Innovative Solution for Optimising Wellbore Stability and Drilling Performance: Western Desert Egypt

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• Project Background & Objectives
• Pre-Drill Phase –
  • Results of Pharos-1x offset review
  • Key recommendations
• Operational Phase –
  • Methodology of relevant time support
• Post well analysis & conclusions
Project Background

- Hellenic Petroleum
- Pharos-1x, 1\textsuperscript{st} well in a 3 well exploration program
- Drilled in late 2009
Project Background

- AFE for Pharos-1x was based on taking 77 days to drill the well
  - Well actually took 103 days to reach TD

- Post well engineering study made 3 key recommendations:
  - Change well profile
  - Perform Geomechanical study
  - Review drilling and tripping practises
Pre-Drill Phase

- Post-mortem & Offset review
  - Identify applicable wells
  - Interpretation of any wellbore failure

- Build rock strength and wellbore stability models
  - Mud weight prediction
  - Fracture gradient prediction
  - Validate using offset data

- Drilling optimisation study
  - Drilling practises
  - Tripping / reaming procedure
  - Bit and BHA strategies to optimise drilling performance
Pre-Drill – Wellbore Stability Assessment
Pharos-1x Post-Portem

- Over pressured shale or potential swabbing of drill string?
- Chemically reactive shale?

<table>
<thead>
<tr>
<th>Clay Mineral</th>
<th>Specific Surface Area (m²/g)</th>
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<tbody>
<tr>
<td>Smectite rich bentonite</td>
<td>600 - 800</td>
</tr>
<tr>
<td>Illite/Illite mixed layer</td>
<td>200 - 250</td>
</tr>
<tr>
<td>Illite</td>
<td>80 - 120</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>20 - 40</td>
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<tr>
<td>Chlorite</td>
<td>0 - 30</td>
</tr>
<tr>
<td>Limestone</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Quartz</td>
<td>&lt;1</td>
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Index test on drill cuttings showed limited reactivity.

Cavings with apparent splintery morphology?
• Rule of thumb guide
  - Bulk water invasion = mm / day
  - Ion diffusion = cm / day
  - Pressure = decimeters / day

Fig. 6. Schematic overview of the development of various fronts around a wellbore in a shale in time. From the central wellbore going out into the formation, the filtrate invasion front is preceded by a solute/ion invasion front, which in turn is preceded by the mud pressure invasion front. There is one to two orders of magnitude difference in penetration depth between the various invasion fronts.

Swab pressures could cause effective underbalance in a shale charged to equivalent mud weight of 10.5ppg
Pre-Drill – Key Recommendations

• 12 ¼” Section
  - Aim to minimise losses and manage cavings
  - Maintain use of “low cost” KCL polymer mud with MW of 9.5ppg
  - Use downhole motor to improve ROP and help maintain verticality
  - TD section just into AEB formation.

• 8 ½” Section
  - Aim to minimise cavings
  - Use HPWBM at 10.5ppg for membrane effectiveness in shale
  - Implement specific drilling and tripping practises
Relevant Time Support

• Engineer provides real time / relevant time support to the drilling team, paying particular attention / devoting resource to the high risk sections.
  • Monitoring drilling parameters to ensure operation is within the limits of the stress model
  • Monitoring for indications of wellbore instability that indicate that the stress model limits have been exceeded
  • Real time interpretation of drilling events to calibrate / validate stress model
  • Provide real time solutions to onshore / rig site based drilling teams to help manage wellbore stability and drilling incidents

• The tools for monitoring wellbore stability and drilling performance were:
Post Well Analysis

Diagram:
- Project Pre-planning
- Drilling Team Peer Review
- Operations Support
- EOW Analysis

Diagram cycles clockwise:
1. Project Pre-planning
2. Drilling Team Peer Review
3. Operations Support
4. EOW Analysis

Cycles back to Project Pre-planning.
• Well 2 was drilled to TD in 56 days, 20 days ahead of AFE curve and 30 days ahead of Pharos-1x
Conclusions

• The Client recognised that an integrated drilling optimisation and wellbore stability approach contribution to the improvement in drilling performance in the 2nd well
• Still opportunity for significant increase in drilling performance through optimised bit and BHA strategy
• Successful integration of the geomechanics and drilling optimisation disciplines was key to determining the root cause of the wellbore stability issues and to taking the correct steps to mitigate the risk

It’s not rocket science

But it is rock science