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MULTIDISCIPLINARY COLLABORATIVE CONCEPT AND EXPERT COLLABORATION IMPROVE DRILLING OPERATIONS AND GEOSTEERING DECISIONS IN VACA MUERTA PLAY, NEUQUÉN BASIN, ARGENTINA

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RESUMEN

Concepto Colaborativo Multidisciplinario y Colaboración Experta Mejoran Operaciones de Perforación y Decisiones de Geonavegación en el *Play* Vaca Muerta, Cuenca Neuquina, Argentina

Al observar todo el potencial de la Cuenca de Vaca Muerta se requiere incrementar el número de pozos con alto angulo y horizontales. Estos pozos más complejos incluyen unos desafíos aún mayores que los pozos previos verticales y correspondientemente más costosos. Reducir los riesgos tanto técnicos como económicos requiere de innovación técnica. La colaboración e integración entre el la compañía operadora y la de servicios han demostrado ser primordiales para mejorar la perforación y las decisiones de geo navegación.

Este documento muestra el beneficio de tener un equipo integrado de navegación de reservorio capaz de acceder un reservorio no convencional del Bloque Loma Campana. Para lograr el objetivo, se incluyen integrantes del equipo con experiencia en diferentes competencias, geólogos, petrofísicos, ingenieros de optimización de perforación en tiempo real, perforadores direccionales e ingenieros de reservorio.

La experiencia de los integrantes de la compañía operadora y de servicios de navegación de reservorio, proveen diferentes técnicas de geo navegación y caracterización del intervalo de interés. Adicionalmente se emplean imágenes de pozo en tiempo real y mediciones de dinámica de perforación en la broca de última generación.

Este documento muestra las decisiones en tiempo real y los fundamentos en tiempo real de este concepto de colaboración multidisciplinario, que combina el conocimiento del campo de los expertos de la compañía operadora, con el conocimiento específico de la respuesta de la herramienta de registro LWD, proporcionado por los expertos en navegación de reservorio. Esta integración permite el posicionamiento preciso de la trayectoria en el intervalo objetivo.

INTRODUCTION

In 2013, the Energy Information Administration (EIA) ranked Argentina as the second-largest resource of shale gas and the fourth-largest resource of shale oil in the world. YPF operates several exploration and development blocks in the Neuquén Basin with highly attractive prospects in the Vaca Muerta formation.

The Vaca Muerta shale play is lithologically associated with a Late Jurassic mixed shale (calcareous and silicoclastic) that was developed along the northwestern part of the Argentinean Patagonia, in the Neuquen Basin (Fernandez Badessich y Berrios, 2013).

The sedimentary architecture corresponds to a distal facies of a mixed carbonate sequence developed between the Jurassic Tithonan and Valanginian ages. The depositional system is composed by a clastic/carbonate succession deposited in a shallow-to deep-sea environment (Rojas *et al.* 2018).

The Quintuco and Vaca Muerta formations are Cretaceous transgressive marine deposits, composed of bituminous marls from the Vaca Muerta formation changing to shallower shelf facies with carbonate and clay deposits in the Quintuco formation (Veiga *et al.* 2005)

The presence of open natural fractures in the Quintuco and upper Vaca Muerta formations have been suspected since 1980, but the difficulties in drilling andlogging the intervals under high formation pressure impeded more accurate formation evaluation (Astesiano *et al.* 2013).

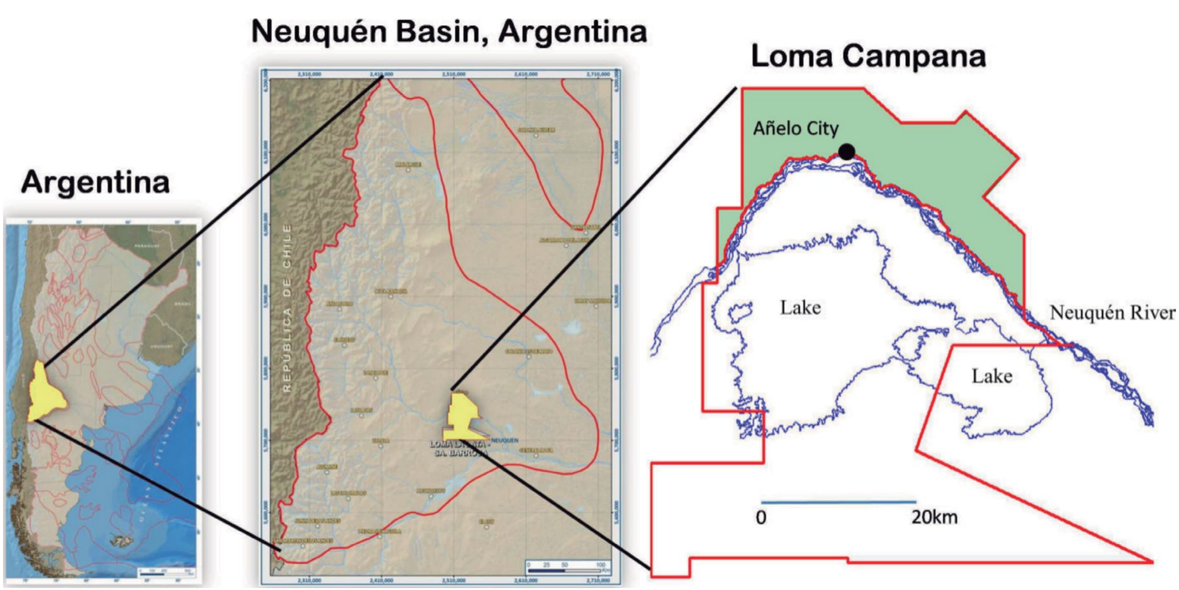

Figure 1. Loma Campana location(Vittore *et al* 2014)

BACKGROUND

The main objective for development of the Loma Campana field is represented by the shales of the Vaca Muerta formation, and Quintuco production levels correspond to a secondary objective of the project.

Realizing the full potential of the Loma Campana oilfield requires an increasing number of high-angle and horizontal wells (HAHZ). With the growing trend toward HAHZ, advanced geosteering services and optimized wellbore positioning are more important to a project's success than ever before. Geosteering has become a fundamental part of the modern field development program because simple geometric well targets do not capture the capabilities and value of today' technologies.

In this context, a new culture of real-time multidisciplinary collaboration was formed toimprove drilling operations and geosteering decisions in the Vaca Muerta play. To accomplish this objective successfully, the team was designed to have members with diverse backgrounds, such asgeologists, petrophysics, real-time drilling optimization engineers, directional drillers, and reservoir engineers, Proper geosteering would optimize wellbore placement in the productive interval, maximizing drilling efficiency and hydrocarbon production.

The concept, functionality and capability of integrating geosteering and LWD toolshave been described in detail by Coghill, *et al.* (2001).

All previous experiences in the field and in similar operations were considered during the planning phase. The planning phase included all key stake holders and operational personnel who wouldbe involved in drilling and planning of the lateral well, including the geologist, the drilling engineer, the service company reservoir navigation engineers, the wellsite geologists, and, if the well had a challenging completion, the completions engineer (Bacon *et al*. 2010).

In the past, wells had been placed in the target and maintained there, and in some cases issues to occur when running completions because of excessive doglegs. Limitations must be set early what would be permissible (Bacon *et al.* 2010).

PRE-WELL PLANNING

An evaluation of available logging and drilling technologies was undertaken to ascertain the optimum configuration for the successful placement and drilling of the lateral. A cost-to-benefit approach to each logging tool, and an open, frank discussion about the best way to approach the reservoir occurred between the service company and the client. This involved modeling thetool responses and several Q&A sessions with an open format to reachthe best solution without adding unnecessary complications, risk and cost to the project (Bacon *et al.* 2010).

The ability to change the wellbore trajectory quickly and accurately whilst obtaining excellent LWD data and continuous borehole images required the selection of a Rotary Closed Loop Drilling System. This technology was also evaluated against a motor run, ifone would be required as a contingency, and procedures were put in place for this situation (Bacon *et al.* 2010).

Conventional well planning techniques required the Geoscience team to select a number of targets defined by their location in3-D space. The Drilling team then triedto construct a well plan satisfying the targets, which also accounted for necessary engineering limitations such as torque and drag, dogleg severity (DLS), the practical limitations of proposed drilling tools, and completion requirements. To achieve awell plan that was acceptable to geoscience and engineering needs, an iterative process requiring numerous adjustments was used before a definitive well plan was approved (Coghill, J., Benefield, M., Poppitt, A., & Skillings, J. 2001).

To improve efficiency and reduce time and costs involved in generating an approved well plan it was necessary to develop aservice that integrated well planning into the 3-D earth model.

When an accurate model was built and verified, thenthe well was planned from the reservoir upwards, based on the geological objectives supplied by the operator. The objectives were defined as stratigraphic well positions. A single meeting was required between the Service Company and key operator personnel from the geoscience and drilling disciplines to provide any further input. Fine-tuning of the wellpath was possible during the meeting; ensuring well planning costs and time were kept to a minimum.

CASE HISTORY

Objective

Geosteer the well path to enhance productivity, achieve a better rate of penetration (ROP), reduce the chances of deformation, and promote the hydraulic fracture efficiency.

Pre Well Modelling

Pre-well modelling performed to determine a probable tool response based on logs from previously logged wells, the planned well path, and interpretations of seismic structures. In response to a request, two wells were proposed to drill and geosteer, so information was gathered and models prepared.

Interpretation of seismic structures did not suggest a complex geology framework, so a smooth synclinal structure was expected and planned lateral sections would be drilled starting at center of this fold and drilled upward toward the north and south.

For the landing, a real-time log comparison against the offset and modelled response were performed, a close correlation evaluated stratigraphic position projected to bit, to adjust the landing depth.

Due to the variable shale character in the gamma ray measurement for the actual target

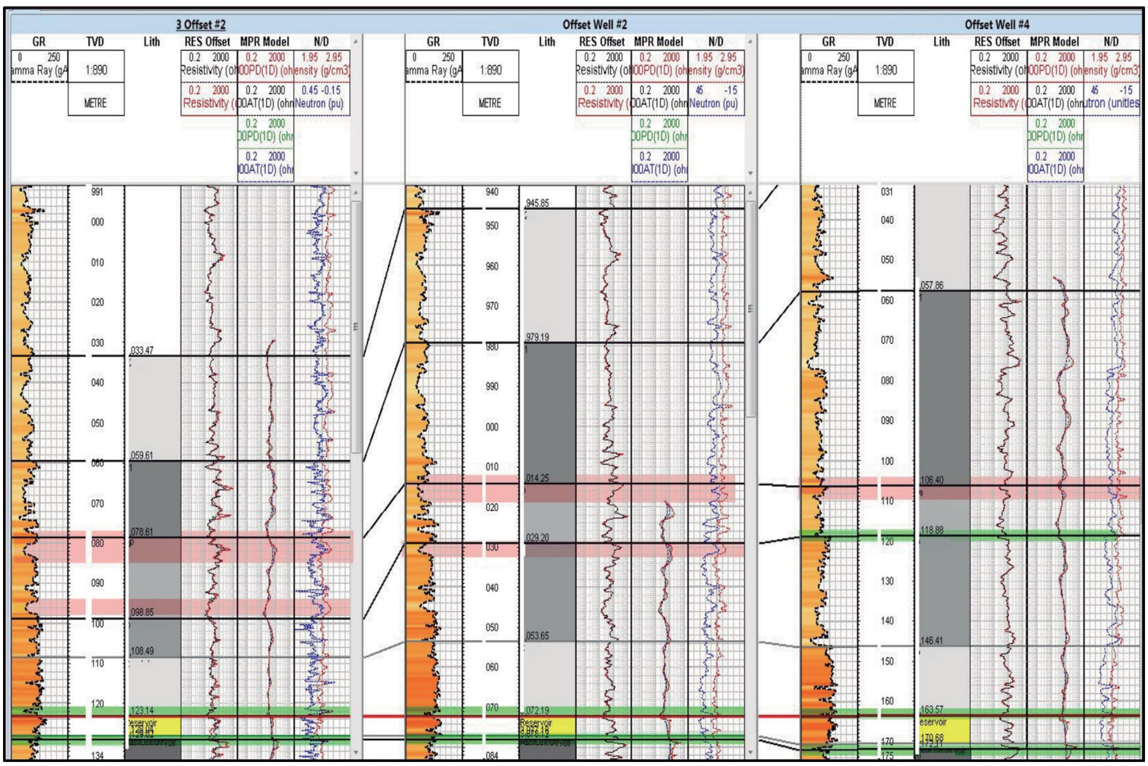

Figure 2. TVD correlation. ~6 m TVD Target interval (in Yellow) defined based on petrophysical features

stratigraphic section, also observed on several offset wells, and that the objective was to steer on this interval, azimuthal gamma ray Image is expected to have several features (sinusoids up or down) if well path is drilling up or down in stratigraphic section, the team could will take advantage of this features to interpret drilling well path up or down in the stratigraphic section and correct the trajectory as requested.

The BHA configuration for the landing included a mud motor and LWD tools, a planned well path maximum DLS of ~7.5deg/30m. Permanent monitoring and continuous updating of the geosteering model was a key task to land and steer to the target interval.

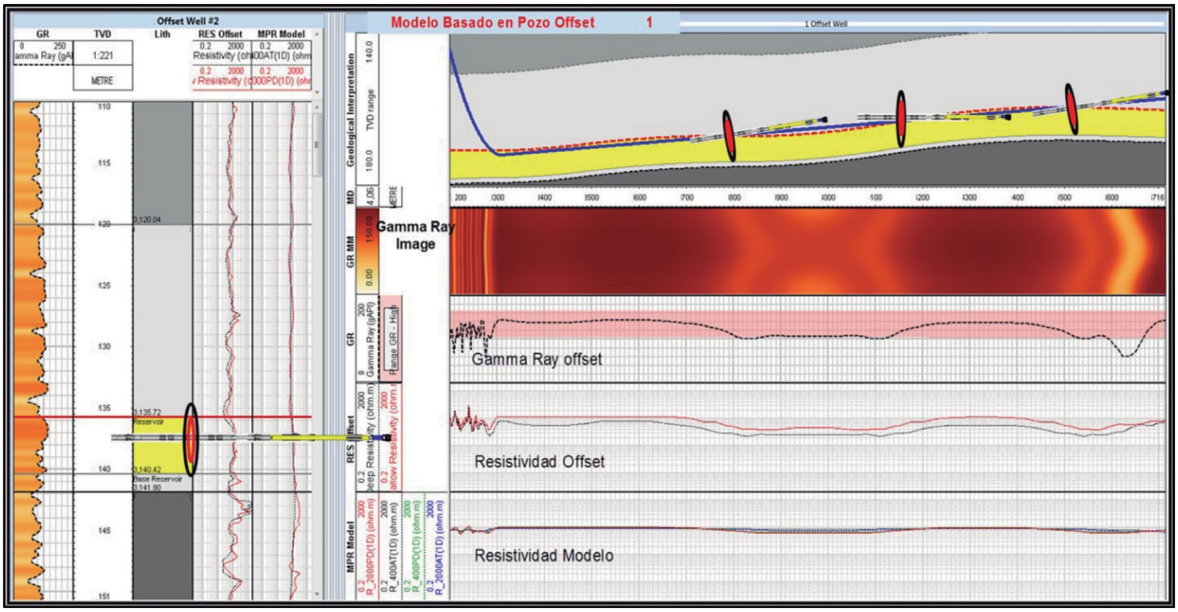

Figure 3. Example of simple forward-model response for the planned well path, based on logs from offset well and assumed a structure with smooth changes in dip angle.

For the lateral section, the BHA configuration included an RSS, a modular mud motor and LWD tools.

Real-Time Data

While drilling, continuous updating of the geosteering model updating enabled correlation of real-time data with the offset data logs. Interpretation suggested adjusting the landing of the well path and modifying the landing TVD ~ 2m deep.

After the landing trajectory and the well path achieve a 90-degree inclination, a decision was made to evaluate the BHA behavior while drilling the lateral section. This evaluation detected that the directional control was not working as expected to maintain 90-degrees of inclination. A decision was made to change the BHA and include the RSS, the modular mud motor and LWD tools and to continue drilling. Deployment of the RSS enabled better directional control, fast and effective well path changes and TVD control.

Several geosteering recommendations were made to position trajectory as requested and then to keep the well path at the same stratigraphic position.

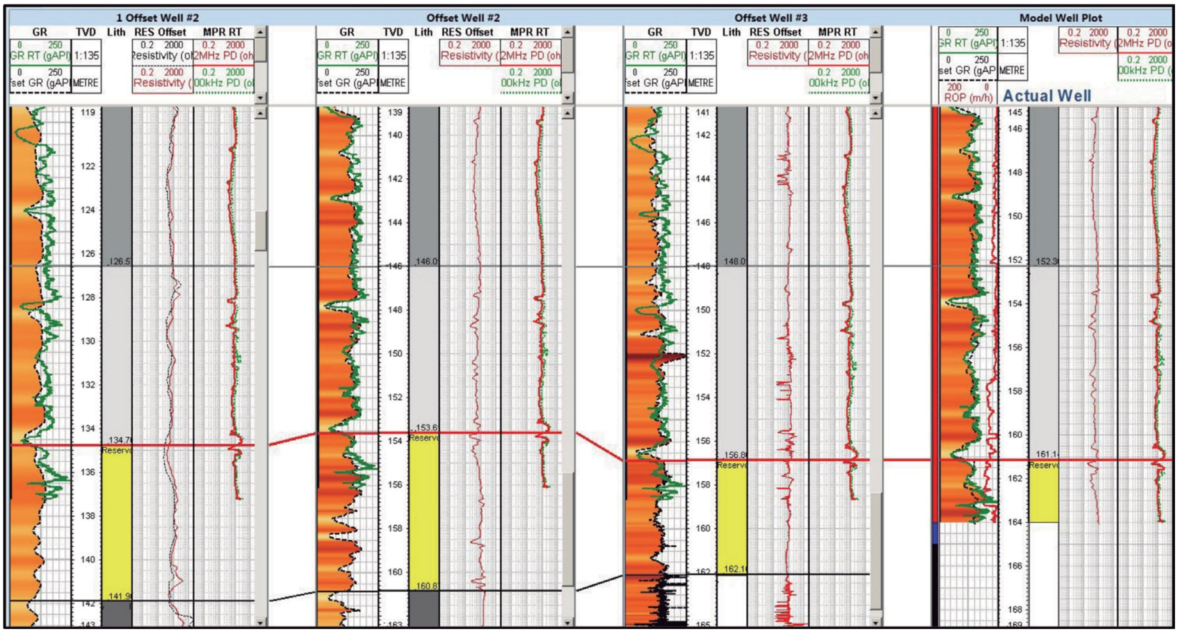

Figure 4. TVD Landing well path correlation. Notice the model well path TVD data indicatedthe trajectory was ~3m TVD below target interval top. This confirmed the accurate decision of landing the well ~ 2m deeper than the planned TVD.

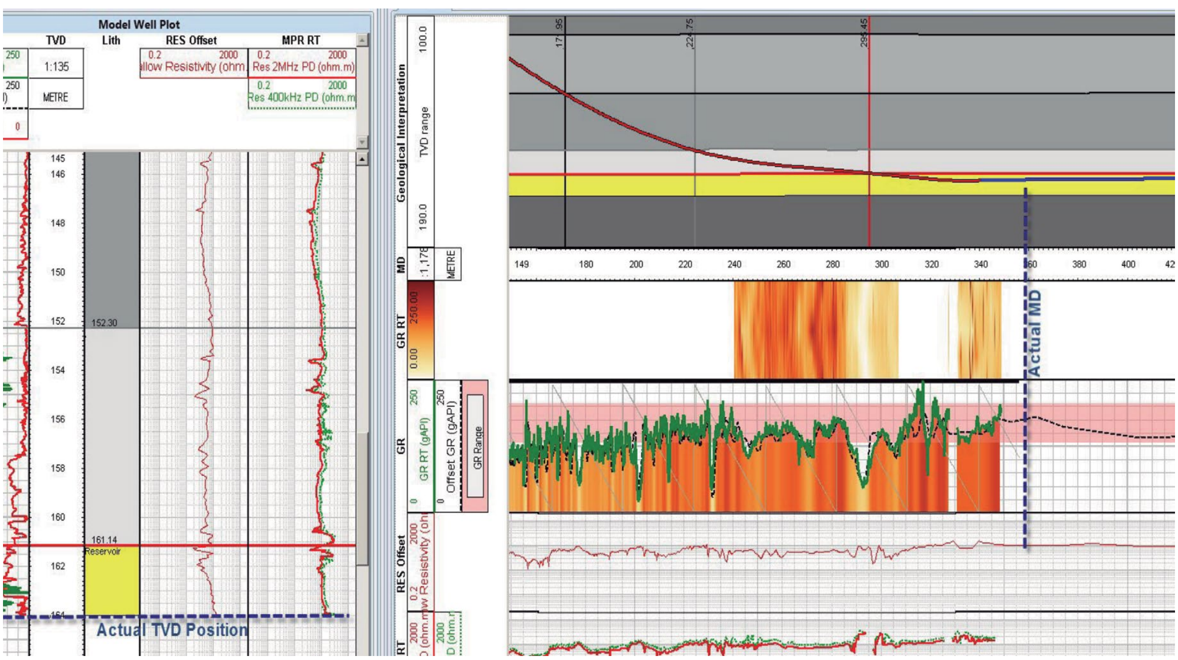

Figure 5. TVD-MD plot. Updated geosteering model with RT data. Data matched theoffset well, also the interpretation matched and indicated the landing TVD and the actual trajectory position inside target Interval.

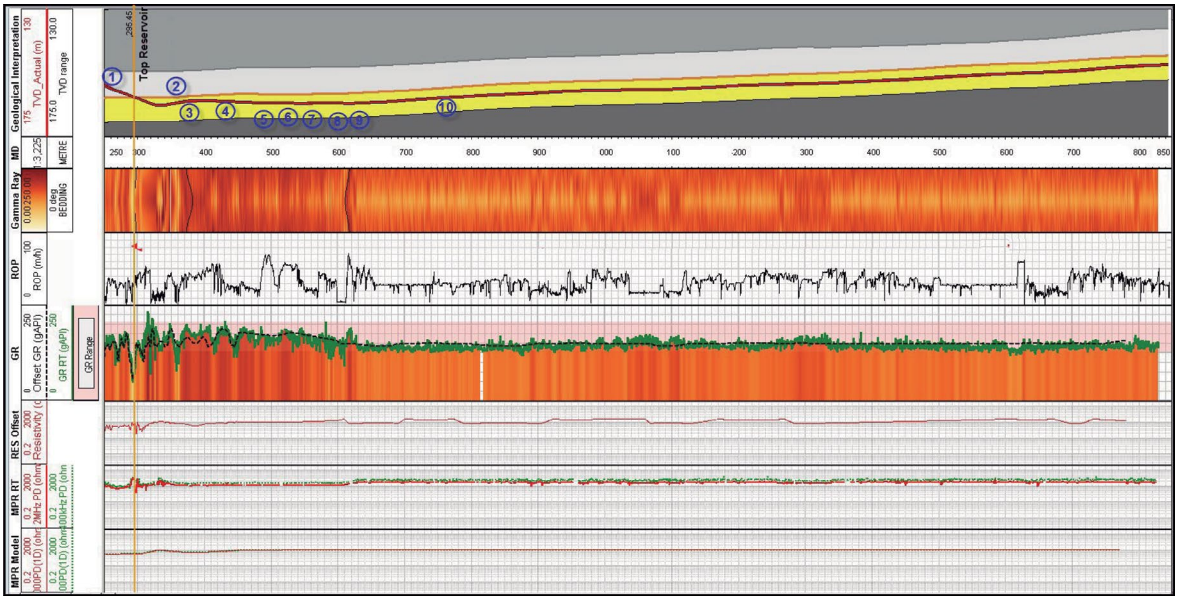

Figure 6. Real-time updated model and final interpretation for the drilled lateral section

RESULTS

- Confirm TVD for landing according to requirements
- Continuous Gamma Ray image features interpretation
- Update geological framework
- RT data interpretation did not give any indication of the wellpathapproaching the top or the base of the target interval.
- Real-time downhole parameters change responses helped guide actions for the drilling and geology teams
- Better directional trajectory control and identification of any abnormal events using bending moment and bending tool face data (local high DLS, spiraling tendencies)
- Directional control was achieved for all lateral sections, the inclination changes were fulfilled by the RSS, according to recommendations
- A total of ~1550m were 100% inside target interval.

CONCLUSION

The field applications presented in this paper demonstrate how the partnership established between operator and service company in the well drilled in the Vaca Muerta basin became a strategy to improve and contribute to successfully access the unconventional play in Loma Campana block.

The multidisciplinary collaborative concept and expert collaboration demonstrate the ability to drill the well, and in geosteering decisions and provide a betteroverview of geologic structures.

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