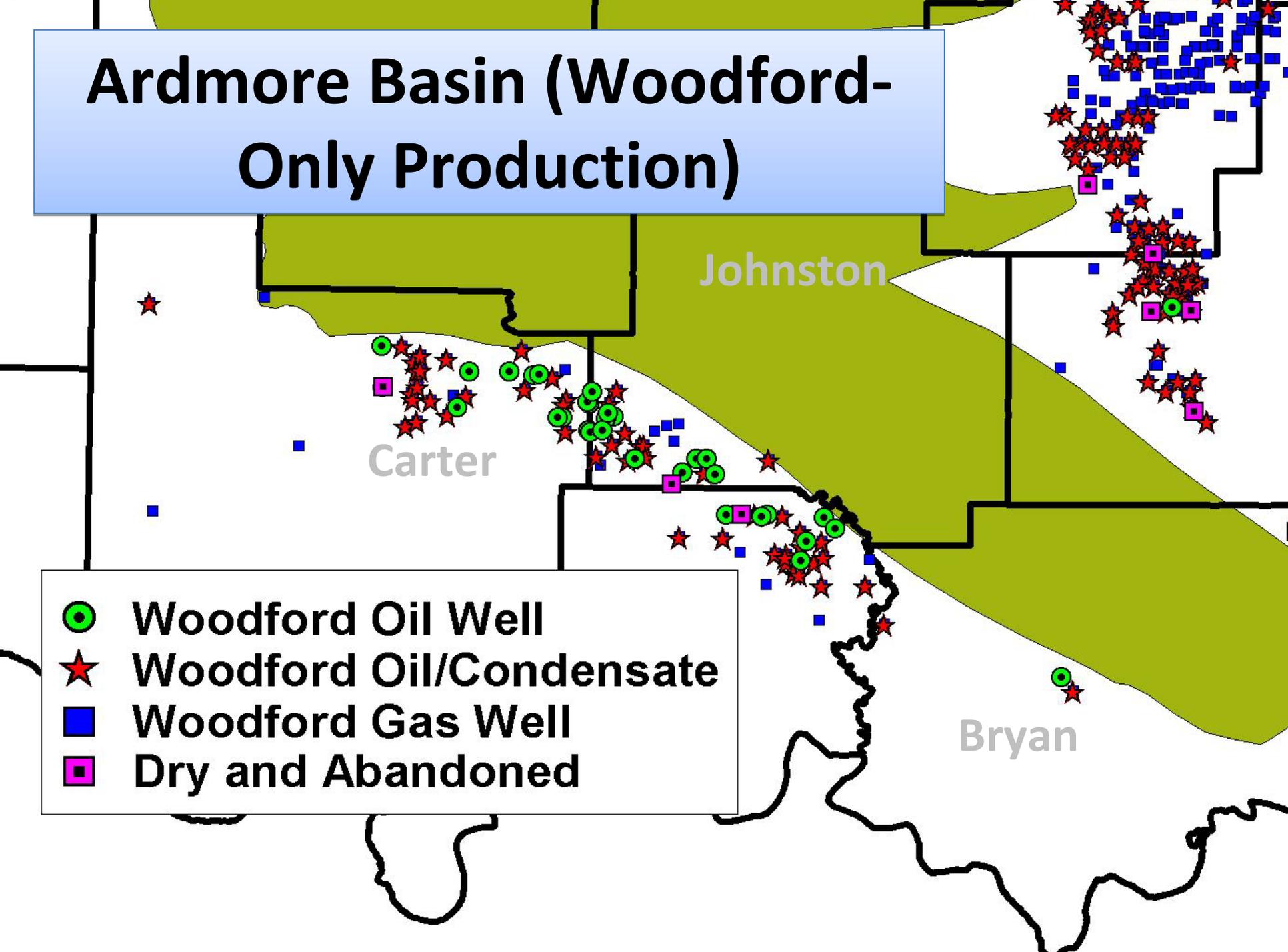
Woodford Shale Play Ardmore Basin, OK and TX Key Geologic Features

There are some nice thick zones here



Source: Energy Information Administration based on well data from HPDI and B. Cardott (OK Geological Survey). Only wells producing from the Woodford Shale with first production after 1-1-2001 are shown. Basins and faults from Northcutt & Campbell (1995), Party et al (2008). Updated: March 30, 2010

Ardmore Basin (Woodford-Only Production)



Johnston

Carter

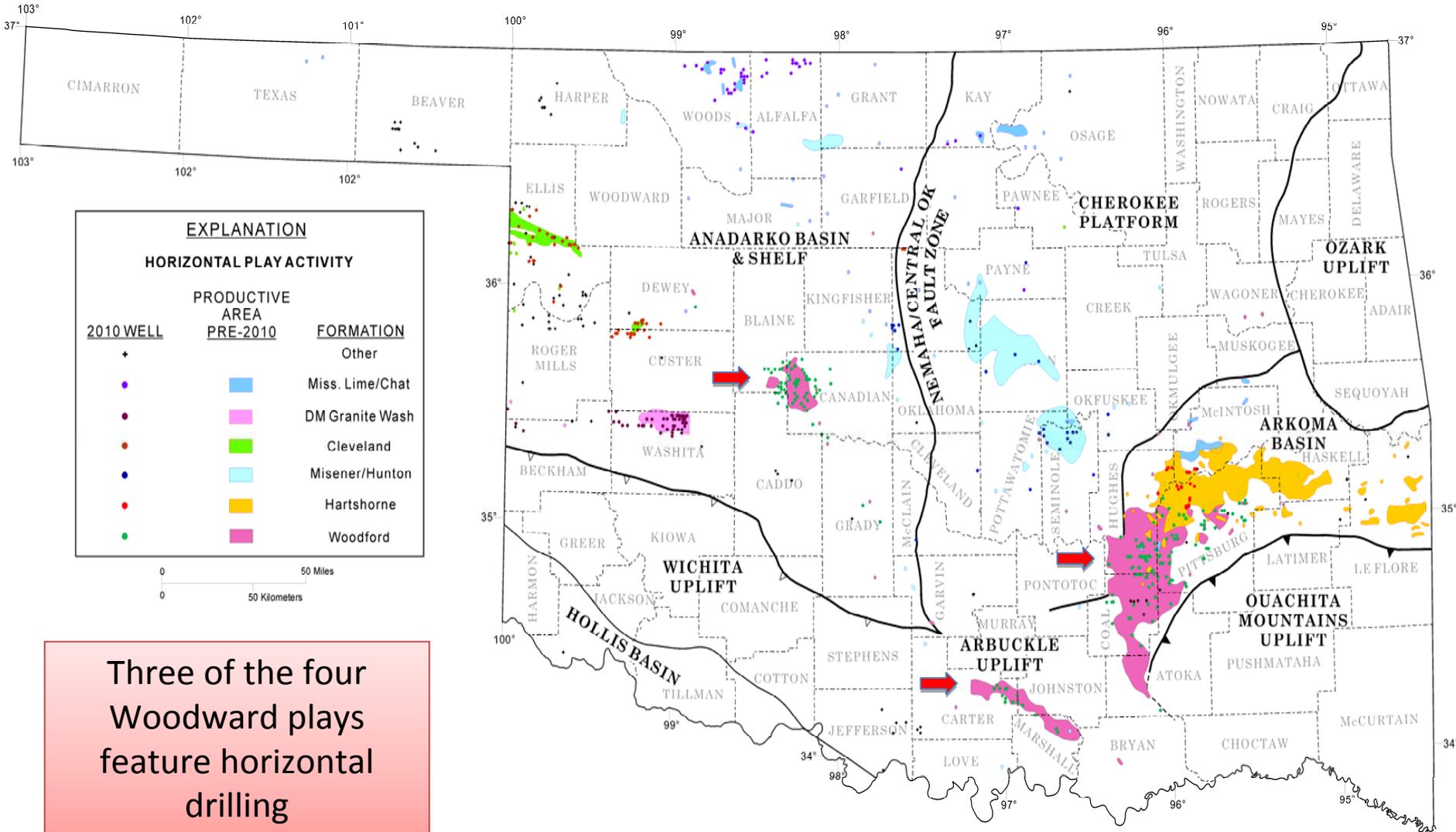
Bryan

- Woodford Oil Well
- ★ Woodford Oil/Condensate
- Woodford Gas Well
- Dry and Abandoned



Oklahoma Active Horizontal Drilling Plays

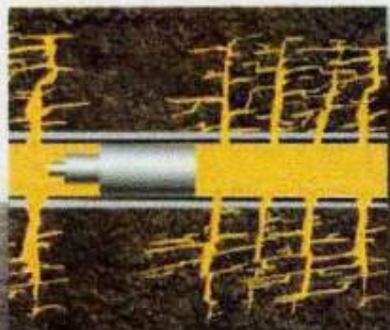
Including 2010 Activity



Horizontal Drilling has had a major impact on these plays!!

**Schematic Drawing
Showing Horizontal Wellbore
&
Induced Fractures Resulting
From Multi-Stage Stimulation**

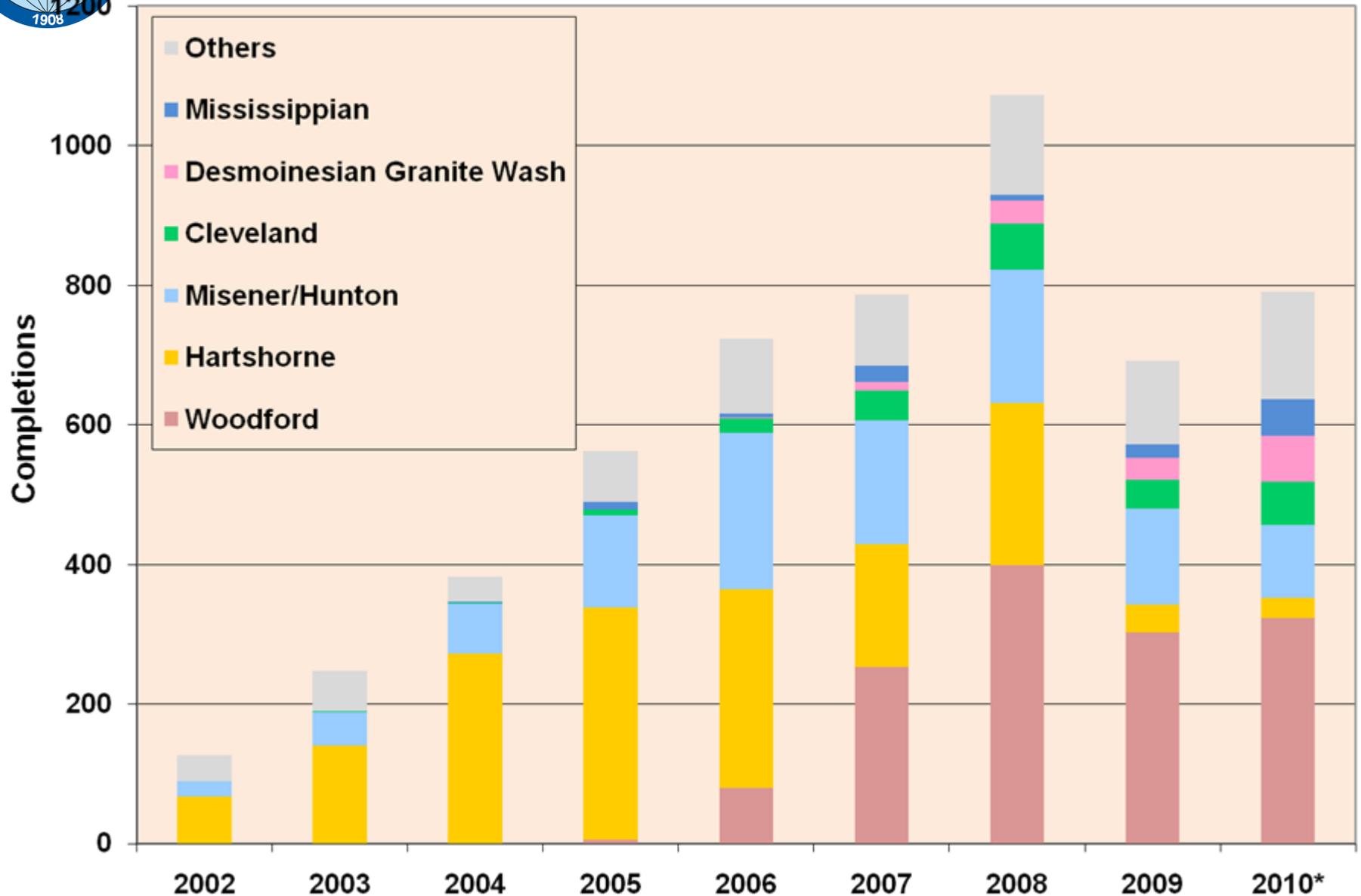
Shale Fractures





Major Oklahoma Horizontal Drilling Plays

Data From IHS Energy through 1-1-2011



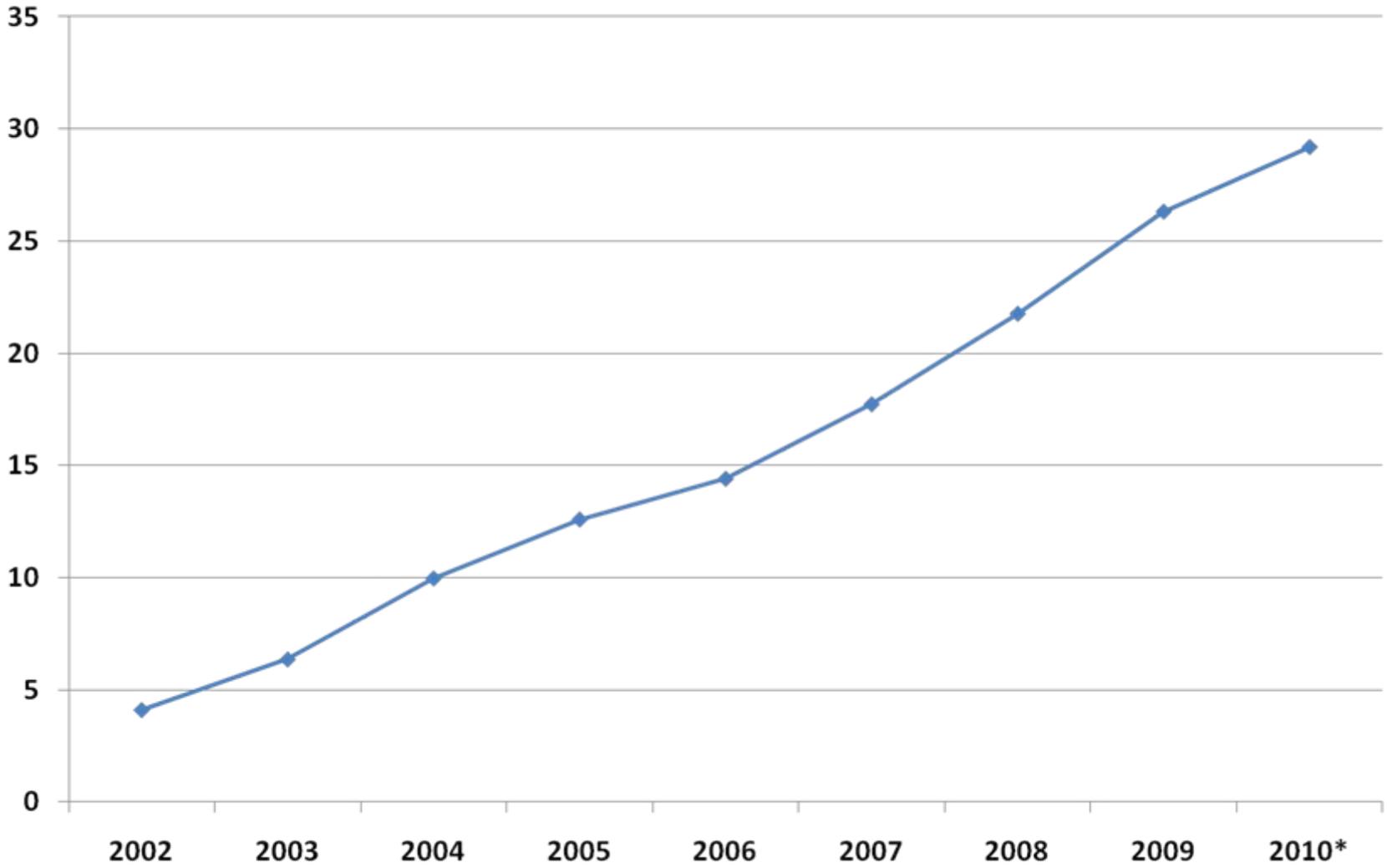
* Projected



Oklahoma Horizontal Drilling as a Percentage of the Total

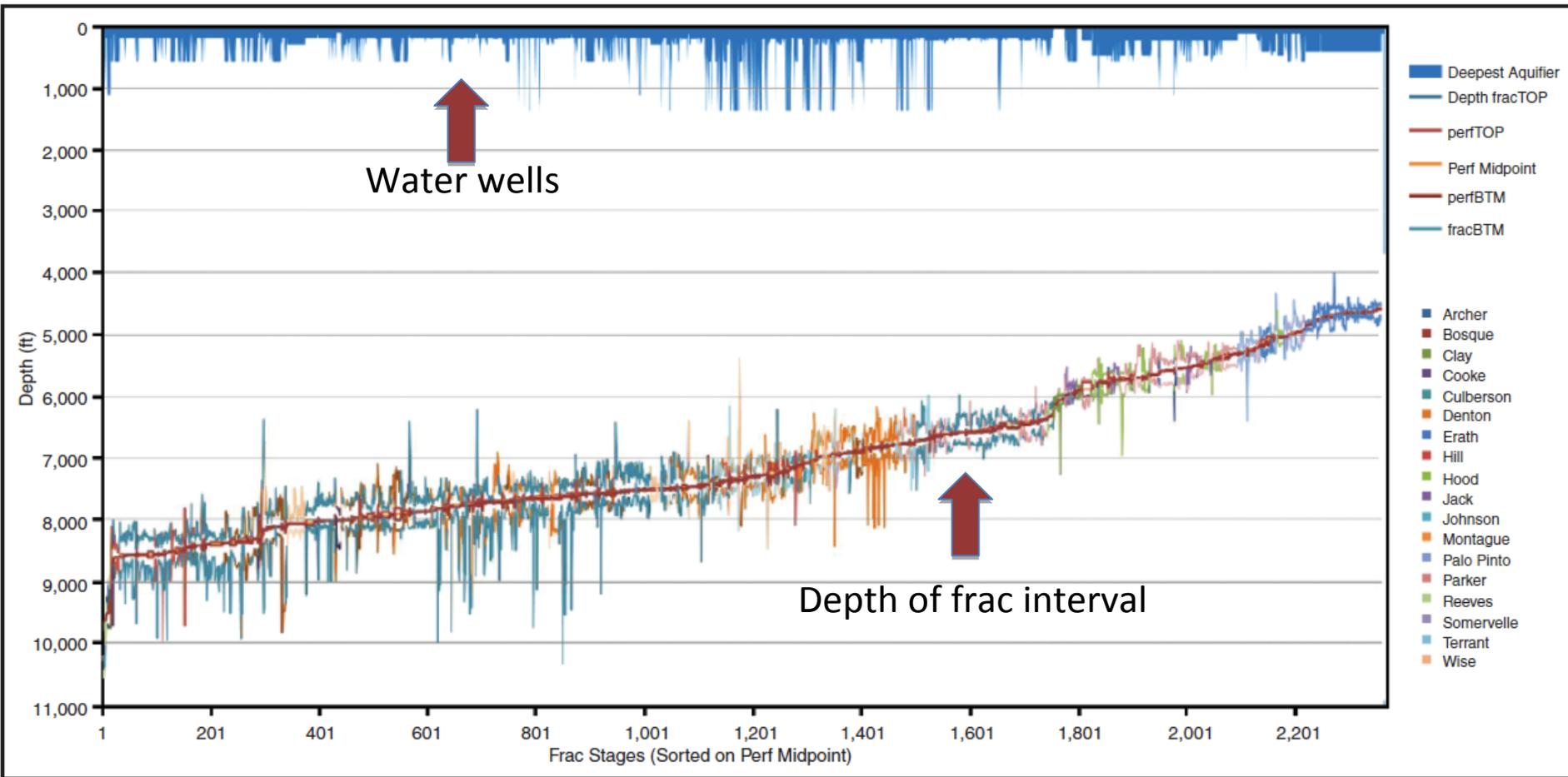
Data From IHS Energy through January 1, 2011

Percent Horizontal Wells



* - Estimate

Barnett Shale Mapped Fracture Treatments (TVD)

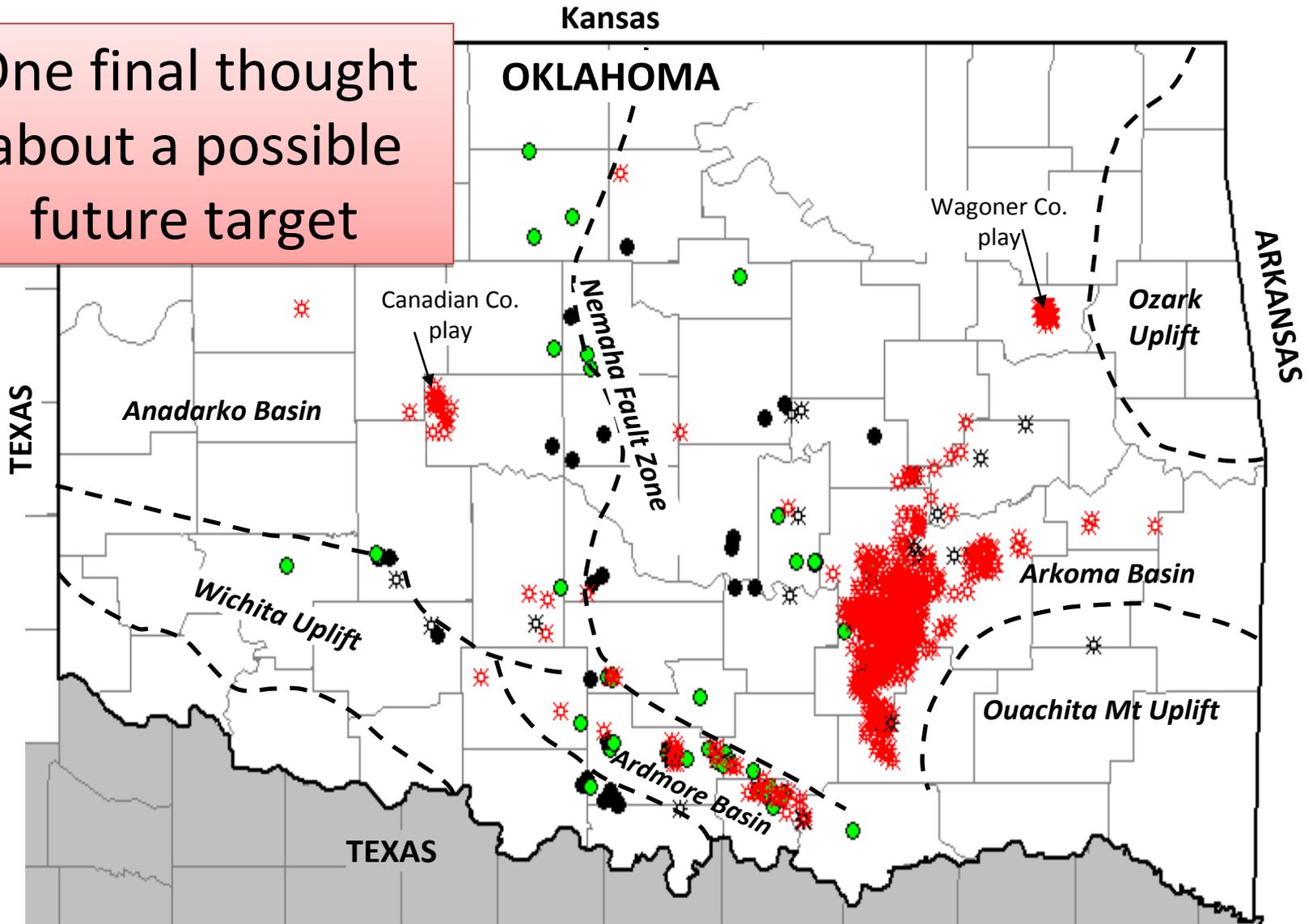


Reproduced for Halliburton Pinnacle with permission from The American Oil & Gas Reporter

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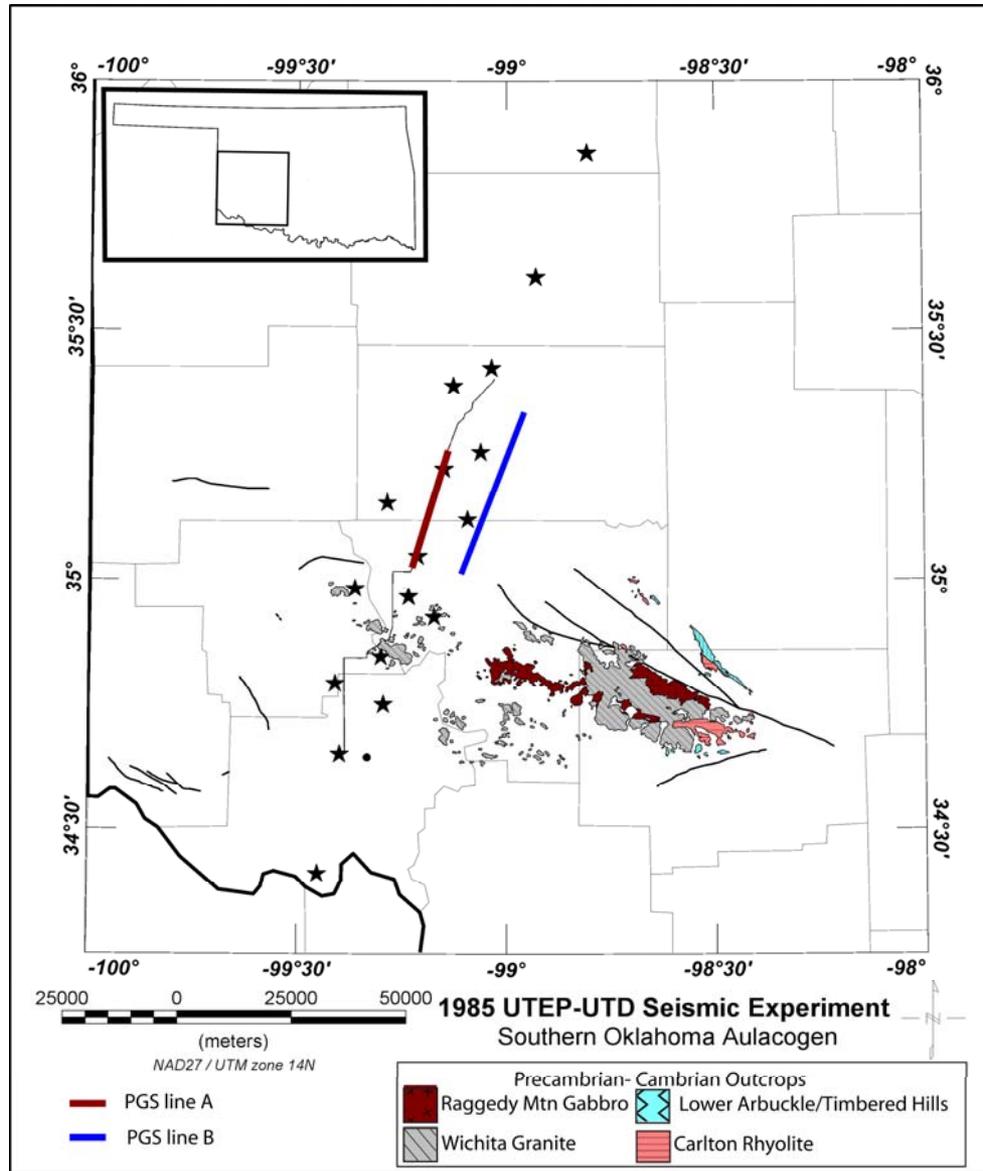
“Fracing” is often mentioned as a hazard to groundwater. This image convincingly demonstrates the huge distance between the frac interval and the water wells!

One final thought
about a possible
future target

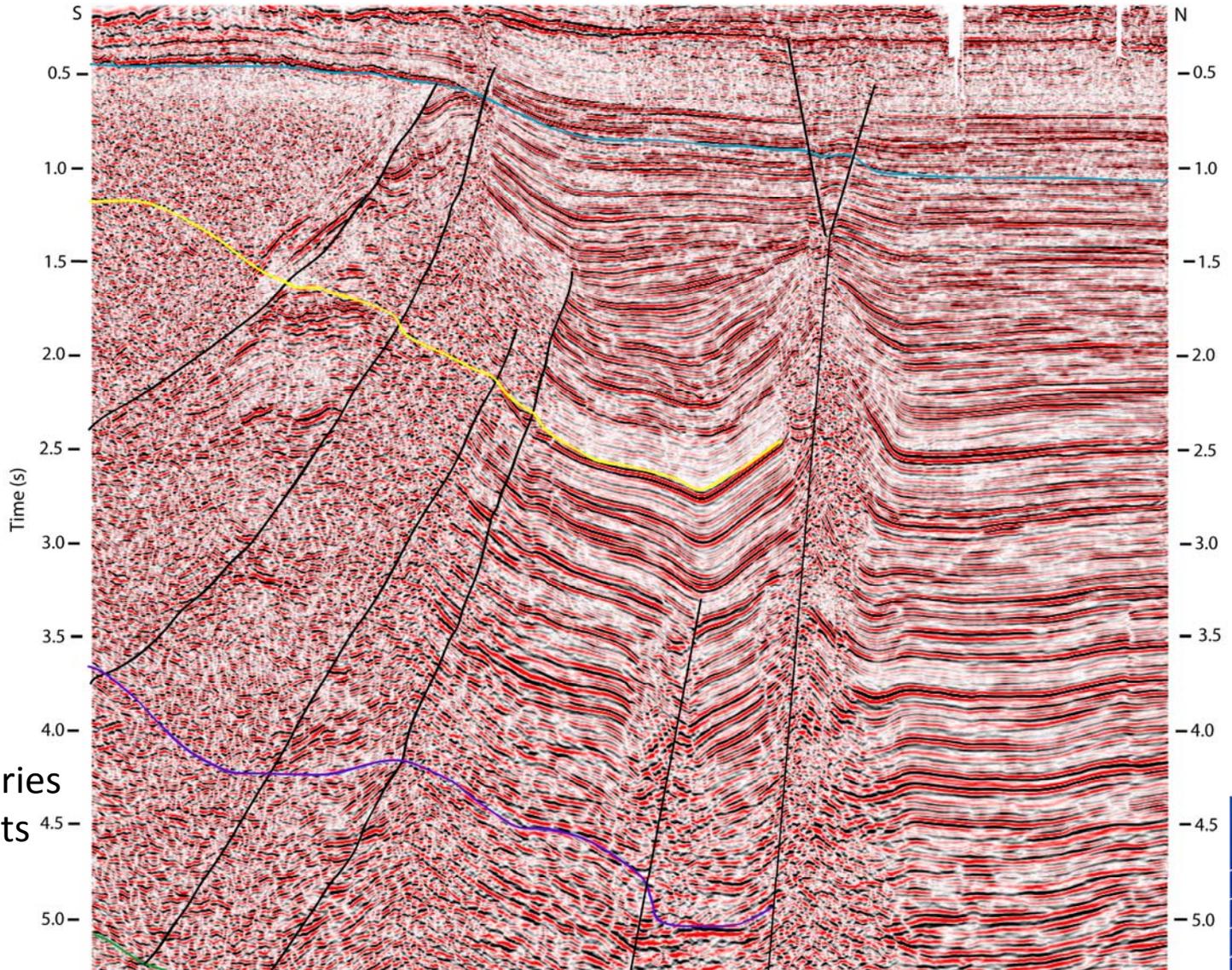


Woodford Shale well completions in Oklahoma (1934–2009). From IHS Energy, 2009.

Data Location



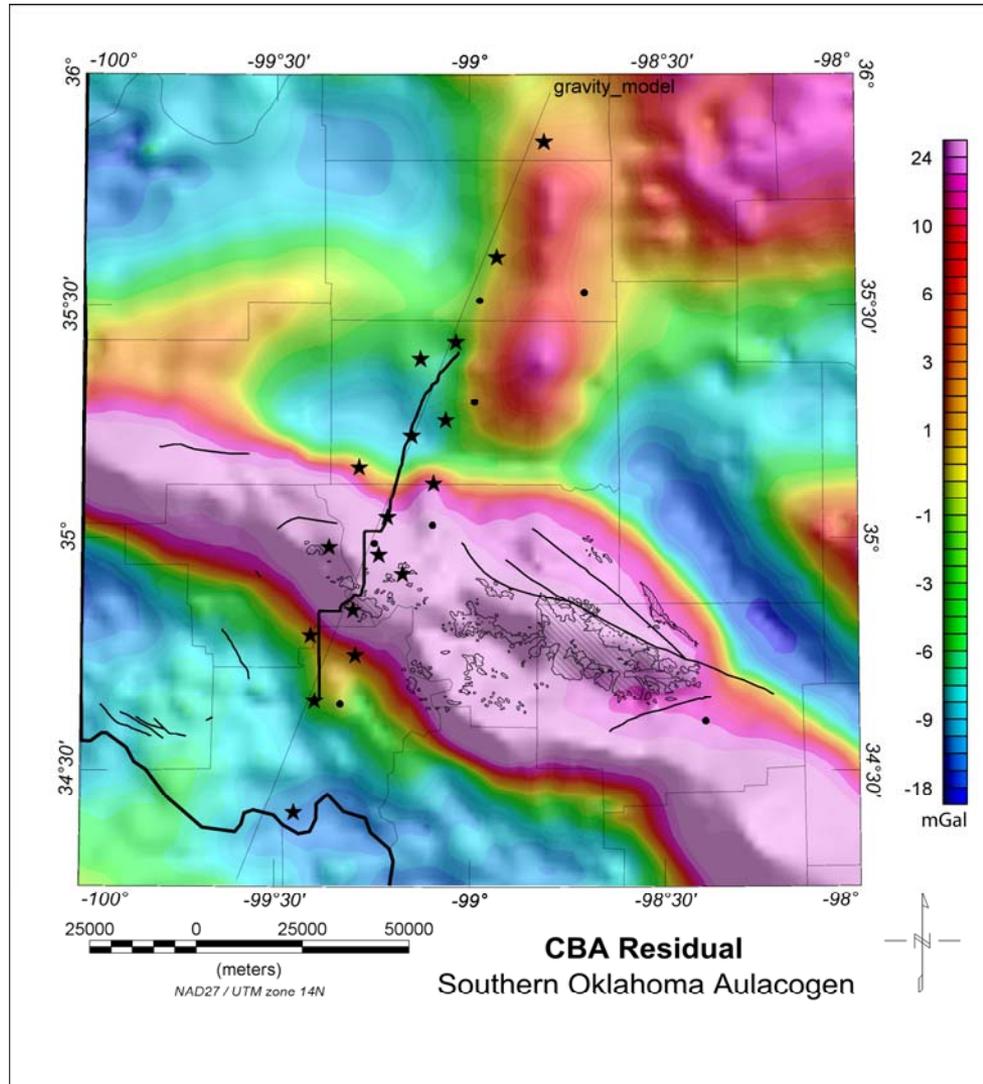
PGS Line B



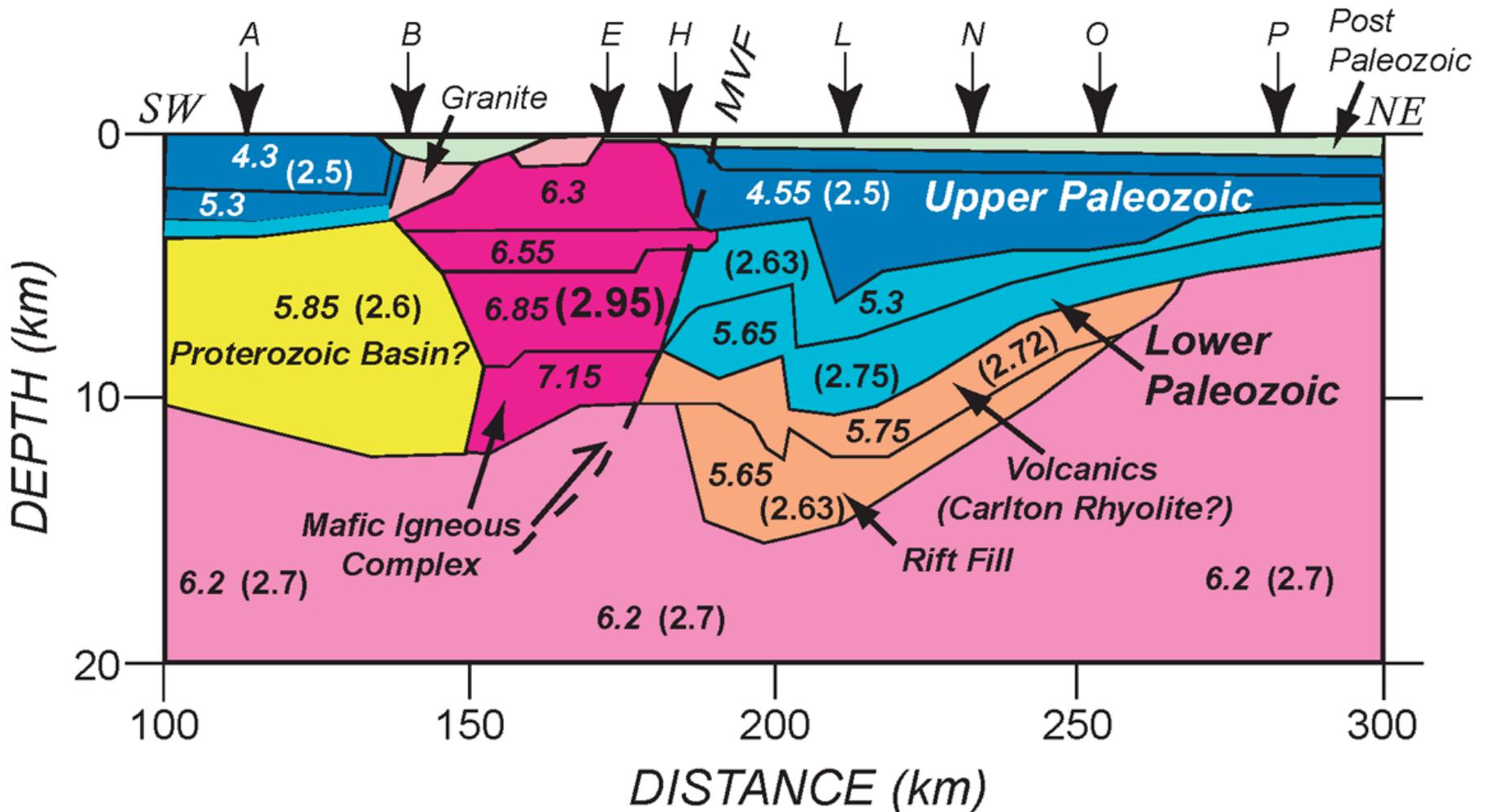
Model boundaries
overlaid & faults
interpreted



Gravity Residual



Regional velocity and density structure



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]

(Production data supplied by PI/Dwights LLC, © 2010, IHS Energy Group)

SUMMARY OF WOODFORD GAS SHALE PLAYS

- 1. The main Woodford Shale gas play is in the western Arkoma Basin at $<1.15\%$ to $>3.0\%$ Ro
- 2. There is an expanding gas and condensate play along the Anadarko Basin shelf @ 1.1% to $>1.5\%$ Ro
- 3. There is a gas and oil play in the Ardmore Basin at $<1.2\%$ Ro
- 4. There is a biogenic methane play in the Cherokee Platform at $<1.2\%$ Ro
- 5. There several clear scenarios for future exploration but Ro and thickness are important considerations



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Oil and Gas Data and References

[Field Discovery Wells](#) (Excel format)

[Links to other Web sites with Oklahoma](#)

[Stratigraphic Chart Stratigraphic Guide](#)

[Stratigraphic chart, front of chart \(pdf\)](#)

[Table of Oklahoma Oil and Gas Reserves](#)

[Currently Available OGS Oil and Gas Statistics](#)

[All OGS Oil and Gas Related Publications](#)

Oklahoma Oil and Gas Maps, Cross Sections

Map GM36. Oklahoma oil and gas field (methane), by Dan T. Boyd. ([pdf](#)) ([data](#))

Map GM37. Oklahoma oil and gas field, Dan T. Boyd. ([pdf](#)) ([data](#))

Map GM38. Oklahoma oil and gas field

Map GM28 Map of Oklahoma Oil and Gas supplement, 1997. ([Data files only](#))

[Type Logs](#)

Oklahoma Hydrocarbon Source Rocks and Gas Shales

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Including October 2008 Gas Shales Workshop Presentations!

[Oklahoma Gas-Shale Completions Map, 1939-2009](#)

[Woodford Shale Gas Well Completions Map, 1939-2009](#)

[Woodford Shale Gas Well Completions Map, 2003-2009](#)

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