Sequence-Stratigraphic and Depositional Framework of the Middle Bakken Formation, Williston Basin, North Dakota*

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Abstract

The Devonian-Mississippian Bakken Formation located in the Williston Basin, North Dakota is a significant oil reservoir with a complex depositional history. The Bakken Formation is composed of three members: (1) mudrock of the lower member; (2) dolomitic silty sandstone of the middle member; and (3) mudrock of the upper member. This study provides a high-resolution sequence-stratigraphic and depositional framework to explain the distribution of facies within the middle Bakken Formation. A total of 37 cores were evaluated in detail over an area of approximately 400 mi² (644 km²). Core descriptions were paired with petrophysical logs to provide lateral correlations between core locations.

The middle Bakken Formation is composed of 11 facies indicative of a tidally-influenced-shallow-marine system. It is divided into three packages (lower, middle, and upper) based on facies and their stacking patterns. The lower package is composed of shallowing-upward offshore to transitional marine facies. The middle package is composed of subtidal ooid facies, and the upper package is composed of fining-upward tidally-influenced facies. Sequence-stratigraphic analysis is used to divide the entire Bakken Formation (lower, middle, and upper members) into five systems tracts: (1) a highstand systems tract of the lower member; (2) two lowstand systems tracts within the lower and middle packages; (3) a transgressive systems tract of the upper middle package; and (4) a highstand systems tract of the upper member. Two sequence boundaries are present: (1) between the lower and middle members; and (2) between the lower and middle packages of the middle Bakken Formation.
Facies-distribution maps within a sequence-stratigraphic context show a stratigraphic pinch-out to the east in the study area, and provides a link to reservoir productivity. The sequence-stratigraphic framework proposed provides a predictive component helpful in determining play elements within the hydrocarbon system, including reservoir size, location, and quality.

References


Website

Sequence-Stratigraphic and Depositional Framework of the Middle Bakken Formation, Williston Basin, ND

Kim Hlava, Kirt Campion, and Sebastian Bayer
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Outline

1. Introduction
2. Core Description
3. Sequence Stratigraphic Interpretation
4. Facies Distribution Maps
5. Application
6. Conclusions
Introduction

- Two Sequences which reflect a clastic/carbonate transition.
  1. Dolomite-dominated siltstone
  2. Calcite-dominated ooid grainstone

- The depositional and sequence stratigraphic framework is tied to reservoir characterization, production, and petroleum system play elements

Database:

1. 40 cores with full well log suites (13 described in detail ~2,700ft [823.2 m])
Questions

- Facies of the Middle Bakken?

- Facies distribution in the Middle Bakken?

- Sequence stratigraphy of the Middle Bakken?

- Application?
Scope/Area of Interest

Williston Basin

Structure contour map on base of Mississippian Sonnenberg and Pramudito, 2009

- Wells
Stratigraphic Interval

- Lodgepole
- Upper Bakken
- Middle Bakken
- Lower Bakken
- Three Forks

Datum: Base of Upper Bakken

~25-30 ft (7.6-9.1 m) avg. thickness

Ages based on Conodont biostratigraphy (Hayes, 1985)
- Marine depositional environment
- Devonian/Mississippian time frame
- Arid climate: within 5-10 degrees of the equator
- Carbonate/clastic mixed system
- Sediment starved – wind blown sand
- Stable tectonic setting
- Low gradient slope

Blakey, 2012. Generalized Late Devonian Paleogeography
Clastic Facies

- Heavily Bioturbated Structureless
- Moderately Bioturbated Structureless
- “Crinkle” Laminated
- Parallel Laminated
- Combined-Flow Ripples

Bioturbation decrease  Energy Increase
Carbonate Facies

Offshore Transition Low/Mid Shoreface Subtidal

Fair-Weather Wave Base

Storm Wave Base

Bioturbation decrease

Energy Increase
Depositional Contacts

Abrupt facies change
At base of Middle Bakken
Below: Lower Bakken
Pyritic Mudstone
Above: Poorly Sorted
Wackestone/Bioturbated
Dolomitic Siltstone

Irregular,
Convoluted Contact
Below: Laminated Dolomitic
Siltstone
Above: Convoluted Ooid
Grainstone
Sequence Stratigraphy

Map showing locations such as Nesson Anticline, Deadwood Canyon Ranch 42-28H, VanHook 1-13H, Stenehjem HD 27-1, and others.
Sequence Stratigraphy

~35 mi (~56 km)

~50 ft (~15 m)

~15 ft (~5 m)

Regressive - Parasequence 1

Lower Bakken

FS

SB

PS2

Base Upper Bakken

Top Upper Bakken

Base Lower Bakken

Top Lower Bakken

Base sandstone grain

Flooding surface

Sequence boundary

SB

FS

SB

~50 ft (~15 m)

~35 mi (~56 km)
Sequence Stratigraphy

~35 mi (~56 km)

~35 ft (~11 m)

~50 ft (~15 m)

Regressive - Parasequence 1

Lower Bakken

PS2

FS

SB

~15 ft (~5 m)
Sequence Stratigraphy

- Lower Bakken
  - PS4 - Ooids
    - PS4- Ooid Grainstone
  - Regressive - Parasequence 1
    - ~50 ft (~15 m)
    - ~35 mi (~56 km) W E

- SB
  - ~15 ft (~5 m)

- FS
  - ~50 ft (~15 m)
Sequence Stratigraphy

Transgressive – Bioclastic Debris

PS4 - Ooids

~50 ft (~15 m)

~35 mi (~56 km)

Regressive - Parasequence 1

~15 ft (~5 m)
Sequence Stratigraphy

Lower Bakken

Debris

Ooid Grainstone

Transgressive – Bioclastic Debris

PS4 - Ooids PS4 - Ooid Grainstone

SB TS/SB TS

Regressive - Parasequence 1

~50ft (~15 m)

~15ft (~5 m)

~35 mi (56.3 km) W E
Facies Distribution

SL

PS 2 Progrades
Facies Distribution

SL

PS 3 Progrades
Facies Distribution

Sequence Boundary
Facies Distribution

Erosion

PS 4 Progrades
PS 4 Progrades

Well

Erosion

PS3 not present due to erosion at the Sequence Boundary
Facies Distribution

Parasequence 1
Parasequence 2
Parasequence 4

PS 4 Progrades

Well

Erosion

PS 1
PS 2
PS 4

Subtidal Erosion

Lower Shoreface

Transition

Offshore

PS3 not present due to erosion at the Sequence Boundary
Reservoir Modeling

1. Facies Broken out by geomechanical properties
2. Facies Mapped and Modeled using Petrel

Can see thickening and thinning of reservoir target and pinch out of ooid facies

Ooid Facies

25X Vertical Exaggeration

~0.7 mi (~1 km)

~24 mi (~38 km)
Facies Mapping

Parshall Area

Ooid Grainstone

Mudstone

Sandstone

~10 mi (16 km)

Lily Bank, Northern Little Bahama Bank

Rankey and Reeder, 2011
Applications - Production

Facies Map

Relative EUR

EROSIONAL EDGE

RESERVOIR TARGET

10 mi

Inc. EUR
Application – Play Elements

Idealized Cross Section

Clastic-Carbonate Transition

Reservoir Target (mid/lower Shoreface)

Lateral Pinch-outs
Potential stratigraphic traps

VE: ~50

EROSIONAL EDGE
Conclusions

■ Developing a sequence-stratigraphic framework is key to determining lithofacies distribution

■ Building a sequence-stratigraphic framework within the Middle Bakken offers a predictive capability that lithostratigraphy does not

■ Careful core description and calibration with well control allows you to map “petrofacies” and calibrate wells in the absence of core data.