Diagnosing flow challenges in horizontal wells with smart completions

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Learning outcomes

1. TGT Through-barrier Diagnostics is a key to assess reservoir flow profile and individual zones isolation.
2. Through-barrier diagnostics can significantly improve smart wells completion design.
3. Workover planning based on conventional PLT technologies are not sufficient in smart wells. Total Flow product is able to deliver accurately flow geometry around the wellbore for optimum workover planning.
Smart Completion

Better Reservoir Management

Zonal Production Control: ICD, AICD, ...

Zonal Stimulation

Zonal Isolation: Packers

Zonal Performance Monitoring: P, T, ...

Sand Control: Screens, Gravel Pack

Multi-laterals
Smart Completion: Flow Challenges

Diagnosing Flow Challenges In Horizontal Wells With Smart Completion
What is the Acoustic Sound Heard in Horizontal Wells?
Acoustic Data Interpretation

Wellbore Flow


Acoustic Data Interpretation

Wellbore Flow


Wellbore Flow

Modelling Procedure

**Modelling results**

- 20% (20 m³/d)
- 80% (80 m³/d)
Cascade® Platform
Profile Accuracy

Variable parameters

Zonal productivity $\sigma_1$

Zonal productivity $\sigma_2$
Profile Accuracy

<table>
<thead>
<tr>
<th>WELL</th>
<th>LITHOLOGY</th>
<th>PERM</th>
<th>TEMPERATURE</th>
<th>ARRAY CAP</th>
<th>CHORUS SPECTRUM</th>
<th>RESERVOIR FLOW</th>
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<tbody>
<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td>100 dB SPL</td>
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<td>25.3 kHz</td>
<td>100 dB SPL</td>
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</table>

Variable parameters

Zonal productivity $\sigma_1$

Zonal productivity $\sigma_2$

Do not reproduce
Profile Accuracy

Variable parameters:

Zonal productivity $\sigma_1$  

Zonal productivity $\sigma_2$
Profile Accuracy

Zonal accuracy ±5%

Zonal accuracy ±2%
Case 1
Diagnostics in Smart Horizontal Wells in Sandstone Reservoir
Case 1: Reservoir Description and Geological Challenges

Geological Challenges:
- Thin oil rim thickness (4-20 m)
- Gas cap (up to 35 m)
- Aquifer (more than 40 m)
- Variable and heterogeneous deposits
- Reservoir is represented by poorly consolidated sandstone
- High oil viscosity in reservoir condition (>50 cP)
- Permeability in heteroliths:
  - Tidal Flat (Delta) facies: ~500-1000 mD,
  - Channel facies: up to 10000 mD

Reservoir cross section
Faults in mid part of reservoir
Net pay ~ 11 m
Net pay up to 4 m

Delta system
Channel facies (sandstone) up to 10000 mD
Tidal Flat (Delta) facies (clay sandstone) 100-1000 mD
Diagnosing Flow Challenges In Horizontal Wells With Smart Completion

**Case 1: Well Information**

- **Completion:**
  - 7” casing and 4-1/2” liner
  - 7 separated zones
  - Swellable packers
  - Autonomous ICD (AICD)
  - Sand screens

- Significant WC growth
- Insignificant increase of GOR
Case 1: Through-barrier Diagnostics Results

**Reservoir Flow Profile**

<table>
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<tr>
<th>Regime</th>
<th>q_1</th>
<th>q_2</th>
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<td></td>
</tr>
<tr>
<td>3rd</td>
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</table>

**Sand**

- 1st Regime
- 2nd Regime
- 3rd Regime

**Chorus Spectrum**

- 1st Regime
- 2nd Regime
- 3rd Regime

**Capacitance**

- 1st Regime
- 2nd Regime

**Temp**

- 1st Regime
- 2nd Regime

**Pressure**

- 1st Regime
- 2nd Regime

**CCL**

- 1st Regime
- 2nd Regime

**GR**

- 1st Regime
- 2nd Regime

**Perm**

- 1st Regime
- 2nd Regime

**Lith**

- 1st Regime
- 2nd Regime

**Well Sketch**

- 1st Regime
- 2nd Regime

**PLT**

- 1st Regime
- 2nd Regime

**Depth, m**

- 1st Regime
- 2nd Regime

**Positive sand control overall**

- ZONE A
- ZONE B

**Wellbore pressure @ 1824 m:**
- Static pass = 104 atm
- 1st flow regime = 86.3 atm, ∆P = 17.7 atm
- 2nd flow regime = 75.8 atm, ∆P = 28.2 atm

**Main inflow of water**

**Main inflow by PLT**

**Diagnosing Flow Challenges In Horizontal Wells With Smart Completions**
Completion Strategy Improvement

Diagnosing Flow Challenges In Horizontal Wells With Smart Completions
Case 2
Diagnostics in Smart Horizontal Wells in Carbonate Reservoir
Introduction to Case 2 - Water Shut-off Based on Conventional PLT

- Water from RSS4 and RSS1 by PLT
- Mechanical water shut-off by closing RSS4 (due to its high WC and low oil contribution): no change in either the water or oil production.
- Further steps: setting a composite bridge plug above RSS1: WC remained the same, but a drop in oil productivity was observed.
- Conclusion: mechanical water shut-off was considered a **failure**, due to a combination of inaccurate diagnostics of the water ingress and complex near wellbore fluid movement.

Case 2: Smart Well in Carbonate Reservoir

Packer bypassing flow by Chorus

Active Zones by Chorus

Inflow from RSS

Water ingress from below via fractured reservoir
Case 2: Smart Well in Carbonate Reservoir

<table>
<thead>
<tr>
<th>ARRAY PLT</th>
<th>WELL SKETCH</th>
<th>LITHOLOGY</th>
<th>PRESSURE</th>
<th>TEMPERATURE</th>
<th>CHORUS SPECTRUM</th>
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<td>81 dB</td>
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<td>P3</td>
<td>P2</td>
<td>BP</td>
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</table>

- **Inflow from RSS3**: Acoustic signature caused by packer bypassing flow from RSS3.
- **Flow from below**: Acoustic signature caused by fracture flow. Water ingress from below survey zone via fractured formation.

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Conclusions

- TGT’s True Flow System provides a complete assessment of reservoir flow dynamics and zonal isolation, in horizontal wells.
- TGT Through-barrier diagnostics can significantly improve smart well completion designs.
- Workover strategy based on conventional PLT is not sufficient in smart wells.
- Horizontal well workovers can be complex and costly. ‘Total Flow’ diagnostics provide the insights you need to plan and execute them efficiently and effectively.
Thank you

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