Volumetric Analysis of Hydrocarbon Reservoirs in'' AKOS'' Field, Niger Delta, Nigeria

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Abstract: **The hydrocarbon volume in the Akos field in the Niger Delta has been computed from eight geophysical well logs and depth structural maps. Two reservoirs (A and B)were delineated from the lithology logs. The lithologies observed from the gamma-ray log are sand, shale and sandy shale. The average petrophysical parameters computed for Reservoir A are 28.68%, 43.35%, 30.55% and 253.1797md for porosity, net-to-gross, water saturation, and permeability respectively. Similarly, Reservoir B has an average porosity (24.56%), net-to-gross (44.59%), water saturation (36.65%) and permeability (162.7688 md). Comparing the computed petrophysical properties with standard values, the result shows that both reservoirs have very good porosity, water saturation, permeability and moderate net to gross. The estimated hydrocarbon in Reservoirs A and B are $23.33 \times 10^6 m^3$ and $72.22 \times 10^6 m^3$ Stock Tank Barrels (STB) respectively.The results of this study have shown the effectiveness of petrophysical evaluation as a tool for understanding the spatial distribution of reservoir properties and it can be used as a guide for evaluating future performance and production behavior of reservoirs.**

Keywords: **Petrophysical Properties, Reservoir, water saturation, porosity**

I. INTRODUCTION

Formation evaluation generally determines the petrophysical parameters and gross volume within hydrocarbon reservoirs. Porosity, permeability, net to gross and water saturation are the main petrophysical properties of reservoir rock and they havea vital impact on hydrocarbon reservoir evaluation and characterization. Petrophysical propertiesare used for hydrocarbon reserveestimation and therefore need serious attention. Reservoir characterization is the integration of different data to describe the reservoir properties of interest in inter-well locations [9, 5, 8]. The reservoir properties such as porosity, net-to-gross, and water saturation are useful for reservoir modeling.

Petrophysical properties are mainly obtained fromgeophysical logs and core samples. The geophysical logs of a reservoir are used in the estimation of reservoir properties such as porosity, water saturation, and others parameter. Seismic data can quantitatively predict reservoir parameters at the location of a well by integrating the well's information with the available seismic data through the intermediary of a synthetic seismogram. During formation evaluation, efforts focus on estimating subsurface physical properties of rock units which are important in hydrocarbon exploration and exploitation. Reservoir characterization is used for estimating producible hydrocarbon [12].

Formation evaluation involves qualitative and quantitative interpretation of geophysical logs to determine some of the petrophysical properties. Most times, reservoir characterization is mainly obtained from composite geophysical well logs [2, 10, 1]. By applying reservoir characterization techniques in a field, asset holders will be able to maximally recover hydrocarbon while minimizing costs. A comprehensive petrophysical evaluation is necessary to optimize development and production. In this study, petrophysical parameters in the onshore field, Niger Delta were evaluated using wireline logsto characterize the reservoirs and estimate the reservoir parameters from the well logs.

II. GEOLOGY OF THE STUDY AREA

The study area (Akos Field) is located in the onshore coastal swamp depositional belt in the eastern part of Niger Delta (Figure 1) and it is located within latitudes 4° 19′ 00" N and 4° 50′ 00" N and Longitudes 6° 02′ 30" E and 7° 10′ 00" E. The base map of the seismic lines is shown in Figure 2.

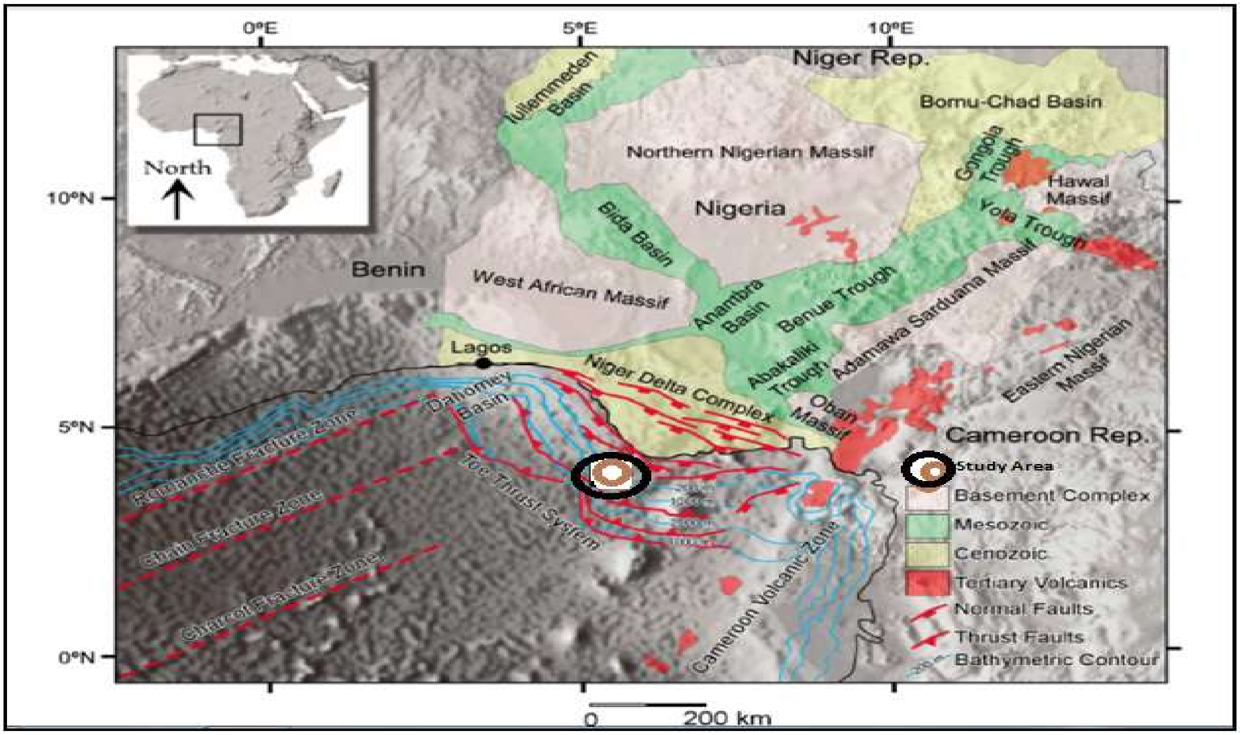

Figure 1: Map Niger Delta showing the study area.

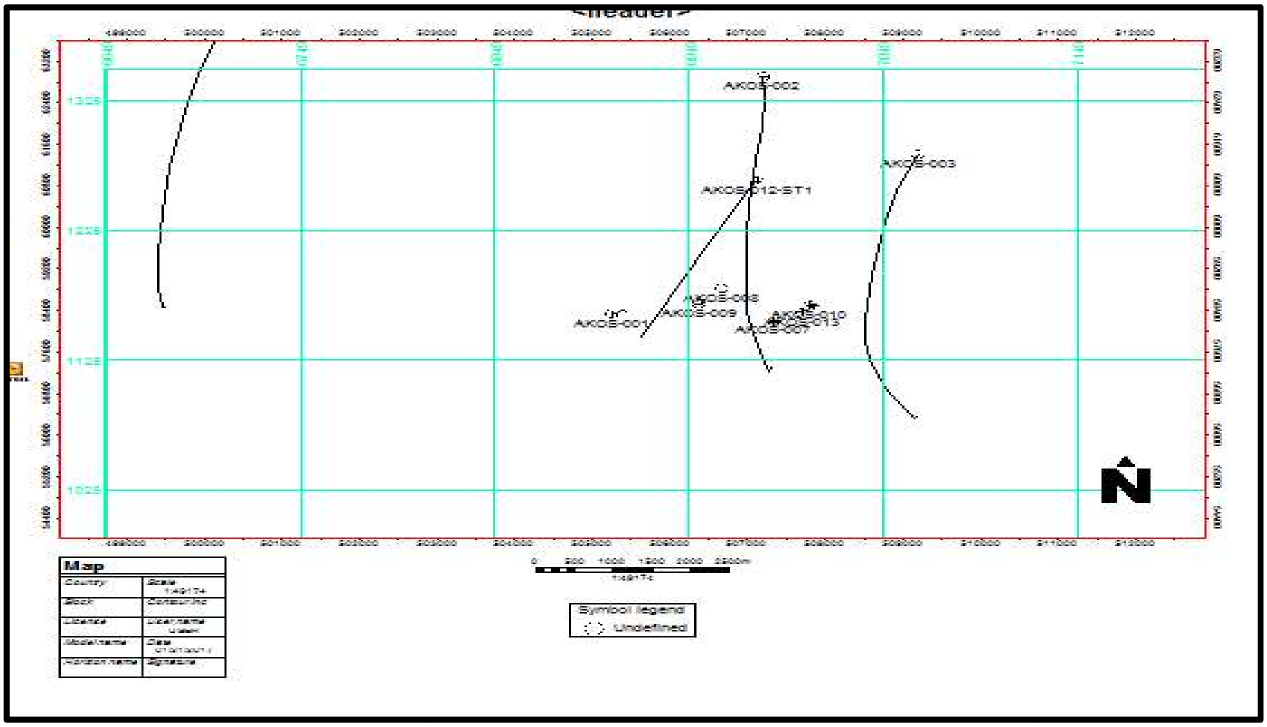

Figure 2: Schematic Base map of the study area.

The Niger-Delta forms one of the world's major Hydrocarbon provinces and it is situated on the Gulf of Guinea on the west coast of Africa (Southern part of Nigeria). It covers an area between longitude 4 – 9ºE and Latitude 4 - 9º N. It has an average area of 75,000 km^2 with an average thickness of about 12km. It is composed of an overall regressive clastic sequence. The Niger Delta was formed as a result of the separation of the African and South American plate, at the site of the triple junction in the late Jurassic and continuing into the Cretaceous, thus leading to the opening of the Southern Atlantic.

The Niger Delta is a low gradient delta plain-shelf slope wedge and the tectonic framework of the continental margin along the west coast of Equatorial Africa is controlled by Cretaceous fractured zones expressed as trenches and ridges in the deep Atlantic. The trough represents a failed rift triple junction associated with the South Atlantic. After the rifting ceased, gravity tectonics became the primary deformation process. The Niger Delta province contains only one identified petroleum system referred to as the Tertiary Niger Delta (Akata-Agbada) petroleum system [15, 7, 11, 13]. The Niger Delta has built out over the collapsed continental margin at the site of the triple junction formed during the Middle Cretaceous[4].

One of the most conspicuous geological features of the Niger Delta is its growth fault pattern. The Niger Delta oil province is characterized by East-West trending syn-sedimentary faults and folds. Most of the oil accumulated in the Niger Delta is contained in the rollover anticline structures. The oil in these structures may be trapped in dip closures or against a Synthetic or antithetic fault (Figure 3).

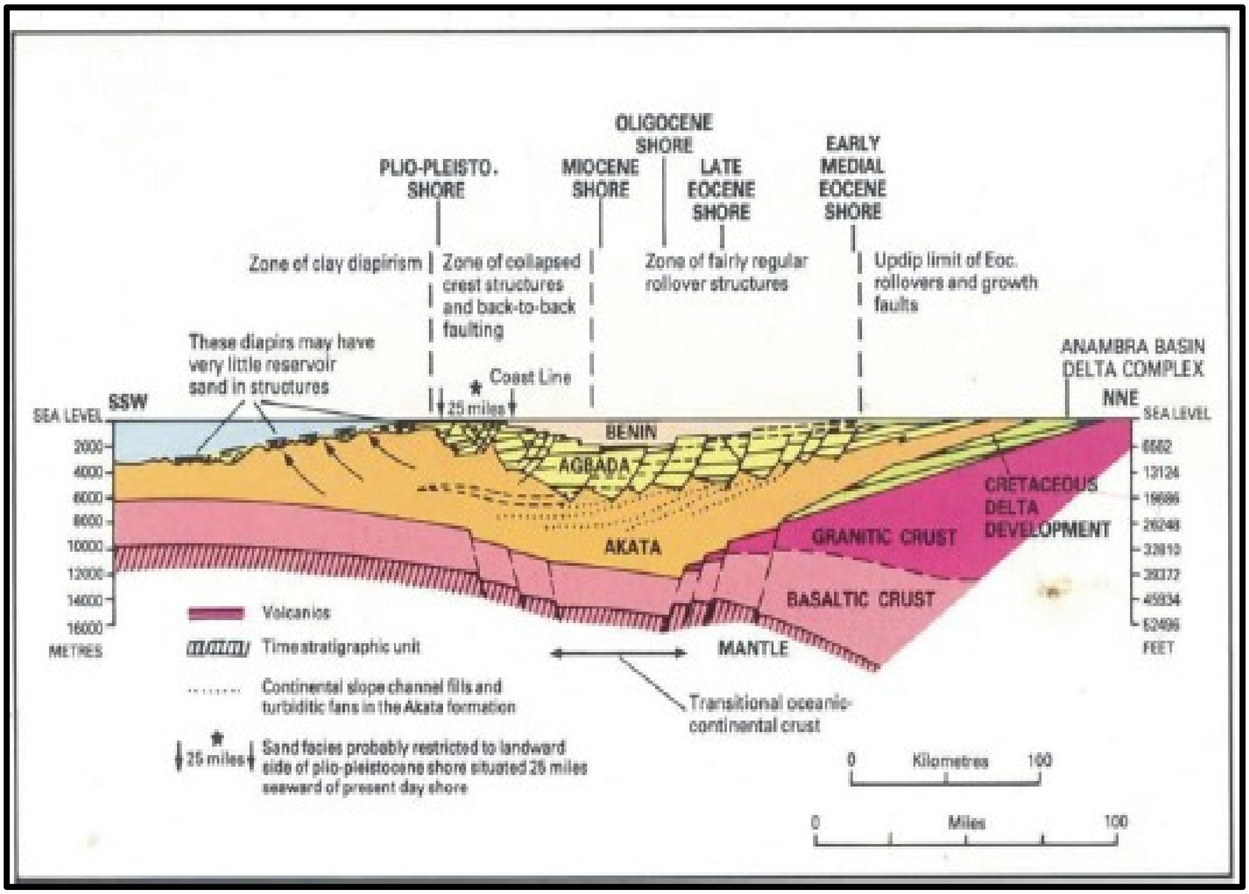

Figure 3: Generalized dip section of the Niger Delta showing the structural provinces of the Delta [17].

III. MATERIALS AND METHODS

The data used for this work consists of eight composite logs obtained from exploratory wells and depth structural maps of the delineated reservoirs. Each of these suites of logs is made up of gamma-ray, resistivity, spontaneous potential, bulk density, and neutron porosity logs. The petrophysical evaluation was implemented using Petrel software. The geophysical logs interpretation involves lithology and reservoir delineation, determination of porosity, water saturation, Net to Gross Ratio (NGS) and permeability. Both qualitative and quantitative interpretation was applied to the logs.

A. Lithology and Reservoir Delineation

The Gamma-ray and resistivity logs were used for lithology and reservoir delineation. For the gamma-ray log, deflections to the left (low values) signify sandstone while the deflection to the right (high values) signifies shale. High values of resistivity correlating with a sandstone zone are an indication of reservoir sand while low values represent shale or reservoir containing saltwater. The depth and thickness of the reservoir were also obtained from the gamma-ray and resistivity logs.

B. Porosity Determination

Porosity is the number of pore spaces or voids in the rock and it is a measure of the amount of fluid (water, oil or gas) the rock will hold. Porosity is one of the primary parameters used for evaluating the amount of hydrocarbon in a reservoir. The density log was used to determine the porosity of the reservoir sands.The porosity values for the reservoirs were derived using the following formula[1];

$$porosity(g/Cc)=\frac{\rho_{ma}-\rho_b}{(\rho_{ma}-\rho_{fl})} \qquad 1$$

Where

ρ_{ma} = Density of the matrix,

ρ_b = Bulk Density,

ρ_{fl} = density of the fluid.

C. Determination Water Saturation

Water saturation (S_w)is an important parameter in reservoir characterization and is used to quantify the hydrocarbon saturation. The fluid saturation of a reservoir is usuallyexpressed as a function of the total pore space. The fluid in a reservoir may be saline water and/or hydrocarbon. The amount of hydrocarbon saturation is a function of the quantity of water in the reservoir, and the higher the water saturation in the reservoir, the lower the amount of hydrocarbon. In this study, water saturation was determined from the equation [14];

$$S_w(\%)=\frac{0.082}{porosity} \qquad 2$$

D. Permeability determination

Permeability is the property of rocks that describes the interconnectivity of the pore spaces of the rocks. Determination of permeability is difficult, however, for this research, the permeability values for the reservoirs was calculated using theequation[16];

$$K(mD)=307+26552(\phi^2)-34540(\phi\times Sw)^2 \qquad 3$$

Where

K= Permeability

ϕ = Porosity

Sw = Water saturation.

E. Net to gross ratio determination

The gamma-ray log was used to estimate the net-to-gross ratio, by first determining the gamma-ray readings of clean sand in the formation, using the formula [2];

$$N/G=\frac{\Sigma h_i}{H}=\frac{Net \quad reservoir}{Gross \quad reservoir} \qquad 4$$

Where:

N/G = Net thickness

H = Gross thickness

Net Thickness = Gross thickness-Shale thickness

F. Seismic Data Interpretation

The seismic interpretation involved horizons and faults identification and mapping. A synthetic seismogram was generated from available sonic and density logs. The reservoir sands identified on the well logs were traced in the seismic sections through the well-to-seismic tie. Time structural mapswere then generated for the various horizons. The available checkshot data were used for converting the time structural mapped to depth structural map.

G. Estimation of reservoir volume

Estimating the quantity of hydrocarbon in the reservoir is a very important stage in the modeling process as it helped in deciding on the best reservoir bearing hydrocarbon. This is very important because it acts as a guide for field exploration and development. After a static model of a field was done, the structural model and the petrophysics model built were used to calculate reserves in terms of Stock Tank of Oil Initially In Place (STOIIP) [14];

$$STOIIP=\frac{7758\times Area\times Thickness\times Porosity\,(1-S_w)\times NTG}{FVF} \qquad \mathbf{5}$$

Where:

STOIIP (mmstb) = stock tank oil initially in place

Sw= water saturation

NTG = net-to-gross ratio

FVF = formation volume factor (a constant)

IV. RESULTS AND DISCUSSION

The results are discussed based on qualitative interpretation, quantitative interpretation, statistical analysis.

A. Qualitative interpretations

Figure 4 depicts the lithostratigraphic correlation panel of the eight (8) wells (Akos 004, 002, 003, 012, 008, 001, 009 and 007) from the gamma-ray and deep resistivity logs. Based on the gamma-ray logs, two lithologies were identified as sand and shale. From the lithology log, the interval colored yellow is sand, while the interval coloredgray is shale. The general litho-stratigraphy of the wells shows an alternating of sand and shale layers indicating the Agbada Formation of the Niger

Delta. The top and base of the reservoir was identified for mapping in the seismic volume.

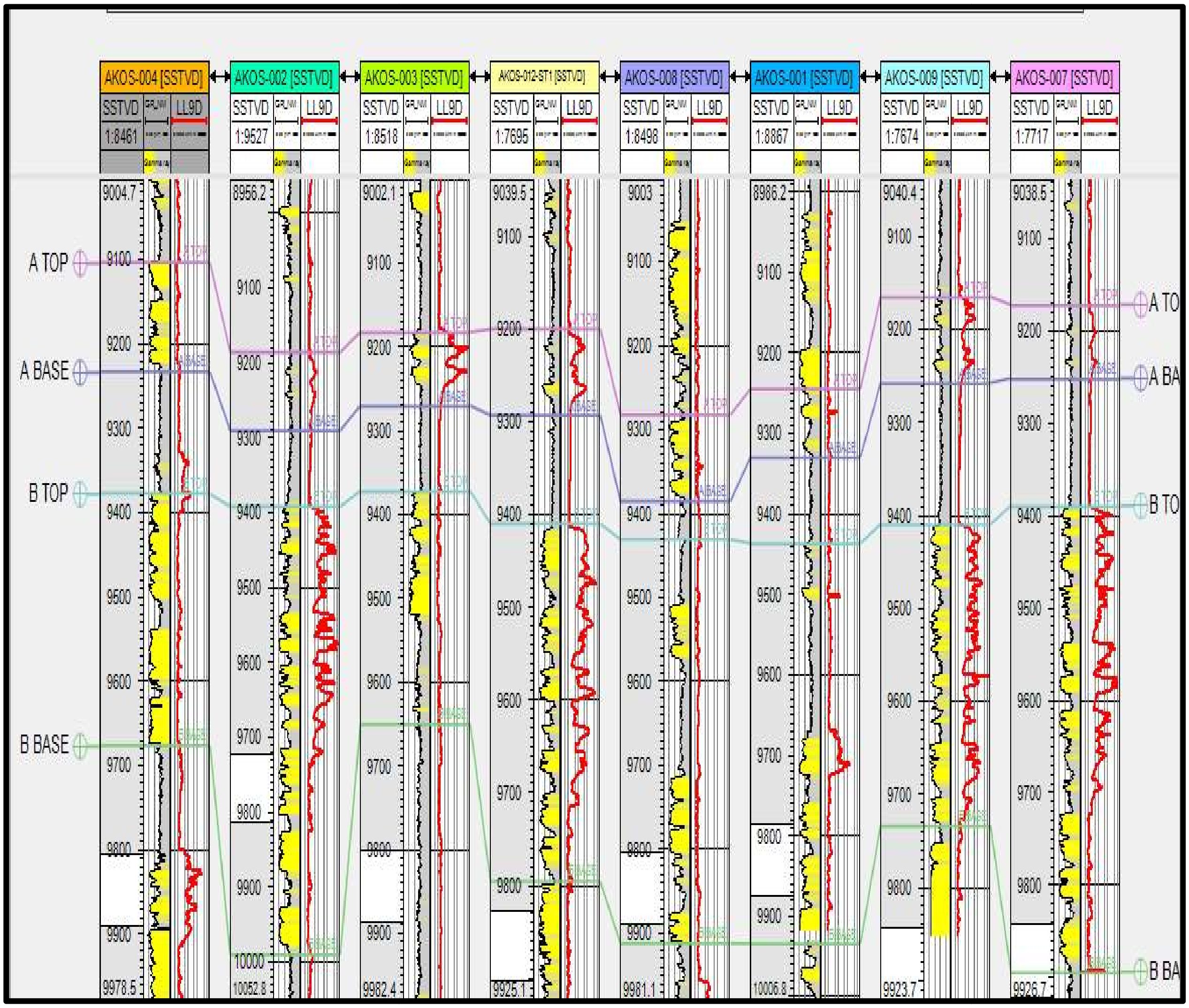

Figure 4: Well log correlation panel of Akos field.

Two reservoirs A and B were delineated and correlated across the field. The well correlation panel shows that each of the sand units extends throughout the field and varies in thickness. There is an increase in the shale layer with depth and a corresponding decrease in the sand layer with depth. This is an indication of the transition from Agbada to Akata formations [3].

B. Quantitativeinterpretation

Various petrophysical properties such as porosity, permeability, Net-to-Gross, and Water saturation were calculated. The calculated petrophysical properties for each well in reservoir A are shown in Table 1.The average petrophysical parameters for reservoir A are 0.286821 for porosity, 253.1797 for permeability, 0.305543 for water saturation and 0.433562 for the net to gross. The computed petrophysical parameters for reservoir B are shown in Table 2. The computed average petrophysical parameters are 0.245688 for porosity, 162.7688 for permeability, 0.36655 for water saturation and 0.44595 for the net to gross. The computed porosity and permeability for the reservoirs A and B were compared with the standard values in Tables 3 and 4.The results show that the two reservoirs have good porosity. The permeability of reservoir A is very good while that of reservoir B is good. Based on these, reservoir A is said to be the most prolific while reservoir B is said to be less prolific within the Akos field. Generally, the two reservoirs exhibit good petrophysicalproperties.

Table 1:Calculated petrophysical parameters for all wells in Reservoir A

Well Name	Porosity (ϕ)	Permeability K(Md)	Water Saturation (Sw)	Net-to-gross (Ntg)
Akos 004	0.275264	186.9494	0.313474	0.423221
Akos 002	0.291306	591.8269	0.301028	0.736318
Akos 003	0.306998	331.4502	0.28083	0.318644
Akos 012	0.251915	100.2499	0.338373	0.474227
Akos 008	0.272421	143.4088	0.306802	0.497537
Akos 001	0.262948	186.5251	0.317611	0.847561
Akos 009	0.325964	345.9852	0.298781	0.170984
Akos 007	0.307749	139.0417	0.287443	0.00000
Avg %	28.68	253.17	30.55	43.35

Table 2: Calculated petrophysical parameters for all wells in Reservoir B

Well Name	Porosity (ϕ)	Permeability K(Md)	Water Saturation (Sw)	Net-to-gross (Ntg)
Akos 004	0.2450	169.99	0.3576	0.2490
Akos 002	0.2435	245.21	0.3646	0.4106
Akos 003	0.2470	160.48	0.3627	0.5858
Akos 012	0.2249	175.42	0.4054	0.5769
Akos 008	0.2819	126.64	0.3121	0.3239
Akos 001	0.1973	52.79	0.4598	0.3791
Akos 009	0.2802	208.24	0.3067	0.5199
Akos 007	0.2457	163.38	0.3635	0.5224
Avg %	24.56	162.76	36.66	44.59

Table 3: Qualitative Evaluation of Porosity

Percentage Porosity	Qualitative Description
0-5	Negligible
5-10	Poor
15-20	Good
20-30	Very Good
> 30	Excellent

Table 4:**:** Qualitative Evaluation of Permeability

Percentage Permeability (md)	Qualitative Description
<10,5	Poor to Fair
15-50	Moderate
50-250	Good
250-1000	Very Good
> 1000	Excellent

C. Generated Seismic Depth Structural Map.

Two-way-depth structural maps generated for two reservoirs A and B are shown in Figures 5 and 6. The two reservoirs sand have a similar structural configuration. The reservoirs are faulted rollover anticlinal structures bounded by growth faults.The area of the reservoir closure was used for the volumetric analysis.

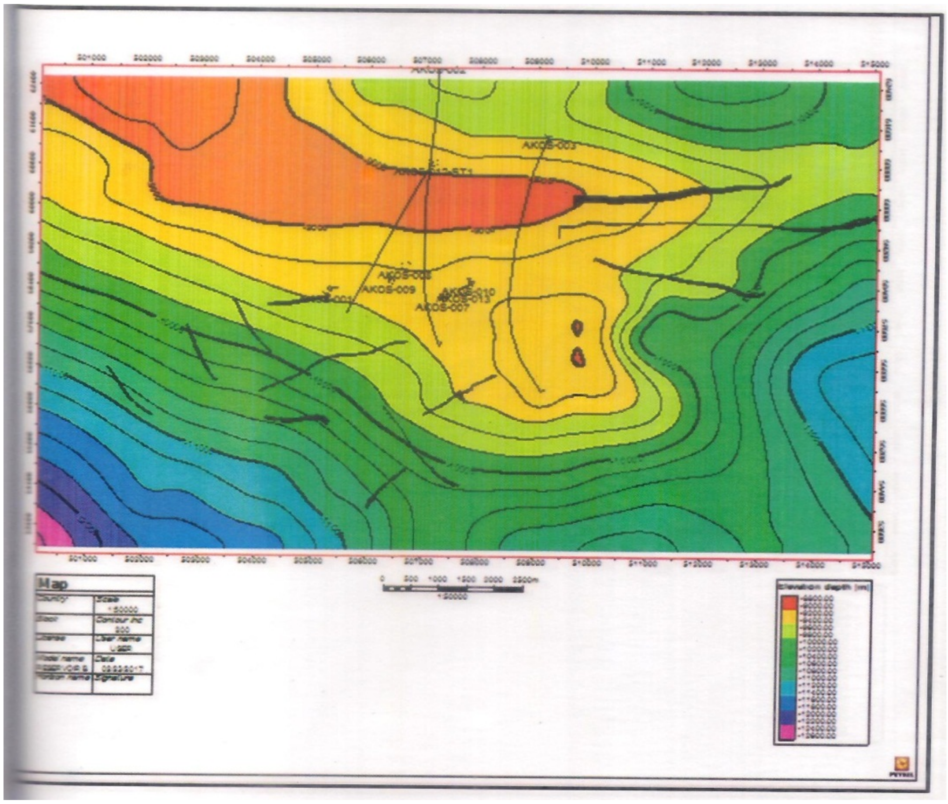

Figure 5: Depth structural map of Reservoir A

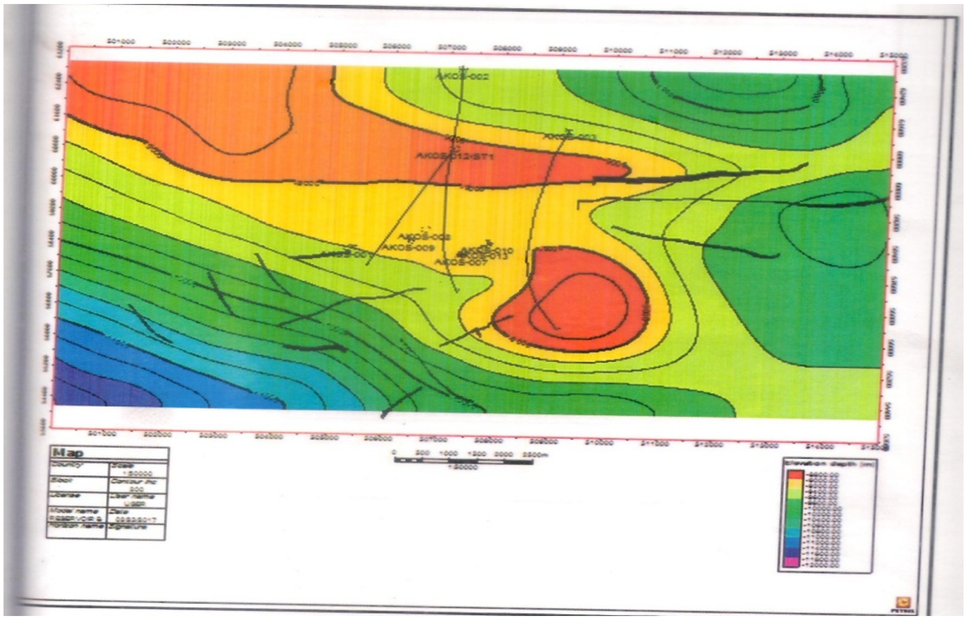

Figure 5: Depth structural map of Reservoir A

D. Estimated Hydrocarbon Volume

The computed average petrophysics parameters for the reservoirs and Stock Tank of Oil Initially In Place (STOIIP) are shown in Table 5. The result shows that the average petrophysical properties of the reservoirs are good. The volume of hydrocarbon obtained in Reservoirs A and B are $23.33 \times 10^6 m^3$ and $72.22 \times 10^6 m^3$ Stock Tank Barrels (STB) respectively.

Table 5: Computed average Petrophysics parameters of reservoirs A and B

Reservoir	Thickness (ft)	Porosity (fraction)	Permeability (mD)	Sw (fraction)	NTG (fraction)	STOIIP (mmstb)
A	116	0.286821	253.1797	0.305543	0.433562	23.33
B	489	0.245688	162.7688	0.36655	0.44595	72.22

V. CONCLUSION

The hydrocarbon volume of Akos Field has been computed from a suite of well logs and depth structural maps obtained from 3D Seismic data in the study area. Two reservoirs A and B were delineated. The average petrophysical parameters for reservoir A are 0.286, 253.18 md, and 0.306 for porosity, permeability and water saturation. Similarly, reservoir B has an average porosity of 0.25, the permeability of 162.77 and water saturation of 0.37. Both reservoirs have good porosity and permeability. The hydrocarbon volume obtained for the reservoirs A and B are $23.33\times10^{6}m^{3}$ and $72.22\times10^{6}m^{3}$ Stock Tank Barrels (STB) respectively. The results show that the hydrocarbon volume is of economic importance and further exploration and production works should be encouraged in the field.

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