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Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl
Increasing Production with Better Well Placement in Unconventional Shale Reservoirs – Challenges and Solutions

Jason Pitcher

Director, CamShale

Cameron
Presentation Outline

• What happens when you assume the “frac will get it”
• Current Best Practice in North America
• Geomechnical Properties that affect Production
• Using Data through the Life Cycle
  ➢ Drilling
  ➢ Completion
  ➢ Stimulation
  ➢ Production
• Summary and conclusion
What happens when you assume the “frac will get it”

8 Month Cum vs # of Stages (Bull Bayou Field)

Marker by API #
Color by Sweetspot

Yes

Non Core Area

Core Area

Old Problem
Old Solution

Fig. 10 - Frac Finding Costs for Project Wells

Pre-Reservoir Description Usage
Average = $0.21  STD Dev = $0.18

Post-Reservoir Description Usage
Average = $0.10  STD Dev = $0.05

Well List

Frac Finding Costs, $/EUR mcf

1998
Presentation Outline

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  - Drilling
  - Completion
  - Stimulation
  - Production

• Summary and conclusion
Drill an Evaluation Well

- Open Hole Logging
- Coring
  - Characterize the Reservoir
  - Define the Target
- Dfit or MiniFrac
Drill a Horizontal / High Angle Well

- LWD consists of Gamma Ray
- Well is geosteered to stratigraphy
- Pattern match gamma response to offset logs

SPE 152580
Complete the Well

- Equally spaced packers or perf intervals
- Spacing between intervals has been decreasing from 400’ (122m) to as low as 100’ (30m).
Stimulate the Well

- Stimulation Design is a one size fits all approach, iterated on empirical data.
Presentation Outline

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  - Production

• Summary and conclusion
Shale Brittleness Index

Rickman et al. Paper SPE 115258
Rock Mechanics from Sonic

Dynamic Young’s modulus

\[ E_D = \rho \frac{(4 - 3 \frac{\Delta t_s^2}{\Delta t_c^2})}{\Delta t_s^2 (1 - \frac{\Delta t_s^2}{\Delta t_c^2})} \]

Mullen et al. SPE 108139

Poisson’s ratio

\[ \mu = \frac{2 - \Delta t_s^2 / \Delta t_c^2}{2 * (1 - \frac{\Delta t_s^2}{\Delta t_c^2})} \]

Convert to Static:

\[ E_s = E_D * (0.8 - \Phi_{Total}) \]

Brittleness Index:

\[ BRIT = \frac{E_s \text{(brit)}}{2} + \mu \text{(brit)} \]

Rickman et al. SPE 115258
For Anisotropic Media:

\[
BRIT = \left[ \frac{100(E_v - E_{v_{\text{min}}})}{(E_{v_{\text{max}}} - E_{v_{\text{min}}})} + \frac{100(\mu_v - \mu_{v_{\text{max}}})}{(\mu_{v_{\text{min}}} - \mu_{v_{\text{max}}})} \right] / 2
\]

\[
TIV_{\text{ratio}} = \frac{DTS_{\text{slow}}}{DTS_{\text{fast}}}
\]

\[
\text{Frac}_{\text{index}} = \frac{BRIT_{\text{index}}}{TIV_{\text{ratio}}}
\]


Buller, D. et al. 2010 SPE 132990 Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells
Brittleness Index vs Gas Production

Post Frac Production Log – day 45, well flowing 9MM

Frac Results

Near WellBore Region 3’ (1m)

Higher Clay Interval

Lower Clay Interval

Buller, D. et al. 2010 SPE 132990
Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells
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• Summary and conclusion
Haynesville #1

Buller, D. et al. 2010 SPE 132990
Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells
Haynesville #2

Buller, D. et al. 2010 SPE 132990
Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells
Haynesville #1 – 9 of 10 Water Fracs Placed – PL rate 8.2 MMCF/D

Haynesville #2 – 6 of 10 Fracs Placed > 50% – PL rate 4.5 MMCF/D
Horizontal Cased Hole Pulsed Neutron Log – Haynesville Shale

Brittleness Index, Fracture Ease, Effective Porosity, Free Gas, & TOC

CHI Model Triple Combo Data

Horizontal In & Out of Primary Target Interval
Horizontal Cased Hole Pulsed Neutron Log – Haynesville Shale

Evenly spaced stages

Unevenly spaced stages
### Haynesville #2

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<th>Prop</th>
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<td>100%</td>
<td>3%</td>
<td>55.4%</td>
<td>35%</td>
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![Graph showing various data points and trends related to the Haynesville #2 well.](image-url)
### Haynesville #2

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Shale Completion Strategy: Based on Formation Brittleness Index

<table>
<thead>
<tr>
<th>Youngs Modulus</th>
<th>Brittleness</th>
<th>Fluid System</th>
<th>Proppant Concentration</th>
<th>Fluid Volume</th>
<th>Proppant Volume</th>
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</thead>
<tbody>
<tr>
<td>7 E 6</td>
<td>70%</td>
<td>Slick Water</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
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<tr>
<td>6 E 6</td>
<td>60%</td>
<td>Slick Water</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5 E 6</td>
<td>50%</td>
<td>Hybrid</td>
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<td></td>
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<td>4 E 6</td>
<td>40%</td>
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<tr>
<td>1 E 6</td>
<td>10%</td>
<td>X-Linked</td>
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</tr>
</tbody>
</table>

Brittleness Fluid System

- 70% Slick Water
- 60% Slick Water
- 50% Hybrid
- 40% Hybrid
- 30% X-Linked
- 20% X-Linked
- 10% X-Linked

SPE 115258
Shale Stimulation Strategy

Summary and Conclusion

• Shale reservoirs are statistical plays
  ✓ Current Practice has limitations

• Well placement strategy dictated by geomechanics

• Geosteering enhances production by maximizing fracable reservoir contact

• Data acquired while drilling has a long shelf life
  ✓ Data used in completion and stimulation optimization
Thank You
Спасибо
Gracias
 Merci
谢谢 你
Grazie
Takk
 شكراً جزيلاً
Sağol
 ありがとう
Obrigado

Jason Pitcher
Director, CamShale
Cameron
Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation:

Click on: Section Evaluation