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Unplanned Casing Shoe Setting Led To A New Well Schematic Optimized Design For Futures Wells At Quesqui Field

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Abstract

This paper documents the successful optimization of well schematic after an unplanned casing setting. That failure required the use of an Ultra Low Invasion Reinforcement Technologies while drilling Q-49 well in Mexico, which changed the well schematic design for all future wells. The use of these technologies allowed for the effective expansion of the operating window, ultimately leading to a successful completion of the drilling stage without the need for additional casing. The study highlights best practices and lessons learned during the drilling process.

The implementation of Wellbore Shielding technology (also known as Ultra Low Invasion) in the recent field development has proven to be an extremely resistant and flexible solution for real-time hole reinforcement while drilling. This technology has enabled continuous operations without compromising well integrity. Constant monitoring of concentration levels through SBT (Sand Bed Test) enables early detection of unfavorable conditions and prompt action, as demonstrated in the case study to be presented. The use of software while drilling also led to early detection and monitoring of the fluid conditions.

This application allowed the operator to increase the operative window over 900 psi, without destabilizing the wellbore. The drilling fluid density used exceeded well above the maximum permissible level of the density gradient, however no destabilization was observed. This solution also resulted in the elimination of an additional casing to isolate the two formation pressures. Since two different formation pressures had to be drilled with the same drilling fluid, the use of this technology represented a dramatic reduction of fluid loss rate, from 15 m/h to less than 0.3 m/hr.

This case study demonstrates how using an appropriate formation-strengthening technology, which is proven to significantly increase the operating window and significantly reduce lost circulation under dynamic conditions without suspending operations for loss control, optimizes operating costs and improves operating conditions, leading to the well's success.

Introduction

Challenges encountered while drilling arise primarily in shale formations with interbedded sandstone and conglomerate lenses alongside laminar turbidite sequences, where low-pressure sands are juxtaposed with over-pressured sands. The complex rock failure mechanisms in these formations further complicate drilling due to the interval's heterogeneity. In specific sections, increased mud density is necessary to control the influx of over-pressured sands, while other sections do not require the same density, leading to well instability.

In such scenarios, increasing mud density without an adequate support mechanism can exacerbate wellbore instability. It is therefore essential to reinforce the wellbore with suitable stabilization methods to mitigate losses and create a shielding effect that enables the formation to withstand additional pressure, thereby expanding the operational window.

The implementation of Wellbore Shielding Technology, recently recognized in the industry as an ultra-low invasion approach, has proven to be both resilient and adaptable, allowing real-time wellbore strengthening while drilling. This technology has facilitated continued drilling without compromising well integrity.

Continuous monitoring of concentrations through Sand Bed Testing (SBT) has enabled prompt detection and immediate response to adverse conditions, as demonstrated in the case study presented.

Wellbore Shielding Technology

The technology is designed to be compatible with the drilling fluid to ensure rapid sealing upon rock penetration, effectively preventing fluid and pressure invasion into pores matrix or microfractures. This containment stabilizes the formation and prevents the propagation of fractures, which otherwise would lead to formation instability and weakening.

In contrast to other materials, the particles used do not penetrate the formation; further, they maintain their size despite the shear stresses induced when drilling fluid is circulated. This durability minimizes the quantity of material required for effective system maintenance. The particles form flexible "shields" at the wellbore wall, creating a barrier of extremely low permeability. Unlike conventional strengthening particles, this protective barrier remains stable under high shear and high-temperature conditions, enabling ultra-low invasion control over a wide range of permeabilities and microfractures (up to 3,000 μm).

Specifically, when a fracture begins to propagate, a low-permeability seal is promptly established over the fracture opening, limiting further fluid invasion and preventing its progression. As commented before, the unique sealing mechanism inhibits the transmission of wellbore pressure to the formation, significantly reducing fluid influx into microfractures, thereby decreasing the likelihood of formation breakdown. Consequently, Wellbore Shielding technology is a preventive solution, reducing non-productive time by preempting fluid losses, pipe sticking, and other wellbore instability issues.

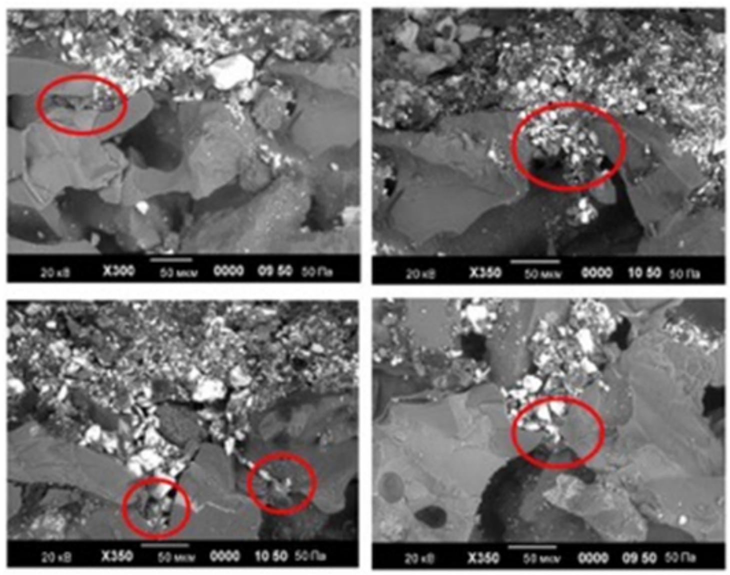


Fig. 1.- SEM: Scanned Electron Microscopy, demonstrating how Wellbore Shielding particles deform to seal the pores and isolate the formation from the drilling fluid.

Drilling Challenge

The following figure illustrates the complexity of the scenario. After setting the 11 ¾” liner at the planned depth, it was observed that the casing shoe was positioned in a low-gradient sand formation, unable to support the exit density. This resulted in a substantial loss of circulation immediately after drilling out the cement. This challenge was effectively managed through collaborative efforts, best practice application, and the strategic use of appropriate wellbore reinforcement technology, ultimately enabling the achievement of maximum density targets and the successful completion of the stage.

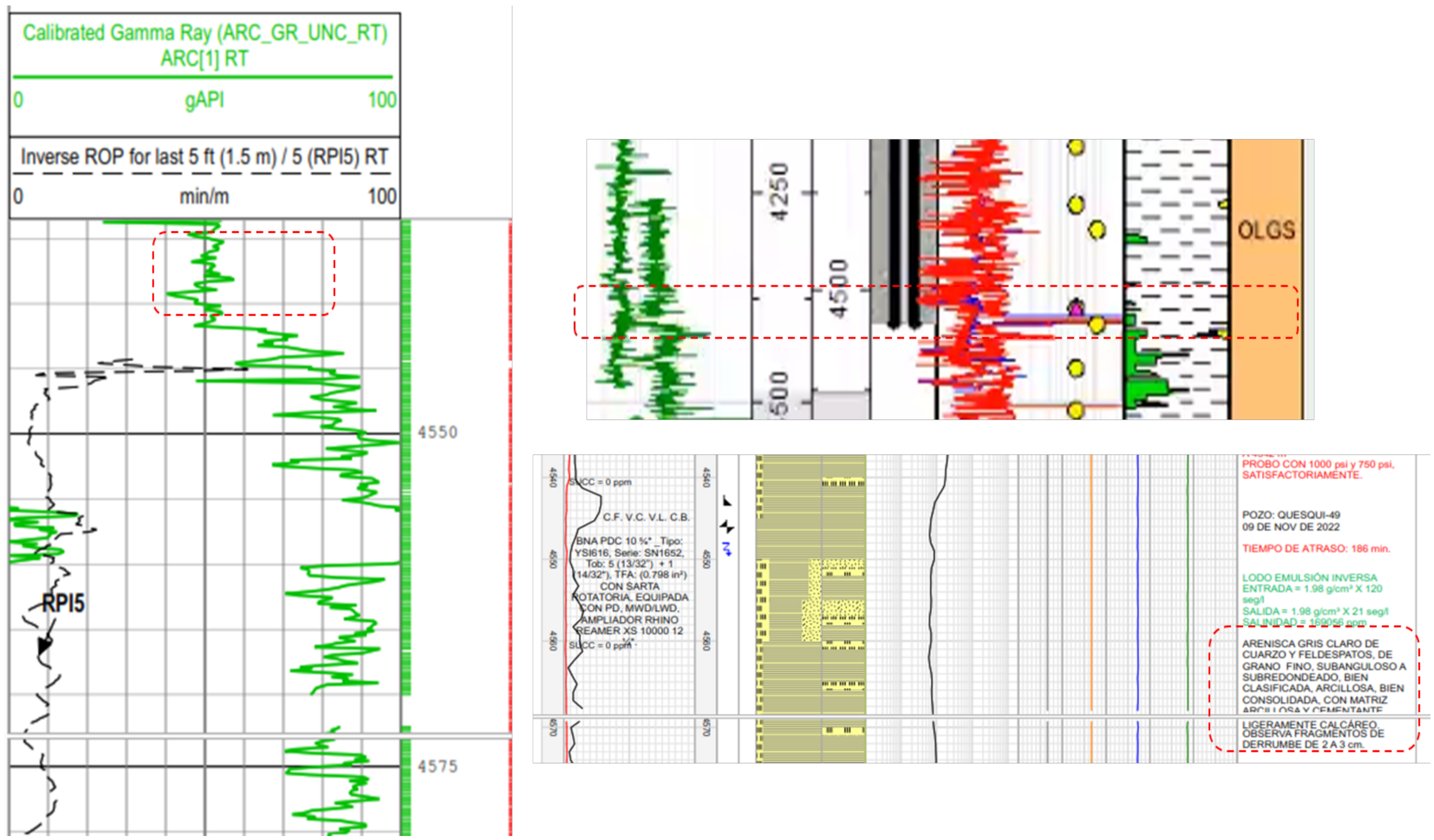


Fig 2.-Real-time logs and master log of well Q-49 demonstrating the formation change immediately after exiting the casing shoe.

Well Instability

The casing shoe was set by mistake 5 meters above the designed depth. The fluid density in the circulating system was adjusted to 2.02 g/cc. Upon drilling out the shoe, total fluid loss to the formation was observed. The wrong setting of casing shoe was confirmed by the real-time resistivity log.

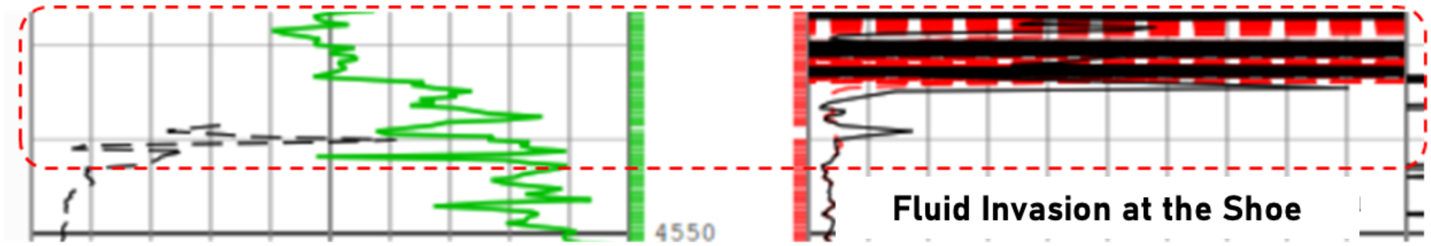


Fig. 3.-Real-time logs of well Q-49

The first measure to regain well stability was reducing the circulating fluid density from 2.02 to 1.98 g/cc to restore partial circulation and create minimal conditions for the introduction of Wellbore Shielding Technology, allowing operations to continue.

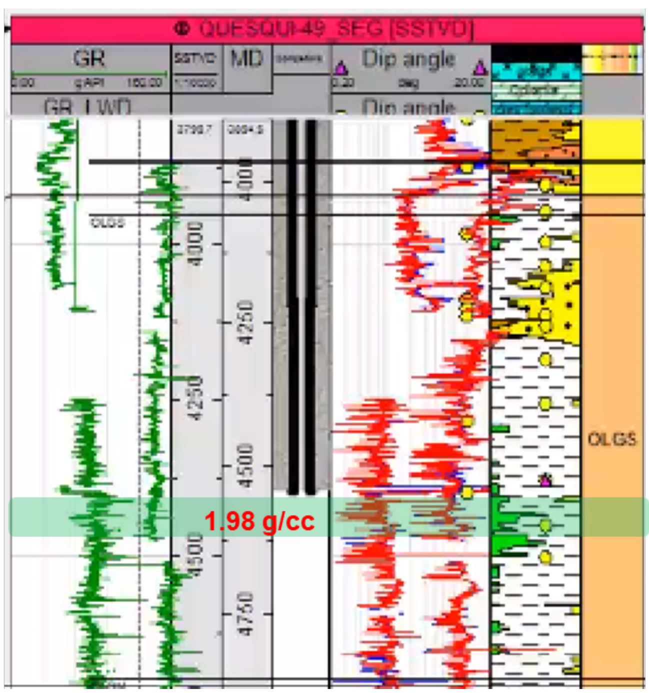


Fig 4.- Maximum support density in sandstone body

Constant monitoring of operational parameters and circulating conditions enabled an assessment of the loss regime to design an adequate concentration of Wellbore Shielding components. Necessary tests and calibrations were conducted to initiate material integration. These procedures provided real-time data to adjust and redesign a more suitable PSD (Particle Size Distribution) to address the existing well conditions.

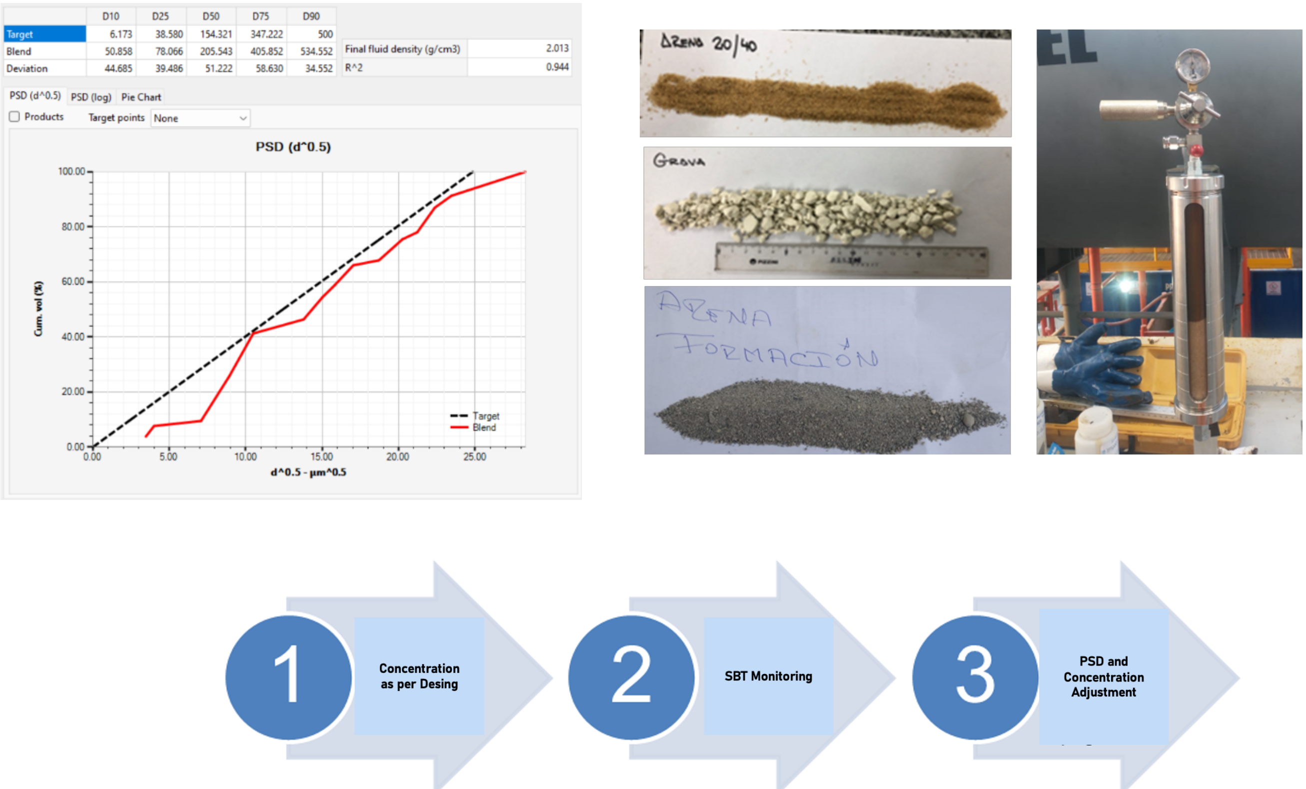


Fig. 5.- Procedure for the application of Wellbore Shielding Technology

After reaching the target concentration in the circulating system, an immediate reduction in fluid loss rate from 7 m³/hr to 1.5 m³/hr was observed. Drilling continued under these optimized conditions from 4,542 m to 4,721 m, with a widened operating window, allowing an increase in fluid density from the initial 1.98 g/cc to a maximum of 2.03 g/cc.

When drilling the interval from 4,721 m to 4,726 m, the circulating fluid density was increased to 2.04 g/cc, resulting in a substantial rise in fluid loss rate from 1.5 m³/hr to 15 m³/hr. An immediate decision was made to reassess the scenario and adjust again.

Formation Analysis

Upon reviewing real-time records and geological data from the well, it was determined that the loss zones had re-emerged near to the previous casing shoe.

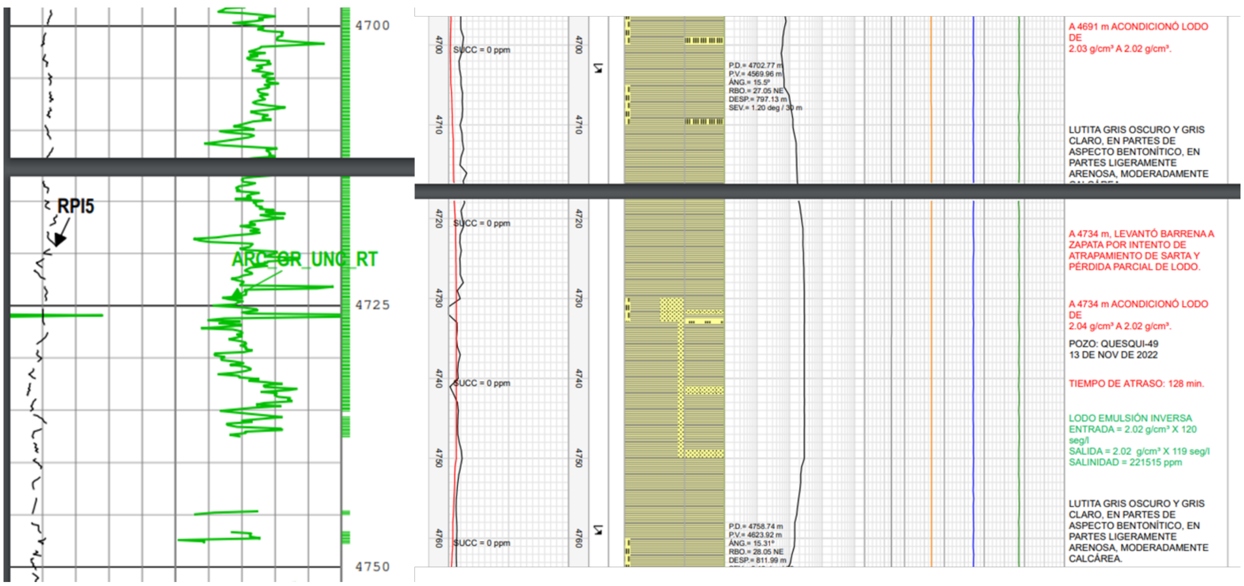


Figure 6.- Real-time Analysis of Formation Conditions

A review of real-time logs and geological data revealed that the loss zones were reoccurring within the shallower formations of this interval, right below the previous casing shoe. In coordination with the operator engineering department, the opening size was assessed, along with potential scenarios that could be encountered. Immediate correction plans to mitigate well instability were implemented, formulating optimized and targeted mixtures of materials to allow drilling operations to resume.

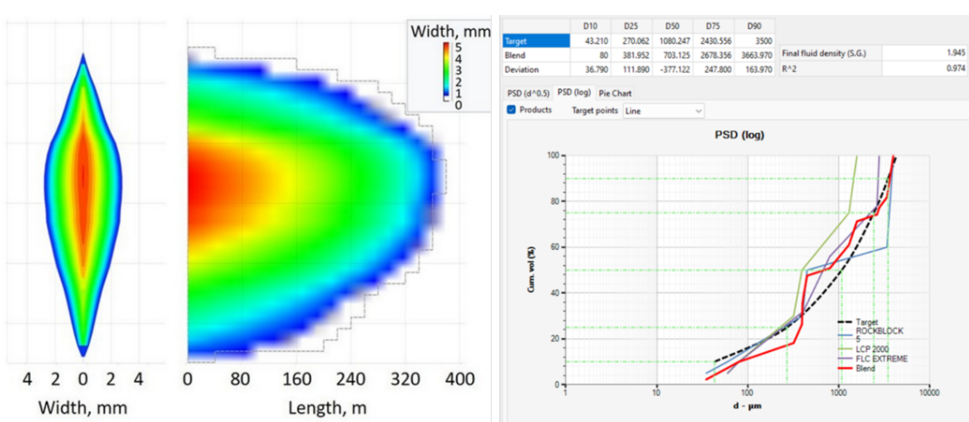


Fig. 7.- Analysis of Fracture Size and Design of Circulation Loss Correction Mixture

Based on the analysis, a new mixture was designed to match the estimated micron size of the fractures. Additionally, an optimized and reinforced prevention system, termed "wide spectrum," was designed to effectively address particle sizes ranging from 1 to 500 microns. This condition was further strengthened by the deployment of bridging pills, expanding coverage as large as 3000 microns. This combination generated a PSD that enabled an immediate seal, preventing pressure transmission into the formation and thereby mitigating the risk of fracture propagation.

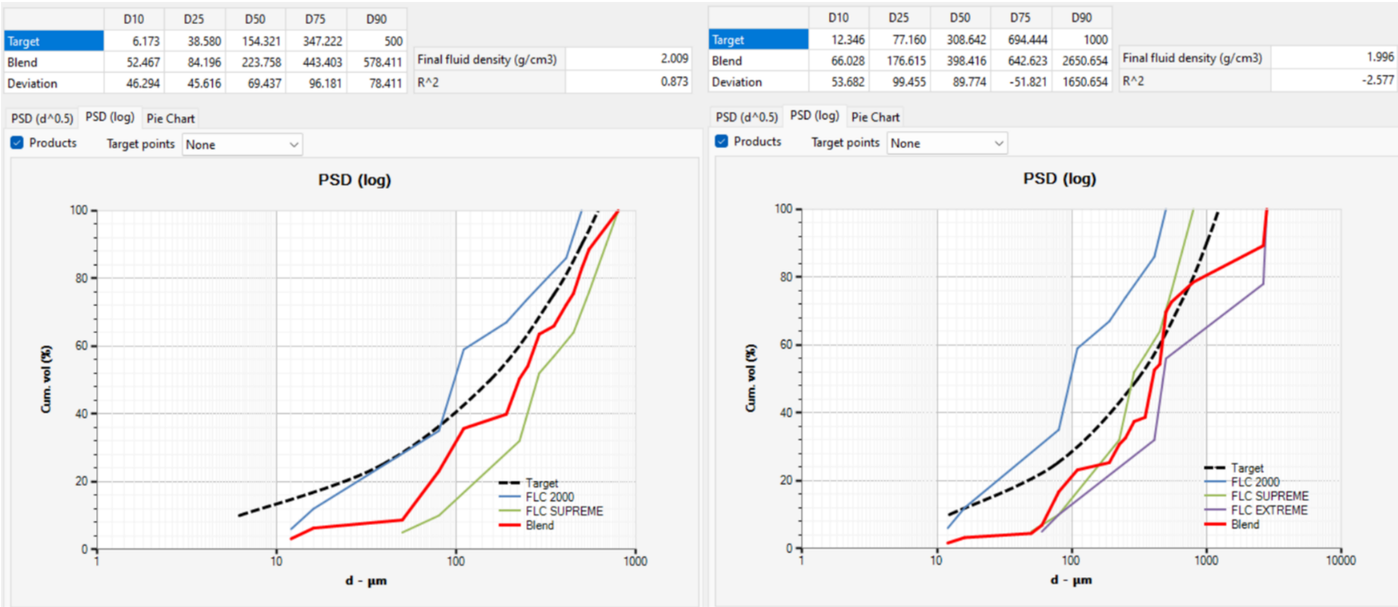


Fig. 8.- Design of Wide Spectrum Mixtures.

Plan Execution

Before resuming operations, a decision was made to lower the drilling fluid density from 2.02 to 2.00 g/cc to restore circulation, though this attempt was unsuccessful. Additional adjustments supported by software outcome and well response were conducted until restoring drilling conditions

A favorable pressure increase was observed, regaining circulation and achieving a better seal. Loss rate was reduced from 15 m³/hr to 7 m³/hr. Once the drilling fluid was homogenized with flexible sealing particles, the loss rate was reduced even more to an average of 3-4 m³/hr, at which safer drilling conditions were achieved.

Drilling continued under those conditions until reaching a depth of 5,077 m, at which the density was increased to 2.02 g/cc.

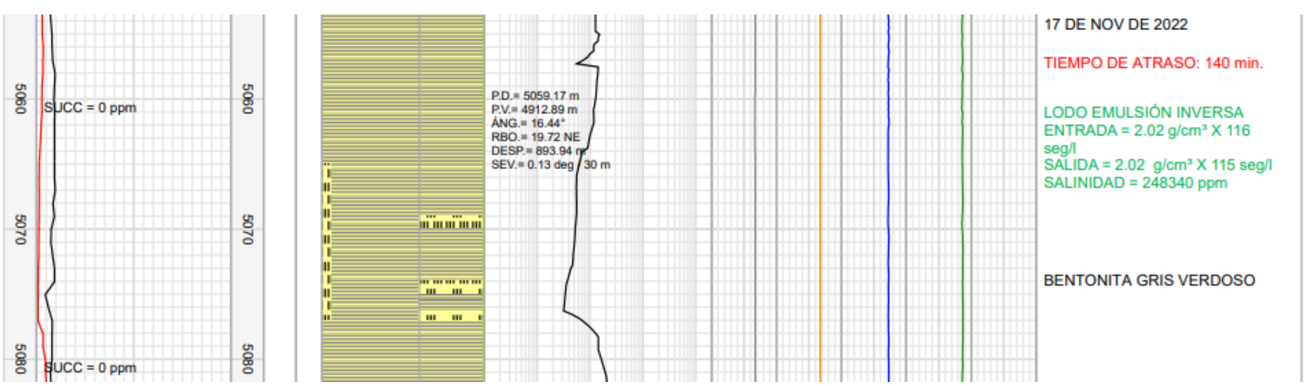


Fig. 9.- Analysis of Formation Conditions

Given the assessed conditions and the current situation, where an increase in density was necessary to continue drilling due to proximity to over-pressured sands requiring higher densities, the decision was made to implement the most aggressive point of the contingency plan. This involved reinforcing and adjusting the particle spectrum of the mixture with a more aggressive particle distribution to ensure greater micron coverage, addressing the observed trend of fracture opening expansion.

Final Results of Plan Execution

The plan execution successfully reduced total fluid loss to the formation, achieving a decrease from 7 m³/hr to 0 m³/hr and accomplishing the planned objectives. This result expanded the operational window, enabling the stage to be completed without interruption.

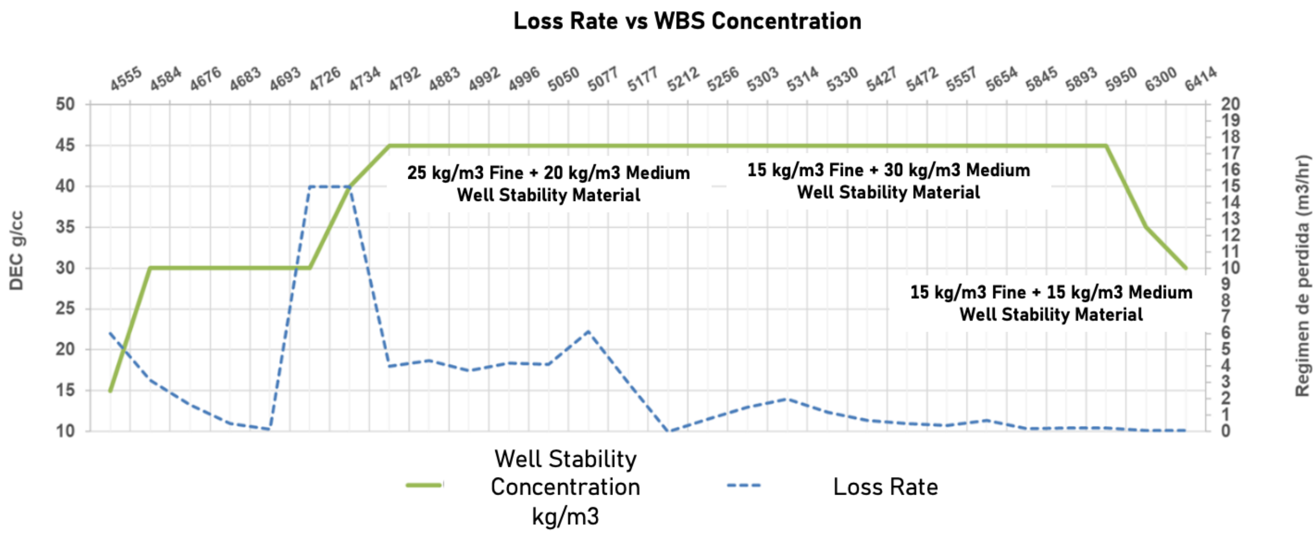
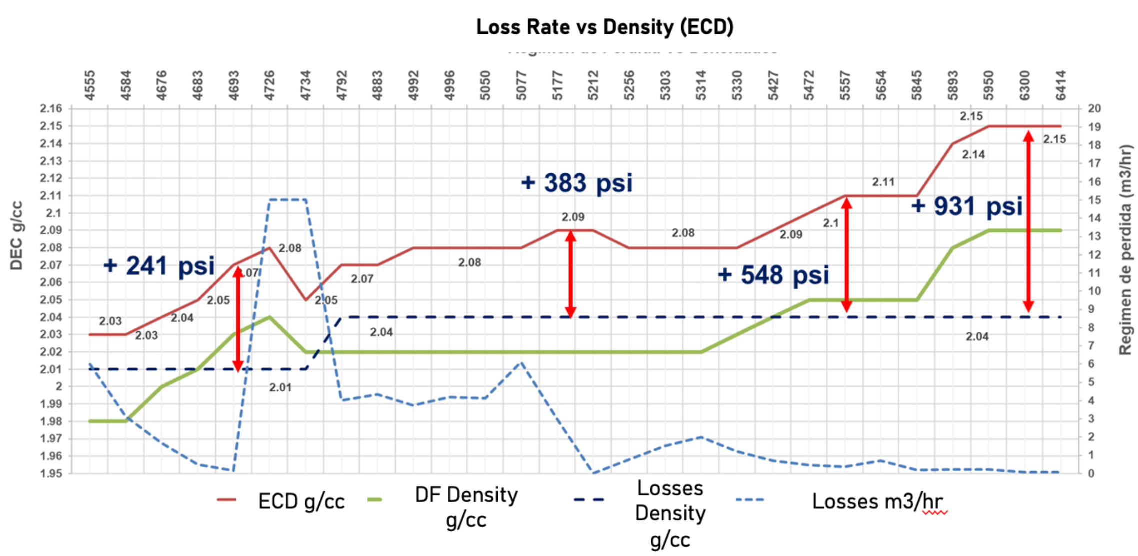


Figure 10.- Loss Rate Vs. Material Concentration

Increase of the Operational Window

Drilling proceeded under stabilized conditions, with no severe drilling fluid losses to the formation, allowing for an increase in the equivalent circulating density (ECD) to values well above the maximum limits previously observed in the loss zone. The target objectives were met, avoiding the need for an additional casing string and achieving an equivalent pressure increase of over 900 psi which also represents an equivalent density increment of 0.11 g/cc.



Graph 11.- Operational Window Behavior

Conclusions

The significant increase in the operational window was primarily enabled by Wellbore Shielding Technology (WST), which allowed the highest density levels in the field without compromising drilling integrity or encountering high rate of loss circulation, when compared offset wells.

Comprehensive characterization of Tertiary formation zones based on location and log correlation effectively reduces geological uncertainty, facilitating the design of an optimal wellbore reinforcement strategy.

The use of materials capable of forming wide-spectrum mixtures from low to medium or high concentrations enabled enough flexibility to adjust and properly seal a heterogeneous range of openings.

Collaboration across all departments with diverse expertise resulted in a successful integration for an effective solution.

References

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