Exploration Insight and Input that Changed Organizational Focus, Strategies and Economic Outcomes: Several Resource Play Examples*

Bill Fairhurst¹, Frank Reid¹, and Nick Pieracacos¹

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Abstract

Eagle Oil & Gas, Co. and its team members have been an early-entrant exploration, capital de-risking and developers of multiple Resource Plays including the Austin Chalk, Bakken, Barnett, Marcellus, Haynesville-Bossier, Wolf-Bone, Mississippian Lime, Woodford, Oklahoma Stack and several others currently being developed. The geologic concepts in the majority of these plays changed, often dramatically, from first concept to acreage acquisition and early drilling. These concepts changes, early definition of the Economic Sweet Spots, changes in Investment Strategy and superior operational results has made a significant positive impact for the Organization(s) and in cases for the Industry within these plays. This presentation will focus on two of these examples. First, on Eagle’s concepts, Strategic observations and project/organizational changes that opened up the economic development of the WolfBone Resource Play in the southern Delaware Basin and secondly, changes made in the Mississippian Lime play in Kansas. Brief mention of strategies to keep our companies in the early developing Bakken and Marcellus will also be provided.

References Cited


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Production from the Permian System

Summary

- Permian system comprised of multiple basins:
  - Delaware Basin
  - Central Basin Platform
  - Midland Basin
- Development progression:
  - Early production from shallow formations on the basin edges
  - Transition to deeper deposits in the central Delaware (Avalon, Bone Spring, & Wolfcamp)
- Recent basin revitalization:
  - Comingled vertical completions
  - Modern horizontal drilling and completion technologies

Permian Basin Structure

 Permian Basin Cross Section (1)

Woodford Shale Isopach
C.I. = 100'
Mississippian Lime Structure Map
C.I. = 500'
Delaware Basin Deposition

- 2 depositional systems in place
  - Deep submarine channels running off the NW Shelf and Central Basin Platform
  - Periods of influx of carbonate debris
- 3rd process in generation of organics in the photic zone across the entire basin as debris settled
  - Mostly organics settling in the deep basin; carbonates mainly deposited on the Shelf and on the Slope

<table>
<thead>
<tr>
<th>MYBP</th>
<th>Stage</th>
<th>Description</th>
<th>Measured Depth (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250-258</td>
<td>Ochoa (Upper Permian)</td>
<td>Mostly salts, anhydrite (evaporates) and some interbedded carbonates.</td>
<td>5,000</td>
</tr>
<tr>
<td>260-270</td>
<td>Delaware Mountain Group (Middle Permian)</td>
<td>Limestone - Good Intermediate casing shoe point.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lamar Limestone</td>
<td>Limestone - Good Intermediate casing shoe point.</td>
<td></td>
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<tr>
<td></td>
<td>Interbedded sandstones and shales.</td>
<td>Excellent reservoirs in traditional traps.</td>
<td></td>
</tr>
<tr>
<td>270-280</td>
<td>Leonardian (Upper-Lower Permian)</td>
<td>1st Bone Spring - Avalon Shale 103 MMBOIP per Section in normally pressured Resource Play.</td>
<td>8,000</td>
</tr>
<tr>
<td></td>
<td>2nd Bone Spring</td>
<td>Potential play in detrital intervals.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hoban</td>
<td>3rd Bone Spring Lime Hydrocarbon Saturated, traditional sandstone reservoir</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Regional Time Line Marker, Excellent Mapping Horizon.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Regional Time Line Marker, Excellent Mapping Horizon.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Hydrocarbon Saturated, traditional sandstone reservoir.</td>
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<tr>
<td></td>
<td>D-E</td>
<td>Regional Time Line Marker, Excellent Mapping Horizon.</td>
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<tr>
<td>280-290</td>
<td>Wolfcampian (Lower-Lower Permian)</td>
<td>Wolfcampian Shale Condensed Zone 108 MMBOIP per Section in high to normally pressured Resource Play.</td>
<td>10,500</td>
</tr>
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<td></td>
<td>A</td>
<td>Wolfcampian Shale Condensed Zone Massively bedded debris flow carbonates derived from shelf and authigenic fine-grained quartz in high TOC shales.</td>
<td>11,500</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Wolfcampian Shale Condensed Zone Massively bedded debris flow carbonates derived from shelf and authigenic fine-grained quartz in high TOC shales.</td>
<td>12,000</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Wolfcampian Shale Condensed Zone Massively bedded debris flow carbonates derived from shelf and authigenic fine-grained quartz in high TOC shales.</td>
<td>13,000</td>
</tr>
</tbody>
</table>
Bone Spring Type Log Section

Bone Spring Hoban Sand
Bone Spring A Sand
Bone Spring C Sand
Hz Bone Spring IP Bubble Map

<250 boe/d
250-500 boe/d
500-750 boe/d
750-1,000 boe/d
1,000+ boe/d

Wells completed as Wolfbone producers after 1/1/2009 – Hoban, Ward, Reeves fields.

All completions >1,000 boe/d are less than 12 mo. old
<table>
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<td>11,500</td>
</tr>
</tbody>
</table>

- **1st Bone Spring - Avalon Shale**: 103 MMBOIP per Section in normally pressured Resource Play.
- **2nd Bone Spring**: Potential play in detrital intervals.
- **3rd Bone Spring Lime**: Regional Time Line Marker, Excellent Mapping Horizon.
- **Wolfcampian Shale**: Regional Maximum Flooding Surface.
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Condensed Shale

“Blue” Carbonate Member

Eagle Oil & Gas Co.
Bell 213 #1
Wolfcamp Shale C
Sheldon Carbonate Member
Wolfcamp Shale D

Sheldon Carbonate Isopach Map

Riverford Exploration, LLC
Sheldon Carbonate Isopach Map
C.I. = 10'

Turbidite Channel Cross-Section
Shale to Basin Floor Contact
Eagle Oil & Gas Co.
Bell 213 #1

Condensed Shale

"Blue" Carbonate Member
A thin chronostratigraphic interval, typically characterized by autothonomous sedimentation and maximum abundance and diversity peaks of planktonic fossils. The maximum flooding surface within this maximum flooding surface condensed section, provides a chronostratigraphic (time) correlation between shelf and slope sediments and is typically “Enriched in Organic Carbon”. 

Condensed Section

A thin chronostratigraphic interval, time correlative marine sediments deposited at extremely slow rates during sediment starvation, through a period of maximum relative sea-level rise and maximum transgression of the shoreline. It is characterized by autothonomous sedimentation in each of the marine environments.
DECREASING SEDIMENTATION RATE

SEA LEVEL

TERRESTRIAL ORGANIC MATTER

MARINE ORGANIC MATTER

OXIC WATER

ANOXIC WATER

(After Creaney & Passey, 1993)
Wolfcamp Shale Isopach Map
C.I. = 50'
Condensed Shale
Production Bubble Map, Portion of Reeves Co., Texas
Latest Production
Wolfcamp Shale Isopach Map
C.I. = 50'

Slope to Basin Floor Contact
Wolfcamp Shale
3rd Order Residual Structure Map
C.I. = 20’
Bubble Map: Current (May, 2013) Daily Production from Wolfcamp

All Other Wells/Leases: Field, Reservoir
Production Logs = Precision Completions

Production Logs Used to Identify Target Intervals

- Eagle has run production logs in 9 Wolfbone wells
- Tool has multiple sensors to identify contributing intervals:
  - Spinner with dual-axis caliper
  - Pressure and temperature sensors
  - Digital Entry Flowview Imaging Tool (DEFT)
  - Water measurement
  - Gas Holdup Optical Sensing Tool (GHOST)
  - Gas measurement

Relative Flow Contribution by Member(1)

- Total Hydrocarbon (boe) vs Water
- Current Hz Target Monroe 39 #2H
- Previously Drilled Hz Target

Full logs available in VDR

Current Wolfbone Targets

Water-bearing zones No longer completed

Mid Wolfcamp Sands D (1 Well)
Mid Wolfcamp Sands C (4 Wells)
Mid Wolfcamp Sands A (8 Wells)
Mid Wolfcamp Sands B (3 Wells)
Mid Wolfcamp Shale A (8 Wells)
Mid Wolfcamp Shale B (9 Wells)
Upr Wolfcamp Shale B (8 Wells)
Upr Wolfcamp Shale A (9 Wells)
2nd BS Shale Upr (2 Wells)
2nd BS Shale Lwr (3 Wells)
3rd BS Sands (9 Wells)
2nd BS Detrital (1 Well)
Focusing the Effort

Peak Rate (boe/d) Approx. Depth

1st BS Shale - Avalon 9,250
2nd BS Detrital 9,600
2nd BS Shale Upr 9,850
2nd BS Shale Lwr 10,150
3rd BS Sands 10,150
Upr Wolfcamp Shale A 10,440
Upr Wolfcamp Shale B 10,700
Md Wolfcamp Shale A 10,900
Md Wolfcamp Shale B 11,100
Md Wolfcamp Sands A 11,400
Md Wolfcamp Sands B 11,650
Md Wolfcamp Sands C 12,000
Md Wolfcamp Sands D 12,250

Most recent wells completed consistently with excellent results

Completed Interval
Completed and Plugged due to Water

Continued improvements lead to targeted completions
First 60-Day Average Production in Sequential Order Completed With 5-Well Moving Average

Average 7 BOPD increase in 60-Day Average with each subsequent completion.
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AAPG-STGS Geosciences
4th Annual Eagle Ford Technology Workshop
San Antonio, Texas
March 9 - 11, 2015
WTI 21st Century

Riverford Exploration, LLC @ 2015

\[ y = 595.57 \ln(x) - 6235.2 \]

\[ R^2 = 0.703 \]
$WTI$ to Euro / $US$ Exchange 21st Century

$y = 2.861e^{2.4272x}$

$R^2 = 0.7503$
$y = 180.41 \ln(x) + 42.33$

$R^2 = 0.4741$

6/2014 - 2/2015

Riverford Exploration, LLC @ 2015

\[ y = 0.5444e^{3.8944x} \]
\[ R^2 = 0.9358 \]

\[ y = 180.41\ln(x) + 42.33 \]
\[ R^2 = 0.4741 \]

6/2014 - 2/2015

Riverford Exploration, LLC @ 2015

$y = 2.861e^{2.4272x}$

$R^2 = 0.7503$
$WTI$ to Euro / $US$ Exchange + Time 21st Century

Riverford Exploration, LLC @ 2015

$y = 3E-07e^{1.0594x}$
$R^2 = 0.7531$
$WTI to Euro / $US Exchange and Time 21st Century
6/2014 - 2/2015

Riverford Exploration, LLC @ 2015

\[ y = 3E-07e^{1.0594x} \]

\[ R^2 = 0.7531 \]
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AAPG-STGS Geosciences
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San Antonio, Texas
March 9 - 11, 2015
<table>
<thead>
<tr>
<th>EPOCH / AGE</th>
<th>% WORLD RES</th>
<th>N AMERICAN EXAMPLES</th>
<th>INTER EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>PENN – E PERMIAN</td>
<td>8</td>
<td>Wolfcamp, Atoka-Strawn, Phosphoria</td>
<td>Coal Measures, N. Caspian</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L DEVONIAN – TOURNAISIAN</td>
<td>8</td>
<td>Bakken, Wdfrd, Mar-Utica, Antrim, NAlb</td>
<td>Duvernay, S. Caspian</td>
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<tr>
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<td></td>
<td></td>
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</tr>
<tr>
<td>PERIOD</td>
<td>% WORLD RES</td>
<td>N AMERICAN EXAMPLES</td>
<td>INTER EXAMPLES</td>
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<tr>
<td>SILURIAN</td>
<td>9</td>
<td>Permian, Mid-Cont, Nigarian-MI</td>
<td>Iranian Platform</td>
</tr>
<tr>
<td>EPOCH</td>
<td>% WORLD RES</td>
<td>N AMERICAN EXAMPLES</td>
<td>INTER EXAMPLES</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>M CRETACEOUS</td>
<td>29</td>
<td>Eagle Ford, Niobrara, N. Slope</td>
<td>Venezuela, S.A., Siberia, S. Atlantic</td>
</tr>
<tr>
<td>L JURASSIC</td>
<td>25</td>
<td>Smackover</td>
<td>N Sea-Greenland, Siberia, Arabian Platform</td>
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<tr>
<td>EPOCH</td>
<td>% WORLD RES</td>
<td>N AMERICAN EXAMPLES</td>
<td>INTER EXAMPLES</td>
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<tr>
<td>---------------</td>
<td>-------------</td>
<td>-----------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Oligocene – Miocene</td>
<td>12.5</td>
<td>Monterey, Gulf Coast</td>
<td>China, Indonesia, Suez, MacKenzie, Venezuela, Trinidad, W. Africa</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Source Rocks:

6 Time Intervals Account for:

- 33% of Phanerozoic Time
- < 5% of the Sedimentary Rock Record
- 93% of Source for all Hydrocarbons Worldwide
Source Rocks:

25% of Hydrocarbon Generated is Expelled from Source Rocks.

25% of Hydrocarbon Expelled from Source Rocks Migrates to and is Trapped within Traditional Traps and 20% of that is recovered (produced) from Traditional Reservoirs.

Therefore, only 1% of Hydrocarbon Generated by a Source Rock is in the Traditional Traps that have been drilled and produced for the last 150 years, including all future production in Traditional Traps and Reservoirs.

75% of Hydrocarbon Generated is still in the Source Rock. At 2% Recovery Factor, Resource Plays could production 50% more than has been and will be produced in all Traditional Reservoirs and Traps.
Blessing of Heterogeneities:

• It is the Heterogeneities in mineralogy, grain size, texture, organic material, stage of maturation that define high potential source rock (resource plays) from low potential systems.

• It is the Heterogeneities within each source rock (resource play) that define the economic “Sweet Spots” within each of those systems from lower-potential, generally more basin-wide distribution of lower quality economic objective acreage.

• It is the responsibility of the Geoscientist working within their teams to define these as early as possible, to be the first to the right play, to be first to the “Sweet Spot” and assist in the optimum development of the resource.
<table>
<thead>
<tr>
<th>Grain Size Range (metric)</th>
<th>Aggregate name (Wentworth Class)</th>
<th>Clay</th>
<th>Silica (Siliciclastic)</th>
<th>Carbonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>256 mm &lt;</td>
<td>Boulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64–256 mm</td>
<td>Cobble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32–64 mm</td>
<td>Very coarse gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16–32 mm</td>
<td>Coarse gravel</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8–16 mm</td>
<td>Medium gravel</td>
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</tr>
<tr>
<td>4–8 mm</td>
<td>Fine gravel</td>
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<tr>
<td>2–4 mm</td>
<td>Very fine gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2 mm</td>
<td>Very coarse sand</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>½–1 mm</td>
<td>Coarse sand</td>
<td></td>
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<tr>
<td>¼–½ mm</td>
<td>Medium sand</td>
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<tr>
<td>125–250 μm</td>
<td>Fine sand</td>
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<tr>
<td>62.5–125 μm</td>
<td>Very fine sand</td>
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</tr>
<tr>
<td>3.90625–62.5 μm</td>
<td>Silt</td>
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<td></td>
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</tr>
<tr>
<td>&lt; 3.90625 μm</td>
<td>SHALE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 μm</td>
<td>Colloid</td>
<td></td>
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</tr>
</tbody>
</table>
Examining Production History of Horizontal vs Vertical Well Performance: WolfBone Case Study, Southern Delaware Basin
Wolfbone Vertical –
- ~1200’ thick.
- 108 MMboe in-place per sq. mile

Avalon –
- ~800’ thick.
- 105 MMboe in-place per sq. mile

<table>
<thead>
<tr>
<th>Period</th>
<th>Unit</th>
<th>~ Depth</th>
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<tr>
<td>Guadalupan</td>
<td>Bell Canyon</td>
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<tr>
<td></td>
<td>Cherry Canyon</td>
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</tr>
<tr>
<td></td>
<td>Brushy Canyon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Avalon Shale</td>
<td>8,800</td>
</tr>
<tr>
<td></td>
<td>Lower Avalon Shale</td>
<td>9,600</td>
</tr>
<tr>
<td></td>
<td>1st Bone Spring Sand</td>
<td>9,850</td>
</tr>
<tr>
<td></td>
<td>2nd Bone Spring Shale Upr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd Bone Spring Shale Lwr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3rd Bone Spring</td>
<td>10,150</td>
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<tr>
<td></td>
<td>Upr Wolfcamp Shale A</td>
<td>10,440</td>
</tr>
<tr>
<td></td>
<td>Upr Wolfcamp Shale B</td>
<td>10,700</td>
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<tr>
<td></td>
<td>Mid Wolfcamp Shale A</td>
<td>10,900</td>
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<td>Mid Wolfcamp Shale B</td>
<td>11,100</td>
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<td></td>
<td>Md Wolfcamp Shale A</td>
<td>11,650</td>
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<tr>
<td></td>
<td>Md Wolfcamp Shale B</td>
<td>12,000</td>
</tr>
<tr>
<td></td>
<td>Md Wolfcamp Sand C</td>
<td>12,250</td>
</tr>
</tbody>
</table>

Stacked Horizontal’s could significantly increase EUR’s

Stacked pay Verticals producing in 3rd Bone - Wolfcamp series
<table>
<thead>
<tr>
<th>Type</th>
<th>Well $</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Mo</th>
<th>EUR</th>
<th>NPV9</th>
<th>D(ROI)</th>
<th>ROI</th>
<th>I(ROR)</th>
<th>Payout</th>
</tr>
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<tbody>
<tr>
<td>Well</td>
<td>($MM)</td>
<td>Prod (BO)</td>
<td>(MBO)</td>
<td>($MM)</td>
<td>I(EFF)</td>
<td>$:$</td>
<td>$:$</td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>V D-F</td>
<td>$3.5</td>
<td>5,000</td>
<td>25</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>V B-C</td>
<td>$3.5</td>
<td>4,000</td>
<td>73</td>
<td>-0.07</td>
<td>0.98</td>
<td>1.16</td>
<td>4.88</td>
<td>6.20</td>
</tr>
<tr>
<td>V A</td>
<td>$3.5</td>
<td>6,500</td>
<td>236</td>
<td>5.27</td>
<td>2.50</td>
<td>4.76</td>
<td>37.45</td>
<td>1.86</td>
</tr>
<tr>
<td>Hrz B</td>
<td>$7.5</td>
<td>10,000</td>
<td>434</td>
<td>11.08</td>
<td>2.47</td>
<td>4.34</td>
<td>37.32</td>
<td>1.91</td>
</tr>
<tr>
<td>Hrz A</td>
<td>$7.5</td>
<td>20,000</td>
<td>722</td>
<td>22.07</td>
<td>3.97</td>
<td>7.97</td>
<td>57.87</td>
<td>1.75</td>
</tr>
<tr>
<td>Hrz A “Best To Date”</td>
<td>$7.5</td>
<td>20,000</td>
<td>268</td>
<td>7.5</td>
<td>2.00</td>
<td>2.31</td>
<td>49.72</td>
<td>1.75</td>
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© Riverford Exploration, LLC, 2012
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<tr>
<th>Type</th>
<th>Well $</th>
<th>EUR</th>
<th>NPV9</th>
<th>D(ROI)</th>
<th>ROI</th>
<th>I(ROR)</th>
<th>Payout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>($MM)</td>
<td>(MBO)</td>
<td>($MM)</td>
<td>I(EFF)</td>
<td>$:$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type Vertical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well</td>
<td>$4.5</td>
<td>180</td>
<td>$3.6</td>
<td>1.80</td>
<td>2.68</td>
<td>24.68%</td>
<td>3.07</td>
</tr>
<tr>
<td>Monroe 28-1</td>
<td>$4.0</td>
<td>257</td>
<td>$8.5</td>
<td>3.11</td>
<td>4.35</td>
<td>67.17%</td>
<td>0.95</td>
</tr>
<tr>
<td>Rawhide (Low D&amp;C$)</td>
<td>$6.0</td>
<td>284</td>
<td>$8.5</td>
<td>2.40</td>
<td>3.26</td>
<td>53.12%</td>
<td>0.95</td>
</tr>
<tr>
<td>Rawhide (High D&amp;C$)</td>
<td>$9.0</td>
<td>284</td>
<td>$5.6</td>
<td>1.62</td>
<td>2.18</td>
<td>25.31%</td>
<td>2.99</td>
</tr>
<tr>
<td>Horizontal</td>
<td>$9.0</td>
<td>627</td>
<td>$26.0</td>
<td>3.87</td>
<td>4.92</td>
<td>100.00%</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Exploration Insight and Input that Changed Organizational Focus, Strategies and Economic Outcomes: Several Resource Play Examples.

Bill Fairhurst
Riverford Exploration, LLC
Frank Reid & Nick Pieracacos

AAPG-STGS Geosciences
4th Annual Eagle Ford Technology Workshop

San Antonio, Texas
March 9 - 11, 2015
Ford County, Kansas

Development of Discrete Traps in the Mississippian Lime
“Identifying the Focal Points in Migration Pathway”
Mississippian Lime Structure Map
C.I. = 100'
C-C' Cross Section: Example Discrete Traps in Pennsylvanian (Morrow) “Mississippian Lime” Traps
Mississippian Productivity - Identified Focus Areas
Iso-Cumulative Production from Vertical Wells

Focus Areas:
Areas of vertical wells averaging greater than 100,000 Bbls/well

Gunsmoke Project Area

Iso-Cumulative EUR Map
C.I. = 20M BO
<table>
<thead>
<tr>
<th>Depth</th>
<th>Formation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1000</td>
<td>Unconformity</td>
<td>Base of the formation</td>
</tr>
<tr>
<td>1000-2000</td>
<td>Limestone</td>
<td>Layer of calcium carbonate</td>
</tr>
<tr>
<td>2000-3000</td>
<td>Sandstone</td>
<td>Sediment formed from sand</td>
</tr>
<tr>
<td>3000-4000</td>
<td>Mudstone</td>
<td>Fine-grained sedimentary rock</td>
</tr>
<tr>
<td>4000-5000</td>
<td>Shale</td>
<td>Clay-rich sedimentary rock</td>
</tr>
<tr>
<td>5000-6000</td>
<td>Coal</td>
<td>Sedimentary rock containing carbon</td>
</tr>
<tr>
<td>6000-7000</td>
<td>Limestone</td>
<td>Another layer of calcium carbonate</td>
</tr>
<tr>
<td>7000-8000</td>
<td>Sandstone</td>
<td>Another sedimentary rock layer</td>
</tr>
<tr>
<td>8000-9000</td>
<td>Mudstone</td>
<td>Another fine-grained sedimentary rock</td>
</tr>
<tr>
<td>9000-10000</td>
<td>Shale</td>
<td>Another clay-rich sedimentary rock</td>
</tr>
</tbody>
</table>

Diagram showing the layers and their corresponding names.
Mississippian Productivity - Identified Focus Areas
Iso-cumulative production of vertical wells

Focus Areas:
Areas of vertical wells averaging greater than 100,000 Bbls/well

Gunsmoke Project Area

Migration Pathway

Iso-Cumulative EUR Map
C.I. = 20M BO
Ford County, Kansas-Structure on Top of Mississipian, Overlain by 2\textsuperscript{nd} order Mississippian Residual

Example of Vertical Reservoirs-C-C’

Sandridge - New Vertical Permits

2\textsuperscript{nd} Order Residual Thick

2\textsuperscript{nd} Order Residual Top of Mississipian Structure Map
Example of Discrete Reservoir Productivity - C-C' - with Cumulative Production/well

Example Wells

Eagle Vertical Permits
C-C’ Cross Section: Example Discrete Traps in Pennsylvanian (Morrow) “Mississippian Lime” Traps

STRATIGRAPHIC X-SEC C-C’
TOP OF VEDIGRIS LIME
7531 FT
C-C’ Production Declines- Typical Vertical Wells
What the Play is not and what it is!

- The Mississippian is not a broad regional source rock. It is a migration pathway sourced from the underlying Woodford shale and laterally long distances.
- The play is not a single zone in the Mississippian. It is definition of discrete traps, likely local unconformities in the Pennsylvanian section.
- Horizontal wells are not the optimal development technique. Vertical wells are highly productive. *(This is an area specific statement; not true for the entire play.)*
- The play is non-commercial for most horizontals and most operators *(again, area specific statement).*
- The play is not hit or miss. It is Mapable!
- Numerous existing vertical wells have a range of production volumes. Mapping of these volumes points to three sub-regional areas where the average well has made in excess of 100,000/bbls. With an average well cost of less than $700,000, verticals in these areas are commercial.
Nuts and Bolts- Where to look?

- Tabulated vertical Mississippian production on county by county basis.
- Contoured Estimated EUR into Iso-Production maps.
- Delineated three distinct areas with EUR greater than 100,000 BO.
- Identified likely migration pathway- porous St. Louis lime.
- Regional truncation of St. Louis sub-crop indicates two re-entrants which funnel migrated hydrocarbon into two focus areas. Each area has numerous wells which average over 100,000 BO EUR.
- Created local structure map, and 2nd order residual isopach of Mississippian lime.
- Locally the average higher EUR wells are located in a band downdip, but along the updip edge of 2nd order residual thicks.
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<table>
<thead>
<tr>
<th>PHASE OF DEVELOPMENT</th>
<th>WHO IS PRIMARY DRIVER IN E&amp;P CO.:</th>
<th>ENTRY COSTS:</th>
<th>INFRASTRUCTURE:</th>
<th>EXAMPLES:</th>
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</thead>
<tbody>
<tr>
<td>EARLY EXPLORATION</td>
<td>GEOLOGIST CONCEPT</td>
<td>$100 / ACRE</td>
<td>EARLY SCOPING OF EXISTING SYSTEMS</td>
<td></td>
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<tr>
<td>LAND ACQUISITION</td>
<td>LAND GEOLOGY</td>
<td>&lt; $1,000 / ACRE</td>
<td>INITIAL PLANNING TO EXPAND EXISTING SYSTEMS</td>
<td>NEVADA, MONTANA, S. TEXAS</td>
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<tr>
<td>EXPLORATION DRILLING</td>
<td>FULL TEAM: ENG, LAND, GEOL</td>
<td>$1,000+ / ACRE</td>
<td>TRUCKING, DEV SYS, TIE EXISTING SYS</td>
<td>UTICA, BUDA, BROWN DENSE</td>
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<tr>
<td>DE-RISKING</td>
<td>FULL TEAM</td>
<td>$5,000 / ACRE + PDP</td>
<td>NEW SYS</td>
<td>TMS, WOLFBONE, N WOODFORD, KS MS LM</td>
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<tr>
<td>EARLY MANUFACTURING</td>
<td>RESERVOIR, DRILLING, OPERATION ENG; GEOL</td>
<td>$5-20,000 / ACRE + PDP, DISC (PDNP, PUD)</td>
<td>EXPANSION &amp; ALTERNATIVES (RAIL)</td>
<td>WOLFBERRY, EAGLE FORD, SCOOP, OK MS LM</td>
</tr>
<tr>
<td>MATURE MANUFACTURING</td>
<td>DRILLING &amp; OPERATION ENG</td>
<td>LAND COST VARIES + PDP, PDNP, DISC (PUD)</td>
<td>DEVELOPMENT OF LONG-TERM PEAK SYSTEMS</td>
<td>BAKKEN, MARCELLUS</td>
</tr>
<tr>
<td>DECLINING</td>
<td>OPERATIOPN ENG, ACCOUNTING, EVENTUALLY LAWYERS</td>
<td>ACREAGE PRICE DECLINING + MATURE PDP</td>
<td></td>
<td>BARNETT, HAYNESVILLE-BOSSIER</td>
</tr>
</tbody>
</table>
E&P Companies

• Small Independents are Pioneers and Early Explorers in New Plays, New Opportunities, and Development of New Fields.

• Mid-Size and Large Independents have the Capital Available and are able to increase production and reserves during early Manufacturing Stages.

• Large Independents and Majors are needed to provide Capital for continued Manufacturing Stage.
E&P Companies

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• Next Stage:
  • Continued Exploration in new plays and de-risking of newly defined plays.
  • Continued Asset Acquisition and
  • M&A
Oil and natural gas companies spending on exploration and development activities increased by 5% in 2013.

Figure 1. Upstream expenditures by category (billion dollars, 2013)


Source: U.S. Energy Information Administration, This Week in Petroleum, normally published Wednesdays after 1:00 pm ET (see...
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