SLIDES: Shale Drilling and Completions

William Fleckenstein
Vertical vs. Horizontal Drilling
## United States Current Rig Count (Baker Hughes)

<table>
<thead>
<tr>
<th>Breakout Information</th>
<th>This Week</th>
<th>+/-</th>
<th>Last Week</th>
<th>+/-</th>
<th>Year Ago</th>
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<tbody>
<tr>
<td>Oil</td>
<td>718</td>
<td>22</td>
<td>696</td>
<td>386</td>
<td>332</td>
</tr>
<tr>
<td>Gas</td>
<td>955</td>
<td>-12</td>
<td>967</td>
<td>221</td>
<td>734</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>10</td>
<td>1</td>
<td>9</td>
<td>-2</td>
<td>12</td>
</tr>
<tr>
<td>Directional</td>
<td>218</td>
<td>-2</td>
<td>220</td>
<td>32</td>
<td>186</td>
</tr>
<tr>
<td>Horizontal</td>
<td>943</td>
<td>24</td>
<td>919</td>
<td>436</td>
<td>507</td>
</tr>
<tr>
<td>Vertical</td>
<td>522</td>
<td>-11</td>
<td>533</td>
<td>137</td>
<td>385</td>
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Drilling Rigs are Different
Why not just a horizontal well?

- **100 ft Vertical well**
  - 160 ft$^2$ of contact
  - 20 x vertical

- **2,000 ft Horizontal well**
  - 3,207 ft$^2$ of contact

- **2,000 ft Horizontal well with 10 x 150 ft fractures**
  - 153,207 ft$^2$ of contact
  - 957 x vertical
  - 48 x horizontal
Demand for more fracs

Vertical vs. HzWell
Comparison of 1st Month Production

IP mmscfd

Vertical Well  HZwell 3 Fracs  HZwell 5 Fracs  HZwell 7 Fracs  HZwell 9 Fracs  HZwell 11 Fracs

K = 0.0001 md
The Reservoir Contact Is Even Better!!

The Marcellus is a fractured reservoir! Note that Jᵢ is more the common fracture and should be the target of production!

Looking WSW
Leroy, New York

Marcellus (Appalachian Plateau, NY)

Photo: Gary Lash
Each Fracture Stimulation Creates a Complex Fracture Network

Figure 1 - Fracture growth and complexity scenarios

(SPE 114173)  
(SPE 119890)  
(SPE 115769)  

Discrete Fracture Network (DFN) Model
Microseismic

- Maps the fracture growth
- Identifies azimuth
- Requires observation well
Microseismic Barnett Shale Horizontal
Prop the Fractures Open
Horizontal Completions with Mechanical Packers

Establish Mechanical Diversion Using Packers

Allow multiple stimulations along horizontal interval
Horizontal Completions
Frac Baffles or Frac Sleeves

Diversion with Expandable Packers
Sleeves are actuated with balls
Coiled Tubing with Sand Plugs
Horizontal Completions
Cemented Perf and Plug

1. Annular Isolation (and diversion accomplished with cement)
2. Frac stages initiated through perforations isolated with bridge plugs
3. Bridge plugs are removed with coiled tubing drilling.
## Size of Fracture Stimulations

### Range Marcellus Shale Fracs

#### Bigger Jobs and Lower Costs – Better Well Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Proppant, lbs.</th>
<th>Water, gallons</th>
<th>Stages</th>
<th>Lateral Length, ft</th>
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<tbody>
<tr>
<td>2006</td>
<td>923,000</td>
<td>2,225,000</td>
<td>3</td>
<td>1,794’</td>
</tr>
<tr>
<td>2007</td>
<td>2,765,000</td>
<td>2,646,000</td>
<td>7</td>
<td>2,198’</td>
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<tr>
<td>2008</td>
<td>3,418,000</td>
<td>3,127,000</td>
<td>8</td>
<td>2,495’</td>
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<tr>
<td>2009 (Short)</td>
<td>3,241,000</td>
<td>3,227,000</td>
<td>8</td>
<td>2,514’</td>
</tr>
<tr>
<td>2009 &amp; 2010 (Long)</td>
<td>5,154,000</td>
<td>3,887,000</td>
<td>10</td>
<td>3,038’</td>
</tr>
</tbody>
</table>
Well Costs (Range Resources)

Marcellus Well Costs

Based upon ~3,000 foot lateral, 10 stage frac and 6 well pad

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Site Preparation</td>
<td>$270,000</td>
</tr>
<tr>
<td>Drilling</td>
<td>1,300,000</td>
</tr>
<tr>
<td>Tubulars</td>
<td>330,000</td>
</tr>
<tr>
<td>Facilities</td>
<td>250,000</td>
</tr>
<tr>
<td>Completion Operations</td>
<td>1,850,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$4,000,000</strong></td>
</tr>
</tbody>
</table>
Lots of Water in “Water Fracs”
Horsepower to pump those water fracs
Protection of Groundwater

Getting a good cement job means:

- Centralization
- Pipe movement and fluid velocity (looking for turbulence)
- Spacer design
- Rheology properties of mud
- Other specific issues to a cement job.