Horizontal Drilling in Kansas: A Case Study

Mark Shreve, Mull Drilling Company

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  (Computer Modeling Group)
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- Art Merrick Consulting
- Scientific Drilling
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- Tim Carr, Principle Investigator
- Paul Gerlach, Reservoir Characterization
- Saibal Bhattacharya, Reservoir Simulation
- Richard Pancake, Technology Transfer
Potential Target

- Compartmentalized Reservoirs
  - Mississippian “Meramecian”

- Thin Beds
  - Lansing - Kansas City
  - Shoaling Carbonates

- Attic Oil
  - Sub Unconformity
  - Ordovician and Mississippian

- Gas / Water Coning
  - Central Kansas Reservoirs

- Low Permeability Gas Reservoirs
  - Mississippian “Cowley Facies”

- SAGD
  - Cherokee Sandstones in Eastern Kansas

- EOR Injectors
  - Multiple Reservoirs

- Fractured Reservoirs
  - Arbuckle, Chat

- Numerous Targets
  - State Level

Modified from Paul Gerlach
Potential Target

- Numerous Targets
  - Mississippian
Numerous Targets

Regional Level
Ness City North Field

- Numerous Targets
- Local Level
Doing Our Homework

- Reservoir characterization
  - Geologic & Petrophysical model
- Engineering analysis
  - Pressure & Production data
  - Reservoir Simulation
    - History Matching
    - Horizontal Infill Performance Prediction
Reservoir Characterization

Geologic Model

Geologic model: log (GR, Res), core, production, DST data
Maps & cross-sections of Mississippian sub-units: 5 layered reservoir model
Reservoir Characterization

*Initial Reservoir Model*

Identification of dominant lithofacies - core studies

- LP1, LP2, LP3 - moldic pack-wackestone
- HP1 & HP2 - moldic packstone

Layer porosity - lower of that calculated from phi-K correlation, and the highest value measured on plugs with same dominant lithofacies

<table>
<thead>
<tr>
<th>Subunit</th>
<th>Phi, %</th>
<th>K, md</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP1</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>LP2</td>
<td>21.5</td>
<td>25</td>
</tr>
<tr>
<td>LP3</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>HP1</td>
<td>23.6</td>
<td>60</td>
</tr>
<tr>
<td>HP2</td>
<td>22.2</td>
<td>40</td>
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</table>
Performance Prediction

Performance Prediction - Infill

Rate performance & best case - Ummel #4 H

- skin = 4.5, Pwf = 675 psi, effective producing length = 400 ft

### Average quarterly bbl/d

<table>
<thead>
<tr>
<th></th>
<th>Oil</th>
<th>Oil (b)</th>
<th>Wtr</th>
<th>Wtr (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st yr</td>
<td>18803</td>
<td>23526</td>
<td>59208</td>
<td>37232</td>
</tr>
<tr>
<td>2nd yr</td>
<td>32128</td>
<td>33560</td>
<td>126069</td>
<td>86816</td>
</tr>
</tbody>
</table>

### Graphical Data

- **Qo**: Oil production
- **Qw**: Water production
- **Qo - best**: Best case oil production
- **Qo - avg 2 mnths**: Average oil production over 2 months
- **Qw - best**: Best case water production
- **Qw - avg 2 mnths**: Average water production over 2 months
Details of Well Work

- Original Plugged Wellbore
- Drill Out Cement Plugs & Set CIBP
- Set Whipstock & Mill Casing
- Drill Build Section
- Drill Lateral Section
- Set Liner
- Final Completion
- Coiled Tubing Workover
Original Plugged Well

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Ummel #4H
Ness City North
T18S R24W Sec. 23
KB 2277

Mississippian 4274 TVD

Drilled: July 1995
Plugged: April 1996

80' TOC
2348' BOC
3730' TOC
3900' BOC

4319'
5-1/2" 15.5#
Ummel #4 Horizontal Well

Horizontal drilling trailer
Drill Out Cement & Set CIBP

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Step 1

Dates: 4/7/00 - 4/10/00
Rig Time: 82 Hours
Approx. Cost $26.4 M
Setting CIBP below whipstock
Set Whipstock - Mill Casing

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Step 2

Dates: 4/10/00 - 4/14/00
Rig Time: 84 Hours
Approx. Cost $24.2 M

Mississippian 4274 TVD

O/W -2035
(4312 TVD)
Running whipstock and starting mill

Starting mill
Shear bolt
Whipstock
Drill Build Section

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Step 3

Dates: 4/14/00 - 4/19/00  
Rig Time: 120 Hours  
Drilling Time: 28 Hours  
Approx. Cost $135.1 M

Mississippian 4274 TVD

Build Section

4-3/4” Hole, 4115-4334 MD, 4279’ TVD  
Build Rate 42.50° /100’  
Azimuth N97.5S, Inclination 75.0°
Directional Drilling Assembly

Motor angle

Drill bit screws here
Installing MWD Tool

Pulpit transmits readings to surface by generating pressure pulses
Drill Lateral Section

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Step 4
Dates: 4/19/00 - 4/21/00
Rig Time: 52 Hours
Drilling Time: 33 Hours
Approx. Cost $44.3 M

Lateral Section
4-3/4” Hole, 4334-4828 MD, 4299’ TVD
Azimuth N94.6S, Inclination 90.0° - 86.8°
Directional Drilling Trailer

MWD computers

MWD workbench
Reservoir Heterogeneity

- Strong Horizontal Heterogeneity
  - 10’ - 100’ Interval
  - Karst Controlled
- Result Poor Lateral Drainage

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Ft. Scott
Cherokee
Mississippian

4200 (4274 TVD)
4300 (4312 TVD)
628’

O/W -2035
Set Liner

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Step 5

Dates: 4/21/00 - 4/21/00
Rig Time: 10 Hours
Approx. Cost $18.2 M

Mississippi 4274 TVD

Liner
4073-4400MD, 10 joints, 3-1/2”, 9.3#
CS Hydril with Baker liner hanger

Open Hole
4400-4828 No Stimulation
Running 3-1/2” CS Hydril liner

Liner hanger rubber
Step 6

Dates: 4/29/00
0-4003, 126 joints, 2-7/8, 6.5# Tubing
4003-4019 Mud Anchor
2-1/2” X 2” X 16’ RWB Pump with 6’ GA
Pumping @4.5 SPM with 74” Length
Initial Production

IP: 85 BOPD & 54 BWPD (4/29/00)

Daily Prod:
55 BO & 50 BW for 2-1/2 months (May to mid-July) with 1000’ of fluid over pump
## Breakdown of Rig Time

<table>
<thead>
<tr>
<th>Work Performed</th>
<th>Approximate Rig Hours</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling out cmt &amp; setting CIBP</td>
<td>82.0</td>
<td>23.5</td>
</tr>
<tr>
<td>Setting whipstock &amp; milling csg</td>
<td>84.5</td>
<td>24.2</td>
</tr>
<tr>
<td>Drilling build section</td>
<td>120.0</td>
<td>34.4</td>
</tr>
<tr>
<td>(actual drilling time)</td>
<td>(27.8)</td>
<td>(8.0)</td>
</tr>
<tr>
<td>Drilling lateral section</td>
<td>52.0</td>
<td>14.9</td>
</tr>
<tr>
<td>(actual drilling time)</td>
<td>(32.8)</td>
<td>(9.4)</td>
</tr>
<tr>
<td>Setting liner through the curve</td>
<td>10.0</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>348.5</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
## Drilling & Completion Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intangible Drilling Costs</td>
<td>$317,497</td>
</tr>
<tr>
<td>Intangible Completion Costs</td>
<td>$32,422</td>
</tr>
<tr>
<td>Equipment</td>
<td>$44,765</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$394,684</strong></td>
</tr>
<tr>
<td><strong>DOE Reimbursement</strong></td>
<td><strong>$116,776</strong></td>
</tr>
<tr>
<td><strong>Net Cost to Mull Drilling Co.</strong></td>
<td><strong>$277,908</strong></td>
</tr>
</tbody>
</table>
Initial Production Problems

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Production Problems

After Two Months Production Fell Off Rapidly. July 31st production: 18 BOPD & 32 BWPD, pumped off

Partial Blockage
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Production Problems

December 2000
Production: 1 BOPD, 3BWPD

Complete Blockages
Workover Operations

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Production Problems

January 2001
Attempted Cleanout With Coiled Tubing and Foam Unit

Could Not Clean Out Beyond 4600' Lost Mud Motor and Bit in Hole
Halliburton coiled tubing and nitrogen foam equipment
Coiled tubing drum and control room

Coiled tubing control room

Coiled tubing drum
Halliburton nitrogen foam unit
Weatherford 2.6” mill and mud motor

- Mud motor
- 2.6” mill
Testing 1-1/2” jetting nozzle
Preparing to run in hole with more aggressive 2-3/4” bit and mud motor – *Lost bit and mud motor in hole*
Workover Operations

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Production Problems

Ran 2-3/8” Liner to 4520’
Note: Attempted to Run Slotted Liner.
Unable to do so Because Circulation Was Needed at End of Liner to Wash Down

Acidized Well with 1000 gallons (20% MCA)

Well Produced 2 BOPD and 260 BWPD
Fluid Level 1800’ Above Pump
2-3/8” flush joint liner

3/8” drilled perforations
Lessons Learned for Horizontal Well

- **Operational Flexibility** *(Maintain Your Options)*
  - New Well vs. Reentry
  - Hole Size
  - Drilling Fluids
  - Case off the Curve
  - Line the Lateral

- **Good Planning**
- **Communication**
- “The Lateral is a Piece of Cake”
- **Horizontal Heterogeneity**
Applying What We Learned

- Horizontal Well Supported Reservoir Characterization

- Mechanical Failure Made Horizontal Well Uneconomic

- Application of Reservoir Characterization Resulted in Extremely Successful Workover in the Field
Pfannenstiel A #2-24
Workover

- Well Originally Completed in LP1 Layer
- Added Perfs in LP2 Layer (structurally lower than original perfs)
- Increased Production –
  Before: 2 BOPD 20 BWPD (91% wtr)
  After: 23 BOPD 125 BWPD (84% wtr)
Recompletion

Perfs Added Based on Results of Simulation