The Devonian Three Forks Formation: Manitoba’s Sinclair Field and Other Prospects

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Sinclair Field

- Early exploration efforts → Dry wells
- Renewed exploration in 2003
- Field status by 2005
- Over 34 000 hectares in area
- Sinclair Unit No. 1 running since 2006, and will be expanding.
- > 880 wells drilled at Sinclair to date
- > 800 wells currently producing
- Proved and probable reserves: 40 Mbbl
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.
- Produces at Sinclair, Daly and Kirkella Fields, and north of Pierson Field.
- 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>
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<tbody>
<tr>
<td>Mississippian</td>
<td>Bakken Formation</td>
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<td>Bakken Formation</td>
<td>Upper Bakken Member</td>
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<td>Middle Bakken Member</td>
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<td>Lower Bakken Member</td>
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<td>?</td>
<td>Big Valley Formation</td>
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<td>Sanish Sand</td>
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<tr>
<td>Devonian</td>
<td>Three Forks Formation</td>
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<td>Torquay Formation</td>
<td>Unit 6</td>
<td>Unit 4</td>
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<td>Unit 5</td>
<td>Unit 3</td>
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<td>Unit 3</td>
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<td>Unit 1</td>
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<td>Saskatchewan</td>
<td>Upper Birdbear</td>
<td>Upper (biothermal facies)</td>
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<tr>
<td>Birdbear Formation</td>
<td>Lower Birdbear</td>
<td>Lower (platform facies)</td>
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</table>
Bakken and Three Forks are closely linked in Manitoba.
Three Forks Structure
Three Forks Structure

- Structural high in Sinclair
- Mappable from the top of the Prairie Evaporite to the top of Lodgepole Formation

Contour Interval = 10 m
Bakken Isopach
• Relatively thin in Manitoba (< 8 m)
• Localized thicks (Waskada Field)
Three Forks Isopach

- Thin in Manitoba due to erosion
- Thickest in the west along the MB-SK border
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
- Highly fractured, unoxidized zone near top of unit; productive at 9-30-7-28W1.
Reference Log – Unit 1

- Lodgepole
- Bakken
  - Unit 4
  - Unit 3
  - Unit 2
  - Unit 1
- Birdbear

Diagram showing stratigraphic units and their relationships with depth.
Three Forks – Unit 1

- Widespread distribution.
- Fairly constant isopach:  
  - average = 16 m.
- Productive in a small isolated pool at Sinclair.
- Future reservoir potential is unknown.
• 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
Unit 1
Birdbear
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 (poor quality).
- Economically productive when Unit 4 is eroded.
Three Forks – Unit 3

- Red-brown highly oxidized silty dolomitic shale.
- Rare reduced halos.
- Thinnest unit: 
  - 3.5 m isopach.
- Generally a tight unit; poor reservoir, but productive when exposed at unconformity in Sinclair.
Reference Log – Unit 3
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 (subunit 4c is best reservoir).
Three Forks – Unit 4

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

Good reservoir porosity and permeability.

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

Fair reservoir porosity and permeability.
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 $K = 4.3 \text{ mD}$
- Average core $\Phi = 16.5\%$
- Oil Saturation = 7.0-34.0 % (Karasinski, 2006)
Three Forks Unit Distribution

- Unit 1 (red)
- Unit 2 (blue)
- Unit 3 (purple)
- Unit 4 (green)
Three Forks Production

Kirkella Field
DIR 11-15-12-29W1: 146 bbl/day*

Daly Field
5-13-10-29W1: 65 bbl/day*

Sinclair Field
HZ 11-8-8-29W1: 115 bbl/day*

North of Pierson Field
HZ 5-8-4-29W1: 3 bbl/day*

Unit 4 (green)
Unit 3 (purple)
Unit 2 (blue)
Unit 1 (red)

* First 12 months daily average oil
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

- Birddtail-Waskada Zone (BWZ)
- Superior Boundary Zone (SBZ)
- Basement hingeline
- Faulting
  - Basement
  - Salt dissolution (Sinclair)
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 BWZ-SBZ eastern edge.
- Unit 2 isopach “plateau” over BWZ.
- Documented faults in seismic:
  - shallow Devonian faulting in west
  - deep basement-derived faulting in east
Tectonic Controls - Evidence

- Thickening coincident with tectonic elements
- Eastern anomalies likely basement driven
- Possible preservation of “Sanish”-like sand or anomalously thickened Middle Bakken in salt collapse structures.

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 - Targets

Three Forks Exploration Targets

Oil Shows
Possible "Sanish"-like sand

Three Forks Edge

Possible "Sanish"-like sand