Restimulating the Bakken

What have we learned?

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SDSM, Oct 7-9, 2010

Background

Recent attempts to history-match field production:

• SPE 119143 – summary of 200 published field trials in which initial frac designs were altered
• SPE 134330 – summary of 143 published reports of the outcome of refrac attempts (worldwide)
• SPE 136757 – evaluation of ~ 100 Bakken refracs

• There are many surprising results that are difficult to explain with traditional models
Introduction

My Definition of Refrac
• A second propped fracture treatment
• Also tri-fracs, quads-, and “cinco-de-fraco” restimulations
• I have excluded a large dataset where propped fracs improve previous acidized or unpropped initial treatments

Goals of Current Research
• Identify restimulation opportunities
• Improve initial designs
• Understand fracture and refrac mechanisms
• Improve production models and frac models

Outline

General Industry Findings
• Why do refracs work?
• Why do refracs fail?

Bakken Refracs – Horizontal Wells
• Previously Published
• Research
  – Operator data, interviews, etc.
  – Press releases (public data)
  – Other refracs I have recorded (public data)

Interpretation and Recommendations
Where Have Refracs Worked?

Well Types
- Oil Wells (under primary depletion, waterflood, or EOR)
- Condensate Wells
- Gas Wells
- Gas Storage Wells
- Water Production Wells
- Water Injection Wells
- Steam Injection Wells
- Huff-n-Puff, cyclic injection/withdrawal Wells
- Disposal Wells

Formation Types
- Carbonates, limestones, dolomites, chalks, evaporites
- Sandstones, cherts, siliceous diatomites
- Coal (CBM), immature ductile shales, brittle shales
- Conglomerates, unconsolidated formations, siltstones

16-page Appendix is attached to SPE 134330 describing all field examples

Why Do Refracs Work? (mechanisms)

Refrac success (worldwide) has been attributed to:

- Enlarged frac (more reservoir contact)
  - Improved pay coverage (add pay in vertical wells)
  - Better lateral coverage (horizontal wells)
- Increased frac conductivity
  - Restore conductivity lost – frac degradation
  - Address unpropped/poorly propped portions
- Reorientation
- Use of more suitable frac fluids
- Re-energizing natural fissures
- Other mechanisms

I believe several of these mechanisms are in play in Bakken refracs
Why Do Refracs Fail? (poorer candidates)

Refrac failure (worldwide) often attributed to:

• Low pressure
  – depleted wells (limited remaining gas reserves)
  – poor recovery of frac fluids
• Diagnostics indicated drainage to reservoir boundaries
• Undesirable existing perforations
• Poor mechanical integrity
• Poor wells often make poorest refrac candidates
  – Unless initial frac was poorly designed or implemented

In the Bakken, we’ve identified new ways to screw up refracs! And new opportunities!

Bakken Caveats & Considerations

– Wide variety of well configurations
  • Single
  • Multilateral
– Wide variety of completion styles
  • Barefoot openhole
  • Cemented
  • Non-isolated preperforated liner
  • Plug and Perf
  • Frac ports / ball activated sleeves
– Wide variety of initial frac designs
  • Non-isolated “pump and pray”
  • Isolation of specific laterals or specific stages with ECP
  • Slickwater/gel
  • Sand/resin/ceramic. 100-mesh, 40/70, 30/50, 20/40, 16/20, 12/18
  • Various extent of overdisplacement
**Horizontal Well Refrac Goals**

(Shah, 2010: 128612)

**Transverse Fractures**
- Limited intersection between transverse frac and wellbore.
- Necessitates:
  - More entry points (diversion/stages/initiate more fracs?)
  - Wider fracs (higher proppant concentrations?)
  - Better proppant?
  - Concern with overdisplacement?

**Longitudinal Fracture**
- Enormous intersection between longitudinal frac and wellbore.
- Minimal conductivity needs
  - Attempt to extend frac length beyond lateral length?
  - Attempt to grow height to cover Three Forks/Bakken package?
  - Improve coverage to contact additional natural fissures?

**Bakken Refracs** (Lantz, 2007: 108117)
- Montana, cemented laterals believed drilled for longitudinal growth
- Initial fracs ~300,000 lb 20/40 RCS
- RA tracer showed incomplete coverage
- Add perfs, refrac 600,000 lb 20/40 sand, 10 ppg slugs, ball sealers

**Observations:**
- Can refrac into new rock from cemented wellbores
- Lower breakdown pressures, but 50% greater net pressure
- Oil rates up, GORs down
- Refracs diverted into undrained areas of the reservoir
- EUR increased 1,300,000 bbls in 16 refractured wellbores
- 1 mechanical problem, but 16 of 17 successful (94%)
Bakken Refracs (Dunek, 2009: 115826)

- Uncemented liner. N-S oriented lateral. Surface tiltmeter mapping
- Unintentional termination of frac job (wellhead isolation tool failure)
  - 3892 bbl crosslinked fluid and 296,000 lb proppant at 48 bpm
- 2nd stimulation treatment 6 weeks later
  - 6533 bbl slickwater and 193,000 lb proppant at 61 bpm

Transverse: 45% toe, mid
Longitudinal: 35%
Horizontal: 20%

Observations:
- Diversion/Initiation at new locations
- Both Transverse and Longitudinal Growth

Bakken Refracs (Eberhard, 2008: WBPC)

Cemented laterals initially treated with sand/RCS

- Reperf/jet new entry points
- Diversion slugs
- 100% success rate
  - 30 days prior – 46 bopd
  - 30 days post refrac – 144 bopd

Uncemented Liners initially treated with sand/RCS

- Retreat existing perfs
- 87% success rate (27 wells)
  - 30 days prior – 64 bopd
  - 30 days post refrac – 122 bopd

Observations:
- Adding entry points helps.
  - Initial cemented laterals failed to drain all rock
  - Bakken wells frac’ed with sand usually benefit from refrac (~90% of time)
**Bakken Refracs** (Besler 2007/2008, SPE 110679 + 2008 WBPC)

Bakken wells initially stimulated with ceramic

- Only ~50% success rate with refracs using ceramic
  - Refrac success appears to correlate with wells in which RA tracer indicated poor diversion
  - In pre-refrac cleanouts, only minimal quantities of ceramic proppant recovered from wellbore

**Observations:**

Less need to refrac if wells treated with ceramic? Perhaps due to reduced proppant flowback or better durability?

- Besler: “Too often, refracs are needed due to poor initial design or implementation”
- Argued prevention may be less expensive than cure

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**Confidential Operators - Clarification**

- Several operators will be referred to as “Operator A” through “Operator H” to mask their identity
- This following slides do NOT contain all wells restimulated in the Bakken – I am under a confidentiality agreement with several additional operators and cannot disclose their work.
Operator H

- Does not pursue multi-stage fracs
- Believes single stage initial treatments followed by single stage refracs provide similar EUR to multi-stage initial treatments

Results:

- Well cost with single-stage frac = $4.2 million
  - EUR 280,000 boe
- Refrac after 12 months = $300,000
  - Incremental EUR 70,000 boe
- Multi-stage initial completion $5.2 million achieves similar EUR of 350,000 boe without refrac

Observations:
- Plan for restimulation?!

Bakken Refracs (Phillips 2007 SPE 108045)

Bakken wells initially stimulated with ceramic and XLG

- Showed 1st month benefit refracturing with sand/slickwater

<table>
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<th>Well Name</th>
<th>30-Day Average (Post-Frac 1)</th>
<th>30-Day Average (Pre-Frac 2)</th>
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<tr>
<td>XL6</td>
<td>152</td>
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**Bakken Refracs (Operator B)**

- 3 Wells initially stimulated with 20/40 ceramic in XLG
- Restimulated 13-39 months later with >200,000 lb 30/50 or 40/70 Ottawa (much information unavailable via public data)
- 2 of 3 wells subsequently TA, but did give short term benefit.

**Bakken Refracs (Operator C)**

- 2 wells initially stimulated with sand > 1,000,000 lbs (staged)
- Restimulated 8-11 months later, slickwater with 100,000 lb 30/50 LWC (bullhead; overflushed)

Limited data, but:
100,000 lb ELWC refracs in slickwater diagnostic plots similar/superior to initial fracs
Saskatchewan Bakken Refracs

- 9 refracs identified in Viewfield area
- 8 initially completed barefoot with 7-8 stages coiled tubing
- 8 recompleted uncemented, ball activated sliding sleeves
- 1 recompleted-cemented liner, abrasive jet, annular refrac
- All 9 show oil increase. Watercut down in 7 of 9 refracs!

Observations on this well
- Oil increased from ~25 to ~140 bopd
- Water decreased from ~250 to <100 bwpd!
- GOR temporarily dropped

Interviews, Operators D, E, & F

Offset Wells [Montana and North Dakota]
- With uncontrolled fracs/refracs, often frac into offset wellbores
  - Some beneficial to offset
  - Some damaging to offset
- Some operators shut in offsets, some “frac protect” by pumping in

Pre-Refrac Cleanouts
- Can recover >300,000 lbs of frac sand!
  - [enough to fill 15,000 ft of 6” hole; over 50% of initial frac sand!]
- Some wells have been cleaned out multiple times and continuously produce frac sand into wellbore
- Pre-refrac sand cleanouts improve refrac success
- Cleanouts of multi-lats can cost $500,000, similar to refrac cost
- Pre-refrac cleanouts of wells treated with ceramic have rarely returned much ceramic proppant [see 110679, 134595, 90604 for info]
Recent Refracs, Operator G

Description
- 9 Refracs in 2009 and early 2010
- 4 in Montana, 5 in North Dakota
- 8 with pre-refrac cleanouts
- 2 duals, 7 triple laterals all preperforated liners
- All initially frac’ed with sand

Success Rate
- 8 of 9 refracs economic (89%).
- 1 refrac damaged production

2009 Refracs, Wells R1 – R5

![Graph showing cumulative oil production and days on production for wells R1 to R5 with refracs marked.](image-url)
**Operator G**

Claims these are traits of Good Refrac Candidates:

- Wells with sand in wellbore
- Wells with inclining GORs
- Wells that were initially single stage or “pump and pray” completions
- Wells that initially relied on fiber for sand transport
- Wells that were understimulated (ie 25 lb/ft lateral -> 200 lb/ft)

Topics omitted due to time limits:

- data from stand-alone cleanouts,
- sand mass removed,
- frac protect,
- other operators,
- running liners with ECP into barefoot wells for refracturing,
- diagnostic plot interpretation,
- many details and specific examples Some of these in SPE 136757
Findings, Opinions, and Ideas

- Refracs can clearly add reserves in the Bakken
  - Some via diversion/reorientation (touch new rock - reduced GOR)
  - Some via another mechanism (increased rate at same or >GOR)
- Proppant flowback is a concern
  - Pumps, frac closure, expense to cleanout
  - Unacceptable to have 300,000 lb sand in wellbore!
- Wells full of frac sand are candidates to cleanout & refrac
  - Was sand never placed or flowed back? Refrac candidates regardless!
  - Don’t refrac a wellbore if already full of sand! [cleanout first]
- Secondary cleanouts have rarely returned ceramic and may not be justified [see 110679, 134595, 90604 for info]
- Fracture/proppant durability is an issue and more frequent refracs appear to be needed with lower strength proppant
- Complex frac geometry (transverse, longitudinal, and hz)

Findings, Opinions, and Ideas

- I prefer to invest more money in initial completion instead of planning to refrac
- Most Bakken fracs have transverse component
  - Flow convergence: more stages, better proppant, higher concentrations!
- When offset wells are improved by “bashing”, this is evidence of inadequate frac continuity/conductivity [SPE 119143]
- Failure to sustain Bakken-Three Forks connection points to loss of conductivity
- Refracturing wells stimulated with sand-up to 90% success
  - Some operators Bakken refrac success has declined to <60%
- Refracturing wells initially stimulated with ceramic has lower frequency of success (but several compelling examples are known)
  - Suggests: transverse elements, prop durability, and flowback resistance
Findings, Opinions, and Ideas

- Bullhead refracs have worked, but also have damaged previously some staged initial treatments
  - Can we design wells that can be easily isolated and refraced?
- Use diversion or more stages to achieve multiple shorter transverse fracs instead of fewer long transverse fracs.
  - Add entry points when feasible
  - If not feasible, diversion efforts are recommended
  - If no isolation – perhaps frac/close/refrac/close/trifrac, etc?
- Overdisplacing jobs has been successful in most cases, but detrimental in others.
  - Avoid where possible, or consider “sacrificial” entry points or additional clusters per stage
- I screenout stages where operationally feasible
  - Are screenout stages immune from damage w/ future bullhead refracs or c/o?
- Oil recovery ~2% to 8% of OOIP? A big target remains!

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When are Refracs Beneficial?

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