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PETROPHYSICAL EVALUATION OF Z-WELL IN X-FIELD, NIGER DELTA BASIN, NIGERIA

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Abstract

Z-well of X-field, Niger Delta Basin was evaluated using log suites including: Gamma Ray (GR)log, Resistivity log and Neutron – Density Cross-plot log to determine the lithology of the formation, hydrocarbon content and the hydrocarbon bearing reservoirs in the well. The Gamma Ray (GR) log was used to identify the lithology of the formation by measuring the natural radioactivity emanating from the formation; with sandstone having low natural radioactivity and shale having high radioactivity emanating from it. The Resistivity (R) log was used to measure the resistivity of the formation, which is the ability of the formation to resist or conduct electric current. The Neutron – Density crossplot log was used to determine the possible hydrocarbon bearing zones and to ascertain whether it is gas, oil or water. The evaluation gave rise to alternating sandstone and shale lithologies, with reservoir zones of fluid content including twenty five (25) hydrocarbon bearing zones and thirteen (13) water bearing zones.

Keywords: Petrophysical, Gamma Ray Log, Resistivity Log, Reservoir, Sand, Shale, Niger Delta

1.0 Introduction

Petrophysics is the study of the physical and chemical properties of rocks and their contained fluids. A major application of petrophysics is in studying reservoirs for the hydrocarbon industry. Petrophysicists are employed to help reservoir engineers and geoscientists understand the rock properties of the reservoir, particularly how pores in the subsurface are interconnected, controlling the accumulation and migration of hydrocarbons. Some of the key properties studied in petrophysics are lithology, porosity, water saturation, permeability and density. A key aspect of petrophysics is measuring and evaluating these rock properties by acquiring well log **[1].**

Location of Study Area.

Well X is located in Field Z, Northern Depobelt, Niger Delta Basin

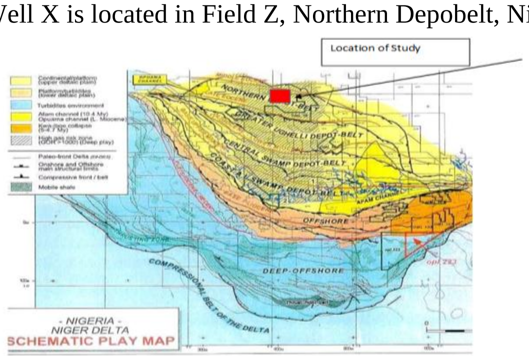

Fig. 1: Map showing location of study – Niger Delta Depo-belt **[2]**

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2.0 Niger Delta Geological Setting

Several workers **[3, 4, 5]** have summarized the structural and tectonic setting of the Niger Delta. According to these authors, the structural evolution of the Niger Delta began with the formation of the Benue Trough in the Early Cretaceous as a failed arm of a triple rift junction associated with the opening of the South Atlantic. According to **[5]**, the initial stage of the evolution involves the rise of a mantle plume in the region of the present Niger Delta, which led to the doming and rifting in the Benue region, developing an RRR triple junction. Three major tectonic phases or epirogenic movements were suggested by **[6]** to have influenced the geologic history of the Benue Trough system, which he subdivided into three paleogeographic areas or sub-basins; the Abakaliki–Benue Trough, the Anambra Basin and the Niger Delta Basin.

The Tertiary Niger Delta covers an area of approximately 75,000 sq km and consists of a regressive clastic succession, which attains a maximum thickness of 12,000m **[7].** The Niger delta is located in the Gulf of Guinea, Central West Africa, at the culmination of the Benue Trough and is considered one of the most prolific hydrocarbon provinces in the world **[8].** The Anambra basin and Abakaliki High to the North, the Cameroun volcanic line to the East, the Dahomey Embayment to the West and the Gulf of Guinea to the South define the boundaries of the Niger Delta. According to **[9]**. The siliciclastic system of the Niger Delta began to prograde across pre-existing continental slope into the deep-sea during the Late Eocene and is still active today. The litho-stratigraphy of the Tertiary Niger Delta (Figure 2) can be divided into three major units: Akata, Agbada and Benin formations, with depositional environments ranging from marine, transitional and continental settings respectively. The Akata, Agbada and Benin formations overlie stretched continental and oceanic crusts **[10].** Their ages range from Eocene to Recent, but they transgress time boundaries. These prograding depositional facies can be distinguished mainly on the basis of their sand-shale ratios.

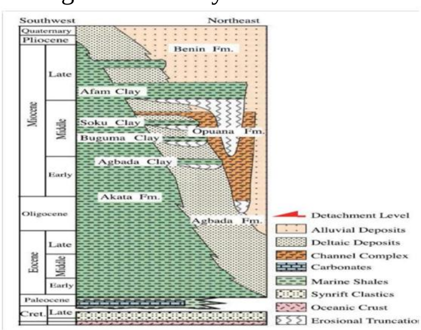

Figure 2: Regional Stratigraphy of the Niger Delta. **[8]**

3.0 Materials and methods

The primary materials used for the study are wireline logs obtained for Well "Z" of the Niger Delta Basin. The logs were obtained from Nigerian Petroleum Development Company, NPDC. The logs contained are:

Gamma Ray Log, Neutron/Density Cross Plot Log, Resistivity Log, and Sonic Log.

Gamma Ray Log:

The Gamma Ray log, commonly given the symbol *GR* is a continuous measurement of the natural radioactivity emanating from the formations. Principal isotopes emitting radiation are Potassium-40, Uranium, and Thorium (K40, U, Th). Sensitive detectors count the number of gamma rays per unit of time. Once the gamma rays are emitted from an isotope in the formation, they progressively reduce in energy as the result of collisions with other atoms in the rock (*Compton scattering*). Compton scattering occurs until the gamma ray is of such a low energy that it is completely absorbed by the formation. Hence, the gamma ray intensity that the log measures is a function of:

- The initial intensity of gamma ray emission, which is a property of the elemental composition of the rock.
- The amount of Compton scattering that the gamma rays encounter, which is related to the distance between the gamma emission and the detector and the density of the intervening material.

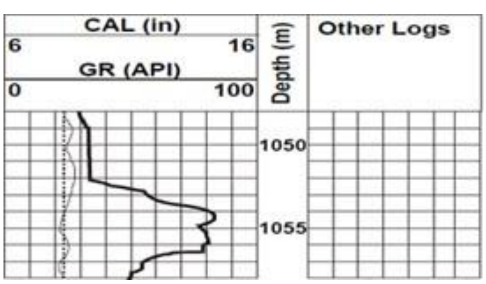

Fig. 3.1: Gamma Log Presentation

Principal isotopes emitting radiation (Potassium-40, Uranium, and Thorium) are more concentrated in clays; thus higher radioactivity in shale than other formations.

Resistivity Log:

The whole of resistivity logging is based upon a few very important equations which relate the resistivity of a formation to the resistivity of the fluids saturating a formation, the porosity of the formation and the fractional degree of saturation of each fluid present. Resistivity is a measure of the ability of a formation to resist or conduct electric current.

Density Log:

The formation density log measures the bulk density of the formation. Its main use is to derive a value for the total porosity of the formation. It is also useful in the detection of gas-bearing formations and in the recognition of evaporites, oil and gas. The bulk density (ρb) of a reservoir is the weighted average density of the present pore fluids (ρfl) and its rock matrix (ρma)

Neutron Log:

The neutron log is sensitive mainly to the amount of hydrogen atoms in a formation. The tool operates by bombarding the formation with high energy neutrons. A source and two detectors are mounted in a tool, which is pressed against the borehole wall. The two detectors only count the returning neutrons which have a thermal energy level. From the ratio of thermal neutrons detected by the far and the near detector, the amount of the hydrogen (H) atoms is empirically determined. The tool assumes H atoms to be present in the pore space (water or hydrocarbons).

Density/Neutron Combination:

The densities and neutron tool both determine the porosity of a reservoir, but do this by measuring different quantities. The density tool measures the bulk density and the neutron tool measures the hydrogen density. For this reason, both tools react differently to certain pore fluids and lithologies. It is standard practice to plot both logs in one track using a scale such that both logs are cross-plotted. In gas bearing zones the recorded is lower and the bulk density is reduced compared with the responses in similar water/oil bearing formation. These effects can be significant depending on the gas saturation in the invaded zone. The resulting (large) separation with neutron on the right and density on the left is called gas separation. This effect for a balloon shape and is therefore popularly known as the "Balloon Effect".

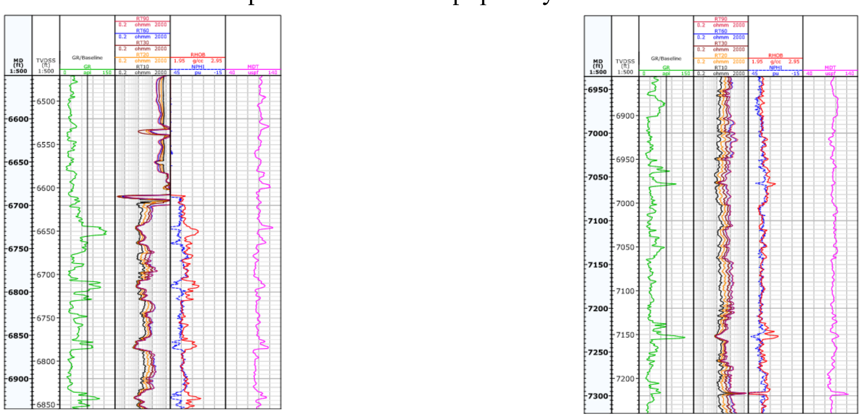

Figure 3.2: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log.*

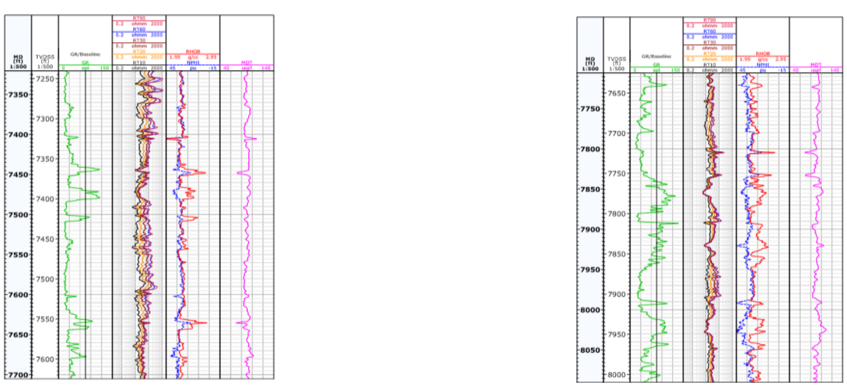

Figure 3.3: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

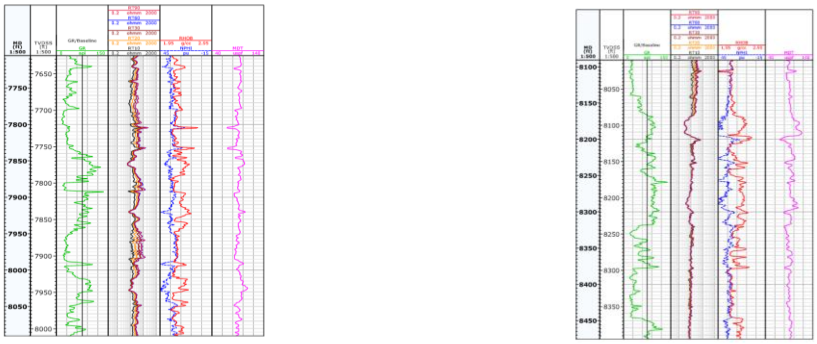

Figure 3.4: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

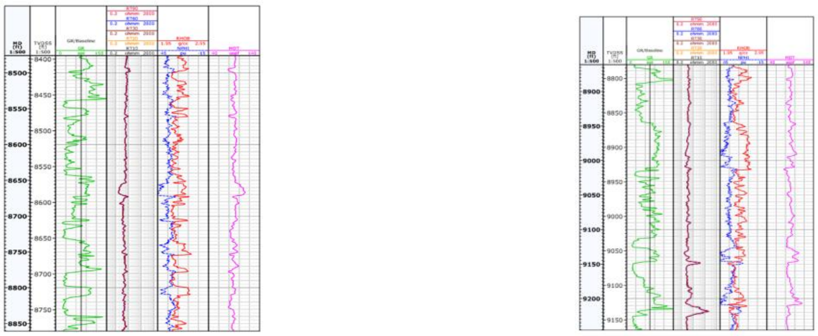

Figure 3.5: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

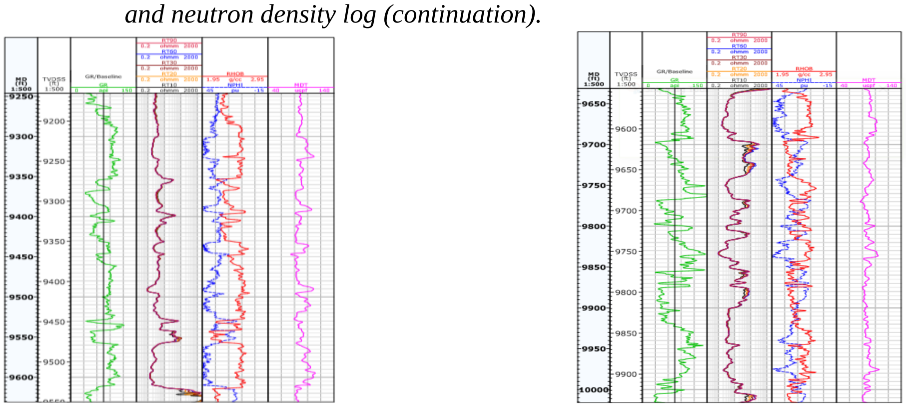

Figure 3.6: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

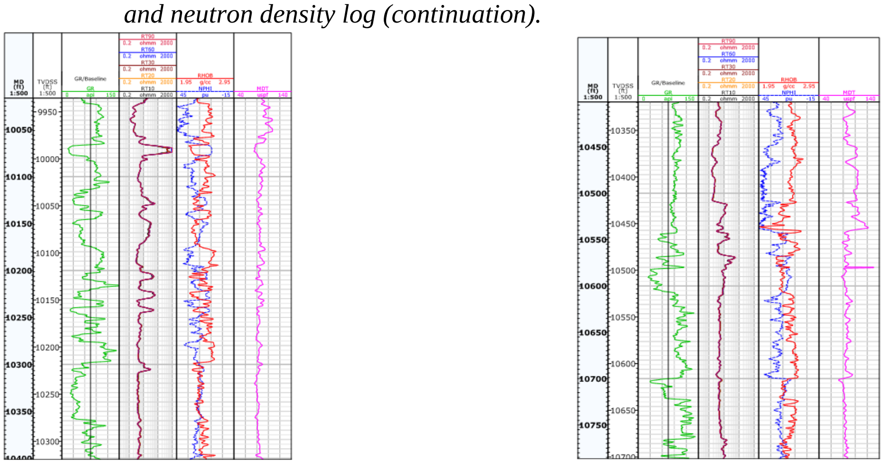

Figure 3.7: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

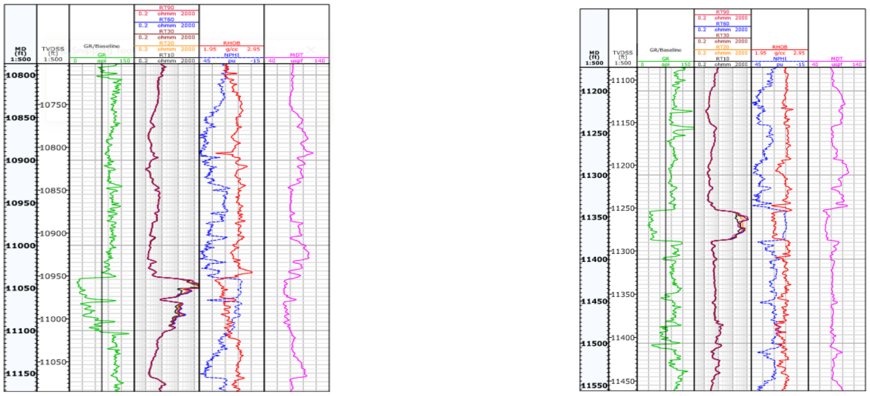

Figure 3.8: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

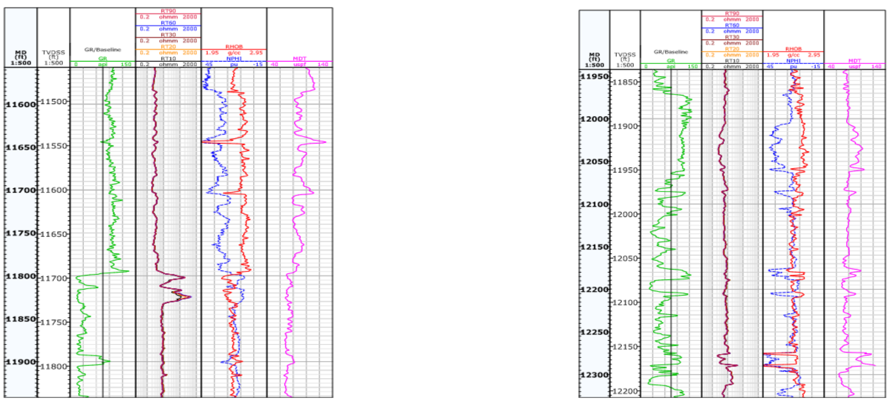

Figure 3.9: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

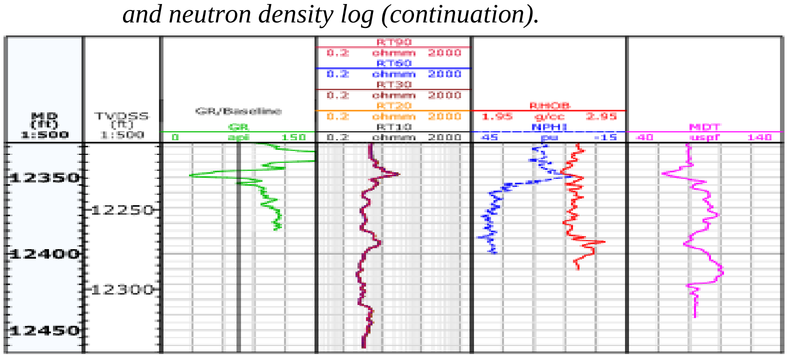

Figure 3.10: *Wire line log for Well X containing Gamma ray log, resistivity log, and neutron density log (continuation).*

Well – Section Evaluation:

Just like in **[11]**, the gamma ray (GR) log was used to identify lithology. Within the log strip shale, on the right hand side, the GR level of the thickest shale bed is read which is assumed to represent a section that is 100% shale, and a straight line through these points is the shale line. Similarly, a sand line is constructed on the left hand side of the log strip, reading the average GR level of thick sands which is equivalent to sands with the lowest GR level.

For quick look evaluation a vertical line is drawn in between the shale and the sand line as is referred to as the cut-off line. All intervals where the GR log is on left are then assumed to be sandstone. For the wireline log used as a case study in the evaluation here, shale line was read at 120 API, while the sand line was read at 30 API, thus making a cut- off line at around 75 API. The level of the GR within a reservoir interval indicates the level of its shaliness, and is calculated as the volume of shale. This volume of shale in reservoir sand has an effect on the porosity, and is thus used in evaluating the effective porosity from the average porosity of a particular reservoir.

Fluid Type Determination:

The resistivity log was used to determine the kind of fluid in a sand reservoir (determined from the Gamma Ray log), which basically can be either water or hydrocarbon. The log was calibrated on a logarithm scale between 0.2 and 2000ohm.m, thus making the different intervals to be 0.2, 2, 20, 200 and 2000ohm.m. Generally, water will show a low deep resistivity reading while hydrocarbons will give a high deep resistivity reading. Typically for the quick look evaluation of the case study wireline log. Any reservoir with resistivity reading higher than 20ohm.m was assumed to contain hydrocarbon, while those less than 20ohm.m were taken to be water. But theoretically, these lesser resistivity readings that indicated water were observed to mostly be around 2ohm.m on the case study log. Furthermore, the type of hydrocarbon present at a particular interval (i.e. whether oil or gas) can also be determined by studying the separation of the porosity logs (neutron and density logs in this case) as explained in the neutron-density combination above. Therefore, identification of potential hydrocarbon reservoir intervals is by looking for the separation of resistivity curves in combination with GR and porosity logs.

Reservoir Sand Facies Classification:

For the classification of reservoir sand facie and depositional environment, the shapes of the gamma rays could be matched or compared with standard log models. In this case the model used was the Electrofacies classification for deltaic environments from Gamma Ray log by **[12]**.

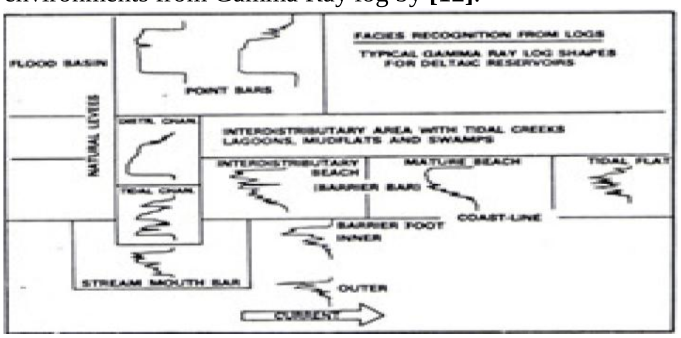

Fig. 3.11: Electro facies classification for deltaic environments from Gamma Ray logs **[12]**

4.0 RESULT AND INTERPRETATION

Table 3.1 shows the result got from the wireline log analysis of the well.

Table 3.1: Well X Petrophysical Evaluation

Zone	S/N	Depth range (ft)	Depth (TVDSS) (ft)	Fluid content	Fluid contact
A	1	10	8125-8135	Water	
B	2	63	8300-8365	Water	
C	3	20	8700-8720	Water	
D	4	5	9065-9070	Oil	Oil-Water
D_2	5	30	9070-9100	Water	
E	6	10	9135-9145	Oil	
F	7	10	9445-9455	Oil	
G	8	13	9465-9480	Oil	
H	9	70	9530-9600	Gas	
I	10	15	9615-9630	Gas	Gas-Oil
I_2	11	30	9630-9665	Oil	
J	12	30	9690-9720	Oil	
K	13	5	9725-9730	Oil	Oil-Water
K_2	14	5	9730-9735	Water	
L	15	40	9775-9815	Oil	Oil-Water
L_2	16	30	9815-9845	Water	
M	17	10	9925-9935	Oil	Oil-Water

M_2	**18**	**10**	**9935-9945**	**Water**	
N	19	15	9985-10000	Gas	
O	20	20	10035-10055	Oil	
P	21	15	10065-10080	Oil	Oil-Water
P_2	22	15	10080-10095	Water	
Q	23	10	10125-10135	Oil	
R	24	10	10140-10150	Oil	
S	25	5	10160-10165	Oil	
T	26	10	10215-10225	Oil	Oil-Water
T_2	27	60	10225-10275	Water	
U	28	10	10460-10470	Oil	
V	29	40	10485-10525	Oil	Oil
W	30	30	10950-10980	Gas	Gas-Oil
W_2	31	20	10980-11000	Oil	Oil-Water
W_3	32	15	11000-11015	Water	
X	33	40	11250-11290	Gas	
Y	34	30	11700-11730	Gas	Gas-Oil
Y_2	35	110	11730-11840	Oil	Oil-Water
Y_3	36	23	11840-11865	Water	
Z	37	60	12000-12060	Water	
2A	38	80	12075-12155	Water	

4.2 INTERPRETATION

Zone A, 8125-8135 depth interval: From the result gotten from the well analysis, depth 8125-8135 showed low Gamma ray log reading signifying a sandstone lithology, low resistivity reading signifying an interval that is not oil prone, and the density/neutron cross plot showed the neutron/density cross plot were tracking each other at very close contact range Therefore, this interval is interpreted as water bearing. May indicate the presence of an aquifer.

Zone B, 8300-8365 depth interval: from the result gotten from the well analysis of the well log at depth 8300-8365 showed low gamma ray log reading signifying a Sandstone lithology, Neutron/density cross plot were tracking each other at very close range indicating water bearing zone, low resistivity reading indicating it not hydrocarbon prone. This may indicate the presence of an aquifer.

Zone C, 8700-8720 depth interval: Well log analysis result at depth 8700-8720 showed a low gamma ray log reading indicating sandstone lithology, neutron/density cross plot were tracking each other at very close range indicating the presence of water, and low resistivity indicating it is thereby indicating the possible presence of an aquifer.

Zone D, 9065-9070 depth interval: The result of well log analysis at depth 9065-9070 showed a mid-range reading in the gamma ray log indicating a sandy-shale lithology, the neutron/density cross plot intersecting and crossing each other and the high reading of the resistivity log indicate the presence of hydrocarbon.

Zone D_2, 9070-9100 depth interval: Well log analysis at this zone showed a low gamma ray log reading indicating sandstone lithology, the neutron/density cross plot were tracking each other at a very close range indicating the presence of water, while the low resistivity indicate that it is not hydrocarbon prone.

Zone E, 9135-9145 depth interval: The well log analysis at this reservoir zone showed low gamma ray log reading indicating sandstone lithology, the neutron/density cross plot intersect each other indicating the presence of hydrocarbon, high resistivity reading at the resistivity log indicate the presence of oil.

Zone F, 9445-9455 depth interval: Well log analysis at this reservoir zone showed low gamma ray log reading indicating sandstone lithology, the neutron/density cross plot intersect indicating hydrocarbon bearing zone, while the resistivity log had a high reading indicating the presence of oil.

Zone G, 9465-9480 depth interval: Well log analysis at this zone showed a low gamma ray log reading indicating sandstone lithology, the neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, the resistivity log had a high reading indicating the presence of Oil.

Zone H, 9530-9560 depth interval: The well log analysis at this zone showed a low gamma ray log reading indicating sandstone lithology, the neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, the resistivity log reading show a very high reading indicating the presence of Gas.

Zone I, 9615-9630 depth interval: Well log analysis at this zone showed a low gamma ray log reading indicating sandstone lithology, the neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, very high resistivity was recorded at the resistivity log indicating the presence of Gas

Zone I_2, 9630-9665 depth interval: The well log analysis at this Zone showed a mid-range reading in the gamma ray log indicating sandyshale lithology, neutron/density cross plot intersect indicating hydrocarbon bearing zone, high resistivity reading at the resistivity log indicating the presence of Oil.

Zone J, 9690-9720 depth interval: The well log analysis at this Zone showed a low gamma ray log reading indicating sandstone lithology, neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, high resistivity reading was recorded at the resistivity log indicating the presence of Oil.

Zone K, 9725-9730 depth interval: The well log analysis at this zone showed a mid-range reading in the gamma ray log indicating a sandyshale lithology, neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, high resistivity value in the resistivity log indicate the presence of Oil.

Zone K_2, 9730-9735 depth interval: The well log analysis at this zone showed a mid-range reading in the gamma ray log indicating a sandy-shale lithology, neutron/density cross plot were tracking each other indicating it is a water bearing zone, the resistivity log had low value indicating it is not hydrocarbon prone.

Zone L, 9775-9815 depth interval: The well log analysis at this zone recorded mid to low gamma ray log reading indicating a lithology reading from sandy-shale to sandstone lithology, neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, high resistivity reading in the resistivity log indicate the presence of Oil.

Zone L_2, 9815-9845 depth interval: The well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, the neutron/density cross plot were tracking each other indicating it a water bearing zone, low resistivity value showed by the resistivity log indicate it is not hydrocarbon prone.

Zone M, 9925-9935 depth interval: The well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, the neutron/density cross plot intersect indicating it is a hydrocarbon bearing zone, high resistivity reading in the resistivity log indicate the presence of Oil.

Zone M_2, 9935-9945 depth interval: The well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, the neutron/density cross plot were tracking each other indicating it is a water bearing zone, low resistivity reading in the resistivity log indicating it is not hydrocarbon prone.

Zone N, 9985-10000 depth interval: The well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, the neutron/density cross plot intersect indicating a hydrocarbon bearing zone, the resistivity log recorded a very high reading indicating the presence of Gas.

Zone O, 10036-10055 depth interval: The well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, the neutron/density cross plot intersect indicating a hydrocarbon bearing zone, the high resistivity value showed by the resistivity log indicate the presences of Oil.

Zone P, 10065-10080 depth interval: Well log analysis of this zone recorded low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, the resistivity log reading is high indicating the presence of Oil.

Zone P_2, 10080-10095 depth interval: Well log analysis of this zone recorded low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot were tracking each other indicating a water bearing zone, the resistivity log reading is low it is not a hydrocarbon prone zone.

Zone Q, 10125-10130 depth interval: Well log analysis of this zone recorded low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect which indicate hydrocarbon bearing zone, high resistivity reading of the resistivity log indicate the presence of Oil.

Zone R, 10140-10150 depth interval: Well log analysis of this zone recorded low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, the resistivity log recorded a high reading indicating the presence of Oil.

Zone S, 10160-10165 depth interval: Well log analysis of this zone recorded a low gamma ray reading indicating a sandstone lithology, neutron/density cross plot interest indicating a hydrocarbon bearing zone, high resistivity reading was recorded at the resistivity log indicating the presence of Oil.

Zone T, 10215-10225 depth interval: Well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, high resistivity reading in the resistivity log indicate the presence of Oil.

Zone T_2, 10225-10275 depth interval: Well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot were tracking each other indicating a water bearing zone, low resistivity reading in the resistivity log indicate it is not hydrocarbon prone.

Zone U, 10460-10470 depth interval: Well log analysis of this zone showed a mid-range reading in the gamma ray log indicating a sandy-shale lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, high resistivity in the resistivity log indicate the presence of Oil.

Zone V, 10483-10505 depth interval: Well log analysis of this zone showed a reading of mid to low gamma ray log reading indicating a lithology reading from sandy-shale to sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, high resistivity reading of the resistivity log indicate the presence of Oil.

Zone W, 10950-10980 depth interval: Well log analysis of this zone showed a low gamma ray reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, the resistivity log show a very high resistivity value indicating the presence of Gas.

Zone W_2, 10980-11000 depth interval: Well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, the resistivity log show a high resistivity reading indicating the presence of Oil.

Zone W_3, 11000-11015 depth interval: Well log analysis of this zone showed a mid-range reading in the gamma ray log indicating a sandy-shale lithology, neutron/density cross plot are tracking each other at close range indicating a water bearing zone, the resistivity log shows a low reading indicating it is not hydrocarbon prone.

Zone X, 11250-11290 depth interval: Well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect which indicate a hydrocarbon bearing zone, a very high resistivity reading recorded at the resistivity log indicate the presence of Gas.

Zone Y, 11700-11730 depth interval: Well log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, very high resistivity value was recorded in the resistivity log indicating the presence of Gas.

Zone Y_2, 11730-11840 depth interval: The log analysis of this zone showed a low gamma ray log reading indicating a sandstone lithology, neutron/density cross plot intersect indicating a hydrocarbon bearing zone, high resistivity reading of the resistivity log indicate the presence of Oil.

Zone Y_3, 11840-11865 depth interval: The well log analysis of this zone showed low gamma ray reading indicating a sandstone lithology, neutron/density cross plot are tracking each other thereby indicating a water bearing zone, low resistivity was recorded at the resistivity log indicating the zone is not hydrocarbon prone.

Zone Z, 12000-12060 depth interval: The well log analysis of this zone showed a low gamma ray reading indicating a sandstone lithology, neutron/density cross plot are tracking each other indicating a water bearing zone, low resistivity reading indicate that the zone is not hydrocarbon prone.

Zone 2A, 12075-12155 depth interval: The well log analysis of this zone showed a low gamma ray reading indicating a sandstone lithology, neutron/density cross plot are tracking each other indicating a water bearing zone, low resistivity reading of the resistivity log showed it is not hydrocarbon prone zone

5.0 CONCLUSION

Well log data (Sonic, Neutron/Density cross-plot, Gamma-ray and Resistivity logs) of Well Z located in the Northern Depo-belt of the Niger Delta Basin were used in the determination of some petrophysical characteristics of the reservoir zones. Gamma Ray log was used to determine the lithology of the well, the Neutron/Density crossplot was used to determine gas and liquid in the sandstone, while Resistivity log combined with Neutron/density crossplot was used to differentiate majorly water from oil and also oil from gas. With the result from the interpretation, the Petrophysical Evaluation of Well Z in Field X had 25 hydrocarbon zones (6 gas zone and 19 oil zone) from the depth of 9,065ft to 11,840ft and shows that the oil well is highly productive well.

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