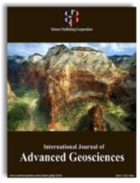
International Journal of Advanced Geosciences, *6 (1) (2018) 145-150*

International Journal of Advanced Geosciences

Website: www.sciencepubco.com/index.php/IJAG
doi: 10.14419/ijag.v6i1.11815
Research paper



Petrophysical Analysis of Well Logs for the Estimation of Oil Reserves in Southern Niger Delta

Paul S. S [1] *, Okwueze, E. E [2], Udo K. I [1]

[1] *Department of Physics, University of Uyo, Uyo, Nigeria*
[2] *Department of Physics, University of Calabar, Calabar, Nigeria*
**Corresponding author E-mail: saspamsc@gmail.com*

Abstract

Gamma Ray log, Resistivity log, Density log, Micro-spherical focus log (MSFL), Deep Induction log (ILD) , Medium Induction log(ILM) and Spontaneous Potential (SP) log were collected for 2 wells in onshore Niger Delta. These insitu well logs were analyzed and interpreted. Porosity, permeability, water saturation, reservoir thickness and Shale volume were estimated for each hydrocarbon bearing zone delineated for each well. The parameters obtained were further analyzed and interpreted quantitatively to estimate the hydrocarbon potentials of each well. Twelve reservoir zones of interest (sand bodies) were delineated, correlated across the field and were ranked using average results of petrophysical parameters. In well one, Reservoirs E and F were identified as the thickest with 41ft each while reservoir A is the smallest in thickness (30ft). Petrophysical properties of hydrocarbon bearing zones delineated in well one ranged from 17.81% to 23.20% for porosity, 1292.09mD to 2018.17mD for permeability and 56.40% to 68.40% for hydrocarbon saturation compared to well 2 with 14.67% to 19.52% for porosity, 1211.61mD to1843.11mD for permeability and 51.80% to 66.40% for hydrocarbon saturation. The estimated averages of petrophysical properties for well one are 20.14% porosity, 1643.65mD permeability, 63.20% hydrocarbon saturation compared to well 2 with 15.55% porosity, 1582.58mD permeability and 61.93% hydrocarbon saturation. Results show 148.45MMBB and 145.91MMBB as oil reserve (Recoverable) for the field. From the results obtained, well one is likely to be more productive than well [2] and the field has exploitable oil in place.

Keywords: *Petro Physical Parameters; Hydrocarbon Reserve; Well Logs; Volumetric Method.*

1. Introduction

Petrophysics is based on the knowledge of well logging. Therefore, well logging is the basis of any petrophysical analysis. Well logging is from the French word 'Carottage e'lectrique'* literally means "electrical coring" that was invented in 1927 by Conrad and Michael Schlumberger (Schlumberger, 2005). Therefore, the record of the measurements of surrounding rocks with sensor (Sonde) located in a borehole as a function of depth for identification of geological formations, formation fluids, correlations of boreholes and evaluation of the productive capabilities of reservoir formation is known as well logging (Telford and Geldart, 1974).

Ever since its invention and adoption, well logging had a wider range of application in borehole geophysics, including geological studies. In oil exploration, the interest is zeroed down to the identification of porous and permeable beds or formations, their thicknesses, extents and the geometrical shape of the formations. Petrophysics is the study of the physical and chemical rock properties and their interactions with fluids (Tiabb and Donaldson, 2004). The productivity of wells in hydrocarbon-bearing reservoirs depends on petrophysical properties which include lithology, Porosity, water saturation, permeability and density. Generally, the petrophysics frame work here is termed formation evaluation, which is the process of using borehole measurements to evaluate the characteristics of subsurface formations (Helander, 1983).

A chemist Michael Smith in his interview in 2005, said, "Suggestion that oil consumption will grow up to 100mbpd by 2020 and that automobile and airline traffic will increase at extraordinary rates is a major concern". OPEC press release on their 2015 annual World outlook says 'oil demand is projected to rise above 97mbpd by 2020 and 110mbpd by 2040. The exact quantity of hydrocarbon reserves disclosed by national governments of countries are often manipulated for political reasons. Over the period 2010-2035 primary energy demand shall increase by 54%. For most of the projection period, oil will remain the energy type with the largest share than coal and gas (OPEC, 2012). With all the uncertainties in predictions and forecasting, it is a necessity to update information about our petroleum reserves, hence, the need for this research to be carried out in the Niger Delta. This work will enhance the development of future prospect and will serve as a reference source for hydrocarbon information in the Niger Delta basin.

2. Field geology and characteristics

Niger Delta basin is an extensional rift basin in the Niger Delta and the Gulf of Guinea on the passive continental margin near the Western coast of Nigeria (Tuttle et al, 1990). It extends throughout the Niger Delta province as defined by Klett and others (1997) From Eocene to the present, the delta has prograded southward, forming depobelts that represent the most active portion of the delta at each stage of development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000km^2 (Kulke, 1995), a sediment volume of 500,000km^3 (Hospers, 1965), and a thickness of over 10km in the basin depocentre (Kaplan and others; 1994). The Niger Delta province contains only one identified petroleum system (Kulke, 1995;

Ekweozor and Daukoru, 1994). This system is referred to as the Tertiary Niger Delta (Akata – Agbada) petroleum system (Avbovbo, 1978). Among the provinces ranked in the U.S Geological survey's world energy assessment (Klett and other, 1997), the Niger Delta province is the twelfth richest in petroleum resources, with 2.2% of the world's discovered oil and 1.4% of the world's discovered gas (Petroconsultants, Inc. 1996a). The study wells are located geographically on 5º 57' 37.8259"N, 5º 40' 37.2805"E and 5º 58' 5.6227"N, 5º 40' 36.1624"E of the southern part of Niger Delta. The study area includes Ovade in Oghara, Ethiope West L.G.A of Delta State (Figure 1).

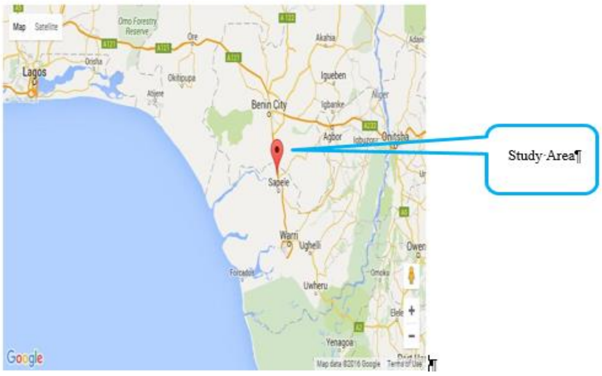


Fig. 1: Map of the Study Area.

3. Methodology

The materials used for this study are well log data which include Wire-line data survey (Gamma ray log, Density log, Spontaneous log, Deep Induction log and Resistivity log). Petrel 2014 version was used in the data analysis.

3.1. Determination of shale volume (V_{sh})

This was derived from the gamma ray log first by determining the gamma ray index I_{GR} (Schlumberger, 1974)

$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$ (Schlumberger, 1974)

Where

I_{GR} = Gammma ray Index

GRlog = gamma ray reading of the formation

GRmin = minimum gamma ray reading (sand base line)

GRmax = maximum gamma ray reading (shale base line)

This work is based on Niger Delta, which consist of tertiary rocks; Larionov's (1969) Shale volume formula for tertiary rocks was used.

$V_{sh} = 0.083\left(2^{3.7 \text{total porosity} I_{GR}} - 1\right)$

3.2. Determination of

This was calculated from density porosity log using the equation:

$$\emptyset_T = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

Where ρ_{ma} = matrix density which is taken to be 2.65g/cc for sandstones (Dresser, 1979)

ρ_b = Bulk density read directly from the log
ρ_f = The fluid density which is taken to be 1 for gas and 0.87 for oil.

3.3. Determination of effective porosity

This is usually based on an adjustment of total porosity by means of estimated shale volume (content).

$\emptyset_{eff} = \emptyset_T - [\emptyset_{sh} * V_{sh}]$ (Dresser, 1979)

Where

$\emptyset_{eff}$ = effective porosity

$\emptyset_T$ = total porosity

$\emptyset_{sh}$ = log reading in a shale zone

V_{sh} = Shale volume

According to Baker, 1992, the criteria for classifying porosity is as follows:

$\emptyset < 0.05$ = Negligible; $0.05 < \emptyset < 0.1$ = Poor; $0.1 < \emptyset < 0.15$ = Fair; $0.15 < \emptyset < 0.25$ = Good; $0.25 < \emptyset < 0.30$ = Very good , $\emptyset > 0.30$ = Excellent

3.4. Determination of formation factor, water saturation and hydrocarbon

Saturation The formation factor was determine by Archie equation, 1942.

$F = \frac{a}{\emptyset^m}$ (Archie, 1942)

Where

Ø = porosity, a = constant (Tortuosity) which is taken as 0.62, m = cementation exponent which is [2] for sands.

The water saturation S_w for the uninvaded zone was determined using the Archie equation:

$S_w^2 = \frac{F * R_w}{R_t}$ (Archie, 1942)

Also,

$$F = \frac{R_o}{R_w}$$

Therefore,

$$S_w^2 = \frac{R_o * R_w}{R_w * R_t}$$

$$S_w = \sqrt{\frac{R_o}{R_t}}$$

S_w = water saturation of the uninvaded zone

R_o = Resistivity of formation at 100% water saturation

R_o = True resistivity of the formation.

F = formation factor

Or
Water saturation can be written as:

$$S_w = \left(\frac{aR_w}{R_t \emptyset^m}\right)^{\frac{1}{n}}$$

Where n = saturation exponent taken as 2 and a = tortuosity.

Hydrocarbon saturation S_h is given as

$$S_h = (100 - S_w)\%$$

$$S_h = 1 - S_w$$

3.5. Determination of permeability and irreducible water saturation

Permeability is related to porosity but not always dependent on it. It is controlled by the connected passages of the pores space (pore throats) (Jürgen, 2015). It is measured in darcies or millidarcies. The permeability was calculated from the equation:

$$K = \left[\frac{250 * \emptyset^3}{S_{wirr}}\right]^2$$

Where S_{wirr} = Irreducible water saturation

Irreducible water saturation is also known as critical water saturation which defines the maximum water saturation that a formation with a given permeability and porosity can retain without producing water.

$$S_{wirr} = \sqrt{\frac{F}{2000}}$$

Where F = formation factor and

$$F = \frac{0.81}{\emptyset^2}$$

3.6. Reserve estimation

The volumetric method for estimating reserves was utilized in this work. This method calculates the amount of oil in place (N_t).

$$OOIP = N_{(t)} = \frac{V_b \emptyset S_{o(t)}}{B_{o(P)}}$$

V_b = Bulk reservoir volume, RB.

$$RB = 758Ah$$

Where 7758 is a constant, conversion factor from acre-ft to barrel.

$$OOIP = N_{(t)} = \frac{RB \emptyset S_{o(t)}}{B_{o(p)}} = \frac{7758Ah\emptyset S_0(t)}{B_{o(p)}}$$

$S_{0(t)}$ = average Oil saturation, fraction

$$S_{0(t)} = 1 - S_{wo}$$

$$OOIP = N(t) = \frac{7758Ah\emptyset[1 - S_{wo}]}{B_{o(p)}}$$

In the equation, above, A = Reservoir area, acres, h = average reservoir thickness, fraction (pay thickness from petrophysics), S_{wo} = Water saturation, B_o = oil formation volume factor at reservoir pressure P, RB/STB.

4. Results and discussion

We have analyzed the available data to map Horizons, delineate lithologies (sand and shale) as well as estimate relevant petrophysical properties (porosity, permeability, shale volume, water saturation, hydrocarbon saturation and net-to-gross ratio).

Figures 2 and 3 show the horizons and identified reservoirs of well 1 and 2 while figure 4 shows the stratigraphic correlation of the two wells. Results for Petrophysical Properties

The well logs used were analyzed to evaluate reservoir properties such as shale volume, porosity, water saturation and permeability in order to obtain the hydrocarbon potential of the wells.

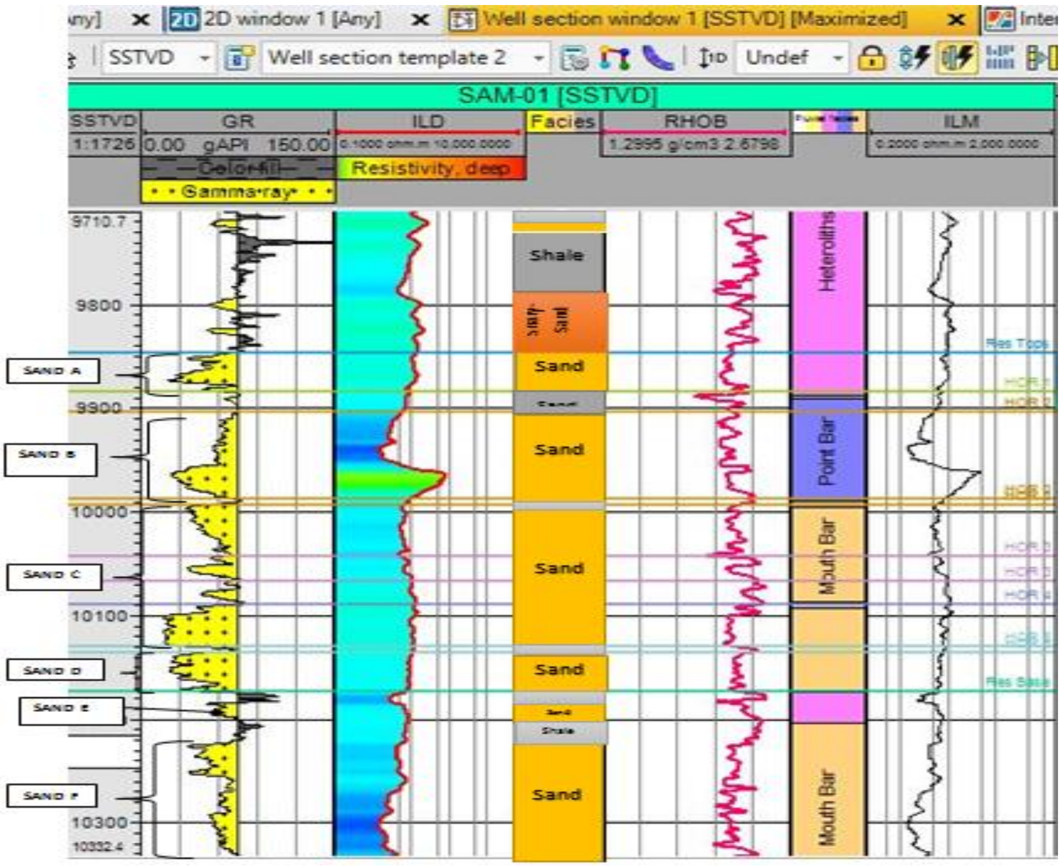


Fig. 2: Well [1] Showing Different Horizons and Reservoir

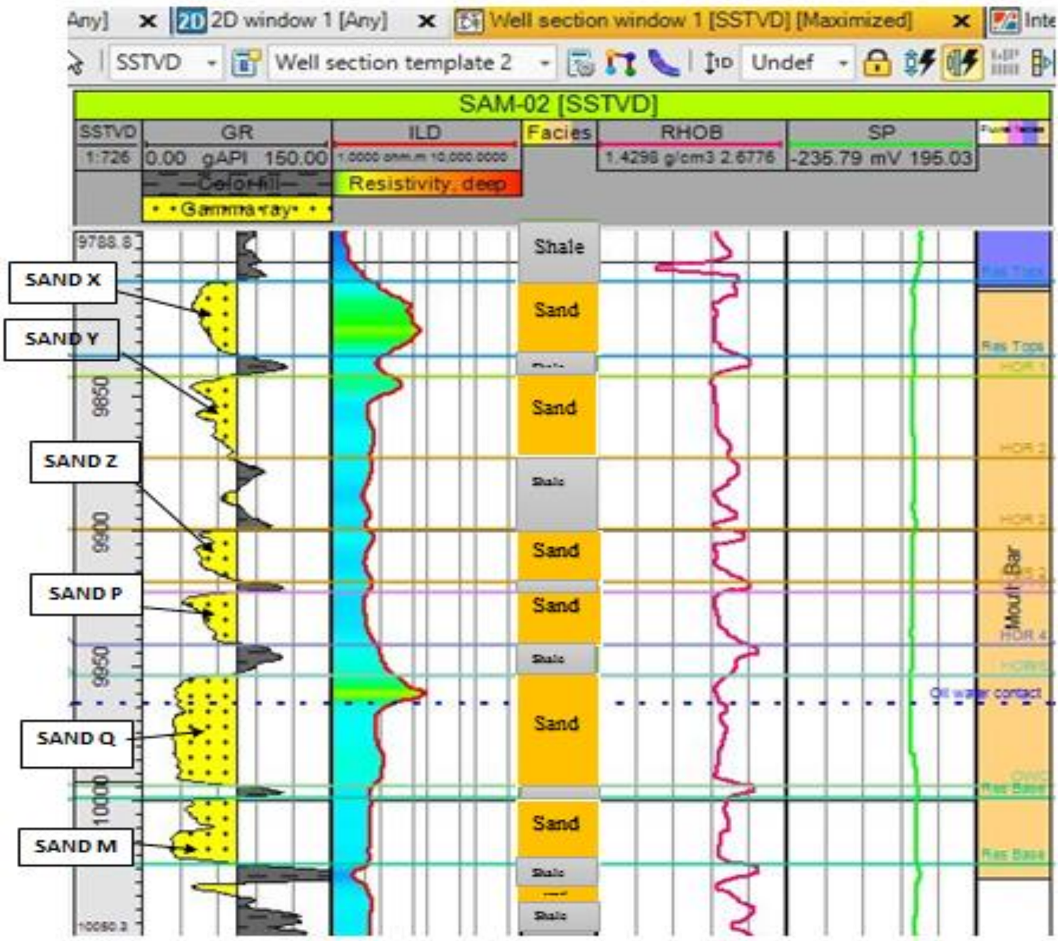


Fig. 3: Well [2] Showing Different Horizons and Reservoirs.

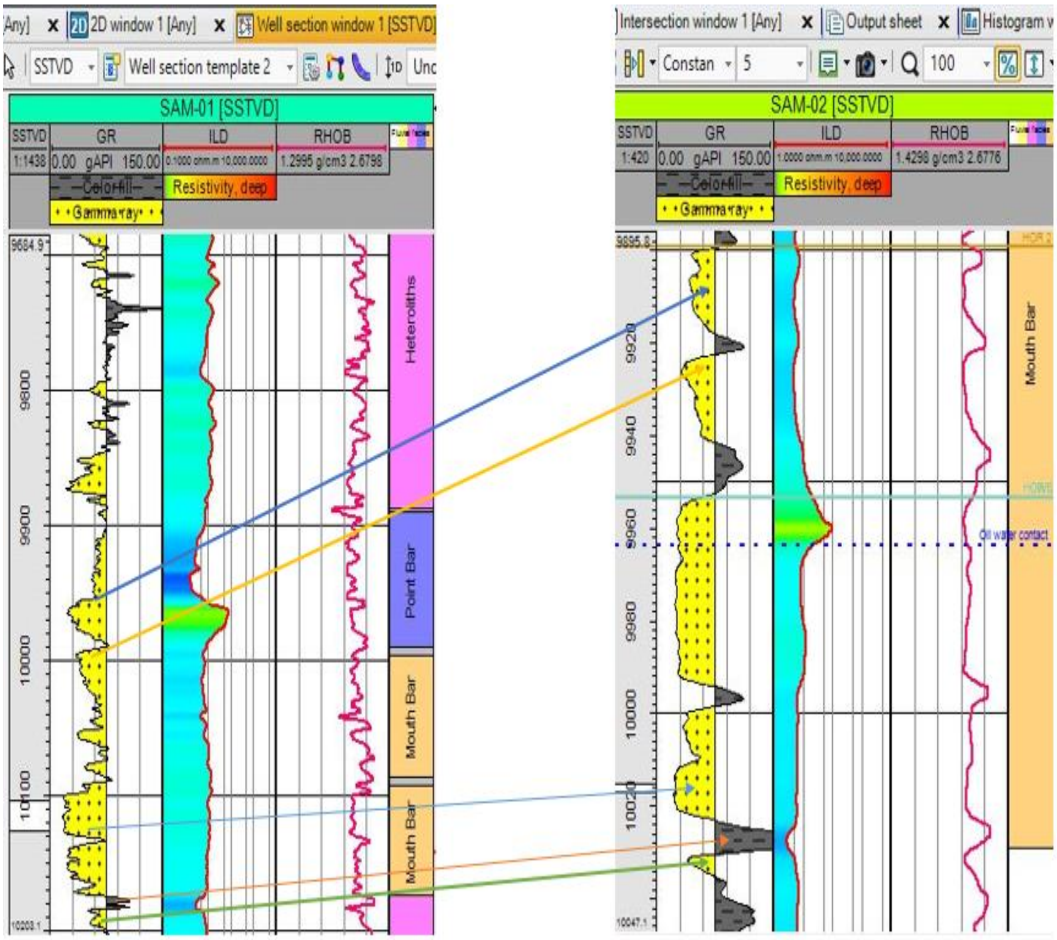


Fig. 4: Stratigraphic Correlation Columns of Well 1 and Well 2.

Table 1: Calculated Petro physical Properties of Study Wells/Reservoirs

WELLS	Sand	Sand Tops(ft)	Sand Bottoms(ft)	Thickness (ft)	V_{sh} (%)	S_w (%)	S_h (%)	K_{oil}	Ø (%)
WELL 1	A	9842	9880	38	22.80	42.80	57.20	1412.44	20.00
	B	9900	9990	90	17.58	32	68	1922.89	20.30
	C	10000	10130	130	7.38	33.50	66.50	2018.17	23.20
	D	10135	10170	35	5.97	31.60	68.4	1652.40	21.24
	E	10190	10200	10	11.81	37.3	62.7	1509.94	18.29
	F	10220	10332	112	6.91	43.60	56.4	1292.09	17.81
	Average				12.1	36.8	63.2	1634.65	20.14
	Total			415					
WELL 2	X	9808	9834	26	16.59	36.30	63.70	1696.40	17.52
	Y	9841	9874	33	43.07	33.60	66.40	1211.61	15.08
	Z	9899	9917	18	28.89	37.96	62.04	1843.11	18.17
	P	9922	9940	18	15.25	36.40	63.60	1695.89	19.52
	Q	9953	9992	39	20.54	38.20	61.80	1705.39	18.36
	M	9999	10022	39	29.38	45.98	54.02	1343.10	14.67
	Average				34.12	38.07	61.93	1582.58	15.55
	Total			173					

Table 2: Summary of Average Petro physical Properties of Well [1] And Well [2]

WELLS	NTG (%)	V_{sh} (%)	S_w (%)	S_h (%)	GR_{min} (API)	GR_{max} (API)	K_{oil} (mD)	Ø (%)	OWC (ft)	STOOIP (STB)
WELL 1	85.6	12.1	36.80	63.20	3.29	163.97	1634.65	20.14	10016.75	52.04×10^6
WELL 2	69.5	34.12	38.07	61.93	8.76	259.1	1582.58	15.55	9964	51.55×10^6

The results of the oil reserves obtained are as follows:
Oil Reserves for Well 1

The Stock Tank Original Oil in Place (STOOIP) = $52.04 \times 10^6 \text{STB} = 329.59\text{MMBBL}$

Where 1 STB (m^3) = 6.29 BBL (conversion factor from STB to BBL)

Oil recovery factor (RF) = 45% = 0.45(given)

$$\text{Oil Reserve} = \text{STOOIP} \times \text{RF}$$

$$\text{Oil Reserve} = 329.59\text{MMBBL} \times 0.45 = 148.455\text{MMB BL}$$

Oil Reserves for Well [2]

$$\text{STOOIP} = 51.55 \times 10^6\text{STB} = 329.59\text{MMBBL}$$

$$\text{Oil Reserve} = \text{STOOIP} \times \text{RF}$$

$$\text{Oil Reserve} = 324.25\text{MMBBL} \times 0.45 = 145.91\text{MMB BL}$$

This means that 148.455MMBBL and 145.91MMBBL are the recoverable oil reserves for well [1] and well 2 respectively.

5. Conclusion

Porosity, permeability, water saturation, reservoir thickness and Shale volume have been estimated for each hydrocarbon bearing zone delineated for each well. The results obtained have been further analyzed and interpreted quantitatively to estimate the hydrocarbon reserves in each well as well as the hydrocarbon potentials of the wells. The volumetric method of reserve estimation using well logs is absolutely a quick and reliable way of evaluating the reserves of any oil field. We have found that the field has great hydrocarbon potential. This is inferred from our results which reveal 148.45MMBB and 145.91MMBB as recoverable oil reserve for well 1 and well 2 respectively. From the results too, well 1 is more likely productive than well 2.

6. Acknowledgement

The authors acknowledge SPDC Nigeria for the data used for this work.

References

[1] Archie, G. E. (1942). The Electrical Resistivity Log as an aid in determining some Reservoir Characteristics. *Journal of Petroleum Technology., Vol.5:* pp.54-62 https://doi.org/10.2118/942054-G.
[2] Avbovbo, A. A., (1978). Tertiary Lithostratigraphy of Niger Delta. American Association of Petroleum Geologists Bulletin, Vol. 62, pp.295-300.
[3] Baker, H.I. (1992). Advanced Wireline and MWD Procedures Manual: B.H.I Technical publications Group.
[4] Doust, H. and Omatsola, E. (1990). Niger Delta. American Association of Petroleum Geologists Bulletin Memoir 48, pp.201-328.
[5] Dresser, A. (1979). Log Interpretation Charts. Dresser Industries Inc., Houston, Texas: p.107
[6] Ekweozor, C. M. and Daukoru, E. M. (1994). Northern delta depobelt portion of the
[7] Akata-Agbada Petroleum System, Niger Delta: AAPG Memoir 60: Tulsa, American Association of Petroleum Geologist, p.599 -614
[8] Helander, D.P. (1983). Fundamentals of formation evaluation: Tulsa, Oklahoma: OGCI Publications, p.6
[9] Hospers, J. (1965). Gravity field and structure of the Niger Delta, Nigeria, West Africa: Geological Society of American Bulletin, v. 76, p. 407-422. https://doi.org/10.1130/0016-7606(1965)76[407:GFASOT]2.0.CO;2.
[10] Jürgen, S. (2015). Basic Well Logging and Formation Evaluation.1st Edition, pp.26-27
[11] Klett, T.R., Ahlbrandt, T.S., Schmoker, J.W., and Dolton, J. L. (1997). Ranking of the world's Oil and Gas Provinces by known Petroleum Volumes: *U.S. Geological Survey Open-file Report.*pp.97-463.
[12] Kaplan, A., Lusser, C.U., Norton, I.O. (1994). Tectonic map of the world, panel 10*: Tulsa, American Association of Petroleum Geologists, scale 1:10,000,000*.
[13] Kulke, H. (1995). Nigeria, in Kulke, H., ed., Regional Petroleum Geology of the World. Part II: Africa, America, Australia and Antarctica: Berlin, Gebruder Borntraeger, pp.143-172.
[14] Larionov, V. (1969). Borehole Radiometry: Moscow, U.S.S.R., Nedra.
[15] Organization of the Petroleum Exporting Countires (2009; 2010; 2011; 2012 and 2015). OPEC Annual Statistical Bulletin.
[16] Petroconsultants (1996a). Petroleum Exploration and Production Database: Houston, Texas, Petroconsultants, Inc.

[17] Schlumberger (2005). Oil field glossary. Available at www.slb.com/oilfieldglossary (Retrieved December, 11th, 2015 at 8:05a.m)
[18] Schlumberger (1974). Log Interpretation Principles,' Applications. Houston: Schlumberger Educational Services, pp.1 – 198.
[19] Telford, W., Geldart, L., Sheriff, R., and Keys, D., (1974). Applied Geophysics, Cambridge University Press, New York.p.645
[20] Tiabb, D. and Donaldson, E. C. (2004). Petrophysics. Oxford: Elsevier.p.1.
[21] Tuttle, M.L.W., Charpentier, R.R., and Brownfield, M.E. (1990). Tertiary Niger Delta (Akata-Agbada) Petroleum System, pp.3-5