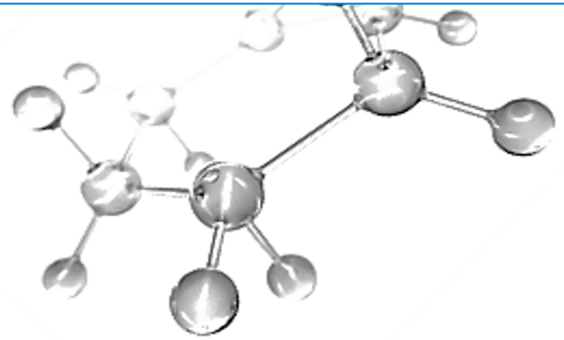


An Overview of Oklahoma Shale Resource Plays

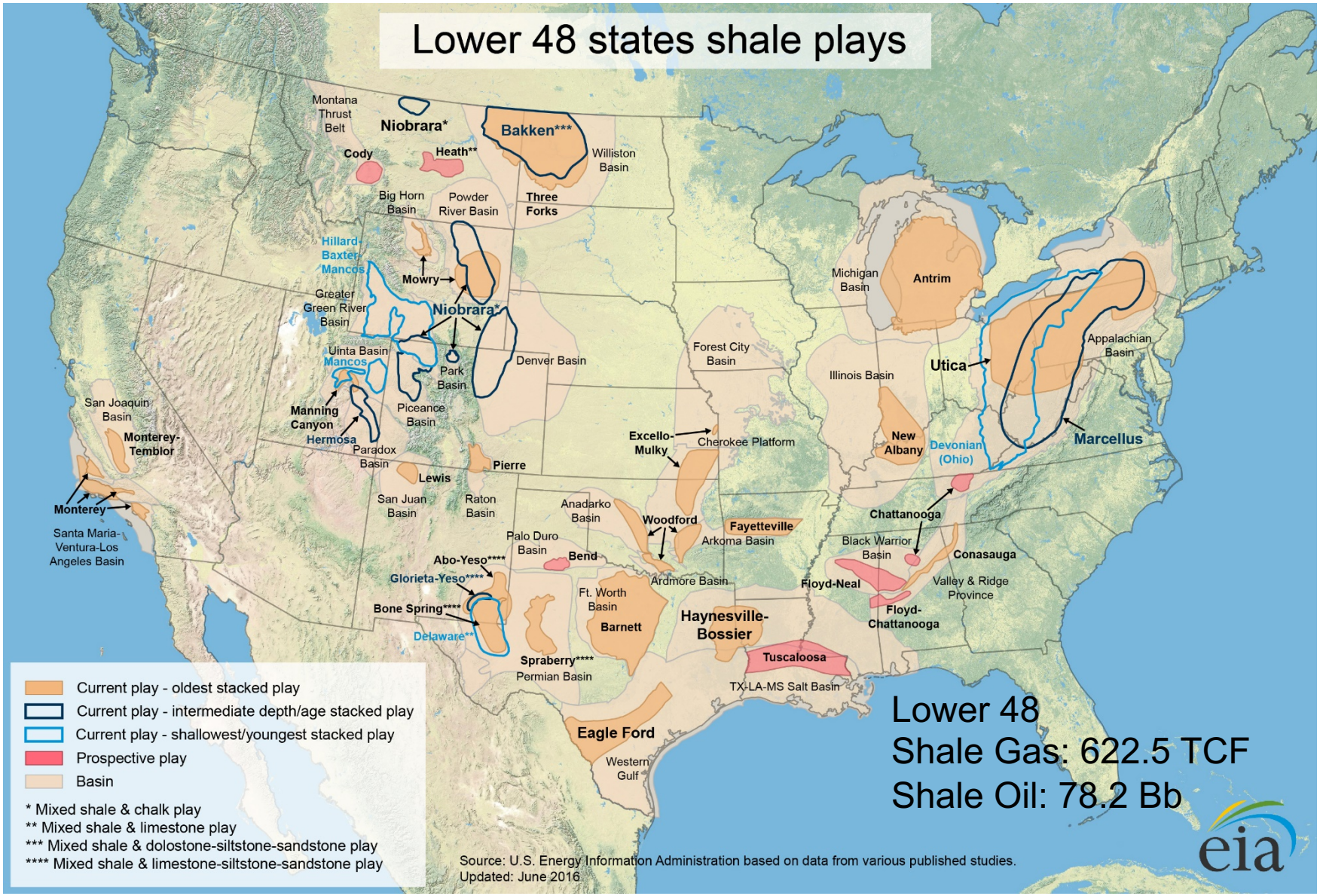
Fnu "Ming" Suriamin*
Brian J. Cardott
Abbas Seyedolali

November 10, 2020

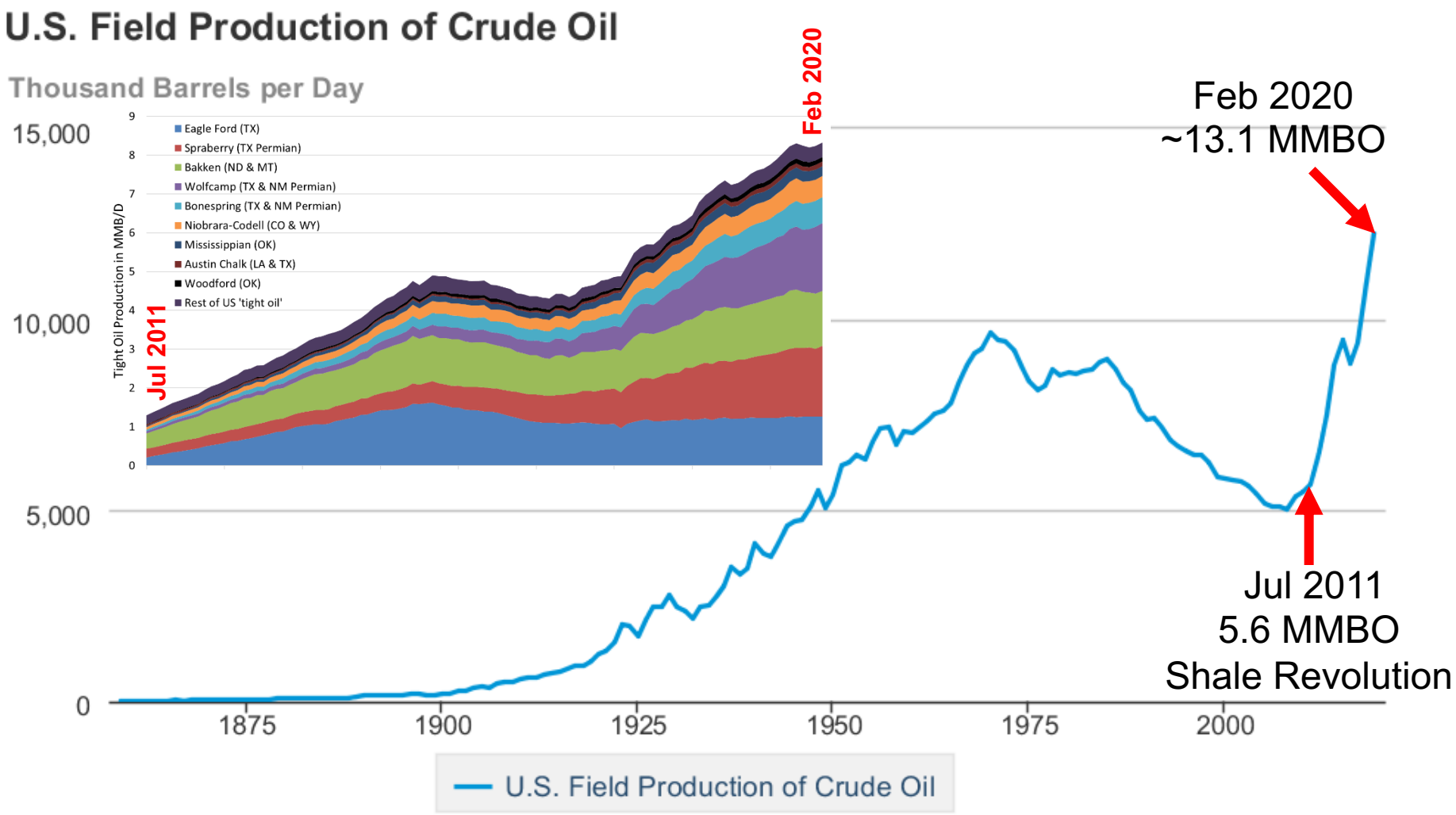
Agenda

- Shale Resource Plays in the United States
- Key Elements of Successful Shale Resource Plays
- Hydrocarbon Source Rocks of Oklahoma
- Evaluation (oldest to youngest):
  - Sylvan
  - Arkansas Novaculite
  - Woodford
  - Caney
  - Goddard/Springer
  - Atoka
  - Pennsylvanian shales

Shale Resource Plays - What has been found?



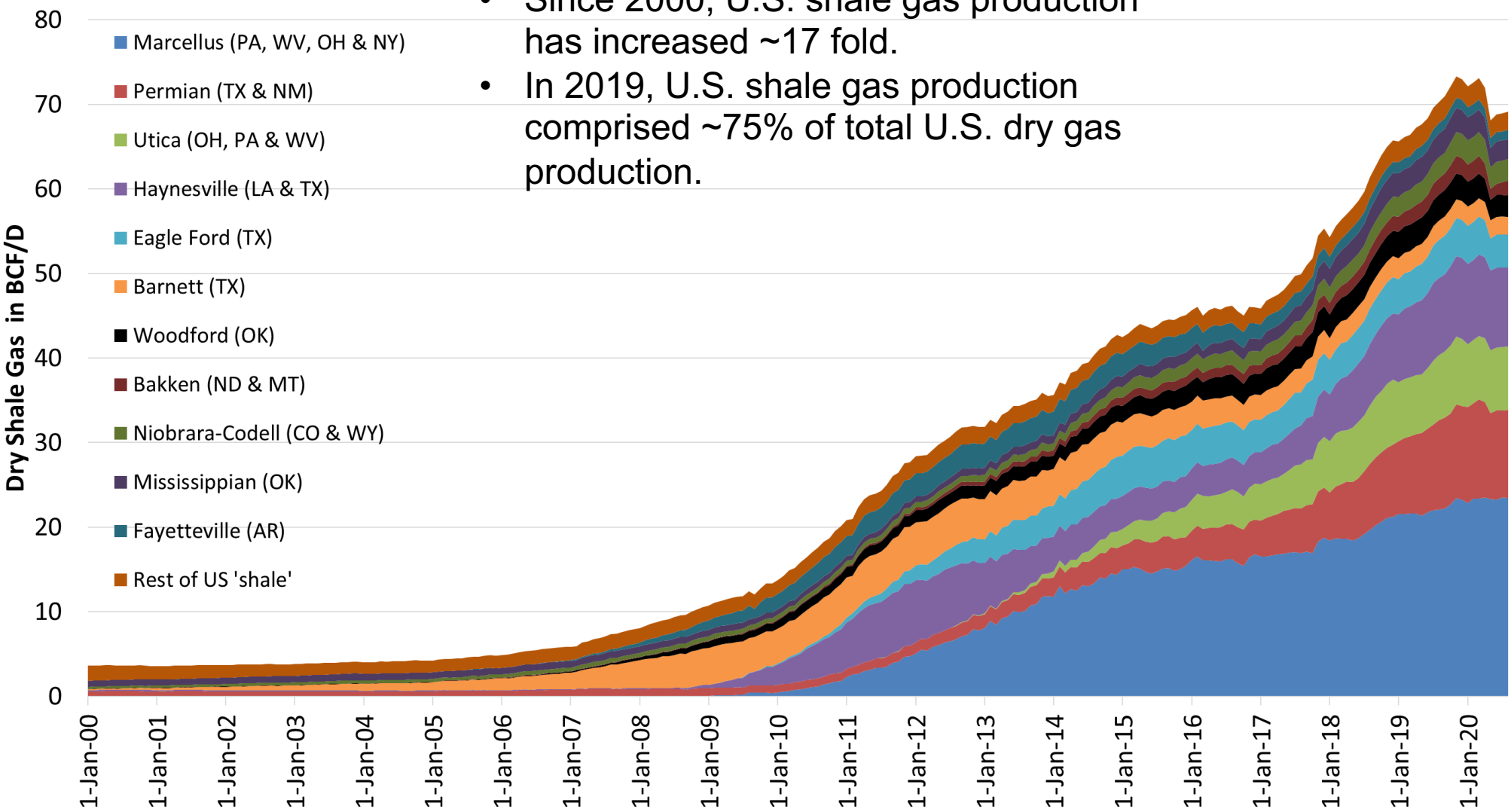
Why are shale resources important?



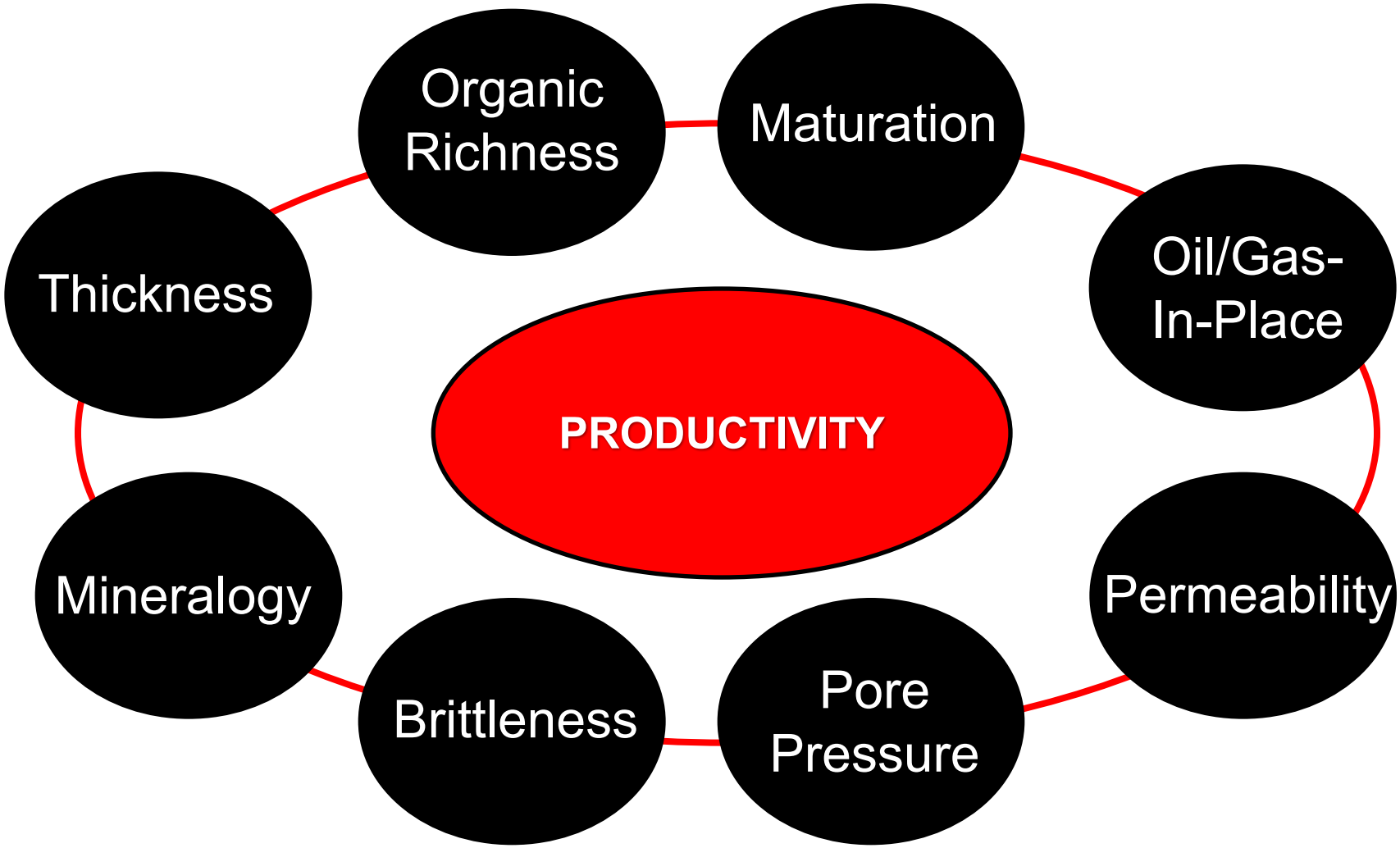
Source: U.S. Energy Information Administration

Why are shale resources important?

- Since 2000, U.S. shale gas production has increased ~17 fold.
- In 2019, U.S. shale gas production comprised ~75% of total U.S. dry gas production.



Key Elements of Successful Shale Resource Plays



Adapted from John Curtis

Ardmore and Marietta Basins Oil and Hydrocarbon Source Rock Study

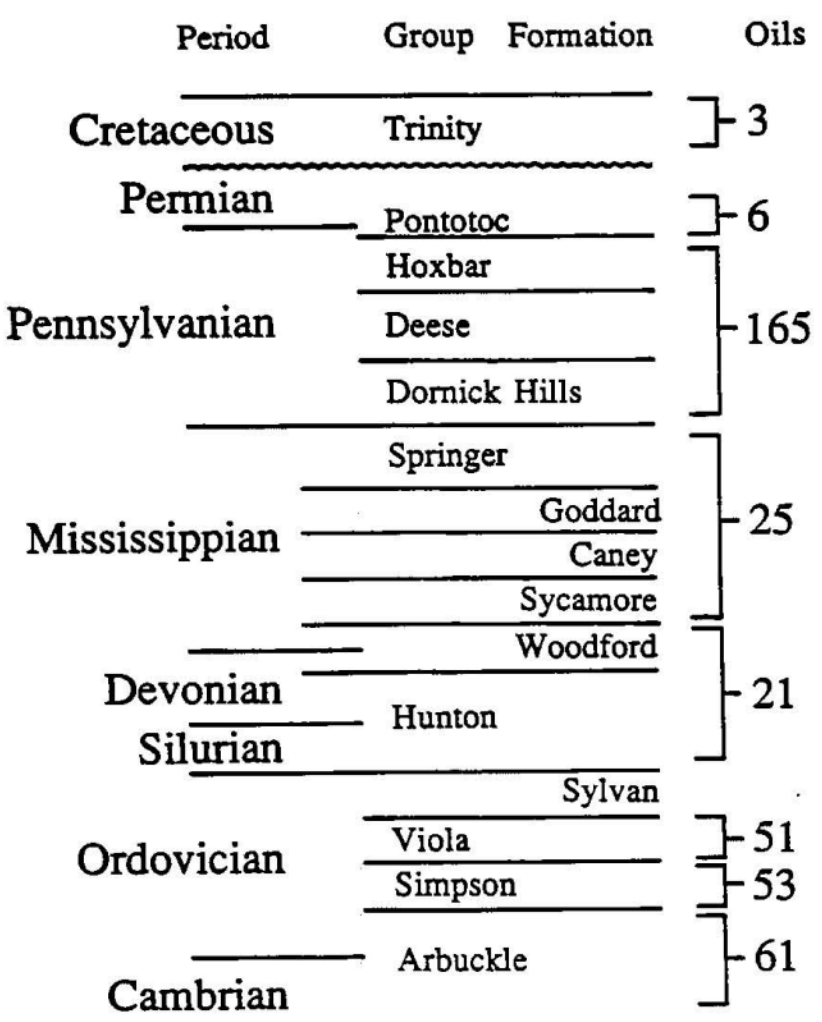


Figure 2. Stratigraphic distribution of 385 oil samples.

Wavrek, 1992

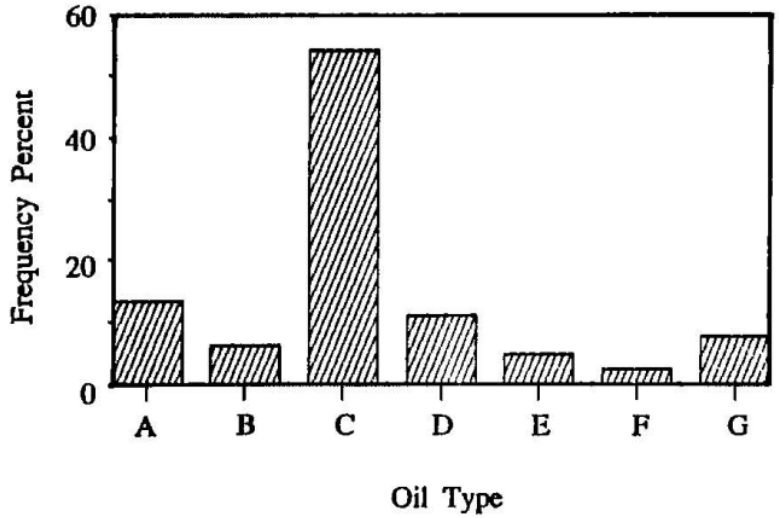


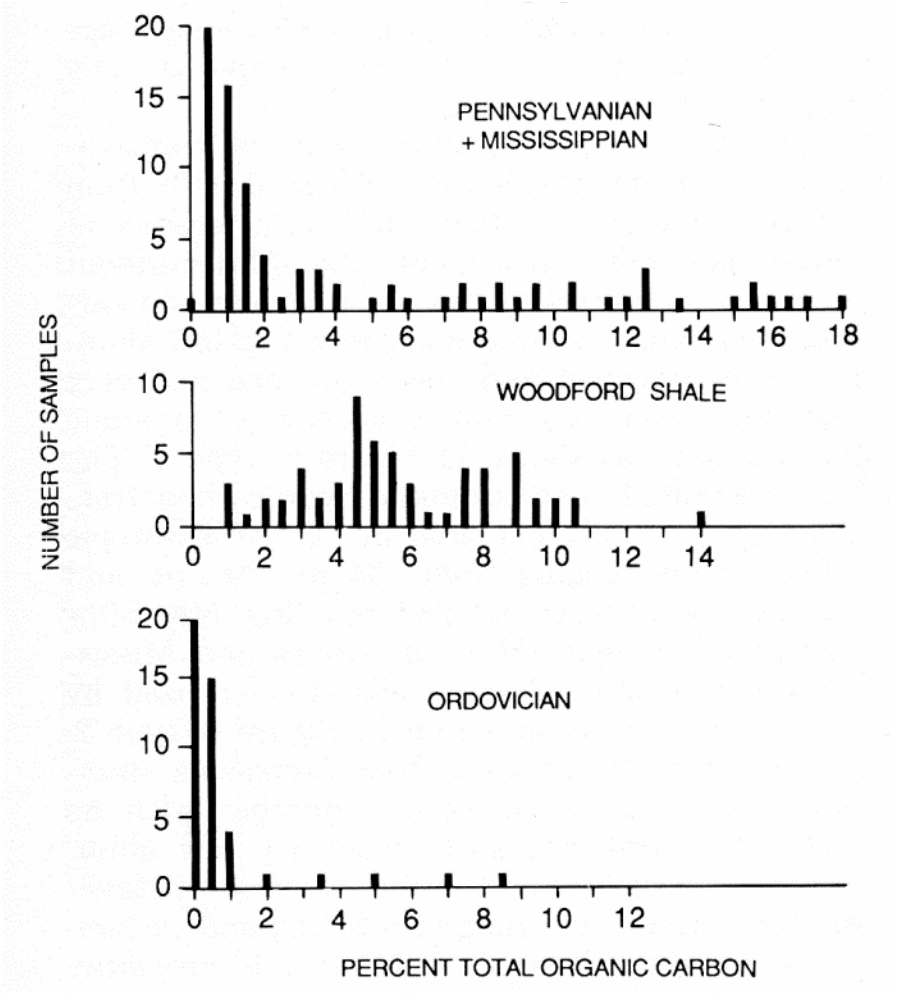
Figure 11. Frequency distribution of oil types reservoired in the Ardmore and Marietta basins.

Source Facies:

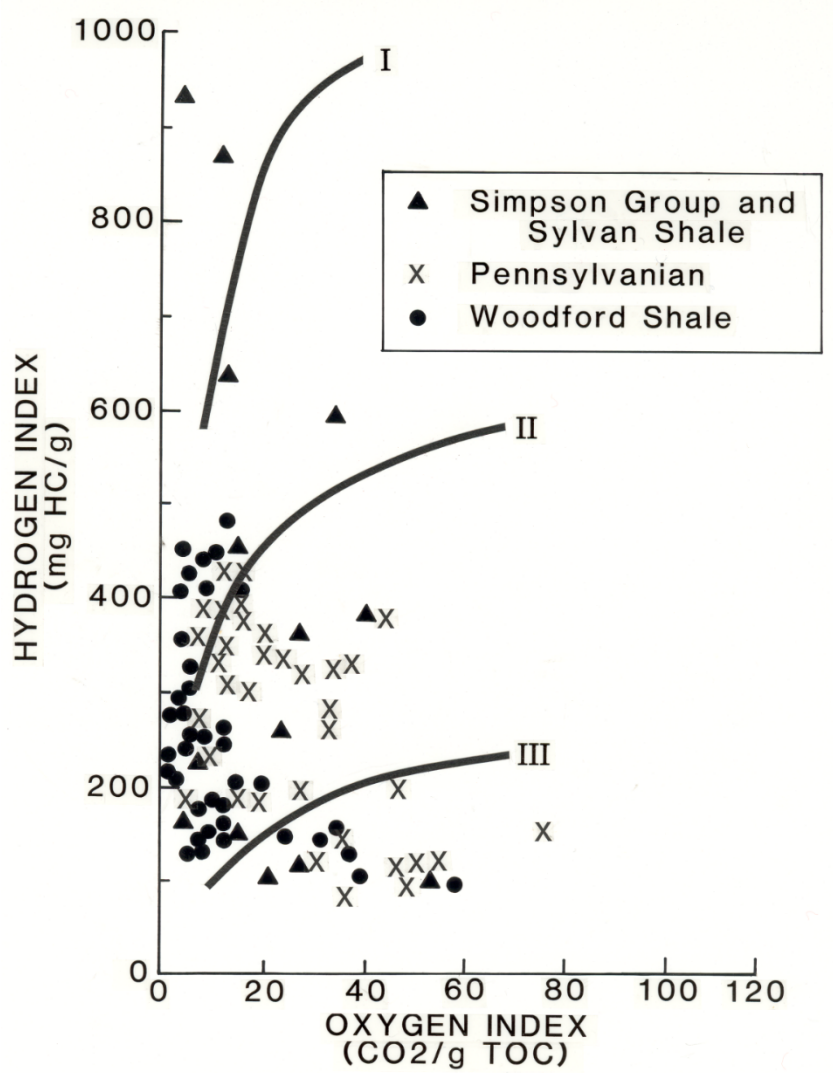
A	Pennsylvanian (Atoka?)
B	Mississippian (Goddard, Caney, Sycamore)
C	Devonian-Mississippian (Woodford)
D	Upper Ordovician (Viola Group)
E	Middle Ordovician (Simpson Group)
F & G	Mixed

Anadarko Basin Oil and Hydrocarbon Source Rock Study

Anadarko Basin Source-Rock TOC

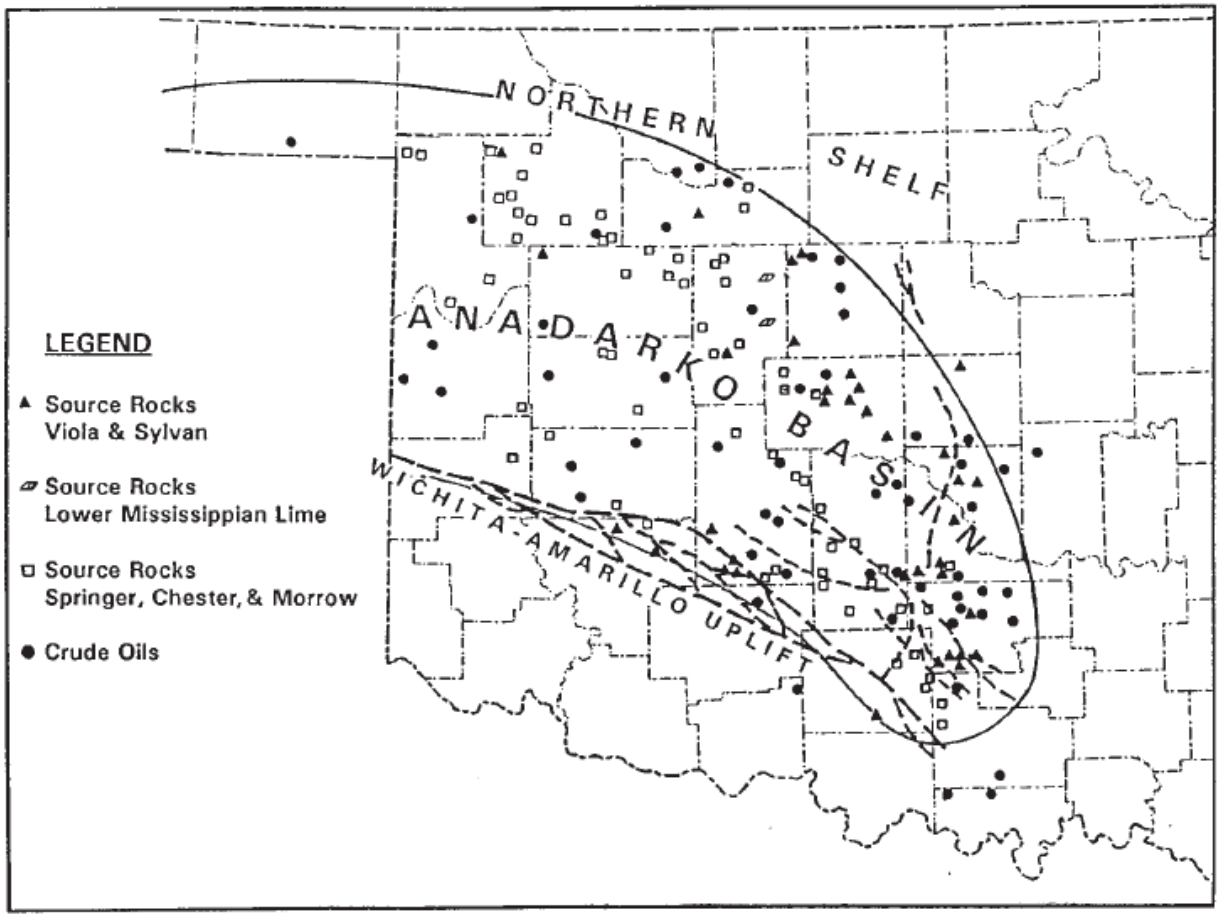


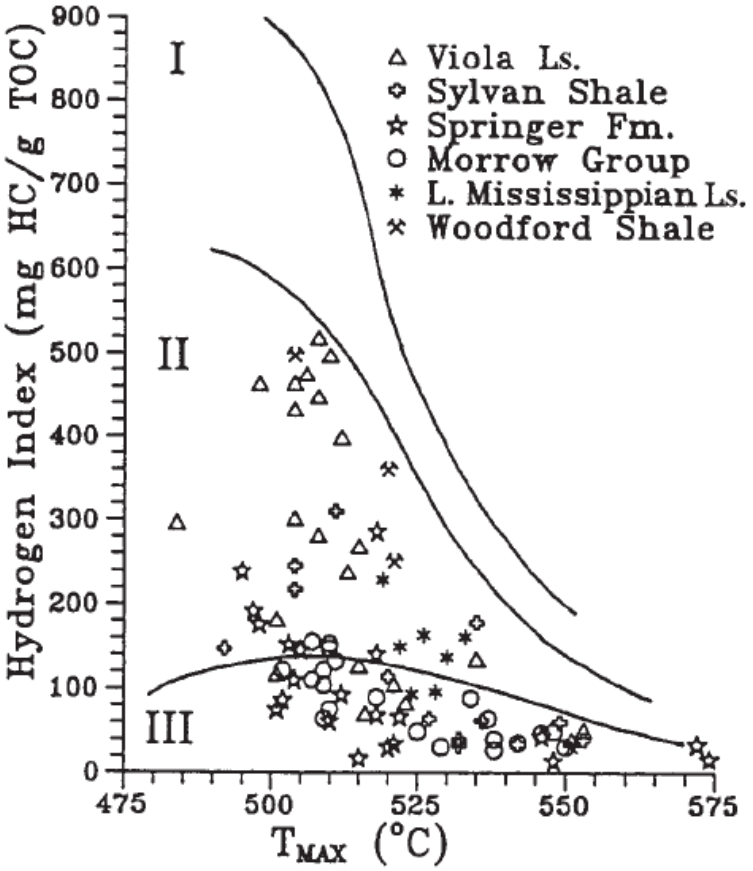
Van Krevelen Type Diagram



Burruss and Hatch, 1989

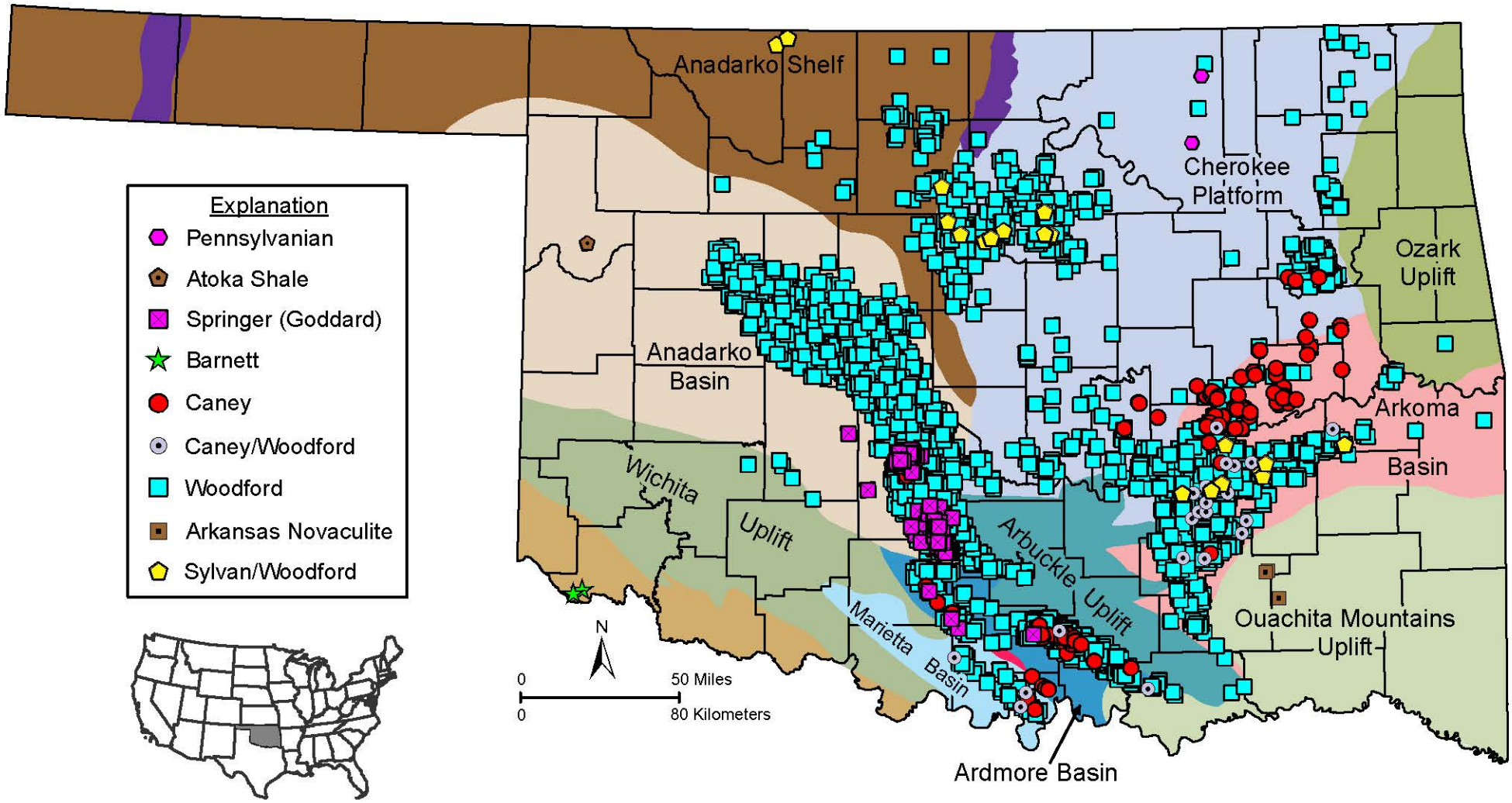
Anadarko Basin Oil and Hydrocarbon Source Rock Study





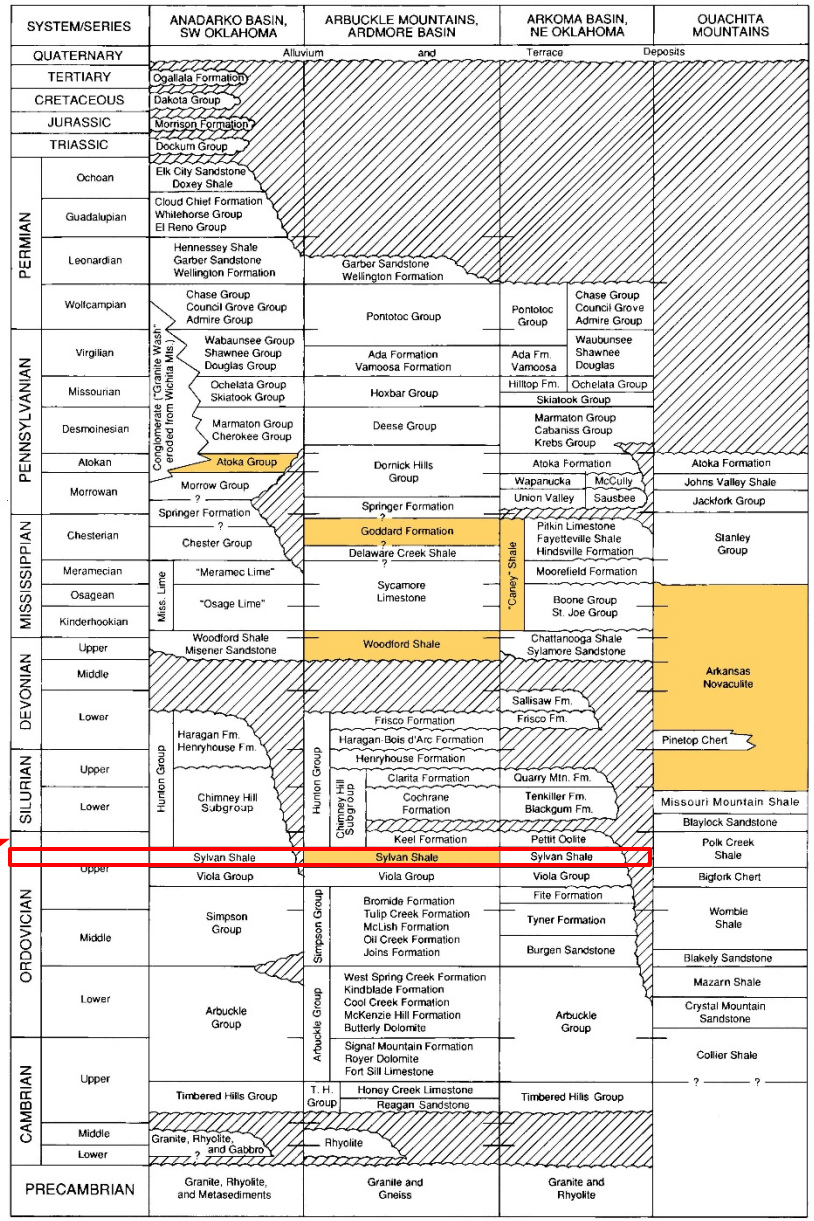
Wang and Philp, 1997

Oklahoma Shale Gas/Oil Completions (1939-2020)



5,907 completions

Sylvan Shale (Ordovician Age)

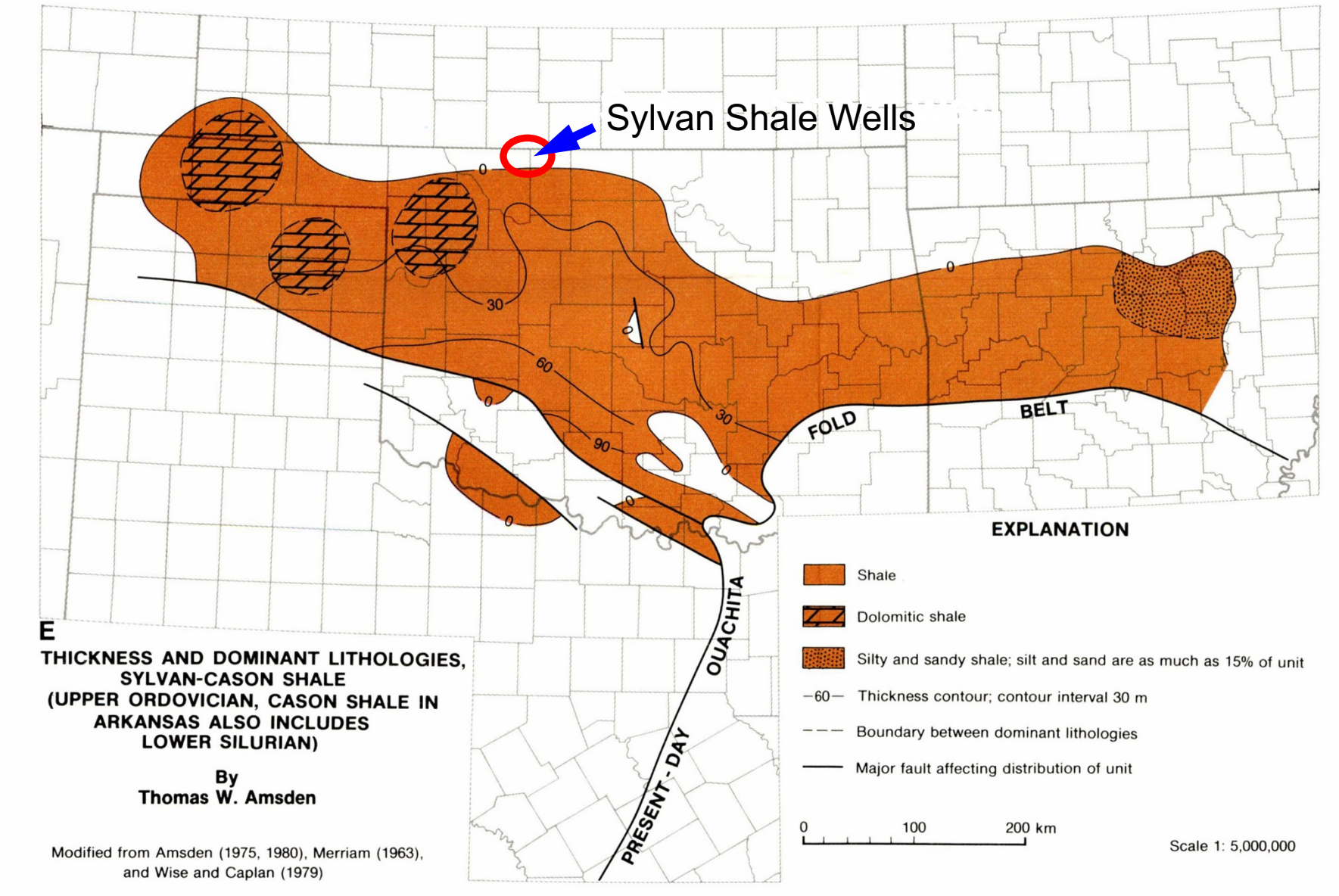


Modified from Cardott, 2017

Kerogen Type	**II (Burruss and Hatch, 1989)** **III (Wang 1993)**
Amount of TOC	**<1% (Wang, 1993)**
Maturity	**>0.5% VRo**

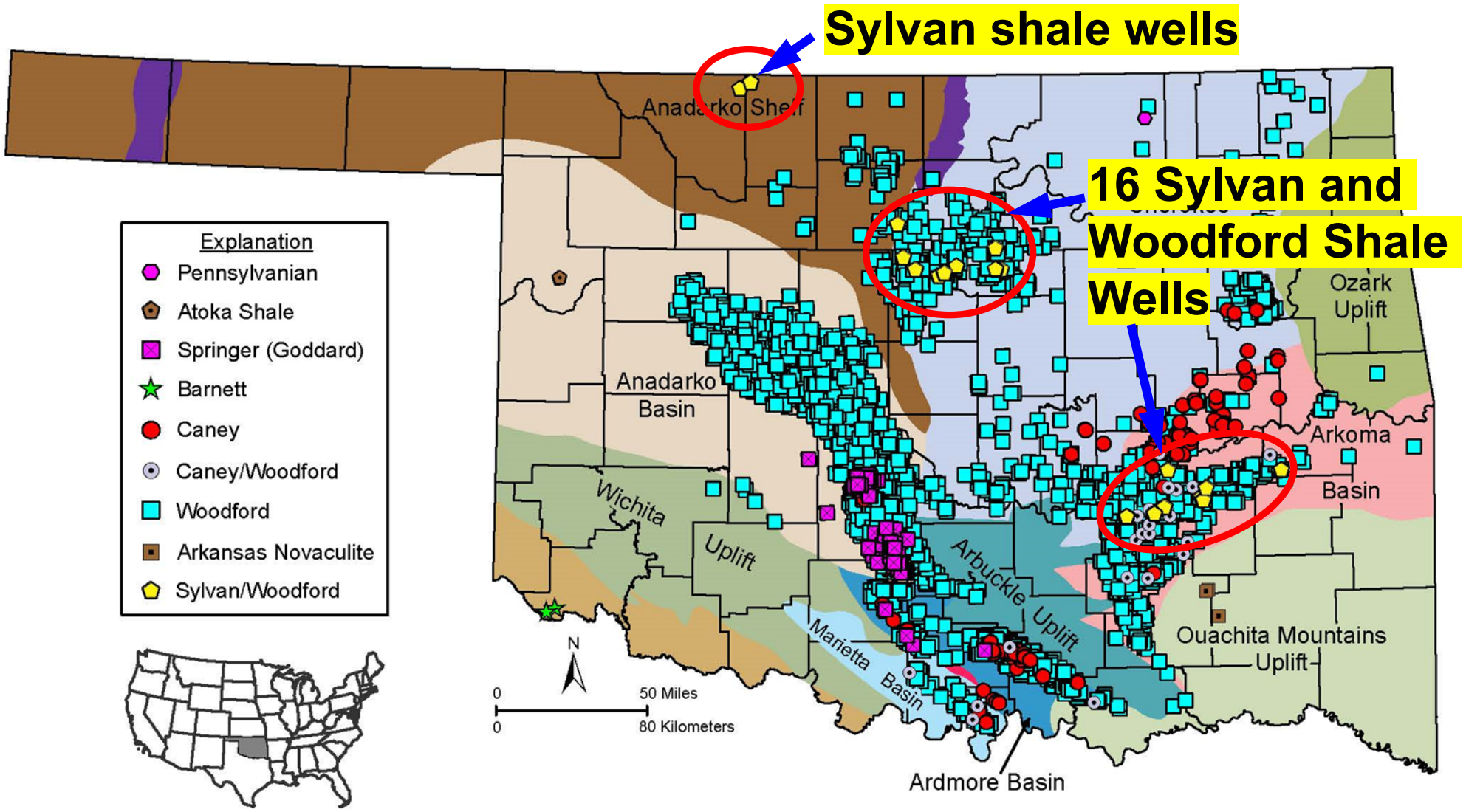
Wang and Philp (1997):
"The Sylvan Shale is thin and organically lean in the Anadarko Basin, and probably **NOT** a source rock in the basin."

Sylvan Shale Isopach Map

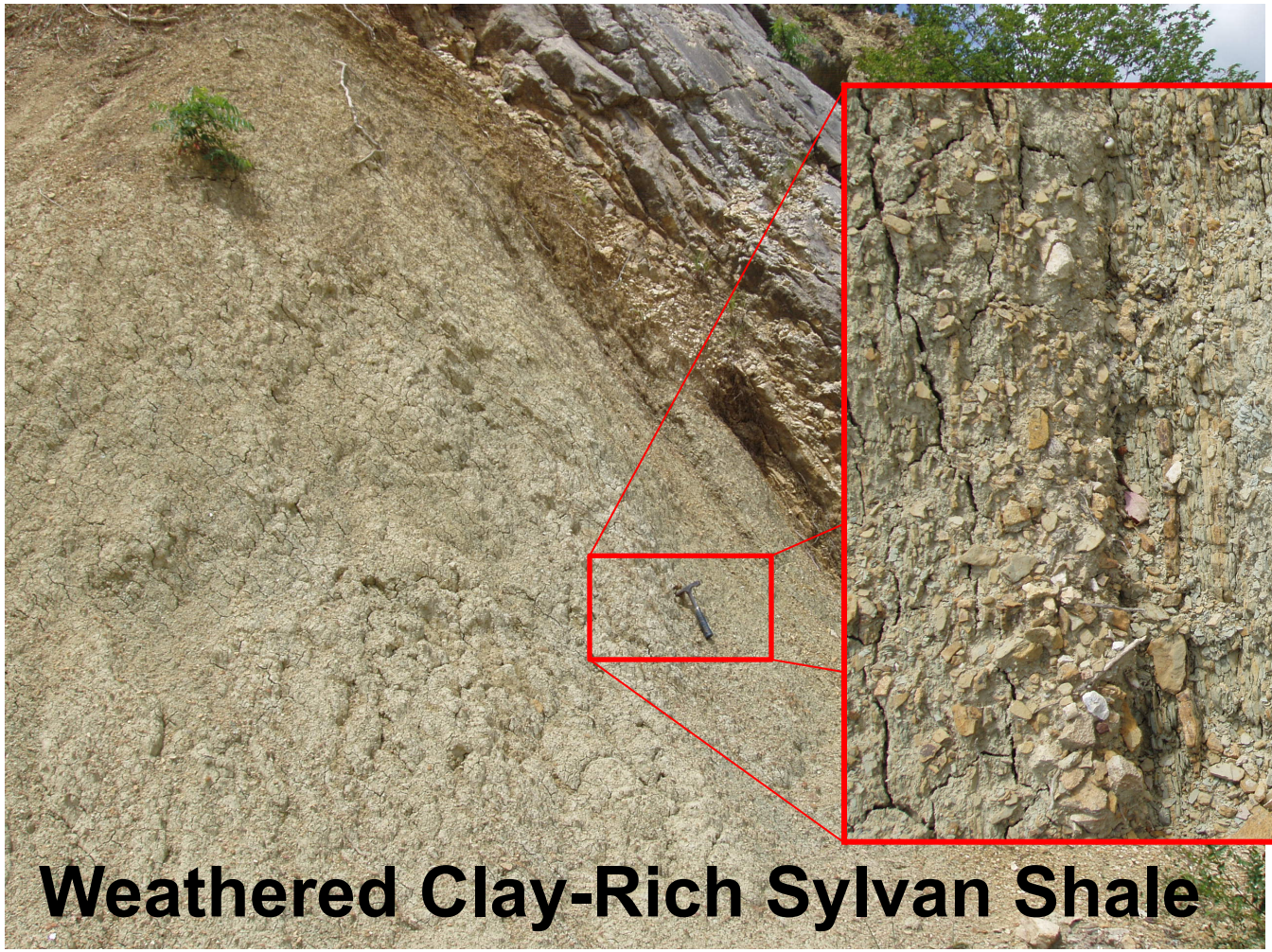


Johnson and others, 1989

Sylvan Shale Wells [2008-2020]



Sylvan Shale in the Arbuckle Mountains

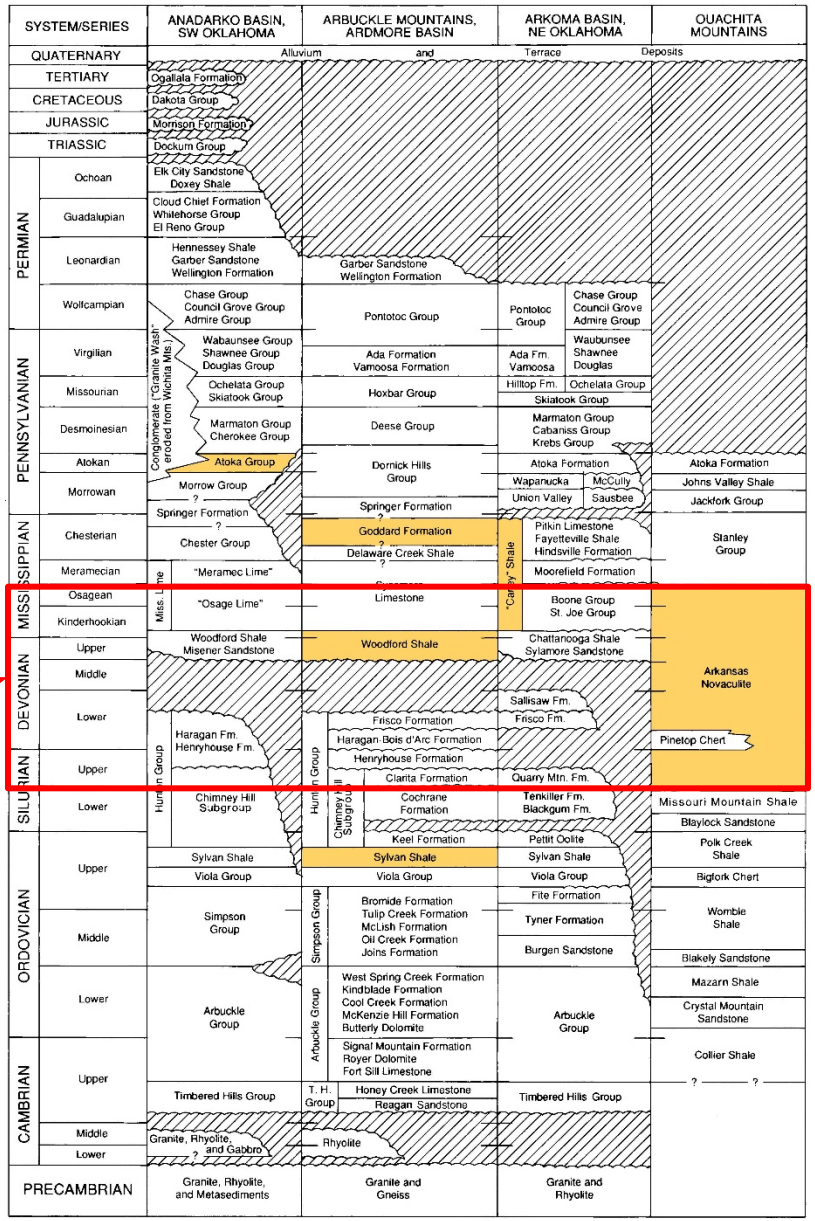


Weathered Clay-Rich Sylvan Shale

Example of Poor Gas Shale (But Good Fracture Barrier)

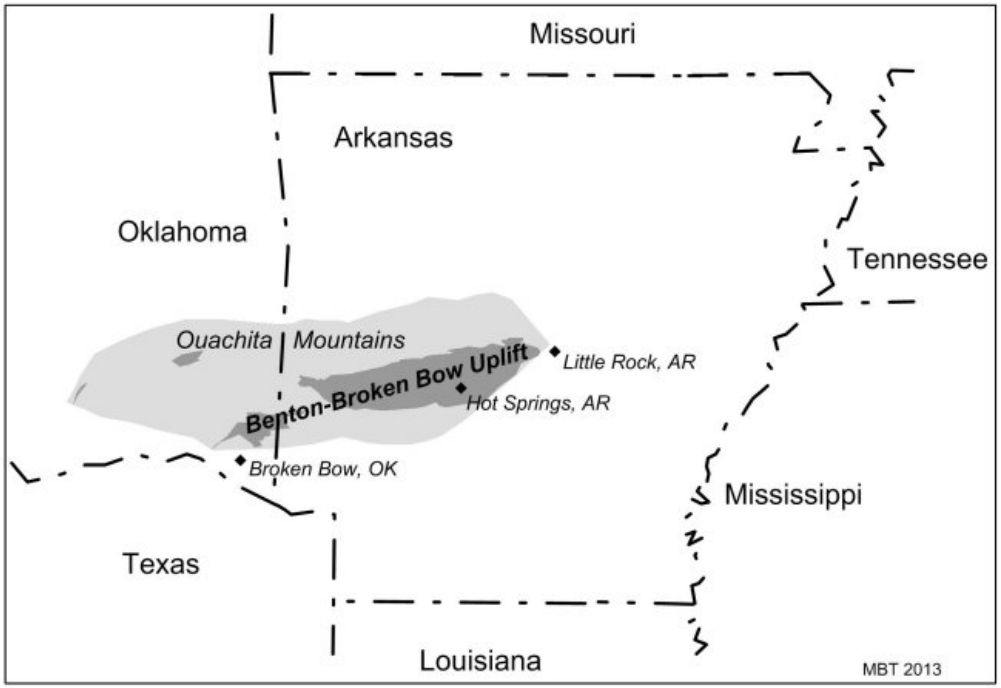
Photographs are courtesy of Brian J. Cardott

Arkansas Novaculite (Silurian-Mississippian Age)



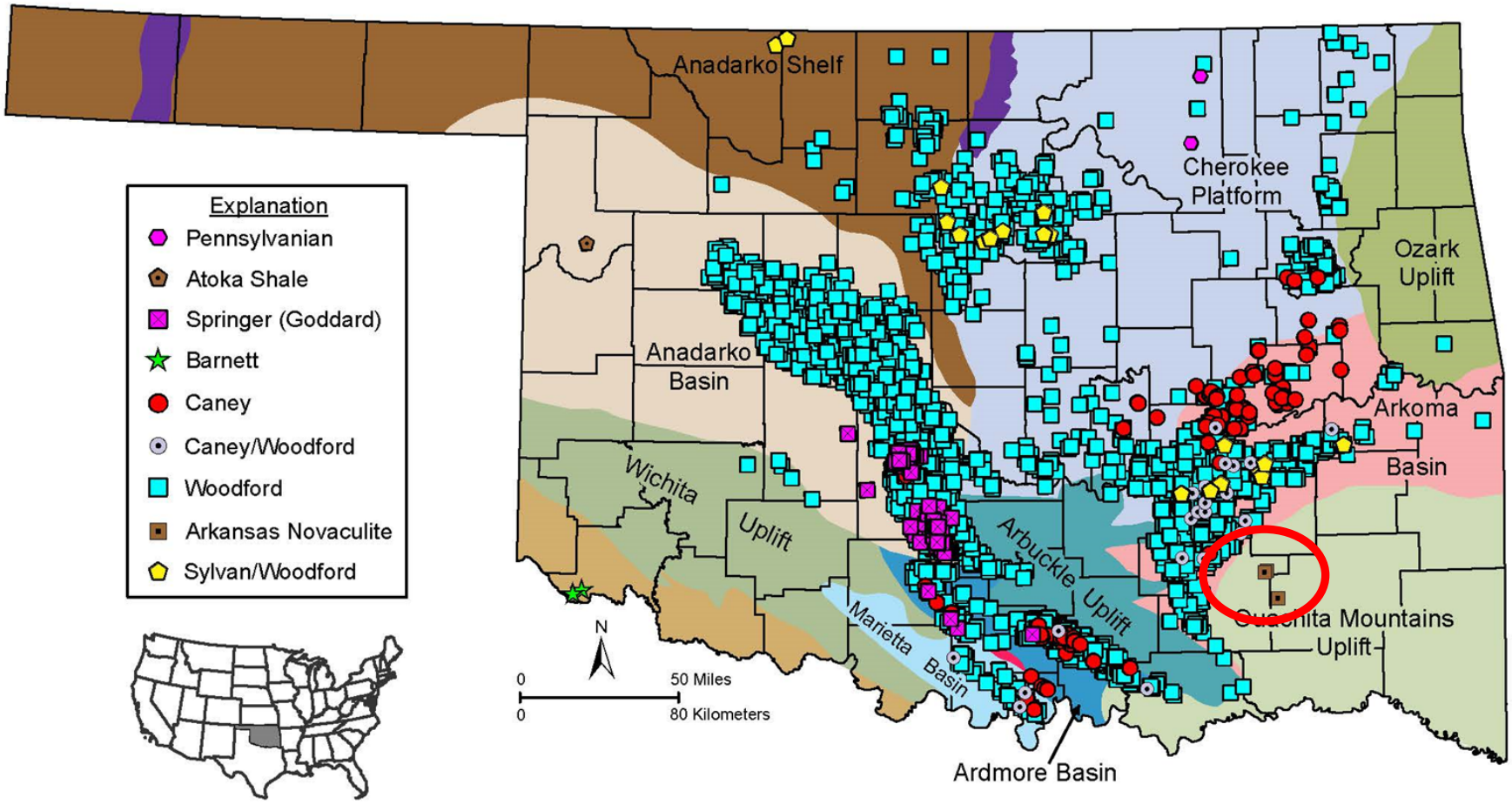
Modified from Cardott, 2017

Source: http://archeology.uark.edu/novaculite/index.html



Kerogen Type	**II and III (Johnson and Cardott, 1992)**
Amount of TOC	**< 1% - 12.5% (Cardott 1994, Weber 1992, 1994, Godo et al. 2011)**
Maturity	**< 0.62% VRo (Cullen and Miller, 2020)** **< 3.32% VRo (Godo et al., 2011)**

Arkansas Novaculite/Bigfork Chert Wells (2009-2020)

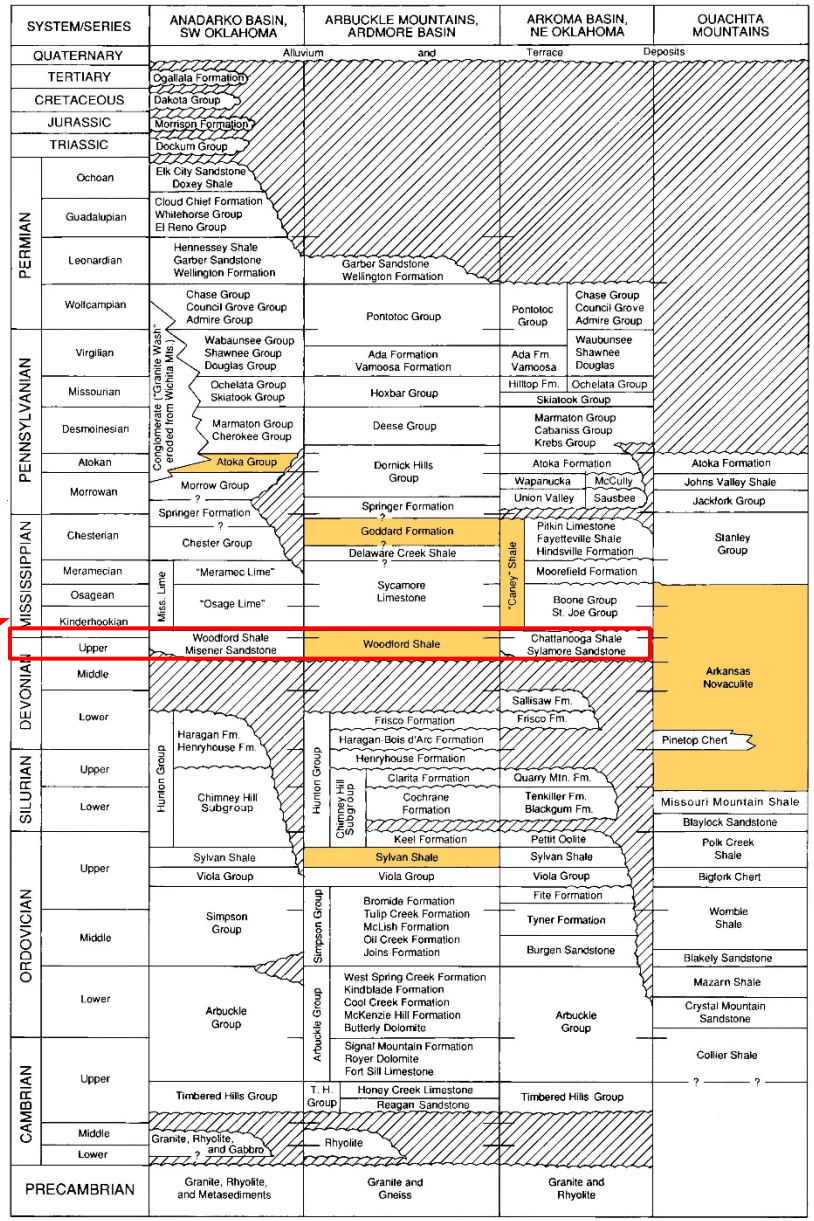


- RKI E&P 2-9 Denton-Perrin (1/2009; 9-2S-15E; 6,250 ft; IP 243 Mcf).
- Longfellow Energy LP 26-3 Wyrick (2/2010; 26-1N-14E; 8,104 ft; IP 2,926 Mcf; as of 2013 cum >1,109 MMcf).
- Longfellow Energy LP 35-3 Ertman Unit (4/2010; 35-1N-14E; 8,890 ft; IP 2,762 Mcf; as of 2013 cum >282 MMcf).

Arkansas Novaculite (Scratch Hill Section, Atoka, OK)

Photographs are courtesy of Brian J Cardott

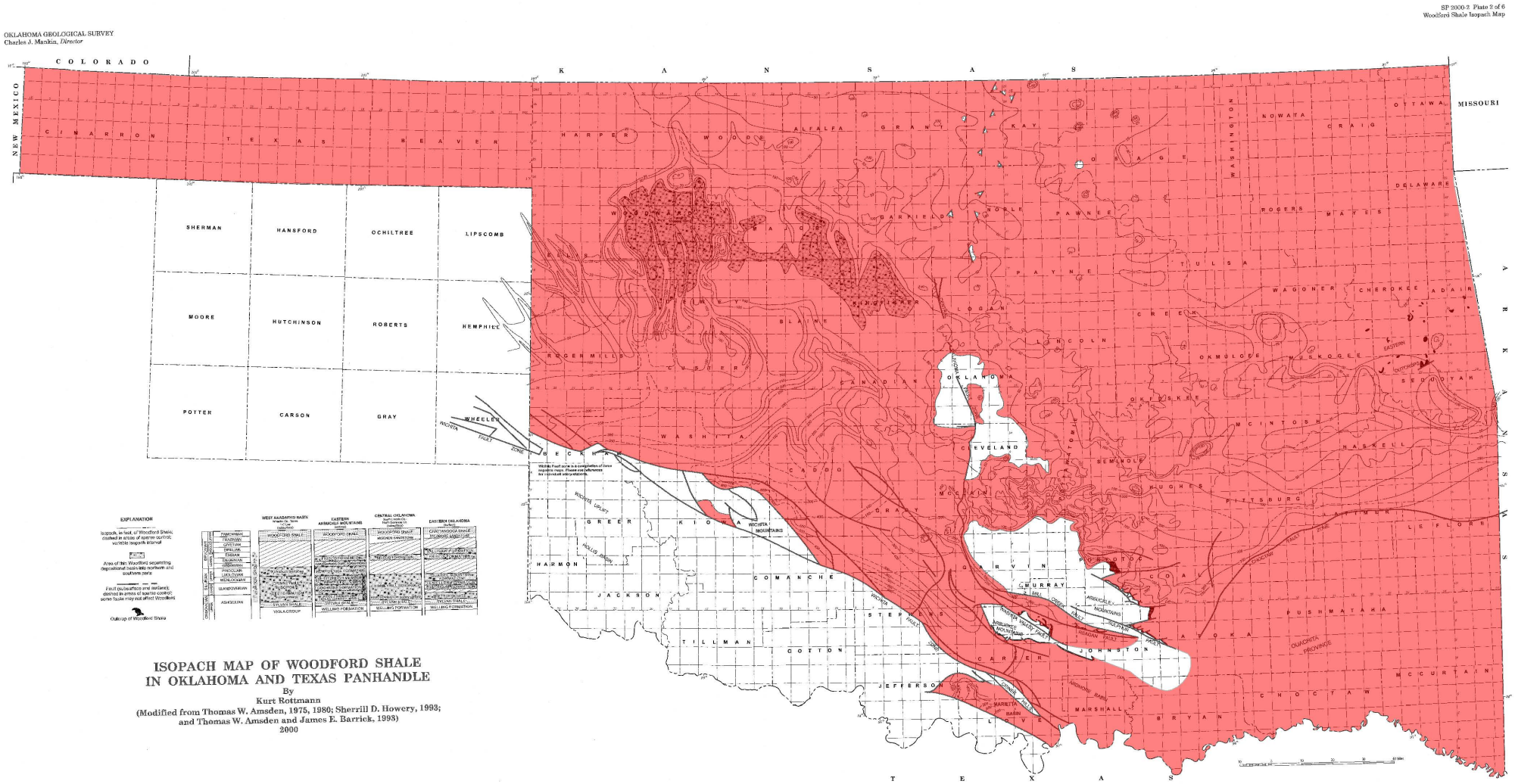
Woodford Shale (Devonian-Mississippian Age)



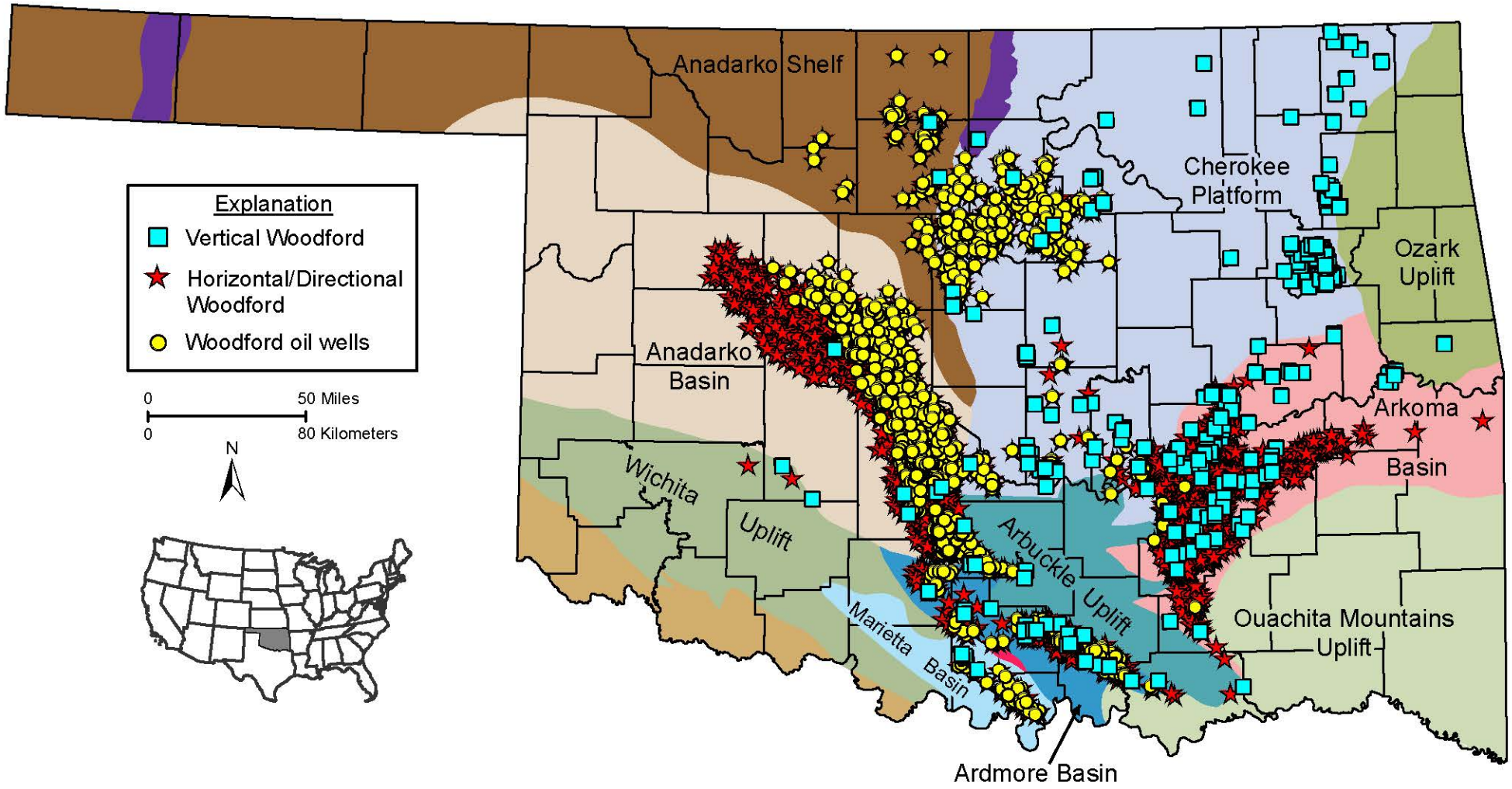
Kerogen Type	II and III
Amount of TOC	<1% – 28%
Maturity	<1% to 6.5% VRo

Modified from Cardott, 2017

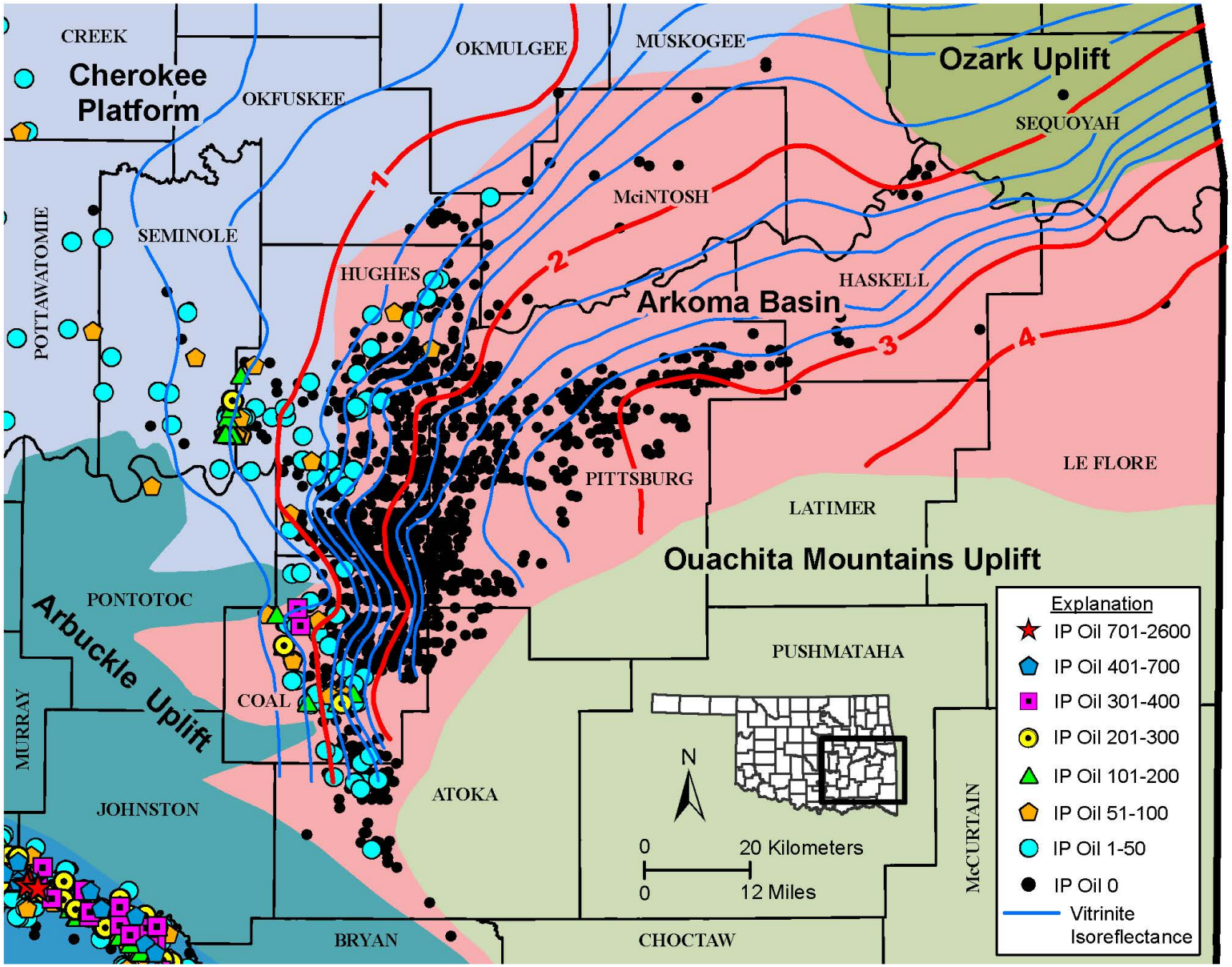
Isopach Map of Woodford Shale



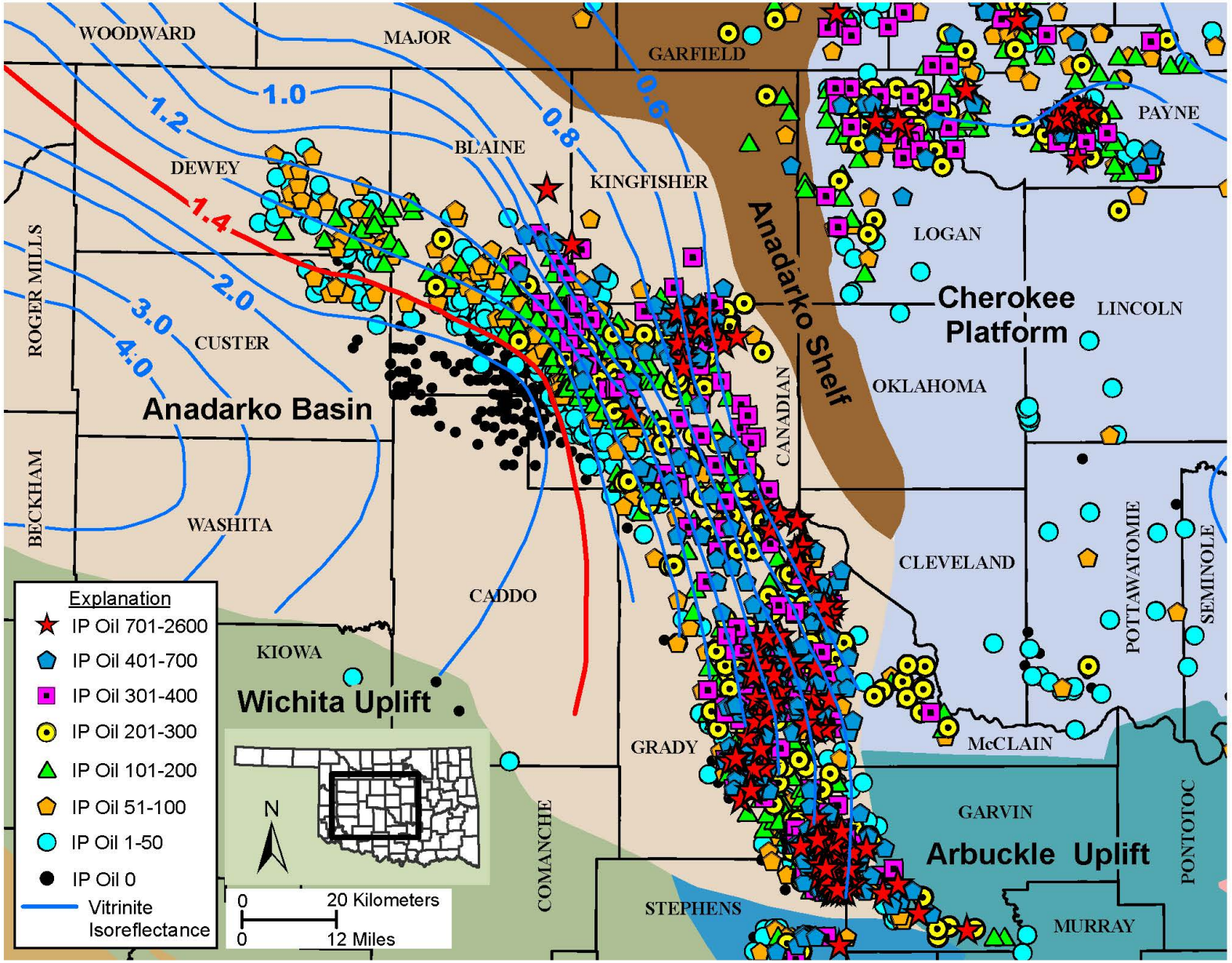
Woodford Shale (2004-2020)



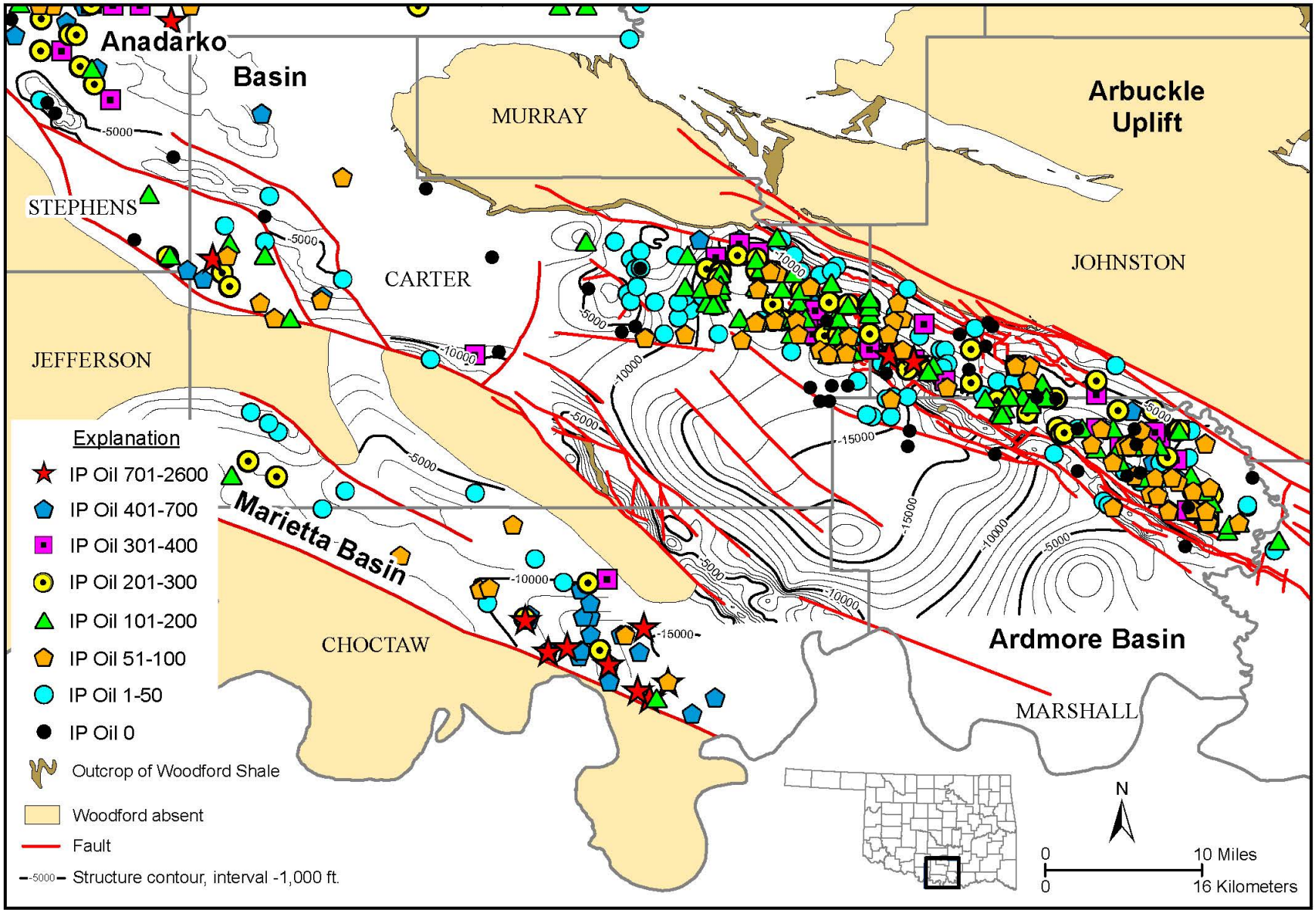
Woodford Shale Arkoma Basin Oil IP



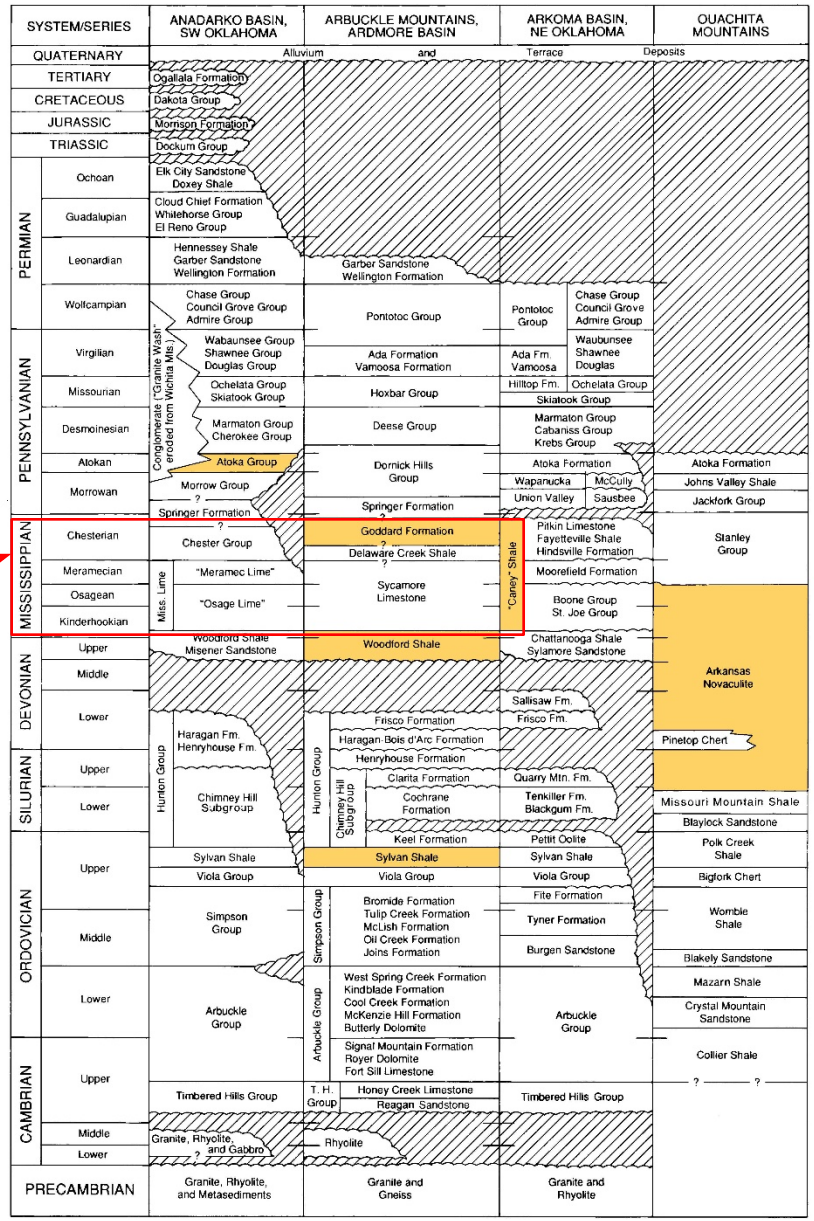
Woodford Shale Anadarko Basin Oil IP



Woodford Shale Ardmore Basin Oil IP



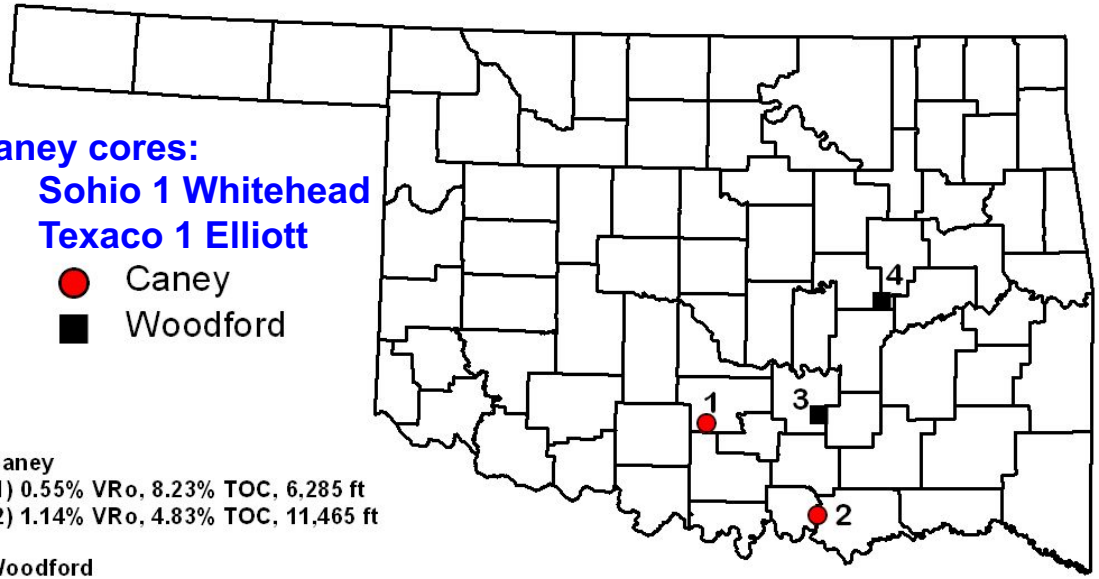
Caney Shale (Mississippian Age)



Modified from Cardott, 2017

[Age equivalent to the Barnett Shale and Fayetteville Shale]

Kerogen Type	II - III
Amount of TOC	~1% – 11.46%
Maturity	0.55 – 1.14% VRo (2 samples)



Caney cores:

1. **Sohio 1 Whitehead**
2. **Texaco 1 Elliott**

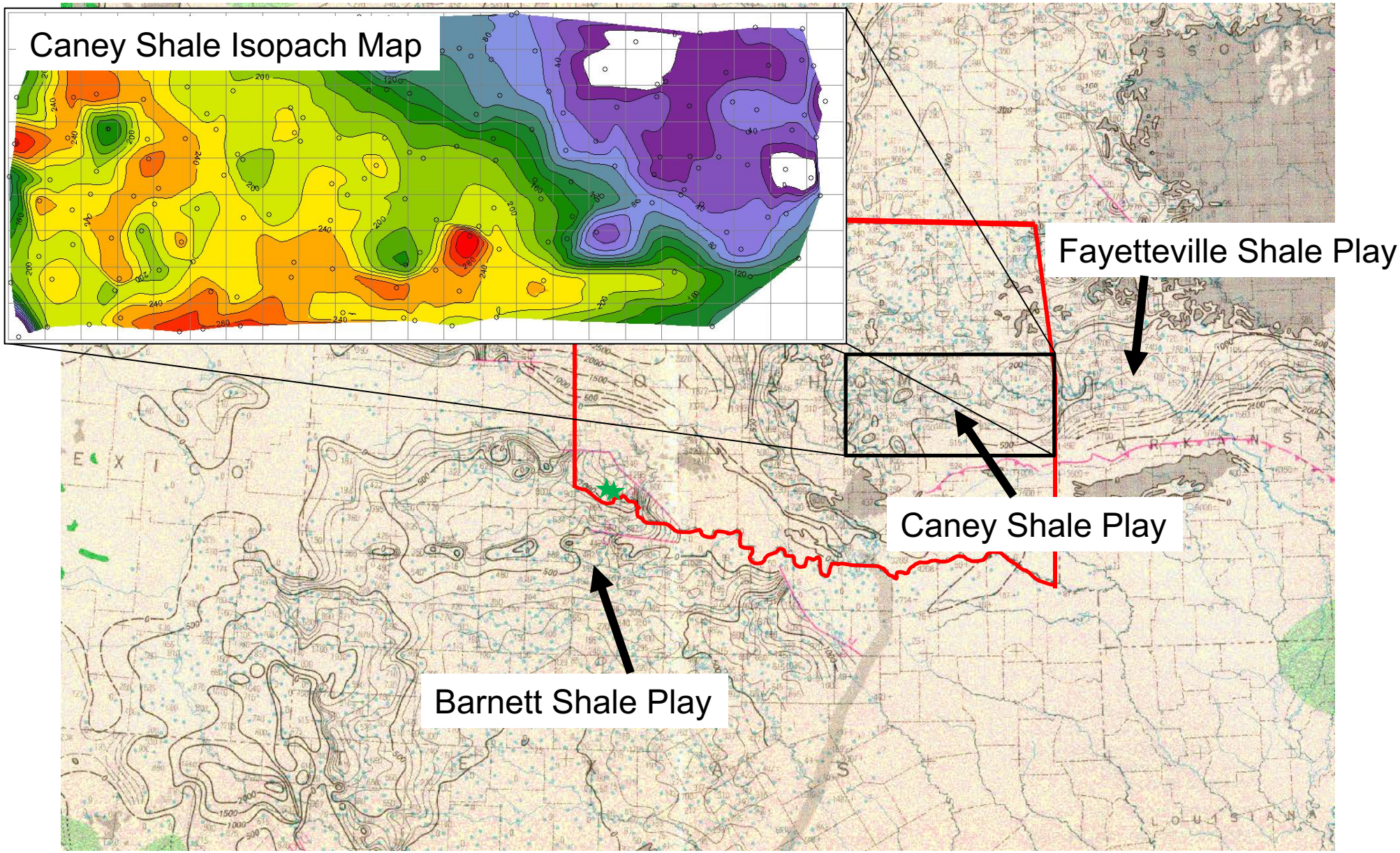
● Caney
■ Woodford

Caney
(1) 0.55% VRo, 8.23% TOC, 6,285 ft
(2) 1.14% VRo, 4.83% TOC, 11,465 ft

Woodford
(3) 0.50% VRo, 7.18% TOC, 3,266 ft
(4) 1.23% VRo, 3.76% TOC, 3,709 ft

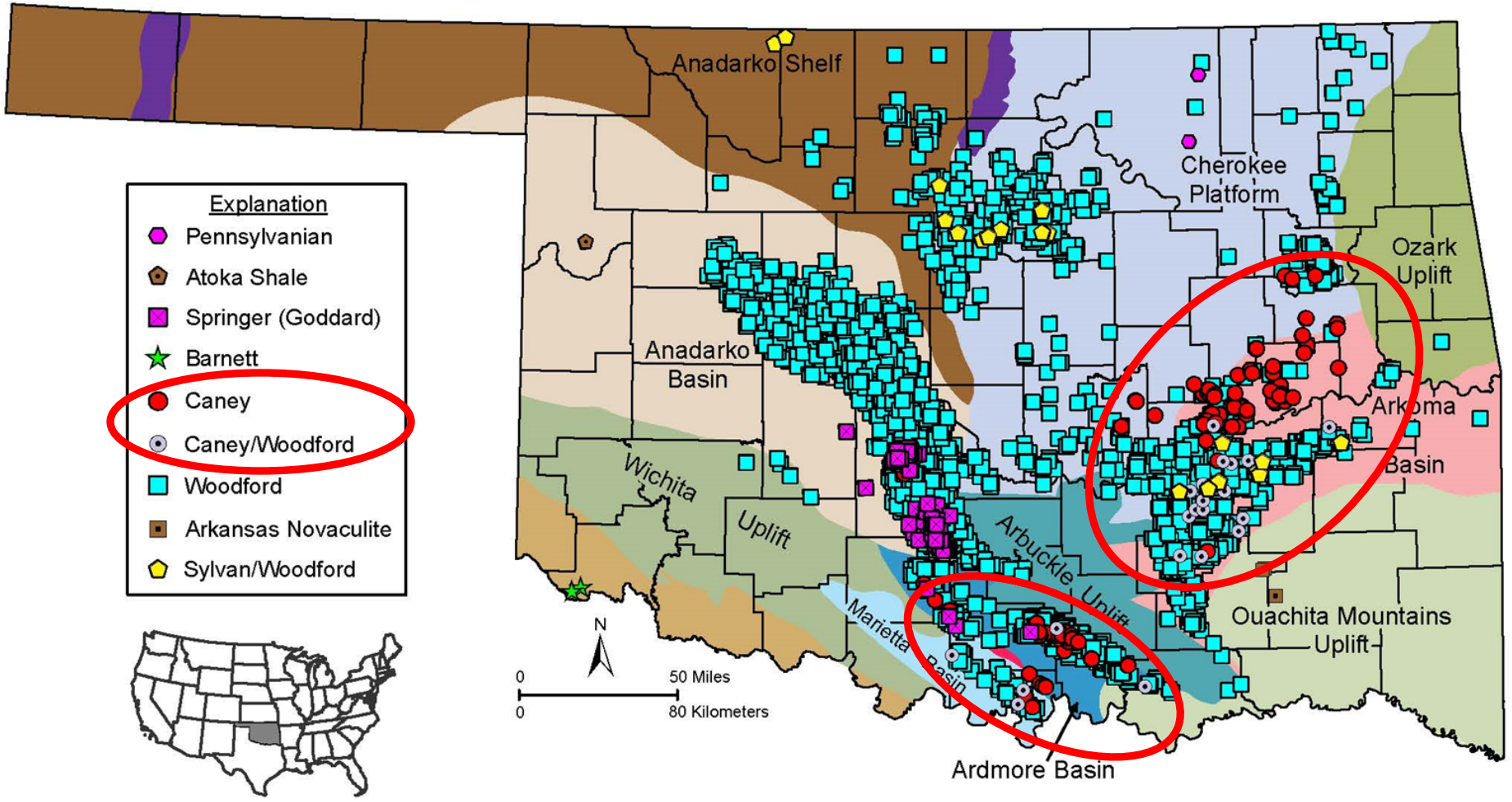
Rock-Eval data compliments of Humble Geochemical Services

Total Mississippian Isopach Map

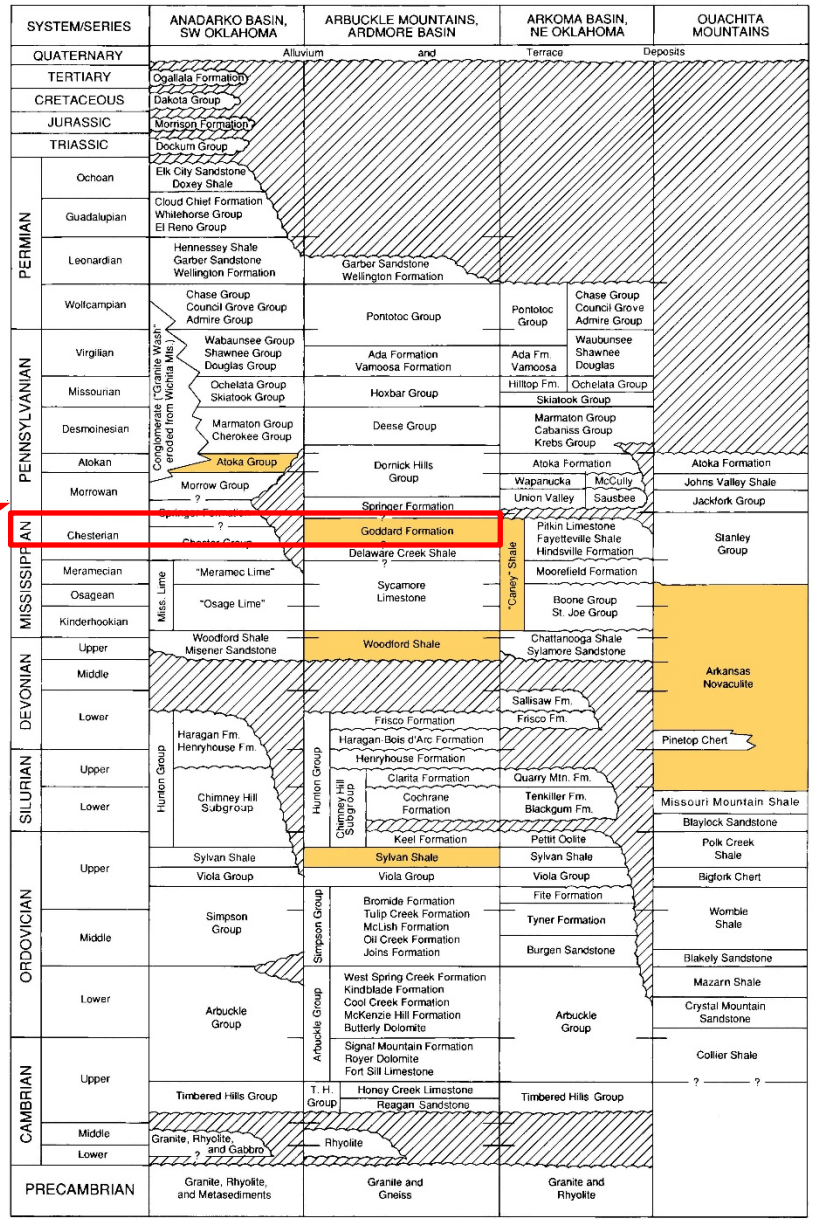


Modified from Schad 2006

Caney Shale (1982 -2020)



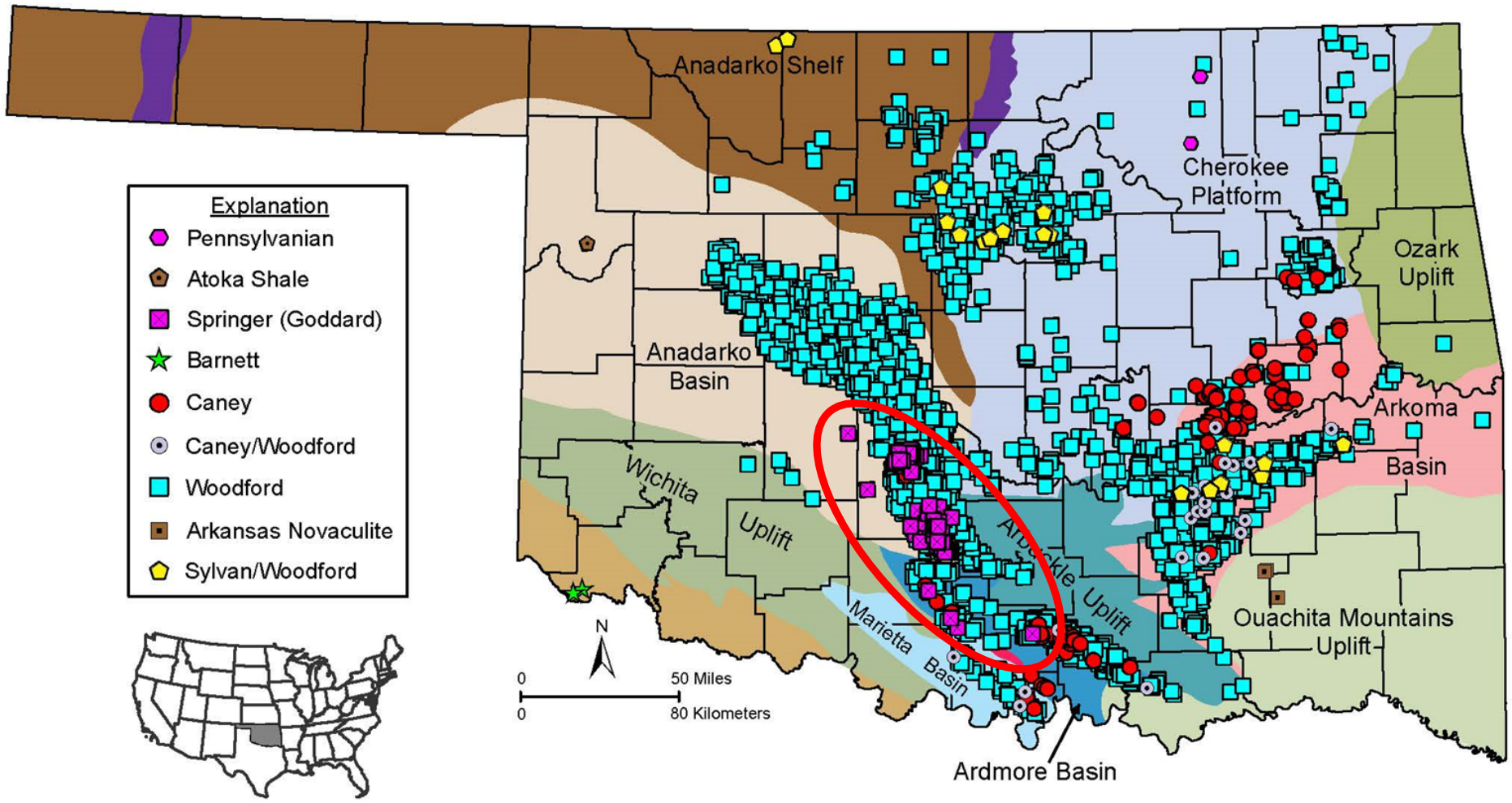
Goddard Formation (Mississippian Age)



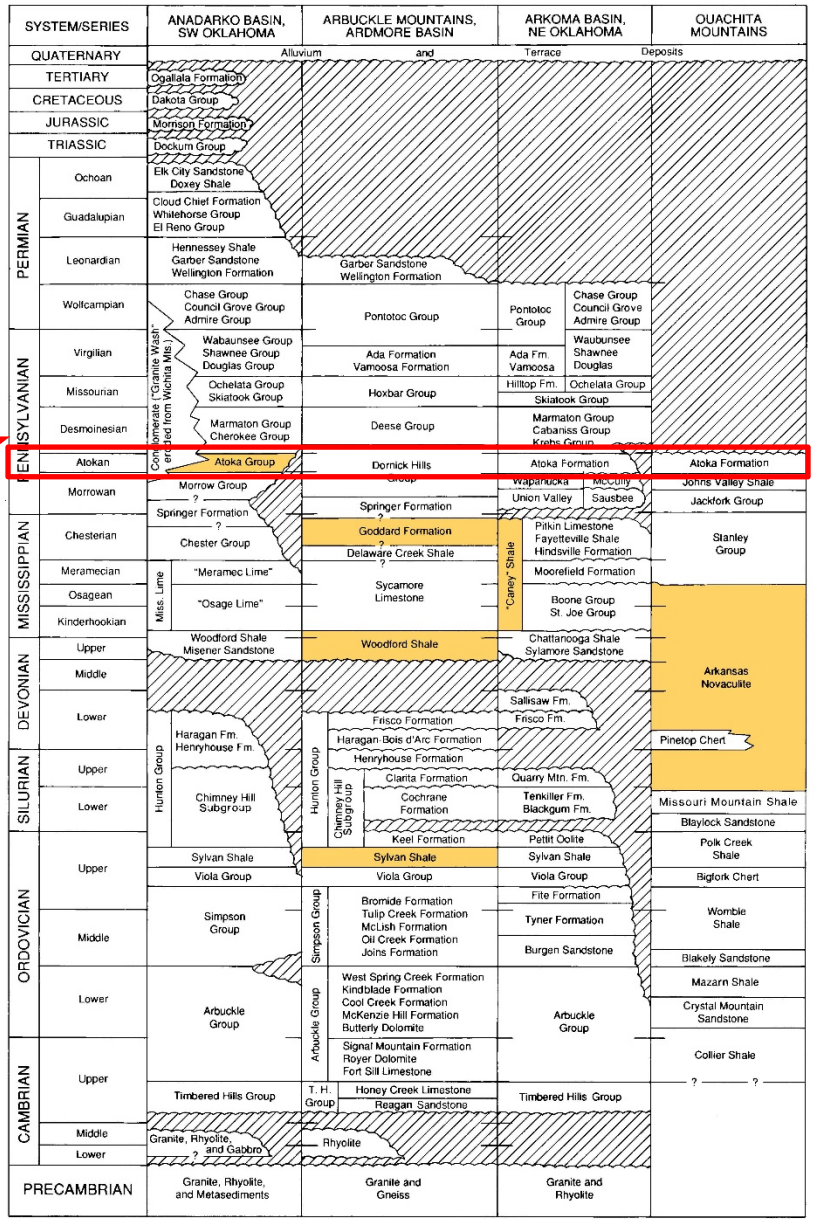
Modified from Cardott, 2017

Pearson, 2016	
Kerogen Type	Mainly Type II and III
Amount of TOC	<1% - 7.77%
Maturity	0.6% - 1.26% VRo

Goddard Formation

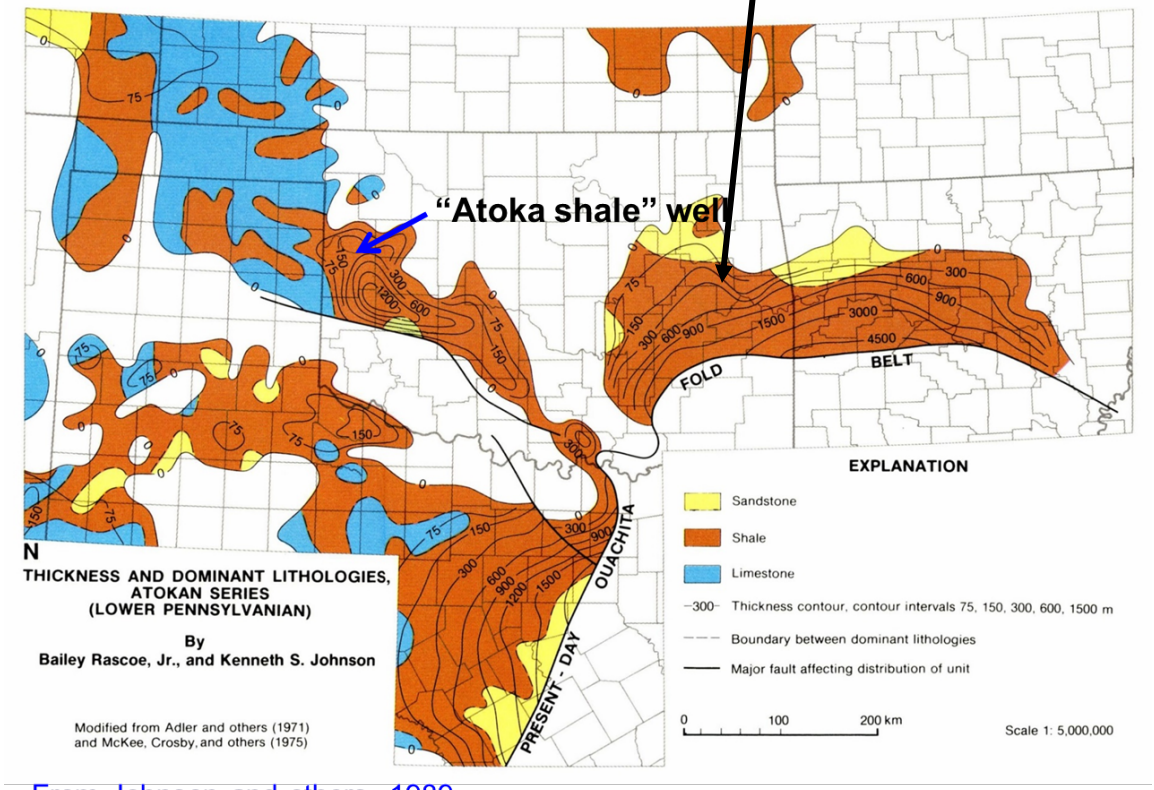


Atoka Shale (Pennsylvanian Age)



Modified from Cardott, 2017

Kerogen Type	**Mainly II and III (Samson, 2005)**
Amount of TOC	**0.22 – 2.92% (Weber, 1992 & Hendrick, 1992)**
Maturity	**<2 - >3.6% VRo (Houseknecht, 1987)**

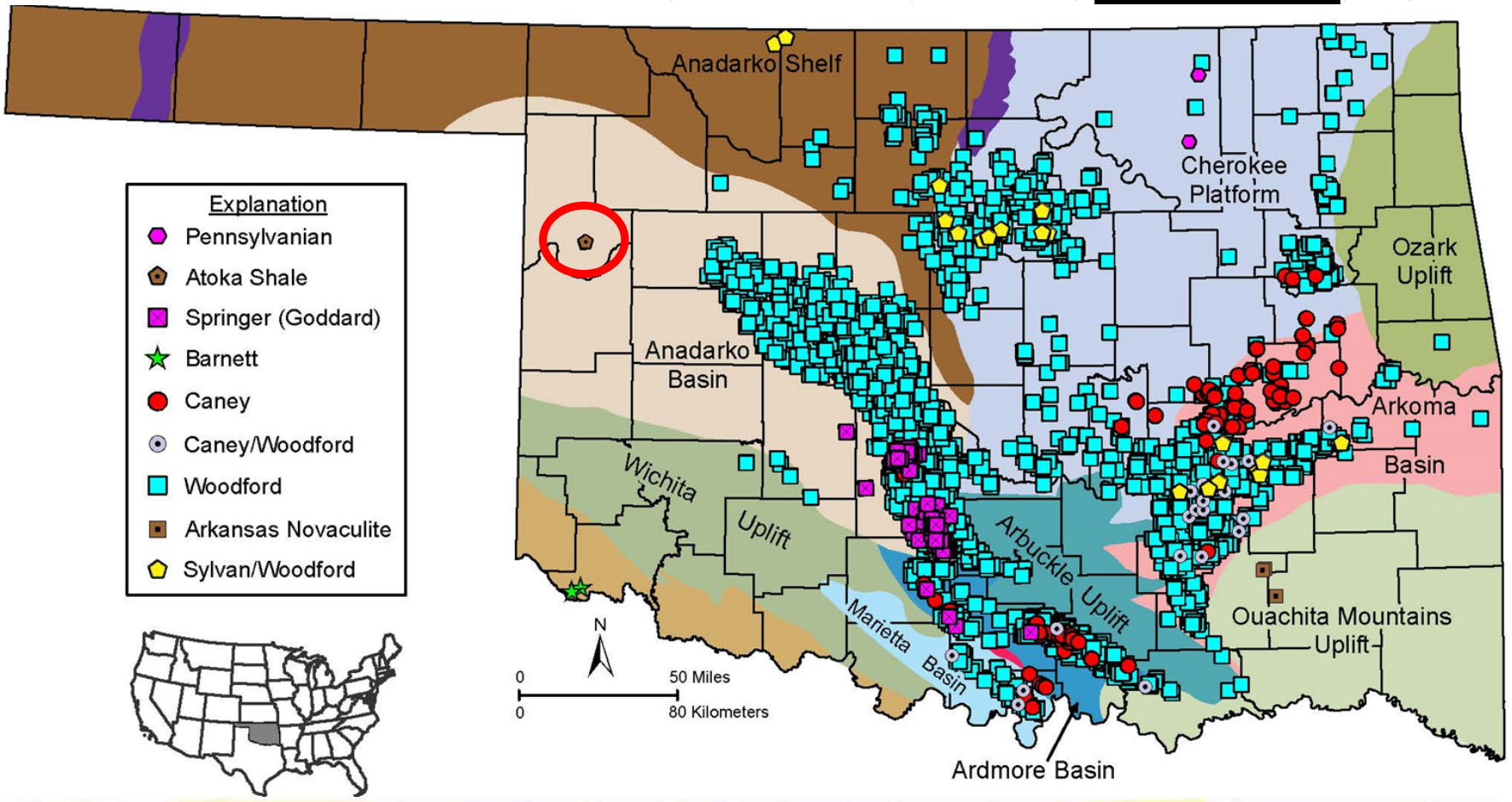


From Johnson and others, 1989

page 29

Atoka Shale (Pennsylvanian Age)

Continental Resources 1-22H Shrewder well; 22-18N-23W; Ellis Co.; "**Atoka Shale**"; 10,926 TVD



An unconventional gas resource play in **Pennsylvanian Atoka shale** is emerging in the **Anadarko** basin in the Texas Panhandle and far western **Oklahoma**. **Continental Resources Inc.**, Enid, Okla., says it has 34,000 net acres in the play as of mid-December 2008. The play stretches about 85 miles from Peek Field in Ellis County, Okla., west to Lipscomb, Ochiltree, eastern Hansford, northeastern Roberts, and northernmost Hemphill counties in the Texas Panhandle. Continental says **EOG Resources Inc.**, Houston, has completed 26 horizontal wells at as much as 7 MMcf/d per well and attributed 400 Bcf of Atoka recovery potential to its 60,000 net acres. **January 7, 2009**

Pennsylvanian Shale (Pennsylvanian Age)

The Relationship between Specific Reservoir Characteristics and the Gas Productive Coals and Carbonaceous Mudstones in the Cherokee Basin*

Steven Tedesco[1]

Search and Discovery Article #10789 (2015)**
Posted November 30, 2015

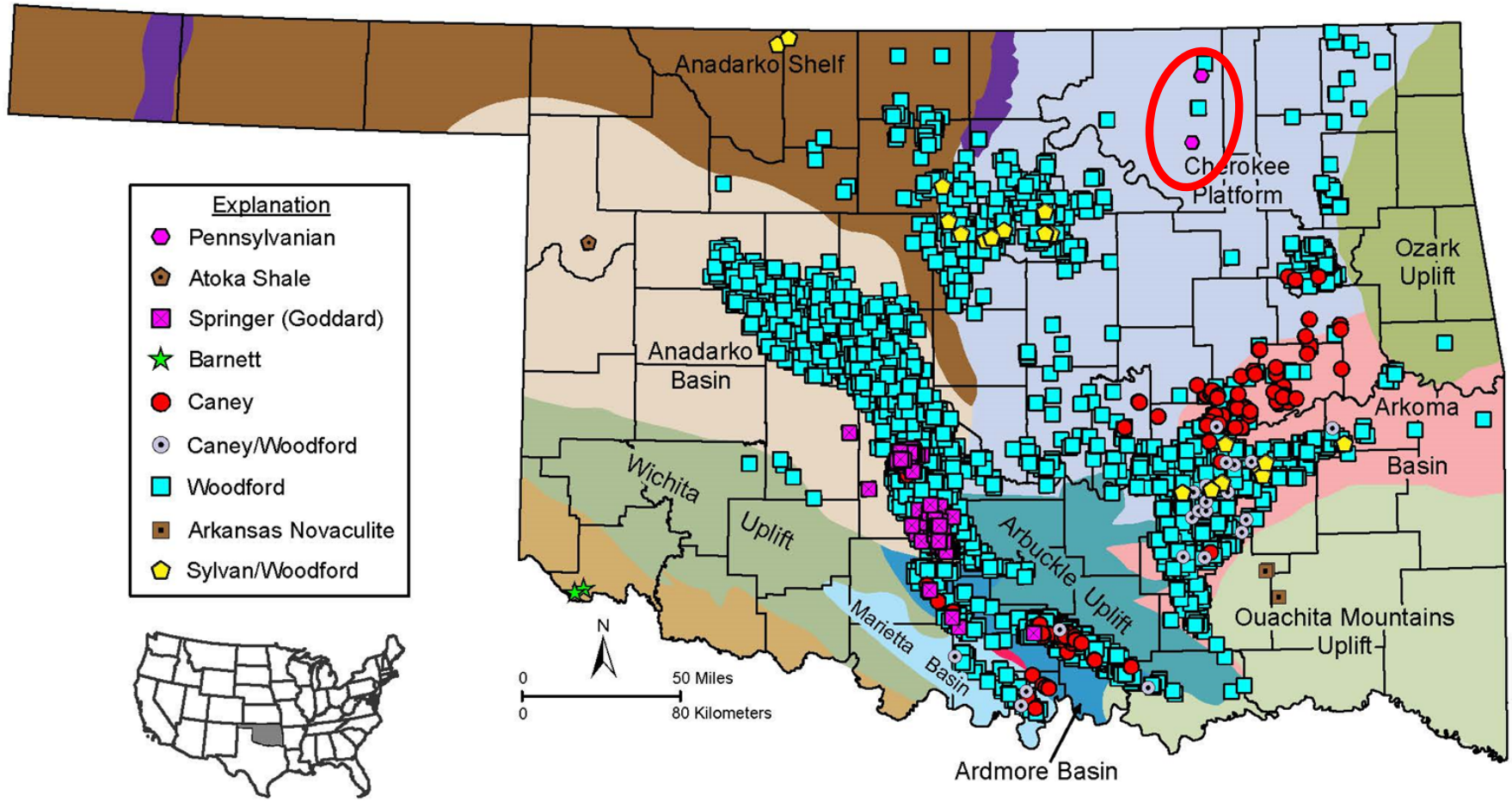
*Adapted from oral presentation given at AAPG Mid-Continent Section meeting in Tulsa, Oklahoma, October 4-6, 2015

[1]Running Foxes Petroleum Inc., Centennial, CO, USA (s.a.tedesco14@runningfoxes.com)

Abstract

The Cherokee Basin is a shallow intracratonic basin that has significant gas production from the Desmoinesian and Atokan age Cherokee Formation coals and carbonaceous mudstones at less than 2,000 feet. The Cherokee Group's coals in the Cherokee Basin were deposited on an abandoned deltaic surface in a coastal setting. Only specific coals, the Mulky, Weir-Pittsburgh, Rowe and Riverton and the Excello Shale within the Cherokee Formation are generally productive whereas the remaining seams and carbonaceous shale are not productive. The basin was subject to thermal maturation in late Pennsylvanian and Permian time caused by expulsion of low temperature hydrothermal fluids from the Anadarko, Ardmore and Arkoma basins that migrated north through the Cherokee Basin into the Forest City Basin. Proximate analysis of the coals indicates that select seams are gas productive due to higher sulfur contents, which allowed hydrocarbon generation at lower temperatures. The Excello Shale is productive because it has over 50% quartz-carbonate minerals making it more brittle allowing hydraulic fracturing stimulation to be effective. The main productive area is in the central part of the basin and is related to the apex of the Silurian-Devonian age Chautauqua Arch. By mapping sulfur trends in coals and quartz-carbonate percentage content trends in carbonaceous mudstones allows a more definitive method to identify areas that will be gas productive.

Pennsylvanian Shales (NE OK)

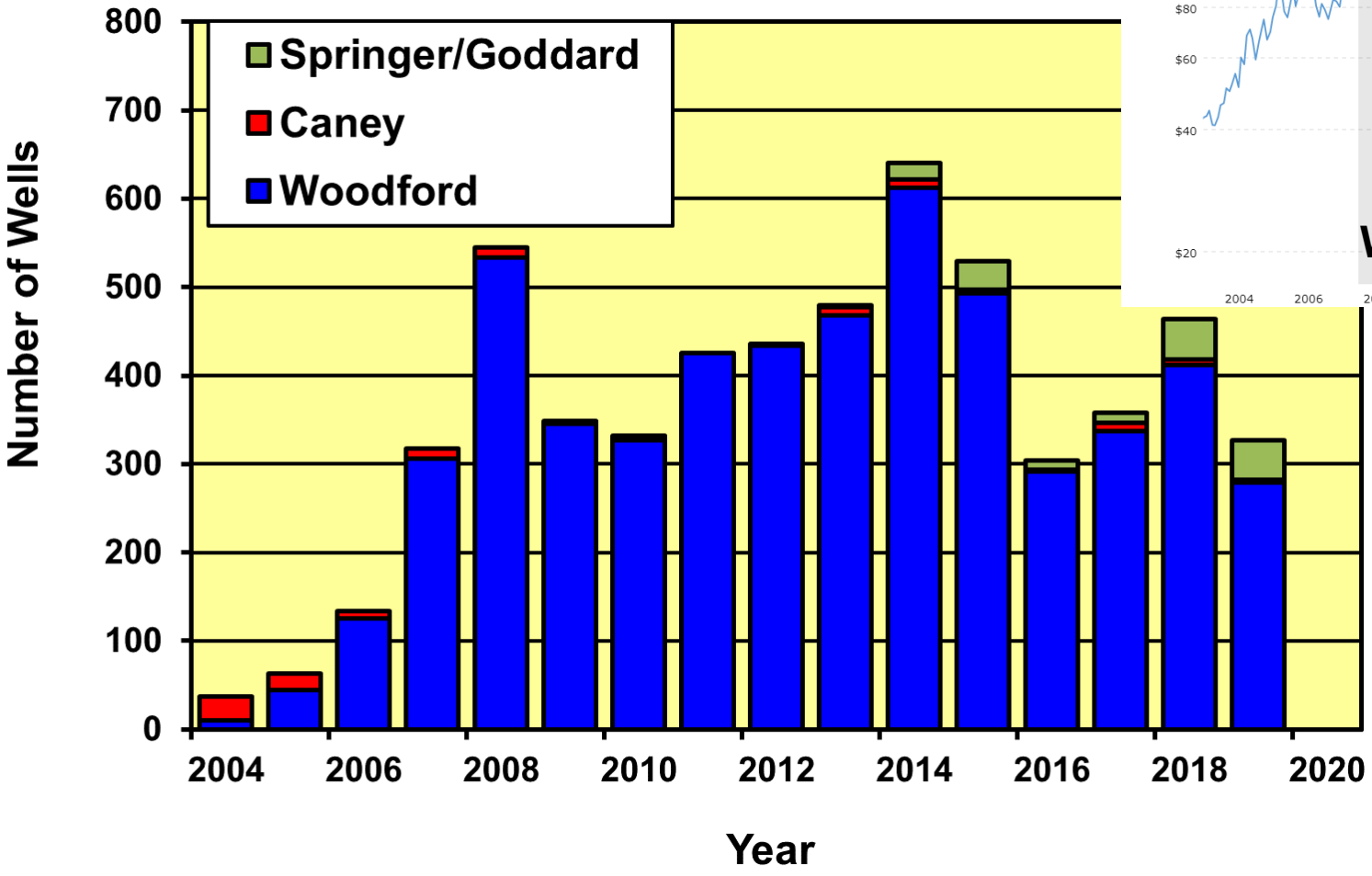


Tedesco, 2015	
Kerogen Type	II, III, and IV
Amount of TOC	<1% - ~12%
Maturity	0.45 – 0.76% VRo

Oklahoma Shale Oil and Gas Well Completions History

5445 Woodford + 131 Caney + 166 Springer/Goddard Wells

2004–2019



All shales are different and complex