International Journal of Scientific Research and Engineering Development-– Volume3 Issue 1, Jan-Feb 2020

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Analytical Approach to Reservoir Property Evaluation of a Field in Niger Delta

Ekone N.O*, Dr. Ehirim C. N.**,Dr. Nwosu, J.I.**

*(World Bank Africa Centre of Excellence, University Of Port Harcourt, Port Harcourt).

** (Department of Physics/Geology University of Port Harcourt, Nigeria.)

Abstract:

In this study, the petrophysical properties were evaluated with a view to understand their effects on the reservoirs and hydrocarbon estimation as well as oil explorations in general.In order to meet this needs, this study was aim at determining some petrophysical parameters for hydrocarbon estimation. A suite of well data comprising of gamma ray log, resistivity log and density logs for three wells of the Field were analyzed to estimate properties such as volume of shale, porosity, permeability, water saturation and net thickness of the reservoirs.Cross plot and petrofacies generated were use in revealing the reservoir quality by classification.The resultsindicated average porosity ranging from 27.47% to 38.46%, permeability values range from 431.99mD to 3179.91mD and water saturation range from 11.46% to 45.51%; inferring high hydrocarbon production for the three reservoirs (L100, M100 and M200) identified from well A, B and C.Crossplot of volume shale and porosity differentiated the shales from the reservoirs and classified into low, mid and high quality sands. There exist a strong linear relationships between permeability and porosity in all the reservoirs identified indicating that they are permeable and have pores that are strongly interconnected.This study reveals that analytical approach to reservoir property evaluation has a significant role to play in reservoirs characterization.

Keywords: Well Logs, Petrophysical properties, Evaluation, Reservoir Quality

I. INTRODUCTION

Increasing global demand for energy has essentially pushed forthe need to search for new oil wells for hydrocarbon estimation as well as efficient reservoir management. Effective description of reservoirs is the key to efficient reservoir management. The broad usefulness of well logging analysis is to transform the raw log data into estimated quantities of oil, gas and water in a formation [1]. The essential goals of petrophysical evaluation reservoir characterization is to definereservoir properties like porosity, lithology, saturation of water, permeability, estimate depth and thickness of zones, and in addition correlate zones suitable for hydrocarbon accumulation, identify productive zones, distinguish between gas, oil and water in a reservoir and to estimatehydrocarbon reserves[2].A reservoir is a subsurface rock that is characterizeby effective porosity and permeability which exploitable amount ofhydrocarbon quantity. Reservoir characterization is undertaken to determine its capability to both store and transmit fluid. Evaluation of lithology, fluid saturation, and porosity are fundamental. Additionally in the assessment of clasticreservoirs in the Niger Delta, characterization of shaliness which is a measure of the cleanliness of the reservoir is a parameter that determines petrophysicalproperties like porosity and hydrocarbon saturation [3].Reservoir quality determination has a useful role to play in reservoir evaluation [4]. Reservoir quality is strongly influenced by the grain sizes in the reservoir and are appreciated when classified as high, medium and low as done in this study.The reservoir quality increased with increasing porosity and permeability. These estimated properties are crucial for both economic evaluations of the reservoir and production planning of an optimum recovery method.This study aim at utilizing a suite of wire lines logs for the evaluation of the hydrocarbon potential of an oil field in onshore, Eastern Niger Delta. Other objectives include Identification of lithology of well A, B, Cand estimation of petrophysical properties such as porosity, hydrocarbon saturation, thickness and permeability of the delineated reservoir.

II. STUDY AREA AND GEOLOGY

The study area is located in the Eastern Part of Niger Delta, Nigeria (Figure1)**.**The Niger Delta is situated within West African continental margin at the apex of the Gulf of Guinea and lies between latitudes 4^{o}N and 7^{o}N and longitudes 3^{o}E and 9^{o}E. The Niger Delta is formedthrough a triple junction during continental break-up in the Cretaceous([5], [6])**.** The area is geologically a sedimentary basin, and consists of three fundamental Formation: Akata,Agbada and the Benin Formations. The Akata is made up of thick shale sequences and it serves as the potential source rock.The Agbada Formation is a major hydrocarbon reservoir and producer in the Niger Delta Basin[7]. This Formation consists of sandstone and shale intercalation. The structural setting of the field is majorly growth faults and rollover anticlines. Due to its complex internal architecture and structural complexity as a result of growth faults development, there is a possibility of having some bypassed reservoirs or reserves compartment.

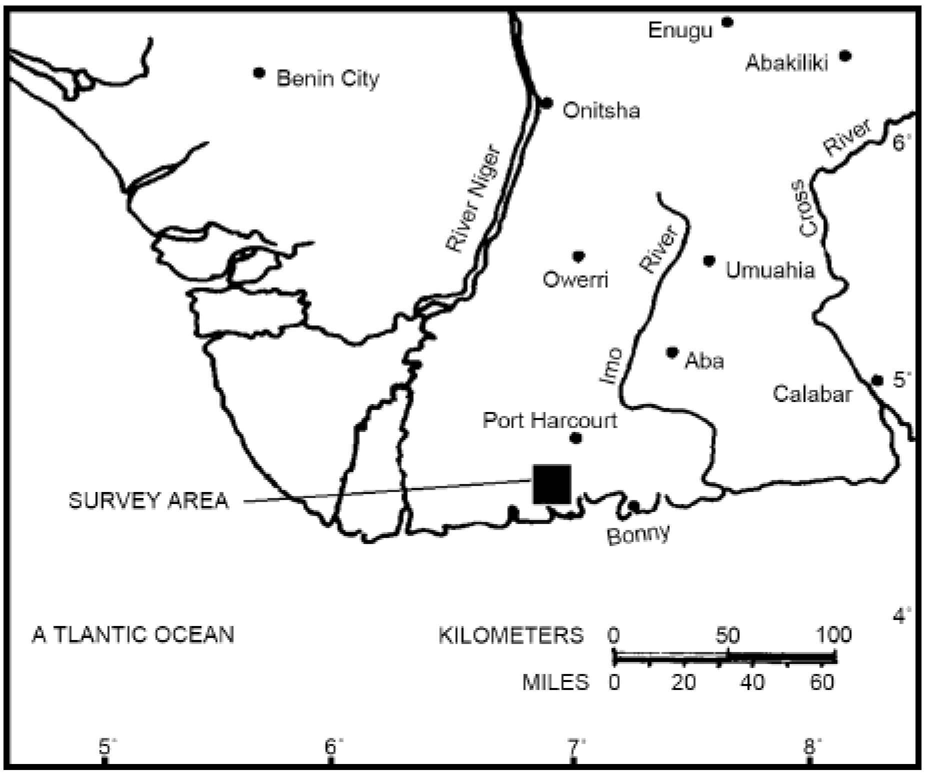

Figure 1: The Location of the study area in the Niger Delta region.

III. MATERIALS AND METHODS

The materials used for this study include the following: a base map showing three well (A,B and C) locationof the study area (Figure 2),a composite well Logs (ASCII): These logs include Gamma ray (GR), resistivity (LLD) and density (RHOB). Integrated approach involving petrophysical data analytical methods were employed to meet the objectives of this study. Interpretation of the well logs data was done interactively in Petrel software from where three (3) reservoir (L100, M100 and M200) units were mapped and evaluated for hydrocarbon potentiality in the study area. The reservoir zones were qualitatively identified by visual inspection of the log signatures by way of eliminating the shale beds and compact beds. Beds with low gamma ray, high resistivity and high density readings indicated sandstones. Gamma rays log which measure the natural radioactivity of the Formations was use for qualitative evaluation of shale content zones delineated from predominantly sand zone hence for identifyinglithologies. A combination of Gamma ray (GR) log and the resistivity log were used to delineate the hydrocarbon bearing zones and correlating sandstone zones which are free of shale in the wells (Figure 3).

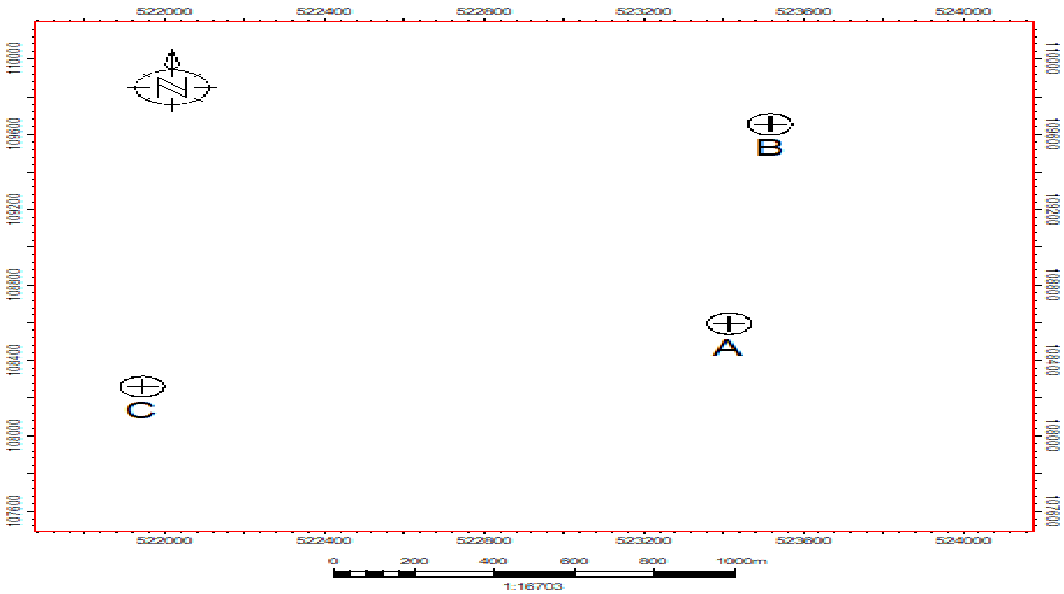

Figure 2: A Base Map Showing Well Location

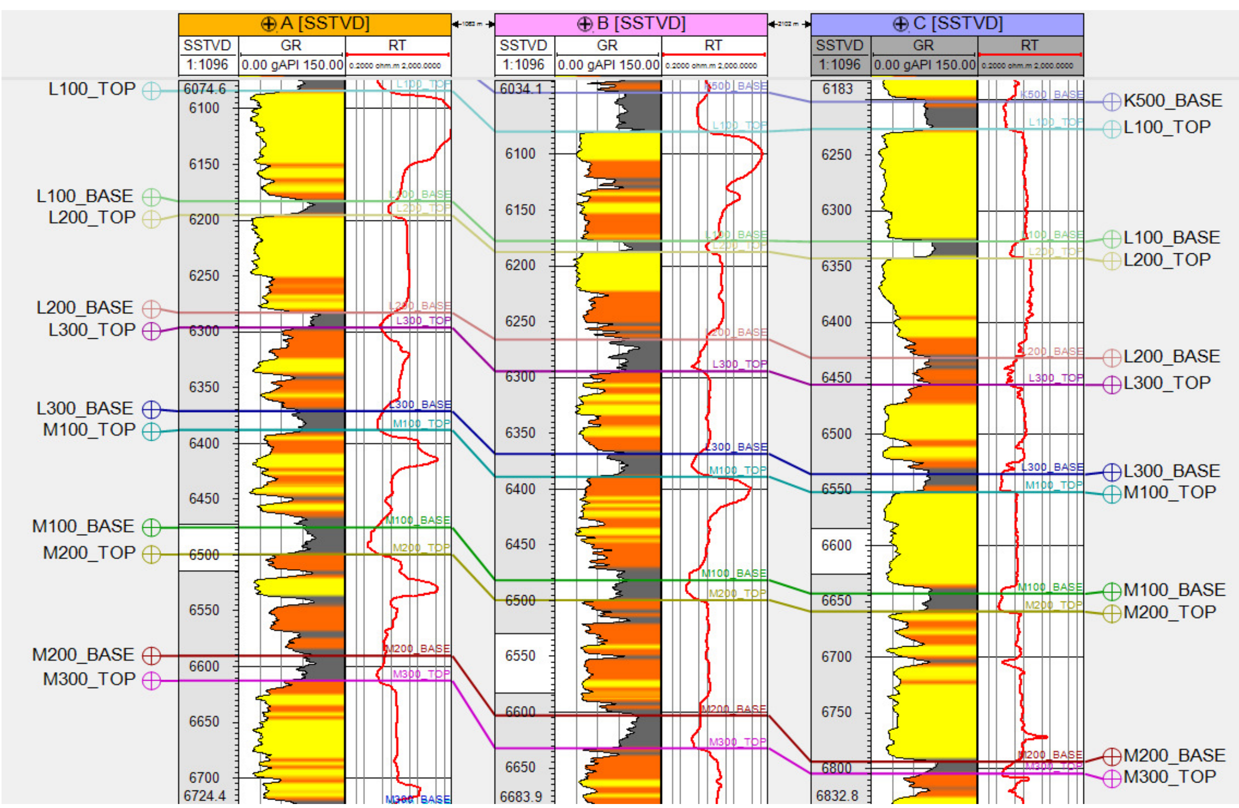

Figure 3: Well Correlation A, B and C (L100 To M200)

The procedure for estimations petrophysical parameter involve quantitatively estimation using some empirical equations for shale volume calculation, porosity, permeability and fluid saturation determinations in the reservoir zones.

SHALE VOLUME

According to author [2], the gamma ray (GR) can be used to compute volume of shale in porous reservoirs. Shale is generally more radioactive than sand. The gamma ray index IGR is first calculated from the gamma ray log as presented in equation 1**:**

$I_{GR} =(GR_{Log} – GR_{min})/(GR_{Max} - GR_{Min})$ ……………………… 1

Where:

IGR is the gamma ray index

*GRlog*is the Gamma Ray Log reading of the formation

*GRmin*is the Gamma Ray for a complete sand (100% clean sand) matrix zone

*GRmax*is the Gamma Ray for a complete shale zone (100% shale)

The volume of shale (Vsh), in these sand bodies was then determined using the gamma ray index obtained above by using Dressler Atlas (1982) equation for calculating volume of shale for unconsolidated sandstone (Equation 2)

$V_{sh} = 0.083[2^{(3.7 \times IGR)} – 1]$………….........................2

Where,

I_{GR} =gamma ray index. V_{sh} = volume of shale. The volume of shale is expressed as a decimal fraction or percentage is called Vshale

POROSITY

Porosity is the proportion of the volume of pore spaces in a rock to the total volume of the rock. The porosity of the reservoir was estimated by using the density log derived porosity (ϕ_D) computationaccording to [8] equation (Equation 3):

$\phi_D = (\rho ma - \rho b)/(\rho ma - \rho f)$………………………………3

Where,

ϕ_D= Total Porosity estimated from density log

ρma= Matrix (or grain) density (*ρma* = 2.65g/cc)

ρb= Bulk density (as obtained from the log and hence incorporates porosity and grain density)

ρf= Density of the fluid. (*ρf* =0.74g/cc, 0.9g/cc and 1.1 g/cc for gas , oil, water respectively)

The Effective Porosity is characterized as the interconnected pore spaces. It accept the non-appearance of shale from the reservoir. It tends to be determined utilizing the accompanying relationship (Equation 4):

$\Phi_e = (1 – V_{Sh}) * \phi_D$ …………………………………….4

Where:

Φe= Effective porosity

PERMEABILITY

According to the author [9] permeability Equation was used in estimating permeability as shown in equation 5

K= [250* (*Φe* ^3)/Swirr]^2 …………………………… 5

where:

K = permeability.

Øa = average porosity.

Swirr = irreducible water saturation

WATER SATURATION

Water saturation refers to fraction or level (percentage) of water volume to that of the pore volume of the rock. Water saturation is estimated from the effective porosity and the resistivity logs. Hydrocarbon saturation (Sh) is the ratio of the pore volume of the rock that is contained with hydrocarbons. It is resolve from the water saturation by the Equation 6

$S_h = 1 - S_W$ 6

The author [10] Equation was utilized in the computation of water saturation. As indicated by [10] determination of the water saturation for the uninvaded zone is accomplished using the Equation 7:

$$S_w^n = (F \times R_w)/R_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where,

Rt= true formation resistivity (Deep Resistivity)

Rw= formation water resistivity at formation temperature

n = Saturation exponent

F = formation factor

The formation factor is actualize by utilizing the Humble equation as shown in equation 8:

$$F = a/Ø_e^m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

Where,

F = formation factor

a = Archie's exponent or tortuosity factor

$Ø_e$ = effective porosity

m = cementation exponent factor = 2

RESERVOIR QUALITY

Cross plots of the computed petrophysical parameters for each reservoirs mapped across wells and petrofacies generation was done to determine reservoir quality.

IV. PRESENTATION OF RESULT

In this study, quantitative interpretation of the reservoirs (L100, M100 and M200) in each well are presented using the above methodology. Table 1: shows the results of some average calculated petrophysical parameters for well A, B and C. Figure (4, 5 and 6) showsthe cross plotof volume of shale against porosity for reservoirL100, M100 and M200 respectively. A cut-off of 40% volume of shale and 18% porosity was chosen in order to differentiate the non-reservoirs or shales from the reservoirs. The reservoir section was further classified into low, mid and high quality sands by porosity binning.Values of porosity between 0.20 and 0.25 were considered as low quality sands, values between 0.25 and 0.32 were considered as mid quality sands and values above 0.32 were considered as high quality.The cross plot of permeability against porosity also shows the shale, low, mid and high quality sand clusters as presented in Figure 7, 8 and 9. After classification, petrofacies logs were generated and displayed on well section as shown in Figure 10, 11 and 12.

Table 1: Summary Table of Reservoir Sand Properties at Well A, B and C

Well A	Depth (ft)	Thickness (ft)	Porosity (%)	Sw (%)	Perm (mD)	Vsh %
L100 Top L100 Base	6143-6240	97	29.63	11.46	891.27	6.51
M100 Top M100 Base	6445-6485	40	29.97	22.51	981.57	9.73
M200-Top M200-Base	6557-6648	91	25.88	39.16	431.99	16.48

Well B	Depth (ft)	Thickness(ft)	Porosity (%)	Sw (%)	Perm (mD)	Vsh %
L100Top L100Base	6140-6240	100	38.46	94.51	3179.91	11.07
M100Top M100 Base	6450-6545	95	35.55	26.62	1923.73	13.78
M200Top M200Base	6560-6665	105	32.18	33.12	950.35	15.05

Well C	Depth (ft)	Thickness(ft)	Porosity (%)	Sw (%)	Perm (mD)	Vsh %
L100 Top L100 Base	6303- 6403	100	28.59	33.96	798.62	4.04
M100 Top M100 Base	6630- 6720	90	31.33	48.18	1356.92	7.02
M200 Top M200 Base	6735-6870	135	27.47	45.51	571.78	8.57

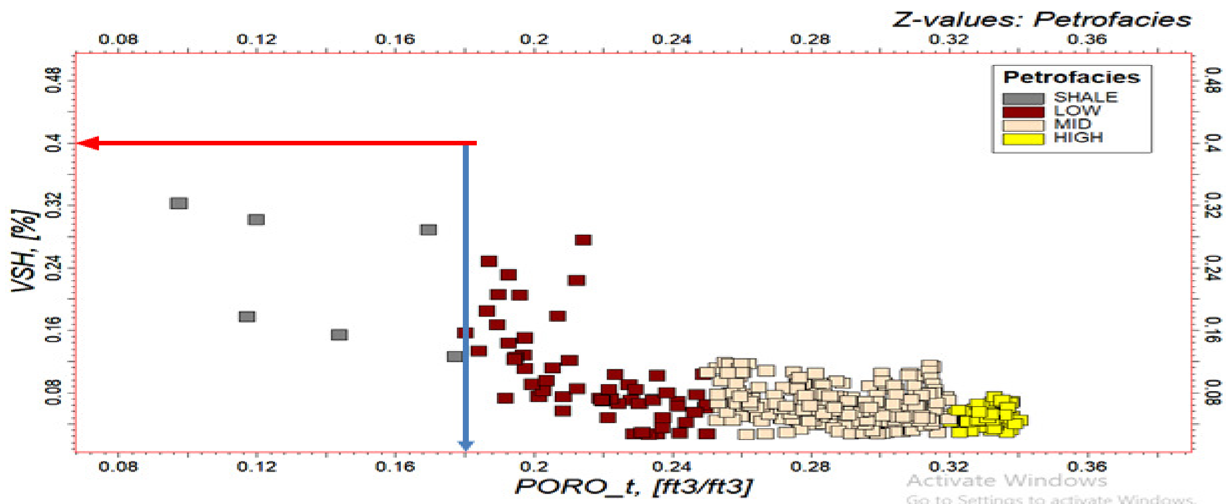

Figure 4: VshaleVs Porosity Cross Plot For Reservior L100

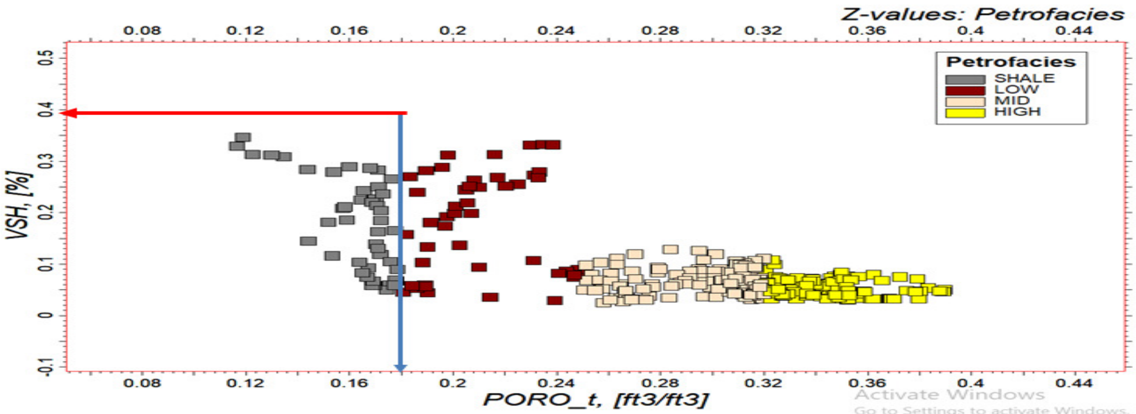

Figure 5: VshaleVs Porosity Cross Plot For Reservior M100

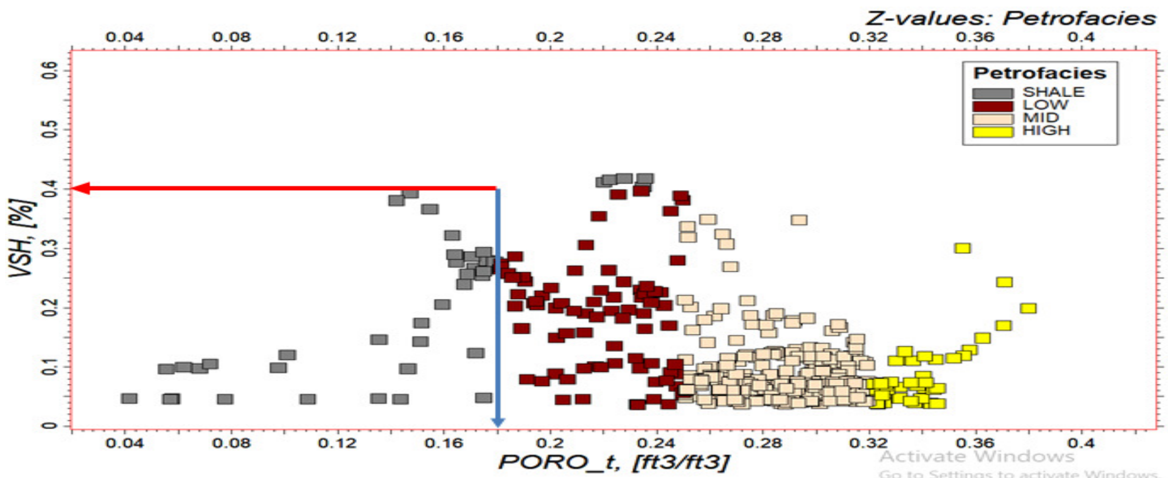

Figure 6: VshaleVs Porosity Cross Plot For Reservoir M200

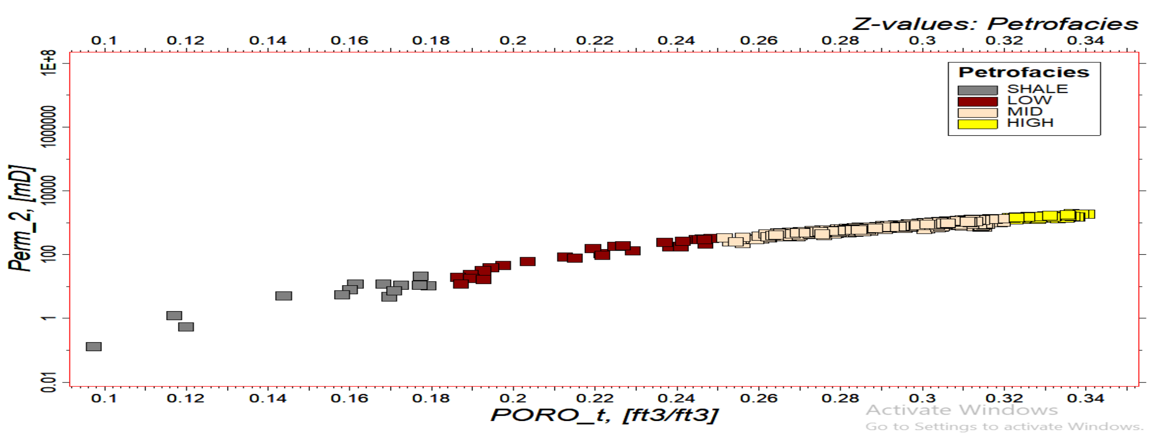

Figure 7: Permeability Vs Porosity Crossplot for Reservoir L100

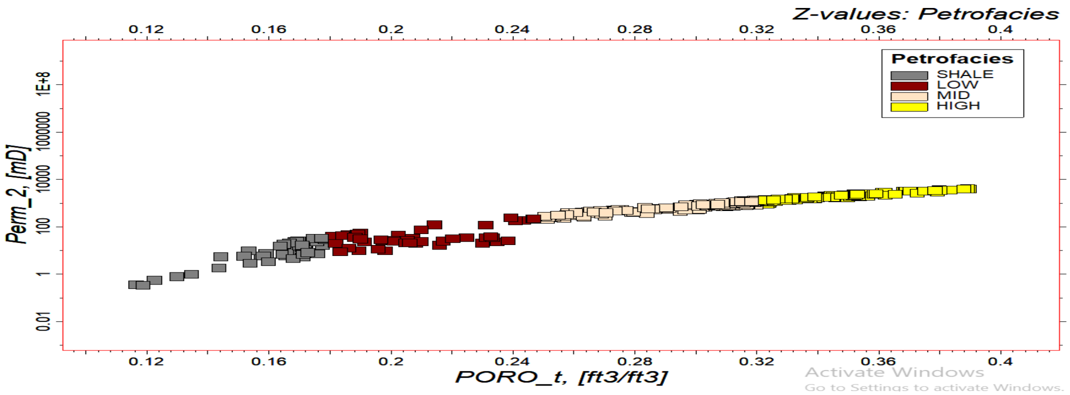

Figure 8: **Permeability Vs Porosity Crossplot for Reservoir M100**

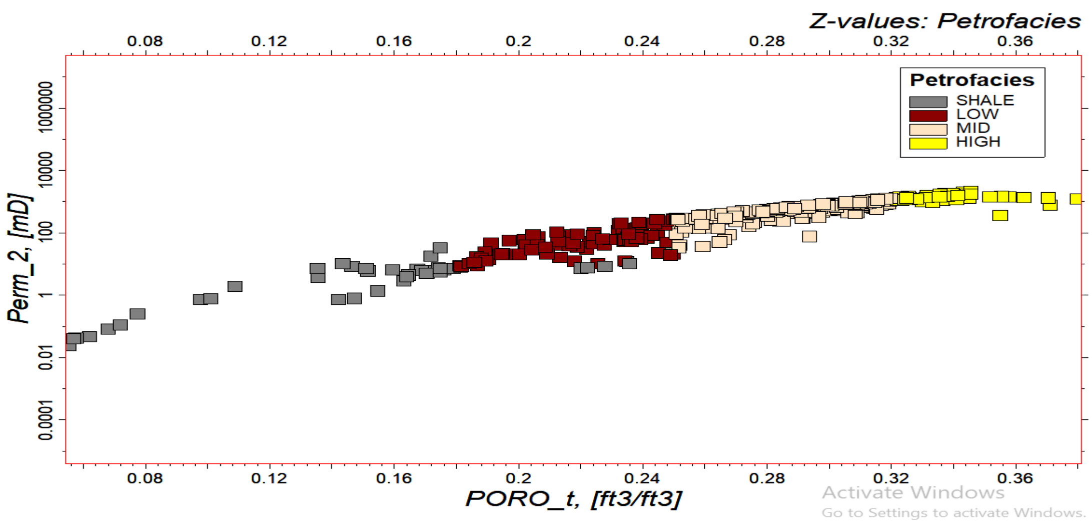

Figure 9: Permeability Vs Porosity Crossplot for Reservoir M200

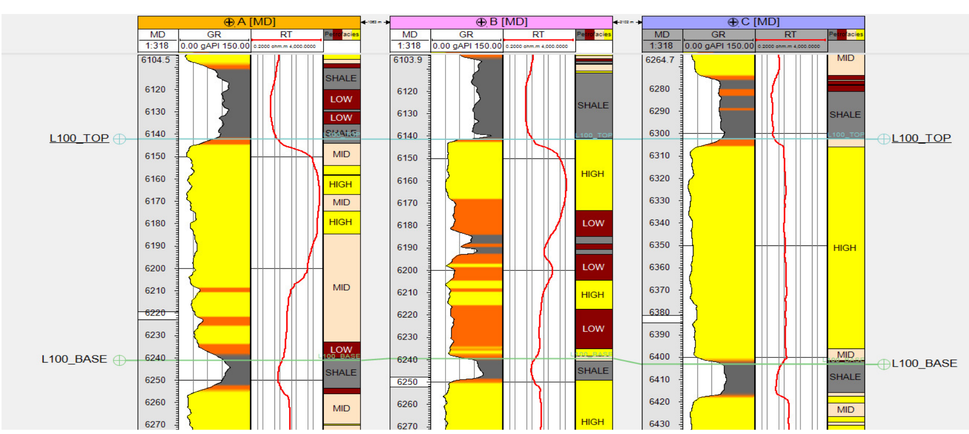

Figure 10: Petrofacies Log Display For L100 Reservoir

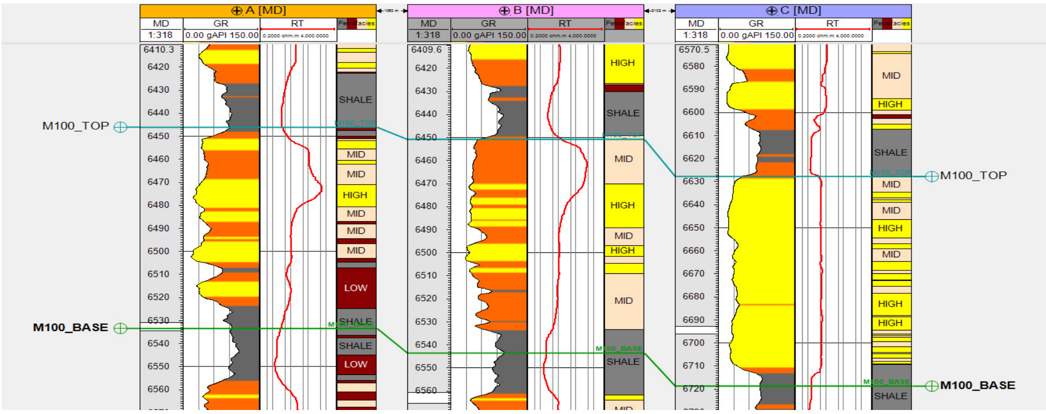

Figure 11: Petrofacies Log Display For M100 Reservoir

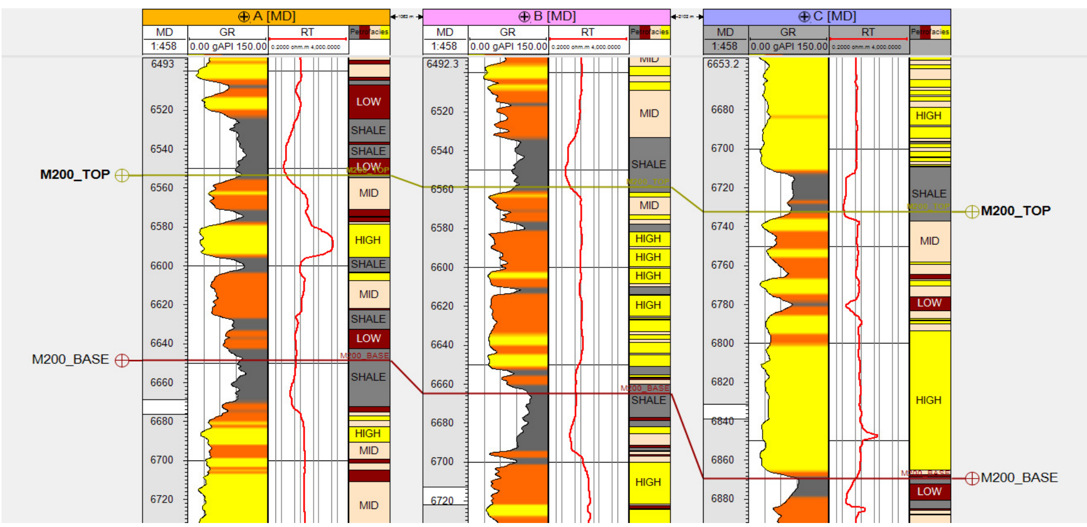

Figure 12: Petrofacies Log Display For M200 Reservoir

V. DISCUSSION OF RESULT

This study defines the hydrocarbon potential of petrophysical characteristics of the delineated reservoir sands. From Table 1, it can be deducted clearly that the sands are well sorted with low values of the Vshale with an average range value of 4.04% to 11.07% for sand L100, 7.02% to 13.78%for sand M100 and 8.57% to 16.48% for sand M200. The average values obtained for porosity and permeability range from 27.47% to 38.46% and 431.99mD to 3179.91mD indicatesqualitative evaluation of the reservoirs to be "very good" and "excellent" in Well A, B and C.The hydrocarbon bearing reservoirs have water saturation (Sw) ranging from 11.46% to 45.51%, except sand L100 of Well B with abnormal high water saturation of 94.51%. This indicate that the proportion of void spaces occupied by water is highconsequently low hydrocarbon saturation and low hydrocarbon production in Well B. However, all other delineated sand shows evidence of low water saturation and hydrocarbon potential in the reservoirs is satisfactory, hence they can be adjudged as producible reservoirs. The crossplots ofVshalevs Porosity of each delineated reservoir zone (Figure 4,5and 6) differentiatethe shales from the reservoirs and classified into low, mid and high quality sands. This defined the quality of the reservoir rock or pay reservoir as seen in the cross plots of Permeability againstPorosity for reservoir L100, M100 and M200 (Figure 7,8 and 9). The cross plots showed that the higher the permeability the higher porosity, vice versa. The petrofacies log displayed in Figure (10,11and 12) depicts the quality reservoir and shows well C have higher quality sand when compared with well A and Well B.

VI. CONCLUSION

Petrophysical properties evaluation of Nick Field for its reservoirs characterization was made possible by careful analysis and interpretation of its well logs. Petrophysical evaluation of the reservoirs showed that the permeability and porosity varies from very good to excellent. Average porosity ranging from 27.47% to 38.46% indicate a suitable reservoir quality, permeability values range from 431.99mD to 3179.91mD and water saturation range from 11.46% to 45.51%; inferring high hydrocarbon production. Cross plot analysis help in better understanding of the lithology and reservoir quality. The petrofacies log generated revealed each productive zoneand the best producible hydrocarbon well. Consequently, this study hasshowed a useful approach of petrophysical evaluation of the reservoirs delineated in the Niger DeltaField.

ACKNOWLEDGMENT The authors are thankful to World Bank, Africa Centre of Excellence, and University of Port Harcourt and also express their sincere thanks to the SHELL, Nigeria for providing their well data for this research.

REFERENCES

[1] Quijada, M. F. and Stewart, R. R., "Petrophysical analysis of well logs from Manitou Lake, Saskatchewan." *CREWES Research Report,* 19 :(2007)

[2] Asquith, G. and Krygowski, D., "Basic Well Log Analysis, 2nd ed., *Tulsa, Oklahoma: American Association of Petroleum Geologists,*1-2, 31-32, 124(2004)

[3] Aigbedion, J.A. and Iyayi, S.E., Formation Evaluation of Oshioka Field, using geophysical well logs Middle-east Journal of Scientific Research (2007) 2(3 – 4) p.107 – 110`

[4] Dresser Atlas., Well logging and Interpretation Techniques. The Course for Home Study, 2nd E (1982).

[5] Doust, H., Petroleum geology of the Niger Delta: Geological Society, London, Special Publications1990, v. 50, p. 365.

[6] Klett, T.R., Ahlbrandt, T.S., Schmoker, J.W., and Dolton, J.L., Ranking of the world's oil and gas provinces by known petroleum volumes: . U.S. Geological Survey Open-file Report 1997, p. 97-463 CD-ROM.

[7]. Tuttle, M.L.W., Charpentier, R.R., and Brownfield, M.E.. Tertiary Niger Delta (Akata-Agbada) Petroleum System (No. 701901), Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa, *in* USGS, ed., The Niger Delta PetroleumSystem: Niger Delta Province,Nigeria, Cameroon, andEquatorial Guinea, Africa: Denver, Colorado, U.S. Department Of The Interioru.S. Geological Survey 1990.

[8] Wyllie, M.R.J. and Rose, W.D. (1950). Some Theoretical Considerations Related to the Quantitative Evaluation of the Physical Characteristics of Reservoir Rock from Electric Log Data, Trans., AIME, Vol. 189, pp. 105.

[9] Tixier, M.P., (1949). Evaluation of Permeability from Electric-Log Resistivity Gradients. Oil & Gas Journal, (June 1949), pp. 113.Tulsa, Ok.

[10] Archie, G. E., The Electrical Resistivity Log as an Aid in Determining Some ReservoirCharacteristics, Transaction of American Institute of Mining, Metallurgical and Petroleum Engineers (AIME), Vol. 146, p. 54-62, 1942.

