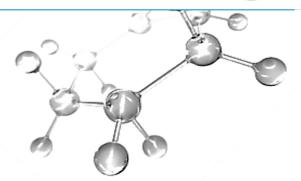
Proudly Serving Oklahomans Since 1908



An Overview of Oklahoma Shale Resource Plays

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

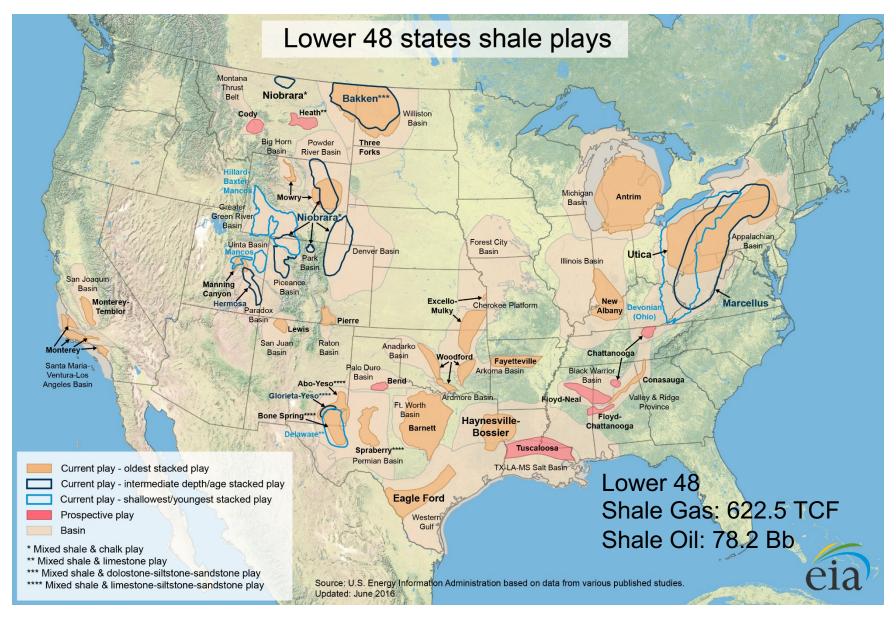
Agenda



- 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

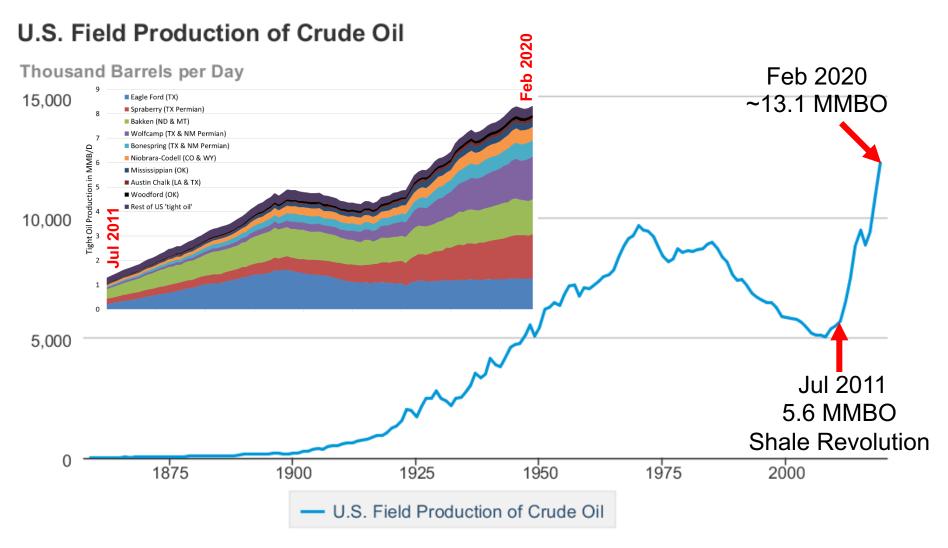
Shale Resource Plays - What has been found?





Why are shale resources important?

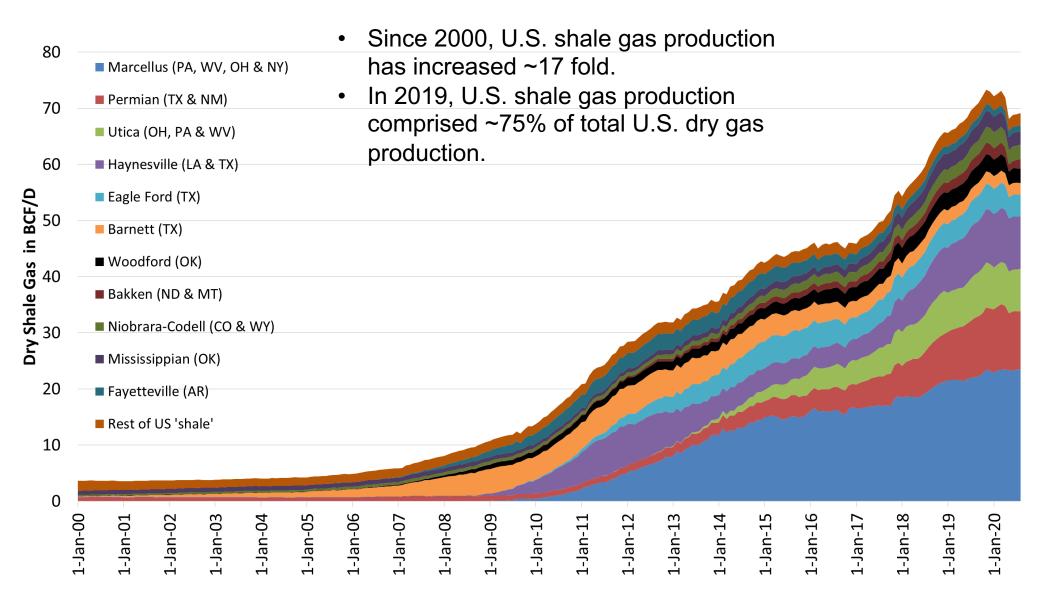






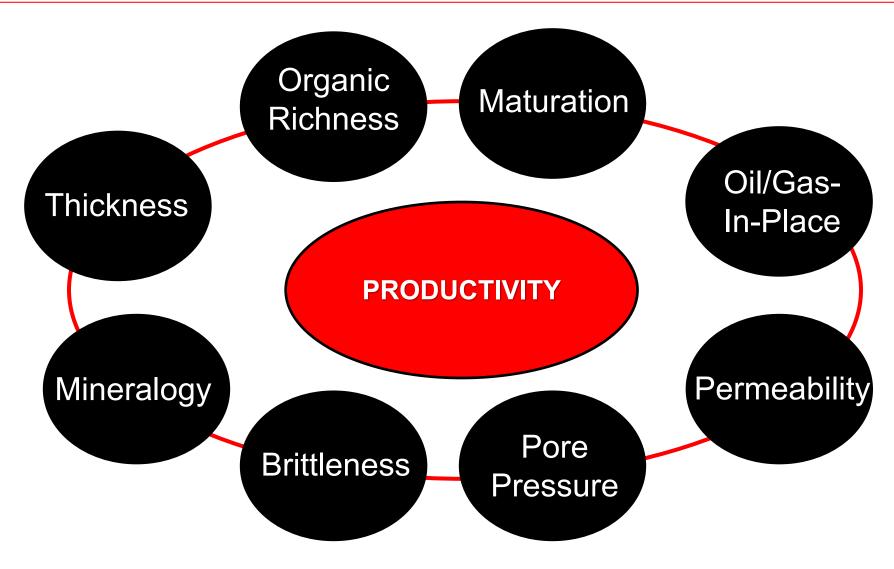
Why are shale resources important?





Key Elements of Successful Shale Resource Plays





Ardmore and Marietta Basins Oil and Hydrocarbon Source Rock Study



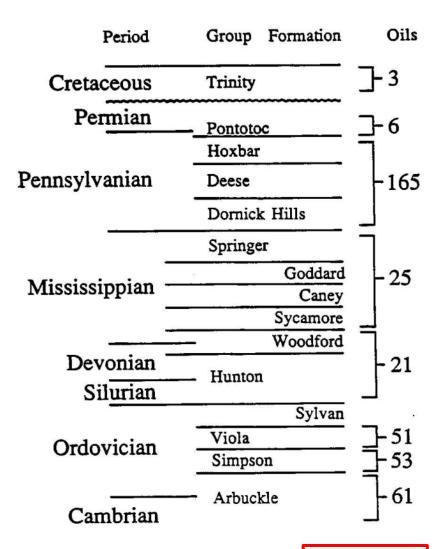


Figure 2. Stratigraphic distribution of 385 oil samples.

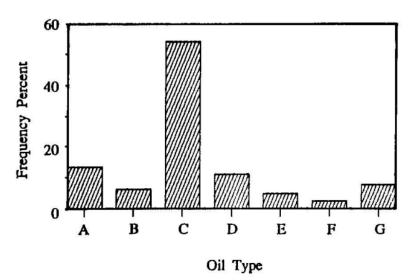


Figure 11. Frequency distribution of oil types reservoired in the Ardmore and Marietta basins.

Source Facies:

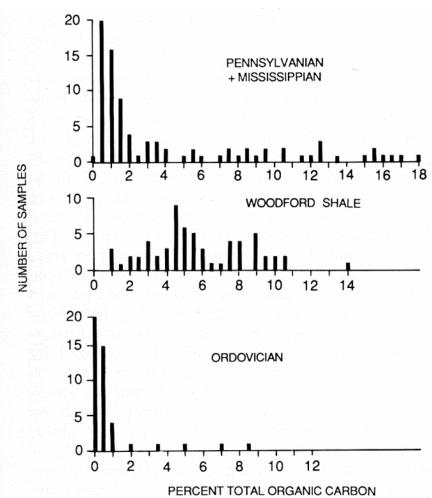
Α	Pennsylvanian (Atoka?)
В	Mississippian (Goddard, Caney, Sycamore)
С	Devonian-Mississippian (Woodford)
D	Upper Ordovician (Viola Group)
E	Middle Ordovician (Simpson Group)
F&G	Mixed

Wavrek, 1992

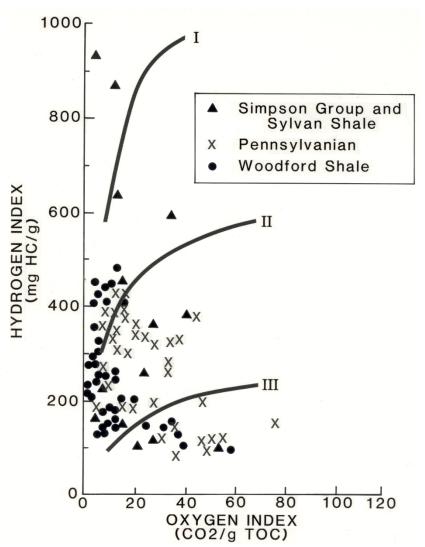
Anadarko Basin Oil and Hydrocarbon Source Rock Study



Anadarko Basin Source-Rock TOC

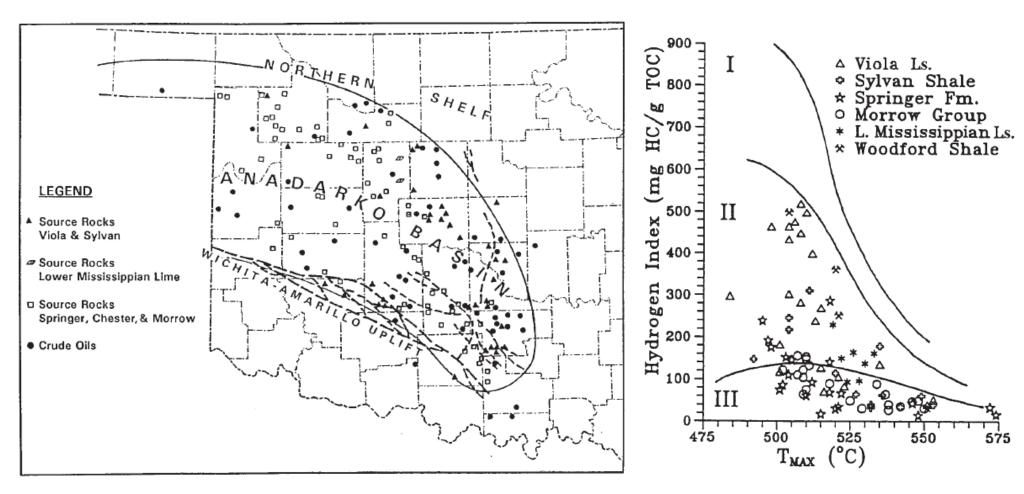


Van Krevelen Type Diagram



Anadarko Basin Oil and Hydrocarbon Source Rock Study

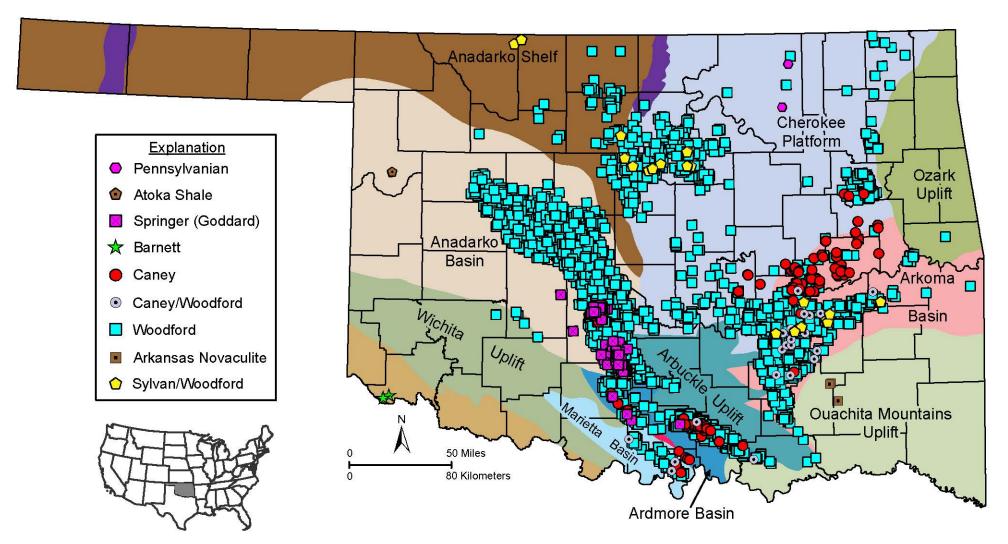




Wang and Philp, 1997

Oklahoma Shale Gas/Oil Completions (1939-2020)





5,907 completions

Sylvan Shale (Ordovician Age)



SY	STEM/SERIES	SERIES ANADARKO BASIN, SW OKLAHOMA			ARBU	CKLE MOUNTAINS, RDMORE BASIN	ARKON NE OK	MA BASIN, ILAHOMA	OUACHITA MOUNTAINS	
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	JURASSIC	120	77777///////		///		Y //			X/////////////////////////////////////
	TRIASSIC	22	mson Formation				<i>\//</i>			
_	THIASSIC	-22	ckum Group	///	///		W.			X/////////////////////////////////////
	Ochoan		City Sandstone Doxey Shale							
AN I	Guadalupian	Wh	ud Chief Formation ilehorse Group Reno Group							
PEHMIAN	Leonardian		Hennessey Shale Garber Sandstone Wellington Formation	1/2		per Sandstone ington Formation				
	Wolfcampian		Chase Group Council Grove Group Admire Group			Pontotoc Group	Pontotoc Council Grove Admire Group			
-	Virgilian	te Wash	Wabaunsee Group Shawnee Group	F		Ada Formation	Ada	a Fm.	Waubunsee Shawnee Douglas	
Ž.	Missourian	("Granite	Douglas Group Ochelata Group	-		amoosa Formation Hoxbar Group		moosa op Fm.	Ochelata Group	
Ľ,	Missouliali		Skiatook Group						ok Group ton Group	
PENNSYLVANIAN	Desmoinesian	Conglomerate	Marmaton Group Cherokee Group			Deese Group		Cabani Krebs (ss Group	
2	Alokan	3	Atoka Group	Dornick Hills			Atoka F	ormation	Atoka Formation	
7	Morrowan	Morrow Group				Group		apanucka		Johns Valley Shale
		Sp	ringer Formation			Springer Formation	27	ion Valle	y Sausbee)	Jackfork Group
MISSISSIFFIAIN	Chesterian	-	? Chester Group			Goddard Formation	ale	Fayette	imestone eville Shale ille Formation	Stanley Group
5	Meramecian	9	"Meramec Lime"				y-Shale		lield Formation	
2	Osagean	Lime				Sycamore — Limestone	Caney	Box	one Group	
Š	Kinderhookian	Miss.	"Osage Lime"				St. Joe Group			
	Upper	5	Woodford Shale — Misener Sandstone			Woodford Shale	Ę.	Chattan Sylamore	ooga Shale — Sandstone	
CEVONIAN	Middle							7777		Arkansas Novaculite
Ž l		- //		6	Frisco Formation		Sallisaw Fm.			Novacome
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ا د			Haragan Fm.		Hara	gan-Bois d'Arc Formation	177	7777	777////	Pinetop Chert Z
-	2011	물	Henryhouse Fm.	Group	\sim	enryhouse Formation	1//	////	//// //	
Š	Upper	Ğ	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	ğ		Clarita Formation	Quarry Mtn. Fm.		.Fm. \///	1
5		Hunton Group	Chimney Hill Subgroup	Hunton	Y dno	Cochrane		Tenkiller	Fm.	Missouri Mountain Sha
3 1	Lower	Ī	Subgroup (Ĭ	page	Formation		Biackgun		Blaylock Sandstone
-		1	V		Chimney Hill Subgroup	Keel Formation	442	ZZZZ Pettit O		Polk Creek
╛		Ì	Sylvan Shale Y			Sylvan Shale		Sylvan S		Shale
	Opper		Viola Group			Viola Group		Viola G	roup 🕢	Bigfork Chert
=			- x8 ii	ਰ		Bromide Formation		Fite Fo	rmation	1
NECONO	Middle		Simpson Group	Simpson Group		Tulip Creek Formation McLish Formation Oil Creek Formation		Tyner Fo	rmation	Womble Shale
₹ [Simit		Joins Formation		Burgen S	Sandstone	Blakely Sandstone
5			-01/1	g.	We:	st Spring Creek Formation Iblade Formation			¥	Mazarn Shale
	Lower		Arbuckle Group	Group	Moh	l Creek Formation Cenzie Hill Formation			ouckle	Crystal Mountain Sandstone
\dashv				rbuckle	Butterly Dolomite Signal Mountain Formation		Group			Collier Shale
2	Upper				Fort	er Dolomite Sill Limestone				? ?
CAMBRIAN		22	Timbered Hills Group	T. H Grou		Reagan Sandstone	1	imbered	Hills Group	
ξŀ	Middle	1 <u>/</u> /	pite Bhyolite	1/	44	4////////	1//	////		1
1	Lower	Grai	nite, Rhyolite, and Gabbro	<u>_</u>	hyolite	~~~	1//	////		1
	ECAMBRIAN		Granite, Rhyolite, and Metasediments	~	je je je	Granile and Gneiss			nite and nyolite	

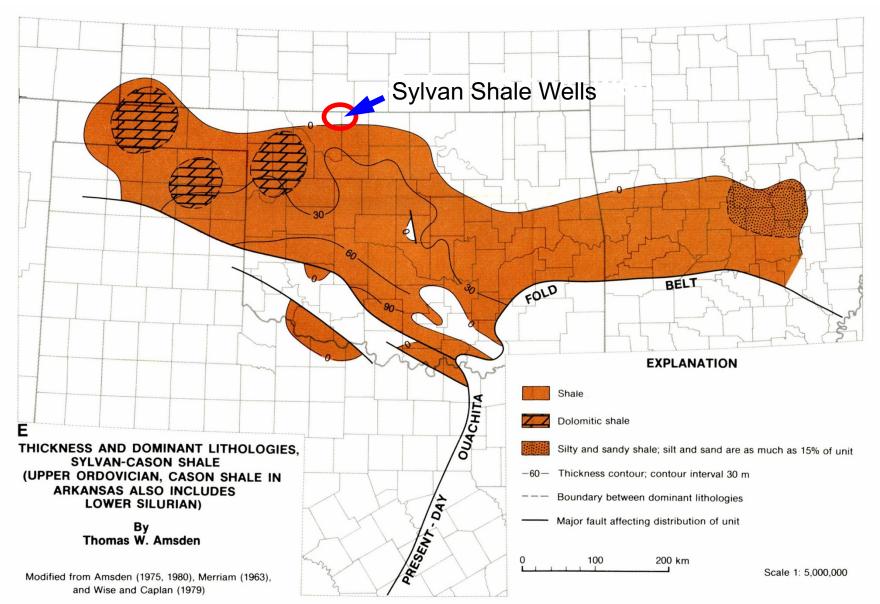
Kerogen Type	II (Burruss and Hatch, 1989) III (Wang 1993)
Amount of TOC	<1% (Wang, 1993)
Maturity	>0.5% VRo

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."

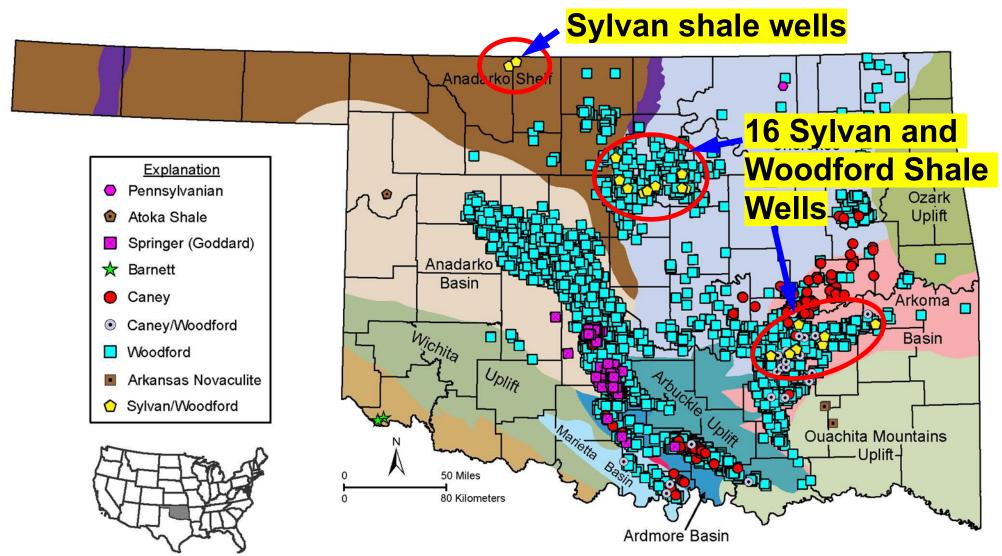
Sylvan Shale Isopach Map





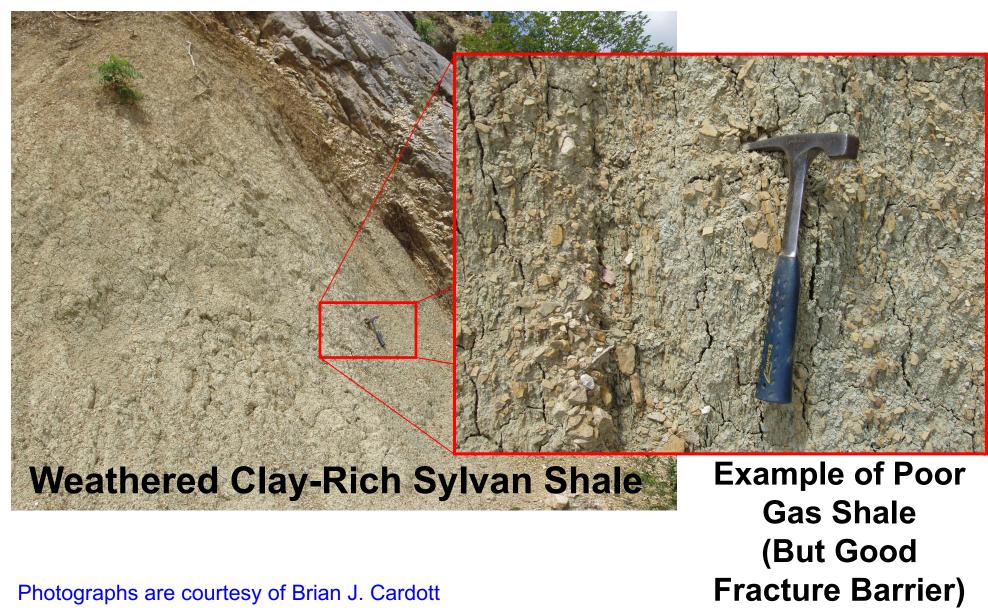
Sylvan Shale Wells [2008-2020]





Sylvan Shale in the Arbuckle Mountains



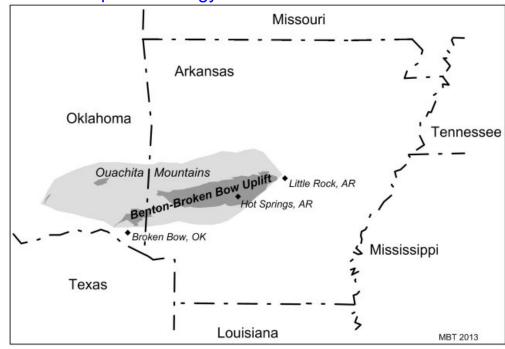


Arkansas Novaculite (Silurian-Mississippian Age)



SY	YSTEM/SERIES ANADARKO BASIN, SW OKLAHOMA			AHOMA ARDMORE BASIN NE OKLAHOMA							OUACHITA MOUNTAINS								
QUATERNARY Alluv										Deposits									
	TERTIARY	Oga	Ilala Formation	<i>\//</i>	///		<i>{//</i>	////	//		X/////////////////////////////////////								
С	RETACEOUS	-	ota Group	X//	///		Y //	////	//		X/////////////////////////////////////								
	JURASSIC	177	~~~~~~//////		///		Y //		//		X///////////								
	TRIASSIC	122	rison Formation	1//			<i>\//</i>			/////	X/////////////////////////////////////								
	THIASSIC	-22	kum Group	X//			<i>\//</i>		//		X////////////								
	Ochoan		City Sandstone Doxey Shale																
IAN	Guadalupian	Whi	ud Chief Formation dehorse Group Reno Group																
PERMIAN	Leonardian		Hennessey Shale Garber Sandstone Wellington Formation	1//		er Sandstone ngton Formation													
	Wolfcampian	5	Chase Group Council Grove Group Admire Group			Pontotoc Group	Po G	ntotoc	Co	ase Group uncil Grove mire Group									
		Wash.	Wahaunsee Group							aubunsee	\/////////////////////////////////////								
z	Virgilian	10-	Shawnee Group Douglas Group		W	Ada Formation moosa Formation		a Fm. moosa		awnee uglas									
≨ ŀ		(*Granite	Ochelata Group	+				op Fm.	_	nelata Group									
3	Missourian					Hoxbar Group		Skiato			1//////////////////////////////////////								
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Ź	Alokan	ન્ફું ફ	Atoka Group	1		Dornick Hills	\vdash	Atoka F	_		Atoka Formation								
2		25	Morrow Group			Group			McCully (Johns Valley Shale									
	Morrowan	morrowati ?		_		Springer Formation		nion Valle		Sausbee	Jackfork Group								
_		Spi	ringer Formation	+	_	_?	ZZ	Pitkin I	Z2	22777 etopo									
8	Chesterian Che		Chester Group	1		Goddard Formation		Fayette	eville	Shale	Stanley								
1		-		1	Del	aware Creek Shale	Shale		_~	ormation	Group								
Ž.	Meramecian	활	"Meramec Lime"	Υ	C		1	Mooret	ield	Formation									
20	Osagean	9	"Osage Lime"	\Box		Limestone	Cai			Group _									
Ē	Kinderhookian	Miss.	oody cano						Joe	Group									
_		\vdash	Woodford Shale -			Woodford Shale		Chattan	00g	Shale -	+								
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4	Lower	~	~~~~~~	The	Frisco Formation		Frisco Fm.		Y///	1									
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AN	Upper	Gro⊔p		Group	H	enryhouse Formation	7//////////////////////////////////////]///7									
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3	Lower	F.	Chimney Hill Subgroup	F.	ron	Cochrane Formation		Tenkiller Blackgun		. \//	Missouri Mountain Sha								
7		-	V V	1	Chimney Subgro		77	ZZZZ	-	77///	Blaylock Sandstone								
		1_	7	1	్రా	Keel Formation		Pettit O	olite	~4/7	Polk Creek								
	Upper	L	Sylvan Shale											Sylvan Shale		Sylvan S		· //	Shale
	Орреі	_	Viola Group	1_		Viola Group	<u> </u>	Viola G	~	~~~~//	Bigfork Chert								
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žί				Si m		Joins Formation	L	Burgen S	sano	stone {	Blakely Sandstone								
δ			-44	1	Wes	Spring Creek Formation				{\}	Mazarn Shale								
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CAMBRIAN		77	77777777777	777	177	7777777777	17	7777	77	77777	1								
3	Middle	Grar	nite, Rhyolite, and Gabbro		hyolite	~{////////	W	////	//	/////	3								
			and Gabbro \	<i>T</i> .		~////////	V/	////	//	/////	1								
	Lower	PRECAMBRIAN Granite, Rhyolite, and Metasediments		177	ZZZ		122	411	//		4								

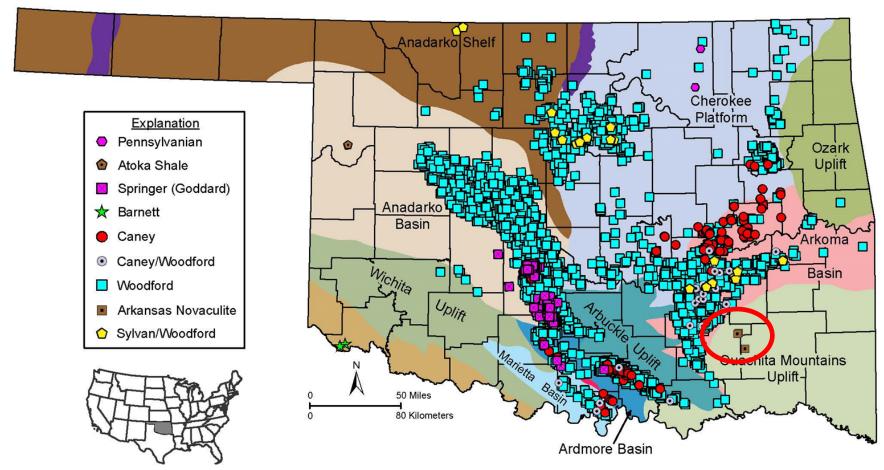
Source: http://archeology.uark.edu/novaculite/index.html



Kerogen Type	II and III (Johnson and Cardott,						
Kerogen Type	1992)						
Amount of TOC	< 1% - 12.5% (Cardott 1994, Weber						
Amount of 10C	1992, 1994, Godo et al. 2011)						
	< 0.62% VRo (Cullen and Miller,						
Maturity	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)





Woodford Shale (Devonian-Mississippian Age)

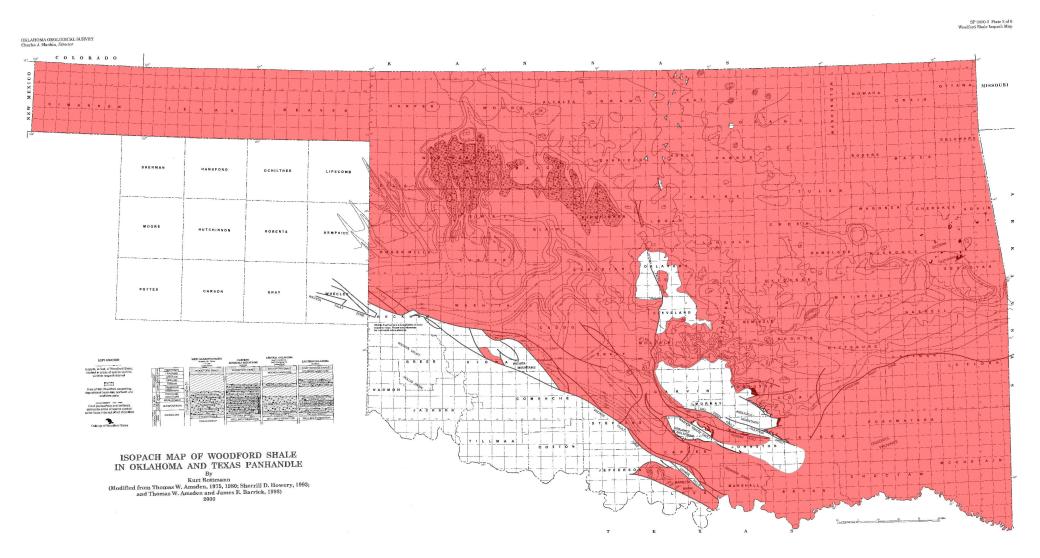


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SY	SYSTEM/SERIES ANADARKO BASIN, SW OKLAHOMA			ARBUCKLE MOUNTAINS, ARDMORE BASIN				IA BAS LAHOI		MOUNTAINS	
QUATERNARY Alluv			vium	~	and	Te	errace	~~	D	eposits	
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С	RETACEOUS	Dak	ota Group	<i>\//</i>	///		1///	///			
	JURASSIC	Mor	rison Formation	W.	///			///	////		
	TRIASSIC	77 Do	kum Group	1//	///			///			
		122	City Sandstone	<i>\//</i>	///		(///	///	////		
	Ochoan	LIK	Doxey Shale					///			
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ERMIAN	Guadalupian		Reno Group	///					///	////	
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Ë	Leonardian		Garber Sandstone Wellington Formation			per Sandstone ington Formation					
_		\vdash	Chase Group	\vdash	****	ingion i ciniation	422	4	Chase	Group	
	Wolfcampian	\setminus	Council Grove Group Admire Group			Pontotoc Group	Pontotoc		Counci	Grove	
		- €	W-b	+		_	Grou	up	Waubu		
_	Virgilian	Granite Wash	Shawnee Group			Ada Formation	Ada F		Shawn	ee	
¥.		anite	Douglas Group	ļ		amoosa Formation	Vamo		Dougla		
AN	Missourian		Ochelata Group Skiatook Group			Hoxbar Group	Hilltop		ochelat k Group	a Group	
PENNSYLVANIAN		Conglomerate	Varmoten Creus						on Grou		
₹	Desmoinesian	lome	Marmaton Group Cherokee Group			Deese Group	1 5	Cabanis Krebs G	ss Group		
ž	Alokan	lo g	Atoka Group	F		Dornick Hills			ormation	- 2//	Atoka Formation
2		عسا	Morrow Group	+		Group		anucka		Cully	Johns Valley Shale
	Morrowan	-	—? <i>——9///</i> /	\vdash		Springer Formation		n Valley		sbee	Jackfork Group
7		Sp	ringer Formation			_?	FZZ.	Pitkin L	imestor		
¥	Chesterian		Chester Group			Goddard Formation	1	Fayette	ville Sh	ale `	Stanley Group
鱼	Meramecian	╁	"Meramec Lime"	_	De	laware Creek Shale	100		eld Forn	~~~	Gioup
MISSISSIPPIAN		Lime	Meramec Line	-		Sycamore	Caney	MOOIBII	~~~	~~~	
SS	Osagean	Miss.	"Osage Lime"	+		Limestone	ုဒ္ဓ		ne Grou Joe Grou		_
₹	Kinderhookian	2	Woodford Shale —							_	
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Σ	Middle	1//		77/	///		////	////	////	7///	Arkansas
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ایتا	Lower	KK	(**************************************	144	722	Frisco Formation		o Fm.		////	
			Haragan Fm.	1	Hara	gan-Bois d'Arc Formation	7777	777	77/		Pinetop Chert Z
z	1001	Henryhouse Fm. Chimney Hill Subgroup			<u></u>	lenryhouse Formation	7//			////	
≨	Upper	G	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	n Group	=-	Clarita Formation	Quar	ry Mtn.	Fm.		
LURIAN	Lower	Ě	Chimney Hill Subgroup	Hunton	ey Hill roup	Cochrane		nkiller f		V//	Missouri Mountain Shale
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_		-	Viola Group	0	ſ	Viola Group	_	/iola Gr	~~	~{//	Bigfork Chert
ORDOVICIAN		-	Simpson	Simpson Group		Bromide Formation Tulip Creek Formation	_			-	Womble
\cong	Middle		Group	son		McLish Formation	Ту	ner Fo	rmation	_\{\)	Shale
8	MINIOR			duig	ĺ	Oil Creek Formation Joins Formation	Bu	ırgen S	andston	e (/)	Blakely Sandstone
등		+		<u> </u>	We	st Spring Creek Formation				$-\langle \rangle$	Mazarn Shale
-	Lower			Group	Kin	Iblade Formation				Ę	
			Arbuckle Group	Gre	McI	Cenzie Hill Formation			uckle	1	Crystal Mountain Sandstone
\vdash		1	чир —	Arbuckle		erly Dolomite	L	Gi	oup	_	_
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A N	Upper	\vdash		-	For	Sill Limestone	<u> </u>				? —— ? ——
CAMBRIAN			Timbered Hills Group	T. H Grou		loney Creek Limestone Reagan Sandstone	Tim	bered i	Hills Gro	oup	
፮.		77	77777777777	7	200	7/1/1/1/1/1/	777	7777	777	7777	
ે	Middle	Gran	nite, Rhyolite, and Gabbro	F	hyolite	~ /////////</td <td>4//</td> <td>///</td> <td>///</td> <td></td> <td></td>	4//	///	///		
	Lower		? and dabbit Y///	h~	~	~~~×////////	Y///	111	111	////	
		4	Titlle L	4LL	Granite and Gneiss			466	466	un	

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

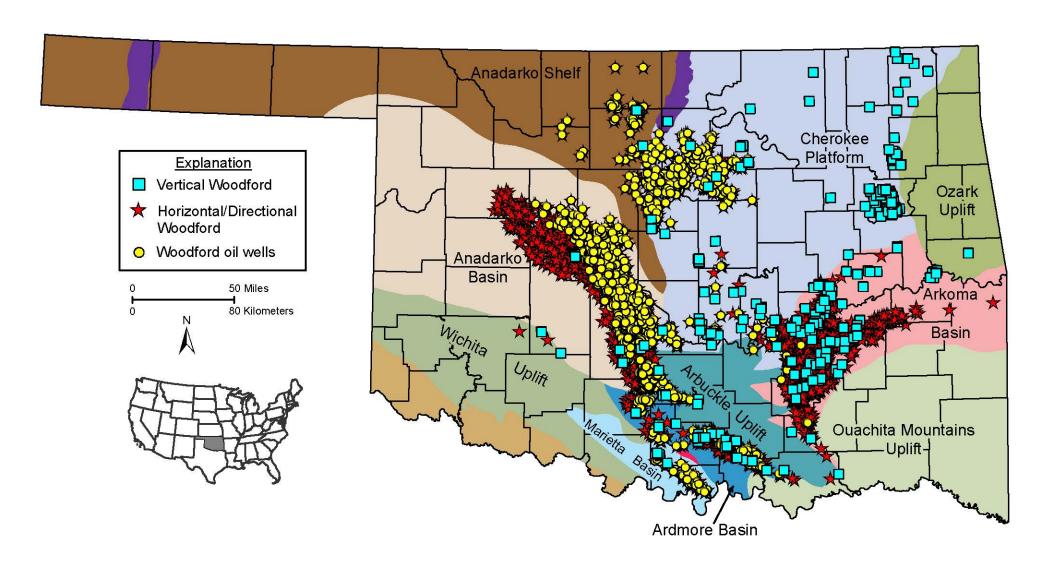
Isopach Map of Woodford Shale





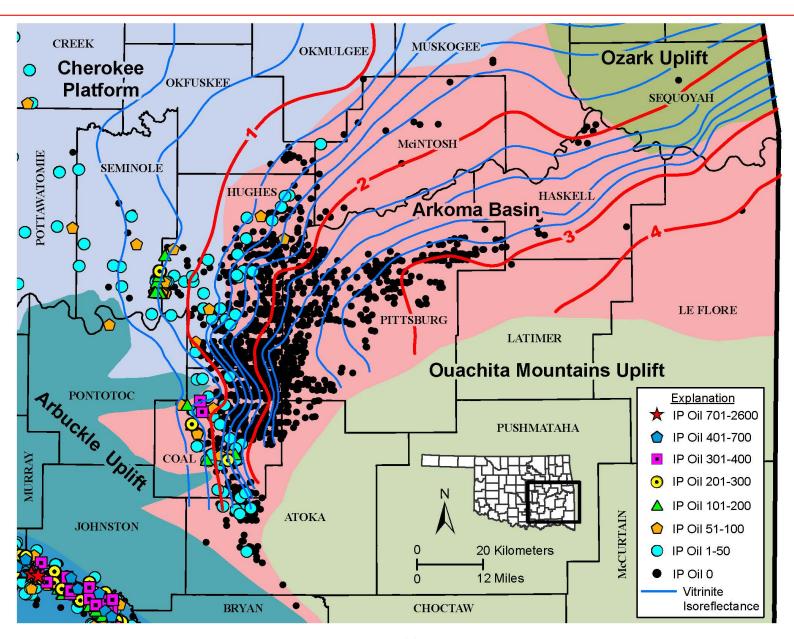
Woodford Shale (2004-2020)





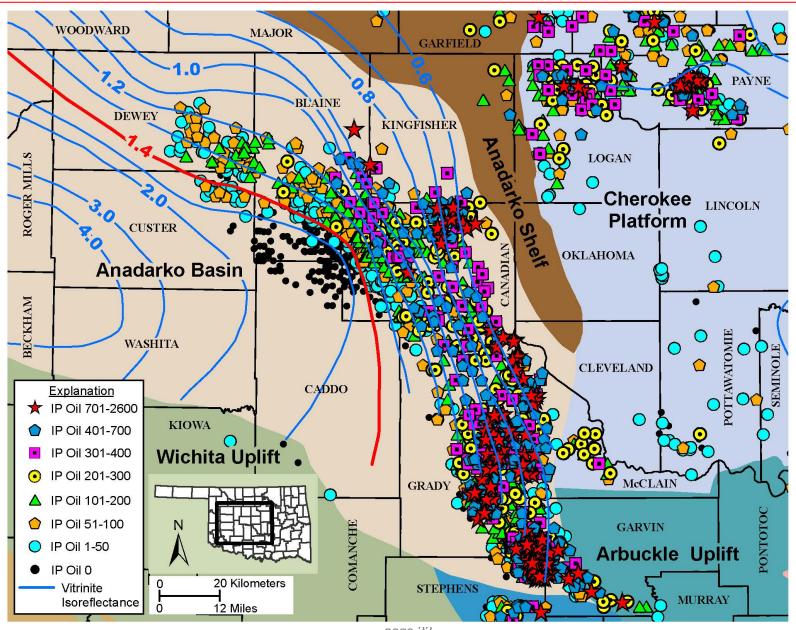
Woodford Shale Arkoma Basin Oil IP





Woodford Shale Anadarko Basin Oil IP

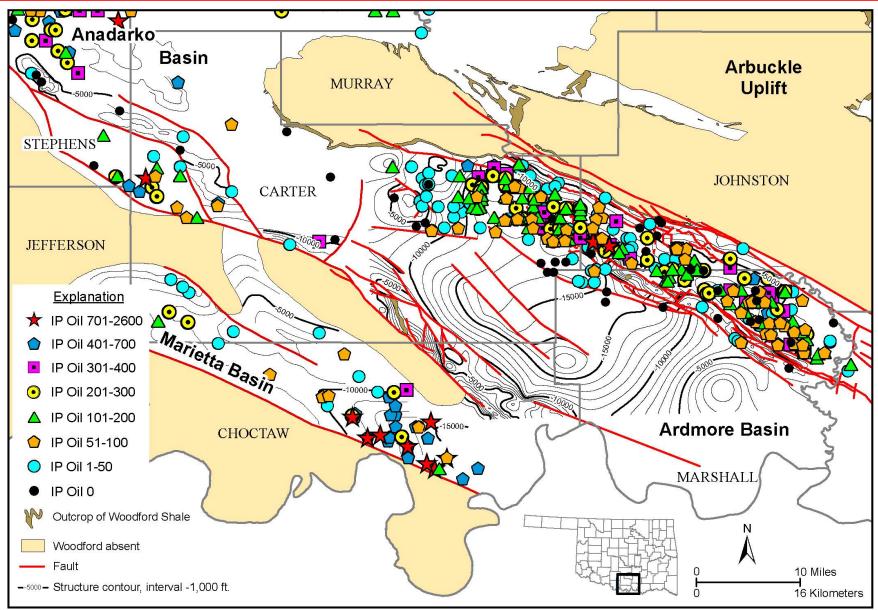




page 22

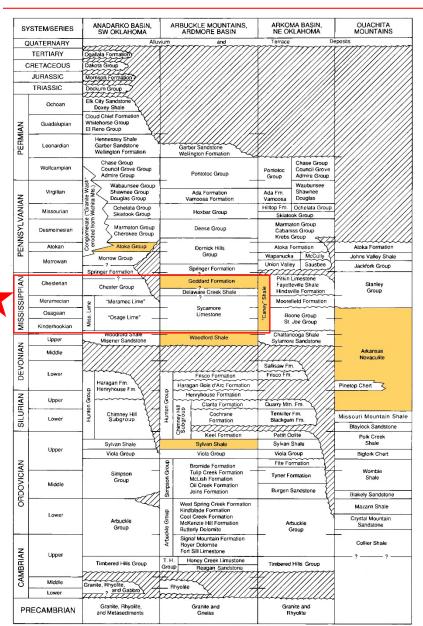
Woodford Shale Ardmore Basin Oil IP





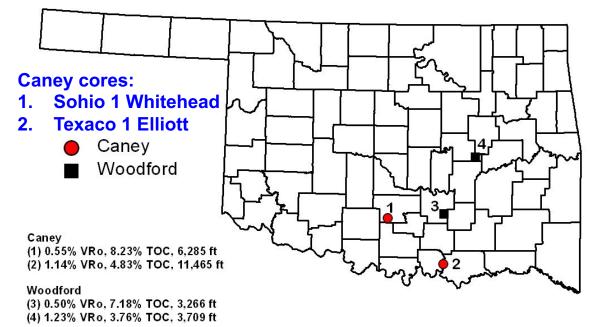
Caney Shale (Mississippian Age)





[Age equivalent to the Barnett Shale and Fayetteville Shale]

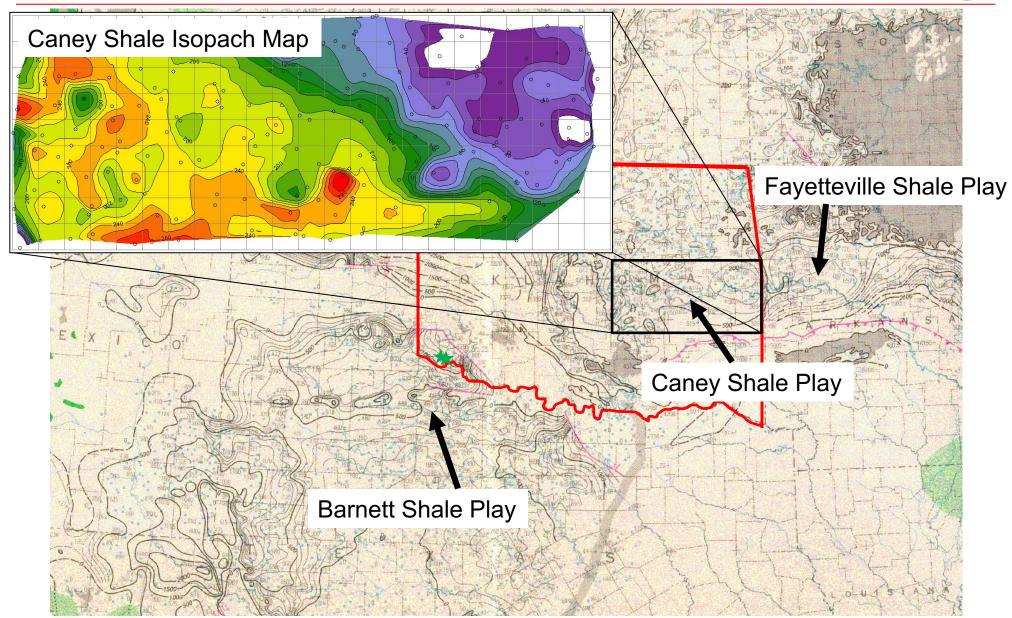
Kerogen Type	11 - 111
Amount of TOC	~1% - 11.46%
N/1 a 4	0.55 – 1.14% VRo
Maturity	(2 samples)



Rock-Eval data compliments of Humble Geochemical Services

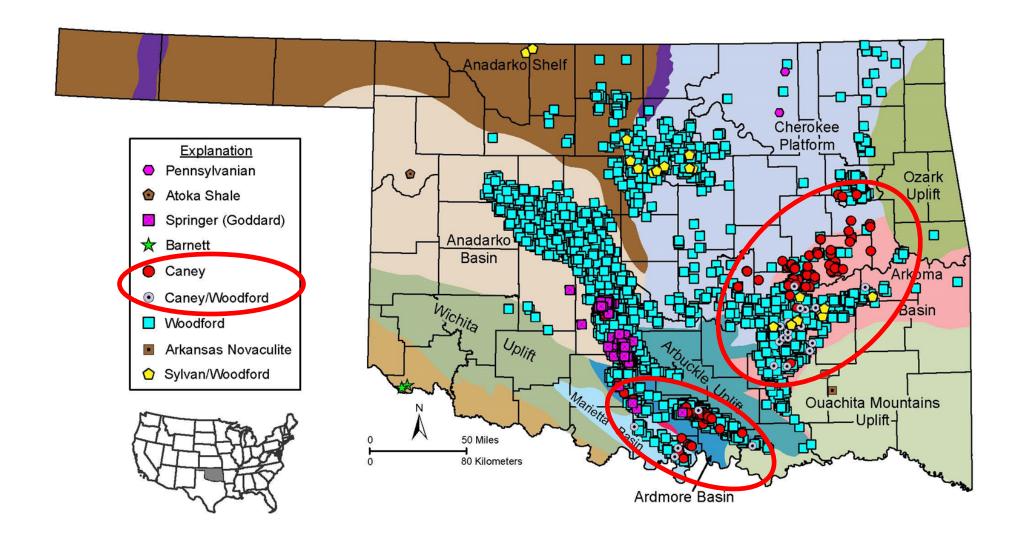
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Caney Shale (1982 -2020)





Goddard Formation (Mississippian Age)

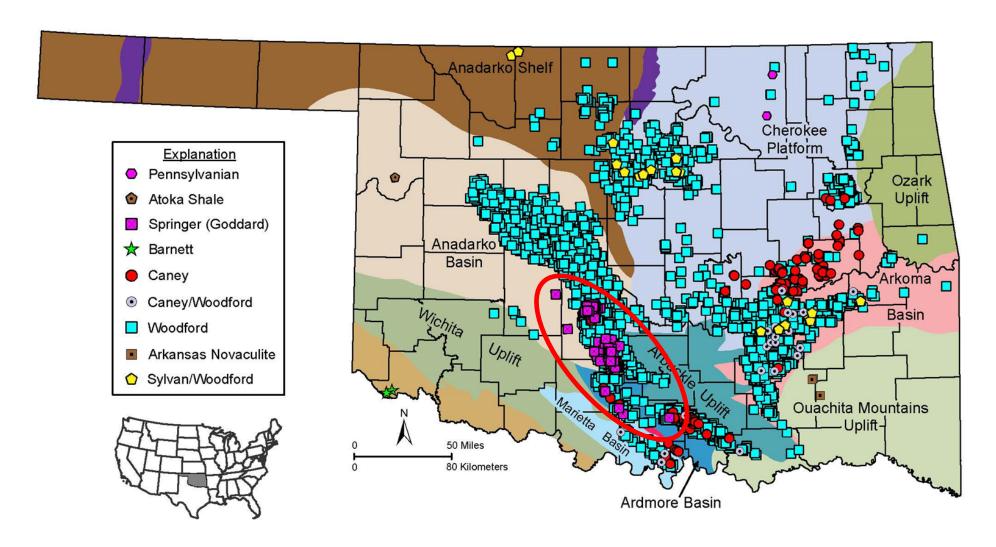


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Pearson, 2016								
Kerogen Type Mainly Type II and II								
Amount of TOC	<1% - 7.77%							
Maturity 0.6% - 1.26% VRo								

Goddard Formation



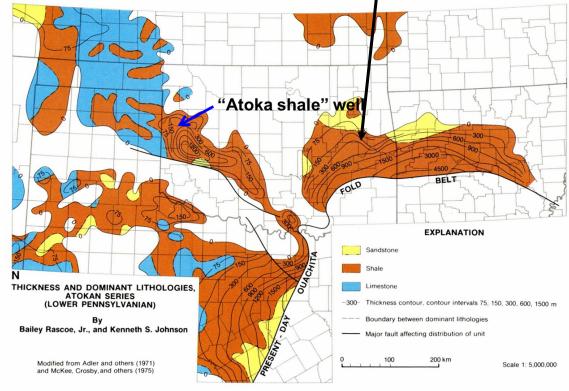


Atoka Shale (Pennsylvanian Age)



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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)

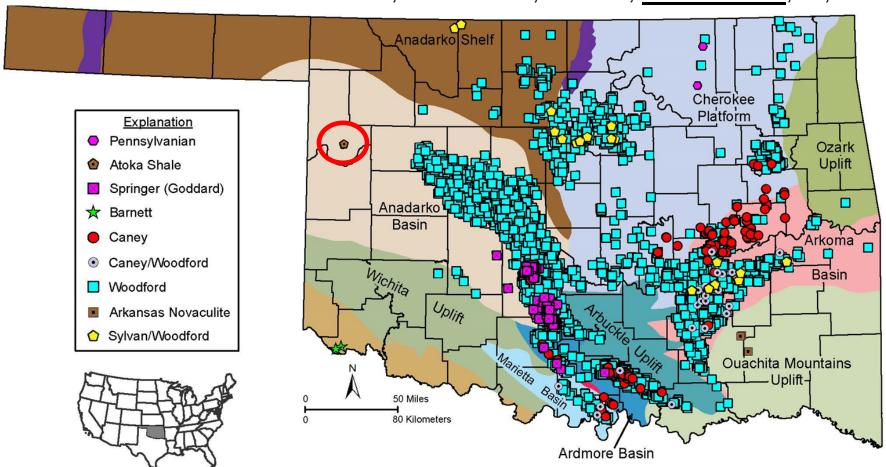


From Johnson and others, 1989 page 29

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 Tedesco¹

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

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.

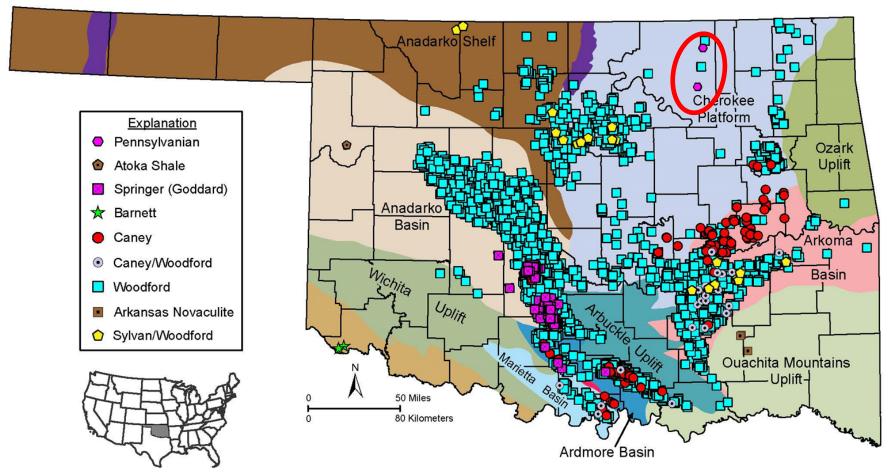
^{*}Adapted from oral presentation given at AAPG Mid-Continent Section meeting in Tulsa, Oklahoma, October 4-6, 2015

^{**}Datapages © 2015 Serial rights given by author. For all other rights contact author directly.

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

Pennsylvanian Shales (NE OK)



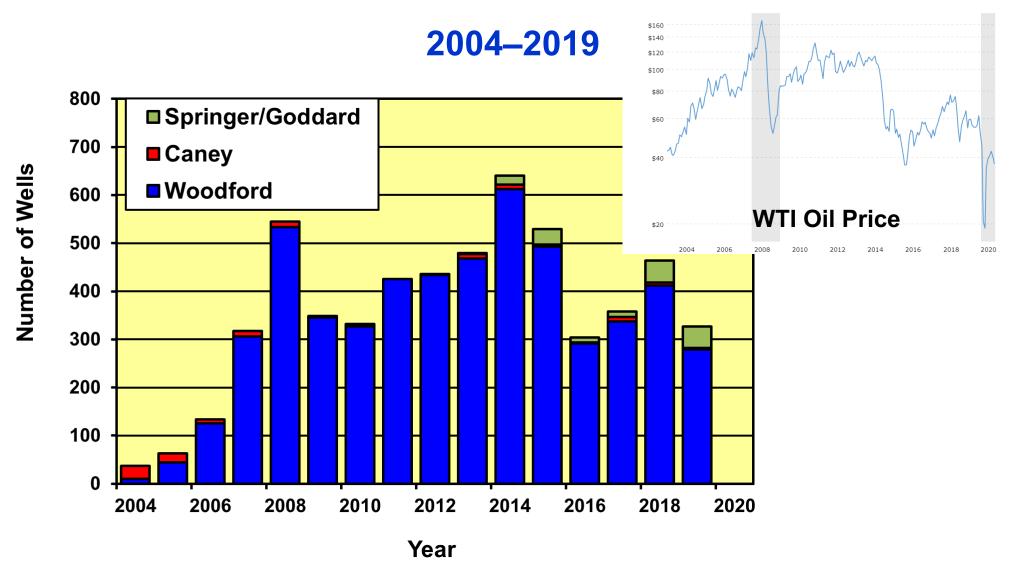


Tedesco, 2015	
Kerogen Type	II, III, and IV
Amount of TOC	<1% - ~12%
Maturity	0.45 – 0.76% VRo

Oklahoma Shale Oil and Gas Well Completions History



5445 Woodford + 131 Caney + 166 Springer/Goddard Wells





All shales are different and complex