Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(6):17-24**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Reservoir Characterization and Structural Mapping of UVO Field, Onshore Niger Delta using Well Logs and 3-D Seismic Data

Peter, S. Ola, *Abdulquadri, O. Alabere

Department of Applied Geology, Federal University of Technology, Akure, P. M. B. 704, Akure, Ondo State, Nigeria

Abstract Reservoir characterization and structural mapping using integration of well logs and 3-D seismic data was carried out to determine the prolificacy of OVU field, onshore Niger delta. The distribution of reservoir physical parameters (porosity, permeability etc.) and availability of traps that favour hydrocarbon accumulation in the field were evaluated. Four hydrocarbon bearing reservoirs were delineated out of several identified sands in the field out of which three horizons were mapped. Two major growth faults, an antithetic fault and five synthetic faults were delineated. Structural closures were identified as rollover anticlines with the trapping mechanism delineated as a Fault assisted anticlinal structure. The computed range of values for gross thickness, volume of shale, net to gross, water saturation, hydrocarbon saturation, total porosity and absolute permeability with respect to each reservoir are: 18-125m, 9 -17%, 83-92%, 18–28%, 62- 82%, 21 – 23%, and 736-3965mD respectively. Hydrocarbon reserves calculations reveals a total reserve of 30.9 billion stock tank barrels of oil.

With the very good to excellent calculated values of petrophysical parameters and high hydrocarbon reserve together with the suitable trapping mechanisms makes the study field prolific. Few wells exist in the southwestern corner of the field where a closure is identified in this study. The area should therefore be subjected to further evaluation with a view to increasing the number of wells there.

Keywords Agbada Formation, Growth fault, Petrophysics, Rollover anticlines

1. Introduction

Pressure on resources due to increasing demand of oil and gas worldwide coupled with rapid depletion of known reserves has necessitated increased exploration of new areas and refining and reprocessing of data from previously explored areas so as to reveal new prospects and better characterize existing ones. The largest component of spending in an exploration program is driven by the need to characterize (potential) reservoirs. This is because better reservoir characterization means higher success rates and fewer wells for exploitation of discovered deposits. Integration of seismic and petrophysical data is the best approach in use to characterize reservoirs and estimate reserves in oil fields for effective productivity. The deposits yet undiscovered both in new and old acreage particularly in an oil province like the Niger Delta are in more complex geological environments and hence the need to reappraise oil fields with high resolution seismic reflection methods and wireline log in an integrated approach. Works done on the Niger Delta basin reveal that the structural configuration and stratigraphy of the basin depends on the interplay between rate of sediment supply and subsidence [10];[8]. Most structural traps observed in the Niger Delta were formed during the syn-sedimentary deformation of the AgbadaParalic sequence [6]. Recent works includes [1] that revealed stratigraphic plays as pinch-outs, unconformities, sand lenses and channels with anticlinal closures as good hydrocarbon prospect; [13] which showed that most reservoir sand lies within marginal marine environment with porosity and permeability ranging from good to excellent; and [2]that revealed the trapping mechanism to be mainly fault assisted anticlinal closure and transitional-to-deltaic depositional environment for the sand facies.The objective of this research is to reappraise OVU field for its petroleum potentials. This research involves characterizing known reservoirs and determination of trapping mechanism in the field with the aim of finding new areas on the field where new wells can be located for effective draining of all the hydrocarbon in the field. Unfortunately production history is not provided for this study which is also limited to the available data.

1.1 Location of the study area and Geologic Setting

UVO field is an onshore oil field in the western Niger Delta region, located in the southern part of Nigeria (Fig. 1). It is located between longitudes 4^{o}15”30”E and 4^{o}25$^{”}$20$^{”}$ E and latitudes 5^{o}12”15”N and 5^{o}15”25”N. The base map of OVU field and the spatial distribution of the wells are as shown in Figure 2. Niger Delta according to [11] is situated within the Gulf of Guinea province with extension throughout the Niger Delta Province. It is situated on the West African continental margin at the apex of the Gulf of Guinea, which formed the site of a triple junction during continental break-up in the Cretaceous [8]. It is a clastic fill of 12,000m with an aerial extent of 75,000sqkm and extending more than 300km from the Apex to the mouth [10]; [14].It has a single petroleum system- the Tertiary Niger Delta (Akata-Agbada) petroleum system [18]. The Niger Delta is a prolific hydrocarbon belt in the world whose formation was initiated during the tertiary [9]; [7]. The delta proper began developing in the Eocene, accumulating sediments that are now over

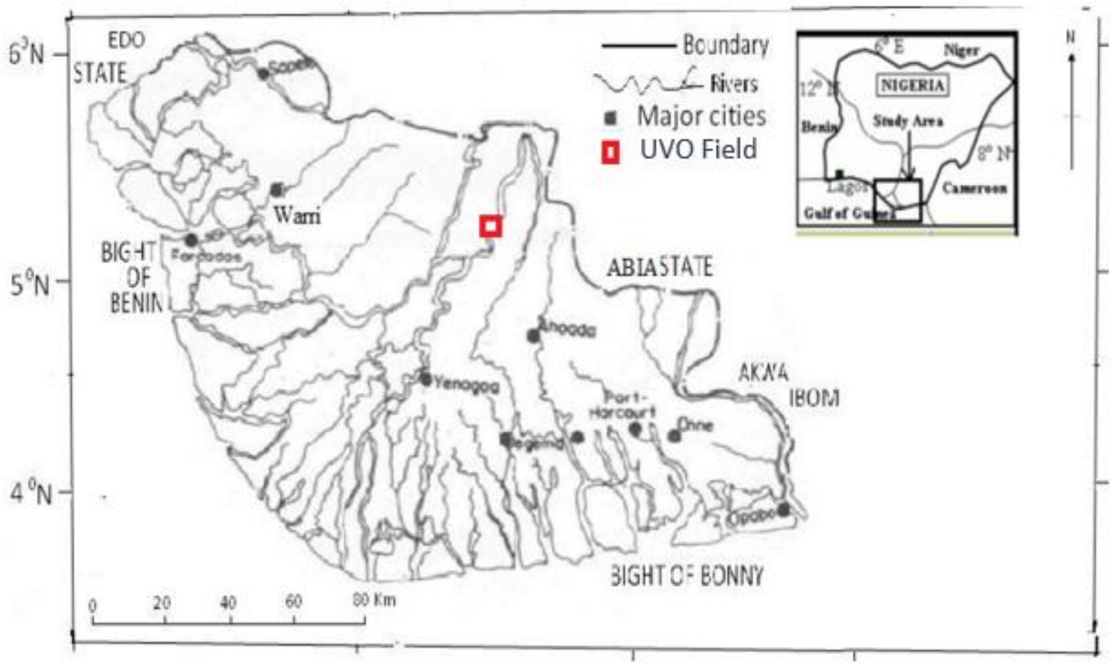


Figure 1: Location Map of study Area (UVO field) in the Niger Delta [12]

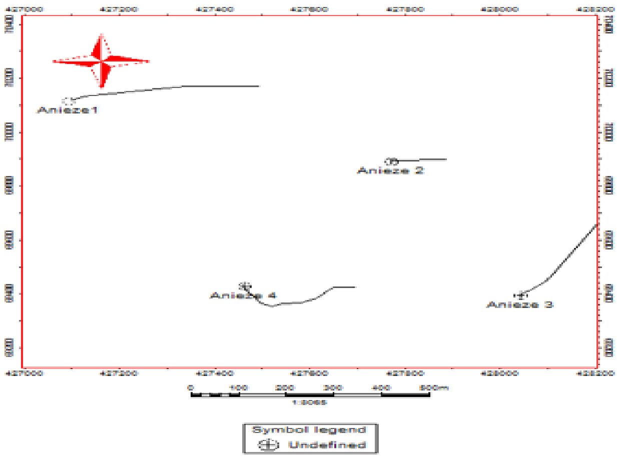


Figure 2: Base Map of UVO Field showing the distribution of wells

10km thick [18]. From the Eocene to the present, the Delta has prograded southwards, forming depobelts that represents the most active portion of the Delta at each stage of its development [8]. [16]identified three lithostratigraphic sub-division for the Tertiary section of the Niger Delta subsurface comprising of Akata, Agbada and Benin Formations from bottom to the top (Fig. 3).These authors observed that the units which are strongly diachronous represent Marine, Paralic siliciclastic, and Continental Facies respectively. Deposition of the three formations occurred in each of the five offlappingsiliclastic sedimentation cycles that comprise the Niger Delta [20] and [19]. Akata is composed of thick shale sequence, clay, silt and minor intercalations of turbiditic sand about 7000 km thick in the central delta and of probable marine origin [8]. It has a sand percentage of less than 30% and assumed to have been formed by transportation of terrestrial organic matter and clays to deep waters at the beginning of the Paleocene [18]. It is the major source rock with possible contribution from the interbedded marine shale of the lowermost Agbada Formation [17]. Agbada Formation is the major reservoir unit consisting of intercalation of sand and shale with over 3700 meter thick and ranges in ages from Eocene to Pleistocene. It is the transition zone with sand percentage ranging from 30 to 70% and represent the deltaic portion of the Niger Delta sequence [8] and[18]. In the lower Agbada Formation, sands and shales were deposited in equal proportions whereas in the upper part, there is more sand with minor shale intercalations [4]. Petroleum occurs throughout the Agbada Formation of the Niger Delta, however several directional trends form an “Oil-rich belt” having the largest Field and lowest gas: oil ratio. The belt coincides with the boundary between the continental and oceanic crust and forms in areas of thickest sedimentary fill [10]. Benin Formation is the uppermost layer of the Niger Delta depositional sequence characterized by high sand percentage (70–100%) deposited in continental environment comprising the fluvial realms (braided and meandering systems) of the upper delta plain. The oldest continental sand is Oligocene in age and it is still currently depositing with thickness of about 2000m thick [8] and [4].

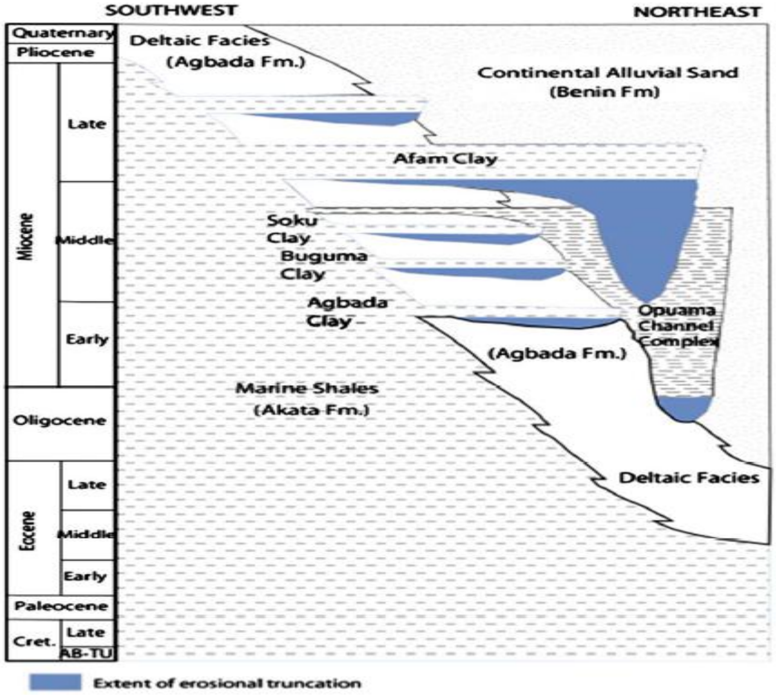


Figure 3: Stratigraphic column of the Niger Delta Basin [15].

According to [8], most common hydrocarbon traps are structural and developed as a result of synsedimentary deformation before migration took place. The severity of structural complexes increases from the Northern delta and Greater Ughellidepobelt to the structurally complex Central swamp and offshore depobelts were the influence of mobile undercompacted shale became very pronounced. The most striking structural features of the Niger Delta are the large syn-sedimenatry growth faults, rollover anticlines and shale diapirs which deformed the delta complex [10]. The types of growth fault are synthetic fault, antithetic fault, collapsed crest fault, and multiple growth faults.

3. Materials and Methodology

Data used for this study includes four (4) composite geophysical well logs, seismic section with inline ranging from 5577-5850 and X-line ranging from 1495-1750, check shot data and base map of the field. The well logs includes gamma ray, resistivity, neutron, density and sonic logs. Lithology delineation, correlation and separation of reservoir rocks from non-reservoir rocks were done using gamma ray log. This gives an idea of lateral continuity of reservoirs on the field and depth variation of reservoirs in each well. Resistivity logs were used to separate hydrocarbon bearing intervals from non-hydrocarbon bearing interval while the combination of Neutron and density logs was used to differentiate gas bearing from oil bearing sand intervals. Petrophysical parameters obtained during the course of the research work includes porosity, permeability, net thickness, net pay thickness, volume of shale, hydrocarbon saturation, water saturation, movable oil saturation, residual oil saturation, effective and relative permeability to oil and effective and relative permeability to water. Structural interpretation was carried out using PETRELTM 2009 software on 3-D seismic data volume.

The inline and crossline ranges from 5577 to 5850 and 1495 to 1750 respectively. The Structural interpretation involves mapping out faults which were identified based on displacement of events and discontinuities in reflections. Bulk density from density log was multiplied by acoustic velocities from sonic log to generate the acoustic impedance log. Wavelet extracted from the seismic data volume was matched with acoustic impedance to generate synthetic seismogram (Fig. 4) for UVO-4 well which was used to perform the seismic to well tie that indicated horizons of interest. Three (3) hydrocarbon bearing horizons were mapped across the field and used in generating time structural contour maps. Velocity model was generated using check shot data and was used to perform time to depth conversion and hence generate depth structural map. Suitable traps and structural closures that favours large accumulation of hydrocarbon were identified from the structural contour maps. Areas covered by the hydrocarbon was calculated and used in estimating reserves for the field.

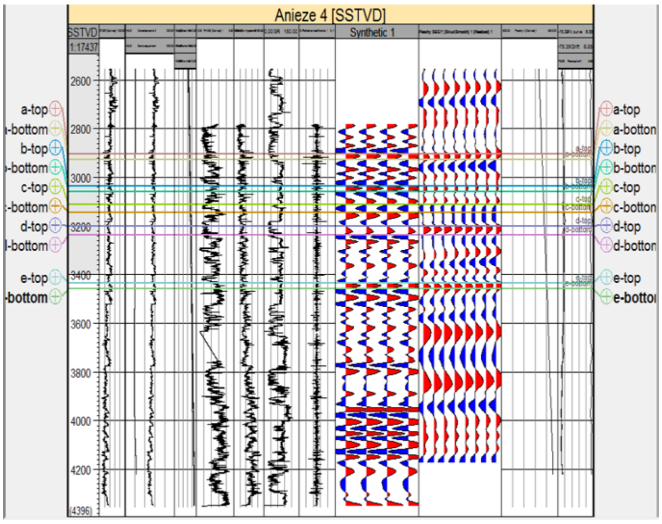
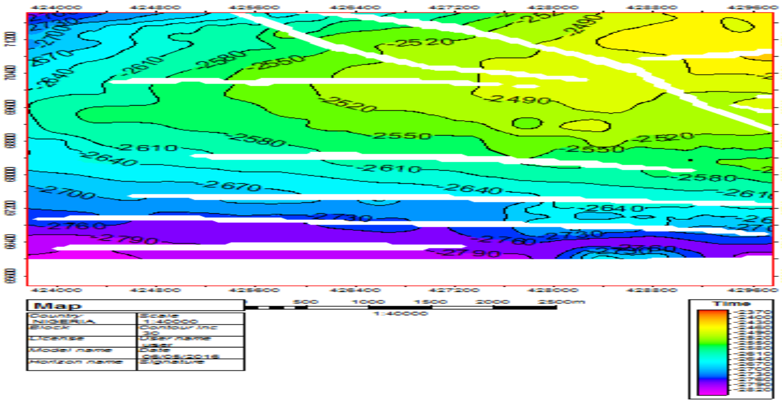
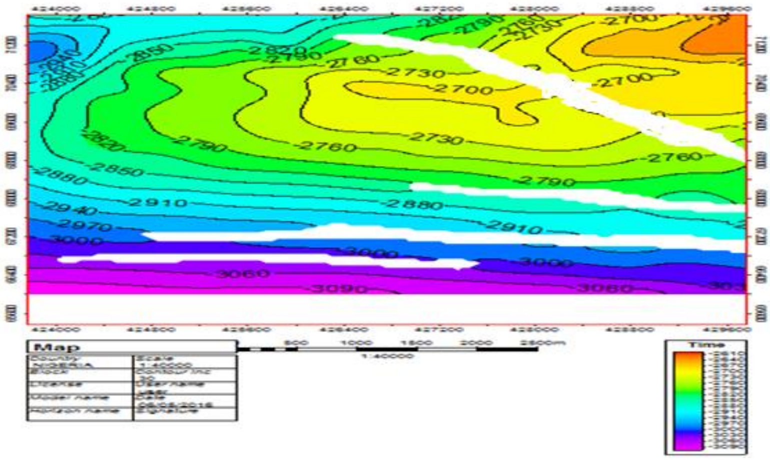


Figure 4: Synthetic seismogram of well UVO-4

4. Results and Discussion

The discussion of results are premised around the principles that define a field has being prolific or not for hydrocarbon production. The prolificacy of the field is determined by the petrophysical properties of its reservoirs, trapping mechanisms which controls the geometry, presence or absence of reservoirs in certain wells and hydrocarbon accumulation in the wells. Time and depth structural contour maps generated for three horizons (named horizon 1-3) defined on top of sand bodies in the field shows system of differently oriented faults (F1 to F8). The maps generated revealed two major faults (F2 and F3) which are growth faults, normal, listric and concave in nature and are very extensive. The major faults trend NW-SW and dip south terminating at the northwest flank of the field. The major faults show a subparallel relationship. The field is dissected by several crestal synthetic (F1, F5, F6, F7, and F8) and antithetic fault, F4 (Fig. 5-7). Most northerly minor faults are synthetic to the major fault F3; those at the parts central are antithetic. Structural closures were identified as rollover anticlines which when displayed on the time-depth structural maps; suggested probable hydrocarbon accumulation on the downthrown side of the fault F7. The hydrocarbon trapping potential of the field is delineated to be Fault assisted anticlinal structure which provides major boundary mechanism that limits the leakage of oil from the reservoir due to displacement of a non-porous strata beside the reservoir across the fault.





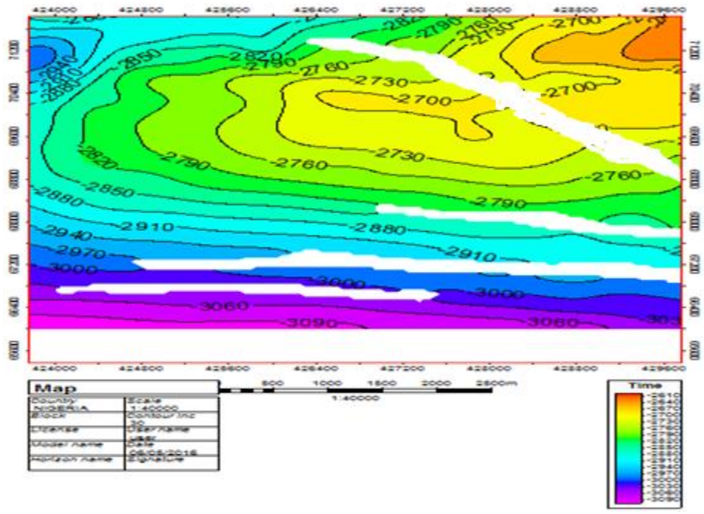
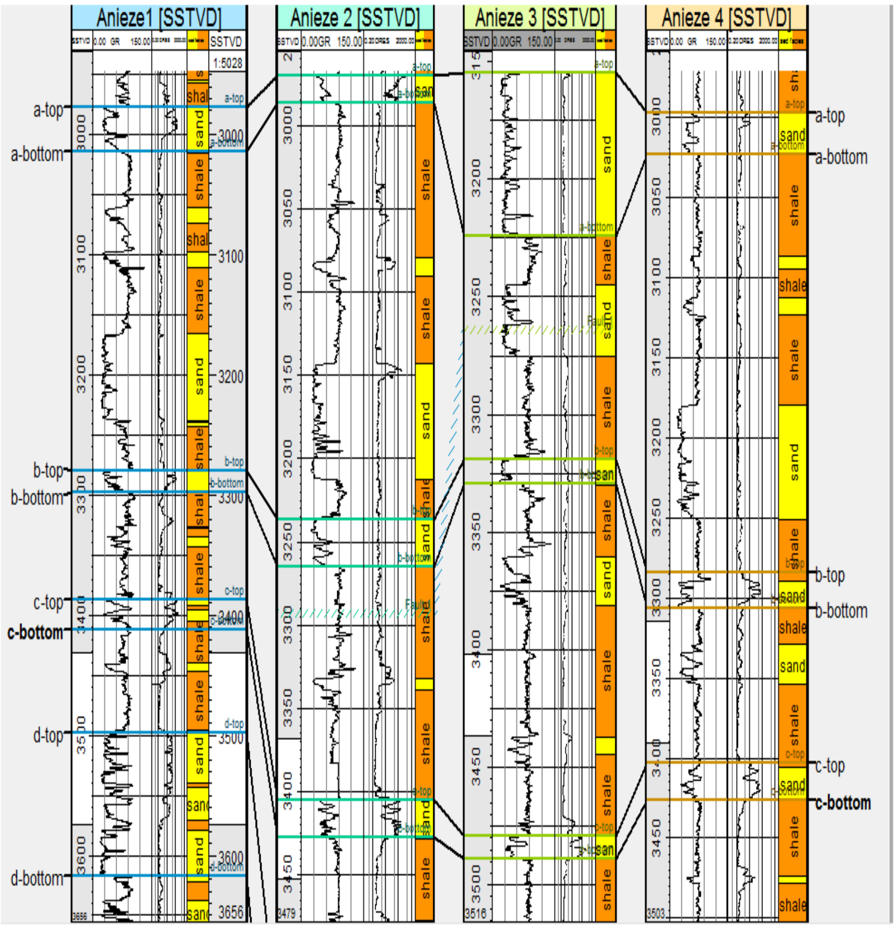


Figure 8 shows the lithologic correlation across the four reservoirs in the field which revealed that the wells penetrated the Agbada formation, the major reservoir unit within the Niger Delta basin. Correlation of reservoirs across the four wells shows that Sand A is laterally continuous at depths (3014.92 – 3058.32)m, (2986.60 – 3003.09)m, (3179.10 – 3249.51)m, (3020 – 3046.75)m. Sand B at depths of (3321.67 – 3338.75)m, (3253.48 – 3281.80)m, (3346.77 –3356.38)m, and (3313.62 – 3329.87)m, Sand C at depth (3429.60 – 3447.38)m, (3422.14 – 3444.83)m, (3508.31 –3518.20)m, (3430.84 – 3449.83)m; and Sand D at depth (3537.78 -3659.78)m, (3558.43 – 3658.77)m, (3558.60 – 3706.31)m, (3546.12 – 3675.63)m in UVO 1, 2, 3, and

4 respectively. The differences in depth from well to well is a result of the complex fault system which causes a downward displacement of reservoirs in UVO-2 and 4 and an upward displacement in UVO 1 and 3. Computed petrophysical parameters of the reservoirs revealed a wide variation in petrophysical properties across the wells. The average water saturation in these reservoirs are low, ranging from 18 to 28%, with corresponding high hydrocarbon saturation, 62 to 82%, indicating that the reservoirs contains more hydrocarbon than water (Table 1). The reservoirs have total porosity values ranging from 21 to 23%, which indicates reservoirs with very good to excellent porosity ([5], 1970) and absolute permeability values ranging from 736mD to 3965mD indicates reservoirs with very good permeability ([3], 1942).



An average volume of shale ranging from 9 to 17% indicates that the reservoirs are mostly clean sands with little shale content. Net pay thickness of the reservoirs ranges from 6 to 52m with reservoir B having the lowest net thickness. High effective permeability to oil (K_o) values ranging from 530 to 3085mD and low effective permeability to water (K_w) values ranging from 2.4 to 42.8mD for the reservoirs across the wells indicates that the reservoirs would preferentially transmit oil in presence of water. Also, high relative permeability to oil values ranging from 37 to 240%, and low relative permeability to water, 0.36 to 9.75% indicates the production of relatively water free hydrocarbons and the proportion of water to hydrocarbon would increase as the relative permeability to water increases. Average hydrocarbon pore volume reveals that 17% of the reservoir pore spaces is completely saturated with hydrocarbon. The average movable oil saturation of the reservoirs ranges from 34 to 60% indicating that this percentage of oil would move during an invasion process and a low average residual oil saturation between 20 to 25% indicates that this percentage of oil would be left in place during a drilling/production program. The low values of residual oil saturation compared to movable oil saturation indicates that a large quantity of the reserve in the field are recoverable and only a few would be left in place at the stage of abandonment. Hydrocarbon reserve calculations computed for three reservoirs (Sand A, B, and C) across the four wells reveals a total reserve of 30.9 billion stock tank barrels of oil for the reservoirs penetrated by the wells with reservoir (sand) B accounting for the lowest reserve due to its low net pay thickness.

Table 1: Average Petrophysical properties for reservoirs in UVO field

Reservoirs	ϕ (%)	Gross (m)	NTG (%)	K (mD)	S_w (%)	S_h (%)	V_{sh} (%)	K_{ro} (mD)	K_o (mD)	K_w (mD)	S_{wirr} (%)	BVW	MOS (%)	ROS (%)
Sand A	21	39	90	2230	29	71	13	0.37	597	43	8.41	0.09	46.39	24.80
Sand B	25	18	92	3965	38	62	9	0.50	3085	26.14	8.66	0.11	41.08	20.50
Sand C	23	18	83	1047	18	82	17	0.60	706	2.32	9.18	0.07	59.25	22.64
Sand D	21	125	89	736	18	82	11	0.59	531	3.03	9.82	0.06	60.04	21.96

5. Conclusions

Lithologic correlation across the four wells revealed that the wells penetrated the Agbada formation, which is the major reservoir unit within the Niger Delta basin. Very good to excellent porosity and absolute permeability together with high hydrocarbon saturation in the field suggest that the reservoirs have potential to transmit hydrocarbon for production in commercial quantitiesin the field. A reserve of 30.9 billion stock tank barrel of oil together with observed suitable trapping mechanisms that can prevent seepage of reserves, showed that the field is prolific and economically in the Niger Delta. Based on the log and seismic interpretation, the field offers prospective structural closures for hydrocarbon accumulation in the southwestern flank and since few well has been drilled in this area, more wells should be drilled to produce any by-pass oil in the area. Further fault and seal analysis should be carried out on the two major faults (F2 and F3) accumulating these hydrocarbon quantities to check the efficiency of these faults in trapping hydrocarbon in this region. Analysis of core samples retrieved from the field during drilling operation should be integrated with petrophysics from wireline logs because this increases the accuracy of petrophysical determinations. Geochemical and biostratigraphic studies should be carried out in order to enhance the interpretation of depositional environment of the reservoirs.

Acknowledgments

The second author is grateful to Integrated Data Service Limited (IDSL), Exxon-Mobil Nigeria for providing the data used for this study, Department of Petroleum Resources for their help in securing the data and OsunrindeTaiwo for sharing the data with the authors. Special thanks to the Department of Applied Geology, Federal University of Technology, Akure, Nigeria for permitting the use of data and providing the stable atmosphere needed for this study.

References

[1]. Aizebeokhai, A.P. & Olayinka, I. (2011). Structural and Stratigraphic mapping of Emi field, offshore Niger Delta. Journal of Geology and Mining Research, 3(2): 25-38.

[2]. Alao, P.A., Olabode, S.O. & Opeloye, S.A. (2013).Integration of seismic and Petrophysics to characterize reservoirs in 'ALA' oil field, Niger Delta. Scientific world Journal, 13: 1-15.

[3]. Archie, G.E. (1942). The Electrical Resistivity Logs as an aid in Determining Reservoir Characteristics. Trans. AIME, 146: 55 -62.

[4]. Avbovbo, A.A. (1978). Tertiary lithostratigraphy of Niger Delta. American Association of Petroleum Geologists Bulletin, 62: 295 - 300.

[5]. Buller, D. (1970). Evaluating Porosity and productivity in clastics and Oomoldic Carbonates. The Technical Review, 35(3): 14- 18.

[6]. Burke, (1972). Longshore drift, submarine canyons and submarine fan in development of Niger Delta. American Association of Petroleum Geologist Bulletin, 56: 1975-1983.

[7]. Bustin, R.M. (1988). Sedimentology and characteristics of dispersed organic matter in the Niger Delta: Origin of source rock in a Deltaic environment, American Association of Petroleum Geologist Bulletin, 72: 277-298.

[8]. Doust, H. &Omatsola, E. (1990): Niger Delta, In: - Edwards, J. D., and Santogrossi, P.A., Eds., Divergent/Passive Margin Basins. AAPG Memoir 48: Tulsa, American Association of Petroleum Geologists, 48:239-248.

[9]. Ekweozor, C.M. &Doukoru, E.M. (1994). Northern Delta Depobelt portion of the Akata-Agbada petroleum system, Niger Delta, Nigeria, in Magoon L.B. and Dow W. G., eds., The Petroleum system from Source to Trap, American Association of Petroleum Geologist Bulletin, v. AAPG Memoir 60: 599-614.

[10]. Evamy, D.D., Haremboure, J., Kamerling, P., Knaap, W.A, Molloy, F.A., and Rowlands, P.H. (1978). Hydrocarbon Habitat of Tertiary Niger Delta. AAPGBulletin 62:1-39.

[11]. Klett, T. R., Ahlbrandt, T. S., Schmoker, J. W. & Dolton, J. L. (1997). Ranking of the world's oil and gas provinces by known petroleum volumes: U.S. Geological Survey Open-file Report, 97-463.

[12]. Obiekezie, T.N. and Bassey E.E. (2015). Petrophysical analysis and volumetric estimation of Out Field, Niger Delta Nigeria, Using seismic and well log data. Physical Science International Journal, 54-65.

[13]. Omoboriowo, A.O., Chiadikobi, K.C. and Chiaghanam O.I. (2012). Depositional Environment and Petrophysical Characteristics of "LEPA" Reservoir, Amma Field, Eastern Niger Delta, Nigeria. International Journal of Pure and Applied Sciences and Technology, 10 (2): 38-61.

[14]. Reijers, T.J.A, Petters S.W., Nwajide C.S. (1997). The Niger Delta Basin. In: Selley RC (ed.) African Sedimentary Basins; Basin of the world, Elsevier, Amsterdam, 3: 151-172.

[15]. Shanon, P.M. &Naylon, N. (1989). Petroleum Basin studies. Graham and Trotman Ltd., London, 169.

[16]. Short, K.C. and Stauble, A.J. (1967). Outline of the Geology of the Niger Delta. American Association of Petroleum Geologist Bulletin, 5: 1761-1779.

[17]. Stacher, P. (1995). Present understanding of the Niger Delta hydrocarbon Habitat, In, Oti, M.N., and Postma G., (Eds.), Geology of Deltas, Rotterdam A.A., Balkema, 257-267.

[18]. Tuttle, M.L.W., Charpentier, R.R., & Brownfield, M.E. (1990). Tertiary Niger Delta (Akata-Agbada) Petroleum System (No. 701901), Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa, In: -USGS, ed., the Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa: Denver, Colorado, U.S. Department of the Interior U.S. Geological Survey.

[19]. Weber, K.J. (1987). Hydrocarbon distribution patterns in Nigerian growth fault structures controlled by structural style and stratigraphy: Journal of Petroleum Science and Engineering, 1:91-104.

[20]. Weber, K.J. & Daukoru, E.M. (1988). Niger Delta reservoir Geology – Historical Growth of sedimentological model and its application to field development. Contributions to the 1988 SPE conference, Port Harcourt, Nigeria, 17.