



Reservoir Modeling and Hydrocarbon Evaluation of Abi-Field, Niger Delta, Nigeria

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Abstract This study examined the application of 3-D seismic and well log data for proper optimization and development of hydrocarbon potential in “ABI” field of Niger-Delta Province. For accurate reservoir modelling and property determination, three well logs and seismic data of 1560 to 1800 Xline and 6800 to 7200 Inline ranges were used to delineate reservoirs of interest and to determine the average petrophysical properties of the reservoirs. The data were conditioned for interpretation using Petrel software. These delineated reservoirs found in each well were then correlated across the field. This study demonstrated the effectiveness of 3-D static modeling technique as a tool for better understanding of spatial distribution of discrete and continuous reservoir properties, hence, has provided a framework for future prediction of reservoir performance and production behavior of the reservoirs. However, appraisal wells should be drilled within the identified prospect areas to enhance optimization of the reservoir.

Keywords Reservoir Modeling, Hydrocarbon

Introduction

In exploration geophysics, subsurface structures and properties of interest include: the reservoir architecture, porosity, fluid Saturation, lithology and permeability. In the procedure for subsurface property modeling, it is usual that geophysicists first provide spatial distribution of seismic attributes from observed seismic record. Seismic attributes can be used for both quantitative and qualitative purposes. Quantitative uses include prediction of physical properties such as porosity or lithology [1-2]. Qualitative uses include detection of stratigraphic and structural features. Then from the derived seismic attributes, we can evaluate and estimate subsurface properties of interest using physical theories, statistical methods and geological model, along with well-log data.

However, uncertainty in seismic interpretation may arise because of many inevitable causes: inconsistent acquisition conditions, lateral velocity variation, poor resolution of data, limited availability of data, insufficient geologic knowledge and many others. The internal architecture of the “ABI” field fluvial reservoirs along with structural complexity caused by growth faults may result in bypassed reservoirs or compartments with additional reserves. This work basically entails the use of integrated 3D seismic and well logs to enhance oil and gas recovery in the basal part of the Agbada Formation.

Objectives of the Study

The aim of this research is to model hydrocarbon reservoirs using quantitative seismic attributes, reservoir estimation and petrophysical properties of “ABI” Field, Niger Delta, Nigeria.



Significance of the Study

In this research, the choice for the combined use of seismic interpretation and PETROPHYSICAL evaluation is a complementary one for accurate reservoir modeling and evaluation in relation to their hydrocarbon potential. The well log data has higher vertical resolution while seismic data has higher horizontal resolution. The outlined principles and techniques in seismic/well log interpretation are relevant in oil field development for the optimization of hydrocarbon reservoirs productivity.

Location of the Study Area

The ABI-field is an onshore oil field in the Niger Delta region, located in the southern part of Nigeria. Niger Delta is situated within the Gulf of Guinea with extension throughout the Niger Delta Province.

The Stratigraphy of the Niger Delta

The stratigraphy of the Niger Delta clastic wedge has been documented during oil exploration and production. Most stratigraphy schemes remain proprietary to the major oil companies operating concessions in the Niger Delta basin. The composite Tertiary sequence of the Niger Delta consists, in ascending order, of the Akata, Agbada and Benin Formation. They composed of estimated 28,000ft (8,535m) of section at the approximated depocenter in the central part of the delta [3]. There is decrease in age basinward, reflecting the overall regression of depositional environment within the Niger Delta caustic wedge. Stratigraphic equivalent units to these three formations are exposed in Southern Nigeria.

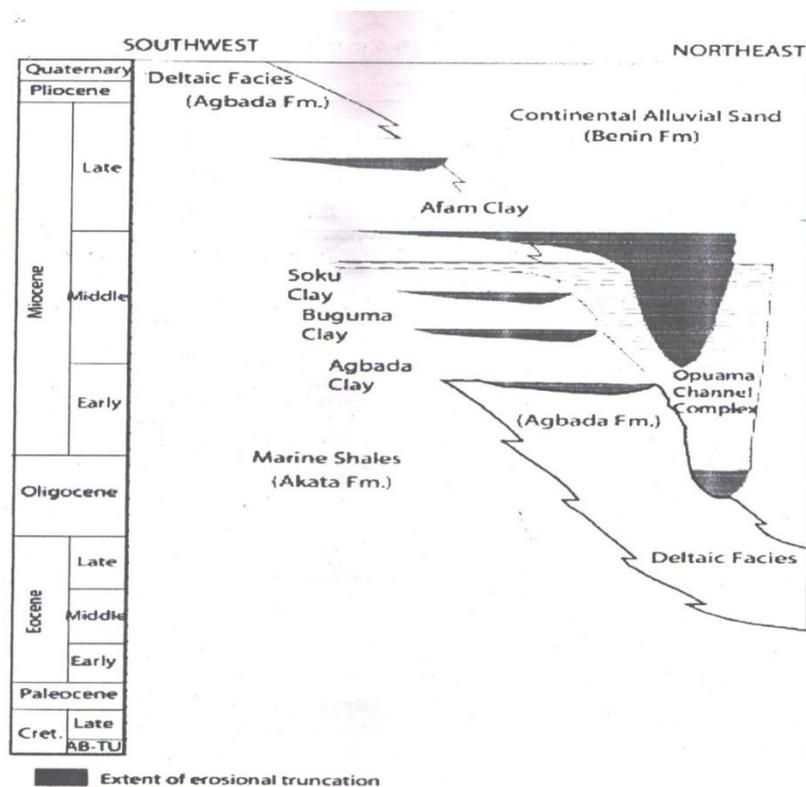


Figure 1: Stratigraphic column showing the three formations of the Niger Delta [4].

Short and Stauble (1967) [5] recognized three sub-surface stratigraphic units in the modern Niger delta - Benin, Agbada and Akata formations. These formations were distinguished according to their depositional environments; marine, deltaic and fluvial environments [6].

(a) Akata Formation The Lithofacie is characterized by uniform shale developments as evidence by gamma-ray (GR) and spontaneous potential (SP) logs. It formed the lowermost unit among the three sub-surface stratigraphic units in Niger Delta, consisting of dark grey sandy, silty shale with plant remains at the top.



With sand and silt increasing towards the top of the formation, the shale are under compacted and many contain lenses of abnormally high pressured siltstone or fine grained sandstone, which are possibly of turbidity origin and were deposited in halo marine (delta front to deeper marine) environments. It occurs at the base of the delta and is of marine origin. The thickness of this sequence ranges from 0m to 6000m and may reach 7,000m in the central part of the delta. Marine shales formed the base of the sequence in each depobelt range from Paleocene to Holocene in age.

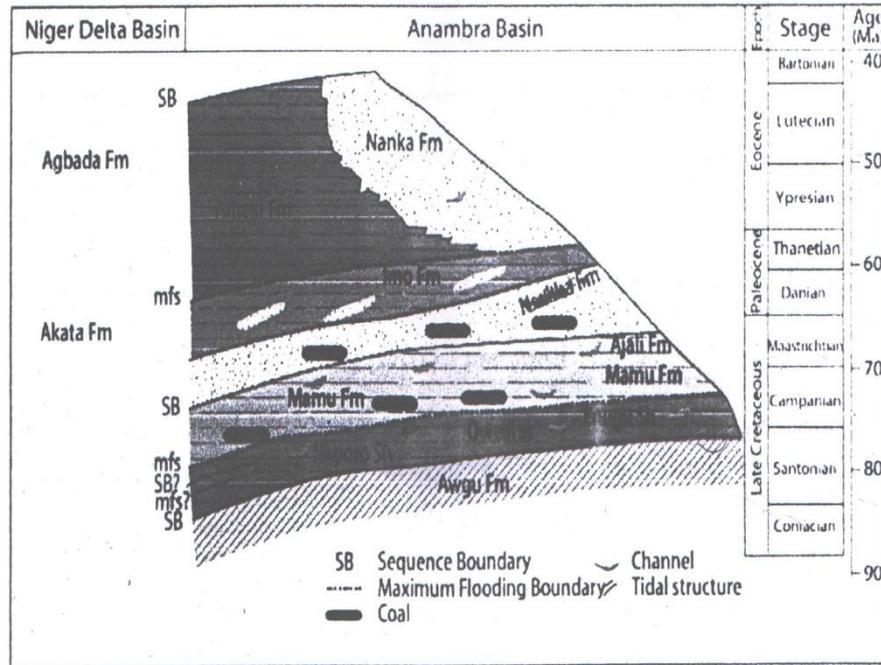


Figure 2: Stratigraphy sections of time equivalent of Niger Delta Basin and Anambra Basin

Table 1: Table of formations of the Niger Delta Area, Nigeria [5]

Subsurface			Surface outcrops		
Youngest Age	known	Oldest known Age	Youngest Age	known	Oldest known Age
Recent Formation	Benin (Afam clay member)	Oligocene	Plio/Pleistocene	Benin Formation	Miocene
Recent Formation	Agbada	Eocene	Miocene	Ogwashi-Asaba Formation	Oligocene
Recent Formation	Akaka	Eocene	Eocene	Ameki Formation	Eocene
Unknown			Lower Eocene	Imo Shale Formation	Paleocene
			Paleocene	Nasuka Formation	Maastrichtian
			Maastrichtian	Ajali Formation	Maastrichtian
			Campanian	Mambu Formation	Campanian
			Campanian/ Maastrichtian	Nkporo Shale	Santonian
			Coniacin/ Maastrichtian	Awgu Shale	Turonian
			Turonian	Eze Aku Shale	Turonian
			Albian	Asu River Group	Albian



They crop out offshore in diapairs along the continental slope and onshore in the northern part of the basin flanks as the Imo shale. Planktonic foraminifera may account for over 50% of the rich microfauna and the benthonic assemblage indicate shallow marine shelf depositional environment.

(b) Agbada Formation The underlying Agbada Formation is a sequence of sandstones and shales of delta-front and deltaic plain origins. The alternating sequence of sandstones and shales of the Agbada Formation to be deposited by alternating cycles of marine and fluvial process (offlap units) determined from electric log patterns, well cores and dipmeter log data.

The sandstones are fine to medium grained, fairly clean and locally calcareous, glauconitic and shaley, and consist dominantly of quartz and potash feldspar with subordinate amounts of plagioclase, Kaolinite and illite. The shales are medium to dark grey, fairly consolidated and silty with localized glauconite. They contain mainly Kaolinite (average value 75%) with small amounts of mixed layers of illite and montmorillonite.

The alternation of fine and coarse clastic provided multiple reservoirs seal and therefore, forms the hydrocarbon prospective sequences in the Niger Delta. The shales contain microfauna that are best developed at the base of each shale unit. Petroleum occurs throughout the Agbada Formation of the Niger Delta [7].

The formation occurs throughout Niger Delta clastic wedge and has a maximum thickness of about 12000ft (4000m). Its outcrops observed in Southern Niger, between Ogwashi and Asaba; is called the Ogwashi – Asaba Formation [4]. It is rich in microfauna at the base decreasing upward and thus indicating an increasing rate of deposition in the delta front. A fluvial origin is indicated by coarseness of the grains and the poor sorting.

(c) Benin Formation: Benin Formation extends from the west across the whole Niger Delta area and southward beyond the present coastline. It is over 90% sandstone with shale intercalations. It is coarse grained, gravely, locally fine grained, poorly sorted, sub-angular to well rounded and bears lignite streaks and wood fragments. It is a continental deposit of probable upper deltaic depositional environment.

Mineralogically, the sandstones consist dominantly of quartz, potash feldspar and minor amounts of plagioclase. Most companies exploring for oil in the Niger Delta arbitrarily define the base of the Benin Formation by the deepest fresh water-bearing sandstone that exhibits high resistivity.

However, Short and Stauble (1967) [5] defined the base of the Benin Formation by the first marine Formation as non- marine origin. The oldest continental sands are probably Oligocene although they lack fauna and are impossible to date directly. Off shore, they become thinner and disappear near the shelf edge. Elele 1 well, 39km northwest of Port Harcourt, is the type section of Benin Formation described by Short and Stauble (1967) [5].

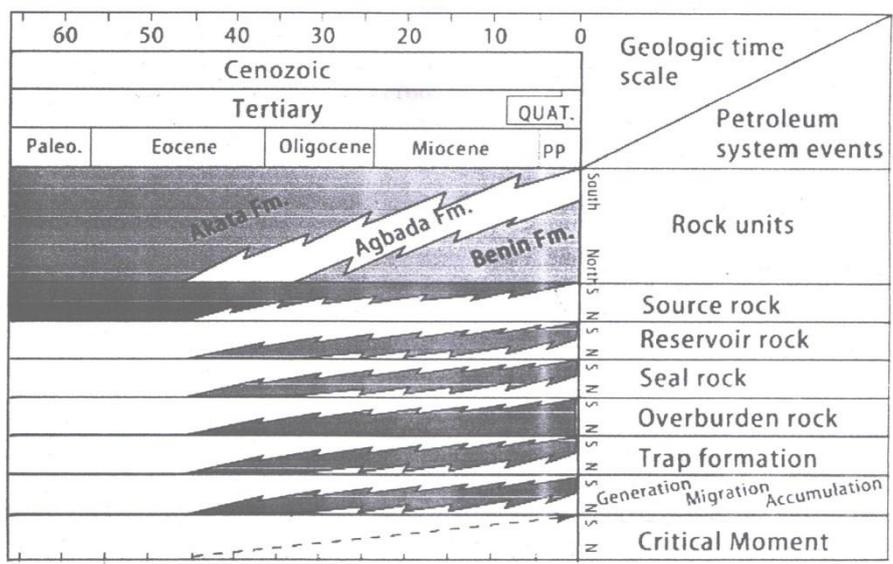


Figure 3 : Events chart for the Niger Delta (Akata/Agbada) Petroleum system

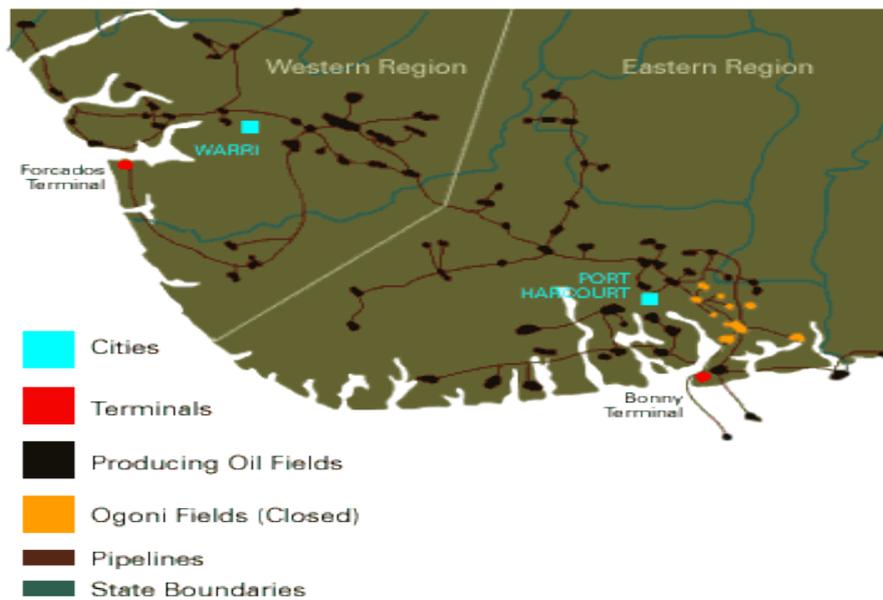


Figure 4: Map of Niger Delta with Producing Oil Fields

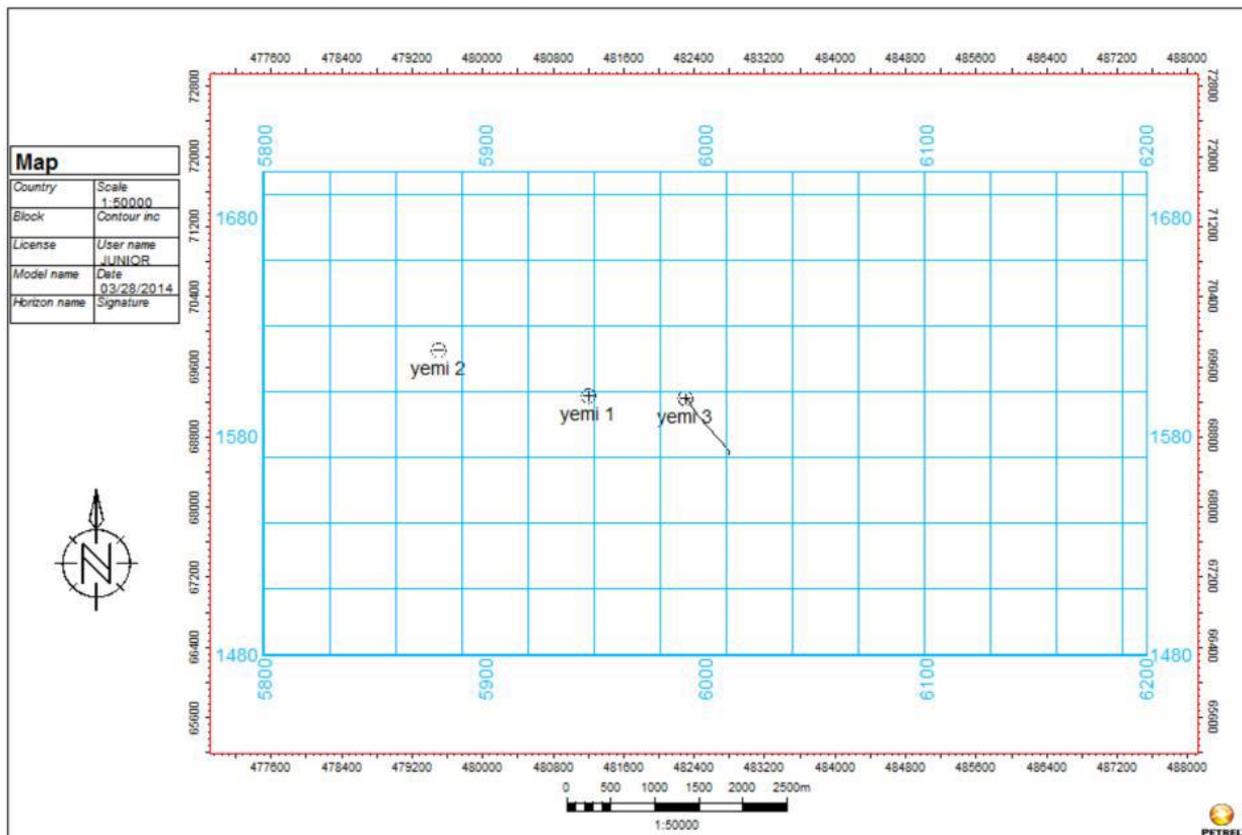


Figure 5: Base-map of the Study Area Showing Wells Location on the Coordinate Points

Methodology

Method of Data Analysis

The given data is properly studied, and then sorted into format which is PETREL compatible. Various folders are created e.g. the well top, well header and time depth conversion files. All the data file are stored in a location on the PC, from where it is accessed.

Before the interpretation process, PETREL™ workflow has defined folders, which are symbolic. Some of the data are imported into this or into users defined ones. According to PETREL™ workflow, the following procedures were observed during the interpretation of “ABI” Field. They are:

Data Import

The sequence of data import begins with the well heads, deviation and logs. The well heads file, contain the well name, surface location of the wells, the top depth, bottom depth and the measured depth (MD). This will allow the display of well position on the base map.

To the well head, the deviation data is attach, which define the path of the deviated wells according to their measured depth respectively. The logs are then imported; attached to the well head and deviation data.

Seismic Data Import

The seismic volume is imported into a user defined folder in SEG-Y format. It is cropped and then realized. From the crop-realized volume, inline, crossline are inserted. After loading into memory, time slice is also inserted.

After the seismic volume is imported into the software, cropping and realization is carried out, so as to reduce the processing time due to the data and to chop away part that is not needed for work, leaving behind only the area of interest.

A 3D window is opened and a new interpretation window to view and also start fault mapping. The faults were mapped on the crosslines and the continuity viewed on the inlines.

After importing our data, the first step in this modeling research work is to quality control various types of data and their consistency to avoid the possible problem of “garbage in equal’s garbage out”. A quality check of the well and seismic data indicated that they were of acceptable quality.

Results and Discussion

In the evaluation of a petroleum reserve, it is necessary to determine accurately certain petrophysical properties such as porosity and permeability of the reservoir rock. In this study, three sands were delineated as hydrocarbon bearing sands within the Agbada formation of the field as shown in the structural well correlation. The sands were identified to be highly prolific in hydrocarbon yield and were completely analysed to estimate their petro-physical parameters.

a) Petrophysical Evaluation of the Reservoirs

Three sands units (A1 to C3) were delineated from the correlation of three wells using well logs. The Lithologic units are consistent across the wells, meaning that most lithologic units are present. Increasing trend of the thickness of the shale units with depth indicate that the sequence is approaching the Akata formation.

Well Abi 1

The reservoirs in this well have average thicknesses from 180 Ft in reservoir A1 to 72 Ft in reservoir C3. The average neutron-density derived porosity for the reservoirs are between 41.5 to 46.4 %, which indicates good average porosity. The porosities are satisfactory for a reservoir to be adjudged a producible reservoir. The water saturation (12.6-31.4 %) for the reservoirs suggest that the reservoirs are mainly hydrocarbon bearing. The low water saturation in reservoirs A1 to C3 (11.6,13.1 and 14.3 %) indicates 79.6 % 86.0 % and 89.2.9 % hydrocarbon saturation respectively .

Well Abi 2

The average porosities of the reservoirs are moderate to good (31.3 %-4.6 %) to accommodate large hydrocarbon yield ,and reservoirs A1 and B2 show evidence of hydrocarbon saturation as the low values of the water saturation in reservoirs A and B (8.0 and 8.5 %) indicates 861.3 % and 85.8 % hydrocarbon saturation respectively with no evidence of hydrocarbon in reservoir C 3. The porosities in these reservoirs are also satisfactory to be adjudged a producible reservoir. The reservoirs in this well have average thicknesses from 142 Ft in reservoir A 1 to 55 Ft in reservoir C.



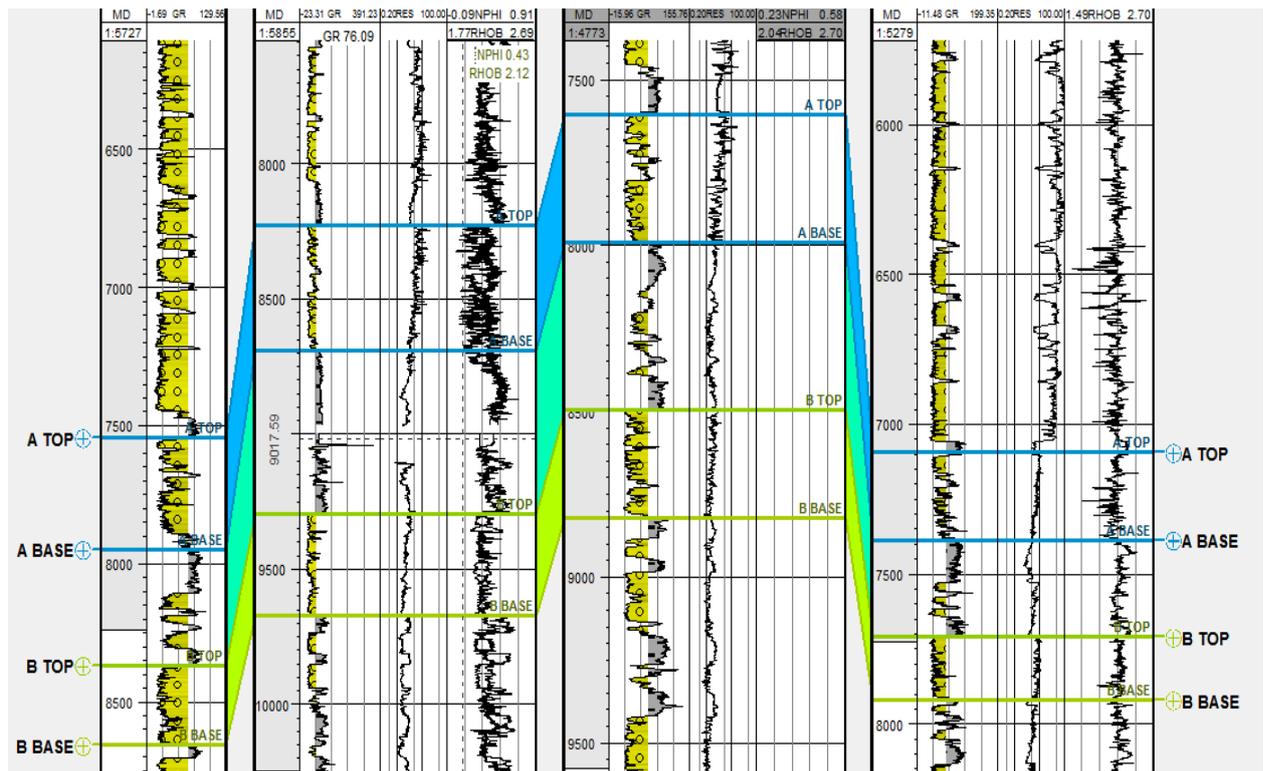


Figure 6: Well Correlation panel

b) Seismic Attributes

The seismic section was mainly used for structural interpretation. The seismic lines have been interpreted which resulted in the construction of time contour maps. From correlative study of all seismic lines with the time contour maps, the following results of structural interpretation are deduced: No definite fault trend is present but localized normal faults do exist due to extensional tectonics. Apart from the three major faults seen on the section, there are other minor faults, about six of them formed by post depositional process. In most cases, they are often referred to as synthetic secondary faults as some are formed on the foot wall and upthrow axis of the major faults. They can also be regarded as antithetic as they were formed on the hanging wall, down-throw axis. The presence of these faults in the study area is an indication that there is a possibility of hydrocarbon accumulation. Baker (1990) and Duventum (1994) described faults as good migration path for hydrocarbon into the reservoir rocks [8-9].

The normal faults also make local scale horst and graben geometries favourable for the accumulation of oil. The time structure map gives information about the seismic reflection two-way time for each hydrocarbon bearing sands. A close examination of this map shows the presence of structures (growth fault and anticline) that can possibly harbour hydrocarbon in the study area.

An anticlinal structure could be observed about the central portion of the study area closing on the major faults. This shows that the trapping mechanism is a fault-assisted anticlinal structure. The major faults polygons around the closures serve as seals which can help to trap hydrocarbons migrating to the surface as a result of gravitational push. The area obtained from the seismic section when combined with the thickness of the reservoir and other petrophysical parameters such as porosity (ϕ) and water saturation (S_w) are used in estimating the volume of hydrocarbon in place in the reservoir. It is worthy of note that the three delineated reservoirs have high potentials for hydrocarbon in sands A1 and B 2 than in sand C3.

Table 1: Computed Petrophysical Parameters from well ABI

ABI	TOP	BOTTOM	THICNESS	DENSITY	ϕ (%)	RW(Ω m)	SW (%)	Sh(%)
A1	3770	4050	180	1.70	42.3	0.426	9.3	78.3
B2	4121	4275	135	1.72	41.5	0.424	10.5	88.5
B3	4356	4520	44	1.75	40.3	0.420	11.0	87.8

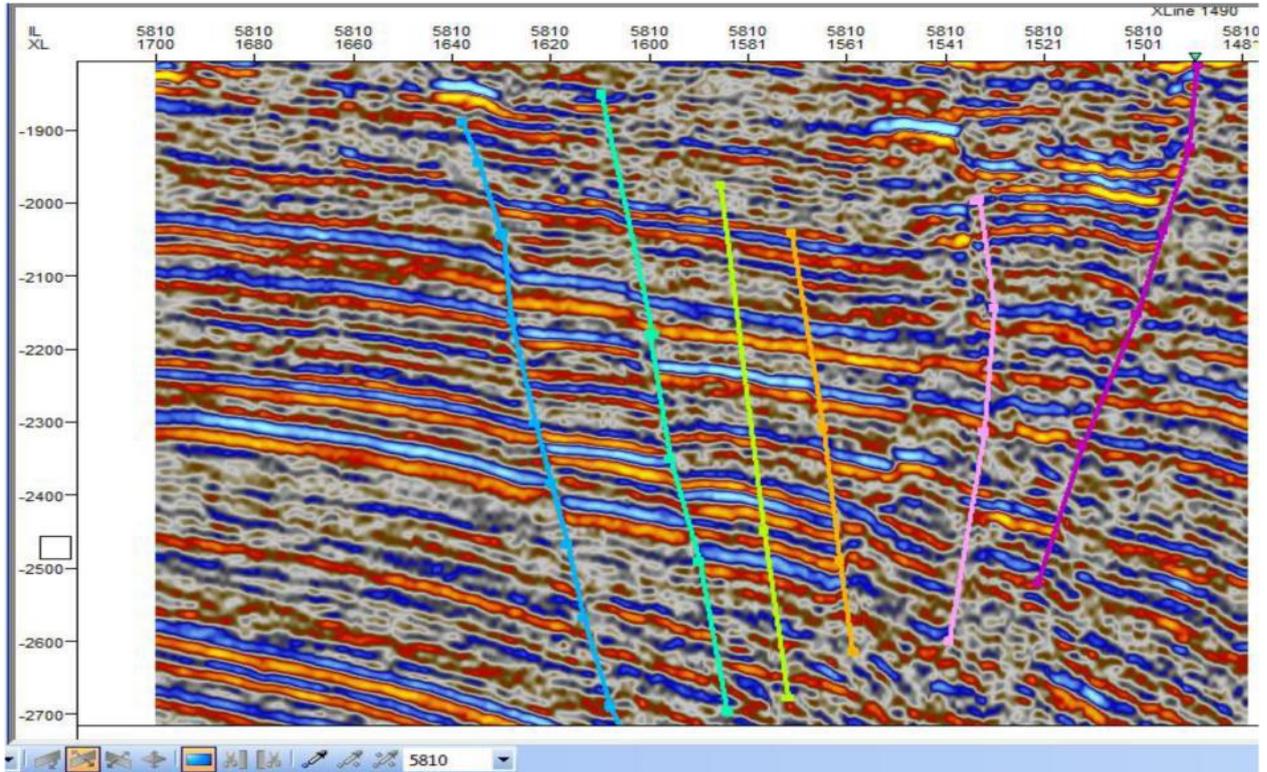


Figure 7: Seismic Interpretation showing Minor Faults

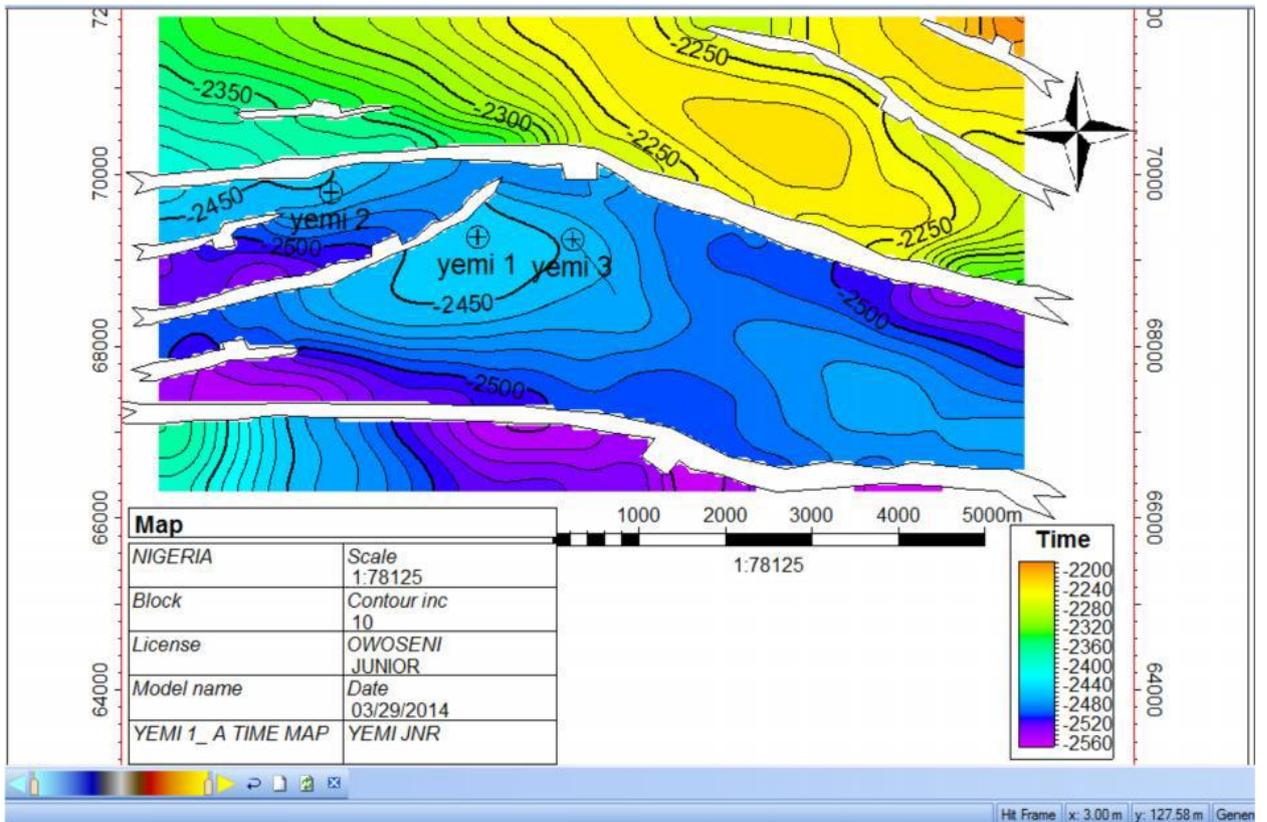


Figure 8: Time contour Map of Sand A

Conclusion

From this research study, the average values of porosity for each productive zone ranges from 28 to 38 %; average values of water saturation ranges from 11 to 32 %, and average values of hydrocarbon saturation ranges from 82.1 to 95.2 % in the three reservoirs identified from the three wells, ABI, ABI 2 and ABI 3. The hydrocarbon saturation indicates two productive zones within the reservoir formation, Sands A and B. The study however concluded that Sand A1 bears a considerable amount of reserves of about 97331581.11STB. From the estimation, it can be concluded that the value of hydrocarbon (either gas or oil) in place for reservoir A1, as revealed by this analysis could be said to be in commercial quantity and the profitability may be high which could cater for the expenses of carrying out the exploration and exploitation of either oil or gas.

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