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Tailored Drilling Fluid Formulation with Nanoparticle Technology Contributes to Colombian Drilling Operation Optimization

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Abstract

Avoiding borehole instability and differentially stuck pipe are the biggest challenges with well construction in Llanos field in Colombia where geomechanical studies suggest differences higher than 1.5 ppg between pore pressure and collapse pressure for interbedded shales and sandstones. When these challenges come together in conjunction with highly deviated inclination section (up to 89°), the drilling fluid design requires the introduction of specialized technology.

New nanoparticle technology was included in the water-based fluid formulation and lab tested for permeability range from 750 milliDarcy up to 2 Darcy with the particle plugging test at 200°F and 1,000 psi differential pressure obtaining a 44% reduction in spurt loss and 26% reduction in total volume compared with the previously used conventional fluid. Lab tests were designed with a focus on the enhancement of membrane efficiency by reducing pressure transmission to minimize caving generation and hole enlargement.

After engineering the solution in the laboratory, a new high-performance water-based fluid was used in five landing sections prior to drilling the horizontal section. In conjunction with operational practices, the liner running time was reduced by approximately 17% with an overall 6% improvement in total operational times (eliminated a wiper trip for the landing interval).

Excellent hole quality was observed based on reduced torque behavior at the end of the section. This allowed for optimized BHA configuration, easy well trajectory build-up, faster tripping and casing runs, and the prevention of pack-off events. The latter was considered as the highest operational risk during planning phase.

Introduction

In Colombia´s Llanos Field, the biggest challenges with planning and well construction are borehole instability and differentially stuck pipe. Drilling through the interbedded formation (comprised of shales, sands, clays) represents 24% of total non-productive time (Escandon, 2021). These risks could be mitigated with a customized drilling fluid design focused on the reduction of filtrate invasion throughout the formation (Deville et al., 2022).

In this case study, the majority of wells drilled in the area had an inclination of less than 60°. However, to increase production and enhance drained area in certain parts of the field, the well design was modified to horizontal. With this new design, increased mud density was necessary to prevent hole instability, particularly in the 8½-in. section. Geomechanical models indicated a significant difference of more than 1.5 ppg between the pore pressure and collapse pressure in the interbedded shales and sandstones (Figure 1).

Planning Phase

During the planning phase, the 8-in. section was identified as the most challenging due to the interbedded sand and shale formations, a common issue in the area (Escandon, 2021). This section faces high collapse pressures in the C7 and C8 Carboneras formations, with collapse pressures of 11.0 ppg at 10% breakout and 13.5 ppg at 0% breakout. In addition, the Mirador formation presents low pore pressure, measuring 8.4 ppg.

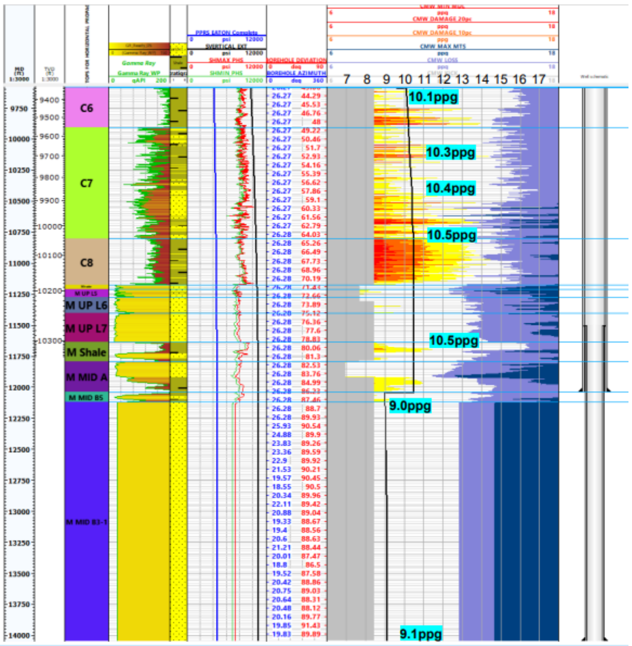

Figure 1 – Geomechanical model - horizontal wells

During the planning phase, two alternatives were considered to reduce the risk of hole instability and stuck pipe. The first alternative involved drilling through the Mirador formation in the next section with the density recommended by geomechanics to avoid differential stuck pipe. The second option focused on the minimization of drilling fluid interaction with the formation. Ultimately, the first alternative was discarded due to the production department's requirements.

The significant reduction of filtration control in a heterogeneous formation (such as shales and sand) helps minimize filtration invasion and, as a result, reduces the pore pressure transmission into the shales (van Oort et al. 1996, van Oort 2003) thereby improving hole stability. In addition, the reduction of fluid invasion by optimizing the cake thickness and creating a semi-permeable membrane helps prevent differential stuck pipe (Deville et al. 2022, Dupriest et al. 2011). To achieve this, nanotechnology was incorporated into the customized drilling fluid design to address a wide range of microfractures and unknown pore sizes. The incumbent drilling fluid used in the area includes traditional products, such as asphalt, polymers, graphite, latex, and sized calcium carbonates.

Drilling Fluid Design

During the drilling fluid design, a comprehensive lab test protocol was developed to ensure proper rheology and filtration control, including high temperature / high pressure test (HTHP) and particle plugging tests (PPT), in alignment with the design parameters agreed upon with the customer.

An increase in drilling fluid rheology was noted when using nanotechnology (WBM + 6 ppb nanocomposite) compared to traditional formulations (WBM + 6 ppb latex). As a result, it was necessary to reduce the amount of xanthan gum by 33% and customize the formulation to maintain target values, particularly the yield point after hot rolling, (200°F, 16 hours), as shown in Figure 2 and Table 1.

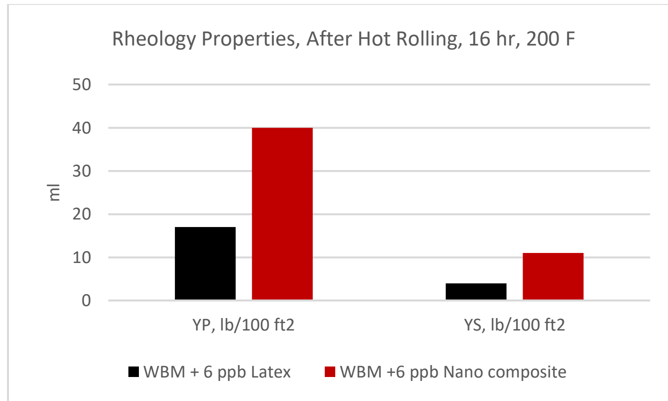

Figure 2. Initial rheology before fluid customization

Table 1. Simplified 10.2 ppg drilling fluid formulation

Description	Conventional formulation, ppb	Formulation with nanocomposite, ppb
Xanthan Gum	1.5	1
Sodium Polyacrylate	0.5	0
Asphalt	3	3
Latex	6	--
Nanocomposite	--	4
Polyanionic Cellulose	3.5	3.5
Graphite	3	3

Filtration tests, including HPHT (200°F) and PPT (200°F, 1000 psi) were conducted, and resulted in a 44% reduction in spurt loss and a 26% reduction in total volume. These tests were performed across a permeability range from 750 mD to 2 Darcy using aloxite disc of 5 microns (air) and 10 microns (air) with 4 ppb of nanocomposite, as shown in Figure 3.

Nanoparticles used are composed of a thermally stable, hybrid organic/inorganic framework. It is produced and applied as an emulsion, for this reason, this nanotechnology showed a reduction in fluid loss in a water-based fluids across a wide range of pore throat size. The hybrid architecture of the nanoparticle – combining a soft, deformable organic portion with a rigid inorganic portion – contributes to seal the small spaces left in the filtercake by other solids and fluid loss additives presented in water-based fluid (Deville 2022).

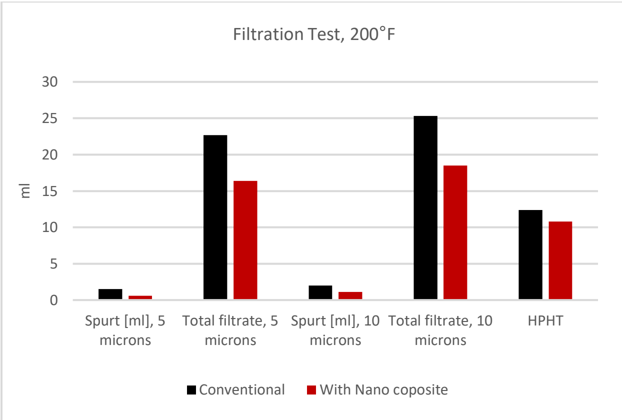

Figure 3. Filtration control properties

Field application and results

During the first application of the nanocomposite (Hz 2 well) in the 8½-in. section of the horizontal well, the well inclination ranged from 46 to 86°, similar to later applications. A total of 1,667 ft was drilled, from 9,612 to 11,279 ft.

To ensure the benefits of the customized formulation with the nanocomposite, detailed follow-up was conducted through HPHT and PPT tests in the field. The results showed a 20% reduction in HPHT, more than 50% reduction in spurt loss, and a 35% average reduction in total PPT on a 10-micron disc at 200°F and 1,000 psi, compared to the previous well drilled with conventional fluid (Hz 1 well), as shown in Figure 4.

The planned time for this section was 405 hours, including the conditioning trip. However, due to the performance during the short trip, the round trip was eliminated, saving more than 41 hours. This resulted in a 6% reduction in the total operational time for the well.

Based on the cavings data collected during the first nanocomposite application, the average cavings rate decreased from 0.8 bbl/hr with conventional fluid to 0.6 bbl/hr despite the breakout in Hz 2 being planned at 10%, compared to 5% in Hz 1 with conventional fluid, as shown in Figure 5.

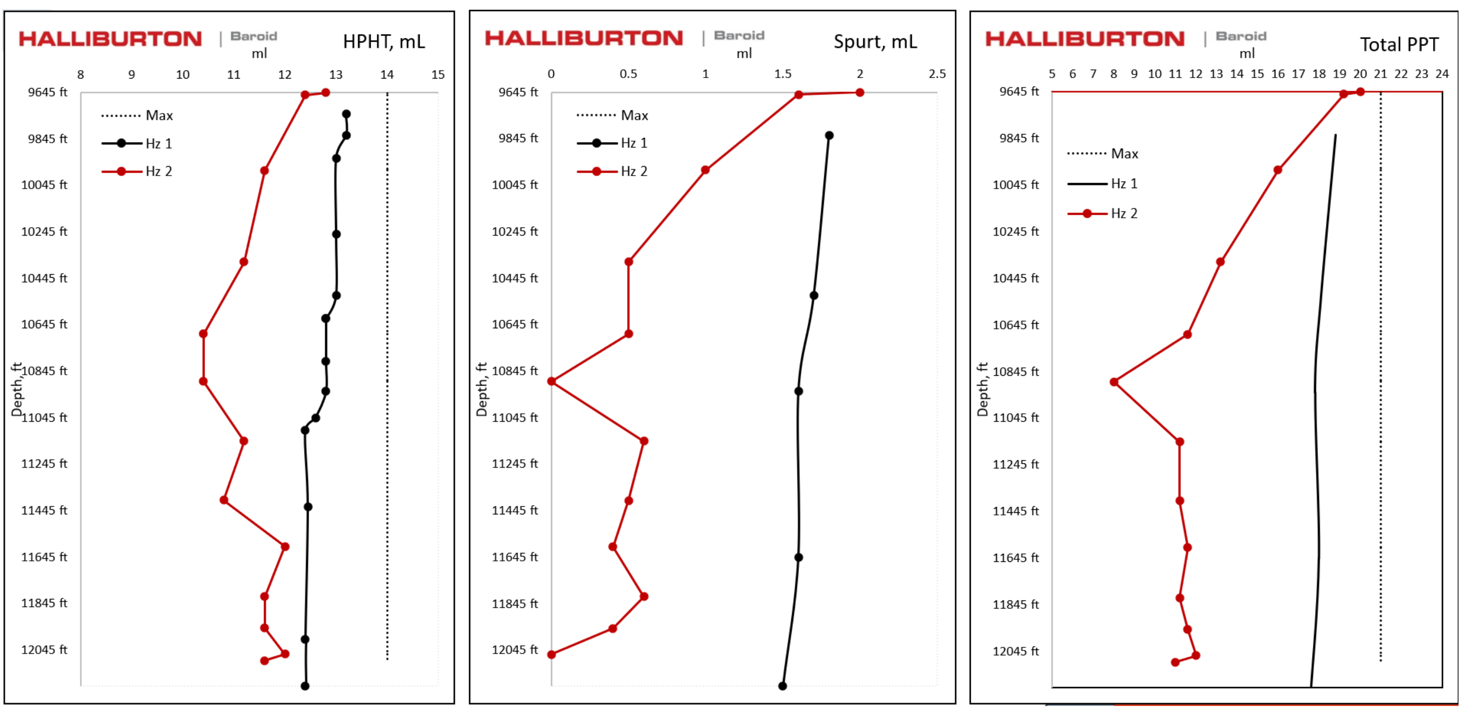

Figure 4. Comparison in filtration properties during well operations between conventional fluid (Hz 1 well) and nanocomposite application (Hz 2 well)

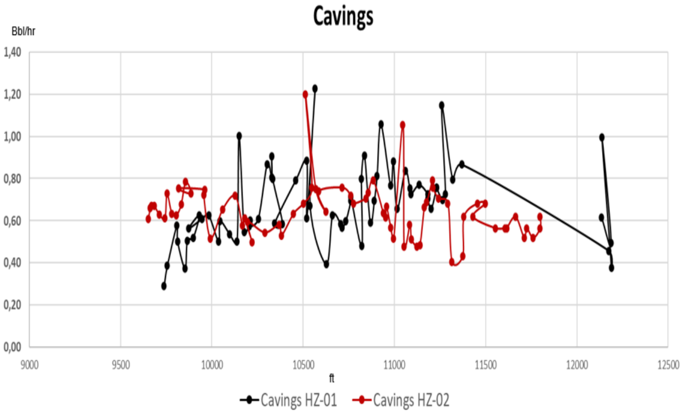

Figure 5. Cavings rate during drilling operation with conventional fluid (Hz 01 well) and with Nano composite (Hz 2 well).

Smoothed operational parameters, such as torque, were observed during drilling operations in wells with nanocomposite application, as shown in Figure 6. This improvement allowed for optimization of the bottom hole assembly (BHA) for subsequent wells.

Drilling fluid optimization, combined with improved operational practices, resulted in a 36% reduction in the 7-in. liner running time on a well-by-well basis, as shown in Figure 7.

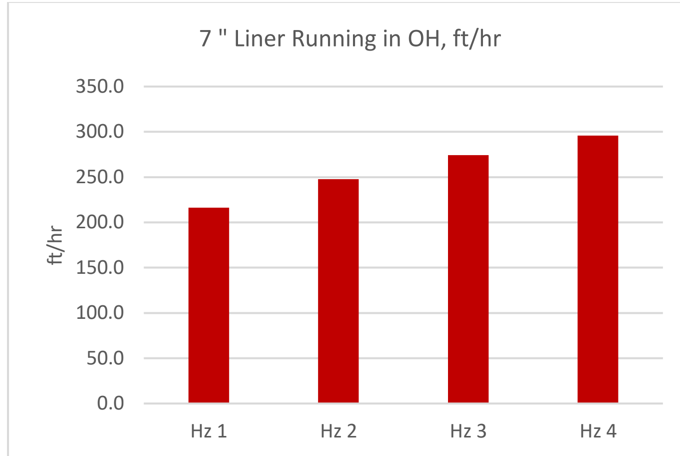

Figure 7. 7-in. liner running velocities in horizontal wells with nanocomposite applications (Hz 2, Hz 3, H4 well)

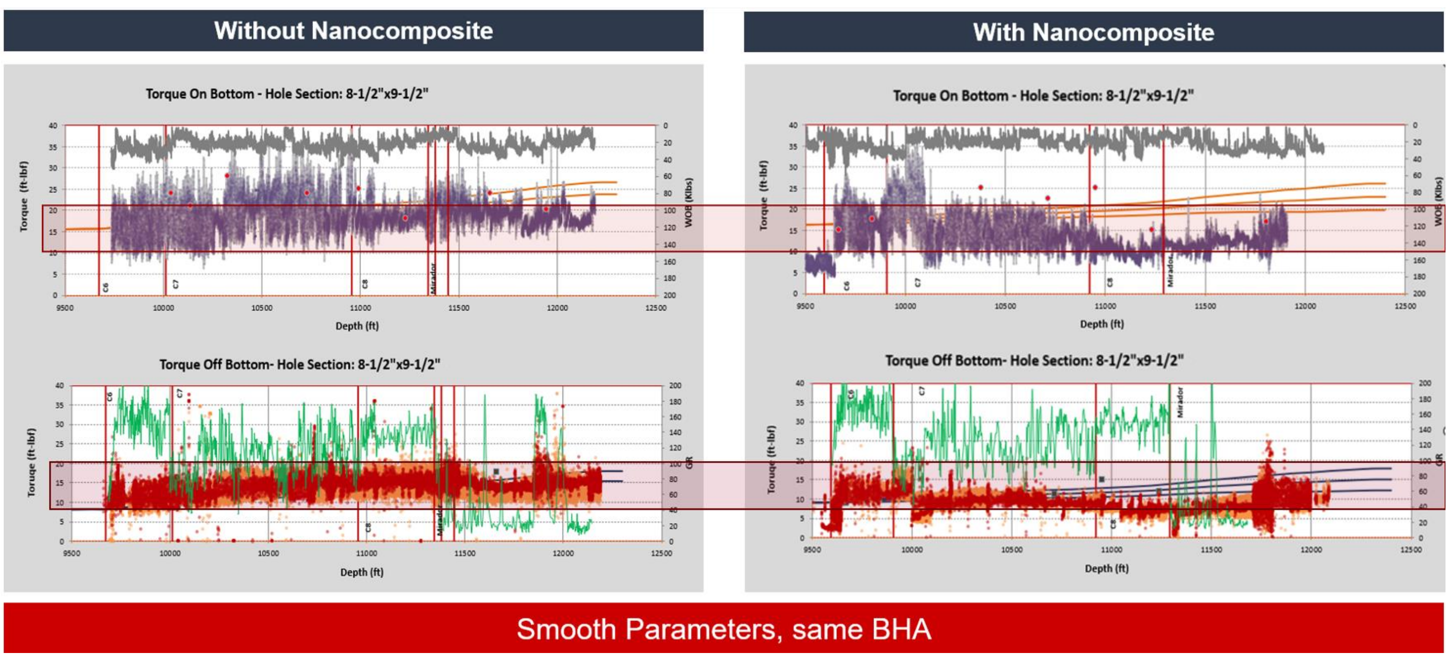

Figure 6. Torque comparison between section drilled with conventional fluid and with nanocomposite.

Conclusions

A comprehensive laboratory test protocol ensured the correct drilling fluid design for field application enhanced operational efficiency.

Accurate risk assessment during the planning phase decreased the likelihood of operational risks.

The probability of hole instability and differentially stuck pipe during drilling and tripping operations was reduced with the improvement of filtration control and minimization of pore pressure transmission into the formation.

Operational practices and customized drilling fluid solutions, including nanoparticles, contributed to a 6% improvement in operational time.

The inclusion of nanoparticle technology in drilling fluids enhanced filtration control properties, and achieved a 44% reduction in spurt loss and a 26% reduction in total volume compared to conventional fluids.

Acknowledgments

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Nomenclature

Ppg = pound per barrel
Bbl = barrels
Bbl / hr = barrels per hour
YP = Yield Point
YS = Yield Stress
BHA = Bottom hole assembly
mD = milliDarcy

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