The Unconventional Mississippian Play
Early Producing and Completion Statistics (& Observations)

Mississippian and Arbuckle Workshop
Oklahoma Geological Survey
October 31, 2012

John Paul (J.P.) Dick, P.E.
Oklahoma City, Oklahoma
Play Evaluation

- Clients and Companies providing or agreeing to provide confidential information include many of the companies active in the Mississippian Play of Northern Oklahoma and Kansas.
- Have collected Completion, Production, and/or Geological Information on over 800 Horizontal Mississippian wells throughout the Play.

Purpose of Data Gathering and analysis was to improve understanding of Mississippian Play and be a source of reliable information/statistics.

- Approximately 1100+ HZ Wells have been Drilled in the Play to date.
- 600+ Wells in Miss Play overall with sufficient Daily or Monthly Data to forecast EUR’s with Confidence (to an economic limit).
- 800+ Wells in Miss Play overall with some completion data for use in comparing EUR results.

“The conventional view serves to protect us from the painful job of thinking”
- John Kenneth Galbraith, quoted in the Associated Press.
Profile of Mississippian Play

- Still Very early in the Development of the play  
  - ~1100 wells into a Potential 100,000 well play  
- Statistical Play with Wide Variation of Results – but Companies that Study and Understand the Mississippi will Prosper  
- Wide Range of Reported Initial Rates & Projected EURs  
  - Unfortunately, no identified correlation of IP’s to EURs…. yet  
- Very Complex Geology - (Chats, Cherts, Dolomites, Limestones) with changes occurring vertically and horizontally - sometimes rapidly  
- Completion/Stimulation Designs Matter – and should vary by area  
- Expect low Oil Cuts, varying GORs, and to move significant volumes of Water in most areas  
- Reservoir appears to be a perfect application of Horizontal Drilling  
- Large Contiguous acreage blocks necessary to reduce project costs

“I’ve Learned one thing – people who know the least seem to know it the loudest”  - Cartoonist Al Capp, quoted in the Buffalo News
Major On-shore US Oil Play

- Vast Area with potential – covering in excess of 17mm acres across the whole play
- Commercial trend which has produced from thousands of vertical wells for over 50 years
- Large amount of vertical well data
  - Provides extensive reservoir control through area correlation and facies distribution and continuity
- Shallow depths -1,600 to 7,000 ft. in “Main” Play
  - but HZ Miss wells as deep as 10,500 TVD
- Gross thickness of up to 800+ ft.
- Areas with High liquids content
  - Primarily mod sweet crude and gas BTU’s ranging from 1050 -1500, some Areas with low H2S
- Lower HP industry equipment required and good infrastructure (& improving) to service the play
Mississippian – 962 Drilled Wells and 85 Active Rigs

<table>
<thead>
<tr>
<th>Wells Drilled</th>
<th>Active Rigs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SandRidge</td>
<td>432</td>
</tr>
<tr>
<td>Chesapeake</td>
<td>266</td>
</tr>
<tr>
<td>Eagle</td>
<td>58</td>
</tr>
<tr>
<td>Calyx</td>
<td>22</td>
</tr>
<tr>
<td>Range</td>
<td>23</td>
</tr>
<tr>
<td>Plymouth</td>
<td>15</td>
</tr>
<tr>
<td>Shell</td>
<td>17</td>
</tr>
<tr>
<td>Territory Res.</td>
<td>10</td>
</tr>
<tr>
<td>Panther</td>
<td>8</td>
</tr>
<tr>
<td>Chaparral</td>
<td>9</td>
</tr>
<tr>
<td>Devon</td>
<td>10</td>
</tr>
<tr>
<td>Other</td>
<td>92</td>
</tr>
<tr>
<td>TOTAL ALL</td>
<td>962</td>
</tr>
</tbody>
</table>

- 432 SandRidge horizontal wells
  - 380 Hz operated wells planned in 2012
  - SD = 8,000 potential locations
- 530 Industry horizontal wells
- 14,700 Vertical Miss wells
- SD ≈ 1.75 Million net acres

(a) Based on 3 wells per section
(b) Drilled well counts as of 09/29/12
Horizontal Mississippian Wells Analysis

- Relationship between IP’s (O,G,W) and EUR’s
- Relationship between Horizontal Wells and Vertical Wells
- Relationship between Frac/Acid/Prop Volumes and HZ EURs
- HZ Target Depth of Formation and EUR Comparison
- EUR improvements over time, by area
- Initial Rate Forecasts & Decline Parameters (De, b)
- Log Derived Volumetric Search for necessary Thickness
- Reservoir and Performance Differences by Area
- Varying Oil Cuts, GORs by area

“If you are out to describe the truth, leave elegance to the tailor”
- Albert Einstein, Quoted in the Asheville, N.C., Citizen-Times
Problems faced in Conducting an Evaluation of the Mississippian Play

- Limits Confidence of New Companies & Investors to Invest in the Play

- Confidentiality of Information from both Operators & Regulatory Bodies
  - Limits outside evaluation of Play

- Partial or Non-Disclosure of Information
  - Information usually excludes # Stages, Stage Lengths, Perforation Details, Proppant Size, Stim Fluids and rates, etc.

- Consistency of Reported Data
  - How are IP’s reported (Max Rates, Ave 1st Mo, Last Day, Guess, etc)
  - When is data released – sometimes 6 months or 1-2 years before info Released

- Production Analysis
  - For analyzing during first 2 years, Best to use Daily Production Data to forecast to get reasonable estimates of Reserves due to downtimes and changes in production methods from Flowing to Gas Lift to ESP’s, etc.
  - Monthly Production issues of Lag Time, Inaccuracies, Omissions, Common Meters, Sales vs Production, Water Volume reporting, Pressures
Statistics and Metrics

“Statistics are like bikinis. They show a lot but not everything”

- Former baseball manager Lou Piniella, quoted in the Cassville Mo., Democrat
# Overall Play Averages

**860 Wells with Completion or Rate information**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
<th>Unit(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave MD</td>
<td>9,496</td>
<td>Ft</td>
<td></td>
</tr>
<tr>
<td>Ave TVD</td>
<td>5,198</td>
<td>Ft</td>
<td></td>
</tr>
<tr>
<td>Ave Drld in Miss</td>
<td>(83)</td>
<td>Ft</td>
<td></td>
</tr>
<tr>
<td>Ave Oil IP</td>
<td>168</td>
<td>BOPD</td>
<td></td>
</tr>
<tr>
<td>Ave Gas IP</td>
<td>777</td>
<td>Mcfd</td>
<td></td>
</tr>
<tr>
<td>Ave IP Water</td>
<td>2,569</td>
<td>BWPD</td>
<td></td>
</tr>
<tr>
<td>Ave BOPDE</td>
<td>297</td>
<td>BOPDE</td>
<td></td>
</tr>
<tr>
<td>Ave IP Oil Cut %</td>
<td>10.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave IP GOR</td>
<td>10,339</td>
<td>scf/bbl</td>
<td></td>
</tr>
<tr>
<td>Ave HZ Compl</td>
<td>3,826</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave IP BOPDE/ft</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave BBls Frac Fl</td>
<td>46,194</td>
<td>BBL/Ft</td>
<td></td>
</tr>
<tr>
<td>Ave BBl Acid</td>
<td>1,261</td>
<td>14.5</td>
<td>Gal/Ft</td>
</tr>
<tr>
<td>Ave Proppant</td>
<td>1,104,724</td>
<td>313.5</td>
<td>#/ft</td>
</tr>
</tbody>
</table>

**616 Wells with EUR's**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
<th>Unit(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave Oil EUR</td>
<td>Overall 91</td>
<td>98</td>
<td>Normalize to 4400'</td>
</tr>
<tr>
<td>Ave Gas EUR</td>
<td>Overall 793</td>
<td>818</td>
<td></td>
</tr>
<tr>
<td>Ave Wtr EUR</td>
<td>1,885</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave MBOE</td>
<td>222</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>Ave Oil Cut</td>
<td>8.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave EUR GOR</td>
<td>15,820</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Oil IP’s vs Oil EURs
Gas IPs vs Gas EURs
Water IP vs MBOE EURs
All Mississippian Play – MBOE EUR’s

All Wells
All Areas
All Operators
Varying Lithologies
Varying Completion Methods
EUR’s improving
Early EURs- may be conservative
All Mississippian Play – Oil (MBO) EUR’s

All Wells
All Areas
All Operators
Varying Lithologies
Varying Completion Methods
EUR;s improving
Early EURs- may be conservative
All Mississippian Play – Gas (MMcf) EUR’s

- All Wells
- All Areas
- All Operators
- Varying Lithologies
- Varying Completion Methods
- EUR’s improving
- Early EURs may be conservative
Mississippian Play – East of Nemaha Ridge – MBOE

Six OK Counties
Shorter Laterals
Generally Lower GOR’s
Varying Lithologies
Varying Completion Methods
Limited well count
EUR;s improving
OH Completions Comparison to Plug & Perf

- Very encouraging results from Open-Hole Packers Method
- About 40+ wells have employed system utilizing casing with OH packers completion design
- Only have completion + production data on 15 confirmed wells
- Additional work to be done. Reports have not been filed nor production reported on many of the wells – performing analysis at this time would result in skewed numbers
Keys to Unlocking the Mississippian Liquids Play

• Use Core, Vertical & HZ Petrophysical (Log) Data/Analysis, Micro-Seismic & Seismic data to determine Structure, Lithology and formation Characteristics – fractures, faults, Porosity, Thickness, etc

• Targeting the correct interval(s) within the Mississippian formation to Minimize drill time and to Maximize Rate and Reserves

• Designing and Performing the “Right” Completions/Stimulations
  – Number of Stages, Perforations, Fluid Volumes/Types,
  – Proppant Types and Amounts, Injection Rates
  – Adapt Designs to area geology and lithology

• Determine what you need to get what you want
Example - Area/Thickness Necessary for Recoveries

- $L = 4400 + 400 = 4,800'$
- $W = 2 \times 600' = 1,200'$
- $A = 5,760,000 \text{ ft}^2 = 132 \text{ acres}$

- $\Phi = 20\%, \ Sw = 65\%, \ R_f = 10\%, \ Bo = 1.4$
  - $H = 30'$, Oil EUR = 153,608 BBls Oil

- $\Phi = 5\%, \ Sw = 65\%, \ R_f = 7.5\%, \ Bo = 1.4$
  - $H = 160'$, Oil EUR = 153,608 BBls Oil

- $\Phi = 5\%, \ Sw = 65\%, \ R_f = 5.0\%, \ Bo = 1.4$
  - $H = 240'$, Oil EUR = 153,608 BBls Oil
TYPE LOG OF MISSISSIPPIAN FORMATION

Top of Mississippian

Solid or Massive

Chat

Woodford
HZ Well TVD vs Top Mississippian

Analyzing Depth of HZ Wells

Most wells concentrated in Top 150’

All Areas

All Operators

Varying Lithologies

Varying Completion Methods
Frac Fluid Volumes, BBls Fluid per Ft HZ Completed
Proppant Volumes, # per Ft HZ Completed
Acid Fluid Volumes, Gal Acid per Ft HZ Completed
Multiple “Production Profiles” have been observed.......

- 50 BOPD IP wells can make >300 MBO or <5 MBO, &
- 1000 BOPD IP wells can make <75 MBO or >300 MBO

- Depends on Lithology, producing methods, stimulation, area
- Initial Oil/Gas Declines Rates (Nominal) range from 40% to 99%
  - County averages range from 65 – 90%
- B factors range from .25 to 2, with most fitting 1.25 – 1.50
- Gas rates usually peak 3-6 mos after 1st prod (up to 1.5 years)
- Oil rates usually peak within 1st 30 days, but up to 12 months
- Water Production declines “similarly” to Oil Production on most wells, although contact with wet Chats can make it look like water drive
Oil Cuts – IP vs EUR’s

Oil Cuts Vary from 0.1% to 50%

Initial and Final oil cuts expected to be similar in most cases
Observed Average Initial Decline Rates by County
## Key Points

- Together Sandridge, Chesapeake, Eagle and Range Resources have drilled a majority of the Hz wells in the Mississippian
  - Type curves are based on some of the most mature Hz wells in the play
- Publically stated single well EURs range from 290 MBoe to 600 MBoe
- Current lateral lengths range from 2,200' to 4,000'
- Chesapeake, Sandridge and Eagle are located in the West part of the play and are approximately 50% liquids
- Range Resources
  - Located in the East part of the play and is 70% liquids
  - Stated recovery factor from 4% to 9% of OOIP
  - Stated their Mississippian play economics rival those of the Marcellus wet gas area
- Halcon and Chaparral have recently publicly disclosed their Hz well EUR projections

### Mississippian Comparative Type Curves

![Graph showing type curves for Range (485 MBoe), SandRidge (456 MBoe), Chesapeake (360 MBoe), and Eagle (470 MBoe).](image)

### Mississippian Single Well Summary

<table>
<thead>
<tr>
<th>Lateral (R)</th>
<th>Chaparral</th>
<th>CHK</th>
<th>Eagle</th>
<th>HK</th>
<th>RRC</th>
<th>SD</th>
<th>Lawco/Century</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUR (MBoe)</td>
<td>200 - 400</td>
<td>400’</td>
<td>3,500’</td>
<td>175</td>
<td>400 - 500</td>
<td>300 - 500</td>
<td>188</td>
</tr>
<tr>
<td>D&amp;C Cost ($MM)</td>
<td>2.5 - 4.0</td>
<td>3.7</td>
<td>3.5</td>
<td>2.5 - 3.5</td>
<td>3.1</td>
<td>3.2</td>
<td>1.7 - 1.9</td>
</tr>
<tr>
<td>LOE ($/Boe)</td>
<td>Unknown</td>
<td>Unknown</td>
<td>2.06</td>
<td>Unknown</td>
<td>Unknown</td>
<td>9.61</td>
<td>13.09</td>
</tr>
<tr>
<td>Location (Area)</td>
<td>East</td>
<td>West</td>
<td>West</td>
<td>East</td>
<td>East</td>
<td>West</td>
<td>East</td>
</tr>
</tbody>
</table>

---

(1) Chaparral Energy Investor Presentation, February 2011
(2) Eagle Energy Presentation
(3) Halcon Resources Investor Presentation, April 2012,
(4) Range Resources Investor Presentation, June 2012
(5) SandRidge Investor Presentation, June 2012
(6) Range Resources Investor Presentation, August 2011
(7) Assumes 500’ of per BIV
Characteristics of Mississippian Play

- Significant Reserve Potential Throughout the Mississippian Reservoir in most all areas evaluated
- Shallow Unconventional Oil Reservoir – with areas of High GOR (Gas)
- Due to Reservoir Characteristics and Heterogeneity, The Mississippian Formation appears a perfect application for Horizontal Drilling
- Three to Five Horizontal Wells likely to be drilled per Section (640 acres). Potential exists for Additional Wells in some sections within Upper and Lower intervals within the Mississippian.
- Up-front costs are higher due to Analyses conducted on initial wells and drilling & installation of Salt Water Disposal Wells/Systems and Power. Infill well costs are expected to decrease appreciably
- Planning & Design can improve performance and economics
- Additional potential exists in the Serendipity of finding other productive formations

“If I had $3,000,000 I wouldn’t drill a Horizontal Mississippian Well, But if I had $30,000,000 I would drill 10 Wells” – J.P. Dick
Underlying Factors
Cap - 3.25 $MM
Opex - 3M $/mo + 3 $/BO + 0.1 $/BW
Gas - 3 $/Mcf
Sev.Tax - OK 7.1%
Thank You

“An Expert is a man who has made all the mistakes which can be made in a narrow field” - Physicist Niels Bohr, Quoted in Wired

John Paul (J.P.) Dick, P.E.
Oklahoma City, Oklahoma