Qualitative Delineation of Hydrocarbon Bearing Reservoir from Preliminary Study of Well Log Data over an Offshore Niger Delta Field.

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ABSTRACT

A preliminary study was carried out on well log data acquired from three wells in the offshore Niger Delta. The objective of the study was to identify and delineate probable hydrocarbon bearing reservoirs. The processing and interpretation of logs was achieved using the Hampson Russel (HR) Software package. Reservoir HD2000 was identified and delineated. The reservoir area was characterized by very low gamma ray counts, high porosity and low water saturation. The wells exhibit a dominantly shale/sand/shale lithology which agrees with Niger Delta geology.

(Keywords: hydrocarbon, reservoir, well logs, gamma ray, porosity, saturation)

INTRODUCTION

The unending high demand for fossil fuels – hydrocarbons has in recent times tremendously increased its search and exploration efforts. Majority of hydrocarbon bearing reservoirs are found in interstitial pore spaces or open fractures of sedimentary rocks like sandstone and limestone or dolomite.

Well logs are invaluable tools when evaluating the hydrocarbon prospect of any given field. Well logs are recordings against depth of any of the characteristics of the rock formation traversed by a measuring apparatus (a logging sonde) in the well-bore. These recordings could be of electrical properties, natural or induced radioactivity, acoustic properties and orientation of the hole of the formations traversed. The well logs obtained could thereafter be applied to qualitatively delineate permeable and probable hydrocarbon bearing formations, estimate hydrocarbon saturation, calculate porosity, pick formation boundaries, perform stratigraphic correlations, reservoir modelling and structural studies. The primary objective for this study is to qualitatively identify and delineate probable hydrocarbon bearing reservoir formations from preliminary study of well log data acquired over the study area.

LOCATION AND GEOLOGY OF THE STUDY AREA

The geology, stratigraphy and structure of the Niger delta basin have been extensively discussed (Short and Stauble, 1967; Owoyemi and Wills, 2006; Bilotti and Shaw, 2005). The Niger delta basin is situated on the continental margin of the Gulf of Guinea between latitude 3^0 and 6^0N and longitude 5^0 and 8^0E. The areal extent of the Niger delta is about 75000km^2 with a clastic fill of about 12000m.

The Niger Delta province is ranked the twelfth richest petroleum resources with 2.2% of the world's discovered oil and 1.4% of world's discovered gas by the US Geological Survey's World Energy Assessment (Klett et al., 1997).

The Niger delta consists of three broad formations: the continental top facies (Benin Formation), the Agbada Formation and the Akata Formation. The Benin Formation is the shallowest of the sequence and consists predominantly of fresh water-bearing continental sands and gravels with no over pressures.

The Agbada Formation underlies the Benin Formation and consists primarily of sand and shale and is of fluviomarine origin. It is the main hydrocarbon-bearing window. Petroleum in the

Niger Delta is produced from sandstone and unconsolidated sands predominantly in the Agbada Formation.

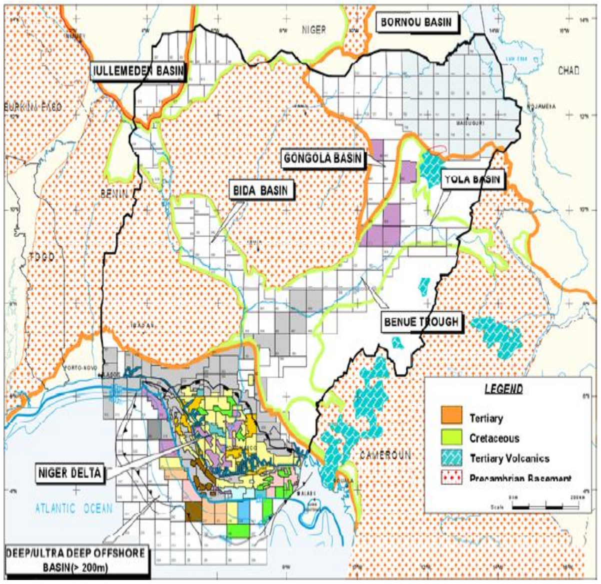

Figure 1: Geological Map of Nigeria showing the Niger Delta Basin.

The Agbada Formation is thickest at the center of the Delta (approximately 457.2m). This is the seat of most oil reservoirs and center of over pressures. The Akata Formation is composed of shale, clays and silts at the base of the known delta sequence. They contain a few streaks of sand, possibly of turbiditic origin. The thickness of this sequence is not known for certain, but may reach 7000m in the central part of the delta (Short and Stauble, 1967).

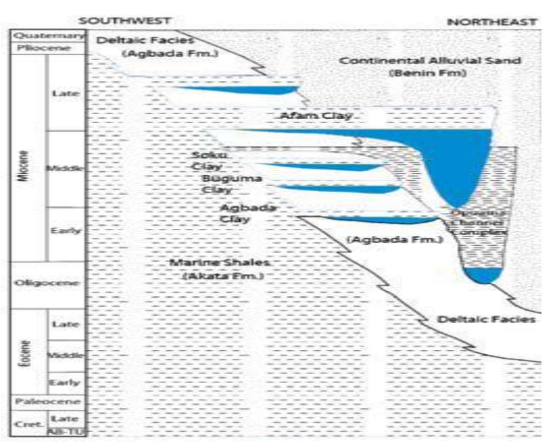

Figure 2: Stratigraphic Column showing the Three Formations of Niger Delta (Short and Stauble, 1967).

MATERIALS AND METHODS

Wire line well log data in LAS format were obtained for three wells from an offshore Niger Delta field. The well log data comprised sonic log, density, self-potential (SP), resistivity log, caliper log, porosity log, shale volumetric log and gamma ray (GR) log (Table 1).

Table 1: Available Log Suite for Each Well.

WELL A	WELL B	WELL C
Density	Density	Density
Gamma ray	Gamma ray	Gamma ray
P-wave	P-wave	P-wave
Resistivity	Resistivity	Resistivity
	Caliper	Caliper
	Porosity	
	Shale volume	

The well log data were processed to obtain to a large extent consistent and accurate logs from well to well. We assumed that the well log data used had been corrected for wash out effects and other borehole irregularities. However, it was imperative to edit the logs further to enhance their fidelity for use in reservoir characterization. The Hampson Russel software package was used for the well log analysis. The logs were de-spiked using a median filter to ensure they contain only appropriate ranges of values.

Median filters were also applied on vital logs such as P-wave velocity and density logs to reduce abundant small spikes on the data. The median filter operation replaces the sample value at the center of the operator with the median of the sample values contained within the operator, the longer the operator length the smoother the log. This process was largely experimental in order to isolate the best log operator length and we observed that with an operator length of 6, the logs were largely well smoothened thus removing the high frequency noise. Small operator lengths would retain spikes in the data and adversely affect future cross plots and synthetic interpretation. On the other hand, if the operator lengths were too large, the cross plots might not be representative of the data and synthetics would not provide adequate details for seismic correlation.

Other logs (porosity and water saturation), were generated using different empirical relations.

Porosity was calculated from density and resistivity according to the equation.

$$\phi = \frac{0.9\sqrt{[R_w/R_t]}(\rho_w - \rho_h) + (\rho_{ma} - \rho_{obs})}{(\rho_{ma} - \rho_h)} \qquad \textbf{(1)}$$

where

ρ_w is the density of formation water = 1.09000 gram/cc

ρ_h is the density of hydrocarbons = 0.75000 gram/cc

ρ_{mx} is the density of Matrix = 2.65000 gram/cc

R_w is the resistivity of formation water – 0.04000 ohm-meters

R_t is true resistivity from the log

P_{obs} is observed density from the log

The Water Saturation S_w was estimated using Archie's equation as expressed below.

$$S_w = \sqrt{a\phi^m \frac{R_w}{R_t}} \qquad \textbf{(2)}$$

where

a is the cementation factor, approximated as = 0.62000

m is the cementation exponent, m = -2.15000

R_w is the formation water resistivity = 0.04000

These rock physics empirical relations were used to generate the missing logs.

RESULTS AND DISCUSSION

Figures 3 –5 show the log signatures from the three wells (A, B, and C) and the delineated HD2000 hydrocarbon reservoir.

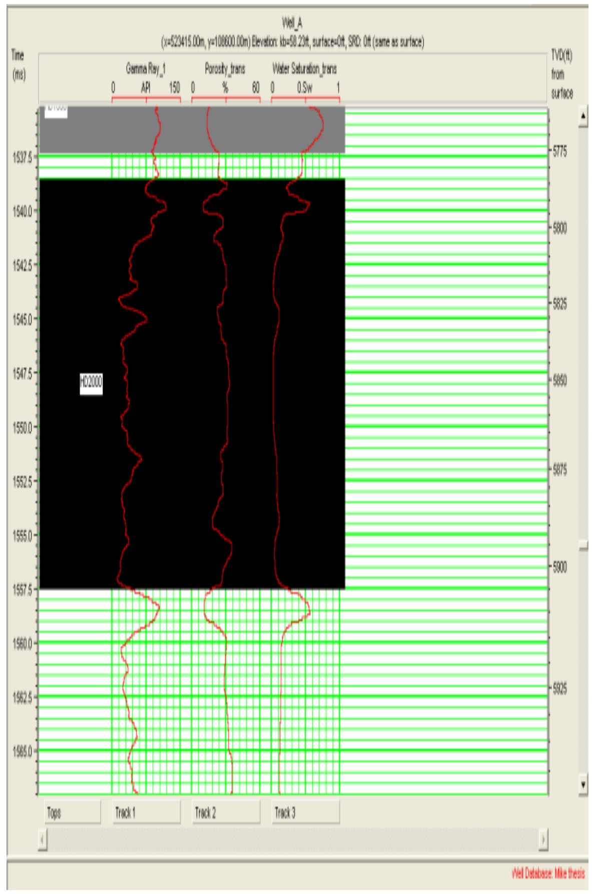

Figure 3: Well A showing Delineated Reservoir HD2000.

Our objective for the study was to investigate and delineate probable hydrocarbon bearing reservoirs and the presence of hydrocarbon at the locations of the exploratory wells. Preliminary study of the well log responses revealed a hydrocarbon-bearing reservoir marked HD2000 with top and base within depth intervals of 5780ft - 5910ft (a thickness of about 130ft) for Well A, 5735ft - 5800ft (thickness of 65ft) for Well B and 5810ft - 6025ft (a thickness of 215ft) for Well C. The hydrocarbon reservoir HD2000 was inferred based on very low GR counts, high porosity and low water saturation values from the well logs.

The wells exhibited predominantly shale/sand/shale sequences (lithology), typical of the Niger Delta basin. Shale lithology was interpreted as regions having high gamma ray values. Similarly, regions of low gamma ray, high resistivity and low water saturation were mapped as sand lithology, which we strongly believe are also regions of high hydrocarbon saturation.

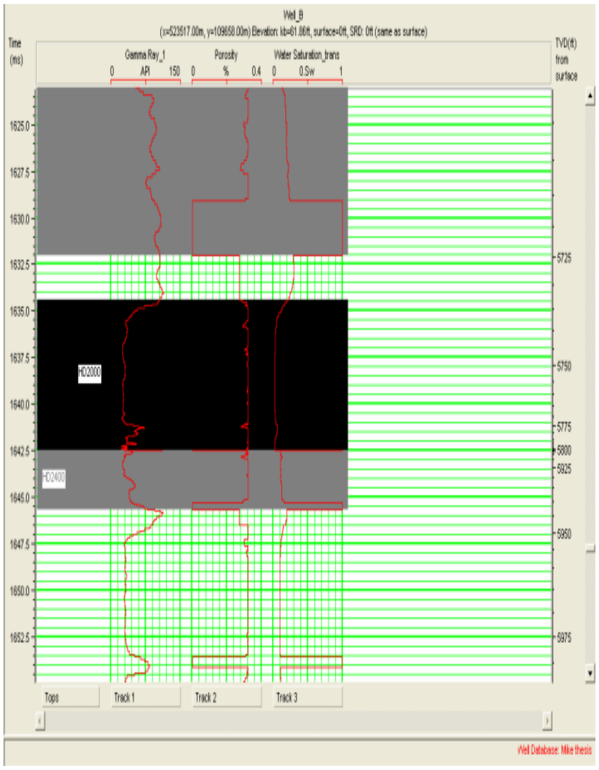

Figure 4: Well B showing Delineated Reservoir HD2000.

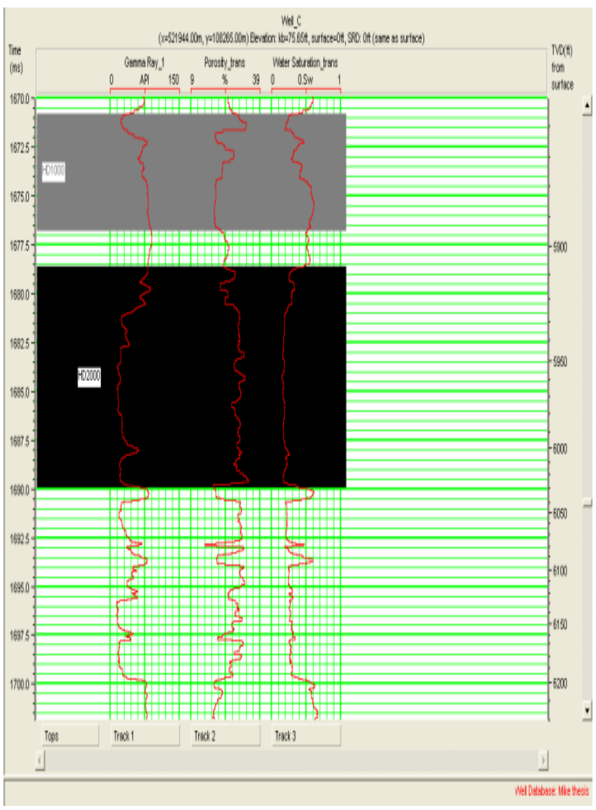

Figure 5: Well C showing Delineated Reservoir HD2000.

CONCLUSION

We have qualitatively delineated Hydrocarbon bearing reservoir HD2000 from preliminary study of wire line well log data acquired from an offshore Niger Delta field. Our estimation of the porosity and hydrocarbon saturation for HD2000 are good enough for potential commercial accumulation of hydrocarbon which could be exploited.

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