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RESERVOIR CHARACTERISATION AND STRUCTURAL INTERPRETATION FOR PROSPECT EVALUATION- A CASE STUDY

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Abstract

This paper presents a case study dealing with reservoir delineation and characterisation of the Basecopia field, part of Niger Delta Nigeria. The data set utilized for this work incorporate 3D seismic data, well log suites containing gamma rays, resistivity and porosity logs (neutron and density). These logs were utilized to focus petro-physical properties in three (3) wells. 780 inlines and 496 crosslines of seismic information covering an area of about 234 km^2 were utilized. Faults were picked and correlated. Horizons of hydrocarbon bearing sands were picked in view of the re-suit from seismic- to-well tie. These were utilized to produce time and depth maps for a horizon keeping in mind the end goal to recognize the different basic highlights inside the field. Petro-physical aftereffects of the study demonstrate the dominating liquid found in the three wells is light oil at True Vertical Depth Sub Surface (TVDSS) of -7109 to -7333 ft. in Well A, -6916 to -7044 ft. in Well B and -7694 to -7858 ft. in Well C. Thereafter, seismic attributes such as the instantaneous frequency and the dominant frequency indicated the presence of channel filled sand containing hydrocarbon in regions around the wells. Hence, the wells can be said to be properly situated within the reservoir hydrocarbon bearing sand with spatial facies evenly distributed. The study however concluded that Well A bears a considerable amount of reserves of about 209.52Mbbls

Keywords: Hydrocarbon; reservoir; seismic attribute; well log; horizon.

1. Introduction

A reliable and accurate reservoir characterization study is inevitable in reservoir management. A major challenge in present day reservoir characterization is to integrate all the different kinds of data to obtain a high-resolution and accurate reservoir model [1]. Hence, Reservoir characterization requires building an accurate model of the reservoir by using appropriate data gathered from previous studies. The seismic data which can cover entire reservoir space has a high uncertainty given the quality and the vertical coarse resolution of seismic. This data sample is much coarser than the data measured in wells, which vary from some centimeters to a few feet. It is important information never the less, but in almost all applications the seismic data cannot have a direct link to the wells properties (lithology, porosity and permeability), and are difficult to use directly in reservoir characterization. Seismic attributes have been increasingly used in both exploration and reservoir characterization studies and routinely been integrated in the seismic interpretation processes [2]. This study aims at integrating seismic data with well log data in identifying reservoir characteristics, qualify and also to quantify reservoirs in order to assess the production potential. The objectives of this study include: To delineate and correlate a hydrocarbon bearing sand across the field, to estimate reservoir fluid saturation and petro-physical properties, to map reservoir lateral extent and delineate the hydrocarbon trapping mechanism at the reservoir level and to extract seismic attributes for spatial facies and fluid distribution.

1.1. Location & Geology of the study area.

The Niger Delta basin is located in Nigeria (figure 1), with clastic wedge shaped along a failed arm of a triple junction framework (aulacogen) initially developed amid separation of the South American and African plates in the late Jurassic [3-4]. The two arms that took after the southwestern and southeastern coast of Nigeria and Cameroon formed into the passive continental margin of West Africa, while the third failed arm formed the Benue Trough. The sub areal bit of the Niger Delta covers around 75,000 square kilometer territory inside the Gulf of Guinea and extending more than 300km from summit to mouth. In spite of the way that the progressed Niger Delta shaped in the early Tertiary, residue began to accumulate in this area in the midst of Mesozoic breaking associated with the partition of the African and South American landmasses [5-7].

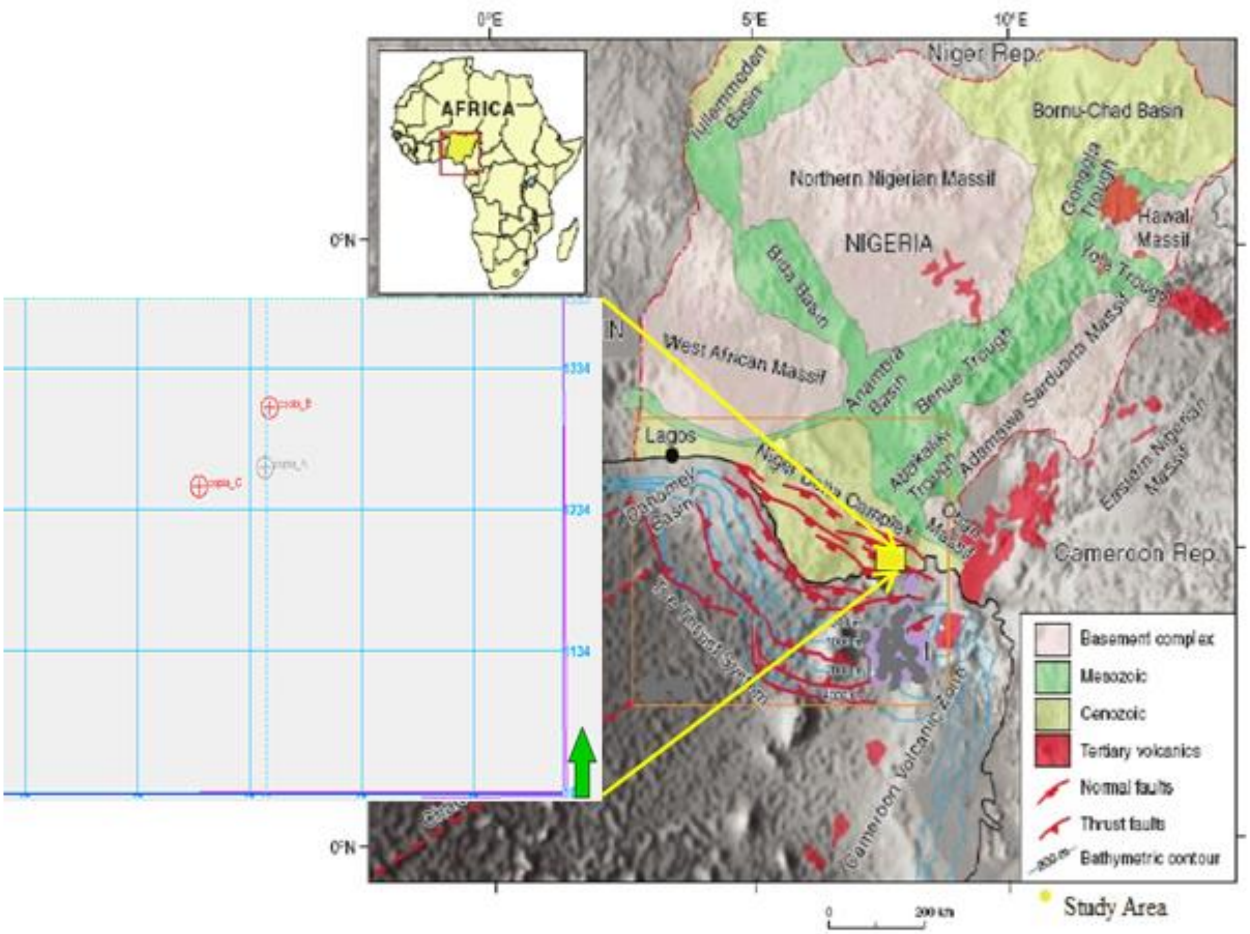

Figure 1. Map of Niger delta showing location of study area and the base map of the study area

There are three major formations in the Niger delta which are the Benin formation (mainly sandstone), the Agbada formation (mixture of sandstones and shales) and the Akata formation (mainly shales) see Fig. 5 on the next page for more explanation

2. Materials and methods

The materials deployed for this research was sourced from Schlumberger and from Basecopia field located in the Niger Delta basin, Nigeria. The seismic data used for this research is approximately 243km^2 in Area, with 780 Inlines and 496 Crosslines interpreted for the purpose of this research work. The well statistics are shown in table 1.

Table 1. Well Statistics

Well	Type	Log Curves	Total Depth (ft))
A	Straight	RHOB, SON3, RT_0, DTN_, GR_NM	10,020
B	Straight	CALF, SON3, FDC, VSH, RT, POR, GR_NM	7,991
C	Straight	LL9D, GRL, FDC, CALS	10,133

Log correlation and well to seismic tie was done using Petrel E&P software on a Windows-based personal computer. Determination of stratigraphic units that are equivalent in age or stratigraphic position was also carried out. This was used to delineate the boundaries of subsurface units for the purpose of preparing subsurface maps and cross sections. Maps were generated after the well tops interpreted from the well data are posted on seismic and the corresponding seismic event are tracked throughout the seismic cube and surfaces are generated and contoured to make a map in time. The time map was converted into a depth map with the aid of a velocity function generated with the aid of the checkshot. All smoothened horizons in time-domain were depth-converted using a suitable velocity model calibrated by the checkshot function available in Well C. The depth-converted horizons were gridded and depth structure maps were generated. Figure 2 below is a schematic representation of the workflow used for analysis of the data set.

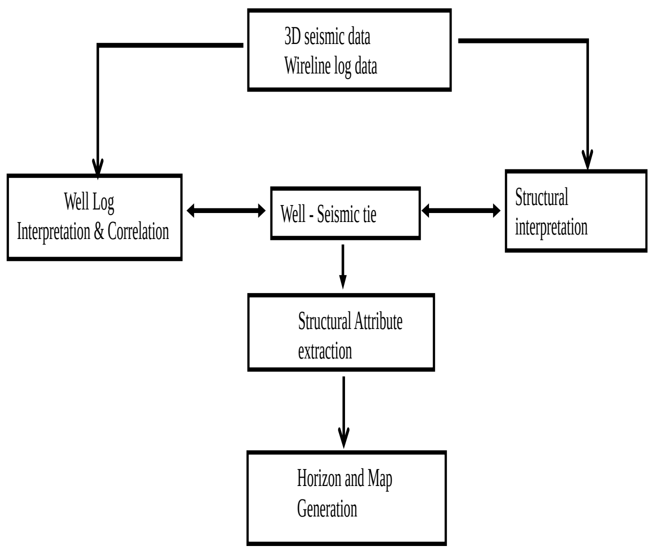

Figure 2. Schematic representation of the workflow used for analysis of the data set

3. Results and discussion

The three (3) wells drilled within the study area mostly encountered the two of the three main lithostratigraphic units of the Niger Delta, the Benin and Agbada formations. The deepest well in the study area, Well C (10, 133ft) encountered the Agbada formation. The zones of interest for this study are the paralic clastics of the Agbada formation which forms the hydrocarbon-prospective sequence in the Niger delta [5]. Correlation, whether with seismic or with well logs is nothing more than pattern recognition. The well correlation shown in Figure 3 enabled the delineation of the reservoir sand across the wells and the determination of spatial distribution of the reservoir fluids. It also gave indication of the reservoir structural geometry and enabled the constraining of the horizon interpretation from the seismic data. Well correlation involves matching well log signatures on different wells. It is done with the well log that indicates the lithology of the formation. In this case, it was done with the gamma ray log. Looking at Figure 3 below, it is observed that Well A has a higher resistivity than Wells B and C as seen in the resistivity log within the reservoir. High resistivity might indicate the presence of hydrocarbons therefore it is suspected that the reservoir in Well A contains more hydrocarbons.

3.1. Petrophysical interpretation

Petrophysical evaluation was carried out within the pay zone intervals as a marker to determine the reservoir properties, quality and volume of oil in place.

Reservoir Sand in well A

This is thick sand with clayey/shale intercalations. The gross thickness is about 207 ft. Although the reservoir sand is oil-bearing extreme care must be taken to avoid the shale during exploitation because the shale can reduce the efficiency of the reservoir by blocking the pore spaces within the reservoir. The sand has a porosity of 29 %, moderate net to gross of 70 % and water saturation of 30 % good enough for exploitation.

Reservoir Sand in well B

It has a sand thickness with a gross interval of 131 ft. and a small inter-bed of shale. The sand is characterized by a porosity value (39 %), net-to-gross of 80 % and low water saturation 20 %. The low water saturation is possibly due to the structural position of the well within the reservoir level.

Reservoir sand in well C

This is clean sand with blocky gamma ray signature. The sand is thick sand 164 ft. It is characterized by a porosity value of 10 %, net-to-gross of 60 % because it is clean and water saturation of 38 %.

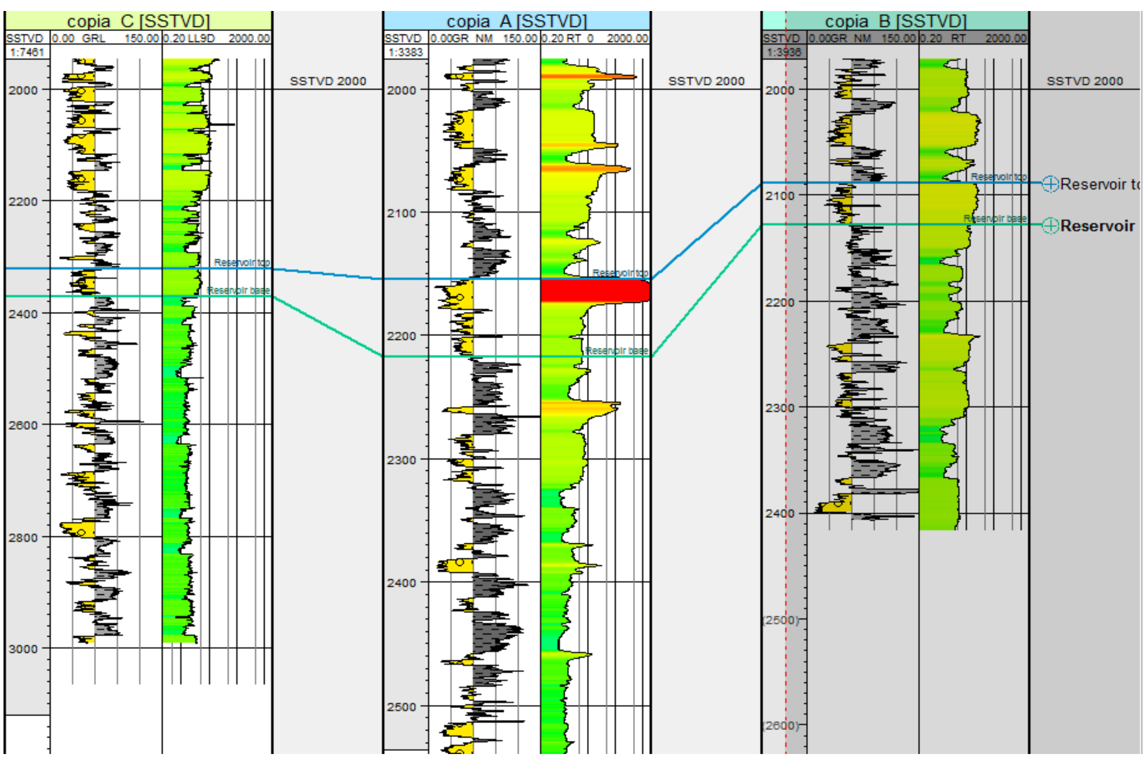

Figure 3. Well log interpretation and correlation showing the identified reservoir sand delineated across the three wells

This horizon mapping was carried out on both inline and crossline seismic sections by mapping the continuous and strong seismic reflections which marks the top of the sandstone reservoirs (figure 4). The synthetic seismogram enabled the identification of the events that indicate the top of the sandstone reservoirs. The validated sand intervals from the well log data were posted on the seismic data using the checkshot data. Also, the generated synthetic seismogram from the well data formed the basis of selecting the seismic character to track or interpret across all the seismic lines (figure 5). Synthetic listric growth fault dominates the structural style observed in the study area. Associated with these growth faults are rollover anticlines, shale ridges and shale diapers which are caused by shale upheaval ridges. Mud diapers are the most common and occur on the landward side of the growth faults restricting sedimentation on the up-thrown side of the faults and enhancing sedimentation on the down-thrown side [8]. Three major faults denoted as Fault 1, Fault 2 and Fault 3 were identified (Figure 5) and marked based on criteria such as abrupt termination of events, overlapping of reflection events and anomalous dip near fault zones. These faults are referred to as simple rollover structure with clay filled channel [5]. The time map of the reservoir top shown in figure 5 was generated from the horizon mapped and was smoothened severally to remove the effect of minor mispicks. Sequel to that, a velocity function calibrated by the checkshot was used to generate the depth map of the reservoir top (figure 7). The main structural traps observed from both maps are faulted (F4 and F5) anticline possibly cored by shales (Figures 6 and 7). The structure maps indicate Northern to North-Central trending high and low features in the southern part. The structural position of well A which is within the seismic data coverage area indicates the consistency of the seismic interpretation.

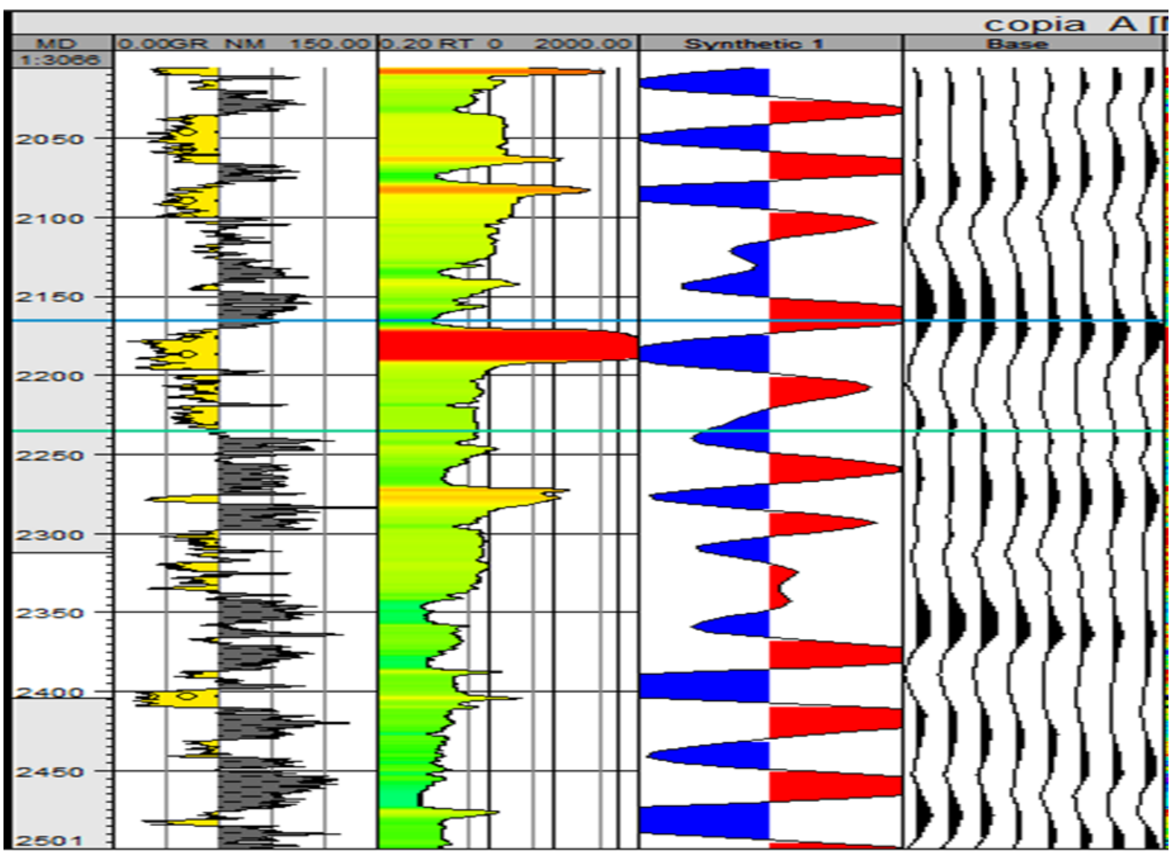

Figure 4. Synthetic seismogram (in black and white) generated from well A

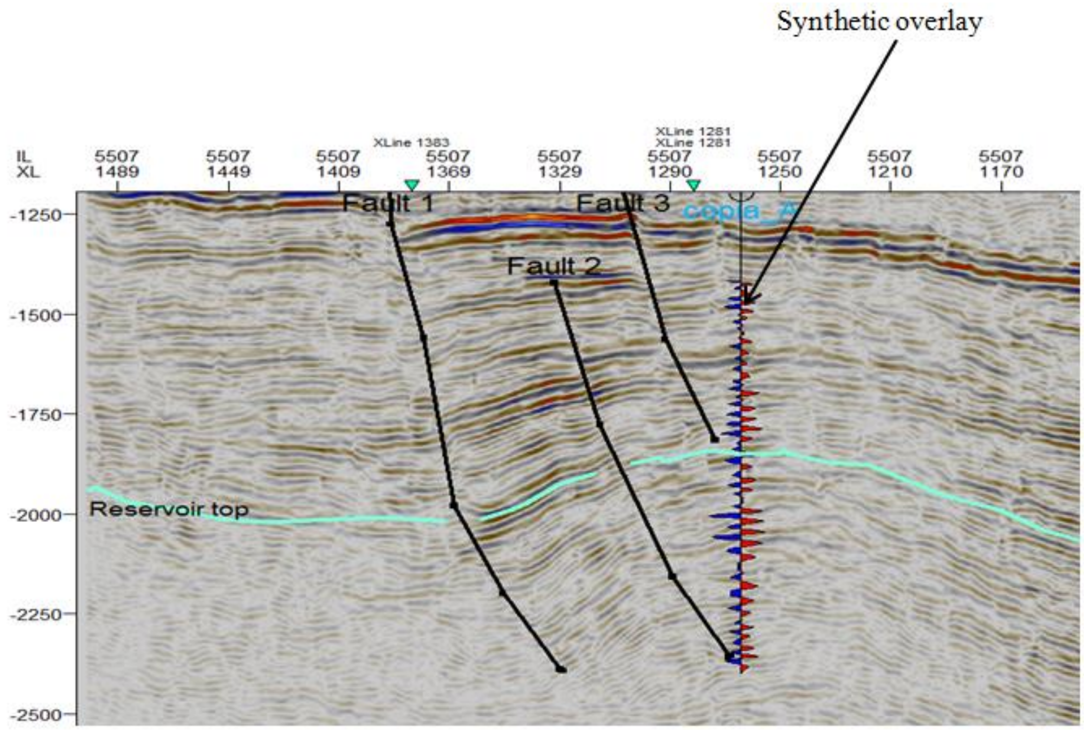

Figure 5. Inline 5507 showing the two mapped faults F1, F2 and F3

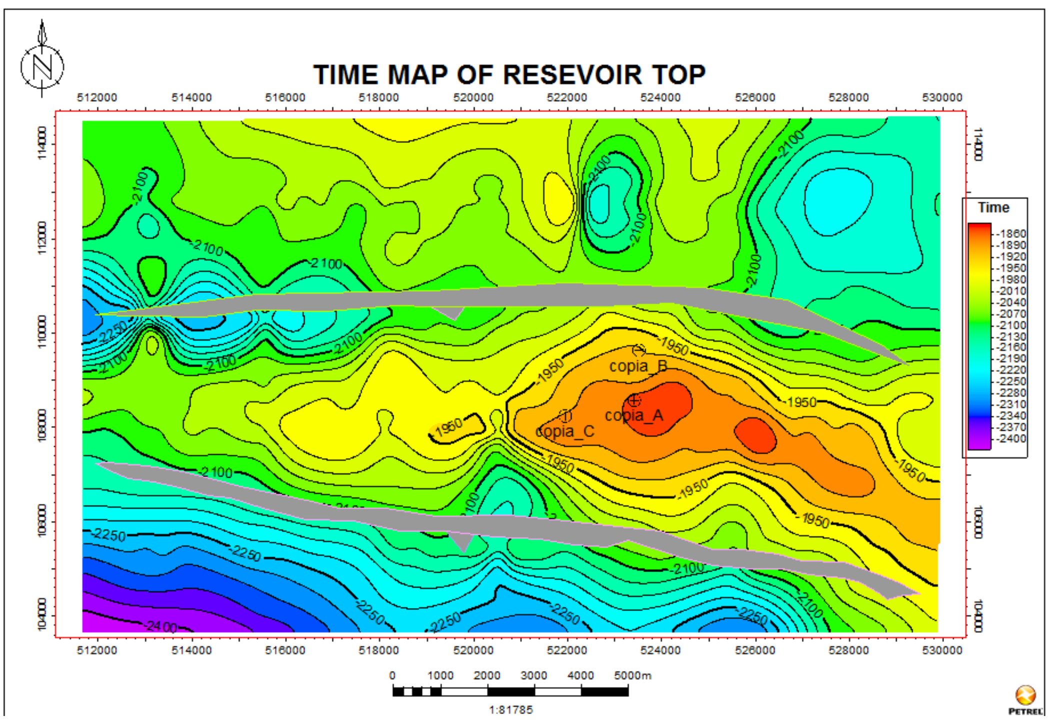

Figure 6. Time structure map of mapped reservoir top.

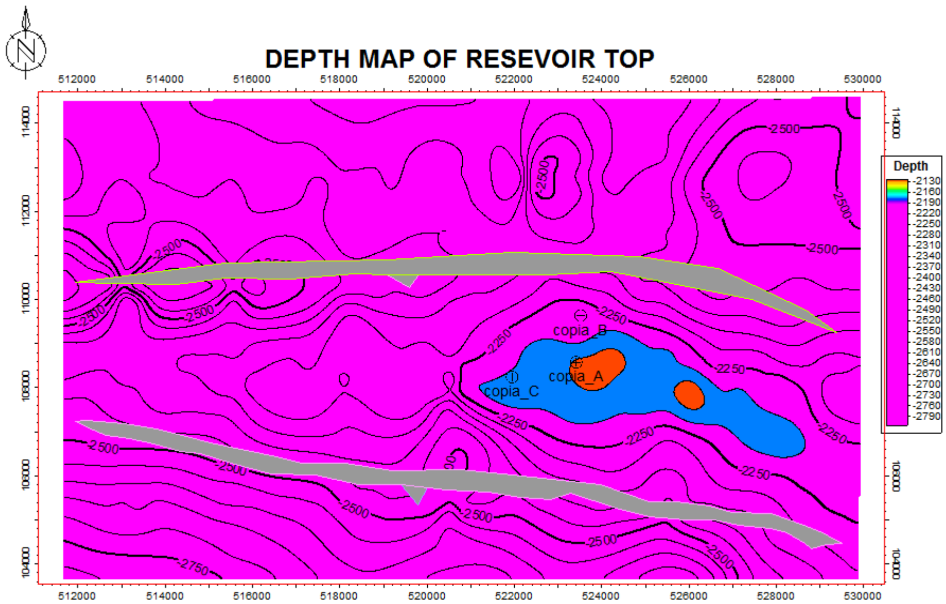

Figure 7. Depth map showing reservoir area

3.2. Cross-Plot analysis

Cross plots are visual representations of the relationship between two or more variables, and they are used to visually identify or detect anomalies which could be interpreted as the presence of hydrocarbon or other fluids and lithologies. Acoustic impedance is a rock property that varies with changes in lithology, porosity, fluid content, depth, pressure and temperature. A plot of acoustic impedance and other well log and elastic parameters can be used as an indicator of lithology, porosity and even the presence of hydrocarbons. Thus, it can be said to be a tool for qualitative and quantitative reservoir analysis and mapping of flow units. Through cross plot analysis of the acoustic impedance and porosity data, we tried to discriminate the lithology and fluid properties of the reservoirs under consideration. Result of the cross-plot analysis for the reservoir from well A is shown in Figure 8.

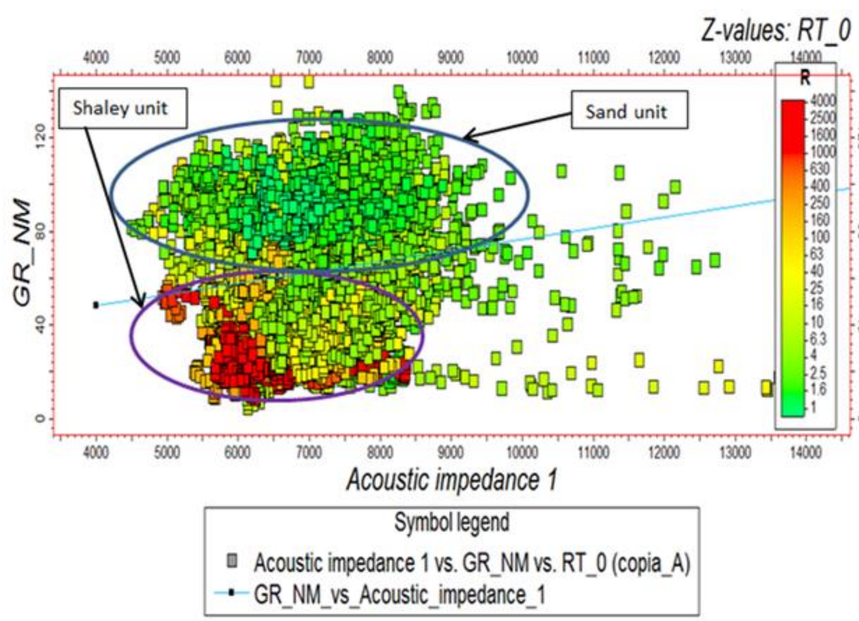

Figure 8. The cross plot of acoustic impedance against porosity from well log

3.3. Seismic attribute analysis

The dominant and instantaneous frequency seismic attributes was used to characterize the reservoir. From Figures 9 and 10, we can see a higher frequency signal around the area where the wells are located indicating the presence of hydrocarbon. As opposed to a Fourier frequency, the instantaneous frequency is for the most part a time-dependent frequency. The instantaneous frequency of a sinusoidal sign is steady and equivalents the oscillating frequency, obviously. This capacity gives the dominant frequency (i. e. the frequency of highest amplitude) of a time wave. The bright yellow spots indicate areas of good permeability, inter-connectivity of pores, channels and vugs and also the presence of hydrocarbon. It is not as clearly indicated in Figure 9 below as a result of errors in data input and approximation in computation.

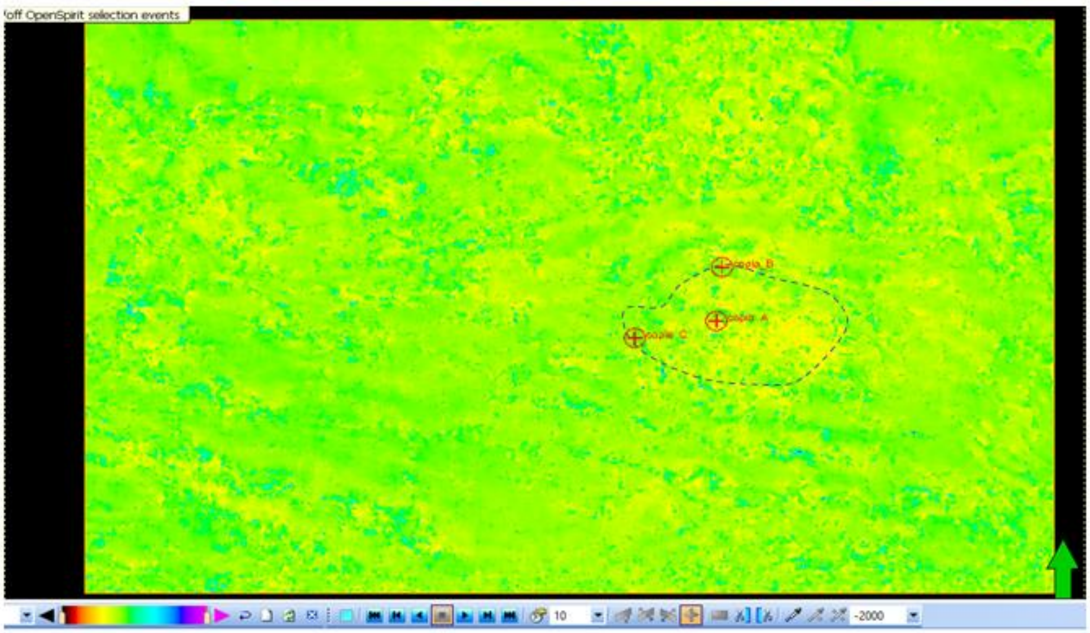

Figure 9. Dominant frequency showing petro-physical property

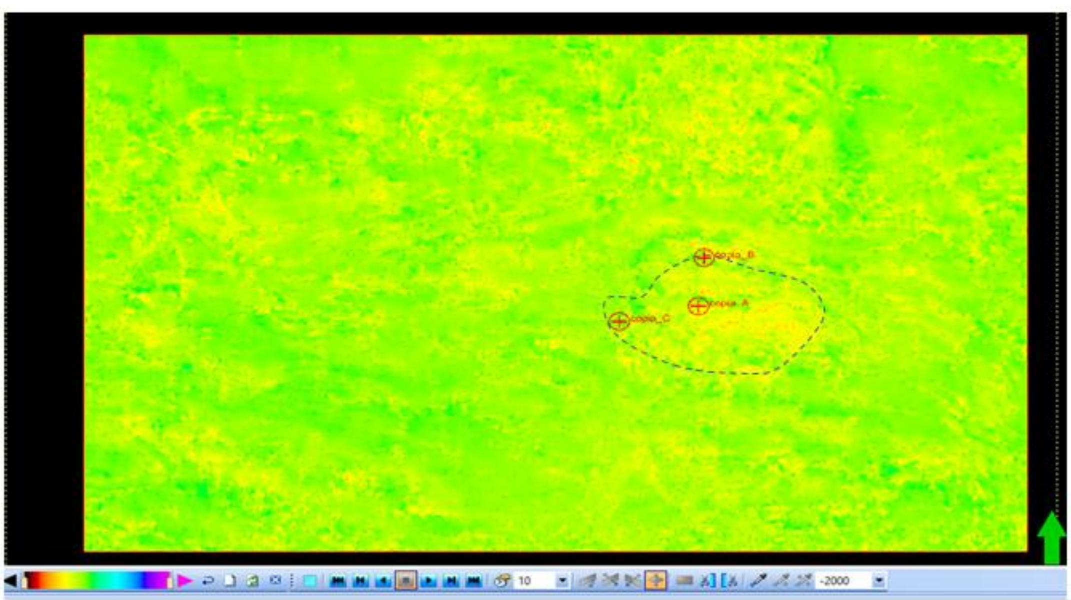

Figure 10. Instantaneous Frequency Attribute showing petro-physical property

Reserve estimate in Well A

$$\text{STOOIP} = \frac{\text{Area} \times \text{thickness} \times \text{NTG} \times \emptyset \times (1-\text{Sw}) \times 7758}{\text{FVF}}$$

where: Area = 3.80 × 10^6 m^2 = 3.8ft^2 ; Thickness= 66ft; Formation Volume factor of oil = 1.2

Therefore, we have $= \frac{3.8 \times 66 \times 70 \times 26 \times 71 \times 7758}{1.2}$ = 2.095×10^{11}bbls ≈ 209.52Mbbls

NB: For the Net-to-gross, porosity and water saturation, the average was taken across all the wells.

4. Conclusion

A sequence in Basecoipa field was successfully chosen and studied and two reservoirs were successfully chosen for the study by well correlation. Three major faults have been interpreted across the field from the seismic sections. The faults are synthetic listric growth faults which are typical of this depobelt in the Niger delta. The depth map of both sand tops indicates that the major trap is a fault assisted closure since the contours closes on the fault (i.e. rollover anticline). This kind of closures are common in the Niger delta and are known to be very efficient in trapping hydrocarbon the anticlinal structural framework mostly cored by shales is maintained even if the fault fails. The integration of both well log signal and the seismic data enabled the identification, petrophysical evaluation, structural framework of the field and the structural trapping mechanism at the identified reservoir level. The estimated reservoir properties including an average porosity of 26%, average net-to-gross of 70% and water saturation of about 71 % has shown that the reservoir sand is good enough and can be considered for exploitation and development. The study however concluded that Well A bears a considerable amount of reserves of about 209.52Mbbls.

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