Prevention of Parent Well Damage due to Offset Frac Communication

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Agenda

• Example of parent well damage
• Confirmation of damage through analytics
• Data gathering to identify and understand damage mechanisms
• Canbriam’s mitigation strategy
• Recent results
What is a parent well?

Parent well: initial well(s) completed
Child well: subsequent well completed offsetting parent well
c-27-H: what is parent well damage?

1) August 2012: Production Commenced (9bcf EUR)
2) July 2015: Hit by c-17-H frac operations
3) October 2015: Resumed Production at 800 mcf/d
4) July 2016: Hit by c-27-H frac operations in July 2016
5) Sept 2016: Milled out BPs to address potential wellbore restriction
6) December 2016: Installed gas lift to address high WGR
Quantifying Damage with Pressure Transient Analysis

- Performed Flow & Build up in 2017:
  - Initial flow period, followed by 52 day shut-in, and second flow period to evaluate offset communication

- Did see some offset communication but concluded not to be the cause of production loss in parent well

- Reservoir pressure estimated to be between 23.8 and 25.2 MPa, depending on model used
Quantifying Damage with PTA

- Unstimulated horizontal well (model 1)
  - Pre-frac communication rate transient analysis yields $k_1 = 9.17 \times 10^{-3} \text{mD}$
  - Non-unique solutions, but supports theory of near-wellbore damage
  - Not depletion or interference, there is a clear reduction in inflow performance in the damaged parent well

- Multi-stage horizontal well (model 2)
  - Parameter | Value
    - Reservoir Pressure ($P_i$) | 23,859 kPa
    - $k_h$ | 0.0038 mD
    - $k_v$ | $8.53 \times 10^{-5}$ mD
    - Well Length | 1920 m
    - Drainage Area | 38.4 ha
    - Skin Factor | 3.8

- Parameter | Value
  - Reservoir Pressure ($P_i$) | 25,200 kPa
  - FCD | 60
  - $x_f$ | 82 m
  - Enhanced Per ($k_1$) | $2.30 \times 10^{-5}$ mD
  - Matrix Perm ($k_2$) | $1.03 \times 10^{-4}$ mD
  - Well Length | 1920 m
  - Drainage Area | 38.4 ha
## Potential Sources of Damage

<table>
<thead>
<tr>
<th>Damage Mechanism</th>
<th>Data and Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphaltenes/Hydrocarbons</td>
<td>Recovered heavy-end hydrocarbon sample from c-44-H wells after being hit by offset frac</td>
</tr>
<tr>
<td>Iron Deposition/Incompatibility</td>
<td>XRD and XRF of flowback samples indicate presence of Fe related compounds</td>
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<tr>
<td>Emulsions</td>
<td>Have seen emulsions on flowback on wells with high salinity frac fluid</td>
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<tr>
<td>Proppant Crushing/Redistribution</td>
<td>Have recovered crushed sand on flowback of wells hit by fracs</td>
</tr>
<tr>
<td>Halite</td>
<td>Recovered halite from c-23-H sand separator</td>
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<tr>
<td>Fines Migration</td>
<td>Minor amounts of clay, crushed sand, and spalling minerals</td>
</tr>
<tr>
<td>Scaling (CaCO3)</td>
<td>Laboratory testing showing minor scaling tendency</td>
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</tbody>
</table>
Sample and Data Gathering

Gas Chromatography

XRD & XRF

Microscope

Silica (proppant) 50%

Heavy-end Hydrocarbons 30%

Formation Fines 20%

Wellbore debris sample from parent well
Analysis of Heavy-end Hydrocarbon Component

Wellbore debris sample from parent well

- Gas Chromatography
- XRD & XRF
- Microscope

- Heavy-end Hydrocarbons: 30%
- Silica (proppant): 50%
- Formation Fines: 20%
Hydrocarbon Sample from Damaged Parent Well

Mole %

Produced Condensate
Wellbore Debris
In the summer of 2017, similar plant solids found throughout gas plant (condensate and water streams) had not been seen in previous 3 years of plant operations. Leading up to the plant issues, changes were made to production chemical program. The formation of the plant solids was a result of hydrocarbon insolubility in new production chemicals. Switched back to previous production chemical and issue at the plant has been resolved. Provided important data to validate a source of parent well damage.
Hydrocarbon analysis of plant solids

- Produced Condensate
- Wellbore Debris
- Plant Solids

Mole %
Heavy-end Hydrocarbon Deposition

- Heavy-end hydrocarbons recovered at various points (from wellbore through gas plant)
- Likely being deposited in reservoir and proppant pack (P,T variation)
- Insoluble in produced condensate at 73°C, but soluble in aromatics
- Accumulation of heavy-end hydrocarbons likely contributing to inflow impairment in parent wells
- Frac hits likely resulting in further accumulation near wellbore (SRV)
Analysis of Formation Fines

Wellbore debris sample from parent well

- Gas Chromatography
- XRD & XRF
- Microscope

- Silica (proppant) 50%
- Heavy-end Hydrocarbons 30%
- Formation Fines 20%
XRD, XRF and SEM performed on insoluble portion of wellbore sample

Results of XRD/XRF indicate ~70% silica (frac sand), ~15% halite, and ~15% iron oxide (varies depending on sample point)

A sample of the insoluble portion was also placed in 15% HCl

The color of the acid solution turned into yellow indicating iron compound present in the solids

The acid was analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES) to determine the metals which dissolved during the acid soak

Iron (288 mg/L), calcium (223 mg/L), and phosphate (48 mg/L) were all present in significant concentrations indicating they came from the solid

Although produced water is only 80ppm iron, and formation is 2-4% FeS, iron represents an abnormally high component of samples take from damaged parent wells (over 100 samples analyzed in 2016-2017)
Analysis of Proppant

Gas Chromatography

XRD & XRF

Microscope

Silica (proppant) 50%

Heavy-end Hydrocarbons 30%

Formation Fines 20%

Wellbore debris sample from parent well
Analysis of Proppant

- 50% of initial sample (by mass) composed of frac sand
- Based upon sieve analysis, appears to be predominantly 40/70 proppant
- Typical pump schedule is 25% - 40/70 lead, 65% - 30/50, and 10% resin tail
- 15-20% of sand was crushed, which can significantly reduce fracture conductivity
- Supports proppant crushing and proppant pack disturbance as sources of potential inflow impairment
- Frac hits likely causing cyclic stress on proppant pack which promotes crushing and proppant pack disturbance
Understanding Damage Mechanisms

1. Heavy-end hydrocarbons
   - Samples recovered at various stages of production and processing point to deposition of heavy-end hydrocarbons
   - Frac hits likely to cause accumulation of heavy hydrocarbons near wellbore
   - Over time, the problem becomes more pronounced

2. Formation fines
   - Laboratory analysis points to iron as common component of samples suspected to be related to parent well damage
   - Iron components acting as nucleation sites for heavy hydrocarbon
   - Water chemistry and quality is critical to mitigating parent well damage
   - Over time, the problem becomes more pronounced

3. Proppant
   - Cyclic stress on proppant pack promotes crushing and proppant pack disturbance
   - Reduction in fracture conductivity is further compounded by formation fines and heavy hydrocarbon accumulation
   - Over time, the problem becomes more pronounced
Canbriam’s Strategy

When time is on your side...

- Field development planning (scheduling) is critical
- Eliminate or minimize parent/child well interaction
- Minimize time between parent and child wells

We don’t always have time on our side...

- Gather data and samples, and work across disciplines
- Understand when and where frac communication will occur
- Need to identify and understand damage mechanisms

Scheduling is the preferred option, but not the only option...

- Protection pump-ins can minimize proppant disturbance, cyclic stresses, and accumulation of fines near wellbore
- Understand your water chemistry and quality
- Understand when to shut-in wells prior to offset frac operations
- Do not clean up a parent well before a child well
**Parent Well Protection**

- Shut-in parent well to allow near wellbore to “pressure up”

- Pump 400m3 of fresh water into parent well (with iron control, clay control, flowback enhancer)

- Pump high pressure gas to maintain pressure in wellbore

- Pressure maintenance is intended to help reduce the impact of offset fracs and reduce cyclic stress on proppant pack during frac communication

- Minimizing cyclic stress should help reduce proppant crushing and frac pack damage

- Gas injection should energize near wellbore and assist in parent well flowback

- Pump low-iron, low TSS produced water as base fluid in child wells, with optimized frac chemistry

- Clean-up child wells before parent wells
What does a protection pump-in look like?

1. Frac hits without protection pump-ins (up to 15,000 kPa pressure cycles)
2. Execution of protection pump-in (water and HP gas)
3. HP gas injection to maintain pressure
Pre and post frac communication well performance

- 5 child wells completed in Q3 2017
- 13 parent wells hit by offset fracs with mitigation (shown in green)
- 1000e3m3/d pre-frac gas production from parent wells
- 1020e3m3/d post-frac gas production from parent wells
- Pre-frac gas rates (tied to well vintage) ranged from 12 to 134 e3m3
Thank you to the Canbriam team

Questions?