HIGH PERFORMANCE WATER BASE FLUID IMPROVES RATE OF PENETRATION AND LOWERS TORQUE. SUCCESSFUL APPLICATION AND RESULTS ACHIEVED BY DRILLING A HORIZONTAL SECTION THROUGH THE RESERVOIR

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ABSTRACT

In a field characterized by highly fractured carbonate reservoirs, the standard drilling fluid practices have been to drill the reservoir using low weight calcium carbonate polymer muds.

While generally successful, use of this fluid has resulted in high torque and low rates of penetration (ROP) in wells with extended horizontal sections. A cost effective alternative was needed to improve in these areas and still meet business objectives.

As detailed in this case history, a High Performance Water-Based Mud (HPWBM) system was introduced to drill the curve and the horizontal section in a side-track of an existing well. The application of this fluid further optimized drilling performance in the field. This resulted in improved control of the wellbore trajectory, reduced the well path tortuosity and greatly improved the ROP.

Use of the HPWBM showed excellent results in reducing torque and increasing ROP while helping extend the lateral and maintain wellbore stability. Lubricity was maintained while drilling the interval, achieving an average ROP of 3.8 m/hr for the curve and an average ROP for the horizontal section of 7.5 m/hr.

The average torque experienced while drilling was 629 kgf.m (4550 lbf.ft) which was well below the torque limit of the drill string. These successful results proved the reliability of the HPWBM, allowing the drilling a 527-meter curve section and a 2010-meter horizontal section in a 6350 m measured depth well with a 3848 m true vertical depth.

INTRODUCTION

Improving ROP and reducing torque by using a HPWBM has resulted in the successful drilling of a challenging side-track well. Similar to a previous successful project[1] in a deep high temperature high pressure field, the bottom zones of an existing well were abandoned and followed by the drilling of a side-track to restore the production capacity and enhance the recovery from the reservoir.

The fractured carbonate reservoir section in this area has historically been drilled with non-damaging, low density polymer muds containing calcium carbonate bridging solids. The hard limestone formations have created difficulties with achieving adequate ROP and extending lateral sections due to torque and drag issues. In this field, the targeted reservoir section is located between 3800 and 4500-meters True Vertical Depth (TVD). Low mud densities are desired to avoid loss of circulation while drilling. Managing the downhole fluid losses in combination with the wellbore trajectory makes it especially difficult to overcome the historically low drilling rate, high torque and wellbore stability issues seen in this field. When planning to extend the lateral section in a side-track of an existing well, a simple fluid using high performance additives was designed.

ORIGINAL WELL PROFILE

Figure 1 shows the profile of the parent well, drilled in the early 1990's[2].
It is characterized by a 6" open hole deviated section completed with a 4 ½" slotted liner.

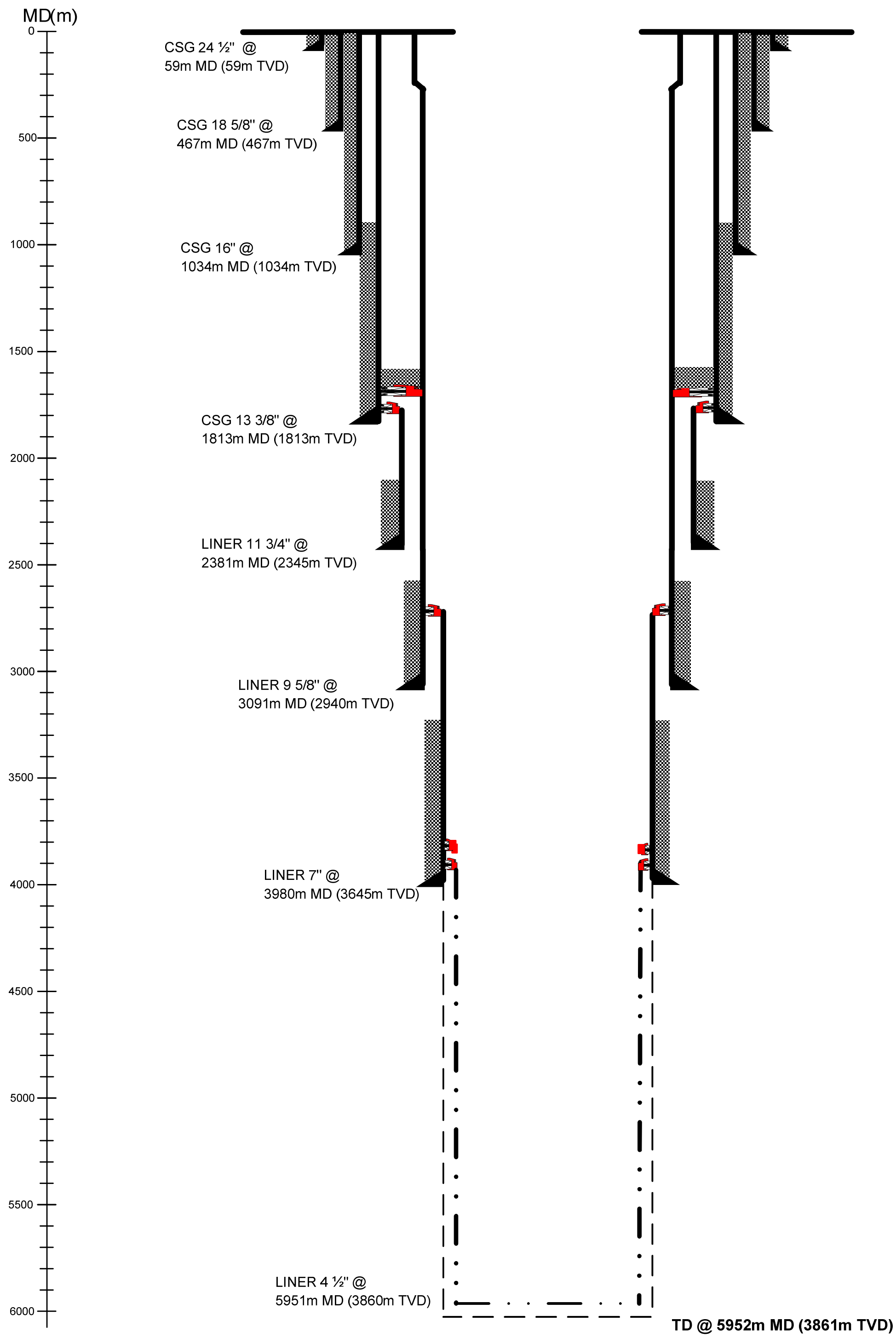

Figure 1 - Parent well profile

SIDE-TRACK WELL DESIGN

In order to optimize productivity, a workover was planned to plug and abandon the bottom hole of the parent well and drill the new side-track well.

The parent well had the 9 5/8" casing shoe at 3091 m MD, and the 7" liner shoe at 3980 m MD.

To reach the new target reservoir, a 6" side-track well was planned to be drilled out from the original 7" production liner previously set at a 35° inclination (see Figure 2). The Kick-Off Point of the side-track was planned to be set at a depth of 3825 m MD.

Figure 3 shows the directional plan for the side-track. Not only does the plan have a horizontal section longer than 2000 m, it also requires an approximate 180° turn in the curve portion of the plan. Extensive torque and drag modelling proved that a fluid with better lubricity than any used previously was needed.

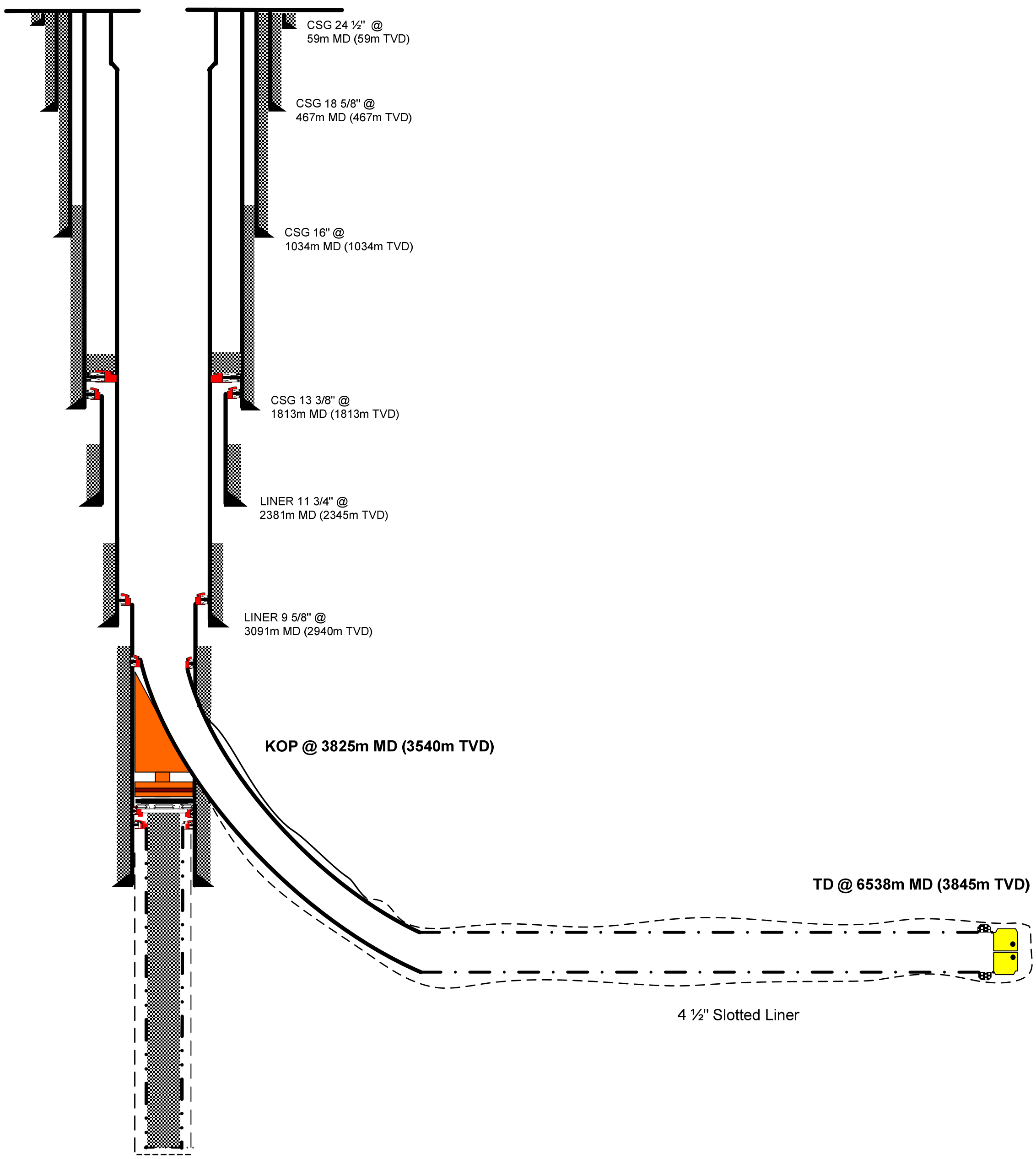

Figure 2 - Side-track well profile

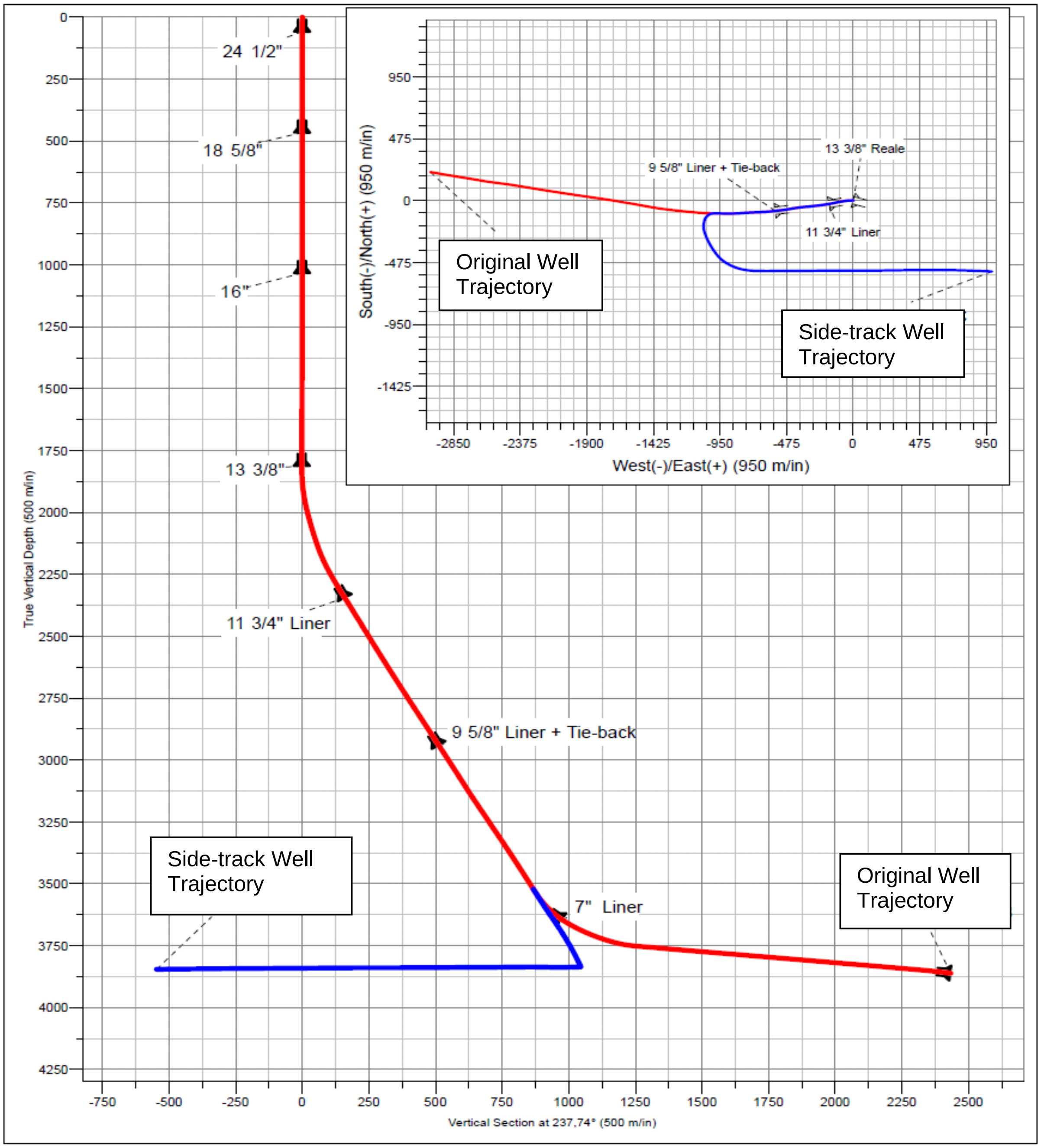

Figure 3 - Wellbore Trajectory

DRILLING FLUID DESIGN

The operational conditions outlined above indicate that the drilling fluid design was critical to well success.

Generally, mud properties have to be carefully selected by taking into consideration the need to:

- maintain wellbore stability as much as possible;
- ensure an accurate hole cleaning and a suitable cuttings removal capability in presence of reduced clearance, to avoid accumulations that may cause stuck pipe, circulation losses, malfunctions/failures of downhole tools;

- appropriately use lubricants and/or microbubbles, to reduce friction during drilling and casing running operations.

Over the last years, the fractured carbonate reservoir section in this area has historically been drilled with non-damaging, low density polymer muds containing calcium carbonate bridging solids. While generally successful, the use of this kind of fluids has created problems in terms of high torque and low ROP in wells with extended horizontal sections. In fact, these old technology Water Based Muds (WBM) were not stable over time, thus requiring continuous reconditioning and dilution; moreover, the geometry of wells and characteristics of formations were prone to generate torque and drag issues, thus increasing the risk of hole instability and stuck pipe.

A reasonable alternative to old-technology WBM could have been the use of low-toxicity oil-based muds (LT-OBM) to drill the deeper well sections; operational performances could have been improved thanks to their inherent lubricity and stability under downhole conditions at high densities. On the other hand, the usage of oil-based muds leads to the production of drill cuttings which require expensive treatments before disposal, causing a drastic increase of the overall waste management costs.

High Performance Drilling Fluid Selection

In order to replace old technology WBMs with more efficiently drilling fluids, a new generation HPWBM was proposed; the technical challenge was to create a fluid able to combine the positive aspects of both oil-based and water-based fluids, i.e.:

- provide the good operational performances of oil-based muds, deriving from such properties as high lubricity, thermal stability at high temperatures, low thixotropic properties and adequate resistance to contamination from solids;
- ensure the low environmental impact and the ease of preparation typical of water-based muds.

The selected drilling fluid was originally designed for application in unconventional resource plays[3,4] and has been used to drill thousands of wells in these areas. In this case, even if the application consists of a horizontal well in a conventional carbonate reservoir, the need to find the best balance between minimizing waste management and improving hole stability leads to the same requirements found in unconventional resource development scenarios.

Drilling rate and torque management are keys to economically executing challenging well plans like this one. Furthermore, stable viscosity under the complete range of conditions expected in the well is fundamental. To demonstrate that the system selected is specially designed to improve in these critical areas, laboratory tests were performed with a review of applicable well histories. Hot rolling and static aging tests were performed along with tests of rheological properties under downhole conditions that provided the necessary information to calculate hydraulic parameters associated with circulating the fluid and the effective removal of drill cuttings.

After the successful laboratory evaluation and confirmation of the successful HPWBM applications in field operations, the fluid was selected for this side-track well.

HPWBM Formulation

The HPWBM system typically consists of three liquid products and an optional HPHT rheology modifier. A clear advantage of the system is simplicity, since it is mostly composed of liquid additives allowing a quick and easy rig site preparation. The system is also compatible with the full range of water-based muds densities, while exhibiting consistently superior lubricity characteristics. As utilized for this application, the system consists of the following major components:

- Patented[5] synthetic liquid polymer viscosifier with secondary filtration control;
- Drilling enhancer that provides lubricity and ROP improvement;
- Conditioning agent to actively water wet solids to reduce enhancer consumption.

In addition to the above components, conventional biopolymer additives are used to further increase the viscosity of the system. It was expected that the low density and solids content would allow the fluid to have excellent performance with minimum quantities of additives. In most applications of lubricants and drilling performance enhancers, a specific concentration is recommended. The HPWBM used for this well relies on field measured values of lubricity using a lubricity meter. Typically, lubricity coefficients (CoF) of 0.10 or less are planned[6]. It was expected that concentrations of drilling enhancer in the 0.8 - 1.0 vol% would provide the CoF needed for this well.

Optimizing hole cleaning by effective cuttings removal is a key activity in planning complicated horizontal sections like the one drilled in this well. Fortunately, cuttings generated in the 6" hole size used in this well are easily removed with a reasonable fluid viscosity profile.

In addition to the lubricity and viscosity, adequate filtration control to prevent thick filter cake was needed. It was found that the secondary function of the system viscosifier provided the level of filtration control needed.

HPWBM Actual Performance

The first benefit achieved during field implementation, was the easiness of HPWBM preparation and reuse, thanks to the low number of products required. This practically turned into the absence of a mud plant, a shorter mixing time, a reduced need of stocking space and a safer products management, with all the associated time and cost reductions.

Furthermore, from the operational point of view, it is important to point out that:

- fresh water has been chosen for this application as base fluid, ensuring the lowest environmental impact;
- the mud remained stable with minimal dilution;
- the mud system was clay-free to avoid the instability associated with clay based fluids;
- even in static conditions for more than 72 hours, no barite sagging was detected;
- rheological properties were maintained appropriate to the hole size and enabled the Equivalent Circulating Density (ECD) and surge/swab pressures to remain well below the formation fracture gradient, thus preventing lost circulation;
- the mud system showed inherently low friction coefficient;
- the mud system showed a unique resistance to contamination from solids and CO_2.

DRILLING RESULTS

After successfully abandoning the lower zones of the parent well, a whipstock was set and the 7" casing exited at 3813 m MD / 3531 m TVD. The curve was drilled and landed just past 4300 m MD with a 90° inclination. The well was then successfully side-tracked to a depth of 6350 m MD with an extended lateral length of 2010 m which was more than expected due to previous well experiences where the torque dictated the lateral length.

The HPWBM maintained wellbore stability and increased the ROP to an average of 3 m/hr during the curve and averaged 7 m/hr during the horizontal section. This gave an average of 95 m drilled per day for the entire length of this section overcoming the difficult wellbore trajectory. The average mud weight held during this section was a low specific gravity of 1.03 showing the cleanliness of the system and the ease to maintain.

Properties for torque, lubricity coefficient, and lubricity concentration are given in Figures 4, 5, and 6. The maximum torque experienced in the well was seen at the casing exit depth. For the whole section it averaged 629 kgf.m (4550 lbf.ft), well below the maximum torque rating of the drilling assembly (see Figure 4). The lubricity coefficient was held at an average of 0.078 (see Figure 5) with an average of 1.2% lubricant (see Figure 6) throughout the section.

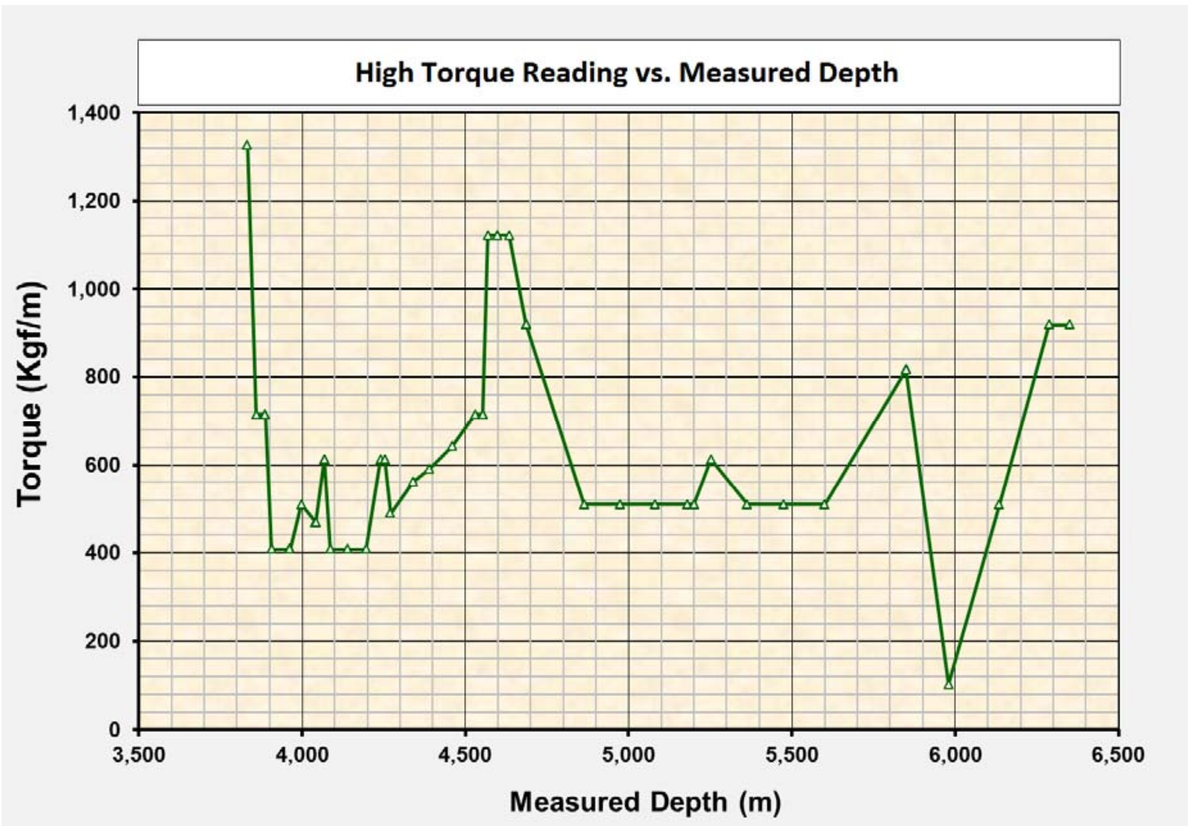

Figure 4 - Well Torque Reading

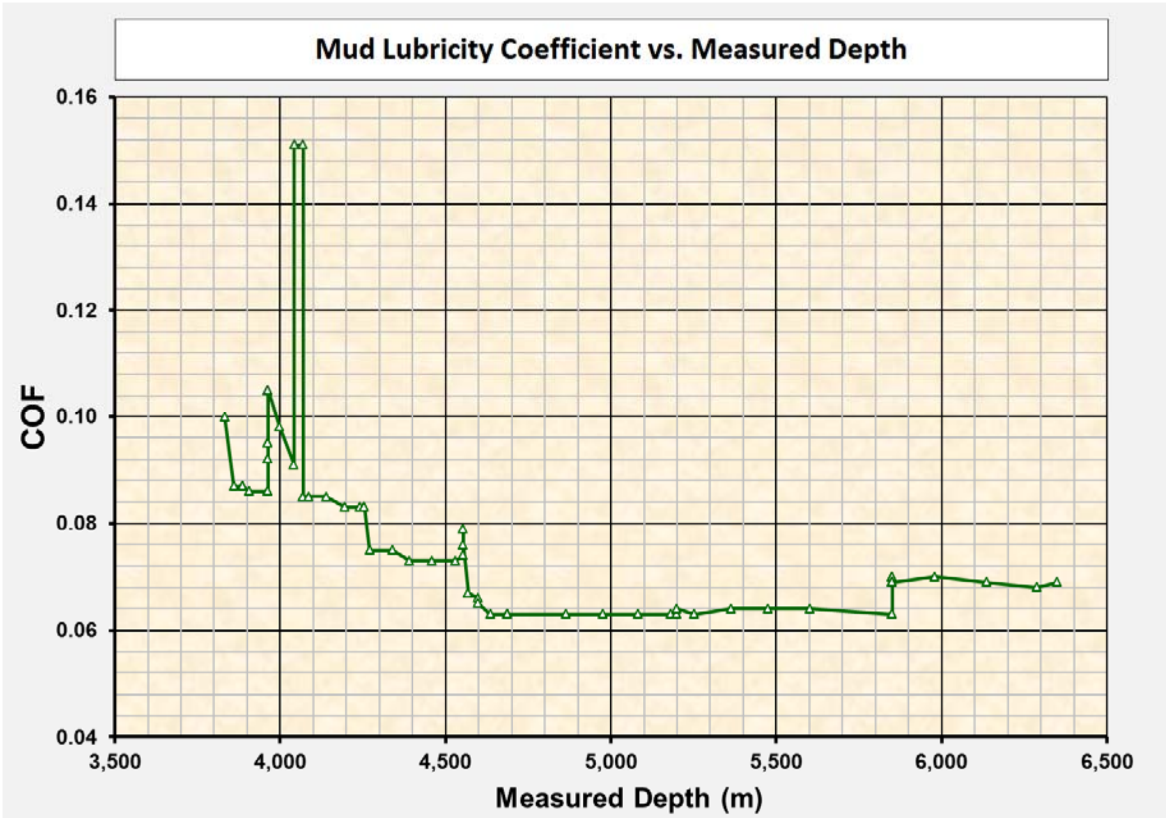

Figure 5 - Lubricity Coefficient

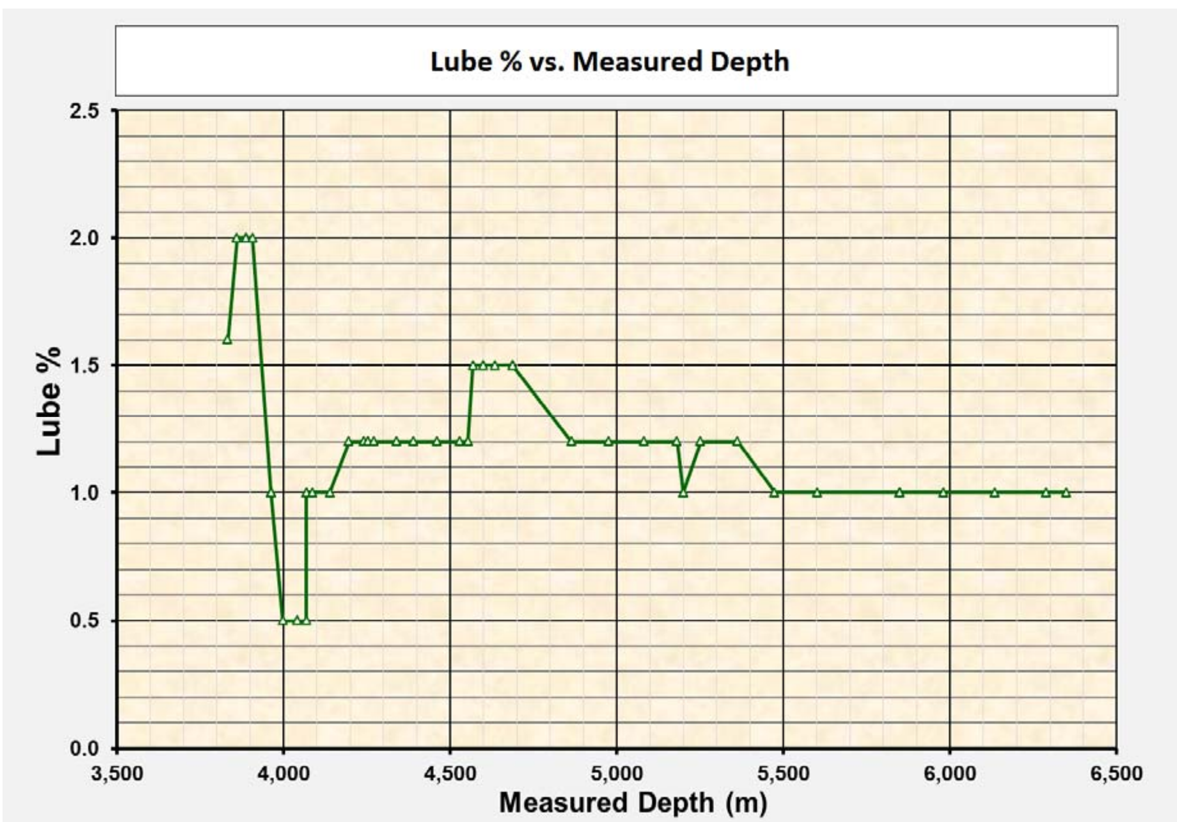

Figure 6 - Lube %

CONCLUSIONS

This paper describes the application of an innovative HPWBM to drill a side-track within an existing well previously drilled with standard drilling fluid practices. The challenging directional profile within a highly fractured carbonate reservoir and the previous experiences in the area with the use of old WBM (which has resulted in high torque and low ROP in wells with extended horizontal sections), dictated the need to find a cost-effective alternative.

The innovative HPWBM, introduced to drill the curve and the horizontal section of the side-track, provided drilling performances similar to those of an oil-based mud, together with the reduced environmental impact typical of a water-based mud, which make it suitable to perform effective drilling operations in critical conditions and challenging environments.

Thanks to the unique properties of the selected HPWBM - high lubricity, stability at high temperatures, little thixotropy and resistance to solids contamination - the side-track was successfully drilled, and the target depth was reached in fewer days than expected. The application of this fluid further optimized drilling performance in the field described in this case history, resulting in improved control of the wellbore trajectory, reduction of the well path tortuosity and greatly improved ROP.

The successful application of this HPWBM is a useful example of what can be accomplished in similar situations in the future. Excellent results can be obtained in drilling long lateral section, as in this case history, where horizontal section of 2010 m in a fractured carbonate reservoir has been realized.

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