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RESEARCH ARTICLE

ESTIMATION OF TOTAL OIL IN PLACE AND AREA EXTENT OF HYDROCARBON ACCUMULATION IN RESERVIORS FROM A NIGER DELTA BASIN OILFIELD USING PETROPHYSICAL PARAMETERS

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ABSTRACT

The purpose of this study was to use petrophysical parameters to estimate the Total Oil in Place (TOIP) and the area extent of hydrocarbon accumulations in reservoirs from an oilfield in the Niger Delta basin. During the project, each hydrocarbon bearing zone identified from two oilfield wells was measured for porosity, permeability, water saturation, reservoir thickness, and shale volume. Using the average results of petrophysical characteristics, twelve reservoir zones of interest (sand bodies) were identified, correlated throughout the field, and ranked. The area extents of the accumulations were then calculated using volumetric equations. It was determined that the recoverable oil reserves for Well-001 and Well-002 were 148.45MMBB and 145.91MMBB, respectively. The accumulation's respective area extents in W-001 and W-002 were determined to be 0.974 acres and 2.92 acres. According to the obtained results, we assert that there is oil and gas that may be exploited in the field under study. We also assert that W-001 may be more productive than W-002 in terms of oil accumulation, while W-002 has greater gas accumulations than W-001. The study's outcome is quite helpful since it gives field asset managers valuable insights they need to create their oilfield exploitation and recovery plans.

KEYWORDS

Petrophysical parameters, hydrocarbon reserve, well logs, volumetric method.

1. Introduction

A seismic section can readily map the area of hydrocarbon concentration, but study of a reservoir's petrophysical characteristics yields more accurate results. Finding porous and permeable beds, as well as their thicknesses, extents, and geometrical shapes, is of utmost importance in oil prospecting. In hydrocarbon-bearing reservoirs, petrophysical characteristics such as density, permeability, water saturation, porosity, and lithology all affect well productivity. Depending on the location of deposition and mechanisms that promote burial and transformation, the majority of oil and gas produced today is an accumulation from the pore spaces of reservoir rocks, which can include sandstone, limestone, or dolomites. The interaction between the pore spaces and pore throats determines the amount of hydrocarbon in place (hydrocarbon saturation), which in turn determines the hydrocarbon content of a reservoir, or the amount of oil or gas contained in a unit volume of a reservoir. Estimating the amount of hydrocarbon expected in a reservoir requires knowledge of the reservoir's extent or region of accumulation and its properties.

The method of estimating hydrocarbon reserves is intricate and requires combining engineering and geological data. The following techniques—volumetric, material balance, production history, and analogy methods—may be employed to estimate reserves, depending on the quantity and caliber of data available. In this paper, we employed the volumetric technique. The reservoir's thickness, pore space, and areal extension are among the details needed for this volume study (Ihianle, 2013). A geological model that geometrically depicts the volume of hydrocarbons in the reservoir serves as the foundation for volumetric estimates of original oil in place (OOIP) and original gas in place (OGIP). However, oil near the surface takes up less space than it does below because gas evolves from the oil as temperature and pressure drop. On the other hand, due to expansion, gas near the surface takes up more space than it does below. Subsurface volumes must therefore be converted to standard volume units determined at surface conditions (Wiki AAPG).

2. Field Geology And Characteristics

The Niger Delta basin is an extensional rift basin located on the passive continental margin close to Nigeria's western coast that spans the Niger Delta and the Gulf of Guinea (Tuttle et al. 2010). It encompasses the entire province of the Niger Delta, as stated by (Klett et al., 1997). Depobelts, which are the most active areas of the delta at each stage of development, are the result of the delta's southerly prograde from the Eocene to the present (Doust and Omatsola, 1990). With an extent of around 300,000 km^2, a sediment volume of 500,000 km^3, and a thickness of more than 10 km in the basin depocentre, these depobelts make up one of the largest regressive deltas in the world (Kulke, 1995; Hospers, 1965; Kaplan et al., 1994). There is just one recognized petroleum system in the province of the Niger Delta (Kulke, 1995; Ekweozor and Daukoru, 1994). The Tertiary Niger Delta (Akata–Agbada) petroleum system is the name given to this system (Avbovbo, 1978). With 2.2% of the world's discovered oil and 1.4% of its discovered gas, the Niger Delta province is the tenth richest in petroleum resources among the provinces listed in the U.S. Geological Survey's world energy assessment (Klett et al., 1997; Petroconsultants, Inc. 1996a). Geographically, the research wells are situated in the southern

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portion of the Niger Delta basin at 5º 57' 37.8259"N, 5º 40' 37.2805"E and 5º 58' 5.6227"N, 5º 40' 36.1624"E. The research area is located in Ethiope West L.G.A. of Delta State, on the Ovade axis of Oghara (Figure 1).

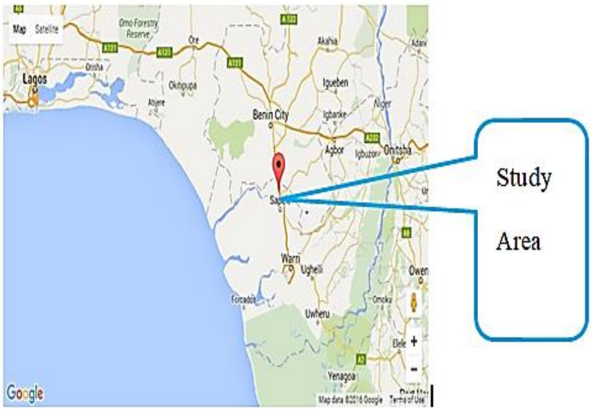

Figure 1: Map of the Niger Delta area showing location of the oilfield (study area).

3. METHODOLOGY

The log suites used in prosecuting the study included; gamma ray log, density log, spontaneous potential (SP) log and resistivity logs.

3.1 Determination of Shale Volume (Vsh)

By initially calculating the gamma ray index using equation 1 below, the shale volume was obtained from the gamma ray log.

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \tag{1}$$

where IGR is gammma ray Index, GRlog is gamma ray reading of the formation, GRmin is the minimum gamma ray reading (sand base line) and GRmax is maximum gamma ray reading (shale base line)

We adopted the shale volume formula (equation 2) for tertiary rocks because Niger Delta according toconsists of tertiary rocks (Larionov's, 1969).

$$V_{sh} = 0.083(2^{3.7I_{GR}} - 1) \tag{2}$$

where Vsh is the shale volume.

3.2 Determination of Total Porosity

Equation 3 was used to determine total porosity from the density porosity log:

$$\emptyset_T = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \tag{3}$$

where ρ_{ma} is the matrix density, which determined to be 2.65g/cc for sandstones (Dresser, 1979). The bulk density b is obtained straight from the log, whereas the fluid density f is assumed to be 1 for gas and 0.87 for oil.

3.3 Determination of Effective Porosity

Usually, effective porosity is calculated by adjusting total porosity using the estimated volume (content) of shale.

$$\emptyset_{eff} = \emptyset_T - [\emptyset_{sh} * V_{sh}] \tag{4}$$

where $\emptyset_{eff}$ = effective porosity, $\emptyset_T$ = total porosity, $\emptyset_{sh}$ = log reading in a shale zone and V_{sh} = Shale volume.

According to Baker (1992), the criteria for classifying porosity are shown in Table 1:

Table 1: Classification of porosity values

Porosity value	Classification
Ø < 0.05	Negligible
0.05<Ø < 0.1	Poor
0.1 < Ø < 0.15	Fair
0.15 < Ø <0.25	Good
0.25 < Ø<0.3	Very good
Ø >0.3	Excellent

3.4 Determination of Formation Factor, Water Saturation and Hydrocarbon Saturation

The formation factor was determined by equation (Archie, 1942).

$$F = \frac{a}{\emptyset^m} \tag{5}$$

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 equation (Archie, 1942):

$$S_w^2 = \frac{F * R_w}{R_t} \tag{6}$$

Recalling that $F = \frac{R_o}{R_w}$, equation 6 becomes

$$S_w = \sqrt{\frac{R_o}{R_t}} \tag{7}$$

S_w = water saturation of the uninvaded zone, R_o = Resistivity of formation at 100% water saturation, R_o = True resistivity of the formation and F = formation factor

Alternatively,

Water saturation can be written as:

$$S_w = \left(\frac{aR_w}{R_t \emptyset^m}\right)^{\frac{1}{n}} \tag{8}$$

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

Hydrocarbon saturation S_h is given as

$$S_h = (100 - S_w)\% \tag{9}$$

or in terms of unity (1) as expressed in equation 10.

$$S_h = 1 - S_w \tag{10}$$

3.5 Determination of Permeability and Irreducible Water Saturation

The permeability was calculated from equation 11:

$$K = \left[\frac{250 * \emptyset^3}{S_{wirr}}\right]^2 \tag{11}$$

where S_{wirr} = Irreducible water saturation.

The maximum water saturation that a formation with a specific permeability and porosity can hold without generating water is known as irreducible water saturation, or critical water saturation.

$$S_{wirr} = \sqrt{\frac{F}{2000}} \tag{12}$$

where F = formation factor and

$$F = \frac{0.81}{\emptyset^2} \tag{13}$$

3.6 Reserve estimation

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

$$OOIP = N_{(t)} = \frac{V_b \emptyset S_{o(t)}}{B_{o(P)}} \tag{14}$$

V_b = Bulk reservoir volume.

V_b = 7758Ah

where the constant 7758 is a conversion factor from acre-ft to barrel.

$$OOIP = N_{(t)} = \frac{RB\emptyset S_{o(t)}}{B_{o(p)}} = \frac{7758Ah\emptyset S_o(t)}{B_{o(p)}} = \frac{V\emptyset S_o(t)}{B_{o(p)}} \tag{15}$$

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

From equation (10),

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

$$OOIP = N(t) = \frac{V\emptyset[1 - S_{wo}]}{B_{o(p)}} \tag{16}$$

In equation 15, A = reservoir area in acres, h = average reservoir thickness expressed as a fraction (pay thickness from petrophysics), S_{wo} = water saturation, B_o = oil formation volume factor at reservoir pressure (reservoir bbl/STB).

4. Results And Discusion

We mapped horizons, delineated lithological units (sand and shale) as well as estimated relevant petrophysical properties namely; porosity, permeability, shale volume, water saturation, hydrocarbon saturation and net-to-gross ratio. Figures 2 and 3 shows the horizons and identified reservoirs of well 1 and 2 while figure 4 shows the stratigraphic correlation of the two wells. Table 2 provides a summary of average petrophysical properties for well 001 and well 002.

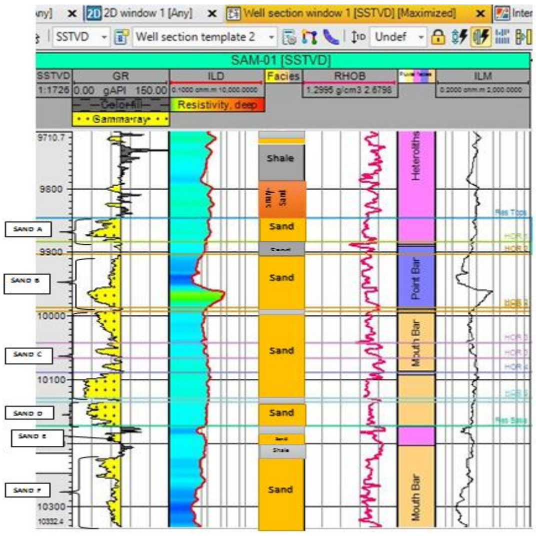

Figure 2: Horizons and identified reservoirs of W-001

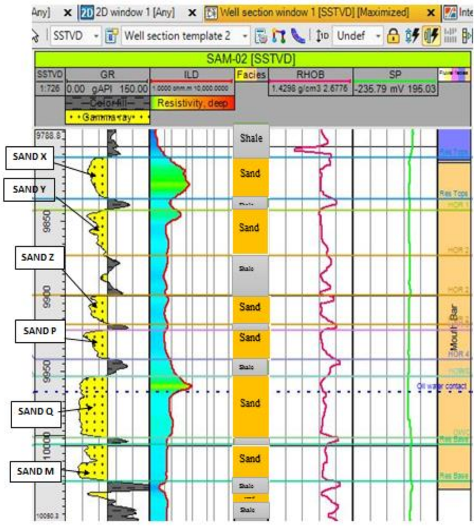

Figure 3: Horizons and identified reservoirs of W-002

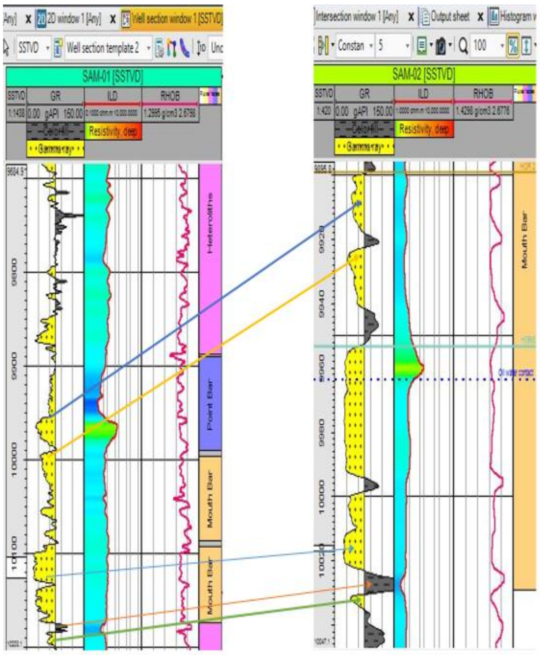

Figure 4: Stratigraphic correlation columns of W-001 and W-002

Table 2: Summary of average petrophysical properties of W-001 and W-002										
WELLS	**NTG (%)**	Vsh **(%)**	Sw **(%)**	Sh **(%)**	GRmin **(API)**	GRmax **(API)**	Koil **(mD)**	Ø **(%)**	**OWC (ft)**	STOOIP (STB)
W-001	85.6	12.1	36.80	63.20	3.29	163.97	1634.65	20.14	10016.75	52.04×106
W-002	69.5	34.12	38.07	61.93	8.76	259.1	1582.58	15.55	9964	51.55×106

The Stock Tank Original Oil in Place (STOOIP) = 52.04×106STB (17)

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

Therefore, the Stock Tank Original Oil in Place for W-001 in BBL is gotten using equation 17 as

STOOIP = 52.04 x 106 x 6.29 BBL

= 327.33MMBBL

The Stock Tank Original oil in place for W-002 in BBL is given by:

STOOIP = 51.55×106 x 6.29BBL

= 324.25MMBBL

4.1 Area Extent Determination

A. For W-001

Substituting the values for Well 001 in table 2 into equation 16 to calculate the volume of the reservoir, V

$\Phi = 0.2014, S_h = 0.603$

$V_1 = 1.766 \times 10^7 ft^3$

but the total thickness of the six reservoirs in well 001, h_1=415ft

Area (A1) extent of the accumulation $= \frac{V_1}{h_1}$

$A_1 = 0.974 acre$

B. For W-002

$OOIP = \frac{7758AH\Phi(1-S_{wo})}{B_O}$

From Table 2, $\Phi = 0.1555, S_h = 0.6193$ and $h_2 = 173ft$

h_2 is the total thickness of the six reservoirs in W-002

$V_2 = \frac{OOIP \times B_o}{7758\Phi(1-S_{wo})}$

$V_2 = 2.2 \times 10^7 ft^3$

Area (A_2) extent of the accumulation $= \frac{V_2}{h_2} = \frac{\mathbf{2.2 \times 10^7 ft^3}}{173ft}$

$A_2 = 2.92acre$

5. Conclusion

This work has presented a concise methodology to estimate the area extent of hydrocarbon accumulation from well logs in the absence of seismic data unlike other methods that require seismic data integration. Porosity, permeability, water saturation, reservoir thickness, and shale volume are examples of petrophysical parameters that have been assessed for each well's designated hydrocarbon bearing zone. To assess the hydrocarbon reserves in each well, the data have been quantitatively interpreted and subjected to additional analysis. The volumetric method of reserve estimation using well logs is absolutely a quick and reliable way of evaluating the reserves of any oilfield. We observed that the field has great hydrocarbon potential. This is further supported by our computed reserves estimates of 148.45MMBB and 145.91MMBB as recoverable hydrocarbon reserve for Well-001 and Well-002 corresponding to 0.974 acres and 2.92 acres as area extents of accumulation in Well-001 and Well-002 respectively. This result would aid asset managers of the field to begin the implementation of drilling and exploitation programs in the oilfield.

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Conflict Of Interest

The authors declare no conflict of interest.

Authors Contributions

The three authors conceived and designed the work, performed the data processing, analysis and interpretation. The first author and third author subsequently wrote the first draft and second drafts of the paper respectively, while the second author vetted, edited and made modifications and additions to the manuscript and now serves as corresponding author. All the authors approved the manuscript in its current form.

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