Wellbore Interconnectivity at FORGE

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September 19th, 2023
Timeline

• Completed **drilling well** 16A(78)-32 in December **2020**

• Conducted three stage **stimulation** in **well 16A(78)-32** in April **2022**

• Completed **drilling** production **well 16B(78)-32** into microseismic cloud of the stimulations in June **2023**

• Conducted **circulation tests** and **demonstrated the connection** between 16A(78)-32 and 16B(78)-32 in July **2023**
Background

Three stages of stimulation near the toe of the injection well 16A(78)-32

<table>
<thead>
<tr>
<th>Stage No.</th>
<th>Treating fluid</th>
<th>Maximum pumping rate (bpm)</th>
<th>Pumped volume (bbl)</th>
<th>Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slickwater</td>
<td>50</td>
<td>4261</td>
<td>Openhole</td>
</tr>
<tr>
<td>2</td>
<td>Slickwater</td>
<td>35</td>
<td>2777</td>
<td>Cased</td>
</tr>
<tr>
<td>3</td>
<td>Crosslink gel</td>
<td>35</td>
<td>3016</td>
<td>Cased</td>
</tr>
</tbody>
</table>

Field stimulation microseismicity
Hari Neupane at INL using Leapfrog Geothermal
• **Hydraulic stimulation** in the injection well 16A(78)-32 in April 2022 (~10,000 bbl injected in total) created a **fracture network**, combination of newly created fractures and natural fractures

• **Production well** 16B(78)-32 was **drilled** to the **microseismic clouds** from the stimulation

• **Connection** between wells 16A(78)-32 and 16B(78)-32 can be **demonstrated by circulation test** through pressure response and fluid communication

after Neupane, 2023
Circulation Tests Description

<table>
<thead>
<tr>
<th>Well 16A</th>
<th>Well 16B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Openhole completion</td>
<td>Cased completion</td>
</tr>
<tr>
<td>200 ft openhole</td>
<td>700 ft openhole</td>
</tr>
</tbody>
</table>

### Circulation test 1
**July 4<sup>th</sup> and 5<sup>th</sup> 2023**

- **Injected volume**: 3300 bbl
- **Maximum pumping rate**: 5 bpm
- **Maximum surface pressure**: 4665 psi

### Circulation test 2
**July 18<sup>th</sup> and 19<sup>th</sup> 2023**

- **Injected volume**: 4450 bbl
- **Maximum pumping rate**: 7.5 bpm
- **Maximum surface pressure**: 4530 psi
Circulation Test 1

- Pressure change in Well 16B(78)-32 shows the connection
- Pressure response in Well 16B(78)-32 – 40-minute delay on July 4th and 5-minute delay on July 5th circulation

Curve change at 13:25

Keep 200 psi back pressure

Slope change at 10:32 a.m.

Close the valve

Pressure response at 14:05, about 40-minute delay

Close throttling valve overnight

Keep 100 psi back pressure

Pressure rise at 10:37 a.m., only 5 minutes delay

Cycling

Pressure change in Well 16B(78)-32 shows the connection

Pressure response in Well 16B(78)-32 – 40-minute delay on July 4th and 5-minute delay on July 5th circulation
Circulation Test 1

- Wellhead pressure at Well 16A(78)-32 is above the fracturing pressure (corresponding pressure is 3000 psi surface pressure)

- For the July 5\textsuperscript{th} circulation stage
  1. re-initiation/reopening pressure is smaller,
  2. shut-in pressure is higher (more fluid in the reservoir),
  3. Well 16B(78)-32 pressure is higher
• Production in 16B demonstrated connection (rate is in the order of 10 bbl per hour)

• Production rate increased with water volume pumped into the injection well - 16A(78)-32
Circulation Test 2

- Instantaneous response in Well 16B(78)-32 for both July 18th and 19th
- Treatment pressure is lower for the July 19th circulation
Circulation Test 2 – July 19 and 20, 2023

Spinner Test Results

- **Stage 1** (openhole, treated with slickwater) and **Stage 3** (cased and perforated, treated with crosslinked gel) take much more fluid than **Stage 2** (cased and perforated, treated with slickwater)
- Production rate for all the circulation tests is around 5-15 bph.
- Actual production rate could be larger for Test 2, because the Stage 3 and potentially Stage 2 connection are behind the casing, which probably accounts for 50% of the flow.
Stiffness Evolution

Stiffness was much reduced in the July 18th and 19th circulation test.

<table>
<thead>
<tr>
<th>Circulation</th>
<th>Stiffness (psi/bbl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 4th</td>
<td>218</td>
</tr>
<tr>
<td>July 5th</td>
<td>257</td>
</tr>
<tr>
<td>July 18th</td>
<td>149</td>
</tr>
<tr>
<td>July 19th</td>
<td>64</td>
</tr>
</tbody>
</table>
Pressure Profile Comparison

- Flat injection pressure trend and lower pressure on July 19th circulation suggests higher conductivity
- Could be due to hours of flowback from Well 16A(78)-32 before the injection on July 19th
Conclusions

1. A connection was definitively established (pressure response and production from Well 16B(78)-32).
2. Injection pressure is above the minimum in situ principal stress.
3. Stimulation previously established a fracture network.
4. Initial cycles showed pressure decline suggesting fracture reopening and potential fracture propagation.
5. Last cycle showed flat pressure trend suggested a connected channel between two wells (precipitation removal due to flowback?).
6. Proppant will be a prerequisite for future treatments.
7. Communication that can be improved with sustained injection into Well 16A(78)-32 (reduced system stiffness and injection pressure)