Outline

- Why/When do we Recommend Refracs?
- Refrac Candidate Selection
- Pilot Testing Results
- Bakken Refrac Campaign Results
- Conclusions
Why Refrac?

**Parent Well Refrac**
- Unbounded existing producer(s)
- New drill offsets
- Protect & revitalize parent well
- Prevent fracture asymmetry on child wells

**Pad Unit Refrac**
- No future development
- All wells producing
- Improve over legacy completion design

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Infill development with single-well producer

Fully developed 4MB x 4TF unit
Surprise, Surprise…

Pressure Communication

- Larger pressure communication toward depleted wells
- Shorter fractures in virgin rock

Microseismic

- Significant activity toward depleted wells
- Fewer events on immediate child wells

Chemical Tracers

- Large early-time communication toward depleted wells
- Direct fluid communication

Consistent evidence of subpar performance of child wells next to depleted wells (w/o re-stimulation)
Parent Well Refrac Objectives

- **Improve Child Wells**
  - Limit asymmetric fracture propagation
  - Limit Three Forks-to-Middle Bakken communication

- **Improve Parent Well**
  - Re-energize existing fractures
  - Contact new reservoir rock

- **Lower Ops. Costs**
  - Best cost opportunity to execute refrac

- **Protect Parent Well**
  - Avoid excessive sand/water loading in wellbore
### Refrac Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>Pump and Pray</strong></td>
<td>No downhole intervention, cost efficient, Poor lateral coverage, Ineffective fracture creation</td>
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<tr>
<td><strong>Mechanical Isolation</strong></td>
<td>Risky, Expensive, Questionable deployment for legacy open-hole swellpackers design</td>
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<tr>
<td><strong>Chemical Diversion</strong></td>
<td>No downhole intervention, less risk, Cost efficient, Acceptable lateral coverage?</td>
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Candidate Selection

Well Integrity
- Pressure test, PBR length, tie-back install, CBL/TOC

Reservoir
- Child well setup, depletion timing, inter-well communication

Financial
- Uplift required to justify investment, ops risks

Understand and manage risks to select suitable candidates.
First Refrac Pilots

- First two refracs in Aug. 2016 in Williams County
- Wells selected as parent wells in unit to be fully developed
- Initial completion and well design representative of the legacy design pre-2014
  - Uncemented liners with 34 PnP stages
  - Legacy 4 MMlb proppant, 70 Mbb1 fluid design
  - On production since 2011/2012 with total fluid (i.e. oil + water) volume >500 Mbb1 per well before refrac
- Extensive diagnostic deployment
Refrac Pilots – Operations

Refrac Design – Parent Wells
- Complete both re-fracs first
- Low-rate pre-fill
- Bull-head stimulation treatment
  - 15 MMlb sand, 70 Mbb1 fluid, vendor diversion material

Frac Design – Child Wells
- Complete immediate offsets to parent well first
- Three Forks: 6 MMlb sand & 130 Mbb1 fluid
- Bakken: 6 MMlb sand & 200 Mbb1 fluid
Refrac Pilots – Diagnostics

**Surface & Downhole Microseismic**
- Lateral coverage during re-frac
- Fracture overlap between wells
- Fracture asymmetry and height growth

**Pressure Monitoring**
- Fracture overlap near the heel
- Indication of fracture asymmetry

**Chemical Tracers**
- Fluid communication during early production
- Constraints to microseismic results
Refrac Pilots – Operations

Pre-Fill Injection

- Managed to re-pressurize the well at 95% of the initial ISIP within the target volume and rate
- Low-rate pre-fill improves subsequent re-frac lateral coverage

Refrac Design

- Frequent small-volume diversion pills
- Adequate fluid viscosity to improve proppant transport
- Low proppant concentration
- Maintain rate as high as possible without interruption
Surface Microseismic Data

Key Observations

- Possible to stimulate >75% lateral with diversion job in un-cemented well (10,000-ft lateral)
- Lateral coverage shrinks over time
- Results confirmed in subsequent Microseismic survey

2700 stations in 70-ft intervals

Well A  Well B

10,000-ft wells 600-ft spacing
Parent Well Production

- Refracs demonstrated substantial EUR uplift (+35% range)
- Initial rate improvement over 5x pre-refrac with sustained pressure support
- Refracs were economical by themselves (i.e., w/o including potential benefits on child wells)
Limiting Asymmetry on Child Wells

Key Observations

- Observed severe fracture asymmetry toward parent wells w/o parent well re-stimulation
- Refrac lessened asymmetry toward depleted well
- Refrac contributed to better fracture placement, and therefore better production of child wells
Child Well Production

- Thanks to parent well refrac, production of child wells immediately next to parent well is consistent with the average well performance in the area.
- Production loss >25% is common for immediate child wells otherwise.

Cum Oil (MBO) vs. Month

- Region Type Curve
- Immediate Child wells
- New wells away from parent

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- Region Type Curve
- Immediate Child wells
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w/ parent well refrac

w/o parent well re-stimulation
Bakken Refrac Campaign to Date

- 12 refracs successfully pumped to date
  - Uncemented liner wells with >30 stages
  - Initial completion with >3MMlb proppant
- >10 more refracs planned in next 6 months
- Refracs executed in Williams, McKenzie, and Mountrail counties
- 1 instance where decided to cancel refrac operations due to mechanical issue during well prep
- Several instances where project approval was challenged by non-consenting partners
**Operational Learnings**

<table>
<thead>
<tr>
<th>Well Prep</th>
<th>Depletion Timing</th>
<th>Logistics</th>
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<tbody>
<tr>
<td>Pre-frac pressure test</td>
<td>Well on vacuum ahead of prep</td>
<td>Continuous frac operations are important to maintain lateral coverage</td>
</tr>
<tr>
<td>Tie-back install</td>
<td>Identifying when/where depletion is too important and cannot be overcome</td>
<td>Supply chain optimization</td>
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<tr>
<td>Pre- and/or post- clean-out run(s)</td>
<td>Understand connectivity to other wells</td>
<td>AL method to handle higher water cut</td>
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Understanding and mitigating risks to manage large-scale implementation
Conclusions

1. Refracs lessen the negative impact of asymmetrical fracture growth around depleted wells
2. Refracs can be economical by themselves
3. Diversion strategy works even without mechanical isolation
4. Currently deploying parent well refrac strategy at large scale
5. Engage well partners early to gain approval
Re-Stimulation Strategy - Bakken Field Study
Ashley Thoma & Lionel Ribeiro

Thank you