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RESERVOIR CHARACTERIZATION OF AN ONSHORE GEOFIELD IN NIGER DELTA, NIGERIA, USING OFFSET WELL DATA

Onyishi G.E.[1], Ugwu G.Z.[1*], Onyishi S.E.[2]

[1]Department of Industrial Physics, Enugu State University of Science and Technology, Enugu, Nigeria

[2]Department of Geology and Mining, Enugu State University of Science and Technology, Enugu, Nigeria

*Corresponding Author Email: gabriel.ugwu@esut.edu.ng

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ABSTRACT: *Three wells (GE_11, G_12 and G_13) in an onshore geofield in the Niger Delta, Nigeria, were used to characterise the reservoirs of the oil field. RokDoc (5.1) and Petrel (2014.1) software were employed for data analysis and characterisation of the reservoirs. A comprehensive petrophysical analysis of each well was carried out in other to ascertain the physical properties such as shale volume, porosity, fluid saturation, net pay thickness and gross pay thickness. The well information was also used to evaluate the lithology and hydrocarbon depth. The hydrocarbon depths in the reservoirs ranged from 3292 to 4121 m, while the hydrocarbon saturation ranged from 0.671 to 0.982. The water saturation ranges from 0.042 to 0.446, while the porosity ranges from 0.145 to 0.216. The bulk volume of water was estimated to vary from 0.015 to 0.025. The reservoir units across the three wells have parameters detailing a characteristically hydrocarbon-bearing reservoir.*

KEYWORDS: *Reservoir, Petrophysical Properties, Hydrocarbon Potential, Lithology, Well Logs.*

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INTRODUCTION

A reservoir is a subsurface rock with effective porosity and permeability, which usually contains a commercially exploitable quantity of hydrocarbon. Niger Delta basin is ranked among the most prolific basins in the world, and its hydrocarbon productivity has made it to be the fulcrum of Nigeria's economy. The basin is often characterised by complex structural deformation and faulting, which could lead to high uncertainties in the reservoir properties (Doust and Omatsola, 1990). The main purpose of reservoir characterisation is to generate a more representative geologic model of the reservoir properties. Therefore, any reservoir characterisation aims to understand the reservoir connectivity in static and dynamic conditions by integrating data from different sources. In building a geologic representation of what a reservoir is most likely to be, it is necessary to adequately capture the uncertainty of not knowing its exact picture (Odai and Ogbe, 2010). Hence, characterisation deals with determining reservoir properties/parameters such as porosity (Φ), permeability, fluid saturation, and Net pay thickness, among other properties.

The use of exploratory wells that are drilled through prospective geological structures has been of greater assistance in evaluating the hydrocarbon potential of the reservoir rocks in a given field. According to Asquith and Krygowski (2004), well logs are used to correlate zones suitable for hydrocarbon accumulation, identify productive zones, determine the depth and thickness of zones, distinguish between gas, oil and water in a reservoir and estimate hydrocarbon reserves. Logs ranging from electrical, nuclear and acoustics have been in use for deriving these parameters.

In this research, we aim to utilise a suite of borehole geophysical wireline logs to evaluate the hydrocarbon potential of an onshore geofield in the Niger Delta of Nigeria by characterizing the reservoirs. The results obtained from this study are therefore based on both petrophysical analysis and well logs interpretations.

Geological Setting

The geofield is located onshore in Niger Delta, Nigeria. The Niger Delta basin is one of the seven sedimentary basins in Nigeria. It is considered the most significant, owing to its petroliferous nature and consequent active hydrocarbon exploration and production operations occurring both onshore and offshore. The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province, as defined by Klett *et al.* (1997). From the Eocene to the present, the delta has prograded south-westward, forming depobelts representing the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world, with an area of about 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenter (Kaplan *et al.*, 1994).

The Niger Delta geology has been studied in detail by several workers (Reyment, 1965; Short and Stauble, 1967; Murat, 1972; Doust and Omatsola, 1990, Morley *et al.*, 1998; Adeogba *et al.*, 2005; Corredor *et al.*, 2005). The Niger Delta Basin is divided into mainly three lithostratigraphic units, the Akata (Palocene−Recent), Agbada (Eocene−Recent) and the Benin (Oligocene−Recent) formations which conform to a Lower pro-delta lithofacies, a Middle delta front lithofacies and an Upper delta top lithofacies respectively (Short and Stauble, 1967). These three units extend across the whole delta, and each range in age from early Tertiary to

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Recent. Figure 1 is the geological map of Nigeria showing the location of the Niger Delta basin and the sectional map of the Niger Delta depobelts and structural limits.

Rollover anticlines in the form of growth faults form the main targets of oil exploration, the hydrocarbons being found in sandstone reservoirs of the Agbada formation (Short and Stauble, 1967).

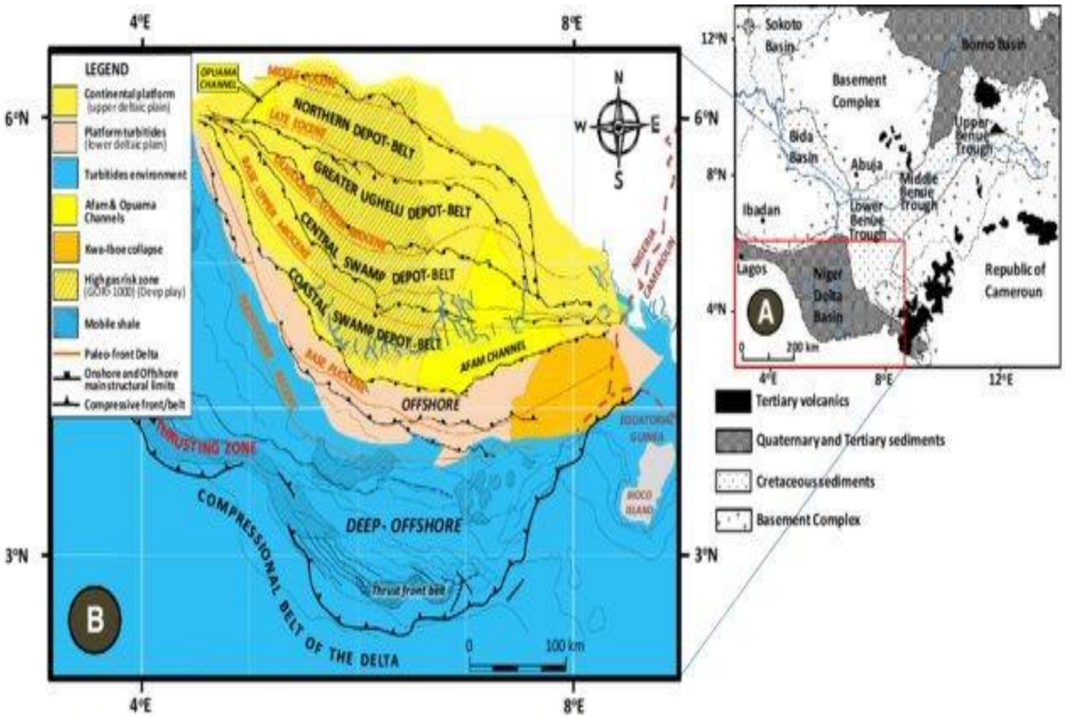

Figure 1. Sectional map of the Niger Delta depobelts and structural limits (Doust and Omatsola, 1990).

MATERIALS AND METHOD

Materials

In this study, the materials used include well-log data from the study area. The data comprise well logs of Gamma-ray (GR), Resistivity (REST), Porosity (RHOB), Density (DST) and Sonic (DT). RokDoc (5.1) (www.ikonscience.com) and Petrel (2014.1) software were used for the data processing and analysis.

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Method

The well data were imported into the software, and the three wells correlated. Well, correlation helped in determining the thickness of the sand being mapped and the lateral continuity of the reservoirs. The gamma-ray log data were thereafter used to calculate the shale volume V_{sh} of the rocks in the three wells from the gamma-ray logs by showing the accurate log response in the clean sand and shale zone. This is important as a threshold value of shale volume is often used to discriminate between reservoir and non-reservoir rock. The shale volume is obtained from the knowledge of the gamma-ray index, $I_{GR,}$ using the relation:

$$I_{GR} = \frac{GR_{log-}GR_{min}}{GR_{max-}GR_{min}} \qquad 1$$

where GR_{log} is the gamma-ray reading at a depth of interest, GR_{min} is the minimum gamma ray reading (usually, the mean minimum through a clean sandstone or carbonate formation), GR_{max} is the maximum gamma ray reading (usually, the mean maximum through a shale or clay formation).

Using Larionov's equation, (Larionov, 1969), the Volume of shale, V_{sh}, was obtained as:

$$V_{sh} = 0.083(2^{3.7*I_{GR}} - 1) \qquad 2$$

Using the formation parameters generated from the log data and basic regional information applicable to the Niger Delta basin enabled determination of other reservoir parameters such as Reservoir thickness, Gross Pay Thickness (GPT), Net Pay Thickness (NPT), Net Gross Ratio (NGR), Water saturation, Hydrocarbon saturation, Moveable and Non-movable hydrocarbon saturation, the Bulk volume of hydrocarbon, Bulk volume of water, etc. To define the net pay and other petrophysical parameters, the cut-off was set as ≤ 0.5 for water saturation, ≥ 0.1 for porosity and ≤ 0.5 for shale volume.

RESULTS AND DISCUSSION

Figure 2 shows the well log traces of the three wells. The yellow interval is sand, while the dark grey interval is shale. The two lithologic bodies were mapped as horizons (top and base) for each correlated reservoir across the wells. The wells display a simple shale-sand-shale sequence which is characteristic of the Niger Delta formations (Figure 2). The result also shows that each of the sand units extends through the three wells in the field at various thicknesses.

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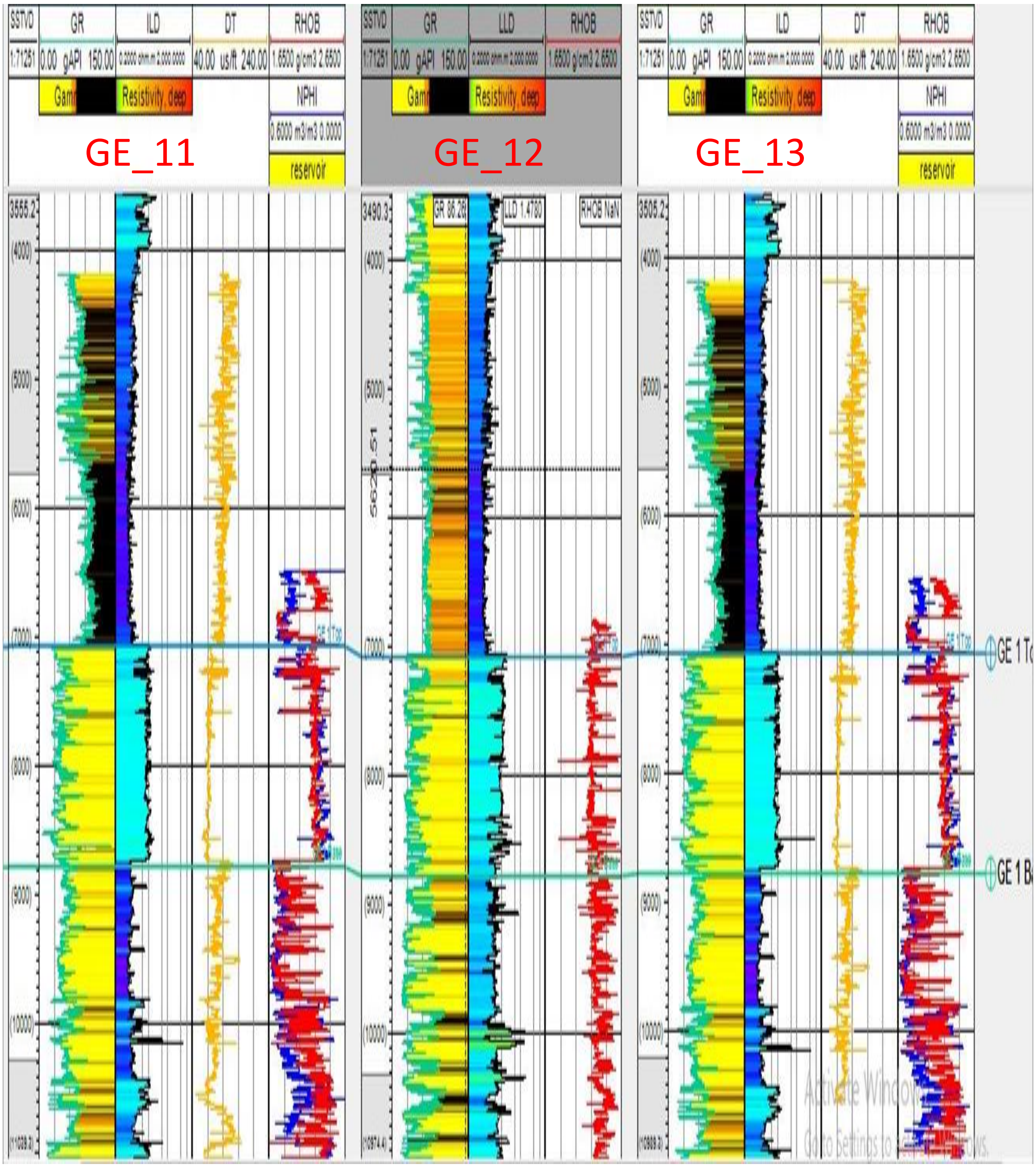

Figure 2. Top and base traces of the reservoirs correlated across the three wells.

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Tables 1−3 summarise the reservoir characterisation of the three wells with the average values of the petrophysical properties. Generally, for a good reservoir, porosity is expectedly high; the volume of shale is low while water saturation is low. Hence the porosity value (0.106 to 0.145), low volume of shale (0.028 to 0.161), and low water saturation (0.042 to 0.146) support the log signatures for a productive reservoir. Also, the high values of Net Pay Thickness NPT (18−31), Bulk Volume of Water BVH (0.092−0.134), Moveable Hydrocarbon Saturation Sh_{mov} (43.2−58.6), as well as other positive parameters in Tables 1−3, suggest that the reservoirs are productive. Therefore, the petrophysical reservoir features are good indicators for hydrocarbon accumulation, especially with high hydrocarbon saturation and low water saturation.

Table 1. Petrophysical parameters of Well GE_11

Reservoir	D (m)	GPT (m)	NPT (m)	NGR (m)	Vsh	Φ	S_w	S_h	S_{xo}	S_{hmov} %	$S_{hnon-mov}$ %	BVW	BVH	F	τ
BASE	4121	58	24	0.501	0.028	0.142	0.042	0.962	0.529	49.68	47.6	0.006	0.112	782	8.6
TOP	3815	211	19	0.091	0.161	0.106	0.147	0.864	0.686	54.1	32.1	0.019	0.092	92	9.1

Table 2. Petrophysical parameters of Well GE_12

Reservoir	D (m)	GPT (m)	NPT (m)	NGR (m)	V_{sh}	Φ	S_w	S_h	S_{xo}	S_{hmov} %	$S_{hnon-mov}$ %	BVW	BVH	F	τ
BASE	3756	60	22	0.411	0.028	0.114	0.042	0.975	0.611	49.1	51.2	0.008	0.110	80.1	9.1
TOP	3451	182	19	0.010	0.020	0.119	0.146	0.671	0.854	43.2	16.71	0.051	0.071	75.2	8.8

Table 3. Petrophysical parameters of Well GE_13

Reservoir	D (m)	GPT (m)	NPT (m)	NGR (m)	V_{sh}	Φ	S_w	S_h	S_{xo}	Shmov %	Shnon-mov. %	BVW	BVH	F	τ
BASE	3396	52	31	0.627	0.091	0.145	0.091	0.982	0.711	58.6	40.20	0.015	0.134	58.6	8.1
TOP	3292	161	18	0.511	0.072	0.116	0.010	0.712	0.817	53.1	13.14	0.025	0.095	40.1	7.0

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LEGEND:

D = Depth GPT = Gross Pay Thickness

NPT = Net Pay Thickness NGR = Net Gross Ratio

Vsh = Volume of Shale Φ = Porosity

S_w = Water Saturation S_h = Hydrocarbon Saturation

S_{xo} = Mud Filtrate Saturation S_{hmov} = Movable Hydrocarbon Saturation

$S_{hnon\text{-}mov}$ = Non-Movable Hydrocarbon Saturation, τ = Tortuosity

F = Formation Factor BVW = Bulk Volume of Water

BVH = Bulk Volume of Hydrocarbon.

CONCLUSION

Gamma-ray, resistivity, density and neutron logs data from three wells were used to analyse and evaluate the hydrocarbon potential of a geofield in an onshore Niger Delta, Nigeria. A correlation of the reservoirs of the wells shows that the lithology characterising the wells is the sand-shale interbedding sequence, with shale increasing with depth, typical of the Agbada formation. The hydrocarbon depth in the reservoirs ranged from 3292 to 4121 m, while the hydrocarbon saturation ranged from 0.671 to 0.982. The estimated petrophysical properties show that the field is viable in terms of hydrocarbon production, with the reservoirs having good hydrocarbon prospects.

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