



Relevance of Geophysical Wireline Logs In Hydrocarbon Reservoir Characterization

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Abstract Suites of borehole logs comprising gamma-ray, electrical resistivity, neutron and density logs from four wells in the offshore Niger Delta were evaluated for their hydrocarbon potential. The various lithologic types penetrated by the wells were differentiated on the basis of the Gamma-Ray log into sand, shale and shaly-sand beds.

Three (3) sand bodies were delineated and correlated across the (O) field. The three sands were further identified as potential hydrocarbon reservoirs. The evaluated petrophysical parameters for the reservoir layers have porosity, range of 24-30 % and hydrocarbon saturation, range of 72–80 %. The logs evaluation indicates that prolific sands are encountered at depth range of 2920-2978 m.

It is therefore evident that the area under study has a good potential for hydrocarbon exploration and exploitation. The use of the geophysical well logs have allowed for the evaluation of rock formation properties such as hydrocarbon saturation, porosity and reservoir thickness that will make drilling and production decisions a lot easier.

Keywords Rock properties, Niger Delta, Saturation, Porosity, well log

Introduction

Well logging is one of the most fundamental methods for reservoir characterization, in oil and gas industry, it is an essential method for geoscientist to acquire more knowledge about the condition below the surface by using physical properties of rocks. This method is very useful to detect hydrocarbon bearing zone, calculate the hydrocarbon volume, and many others [1, 9].

Formation evaluation is the study of the properties of the rock and their relationship to the fluids they contain in both static and flowing states using wireline logs [2, 8].

The formation of the Niger Delta- Nigeria consists of sands and shales with the former ranging from fluvial (channel) to fluviomarine (barrier bar), while the later are generally fluviomarine or lagoonal. These formations are mostly unconsolidated and it is often not feasible to take core samples or make drill stem tests. Formation evaluation is consequently based mostly on logs. Petrophysical parameters like the lithology fluid content, porosity, water saturation and hydrocarbon saturation are derived; from the well log data [3,10].

Petroleum deposits occur as a result of the deposition of plants and animals matter in areas which are slowly subsidizing. These areas which are usually in the sea or along if margin in the coastal lagoons and occasionally in lakes or inland swamps. Sediments are deposited along with organic matters and rate of deposition of the sediments must be sufficiently rapid that at least part of the organic matter is preserved buried before being destroyed or decayed [7]. As time goes on and the area continue to sink slowly (because of weight of sediments) the organic materials are buried deeper and hence is exposed to higher temperature and pressure. Eventually, chemical changes result in the formation of petroleum; a complex highly variable mixture of hydrocarbon, including liquid and gases.

Sedimentary rocks are porous, porosity being the fractional volume of the rock occupied by cavities or pores. Petroleum collects these cavities, intermingled with water which are buried with the sediments.



When a significant fraction of the pool inter-connected so that is permeable the oil and gas tends to rise and will eventually reach the surface of the earth and be dissipated unless they encounter a barrier which stops the upward immigration such as barrier produces a trap.

Since the petroleum deposit is beneath the surface operation of deciding when the drilling should be stopped. The logs are useful to geophysicists and geologists as they help them make relevant decisions.

Three major litho stratigraphic units have been recognized in the Niger Delta- Nigeria [2,6]. These are the Akata, Agbada and Benin formations. Details of the geology of the Niger Delta has been discussed by several authors.

The Benin formation, which is a loose fresh water bearing sand with occasional lignite the clay and going up to 2,286m deep with no pressures. The Agbada formation is made up of alternation sands and shales. The sands are mostly encountered at the upper parts while shales are found mostly at the lower parts [11,12]. The Agbada formation is the thickest at the center of the Delta and goes up to 457.2m. This is the seat of most oil reservoirs and center of over pressures (Figure 1).

Formation evaluation in the area of study within Niger Delta basin will allow an estimate to be made of porosity, fluid content and type and lithology with geophysical well logs [11, 12]. The physical and chemical properties of the rock determined in this way are an invaluable aid to describing sub-surface geology [3].

The overall aim of this study is to delineate the reservoir units for correlation and evaluation of rock formation properties in 'O' Field in the Niger Delta using well log data".

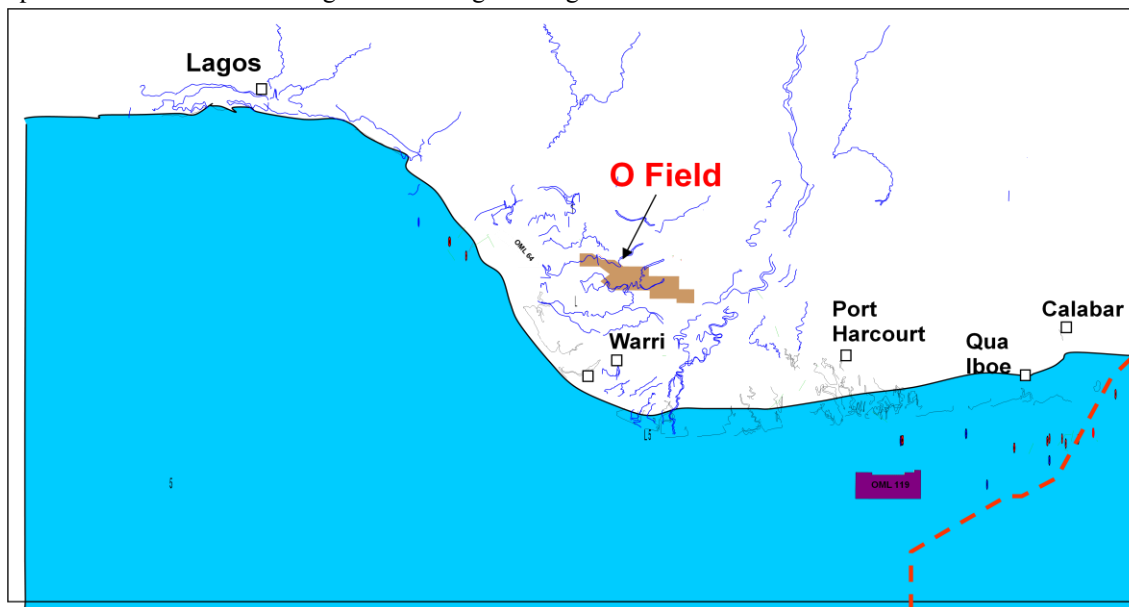


Figure 1: Map of the Niger Delta showing the Study Area

Location of the Study Area

The area of study (O Field) is located between longitudes 4° and 9° E and latitudes 4° and 7° N in the Southern part of Nigeria (Figure 1).

The Niger Delta occupies a land area limited by the Benin flank, the Ameki basin, the Calabar flank and the present coast line (Fig -1). This land area may be referred to as the subaerial part of the Niger Delta and the marine area, which corresponds to the subaqueous part of the Niger Delta is limited by the coastline and the farther side of the continental rise, thus comprising the continental shelf, slope and rise off the subaerial Delta [7].

Materials and Methods

Materials used for the relevance of geophysical wireline logs in hydrocarbon reservoir characterization are techlog software, gamma ray log, density and neutron log.

Techlog software is a well bore petrophysical application composed of a platform and a suite of ass-on-application modules.

The techlog platform dynamically incorporates the latest data from the well site for review and detailed analysis. Data can be streamed directly from the well site for real-time processing and instantaneous analysis aiding decision making during operations.

The techlog platform enables you to perform both basic and advanced interpretation on all wellbore data types, including your own petrophysical workflow to generate meaningful quick-look interpretations based on local expertise and the application of industry standard methods for lithology, porosity, saturation, permeability.

All common data formats are easily loaded through a powerful drag-and-drop interface into the techlog platform. You can quickly create a log view to visualize, validate and correct data for environmental and signal noise effects.

Archie developed his famous equation with in clay free reservoirs to calculate, from well log parameters, the water saturation (S_w) of the uninvaded zone in a formation next to a borehole. The Archie equation can be expressed as follows:

$$S_w^n = \frac{a R_w}{(\phi^m \times R_t)} \quad (1.1)$$

where S_w = water saturation of the uninvaded zone

n = saturation exponent, which varies from 1.8 to 4.0 but normally is 2.0;

R_w = formation water resistivity at formation temperature,

Φ = Porosity,

m = cementation exponent, which varies from 1.7 to 3.0 but normally is 1.8 in the Niger Delta;

R_t = true resistivity of the formation, corrected for invasion, borehole, thin bed, and other effects. The formation factor is,

$$F = \frac{a}{\phi^m}, \text{ where } a = 1 \text{ (The tortuosity factor)}$$

The Simandoux equation is a good general purpose equation that accounts for the influence of shale with regard to water saturation. The Simandoux equation is

$$\frac{1}{R_t} = \frac{S_w^2}{F \times R_w (1 - V_{SH})} + \frac{V_{SH} \times S_w}{R_{SH}} \quad [9,13] \quad (\text{Ohm})^{-1} \quad (1.2)$$

where,

(a) S_w = water saturation

(b) F = formation resistivity factor

(c) R_{SH} = resistivity of shale

(d) V_{SH} = volume of shale

(e) R_w = resistivity of formation waters

(f) R_t = true formation resistivity

(g) n = saturation exponent

(i) Volume of Shale was derived from the gamma ray log first by determining the gamma ray index I_{GR} [13]

$$I_{GR} = \frac{(GR_{log} - GR_{min})}{(GR_{max} - GR_{min})} \quad (1.3)$$

where I_{GR} = gamma ray index; GR_{log} = gamma ray reading of the formation; GR_{min} = minimum gamma ray reading (sand baseline); GR_{max} = maximum gamma ray reading (Shale baseline).

For the purpose of this research work, volume of shale for tertiary rocks was used:

$$V_{sh} = 0.083 (2^{(3.7 \times IGR)} - 1) \quad (1.4)$$

Porosity Φ was calculated from density porosity log using the equation:

$$\Phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \quad (1.5)$$

where,



ρ_{ma} = matrix density = 2.65g/cc for sandstone (reference), ρ_b = bulk density which is taken to be 1 for gas and 0.87 for oil (reference).

Table 1: Petrolphysical Results

Reservoir	GR (API)	Intervals (m)	Gross Thickness (m)	Bulk Density (g/cc)	Porosity (Ø %)	Water Saturation (%)	Hydrocarbon Saturation
1	48	2920-2928	8	2.19	27	20	0.80
2	22	2944-2952	8	2.23	24	25	0.75
3	18	2966-2978	10	2.33	30	28	0.72

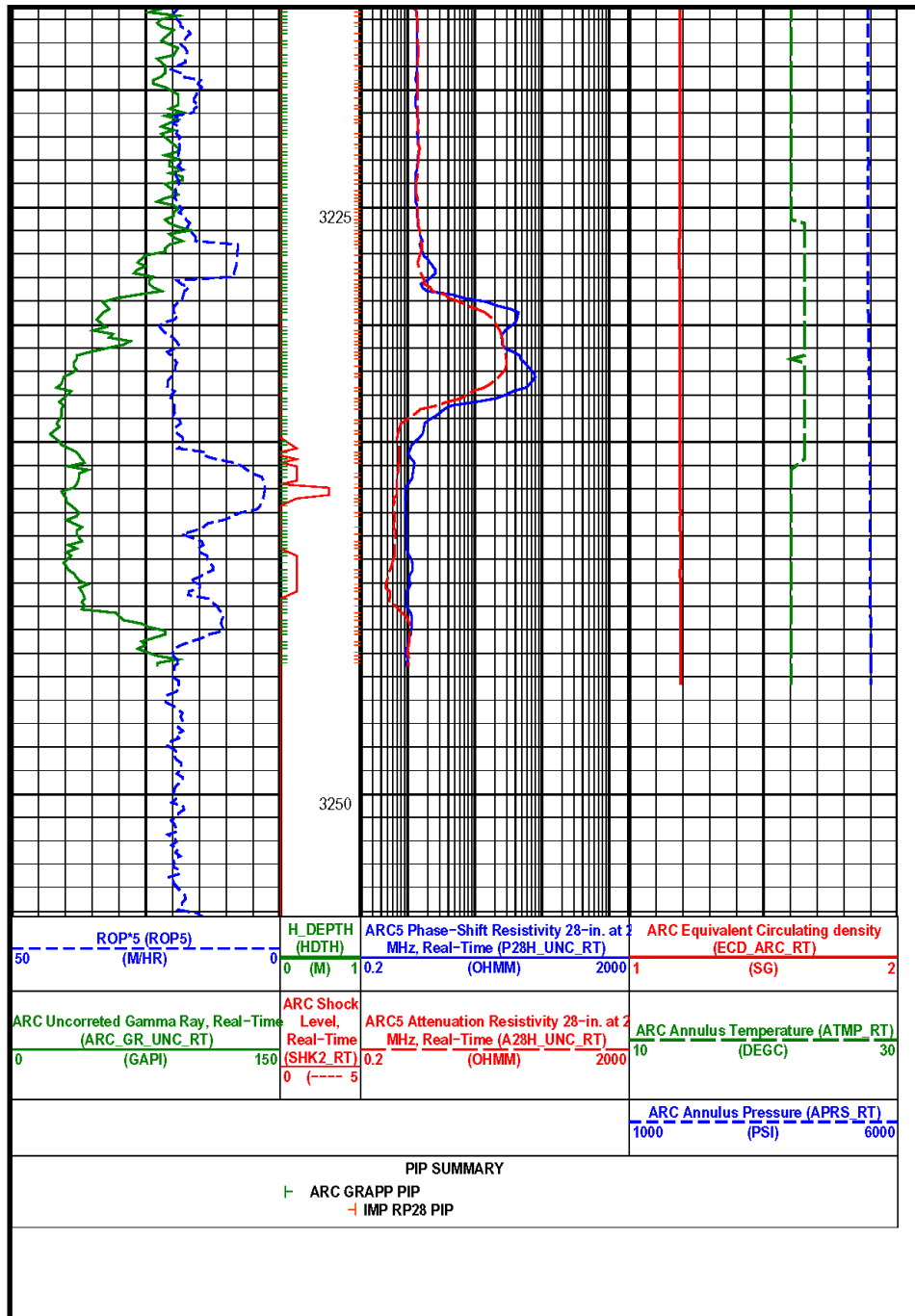


Figure 2: Well logs showing Niger Delta Sand Reservoir

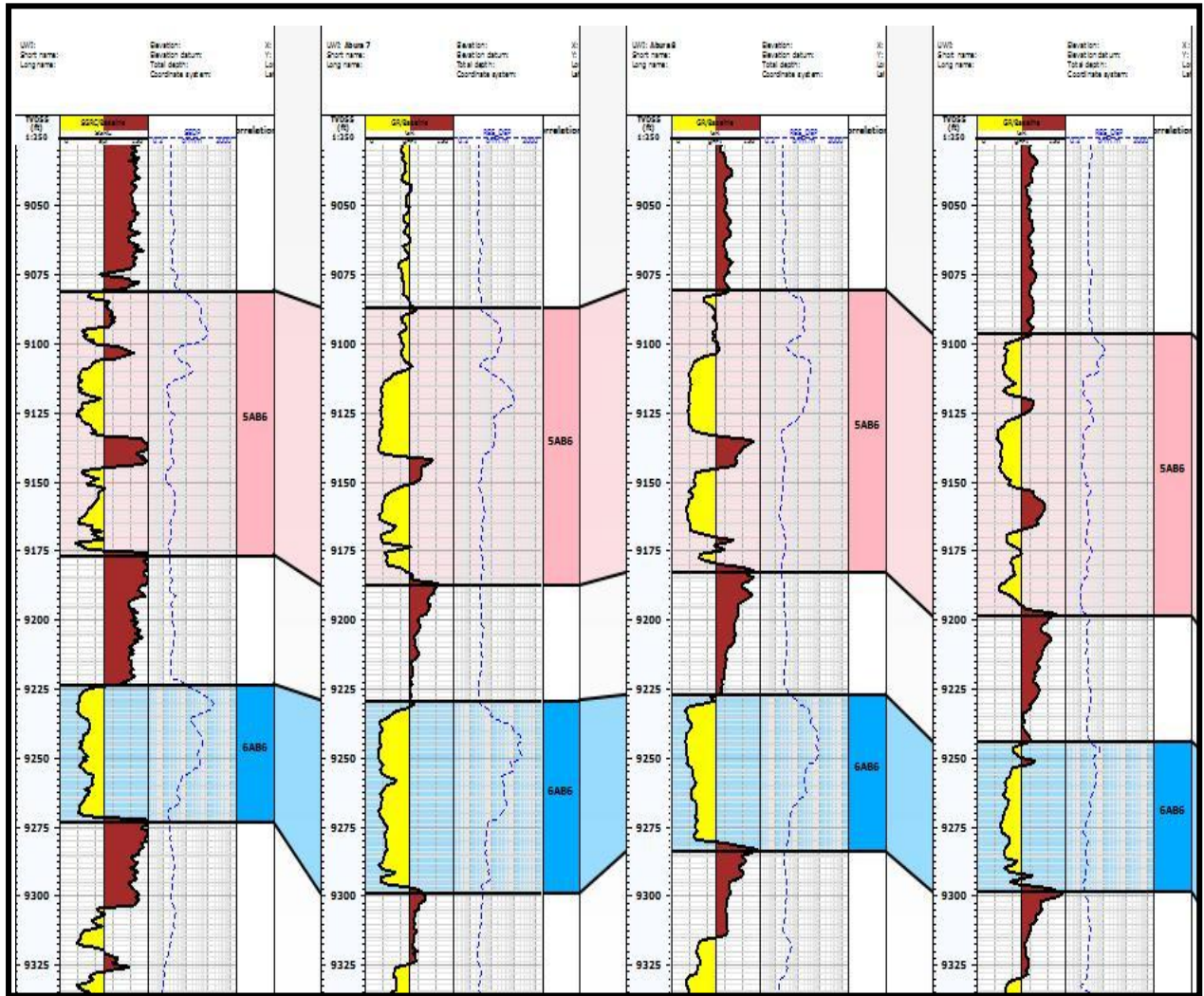


Figure 3: Correlation of wells in area of study, Niger Delta –Nigeria

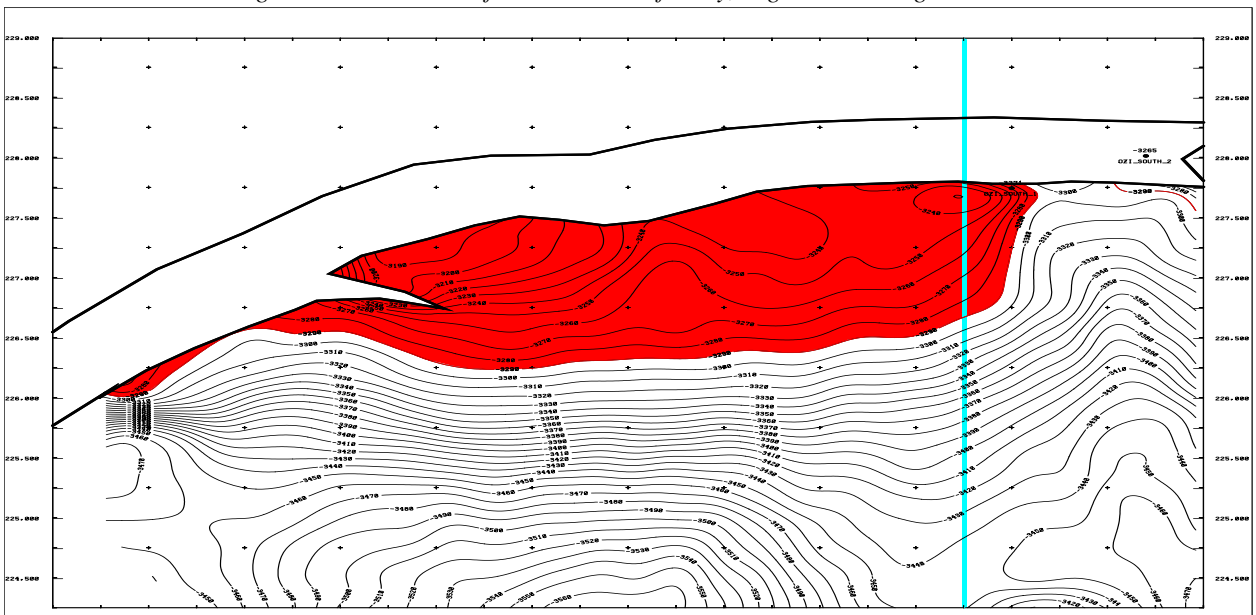


Figure 4: A8.0 Top Reservoir Depth Map

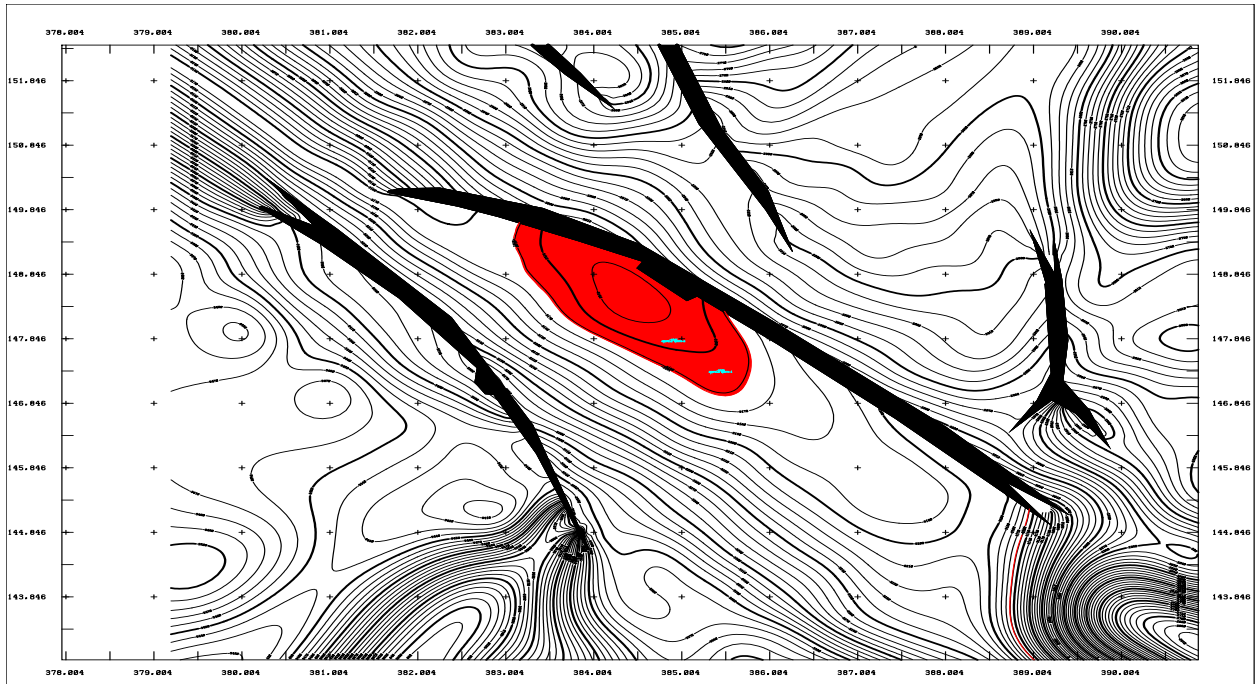


Figure 5: A8.1 Top Reservoir Depth Map

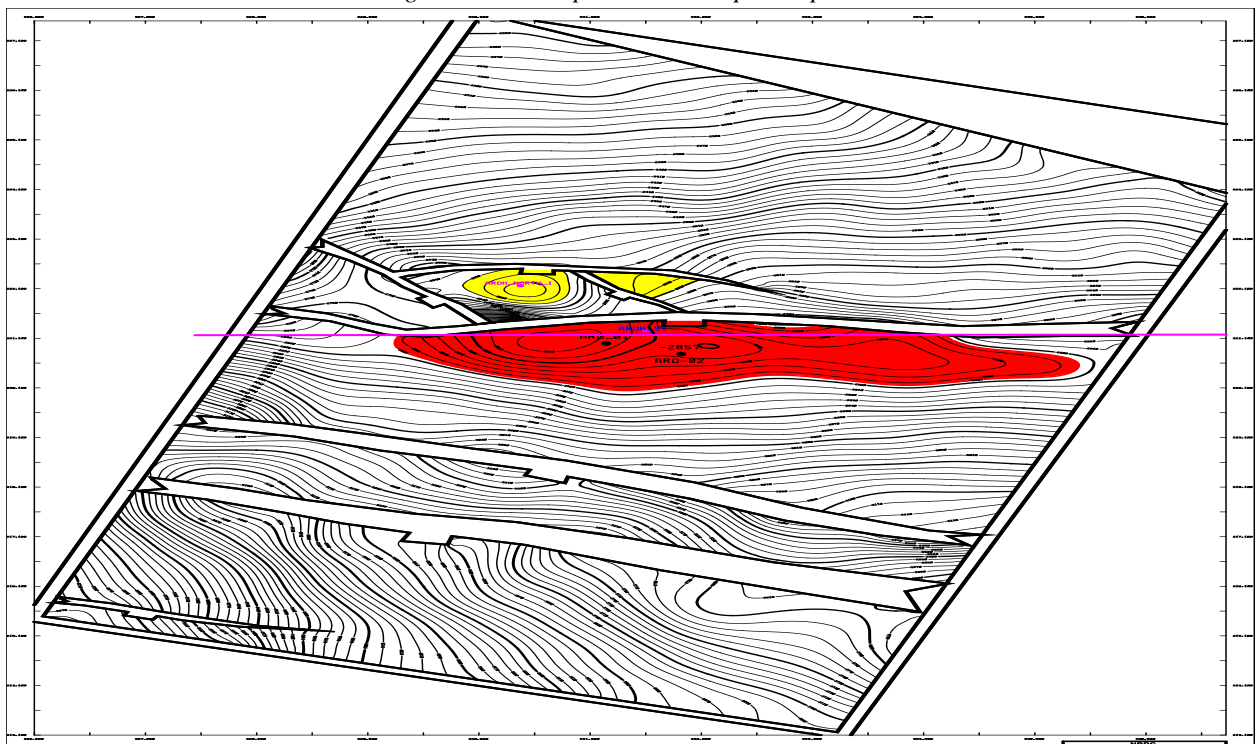


Figure 6: A8.2 Top Reservoir Depth

Results and Discussion

From the results of the GR logs, it is evident that the lithology of the study area consists mainly sand and shale interbeddings. At the upper part of the wells, the sands are thick (>70m) and are fresh water-bearing while towards the bottom of the wells there is increasingly more shale than sands. At greater depths, that is below the fresh water sands are the hydrocarbon-bearing sands overlying salt water sands (Figure 2). It can then be said that the wells penetrated both Benin and Agbada formations and probably the top of Akata formation in which case the fresh water sands belong to the Benin formation and intervals that are hydrocarbon-bearing including



correlated intervals belong to the Agbada formation (Table1). The top reservoir depth maps Figures 4-6 with the areas in Square feet indicates area saturated with hydrocarbon.

The combination of both neutron and density porosity values will indicate gaseous formation if the neutron porosity is less than density porosity, while a low density porosity value and a high neutron porosity values will indicate shale above water-bearing formations where the neutron and density logs will overlay if recorded on compatible scales. Good well to well correlation was established in the area of the

Study in Niger Delta- Nigeria as shown in Figure 3. From the comparison of the values of the petrophysical parameters and the water saturation values of the productive intervals (Table 1), it is observed that the values for interval I, well A and also those of interval I, well B compare with those of interval I, well C and D. This confirms the lithological correlation earlier made in figure 3. Gas-Water Contact has been encountered by the well at 2984 m TVDSS. The use of the geophysical well logs have allowed for the evaluation of rock formation properties such as hydrocarbon saturation, porosity ,etc that will make drilling and production decisions a lot easier.

Conclusion

Three (3) sand bodies were delineated and correlated across the (O) field. The three sands were further identified as potential hydrocarbon reservoirs. The evaluated petrophysical parameters for the reservoir layers have porosity, range of 24-30 % and hydrocarbon saturation, range of 72-80 %. The logs evaluation indicates that prolific sands are encountered at depth range of 2920 – 2978 m.

The resistivity log was used in combination with gamma ray log to correlate and determine well boundaries, true formation resistivity, porosity, presence of hydrocarbon and gas-oil-water contact. While the density and neutron log was used to calculate rock porosity, matrix density and determined hydrocarbon type (gas or oil). Gas-Water Contact has been encountered by the well at 2984 m TVDSS. The use of the geophysical well logs have allowed for the evaluation of rock formation properties such as hydrocarbon saturation, porosity, etc that will make drilling and production decisions a lot easier. This study has established the relevance of the well logs method of calculating porosity, thickness of the reservoir, gas-water/oil contact and hydrocarbon saturation and their correlation with other wells.

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