#### The Diagenesis and Petroleum Potential of the Mowry Shale in the Powder River Basin, Wyoming

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### **Diagenetic Processes**

70

10°

20°

30°

60°

70°

80°-

90°

30

O 40°

emperature 50°

**Early Diagenesis** 

- **Early Mineralization**
- Bioturbation

**Burial Diagenesis** 

- Mechanical and Chemical Compaction \_
- **Biogenic Silica Diagenesis**
- Illitization of Smectite
- **Organic Matter Catagenesis**
- **Deep Burial Mineralization**







## Silica Diagenesis - Silica Source



- Biogenic Opal
- Illitization of Smectite
- Volcanic Ash



# Silica Diagenesis – Opal-A Conversion



Lynne, 2007

## Early Diagenetic Alterations

Bioturbation







mag ⊞ HFW WD HV det \_\_\_\_\_\_ 30 μm \_\_\_\_\_ 2 500 x 59.7 μm 10.9 mm 15.00 kV ETD Stratum - HH-57896 - Sample

### Late Diagenetic Alterations



Fe-Dolomite



#### Kaolinite & Chlorite





### Silicification of the Matrix



## Microcrystalline Quartz Preserved Pores

iew field: 17.6 un

Det: SE

SEM MAG: 11 7 kg



# **Bitumen Expulsion**





## **Organic Matter Hosted Pores**

















## Other Pore Systems



## Study Area





### **Diagenetic Transitions**



Well	SSTVD (ft)
Alcova Res.	5,185
TCF	-3,736
Well 5	-5,611
Well 1	-7,575

#### Alcova Reservoir Well





- Mineral Matrix Pores
- 80% Expandable interlayers I/S
- Partial Early Bitumen Formation
- No OM-hosted pores
- Ro: 0.51%









### TCF Well



- Mostly Mineral Matrix Pores

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- 80% Expandable interlayers I/S
- Moderate Bitumen Formation
- Minor OM-hosted pores
- Ro: 0.75%







### Well 5





- Dominate Pore Type: Unknown
- 20% Expandable interlayers I/S
- Bitumen Formation
- Expect OM-hosted pores
- Ro: 0.98%









### Well 1









- Mineral Matrix Pores are less common
- 20% Expandable interlayers I/S
- Extensive Bitumen Formation
- OM-hosted pores are most abundant pore type
- Ro: 1.26%





### Illitization of Smectite



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#### Mineralogical Maturity Trends













#### Catagenesis Trends





### Bitumen Network Perm Development



<sup>\*</sup> Ro calculated from Tmax

#### Paragenetic Sequence





#### **Petroleum Potential**



Average TOC: 2.71 wt.% (n=164)

- Upper Mowry: 2.35 wt.%
- Middle Mowry: 3.03%
- Lower Mowry: 2.56 wt.%

Avg S1 in peak oil maturity wells: 1.8 mg/g - Middle Mowry: 33% higher than Upper and Lower

Avg S2 in Alcova Reservoir well: 11.06 mg/g - Middle Mowry 42% higher



### TOC and Saturations by Formation Member



### Generated Hydrocarbon Calculations

Step 1: 
$$HI_0 = \left(\frac{\% Type I}{100} x750\right) + \left(\frac{\% Type II}{100} x450\right) + \left(\frac{\% Type III}{100} x125\right) + \left(\frac{\% Type IV}{100} x50\right)$$

Step 2: 
$$TR_{HI} = 1 - \frac{HI_{pd}[1200 - HI_o(1 - PI_o)]}{HI_o[1200 - HI_{pd}(1 - PI_{pd})]}$$

Step 3: 
$$TOC_o = \frac{HI_{pd} \left(\frac{TOC_{pd}}{1+k}\right) x 83.33}{\left[HI_o x (1-TR_{HI}) \left(83.33 - \left(\frac{TOC_{pd}}{1+k}\right)\right)\right] - \left[HI_{pd} \left(\frac{TOC_{pd}}{1+k}\right)\right]}$$

Step 4:  $S2_o = \frac{HI_o \ x \ TOC_o}{100}$ 

Step 5: Generated Hydrocarbons =  $S2_o - S2_{pd}$ 

Jarvie et al., 2007

#### Middle Mowry





### Source Rock Quality in the PRB





Mowry Present Day TOC Map

Mowry Tmax Maturity Map

#### Hydrocarbon Generation In the PRB





Mowry Generated Hydrocarbons Map



Mowry Available Hydrocarbons Map

### Main Takeaways



- Primary diagenetic processes affecting reservoir properties:
  - Silicification of matrix from biogenic silica source
  - Illitization of smectite
  - Organic matter catagenesis and porosity development
- Hydrocarbon Generation
  - Average Original Potential of the Mowry is 329 bbls/a-ft
  - The three wells in the late oil window have generated on average 234 bbls/a-ft
  - Wells in the peak oil window have the highest retention factor of 67%
  - The amount of generated hydrocarbons varies between the northern and southern Powder River Basin

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