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WOLFCAMP HORIZONTAL PLAY MIDLAND BASIN, WEST TEXAS

IHS Geoscience Webinar Series

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Agenda

- Introduction
- Play History
- Data Summary
- Geologic Characteristics
- Source Rock Characteristics
- Sweet Spot
- Play Particulars
- Summary
- Question & Answer

Play History – Santa Rita No. 1

- 1923 – Drilled and completed. It was one of the first producing oil wells in the Permian Basin. Santa Rita is the patron saint of impossible dreams.
- 1958 - The original production equipment was restored and moved to the Univ Texas - Austin campus, corner of San Jacinto Blvd and Trinity Street.
- 1990 - Marathon plugged the well after 67 years of production.

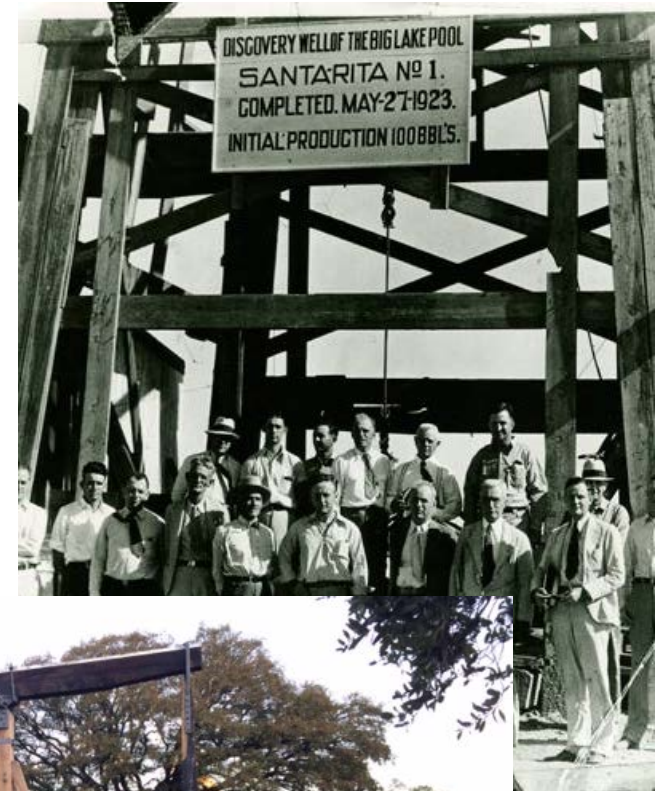
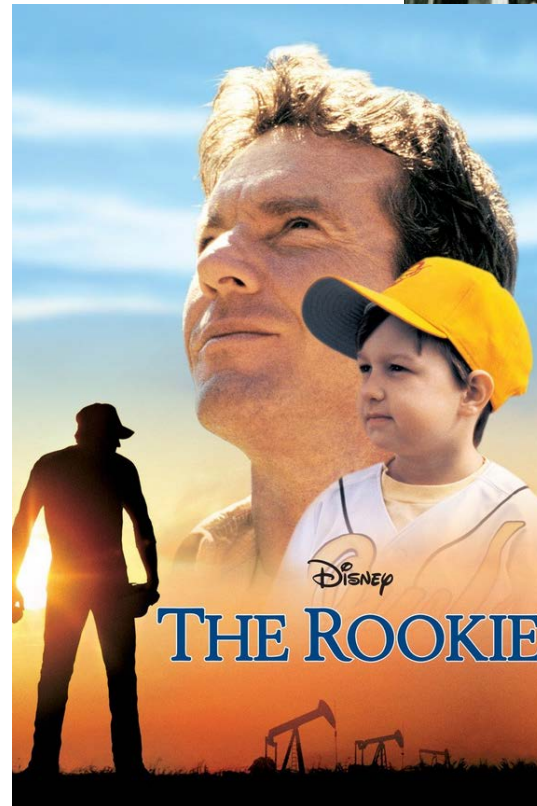


Photo by Rachael Moreland

Play History – Santa Rita No. 1

- The Santa Rita No. 1 played a role in the 2002 film, “The Rookie”, starring Dennis Quaid.



Data Summary

- Enerdeq – Greater Permian Basin
571,119 wells
- GDS Interpreted Formation Tops
284,945 wells
- Enerdeq – Midland Basin
116,302 wells
- Wolfcamp Shale Bench Correlations
6,200 wells

Midland Basin Summary

- 116,302 Total wells drilled
- 96,894 Wells produced oil & gas
- Success Rate = 83%
- South & Central portions of Basin are the most productive
- 5114 Total HZ wells drilled
(all reservoirs included)


USGS Report released Nov 15, 2016



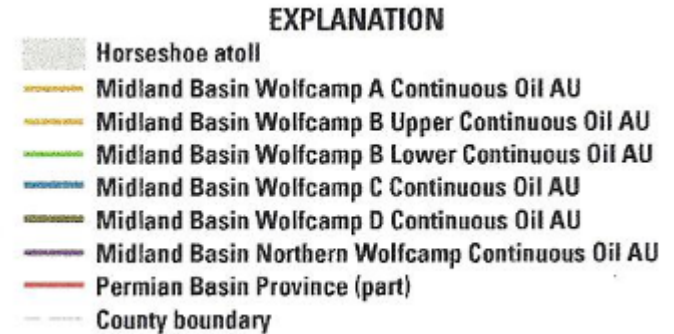
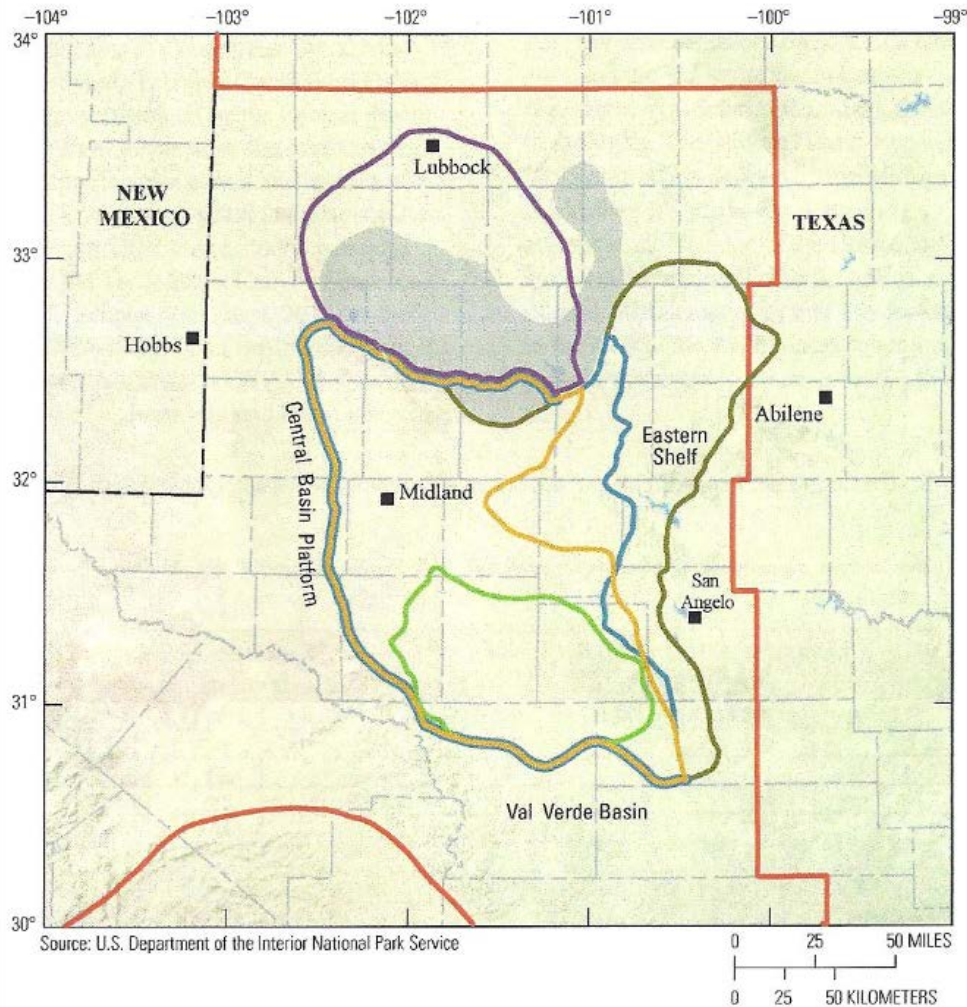
National and Global Petroleum Assessment

Assessment of Undiscovered Continuous Oil Resources in the Wolfcamp Shale of the Midland Basin, Permian Basin Province, Texas, 2016

Using a geology-based assessment methodology, the U.S. Geological Survey assessed technically recoverable mean resources of 20 billion barrels of oil and 16 trillion cubic feet of gas in the Wolfcamp shale in the Midland Basin part of the Permian Basin Province, Texas.

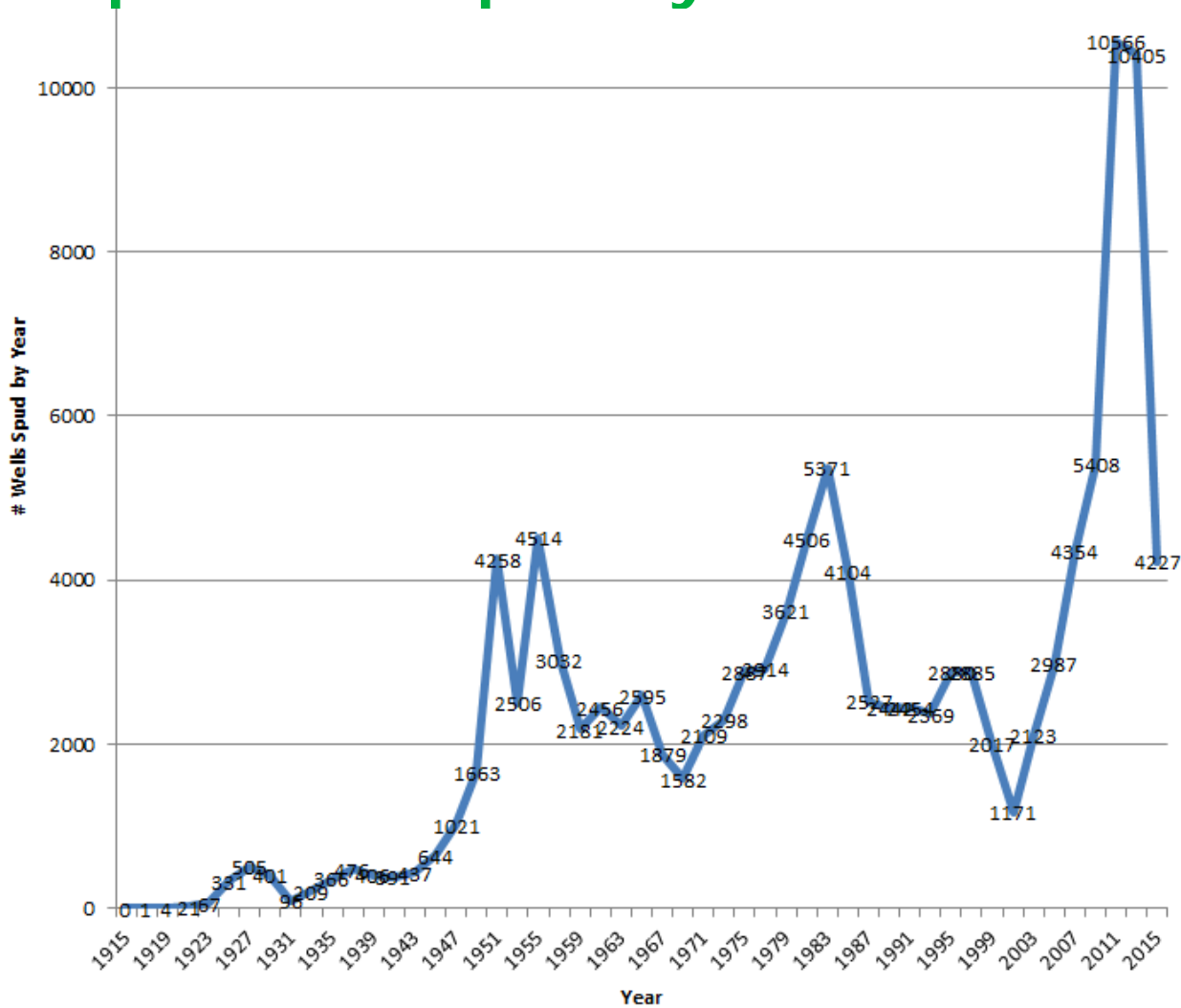


Play Map – Greater Permian Basin



From USGS, Gaswirth, et al (2016)

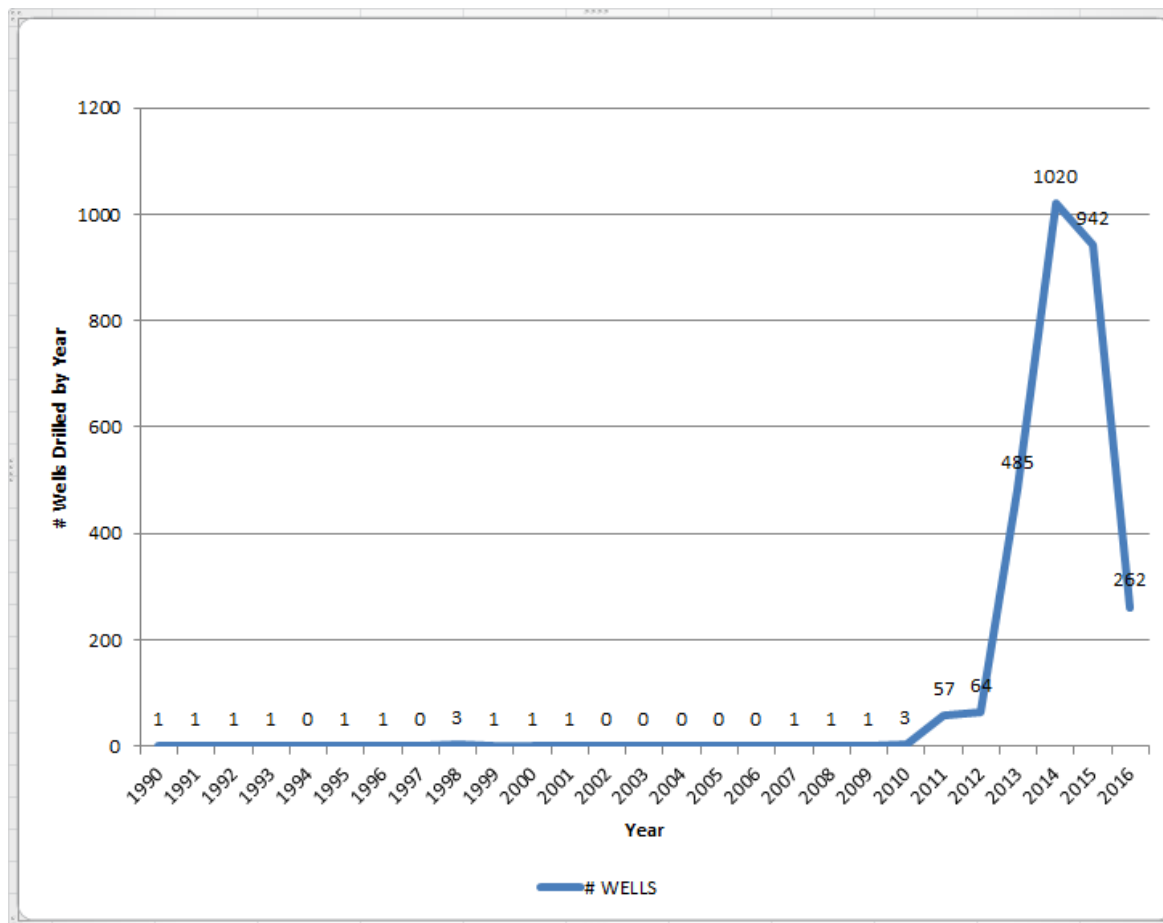
Wolfcamp+ Wells Spud by Year



Play History

- 1950-1990 - Vertical play ±Spraberry; 27,114 wells drilled
- 1990-2001 - 12 HZ wells drilled
- 2002-2006 - No HZ wells drilled
- 2007-2010 - 6 HZ wells drilled
- 2011 - 57 HZ wells drilled
- 2012 - 164 HZ wells drilled
- 2013 - 485 HZ wells drilled
- 2014 - 1020 HZ wells drilled
- 2015 - 942 HZ wells drilled
- 2016 - 262 HZ wells drilled (thru May)

Wolfcamp HZ Wells Drilled by Year



Data from Enerdeq, thru August 2016

Regional Stratigraphy

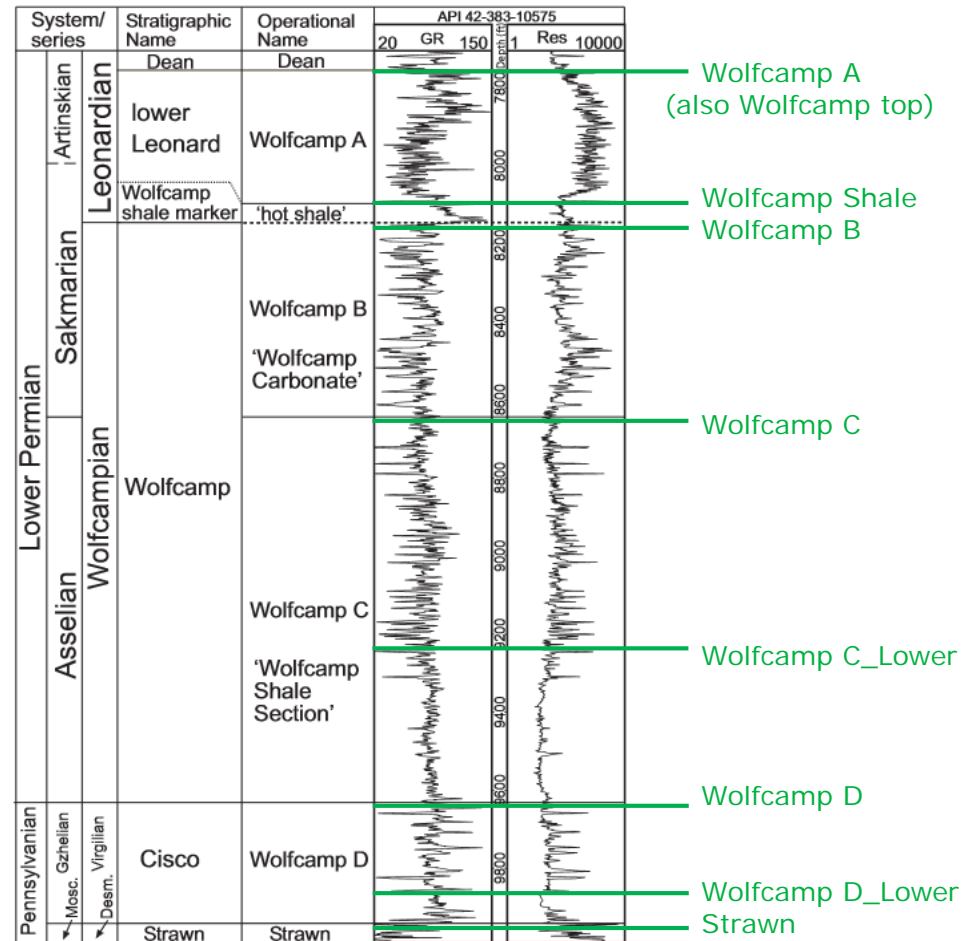
- Stratigraphy of Midland Basin consists of thick Permian & Pennsylvanian sections
- Several productive plays; focus here is on the Wolfcamp
- Wolfcamp has been an active vertical play in the Midland Basin since the 1950's
- Wolfcamp now an unconventional play

GDS DATA BASE		MIDLAND BASIN	
SYSTEM	SERIES	CENTRAL BASIN PLATFORM	MIDLAND BASIN
Permian	Ochoa	Dewey Lake	Dewey Lake
		Rustler	Rustler
	Guadalupe	Salado	Salado
		Tansil	Tansil
		Yates	Yates
		Seven Rivers	Seven Rivers
		Queen	Queen
		Grayburg	Grayburg
		San Andres	San Andres PI marker
	Leonard	Glorieta	Glorieta
		Holt	Upp. Spraberry
		San Angelo	
		Clearfork	Lwr. Spraberry
		Tubb	Dean
Wolfcamp			
Pennsylvanian	Cisco	Cisco	Cisco PPRF
	Canyon	Canyon	Canyon Horseshoe
	Strawn	Strawn	Strawn Atoll
Pennsylvanian	Atoka	Atoka	Atoka
	Morrow	Morrow	Morrow
	Springer		

From Roberts (1989) and GDS

Wolfcamp Shale Benches - Type Log

- Type log for the Wolfcamp Section in the Midland Basin
- Clinton Oil #2 O. L. Greer
API# 42-383-10575
- These 6 Wolfcamp Benches correlated in 6,200 wells in Wolfberry Trend in Midland, Glasscock, Reagan and Upton Counties
- These correlations also tied to over 2,800 HZ wells



Data from IHS Energy (2016) and Baumgardner, et al (2014);
Modified Feb 2016

Stratigraphy

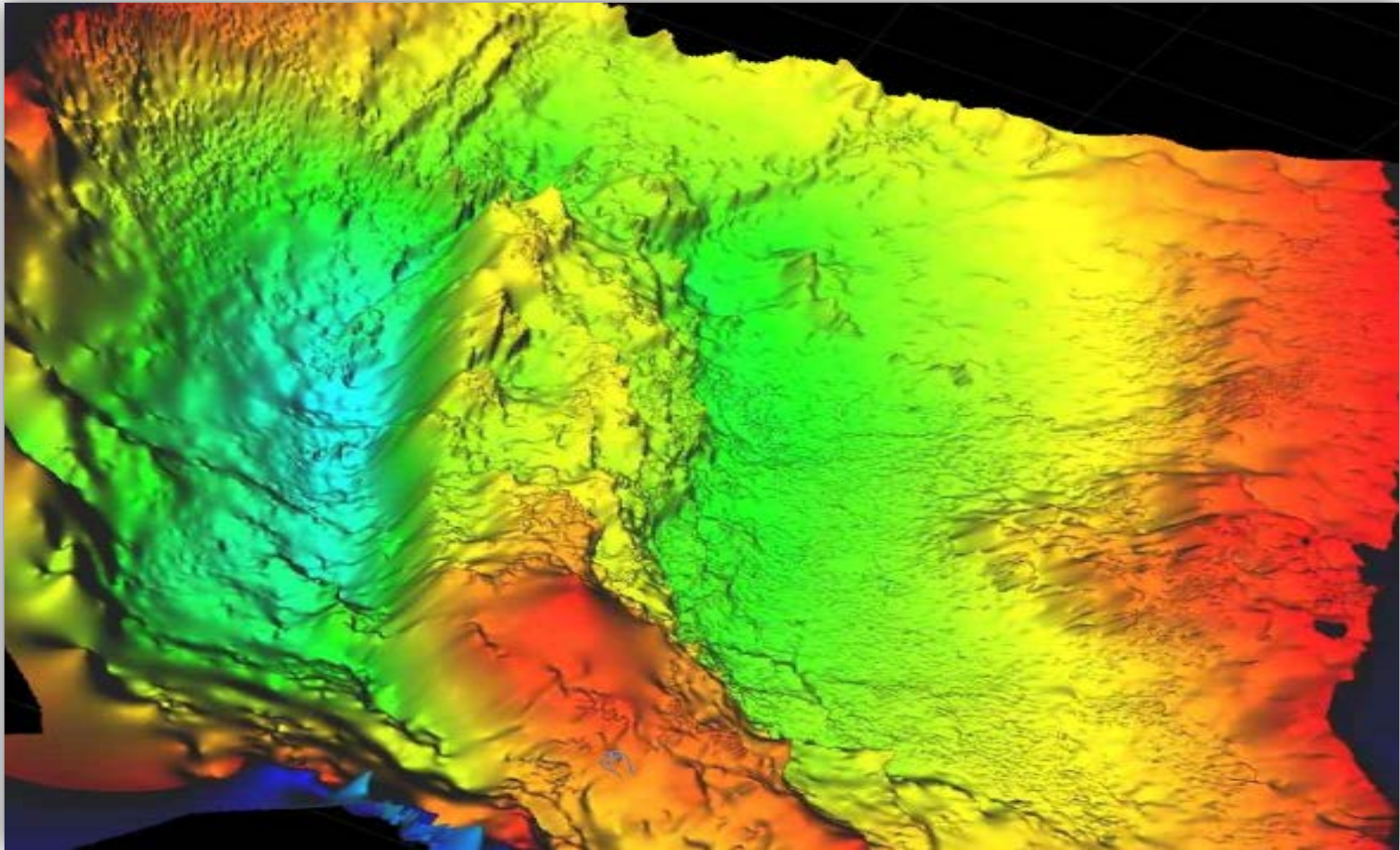
- Lithology: Mostly shale and argillaceous carbonates
- Some sand and sandy intervals near basin edges
- Facies exhibit abrupt lateral changes
- 6 shale horizons or benches



Geologic Characteristics

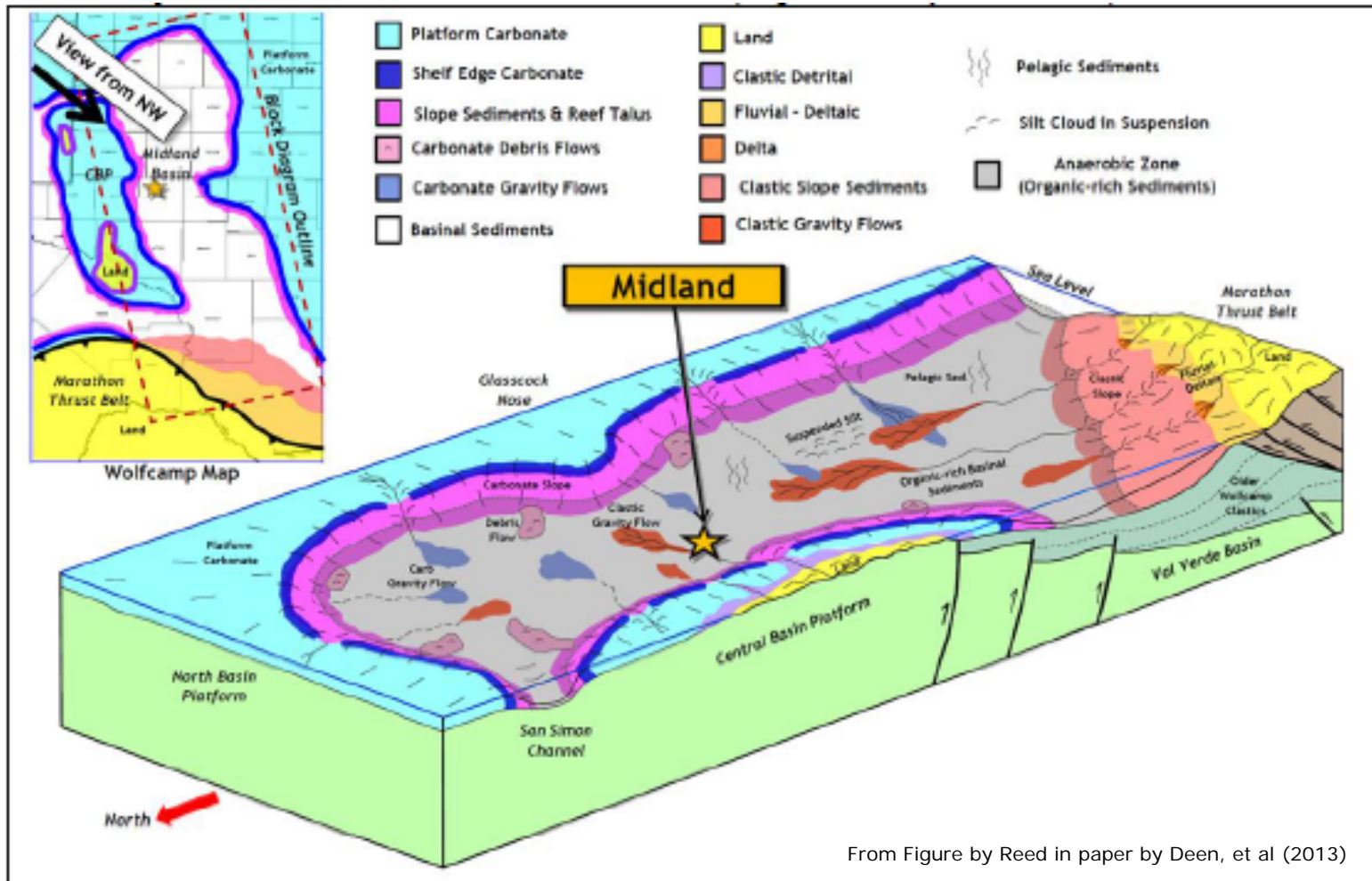
- Depths: 4,000 – 10,000 ft
- Thickness: 185 - 4,600 ft
 - > Average thickness: 2,029 ft
- Porosity: 4% - 12%
 - > Average porosity: 7%
- Permeability: as low as 10mD
- Type locality at Wolfcamp Hills in Glass Mountains, west of Marathon, Texas (Udden, 1917; King, 1937)

Permian Basin 3D Wolfcamp Structure



Note: Generated from 110,000 Wolfcamp tops; view is to the north

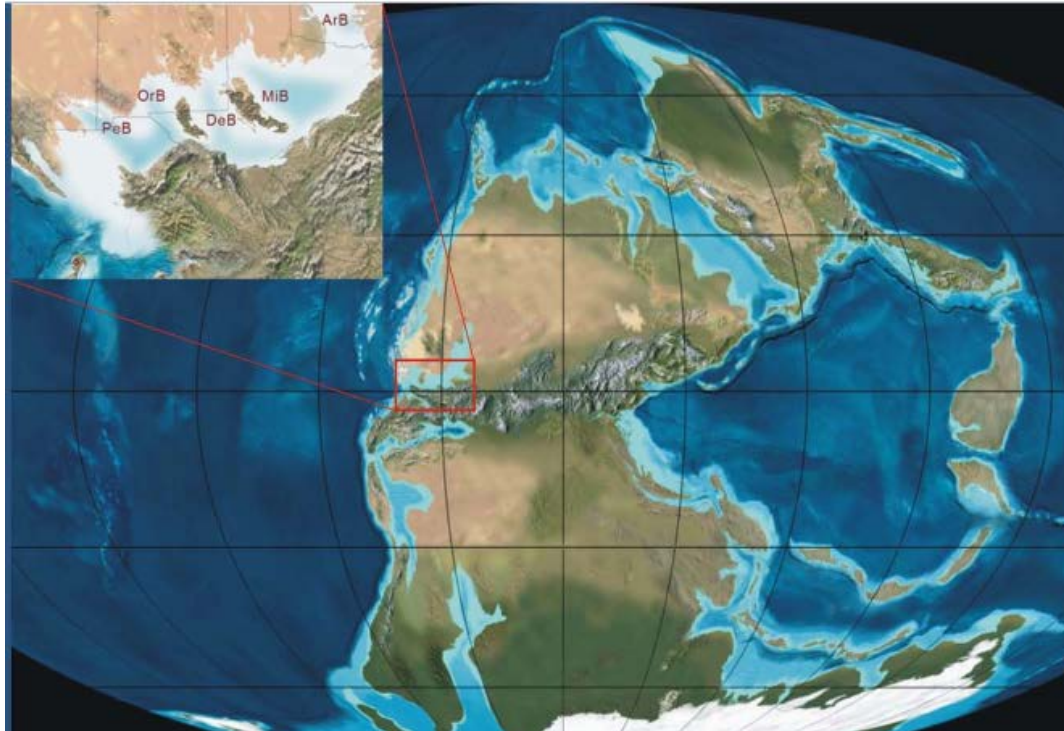
Midland Basin Block Diagram



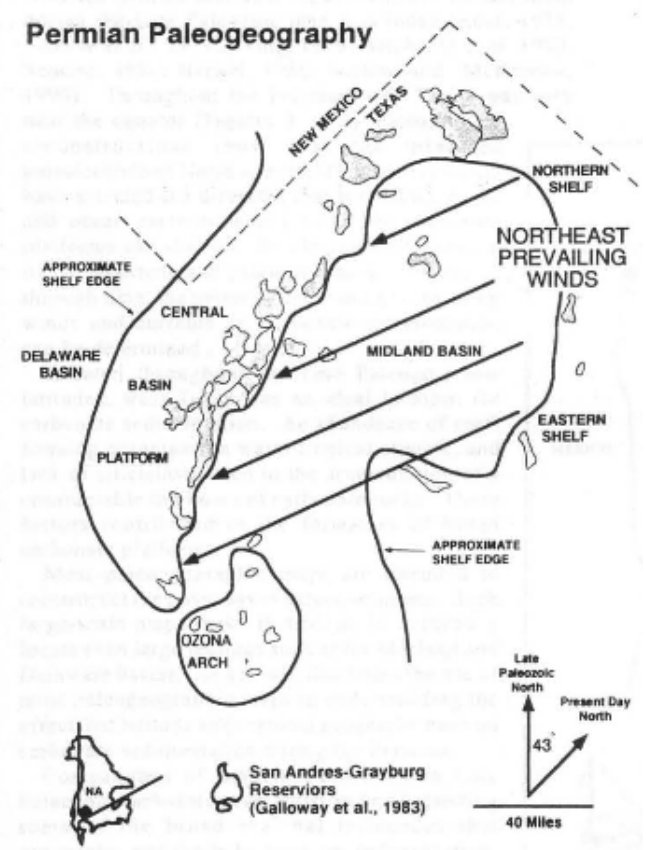
From Figure by Reed in paper by Deen, et al (2013)

Facies of Wolfcamp A & B; View is to the Southeast.

Wolfcampian Paleogeography of the Midland Basin

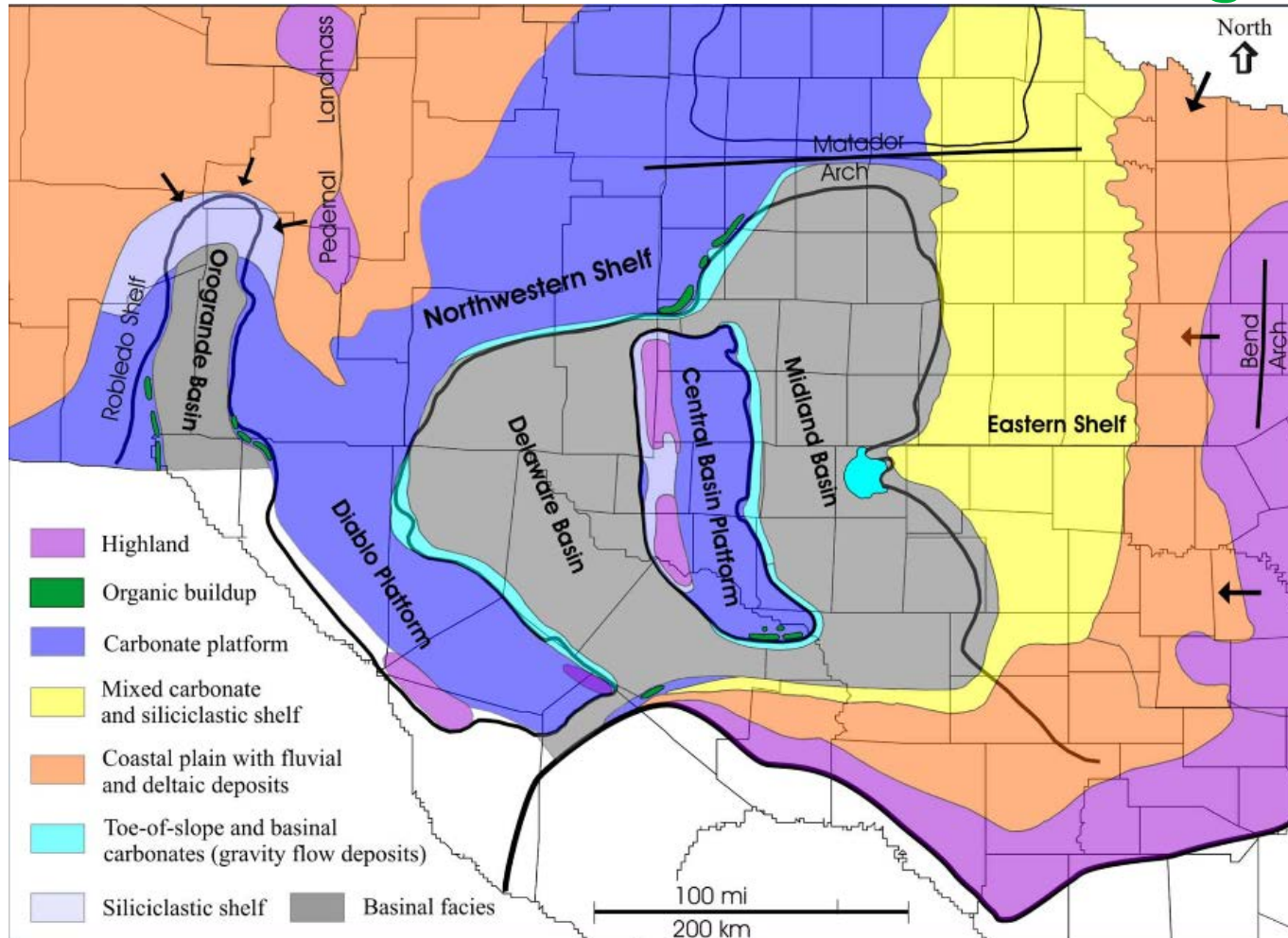


From Blakey (2014)



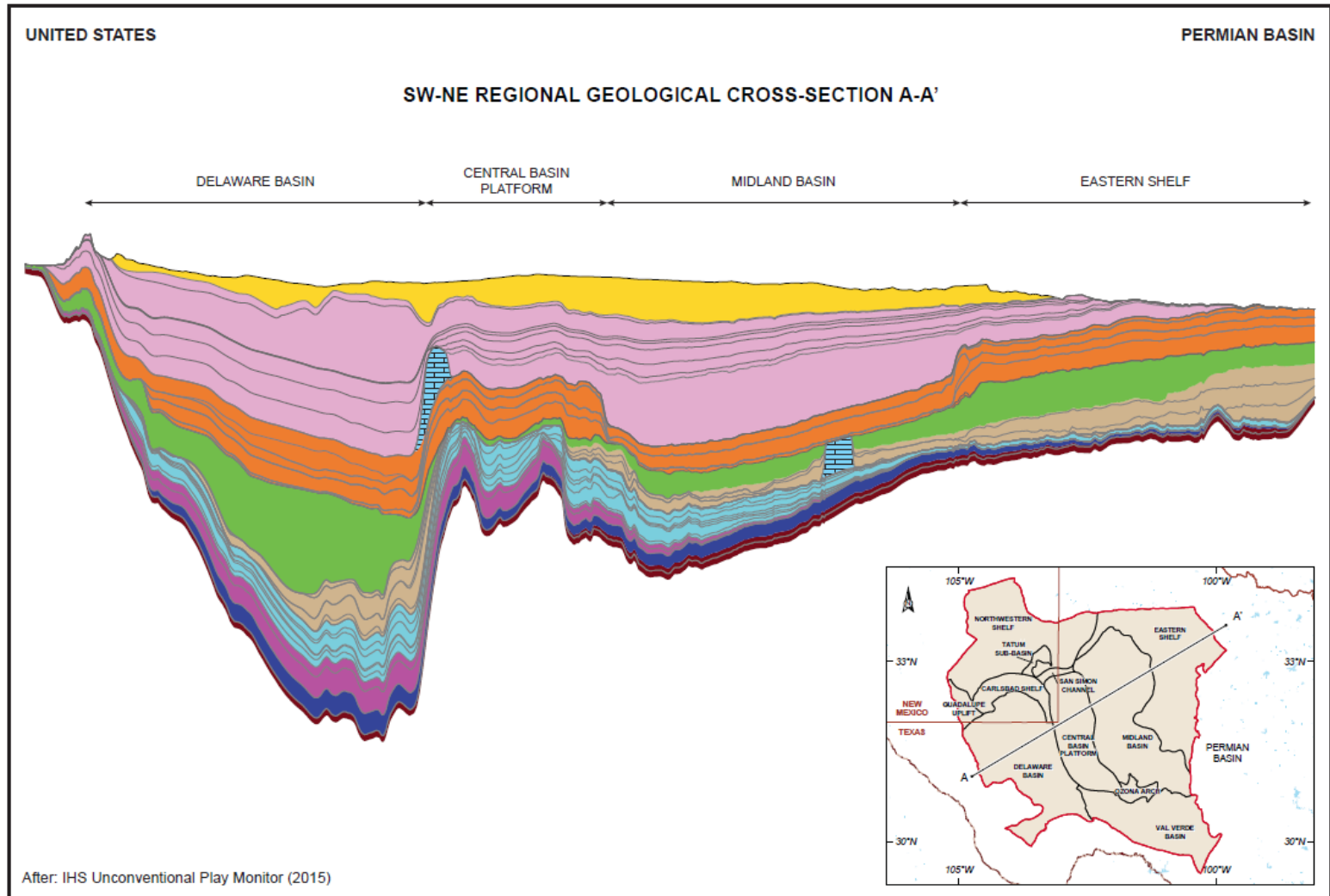
From Fu (2011)

Paleogeography – Late Wolfcampian in Permian Basin Region



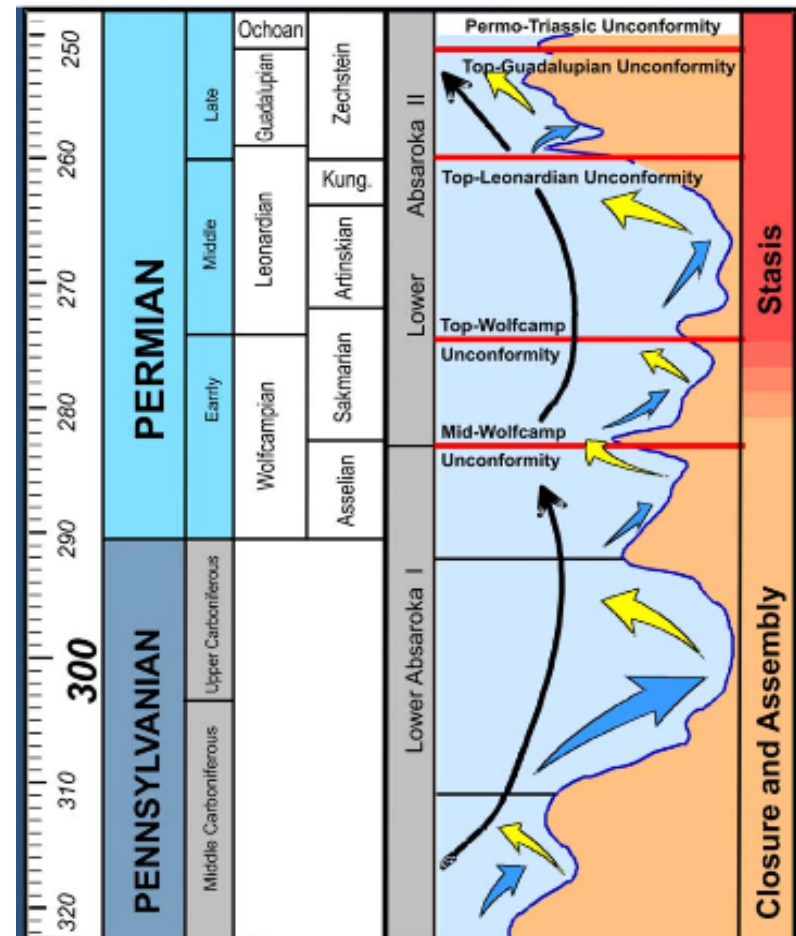
From Fu (2011)

Greater Permian Basin Cross Section



Midland Basin Sequence Boundaries

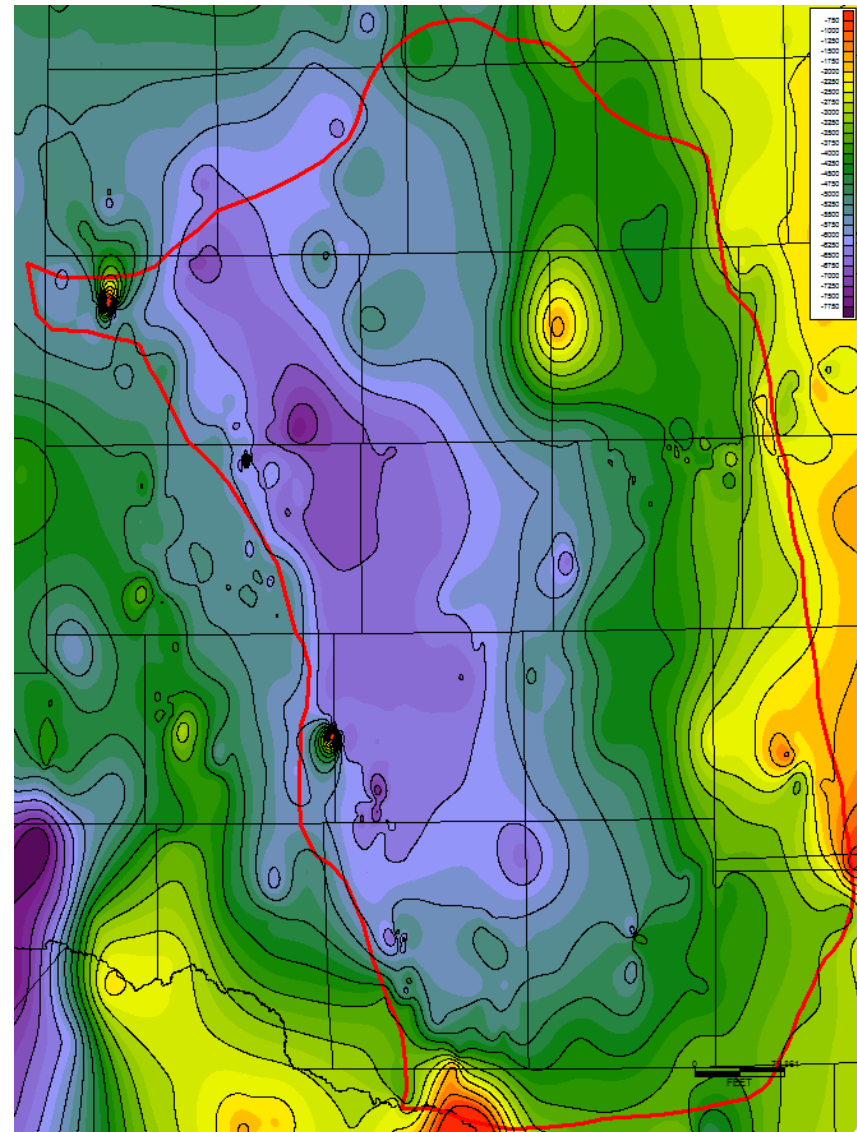
- Sequence boundaries are related to transgressive and regressive seas
- 2nd Order Sequence boundaries present during Wolfcampian time
- TOC & Source Rock Quality patterns are related to flooding surfaces.
- Creaney and Passey (1993) showed that patterns in vertical distribution of TOC can be explained using sequence stratigraphic concepts.
- The maximum TOC in a vertical profile correlates to the maximum flooding surface in a marine sequence.



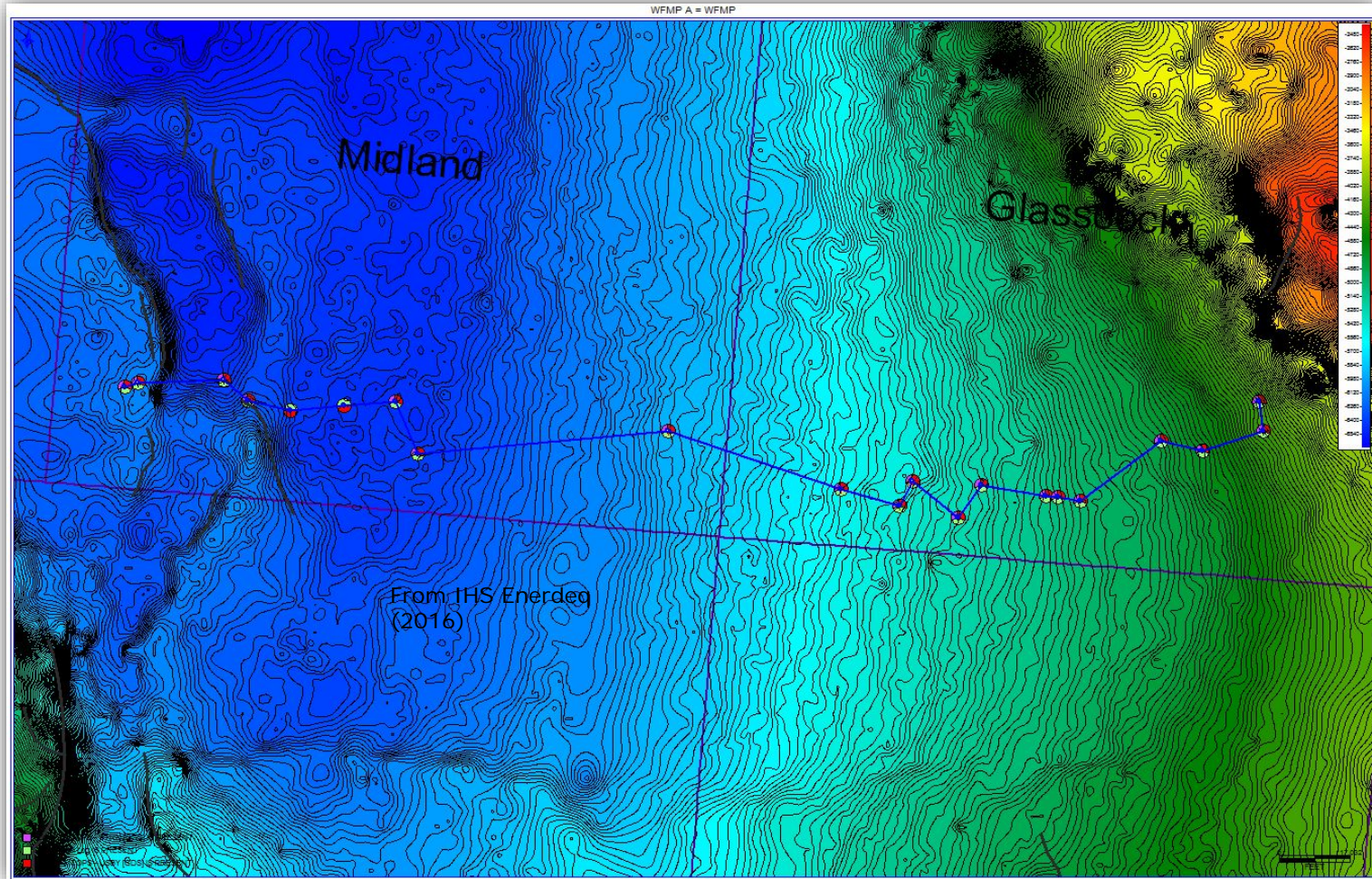
From Fu (2011)

Wolfcamp Structure

- Asymmetric basin geometry
- Contoured top of Wolfcamp Fm
- Contour Interval = 500 ft
- Tops from GDS correlated tops data (260,000+ correlated wells in Permian Basin)



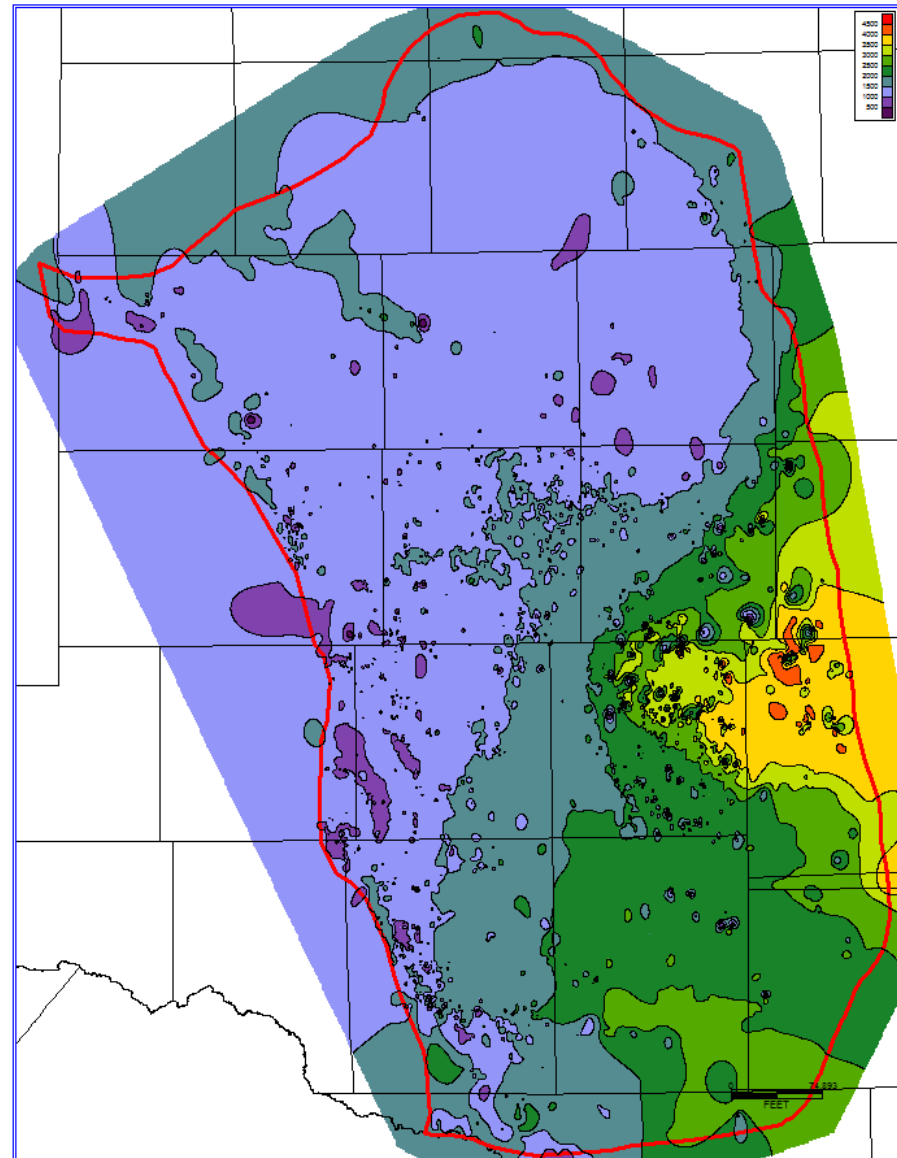
Wolfcamp Structure



Contour Interval = 25 feet

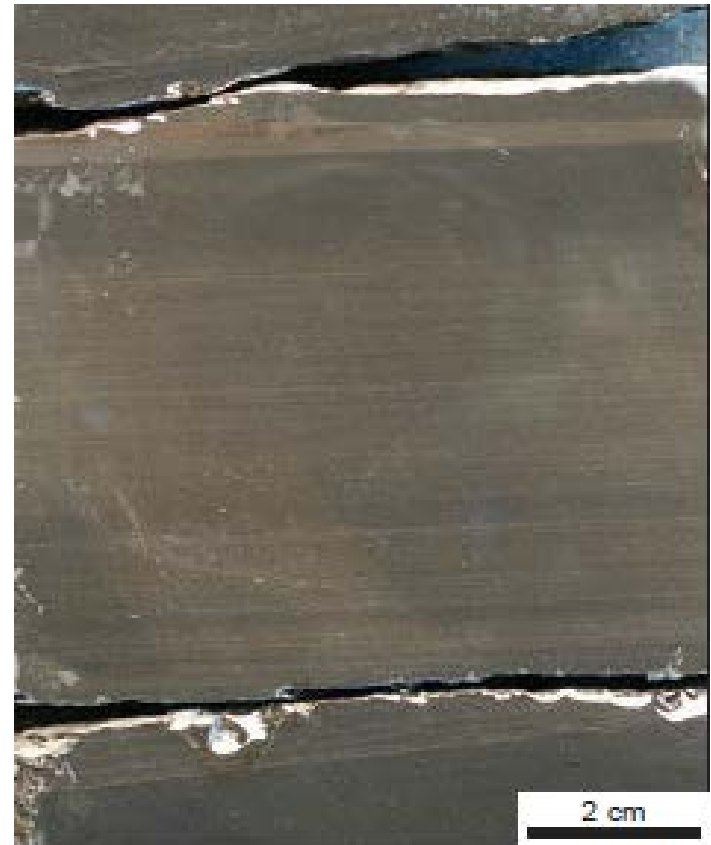
Wolfcamp Isopach

- Top of Wolfcamp A to top of Strawn
- Contour Interval = 500 ft
- Wolfcamp is 185 - 4600 ft thick
- Thickens to the south and east
- Tops from GDS correlated tops data (260,000+ correlated wells in Permian Basin)



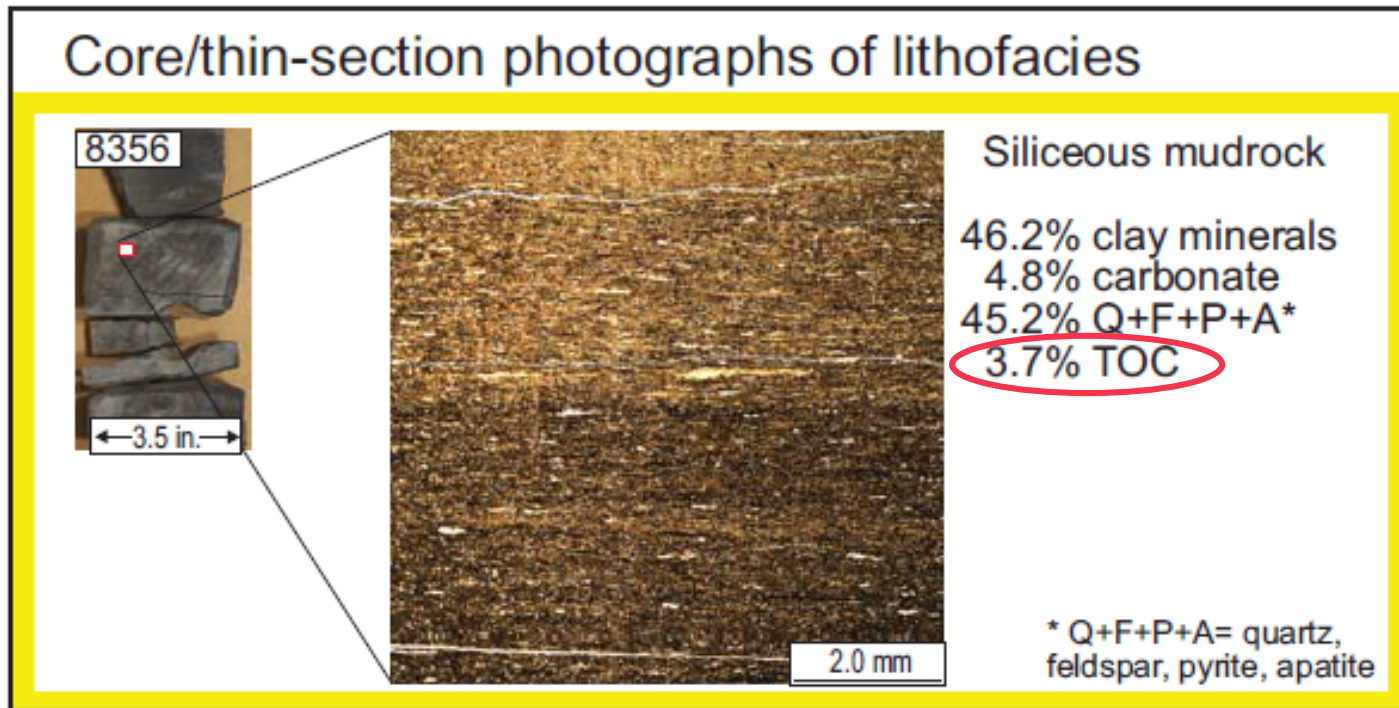
Source Rock Characteristics

- Several thick shales: A, B, C upper, C lower, D upper, and D lower
- TOC Range: 1% - 7%
Good to Excellent Source Rock
- TOC highest in siliceous mudrocks and is diluted by carbonates; therefore, TOC is facies dependent
Baumgardner, et al (2014)
- Zones most drilled: A and B
- Shales respond well to fracture stimulation due to calcite content



Core of Wolfcamp B - siliceous mudrock
Good to Excellent source rock
- from Baumgardner, et al (2014)

Source Rock

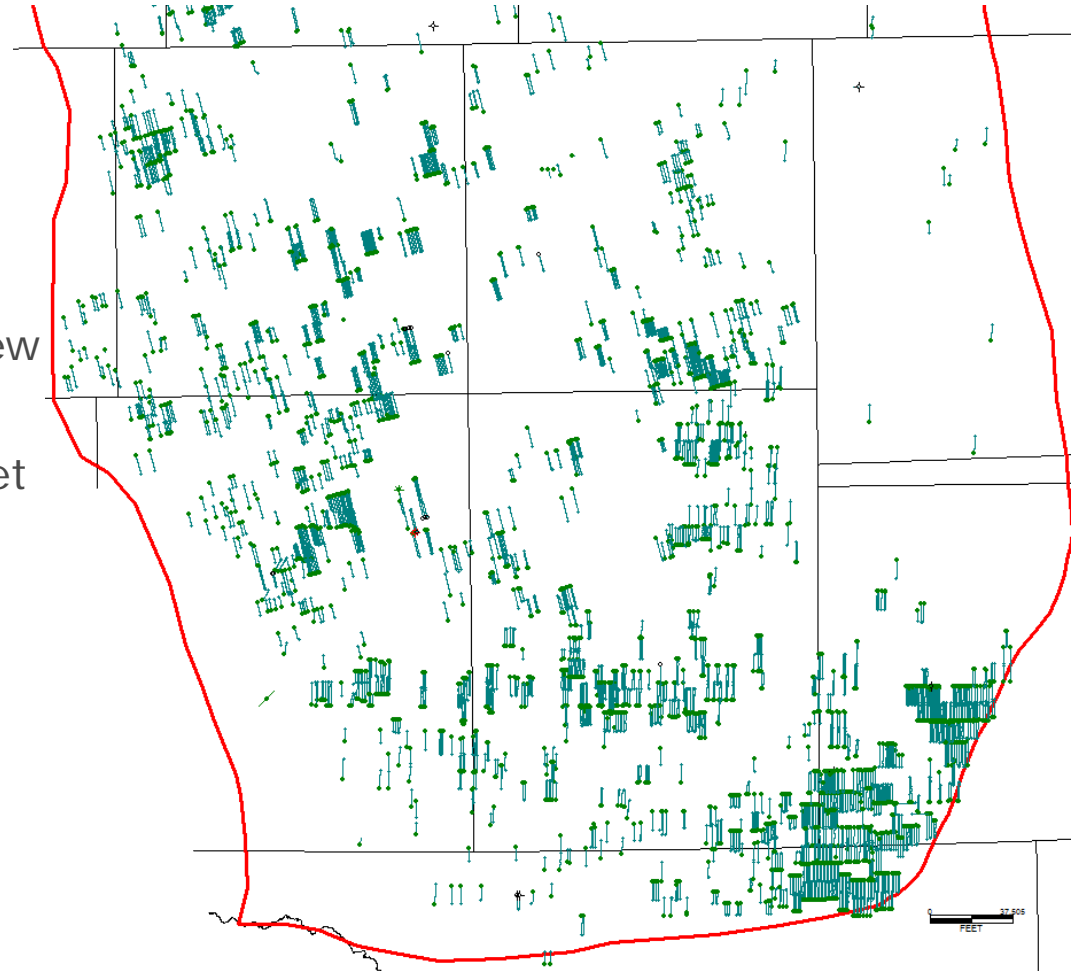


Samples from PanAmerican #1 O.L. Greer, Depth=8356 ft

- Wolfcamp B
- Siliceous mudrock – Source Rock; TOC of 3.7%

Natural Fractures

- Map of Southern Midland Basin
- 2712 Wolfcamp HZ wells this view
- Pattern of laterals suggests the direction of dominant fracture set
- Present day S_{hmax} is E-W and is consistent with drilling induced fractures (Nelson, et al, 2013)



Sweet Spot - Definition

Sweet Spot - the place in a shale play where specific geologic factors coalesce with the best production.

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The geoscientist defines the sweet spot as early as possible so as to be first to the right play, to be first to the sweet spot, and to assist in optimally developing the resource.

Adapted from Fairhurst and Reid (2016).

Sweet Spot Factors

- Source Rock: Thickness, TOC, Maturity, Porosity, K, Kerogen

From: Deem, et al (2014); Fairhurst (2016).

Sweet Spot Factors

- Source Rock: Thickness, TOC, Maturity, Porosity, K, Kerogen
- Lithology
 - some silica & calcite are good, but not too much
 - Clay content

From: Deem, et al (2014); Fairhurst (2016).

Sweet Spot Factors

- Source Rock: Thickness, TOC, Maturity, Porosity, K, Kerogen
- Lithology
 - some silica & calcite are good, but not too much
 - Clay content
- Fractures
 - Greater Quantity can be either good or bad
 - Relation to Faulting

From: Deem, et al (2014); Fairhurst (2016).

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 - some silica & calcite are good, but not too much
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 - Relation to Faulting
- Reservoir Pressure
- Oil Viscosity

Adapted From: Deen, et al (2014); Fairhurst (2016).

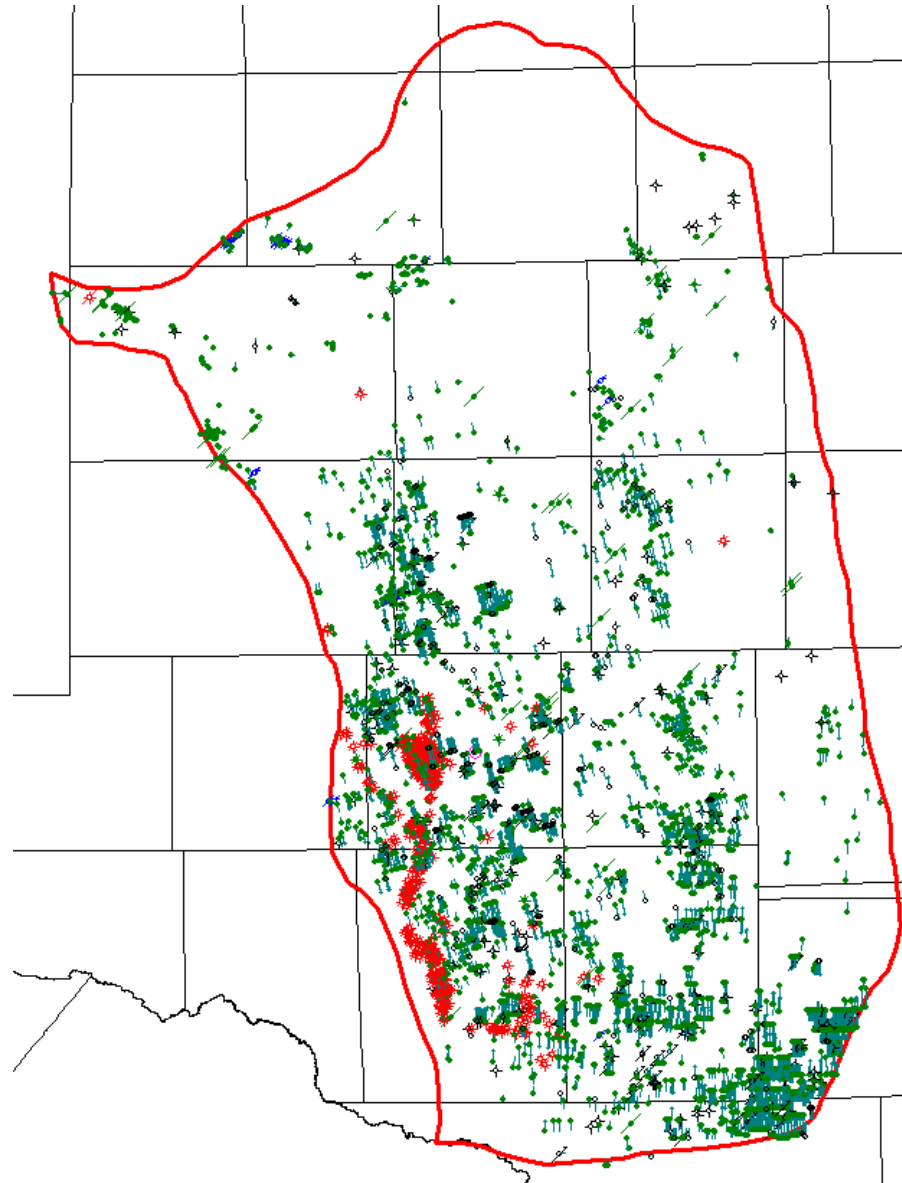
Horizontal Play Particulars

- 5,114 HZ wells drilled in Midland Basin
- 3,017 HZ wells Wolfcamp;
 - drilled by 61 operators
 - 20% ops drilled 80% of wells
- Top 3 operators are:
 - Pioneer Natural Resources
 - Apache Corp
 - Laredo Petroleum



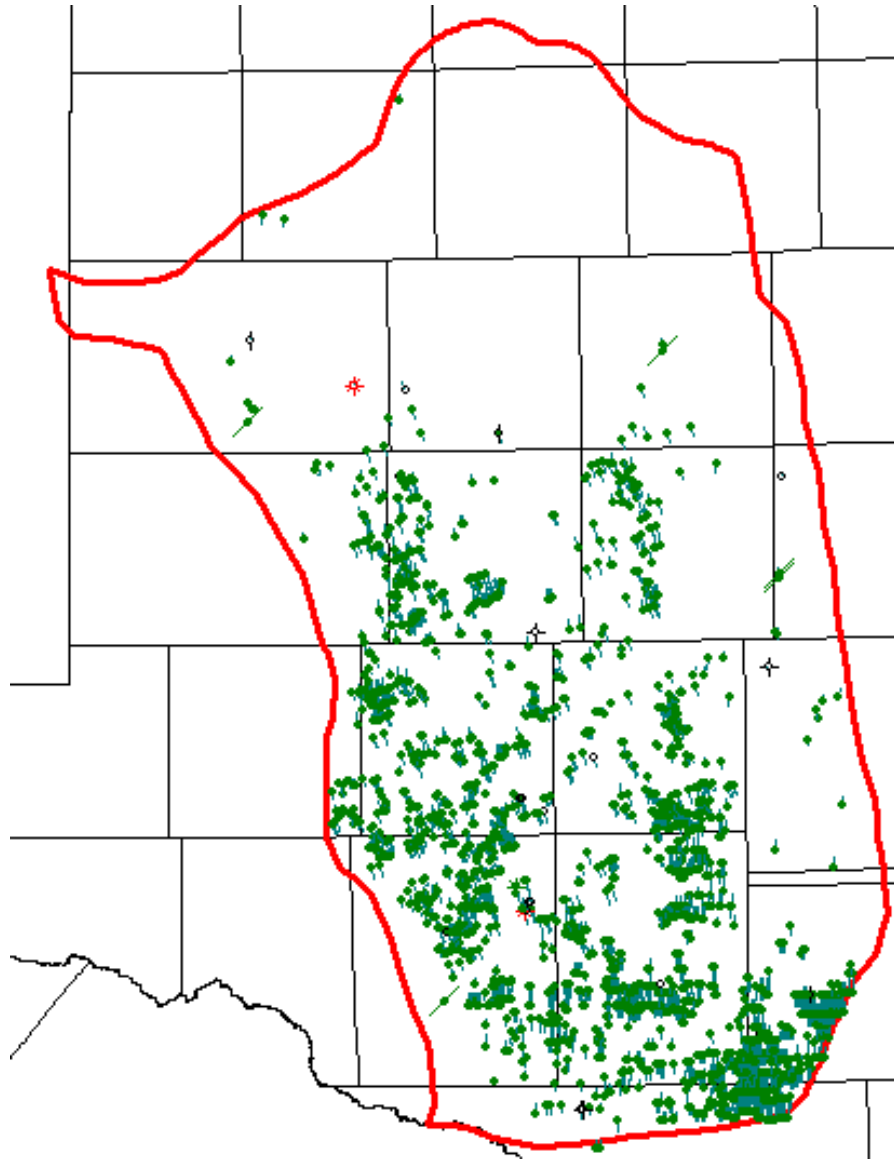
Play Particulars

- 5,114 total HZ wells drilled in Midland Basin

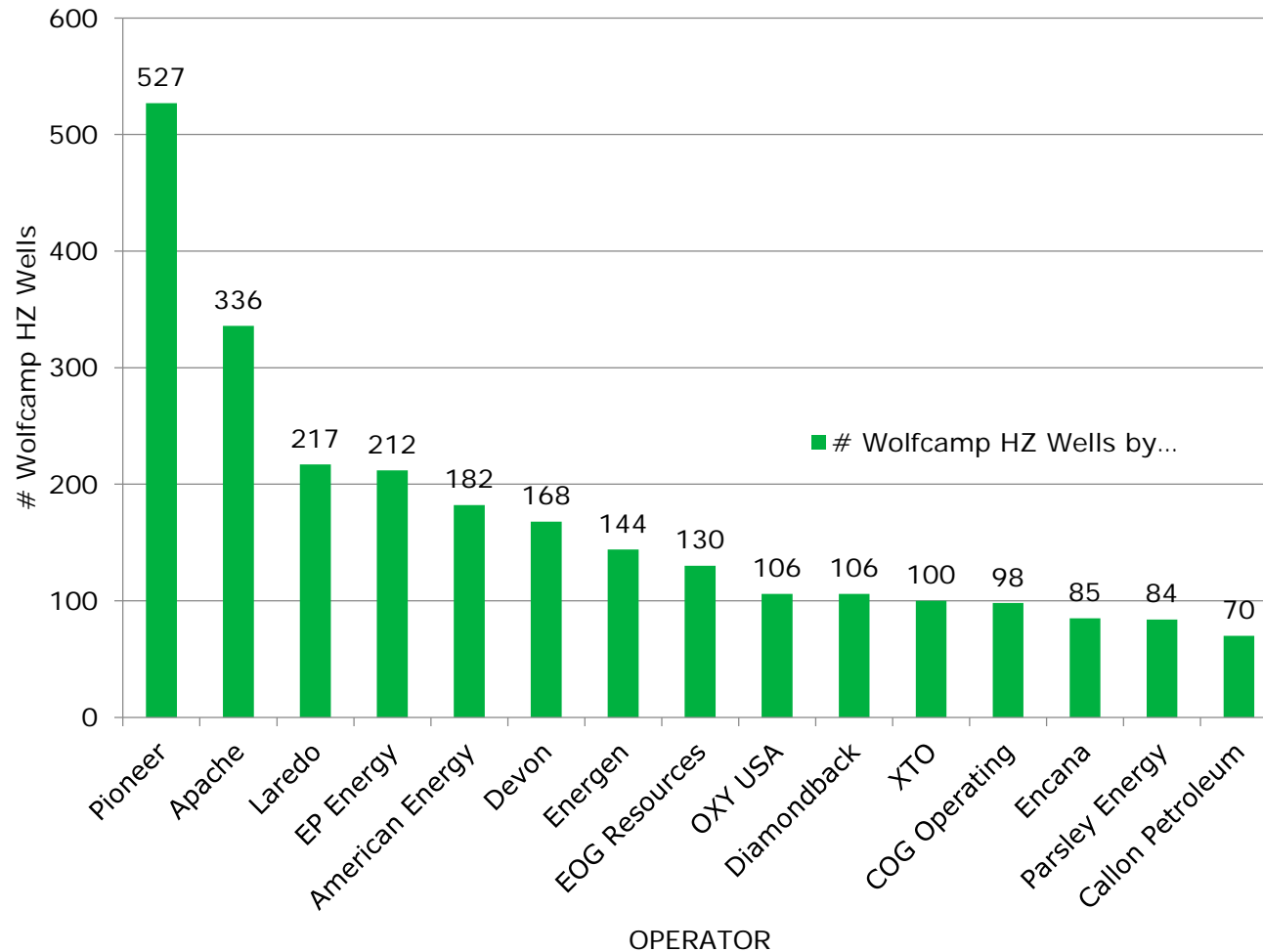


Play Particulars

- 3,017 total HZ wells drilled in Wolfcamp Formation

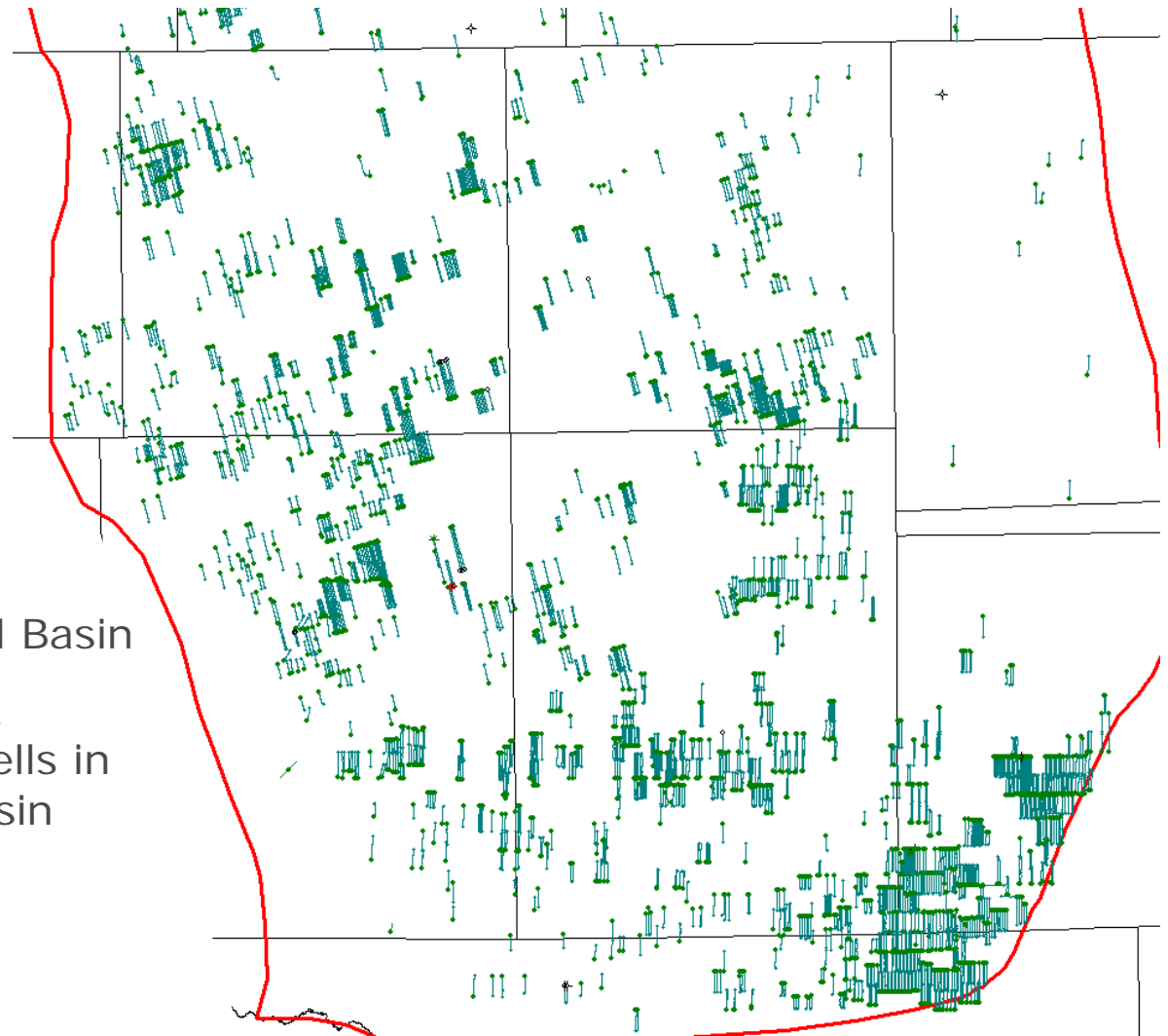


Wolfcamp HZ Wells by Operator



Data from Enerdeq thru May 2016

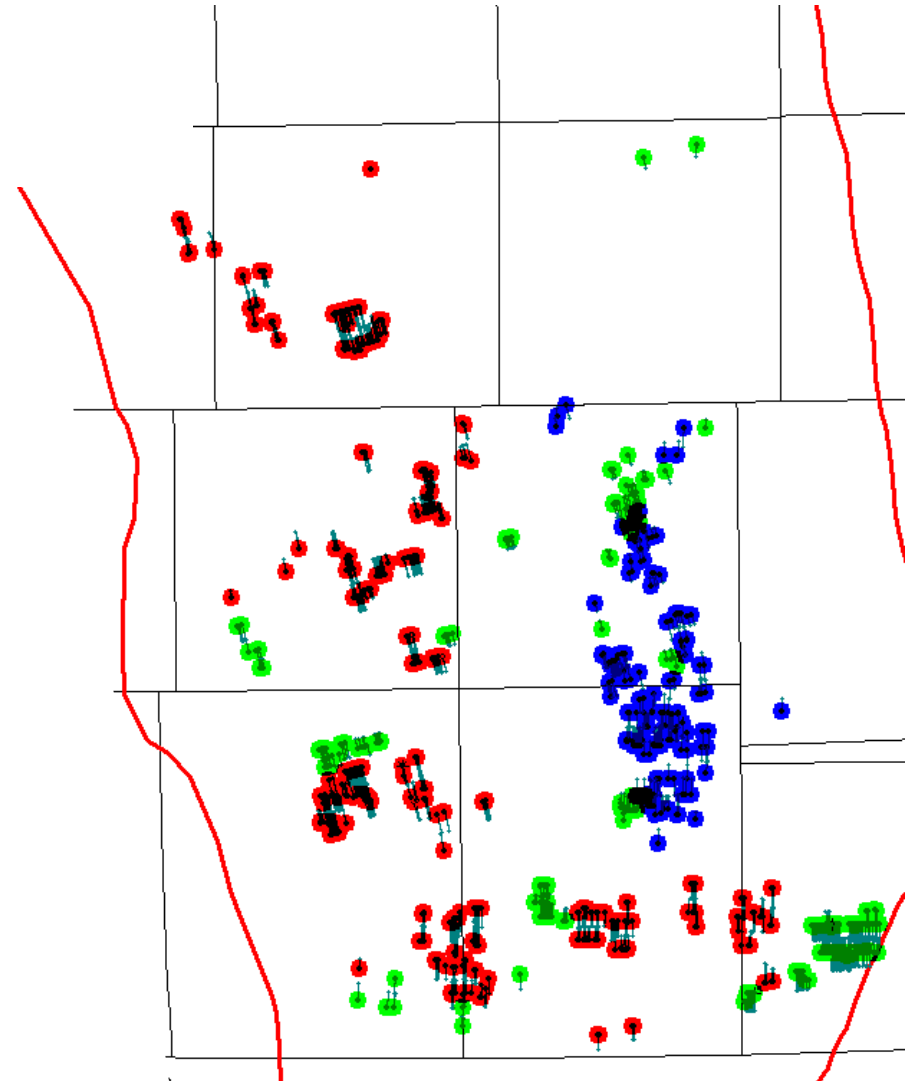
Top 15 Wolfcamp HZ Operators - Midland Basin



- Map of Southern Midland Basin
- The top 15 Wolfcamp HZ Operators have 2,510 wells in the southern Midland Basin

Top 3 Wolfcamp HZ Operators - Midland Basin

- The top 3 Wolfcamp HZ Operators have 1,080 wells in the southern Midland Basin
- These include:
 - > Pioneer Natural Resources ●
 - > Apache Corporation ●
 - > Laredo Petroleum ●

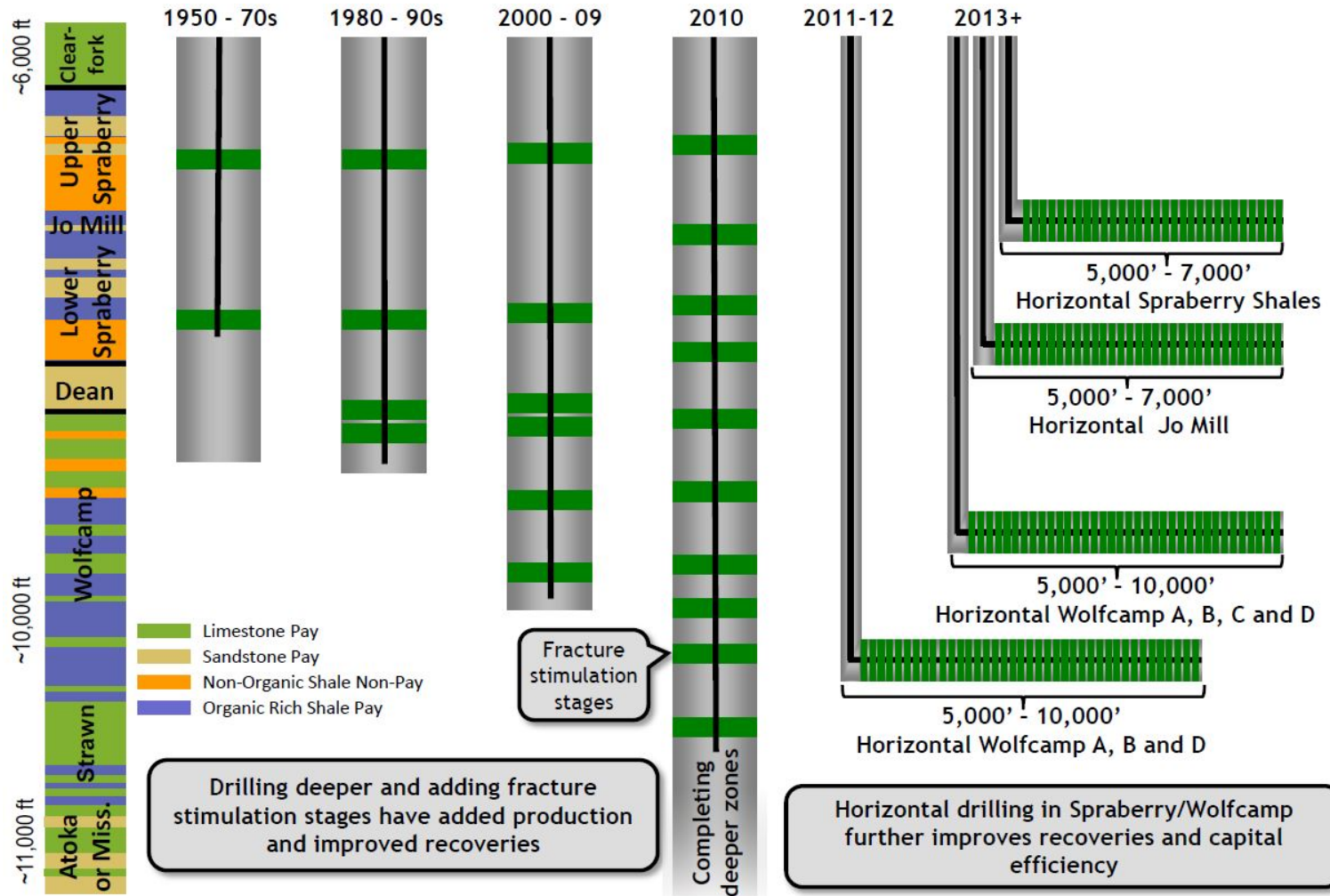


Play Particulars – Lateral Lengths

- Total Wolfcamp HZ = 3,017 wells
- Average Lateral Length = 7,107 ft
- 122 wells with laterals > 10,000 ft
- Laterals now being drilled > 13,000 ft
 - i.e. by Pioneer



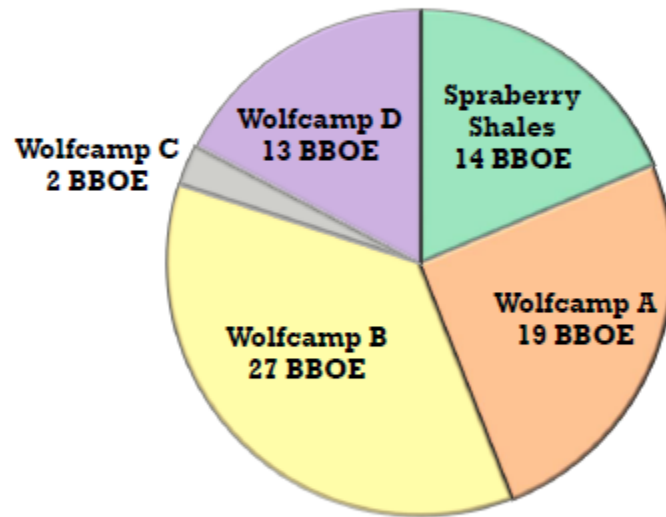
Wolfcamp Play



From Pioneer Natural Resources (2013)

MIDLAND BASIN HORIZONTAL RESOURCE POTENTIAL

75 BBOE Recoverable Resource Potential



- 75 BBOE recoverable resource potential in shale intervals where successful horizontal wells have been drilled
- Assumes 140-acre spacing on 75% of acreage and downspacing to 100-acres on 25% of acreage; additional down-spacing potential exists
- Additional horizontal potential from other intervals (e.g. Clearfork, Middle Spraberry Shale, Atoka, Woodford)

Source: Pioneer Natl Resources Dec 2016 Investors Presentation

Summary

- Based upon areal extent, abundant and thick source rocks, and stacked pay zones, the **Wolfcamp Play is one of the largest resource plays in the world.**
- When Wolfcamp and the overlying Spraberry Formation are combined, i.e. The Wolfberry Play, this may be the largest resource play in the world.
- Total Recoverable Reserves for the Wolfcamp Play may exceed 20 billion barrels oil. Estimates range from 20 – 75 billion barrels of oil.



Questions?

