Drilling the Middle Bakken

Kelly Olds
Whiting Petroleum Corporation
- Went Public in Nov 2003
- Market Cap $1.8 B
- Proved Reserves 250.8 MMBOE
- Production 9/08 51.7 mboe/d
Reported Initial Oil Rate
North Dakota Middle Bakken Horizontal Wells since 2000
North Dakota Industrial Commission
October, 2008
Well Configuration?

640 acres

Or

1280 acres

Or
Original Tri-lateral Design
Single-leg Horizontal

Sliding Sleeves (10)

Swell Packers (9)
Components of System

- Oil Swelling open-hole packers
  - 3’x5.75” tools in 6.00” hole
- Sliding Sleeves (ball actuated)
  - Slotted frac ports
  - Spaced 900’ apart
- Double Float-shoe and Float collar
  - For wellbore isolation
  - Could use P-sleeve
- Liner hanger/packer
Oil-Swelling, Open-hole Packer

3’x 5.75” element
## Repacker™ Swell Predictor

### Job Details
- **Customer:**
- **Well Name:**
- **Geographic Location:**
- **Date:**

### Well Data Input

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well MD</td>
<td></td>
<td>mts</td>
</tr>
<tr>
<td>Well TDV</td>
<td></td>
<td>mts</td>
</tr>
<tr>
<td>Run-in Drift</td>
<td>3</td>
<td>ft</td>
</tr>
<tr>
<td>Max Deviation</td>
<td>40</td>
<td>Degrees</td>
</tr>
<tr>
<td>Max Dog-Leg Severity</td>
<td>60</td>
<td>Deg/100ft</td>
</tr>
<tr>
<td>Setting Depth</td>
<td>400</td>
<td>mts</td>
</tr>
<tr>
<td>Setting Depth Deviation</td>
<td>5</td>
<td>Degrees</td>
</tr>
<tr>
<td>Setting Depth Hole Size</td>
<td>8</td>
<td>in</td>
</tr>
<tr>
<td>Open Hole/Cased</td>
<td>Open</td>
<td></td>
</tr>
</tbody>
</table>

### Wellbore Fluid

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>API</th>
</tr>
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<tbody>
<tr>
<td>Salinity</td>
<td>3%</td>
</tr>
<tr>
<td>Viscosity</td>
<td>CP</td>
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</table>

<table>
<thead>
<tr>
<th>Run-in Time to Setting Depth</th>
<th>Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHT (Setting Conditions)</td>
<td>220</td>
</tr>
<tr>
<td>BHT (Flowing Conditions)</td>
<td></td>
</tr>
<tr>
<td>BHP (Static)</td>
<td>PSI</td>
</tr>
<tr>
<td>BHP (Flowing)</td>
<td>PSI</td>
</tr>
</tbody>
</table>

| Additional Comments (Mineral Presence, Wellbore Stability, Gauged Hole, etc.) |

### Packer Description

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandrel Size</td>
<td>4.5</td>
<td>in</td>
</tr>
<tr>
<td>Element OD</td>
<td>5.75</td>
<td>in</td>
</tr>
<tr>
<td>Element Length</td>
<td>3</td>
<td>ft</td>
</tr>
<tr>
<td>Packer Style</td>
<td>Mandrel Wrapped</td>
<td></td>
</tr>
<tr>
<td>Activation Fluid</td>
<td>Oil</td>
<td></td>
</tr>
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</table>

### Output Calculations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Swell</td>
<td>22.9%</td>
</tr>
<tr>
<td>Pressure Differential</td>
<td>4072</td>
</tr>
<tr>
<td>Time to Swell (Est.)</td>
<td>23</td>
</tr>
</tbody>
</table>

Baker Oil Tools Representative
Typical Bakken Frac Design

“Hybrid” Frac design

1.8 Million lbs proppant
  600,000 lbs 100 mesh
  1,200,000 lbs 20/40 sand

18,000 barrels fluid

30-40 BPM

Continuous 10-12 hrs. pumping
8 stage frac

Treating Pressure (psi) — A
Calc'd Bottomhole Pr (psi) — A
Slurry Rate (bpm) — B
Slurry Proppant Conc (lb/gal) — C
Bottomhole Proppant Conc (lb/gal) — C
Hydrostatic Pressure (psi) — D

A
B
C
D

12000
6000
0
10000
50
0
50

A
B
C
D

Treating Pressure (psi)
Calc'd Bottomhole Pr (psi)
Slurry Rate (bpm)
Slurry Proppant Conc (lb/gal)
Bottomhole Proppant Conc (lb/gal)
Hydrostatic Pressure (psi)
Two Frac stages with varying treating Pressures
Wellbore Diagram

80"

16" Conductor

13-1/2" Hole

Surface:
9-5/8" 36# J55 LTC

8 3/4" Hole

Est. TOC 1,000' above Dakota Silt

2,000'

2-7/8" production tubing to KOP

build rate 11°/100 ft.

PRODUCTION CASING:
7" 29# N-80 LTC

TD @ 20,000' MD
10,300' TVD
Surface Hole

- 13½” hole - 50’ into Pierre Shale ±2,000’
- 9-5/8” 36# J-55 STC

Problems
- Lost Returns
  - Drill blind if possible
  - Cement if needed
Vertical Section

- OBM in 8 3/4” hole
- MW 9.6 to 9.8
- Unmanned MWD for surveys
- Dakota Silt
- Salts
  - Dunham, Pine, Opeche, Charles
- Nitrogen kicks - Minnekahta
- Lost Circ – Mission Canyon
- H₂S – (Bakken is Sweet)
Build Section

- 11° /100’ build rate
- 2.38° fixed motor
- PDC bit
- Raise MW to 10.1+
- Casing Point must cross hard line
7” 29# L-80 LTC

7” 32# HCL-80 LTC
  - 200’ above & below salts

Top of Tail cement – 500’ above salt

Top of lead cement – 1,000’ above Dakota
Why Underbalanced Drilling?

- Not an issue until you hit a fracture
- Pore Pressure
  - West Side ±12.5 lb/gal
  - East Side ±14.0 lb/gal
- Ballooning?
  - Lost circ vs Flow
Underbalanced Drilling

- Rotating head rated to 2,500 psi.
- Hold 500 psi on annulus
- Drill w/5-30’ flare
- Trip w/800 psi to casing shoe
- Spot Kill mud in casing
Pioneer rig 66

11” 5000 psi rotating head & BOP system

Table level

- 318"
- 263"
- 180"
- 91"

Ground level

- 23"
- 59"
- 83"
- 116"
- 140"
- 188"
- 269"
- 285"

Rotating head

7” orbit valve

Spacer spool

Annular

Variable pipe rams

Blind Rams

7” casing rams

Well press gauges

Mud cross drilling choke

Mud cross Choke & kill lines

Casing bowl & head

Speed spool

30 Ft

318” 23” 116” 140” 188” 269” 285”

Pioneer rig 66

318” 263” 180” 91”
Drill Lateral

- 6” hole w/PDC bit
- 1½° bent motor
- Max dogleg 5.0°/100 ft
- 4” XT39 drill pipe
- OBM vs Water
OBM vs Water

**OBM**
- Raise MW as needed
- Less drag
- Less pipe wear

**Water**
- Faster
- Cheaper
- More pipe wear
- Limited Density
Torque & Drag

- Not much problem until ±16,000’
- Max Torque ±20,000 ft/lbs
- Lube sweeps – various brands
- Agitator / shock sub
- Beads
  - Bead recovery units
4½” Liner

- Reamer run
  - 3 x 5-7/8” mills
- Spot lube
- Work liner if necessary
- Buckling problem at 16,000’+
Drilling Curve

Kinnoin 11-14H

Plan

Surface Casing @ 2100 ft

KOP #1 @ 9294 ft

7” casing @ 10112 ft

TD @ 19813 ft
Sanish Field Well Results

### 30- and 60-day Average Production Rates for Whiting Operated Sanish Field Wells

<table>
<thead>
<tr>
<th>Well Name</th>
<th>WI</th>
<th>NRI</th>
<th>Comp. Date</th>
<th>IP (BOE/D) 24hr. Test</th>
<th>Average 1st 30 Days (BOE/D)</th>
<th>Average 1st 60 Days (BOE/D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinnamon 11-14H</td>
<td>52%</td>
<td>42%</td>
<td>1/20/08</td>
<td>3,648</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Richardson Federal 11-9H</td>
<td>85%</td>
<td>69%</td>
<td>1/22/08</td>
<td>4,579 (1)</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Roggenbuck 11-25H</td>
<td>78%</td>
<td>64%</td>
<td>1/13/08</td>
<td>1,959</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Lacey 11-10H</td>
<td>73%</td>
<td>59%</td>
<td>0/29/08</td>
<td>1,811</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Pennington 11-3H</td>
<td>66%</td>
<td>54%</td>
<td>0/20/08</td>
<td>1,473</td>
<td>714</td>
<td>N/A</td>
</tr>
<tr>
<td>Nesheim 1-24H</td>
<td>67%</td>
<td>54%</td>
<td>1/10/08</td>
<td>2,169</td>
<td>1,048</td>
<td>N/A</td>
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<tr>
<td>Brehm 4/-5H</td>
<td>99%</td>
<td>81%</td>
<td>0/10/08</td>
<td>2,226</td>
<td>709</td>
<td>N/A</td>
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<tr>
<td>Kannianen 11-4H</td>
<td>95%</td>
<td>77%</td>
<td>0/09/08</td>
<td>1,298</td>
<td>914</td>
<td>714</td>
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<tr>
<td>Smith 11-7H</td>
<td>69%</td>
<td>56%</td>
<td>0/31/08</td>
<td>2,421</td>
<td>717 (2)</td>
<td>757</td>
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<tr>
<td>Littlefield 11-29H</td>
<td>93%</td>
<td>75%</td>
<td>0/27/08</td>
<td>1,856</td>
<td>673 (2)</td>
<td>640</td>
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<tr>
<td>Steneth Trust 11-5H</td>
<td>73%</td>
<td>59%</td>
<td>0/21/08</td>
<td>3,044</td>
<td>903 (2)</td>
<td>717</td>
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<tr>
<td>Lacey 1-16H</td>
<td>86%</td>
<td>70%</td>
<td>0/01/08</td>
<td>2,330</td>
<td>976</td>
<td>793</td>
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<td>Bahr 11-34H</td>
<td>54%</td>
<td>44%</td>
<td>0/20/08</td>
<td>3,245</td>
<td>1,335</td>
<td>969</td>
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<tr>
<td>Abbott 11-18H</td>
<td>99%</td>
<td>80%</td>
<td>0/16/08</td>
<td>1,059</td>
<td>1,088</td>
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<tr>
<td>Locken 14-28H</td>
<td>76%</td>
<td>63%</td>
<td>0/31/08</td>
<td>1,719</td>
<td>935</td>
<td>756</td>
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<td>Braeslet 11-11H</td>
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<td>79%</td>
<td>0/23/08</td>
<td>2,997</td>
<td>1,505</td>
<td>1,271</td>
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<td>Maynard Uran Tr. 11-24H</td>
<td>84%</td>
<td>68%</td>
<td>0/23/08</td>
<td>2,132</td>
<td>1,056</td>
<td>883</td>
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<tr>
<td>Petersen 11-34H</td>
<td>91%</td>
<td>75%</td>
<td>0/19/08</td>
<td>1,088</td>
<td>541</td>
<td>437</td>
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<tr>
<td>Liffrig 11-27H</td>
<td>81%</td>
<td>67%</td>
<td>0/24/08</td>
<td>2,530</td>
<td>1,114</td>
<td>932</td>
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<tr>
<td>Locken 11-22H</td>
<td>99%</td>
<td>82%</td>
<td>1/10/07</td>
<td>1,651</td>
<td>946</td>
<td>756</td>
</tr>
<tr>
<td>Paey State 11-25H</td>
<td>99%</td>
<td>80%</td>
<td>0/13/07</td>
<td>1,254</td>
<td>825</td>
<td>738</td>
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<tr>
<td>Averages</td>
<td>82%</td>
<td>67%</td>
<td></td>
<td>2,262</td>
<td>941</td>
<td>804</td>
</tr>
</tbody>
</table>

(1) The Richardson Federal 11-9H recorded the highest initial rate for any Bakken well drilled to date, according to the NDIC.
(2) The first 36-day average production rate was restricted due to maintenance on the Enbridge crude oil line.
Questions?