Middle Bakken Play
Technical Problems and Questions
Possible Solutions

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Geologic Investigation No. 16
A little girl complained to her mom that her stomach hurt really bad.

Her mom told her that was because it was empty and she had to put something in it to make it stop hurting.

She had a snack and her stomach ache went away.

That night her mother’s boss and his wife came over for dinner.

Before they sat down to eat the boss complained that he must be getting sick. His head was killing him.

The little girl told her mom’s boss, “My mom says that’s because your head is empty. You have to put something in it to make it quit hurting.”
Non-confidential Drilling Results to Date

- Ten (10) wells total
  - Single lateral - Open hole re-entry (1)
  - Re-Entry – Open hole – Lodgepole liner uncemented (1)
  - Dual lateral - OH or perforated liners – Lodgepole liner uncemented (4)
    - Proppant fractured (3), Unstimulated (1)
  - Single lateral - Perforated liner (4)
  - Dual lateral - Co-planar – Perforated liners (0)
Non-confidential Drilling Results to Date

- Single lateral - Open hole re-entry (1)
  - IP 332 BO / 34 BW / 95 MCFD
  - Proppant Fractured almost immediately
    - 87 BO / 146 BW / 150 MCFD
  - Current 43 BO / 10 BW / 89 MCFD
  - 25,000 cumulative BO
  - Breakeven at $22/BO
- Problems and Questions
  - 1st ND attempt – marginally successful
  - Hole stability in upper shale?
  - Proppant fracture growth into Lodgepole?
Re-Entry – Open hole – Lodgepole liner uncemented
Non-confidential Drilling Results to Date

- Re-Entry – Open hole – Lodgepole liner uncemented
  - IP 263 BO / 0 BW / 177 MCFD
  - Proppant Fractured after 4 months and 19,000 BO
    - 304 BO / 0 BW / 172 MCFD
  - Current 304 BO / 0 BW / 172 MCFD
  - 23,000 cumulative BO
- Problems and Questions
  - This worked!
  - Liner maintained hole stability?
  - Liner hanger packer kept proppant fracture in zone?
  - Pressure drawdown kept proppant fracture in zone?
  - Good rock?
Dual lateral - OH or perforated liners – Lodgepole liner uncemented
Non-confidential Drilling Results to Date

- Dual lateral - OH or perforated liners – Lodgepole liner uncemented
  - IP 51 BO / 171 BW / 44 MCFD
  - Proppant Fractured immediately to after 1 month
    - 134 BO / 179 BW / 125 MCFD
  - Current 32 BO / 37 BW / 72 MCFD
  - 11,000 cumulative BO
  - Breakeven at $45/BO
- Problems and Questions
  - This has not worked!
  - Liner maintains hole stability?
  - Proppant fracture growth into Lodgepole?
    - One well has water salinity and H₂S indicative of Mission Canyon
    - 2 wells have isolated the lateral the uncemented through the Lodgepole leg (what to do with spacing?)
  - Only the best rock and more pressure drawdown to keep prop fracture in zone?
CURRENT WELLBORE DIAGRAM

Well: Stacey Lynne #1-12H
Field: Wildcat
City/State: Williams, ND
Location: Sec 1-156N-96W
Formation: Bakken
Date: 5/23/2004

16" Conductor @ 40'

9-5/8" 36# Surface @ 2,423'

TOC = 4550'
Cement Bond Log

Tubing
2-7/8" 50# L-80

Deviation Point 750'

Window @ 9237-54'

TD 14,968 MD
+ 6,860' VB

5" 15.0# N-60 Liner, TOL, 9258' EOL 13,966'

SC2p Pkr with 3500 psi pump out plug @ 9264
KOP 9270' Initial Inc 13.7 Deg TD 13,921' MD
4,681' VB

5" 15.04 SSFJ HCL-80 Liner, TOL, 8,968' EOL 13,521'
7" 29-320# csg @ 10,171' MD 89 Deg

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 6/23/05 CASE NO. 8561
Introduced By
Exhibit # 10
Identified By

Marex Petroleum Corporation
Case No. 8561
6/23/05
Exhibit No. 10
Non-confidential Drilling Results to Date

- Dual lateral - OH or perforated liners – Lodgepole liner uncemented
  - IP 463 BO / 12 BW / 512 MCFD
  - Not proppant fractured yet (planned to wait – MECHANICAL)
  - Current 172 BO / 0 BW / 166 MCFD
  - 22,000 cumulative BO
  - Breakeven at $18/BO

Problems and Questions

- This worked (sort of)
- Liners maintaining hole stability?
- Complicated mechanically?
- Good rock?
- Pressure drawdown may keep proppant fracture in zone?
- Mechanical problems may prevent proppant fracturing?
Single lateral - perforated liner – Lodgepole cemented
Non-confidential Drilling Results to Date

- Single lateral - perforated liner – Lodgepole cemented
  - IP 275 BO / 107 BW / 264 MCFD
  - Proppant Fractured immediately to after 3 months
    - 179 BO / 110 BW / 183 MCFD
  - Current 83 BO / 20 BW / 126 MCFD
  - 12,000 cumulative BO
  - Breakeven at $25/BO
- Problems and Questions
  - This has worked (fairly well)
  - Casing maintains hole and stops fracture growth into Lodgepole?
  - Mechanically simple?
  - Good rock?
  - More pressure drawdown to improve keep proppant fracture in zone?
Conclusions

- ND bottom hole temperature is higher
- ND is clastic versus carbonate
- ND bottom hole pressure is higher (.50-.58 psi/ft)
- Bakken shale open hole is not stable
- Rock properties (Julie)
  - Naturally fractured
  - Oil wet
  - Swelling and migrating clays
Planar and Co-planar Designs

- BTA, JMG, Black Rock
  - Long Single lateral 1280
- Murex
  - Coplanar 1280
- Headington, Ansbro, Burlington, Missouri Basin, Stephens
  - Coplanar 1280
- Continental
  - Coplanar 1280
- BR & Denali
  - Coplanar 640
- Nance, Amerada, EOG, Tri-C, Lyco, Hunt, Sam Gary, Headington, Stephens
  - Single lateral and coplanar 640
ALTERNATIVE NO. 1

DUAL HORIZONTAL BAKKEN LATERAL

ALTERNATIVE NO. 2

SINGLE HORIZONTAL BAKKEN LATERAL
Planar and Co-planar

- Long Single Planar Lateral - $2,900,000
  - Less mechanical risk
  - Simpler more effective re-frac
- Coplanar - $3,500,000 if nothing goes wrong
  - $4,000,000+ and no proppant frac if liner or tool problems
  - Ability to re-frac?
Can evaluate spacing unit for $2,900,000 (8550’ lateral $340/ft)
- Less mechanical risk and simpler more effective frac and re-frac
- $5,800,000 total development cost if 2\textsuperscript{nd} well justified (17,100’ of lateral)
- Wells are just 500’ closer than if drilled down quarter section lines

Coplanar - $3,500,000 if nothing goes wrong
- 9,600-13,000’ lateral $265-366/ft)
- $4,000,000+ and no proppant frac if liner or tool problems ($303+/ft)
- Ability to re-frac?
- $7,000,000 total development cost if 2\textsuperscript{nd} well (20-21,500’ of laterals $327/ft)
The Basics
Bakken Formation in North Dakota

- Upper & Lower Black Shale
  - World Class Source Rock
    - TOC’s as high as 40%
    - HC Generation - 200 to 400 BBbls of Oil
- Clastic Middle Member
  - 5 Lithofacies
    - Primarily Sandstones and Siltstones with Interbeds of Dolostone and Limestone
    - Low Porosity & Permeability
## Stratigraphy
Central Bakken Basin in North Dakota

<table>
<thead>
<tr>
<th>South</th>
<th></th>
<th>North</th>
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<tbody>
<tr>
<td>Upper Shale Member</td>
<td></td>
<td>Mississippian Lodgepole Formation</td>
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<tr>
<td>Transitional Facies – L5</td>
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<td>Lithofacies 4</td>
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<td>Lithofacies 4</td>
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<td>Lithofacies 3</td>
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<td>Lithofacies 3</td>
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<td>Lithofacies 2</td>
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<tr>
<td>Transitional Facies - L1</td>
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<td>Lower Shale Member</td>
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<td>Lower Shale Member</td>
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Devonian Three Forks
Stratigraphy
Bakken Limit in North Dakota

South

Mississippian Lodgepole Formation

Upper Shale Member

Transitional Facies – L5

Upper (Productive)

Devonian
Three Forks

Lithofacies 2

Lower

Transitional Facies - L1

Lower Shale Member

North

Mississippian Bakken Formation
Lithofacies 5

Lithofacies 4

Lithofacies 3

Lithofacies 2

Lithofacies 1

Lower Shale

Upper Shale

Shell Oil Co. #32-4 Young Bear

Conoco, Inc. #17 Watterud “A”
Lithofacies 5

Lithofacies 4

Lithofacies 3

Lithofacies 2

Lithofacies 1

Lower Shale

Upper Shale

Meridian Oil, Inc.
#44-27 MOI

Shell Oil Co.
#32-4 Young Bear
Lithofacies of the Middle Member

Upper Shale
- Lithofacies 5
- Lithofacies 4
- Lithofacies 3
- Lithofacies 2
- Lithofacies 1

Lower Shale

SENW Sec. 11, T160N, R95W
Conoco, Inc. - #17 Watterud “A”

Central Basin Facies

(From LeFever and others, 1991)
Middle Member Bakken
Porosity Types

- Clastic Sequence with Carbonate Interbeds
- Primary Porosity
  - Interparticle to Intercrystalline
Middle Member Bakken
Porosity Types

- **Secondary Porosity**
  - Dolomitization
    - Matrix
    - Cement

- **Fractures**
  - Regional
  - HC Generation

Intercrystalline

Fracture
Tectonic Fracturing
Salt Dissolution

Complete or Partial Dissolution of the Prairie Salt

- Depositional Edge
- Overlying Basement Structures
- Other Geologic Features
Tectonic Fracturing
Regional Fractures
Upper Bakken Shale

Lithofacies 4
Non-Tectonic Fractures

HC Generation - Upper Bakken Shale

Texaco, Inc - #1-5 Thompson
Implications
Fractures

* Necessary for Production?
  * Natural
  * Artificial
    * Enhances Existing $\phi$ and $K$ and Fractures
    * Production pathway for the Shales

* Result in an Increase in Production
  * Providing a Conduit for Oil to the Borehole resulting in High Production Rates
Implications
Fractures

Problems

- Result in Borehole Stability Problems
- High Potential for Damage of Micro-fractures
  - Over-balanced muds
  - Rapid Pressure Drawdown
  - Water-blocking (Bakken is “Oil-Wet”)
- May Influence the direction of the Fracture-Stimulation Treatment
Middle Member Bakken
Accessory Minerals

- **Pyrite**
  - **Iron Oxides**
    - Response to Acid
    - Wireline Log Effects

- **Clays**
  - **Illite, Chlorite & mixed-layer Clays**
    - Response to Acid
    - Response to Water

- **Organic Material**
  - **TOC’s > 0.5%**
    - Wireline Log Effects
Lithofacies of the Middle Member

(From LeFever and others, 1991)
Shell Oil Company - #12-6-44 U.S.A.
SENWNW Sec. 6-T.148N.-R.104W.
Conclusions

- The Lithofacies are present basinwide.
- Primary reservoir porosity may be enhanced by diagenesis, tectonic fractures, and/or fractures from HC generation.
- Porosity enhancement is not restricted to a single lithofacies within the Middle Member.
- Type of fluid used while drilling may have adverse effects on production.
- The presence of vertical fractures in areas of intense HC generation may affect the outcome of stimulation treatment.
Conclusions

- Barnett Shale, Texas is a good analog to the Bakken
- Low Porosity/Low Permeability Source Rock
- Gelled-water vs. Slick-water Fracture Stimulation Treatment
- Success with Multiple Fracture Treatments