Influence of Rock Type and Maturity on Core-Scale Reservoir Characteristics of the Mowry Shale, Powder River Basin, WY

Alexa Socianu
Ph.D. Candidate
asocianu@mymail.mines.edu
MudTOC Consortium Meeting
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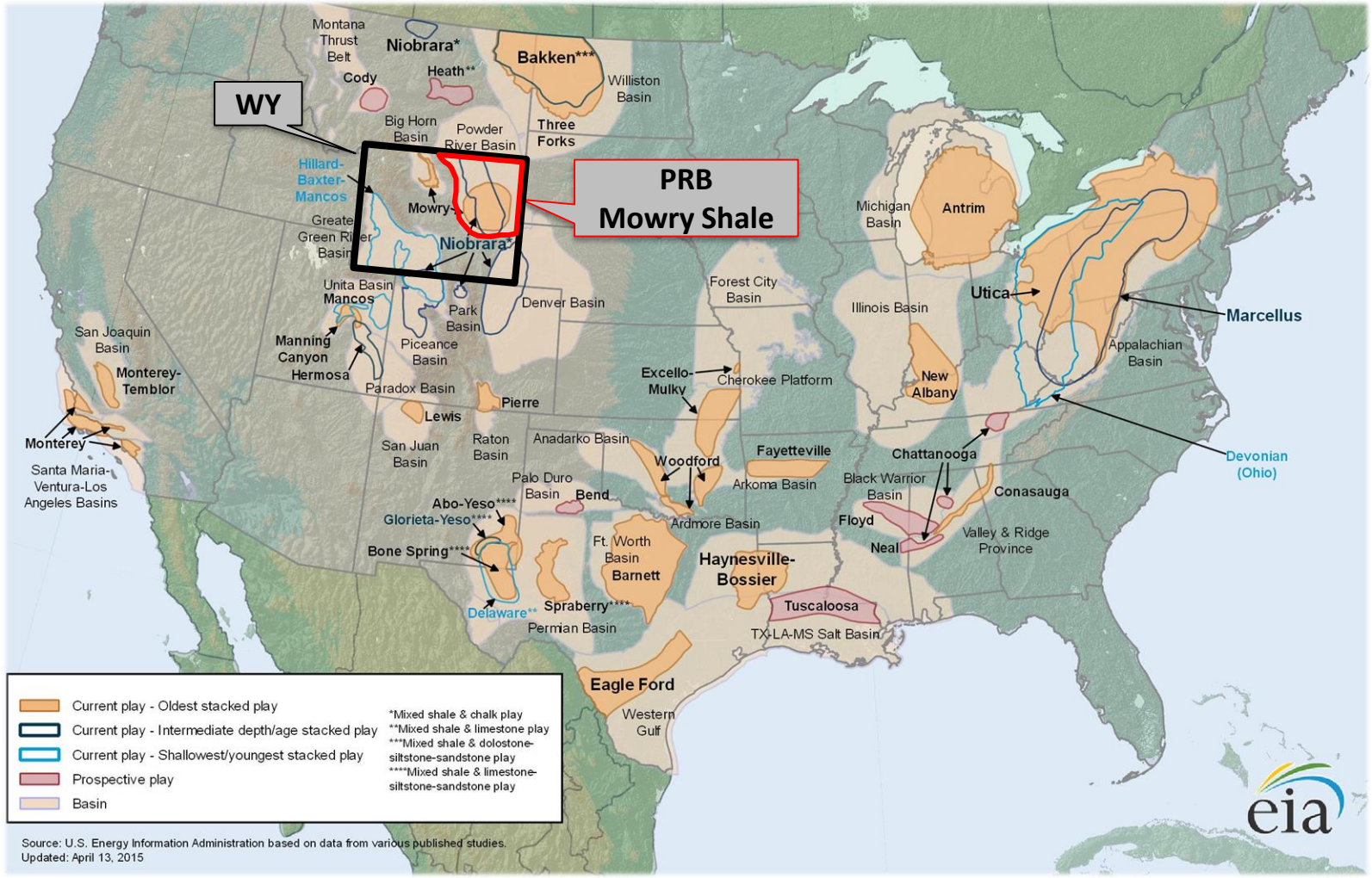
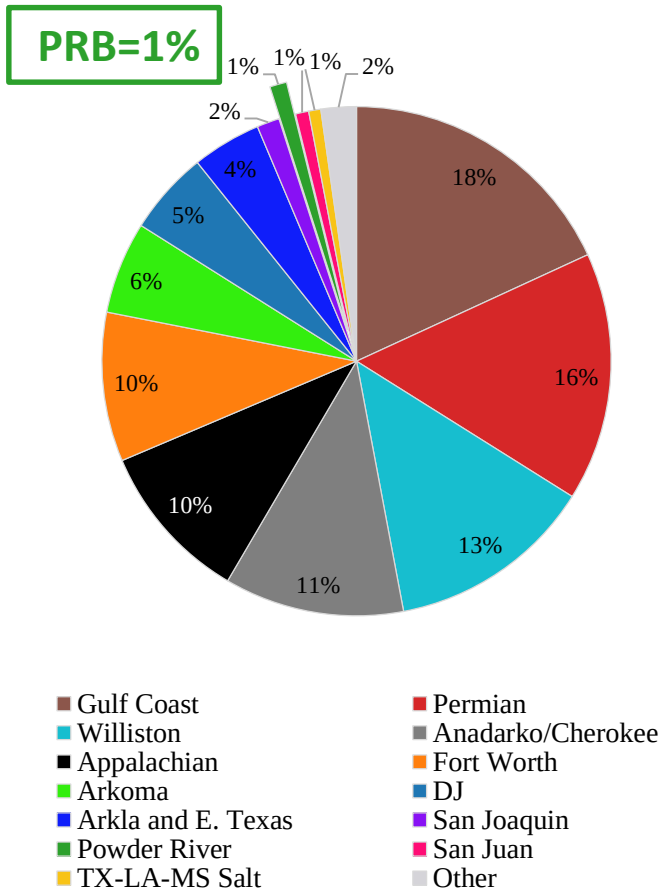
Lower 48 U.S. Shale Plays



Horizontal Well Count by Basin

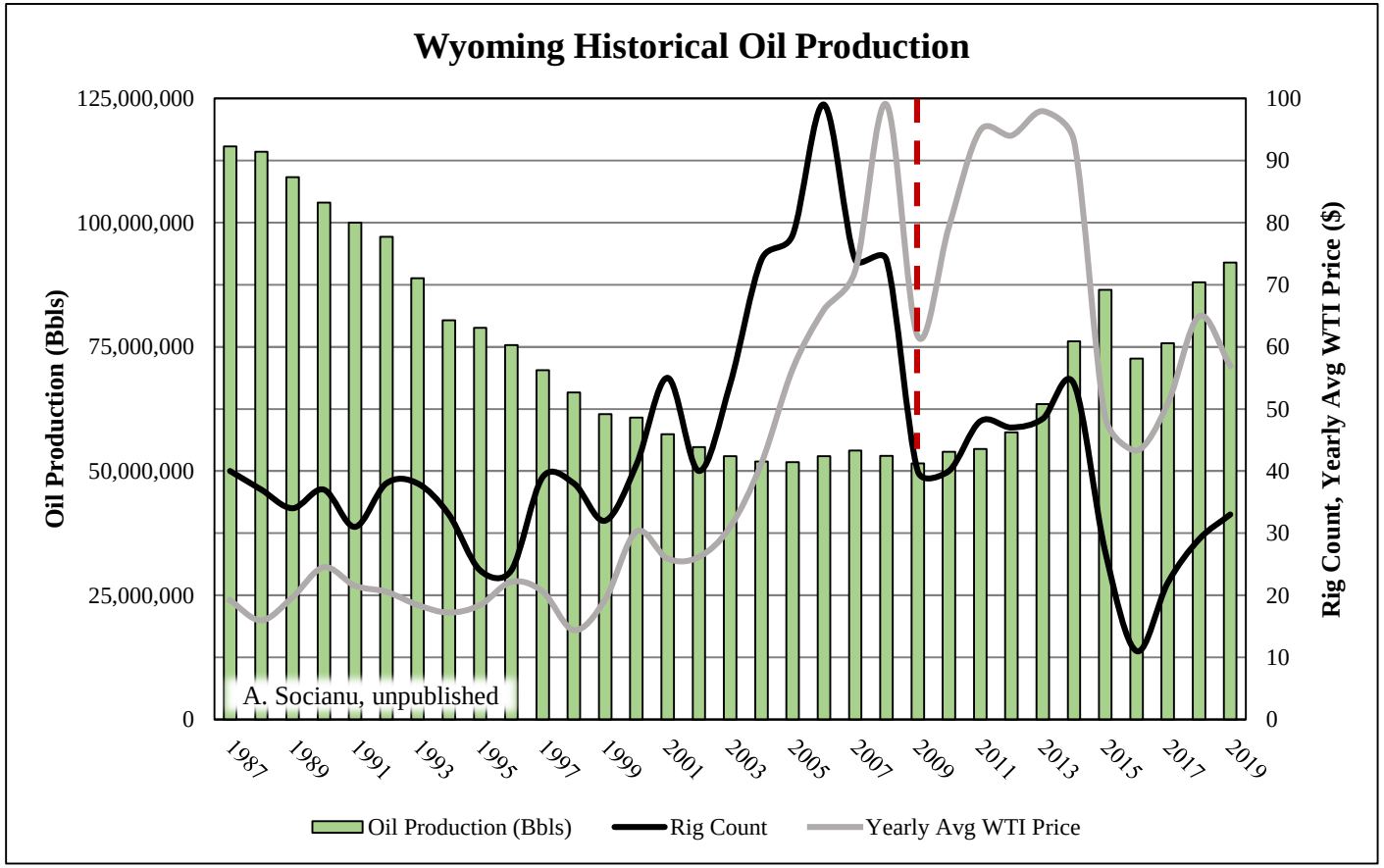


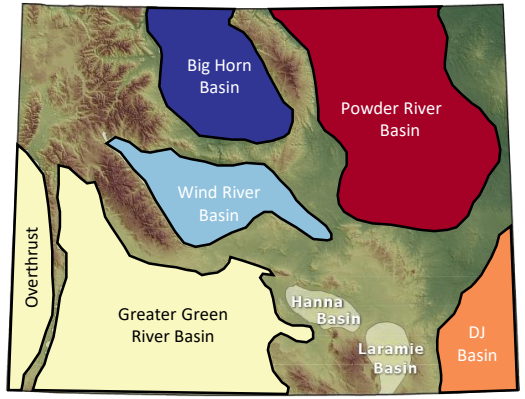
Source: DrillingInfo

Booms and Busts in Wyoming

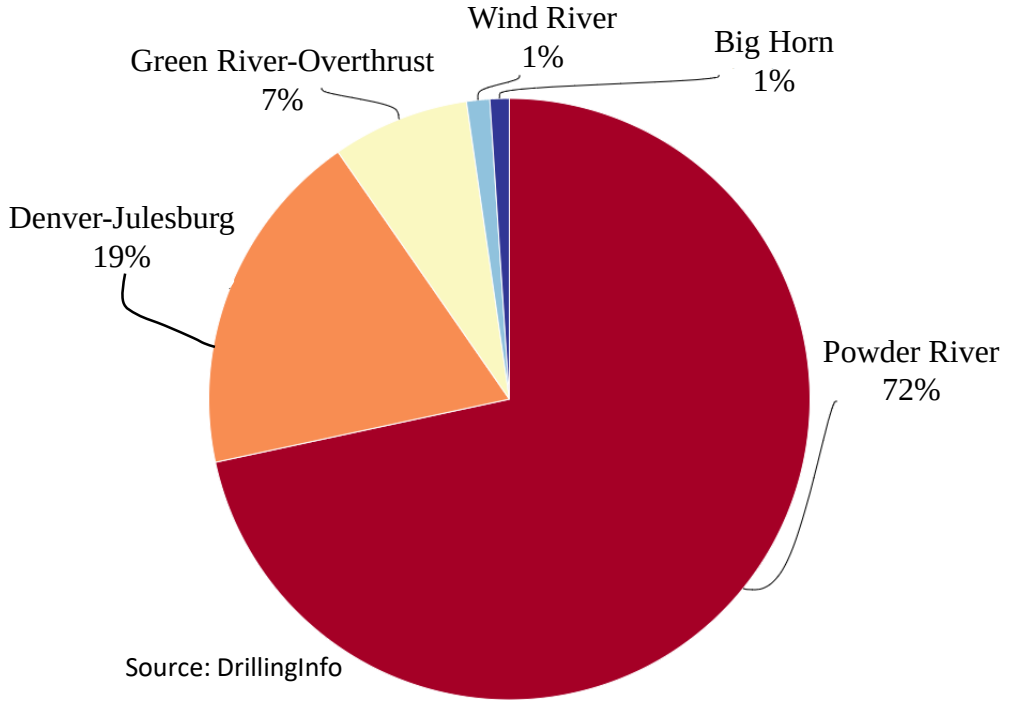
Conventional Decline → Unconventional Production

2020





Hz Wells Spud in Wyoming Since 2009 by Basin – 2916 Total



Source: DrillingInfo

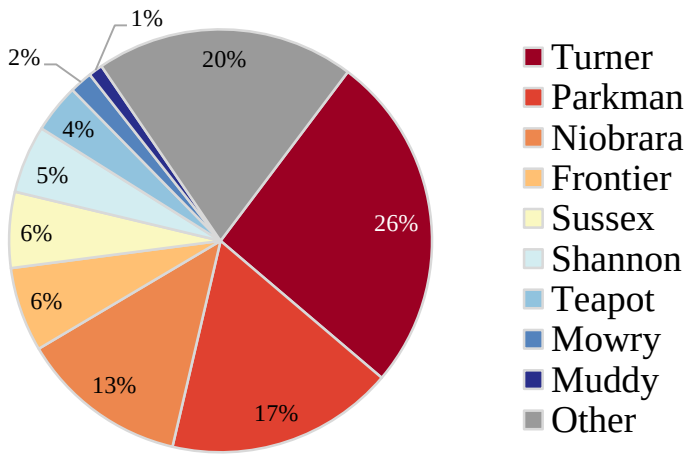
Sources: Historical Production from WOGCC; Rig Count from Baker Hughes;
WTI from https://www.statista.com/statistics/266659/west-texas-intermediate-oil-prices/

Motivation

- Mowry Shale is a prolific source rock in the PRB 198MMBO, 198 BCF estimated undiscovered resource (Anna, 2009)
- Mowry accounts for ~2% of all hz wells in the PRB
- Hz Mowry results are improving with time, but still <40 wells drilled – **we have a lot to learn**

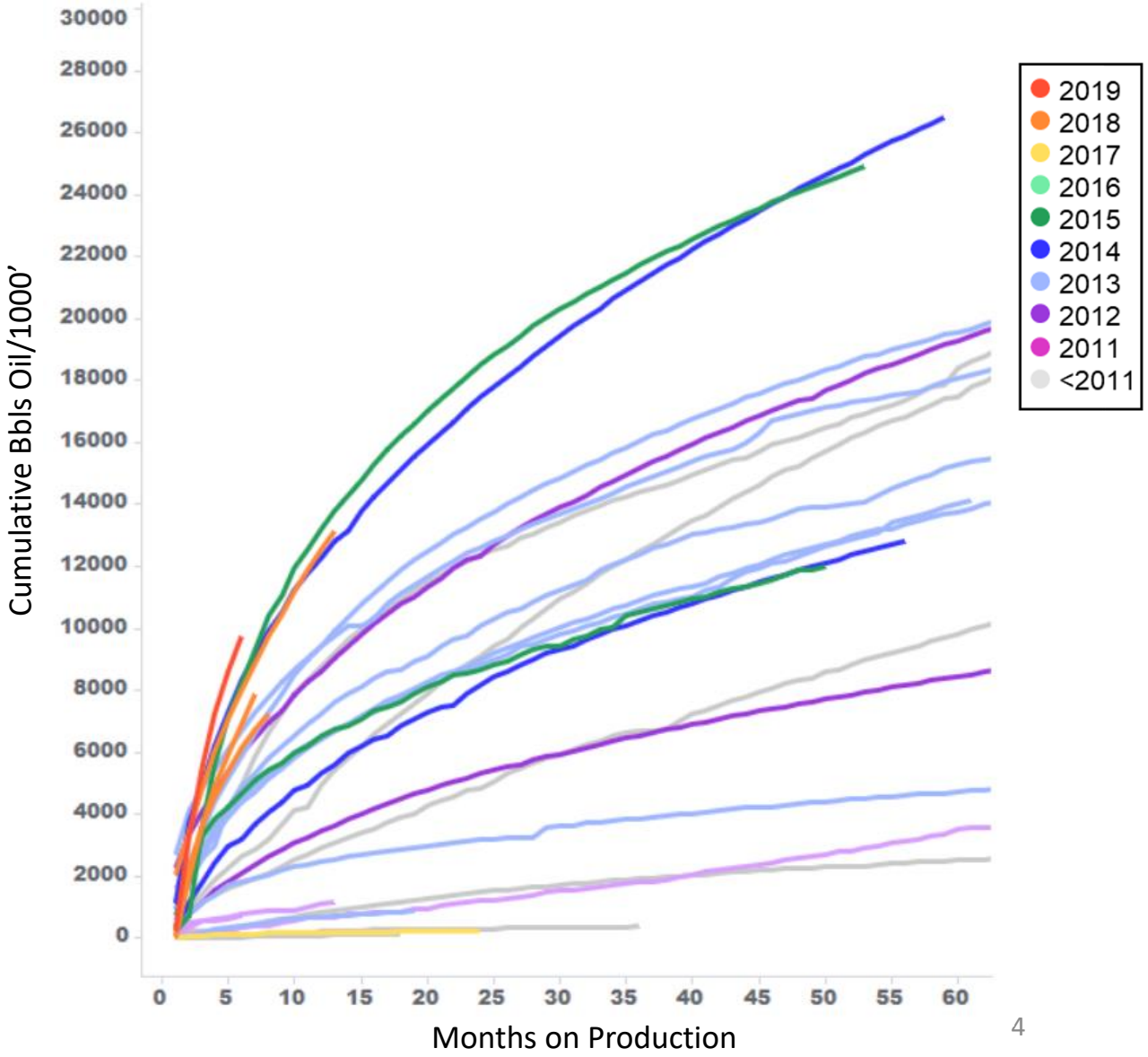
PRB Horizontal Well Count by Target

Mowry=2%

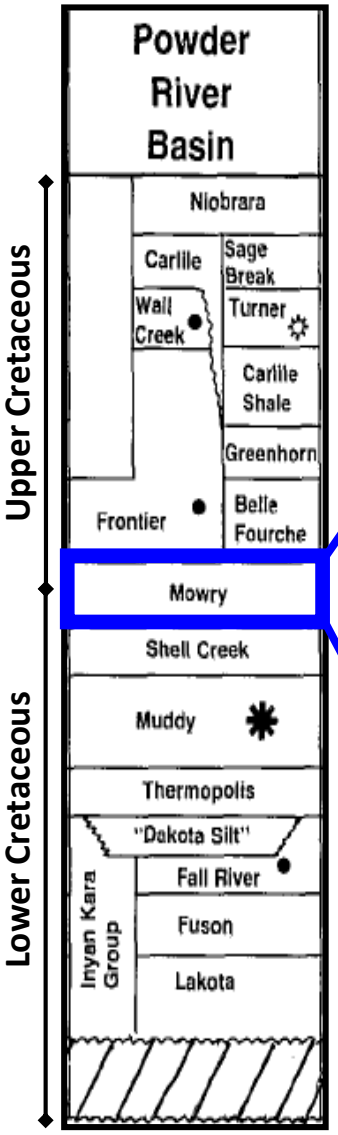


Source: DrillingInfo

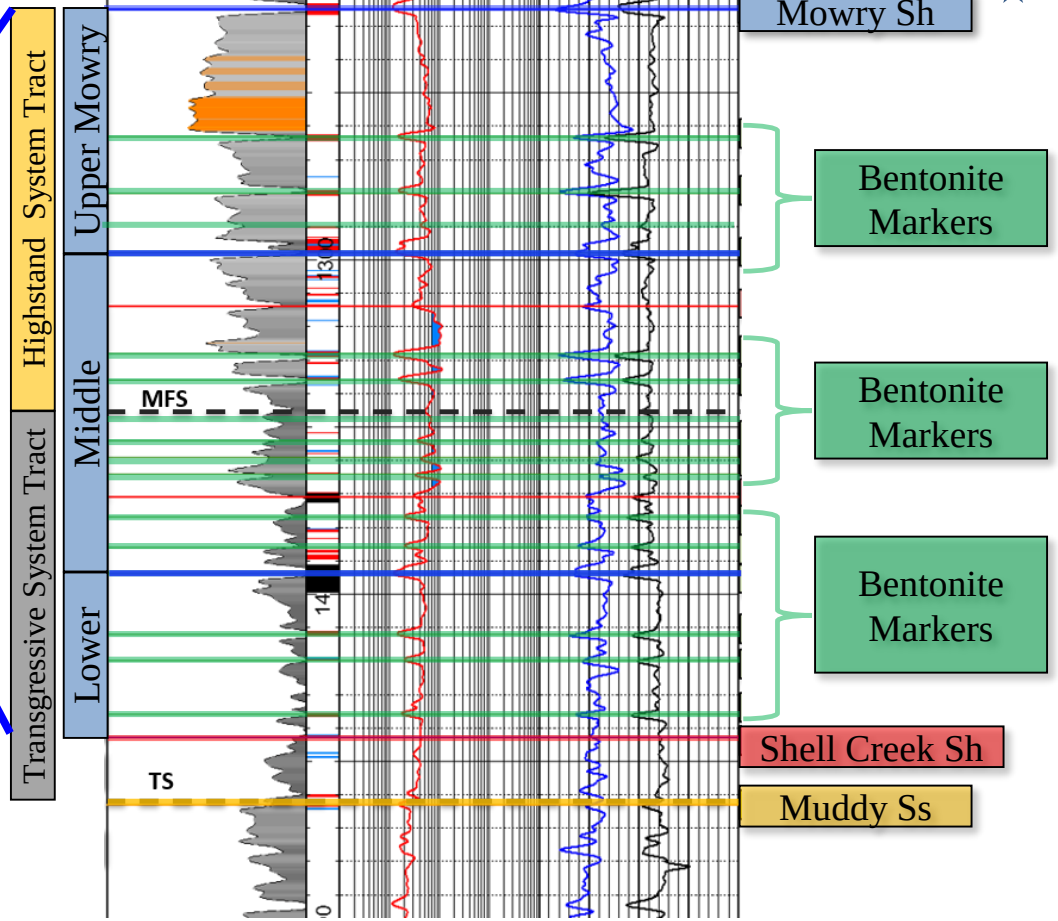
Normalized Hz Mowry Shale Production Results

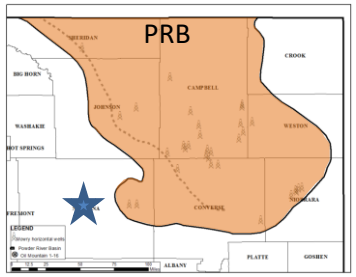


Mowry Shale Background Info



From Burtner and Warner, 1984





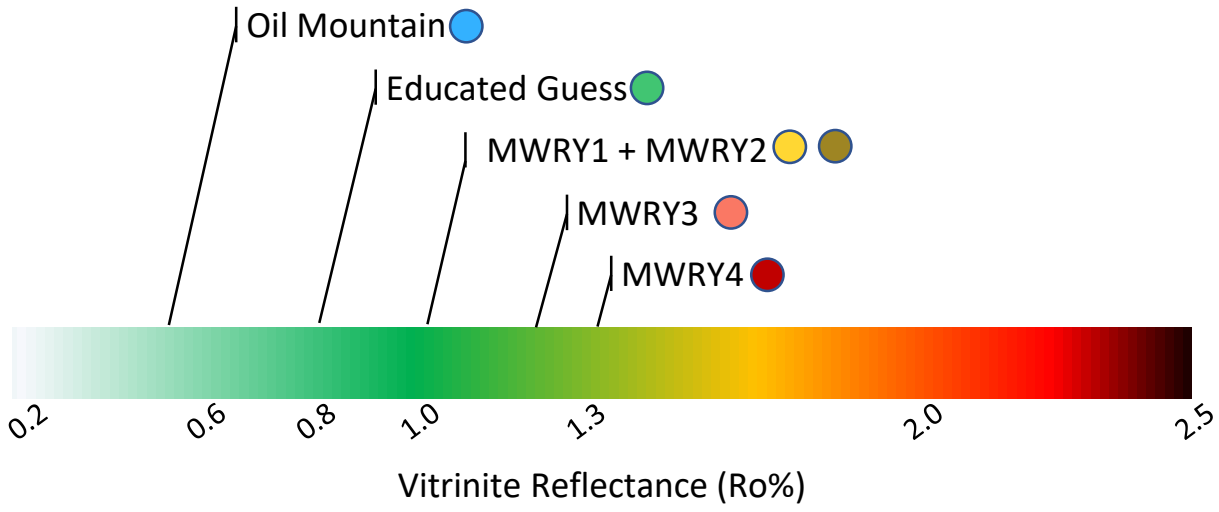
Gross Thickness	130' – 250' (PRB)
TOC	<1 – 8wt% Avg 2-3 wt%
Porosity	5-9% Avg 7%
Perm	200-300 nD
Sw	>50%, often >90% in Upper Mowry
Kerogen	Mixed Type II/Type III

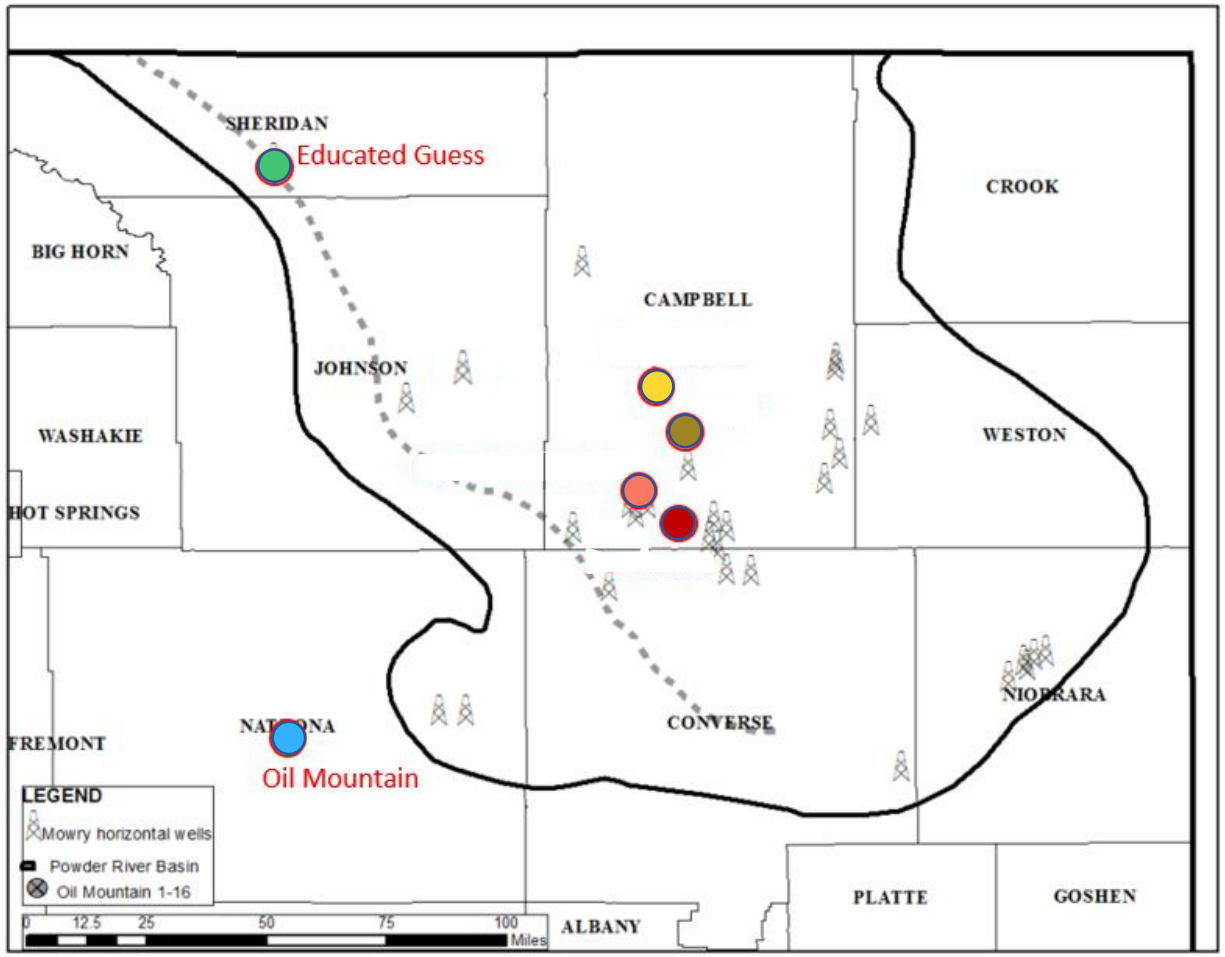
Research Cores

Six cores with near-complete Mowry Shale cored intervals, including:

- 191 XRD data points
- 206 Crushed rock (GRI/SRP) datapoints
- 209 Rock Eval datapoints

Samples from all cores representing all major facies and subunits



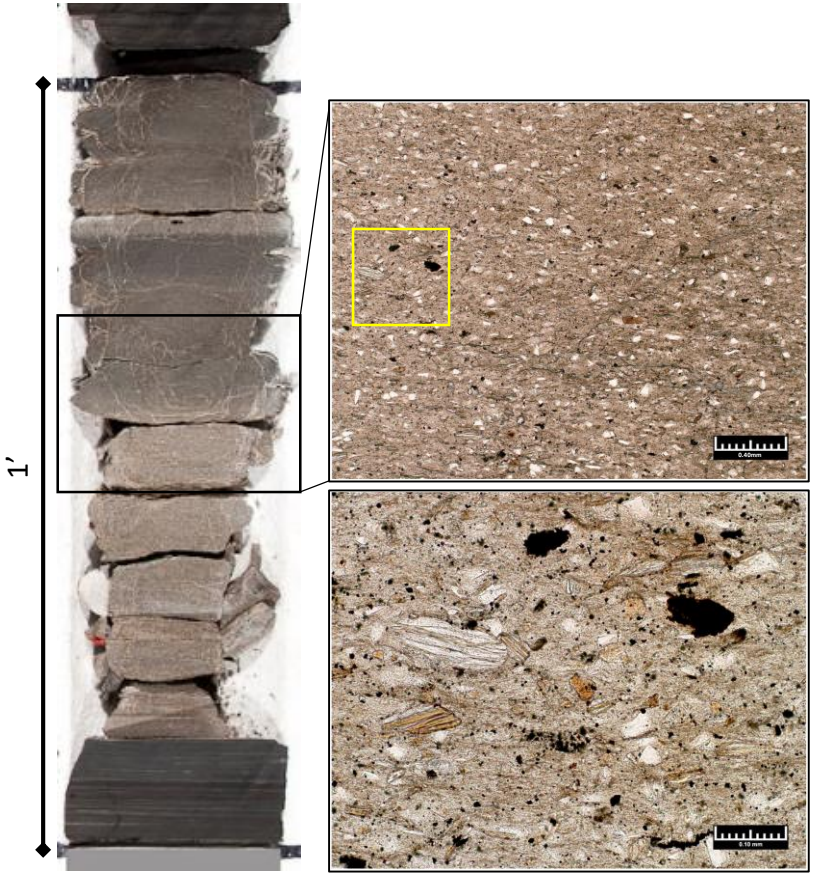


Mowry Hz Producer

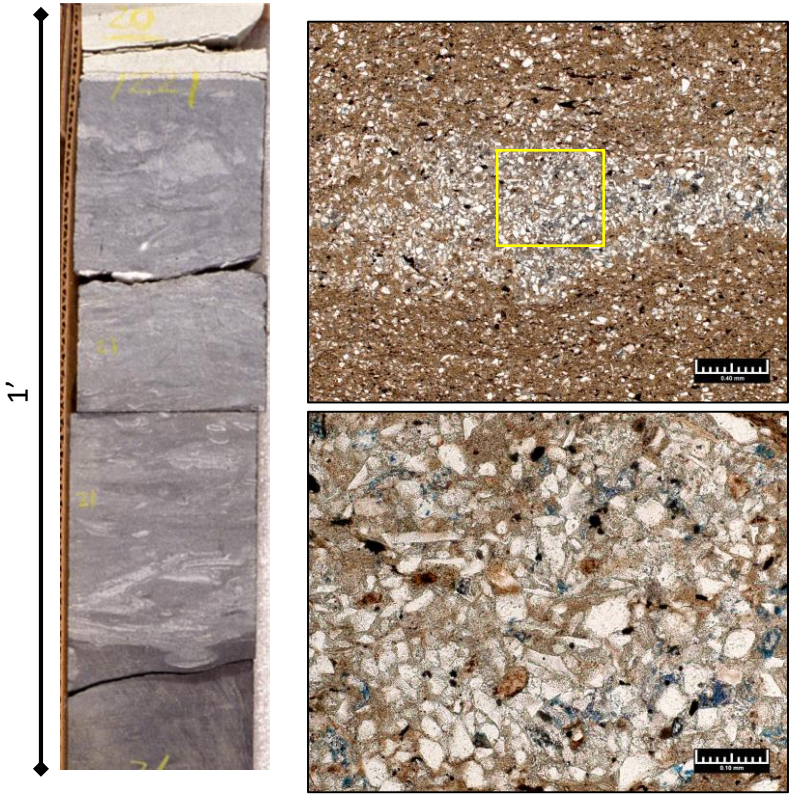
Available Research Cores

Major Identified Facies

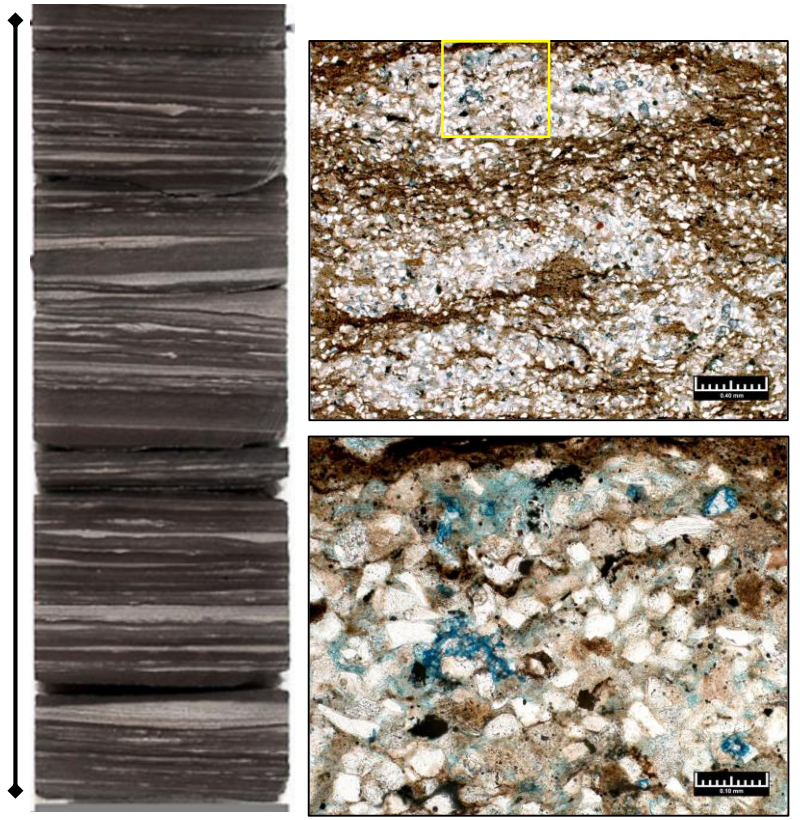
Bentonite



Bioturbated Sandy Mudst



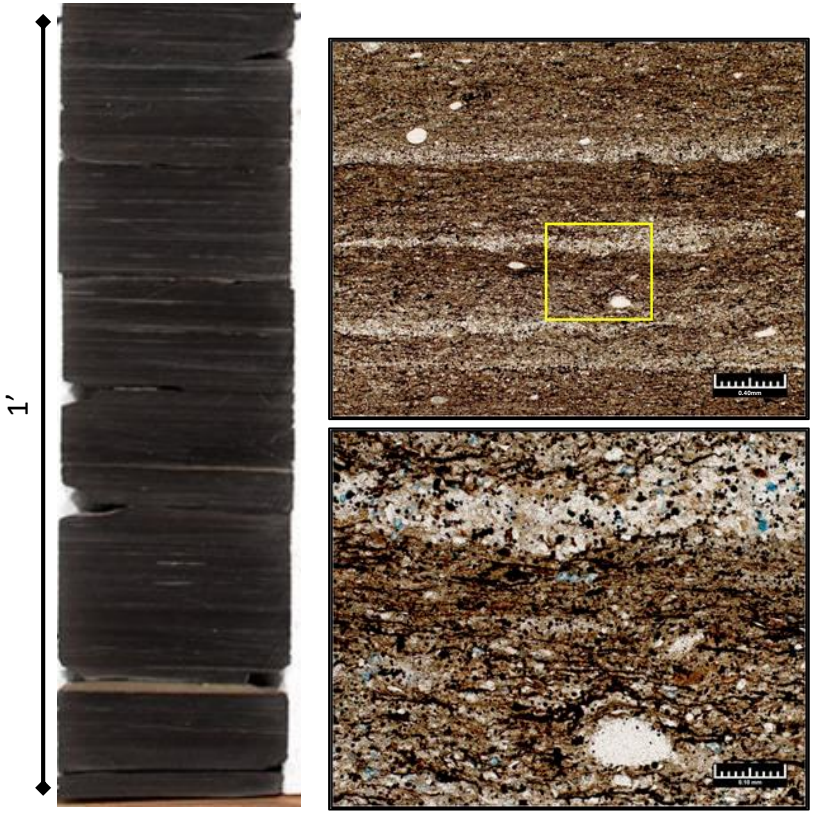
Thickly Lam Silty Mudst



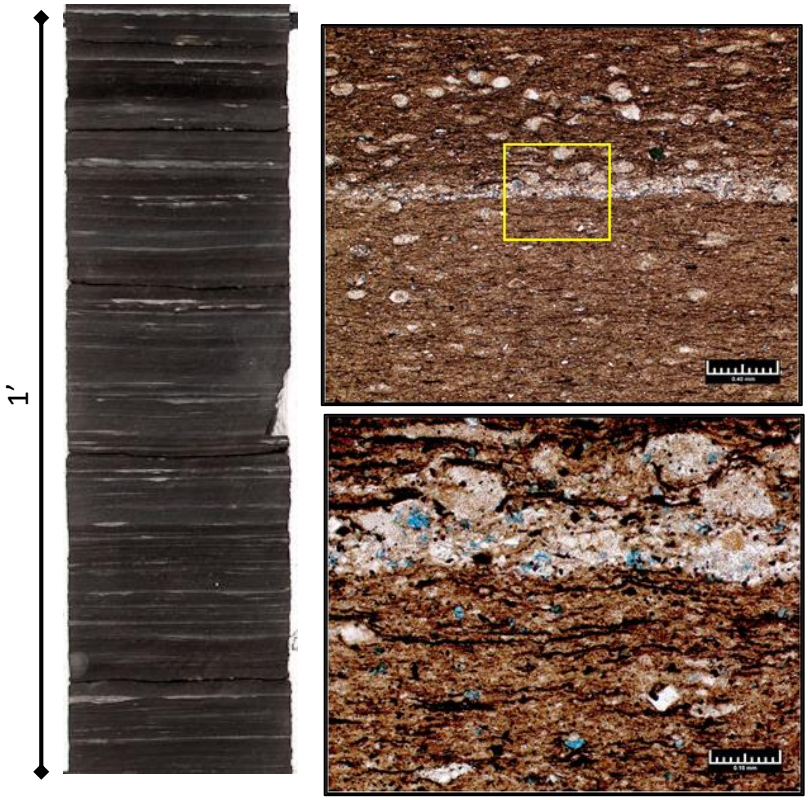
Photomicrograph Scale Bars
Upper Image - 400µm
Lower Image - 100µm

Major Identified Facies Cont'd

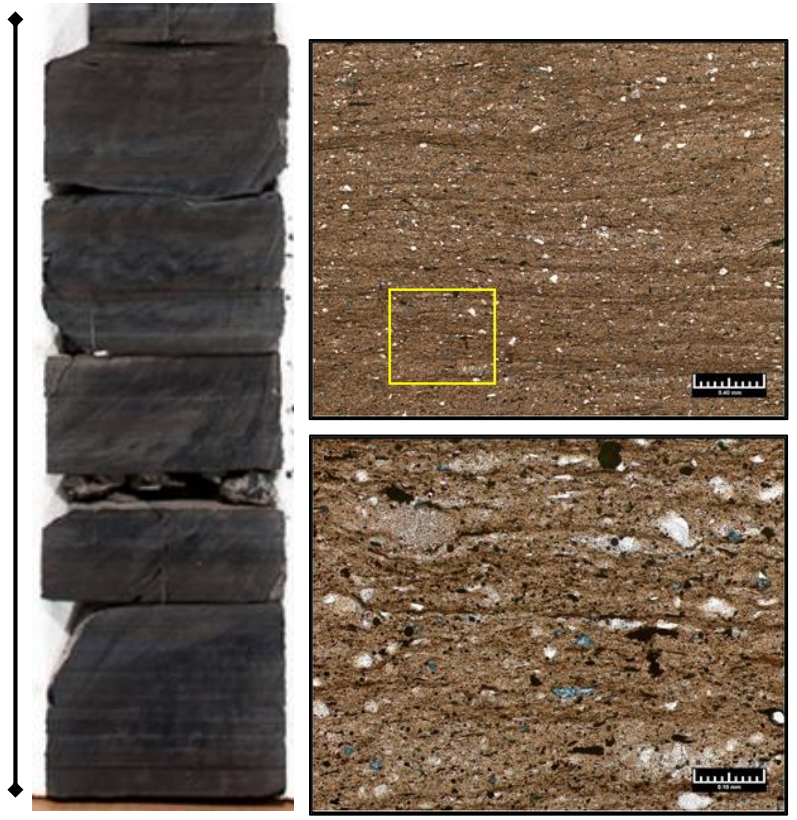
Thinly Lam Silty Mudst



Lam Silty Siliceous Mudst



Siliceous Silty Mudst



Photomicrograph Scale Bars
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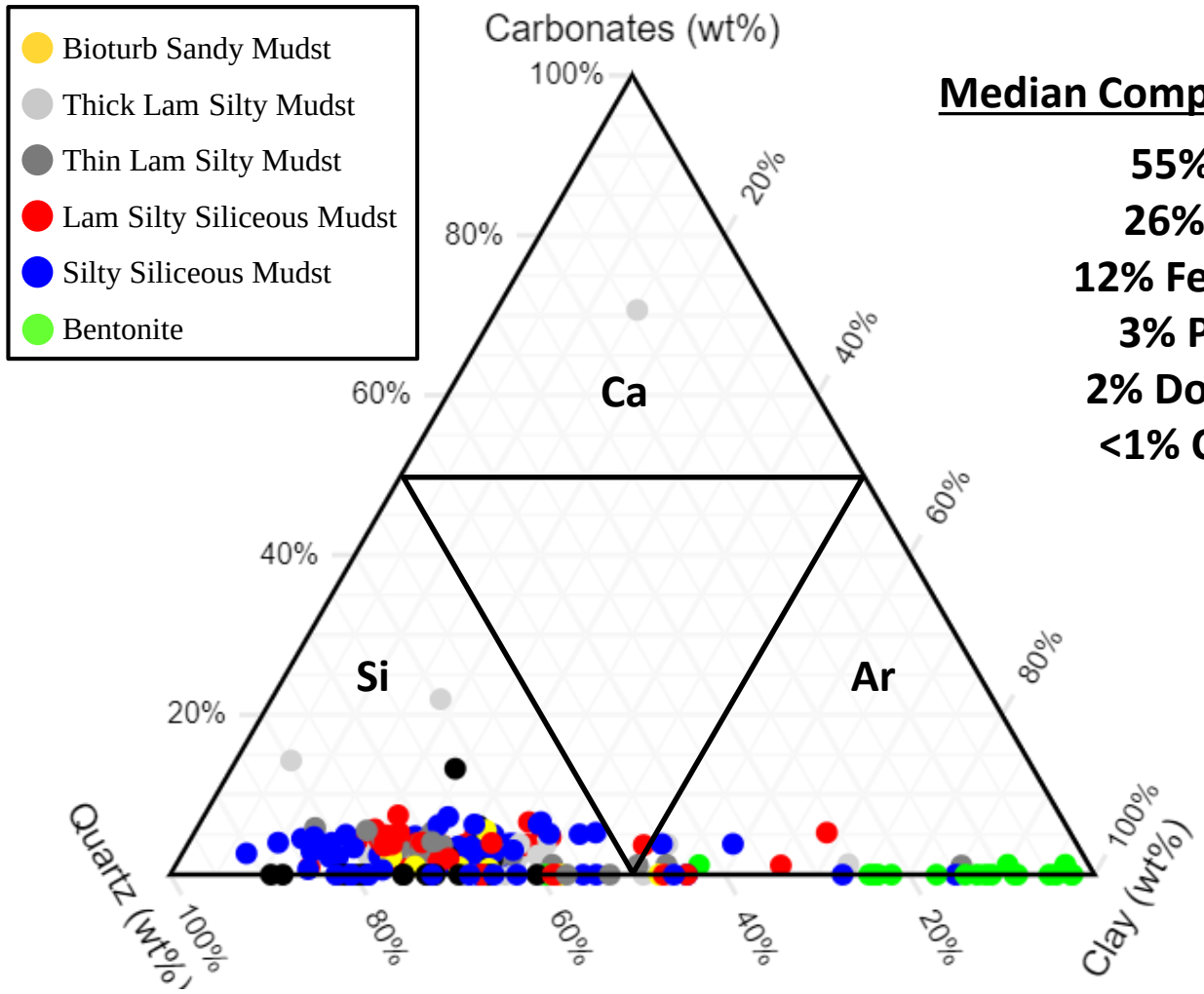
Lower Image - 100µm

Mineralogy – Bulk Analysis

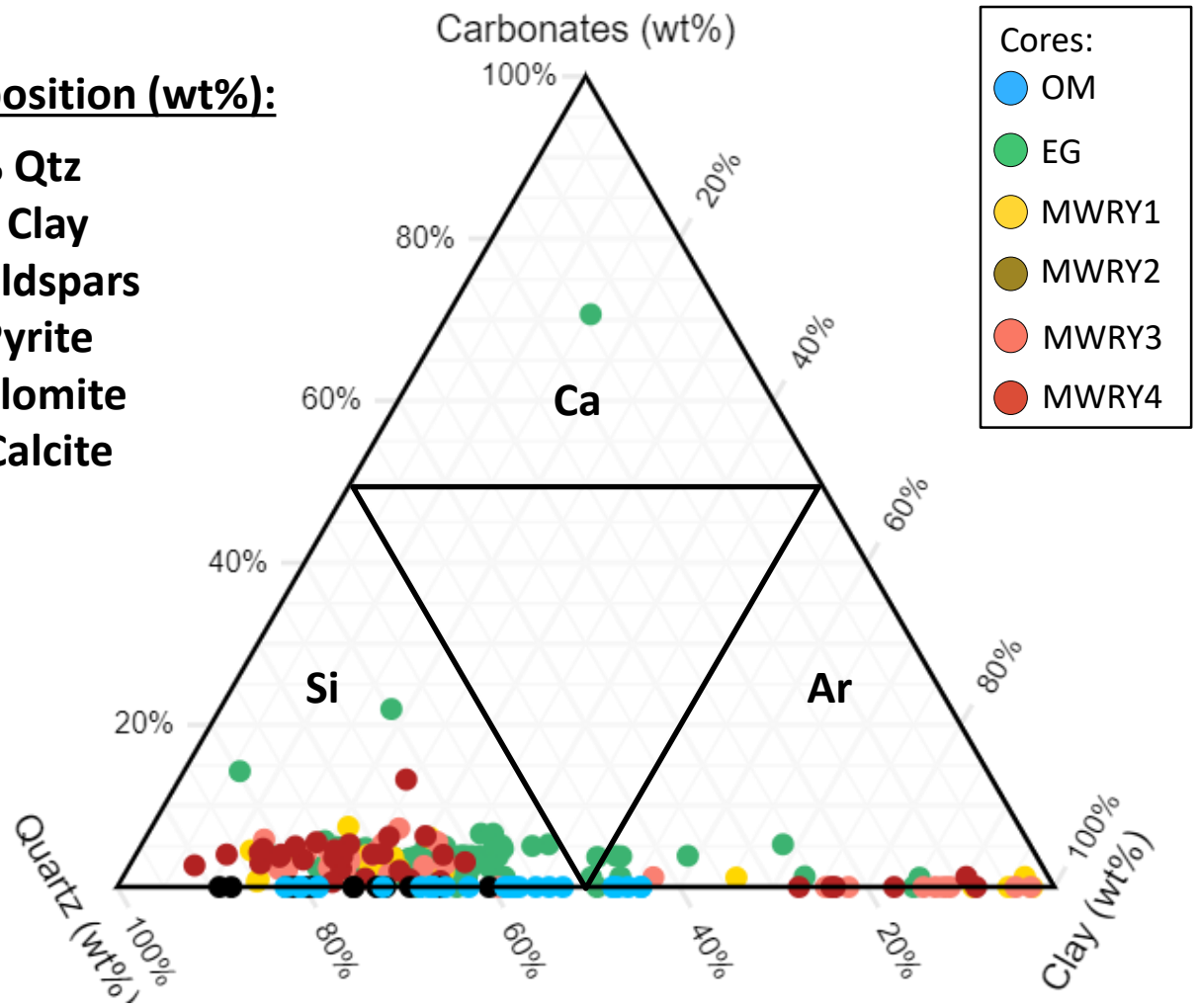
Facies



Median Composition (wt%):

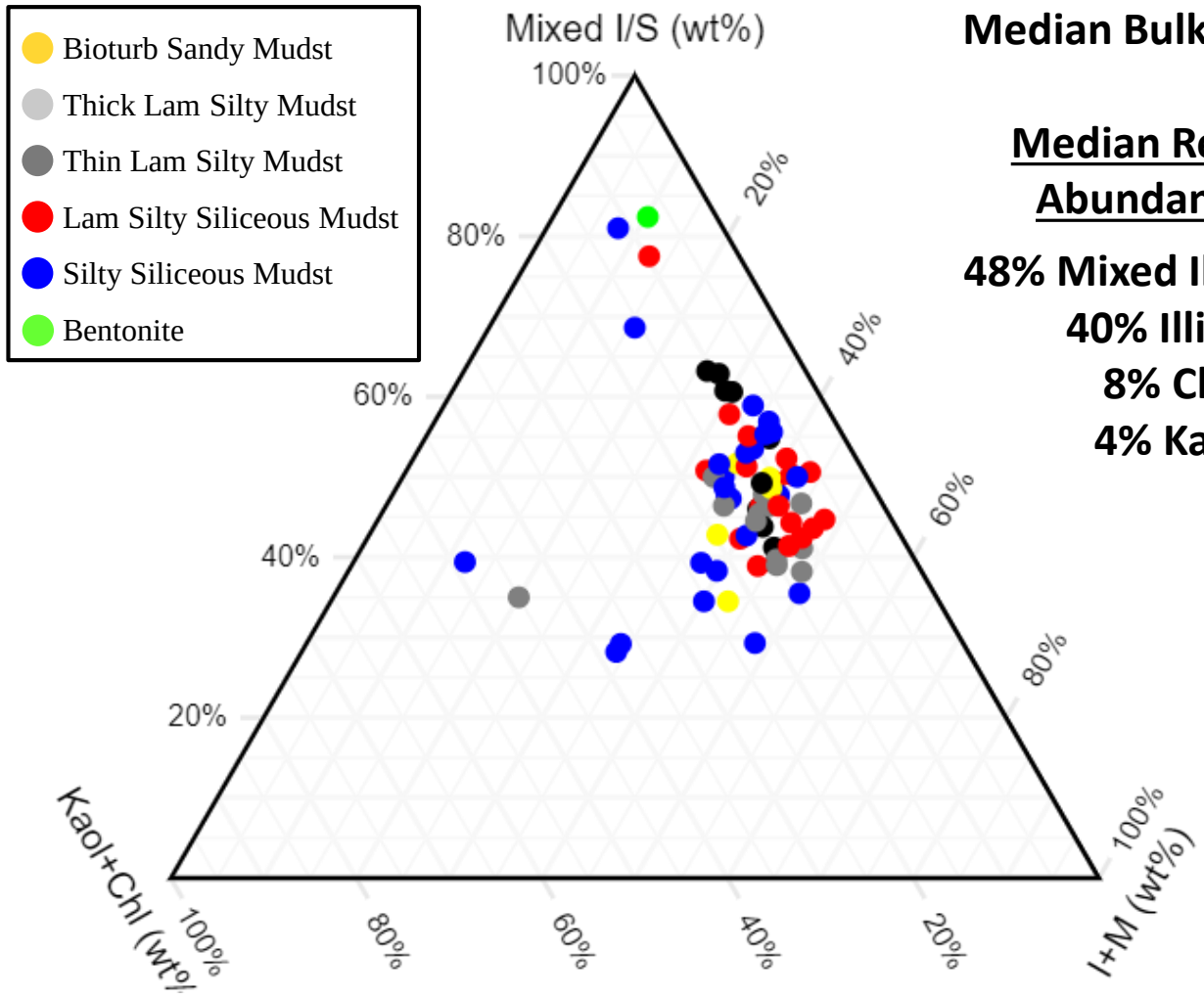
55% Qtz
26% Clay
12% Feldspars
3% Pyrite
2% Dolomite
<1% Calcite

Cores



Mineralogy – Clay Analysis

Facies

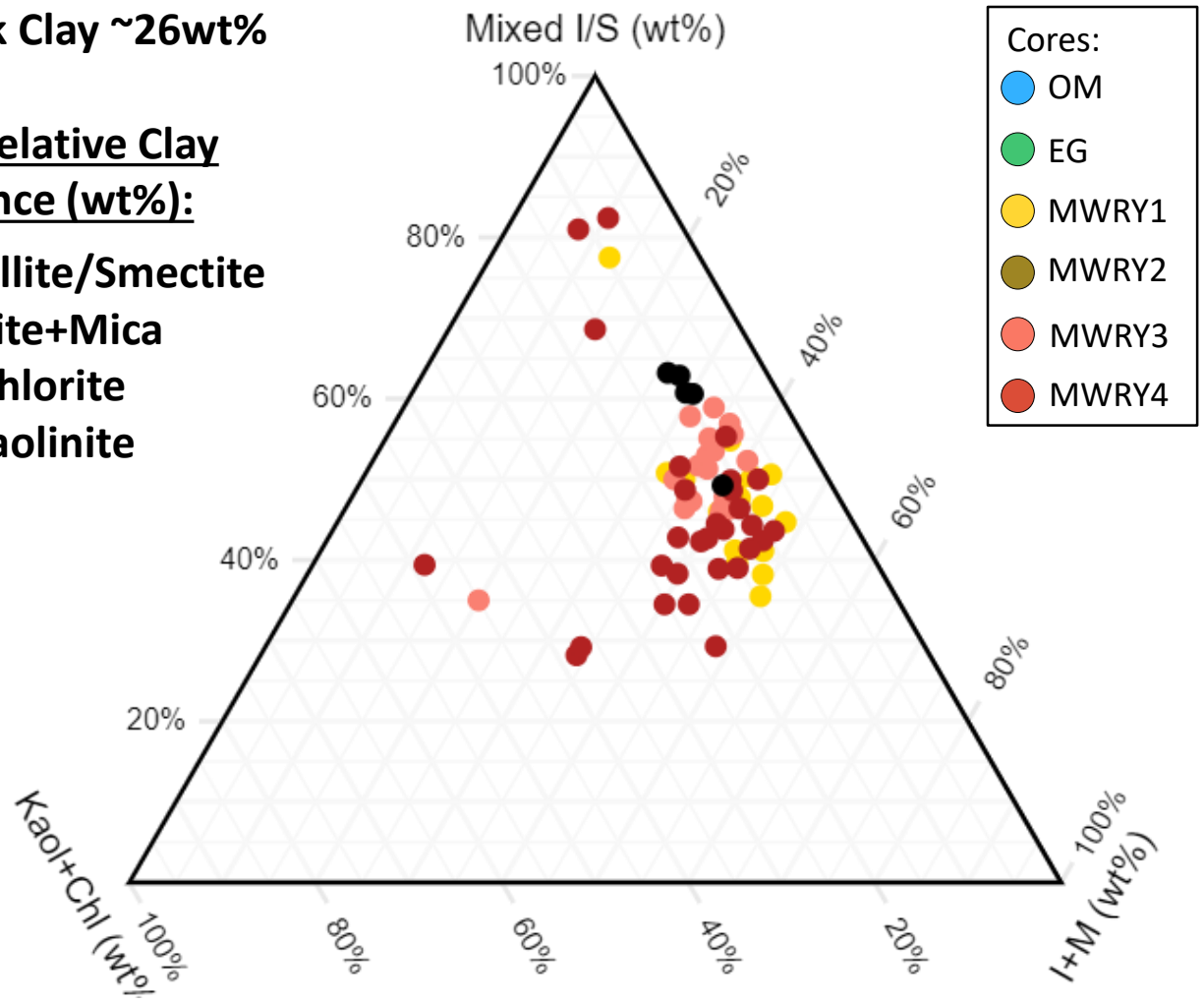


Median Bulk Clay ~26wt%

Median Relative Clay Abundance (wt%):

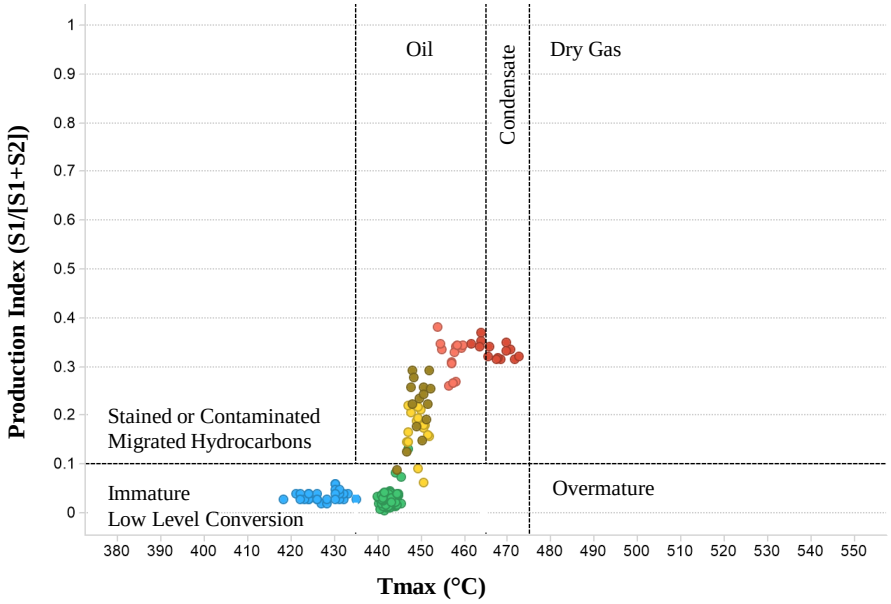
48% Mixed Illite/Smectite
40% Illite+Mica
8% Chlorite
4% Kaolinite

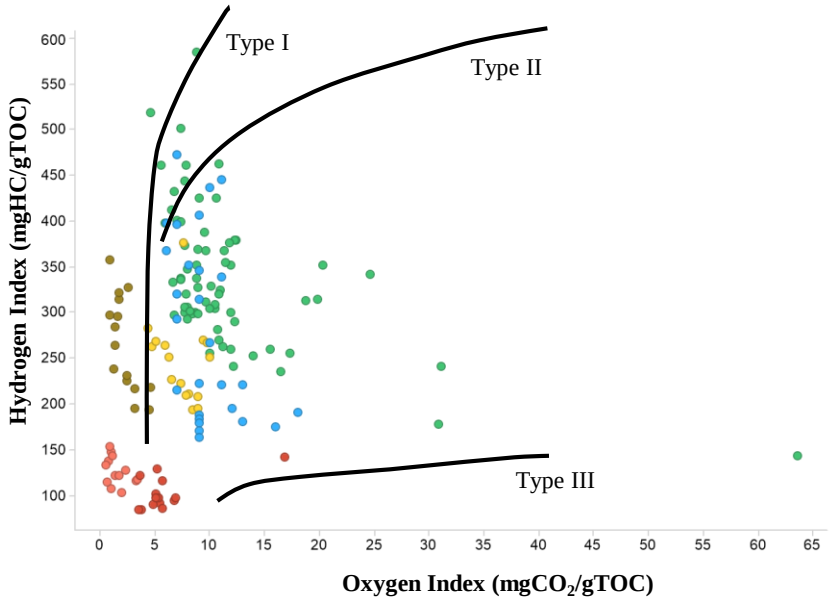
Cores

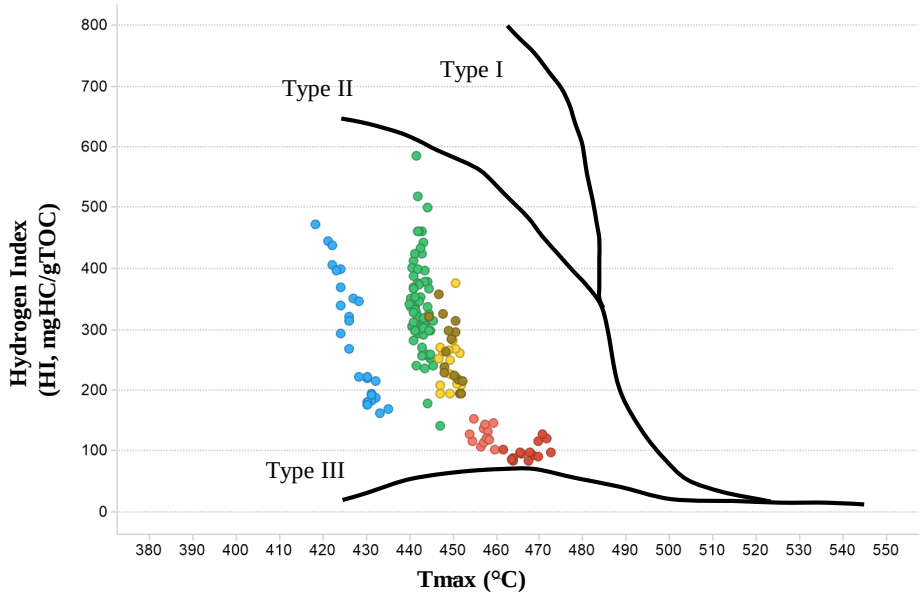


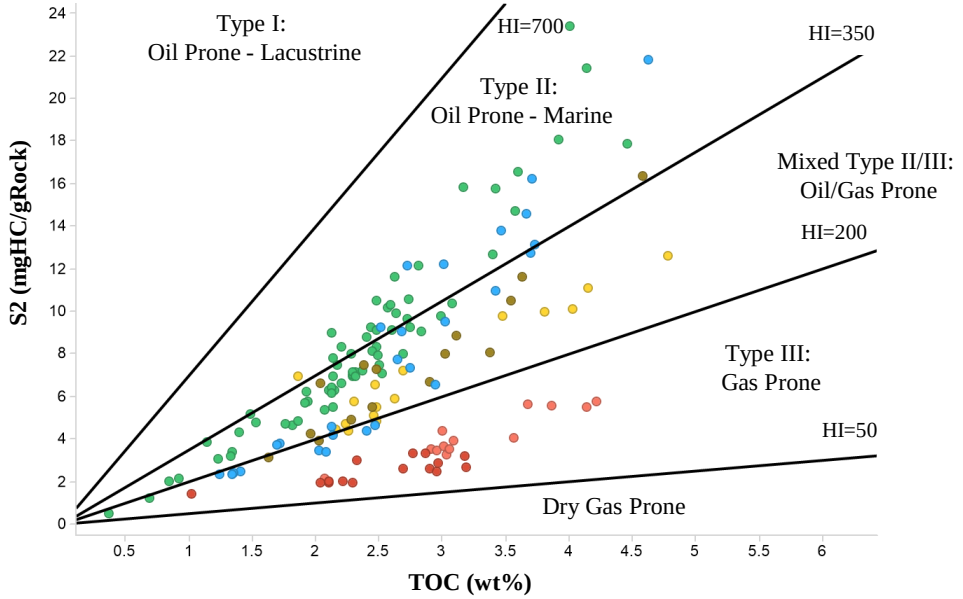
Kerogen Quality and Type

Cores:
- OM
- EG
- MWRY1
- MWRY2
- MWRY3
- MWRY4





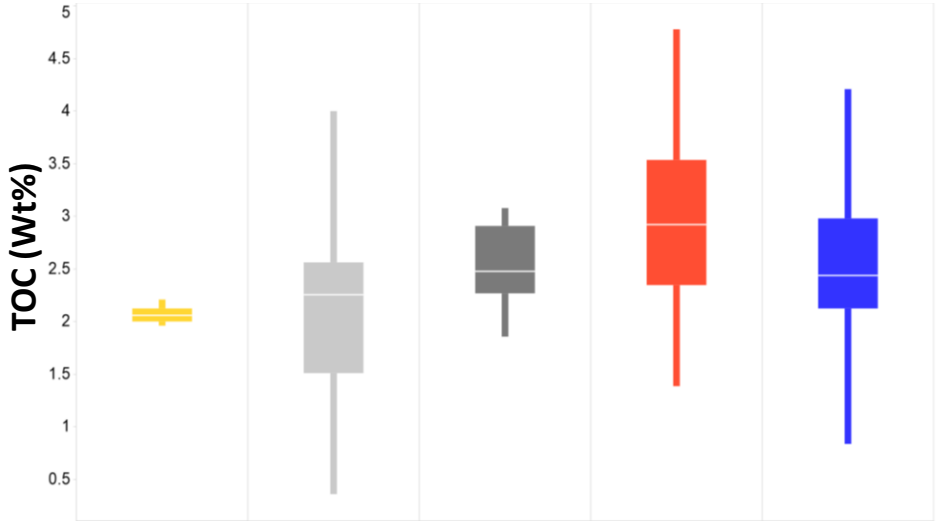


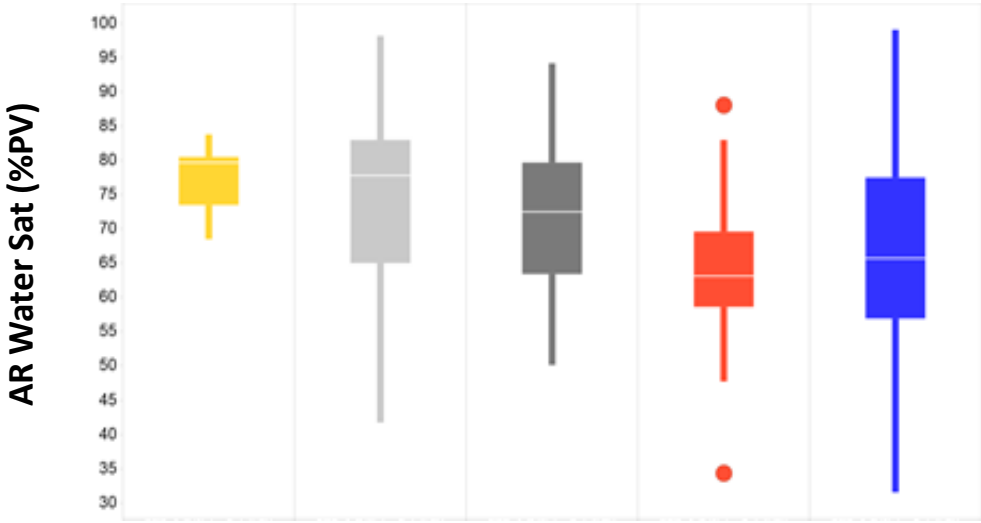


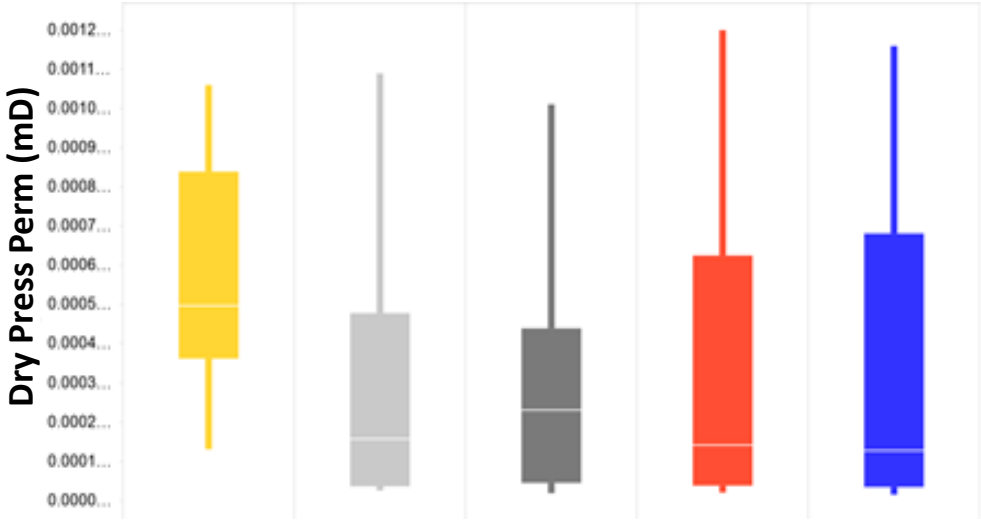
Facies Trends

Coarser, siltier facies exhibit:

- Lower average TOC
- Higher water saturations
- Moderately increased porosity
- Enhanced permeability

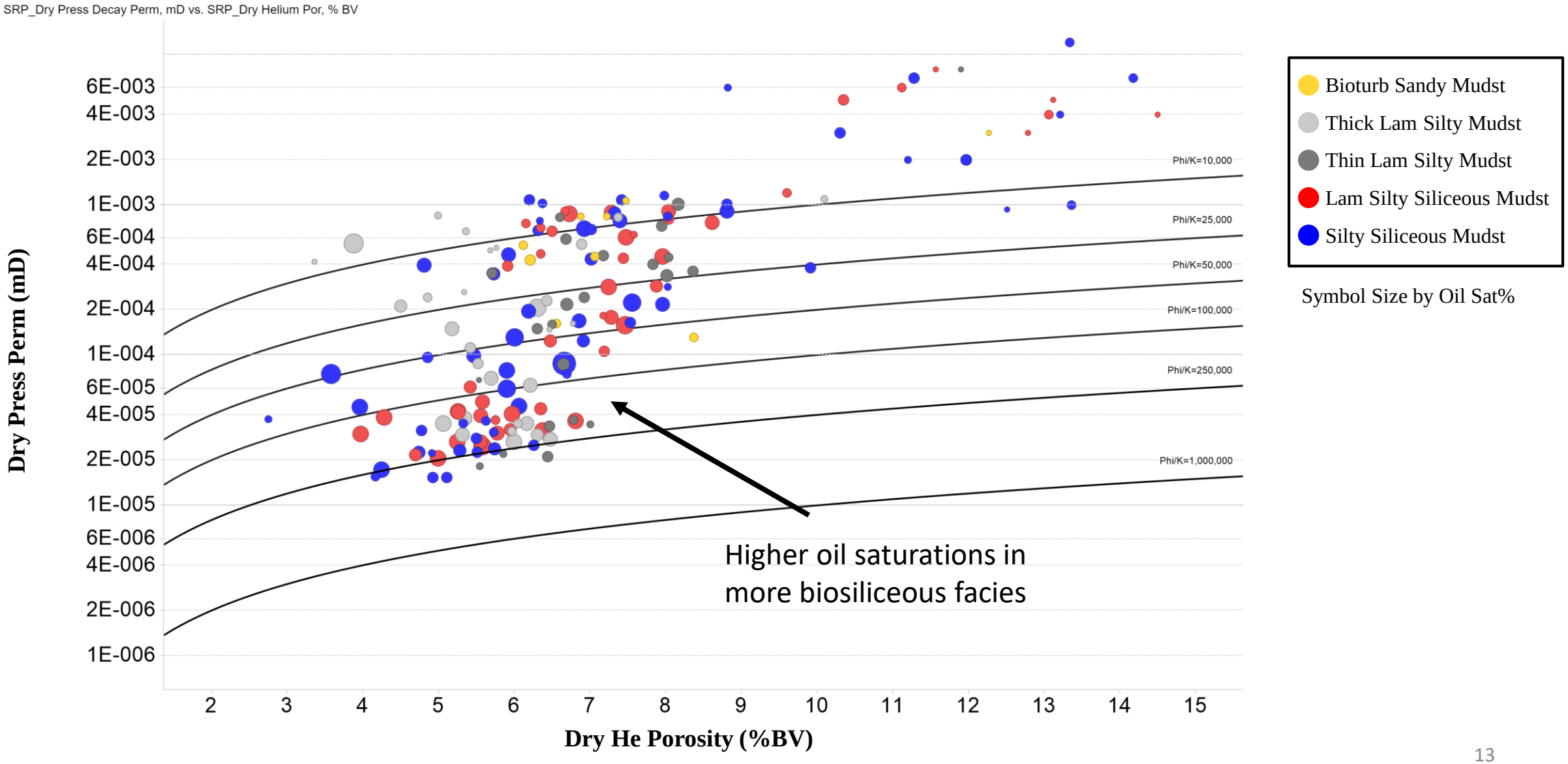






- Bioturb Sandy Mudst
- Thick Lam Silty Mudst
- Thin Lam Silty Mudst
- Lam Silty Siliceous Mudst
- Silty Siliceous Mudst

Facies Trends, Cont'd

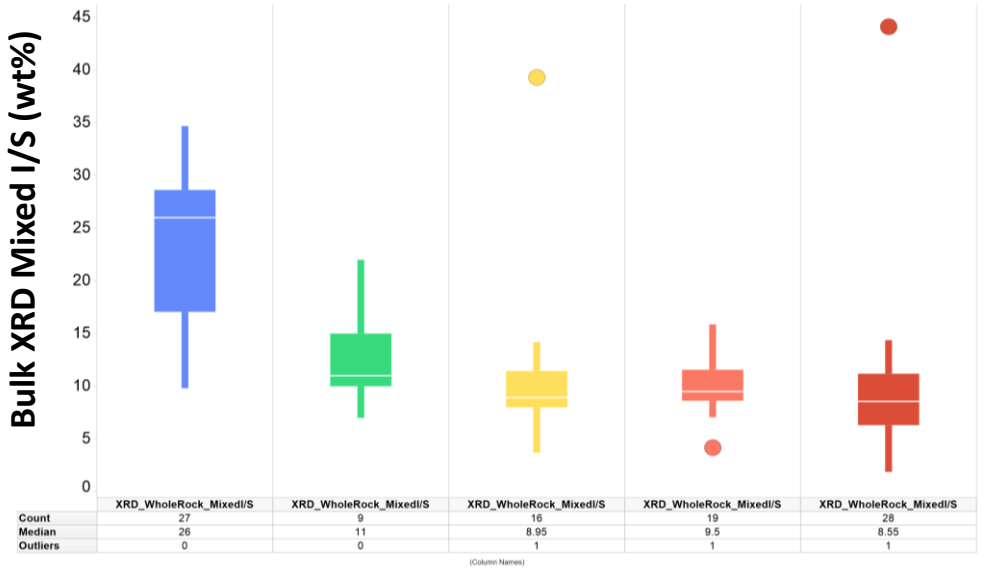


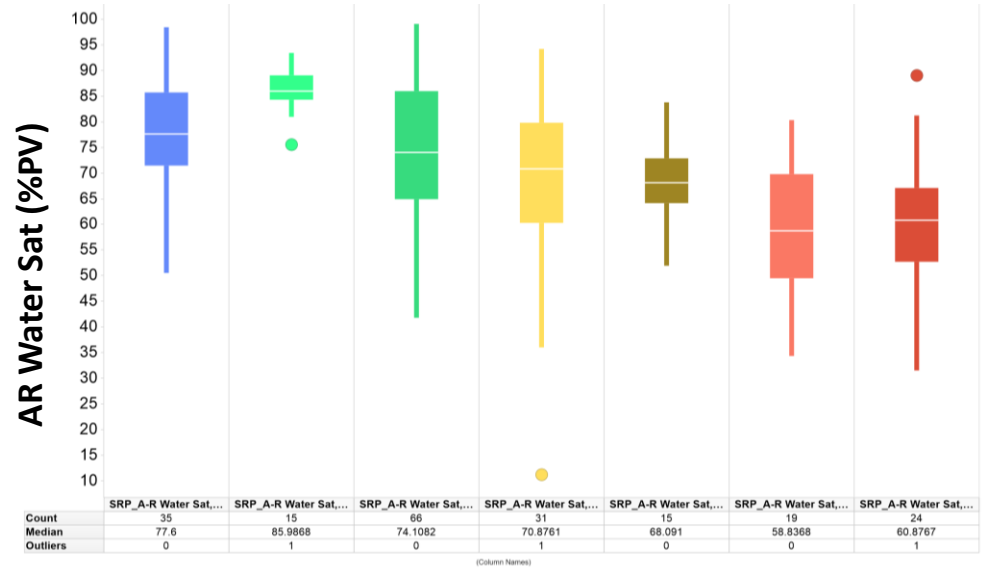
Maturity Trends

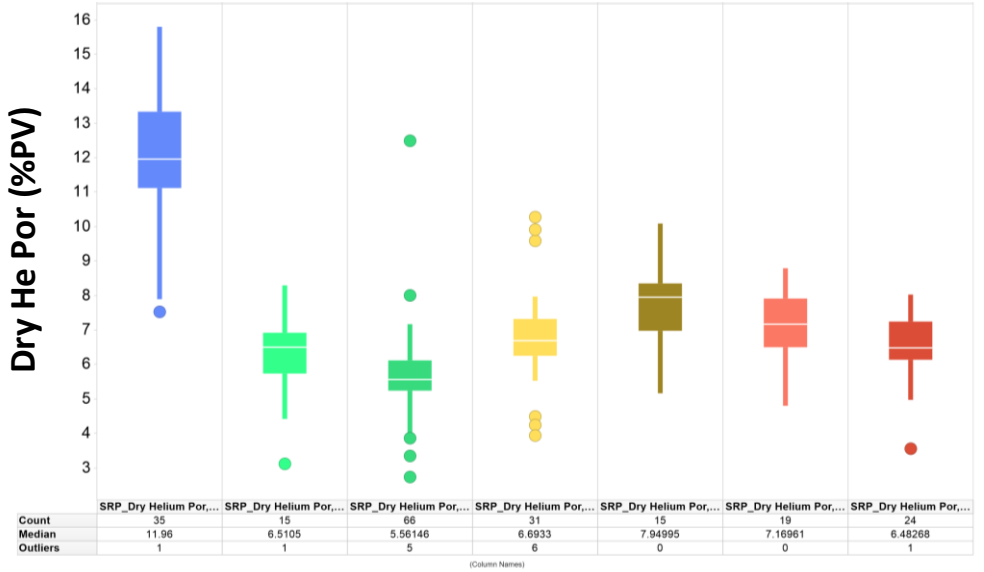
More mature cores exhibit:

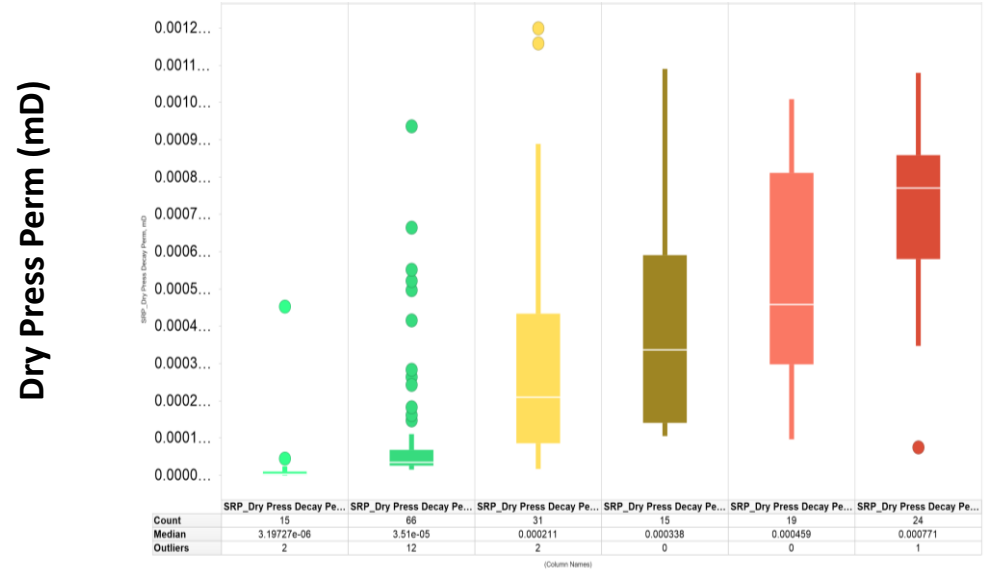
- Lower mixed I/S
- Lower water saturations
- Increased porosity
- Enhanced permeability

Cores:
- OM
- EG
- MWRY1
- MWRY2
- MWRY3
- MWRY4

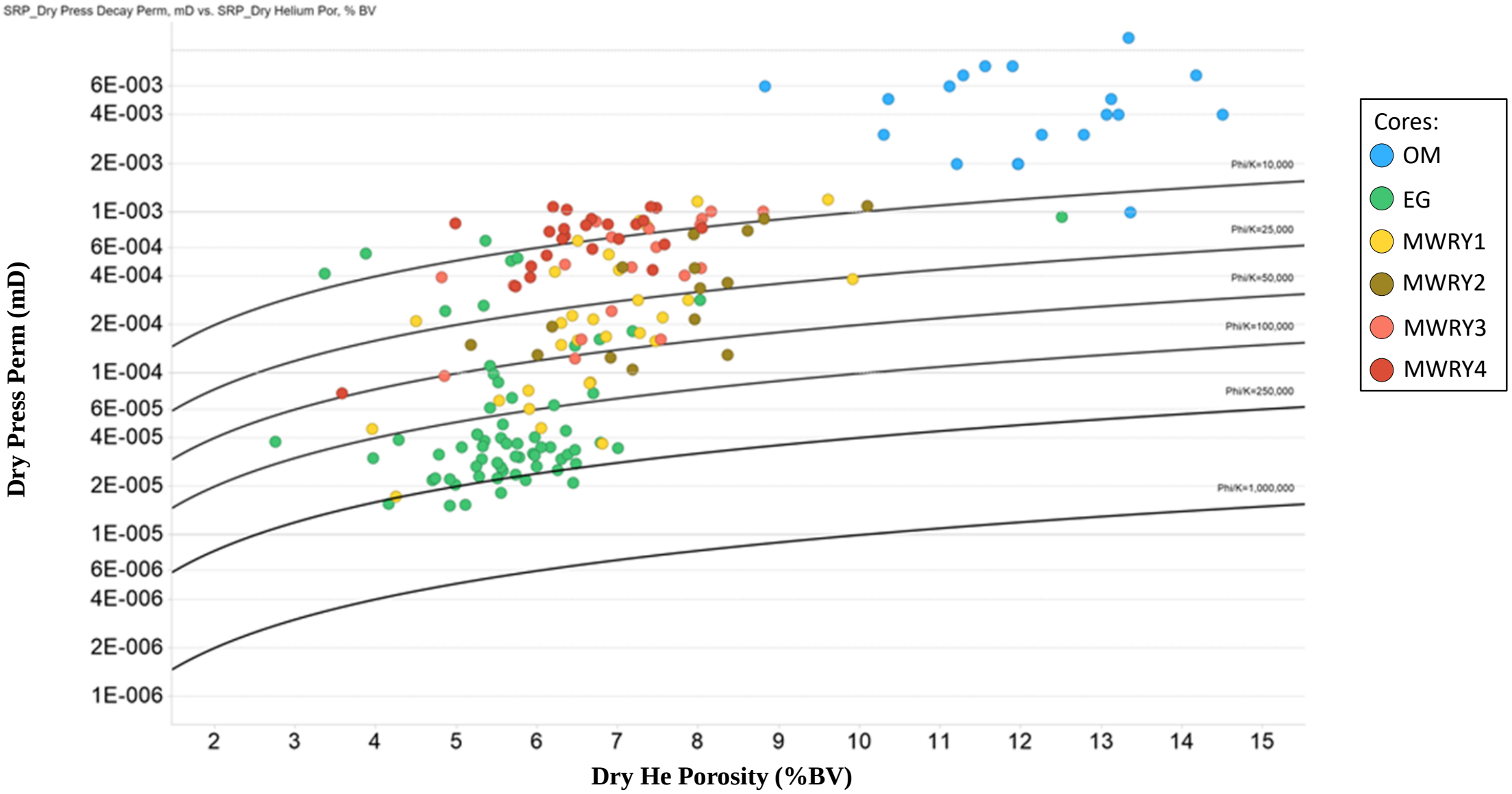




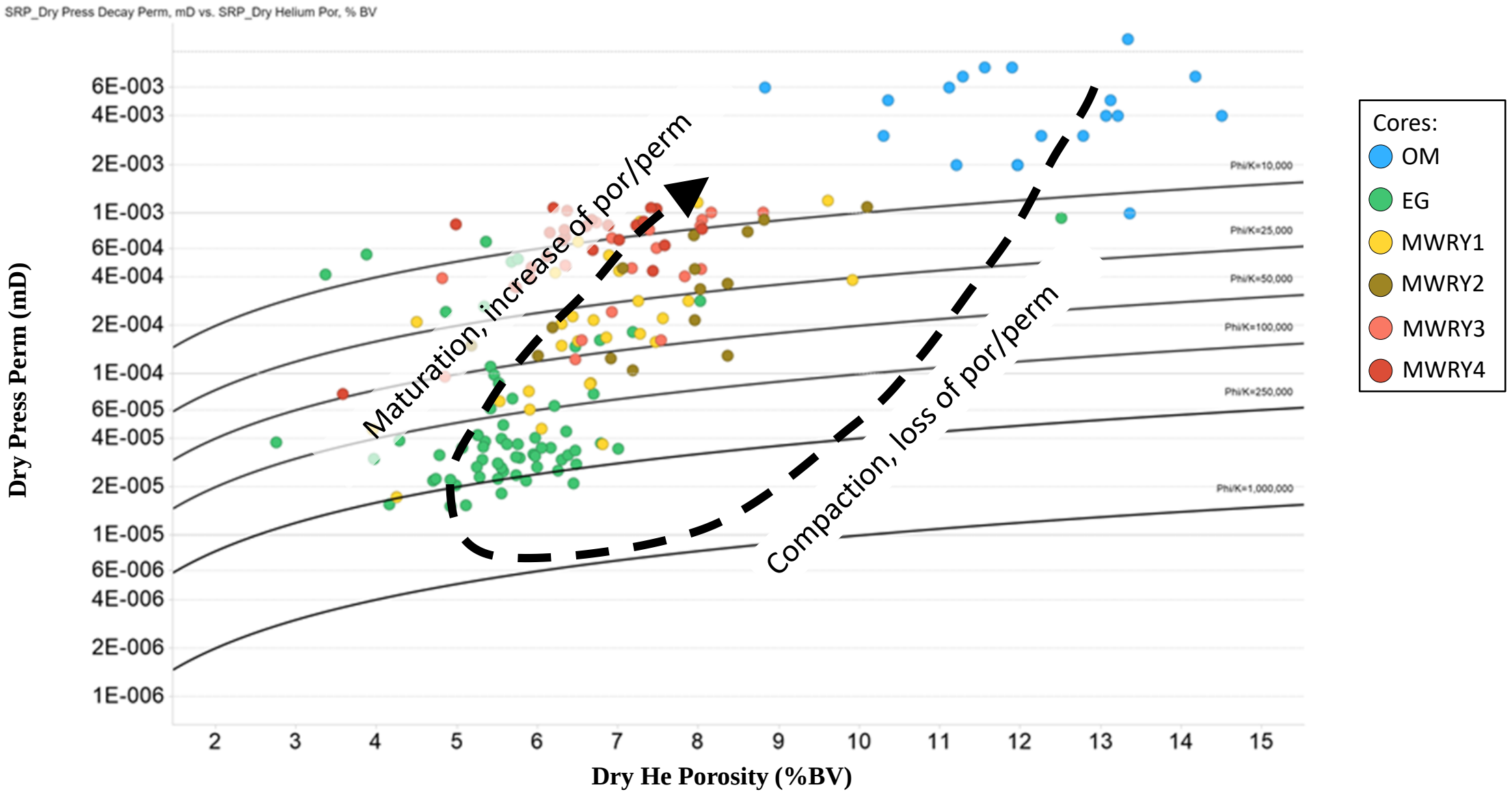




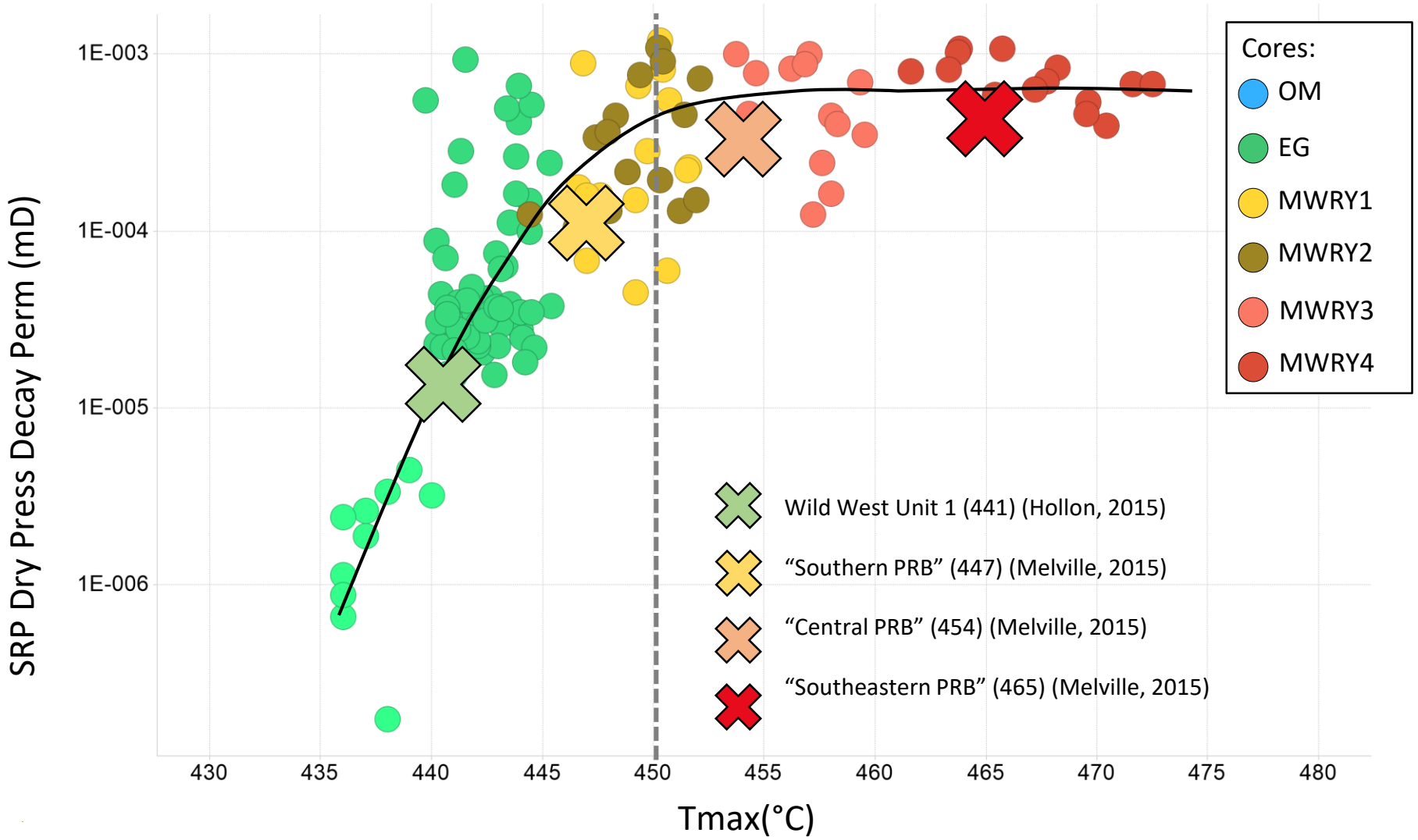
Maturity Trends, Cont'd



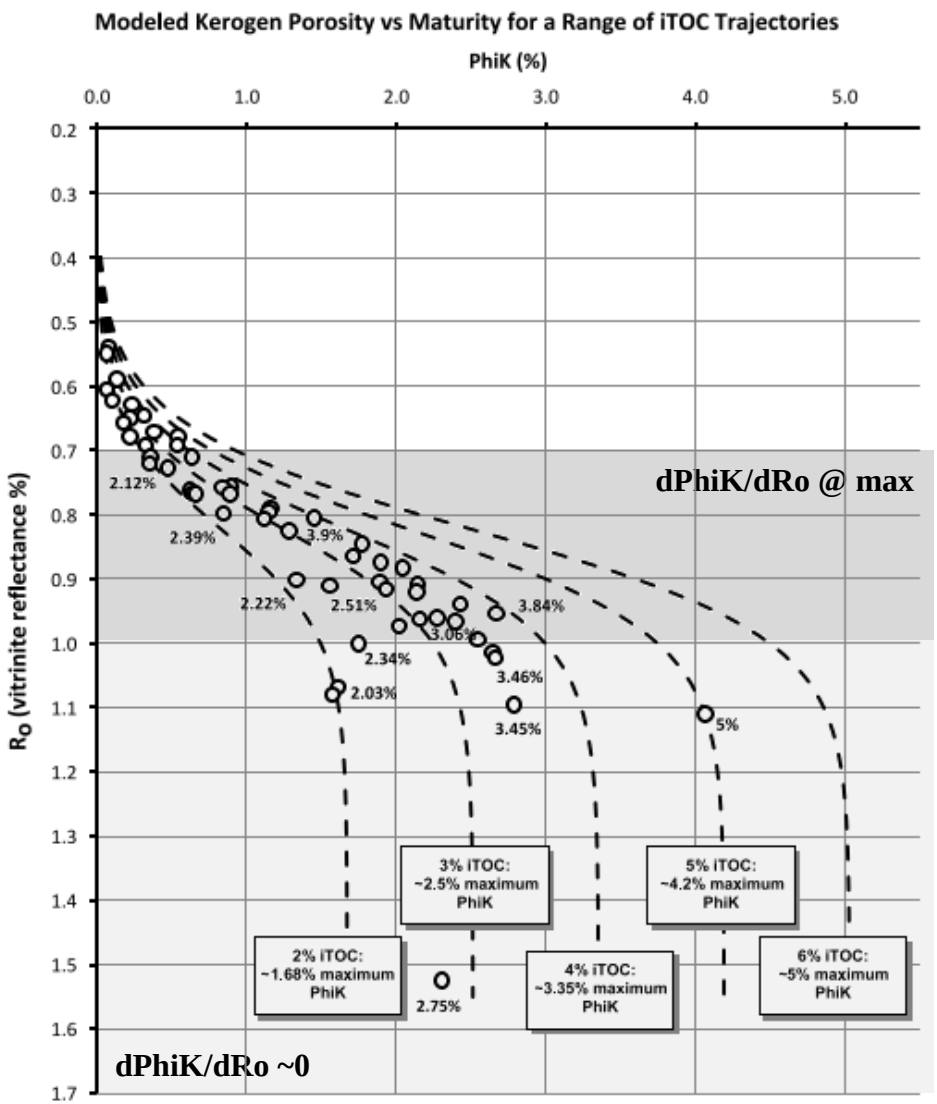
Maturity Trends, Cont'd

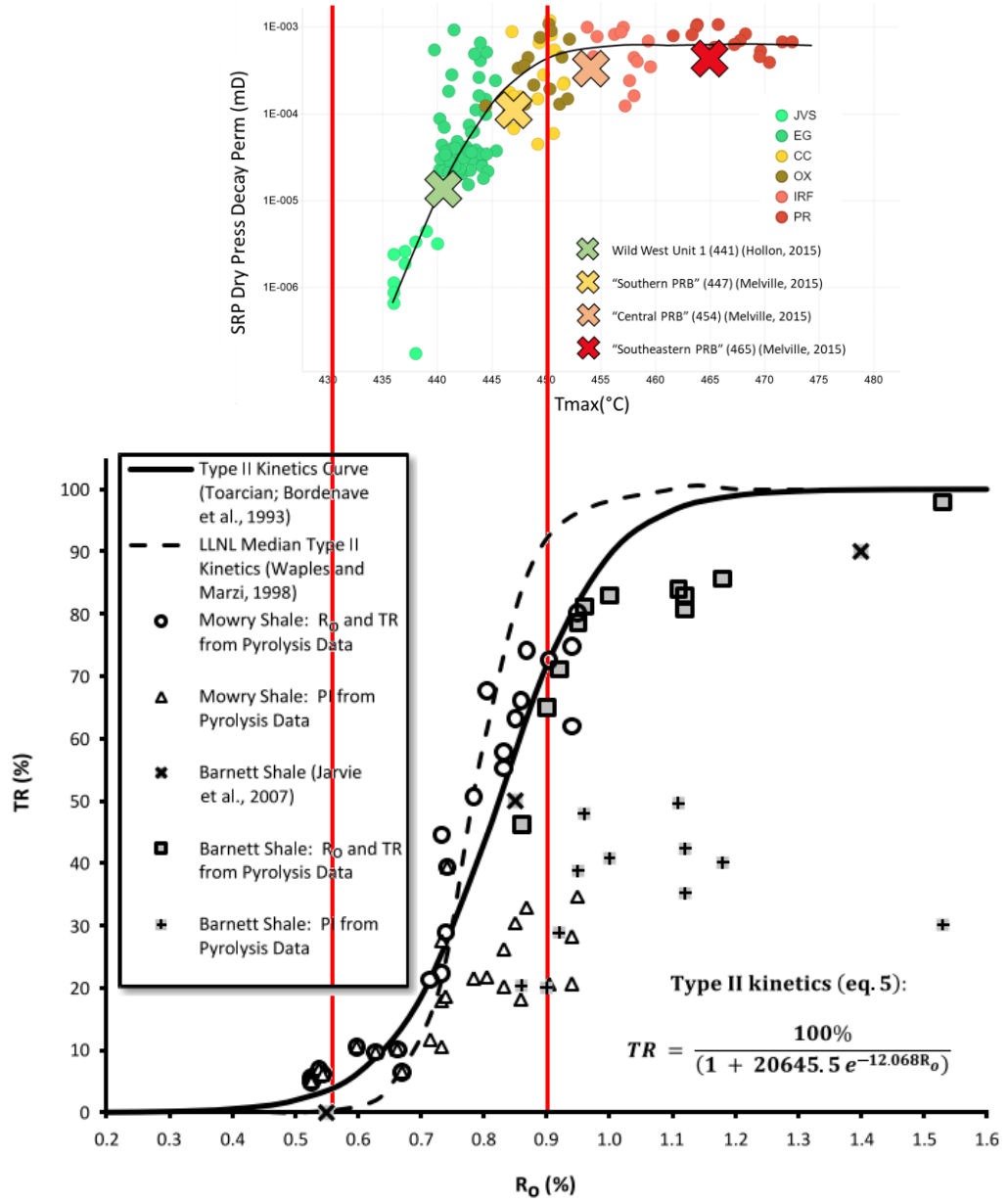


Permeability and Tmax



Permeability Trends





Figures modified from Modica and Lapierre, 2012

Next Steps: Influences on Pore Structure

Possible factors impacting pore size development:

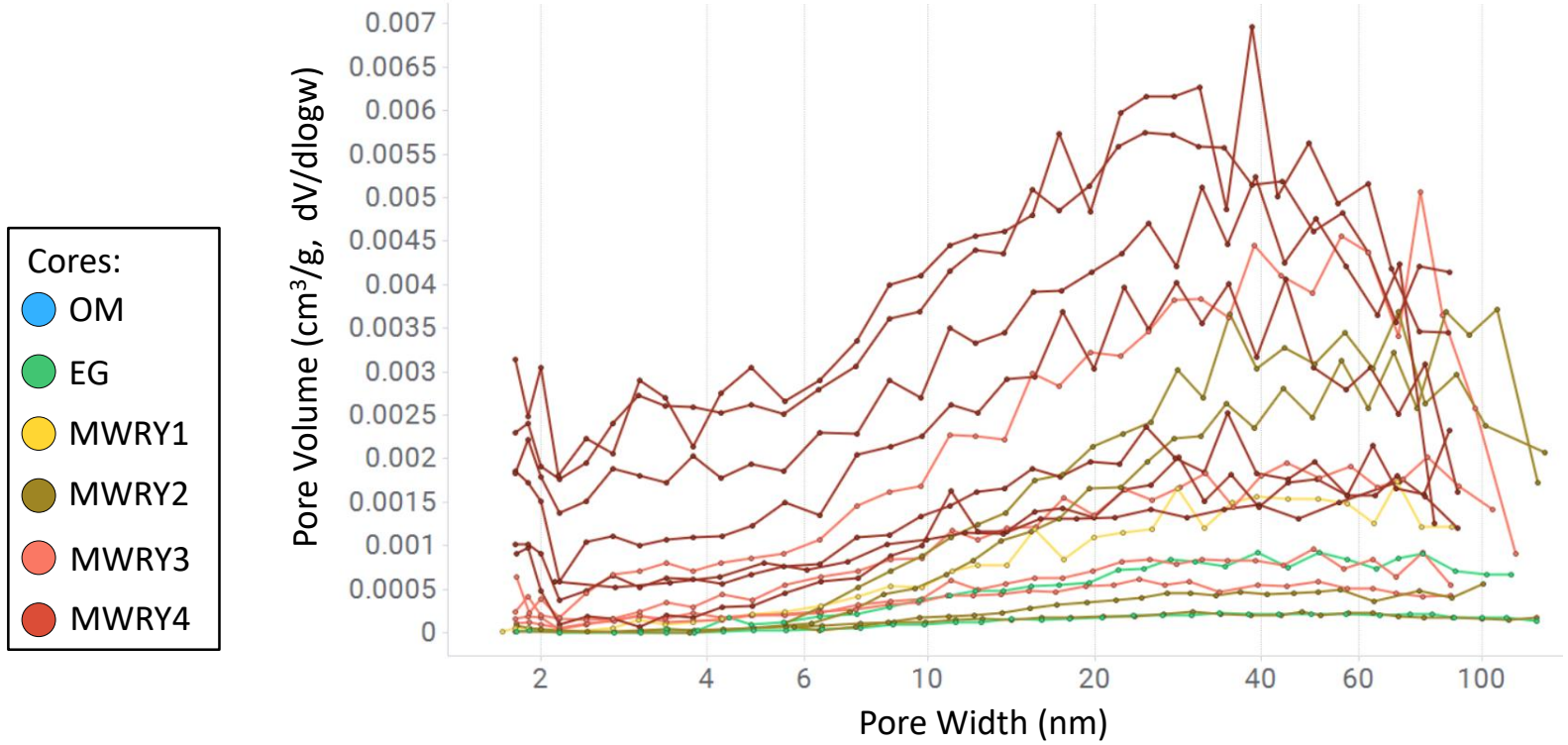
- Facies
- Maturity
- TOC content
- Clay content
- Silica diagenesis
- Compaction

Methods:

1) Low-pressure Nitrogen Gas Adsorption
   -Investigate pore size distributions

2) Ion-milled SEM samples
   - Visually qualify gas ads results

Preliminary results:



Summary

Key Findings:

1) Six main facies recognized in the distal, Powder River Basin Mowry Shale

2) Coarser facies exhibit higher detrital silica content, lower TOC, higher water saturations, increased porosity, and increased permeability

3) Higher maturity samples exhibit lower mixed I/S clay content, lower water saturations, increased porosity, and enhanced permeability

4) Strong and apparently predictable relationship between maturity and permeability, consistent with previous models of organic matter transformation, but other influences on the pore structure are also possible and will be the subject of ongoing research

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