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RESEARCH ARTICLE

HYDROCARBON RESERVOIR CHARACTERIZATION USING WELL LOG IN PART OF NIGER DELTA, NIGERIA

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ABSTRACT

Hydrocarbon reservoir characterization using well log in part of Niger Delta, Nigeria was done in order to examine the potentiality and productivity of the reservoir. A suite of well log data consisting of gamma ray, density, resistivity and neutron logs obtained from two wells within the area of study were used for this research. Gamma ray log was used for lithology identification and differentiation, resistivity log was used to identify the type of fluid present in the reservoir, density log was used to detect gas bearing zones in the reservoir while neutron log was used to distinguish gas from oil in sandstone and shale reservoirs. The results of this study showed sand bodies were delineated and correlated across the wells and were inferred as potential hydrocarbon reservoirs. The result also showed that there is an increase in both porosity and permeability, evaluated petrophysical parameters showed that porosity values range between 0.0391 – 0.3019, water saturation values range from 0.1660 – 1.6740 while hydrocarbon saturation values range from 0.0013 – 0.7296 and net to gross values range from 0.5332 – 0.9674.

KEYWORDS

Fault, Petrophysical, Volumetric, Saturation, Horizon.

1. Introduction

Characterization of hydrocarbon reservoir is essential in development and exploratory phases of a prospect and combines different geoscientific analysis and results to minimize risk and improve understanding of the reservoir. This requires the use of empirical formula to obtain reservoir parameters such as porosity, permeability, fluid saturation (oil, water or gas saturation), volume of shale, formation factor etc. Characterization of hydrocarbon reservoir generally helps in determining the volume of gross within the trap that is capable of holding hydrocarbons. The accuracy in determining thickness and other petro-physical parameters of a reservoir is basic in characterization of such reservoir (Schlumberger, 2000). Understanding hydrocarbon reservoir characterization and volumetric analysis is a primary factor in quantifying producible hydrocarbon (Schlumberger, 1989). Reservoir characterization can be done using information obtained from well logs especially using gamma ray, resistivity, neutron and density logs (Asquith and Krygowski, 2004).

Hydrocarbon reservoirs are crucial sources of oil and gas, and understanding their formation and properties is vital for successful exploration and production. According to Knut, hydrocarbon reservoirs are typically formed in sedimentary basins through a combination of organic matter accumulation, burial, and diagenesis (Knut, 2010). The formation process begins with the deposition of organic-rich sediments in marine or lacustrine environments. Over time, these sediments undergo compaction and burial, leading to the transformation of organic matter into hydrocarbons through thermal maturation (Knut, 2010).

2. Geology of The Study Area

Niger Delta Basin came into existence from a failed rift junction which occurred during the separation of South American plate and African plate. The rift started during late Jurassic and ended in mid-cretaceous. Five depobelts which include Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp and Offshore Swamp are found in the Niger Delta basin. It is made up of three stratigraphic units, which are Akata Formation, Agbada Formation and Benin Formation (Avbovbo, 1978).

The Akata Formation is the basal unit in Niger Delta Basin, it is a marine sedimentary formation with thickness of about 7000m. It comprises low compacted shale intercalation, clays as well as silts at the base, with lenses of sandstone having anomalous top high pressure. This formation is identified by the presence of interbedded sandstone and shale with thickness of over 3000m. Shales of Agbada Formation were believed by geologists to be hydrocarbon source rocks, though, major source rocks in the Niger Delta are from Akata Formation. Benin Formation is the youngest and top most formation in the Niger Delta, with thickness of about 2000m and composed of sands, sandstones and little shale intercalations (Doust and Omatsola, 1990).

3. Materials and Method

3.1 Materials

Well log suite (consisting of gamma ray, density, resistivity, and neutron logs), microsoft excel spread sheet and petrel software are the material used for this study.

3.2 Methodology

3.2.1 Determination of Shale Volume (V_{sh})

Volume of shale is the fraction of shale present in the reservoir or

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formation. It can also be defined as the fraction of the reservoir occupied by shale (Cannon, 2017). Shale volume was determined using gamma ray index notation and Lorinov's equation as shown in equations (1) and (2).

Gamma ray index (GR_{Index}) was determined prior to determining the volume of shale based on Schlumberger (1989);

$$GR_{Index} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad (1)$$

The non-linear Larinov (1969) equation for tertiary shaly reservoir was used for estimating the volume of shale:

$$V_{sh} = 0.083(2^{3.7GR_{Index}} - 1) \quad (2)$$

Where $GR_{Index} = Gamma\ ray\ index$

GR_{log} = Log reading of the formation

GR_{min} = Log reading in sand zone.

GR_{max} = Log reading in shale zone.

3.2.2 Determination of Effective Porosity (Φ_e)

Effective porosity is the ratio of interconnected pore spaces to the bulk volume of the reservoir rocks, it controls the flow of fluid within the reservoir. Effective porosity ($\boldsymbol{\Phi_e}$) was determined using an empirical equation which relates the volume of shale (V_{sh}) and total porosity ($\boldsymbol{\Phi_t}$) (Dresser, 1979):

$$\Phi_e = (1 - V_{sh}) \times \Phi_t \quad (3)$$

Where $\Phi_e = Effective\ porosity$

$V_{sh} = Volume\ of\ shale$

$\Phi_t = Total\ porosity$

Prior to determining Φ_e, total porosity Φ_t which is the ratio of total void space to the bulk volume was first estimated using density log as shown in equation 4:

$$\Phi_t = \frac{\rho_{mat} - \rho_{log}}{\rho_{mat} - \rho_f} \quad (4)$$

Where Φ_t = Porosity derived from density log.

P_{mat} = Density of rock matrix

P_{log} = Formation bulk density read directly for the log.

P_f = Density of formation fluid

3.2.3 Determination of Permeability (K)

Permeability controls the ease with which fluid flows through a porous medium, it is an inherent property of a porous medium and does not depend on the fluids involved. It is denoted by K and its unit is in Darcy or millidarcy.

Permeability was determined using equation (5) as proposed for estimation of reservoir permeability in Niger Delta region (Owolabi et al., 1994).

$$K = 307 + 26552\Phi_e^2 - 34540(\Phi_e \times S_{irr})^2 \quad (5)$$

Where $K = Permeability\ of\ reservoir$

$\Phi_e = Effective\ porosity$

$S_{irr} = Irreducible\ water\ saturation$

Irreducible water saturation which represents the maximum water saturation that a reservoir with a given permeability and porosity can retain without producing water was obtained using equation (6).

$$S_{irr} = \left(\frac{F}{2000}\right)^{\frac{1}{2}} \quad (6)$$

Where F = Formation factor

Formation factor was obtained using Humble's formula (equation 7) for unconsolidated formation of typical Niger Delta sandstone,

$$F = \frac{0.62}{\Phi^{2.15}} \quad (7)$$

Where Φ = Total porosity

3.2.4 Determination of Fluid Saturation (S_f)

Fluid saturation is the fractional volume of pore space (void) occupied by fluid. Mathematically expressed as:

$$S_f = \frac{volume\ of\ fluid}{volume\ of\ pore} = \frac{V_f}{V_p} \quad (8)$$

In this study, the following equations were used to determine the saturation of fluid present in the reservoir as thus:

$$S_w = \frac{volume\ of\ water}{volume\ of\ pore} = \frac{V_w}{V_p} \quad (9)$$

$$S_o = \frac{volume\ of\ oil}{volume\ of\ pore} = \frac{V_o}{V_p} \quad (10)$$

$$S_g = \frac{volume\ of\ gas}{volume\ of\ pore} = \frac{V_g}{V_p} \quad (11)$$

Where $S_w = Water\ saturation$

$S_o = Oil\ saturation$

$S_g = Gas\ saturation$

4. Results and Discussion

4.1 Results

Results of the petrophysical parameters are presented in tables 1 and 2 for well 1 and well 2 respectively.

Table 1: Petrophysical Parameters of Well 1

Shale Volume (%)	Effective Porosity (%)	Water Saturation (%)	Hydrocarbon Saturation	Net-to-Gross
0.0126 – 0.5294	0.0760 – 0.3019	0.1660 – 1.6740	0.0673 – 0.6645	0.7406 – 0.9674

Table 2: Petrophysical Parameters of well 7

Volume of Shale (%)	Effective Porosity (%)	Water Saturation (%)	Hydrocarbon Saturation	Net-to-Gross
0.0148 – 0.4668	0.0391 – 0.2010	0.2704 – 1.0013	0.0013 – 0.7296	0.5332 – 0.9653

4.2 Discussion

4.2.1 Well Log Interpretation

Results from the well log interpretation defined the lithology penetrated by the wells to be sand and sand-shale intercalation of Benin and Agbada Formations. The reservoir lithologies are dominantly sandstones and siltstones as shown in figures 1 and 2 for wells 1 and 7 respectively.

4.2.2 Petrophysical Interpretation

Petro-physical parameters were evaluated for all the reservoirs across the two wells. (Well 1 and Well 7). The reservoir parameters evaluated include: thickness, net-to-gross (NTG), effective porosity, volume of shale (V_{sh}), and fluid saturation [water saturation (S_w) and hydrocarbon saturation (S_h)].

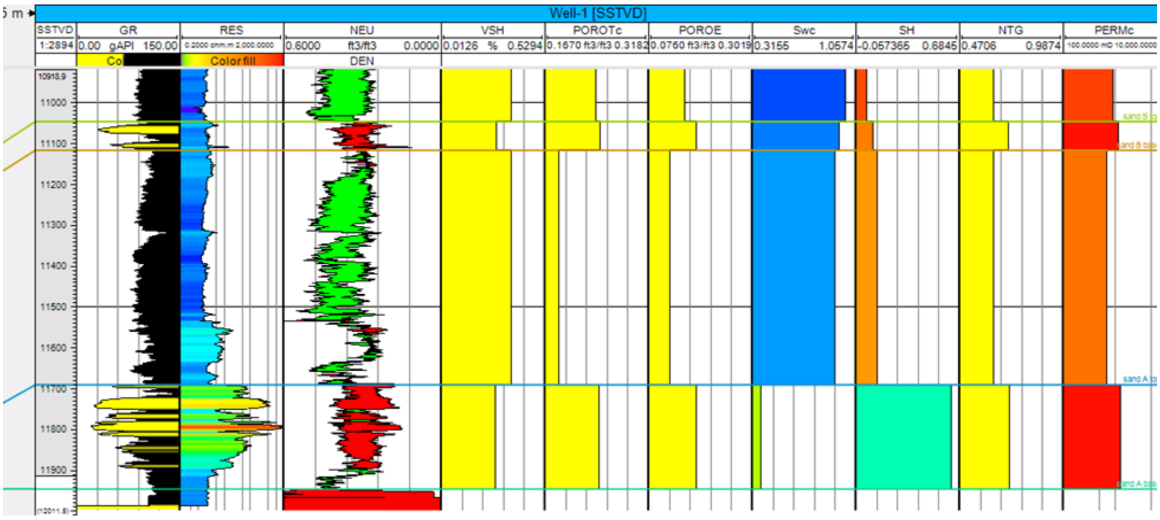

Figure 1: Display of Well Log and Reservoir for Well 1

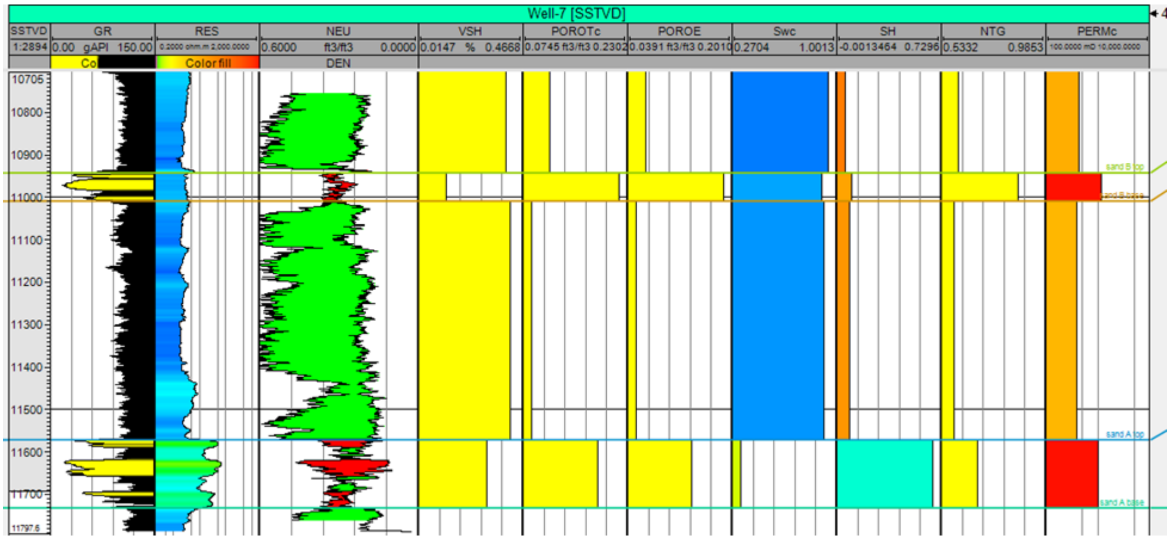

Figure 2: Display of Well Log and Reservoir for Well 7

5. Conclusion

The dominant lithology in the study area are sandstones, siltstones and shales. The volumetric analysis of identified reservoirs of the two wells (Well 1 and Well 7) carried out showed that the two delineated reservoirs were identified as hydrocarbon bearing units across the two wells.

Average value of reservoir parameters evaluated for porosity, water saturation and net to gross gave 0.1382, 0.3331 and 0.6898 respectively.

References

Asquith, G., and Krygowski, D., 2004. Basic Well Log Analysis, 2nd ed., Tulsa, Oklahoma: American Association of Petroleum Geologists, 1-2, Pp. 31-32.

Avbovbo, A.A., 1978. Tertiary Lithostratigraphy of the Niger Delta. American Association of Petroleum Geologists Bulletin, 62 (2), Pp. 295 – 306.

Cannon, S., 2017. Petrophysics: A practical guide. John Wiley and Sons Ltd, UK. Pp. 247 – 250.

Doust, H., and Omatsola, E., 1990. Niger Delta, in, Edwards, J. D. and Santogrossi, P.A. (eds.), Divergent/Passive Margin Basins, AAPG Memoir 48: Tulas. American Association of Petroleum Geologists, Pp. 239-248.

Dresser, A., 1979. Log Interpretation Charts. Dresser Industries Inc., Houston, Texas, Pp. 107.

Knut, B., 2010. Petroleum Geoscience: From Sedimentary Environment to Rock Physics. Springer Heidelberg Dordrecht London, New York.

Obiora, D.N., Gbenga, D., Ogobiri, G., 2016. Reservoir Characterization and Formation Evaluation of a "Royal Onshore Field", Southern Niger Delta using Geophysical Well Log Data. J. of Geol. Society of India, Pp. 591 – 600.

Okwoli, E., Obiora, D.N., Adewoye, O., Chukudebelu, J.U., Ezema, P.O., 2015. Reservoir characteriztion and volumetric analysis of Lona Field, Niger Delta, using 3-D seismic data and well log data. Petroluem and Coal, 57 (2), Pp. 108 – 119.

Owolabi, O.O., Longjohn, T.F. and Ajienka J.A., 1994. An empirical Expression for Permeability in Unconsolidated Sands of Eastern Niger Delta: Journal of Petroleum Geology, 17 (1), Pp. 111 – 116.

Schlumberger Educational Services, 1989. Log Interpretation Principles/Application. Schlumberger Educational Services: Houston. Pp. 13 – 19.

Schlumberger, 2000. Basic Well Log Interpretation. *Schlumberger Educational Services.*