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HYDROCARBON FORMATION EVALUATION USING WELL LOG DATA OF WELL TMG-02, OPOLO FIELD, NIGER DELTA

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ABSTRACT

Well TMG-02 with the depth interval of 5058.77 to 9389.43ft of Opolo field located in the Niger delta was assessed for hydrocarbon using suite of geophysical well logs. Suite includes gamma ray (GR), formation density (RHOB), neutron porosity (NPHI), and resistivity logs. The analysis was carried out to estimate the field's hydrocarbon prospect by identifying hydrocarbon bearing reservoirs and their properties. The quantitative and qualitative results, identified thicker units of sand than shale lithology, three reservoirs A, B, C within the depth ranges from 5058.77ft to 9389.43ft, capable of accumulating hydrocarbon based on the petrophysical parameters calculated were delineated. The effective porosity for each of the reservoir are: 27%, 24% and 19% respectively. It was observed that reservoir A, B had excellent permeability while reservoir C was low as a result of thicker shale sequence within the reservoir. The result obtained shows presence of hydrocarbon bearing gas water contact in Reservoir A at depth of 5119.70ft, gas oil contact and oil water contact at depths 7310.00ft and 7438.69ft in Reservoir B and Gas water contact at depth 9032.00ft at Reservoir C.

Keywords: Hydrocarbon, Reservoir, Quantitative and Qualitative

INTRODUCTION

Geophysical borehole logging or wireline logging gives valuable information of strata as a result of variation in some physical properties of the well through which the bore hole is drilled. Rock properties and relationship between rocks is used to identify, quantify and evaluate hydrocarbon reservoir, source rock and seals.

Well log data are used for correlating zones of interest and also defining physical rock characteristics such as lithology, porosity, pore geometry, permeability and fluid typing. Zone parameters such as depth, thickness, and reserves can also be estimated using well logs. Well logs can contain essential information on the sampled formation by various petrophysical measurements, making them one of the most useful methods for a formation appraisal (Williams, *et al*, 2011). All these are integrated in interpreting and discussing properties related to reservoir characterization.

The academia and oil and gas industries have at various times and now used geophysical logs to conduct petrophysical analyses of various oil fields in the Niger Delta (Stacher, 1995; Aigbedion and Iyayi, 2007; Omoboriowo, 2012; Ameloko and Owoseni, 2015; Emujakporue, 2016). Petrophysical analysis technology will continue to advance because of its relevance in oil and gas industry. Its importance cannot be overstated, and there is always the need to re-characterize hydrocarbon potentials in our oil fields as a result of depleted oil reserves in our oil field as it has a great effect on Nigeria economy.

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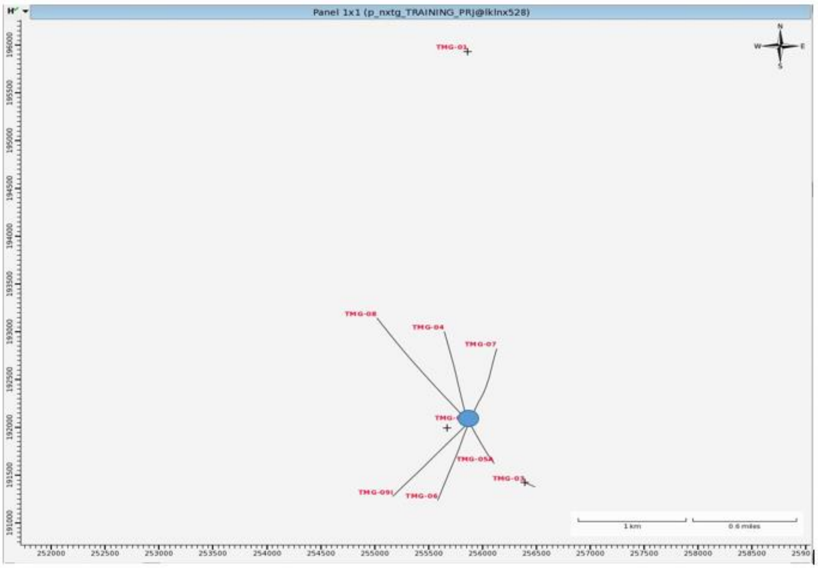


Figure 1: The Base map of the study area showing location of well TMG-02 (blue circle).

Several authors have worked on petrophysical analysis of different wells and fields in the Niger Delta with the aim of evaluating the hydrocarbon potential and reserves in the area. Few works are reviewed here in: Adaeze and Chukwuma, (2012), carried out a research on the Petrophysical evaluation of uzek well using well log and core data, Offshore Depobelt, Niger Delta. The analysis identified four (4) hydrocarbon-bearing reservoirs (I, P, Q, and R). Average permeability values of the reservoirs are above 1000md, while porosity values ranged between 20 -30%, reflecting well sorted coarse grained sandstone reservoirs with minimal cementation, indicating very excellent reservoir quality. And the reservoirs in Uzek were permeable, with properties of the well enough to permit hydrocarbon production. Amigun, *et al*., (2012), carried out a research on Petrophysical analysis of well logs for reservoir evaluation: A case study of ‘Laja’ Oil Field, Niger Delta. The results on the whole suggested that the reservoir sand units of ‘Laja’ Field contain significant accumulations of hydrocarbon. Oyovwikowhe - Maju, et al., (2019), studied the log analysis results of a suite of conventional wireline logs from two wells in ‘Ictorian’ Field located in the Niger delta with the aim of evaluating hydrocarbon prospect of the field. Their results show that the analyzed reservoirs have good permeability. The calculated values indicate that porosity, permeability values from the hydrocarbon bearing reservoirs were good enough for commercial accumulation in the Niger Delta. Aigbogun and Mujakperuo, (2020), worked on Well log data from Three wells (01, 03 and 04) for the Formation evaluation of the onshore X-field, Niger Delta. The results demonstrated that formation evaluation has a vital role to play in reservoir characterization. Lurogho, and Abe, (2020), studied the petrophysical properties of the reservoirs in Explorer well and delineated twelve hydrocarbon-bearing reservoirs from three wells in commercial quantity.

Well TMG-02 (figure 1) is located in Niger Delta, a large acute delta that stretches between longitudes 30°° and 90°E and latitudes 40° and 60°' N, covering an area of about 7500 km^2 (Doust and Omatsola, 1989; Amigun, *et al*, (2012); Oyovwikowhe - Maju, and Njoku, (2019). The present study aimed at using a set of well logs to assess the hydrocarbon potential of Opolo well in the Niger Delta by determining the reservoir depth and thickness, evaluating the different hydrocarbon formation and determining petrophysical properties such as porosity, hydrocarbon saturation, thickness and permeability of the wells

Subsurface stratigraphy of Niger Delta

Short and Stauble, (1967); Weber and Daukoru, (1975); Doust and Omatsola, 1989), have identified three subsurface lithostratigraphic units in the Niger delta based on their lithology and depositional environment namely: the Benin Formation, Agbada Formation and Akata Formation.

The Benin Formation is the youngest**,** continental and upper coastal plain sands deposit, which may be of 2000m thick (Aigbogun and Mujakperuo, 2020), ranging from Paleocene to Recent in age (Stacher, (1995); Lurogho, and Abe, (2020). Agbada Formation, , can be found throughout the Niger Delta clastic wedge and can be up to 13,000 feet thick. It's known as the Ogwashi-Asaba Formation where it appears in southern Nigeria (between Ogwashi and Asaba). The lithologies are composed of alternating sands, silts, and shales grouped in ten to hundred-foot successions with progressive grain size and bed thickness variations. In general, the strata is thought to have formed in fluvial-deltaic environments. Akata Formation the basal unit consist of thick shale series (potential source rock), turbidite sand and tiny amounts of clay and silt, at the delta's base starting in the Paleocene and continuing into the Recent, when terrestrial organic matter and clays were carried to deep water locations defined by low energy conditions and oxygen shortage (Stacher,1995). The formation, which runs the length of the delta, is often over pressured, the thickness is estimated to about 6,000m.

MATERIALS AND METHODOLOGY

Well log Data

The available open-hole wire line log data of Well TMG-02 with intervals from 5058.77 to 9389.43ft were used in this study. These logs include gamma ray (GR), formation density (RHOB), neutron porosity (NPHI), and resistivity logs. The well logs are digitized by converting field analog prints into digital data which stored as a data base for easy access and calculation.

Workflow

The hydrocarbon prospect in TMG-2 wells were assessed using Techlog software and a suite of well logs which include gamma ray, deep resistivity, bulk resistivity and neutron porosity logs.

Petrophysical Analysis

The well logs data were analyzed and used as a supplementary method for getting some results on lithology, porosity, pore geometry, permeability, fluid type (figure 2) and for correlating zones of interest. Zone parameters such as depth, thickness, and reserves were also be estimated.

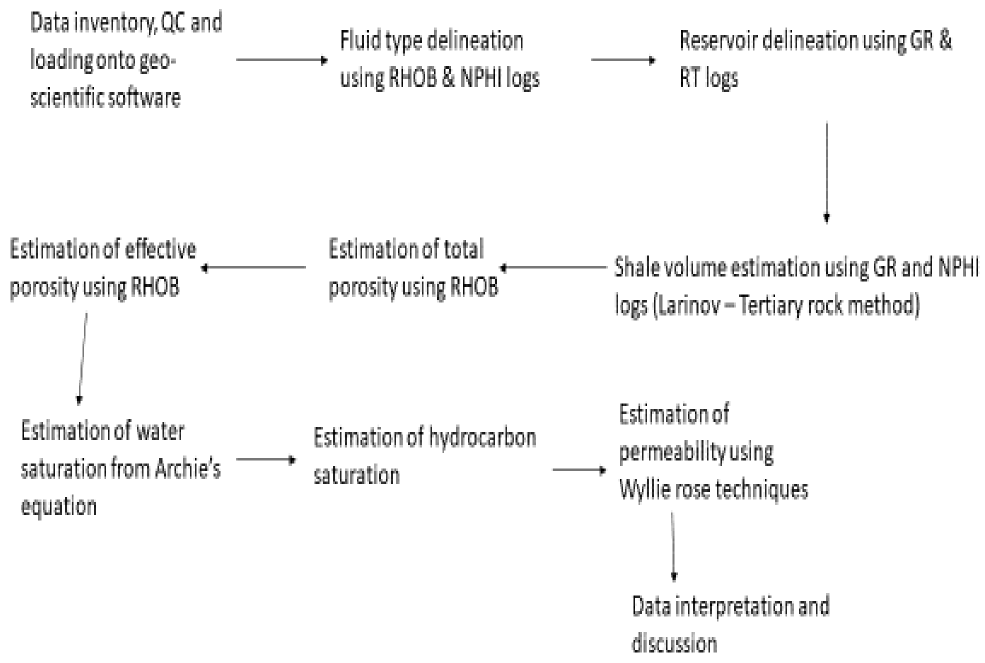


Figure 2: Workflow for analysis of well TMG-2

All data sets were integrated for interpretation and discussions in relation to reservoir characterization in the present study.

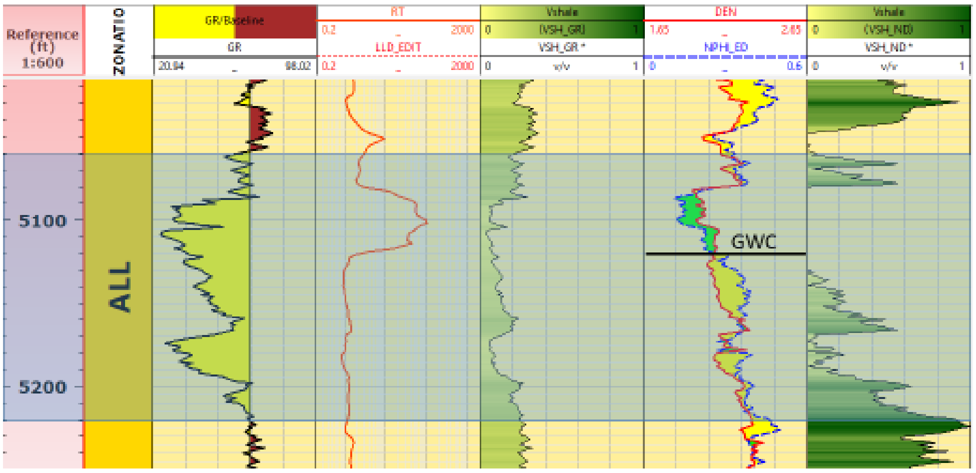
RESULTS AND DISCUSSIONS

From analysis and study carried out Sand volume, high resistivity porosity, and fluid content measurements were used to quantify the reservoir zones. Three reservoirs were discovered and classified A to C (Table 1) based on the qualitative and quantitative interpretations. Three (3) hydrocarbon-bearing reservoirs were recognized within depths 5058.77 to 5229.78 ft, 7284.97 to 7648.43ft, and 8670.43 to9383.43ft of well TMG-02, after carefully applying water saturation to define net pay. These reservoirs were labeled reservoir A, B, and C respectively. The reservoirs' hydrocarbon types were determined using evidence from neutron density log signatures at various depths (figure 3, 4, 5,). The neutron and density logs were separated, with the neutron log diverting to the right and the density log deviating to the left, indicating gas. A balloon form also suggested gas, but the two curves tracking together indicated oil in the reservoirs (Table 2).

It was observed that nearly constant caliper curve within reservoir intervals denotes healthy borehole conditions and permeability

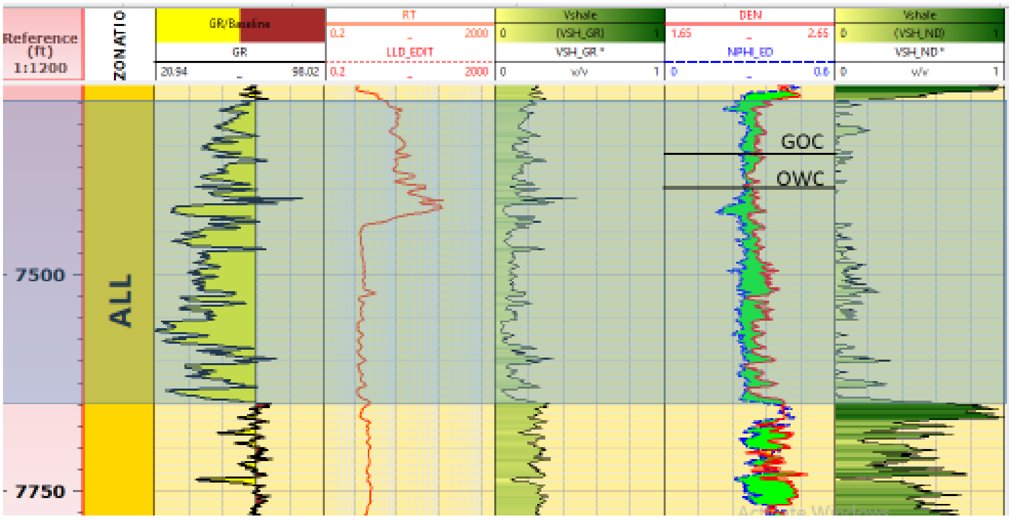
Table 1: Delineated reservoirs tops and bottoms from volume of shale computations from GR and NPHI, using the Larinov Tertiary rock method.

Reservoirs	Tops (ft)	Bottoms (ft)
A	5058.77	5229.78
B	7284.97	7648.43
C	8670.43	9383.43



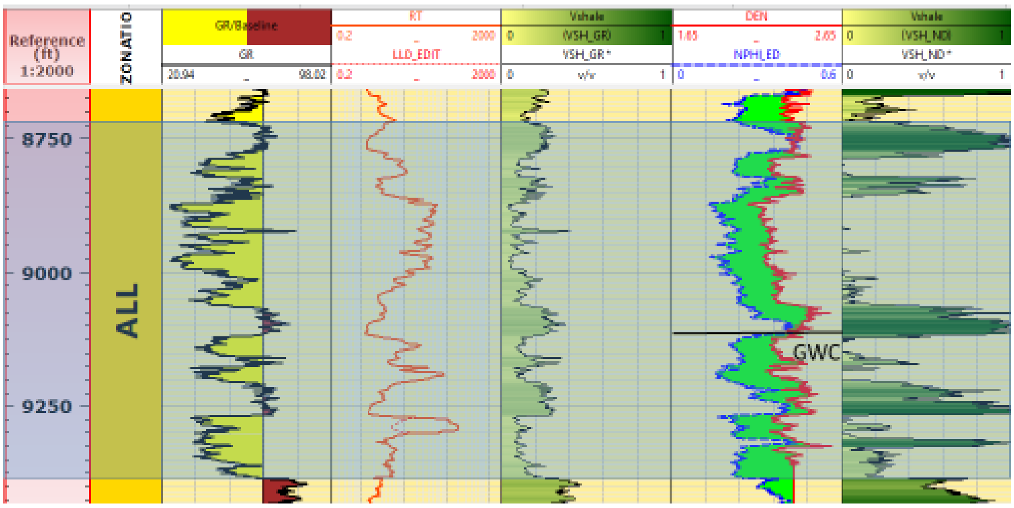
Gwc – Gas water contact

Figure 3: Volume of shale estimation, and fluid type definition of reservoir A



GOC- Gas oil contact; OWC- Oil water contact

Figure 4: Volume of shale estimation and fluid type definition of reservoir B



GWC – Gas water contact

Figure 5: Volume of shale estimation and fluid type definition of reservoir C

The average Vsh calculated in the reservoirs A, B and C (figure 3, 4 &5) is 0.15, 0.14 and 0.18 respectively. This depicts high quantity of shales in the reservoirs of TMG-02 well (Table 2).

High values of deep resistivity logs, which probably indicates the presence of non-conducive hydrocarbons (gas) and further confirmed by crossover shape between the neutron porosity and bulk (balloon effect) were observed.

Table 2: Quantitative Estimation of Reservoir Petrophysical Parameters

Reservoirs		VSH_GR	PHIT_D	K (mD)	SW_AR	SH	Depth of contact	Fluid Contact
A	0.15	0.31	0.27	431.43	0.82	0.18	5119.70	GWC
B	0.14	0.26	0.24	209.81	0.79	0.21	7310.00 7438.69	GOC OWC
C	0.18	0.19	0.14	40.61	0.79	0.23	9032.00	GWC

Definition of abbreviations: VSH_G: Estimation of volume of shale from gamma ray log, PHIE_D: Effective porosity from density, PHIT_D: Total porosity from density,SW_AR: Water saturation from Archie's equation, SH : Hydrocarbon saturation (1-SW_AR), K(mD): Permeability from Wyllie Rose Method, using Timur coefficient and measured in millidarcy, GWC: Gas water contact, GOC : Gas oil contact, OWC: Oil water contact

WATER SATURATION

The calculated water saturation is shown in blue while the red color in the same track represents the hydrocarbon saturation (Figure 6, 7, 8 &9)

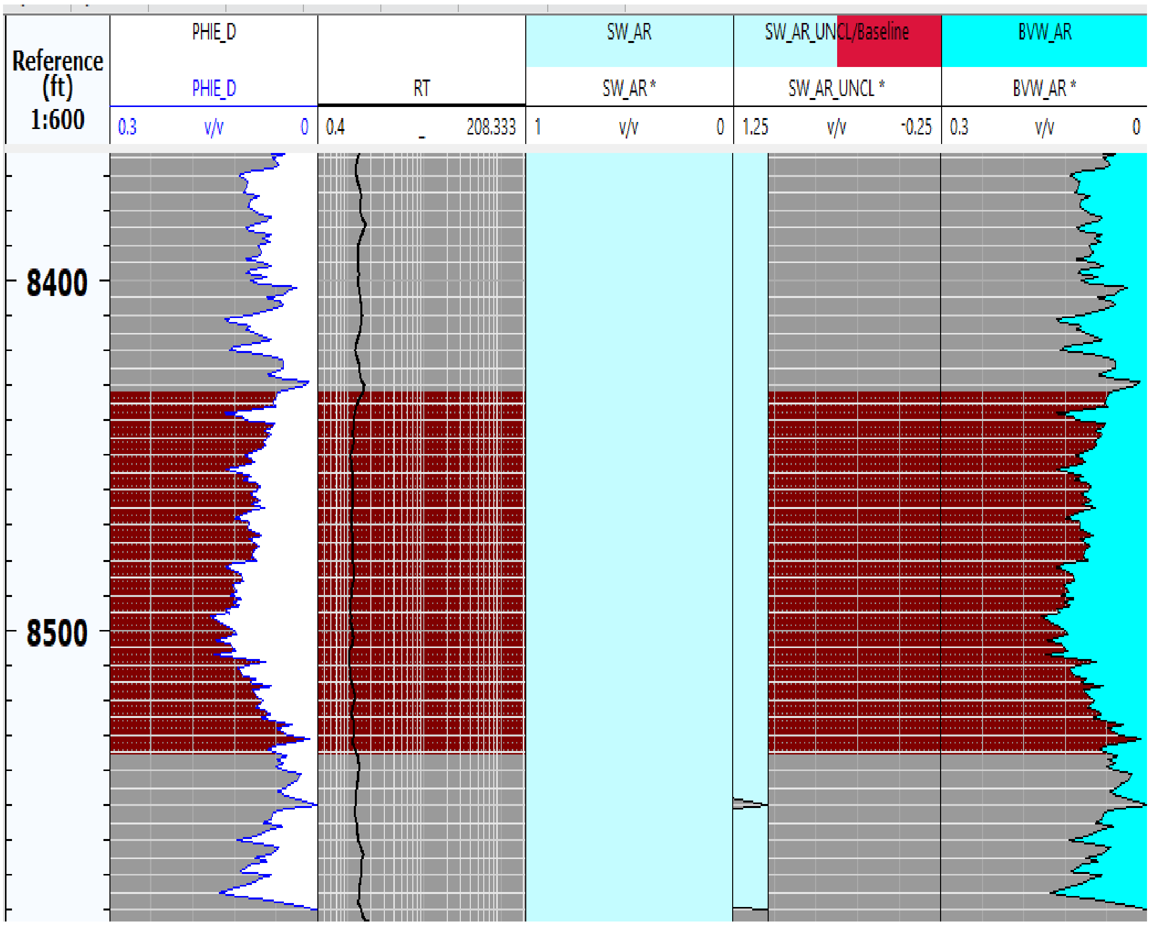


Figure 6: Clean, water bearing interval utilized in the computation of Archie water saturation

The average calculated total porosity was relatively high, reaching 0.31, 0.26, 0.19 respectively in the three reservoirs while the corresponding effective porosities values shows that reservoirs are in the class of fair, good and very good. This classification is in accordance to Baker (1992).

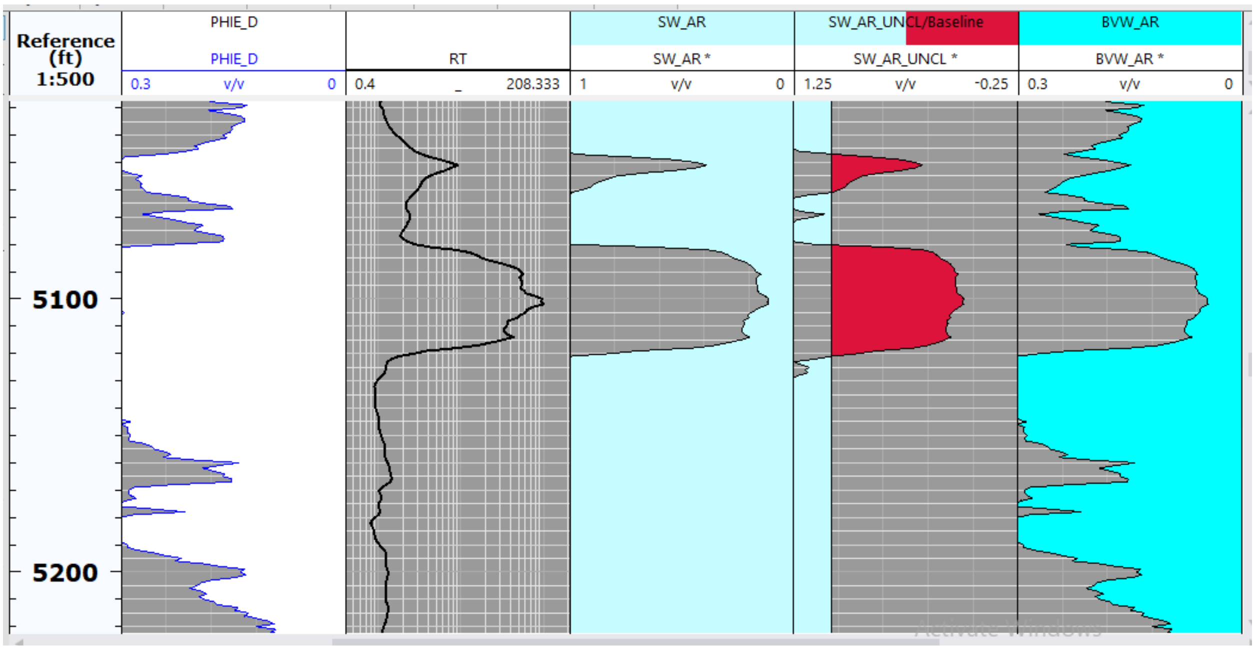


Figure 7: Estimation of water saturation model in reservoir A using Archie equation

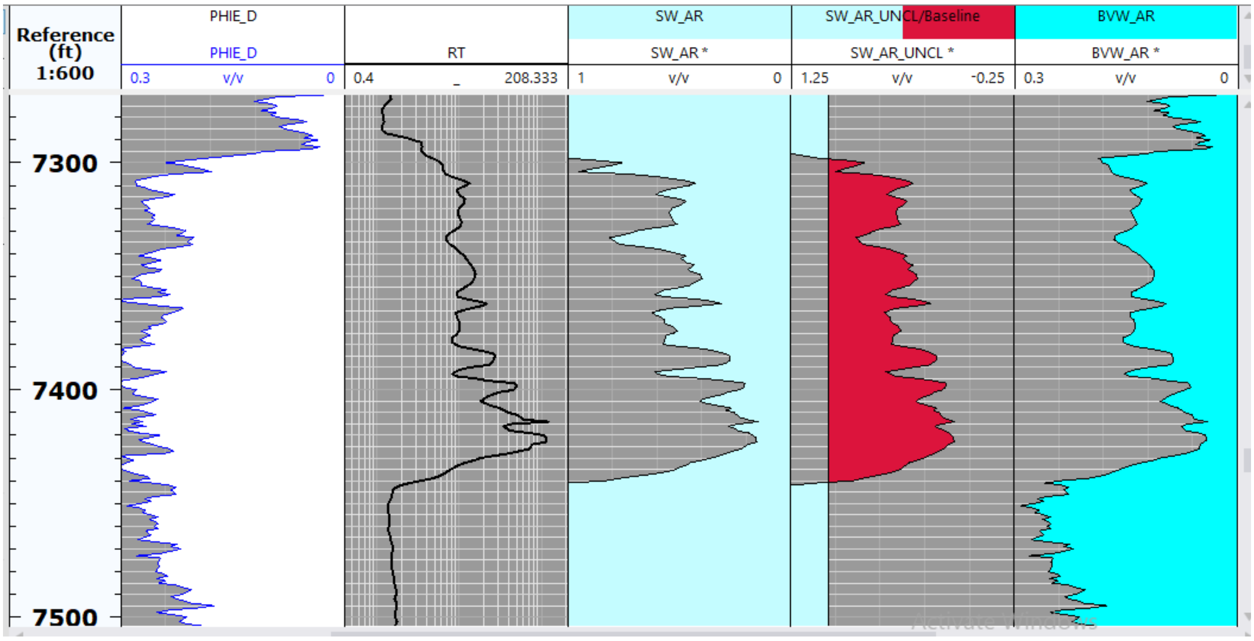


Figure 8: Estimation of water saturation model in reservoir B using Archie equation

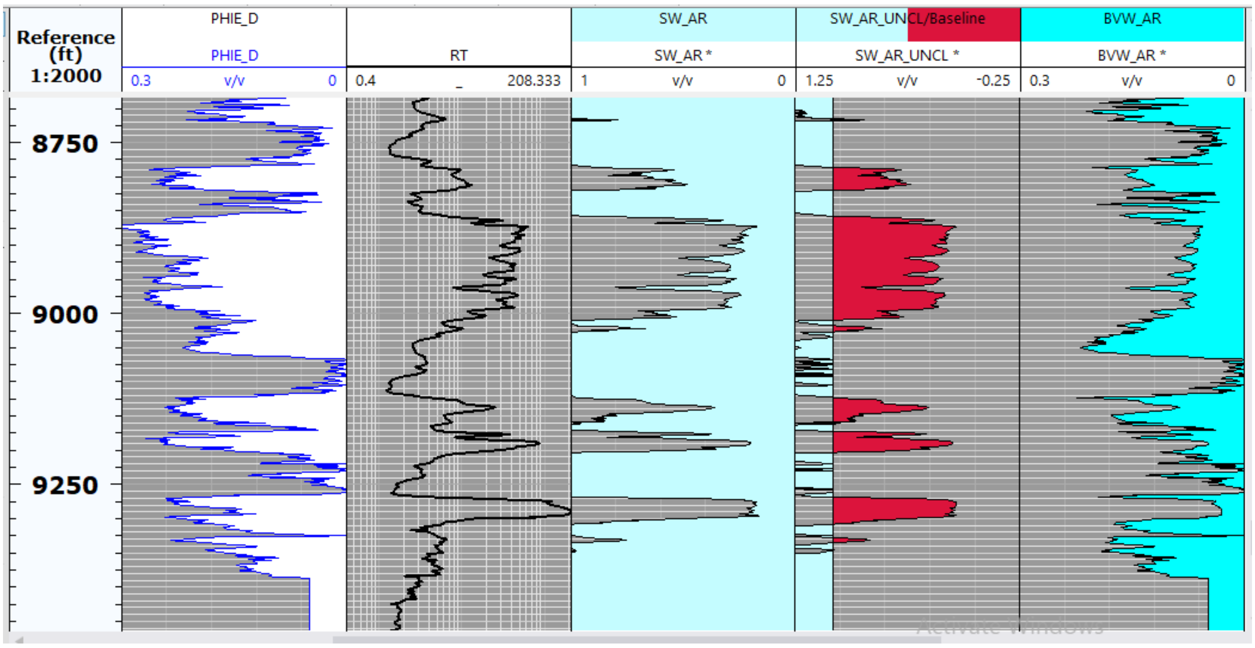


Figure 9: Estimation of water saturation model in reservoir C using Archie equation

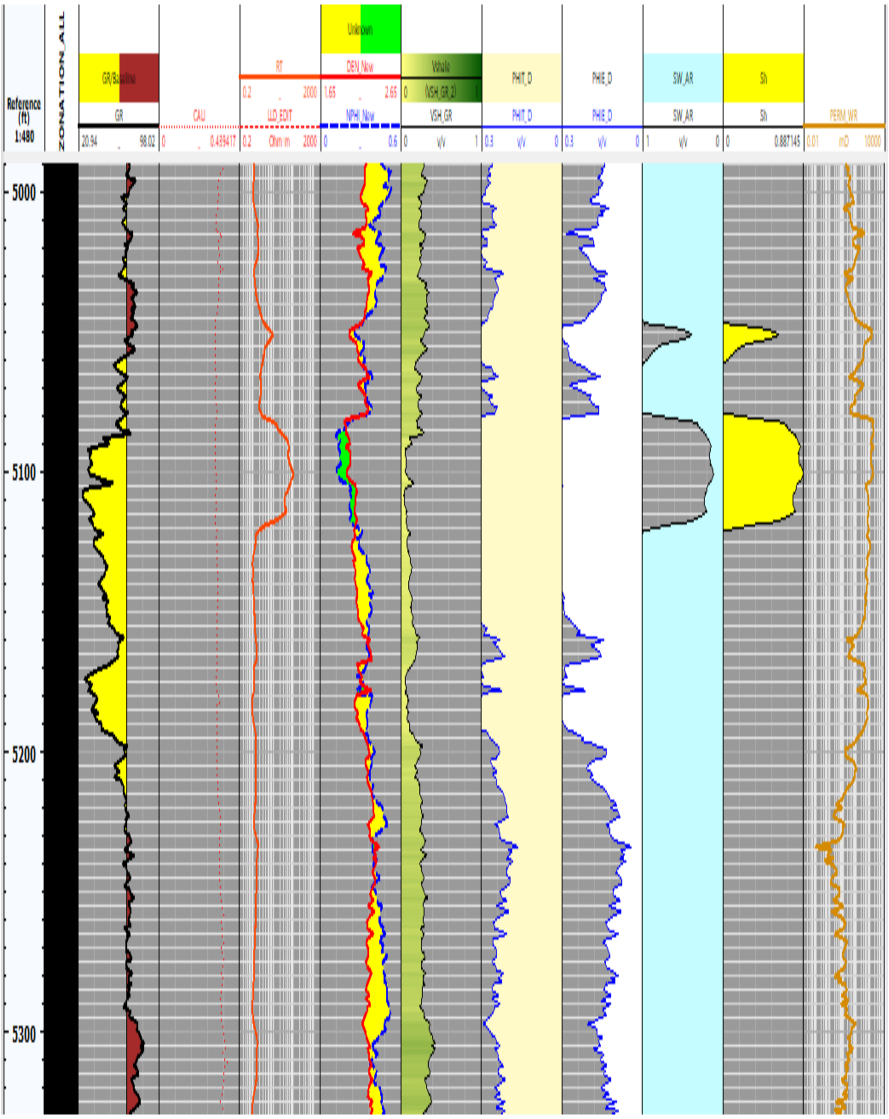


Figure 10: Qualitative Estimation of Reservoir Petrophysical Parameters in Reservoir A

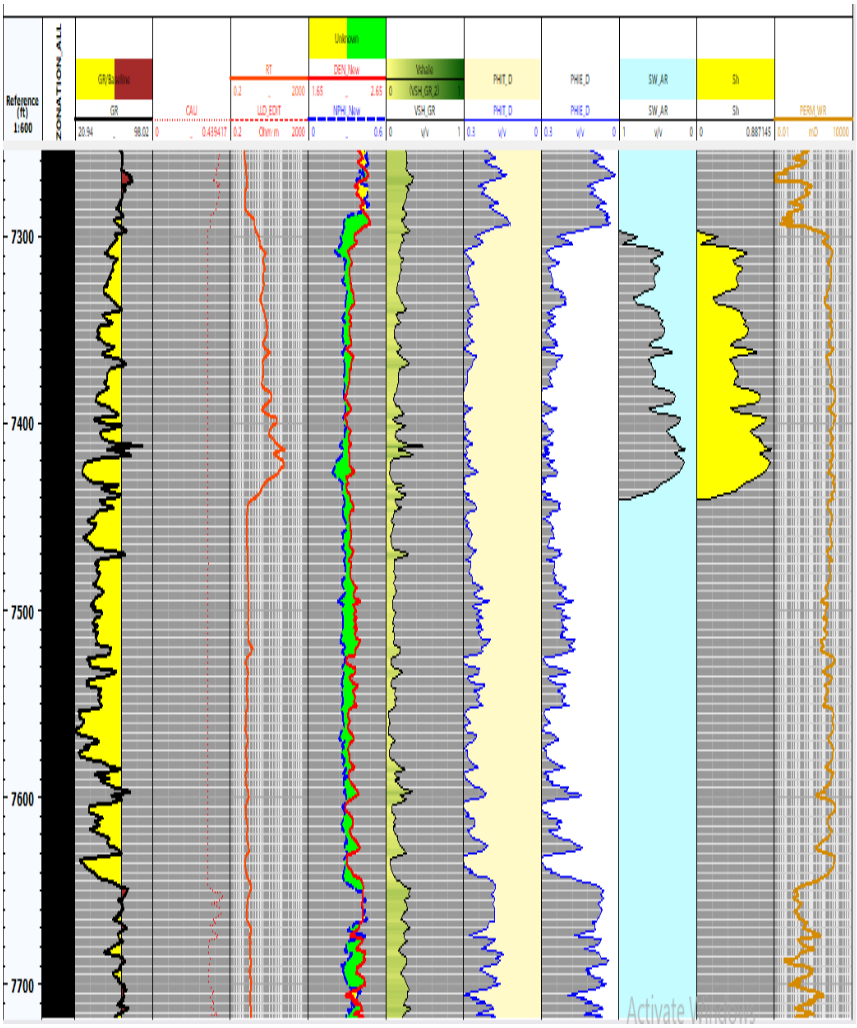


Figure 11: Qualitative Estimation of Reservoir Petrophysical Parameters in Reservoir B

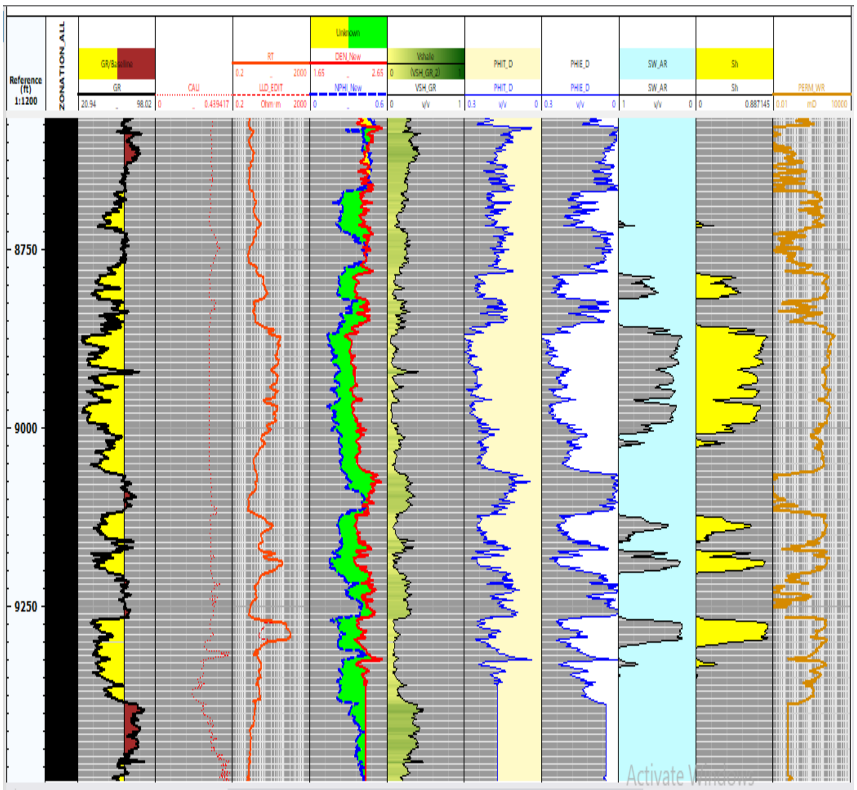


Figure 12: Qualitative Estimation of Reservoir Petrophysical Parameters in Reservoir C

The calculated water saturation is shown in blue (fig 7) in the various qualitative petrophysical interpretation while fig 8 on same plots represents the hydrocarbon saturation. Table 2 also shows the equivalent water and hydrocarbon saturation models for the three delineated reservoirs. The reservoirs contained more of water based on average parameters (Table 2).

The Wyllie-Rose relationship was used to compute for permeability in the identified reservoirs of TMG-02 well and the Timur method was used in calculating the Wyllie Rose coefficient accordingly. This parameter refers to a rock's ability to transmit fluid within the reservoirs. It is related to porosity but not always dependent on it. The size of the connecting pore mouths between the pores controls it (Asquith and Krygowski, (2004); Godwin, *et al,* (2012); Ehinola and Ayodeji (2019). According to Rider, (1986) it can be observed that reservoirs A and B have excellent permeability while reservoir C is low and this is as a result of the thick shale sequences within the reservoirs. Further quantitative analysis within reservoir C still gave excellent result of 126.64mD between the depth interval of 8784.8FT and 9066.6FT.

CONCLUSION

Porosity, permeability, volume of shales, density, gamma ray and resistivity logs were employed in the analysis of three (3) reservoirs in well TMG-02. Quantitative and qualitative results of the reservoirs delineated from well TMG-02 contained significant accumulations capable of producing hydrocarbon. The lithologies characterizing these wells were sand, shale and sand with shale intercalations.

The effective porosity of the reservoirs were 27 percent, 24 percent, and 19 percent, respectively. Reservoir A, B had great permeability, because of the deep shale sequence within the reservoir, Reservoir C had low permeability. The three reservoirs have a depth range of 5058.77 to 9389.43 ft. The results suggest a hydrocarbon bearing gas water contact in Reservoir A at a depth of 5119.70ft, gas-oil contact and oil-water contact at depths of 7310.00 feet and 7438.69 ft in Reservoir B, and gas-water contact at depths of 9032.00 ft in Reservoir C.

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