The Devonian
Three Forks Formation:

Manitoba’s Newest Oil Play

Michelle Nicolas, P.Geo.
Manitoba Geological Survey
Three Forks Study Area

Sinclair

Three Forks Subcrop Edge
Sinclair Field

- Early exploration efforts → Dry wells
- Renewed exploration in 2003
- Field status by 2005
- Over 32,000 hectares in area
- Sinclair Unit No. 1 running by 2006
- 608 wells drilled at Sinclair to date
- 530 currently producing
- Estimated reserves: 6.8 million m³
Three Forks Formation

- Cyclical transgressive-regressive sequence of argillaceous dolomites, brecciated, interbedded and interlaminated with silty dolomitic shales and claystones.

- Complex diagenetic and oxidation-reduction history.

- Primary producing unit at Sinclair Field.

- Secondary producing unit at Daly and Kirkella Fields.

- Commingled with Middle Bakken.

- Subdivided into four units
  - Units subdivision equivalent to units in Christopher (1961)
### Three Forks Stratigraphy

<table>
<thead>
<tr>
<th>Era</th>
<th>Southeastern Saskatchewan</th>
<th>Manitoba</th>
<th>North Dakota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippian</td>
<td>Bakken Formation</td>
<td>Bakken Formation</td>
<td>Bakken Formation</td>
</tr>
<tr>
<td></td>
<td>Upper Bakken Member</td>
<td>Upper Bakken Member</td>
<td>Upper Member</td>
</tr>
<tr>
<td></td>
<td>Middle Bakken Member</td>
<td>Middle Bakken Member</td>
<td>Middle Member</td>
</tr>
<tr>
<td></td>
<td>Lower Bakken Member</td>
<td>Lower Bakken Member</td>
<td>Lower Member</td>
</tr>
<tr>
<td>?</td>
<td>Big Valley Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Devonian</td>
<td>Three Forks Group</td>
<td></td>
<td>Three Forks Formation</td>
</tr>
<tr>
<td></td>
<td>Torquay Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Qu'Appelle Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Three Forks Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Birdbear</td>
<td></td>
<td>Birdbear Formation</td>
</tr>
<tr>
<td></td>
<td>Lower Birdbear</td>
<td></td>
<td>Lower (platform facies)</td>
</tr>
<tr>
<td></td>
<td>Saskatchewan Group</td>
<td></td>
<td>Jefferson Group</td>
</tr>
<tr>
<td></td>
<td>Birdbear Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Birdbear</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Three Forks Structure

Contour Interval = 10 m
Three Forks Isopach

- Thickest in the west along the MB-SK border
- Localized thickening in the east

Contour Interval = 5 m
Three Forks – Unit 1

- Lowermost unit
- Highly oxidized with reduction halos
- Original fabric: Brecciated argillaceous dolomite with grey-green silty shale matrix
- Limited core availability

14-32-10-24W1
Reference Log – Unit 1

Lodgepole
Bakken
Unit 4
Unit 3
Unit 2
Unit 1
Birdbear
Three Forks – Unit 1

- Widespread distribution
- Fairly constant isopach
  - average = 16 m
- Productive in small isolated pools at Sinclair
- Future reservoir potential is unknown
Three Forks – Unit 2

- Interbedded siltstone, shales and claystones
- Massive and brecciated in places
- Partially oxidized
- Porosity decreases with depth
Reference Log – Unit 2

Lodgepole

Bakken
- Unit 4
- Unit 3
- Unit 2

Birdbear
- Unit 1
Three Forks – Unit 2

- Isopach: 1-19m
  - Uneroded: ~15 m
- Edge roughly follows the eastern boundary of the BWA & SBZ
- Primary reservoir in Daly
- Secondary reservoir unit in Sinclair
Three Forks – Unit 3

- Red-brown highly oxidized silty dolomitic shale
- Rare reduced halos
- Thinnest unit
  - 3.5 m isopach
- Not a good reservoir, but productive when at unconformity in Sinclair
Reference Log – Unit 3

- Lodgepole
- Bakken
  - Unit 4
  - Unit 3
  - Unit 2
  - Unit 1
- Birdbear
Three Forks – Unit 3

- Distribution follows Unit 4 closely
- More section preserved in isolated wells in the east
Three Forks – Unit 4

- Interbedded siltstone, argillaceous dolomites and silty dolomitic shale with thick subunits of distorted bedding and brecciated dolomitic siltstone

- Primary, most productive reservoir unit
Three Forks – Unit 4

Subunit 4b
4-29-8-29W1
Plain and UV light

Subunit 4c
4-29-8-29W1
Plain and UV light
Reference Log – Unit 4

Lodgepole

Bakken

Unit 4

Unit 3

Unit 2

Unit 1

Birdbear
Three Forks – Unit 4

- Isopach: 1-14 m
  - average = 6 m
- Limited distribution
  - Restricted to the Ranges 29 & 28 W1
  - More section preserved in isolated wells in the east
- Primary reservoir at Sinclair
  - Also SW Daly and Kirkella
- Average core $K = 4.3$ mD
- Average core $\phi = 16.5\%$
- Oil Saturation = 7.0-34.0 % (Karasinski, 2006)
Depositional Environment

• “Deposited along a temperate, carbonate tidal flat that grades basinward towards an unrimmed carbonate platform.” (Karasinski, 2006)

• Karasinski (2006)
  – Unrimmed platform facies
  – High-energy peritidal facies
  – Subaqueous debris flow facies
Diagenesis

- Karasinski (2006)
  - Complete dolomitization
    - Early stage: Upper Devonian & Mississippian seawater
    - Late stage: post-Middle Bakken shallow burial and diluted meteoric waters
  - Porosity
    - Fracture porosity
    - Vuggy porosity
    - Moldic porosity
  - Mineralization/cementation
    - Phosphates (early stage)
    - Pyrite (early and late stage)
      » Reducing environment
    - Ferric minerals (hematite and Fe-sulphates; late stage)
      » Oxidizing environment
    - Halite (late stage)
    - Authigenic silicates (quartz, K-feldpar, illite; late stage)
    - Anhydrite (latest stage)
Tectonic Controls

- Birdtail-Waskada Axis (BWA)
- Superior Boundary Zone (SBZ)
- Basement hingeline
- Faulting
  - Basement
  - Salt dissolution
Tectonic Controls - Evidence

- Isopach variations and Unit 4 edge parallel to areas of proposed faulting.
- Rapid truncation of Unit 4 (up to 20 m offset)
- Unit 2 edge coincident with BWA-SBZ eastern edge.
- Unit 2 isopach “plateau” over BWA.
- Documented faults in seismic:
  - shallow Devonian faulting in west
  - deep basement-derived faulting in east
• Thickening coincident with tectonic elements
• Eastern anomalies likely basement driven

Isopach Contour Interval = 5 m
Conclusions

• Sinclair is the newest oil field in Manitoba with excellent reserves
• Sinclair Field still growing
• Stratigraphic and structural/tectonic controls on reservoir and oil accumulations
• Largely unexplored and has excellent exploration potential
• Preliminary mapping shows areas of potential targets
Conclusions - Future Work

• Core and sample logging throughout Three Forks depositional area

• Three Forks reservoir overview
  • Sinclair
  • Daly
  • Kirlella
  • Other Areas

• Exploration model
Conclusions - Targets

Three Forks Exploration Targets