

# **Mowry Shale - Outcrop to Production\***

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## **Abstract**

The increase in commodity prices and development of technology in the late 2000s created opportunity to exploit previously uneconomic drilling targets, including a number of oil-generating shales. Two important source-rock shales in the Northern Rocky Mountains are the Mowry and Niobrara shales. Although both shales have been drilled using current completion techniques, the Niobrara has been targeted much more than the Mowry in the Powder River Basin. Momper and Williams (1984) estimated that the Mowry Shale has generated 11.9 billion barrels of oil and expelled 7% or approximately 830 million barrels of oil in the southern Powder River Basin. This illustrates the importance of the Mowry Shale to oil production in eastern Wyoming. A small number of vertical and horizontal wells in the Powder River Basin produce oil from the Mowry but few of these have been economic. The keys to drilling, completing, and economically producing the Mowry have yet to be discovered. The Mowry Shale is a siliceous shale, which makes it very brittle. It is interbedded with bentonites and other clay minerals. Although the carbonate-based Niobrara Shale has interbedded bentonites and other clays, the Mowry has some different issues with respect to drilling and completing than the Niobrara. This presentation will review geologic aspects of the Mowry and review historic and recent development.

## **References Cited**

Burtner, R.L., and M.A. Warner, 1984, Hydrocarbon Generation in Lower Cretaceous Mowry and Skull Creek Shales of the Northern Rocky Mountain Area, *in* J. Woodward, F.F. Meissner, and J.L. Clayton (eds.), Hydrocarbon Source Rocks of the Greater Rocky Mountain Region: Rocky Mountain Association of Geologists Guidebook, p. 449-467.

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Hollon, Z.G., 2014, Elemental Chemostratigraphy and Reservoir Properties of the Mowry Shale in the Bighorn and Powder River Basins, Wyoming, USA: MS Thesis, Colorado School of Mines, Golden, Colorado, 156 p.

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Momper, J.A., and J.A. Williams, 1984, Geochemical Exploration in the Powder River Basin *in* G. Demaison and R.J. Murriss (eds.), Petroleum Geochemistry and Basin Evaluation: American Association of Petroleum Geologists Memoirs, v. 35, p. 181-191.

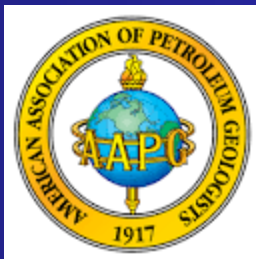
Socianu, A., J. Kaszuba, and G. Gustason, 2015, Importance of Core and Outcrop Investigations for Evaluating TOC Distribution in Unconventional Systems: An Example from the Mowry Shale: Unconventional Resources Technology Conference, San Antonio, Texas, 20-22 July 2015, p. 704-713.

# **Mowry Shale Outcrop to Production**

**American Association of Petroleum  
Geologists**

**2016 Pacific and Rocky Mountain**

**Joint Meeting  
October 3, 2016**



**Andrew Finley**

# **Outline**

**Location and Activity**

**Powder River Basin Stratigraphic  
Column**

**Lithology and Facies Distribution**

**Outcrop and Core**

**Hydrocarbon Potential**

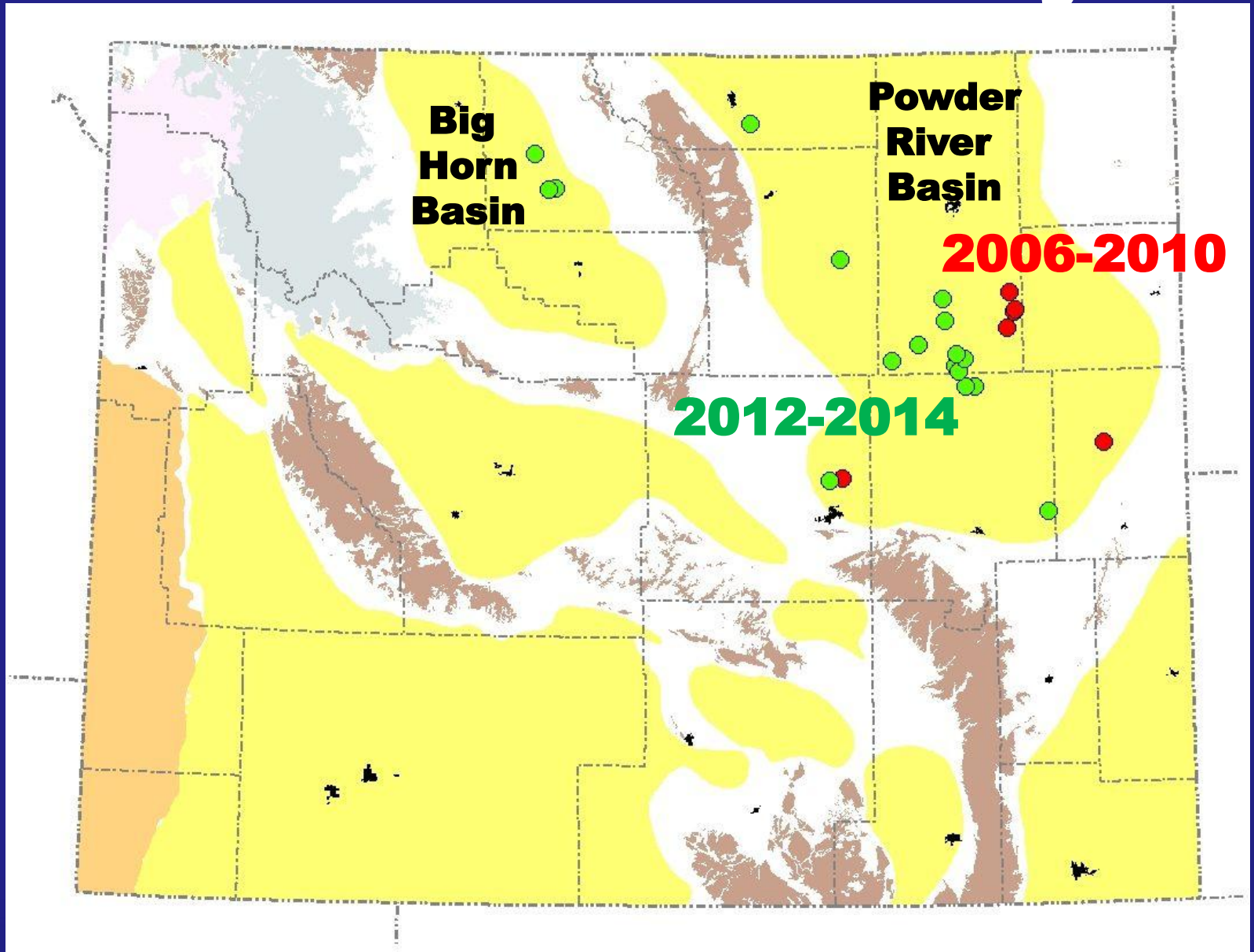
**Drilling and Completions**

**Performance**

**Observations**

**Conclusions**

# Location and Activity

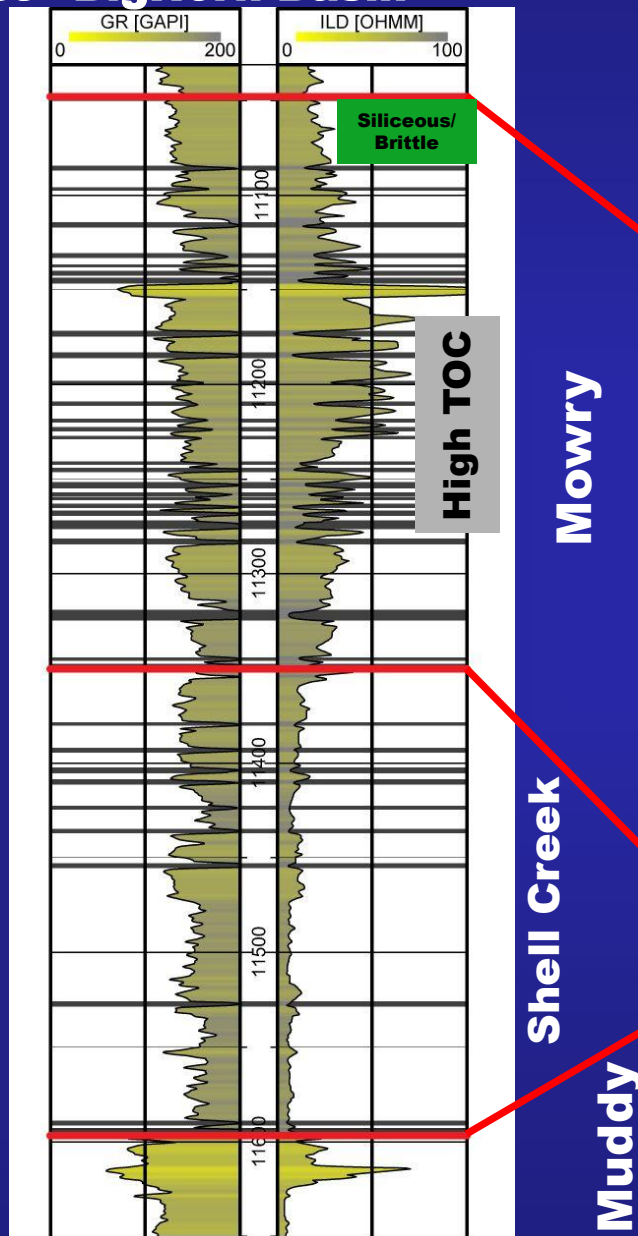


# Powder River Basin Stratigraphic Column

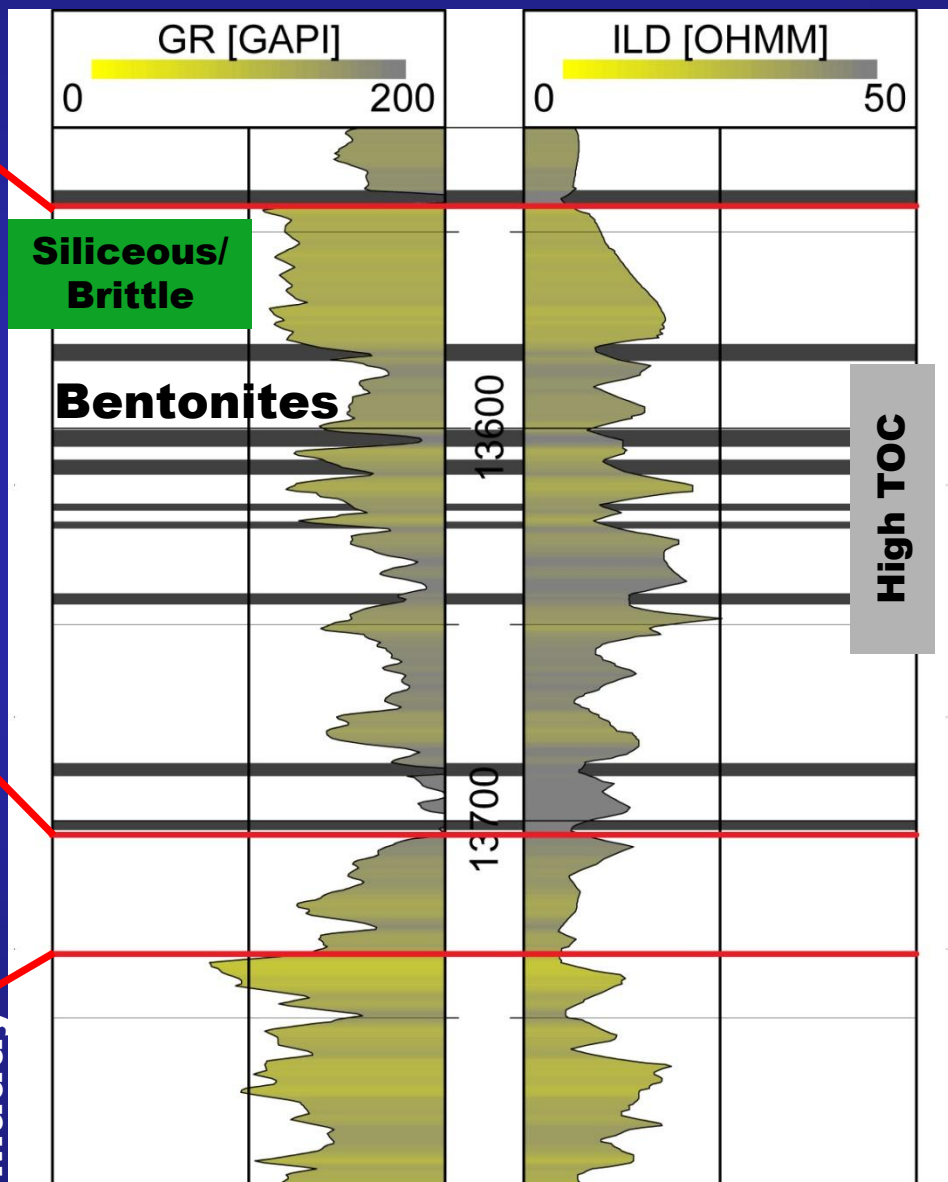
UPPER CRETACEOUS	MAY		FARRMAN SS. MBR.	PIERRE SH.		
	CODY SH.	SUSSEX SS. MBR.		NIOBRARA FM.		
		SHANNON SS. MBR.				
		STEELE SH.				
		NIOBRARA MBR.				
		SAGE BREAKS MBR.				
	FRONTIER FM.	WALL CREEK MBR.		CARLILE SHALE	SAGE BREAKS MBR.	
		BELLE FOURCHE MBR.			TURNER SANDY MBR.	
		"2ND WALL CREEK SAND"		POOL CREEK MBR.		
		BELLE FOURCHE MBR.		GREENHORN FM.		
MOWRY SH.		BELLE FOURCHE SH.				
MOWRY SH.		MOWRY SH.				
LOWER CRETACEOUS	MUDDY SS.		NEWCASTLE SS.			
	THERMOPOLIS SH.		SKULL CREEK SH.			
	INYAN KARA GP.	FALL RIVER FM. (DAKOTA)		INYAN KARA GP.		
		LAKOTA FM.				
	MORRISON FM		MORRISON FM			

# Type Logs

## West - BigHorn Basin



## East - Powder River Basin



# **Lithology**

**Medium to dark gray organic-rich  
siliceous shale**

**Silty shale**

**Bioturbated sandstone**

**Bentonite**

**Silica is thought to be dominantly  
biogenic**

# Mowry Paleogeography w/ TOC

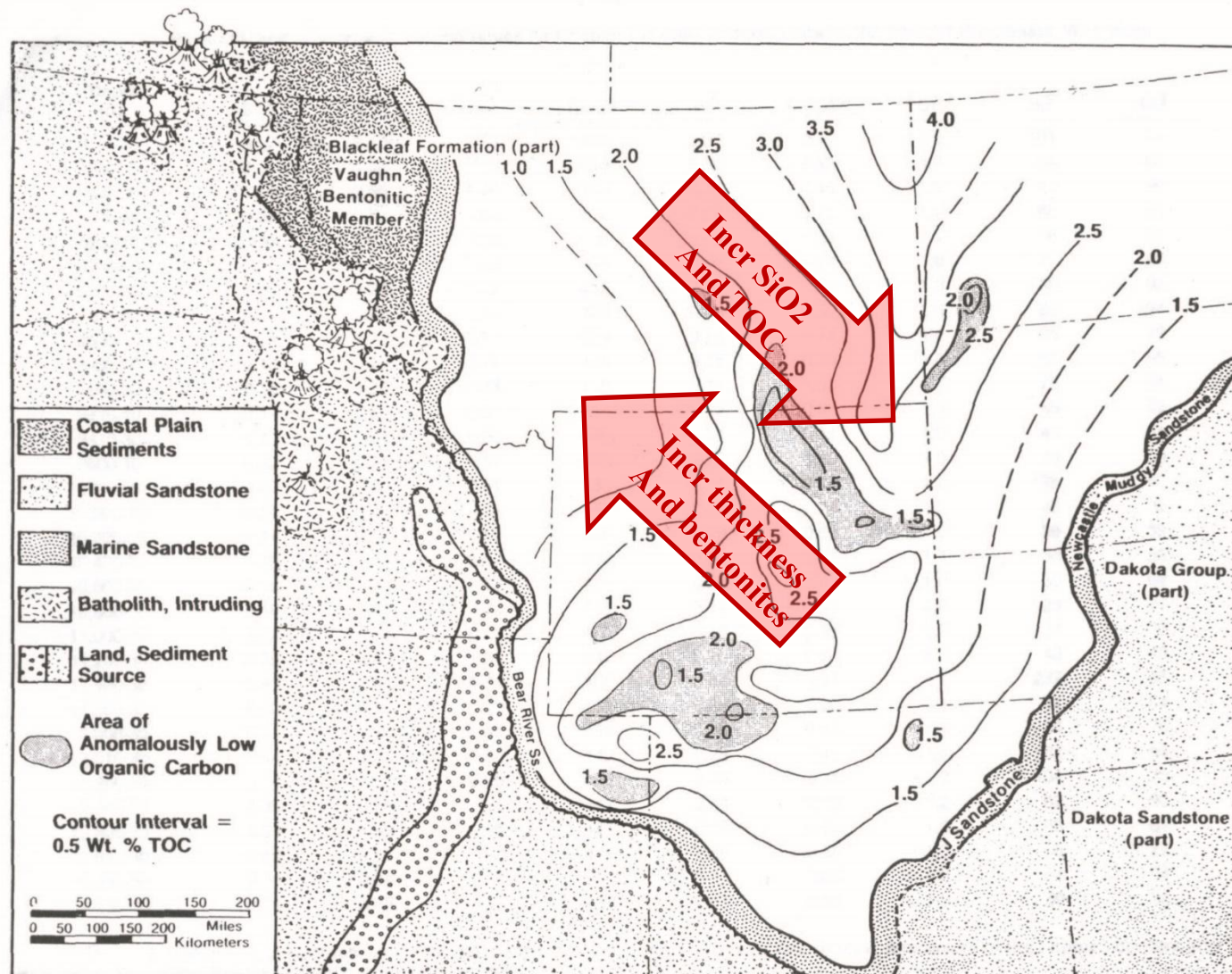


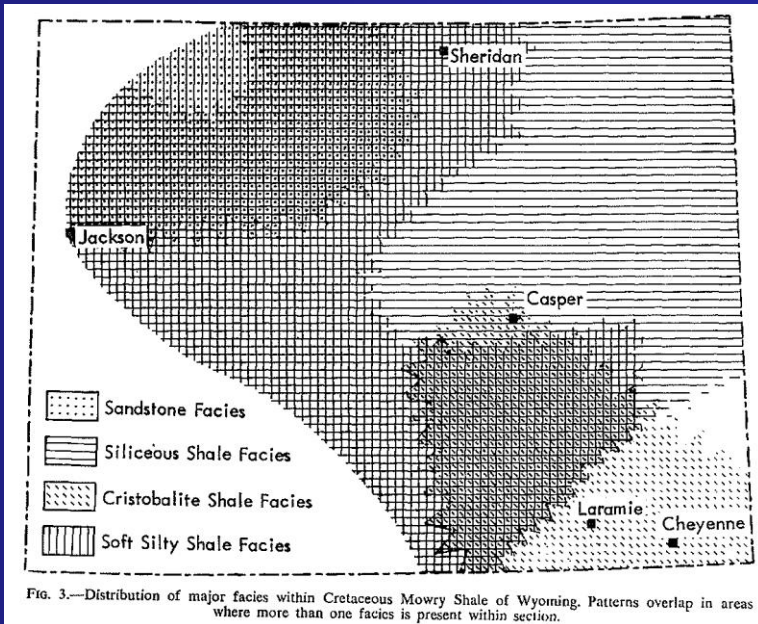
Figure 15. Regional distribution of total organic carbon (TOC) in the Mowry Shale. Note that most areas of anomalously low TOC values coincide with the deeper portions of Laramide structural basins.

Burtner &  
Warner,  
1984

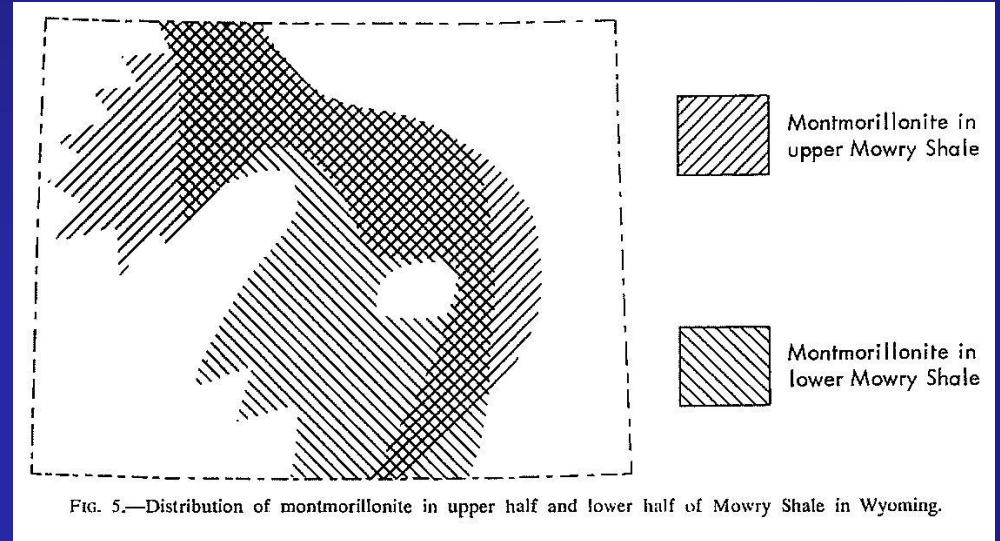
# Facies Distribution

## Smectite

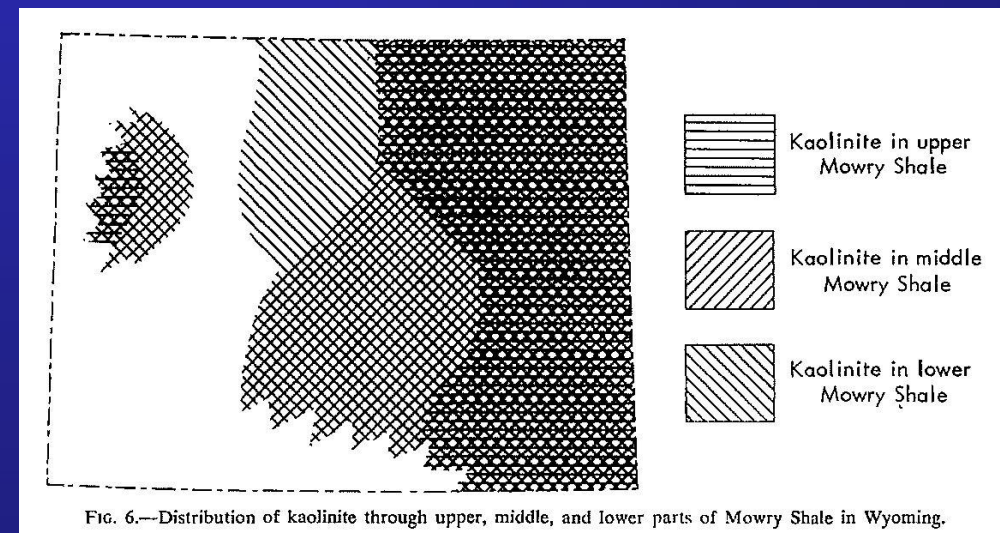
### Facies



**Davis, 1970**



### Kaolinite



# **XRD Comparison of SW VS SE PRB**

	<b>SW</b>	<b>SE</b>
<b>Quartz</b>	<b>50%</b>	<b>50%</b>
<b>Chlorite</b>	<b>1%</b>	<b>10%</b>
<b>Kaolinite</b>	<b>2%</b>	<b>5%</b>
<b>Illite</b>	<b>7%</b>	<b>9%</b>
<b>Mixed Illite/Smectite</b>	<b>22%</b>	<b>12%</b>

# Hydrocarbon Potential

**Momper and Williams, 1984**

**3% Average TOC**

**160 BBOOIP**

**11.9 BBO expelled (7% efficiency)**

**Predominantly Type II Kerogen**

**Modica and Lapierre, 2012**

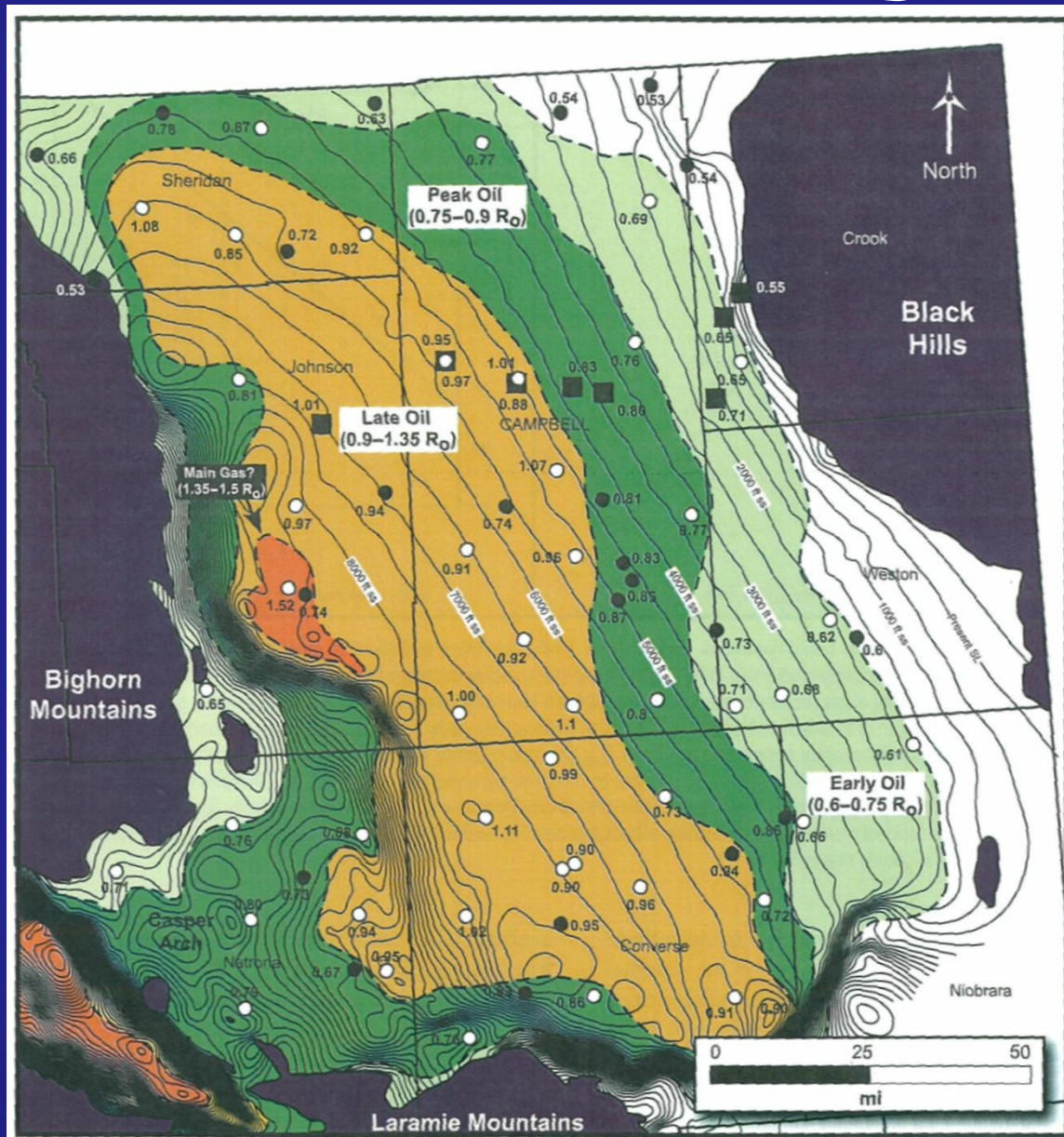
**Mowry maturation results in development of up to  
2.5 to 3.3% kerogen porosity**

**Kerogen porosity model hypothesizes that dominant  
storage capacity in source rocks is in  
kerogen porosity with little to no storage in  
mineral pores.**

**This idea seems to be supported by recent work in  
FIB-SEM studies.**

**Is Mowry a mineral porosity, kerogen  
porosity, natural fracture play or  
combination?**

# PRB Maturity



**Modica and  
Lapierre, 2012**

# TOC Perm and Targets

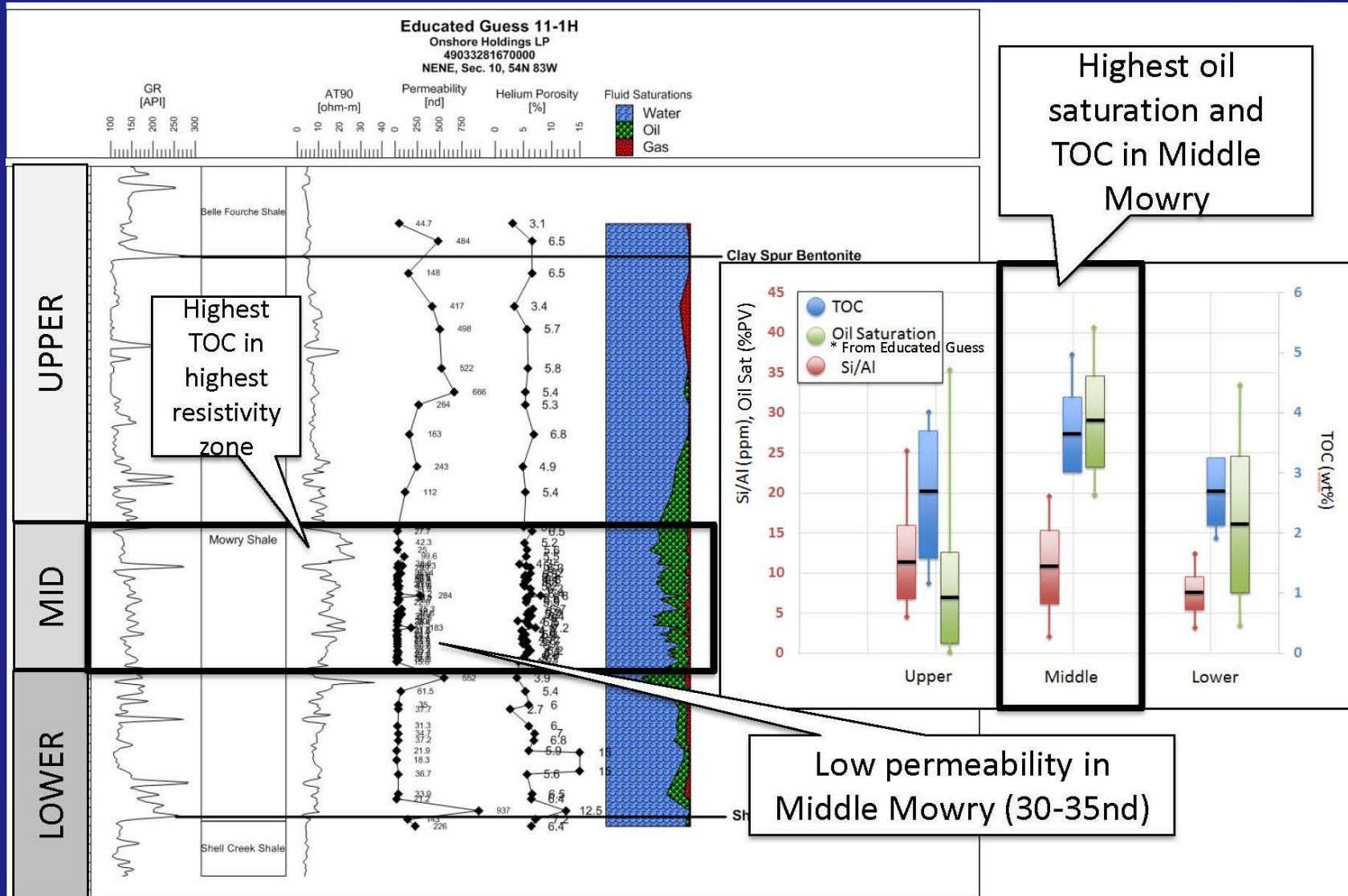


Figure modified from Hollon, 2014

# Mowry in Outcrop

**Frontier/Belle Fourche**



**Mowry Forms Ridges**



**Fractures**



**Tree Roots Exploiting Orthogonal Fractures**



# Mowry in Core



**Open  
Fracture  
12,000'+**



**Expulsion  
Fractures**



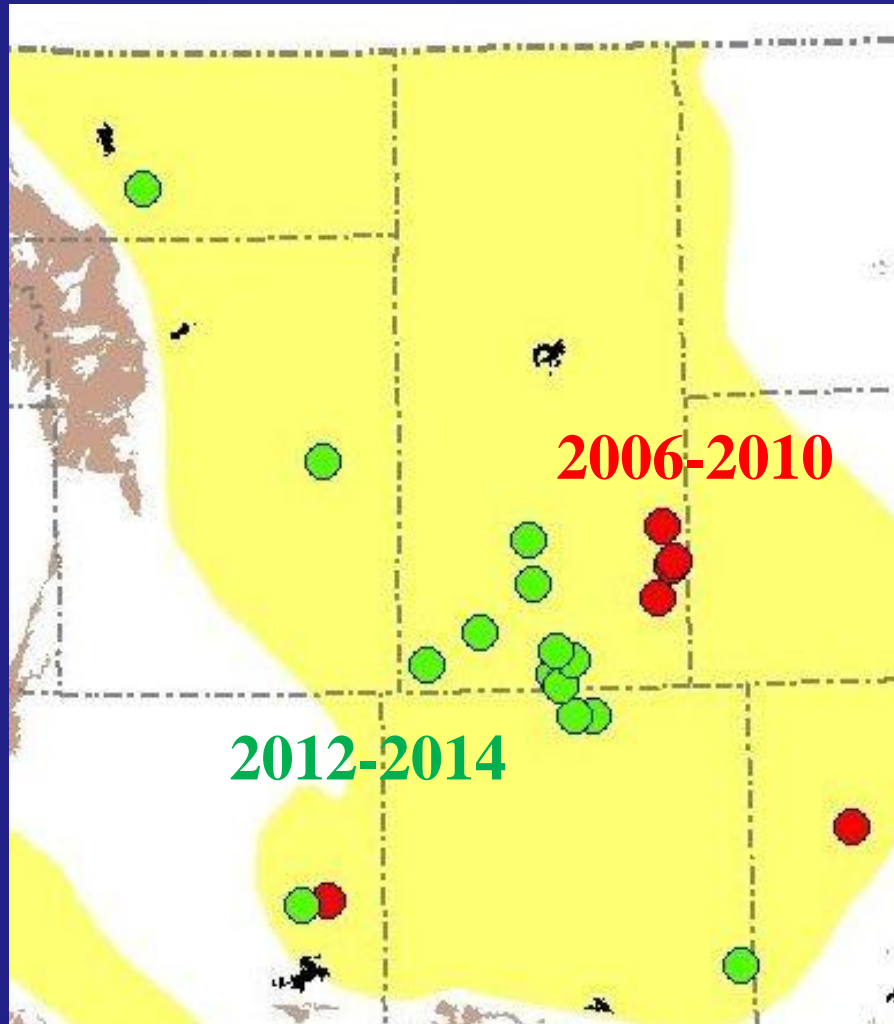
**Natural  
Fractures**



**Bentonite**

# Drilling and Completions

## 2006-2010



### Brigham, Baytex

**4,000' horizontals**

**3-11 Stages**

**½ Million # Sand**

**Slick water/linear gel**

### EOG

**4,000' horizontal**

**15 Stages**

**2½ Million # Sand**

**XL**

## 2012-2014

### EOG, Devon, Peak

**4,000' – 9,000' horizontals**

**15 – 45 Stages**

**2 – 14 Million # Sand**

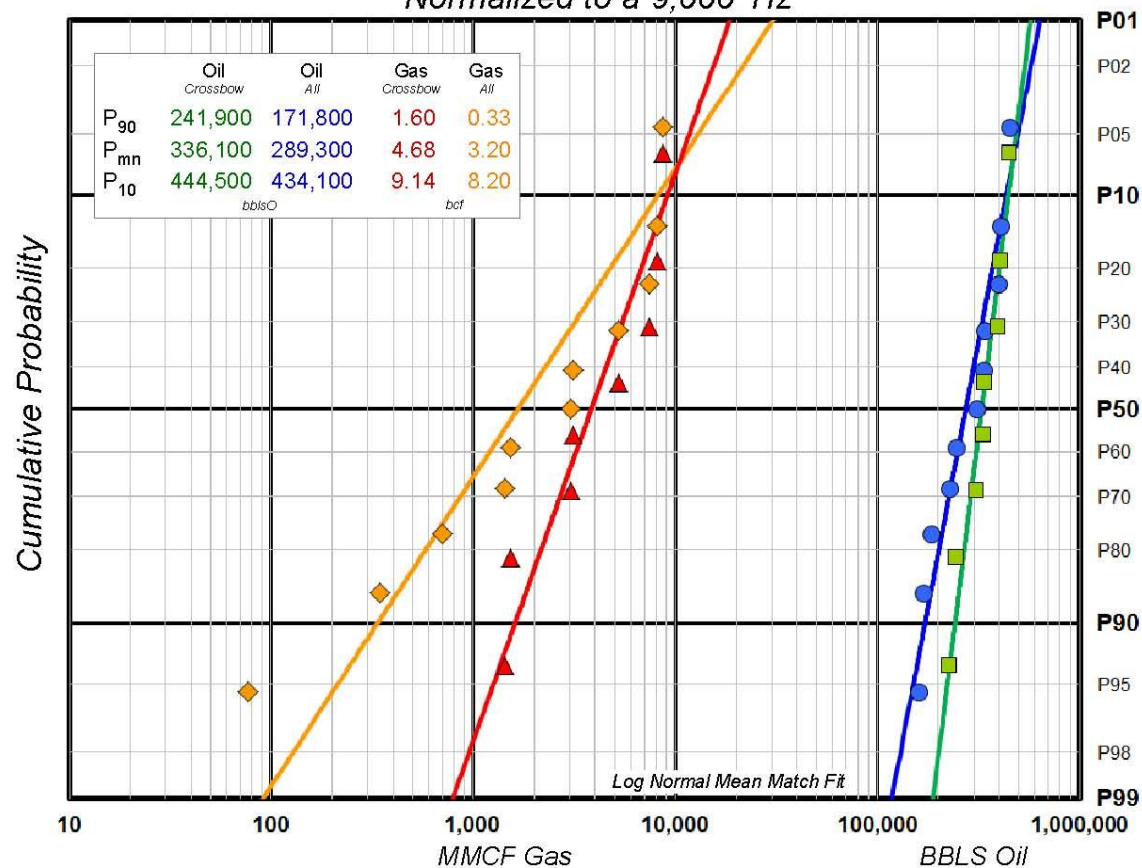
**XL, Hybrid (350-450 MMBF)**

# Performance

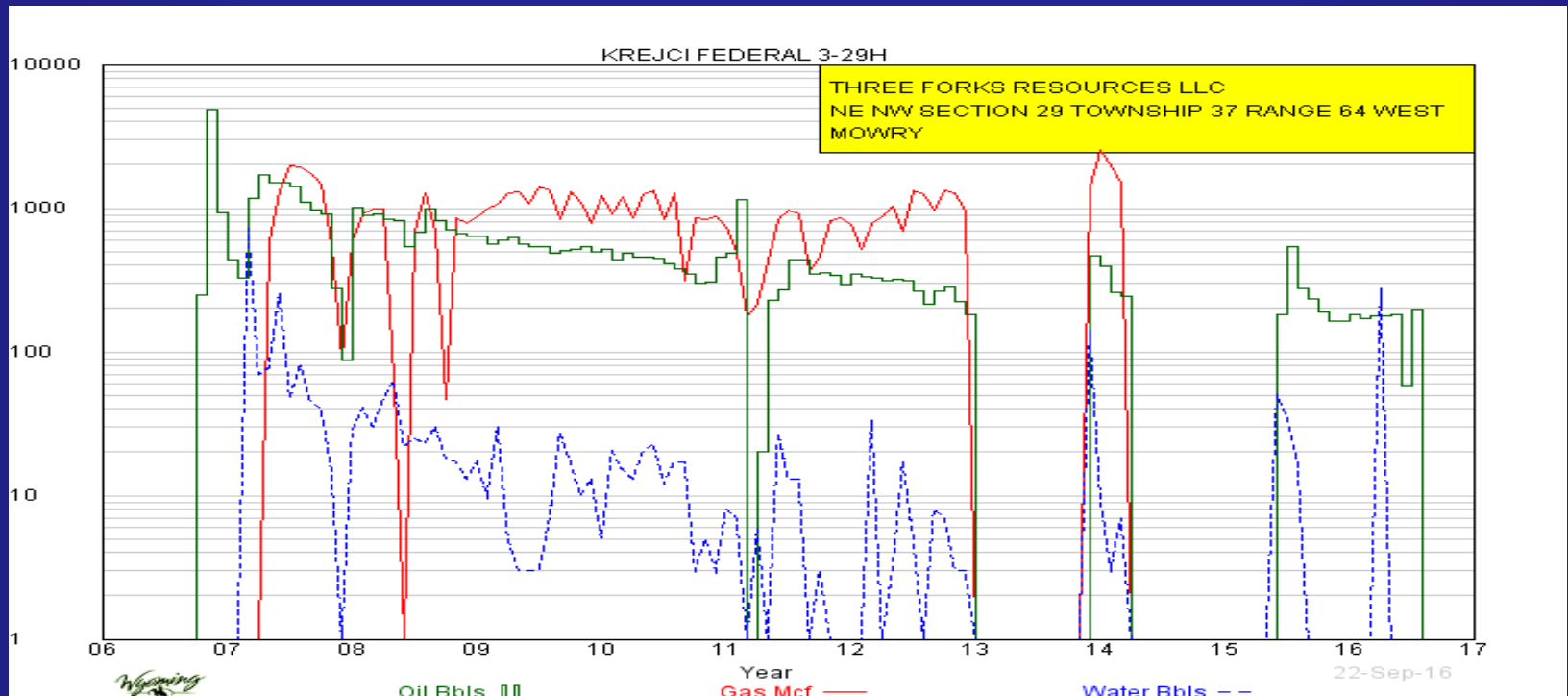
## Mowry Hz EUR Range Distribution

Powder River Basin

Normalized to a 9,000' Hz

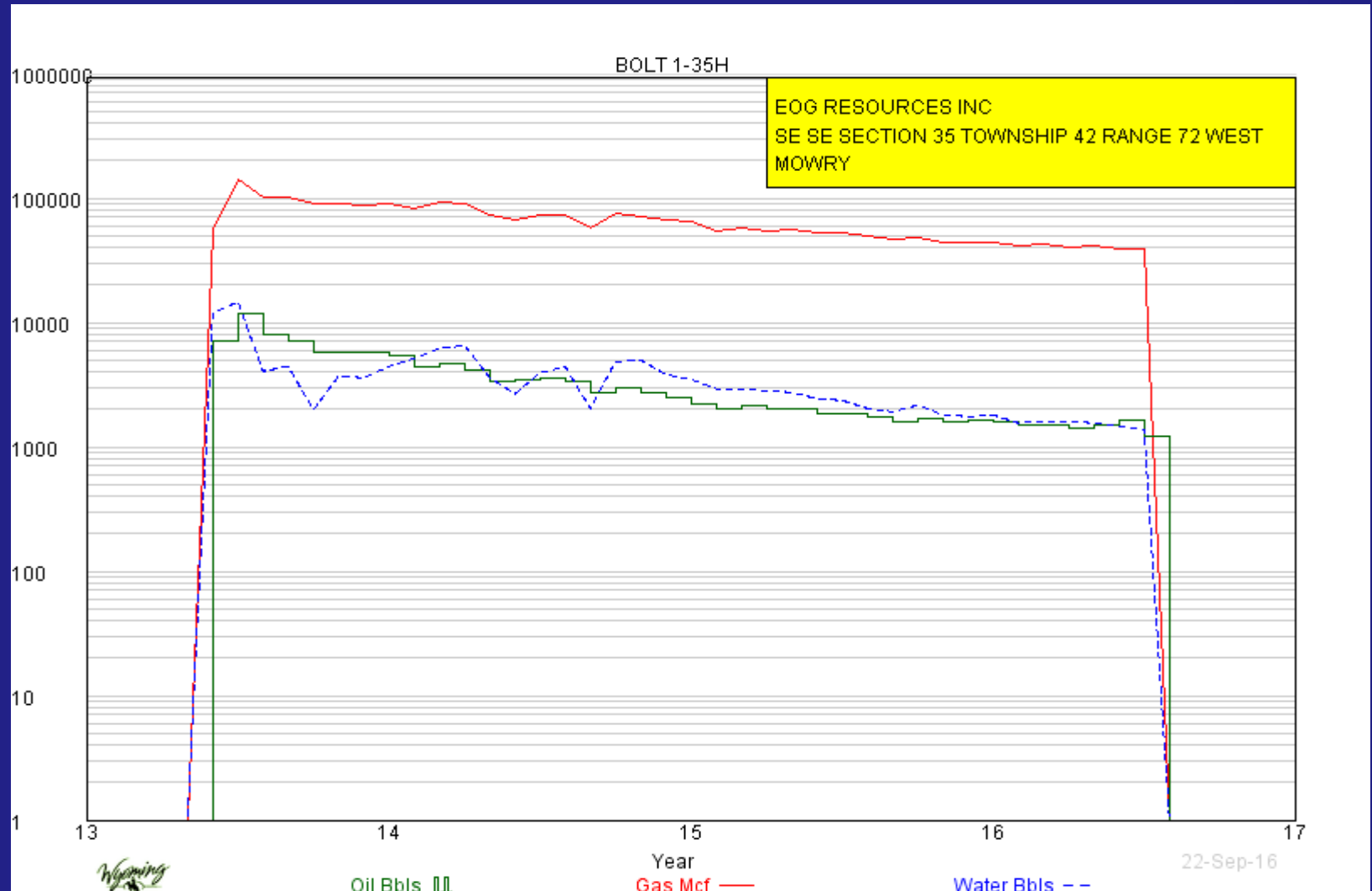


# Performance



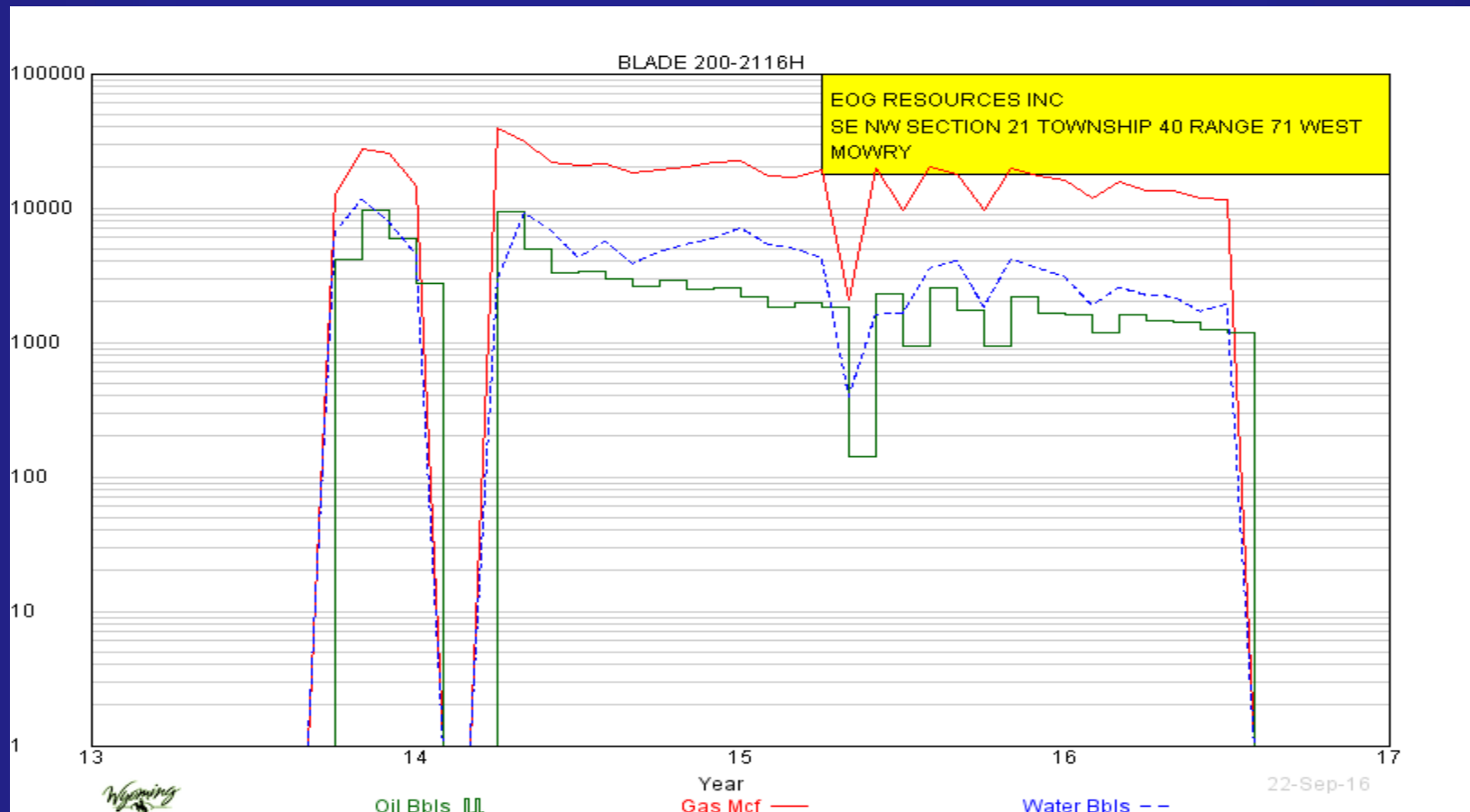
Cum: 51 MBO, 69 MMCFG, 3 MBW

# Performance



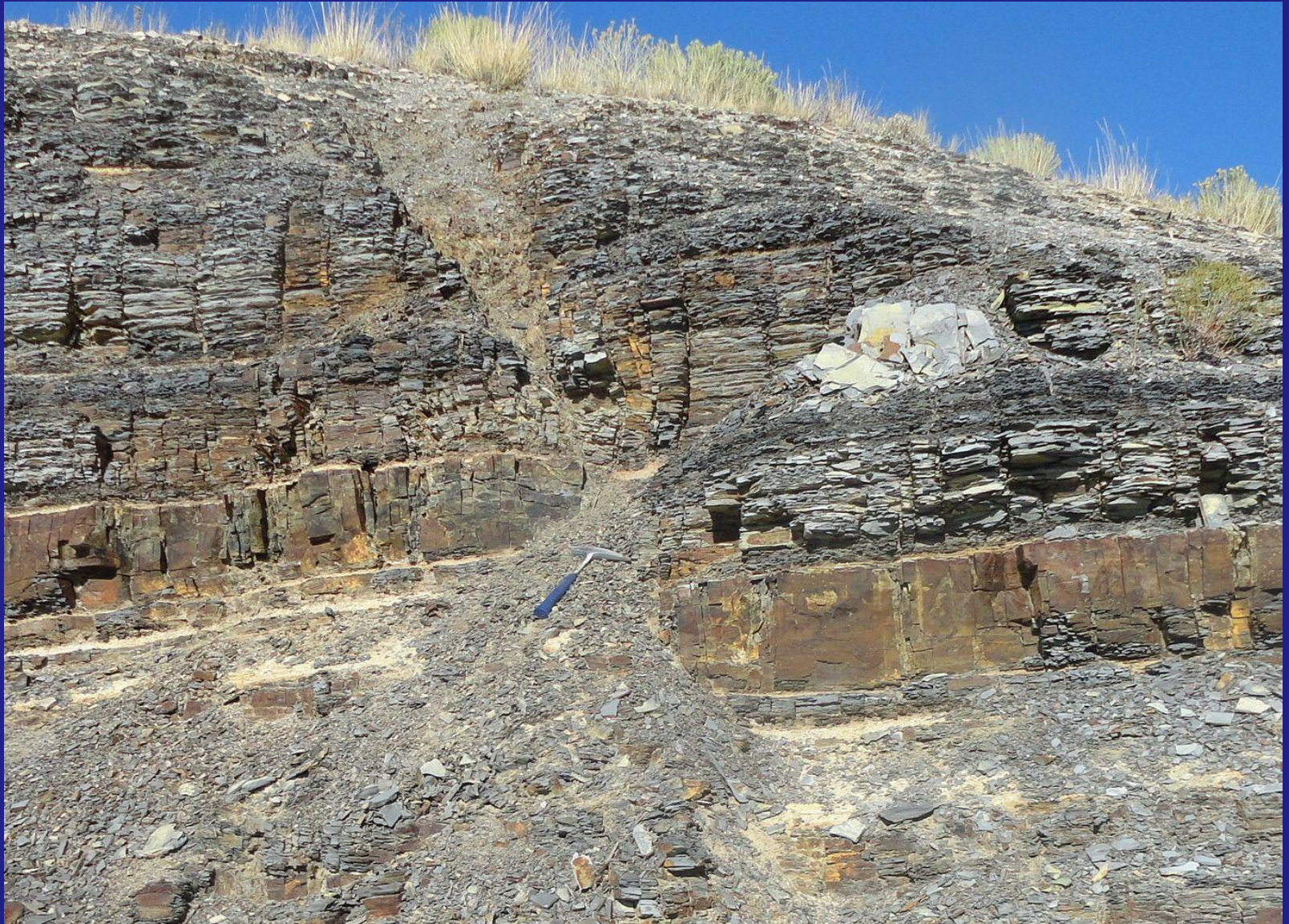
Cum: 127 MBO, 2,484 MMCFG, 136 MBW

# Performance



Cum: 86 MBO, 578 MMCFG, 137 MBW

# Observations - Bentonite Sealing Fault



# Observations

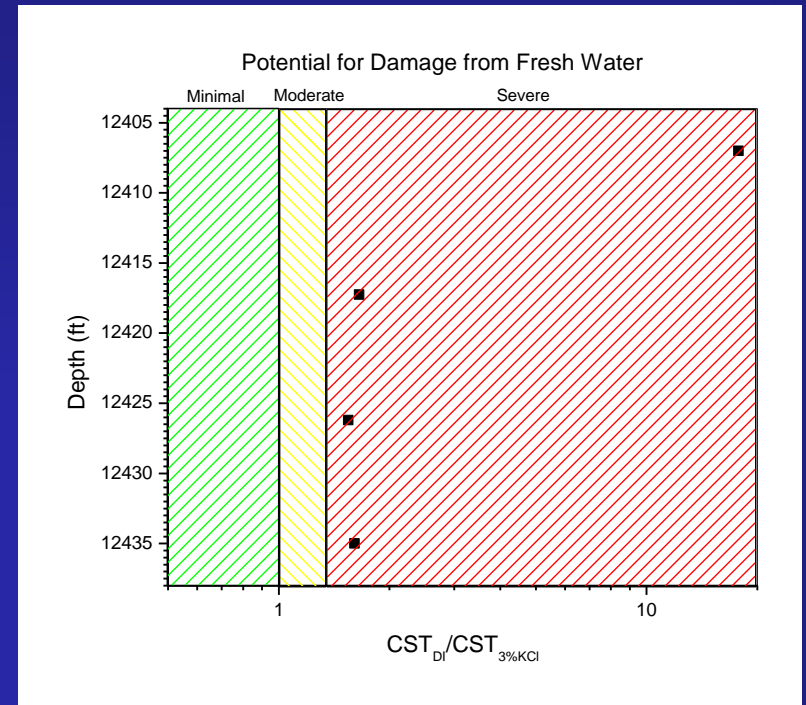
**What is the play?**

**Kerogen porosity, mineral porosity or natural fracture play?**

**What is the target?**

**Highest TOC is in Middle Mowry?**

**Highest silica content is at top of Mowry?**



# Summary

**What is the nature of the Mowry play?**

**Kerogen porosity?      Macro porosity?**

**Hydraulic fractures?      Natural fractures?**

**Damage during drilling and completion?**

**Downhole fluid compatibility?**

**Are high EUR/high GOR wells due to effective perm created during completion or is the inherent perm system inhibiting oil production?**

**Do we know the right questions?**

# Acknowledgements

- **AAPG**
- **RMS-PS**
- **Paul Lawless – Helis Oil and Gas**