[PS]Generating Value through New Logging Technology and Analytical Methods - Case Study from Offshore West Africa*

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Abstract

The West Africa basin encompasses a vast diversity of geological depositional settings, in and from which hydrocarbons are being explored and produced. Offshore, Cretaceous aged turbidity slope-channels and fan systems still prove to contain volumetrically significant oil and gas reservoirs. An intelligent petrophysical evaluation is essential to enable the most adequate development and production strategy to be deployed. The siliciclastic rock units can be structurally heterogeneous, with the reservoir distribution and quality highly variable, making it hard for conventional logs data to pick potential reservoirs with pay. This article illustrates remarkable examples of intelligent logging assessments in highly complex reservoir units with focus on successful applications of novel technology deployed in effective and efficient fashion.

These reservoirs have variable thickness and generally medium permeability (200-800 mD); but silt and clay laminations and tight material are affecting the reservoir quality in some layers, resulting in changes in the well productivity and sweep properties. The fresh to very fresh formation water environment diminishes the contrast of water to hydrocarbons making it difficult for any salinity based measurement technique, like resistivity, to easily unravel hydrocarbon bearing intervals. Besides, some of the reservoirs are stacked sand bodies with varying salinity values among the different hydraulic units and cannot be accessed by conventional open-hole logging. Novel dielectric dispersion and high definition spectroscopy technology are game changers in their respective range of applications. Whether run in combination with other measurements and analyzed in an integrated approach or as stand-alone analysis if needs arise, the appropriate use of these techniques highly reduce uncertainty of hydrocarbon volume and net producible fractions. Comparison of the formation evaluation results to actual well testing confirms the improvements in reservoir description from the addition of advanced logging measurements (at early stage of reservoir development) into reservoir models. The information provided guides optimal perforation and completion design and helps in defining future field development plans.

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Bankole, S.I., E. Schrank, B.D. Erdtmann, and S.O. Akande, 2006, Palynostratigraphic Age and Paleoenvironments of the newly exposed section of the Oshosun Formation in the Sagamu Quarry, Dahomey Basin: Nigerian Association of Petroleum Explorationists Bulletin, v. 19, 1 p. 25-3.

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Generating Value through New Logging Technology and Analytical Methods—Case study from offshore West Africa

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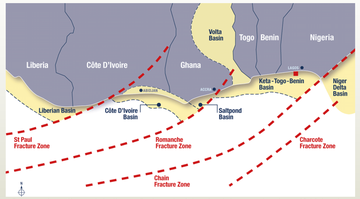
ABSTRACT

The West Africa basin encompasses a vast diversity of geological settings with proved resources. Offshore, Cretaceous aged turbidity slope-channels and fan systems still prove to contain volumetrically significant oil and gas reservoirs.
Siliciclastic reservoirs are structurally heterogeneous with variable quality and complex connectivity paths between hydraulic units. An intelligent petrophysical evaluation is essential for most adequate development and production strategy.



Source: http://www.lekoil.com/index.php/nigeria-dahomey-basin-opl310.html

Remarkable examples of efficient logging assessments in highly complex reservoir units with focus on successful application of novel technology are presented.
The reservoirs have accessible permeability; but silt and clay laminations and tight material cause changes in the well productivity and sweep properties. The fresh to very fresh formation water environment diminish the contrast of water to hydrocarbon making it difficult for any conventional technique to easily unravel oil bearing intervals. Besides, some of the reservoirs cannot be accessed by conventional logging open hole conveyance.

Novel dielectric dispersion and high definition spectroscopy technology are game changers in their respective range of applications. Whether run in combination with other measurements and analyzed in integrated approach or as standalone analysis, their appropriate use highly reduce uncertainty of hydrocarbon volume and net producible fractions.
Comparison of the advanced formation evaluation results to actual well testing confirms the improvements in reservoir description at early stage of reservoir development into reservoir models.
The information provided guide optimal perforation and completion design and help defining future field development plans.

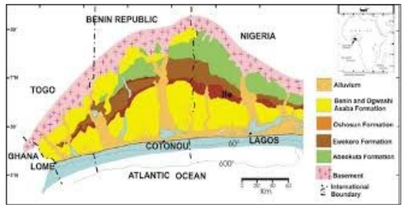
Introduction

The Gulf of guinea is a very appealing oilfield venue with prolific oil and gas production fields; yet the current market price require revising proven reserves evaluation programs to find that additional drop of oil to maintain production increase.
Logging has a primary role on proper description of existing reservoir systems and screening of new productive sand units for optimal development plan and production strategy. Decisions need to be made instantly and be effective for quick yet robust selection of completion intervals and recoverable rates.

Study Area

This study documents two recent development wells drilled through a complex shaly sand sequence in the Dahomey (Benin) basin.
The Location is in the middle of the continental margin of the Northern Gulf of Guinea including the South of West Nigeria, Benin, Togo, and Ghana.

Multiple reservoir rocks and a variety of potential trapping mechanisms are encountered in the sedimentary basin of interest.
The lithology ranges from coarse sandstones and conglomerates to thin layers of silty sands or shale.



Map of Dahomey (Benin) Embayment (Source: Bankole et al., 2005)

The are was proven to be an oil prone after the discovery of the Seme oil field in 1968 (Marc et al., 1994). Oil from the main sand reservoirs within the field is fairly heavy, low sulfur crude; with lower viscosity compared to water.

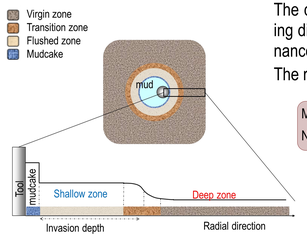
Connate water are fresh with low and variable salinity. A wet formation could show a resistivity spike due to presence of hydrocarbon or fresh water and fine-grained matrix. Conversely, a pay zone could be interpreted as wet due to low resistivity contrast to hydrocarbon and between mud filtrate and formation water complicating any conventional saturation analysis. Moreover, the vertical hydraulic connectivity across the oil column can be compromised by low permeability layers impacting the reservoir quality and increasing the chances of the sand lobes to be compartmentalized with potential for compositional grading.

A comprehensive suite of state-of-the-art wireline logs is required in order to fully characterize the formations penetrated by the wells drilled in the area and confirm the presence and amounts of viable hydrocarbon.
Two advanced measurements which were recorded and proved to be essential to formation evaluation are novel dielectric dispersion and high definition spectroscopy measurements.

CASE STUDY A: Open Hole Advanced Technology Application

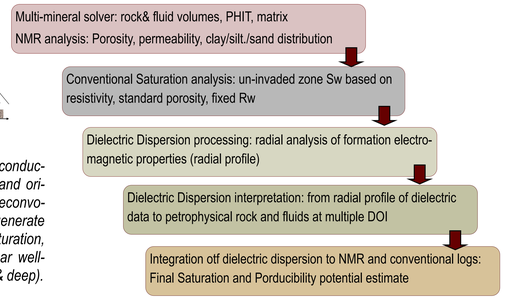
Development well drilled with water base mud through a shaly sand sequence.
Carbonate layers and silt and clay laminations affect the reservoir quality. The vertical connectivity across the fluid column may be compromised, increasing the chances of the reservoirs being compartmentalized.
Oil zones are concealed by fresh water zones and extremely low contrast between the resistivity in oil-filled zones and those saturated with fresh water making it difficult to decide what zones to complete based on conventional methods only. Additionally, the low salinity contrast of mud filtrate and formation water coupled with the low resistivity contrast to hydrocarbon complicate the interpretation of the invasion process from the resistivity profiles .

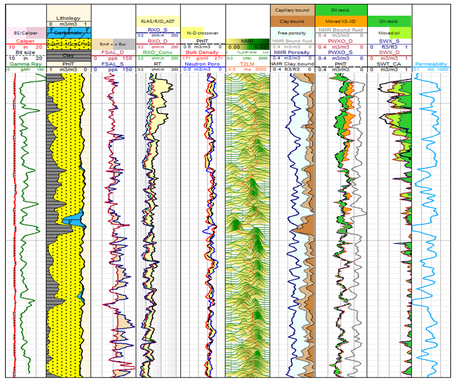
Among the other logs data, the integration of dielectric dispersion and high resolution magnetic resonance measurement is essential to determine whether or not hydrocarbon exists, quantify the volume of hydrocarbon and its ability to move, hence making it easy to select the perforation intervals and completion design.



Dielectric dispersion measures permittivity and conductivity at multiple frequencies, antenna spacing and orientations. Curve-fitting technique and signals' deconvolution characterize the dispersion pattern to generate high resolution answers: water volume and saturation, formation water salinity, rock texture in the near wellbore region; radially into the formation (shallow & deep).

The data analysis was performed adopting a step-by-step workflow integrating dielectric dispersion processed results with high resolution magnetic resonance signal analysis, laterolog resistivity, neutron-density log data.
The results are compared with more traditional formation evaluation.





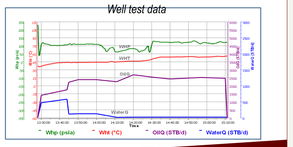
The complementary data and similar sensitive volumes and resolution of dielectric and NMR make these measurements a natural method for improved analysis of rock and movable fluids.

The deep saturation, improved by NMR porosity and salinity profile from dielectric, was compared to shallow and deep saturation from dielectric dispersion to better quantify the pay thickness. Alongside, the two-water filled porosity help to define movable fractions and to verify the movable fluid fractions with oil in top of water with evident transition zone.

Composite log plot — The saturation profile and porosity analysis from dielectric dispersion measurements coupled with NMR indicate that hydrocarbon column is higher than that computed with conventional resistivity based interpretation (1:200 scale).

Based on the advanced logging data and analysis, decision on further well development and completion strategy was successfully made.

The well test program was optimized; the detail provided by dielectric dispersion-NMR integrated effort also guided the selection of perforation intervals improving the chances of producing maximum oil at lowest water cut values.



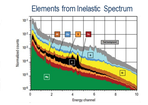
CASE STUDY B: Cased Hole Advanced Technology Application

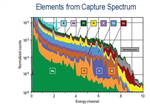
Subsequent development well drilled in a complex sector of the field. Formation evaluation was planned through open hole logging. However accessing the target reservoirs is risky; hence the decision to immediately set the casing.

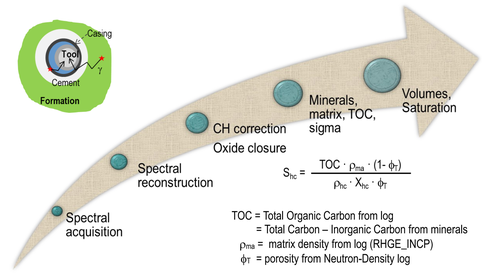
A first attempt to delineate reservoir potential using cased-hole density and neutron with resistivity while drilling was useful, but data analysis considered inconclusive when compared to regional experience and offset data. The formation resistivity is generally low, and responds to variation in mineralogy and connate water properties, but offset well indicate that finding oil at similar values is not uncommon.

Considered the importance of getting confident answer, novel high definition spectroscopy measurement was mobilized and recorded behind 7-inches casing; and solved the enigma.
In addition to objective mineralogy and matrix properties from capture and inelastic gamma ray spectra analysis, the advanced measurement determined accurate organic carbon content which was immediately converted to fluids volume across the reservoir of interest.
The resulting quantification of the oil saturation is direct and independent of resistivity-based methods and variation in water salinity and clay content; hence resolute and confident.

This is the first successful application of the methodology in the region and challenging cased-hole logging conditions in West Africa.







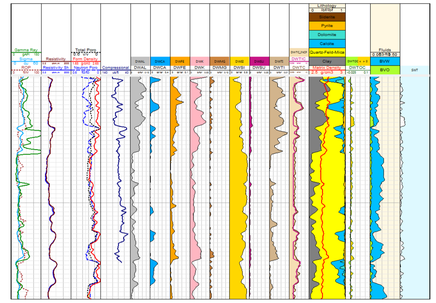
Inelastic and Capture elemental yields are measured and immediately converted to dry weight elements using full closure. Simultaneously, the inorganic carbon from contributing minerals is subtracted from Total carbon to accurately obtain the Total Organic Carbon (TOC).

This is directly used to measure oil saturation when integrated matrix density also provided by spectroscopy and

The log results confirm the presence of quality sands intercalated by shale layers and cementation at certain levels. The accurate mineralogy helps the understanding of other logs response and provides confident fluid volumes and saturation.

Most of the reservoir described by the spectroscopy measurement have low carbon content, indicating the well would produce water; a critical infor-

Composite log plot — Quantitative mineralogy, clay content, matrix density and accurate carbon content are provided by the spectroscopy to confirm the reservoir would produce water (1:200 scale).



CONCLUSIONS

The results of this study show that a significant contribution can be made to the reduction of reservoir uncertainties in the presence of complex lithology and fluids profile in low contrast reservoir sequence.

Based on the novel technology application and interpretation frameworks, either in open-hole or after setting the casing, the prediction of hydrocarbon- and water-producing intervals sees a significant improvement with direct implications for the field development plans.

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