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# PETROPHYSICAL PARAMETERS ESTIMATION OF AN OFFSHORE NIGER DELTA "X" FIELD USING WELL LOG DATA

ADIZUA, O. F.
Department of Physics
University of Port Harcourt, Port Harcourt, Rivers State, Nigeria

ORUADE, L.
Geoscientist and Private Contractor

*Abstract* — **The petrophysical parameters of an offshore Niger Delta "X" field was estimated using well log data. Two viable hydrocarbon bearing reservoirs (pay zones) were delineated and tagged $R_1$ and $R_2$ after a detailed interpretation of the log responses. The reservoir petrophysical parameters namely; porosity, water saturation and hydrocarbon saturation were thereafter computed at the reservoir intervals of interest. The reservoirs $R_1$ and $R_2$ had porosity values ranging from 0.20 to 0.24 and 0.36 to 0.39 respectively, while water saturation values for $R_1$ and $R_2$ ranged from 0.10 to 0.19 and 0.09 to 0.11 respectively. Hydrocarbon saturation values for $R_1$ and $R_2$ ranged from 0.81 to 0.90 and 0.88 to 0.91 respectively. The average reservoir thickness was 45ft for $R_1$ and 55ft for $R_2$.**

*Keywords*— **Petrophysical Parameters, Well log response, Offshore Niger Delta, Log Interpretation, Pay Zones**

## I. INTRODUCTION

The soaring demand for hydrocarbon resources in recent times has remarkably increased the search, exploration and exploitation efforts for the resource. Hydrocarbons are usually stored in interstitial pore spaces, open fractures or cracks of sedimentary rocks like sandstones forming hydrocarbon reservoirs when there is a trapping or sealing mechanism. Well logs are critical tools deployed when evaluating the hydrocarbon prospect of a given field. They are recordings of measurements as a function of depth of properties of the rock formation traversed by a measuring apparatus called a logging sonde in the well-bore. These rock properties could be electrical properties, natural or induced radioactivity, acoustic properties and orientation of the hole of the formations traversed by the logging sonde. The well log measurements obtained could thereafter be digitized or plotted as well log charts and adapted for a variety of applications such as to qualitatively delineate permeable and probable hydrocarbon bearing formations, estimate petrophysical parameters, pick formation boundaries and perform stratigraphic correlations, reservoir modeling applications and for structural studies.

The principal objective for this study is to quantitatively estimate petrophysical parameters of an offshore Niger Delta "X" field using measurements derived from a suite of well logs acquired in the present field. A previous study was targeted at qualitatively delineating probable and viable hydrocarbon bearing zones or reservoirs and the characterization of the reservoirs for their fluid contents (Adizua, O. F. and Oruade, L., 2018). The results that would be obtained from the present study in addition to that previously obtained would be immensely useful in petroleum field operations and in implementing reservoir management decisions to achieve the optimal field development plan for the prospect field.

Several researchers, Abu et. al. (2014), Ohakwere-Eze, M. C. and Adizua, O. F. (2014), Okumoko et. al. (2014), John et. al. (2013), Omoboriowo A. O. et. al. (2012) have carried out investigations on formation evaluation and estimation of petrophysical properties of potential hydrocarbon reservoirs in both onshore and offshore parts of the Niger delta basin and in other sedimentary basins around the world. The present study is targeted at quantitatively estimating petrophysical parameters needed to evaluate the hydrocarbon potential of the prospect field. The parameters of interest are porosity, water saturation and hydrocarbon saturation. These parameters would be estimated from a suite of well logs acquired from the prospect field. The results that would be obtained would supply vital data for successfully implementing exploitation programs for the delineated hydrocarbon reservoirs.

### 1.1. Geological framework of the Study Area/Brief Geology of the Niger Delta

The Niger Delta basin is situated in the gulf of Guinea and extends throughout the Niger Delta province (Klett et. al. 1997). Throughout its history the delta has fed been by Niger, Benue and Cross Rivers, which between them drain $10^6$ $km^2$ of the continental lowland savanna. From the apex to the coast the subsea portion stretches more than 300km covering an area of about 75,000$km^2$. Below the gulf of Guinea two enormous lobes protrudes a further 250km into the deep waters.

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Hydrocarbons have been located in all the depobelts of the Niger Delta, in good quality sandstone reservoir belonging to the main deltaic sequence. Most of the larger accumulation occur in roll over anticlines in the hanging walls of growth faults where there may be trapped in either dip or fault closures. The hydrocarbons are found in multiple pay sands with relatively short common and adjacent fault blocks usually have independent accumulations.

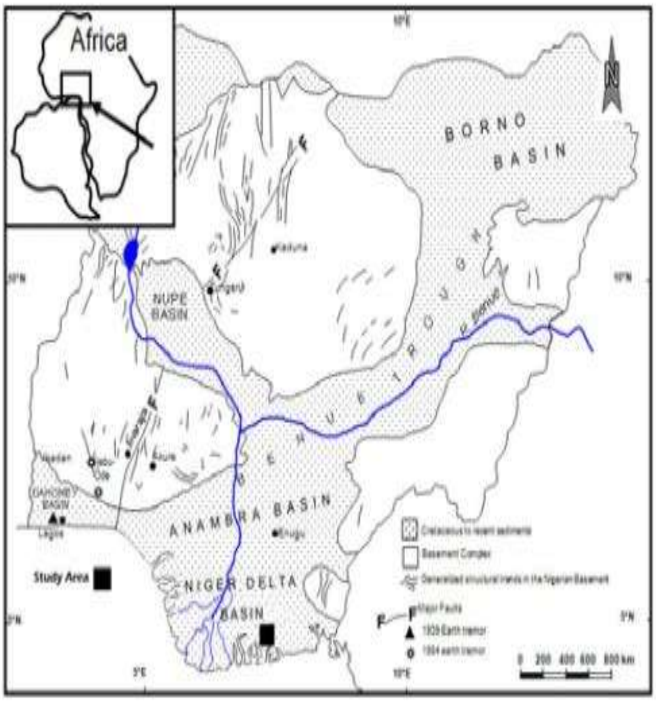


Figure-1.0: Generalized geologic map of Nigeria showing location of the study area. (Adapted after Odeyemi et. al., 1999)

## II. MATERIALS AND METHOD

The materials used for the study comprised of a suite of well logs (gamma ray log, resistivity log, neutron porosity log and density log) obtained from two well locations in the present field in LAS format. The logs were thereafter loaded, digitized and edited using the Hampson- Russel (HR) software tool. The digitized and edited well log was named Aroh 1 and Aroh 2. Aroh 1 (Figure 2.0) shows the suite of well log signatures from well 1 location, with the gamma ray log in track 1, the resistivity log in track 2, the density log in track 3 and the neutron porosity log in track 4.

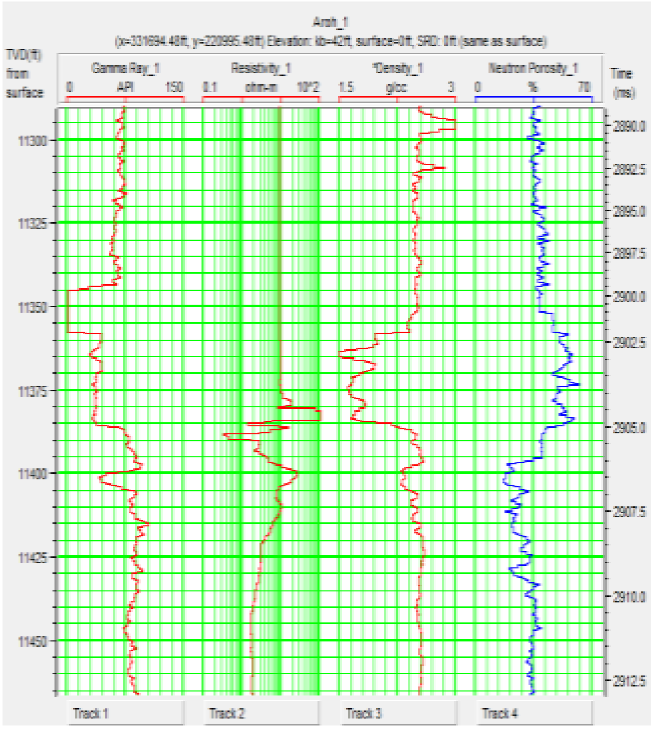


Figure 2.0: The four (4) well log signatures acquired from well 1

Aroh 2 (Figure 3.0) equally shows the display of the suite of well log signatures from well 2 location, with the gamma ray log in track 1, the resistivity log in track 2, the density log in track 3 and the neutron porosity log in track 4.

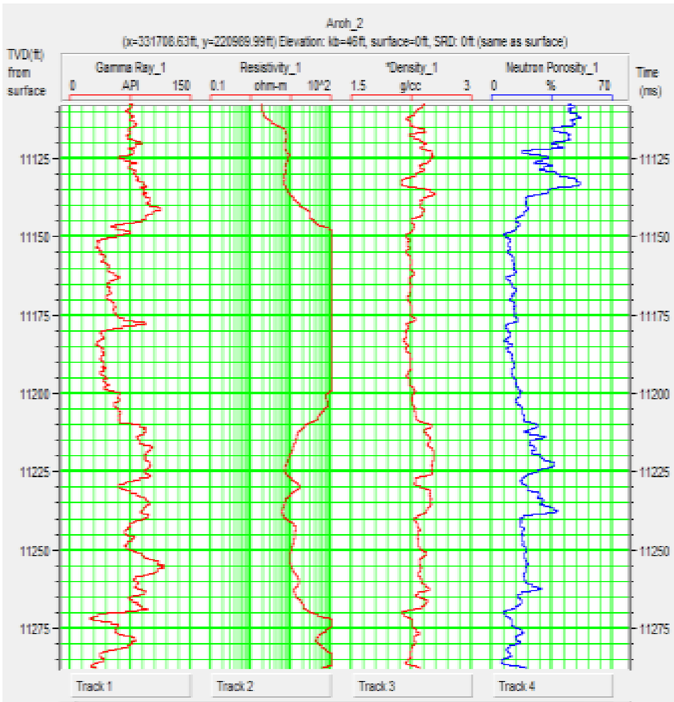


Figure 3.0: The four (4) well log signatures acquired from well 2

Detailed well log analysis and interpretation to identify hydrocarbon bearing reservoirs (potential pay zones) and to characterize the reservoir for fluid type has already been achieved in a previous study (Adizua, O. F. and Oruade, L., 2018). This present study is therefore aimed at estimating reservoir petrophysical parameters like porosity, water saturation and hydrocarbon saturation in the already mapped reservoirs to aid in the exploitation programs to be carried out in the prospect field.

### 2.1 Estimation of Petrophysical Parameters

**(a) Determination of Reservoir Porosity (ϕ)**

The porosity of reservoir rocks could be derived from the density log, neutron porosity log or a combination of both neutron porosity and density logs. The estimation of reservoir porosity for this study was estimated using density log measurements.

**Procedure:** Porosity (ϕ) could be obtained from the bulk density of a formation by using the equation:

$$\phi = \frac{\rho ma - \rho_b}{\rho ma - \rho_f}$$

if $\rho_{ma}$ (density of the matrix), $\rho_b$ (bulk density), $\rho_f$ (fluid density) are known as is the case for the present study. The average porosity value at each depth interval of the reservoir was computed using the afore-stated empirical relation and the values obtained were carefully documented.

**(b) Determination of Water Saturation ($S_w$)**

The calculation of formation water saturation requires; the true formation resistivity ($R_t$), formation water resistivity ($R_w$) and the calculated value of the formation factor (F). True resistivity can be obtained directly from the resistivity log, while the formation factor F is computed by the relation,

$$F = \frac{a}{\phi^m}$$

where a = tourtosity
m = cementation factor
ϕ = porosity

The water saturation could thereafter be computed using the computed formation factor by means of the Archie's equation:

$$S_w = \sqrt{\frac{FRw}{Rt}}$$

The values of water saturation, based on the values of F, $R_t$ and $R_w$ at each depth interval of the target reservoirs were equally computed and the result carefully documented.

**(c) Determination of Hydrocarbon Saturation ($S_h$)**

Hydrocarbon saturation was subsequently computed and documented using the very familiar empirical relation;

$$S_h = 1 - S_w$$

where $S_w$ is the water saturation.

## III. PRESENTATION OF RESULTS AND DISCUSSIONS.

From the well log signatures (Aroh 1 and Aroh 2), two viable reservoir sand units ($R_1$ and $R_2$) have already been delineated in a previous study by authors using the gamma ray responses over the logged intervals. The mapped reservoirs are shown in Figures 4.0 and 5.0.

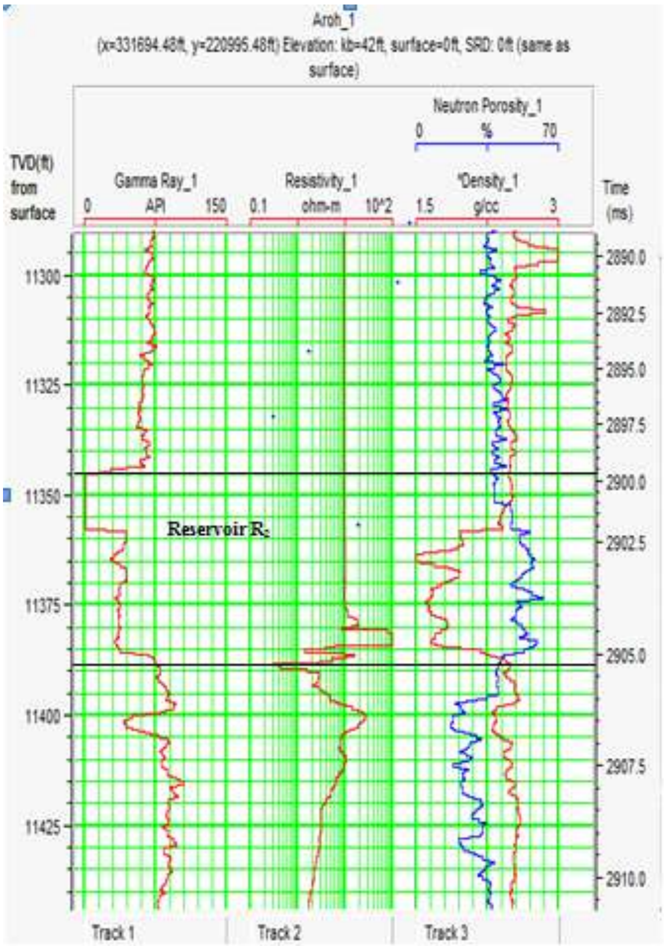


Figure 4.0: The well log signatures for Aroh 1 with density and neutron porosity logs tied together showing delineated reservoir $R_2$. (Adizua, O. F. and Oruade, L., 2018).

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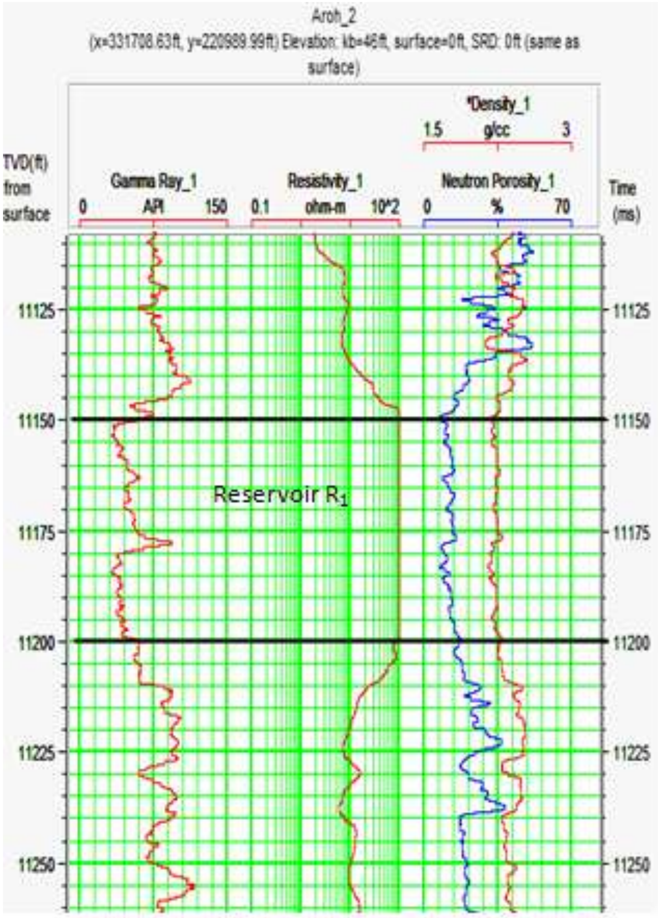


Figure 5.0: The well log signatures for Aroh 2 with density and neutron porosity logs tied together showing delineated reservoir $R_1$ (Adizua, O. F. and Oruade, L., 2018).

Within these reservoir zones of interest average petrophysical parameters namely porosity, water saturation and hydrocarbon saturation have been computed at depth intervals of 5ft and the results are as presented in Tables 1 and 2.

Table 1: Estimated Petrophysical Parameters for Aroh-1

| Top (Ft) | Base (Ft) | $R_t$ (Ω-m) | Neutron log (%) | Density log (g/cc) | Porosity $\phi$ | Water Saturation $S_w$ | Hydrocarbon Saturation $S_h$ |
|---|---|---|---|---|---|---|---|
| 11360 | 11365 | 10.20 | 52.50 | 1.75 | 0.39 | 0.18 | 0.82 |
| 11365 | 11370 | 10.20 | 49.00 | 1.73 | 0.39 | 0.18 | 0.82 |
| 11370 | 11375 | 10.00 | 52.50 | 1.80 | 0.36 | 0.19 | 0.81 |
| 11375 | 11380 | 15.00 | 49.83 | 1.76 | 0.38 | 0.15 | 0.85 |
| 11380 | 11385 | 36.83 | 56.00 | 1.76 | 0.38 | 0.10 | 0.90 |

Table 2: Estimated Petrophysical Parameters for Aroh-2

| Top (Ft) | Base (Ft) | $R_t$ (Ω-m) | Neutron log (%) | Density log (g/cc) | Porosity $\phi$ | Water Saturation $S_w$ | Hydrocarbon Saturation $S_h$ |
|---|---|---|---|---|---|---|---|
| 11150 | 11155 | 100 | 7.25 | 2.25 | 0.21 | 0.11 | 0.89 |
| 11155 | 11160 | 100 | 10.50 | 2.25 | 0.21 | 0.11 | 0.89 |
| 11160 | 11165 | 100 | 10.50 | 2.27 | 0.20 | 0.12 | 0.88 |
| 11165 | 11170 | 100 | 10.75 | 2.25 | 0.21 | 0.11 | 0.89 |
| 11170 | 11175 | 100 | 10.75 | 2.25 | 0.21 | 0.11 | 0.89 |
| 11175 | 11180 | 100 | 10.50 | 2.26 | 0.20 | 0.11 | 0.89 |
| 11180 | 11185 | 100 | 10.50 | 2.18 | 0.24 | 0.09 | 0.91 |
| 11185 | 11190 | 100 | 10.50 | 2.22 | 0.22 | 0.10 | 0.90 |
| 11190 | 11195 | 100 | 14.00 | 2.22 | 0.22 | 0.10 | 0.90 |
| 11195 | 11200 | 100 | 14.25 | 2.26 | 0.20 | 0.16 | 0.89 |

From the computed reservoir porosities, it is obvious that reservoir $R_2$ has a better porosity when compared to $R_1$ as their average porosities are 0.38 and 0.21 respectively over the reservoir intervals of interest. The hydrocarbon saturation for both reservoirs had values in very close proximity. The average hydrocarbon saturation for $R_2$ was 0.84 while that of $R_1$ was 0.89. The computed values for hydrocarbon saturation are very good indicators that the prospect field has an appreciable amount of hydrocarbons that could be exploited or tapped.

## IV. CONCLUSIONS

The results obtained for the petrophysical parameters (porosity, water saturation and hydrocarbon saturation) from the well logs have offered an insight into the viability of the prospect field. It is very crucial to have a detailed and quantitative estimate of the petrophysical parameters of any given reservoir before an actual production process can be commenced to avert unnecessary losses associated with hitting up dry holes. The results obtained therefore would be useful for implementing exploitation programs in the field and would serve as input data for other post-logging procedures and applications.

**Acknowledgment**

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