Cyclic Sedimentation Patterns of the Mississippian-Devonian Bakken Formation, North Dakota*

Julie A. LeFever¹ and Stephan H. Nordeng¹

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Abstract

The Devonian-Mississippian age Bakken Formation records at least two episodes of rising sea level. The vertical and lateral lithofacies left by both transgressive events suggest a pattern of cyclical sedimentation that coincides with the transition between shallow tidal dominated carbonates of the Upper Devonian Three Forks Formation and the open marine platform to platform slope carbonates of the Lower Mississippian Lodgepole Formation. The basal deposits of both transgressions contain thin discontinuous nearshore or beach sandstones that grade upward into the organic-rich, oxygen-stratified hemipelagic muds that make the two Bakken shales world class source rocks.

The initial transgression is represented by basal sandstone that unconformably overlies the Three Forks Formation and is informally referred to as the “Sanish Sand”. The basal sandstones typically grade upward into a regionally extensive siltstone that is usually found in depositional lows along the basin margin. Farther into the basin the Three Forks grades directly into the organic-rich portion of the lower Bakken with no obvious unconformity. Maximum transgression culminated with the deposition of the lower Bakken shale.

The lower portion of the middle member consists of carbonate-siliciclastic rocks that coarsen upward from sediments dominated by mud-sized material through a thinly bedded or laminated algal section and into a very fine- to fine-grained sandstone that forms a conspicuous “clean gamma-ray” bench within the middle Bakken that is referred to as Lithofacies 3 in North Dakota. The vertical distribution of facies within the middle Bakken below Lithofacies 3 (L3) is consistent with a gradual fall in sea level, with L3 marking the lowstand of this regressive period.

A repeat of the initial transgressive sequence is observed in the rocks overlying L3. A series of finely laminated algal-bearing siltstones grade upward into silty lime mudstones that are ultimately capped by the upper Bakken shale as the Bakken seas reach their maximum transgression.
The coincidence of localized “thinning” trends in all three members of the Bakken Formation suggests that local structural features were active during deposition of the Bakken Formation. These features allow for the preservation of the rock sequence previously discussed. These active structural features, in association with Prairie Salt tectonics, also increase the potential to develop a good reservoir.

**Selected References**


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North Dakota Geological Survey
Objectives

- Nomenclature
  - Existing
  - Problems
- Examine the characteristics of the rock section
  - Specifically lower Bakken shale to Three Forks
- Geologic setting
- Possible mechanisms for the preservation
- Preliminary conclusions
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<thead>
<tr>
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<tbody>
<tr>
<td>North Dakota</td>
<td>Williston Basin</td>
<td>Saskatchewan</td>
<td>North Dakota</td>
</tr>
<tr>
<td>Lodgepole Formation</td>
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<tr>
<td>Bakken Formation</td>
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<tr>
<td>“Sanish Sand”</td>
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<td>Big Valley Formation</td>
<td>Three Forks Formation</td>
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<tr>
<td>Three Forks Formation</td>
<td>Three Forks Formation</td>
<td>Torquay Formation</td>
<td>Sanish Member</td>
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</table>


<table>
<thead>
<tr>
<th>Lithology</th>
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<tbody>
<tr>
<td>Two black shales separated by a sequence of laminated sands, oolitic calcarenites, a massive siltstones.</td>
</tr>
<tr>
<td>Consists of a sea-green to dark grey black to black, pyritic, non-calcareous silty shale to earthy mudstone</td>
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<tr>
<td>Tan dolomite interbedded with green shale.</td>
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</tbody>
</table>

**Saskatchewan Sequence**

<table>
<thead>
<tr>
<th>Christopher 1966</th>
<th>Bakken Formation</th>
<th>Big Valley Formation</th>
<th>Torquay Formation</th>
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<tbody>
<tr>
<td>Saskatchewan</td>
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101/121101317W2/00

GR

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4400

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4500

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North Dakota – Lower Bakken Silt

Lodgepole Formation
- upper shale

Bakken Formation
- middle member
- lower shale
  - “silt”

Three Forks Formation

33-105-01693-0000
Brigham – Olson 10-15 1-H

GR

10600
10650

Lower Shale
Lower Silt
Three Forks Fm

Three Forks Formation
SK – ND Correlations

101/121101317 W2/00
Richfield – #11-12 Bechard

33-105-01693-0000
Brigham – Olson 10-15 1-H

GR

4500
Souris Valley = Lodgepole Formation

10600
Bakken Formation

10650
Big Valley Fm

Torquay Fm = Three Forks Fm

Lower Bakken Silt
Isopach of the Lower Bakken Shale

Map showing the distribution of the Lower Bakken Shale with contour lines and labels for Upper, Middle, and Lower shale and silt layers. The Bakken Limit is indicated on the map. The map also includes a section showing the thickness of the shale layers with a scale in feet (1050, 1060, 1065, 1070).
Isopach of the Lower Bakken Silt

- Less organic-rich
- Greater silt/carbonate component
- Maximum thickness 58 ft.
- Linear trough-like feature
Isopach of the Lower Bakken Silt

Possible Interpretations For Depositional Pattern

Faulting
- Heart River
- Central Montana Trough
- Trans-Hudson Orogenic Belt
- N-S Basement Faults

Dissolution of Salt
- Devonian Prairie Salt
- Hummingbird Trough

Combination of Both
## Basal Bakken Beds

<table>
<thead>
<tr>
<th>North Dakota Geological Society</th>
<th>Berwick 2008</th>
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<td>“Sanish Sand”</td>
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<td><strong>Three Forks Formation</strong></td>
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</table>
“Sanish”

Refers to:

- A former town that “vanished” under Lake Sakakawea
“Sanish”

Refers to:

- Informal sandstone bed described in the 50s along the Antelope Anticline
  - Regulatory “Pool” name
- Mountrail County oil field (that produces from the Bakken)
- The uppermost section of the Three Forks Formation
Basal Bakken Beds

33-025-00868-0000
Anschutz – Sadowsky 24-14H

Black Shale
Open Marine Oxygen Stratified

Limestone
Open Marine

Brachiopod-bearing Lime Mudstone
Shelf

Mudstone with Storm Deposits
Intertidal

Skolithus Sandstone
Subtidal – Supratidal

Three Forks Fm

Bakken Fm

Transgressive
Isopach of Basal Bakken Beds

- Mixed siliciclastics/carbonates
- Maximum thickness - 52 ft
- Unconformable - Three Forks Formation
- Restricted to the southwest
- Linear trend
Basal Bakken Beds – Lower Bakken Silt

Strong correlation to faulting and salt dissolution

Strong NW-SE fabric?
Bakken Bed Comparison

33-061-00490-0000
Amerada-Hess – Sara Barstad 6-44H

Upper Black Shale

Lithofacies L5
Brachiopod-bearing Lime Mudstone

Lithofacies L4
Mudstone with Storm Deposits

Lithofacies L3
Sandstone

Upper Middle Bakken Beds

Basal Bakken Beds

Upper Middle Bakken

Bakken Fm

Upper Bakken

Lower Black Shale

Open Marine Oxygen Stratified

Limestone

Open Marine

Brachiopod-bearing Lime Mudstone

Mudstone with Storm Deposits

Subtideal – Supratidal

Shelf

Transgressive

33-025-00868-0000
Anschutz – Sadowsky 24-14H

Skolithus Sandstone

Intertidal

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Lithofacies L5
Brachiopod-bearing Lime Mudstone

Lithofacies L4
Mudstone with Storm Deposits

Lithofacies L3
Sandstone

Three Forks Fm

Basal Bakken Beds

Upper Bakken

Lower Black Shale

Open Marine Oxygen Stratified

Limestone

Open Marine

Brachiopod-bearing Lime Mudstone

Mudstone with Storm Deposits

Subtideal – Supratidal

Shelf

Transgressive
Basal Bakken represents an additional section of rocks below the lower shale
- Usually unconformable above and below
- Transgressive
- Slight variations in lithologies occur due to local structure
- the usage of the term “Sanish” should be dropped (and perhaps it should “vanish” like the “town”)
- Regulatory impact
- Repeat of two depositional cycles involving the same vertical and lateral facies, with the first incompletely preserved due to local tectonics