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3-D Seismic Attributes for Reservoir Characterization of "Y" Field Niger Delta, Nigeria.

Ajisafe, Y.C[1]., Ako, B. D[2].
[1]Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria
[2]Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract: *An integrated interpretation of seismic and well log data over "Y" Field in the Niger Delta area of Nigeria was carried out with the aim of characterizing reservoir-rocks using quantitative seismic attributes and petrophysical properties. 3-D seismic sections, composite well logs and check-shot data were used. Calibration of wells to seismic was carried out. Depths and thicknesses of hydrocarbon bearing zones were obtained from correlated wells. Structural maps were used to study the geometry of reservoirs in the field. Well log data showed that the area of study was characterized by sand-shale inter-beds. Three reservoirs were mapped at depth range of 1524 to 1800 m, with thicknesses of 10- 45 m. Porosity of the reservoirs ranged from 30- 40 %, water saturation 30-45 % and hydrocarbon saturation 65- 80 %. Seismic attribute maps revealed presence of hydrocarbons in the identified sands. There was a good correlation between the structural high and zones of anomalous amplitude. It was concluded that seismic attributes could be used to predict reservoir rock properties and characterize reservoir.*

Keywords: *Hydrocarbon, Petrophysical properties, Reservoir Characterization, Reservoir Rocks, Seismic Attributes.*

I. Introduction

Reservoir characterization is the process of mapping a reservoir's thickness, net-to-gross ratio, pore fluid, porosity, permeability and water saturation. Reservoir characterization requires the construction of detailed 3D petrophysical property models contained within a geological framework. Structural interpretation of seismic data has been and continues to be important in the generation of the framework of the reservoir model [1].

Seismic attributes was defined as all of the measured, computed or implied quantities obtained from the seismic data. Seismic attributes provide a link between rock properties and seismic data. They are directly or indirectly related to rock properties, and are directly measured from the seismic data [2]. The advantage of using well and seismic data rather than well data only, is that the seismic data can be used to interpolate and extrapolate between and beyond sparse well control [3].

Reservoir models constructed from log data alone display an excellent vertical resolution and a poor areal (horizontal) resolution [4]. This is a direct reflection of the resolution characteristics of the log data - high vertical resolution and limited depth of investigation. Seismic data possess the opposite resolution characteristics: high areal resolution (bin size of the 3D survey) and poor vertical resolution (function of the seismic frequency content and velocity of the reservoir).

In the reservoir characterization, 3D seismic attributes are calibrated against real and simulated well data to identify hydrocarbon accumulations and reservoir compartmentalization [5]. The success of reservoir characterization depends on the comprehensive integration of various disciplines. Complex structural interpretation results, seismic/sequence stratigraphy approach, core/log data, common geological knowledge and depositional/facies environment modeling are essential parts in reservoir geological model building [6]. Reservoir characterization includes determination of reservoir limits, structure, volume and reservoir properties such as porosity, permeability, net pay thickness, and heterogeneity [7]. Seismic attributes have been used in the past as a way of qualitatively inferring rock and fluid properties from seismic data. The aim of this study is to characterize reservoir-rocks using quantitative seismic attributes and estimate petrophysical properties of "Y" Field Niger Delta**.**

II. Geology Of The Niger Delta

The Niger Delta Basin, situated at the apex of the Gulf of Guinea on the West Coast of Africa, is one of the most prolific deltaic hydrocarbons provinces in the World. The Niger Delta is located between Latitudes 4^0 and 6^0N and between Longitude 3^0 and 9^0E [8]. The Niger Delta is flanked on the northwest by a thick outcrop of uppermost Cretaceous sedimentary rocks, which in turn rest unconformably on an extensive Precambrian Basement Complex. A narrow step-faulted hinge zone trending Northwest-Southeast marks the transition from Niger delta Tertiary growth fault tectonics to the uniformly dipping beds of the upper Cretaceous delta (Fig. 1).

The Niger Delta represents a typical offlap sequence in which the Benin, Agbada, and Akata Formations are time-equivalent, proximal to distal, prograding facies units. This progradation was influenced by synsedimentary growth faults whereby the rate of forward advance of the sandy Benin Formation was temporarily retarded when a major growth fault was activated at the delta front. The downthrown part of this active boundary fault became the new focus of Agbada or paralic facies deposition until subsidence in front of the fault was stabilized or filled to near sea-level. The sandstone of the Benin Formation then resumed its rapid ocean ward advance over the newly established depobelt.

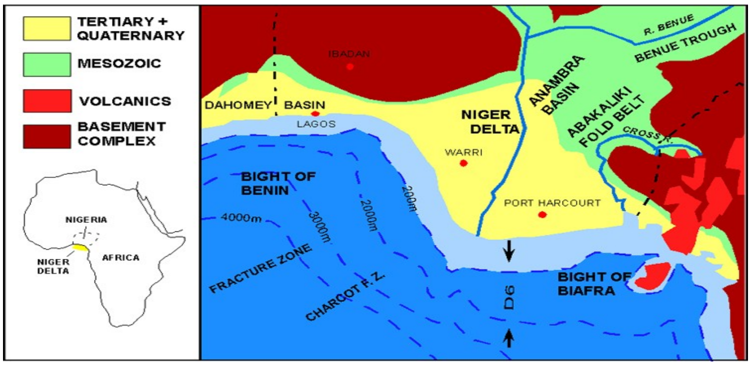

Figure 1: Geological Map of Niger Delta [9].

III. Methodology

The dataset for this study comprised 3D seismic data, a suite of geophysical wire-line logs from two wells and velocity checkshot survey data. Seismic attributes such as zero phase amplitude (maximum and RMS), and impedance, derived by seismic interpretation techniques were used to describe reservoir properties based on physical links to seismic wave propagation using the GeoFrame software. Fifty (50) in-lines and fifty five (55) cross-lines were analyzed in "Y" Field for this research work. Calibration of wells to seismic was carried out in order to evaluate the geologic conditions. Well data provide high resolution depth related information, while seismic data provide spatially dense, but vertically lower resolution time related information. Attribute maps were drawn along the horizons mapped. Correlation of wells to obtain depth and thickness of the hydrocarbon bearing zones, and cross plot to discriminate the fluid types, either oil or gas or condensate was carried out. Computation of petrophysical properties was carried out.

IV. Discussion Of Results

4.1 Structural Analysis

Faults were picked on the basis of abrupt termination of event, change in pattern of events and dip of events. A total of four faults were mapped. The faults mapped have curved; concave-upward fault planes in down dip direction. Four reflection events were picked on the seismic sections (Fig. 2). The horizon 1 at 0.8256 seconds is marked with purple colour, the top of reservoir (horizon 2) at 1.250 seconds is marked with lemon green colour, and horizon 3 is marked at 1.750 seconds with yellow colour and horizon 4 with green colour; at 2.500 seconds. Fig. 2 depicts a typical seismic section, showing the arbitrary cross section between well 01 and well 02 with horizons mapped across the section.

The time maps generated show that the most dominant trap in "Y" Field was the crescentic growth fault generated rollover anticlines trending northeast–southwest and northwest–southeast. The rollovers develop as a result of bending of the downthrown side fault block as it conforms to curve fault surface. The anticlinal trap hydrocarbon may possibly have collected at these locally high points in the subsurface, which is where the high contours are closed against fault (Figs. 3a&3b).

The hydrocarbons are predominantly trapped by rollover anticlines and fault closures in "Y" Field. The areas where the contours enclosed represented by thick black contour lines are good locations for drilling of well in "Y" Field (Figs 4a&4b).

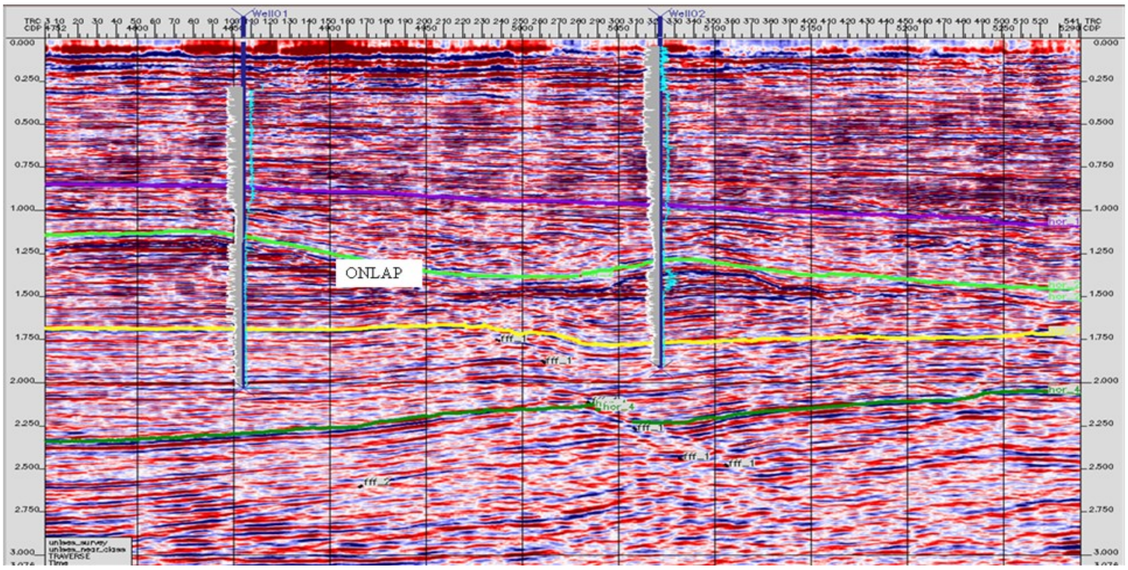

Figure 2: A seismic section, showing the cross section between the two wells and mapped horizons and onlap suggesting stratigraphic trap for hydrocarbon.

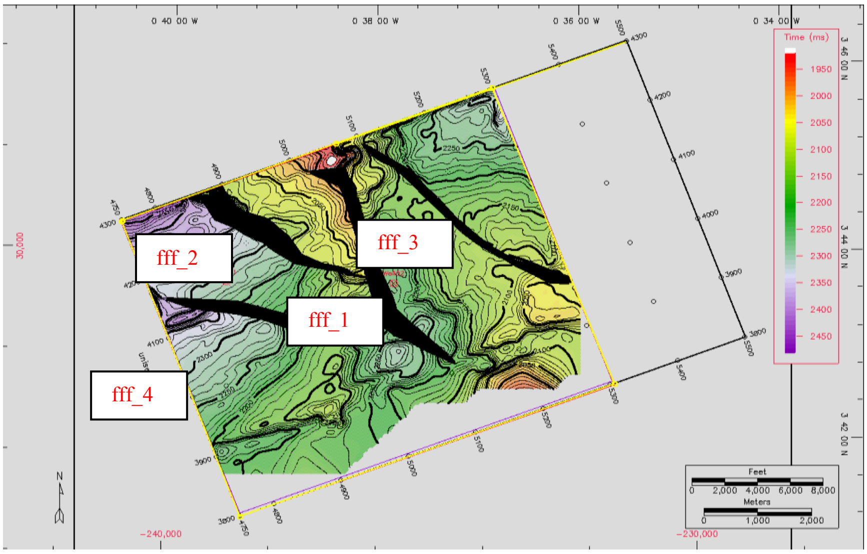

Figure 3a: Time map for Horizon 4(structural trap) with contour interval 10ms

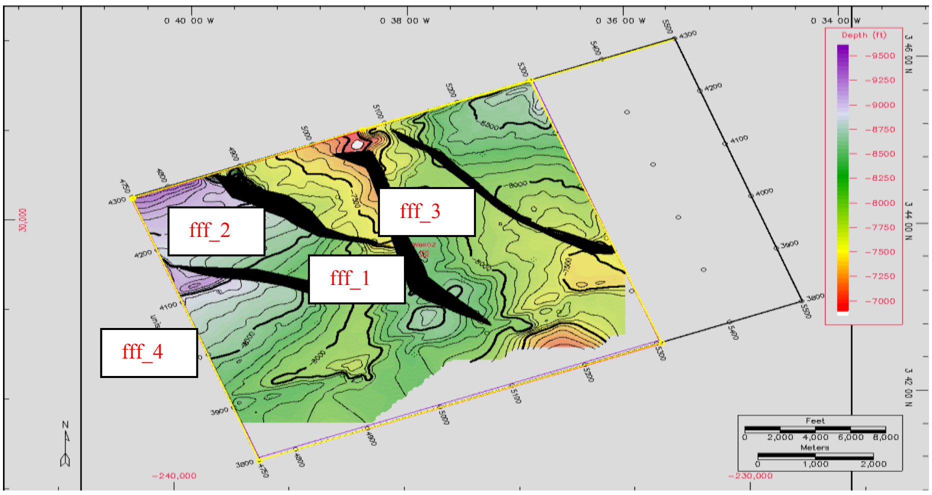

Figure 3b: Depth structural map of Horizon 4.

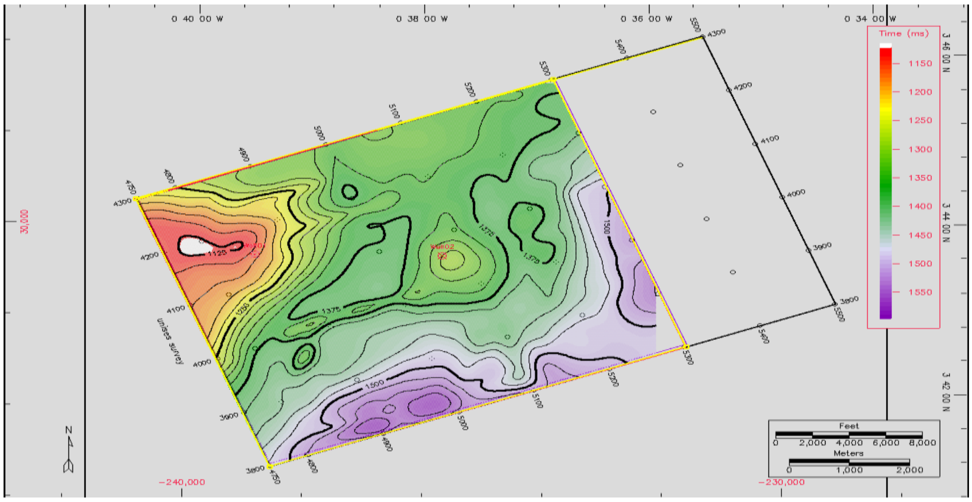

Figure 4a: Time map for Horizon 2 (top of the stratigraphic trap); contour interval is 25ms

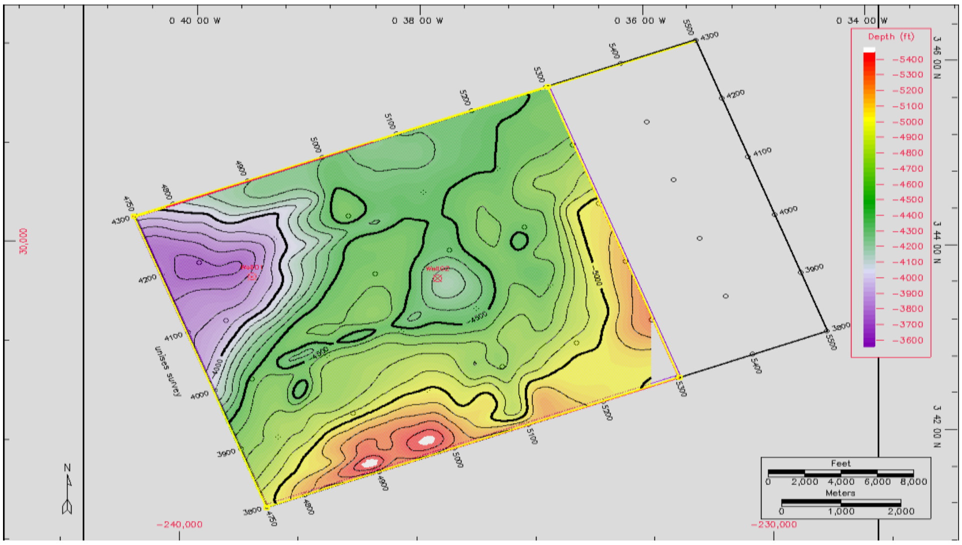

Figure 4b: Depth structural map of Horizon 2.

4.2 Seismic Attributes Interpretation of "Y" Field

The amplitude maps (Figs.5and 6) show areal extent of the bright spots (Sweet spots) of various seismic attributes computed for reservoir sands. Having identified a number of qualitatively bright spots, seismic amplitude was correlated with the well-log data of interest. The bright spots may be caused by increased gas saturation along the top of the reservoir. The observed outstandingly strong reflection (bright spots) is indicative of reservoir rocks, which may be due to the presence of hydrocarbons in the identified sands (Fig. 5).

Fig. 6 is a maximum amplitude map of Horizon 2 – the top of L300 sand, amplitude levels are portrayed by the intensity of the colour, high amplitudes being represented by the range of reddish yellow colour and the lower amplitude by the range of dark blue areas. The high amplitude pattern observed around the well locations indicates bright spot which may be caused by a locally greater-than-normal velocity contrast between two layers. Similar bright spots were located on Horizon 4 around the wells may probably be good prospects which is not proven (Fig.7). The bright spot observed on the upthrown of the antithetic (fff_2) fault and on the downthrown of the main structure building (fff_1) fault validates the result from the depth maps superimposed on the amplitude map (Fig.8). High amplitude was observed around the drilled wells and other locations away from them. Fig. 9 is the root mean square (RMS) amplitude map of Horizon 2 showing isolated amplitude anomalies around well locations. Figure 10 is the root mean square (RMS) amplitude map of Horizon 4 showing extreme amplitude anomalies around well locations.

Amplitude maps were generated for the mapped horizons to compliment the structural interpretation. The distinct zones of anomalous amplitude coincide with structural high (Fig.11) already delineated and which also coincided with the regions where wells have been drilled. Since the amplitude map correlates with the structurally high locations and bright spots from seismic attributes analysis, the distribution of low amplitudes and high amplitudes would be a useful guide in development well drilling of "Y" Field.

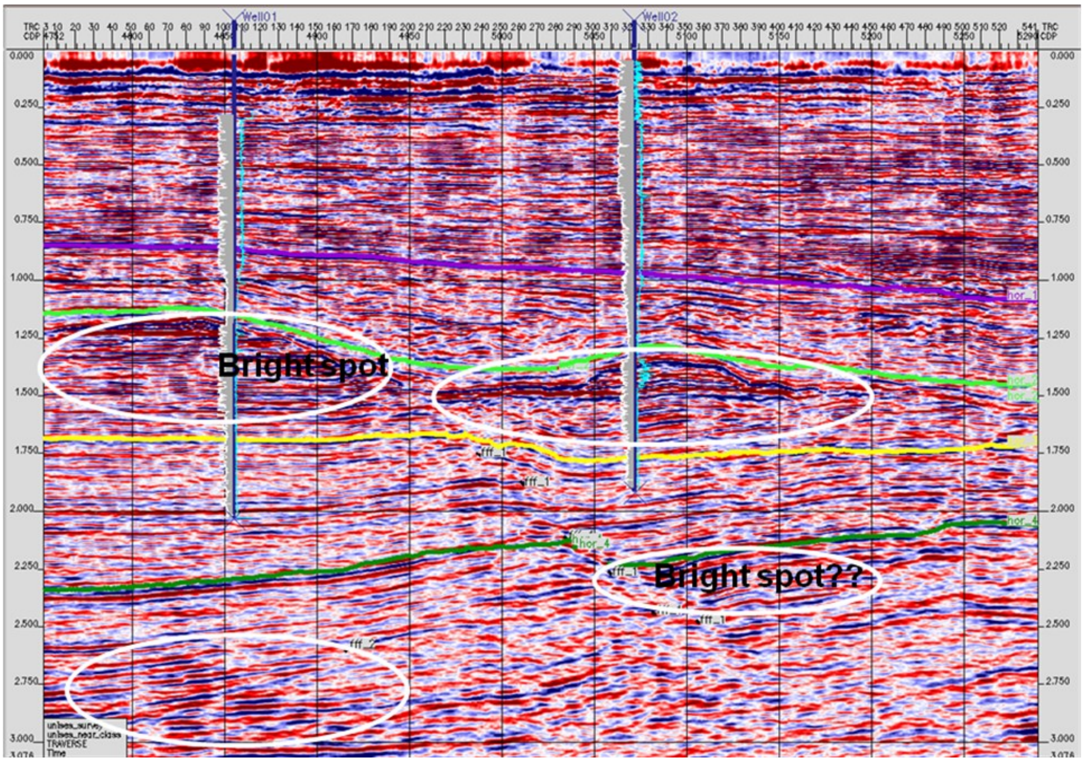

Figure 5: An abitrary line through the seismic section, showing the bright spots (high amplitude) as hydrocarbon indicator.

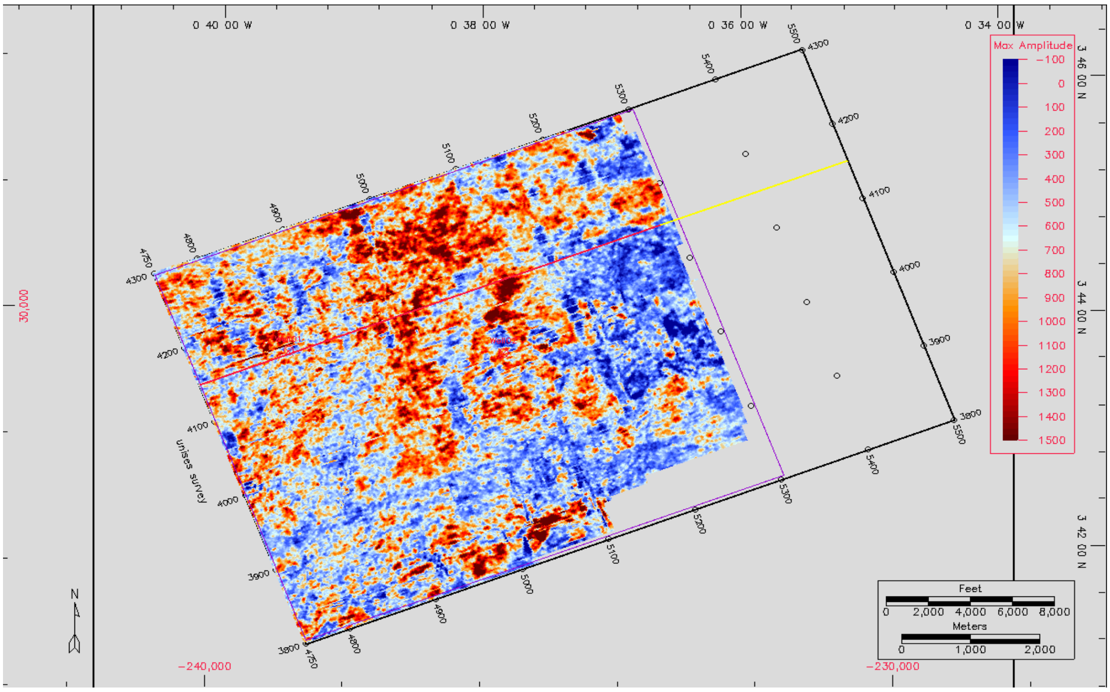

Figure 6: Maximum Amplitude Attribute Map of Horizon 2.

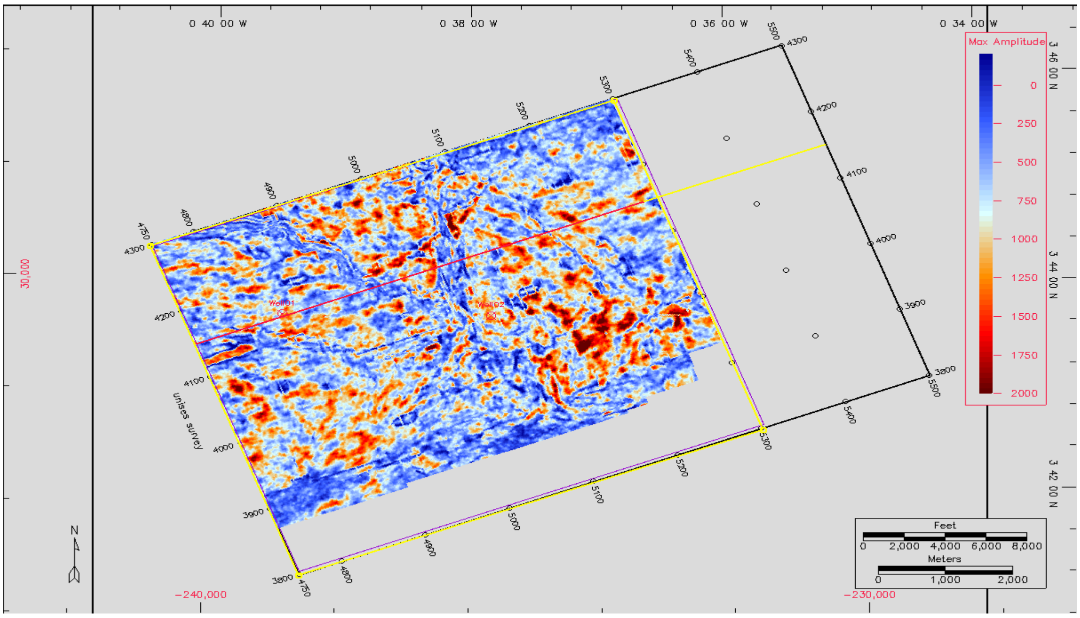

Figure 7: Maximum Amplitude Attribute Map of Horizon 4.

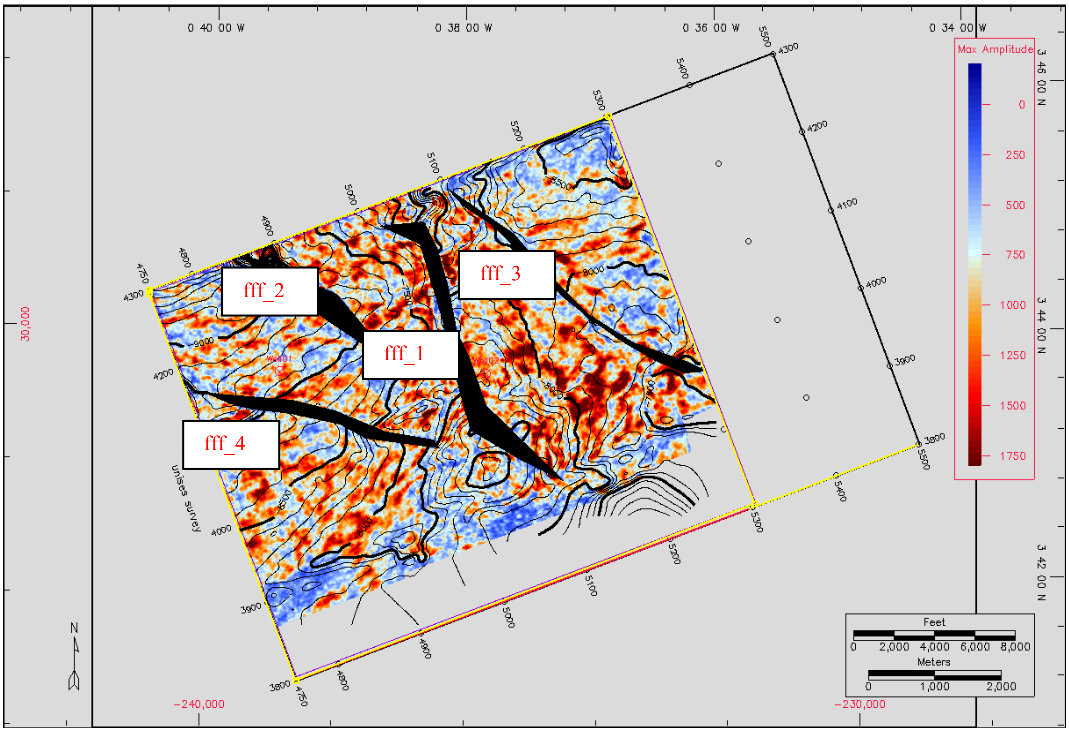

Figure 8: Superimposition of Depth Contour Map on Maximum Amplitude of Horizon 4.

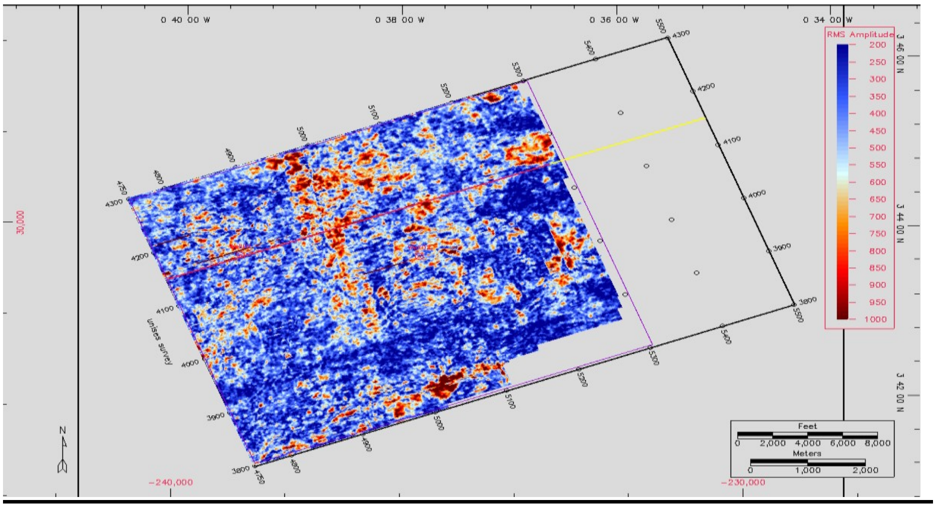

Figure 9: RMS Amplitude Attribute Map of Horizon 2.

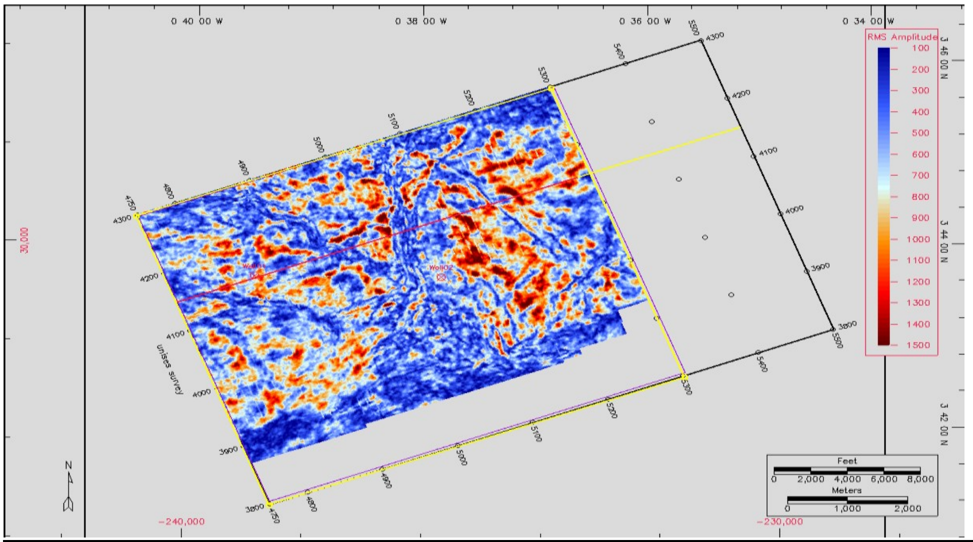

Figure 10: RMS Amplitude Attribute Map of Horizon 4.

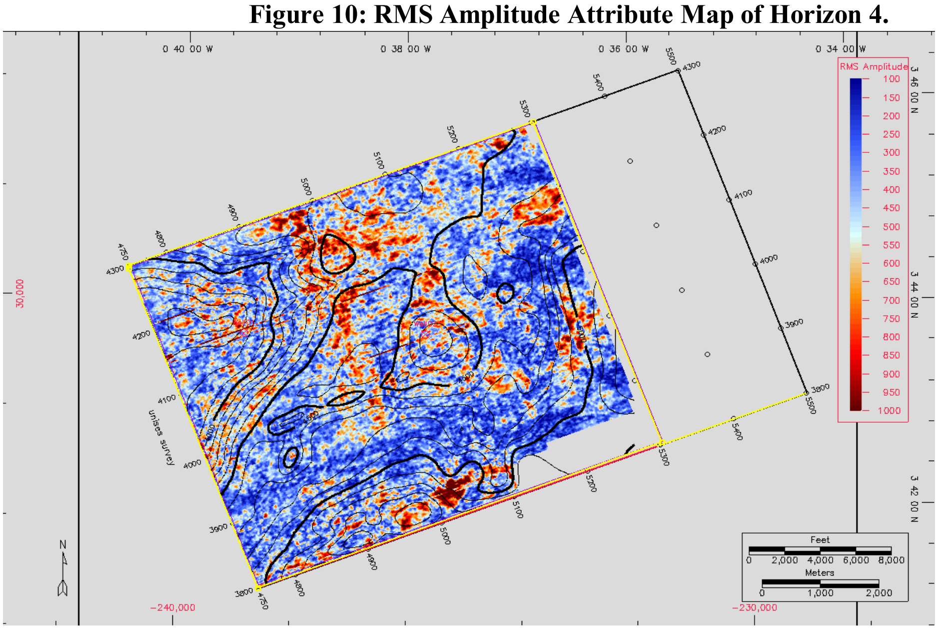

Figure 11: Superimposition of Depth Contour Map on RMS Amplitude of Horizon 2

4.3 Formation Evaluation

Gamma-ray (GR) log were used to identify the lithology in both wells penetrated. The lithology was identified by defining shale base line, which is a constant line in front of the shale and in front of the sand; there is an excursion from the shale base line. Thick sand at a depth of 304.8 to 926.7 m (1000 - 3040 ft) was delimited in well 01. Well 02 contain thick sand layer at a depth of 100 to 914.4 m (328 - 3000 ft). At a depth of 1234.5 to 1676.4 m (4050 - 5500ft), and 1402.1 to 1768m (4600 – 5800 ft) thick sand (identified reservoir sand) was observed in well 01 and well 02 respectively. Figure 12 shows the stratigraphic cross section within the study area. The major lithologies encountered in the study area were basically shale and sand, some of which occurs as interbeds. The reservoir sand was evaluated quantitatively for porosity, water saturation and net pay. Porosity values for the entire mapped surface is very good with a range of 30-40%, water saturation is 30-45% and hydrocarbon saturation 65-80%.

Neutron density logs were used to define hydrocarbon type present in "Y" Field. The combination of neutron and density logs was used for reservoir L300 in both wells to detect gas zone. At these intervals, density porosity was observed to be greater than neutron porosity and the curves cross over each other, therefore were identified as gas bearing zones.

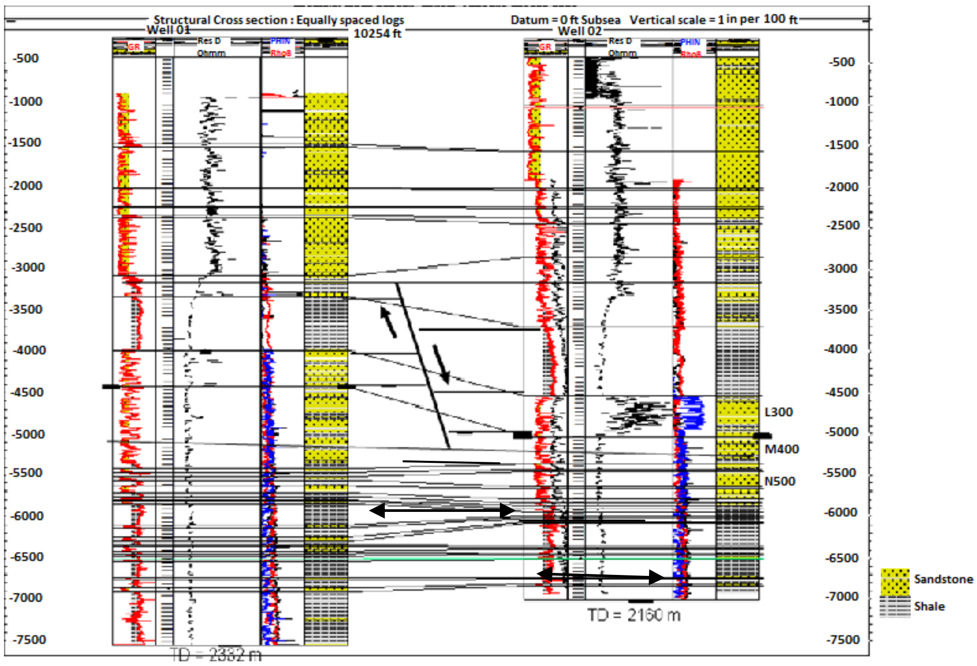

Figure 12: Correlation across the wells of "Y" Field showing mapped sands

V. Conclusions

The subsurface geology and hydrocarbon potential of "Y" field offshore Niger Delta have been studied using 3D seismic, composite well logs, and check-shot data. The major and minor faults were delineated and mapped which reveals that the area is highly faulted, typical of the tectonic setting of Niger Delta. Sand marked as L300 was identified based on log curve signatures of the Gamma ray log, Neutron log, Formation density log, and Resistivity logs. It was correlated across the wells and hydrocarbon intervals in "Y" field were mapped on to the seismic section using time-depth data. Four prominent horizons were picked across the in-lines and the cross-lines, at average times of 0.825, 1.250, 1.750 and 2.500 seconds respectively.

Time and depth structural maps of these surfaces were also generated to study the geometry of the structure harbouring oil and gas in the field. Vertical time thickness maps show the identified sand has varying thickness amongst the various units inherent in the sand. Depth maps by average velocity gave the various depth to the surface mapped. Also, they reveal that the trapping mechanism in "Y" field is largely by means of anticlinal dip closures, as the trap is due to the dip element. The mapped structure is a faulted anticline. Lithologic panels derived from well log data show that the area of study is characterized by sand-shale inter-beds.

Attribute maps such as amplitude (maximum and RMS) and relative acoustic impedance were also extracted to complement the structural maps. There is a strong relationship between the maps as the structural high coincided with zones of anomalous amplitude. Seismic attributes display maps reveals outstandingly strong reflection (bright spots) which may be indicative of reservoir rocks due to the presence of hydrocarbons in the identified sand. The integration of seismic amplitude and well properties, gave optimally located well platforms.

Seismic attribute analysis has been used successfully in this research work to predict reservoir rock properties, characterize reservoir sand quantitatively, which can lead to optimally selected drilling location of development wells in "Y" Field. It is cost effective.

VI. Recommendations

- Significant improvements could be achieved by subjecting the identified hydrocarbon prospects to further analysis.
- It is recommended that the proposed propective zones be drilled deeper than the existing wells.

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