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AN INFORMATION ON P_s FIELD RESERVOIR WORTH USING WELL LOG DATA IN THE NIGER DELTA BASIN

BY

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Abstract

In order to account for the geologic, engineering, economic valuation, its reserves, and their producibility of P_s Field reservoir, this research was carried out. Well, log data from wells Pp1, Pp2, and Pp3 were available for this study. The analysis and processing were made using Microsoft Excel. The appropriate petrophysical properties were determined and the research goal was achieved. The results obtained from well Pp1 include average values of Water Saturation, Porosity, and permeability as 23.3%, 21.4%, and 1468.8mD respectively. This means that 76.7% of hydrocarbon saturation is available with adequate connectivity of pores for accumulation and migration of reservoir fluids. For Pp2, the average of 26%, 29.5%, and 2318.3mD were the results respectively. Therefore, the hydrocarbon saturation is about 74% with a very good class of porous formation and hence, can store and transmit fluid. The averages noted from well Pp1 for Water Saturation, Porosity, and Permeability correspond to 19.14%, 23%, and 1428.13mD. In all the outcomes, the hydrocarbon potential of the P_s Field is very high. Its ability to store and transmit fluid is very good and commercially viable.

Keywords: *Gamma-ray, Porosity, Permeability, Shale volume, Water saturation, Hydrocarbon saturation*

INTRODUCTION

Reservoir quality may be seen as a qualitative assessment of the ability of a rock to produce fluid (it could be hydrocarbon). It controls the storage, spreading, and flow of fluids within a reservoir. Porosity and permeability are significant parameters that are measured on rock samples and from well logs (Slatt, 2013a; 2013b). Problems that could affect reservoir quality include fine fraction migration, acid sensitivity, and swelling clays. The hydrocarbon storage capacity and deliverability are considered. This storage capacity is categorized by the effective porosity (volume percentage of the interconnected pores in a rock) and the size of the reservoir; the deliverability is a function of the permeability. The remaining space in the rock is the matrix of the rock and, if present, nonconnected pore space. Log and core analysis derived porosity (total porosity) may be (Thom, 1991). The quality of an oil reservoir is also determined by the wettability as it affects the amount of water production. Moreso, the capillary pressure of a reservoir affects the size and circulation of water saturation and as well, the hydrocarbon volume. Compaction decreases the porosity and permeability of a rock as it causes grain rotation and reordering into a constricted packing formation, plastic deformation of ductile grains that flow into adjacent pores and pore throats, fracturing and crushing of brittle grains, and pressure solution in the form of grain suturing and stylolitization (McBride, 1984).

Imikanasua et al. (2022) have worked on Reservoir Quality in Field “D” in the Niger Delta and concluded that the formations are homogeneous and near irreducible water saturation. With the Field having a high potential for hydrocarbon production and accumulation. Agoha et al. (2021) were able to identify some reservoirs with high water saturation, although a good number have low water saturation. Ones with low water saturation were recommended as those with good prospects for hydrocarbon exploration and production. Adiela et al (2017), Adiela and Okumoko (2018), and Ameloko, and Oseghe (2013) are among those who have examined the petrophysical properties of reservoir rocks in different Fields using wireline logs in the Niger Delta basin.

This research goal is to delineate the petrophysical properties and describe the quality of the P_s Field reservoir. With precise information on the reservoir quality, an estimate may be made on commercial quantities of hydrocarbons availability. This involves a geologic, engineering, economic valuation, its reserves, and their producibility (Energy Glossary, 2024). Suites of logs of wells Pp1, Pp2, and Pp3 of the Ps Field are to be studied. Wireline logs could be lithology indicators (gamma ray, sonic, density, and neutron logs), porosity logs

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(sonic, density, and neutron logs), and fluid saturation logs (resistivity logs) (Asquith and Gibson, 1982; Reservoir quality, 2022).

LOCATION AND GEOLOGY INFORMATION

As documented in Atat et al. (2024), Reijers *et al.* (1996), Akpabio *et al.* (2023a), Atat et al. (2020a) and Umoren *et al*. (2019), the Niger Delta is located between latitudes 3º N and 6º N and longitudes 5º E and 8º E (Atat et al., 2023a). Everywhere in the region experiences two separate seasons: the wet and the dry (Atat et al., 2024; George *et al*., 2017; Atat *et al*., 2020b; Ejoh et al., 2023; Atat and Umoren, 2016).

Niger Delta region is a major source of hydrocarbon; more than 90% of oil and gas produced in Nigeria comes from the region (Usen, 2003). It is a region with an abundance of crude oil with a sediment thickness of nearly 500000 km^3 (Atat et al., 2024). This has been recognized in Atat et al. (2020c), Atat *et al.* (2020b), and Umoren *et al*. (2020). The basal Akata, the Agbada, and the Benin Formations are the three lithostratigraphic units observed (Atat et al., 2023b; Atat and Umoren, 2016) with the Agbada lying below the Benin formation (Atat et al., 2023b).

METHODOLOGY

The oil field of investigation is Ps. The wells are Pp1, Pp2 and Pp3. Suites of log were generated from the data obtained from the onshore oil field in the Niger Delta basin. Lithology (sand and shale) baseline was identified such that a gamma ray index greater than 65 API was noted for shale and gamma ray less than 65 API was marked for sand. Microsoft Excel was adequate for these processes. The colours for each parameter include: orange for gamma, blue for porosity%, green for permeability, brown for water Saturation, light blue for volume of shale, yellow for irreducible water saturation, black for hydrocarbon saturation, purple for gamma-ray index and red for effective porosity.

For calculated parameters, Equations 1 to 7 and 9 to12 are suitable and were employed for the outcomes of gamma ray index, volume of shale, total porosity, effective porosity, irreducible water saturation, formation factor, permeability, water saturation, hydrocarbon saturation, bulk volume of water and transmissivity respectively. Figure 1 presents the workflow of different stages of the study.

Determination of Gamma Ray Index (IGR)

The gamma-ray log may be used to identify lithologies. Shale-free sandstones have low concentrations of radioactive material resulting in low gamma-ray readings. Increase in the shale content in the formation leads to an increase in the gamma-ray log-response due to the high concentration of radioactive materials. Equation 1 was adequate for this finding (Schlumberger, 1974).

$$IGR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \qquad (1)$$

Where GR_{log} is the measured gamma ray log reading

GR_{min} is the minimum gamma-ray log reading in clean sand?

GR_{max} is the maximum gamma-ray log reading in clean shale?

Determination of shale volume (V_{sh})

The shale volume is a necessary parameter if effective porosity information is to be obtained; it may be calculated from the gamma-ray index (IGR) using Dresser (1979) formula (Equation 2) (Larionov, 1969).

$$V_{sh} = 0.083\left(2^{(3.7IGR)} - 1\right) \qquad (2)$$

Determination of porosity

Porosity **($\emptyset_T$)** may be seen as the ratio of volume of empty space (pore volume) to the volume of rock (bulk volume) in a formation; it may be expressed in fraction (Equation 3) (Schlumberger, 1989; Umoren et al., 2023; Umoren et al., 2024; Serra, 1984; Akpabio et al., 2023b) or percentage. It can be used to account for how much fluid a rock can hold. It is calculated from density, sonic, or neutron logs.

$$\emptyset_T = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \qquad (3)$$

Where $\emptyset_T =$ total porosity

ρ_{ma} = density of rock matrix = 2.65 g/cm^3 for sandstone

$\rho_b =$ measured or bulk density

$\rho_f =$ fluid density; taken as 0.85 for oil and 0.2 for gas

The effective porosity ($\emptyset_{eff}$) was achieved using Equation 4. It may also be obtained using Asquith and Gibson (1982) recommendation.

$$\emptyset_{eff} = (1 - V_{sh})\emptyset_T \qquad (4)$$

Where V_{sh} is the volume of shale.

Formation factor relates with the effective porosity and aids the outcome of irreducible water saturation to yield permeability. Equation 5 satisfies the finding of irreducible water (Adiela et al., 2017).

$$S_{wir} = (5 \times 10^{-4}F)^{1/2} \qquad (5)$$

F is the formation factor which is expressed mathematically in Equation 6 (Akpabio et al., 2023b).

$$F = \frac{a}{\emptyset_{eff}^m} \qquad (6)$$

Where a and m are tortuosity and cementation factors taken as 1 and 1.65 respectively in the computation.

Determination of Permeability (K)

Permeability is defined as the ability of a reservoir to conduct or transmit fluids through the rock matrix: it is the flow capacity of a reservoir. It is also the ability of a fluid to flow within the interconnected pore of a porous medium. If the pore is connected, they are said to be permeable.

The permeability of a given rock to the flow of a single homogeneous fluid is a constant, provided the fluid does not interact with the rock (Schlumberger,1989).

Equation 7 is the appropriate equation for this finding since it is an oil reservoir (Imikanasua et al., 2022).

$$K = 307 + \left(26552\emptyset_{eff}^2\right) - \left(34540 - (\emptyset_{eff}S_{wir})^2\right) \qquad (7)$$

If it were a gas reservoir, Equation 8 would have been suitable.

$$K = \left(30.7 + 2655\emptyset_{eff}^{2}\right) - 3454(\emptyset_{eff} S_{wir})^{2} \quad (8)$$

Where $S_{wir} =$ is the irreducible water saturation

K is the permeability

$\emptyset_{eff}$ is the effective porosity

Water saturation (S_w) is the measure of the pore volume of the rock filled with formation water, the water may be mobile or capillary bound. Equation 9 (Adiela et al., 2017) was used to estimate the water saturation.

$$S_w = \left(\frac{R_w}{R_t}\right)^{0.5} \quad (9)$$

Where R_w is the formation water resistivity or resistivity of water-bearing rock (about 0.269).

R_t is the true formation resistivity or the true resistivity of the rock.

Determination of hydrocarbon saturation

The hydrocarbon saturation was deduced from water saturation as stated in Equation 10.

$$HS = 1 - S_w \quad (10)$$

S_w is the water saturation.

Determination of bulk volume of water

If values of bulk volume of water calculated at several depths in a formation are constant or very close to constants, they indicate that the zone is homogeneous and at irreducible water saturation.

The product of a formation water saturation and porosity is the bulk volume of water (Equation 11) (Morris and Biggs, 1967).

$$BVW = S_w \times \emptyset_{eff} \quad (11)$$

Determination of Transmissivity

Transmissivity is the product of reservoir thickness and permeability. Equation 12 was used to calculate the fluid transmissivity.

$$T = R_{Th} K \quad (12)$$

Where T is the transmissivity

K is the permeability

R_{Th} is the reservoir thickness

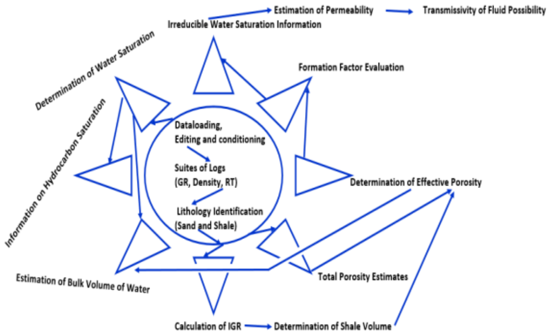

Figure 1: The Research Workflow.

RESULT AND DISCUSSION

Result

The research on the merits of P_s Field reservoir have been conducted. Figures 2 to 10 are the results of the study. Figures 2, 5, and 8 present the first stage of the results obtained from Wells Pp1 to Pp3 respectively. The outcomes of the irreducible water saturation, Water Saturation, hydrocarbon saturation, and effective porosity correspond to Figures 3, 6, and 9. Volume of shale, permeability, and gamma ray index (purple) information were assessed and findings presented in Figures 4, 7, and 10. Other necessary values obtained are deliberated in the discussion subsection.

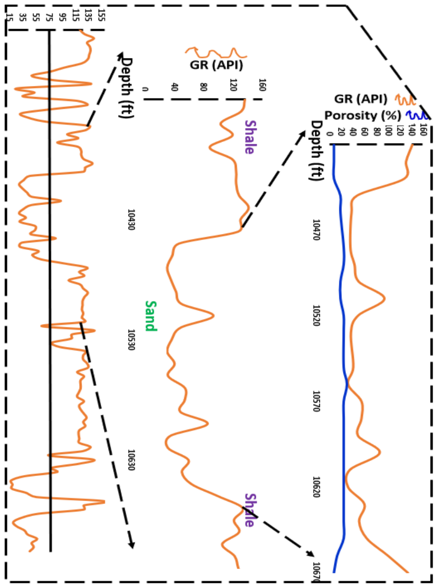

Figure 2: Well Pp1 curves of gamma-ray (orange) and porosity (blue).

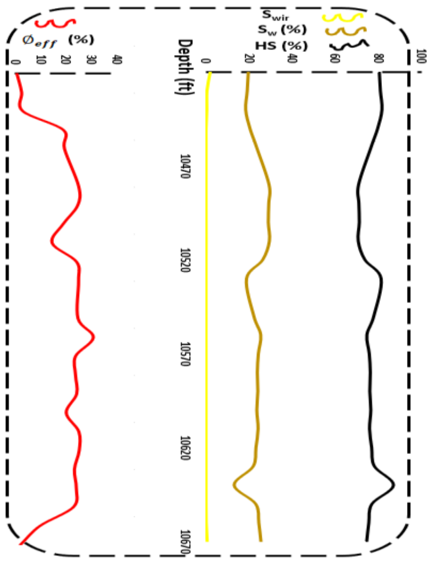

Figure 3: The curves of irreducible water saturation (yellow), Water Saturation (brown) and hydrocarbon saturation (black), and effective porosity(red) from Well Pp1.

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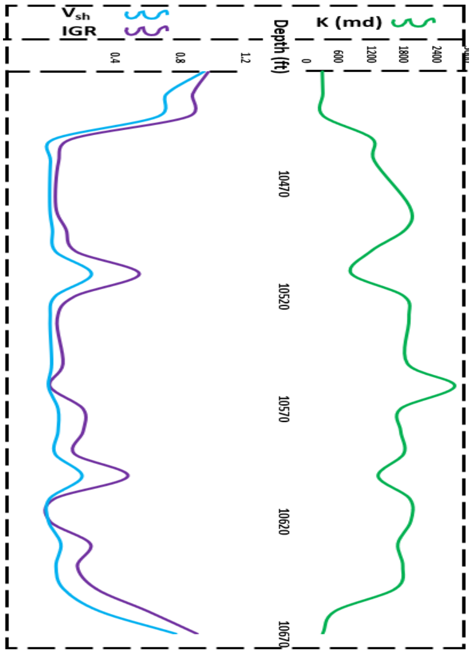

Figure 4: Well Pp1 outcome of the volume of shale (light blue), the permeability (green), and the gamma-ray index (purple).

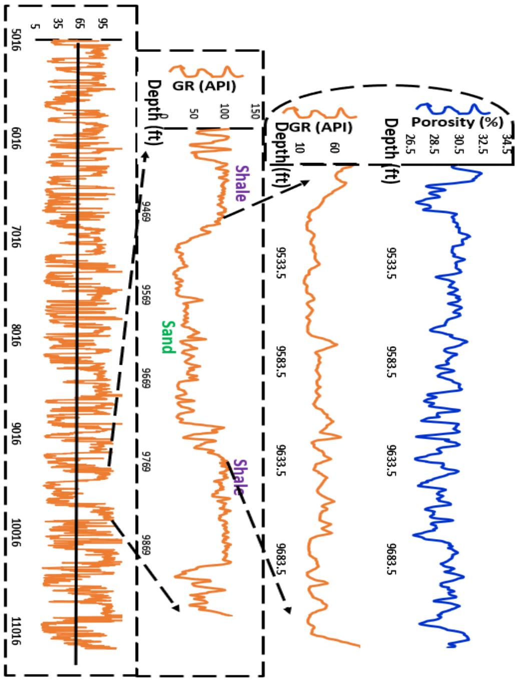

Figure 5: Well Pp2 curves of gamma-ray (orange) and porosity (blue).

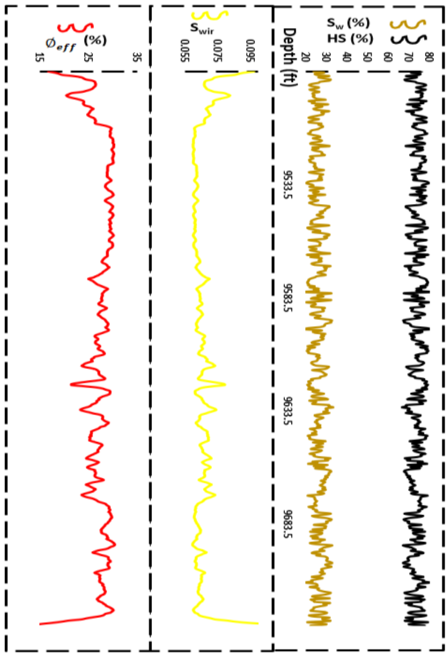

Figure 6: The curves of irreducible water saturation (yellow), Water Saturation (brown) and hydrocarbon saturation (black), and effective porosity(red) from Well Pp2.

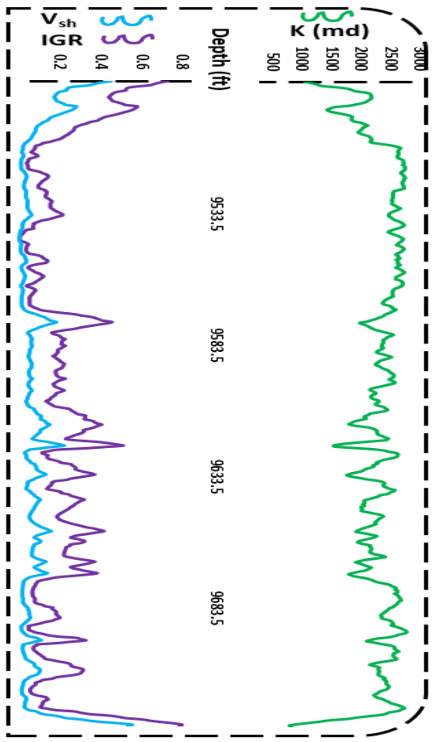

Figure 7: Well Pp2 outcome of the volume of shale (light blue), the permeability (green), and the gamma-ray index (purple).

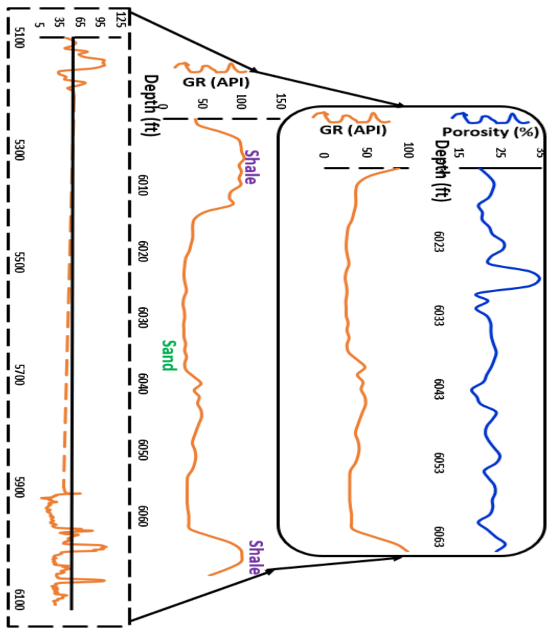

Figure 8: Well Pp3 curves of gamma-ray (orange) and porosity (blue).

Figure 9: The curves of irreducible water saturation (yellow), Water Saturation (brown) and hydrocarbon saturation (black), and effective porosity(red) from Well Pp3.

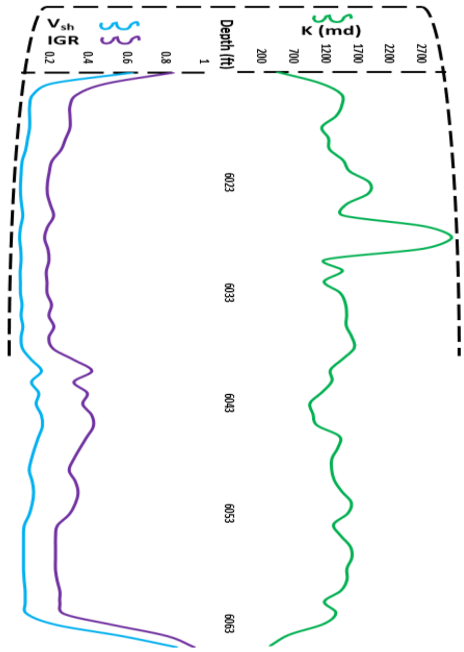

Figure 10: Well Pp3 outcome of the volume of shale (light blue), the permeability (green), and the gamma-ray index (purple).

Discussion

For Well Pp1

The Pp1 reservoir is at an interval of 10420ft to 10670ft such that its thickness is 250ft; the net thickness of sand is about 60ft and the volume of shale has an average value of 0.17. The average porosity value is 21.4% indicating a good class of porosity (Atat, et al, 2022). The average value of permeability is 1468.8mD signifying a good permeability value. The average value of irreducible water saturation is 0.2. The average value of water saturation is 23.3%. The hydrocarbon potential value is about 76.7% which indicates that the reservoir is very productive. The bulk volume of water shows 0.05 while the transmissivity value for the reservoir is 3720mDft.

For Well Pp2

The reservoir of well Pp2 is noted from 9483.5ft to 9728.5ft. The thickness of the reservoir is 245ft; the net thickness of sand is 181ft and the volume of shale obtained has the average value of 0.07. The average porosity value is 29.5% indicating good porosity class (Atat, et al, 2022). The average value for permeability is 2318.3mD which expresses good permeability information. The average value of irreducible water saturation is 0.07. The average value of water saturation is 26%; therefore, hydrocarbon is 74.0% which points to the reservoir being very productive. The bulk volume of water is 0.07; the transmissivity value of the reservoir fluid is about 567983.5mDft on average.

For Well Pp3

The depth thickness of the reservoir marked ranges from 6013ft to 6065ft. This gives a thickness as 52ft; the net thickness of the sand is 42ft with the volume of shale as 0.12 on average. The average porosity value is 23% and suggests a

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class of good porosity (Atat, et al, 2022). The average value of permeability is 1428.13mD and informs good and appreciable outcomes. The average value of irreducible water saturation is 0.18. The average value for water saturation is 19.14%. The hydrocarbon value is 80.86% which indicates that the reservoir is very productive. The bulk volume of water is 0.04; the transmissivity value of the reservoir is 567983.5mDft.

CONCLUSION

The research has revealed the reservoir worth of the wells Pp1, Pp2 and Pp3. The estimation of the necessary parameters has shown that the reservoirs are of good quality with huge hydrocarbon potential. They are highly porous and classified as good. The permeability and porosity information have indicated that the wells have the ability to accumulate and transmit fluid. The reservoirs net to-gross thickness and transmissivity are both appreciable.

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