

# **Devonian-Mississippian Petroleum Systems of Southern Laurasia: What Makes the STACK-Merge-SCOOP Play in Oklahoma so Special\***

**Andrew Cullen<sup>1</sup>**

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<sup>1</sup>Warwick Energy, Oklahoma City, Oklahoma ([andrew.cullen@warwick-energy.com](mailto:andrew.cullen@warwick-energy.com))

## **Abstract**

Devonian-Mississippian unconventional plays and reservoirs of the greater Mid-Continent encompass the full range of unconventional tight reservoirs and play types. From shelf to basin, the Mississippian Lime, STACK, Merge, SCOOP, and Barnett Shale plays comprise a petroleum megasystem that records a change in source rock depositional environments. Devonian siliceous mudrocks of the Woodford Formation were deposited on locally incised shallow marine platforms, whereas Early Mississippian (Lower Carboniferous) siliceous source rocks were deposited in a foreland basin created by continental collision of Gondwana with Laurasia during closure of the southern Iapetus Ocean. This article explores the question of why the Meramec siltstones and correlative lithofacies in the STACK, Merge, and SCOOP are so prolific relative to other Devonian-Mississippian basins and embayments of southern Laurasia that share lithostatigraphic characteristics: Rancheria Formation (New Mexico), Barnett Shale (Permian Basin), Moorefield Shale (Arkansas), and Borden Siltstone (Illinois Basin).

## **References Cited**

Gutschick, R.C., and C.A. Sandberg, 1983, Mississippian continental margins of the conterminous United States: Society of Economic Paleontologists and Mineralogists, Special Publication No. 33, p. 79-96.

Higley, D.K., M.E. Henry, M.D. Lewan, and J.K. Pitman, 2003, The New Albany Shale Petroleum System, Illinois Basin - Data and Map Image Archive from the Material-Balance Assessment: USGS Open-File Report 03-037, Website accessed September 27, 2017.  
<http://pubs.usgs.gov/of/2003/ofr-03-037/>

Klemme, H.D., and G.F. Ulmishek, 1991, Effective petroleum source rocks of the world: Stratigraphic distribution and controlling depositional factors: AAPG Bulletin, v. 75/12, p. 1809-1851.

Schaefer, Keith, 2013, Illinois Basin's New Albany Shale: The next big U.S. horizontal oil play?: Oil and Gas Investments Bulletin, September 23. Website accessed September 27, 2017.

<https://oilandgas-investments.com/2013/oil-and-gas-financial/illinois-new-albany-shale-oil/>

Sorkhabi, Rasoul, 2009, The Earth's richest source rocks: GeoExpro, v. 6/6, p. 20-27.

Stevenson, D.L., 1964, Carper sand oil production in St. James, Wilberton, and St. Paul pools, Fayette County, Illinois: Illinois State Geological Survey, Circular 362, 12 p.

# Devonossippian Petroleum Systems of Southern Laurasia: What Makes the STACK-MERGE-SCOOP in Oklahoma so Special?

**Andrew Cullen\***  
**Warwick Energy**

**\* On behalf the Warwick's Geology Team: Doug Bellis, Mallory Zelawski, Colton Portwood, Ursula Faus, Corey Dimond, Tricia Rudd, Sumeer Karla- honorary**

**Acknowledgements to our University of Oklahoma co-collaborators:  
Matt Pranter, Zulfiquar Reza, Paul Philp, Josh Miller, Garrett Hickman, Bradley Cronk**

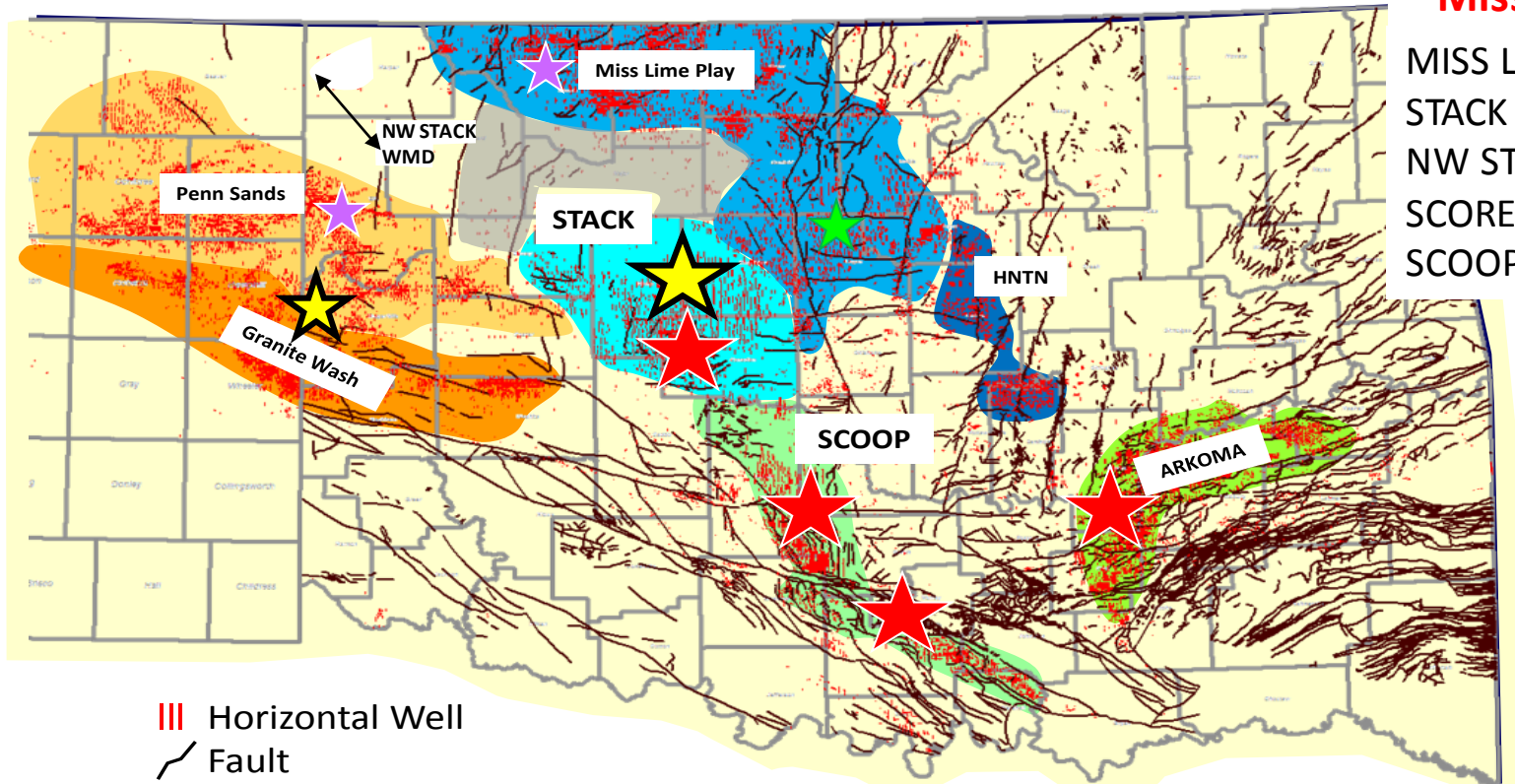
**Special Thanks**  
**Kate Richard for inspiration & leadership**  
**AAPG for the quite unexpected invitation to speak.**

- **STACK-SCOOP Regional Setting**
- **Stratigraphic Considerations & Correlations**
- **Reservoir Characterizations**
- **Charge-Maturity-Migration Considerations**
- **Overpressures**
- **How the Midcontinent Mega-Systems works.**
- **Southern Laurasia Devonian-Mississippian systems.**
- **Play Analysis: Why the STACK is special.**
- **Conclusions**



28,000 horizontal wells. Vertical wells are now the exception

## OKLAHOMA'S PRINCIPAL HORIZONTAL PLAYS



## Mississippian Plays

MISS LIME  
STACK  
NW STACK – WMD  
SCORE  
SCOOP

N  
↓  
S

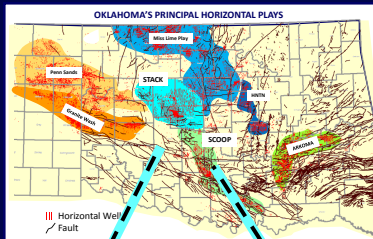
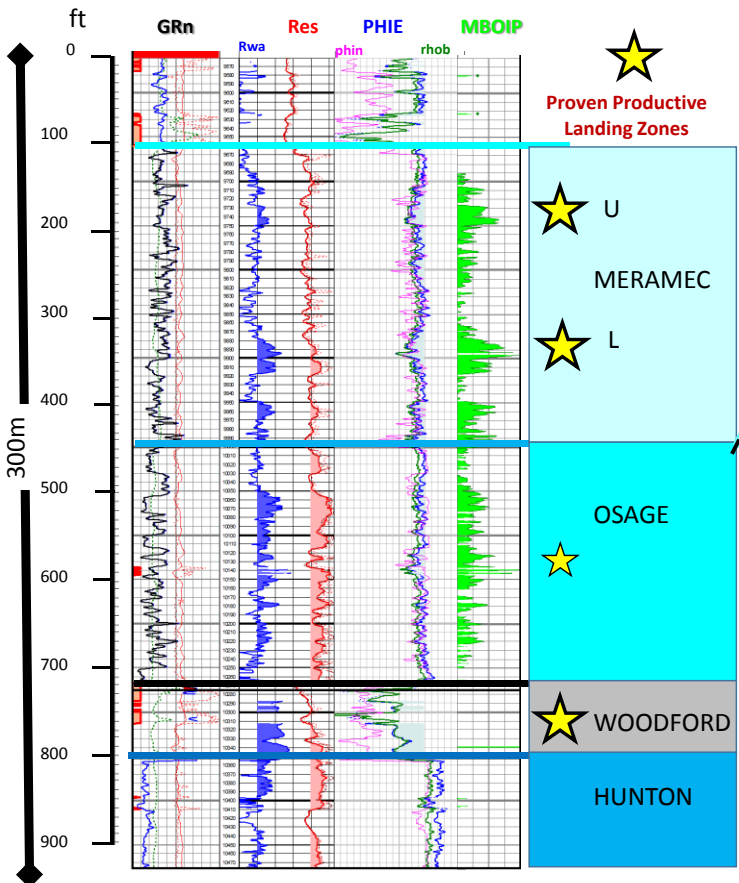
## 4 Horizontal Play Types (nearly all worked vertically somewhere)

1. Source-rock shales (Woodford and Springer shales) ★
2. Tight reservoirs adjacent to source rocks (Meramec, Granite Wash) ★
3. Tight reservoirs with long distance migration (Miss Lime) ★
4. Dewatering of dual porosity carbonates ★

# STACK & SCOOP: MULTIPLE STACKED HORIZONTAL TARGETS

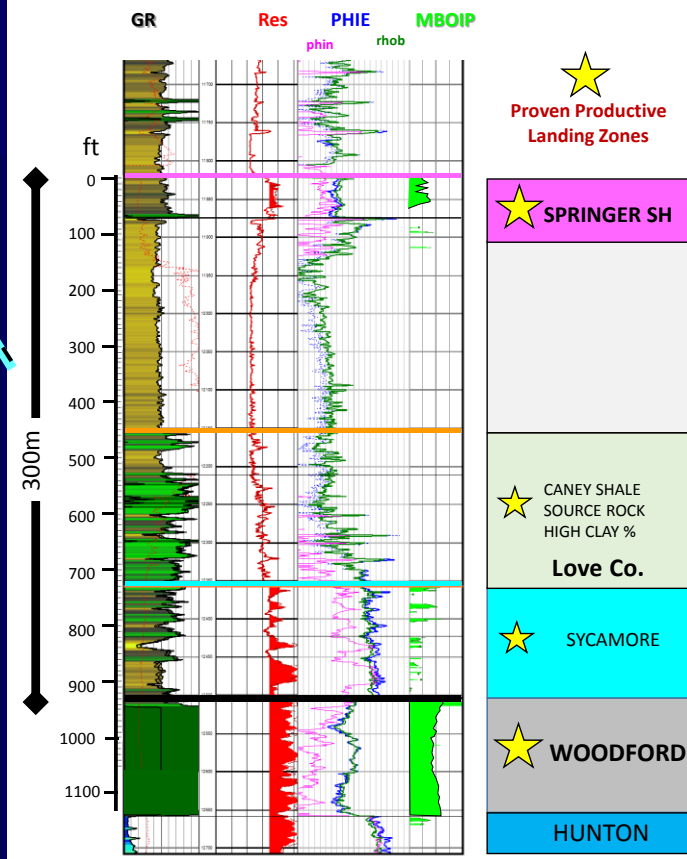
GULF OIL CORP  
SHAFFER 1-23  
660 FSL 1980 FWL  
TWP: 16 N - Range: 10 W - Sec. 23

## TYPE LOG STACK



WESTERN O&G DEV CORP  
HART 1-25  
2130 FSL 1320 FEL  
TWP: 7 N - Range: 8 W - Sec. 25

## TYPE LOG SCOOP



## STACK

Woodford was the initial basal target  
Current focus is on the Meramec.  
Osage productive & being appraised

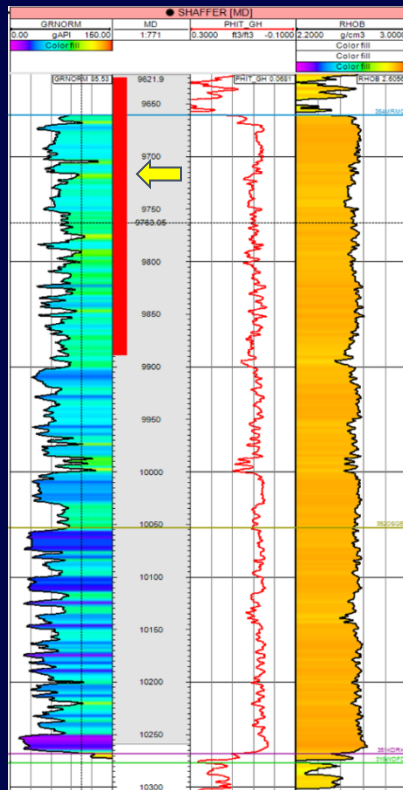
## SCOOP

Woodford original target- active drilling.  
Springer discovered later – active drilling  
Sycamore productive & being appraised

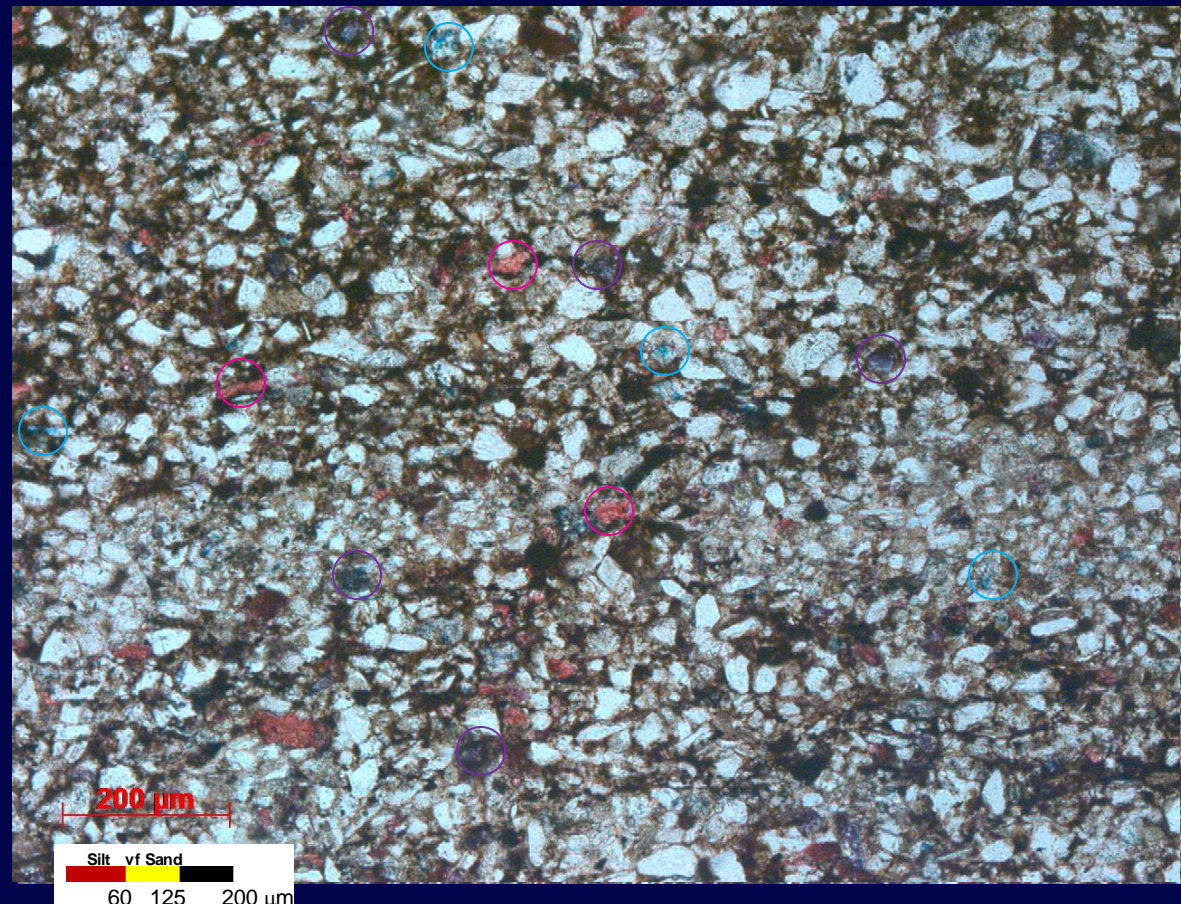


## Siltstone Argillaceous Calcareous

- Well-sorted, sub-angular silt-sized quartz grains
- Pink grains are carbonate skeletal fragments.
- Light blue is epoxy filled porosity.
- Violet rhombs Fe-dolomite



GS 9716.5ft



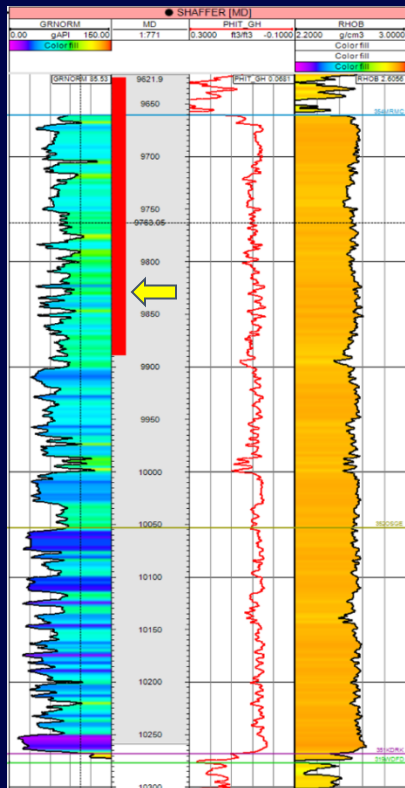


# MERAMEC IS A CLASTIC RESERVOIR

- Local carbonate factory mixed with transported silt-sized quartz

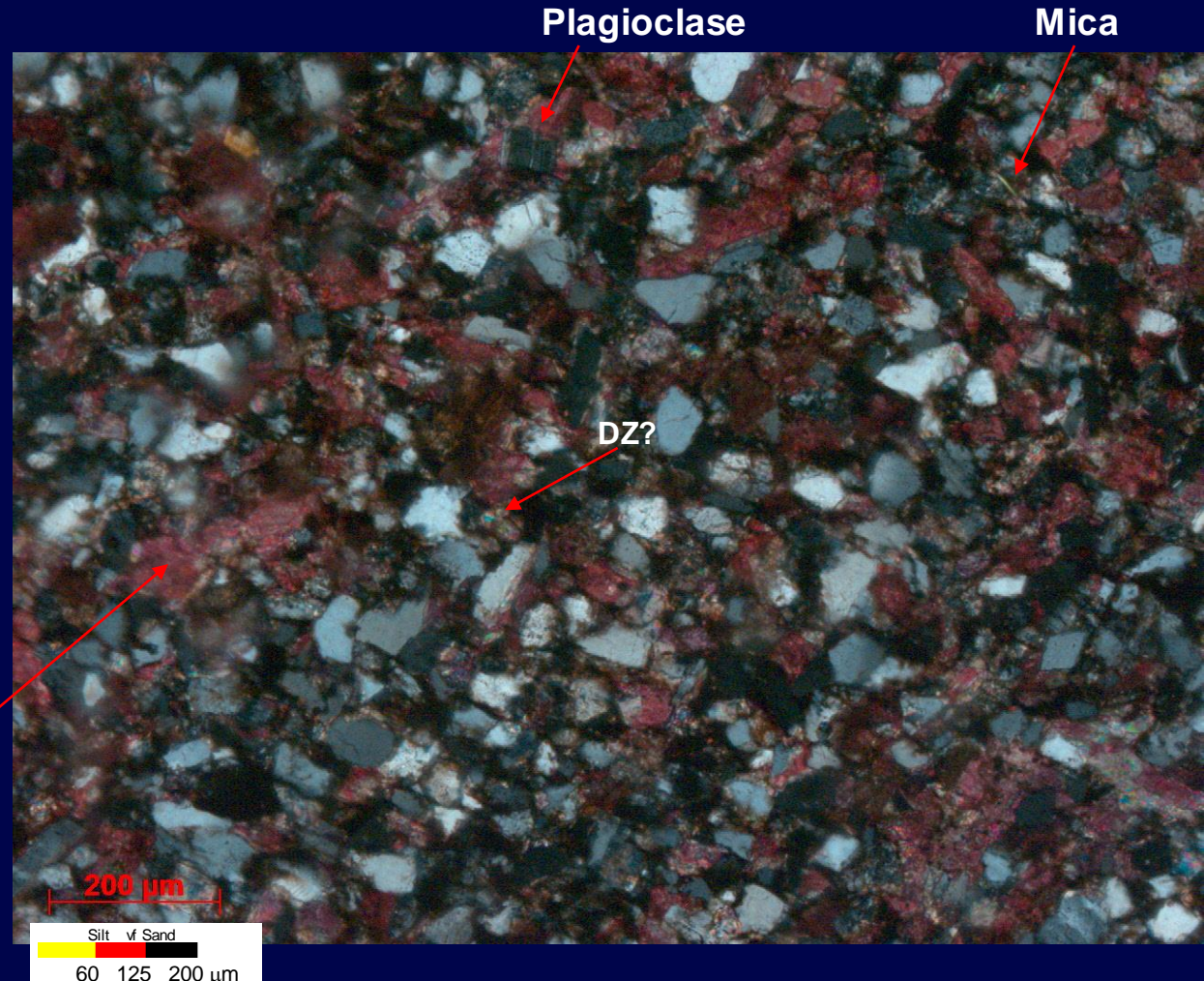
- Predominantly angular silt-sized quartz and plagioclase grains
- Intergranular pores is occluded by calcite and Fe-dolomite cement
- Accessory minerals: mica, pyrites, zircon?

## Calcareous Siltstone

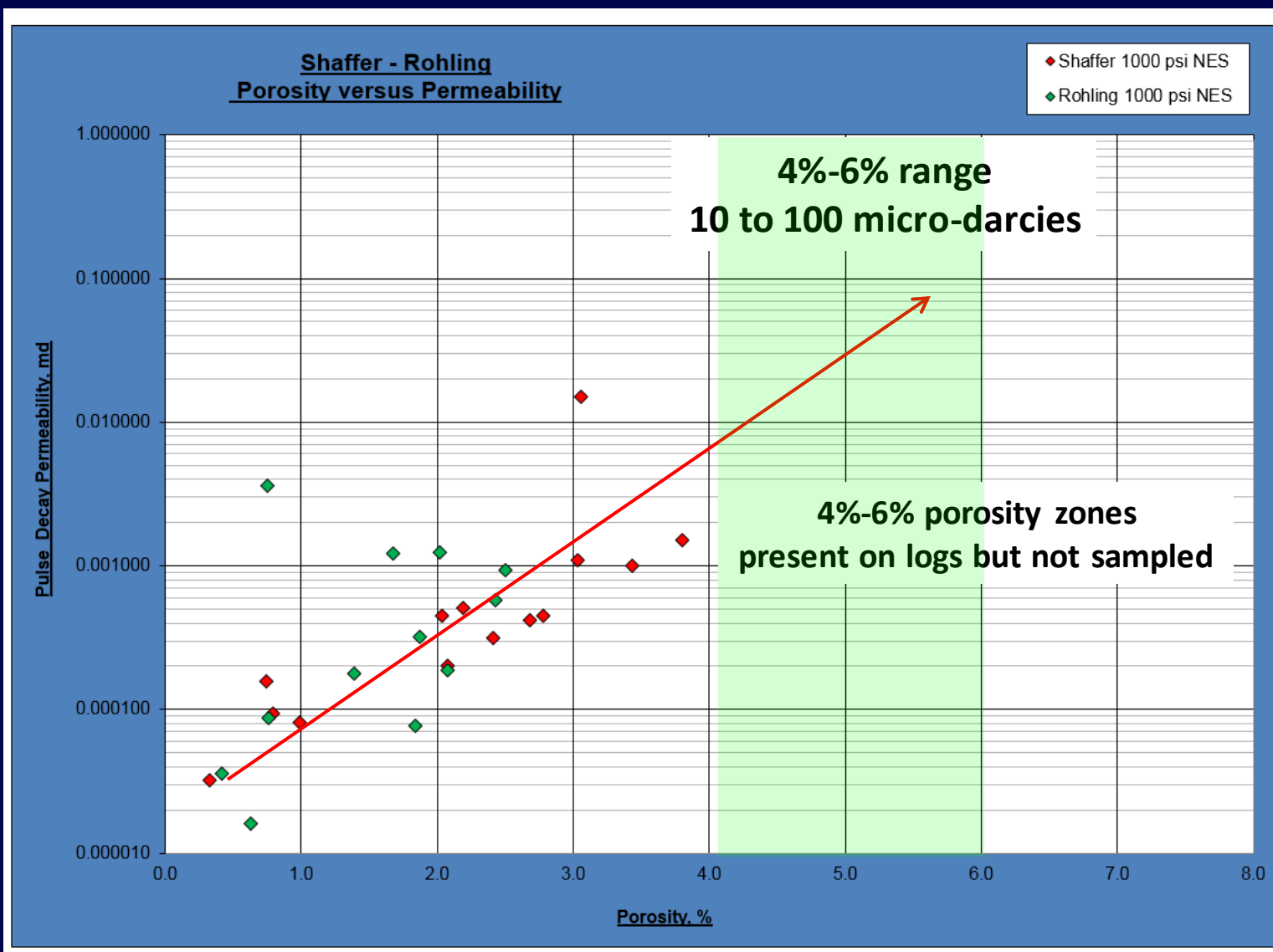


GS 9821.5ft

Calcite  
Cement



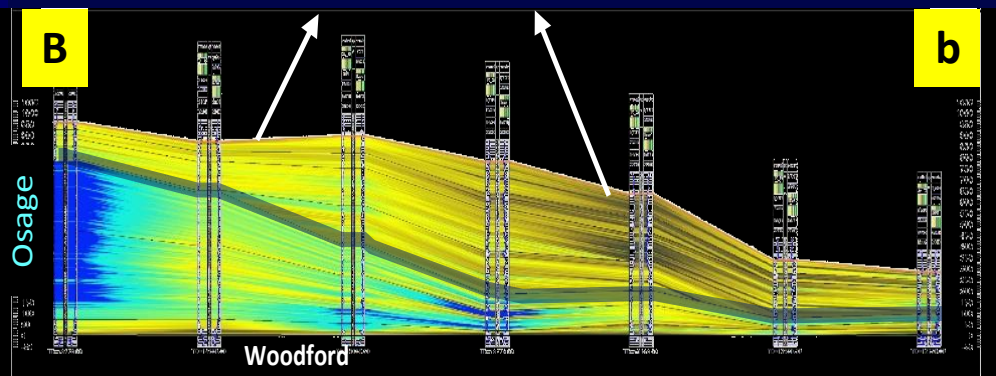
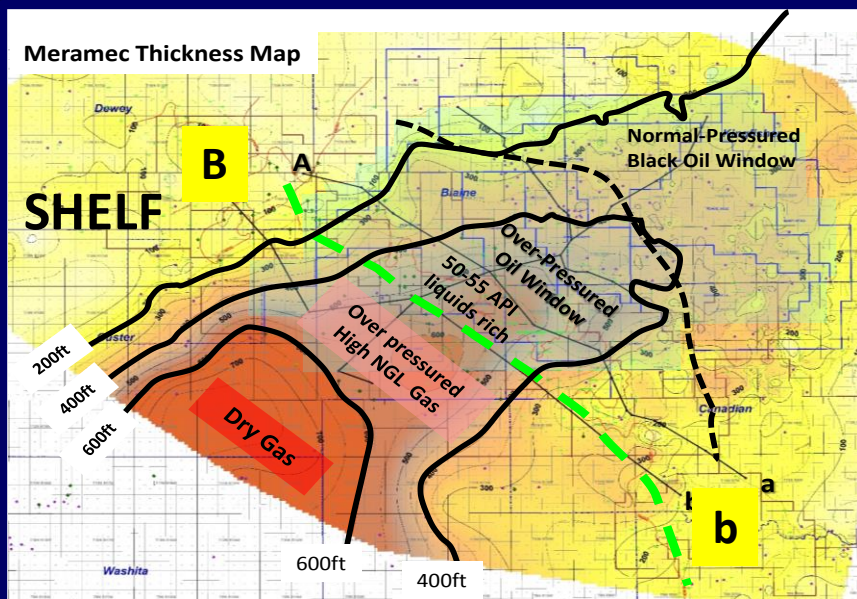
Silt < 60  $\mu\text{m}$  = .06 mm



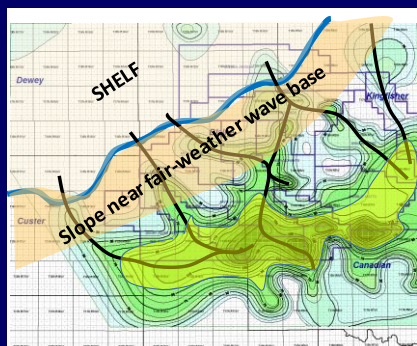


# MERAMEC DEPOSITIONAL MODEL

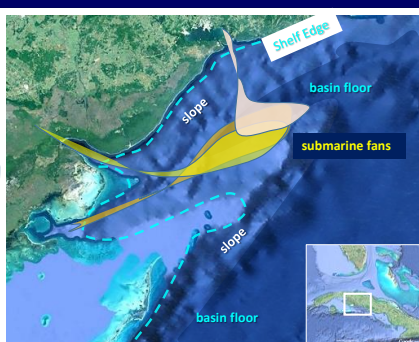
The Meramec formation: siltstones deposited as clinoforms & small fan lobes on a low angle ( $<0.2^\circ$ ) ramp outboard of the Osage shelf.



Wave / current influenced traction deposition



6% PHI ISOPACH



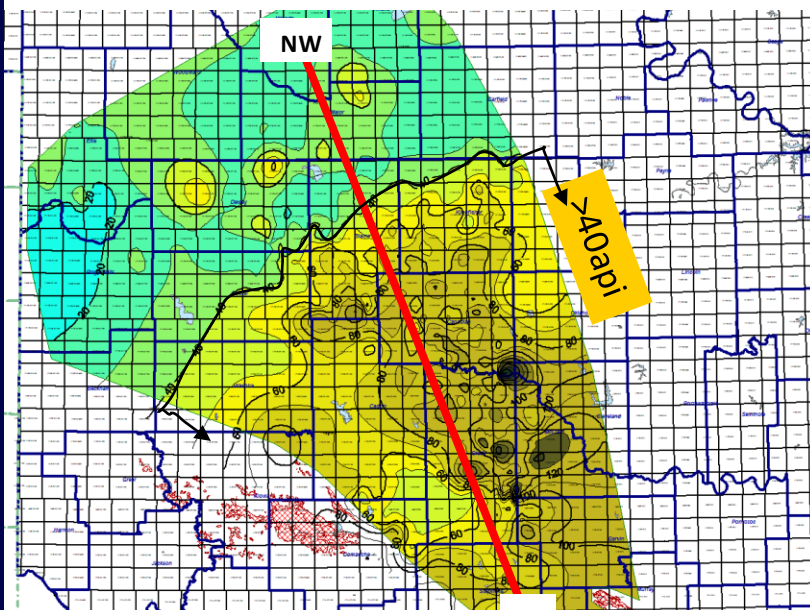
Southern Cuba: analog for depositional setting of Meramec; toe of slope submarine fans



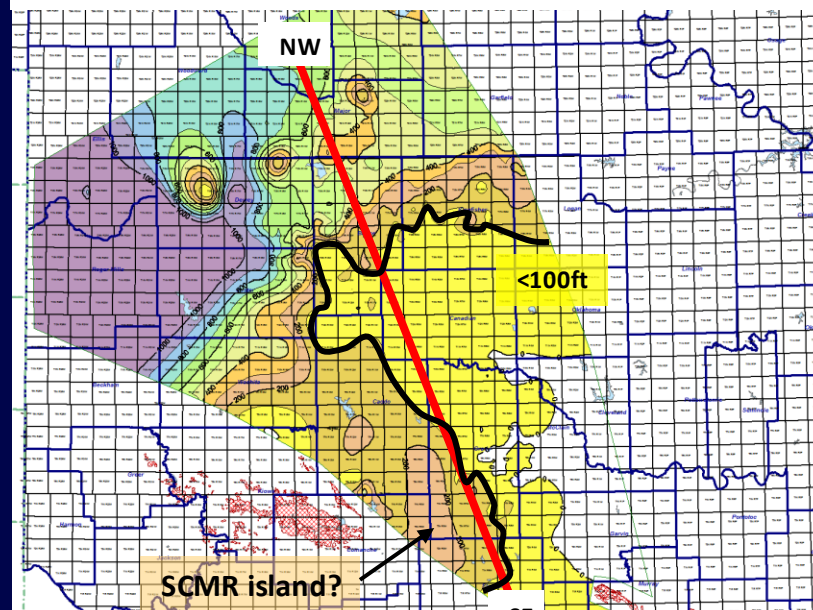
# STACK TO SCOOP CORRELATION

## MERAMEC~ LOWER CANEY / "OSAGE" ~ SYCAMORE

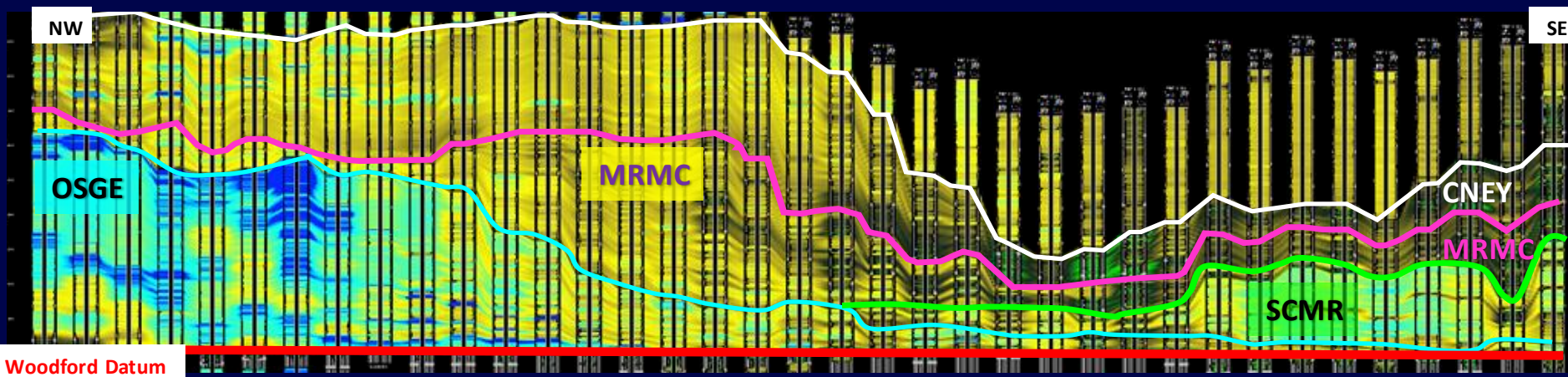
MRMC-CNEY to WDFD Avg. Gamma Ray



MRMC-CNEY to WDFD Net Ft. GR <40 API



Increase in average gamma ray correlates with decrease thickness of sand & carbonate

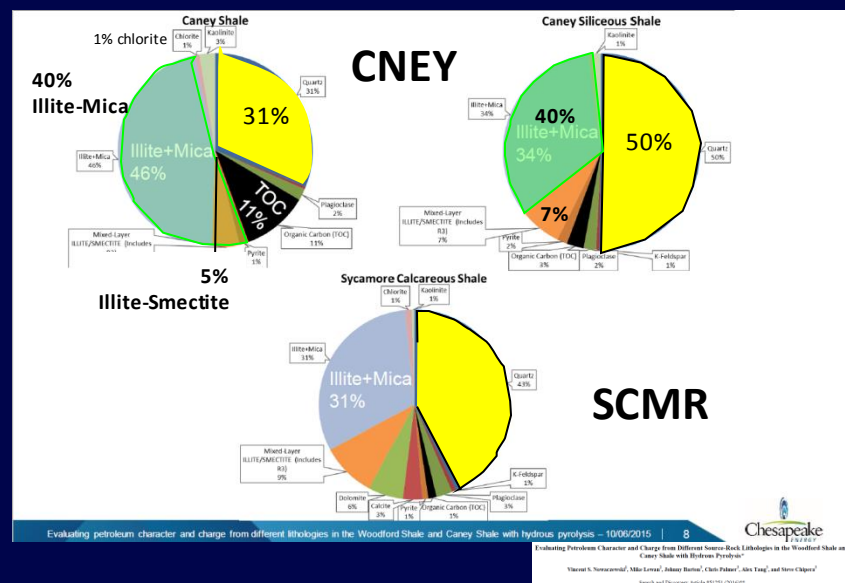
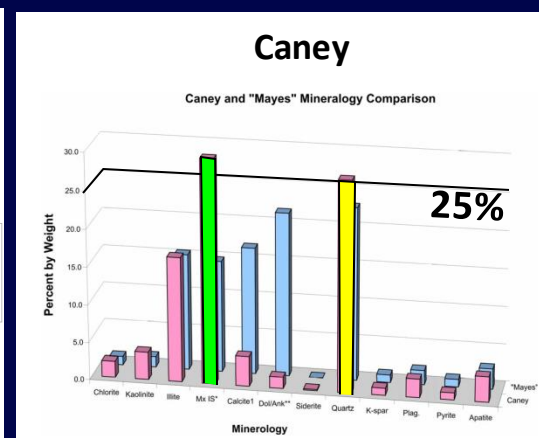
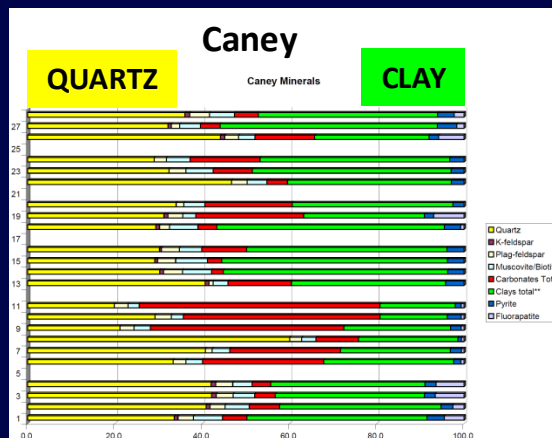


# MERAMEC to CANEY XRD facies down-dip change

- Increasing clay % at expense of carbonate, much lower chlorite
- Increasing % TOC basinward

## Whole Rock Mineralogy (Weight %)

MRMC STACK	(n=25)	AVG	SD
	Quartz	37.71	12.92
	K-Feldspar	1.65	1.19
	Plagioclase	6.67	1.92
	Calcite	37.82	21.95
	Ankerite	0.10	0.27
	Fe-Dolomite	3.51	2.75
	Pyrite	0.68	0.43
	Apatite	0.66	1.17
	Phyllosilicates	11.19	6.96
	Phyllosilicates	AVG	SD
	ML I/S	13.03	9.72
% detrital ?	Illite&Mica	56.52	11.84
	Kaolinite	10.30	6.65
	Chlorite	20.15	8.87



Fresh water mixing OR altered mafic igneous rock fragments?

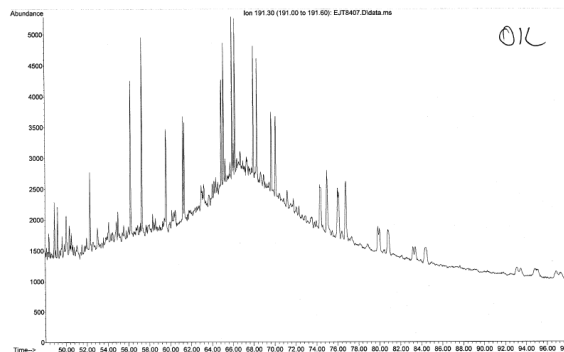


# MERAMEC OIL-SOURCE ROCK CORRELATION

- Good source rocks present but discreet beds are not common.
- Thinner laminae and dispersed organic matter are common.
- Meramec is partly self sourced – imprints Woodford + Caney

## MERAMEC OIL -STACK BLURTON 6-7 16N 10W Rock extract from core

Acquired : 29 Jan 2017 20:07 using AcqMethod GC100SPLETS1,4 MID3\_8-19-16 AS.M  
Instrument : 5975.2  
Sample Name: WarwicK\_MB\_SAT  
Misc Info : Water Bath  
Vial Number: 14

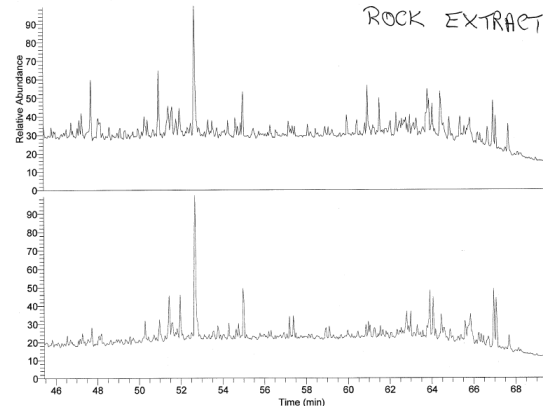


C:\kcalburdata\SERVICE823

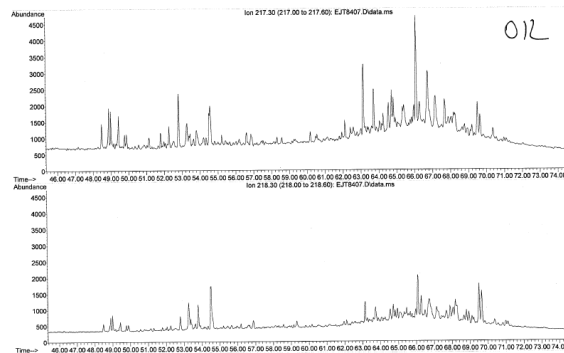
1/29/2017 11:07:33 AM

MEREMAC SAT.

RT: 45.44 - 70.07



File : D:\MSD DATA\ET\BJT9407.D  
Operator :  
Acquired : 29 Jan 2017 20:07 using AcqMethod GC100SPLETS1,4 MID3\_8-19-16 AS.M  
Instrument : 5975.2  
Sample Name: WarwicK\_MB\_SAT  
Misc Info : Water Bath  
Vial Number: 14

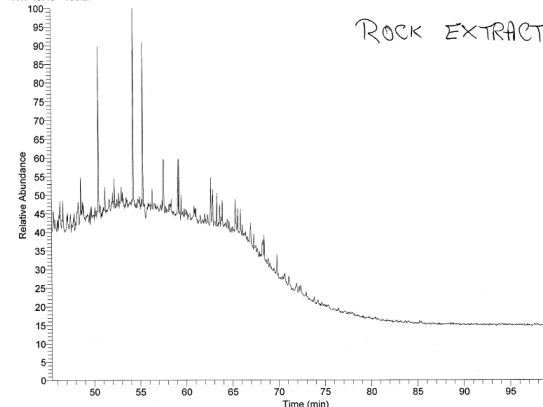


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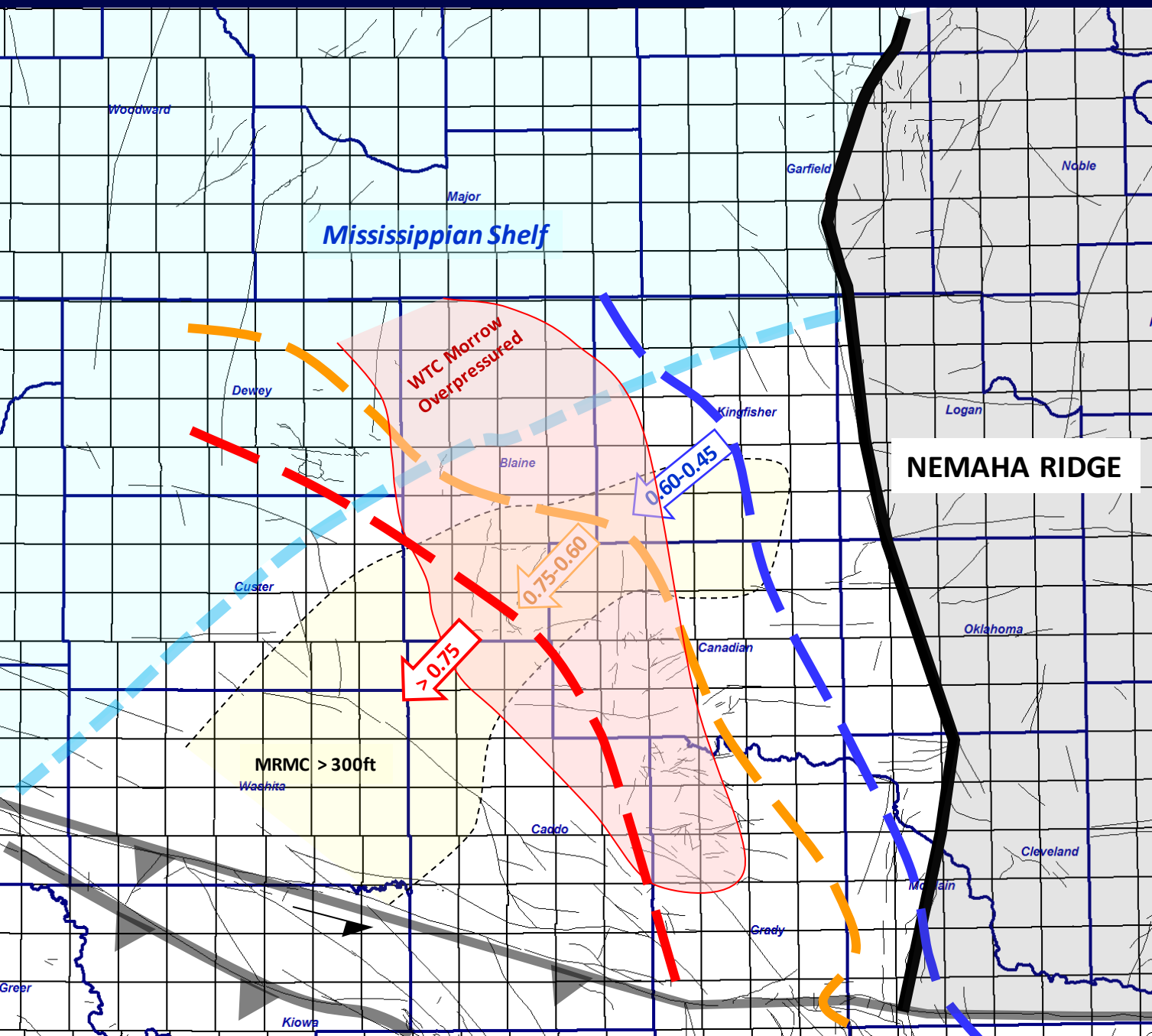
RT: 45.40 - 100.27



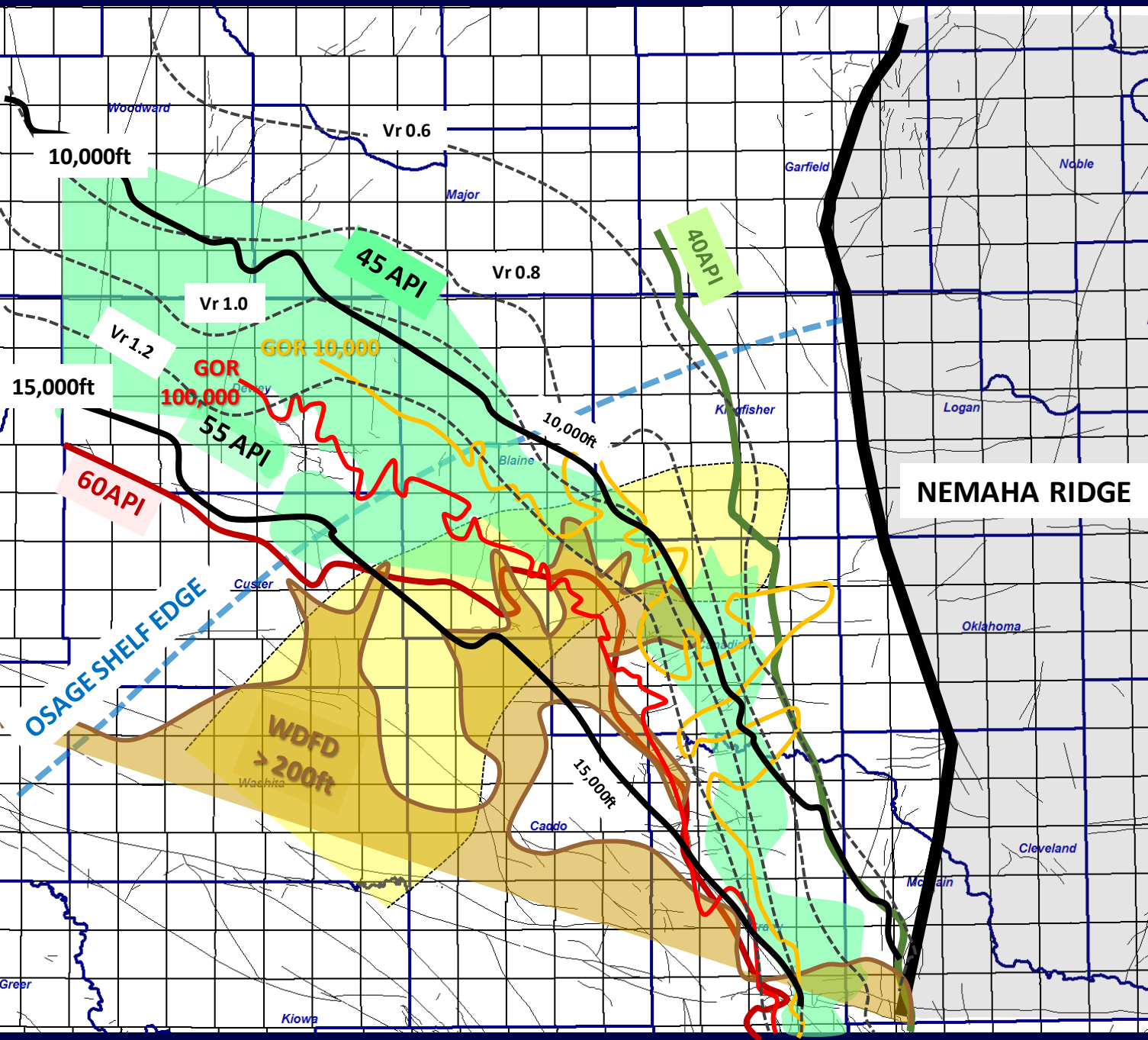
TOC 6.36%  
Tmax 444 °C  
HI 323

Play	TOC (%)	Ro	HI
Caney	1.2-9	0.8-2.0	20-180
Woodford	3-10	0.7-1.5	50-200

# OVERPRESSURE SANWICH BETWEEN 2 OVERPRESSURE SYSTEMS



# WOODFORD - MERAMEC MATURITY & FLUID PROPERTIES

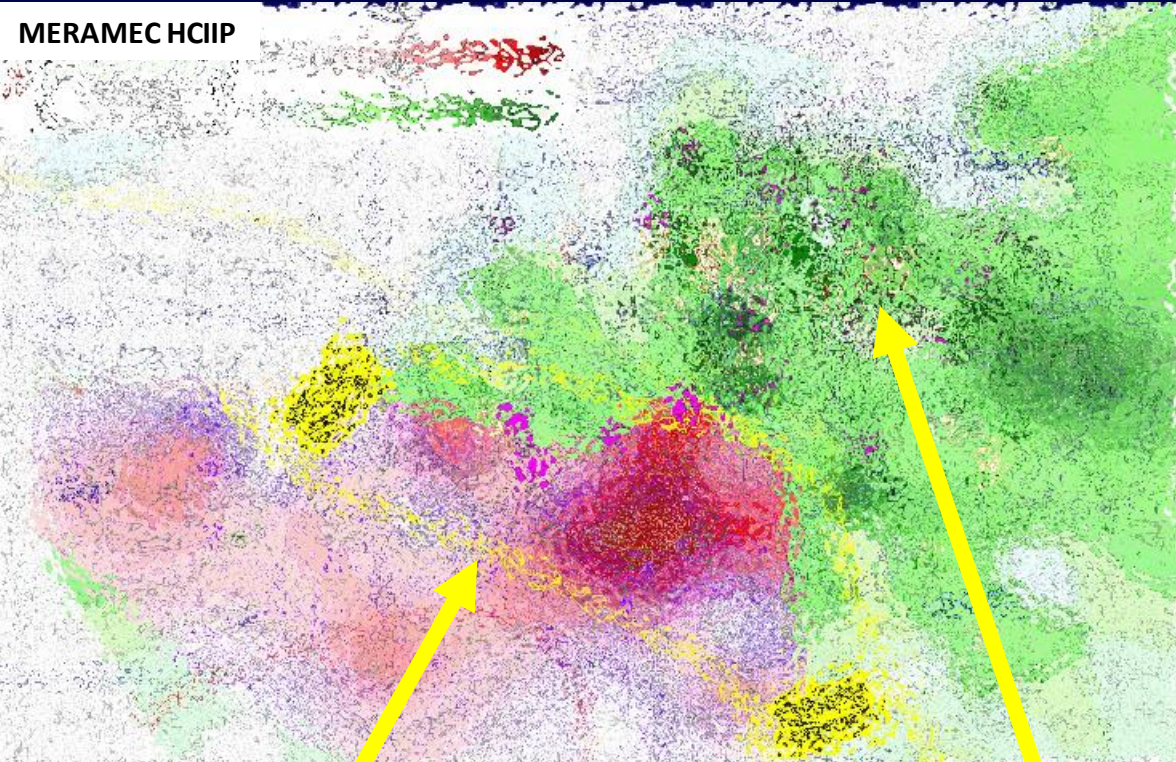


WARWICK

## STOCK TANK OIL and GAS IN PLACE

## ESTIMATED ULTIMATE RESERVES

**MERAMEC HCIIP**

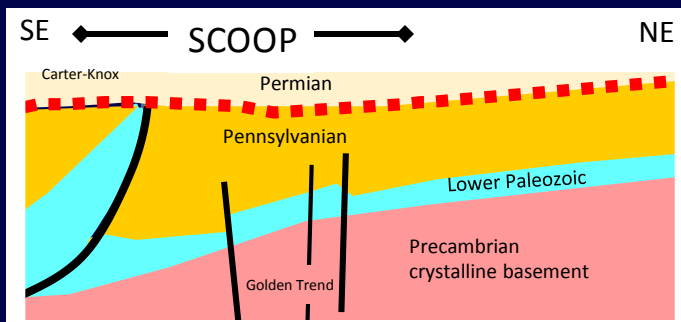
A micrograph showing a large, irregular, multi-colored mass (red, purple, yellow, green) against a light background. Two yellow arrows point to the mass. The mass appears to be a complex, possibly biological or chemical, structure. The background is a light, textured surface. The overall image is a high-magnification view of a sample.[illegible]

## High-NGL to dry gas window with wells up to ~20bcfg EUR

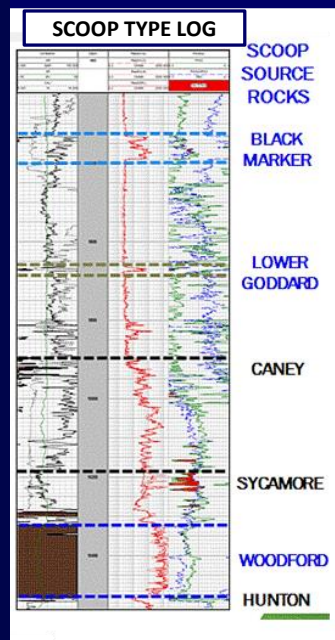
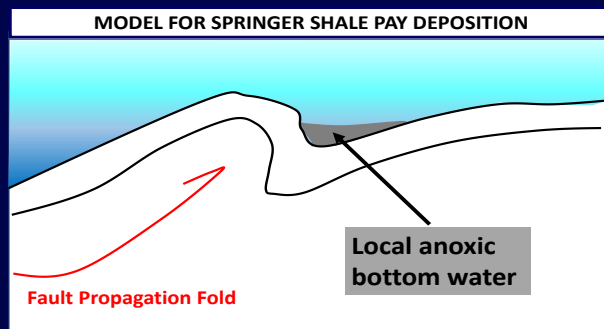


# SCOOP:WOODFORD + SPRINGER PRIMARY TARGETS

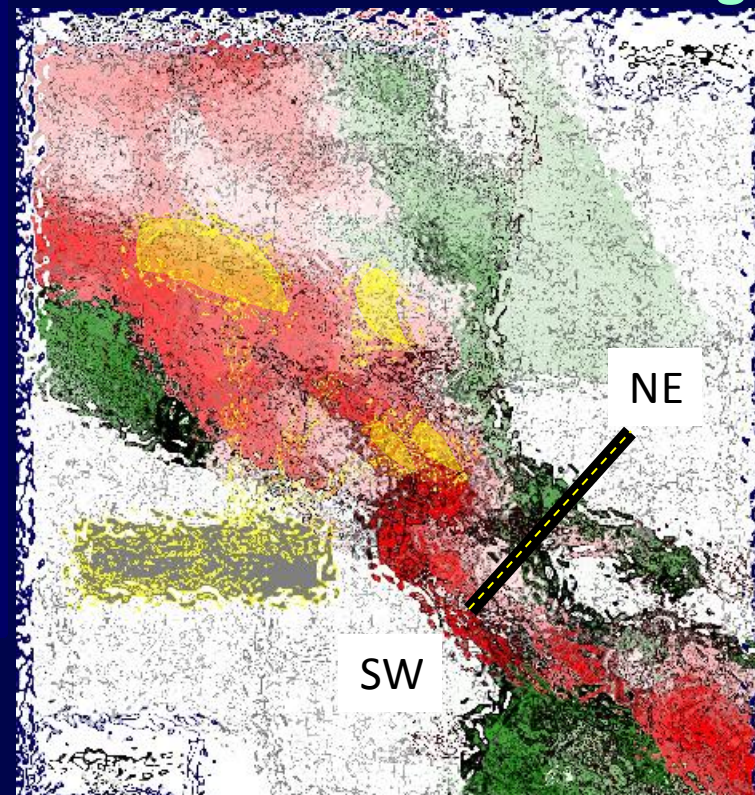
SCOOP - Woodford western extension of Arkoma shale play. Springer discovered later Prolific legacy vertical production in the Golden Trend and Carter-Knox  
Woodford shale thick enough to support stacked completions with 12 well down-spacing



Springer restricted deposition only locally overlies Woodford



SCOOP Woodford play  
EUR: 976mmbo and 28tcfg



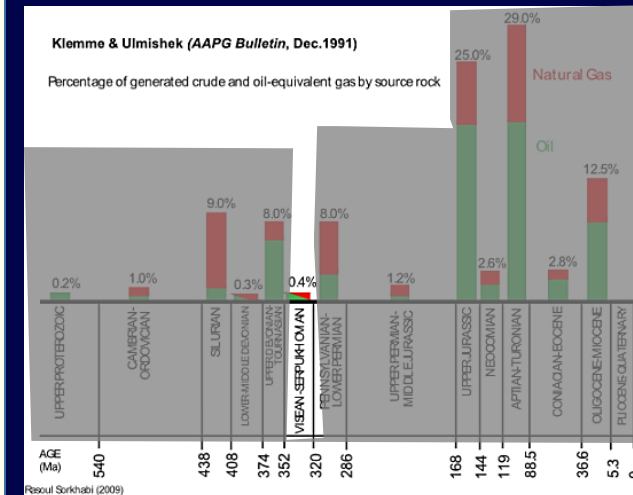


# In addition to the Woodford, excellent regional Mississippian age source rocks in Oklahoma, Texas, and Arkansas★

				Kansas	Anadarko STACK	Anadarko SCOOP	Ft. Worth	Arkansas
322	Pennsylvanian							
324	Mississippian 323	Serpukovian	Chesterian		Chester	Goddard	Barnett	Pitkin Lime
326				St. Genevieve				
328								Fayetteville
330								★
332		Viséan 331						
334			Meramecian	St. Louis	Meramec	Caney		Moorefield
336		●						
338				Salem				★
340								
342		●		Warsaw				
344			Osagean	Cowley	Osage	Sycamore		Boone-St. Joe
346								
348		Tournaisian 347						
350								
352								
354								
356			Kinderhookian					
358					Woodford	Woodford		Chattanooga
360	Devonian 359	Late	Famennian					
362								
364		●						
366								
368								
370								
372								
374			Fransian					
376								
378								
380								
382								
384		Middle	Givetian					
386								
388								

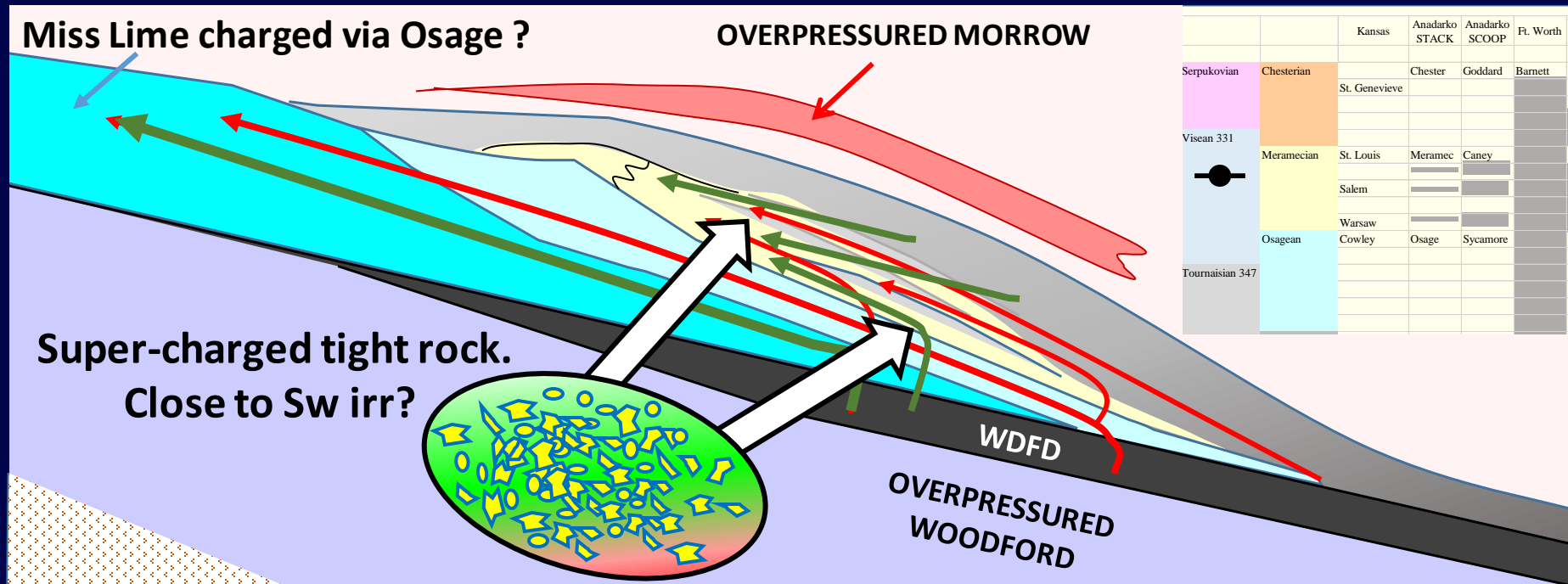
From a global perspective development of Barnett, Fayetteville, Moorefield, Caney, and Meramec source rocks is anomalous.

World-wide only 0.4% of generated HC are from Mississippian source rocks.



# REGIONAL CONSIDERATIONS: CHARGE & TRAP

- STACK-SCORE is essentially a mega-stratigraphic trap



**Rapid Burial 300-250 Ma**  
**Peak generation & expulsion**

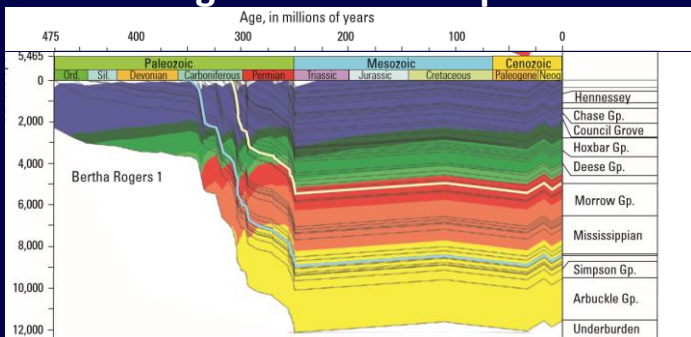
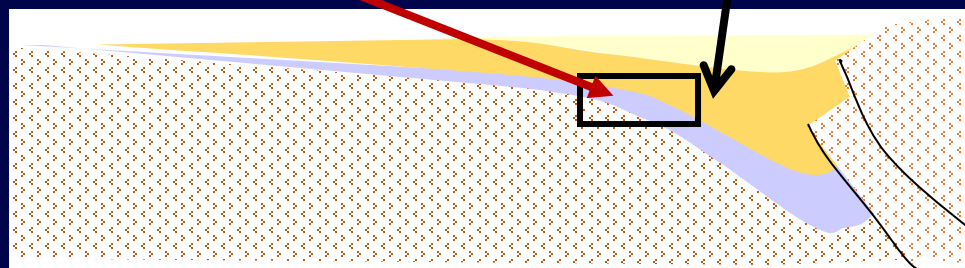


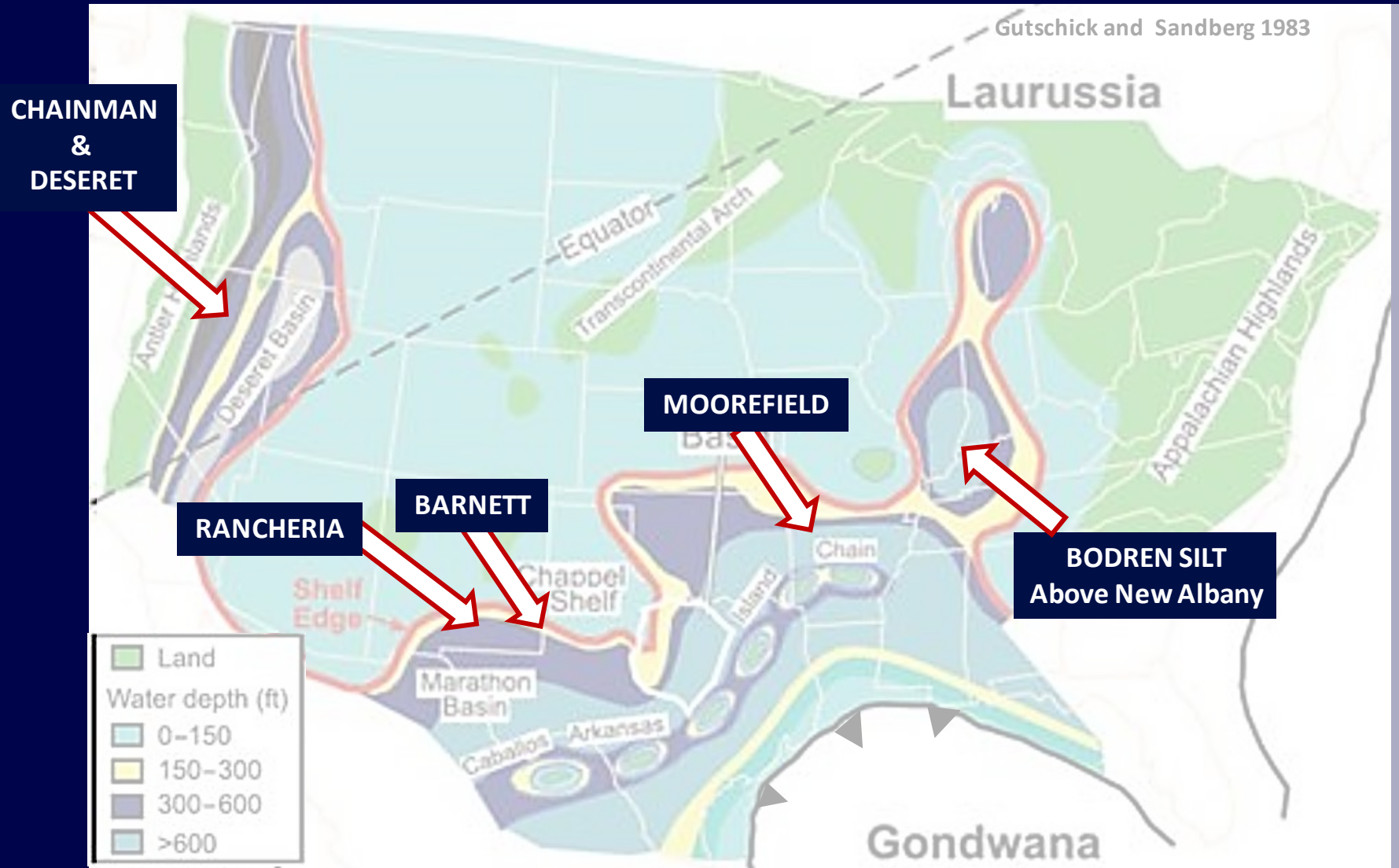
Figure 20. Burial history curves for the Bertha Rogers 1 and Petree Ranch 1 wells. Modeled

**Foreland basin**  
**Penn sands OP disequilibrium compaction**



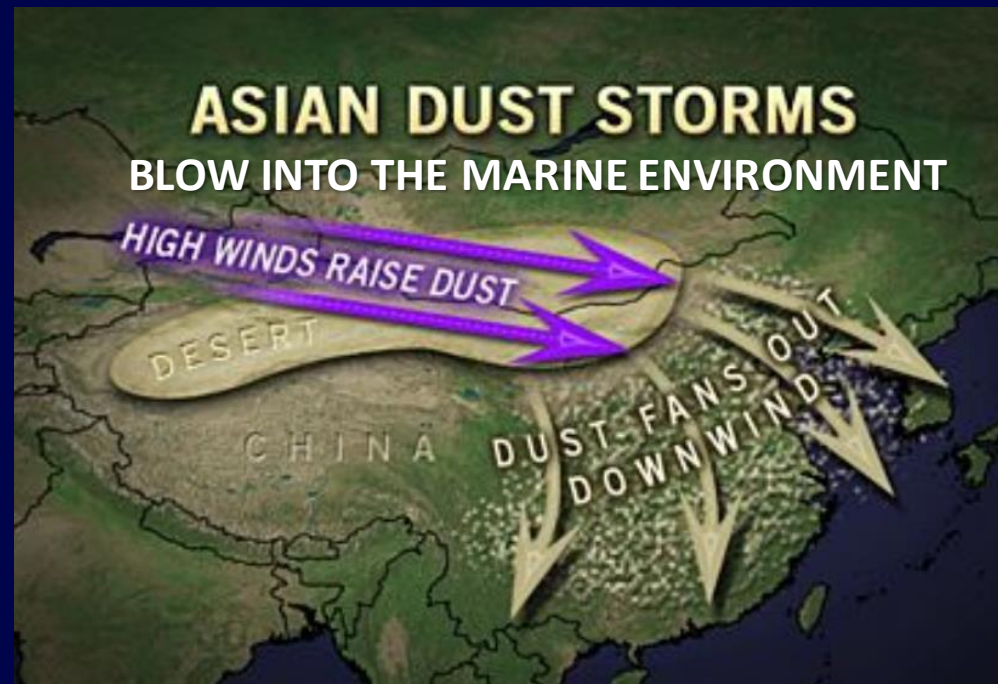
# PLAYMAKER CONSIDERATIONS: WHERE TO GO TO FIND ANOTHER ONE?

- **SOURCE ROCKS** – restricted circulation in peripheral foreland basins



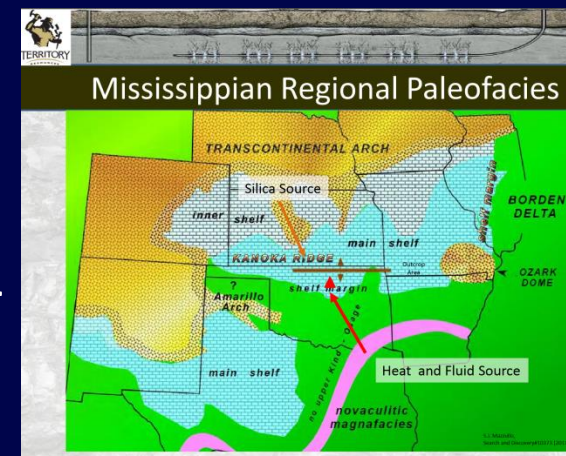


- RESERVOIR- WHAT'S THE SOURCE OF THE MERAMEC SILTSTONES?
- ARE THEY RE-WORKED LOESS DEPOSITS? If so how widespread are they?

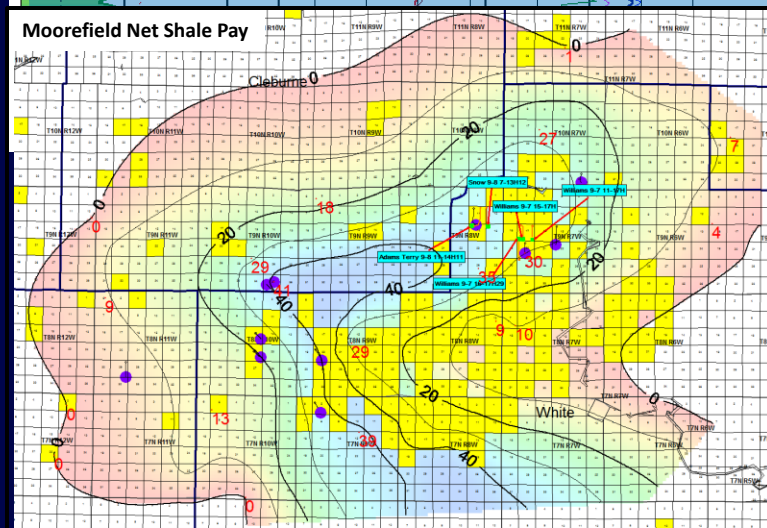
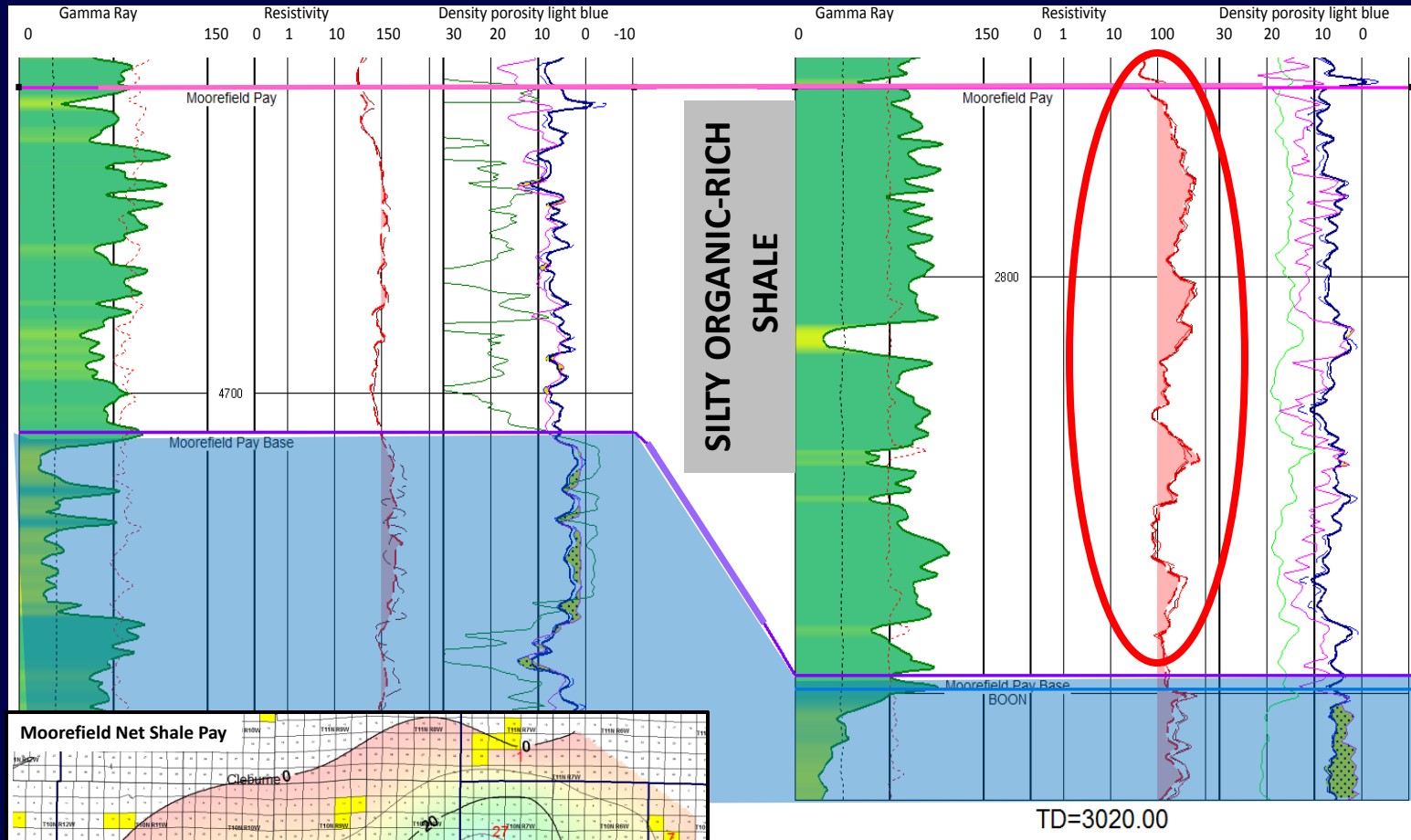


The Borden Silt in Illinois is a slightly calcareous, glauconitic, fine-grained siltstone. Some fine sandstone and siltstones near the base of the Borden contain oil (Stevenson, 1964).

IL State students presented Borden Silt detrital zircon data at GSA-2016. Rather than a transition from continental to Appalachian derived sediment, the Borden has a unique northerly provenance and was likely transported by wind rather than water.

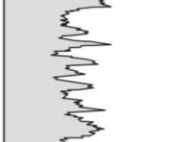
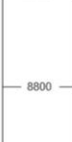

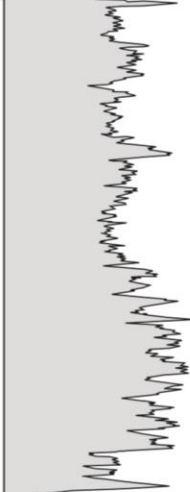



# ARKOMA BASIN: The Moorefield shale is an emerging play





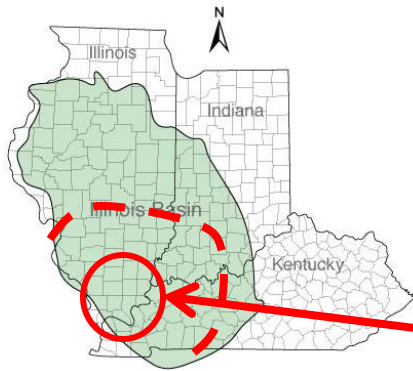
WARWICK

Humble York #C-1 Ector County, TX			
	GR	Depth (ft)	Resistivity
PENNSYLVANIAN			
MISSISSIPPIAN		8800	
		8900	
		9000	
		9100	
		9200	
		9300	
		9400	
		9500	
		9600	
DEVONIAN		9700	
		9800	

# ILLINOIS BASIN: Could BORDEN SILT represent an exploration target? Charge from New Albany / Woodford equivalent.

## Illinois Basin's New Albany Shale: The Next Big U.S. Horizontal Oil Play?

by KEITH SCHAEFER on SEPTEMBER 23, 2013

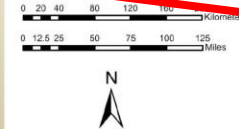
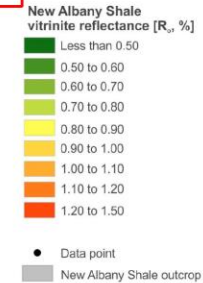


## Map of vitrinite reflectance ( $R_o$ ) of the New Albany Shale

Immature <0.60  
Early mature 0.60-0.65  
Peak mature 0.65-0.90  
Late mature 0.90-1.35  
Post-mature >1.35

$R_o$  range: 0.35-1.50%

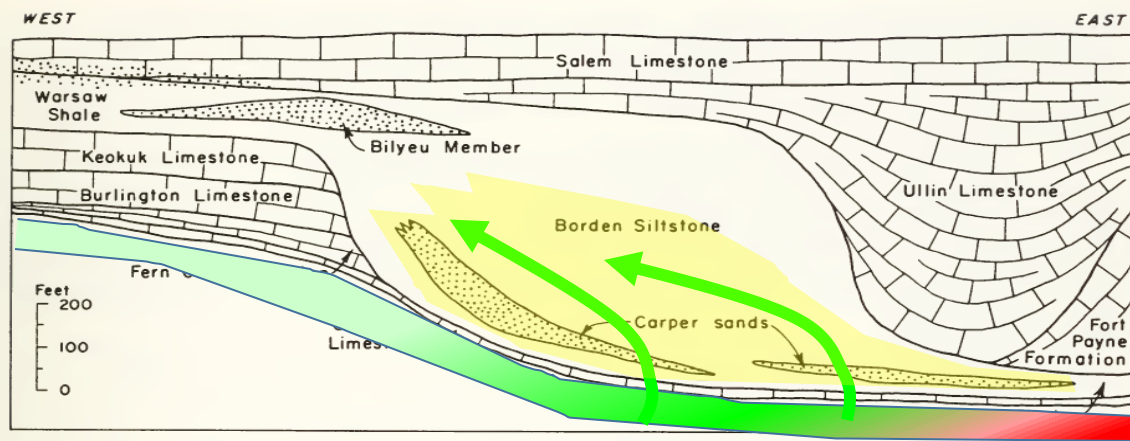
Higley et al. 2003



Should we reconsider the onset of oil window?  
What is the effect of vitrinite suppression?

## TURBIDITES IN THE BORDEN SILTSTONE

5



# **Devonossippian Petroleum Systems of Southern Laurasia:**

## **What Makes the STACK-MERGE-SCOOP in Oklahoma so Special**

- **SUPER CHARGED FROM MULTIPLE SOURCE ROCKS**
- **HIGH GOR = STRONG DEPLETION DRIVE**
- **HIGH API GRAVITY = LOW VISCOSITY**
- **THICK SILTSTONE RESERVOIR (200-600ft)**
- **PERMEABILITY IN THE MICRO-DARCY RANGE**
- **OVERPRESSURE SANDWICH**

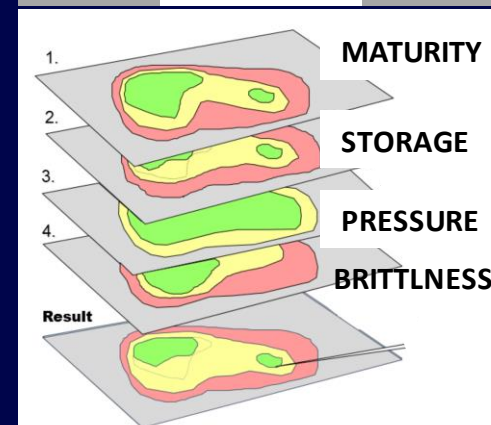
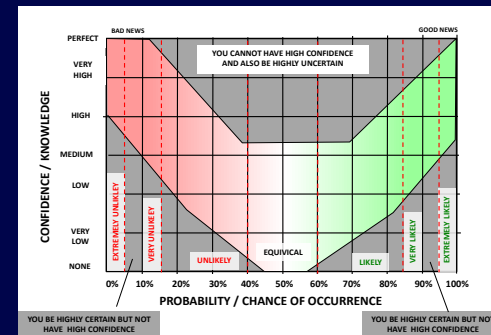
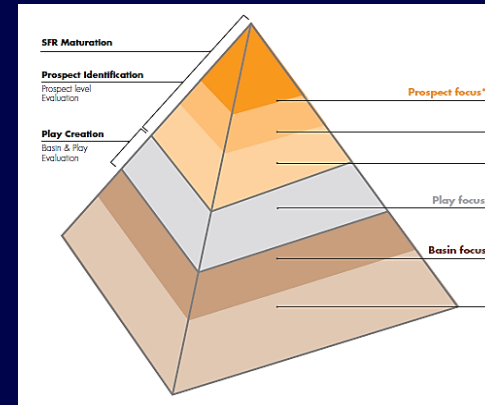
# SOME FINAL PLAYMAKER THOUGHTS

- BUILD YOUR PLAYS FROM THE BOTTOM UP
- BE HONEST ABOUT YOUR CONFIDENCE & RISKS
- APPLY RISK SEGMENT MAPPING TO HIGH GRADE

"You've got to play the game  
with fear and arrogance"  
Crash Davis



Don't forget to learn your clichés.





**THANK YOU! QUESTIONS?**



Klias Peninsula NW Borneo: Padas River debouching mud and silt into Brunei Bay