Unconventional “Shale Plays” in MT

A Look at the Geology & Development of the Bakken and Heath Formations

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Montana Bureau of Mines and Geology
Why Shales?

• Traditional “Source Rocks”
  – Mostly clays - often high organic content
  – Little available pore space and virtually no matrix permeability

• Kerogens are baked into oil & gas; migrate out of the shale and into conventional traps

• New technology has turned these traditional source rocks into reservoir targets
Horizontal Drilling & Frac’ing

Technology’s Role

Why the revolution?

Fracture stimulation 5,000’ – 15,000’ below the surface

- Migrating hydrocarbons
- Porous and permeable reservoir layer
- Frack
- Shale organic rich source layer
- Hydrocarbon Trap
- Impermeable sealing layer
Bakken has been the “Proving Ground”

Current estimates of recoverable oil from the Bakken/ThreeForks range from 3-24 Billion bbls

Oil from Shale now ~16% of US Production

*Most is from the Bakken (600,000 bopd)*
North American shale plays
(as of May 2011)

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011
Requirements for Shale Resource Plays

• **Large area** of organic-rich source rock

• **Heat**, pressure, and time to mature

• **Expulsion** of HC from source rocks into adjacent rocks

• **Trapping** of HC in overlying and underlying reservoirs that are porous, but low permeability

• **Technology** to extract HC using natural or artificial fractures

Lynn Helms, ND DMR
Exshaw / Bakken
One big transgression

Key
- Structural Features
- Extent of Bakken & Exshaw Formations
--- Williston Basin Outline

Chatellier, 2010
<table>
<thead>
<tr>
<th>Sequence</th>
<th>Systems</th>
<th>Lithology</th>
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<td>Amsden</td>
<td>Tyler</td>
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<td>Otter</td>
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<td>Dawson Bay</td>
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<td>Red River</td>
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<td>Winnipeg Grp</td>
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<td>405 (125)</td>
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<tr>
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<td>Cambro-Ord</td>
<td>Deadwood</td>
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<td>900 (270)</td>
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**Williston Basin Stratigraphy**

- Bakken
- Three Forks
The Bakken “Petroleum System”

DEPTH: 9,000-11,000 feet
Exshaw siltstone
(Middle Bakken)

Exshaw shale
(Lower Bakken)

Palliser
(Three Forks)

Chatellier, 2010
Burial & Oil Generation

“BAKKEN KITCHEN” CONTINUOUS OVERPRESSURED OIL CELL

MIGRATED OIL CONVENTIONAL TRAP

Source: Continental Resources
The Early Years

Bakken Shale Producing Wells
Bbl Oil per Day (Mean per Quarter)
- 0 - 100
- 101 - 500
- > 500

Gas-Oil Ratio (Mean per Quarter)
- 0 - 1,000 (Oil Bbl >> Gas BOE)
- 1,001 - 6,000 (Oil Bbl > Gas BOE)
- > 6,000 (Gas BOE > Oil Bbl)

Bakken Depositional Limit

1996: Middle Bakken Vertical well Tests Elm Coulee Field

2000: Elm Coulee Middle Bakken Horizontal wells Discovery

1967: Upper Bakken Shale Horizontal Wells Billings Nose

1976: Upper Bakken Shale, Vertical wells Billings Nose

1953 Discovery Well
Elm Coulee Field
The Shift to ND
Geology dictates where the rigs go

**Middle Bakken / Three Forks Pay Variation**

- **Montana**
- **North Dakota**

**Legend**
- Green: Dolomite/silty dolomite
- Blue: Limestone/shale
- Yellow: Sand
- **MB**: Lodgepole Limestone (depth: ~10,000')
- **TFS**: Three Forks/Sanish Formation

*Modified from CRI web, 2010*

**Key Points**

- Middle Bakken pay not a shale lithology
  - Complex, laterally varying lithology & play types
  - Stratigraphic / diagenetic trap drivers

- Underlying Three Forks 'non-shale' play potential established 2008
  - Also sourced by Bakken shale
  - Dual zone development underway

*From ConocoPhillips*
In MT, the “Boom” has Passed?
Current Activity

- Rigs are trickling back into MT
  - 10-15 rigs to drill & hold leases for Bakken/Three Forks targets
- Still some Elm Coulee infill wells
- Geopressured area along MT-ND border
- South edge Elm Coulee - upper shale
- Marginal production to the north
- No economic production NW of Brockton-Froid fault zone yet
Glacier Co., MT

- Maybe a dozen wells in last 3 years
- < 50 bopd max
- no pressure?

There will continue to be Bakken drilling in Elm Coulee and to the north (?), but probably not elsewhere in the State .....at least for now.
Heath Formation

Depth: 0 to 5000’
Some in Judith Basin

Alberta Shelf

Wyoming Shelf
Central Montana Stratigraphy

Not simple layer-cake
Heath Formation – Complex Mix of Lithologies

Key components:

- Middle Carbonate Member (up to 40' thick)
  - Thin limestones and dolomites
  - Porosity developed in places (up to 13%, 5% avg)
  - Possible ‘carrier’ beds; tested oil
    Brittle, fractures – especially on structure

- Cox Ranch Member (“Hot” Shale)
  - 10 to 60 feet thick (4 – 20% porosity, 11% avg)
  - High organic content
  - Thermally mature to volatile oil window
  - Tested 30 – 35.5 API gravity oil

SHALE +/- Coal, gypsum, DM, LS
Source: Central Montana Heath Prospect Geological Report, 2009, Great Northern Gas Company
Complex Geology: folded & faulted

Oil Migrated into Permeable Rocks & Conventional Traps

- Over 40 oil fields in Central MT
- Most are Amsden-Tyler
- Cumulative oil production 110-140 MMBO (sourced from Heath)

From AAPG-RMS 1972
Exploration Status?

• We just don’t know that much yet; few wells drilled

• Since 2009
  – ~10 vertical wells drilled
    • Coring: oil shows, fractures, water/oil saturation, porosity, etc
  – ~15 horizontal wells drilled
    • Operators testing drilling and completion techniques
    • Only 2-3 on production

• 1 rig currently running
Cabot 100,000 acres
Fidelity 80,000 acres
Central MT Resources
Cirque Resources
Voyager 33,500 acres
Endeavor 75,000 acres

Cabot O&G
Fidelity E&P
Central MT Resources
Cirque Resources
True Oil LLC

Asfaloth (H11) 0 / 50 BW
Firefoot (H11) 1 BO / 8 BW
EOG Bakken ’08

Schmidt (H12) IP? 250 BO / 65 BW

Rock Happy (H12) IP 271 BO/428 BW

Snowmane (H11)
1B (H11) 1 BO / 1 BW
2 (D11) 1 BO / 30 BW
3 (V11) 0 BO / 60 BW
4 (V11) 10 BO / 50 BW

Hit Parade (H12) IP 93 BO / 368 BW
40 BO / 100 BW

Garnet (H10) DH

Shadowfax (H11)
IP 10 BO / 36 BW
<1 BO / <1 BW

Firefoot (H11) IP 10 BO / 36 BW
<1 BO / <1 BW

40 BO / 100 BW

Shadowfax (H11)
2 (D11) 1 BO / 30 BW
3 (V11) 0 BO / 60 BW
4 (V11) 10 BO / 50 BW

EOG
'B08
Bakken
Example: Recent Heath Production Graph

Hit Parade 31-3H Production History – Section 31 T11N R30E
Date of First Production: 12/5/11, IPF of 93 BO & 368 BW on 1/4/2012

Heath Volumetrics

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<th>Parameter</th>
<th>Value</th>
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<tbody>
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<td>Aerial Extent</td>
<td>640 acres</td>
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<tr>
<td>Pay Thickness</td>
<td>103 ft</td>
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<tr>
<td>Porosity</td>
<td>8.7 %</td>
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<tr>
<td>Water Saturation</td>
<td>42.1 %</td>
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<tr>
<td>Oil Gravity</td>
<td>35 degrees API @ 60 degrees F</td>
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<tr>
<td>GOR</td>
<td>215 scf/bbl</td>
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<tr>
<td>Gas Gravity</td>
<td>1.06</td>
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<tr>
<td>Reservoir Temperature</td>
<td>147 degrees F</td>
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<td>Oil Formation Volume Factor</td>
<td>1.15 STB/RB by correlation</td>
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<td>OOIP</td>
<td>22,400,976 STB</td>
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<td>Primary Recovery Factor (%)</td>
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<td>Recoverable Oil</td>
<td>16,000 STB</td>
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<tr>
<td>Recoverable Gas</td>
<td>3,440 MCF</td>
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</table>
So, is it another Bakken?

We probably won’t know for a while yet……..“wait & see”

• The potential is certainly there: Both have
  – Organic rich black shales of similar age
  – Low porosity, low perm shales, high TOC
  – Both in oil window – thermally mature
Heath is a little more Complex

• Oil has migrated out of the system
  – Juxtaposition with conventional reservoirs
  – Faults may provide pathways

• Central MT is structurally complex: faulted / folded, erosional unconformities

• Testing different zones – which is the “Reservoir”? 

• Reservoir Pressure – can production be sustained?

......remember, it took ~50 years for the Bakken to become what it is today
Hydrofracturing (“fracking”)

- Hydrofracturing is also not new (late 1940’s)
- Pressurize to exceed fracture gradient, crack the rocks & prop the cracks open
- Create pathways for fluid flow (permeability)
- Frac fluid is ~99% water and sand (or ceramics); 1% things to worry about.

- Fracking has not caused any earthquakes
- Water contamination can be mitigated; water conservation may be a bigger issue
Potential Impacts on Groundwater?

- Potential for leakage of Frac fluid into groundwater aquifers
  - At depth due to frac’ing
  - Surface spills
  - Operators do not want to frac into water-bearing fms
    (they end up with an $8-10 million saltwater well)

- Water consumption
  - 2-mile lateral uses ~2 million gal of water for frac job.
Surface casing and cement are always required to isolate & protect aquifers.
MBOG Frac’ing Rules Adopted 2011


• Pressure test casing & equipment
• Must report composition of Frac fluid
  • Either public website (fracfocus.org) OR
  • File form in MBOG office – also public information
• Constituents deemed to be proprietary can remain protected unless health care emergency demands disclosure
Hydraulic Fracturing Fluid Product Component Information Disclosure

Hydraulic Fracturing Fluid Composition:

<table>
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<tr>
<th>Trade Name</th>
<th>Supplier</th>
<th>Purpose</th>
<th>Ingredients</th>
<th>(CAS #)</th>
<th>Concentration in Additive (% by mass)**</th>
<th>Concentration in HF Fluid (% by mass)**</th>
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<tr>
<td>WF125,</td>
<td>Schlumberger</td>
<td>Base Fluid, Bactericide, Breaker, Crosslinker,</td>
<td>Water (including Mix Water Supplied by Client)</td>
<td>14808-60-7</td>
<td>59.84812%</td>
<td>83.96459%</td>
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<td>YF125FLEX</td>
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<td>Non-Ethanolizing Agent, Propellant, Sand, Stabilizer</td>
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<td></td>
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<td>Crystalline silica</td>
<td>14840-99-9</td>
<td>5.41984%</td>
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<td>Ceramic materials and waxes, chemicals</td>
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<td>Distillate (petroleum), hydrocracked light</td>
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