

Best Practices in the Optimization of Drilling Operations in Peru Offshore through Improvement of Borehole Conditions and Hole-Cleaning Practices

Adrian Zanga, Elixio Martins, Pacific Rubiales; Cristina Caverio, Felipe Gonzalez, Jose Palomino, Jose Vasquez, Marcelo Motta, Mauricio Peña, Rogelio Lopez, Victor Laguna, Schlumberger.

Copyright 2015, AADE

This paper was prepared for presentation at the 2015 AADE National Technical Conference and Exhibition held at the Henry B. Gonzalez Convention Center, San Antonio, Texas, April 8-9, 2015. This conference was sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individual(s) listed as author(s) of this work.

Abstract

To compensate for the decline of oil production experienced since mid-1990s, the Peruvian government has decided to increase the exploitation of proven reserves in offshore oil fields. One of the most active offshore blocks for drilling is the Z-1, which includes the Albacora and Corvina oil fields; this block contains 10% of Peru's proven oil crude reserves, and a recent well drilled in the Albacora field enhanced the average well production rate by 400%. These results have motivated the oil operator to increase drilling activity in this block. However, repetitive drilling incidents, particularly those experienced in the CX15 platform in the Corvina field, have significantly increased drilling costs. For example, in 2014, sidetracks had to be performed in two consecutive wells due to stuck pipe incidents, both accumulated cost of USD 5.8 million.

To make drilling in Z-1 cost effective, the operator introduced a new mud system and conducted a geomechanical study to improve borehole conditions. In line with this effort, the directional drilling service and mud companies, along with geomechanics engineers, and sponsored by the oil operator, defined a strategy based in two components: mud design for borehole strengthening and bridging and multidisciplinary synergy to enhance hole-cleaning practices and hole stability. The mud system used in the first wells didn't have the right properties to provide enough mechanical and chemical stability; hence the operator based the strategy in introducing a high performance mud with high quality additives, and implementation of right operational practices, as per lessons learned captured in the previous drilling campaign in the platform CX11.

The implementation of this strategy in the first well resulted in the elimination of nonproductive time (NPT) due to hole-stability incidents, and the well was drilled without sidetracks. Drilling and casing operations were optimized, and the operator was able to reduce the well cost by 43%. This success has been repeated in every well.

Introduction

The Z-1 block, offshore Peru, contains 10% of Peru's proven reserves and is one of the most active drilling areas in Peru. The Z-1 block encompasses the Albacora and Corvina

fields. Although drilling has met with success in increasing the average well production in the block, issues related to hole cleaning and hole stability must be overcome to make drilling cost effective.

At the beginning of the current Pacific Rubiales drilling campaign in the Corvina field with the CX15 platform, the first four wells drilled had significant nonproductive time (NPT) due to problems such as stuck pipe, wellbore instability, and hole-cleaning, resulting in excessive bottomhole assembly (BHA) tripping time and at least one sidetrack on each one of the wells drilled. These incidents occurred in the 8 ½-in. section, where the zone of interest is drilled, and where the wells pose the biggest challenges in terms of wellbore stability, due to overpressured and permeable formation drilled with the same mud weight.

This paper will discuss the engineering and technological strategies implemented by the operator and service companies that allowed drilling these formations without the need of modifying the well geometry with additional casing strings, which would lead to higher CAPEX and potential reduction in production rate.

Geological Challenges

Corvina field is located offshore in shallow waters of Tumbes basin. Average water depth of the area is approximately 61 m. The stratigraphic column of Tumbes basin (Figure 1) shows that sediments were deposited in five stratigraphic sequences overlying Eocene sediments: Heath, Zorritos, Cardalitos, Tumbes, and Mal Pelo. The Zorritos unit is the main target for Corvina wells, and it is characterized by sandstone and conglomerates with shales. The seal for Zorritos' oil reservoir is the shale of the Cardalitos unit.

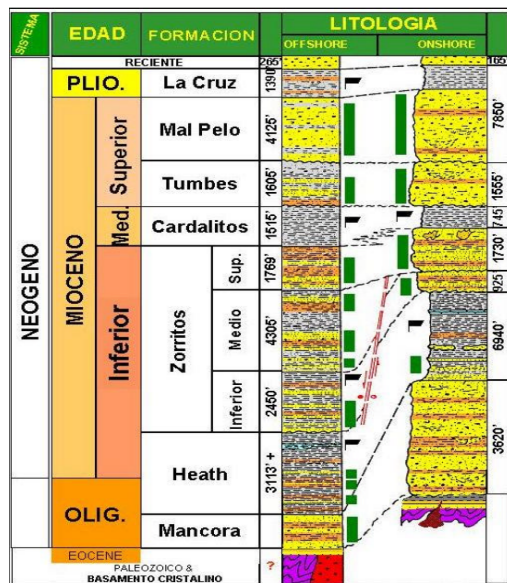


Figure 1. Stratigraphic column of the Tumbes basin (source: PeruPetro).

Compressional slowness data (DT) in these wells evidence an undercompaction effect from the Cardalitos to the Zorritos. This means that the rates of sedimentation and compaction were higher than the rate of fluid expulsion and migration. Because of the low permeability of clays and shaly zones, the section is overpressured.

High mud weights are required to drill this formation; hence, the 9 5/8-in. casing must be placed at the pressure ramp entering the Cardalitos to prevent fracturing the 13 3/8-in. shoe. The drilling challenge comes when the 8 1/2-in. section must be drilled with the same mud weight through high-pressure shales and depleted sands in the Zorritos unit. Initial drilling strategies, that gave good performance results in the previous CX11 drilling campaign, were not effective due to the inability to control high levels of filtrate mud and improper chemical inhibition. Moderate mud densities had to be used to prevent differential sticking risks, but this resulted in wellbore stability problems that led to lengthy trips due to several restrictions and a sidetrack in one well due to the BHA packing off, in which the wellbore stability was compromised by the mud used that did not contain the required mechanical sealing additive.

From the mineralogical point of view, clays encountered in the different formations in Corvina field are smectites (Figure 2). Smectites have two very particular properties that have influenced in the drilling operation and provide extra difficulty during petrophysical evaluation:

1. Because of the strong affinity of smectite to water, wet clay porosity (WCLP) can reach up to 40%.
2. Water changes in smectite produce dimensional changes, thus fractures (dehydration) or swelling (hydration). These dimensional changes are the inherent cause of chemical instability. If not

controlled, the borehole walls weaken and eventually collapse. From the petrophysical side, the high porosity of smectite makes it difficult to determine effective porosity and may mask pay intervals in shaly sands. High contents of smectite also represent a problem due to incomplete logging data sets or data severely affected by large washouts in the formation due to wellbore instability.

These properties of the mineralogy of Cardalitos' shales, pose additional wellbore stability challenges since water-base mud systems are required. Insufficient mud density to prevent shear failure of the rock and ineffective mud inhibition to reduce chemical instability, plus the inability to properly bridge the depleted formation, have been the root causes that have prevented successful drilling of the first Corvina wells.

Engineering and Technological Solutions

Calibrated Geomechanical Model for CX15 Platform

The first wellbore stability study for Corvina field was done while starting the 2008–2009 drilling campaign with the CX11 platform located at approximately 5,800 ft from the CX15 platform. The most relevant finding in this study was a pressure ramp entering Cardalitos with high collapse gradient. This geomechanical model supported the plan to set the casing depth on the top of Cardalitos formation to minimize the risk of differential sticking in the Tumbes formation and recommended the required mud weight for the 8 1/2-in. section in CX11 wells.

A sensitivity analysis was performed on the Corvina field mechanical earth model (MEM) (Figure 3) to explain how the wellbore stability is affected by the well trajectory profile. This sensitivity analysis presents the collapse pressure (equivalent mud weight) at different wellbore inclinations and azimuths. The calculations for this analysis considered the stress magnitudes, rock properties, and stress orientation at specific depth. The analysis was referenced to a critical interval in Cardalitos formation.

It is important to mention that CX11 wells were drilled with a southeast orientation, and the model was constructed and calibrated with all the information available in 2008. After drilling the CX15 wells, which were oriented to northeast, more information about the rock stresses was acquired with sonic logs and oriented calipers. This helped to calibrate the MEM for Corvina field. Consequently, the model better represented what happened in each drilled well and how much mud density was required to overcome the collapse pressure for a specific deviation and azimuth. An important finding on the sensitivity analysis was that formation stress direction does not have a strong variation of the mud weight requirements to prevent collapsing. This is in contrast to the effect of well inclination, which does show a significant variation. Therefore, higher inclinations require higher mud density to keep the wellbore stable (Figure 3).

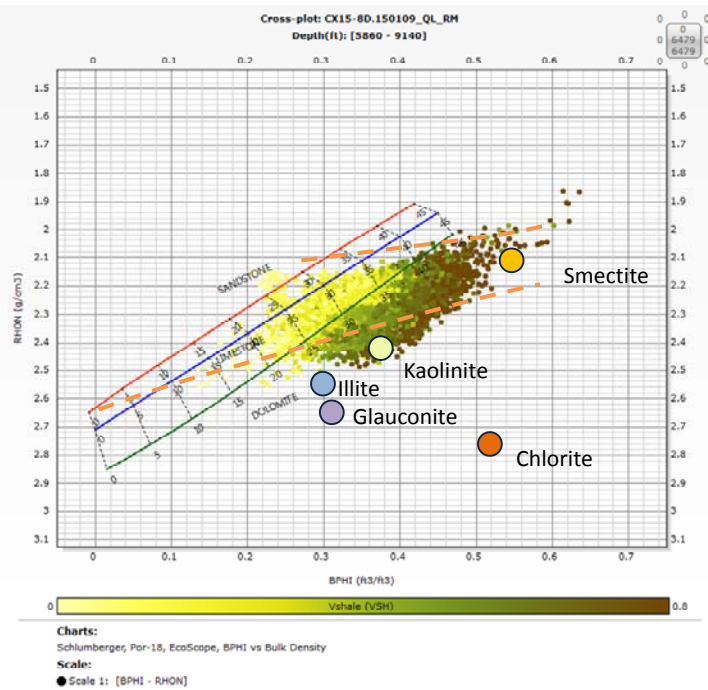


Figure 2. Best thermal neutron porosity (BPHI) versus bulk density crossplot in Cardalitos and Zorritos formations in well CX15-8D.

The calibrated MEM indicated that the mud weights used in the CX11 platform drilling campaign were correct for the well profile used, and these were also applied to the current CX15 platform. However, this strategy was not operationally possible due to the differential sticking events experienced at the Zorritos sands. Hence, there was a need to explore better alternatives for drilling fluids to enhance formation bridging to isolate high hydrostatic overbalance.

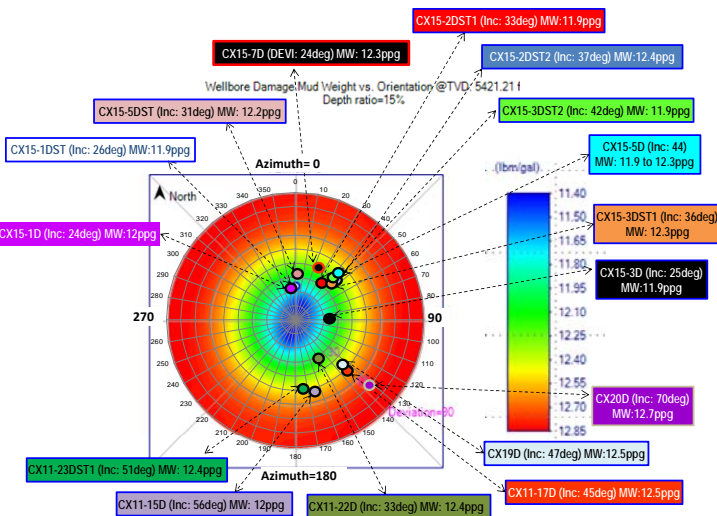


Figure 3. Sensitivity analysis for Cardalitos formation, CX11 and CX15 wells

The sensitivity analysis also provided useful information for the optimization of the well trajectory profile to enhance hole-cleaning and reduce wellbore instability. The geological requirement for the first wells was to cross the geological target with low inclination. This required an S-type trajectory profile, which had to be designed with a high-angle tangent ($\sim 50^\circ$ of inclination) to gain the required displacement to reach the target, and then a drop in inclination at the Cardalitos formation to enter Zorritos sands with the required low inclination (Figure 4a). This type of trajectory presented several problems: higher difficulty for hole cleaning due the generation of a cuttings bed in a high-angle well; higher requirements of mud weight up to 12.6 ppg, as per the sensitivity analysis for inclinations of 50° ; and mechanically induced instability in the wellbore due to high side forces in the dropping curve, as occurred in wells CX15-1D and CX15-2D (Figure 4b).

The operator's geology department and drilling engineering team looked at alternatives for the highest possible angles that the geological targets could be crossed to optimize the well profile in terms of hole cleaning and wellbore stability improvement. This study was supported with the MEM sensitivity analysis and evidence of wellbore instability in the caliper logs at the dropping curves, which could have been worsened by high drilling and reaming side forces in Cardalitos formation (Figure 4b). The result of this study allowed the optimization of the well trajectory design with a J-type profile, which required lower inclinations (22 to 35°) for the tangent section, which would enable easier transportation of cuttings for hole-cleaning and would require lower mud weights to minimize rock collapsing. This profile also reduces side forces at the unstable shale in the Cardalitos formation since no directional work is required through this zone.

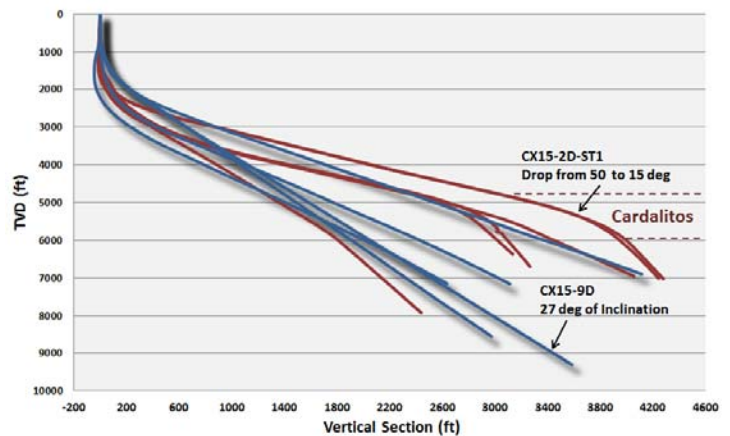


Figure 4a. Trajectory profiles of CX15 wells. Red curves, first wells drilled. Blue curves, optimized well profiles.

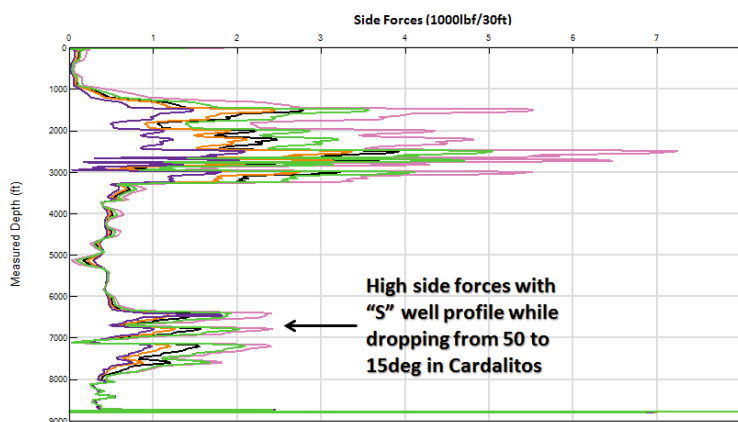


Figure 4b. Side-forces analysis in CX15-2D-ST1 well

Drilling Fluid Design Strategy: Strengthening, Inhibition, and Bridging

One of the main issues in drilling directional wells is wellbore stability while drilling shale formations, Li et al.¹. This formation instability may be caused by various isolated or combined reasons. In shale formations, there may be wellbore destabilization driven by microfracture propagation due to pressure transmission, incorrect drilling fluid inhibition leading to wellbore instability due to chemical interaction with drilled formations, and excessive osmotic pressure due to a disproportionate difference between water activity (A_w) of the drilling fluid and drilled formation. These three effects are inwardly connected and are managed by drilling fluids properties.

The destabilization driven by incorrect drilling fluid properties may occur in oil-base and water-base drilling fluids. As mentioned by Rojas et al.², the excess salinity of the internal phase of an oil-base mud (OBM) can be detrimental to wellbore stability of naturally fractured formations. The low A_w of the brine phase might promote dehydration in a shale formation, and this could lead to increased tensile failure and therefore wellbore instability. Consequently, the water phase salinity (WPS) must be properly adjusted to a given formation drilled. Microfractures can occur naturally exist or can be hydraulically induced during drilling operations. The hydrostatic pressure imposed by the drilling fluid column and the potential drilling fluids penetration into such microfractures is closely connected to their propagation (Gomez and He³).

As mentioned by Meng et al.⁴, the severity of wellbore instability originated by microfracture propagation demands a proper mitigation measure and must be considered when designing a drilling fluid for any given application. Various materials are suggested as beneficial to control/minimize drilling fluid invasion into the formation. Some of these materials are believed to have a plastering capacity that aids in the plugging/bridging of microfractures (Davis and Tooman⁵). The reduction in the invasion by the drilling fluid and filtrate is driven by the extrusion of such materials into the microfractures and bedding planes leading to a more stable wellbore.

As mentioned by Gomez and Patel⁶, numerous shale inhibitors with clearly different action mechanisms are available. This allows the selection and usage of the proper shale inhibitor to a given formation.

An inappropriately low level of inhibition by the drilling fluid may cause wellbore instability issues. The results of the interaction between shale formations and drilling fluid is, generally, more intense when any proper shale inhibitor (chemical or physical) is absent or is present in inappropriately low concentration. In such situations, the shale formations may tend to destabilize by hydrating, swelling, or dispersing or have more intense microfracture propagation. Isolation of these mechanisms, physical and chemical, still can lead to drilling issues related to wellbore instability, but when combined, the synergic effect usually leads to a more unstable wellbore.

Analysis of the CX15 platform history showed that the first four wells drilled experienced a certain level of instability in the Cardalitos and upper Zorritos, which was evidenced by wellbore cavings (Figure 5, bottom left) and the logging-while-drilling (LWD) caliper log taken through that interval (Figure 5, top). This type of instability was associated with both insufficient mud weight while drilling overpressurized formation and trying to prevent differential sticking incidents at exposed sands in the same section and insufficient inhibition of shales causing a chemical instability that weakened the borehole walls. Evidence of insufficient inhibition was encountered in the post-run conditions of the 8 1/2-in. drill bit in the CX15-1D-ST well, which came out with some blades balled up with hydrated shale (Figure 5, bottom right). Wireline caliper logs in a subsequent well also showed larger washouts causing microfracture propagation due to overhydration of shales.

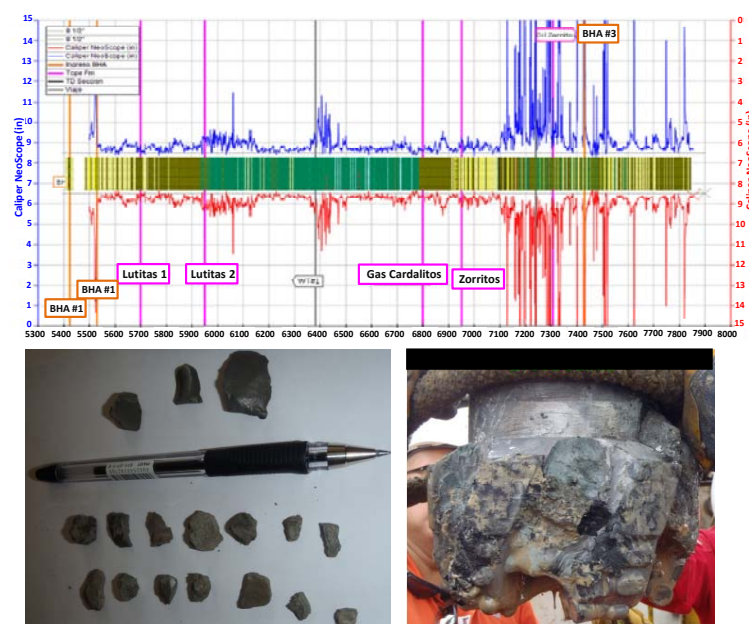


Figure 5. Top: Ultrasonic caliper log with an LWD nuclear tool through Cardalitos and Zorritos formation. Bottom left: Sample of angular cavings while drilling the Cardalitos. Bottom right: Bit balled up with shale from the Cardalitos.

The operator made several efforts to improve the wellbore conditions by changing the mud system from amine to sulfate-base without positive results, eventually other changes were made ending with a potassium-base mud without any improvement. The operator decided to perform audits to the mud products and the results obtained led them to take the decision to use a different mud company.

To properly assess the driving mechanisms of these issues the operator provided the new mud company with some formation samples of Corvina and the nearby Albacora field (Table 1) that were used to evaluate the reactivity profile of the wells, in addition to the mud properties used in CX11.

	9180 ft	9685 ft	10045 ft
Smectite	30.6%	8.8%	16.3%
Muscovite	9.8%	6.1%	15.0%
Quartz	12.9%	20.4%	28.0%
Albite	10.2%	6.6%	2.7%
Feldspar	19.1%	8.5%	29.0%
Montmorillonite	17.4%	2.4%	4.2%
Kaolinite	0.0%	1.7%	5.2%

Table 1. ALBACORA 18D mineralogy

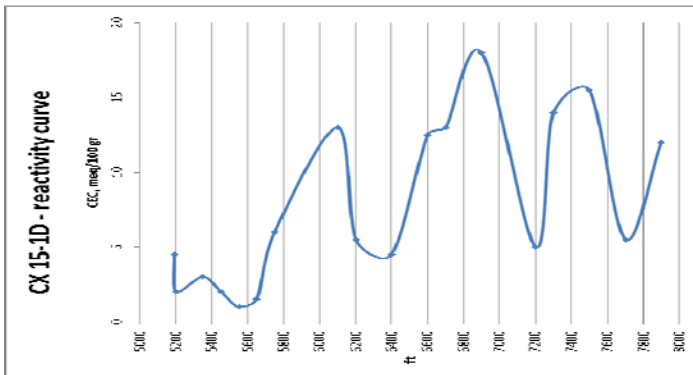


Figure 6. Reactivity curves calculated for CX15-1D

The reactivity curves of CX15-1D (Figure 6) and Albacora 18D wells were analyzed, and it was clear that formations of various levels of reactivity were present, therefore requiring different inhibition levels. Because most of issues were related to low-inhibition behavior of the drilling fluid previously used, the drilling fluid was designed to minimize such issues. The drilling fluid design was based on a polyamine (4 to 6 ppb) working together with potassium salt (25 to 30 g/L) to obtain the synergy effect of both inhibition mechanisms. However, the samples provided did not present the necessary integrity to evaluate potential existing microfractures in the drilled formation. However, based on the reactivity levels, the mineralogy, and the wellbore behavior, the potential existence of microfractured formation was assumed as a fact.

To control the wellbore instability issue observed in Cardalitos formation, a liquid gilsonite suspension was used to properly seal the assumed existing microfractures. This product also had the double function of minimizing the fluid loss into the permeable formations drilled, thereby reducing the risk of stuck pipe due to high differential pressure. The

sealing obtained by the use of the liquid gilsonite suspension aided in obtaining a stable wellbore, even with the increment of density to the range of 12.4 to 12.5 ppg, which was suggested from the calibrated geomechanical model to reduce rock shear failure (collapse).

Once this mud design was implemented, a significant improvement in tripping time was observed at the 8 ½-in. sections. Tight spots and restrictions while tripping, which were caused by wellbore instability, were significantly reduced, which resulted in much faster tripping operations and fewer trips required for borehole conditioning and cleaning (Figure 7).

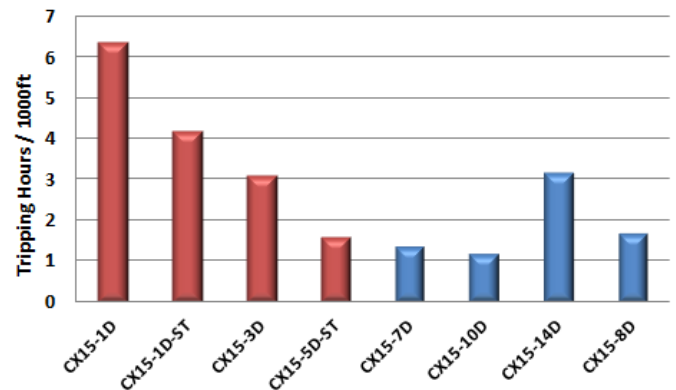


Figure 7. Tripping time, normalized at hours per 1,000 tripped feet, in CX15 platform. Wells in blue were drilled with the new mud system.

The problem of stuck pipe observed in Zorritos formation due to differential pressure was addressed by using mud company proprietary software, based on the ideal packing theory, to develop an adequate particle size distribution to properly seal the formation pore throat, Cargnel, R.D. and Luzardo⁷. This decreases the pressure transmission effect and therefore minimizes the potential for stuck pipe.

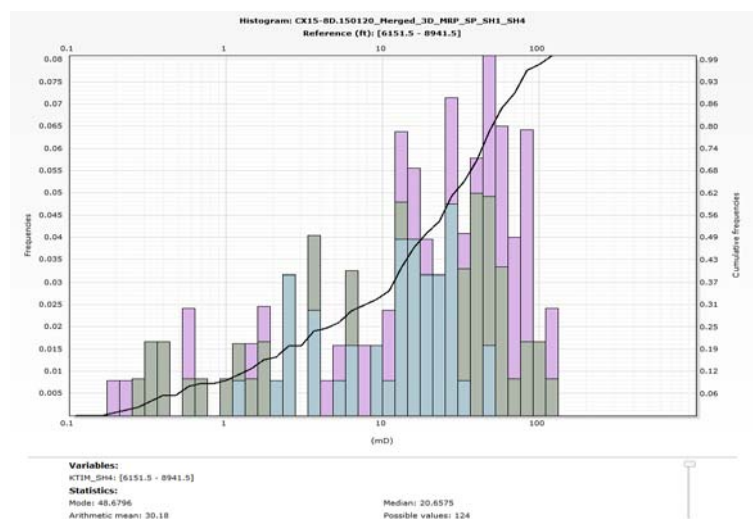


Figure 8. Histogram for permeability distribution in the Zorritos formation, used to estimate pore throat dimensions in sand.

As observed in the histogram in Figure 8, the permeability distribution in the cleanest sands is in the range of 70 to 100 md. This information, when plotted into the proprietary software delivers a target particle size distribution to be used as the objective for obtaining proper sealing (Figure 9).

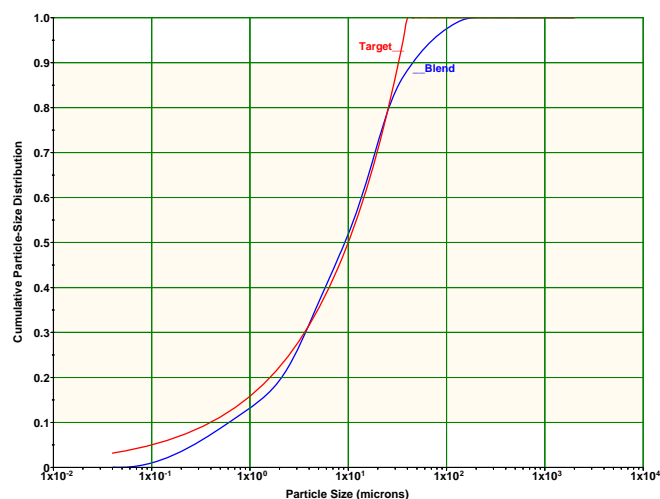


Figure 9. Analysis to determine particle size distribution based on the results obtained from the histogram for permeability distribution

The graph in Figure 9 compares target particle size distribution and the modeled distribution using the proprietary software and the data obtained from the oil operator. It worth mentioning that the blend particle size can be engineered using various different solids to achieve the required target.

This technique has been used to properly isolate the formation pressure from the annulus hydrostatic pressure in recent Corvina wells and maintain the filtrate at minimum levels. This allowed enabled the use of the required mud weight of 12.4 to 12.5 ppg to avoid rock shear failure at shales of Cardalitos and Zorritos, and, at the same time, reduce the risk of suck pipe due to high differential pressure at the target sands in Zorritos. Differential sticking incidents were completely eliminated in all recent wells with the improved formation bridging strategy.

Drilling Practices for Proper Hole-Cleaning

Most of the delays in the drilling process of Corvina wells occurred during tripping operations of the problematic 8 1/2 in section. Hence, the operator conducted an initiative with the directional and drilling fluids companies to implement a strategy to enhance hole cleaning and also to improve drilling practices to better transport cuttings out of the hole and to manage tight spots.

The new drilling fluid system proposed by the mud company and accepted by the operator, with its enhanced properties for clay inhibition, was able to maintain consistent rheological parameters, especially for the low-shear yield

point readings (LSPY), which have the highest effect on cuttings transportation in high-angle wells (Figure 10).

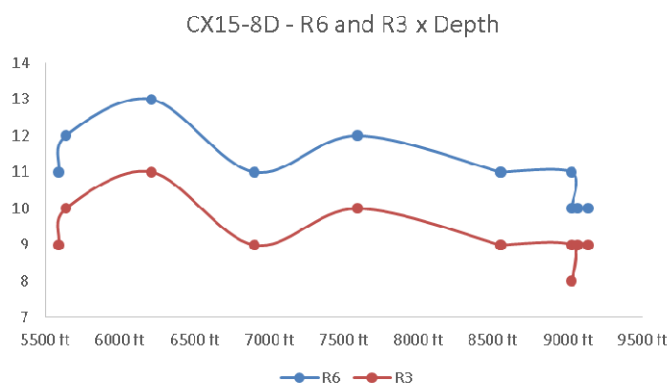


Figure 10. Low-shear fann readings measured while drilling the CX15-8D well with the new mud design.

This enabled a constant drilling performance without interruptions to replace contaminated mud, which had been required in the first problematic wells, and resulted in better hole cleaning through the entire section.

The improved drilling fluid system, combined with an optimized BHA with a fully rotating steerable system (RSS) for cuttings transportation, achieved better hole quality, with significant reduction in formation breakouts and enabled drilling with constant annular velocities along the openhole interval. The caliper log comparison in Figure 11 shows how the chemical and mechanical instability was reduced with the new mud design and proper mud density. The figure also shows how the eccentric cutting action with the mud motor BHA used initially produced a rugose borehole, which was the case in the well CX15-14D. Such rugosity was significantly reduced with good improvement in the quality of the borehole with the addition of the RSS as drive system in the BHA, which was the case for the well CX15-8D.

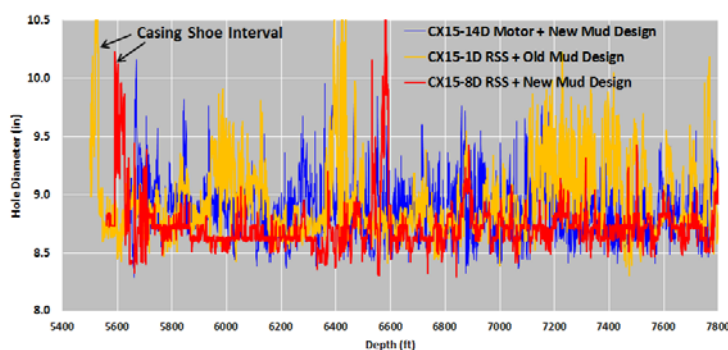


Figure 11. LWD ultrasonic caliper comparison between wells drilled with the old mud system and new mud system and with mud motor and RSS BHAs.

The hydraulic simulations were run with real rheological parameters used for the 8 1/2-in. section and the actual borehole diameter as per the caliper log taken in this interval. The simulations showed no cuttings bed formed with a rotary speed of 130 rpm, used in the RSS BHA whereas the maximum allowable RPMs used for the mud motor BHA of 80 rpm formed a cuttings bed of 0.3 in. This, added to the optimized rheological properties of the mud, not only helped to have more efficient trips, but also reduced the formation friction factors, leading to more stable drilling dynamics with lower levels of stick-slip, which is an effect of torsional vibration that typically increases with higher friction between the BHA/bit and the borehole walls, Omojuwa et al ⁸. The figure 12 shows that the wells drilled with the new mud system, which are enclosed with a blue square, experienced low level of stick-slip most of the time (Low stick-slip ratio).

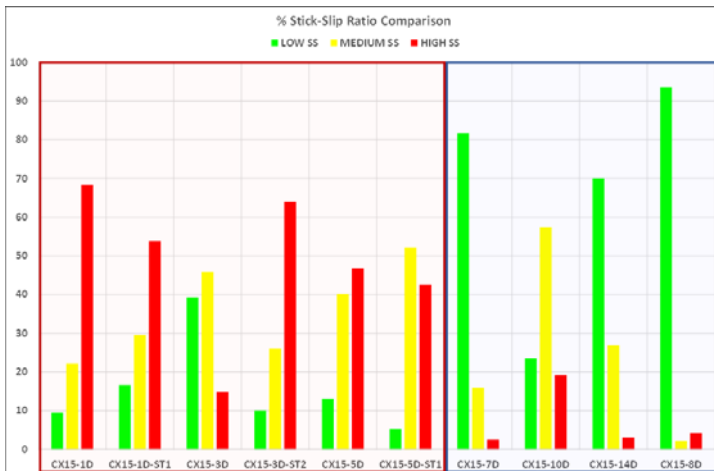


Figure 12. Stick-Slip ratio measured in the 8 1/2-in. section of wells drilled in the CX15 platform. The color bars represent the percentage of the stick-slip level measured in time, for the section length. % Stick-slip ratio = (stick-slip / 2 * surface rpm) * 100.

Real-time surveillance of well execution and continuous communication between the execution teams, operator and service companies, at the rig site and drilling engineering in town, were key to ensuring adherence to agreed drilling parameters for proper hole cleaning and early identification of remedial actions when restrictions were encountered. The torque-and-drag model, which was continuously updated at every connection, was the main indicator to apply corrective measures to improve hole-cleaning conditions.

Results and Continuous Drilling Efficiency Improvement

A significant improvement in drilling performance and efficiency was observed in the very first well in which the new drilling system was implemented. The well CX15-7D was drilled without stuck pipe incidents, and tripping operations with BHA and casing were performed without major difficulties. Optimization of hole cleaning by the addition of

heavy viscous pills every 500 ft, with 2 ppg above current mud weight, also contributed to the improvement of tripping operations. This well was drilled in 27 days, which resulted in 78% optimization compared with the best offset well (Figure 13). Since this well was completed, drilling operations have been optimized to get continuous improvements in tripping and daily rate of penetration (ROP) in every well, with constant ROP performance in the last wells (Figure 14). The recent well CX15-8D, in which the BHA included an RSS tool, was drilled in 30 days without stuck pipe incidents. Such achievement is also a result of big improvements in rig efficiency and operator logistics.

The strategy implemented by the operator and service companies for borehole integrity enhancement and hole cleaning was definitely key in optimizing the CX15 platform drilling campaign. This was also evidenced in a 43% reduction of cuttings recovered in the last wells, compared to those completed with sidetracks, which is attributed to boreholes drilled in gauge. Additionally, significant savings in mud volumes have been recorded of up to 50%, thanks to the good control of rheological properties of the drilling fluid, which was not possible in the first wells where extra fluid was required to replace contaminated mud.

The improvement in the quality of the borehole in recent wells has also resulted in benefits to petrophysical analysis due to the better quality of electrical and nuclear logs. This has led to better interpretation of the reservoir properties and thus more accurate estimation of hydrocarbon production.

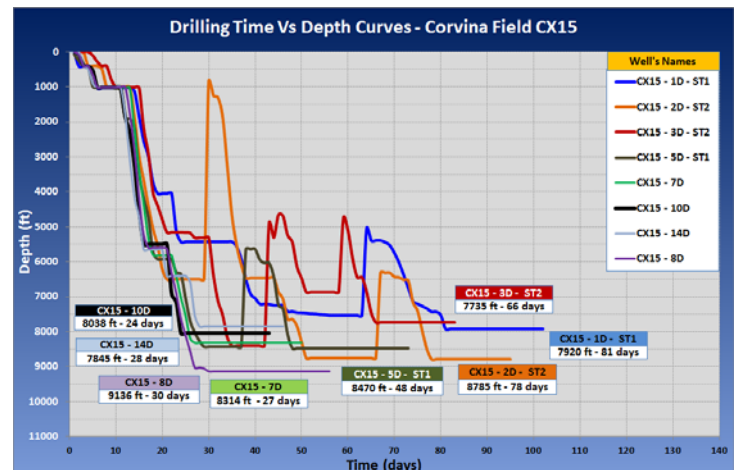


Figure 13. Drilling time versus depth curves of all wells drilled in CX15 platform. Wells CX15-7D, CX15-10D, CX15-14D, and CX15-8D were drilled with new mud system. Number of days in figure's levels corresponds to drilling days, excluding completion's operations

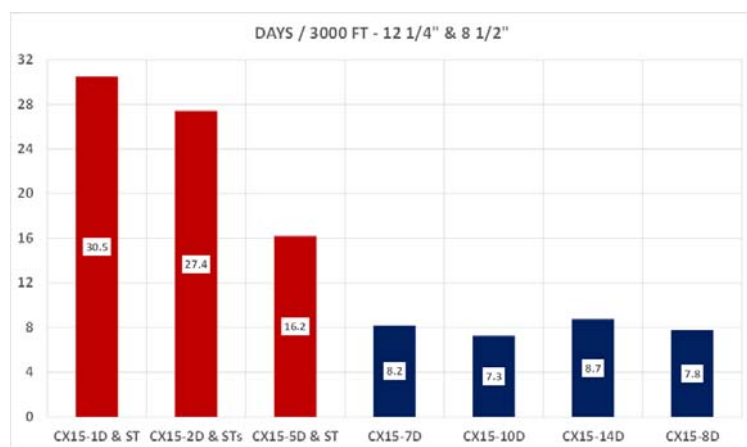


Figure 13. ROP per well presented as footage drilled per day, normalized at days per 3,000 ft drilled.

Conclusions

Drilling through formations with overpressured rock and depleted sands in the same section is possible with effective bridging strategies, which is only achieved by the systematic analysis of the particle size and distribution to properly isolate the sand pore throat.

Rock resistance to collapse can be seriously compromised by chemical instability, as result of improper mud inhibition when drilling shale formation with different levels of reactivity. Existence of micro-fractures in this formation can't be ignored, which could accelerate the chemical and mechanical instability, hence the need of an effective formation strengthening and sealing strategy.

A calibrated geomechanical model with its sensitivity studies, can give important information to optimize the well trajectory profile to facilitate improvement of the wellbore stability. A well trajectory design with lower inclinations at naturally unstable formation, plus avoidance of big changes in direction and inclination at these intervals can prevent drilling complications due to wellbore instability.

Drilling dynamics can be significantly improved when there is a good borehole quality, this was achieved in the CX15 drilling campaign through proper formation inhibition and the use of a full rotating rotary steerable system, which also provided the conditions to enhance hole cleaning with high surface rotary speed.

The substantial enhancement in drilling performance in the CX15 platform was not only achieved with technological solutions and good drilling practices, but also with a good synergy in the planning and execution phase, between mud and directional service companies and the oil operator.

Acknowledgments

The authors wish to thank Pacific Rubiales and Schlumberger for permission to publish this work.

Special thanks to operational people directly involved in the drilling campaign of CX15 platform for their support and commitment in the application of this performance improvement strategies. We thank them for ensuring that the operations were safely and successfully executed.

Thanks to the service companies' line management, Luis Castro and German Macias, for providing all necessary resources to provide the best service quality

References

1. Li, G., Zhang, J., Zhao, H. and Hou, Y. "Nanotechnology to Improve Sealing Ability of Drilling Fluids for Shale with Micro-Cracks During Drilling." SPE 156997, SPE International Oilfield Nanotechnology Conference, Noordwijk, The Netherlands, 12-14 June, 2012.
2. Rojas, J.C., Clark, D.E., Greene, B. and Zhang, J.. "Optimized Salinity Delivers Improved Drilling Performance." AADE-06-DF-HO-11, AADE Drilling Fluid Technical Conference, Houston, Texas, USA, 11-12 April, 2006.
3. Gomez, S. and He, Q. "Fighting Wellbore Instability: Customizing Drilling Fluid Based on Laboratory Studies of Shale-Fluid Interactions." SPE 155536, IADC/SPE Asia Pacific Drilling Technology Conference, Tianjin, China, 9-11 July, 2012.
4. Meng, F. and Fuh, G. "Wellbore Stability Evaluation Guideline for Reducing Non-Productive Time." IPTC 16567, International Petroleum Technology Conference, Beijing, China, 26-28 March, 2013.
5. Davis, N. and Tooman C.E. "New Laboratory Tests Evaluate the Effectiveness of Asphaltene Resin as a Borehole Stabilizer." SPE 17203, *SPE Journal*, vol. 4, no. 1. (March 1989).
6. Gomez, S. and Patel, A. "Shale Inhibition: What Works?" SPE 164108, SPE International Symposium on Oilfield Chemistry, The Woodlands, Texas, USA, 8-10 April, 2013.
7. Cargnel, R.D. and Luzardo, J.P. "Particle Size Distribution Selection of CaCO₃ in Drill-In Fluids: Theory and Applications." SPE 53937, SPE Latin American and Caribbean Petroleum Engineering Conference, Caracas, Venezuela, 21-23 April, 1999.
8. Omojuwa, E., Osisanya, S., and Ahmed, R. "Dynamic Analysis of Stick-Slip Motion of Drillstring While Drilling". SPE 150755, Annual International Conference and Exhibition, Abuja, Nigeria, 30 July-3 August, 2011.