SLIDES: Shale Drilling and Completions

William Fleckenstein

Follow this and additional works at: http://scholar.law.colorado.edu/shale-plays-in-intermountain-west

Part of the Climate Commons, Energy Law Commons, Energy Policy Commons, Environmental Health and Protection Commons, Environmental Law Commons, Environmental Policy Commons, Geotechnical Engineering Commons, Hydraulic Engineering Commons, Natural Resource Economics Commons, Natural Resources and Conservation Commons, Natural Resources Law Commons, Natural Resources Management and Policy Commons, Oil, Gas, and Energy Commons, Oil, Gas, and Mineral Law Commons, Science and Technology Commons, State and Local Government Law Commons, Sustainability Commons, Water Law Commons, and the Water Resource Management Commons

Citation Information
http://scholar.law.colorado.edu/shale-plays-in-intermountain-west/5

Reproduced with permission of the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment (formerly the Natural Resources Law Center) at the University of Colorado Law School.
Shale Drilling and Completions

William Fleckenstein, P.E.
BP Adjunct Professor
Colorado School of Mines
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>
</tr>
</thead>
<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>
</tr>
</tbody>
</table>
Drilling Rigs are Different
Why not just a horizontal well?

100 ft Vertical well
160 ft² of contact
3,207 ft² of contact
20 x vertical

2,000 ft Horizontal well
2,000 ft Horizontal well with 10 x 150 ft fractures
153,207 ft² of contact
957 x vertical
48 x horizontal
Demand for more fracs

Vertical vs. HZWell
Comparison of 1st Month Production

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

The Marcellus is a fractured reservoir! Note that J_{1} is more the common fracture and should be the target of production!

Marcellus (Appalachian Plateau, NY)
Each Fracture Stimulation Creates a Complex Fracture Network

Figure 1 - Fracture growth and complexity scenarios

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 Stimulation

**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>
</tr>
</thead>
<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>
</tr>
<tr>
<td>2008</td>
<td>3,418,000</td>
<td>3,127,000</td>
<td>8</td>
<td>2,495’</td>
</tr>
<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>
## 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>
</tr>
</thead>
<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><strong>Completion Operations</strong></td>
<td><strong>1,850,000</strong></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.