VOLVER

INTEGRATION OF MUD LOGGING AND ADVANCED WIRELINE LOG DATA IN FORMATION EVALUATION. A CASE STUDY FROM AN EXPLORATORY WELL IN VENEZUELA

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RESUMEN

Evaluación de Formaciones Integrando Datos de Registro de Lodo y de Herramientas Avanzadas de Registros con Guaya Eléctrica. Un Caso de Estudio de un Pozo Exploratorio en Venezuela.

Mantener e incrementar los niveles de producción de hidrocarburo en la Cuenca del Sur de Venezuela requiere una campaña exploratoria en campos poco conocidos y con reservorios complejos, buscando así nuevas reservas. Existen muchos desafíos en la evaluación de formaciones en pozos exploratorios debido a las incertidumbres que pueden presentarse, tales como: parámetros petrofísicos, litología y tipo de fluido, entre otros. El objetivo en este caso de estudio, es reducir estas incertidumbres en un área donde la información disponible propone la presencia de agua de formación con diferentes salinidades, litología compleja, e incertidumbre en el tipo de hidrocarburo presente en el reservorio.

Un flujograma paso a paso fue realizado por el equipo de petrofísica, geología e ingeniería de reservorio para caracterizar el reservorio. El primer paso fue el análisis de cromatografía y ripios desde la cabina de registro de lodo durante la perforación. El segundo paso fue determinar las principales zonas del reservorio con ayuda de los registros petrofísicos convencionales y avanzados (espectroscopia, dispersión dieléctrica y resonancia magnética nuclear). El tercer paso consistió en la caracterización sedimentológica y estructural en las adyacencias del pozo usando la imagen micro-resistiva, estimando las heterogeneidades texturales del reservorio y evaluando la forma del hoyo. El cuarto paso fue determinar el perfil de presiones de las zonas prospectivas del reservorio, determinando así unidades de flujo y densidad de fluido para inferir el tipo de fluido involucrado. El último paso fue tomar muestras de fluido usando un probador de formación incluyendo análisis de fluido a condiciones de fondo en tiempo real.

Esta evaluación de pozo demuestra la importancia de combinar diferentes tipos de mediciones y la integración de diferentes disciplinas para obtener una evaluación de formación más precisa y aplicable a campos complejos en Venezuela, que son la clave para los planes de desarrollo. El resultado satisfactorio abre nuevas oportunidades en el área, permitiendo la planificación, diseño y perforación de pozos de desarrollo y evaluación.

INTRODUCTION

Exploratory Campaign

Nowadays in Venezuela, there is an exploratory campaign with the aim to find light oil reserves, which are necessary for diluting and improving the heavy and extra-heavy oil produced in the Orinoco Belt. Las Lomas field is located in southwestern Venezuela, in the Barinas basin, near the Andean flank (Fig. 1). The exploratory well LLM-B was drilled to evaluate the oil potential in the Escandalosa (carbonates) and Gobernador (sands) formations.

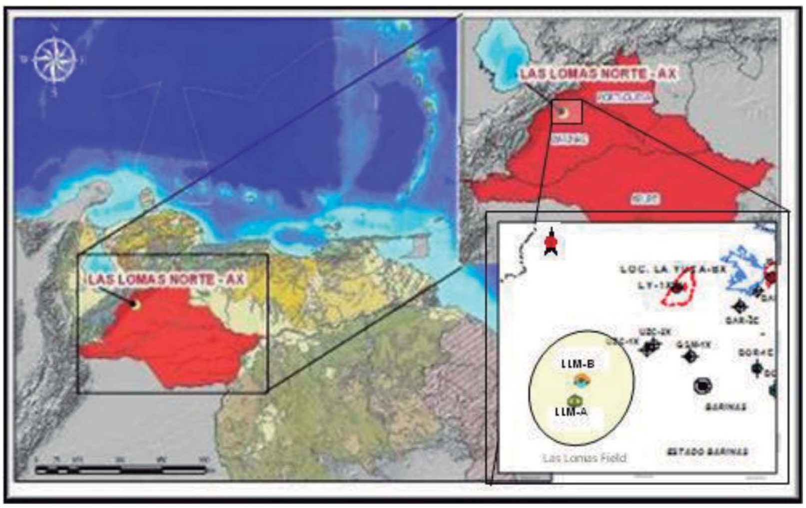

Figure 1. Geographic location, Las Lomas field, Venezuela.

Geological Framework

The Eocene Gobernador Formation is an important hydrocarbon reservoir in the Barinas Basin and forms a regional extensive sand sheet, covering more than 26,000 squared-kilometers. The formation overlies a major unconformity extending from the upper Cretaceous to the middle Eocene which marked the transition from a passive to a foreland tectonic setting. The sandstones were deposited on a fluvial-eroded Cretaceous surface affected by synsedimentarytectonism and onlaps onto uplifting arches to the north and south, and the Guayana shield to the southwest, which constituted the primary source of fluvial sand. The Gobernador thickness varies from 40 to 300 feet (12 to 91 meters) and was controlled by synsedimentary folding and fluvial incision. In the zones of fluvial incision, the base of the formation is comprised of medium to coarse-grained conglomeratic cross-bedded sandstones deposited within large bedload-dominant braided rivers. Also the regional facies patterns indicate a northward evolution into more open marine conditions, with fine-grained sandstones overlain by bioclastic carbonates. These regional facies variations as well as the effects of synsedimentarytectonism on sandstone thickness have an important implication for regional exploration strategies in the basin.

INTEGRATED WORKFLOW USING MUD LOGGING AND ADVANCED WIRELINE LOGS

There are numerous challenges when performing a formation evaluation in exploratory wells due to the uncertainties that can be present, such as petrophysical parameters, water salinity, lithology, fluid type, permeability, and formation pressures, among others. In this case study, the objective is to reduce the uncertainty in the petrophysical evaluation in an exploratory well in an area where data suggest the presence of low and variable water salinity (freshwater zones), complex lithology, and uncertainty in the hydrocarbon type present in the reservoir (i.e., gas or light oil).

An innovative workflow with the help of new technologies was used to make a proper formation evaluation analyzing mud logging along with advanced wireline log data such as conventional triple combo logs, dielectric analysis, nuclear magnetic resonance (NMR), micro-images, spectroscopy, and formation tester samples and pressures. The objective of this workflow is to reduce the uncertainty in the formation evaluation, using all the available information.

A five step approach was put in place with a strong interaction between the petrophysics, geology and reservoir engineering team to fully determine and characterize the reservoir zones:

1. Analyze the cuttings and chromatographic interpretation from the mud logging cabin during drilling.
2. Determine the main potential reservoir zones with the help of the static petrophysical logs: density, porosity, and resistivity, as well as mineralogy, dielectric and magnetic resonance measurements.
3. Determine the characteristics of the potential zones using a micro-imager tool. The latter allows to update the geological structure of the drilled section, estimate textural heterogeneities (i.e. internal structures), and define the thickness of reservoir zones and borehole geometry (i.e. borehole ovalization, wash-outs and mudcake thickness).
4. Perform pressure profiling of the potential reservoir zones in order to determine flow units and to infer fluid density and thus fluid type from pressure gradients.
5. Confirm the fluid type that had been inferred from petrophysical logs and pressures gradients; this was done in real time from downhole fluid analysis at an attempted pumping station beyond the invasion. This information was critical at an early stage and key in the design of the reservoir completion.

By integrating these advanced logs to solve the fluid uncertainty, the value of each measurement is enhanced and used to its fullest potential, creating a final product that justifies the use of advanced logs in exploratory wells on land.

MUD LOGGING

The analysis of the cuttings from the mud logging is very important to define potential reservoir zones, thorough lithological analysis and interpretation of the fluorescence can indicate prospective intervals. According to the fluorescence intensity, color and cut can used to interpret the possible type of hydrocarbon and mobility in the rock.

During the drilling phase, some prospective intervals were determined. The fluorescence was light yellow color of moderate intensity, and the cut was slow. These characteristics indicated a 35 to 41 °API oil and a low-to moderate porosity/permeability interval.

Also important in mud logging analysis is mud gas chromatography, which is the interpretation of the gases detected by the chromatograph in the cabin. The chromatograph performs an analysis of samples taken by means of an instrument called a trap, placed at the end of the flow line from the well. Detected gases are burned, and these are quantified and discriminated according to their components: methane (C_1), ethane (C_2), propane (C_3), butane (C_4^+) and pentane (C_5^+). This chromatographic analysis was performed to identify the type of fluid in the Gobernador Formation.

The mud gas analysis was executed through three methods: Pixler ratio, Triangular Gas Ratio plot and Wetness/Balance - Character. The interpretation of these three methods gives us the origin of the gases analyzed. The Pixler Ratio plot (Fig. 2A) show in the vertical axis in logarithmic scale the relation between the C_1 and the others gases (Pixler, B. 1969), the sample of gas in the Gobernador Formation is represented in the graph how a line inside the gas zone. The next method, Triangular Gas Ratio plot (Fig. 2B), display the relations C_2/Σ, C_3/Σ and nC_4/Σ, according to the area where the interception is marked inside or outside the ovoid, is related to the type of fluid present in the formation (Crampin, T. 2013). In this case, the triangulation of the relations is outside the ovoid, near to the top, generally interpreted as gas zone.

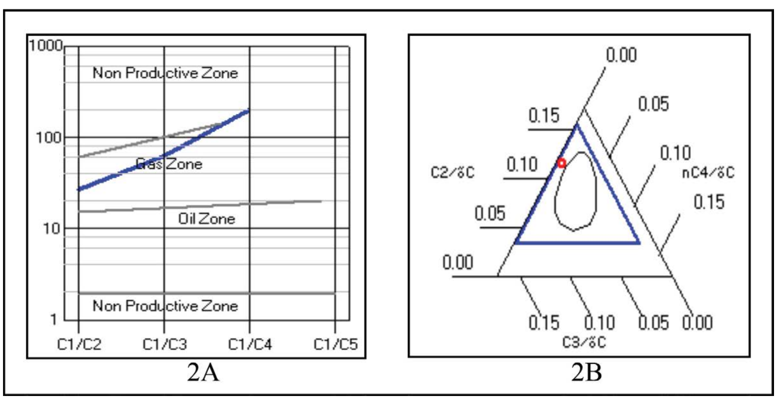

Figure 2. Interpretation Pixler Ratio and Triangular Gas Ratio plot, Gobernador formation, LLM-B.

The last method is the relation Wetness/Balance and Character (Haworth, J. *et al* 1985), this is calculated based in the equations described below:

Wetness-Balance:

$$\text{Wetness (Wh)} = (C_2+C_3+C_4+C_5)/(C_1+ C_2+C_3+C_4+C_5) \times 100$$

$$\text{Balance (Bh)} = (C_1+C_2)/(C_3+C_4+C_5)$$

Character (Ch) Ratio:

$$\text{Character (Ch)} = (C_4+C_5)/C_3$$

The Wetness (Wh)/Balance (Bh) and Character (Ch) is a methodology widely used, and it is based in the relations between the density of the gases (C_1 to C_5). The graph built show at the top of the Gobernador formation (Fig. 3) high values of Wh (>50) and lower Bh, denoting in this case presence of water. Otherwise, in the next interval change the behavior of the curves, decreasing Wh and rising Bh, in all this zone the indicators decreasing and risen but with the tendency to be closer, this can be interpreted as a zone with light oil and gas (Unrau S., *et al.* 2012). At the button of the zone in study, the Bh increase abruptly and Wh decrease, this tendency is generally related with dry gas.

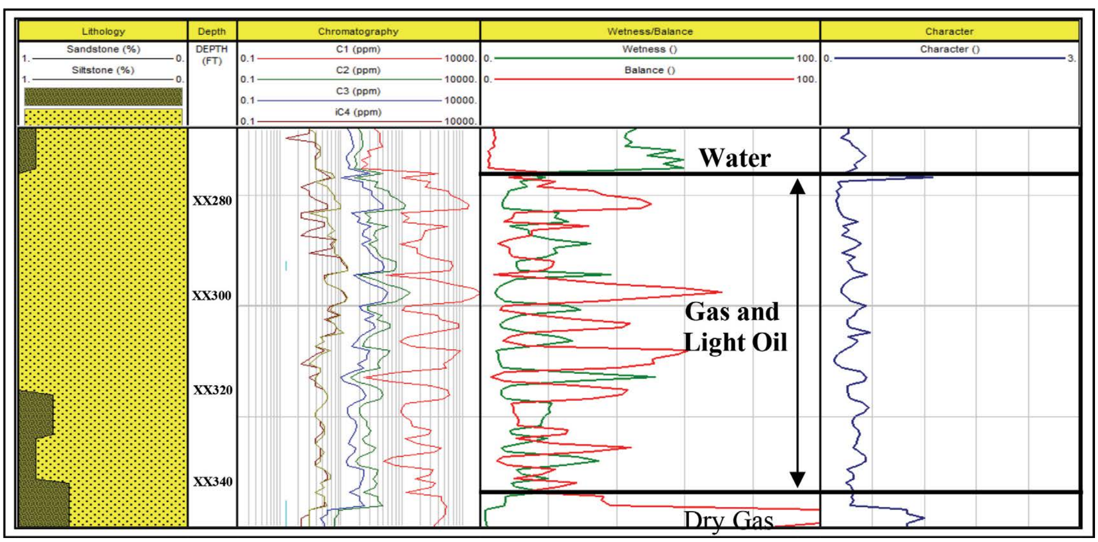

Figure 3. Wetness/Balance and Character Interpretation, GobernadorFormation, LLM-B.

The chromatographic analysis through three different methods allow infer a zone in the Gobernador Formation with presence of gas and light oil, followed below by an interval with dry gas.

PETROPHYSICS

The study was divided into two phases: first, an analysis of the mineral composition was performed, and second, a fluid model was developed. The mineral composition was verified with the borehole image with the micro-imager tool to obtain a better understanding of the geological model present in this field.

There are several challenges when performing a formation evaluation in exploratory wells due to the uncertainties that can be present, such as: petrophysical parameters, lithology, and fluid type, among others. In this case study, the objective is to reduce the uncertainty in the formation evaluation in an exploratory well; according to the information available from the area, the water salinity is low and variable, the lithology is complex and there is an uncertainty regarding the type of hydrocarbon present in the Reservoir. Conventional logs are not capable of resolving all the uncertainties of the petrophysical evaluation in complex environments, such as water formation salinity, oil mobility, free water volume, fluid type, etc. For this reason, advanced petrophysical logs were added to the evaluation program. They are briefly discussed below.

The most important tool for mineralogical analysis is the elemental spectroscopy tool. The Elemental Capture Spectroscopy measurement provides valuable information regarding the clay and the main mineral concentration within the formations; it also provides a variable matrix density which allows an accurate calculation of porosity.

To characterize the fluid model, the expert magnetic resonance tool was run in saturation profile mode, which provides fluid typing information in a continuous depth log at three independent depths of investigation and additionally allows the creation of T1-diffusion maps on selected intervals for quality control.

The dielectric tool was added to the logging program to complement the NMR interpretation. Dielectric tool provides the following answers when run in OBM wells: 1. Water filled porosity, with a shallow depth of investigation, typically 1 to 3 inches of depth of investigation in OBM; 2. Formation water salinity, assuming that only the oil phase from the OBM emulsion invades the formation, the salinity estimated from dielectric analysis should approach formation water salinity; this salinity can be later combined with deep resistivity to estimate more accurately water resistivity in zones where formation water salinity is unknown or variable; 3. Dielectric shallow zone resistivity (RXO_ADT), which is particularly useful in OBM because it is a quick indicator of movable water (water displaced by OBM); when this occurs in OBM, then RXO_ADT > Rt. When RXO_ADT ≈ Rt then we are in front of an impermeable zone or a zone at irreducible water saturation, Swirr.

The petrophysical evaluation combining the measurements mentioned above is presented in Figs. 4 and 6. The Gamma Ray, Spectral Gamma Ray and Caliper are presented in the first track, followed by the default mineralogy obtained from the elemental capture spectroscopy (track

2), and the resistivity in the third track. The comparison between the RXO obtained from the dielectric tool and the deep resistivity is shown in track 4, in order to give a quick indication of potential presence of movable water (water displaced by OBM). Then the volumes and saturations from the invaded zone (Sxo) from the dielectric tool compared to those of a deep zone computed from Deep Resistivity are presented in track 5 and 6 respectively. The results of multi-mineral solver (ELAN) are shown in track 7, and compare well with default ECS lithology; formation water salinity estimated by dielectric measurement and from water samples are shown in track 8. Track 9 is a porosity track including the density and neutron measurement, compared to the porosities obtained from the different depths of investigation of the magnetic resonance measurements, the density neutron crossover shows the gas effect. The last 3 tracks 11, 12 and 13 show the saturation profiling data from the three shells or depths of investigation (1.5in, 2.7in and 4in) from the magnetic resonance tool. In this track six shadings are shown: Bound water shading is the area between right limit and bound water volume from magnetic resonance measurement, free water shading is the area between free water volume and bound water volume from magnetic resonance measurement, oil shading is the area between volume of oil and free water volume from

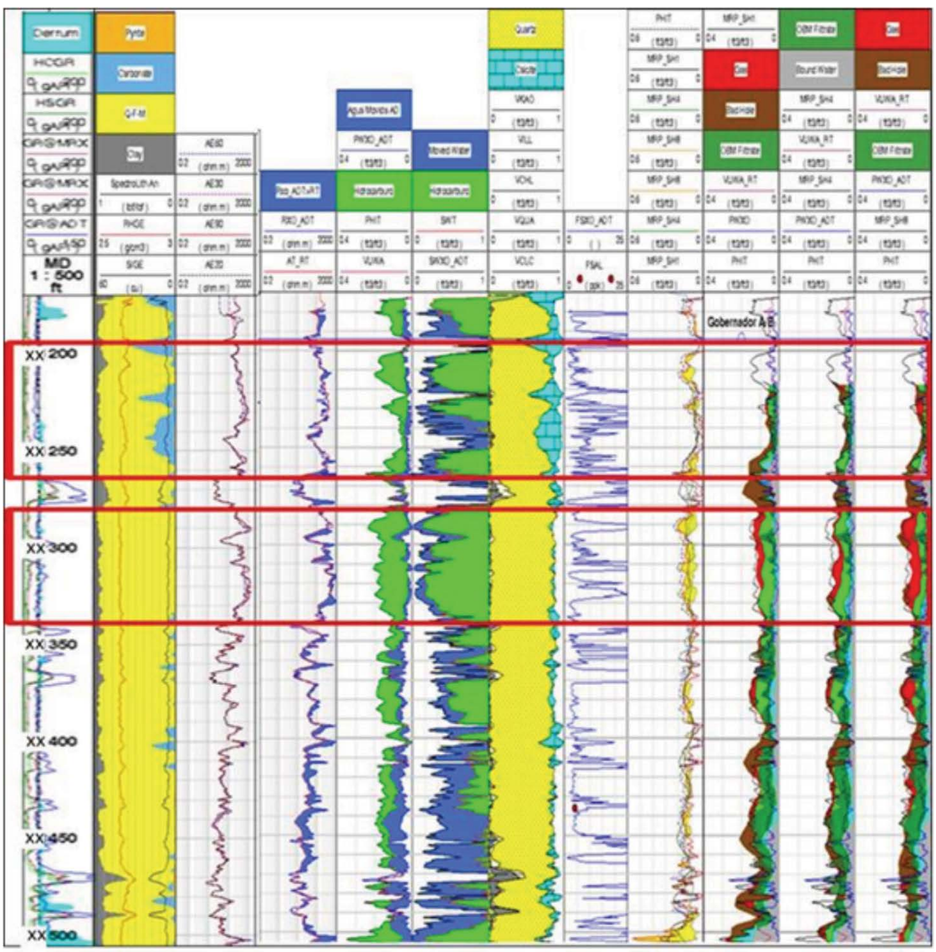

Figure 4. Open hole composite log from Gobernador Formation (xx200-xx350 ft interval).

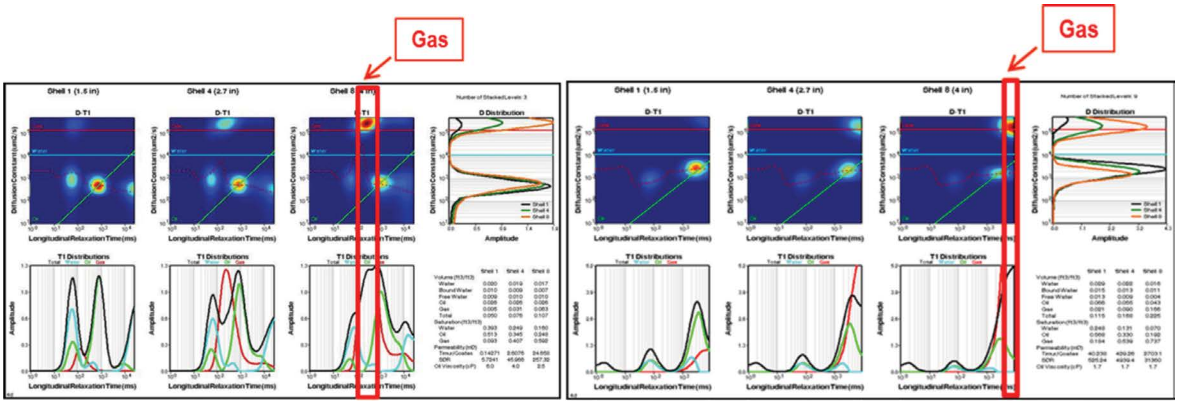

Figure 5. Magnetic resonance maps from Gobernador Formation (xx200-xx350 ft interval).

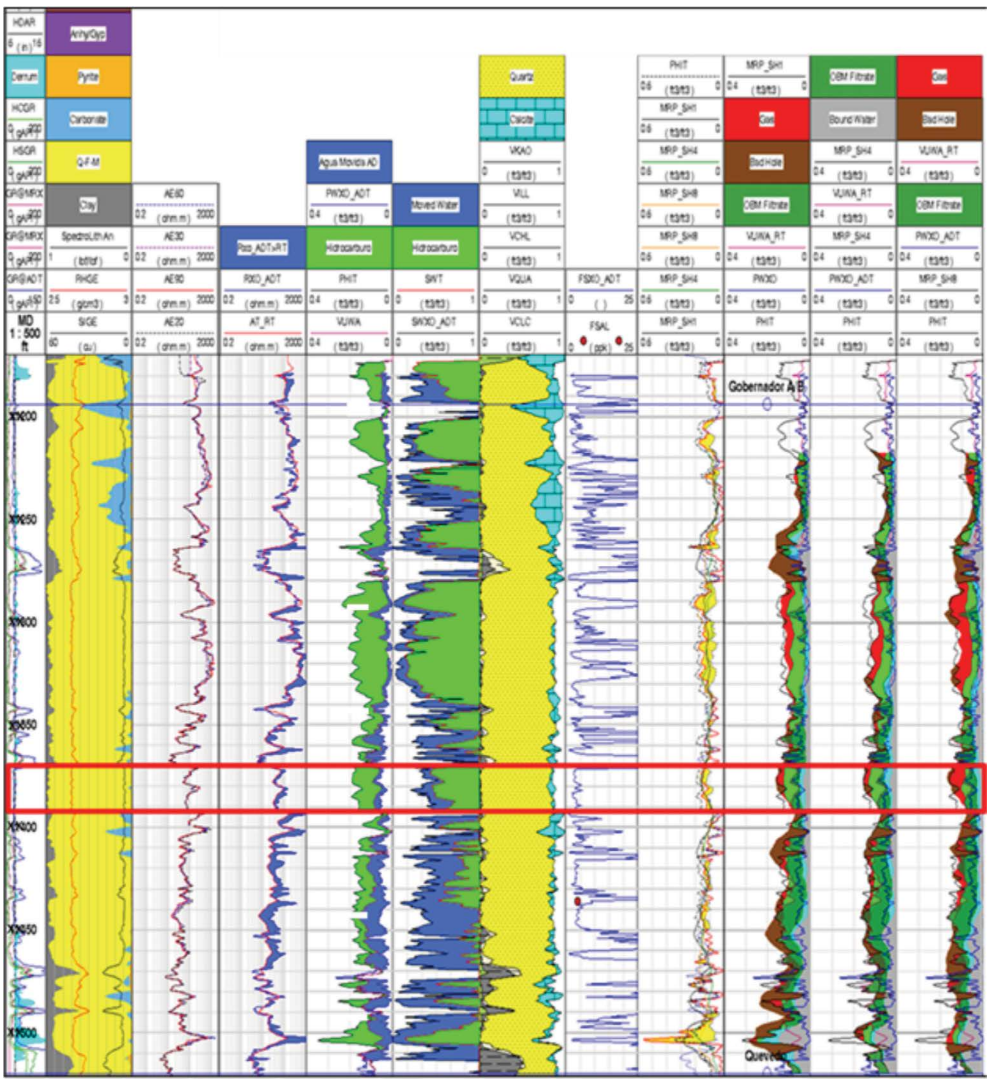

Figure 6. Open hole composite log from Gobernador Formation (xx370-xx390 ft interval).

magnetic resonance measurement, Oil based mud shading is the area between water volume in the virgin zone from standard evaluation and free water volume from the magnetic measurement, gas shading is the area between total porosity from magnetic resonance and oil volume and bad hole shading is the area between total porosity from neutron measurement and total porosity from magnetic resonance.

In this case petrophysics and reservoir team were thinking of the presence of light or condensate hydrocarbon. What we can see from the petrophysical evaluation is that RXO is very similar to RT suggesting that we are in front of an impermeable zone or a zone at irreducible water saturation, meaning a prospective zone. The magnetic resonance tool is clearly showing the presence of gas at high relaxation time, which signal is increasing with depth of investigation.

Figs. 5 and 7 show fluid map base on magnetic resonance measurement for three depth of investigation (1.5, 2.7 y 4 inches), even when the porosity is very low, theses maps shows gas signal at high diffusion and high relaxation time, this gas signal increase with the depth of investigation. This behavior in the magnetic resonance reading is consistent with the dielectric tool measurement in the same interval.

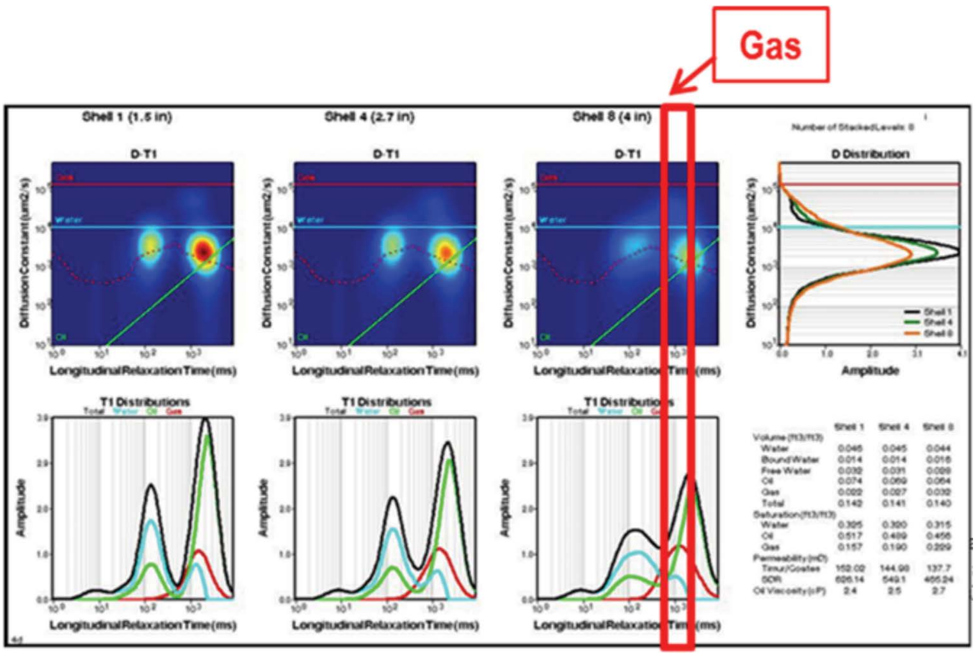

Figure 7. Magnetic resonance maps from Gobernador formation (xx370-xx390 ft interval).

The evaluation of Fig. 8 showed the presence of water from the formation. If we look at the diffusion map at the different depth of investigation, we can see the invasion of the oil based mud, and the signal of OBM; and also we can start to see the presence of water from the formation at the deepest depth of investigation. In this interval the dielectric tool shows movable water with RXO_ADT >RT.

Fig. 9 show fluid map base on magnetic resonance measurement for three depths of investigation (1.5, 2.7 y 4 inches), this map show OBM filtrate signal at high relaxation time but low diffusion constant overlaying the oil line in the map. This behavior in the magnetic resonance reading is consistent with the dielectric tool measurement in the same interval.

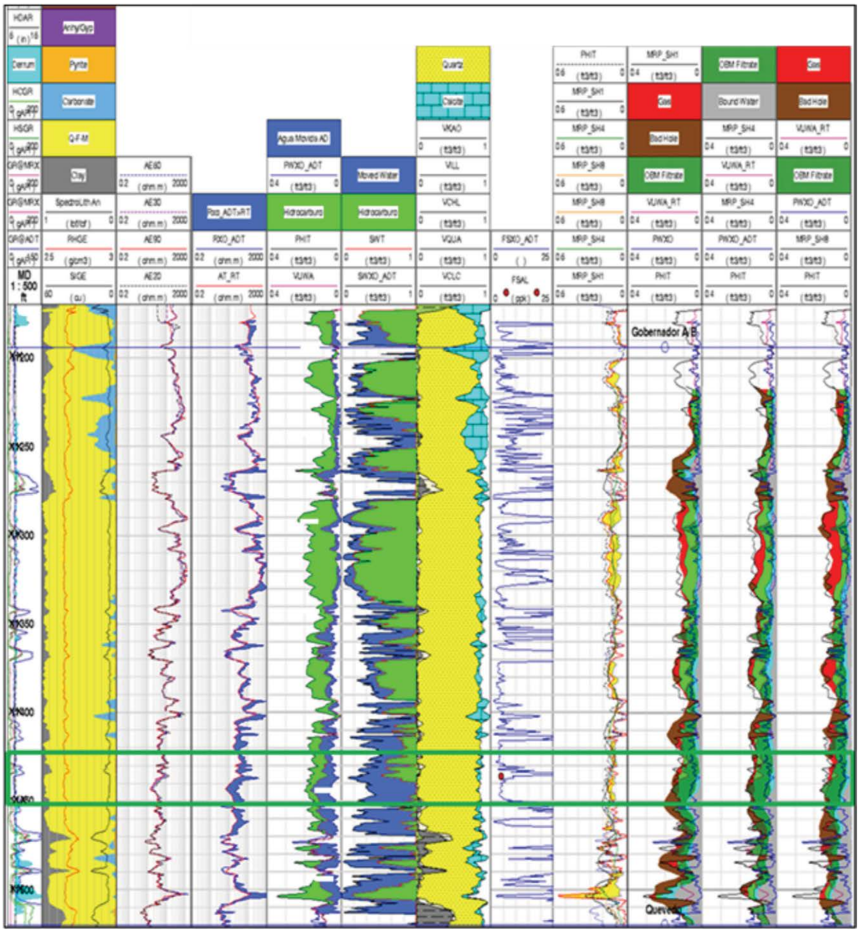

Figure 8. Open hole composite log from Gobernador Formation (xx420-xx450 ft interval).

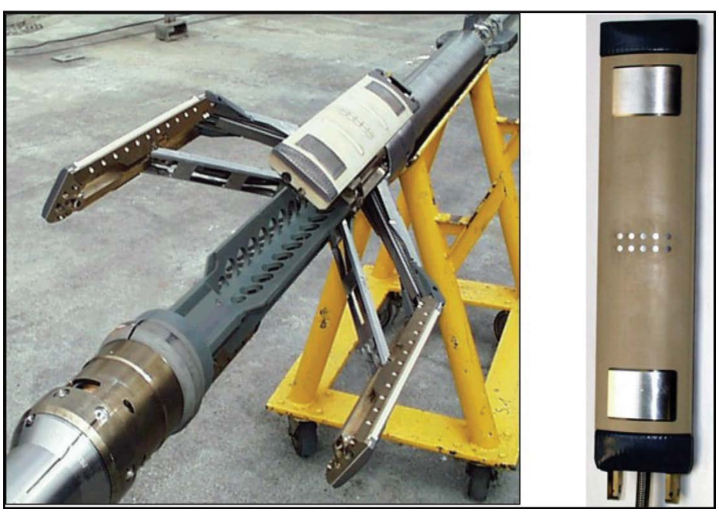

Figure 9. Magnetic resonance maps from Gobernador Formation (xx420-xx450 ft interval).

GEOLOGY

Borehole Images in oil-Base Mud

The oil-based micro-imager tool was used as part of the key measurements to describe the geological features in the subject formation (i.e. Gobernador Formation). The oil-base micro-imager is a micro- scanning tool with a vertical resolution of 1.2 in and include 40 sensors placed on four tool pads arrangement (Fig. 10). The coverage of the tool in an 8 in borehole approximately 32%. This tool provides an oriented image of continuous resistivity variations azimuthaly around the borehole circumference. These images enable the geologist to interpret geological features such as bedding, laminations, fractures, faults and folds which helps significantly in the reservoir description phase.

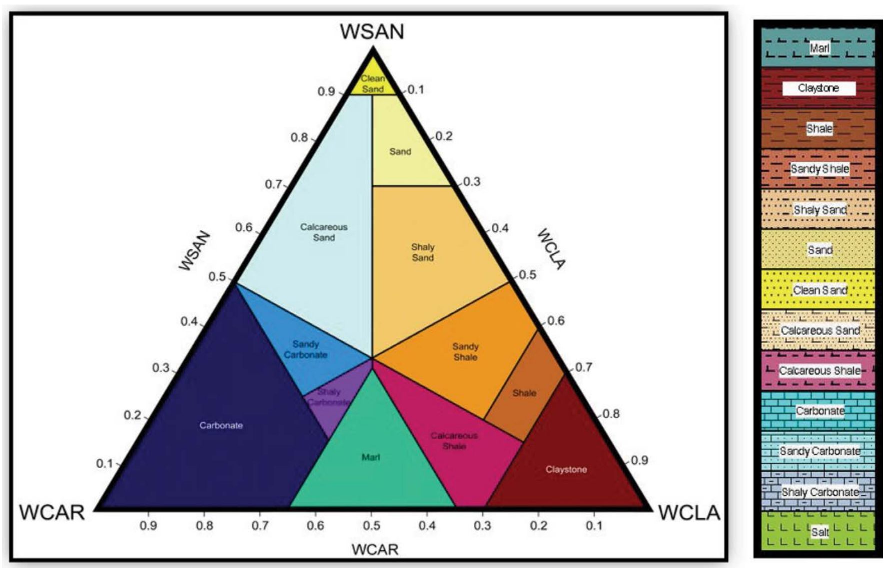

Figure 10. Oil base mud micro-imager Tool.

The oil-based micro-imager allows to update the geological structure of logged section, and helped in the assessment of the textural heterogeneities of the formation, thickness of reservoir zones and define borehole geometry conditions. It was also used to select pressure measurement and fluid sampling points for formation tester objectives. This is especially critical for operations where geometry analysis and fracture characteristics will determine the success or failure of a given test interval. Testing intervals are selected based on integrated well log interpretation and oil base mud micro-imager analysis. This analysis allowed to define naturally fractured intervals along with intervals where induced fractures, borehole breakouts, borehole ovalization and washouts and thick mudcake zones were present; defining those. Those intervals helped to select well testing and fluid sampling intervals.

Facies Identification

Lithofacies were identified and properlyassessed in this study by mean of using a novel classification scheme entitled the hight resolution set of lithofacies and a procedure that uses the strengths of the neutron capture spectroscopy measurement and high resolution micro-resistivity images to quickly generate lithofacies over the entire logged interval. This classification system uses the dry weight mineralogical output from wireline elemental capture spectroscopy data, and utilizes a standardized ternary diagram with a corresponding set of conditions to create dry-weight mineralogy-based lithofacies. The results of this classification are further refined to high resolution using calibrated micro-resistivity image data (Fig. 11).

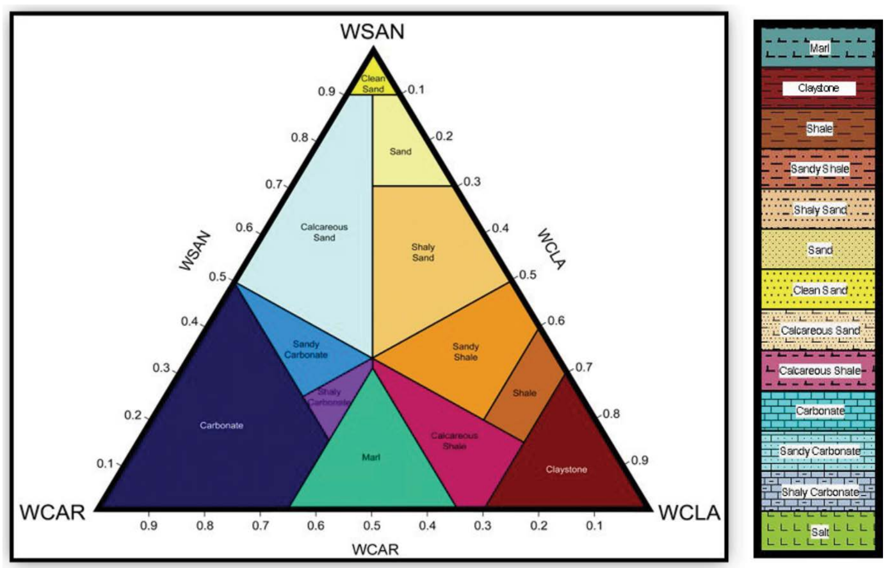

Figure 11. The lithofacies classification ternary diagram used in the study for the Gobernador Formation.

Texture Heterogeneity – Electrofacies

Based on the interpretation of the oil-base mud microimager images and the response of the open-hole logs, the following electrofacies were identified in the Gobernador Formation:

- Parallel to subparallel sandstones laminations (plane laminated sandstones) (Fig. 12).
- Cross-bedded sandstones (Fig. 13).
- Calcareous sandstones (Fig. 14).
- Shaly sandstones with laminations (Fig. 15).

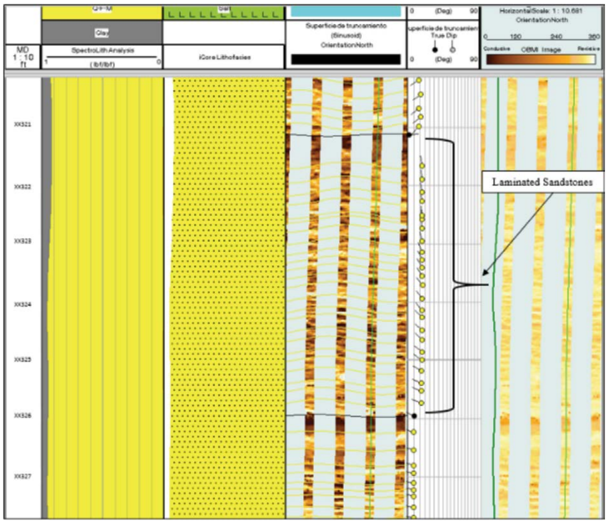

Figure 12. Laminated Sandstones the Gobernador Formation.

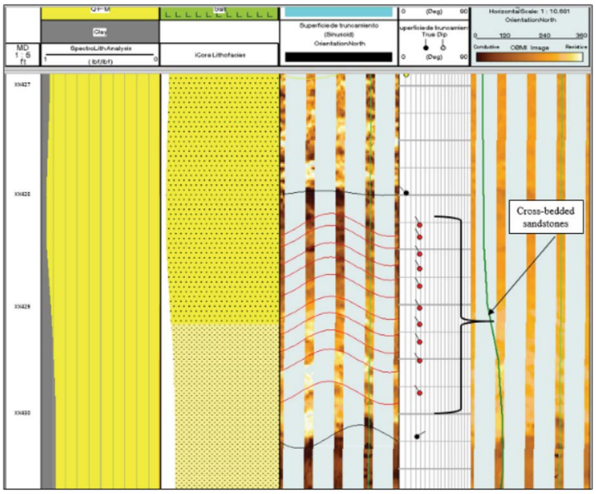

Figure 13.Cross-bedded sandstones identified within the Gobernador Formation.

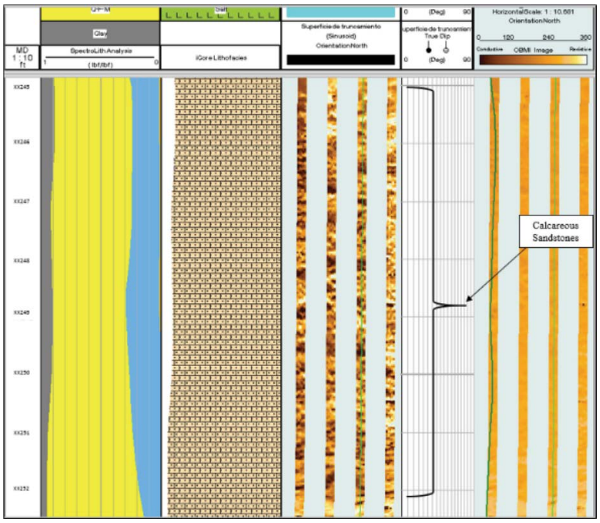

Figure 14.Calcareous Sandstones identified in the Gobernador Formation.

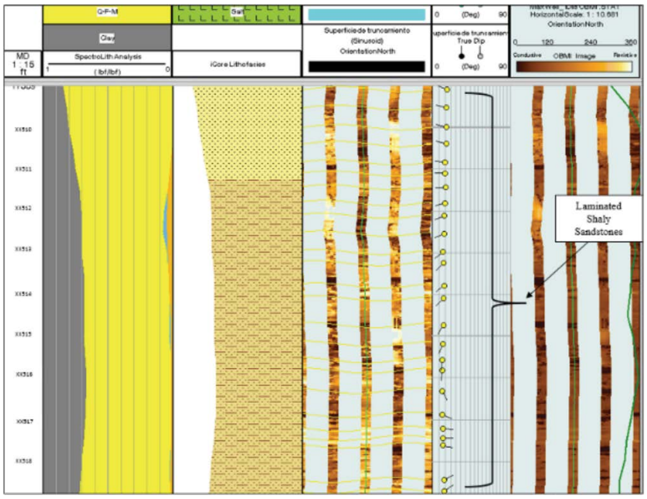

Figure 15. Laminated shaly sandstones in the Gobernador Formation.

Geological Description – Gobernador Formation

Through a combination of petrophysical, geological and reservoir engineering analysis four main zones (these zones based on the analysis and petrophysical, geological and reservoir engineering integration) have been identified in the Gobernador Formation (Fig. 16), where a description will be made separately as follows:

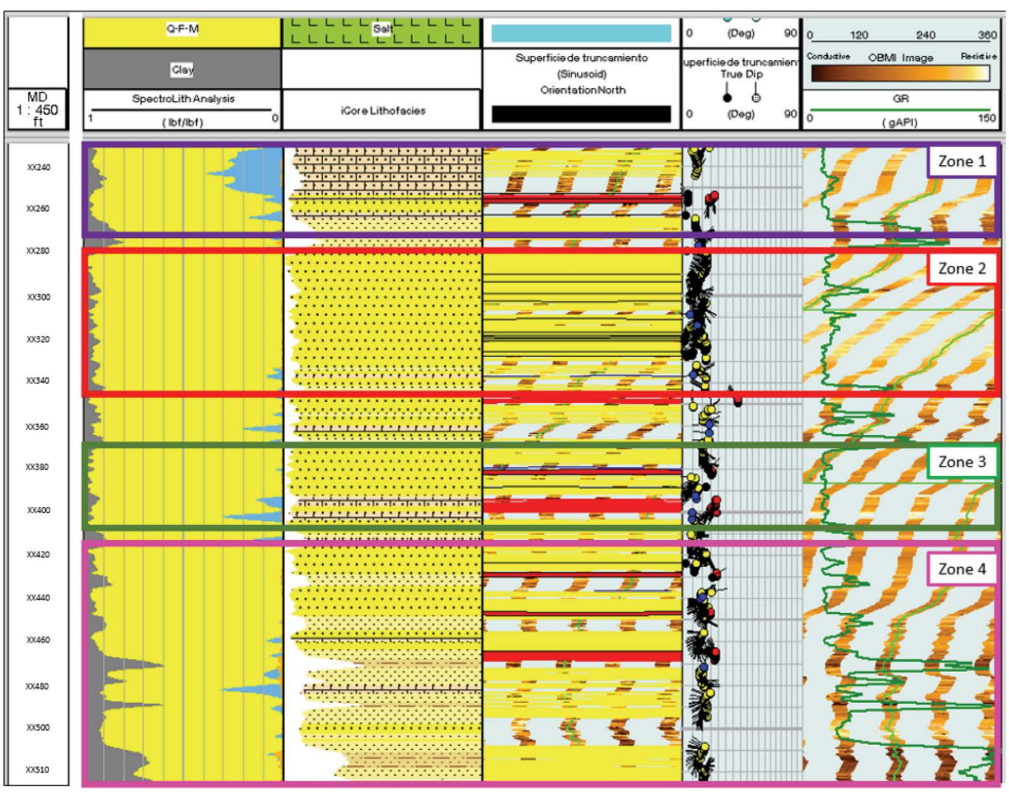

Figure 16. Main zones based on the analysis and petrophysical, geological and reservoir engineering integration in the Gobernador Formation.

Zone 1

Zone 1 has a total thickness around 70 ft. Cylindrical stacking has been observed in all the interval. The lower part of the zone corresponds to fine grained shaly sandstones bodies with parallel laminations, above the shaly body fine to medium clean sandstones are developed with cross beds oriented towards the SSW (average dip of 16.8°). In the middle and upper part of the interval an increase in calcareous content is observed in the neutron capture spectroscopy measurement. These bodies correspond with fine to medium grained calcareous sandstones with parallel and subparallel laminations.

Zone 2

Zone 2 correspond to fine to medium grained sandstones with a cylindrical stacking (thickness of interval is around 70 ft). Localized calcareous material is observed in the zone, where resistivity in the borehole image increases. An increased laminations density is recognized towards the upper part of the interval. In the lower section, cross-bedding events oriented towards the SSW were observed (average dip of 17.4°); in the middle and upper section only cossets of parallel and subparallel laminations events were identified. Variations in the azimuth directions of events could be related with high energy systems during sedimentation process. Also within the sandstones bodies, erosive surfaces and truncation surfaces are observed indicating change and variations in the directions of current flows. In the oil-base mud microimager small increments in the conductivity could be associated with interbedded barriers between sands bodies.

Zone 3

Zone 3 has similar characteristics to previous zone. Cylindrical stacking of sand bodies has been identified with a thickness around 20 ft. Parallel and subparallel laminations and cross bedding events disposed the NNW (average dip of 14.2°). Variations in the dip magnitude and azimuth are also displayed in the laminar events. To the top of the zone a decrease in micro-resistivity of the image is observed and could be associated with an increase of clay content or decreased in grain size.

Zone 4

Zone 4 was interpreted as fine to medium grained sandstones with a cylindrical stacking. The thickness of the interval is around 30 ft. inside sand bodies' cosets of parallel and subparallel laminations and cross bedding events were identified. Variations in dip and azimuth, could be associated with changes in the energy during the sedimentation process. In the middle part of the zone, a conductivity increment was observed indicating presence of heterogeneities inside sandstone (grain size variation and a clay increase was identified through the neutron capture spectroscopy tool).

Borehole Geometry Analysis

In the LLM-B Well, induced fractures or breakout events in the oil base mud micro-imager were not identified. So it was not possible to characterize maximum and minimum stress direction. By analyzing calipers curves from oil-base mud micro-imager (C1 and C2) held in the wellbore software platform, it was possible to create a 3D borehole shape. In the case of Gobernador Formation, rugosity in the borehole wall is recognize but to the lower part ovalization is present (Fig. 17).

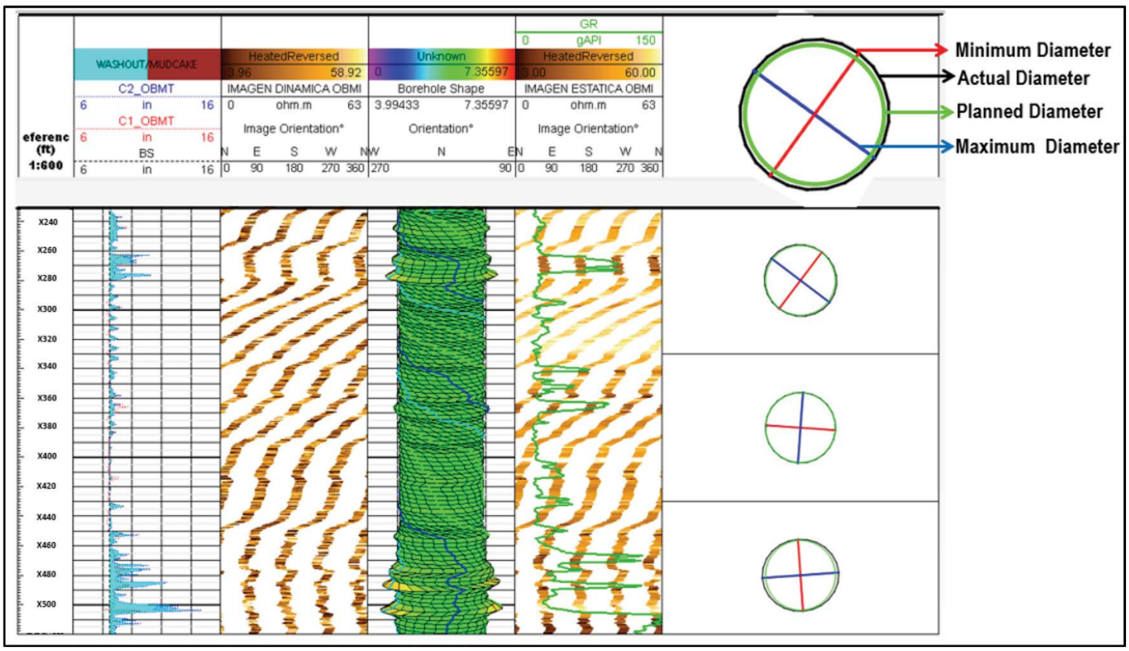

Figure17. 3D Borehole Shape plots. Gobernador Formation.

FORMATION TESTING

Pressure and Downhole Fluid Analysis

Downhole fluid measurements stations were combined with formation pressure profiles to characterize the distribution of reservoir fluids, determine if there are any vertical barriers, identify the type of fluids and fluid contacts, and collect samples to characterize the fluids in the laboratory.

Downhole fluid analysis (DFA) is a combination of optical and in-situ density sensors for the determination of fluid composition, gas/oil ratio (GOR), density, viscosity, fluorescence, reflectance, resistivity, pH, temperature, and pressure (Dong, C *et al.* 2008). Fluid composition (C_1, C_2, C_3-C_5, C_6^+) and GOR are determined through the analysis of light-absorption properties of fluids using a precision grating spectrometer. Water and oil fractions, fluid coloration, CO_2 content of gas reservoirs, and pH of water-producing zones are studied with a filter-array spectrometer. Reflection (refractive index) and fluorescence are studied with a dedicated optical cell (Dong, C *et al.* 2008). Two different vibrational sensors exist for density and viscosity measurements. DFA data are integrated with pressure data analysis using excess the pressure technique to identify reservoir compartments and in-situ fluid characterization. Fig. 18 shows a schematic of the DFA sensors.

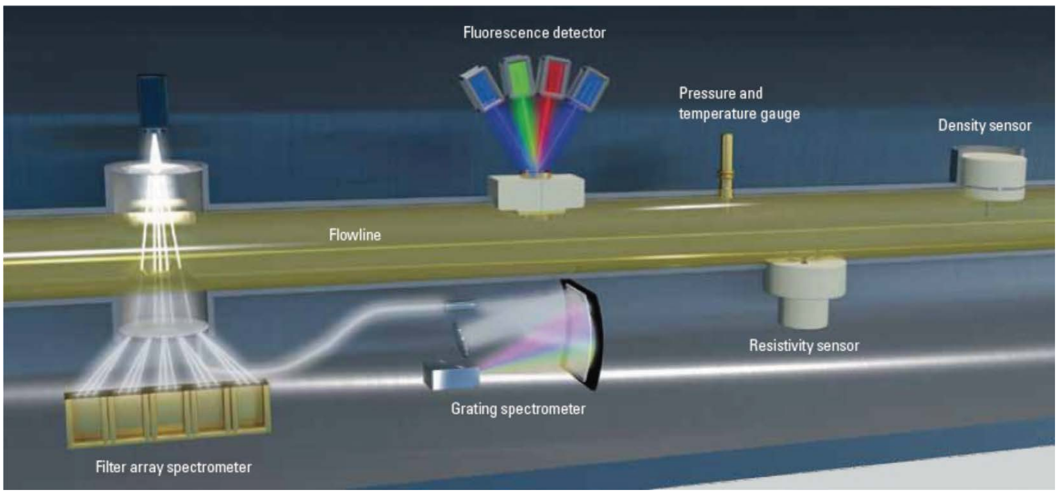

Figure 18. DFA sensors.

The data acquisition was done using a single probe module with large-diameter probe for pretest and fluid sampling using wireline conveyance. Likewise, for performing the DFA stations, a DFA tool was run downstream of the pumpout module to characterize the fluid in real time (fluid identification) and determine when to collect the fluid samples.

A total of 53 pretests were acquired, of which 40 provided reliable formation pressures in this exploratory well. In addition to pretest stations, there were seven fluid identification and sampling stations to characterize the fluids. This section was divided in three zones based on formation pressure tendency (upper, middle, and bottom), as shown in Fig. 19.

In the upper section, a pressure gradient was constructed to identify the fluid type across the interval and the calculated value for the gradient was 0.108 psi/ft (0.25 g/cm^3). The fluid density

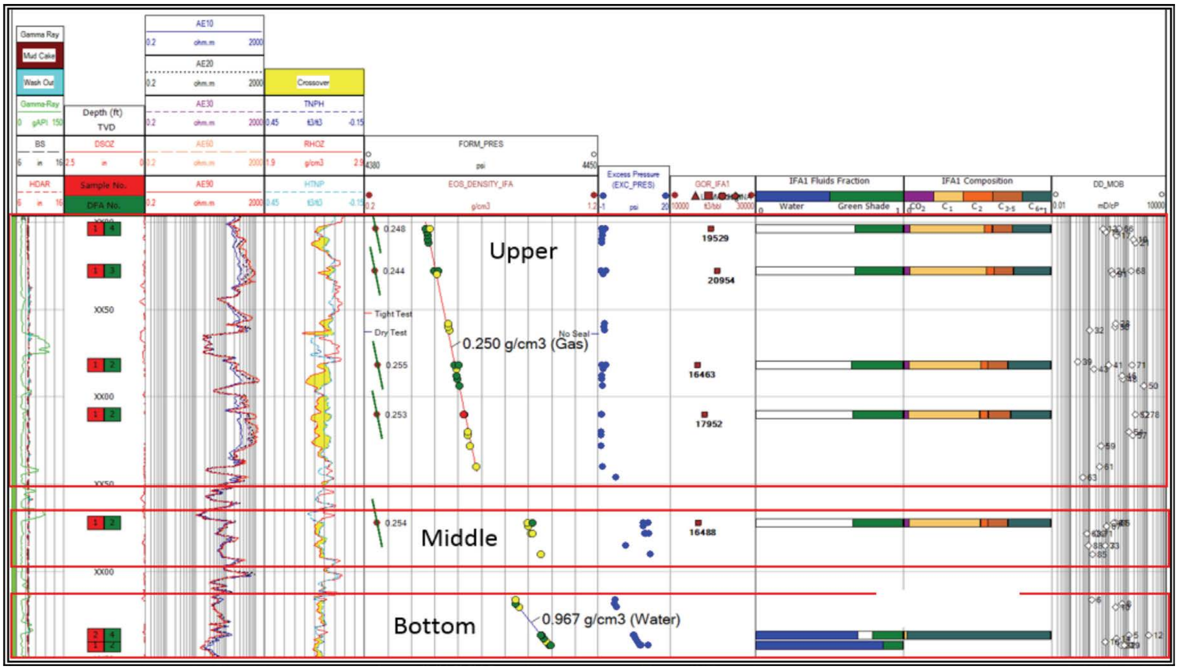

Figure 19. Openhole composite log from upper, middle, and bottom zone including pressure, gradient, and DFA.

obtained using the pressure gradient is very similar to that expected for gas. Additionally, fluid identification was done using DFA at four different depths. As shown in the pressure analysis, gas was seen with a fluid density of 0.244 to 0.255 g/cm3 and the GOR was 16,463 to 20,954 scf/bbl. The density and GOR measurements suggested small compositional fluid variations with depth. Fig. 20 shows one DFA log at XX228 ft, including GOR, fluid composition, fluorescence, reflection, oil/water fraction, and fluid density.

Figure 20. DFA log, station at XX228 ft in upper zone.

In the middle section, fluid identification was done using DFA at one depth. Fluid density was 0.254 g/cm^3, which suggests the presence of gas as the previous section. The GOR was 16,458 scf/bbl. A reliable pressure gradient could not be constructed because of the lack of linearity of the pressure points. The formation pressures acquired in this section were higher than expected by extrapolating the pressure tendency from the upper section, which suggests a lack of vertical connectivity. The supercharging effect could be affecting formation pressure values in this section due to low mobility. However, after a sampling station, a pretest was performed, and good repeatability was obtained comparing this with the rest of the pretest data, and the possibility of a supercharging effect was discarded. The different pressure tendency between upper and middle section was accepted.

In the bottom section, a pressure gradient was constructed, and the value was 0.42 psi/ft (0.967 g/cm^3), indicating the presence of formation water. DFA was used at two depths for fluid identification. The first DFA station at XX436 confirmed the presence of free water and movable light oil (confirmed by laboratory results), suggesting a transition zone. Fig. 21 shows the DFA log of this station, including GOR, fluid composition, fluorescence, reflection, and oil/water fraction. Water appeared after 90 liters pumped. The second DFA station was done 6 ft below the first station and showed formation water and a few native oil tracers.

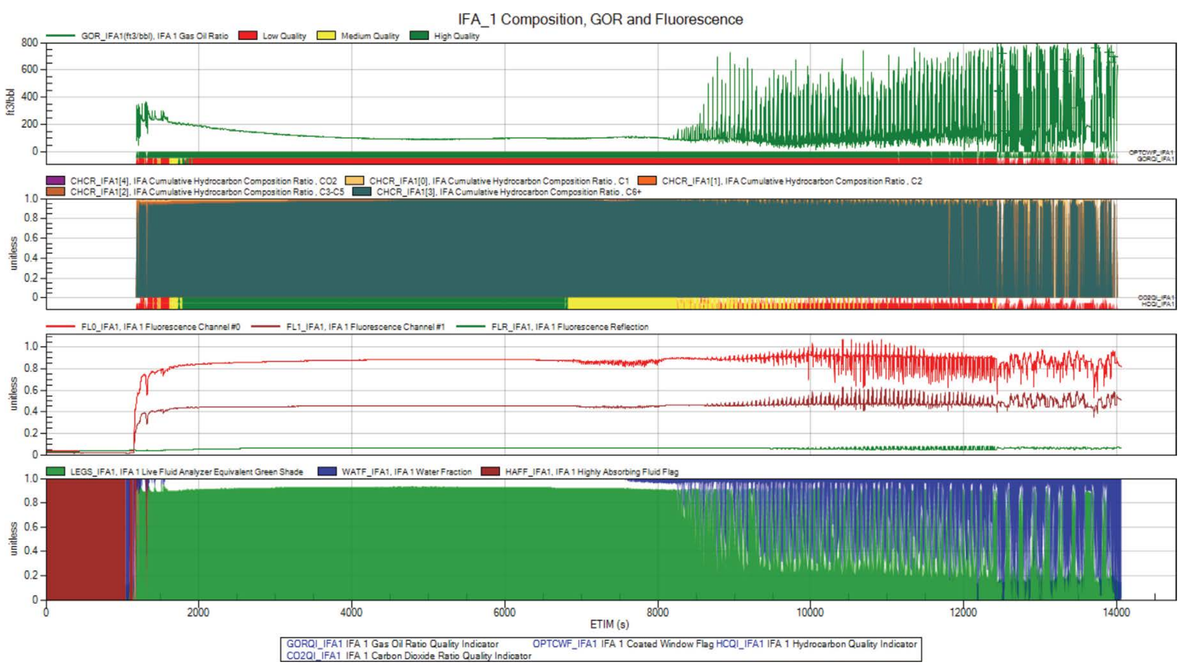

Figure 21. DFA log, station at XX436 ft in bottom zone.

All the results, gradients and DFA, are in agreement with the petrophysical evaluation results and help to define the reservoir fluid model in this new discovery: a condensate gas reservoir in the upper and middle sections and, at the bottom, a transition zone with water and light oil and then only water.

Samples were recovered in all seven sampling stations and sent to the laboratory for analysis. Comparison of the results between downhole (DFA) and laboratory measurements were in good agreement. Laboratory results confirmed condensate gas and the presence of a transition zone and enabled the determination of the salinity of the formation water. Laboratory results are often not available until weeks after the sampling acquisition; for that reason, reliable DFA data was very important to improve completion and production testing design.A comparison of DFA and laboratory results is shown in Table 1.

Depth (ft) MD	Fluid	C1, %wt		C2, %wt		C3 - C5, %wt		C6+. %wt		CO2, %wt		GOR, scf/bbl	
		DFA	Lab	DFA	Lab	DFA	Lab	DFA	Lab	DFA	Lab	DFA	Lab
XX204.5	Gas	51	52	6	6.82	13	11.9	26	24.9	4	4.38	19529	21977
XX228	Gas	52	52	6	6.83	13	11.98	25	24.7	4	4.49	20954	21472
XX282	Gas	49	50.5	5	6.87	14	13.23	28	25.27	4	4.13	16463	21680
XX310	Gas	48	49.34	6	6.92	15	13.96	27	25.7	3	4.08	17952	21751
XX372	Gas	49	47.22	5	6.47	13	12.58	29	29.83	4	3.9	16448	15791
XX436	Water + Oil												
XX442	Water + Oil Tracers												

Table 1. Comparison of DFA and laboratory results.

CONCLUSIONS

Las Lomas Field is located at the southwest of Venezuela within the Barinas basin, near to southern flank of the Venezuelan's Andes, it is a challenging environment for formation evaluation as a low and variable water salinity, complex lithology and uncertainty on the hydrocarbon type present in the reservoir. The integration of mud logging data in the formation evaluation allowed to predict potential zones and helped tremendously in the wireline logs program increasing the possibilities of a very successful completion and production rate.

The chromatography interpretation is a useful method to the determination of fluids inside of formations, but this need lithological information from the field drilled to work accurately, and the respective calibration with others wells. The study of an exploratory well has to take into accounts the inherent errors due to different varying (gas trap, gas measure system) and the lack of data from the area.

From the petrophysical evaluation is that RXO is very similar to RT suggesting that we are in front of an impermeable zone or a zone at irreducible water saturation, meaning a prospective zone. The magnetic resonance tool is clearly showing the presence of gas, which signal is increasing with depth of investigation.

The magnetic resonance maps in saturation profile mode, help us to identify the fluid that are in the formation, gas or light hydrocarbon shown high diffusion and high relaxation time on the other hand the oil base mud have high relaxation time but low diffusion constant overlaying the oil line in the map, these differences allows us to identify clearly the fluid based on magnetic resonance tool response.

All the results, gradients and DFA, are in agreement with the petrophysical evaluation results and help to define the reservoir fluids model in this new discovery, a condensate gas reservoir on upper and middle section and at the bottom a transition zone with water and light oil and then only water. The upper and middle section have different pressure tendency.

The borehole image log was used to perform structural analysis, facies identification, textural analysis and borehole geometry evaluation. Facies identification and textural analysis provided a better understating of the sedimentological conditions and the depositacional environment associated with Gobernador Formation. Through the Facies identification, it was possible to identify that cross-bedded sandstones and parallel to subparallel laminated sandstones represented the lithofacies with the best petrophysical properties. The relationship between these lithofacies with the petrophysical evaluation has proven to be a very useful technique in the analysis of the Gobernador Formation reservoir.

The integration of all available measurements from different disciplines in this well demonstrated the importance of a through and most reliable formation evaluation which will definitely and positively impact the development plans for the area and subsequently its economics.

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