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Reservoir Characteristics Estimation of the Alakiri Field, Niger Delta, Nigeria, Using Well Log Data

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Abstract

In order to mitigate the problems associated with facies within tight reservoirs, this study estimates the petrophysical properties of the Alakiri field using well log data and Petrel software. Gamma ray and resistivity logs were integrated to delineate and correlate two probable hydrocarbon-bearing zones. Sand and shale lithofacies were the two lithologies delineated with varying intercalation. Porosity, permeability, shale volume, fluid saturations, and net pay thickness were the estimated petrophysical properties within the reservoir intervals. Results show that the reservoirs were located at depths 3300-3445m and 3305-3485m for wells OTIG-2 and OTIG-7, respectively. From the analysis of the findings, the reservoir B interval has the best petrophysical properties and hence, better hydrocarbon potential. This is due to its relatively high average porosity (20%), permeability (206 mD), and hydrocarbon saturation (0.7), as well as less volume of shale (0.3) and water saturation (0.3). Again, the estimated porosity >12% and permeability <1000mD classified the reservoir as a tight reservoir. Furthermore, due to the average NTG value of 0.7 and volume of shale of 0.3, with high hydrocarbon saturation of 0.7 and water saturation not more than 0.3, the reservoir is said to be a clean sand reservoir. Thus, reservoir B possesses the best petrophysical property deposition in this field. It is recommended that the findings of this study be adopted during field planning and development. Again, a further investigation deploying the integration of well and seismic data sets should be undertaken to ascertain the general lithostratigraphy of the entire field.

Keywords: Reservoir, Porosity, Permeability, Alakiri Field, Fluid Saturation

Introduction

In the oil and gas industry, one of the ultimate goals is to explore and produce hydrocarbons in an economically safe and environmentally friendly manner. This is geared towards the reduction of the operational cost and environmental geohazards associated with hydrocarbon exploration, as well as providing practical solutions to affordable and clean/sustainable energy practices, responsible consumption and production of energy resources enshrined in goals seven (7) and twelve (12) of the United Nations (UN) 2030 agenda for Sustainable Development Goals (SDGs). As the energy demand of the globe continues to grow exponentially due to improved standards of lifestyle associated with technological advancement and breakthroughs, so also are the challenges associated with exploration and development of new fields (Bayowa et al., 2020). As a result, the estimation of the reservoir properties of these new fields becomes paramount. This is because oil exploration has gradually shifted to more challenging environments, and thus the need to reduce exploration uncertainty and maximize recovery if supply is to keep up with demand. This need has therefore engendered a multidimensional approach to reservoir evaluation, which combines geophysics, geology, petrophysics, reservoir engineering and geo-statistics for detailed evaluation of reservoir properties (Aigbofun et al., 2020; Olawale et al., 2018).The integration of various discipline such as complex structural interpretation, seismic and sequence stratigraphy, core and log data, basic geological knowledge and depositional facies and environment modeling which are all critical parts in the building of reservoir geological model are the dependent variables for the success of the characterization process (Kalu et al., 2020). The petrophysical reservoir properties of this field are of interest in this study.

Any rock that has enough porosity and permeability to enable hydrocarbon to accumulate and be produced in commercial quantities is said to be a reservoir (Rubaya et al., 2017). According to Ulasi et al. (2012), a reservoir

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is a subsurface rock that has effective porosity and permeability that contains commercially exploitable quantity of hydrocarbon. Reservoir evaluation and characterization are undertaken to determine the rocks ability to both store and transmit fluid. Reservoir characterization integrates all available data to define the geometry, distribution of physical parameters, and chemical properties of reservoirs (Rubaya et al., 2017). It is the process of mapping reservoir properties and it provides the understanding of the geometry of reservoirs and how it reacts to the production strategy (Ajisafe & Ako, 2013).

The petrophysical properties of rocks are those that measure the characteristics used in describing both the physical and chemical behaviour of rocks (Mahdi & Farman, 2023). Porosity (ϕ), permeability (K), saturations (both water and hydrocarbon), volume of shale (VSH), and net-to-gross reservoir thickness are the reservoir properties of interest in this study. In geosciences, any rock with good porosity and permeability for hydrocarbon accumulation in commercial quantities is said to be a reservoir. (Rubaya et al., 2017). The accurate estimation of these properties lies at the basis of the well performance and general characterization of the oil fields. The reservoir facies evaluation (Ogbuagu & Igbor, 2025a), reservoir compaction delineation (Ekone et al., 2020), reservoir geomechanical characterization (Ogbuagu et al., 2025), and other technical challenges in geosciences have been mitigated using the petrophysical properties investigation. Furthermore, the understanding of the relationships between rock and fluids within the reservoirs all lies in the determination of the petrophysical properties of the reservoirs. This provides a comprehensive understanding of the entire field when accurately estimated. In the Niger Delta basin, several investigations on the petrophysical properties determination have been undertaken (Ameloko & Owoseni, 2015; Adiela & Okumoko, 2019; Ekone et al., 2020; Lawson & Balogun, 2023; Opiriyabo & Akpan, 2024; Ogbuagu & Igbor, 2025a). However, from the literature, no such investigation has been carried out in this oil field, Alakiri, to the best of our knowledge.

Thus, this study intends to fill this gap discovered in the literature by estimating the petrophysical properties of this oil field using well log data. This is aimed at using the estimated properties for the hydrocarbon potential evaluation of the reservoirs, as well as the general well performance investigation of the entire field. The determination of porosity, permeability, shale volume, various fluid saturations, NTG, as well as the delineation of permeable and non-permeable zones of the formations are the key objectives of this study.

Location and Geology of the Study Area

The Alakiri oil field is located in Okirika, Niger Delta, delineated by latitude 4.00°N-6.00°N and Longitude 4.00°E-8.00°E (Figure 1). The Niger Delta is known to be a river dominated basin from the post Oligocene. Typical, it is a wave-dominated basin with well-developed shore face sands, beach ridges, tidal channels, mangrove, and fresh water swamps (Doust & Omatsola, 1990). Lithostratigraphically, it is one of the world's largest Deltas and shows overall upward transition from marine shale (Akata Formation) through a sand/shale paralic interval (Agbada Formation) to continental sands of the Benin Formation (Whiteman, 1982; Asadu et al., 2015).

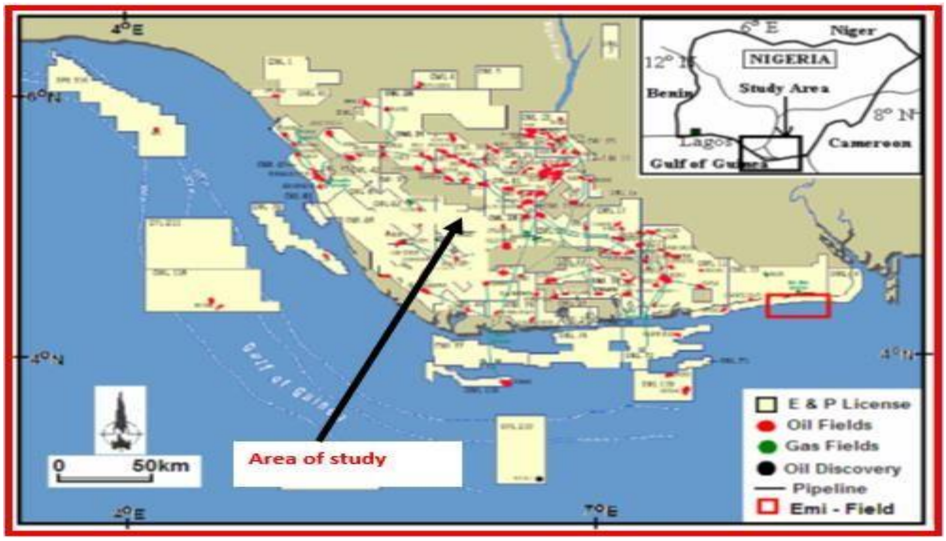

Figure 1. Study Area Map (Nton & Esan, 2010)

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Materials and Methods

The study utilized suites of well logs (comprising the caliper, density, gamma ray, resistivity, and Neutron-porosity logs), Schlumberger 2014 Petrel software, a laptop, and Microsoft Office packages. The well log data sets were provided by the oil company operating in the study area under a bilateral confidentiality agreement.

After the importation of the two wells (OTIG 2 and OTIG 7) into the software, a detailed quality check and editing were done for good log signature display. The integration of gamma ray and resistivity logs was then used for the reservoir delineation and correlation. From the correlated reservoirs, the relevant petrophysical properties were estimated and evaluated using relations found in literature, as well as software's built-in relations.

Results Presentation

The results of this study are presented in two distinct categories: reservoir identification and correlation, and petrophysical properties estimation and evaluation.

Reservoir Identification and Correlation.

Using the integration of gamma ray and resistivity logs, two probable hydrocarbon-bearing reservoir intervals were delineated and correlated across wells OTIG 2 and OTIG 7 (Figure 2). The reservoirs were located at depths 3300-3445m and 3305-3485m for wells OTIG 2 and OTIG 7, respectively. The well correlations were done to reveal the general stratigraphic continuity and equivalent reservoir identification of the entire field (Opiriyabo & Akpam, 2024; Ogbuagu & Igbor, 2025a). The top and base of the reservoirs were marked and designated as Sand A/B-Top and Sand A/B-Base, respectively. The delineated reservoir intervals are made up of the intercalation of sand and shale lithofacies.

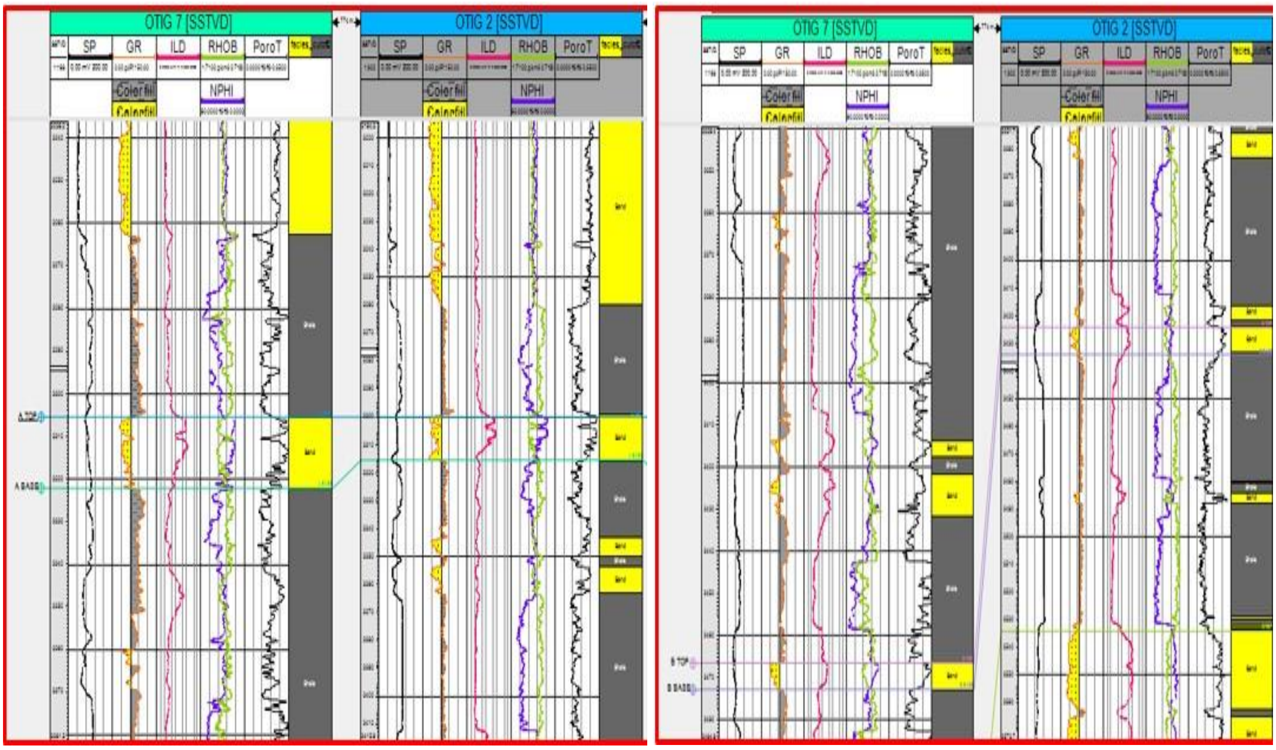

Fig. 2. Identified and Correlated Reservoirs

Petrophysical Properties Estimation and Evaluation

From the correlated reservoirs, the petrophysical properties within the two delineated reservoir intervals were estimated and evaluated (Figures 3 and 4; Tables 1 and 2). Volume of shale (VSH), net-to-gross ratio (N/G), porosity (ϕ), irreducible water saturation (Swirr), water saturation (Sw), hydrocarbon saturation (SH), and permeability (K) are the estimated petrophysical properties. Results show that the reservoir B interval has the best petrophysical properties and hence, better hydrocarbon potential due to its relatively high average porosity (20%), permeability (206 mD), and hydrocarbon saturation (0.7), as well as less volume of shale (0.3) and water saturation (0.3). This suggests that the reservoir B interval possesses the best hydrocarbon potential in the field and can be adopted for further investigation.

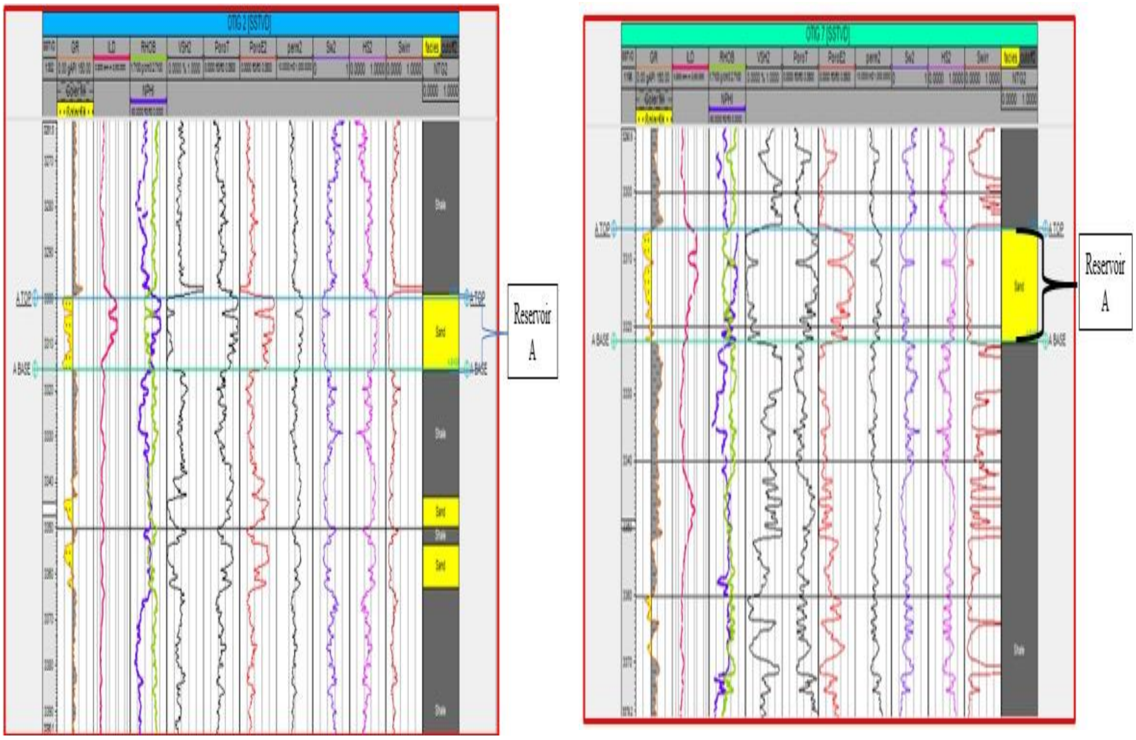

Fig. 3. Estimated Petrophysical Properties for Reservoir A

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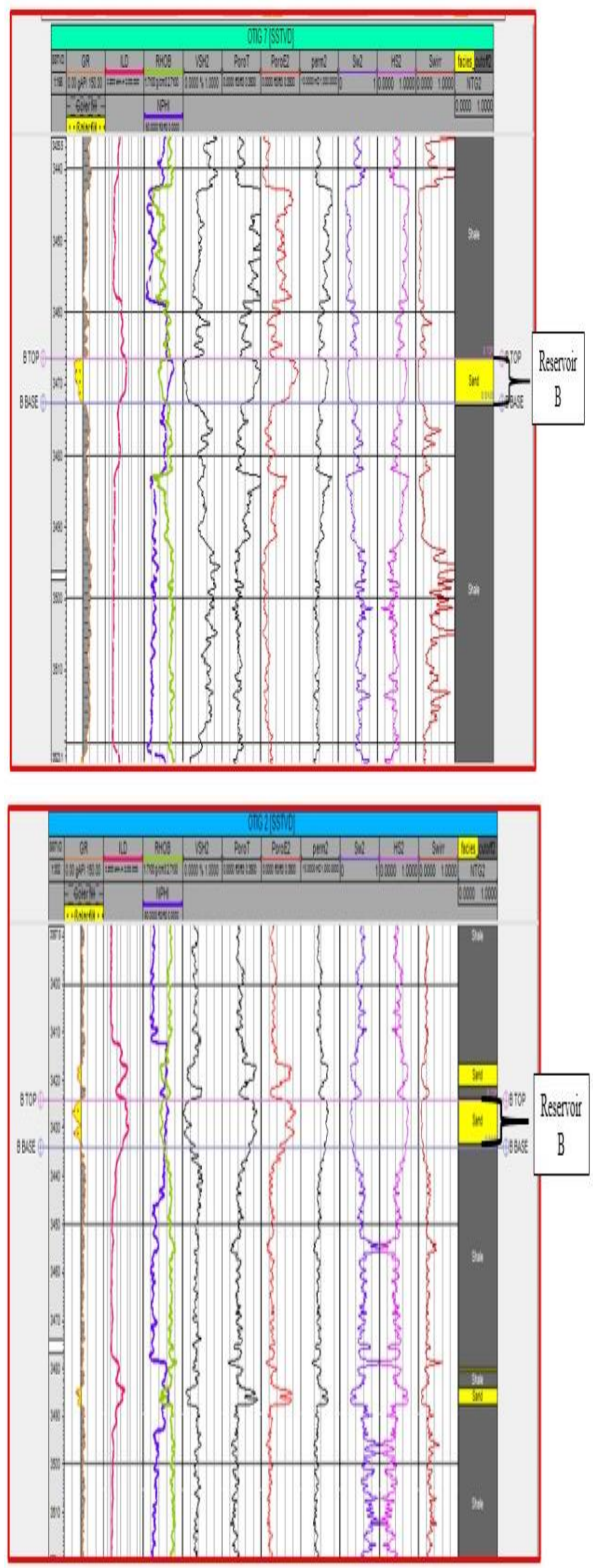

Fig. 4. Estimated Petrophysical Properties for Reservoir B

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Table 1. Petrophysical Properties for Reservoir A

Well	Top (m) Base (m)	Thickness (m)	Net thickness of sand (m)	Vsh	N/G Ratio	ϕ (%)	Swirr	S_w	S_H	K (mD)
OTIG2	3300 3320	20	8	0.2	0.8	20	0.14	0.4	0.6	152
OTIG7	3305 3330	25	7.5	0.5	0.5	14	0.12	0.4	0.6	241

Table 2. Petrophysical Properties for Reservoir B

WELL	Top (m) Base (m)	Thickness (m)	Net thickness of sand (m)	Vsh	N/G Ratio	ϕ (%)	S_{wirr}	S_w	S_H	K (mD)
OTIG2	3425 3445	20	15.6	0.2	0.80	20	0.14	0.3	0.7	171
OTIG7	3460 3485	25	5	0.4	0.6	20	0.12	0.3	0.7	241

Discussion

As a core characteristic of the Niger Delta basin (most especially the hydrocarbon-rich Agbada formation), the lithology of the Alakiri field was found to be heterogeneous in nature (Adiela & Okumoko, 2019; Kamayou et al., 2021). Results depict that the delineated reservoirs were composed of sand (predominantly) and shale lithofacies with varying intercalation (Figure 2). Similar studies in the basin (Niger Delta) revealed similar results (Ulasi et al., 2012; Omudu & Ebeniro, 2016; Adeyemi, 2018; Aigbogun, 2020; Ogbuagu & Igbor, 2025a). Again, the result of the well correlation shows that each sand unit extends along the length of the field and exhibits variations in thickness, with certain units being shallower or deeper than their adjacent counterparts. This is evident in the values of the estimated petrophysical properties (Tables 1-2). The connectivity and depositional heterogeneity of the reservoirs could be fingered as the causative factors of these variations (Doust & Omatsola, 1990; Reijers, 2011).

It has been reported that any reservoir with porosity >12% and permeability <1000mD is said to be a tight reservoir (Ekone et al., 2020; Lawson & Balogun, 2023). Results show that the average porosity and permeability are 20% and 206 mD, respectively. This suggests that the reservoirs in this field are said to be tight reservoirs. Again, due to the average NTG value of 0.7 and volume of shale of 0.3, with high hydrocarbon saturation of 0.7 and water saturation not more than 0.3, reservoir B interval is said to be a clean sand reservoir (Lawson & Balogun, 2023). This depicts that reservoir A is the best hydrocarbon-saturated interval in the field.

Conclusion

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The estimation of the petrophysical properties of the Alakiri field using well log data has been undertaken. Results show that the delineated reservoir intervals are heterogeneous in nature and predominantly sands, with varying shale intercalation. The analysis of the results reveals that reservoir B has the best petrophysical property deposition, and it is said to be a tight and clean sand reservoir.

Recommendations

1. It is recommended that the findings of this study be adopted during field planning and development within the study area.
2. Again, a further investigation deploying the integration of well and seismic data sets should be undertaken to ascertain the general lithostratigraphy of the entire field.

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