HORIZONTAL DRILLING IN MATURE FIELDS

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TECHNOLOGY
Evolution of Completion Technology

<table>
<thead>
<tr>
<th></th>
<th>Vintage</th>
<th>Area Contacted (Ft²)</th>
<th>Extractable Perm (md)**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Hole</td>
<td>1800s</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Perforating</td>
<td>1920s</td>
<td>500</td>
<td>10</td>
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<tr>
<td>Fracturing</td>
<td>1940s</td>
<td>3,200</td>
<td>1</td>
</tr>
<tr>
<td>Big Fracs</td>
<td>1980s</td>
<td>240,000</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Horizontal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Hole</td>
<td>1980s</td>
<td>8,000</td>
<td>1</td>
</tr>
<tr>
<td>Bi-Wing Fracs</td>
<td>2000</td>
<td>1,200,000</td>
<td>0.001</td>
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<tr>
<td>Complex Fracs</td>
<td>2005</td>
<td>10,000,000</td>
<td>0.00001</td>
</tr>
<tr>
<td>Many-Stage Complex</td>
<td>2009</td>
<td>20,000,000</td>
<td>0.000001</td>
</tr>
</tbody>
</table>

* Normalized to 100' Height, 4,000' Lateral
** Matrix In-Situ Permeability Extractable for Gas and Oil, md = millidarcy.
Horizontal Completions

Port Collar + OH Packer System – Stage 1

Pressure up the hydraulic frac port tool
Liner hanger and open hole packers set
Alternative is swellable packers
1st stage of frac performed on toe of well

George Waters, Schlumberger, SPE Distinguished Lecturer
Horizontal Completions

Port Collar + OH Packer System – Stage 2

A ball is dropped in order to activate the frac port tool and 2nd stage is performed

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Port Collar + OH Packer System – Stage 5

The 5th frac port tool is activated and job is completed

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- Conventional
- Jonah
- Parkman
- Frontier
Short radius ‘frac clouds’
Wyoming Oil & Gas Permits 9/09 – 8/12
Wyoming Gas Permits 9/09 – 8/12
Wyoming
Oil Permits 9/09 – 8/12
Horizontal Permits by County 2012

Top 3 Counties PRB

- Campbell
- Converse
- Laramie
Wyoming Monthly Production
Yearly Gas Production 1978-now
Yearly Oil Production 1978-now
Average MCF Gas per Day on Monthly Basis
Average BBLs Oil per Day on Monthly Basis
Upper Cretaceous
PRB: Total vs Federal Well #s
PRB: Producing vs Idle Well #s
Powder River Basin

![Graph showing total gas Mcf and total oil bbls on monthly basis from 1978 to 2012. The graph indicates a significant increase in gas production starting around 2006.]
Powder River Basin

Barrels/month

Total Oil Bbls
Powder River Basin
Figure 2. Generalized east-west cross section of Powder River Basin showing a west side basin axis. Black Hills monocline is shown in Cretaceous and Paleozoic rocks on east side of basin.
Upper Cretaceous
Mowry Shale (Lower Cretaceous)
PRB Mowry Production: 1978-2011
Mowry vertical producers

grey = USGS Mowry Continuous Oil AU
Frontier (Upper Cretaceous)
PRB Frontier Production: 1978-2011

Does not include Turner or Wall Creek

MCF or BBLs on Yearly Basis

PRB Frontier Oil Production: 1978-2011

Does not include Turner or Wall Creek

BBLS on Yearly Basis


Oil

Goolsby, Finley & Associates, LLC
Success! (between dry holes)

1\textsuperscript{st} long lateral in Wyoming

11/11 – 7/12
181,252 BBLs
186,625 MCF
37,690 BBLs

26 stage completion
Niobrara (Upper Cretaceous)

Outcrop near Douglas, WY

Outcrop in DJ Basin, CO
PRB Niobrara Production: 1978-2011

Goolsby, Finley & Associates, LLC
Shannon (Upper Cretaceous)
PRB Shannon Production: 1978-2011

MCF or BBLs on Yearly Basis

Oil

Gas

Goolsby, Finley & Associates, LLC
green = producers
blue = horizontal wells
red = permits / spuds
grey = USGS Sussex-Shannon Sandstones AU
Bioturbated mudstone and sandstone overlie LRM trough-cross-bedded fine- to medium-grained sandstone
PRB Sussex Production: 1978-2011

![Graph showing PRB Sussex Production from 1978 to 2011, with data points for both oil and gas production on a yearly basis. The graph displays a trend where oil production peaked in 1985, while gas production showed fluctuations with a peak in 1985 as well.](image-url)
Sussex
Vertical Producers

Kaycee
Midwest
Casper
Glenrock
Douglas

grey = USGS Sussex-Shannon Sandstones AU
Parkman (Upper Cretaceous)
PRB Parkman Production: 1978-2011
Parkman
Vertical Producers

grey = USGS Mesaverde-Lewis Sandstones AU
green = producers

blue = horizontal wells

red = permits / spuds

grey = USGS Mesaverde-Lewis Sandstones AU
What does this really mean?