IMPROVING OIL RECOVERY AT OSAGE FIELD, WESTON COUNTY, WYOMING

Marron Bingle-Davis and Nick Jones
OSAGE HISTORY

- Discovered in 1919 – Natural Oil Seeps
- First well – 1919 – Mike Henry Oil Co. No. 1 in NESE Sec 5 T46N-R63W
  - 330 ft deep
- First deep well – 1920 – Alliance Oil Co. No. 1 in NWNE Sec 19 T46N-R63W
  - 1,335 ft deep
  - IP 200 BOPD
- Refinery capable of 500 BOPD built by mid 1920
- Osage town quickly established to accommodate expanding field
Town of Osage, circa 1920

Sioux Oil Refinery, Newcastle

Portable Star Drilling Machine, circa 1928
By 1921, over 100 wells at 1-50 BOPD with field total of ~550 BOPD

By 1941, over 1,000 wells drilled
  • Second boom in 1940s

Waterfloods initiated in late 1950s
  • Another increase in drilling activity

Continuous drilling since 1919
RockWell Petroleum purchased Osage for oil mining in 2006
- Drilled 14 ft x 14 ft portal underneath formation
- Drilled small horizontal wells from a single well room up into formation

Osage Partners, LLC purchased Osage in 2012
CURRENT FIELD STATUS

- ~600 active wells (200 producers, 200 shut-in, 200 injectors)
- 4 active secondary recovery units
  - Initiated between 1955 and 1968
- 125 MMBBLS OOIP in field
- 32 MMBO cumulative production; 26% Recovery
  - 20 MMBO on Primary
  - 12 MMBO on Secondary
- Currently producing 100-130 BOPD
OSAGE GEOLOGY

- Muddy/Newcastle Formation primary producer at Osage
  - Some Belle Fourche production
- Up to 7 distinct sands
- Fluvial and likely marginal marine up-section
- High clay content in some sands poses problem for waterfloods
Osage Field

- Osage part of Fiddler Creek trend of Muddy/Newcastle production
- Field produces from 200 to 4,000 ft deep
- Some wells have made over 200,000 BO
- High oil saturations make Osage a good target for chemical flooding
NEW DEVELOPMENTS
HORIZONTAL DRILLING

- Previous operators produced best intervals ignoring the remainder of the formation
  - Core data and logs suggest all oil saturated but often tight
- Drill short radius horizontal wells with short laterals to inexpensively improve the kh

Rig at Osage
MUD MOTORS VS ROTARY STEERABLE TOOLS

- Currently testing two horizontal technologies at Osage
  - Mud Motors
    - Main draw – very cost effective, proven successful
  - Rotary Steerable
    - Main draw – no MWD, supposedly reproducible
- Build curve in ≤120 ft
- Drill laterally 1,000 ft
- Open hole completion – no fracture stimulation
- Solar PC pump in curve
- Completed well = < $100,000

- Successfully drilled 5 wells with mud motors
- Attempted 1 well with rotary steerable – tool failure, currently being rebuilt

Built curve in 113 ft TVD
Built to 100°
200 ft lateral
Basal 5-7 sands are main target for horizontal drilling, but the uncommon 1 sand and even the waterflooded 3-4 sands may be potential targets – Up to 150 MMBBLS OOIP for just the basal sands
6-well pad on 160 ac = 24 wells/section = 553 wells over 13,800 acres

Testing Area

Estimated 240,000 BO /section recoverable – 5.5 MMBO recoverable across field

Due to low cost in drilling – Well only needs 2,000 BBLS to payout
We are currently drilling the first three wells on the NE of section 17 pad – Beginning of field-wide expansion beyond testing
SOLAR PROGRESSIVE CAVITY PUMPS

- Lower operation costs
  - No electricity, pumping unit parts that often need replacing, need less babysitting
- Pumps up to 3,200 ft
- Pumps at any temperature since moving parts below frost line
- Installed 14 so far
- Makes uneconomic wells economic
  - Put many wells back on production
- Able to place pump on side
ASP PILOT – BRADLEY UNIT

- TIORCO analyzed Osage oil and performed core floods using core from eastern side of field
  - Positive results especially in presence of sacrificial agent for high amount of clays
- Pilot area included 64 acres; 7 producers; 4 injectors
  - 1.2 MMBBLS OOIP – Up to 180,000 BO recovery
  - Possibility of producing an additional 8-18 MMBO field-wide
- Currently project on hold
**ASP CORE FLOOD (OIL RECOVERY ANALYSIS)**

<table>
<thead>
<tr>
<th>PV</th>
<th>0.07</th>
<th>0.23</th>
<th>0.40</th>
<th>0.56</th>
<th>0.76</th>
<th>0.93</th>
<th>1.14</th>
<th>1.31</th>
<th>1.48</th>
<th>1.65</th>
</tr>
</thead>
</table>

Oil Recovery in 1 PV (including ASP slug):
- 37% of Residual oil
- 58% of OOIP

Incremental Oil Recovery from WF:
- 41% of Residual oil
- 28% of OOIP
Petrographic analysis
- 35 thins sections from four cores

XRD and CEC
- Whole-rock XRD on 14 samples
- Clay mounts of 35 samples for XRD
- CEC on 15 samples
- Petrography and XRD focus on clay analysis
- Detailed core description for paleoenvironment
Notes: Points along curves indicate approximate location of samples.
Calcite Cement

Shell fragments?

292.5 ft
1 sand

342 mD
30.3 % porosity
13 % Sw
45.8 % So

Clean, very fine-grained sand; Minor Kaolinite and Chlorite
Flaser-irregular bedded, mud-rich very fine-grained sandstone and siltstone; Carbonaceous streaks common; Kaolinite in cleaner sands and Chlorite

2.48 mD
19 % porosity
26.3 % Sw
38.4 % So

Organics
- Conduct single well tracer test for evaluation of ASP formula.
- Two tests performed – Test 1 before EOR and Test 2 after a shut-in period.
- Chemical reaction occurs *in situ* while shut-in; new tracer arrives at surface before old tracer as fluid produced back in presence of oil.
- Result in $S_{or}$ before and after EOR.

\[ \text{EtAc (ethyl acetate)} + \text{H}_2\text{O} \rightarrow \text{EtOH (ethyl alcohol)} + \text{HAc} \]

**Localized EOR Flood**

**20 Feet**

---

**Evaluation of Residual Oil Saturation Before and After Alkaline-Surfactant-Polymer Injection**

September-October 2014

Osage Oil Field
Osage, Wyoming
OBU 4-24
Perforated Interval: 1,319'-1,322'; 1,330'-1,332'

Final Report
Prepared for
Osage Partners, LLC.

by
Chemical Tracers, Inc.,
1814 Steele
Laramie, Wyoming 82070
(307) 742-4618
(307) 742-4972 Fax
www.chemtracers.com
- Test 1: Injected 350 BBLs of produced water
- Well shut-in 3 days
- Test 2: Injected 8 BBLs of preflush, 10 BBLs of ASP, and 6 BBLs of polymer
- Took 3 days to produce fluid back

Test 1: $S_{or} = 32\% \pm 4\%$
Test 2: $S_{or} = 10\% \pm 5\%$

22% Recovery from ASP
Known chemical EOR projects in Muddy/Newcastle reservoirs

- Mush Creek -1969? – Polymer – Profitable
- Bell Creek -1977 – Surfactant – Successful
- Fiddler Creek -1985 – Polymer – Incomplete
- Clareton -1985 – Polymer – Discouraging results
- Osage - 2014 – Alkaline Surfactant Polymer – Successful

Average residual/immobile oil saturation ~30%

*Polymer + Alkaline & Surfactant = 20 to 25% recovery of residual oil saturation.

e.g. (OOIP * 0.3)=Rso  \( \rightarrow 0.25*Rso=\) Potential Incremental Production
Target Fields - Muddy/Newcastle reservoirs amenable to ASP
OSAGE SUMMARY

- Producing since 1919 out of the Newcastle Fm from 200 to 4,000 ft

- Three drilling booms
  - 1920s – 100s of wells
  - 1940s – Over a 1,000 wells
  - 1950s – 1970s – Successful waterflooding

- 32 MMBO produced (26% RF); Currently 100-130 BOPD

- Osage Partners, LLC took over in 2012
  - TIORCO and EORI conducted geologic and chemical analyses for ASP chemical flooding - proved successful by tracer test
  - Horizontal drilling to access previously unproduced intervals – plan on over 500 wells across whole field
  - Solar PC pumps to significantly reduce operations costs so as to put 200+ shut-in wells back on production
ACKNOWLEDGEMENTS:

- Wayne Neumiller (Osage Partners, LLC)
- Mark Erickson (Osage Partners, LLC)
- Mark Choury (Osage Partners, LLC)
- Becky Podio (Osage Partners, LLC)
- Stephen Tygard (Osage Partners, LLC)
- Curtis Chopping (EORI)
- Peigui Yin (EORI)
- Charlie Carlisle (CTI)
- Scott Badham (CTI)
- Mike Lantz (TIORCO)
- Neeraj Rohilla (TIORCO)
- Ravi Ravikiran (TIORCO)
- Paul Knox (TIORCO)
THANK YOU FOR YOUR TIME

ANY QUESTIONS?