

STRUCTURAL INTERPRETATION OF “ZULU” OIL FIELD, NIGER DELTA

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ABSTRACT

Standard method for structural analysis was applied in the delineation of subsurface structures using seismic and well log data from “ZULU” oil field Niger Delta. Hydrocarbon potential of “ZULU” oil field was evaluated to delineate the geometry of the reservoir of interest. The tops of the modeled reservoir were obtained at 2,365 m; 2,335 m; 2,331m and 2,265 m for well-1, well-2, well-3, and well-4 respectively. Faults were interpreted and identified (F1, F2, and F3) using fault sticks, which was modeled to generate the skeletons. It was observed that the fault skeletons showed pillar gridded pattern that produced the reservoir which shows enclosed anticline structures that serves as a good traps for hydrocarbon accumulation.

Key words: Fault skeleton, Pillar gridded, Zulu and Accumulation.

INTRODUCTION

Structural interpretation of seismic data, Petrology and depositional environment of the reservoir sandstone from different part of the Niger Delta have been carried out to determine the hydrocarbon potentials of the area (Ajakaiye and Bally, 2002; Morgan, 2003). Subsurface configurations must be understood in detail to effectively delineate the structures that are favourable for hydrocarbon accumulation. This is because hydrocarbons are found in geological traps; these traps may be structural or stratigraphic in nature (Coffen, 1984). Majority of traps in the Niger Delta are structural even though stratigraphic and combined structural-stratigraphic traps are not common (Doust and Omatsola, 1990). In Niger Delta hydrocarbon fields, structural traps are

prevalent while stratigraphic trap also do exist (Michele *et al*; 2012), during syn-sedimentary deformation of the Agbada paralic sequence was the development of structural trap sequence (Evamy *et al*; 1978). Stratigraphic traps develop between the diapiric structures of Niger Delta province where there are compartments of sand stone (Beka and Oti, 1995).

Niger Delta is ranked among the major prolific deltaic hydrocarbon provinces in the world and is the most significant in West African continental margin. Oil and gas are principally produced from sandstones and unconsolidated sands predominately in the Agbada formation. Several geological and geophysical investigations have been performed in the Niger Delta basin starting

about fifty years ago for oil and gas prospecting (Aizebeokhai and Olayinka, 2011; Cobbold *et al*; 2009; Emujakporue and Ngwueke, 2013). Hydrocarbon bearing fields are characterized by multiple heterogeneous reservoirs stacked over intervals of 10,000ft thickness (Onyeagoro, 1998), the heterogeneities which occur at all scales from pore scale to major reservoir units result to spatial variation in the reservoir properties (Martin *et al*; 2012). The problem many oil and gas industries do face is to delineate the complexity of the reservoir and where wells are supposed to be drilled. Accurate understanding of hydrocarbon reservoir prior to production can only be achieved by the work of reservoir characterization model; hence structural seismic interpretation provides the spatial heterogeneity of hydrocarbon reservoir.

Fault surfaces are common sub-terranean structures which are associated with displacement or offset of subsurface layer, there are known to be essential for hydrocarbon exploration since they are associated with hydrocarbon accumulation and flow paths for the purpose of mapping complex geologic structures. The most reliable component of hydrocarbon structural model is done by identifying, extracting and modeling the fault surfaces from the realized 3D seismic data. Extractions of fault surfaces from seismic data have been known to be a qualitative technique and therefore require a careful human interpretation (Isreal *et al*; 2006).

The aim of the study seeks to generate the structural model of reservoirs in order to have a better understanding of the subsurface of the field location, thus hydrocarbon production can be optimized.

Geology of Niger Delta

Niger Delta is among the hydrocarbon prolific basins in the world (Alao *et al*; 2013). Around the West African continental margin, it is significantly recognized for hydrocarbon production and located at the southern Nigeria boarding the Atlantic Ocean (Ekine and Ibe, 2013).

It covers an area between longitude 4-9⁰E and latitude 4-9⁰N; it is also composed of an overall regressive clastic sequence, which reaches a maximum thickness of about 12km (Evamy *et al*, 1978; Emujakporue and Ngwueke, 2013). The three primary lithostratigraphic units (Akata, Agbada and Benin formation) as portrayed by the subsurface of the Niger Delta decrease in age basin ward, showing in general the regression of depositional environments in the Niger Delta clastic wedge. The type section of the Akata formation was defined in Akata well-1 which is 80km East of Port Harcourt (Short and Stauble, 1967). A total depth of 11,121ft (3,680) was reached in the Akata well-1 without getting the base of the formation. The top of the formation showed the deepest occurrence of deltaic sandstone beds (7,180ft in Akata well-1); its thickness is about 21,000ft thick in the central part of the clastic wedge (Doust and Omatsola, 1989).

The Agbada formation is defined in the Agbada well-2 drilled about 11km North-North West of Port Harcourt (Short and Stauble, 1967). The well reached a total depth of 9,500ft but did not get to the base of the formation. It has a maximum thickness of about 13,000ft (Doust and Omatsola, 1989), the lithology is made up of sand, silt sand and shale arranged within 10-100ft successions defined by progressive

upward changes in grain size and bed thickness.

The Benin formation is comprised of the top part of Niger Delta clastic wedge from Benin-Onitsha area in the North to beyond the present coastline (Short and Stauble, 1967). The top of the formation is the recent sub-aerially which exposed delta top surface and its base extends to a depth of 4,600ft; it is defined by the youngest marine shale. Shallow parts of the formation are composed entirely of non-marine sand deposited in alluvial or upper coastal plain environments during progradation of the delta (Doust and Omatsola, 1989). Although lack of preserved fauna inhibits accurate age dating, the age of the formation is estimated to range from Oligocene to recent (Short and Stauble, 1967).

MATERIALS AND METHOD

The data comprised of digitized composite well logs in LAS format from four offshore wells, 3D seismic data, base map and petrel geophysical software. The data was imported into petrel workstation. Signatures of the available log were displayed in the log section window while the seismic data were realized to show both the inline and x-line seismic section. The lithology penetrated by the wells were delineated using gamma ray (GR) logs, thus the major lithology delineated were sand and shale beds. Hydrocarbon reservoirs were suggested to be sand beds since they are porous and permeable unlike shale that is porous but not permeable.

For reservoir areas of interest, resistivity log from each well was used to delineate the presence of hydrocarbon; high resistivity

value indicates hydrocarbon accumulation while low resistivity value indicates presence of water in the reservoir. The oil-water was delineated using the density log, it was necessary to determine changes that form the reservoirs which span the area of the field. Well to seismic correlation was carried out to map and tie similar reservoir across the well and seismic in "Zulu" oil field. Static shift was applied to the synthetic so as to match up with the seismic at Z1000-top and Z1000-base of Zulu-001 well log. These points form the formation top and base. The essence of well to seismic tie was to provide more confidence in seismic interpretation (Fig.3).

RESULTS

The major motive of structural interpretation is to use well and seismic section to delineate the subsurface structures which are potential areas of hydrocarbon exploration (Emujakporue and Ngwueke, 2013).

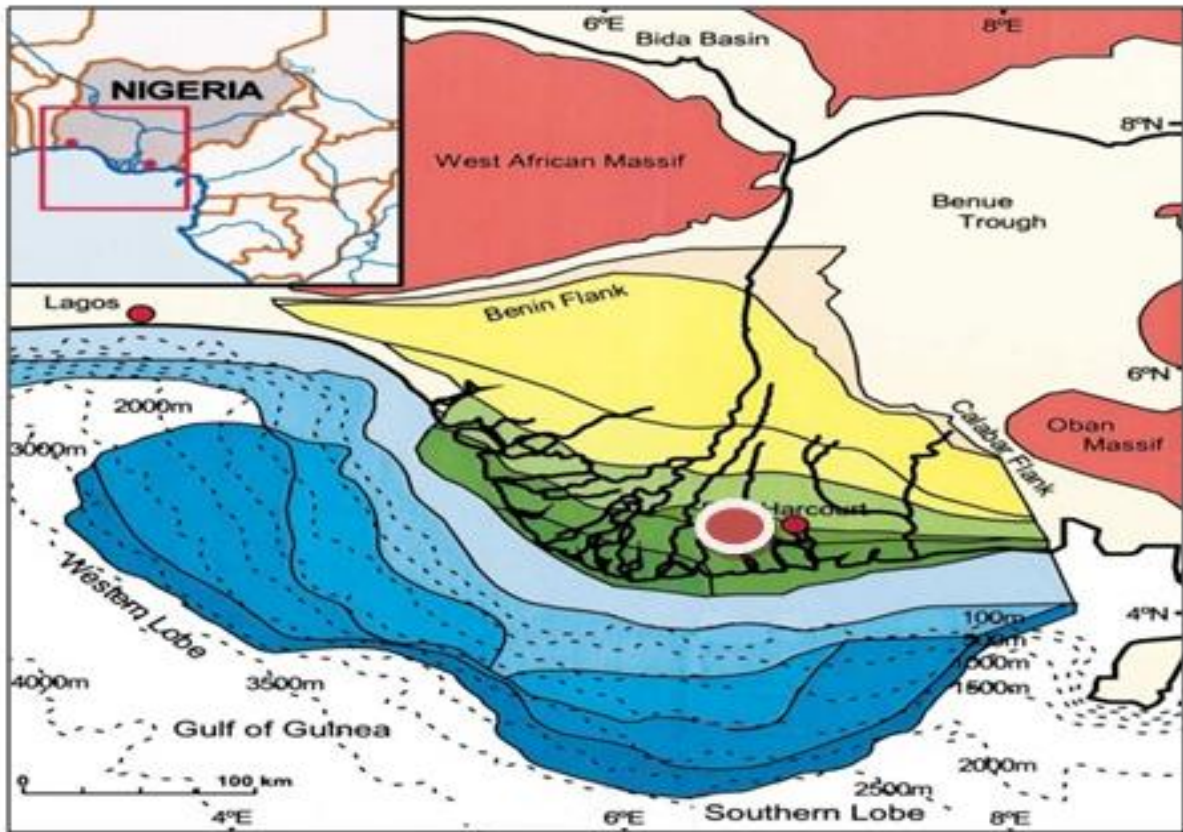


Fig. 1: Map of Niger Delta showing the possible location of the study area

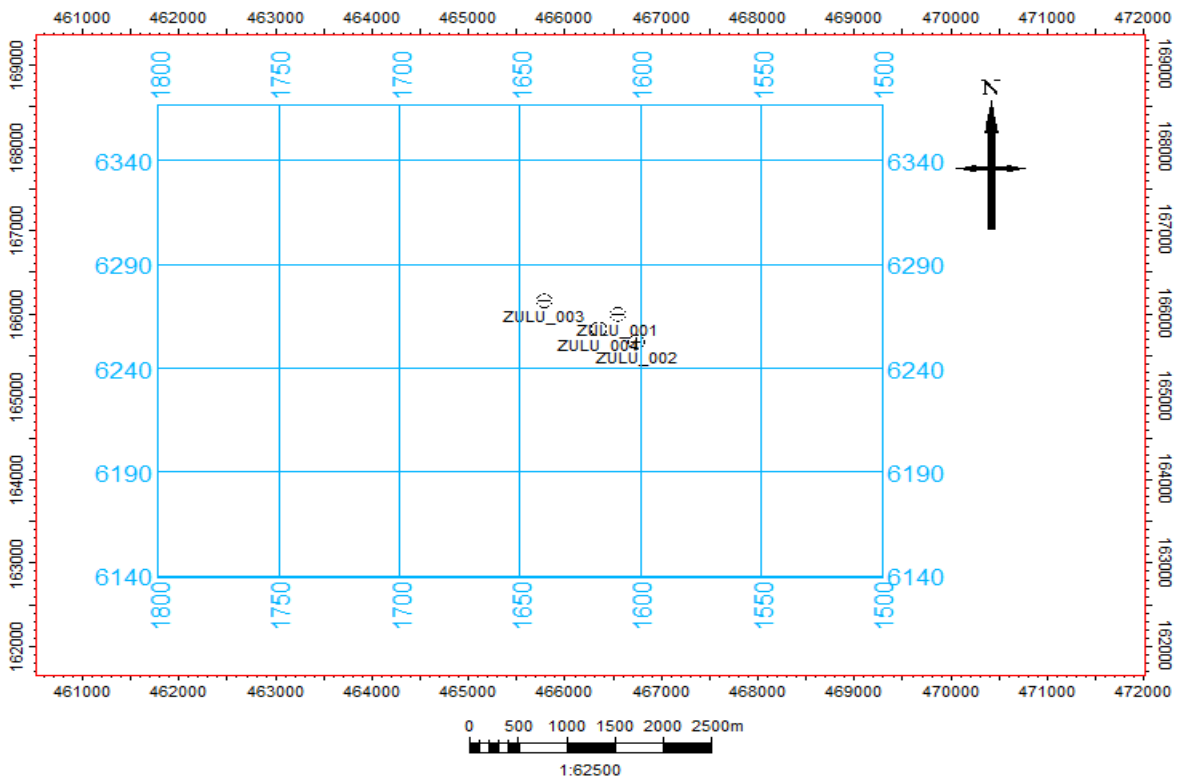


Fig. 2: Base map of the study area

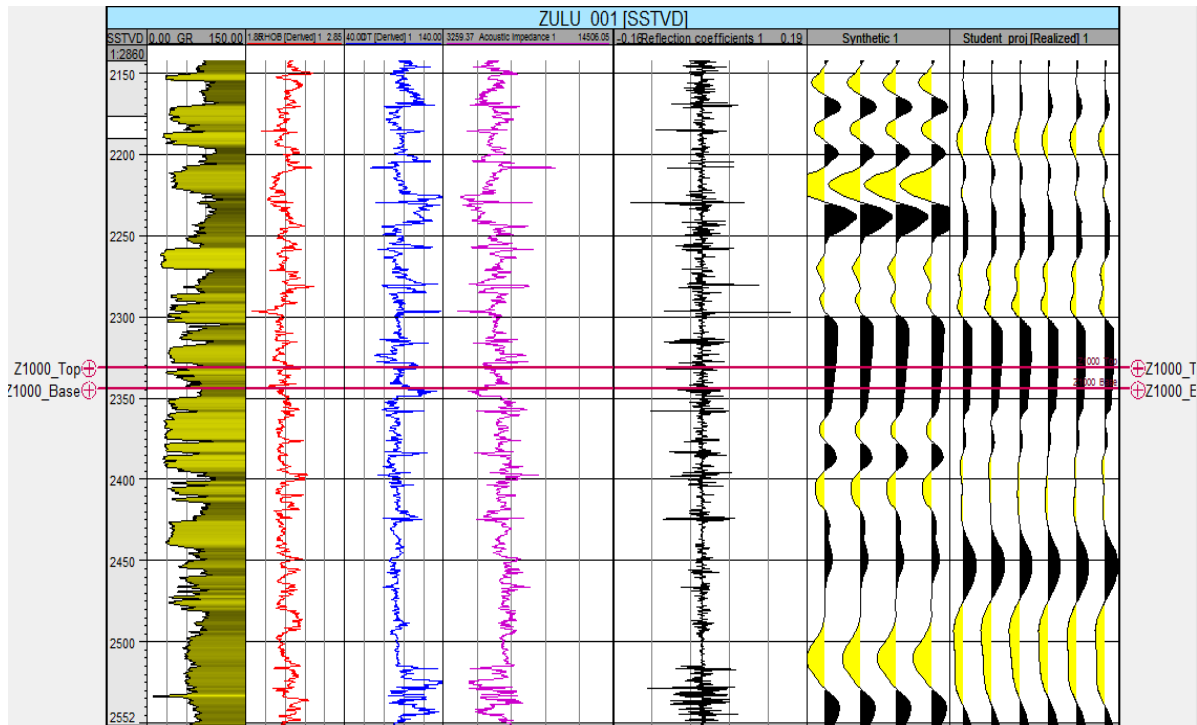


Fig.3: Well to seismic tie

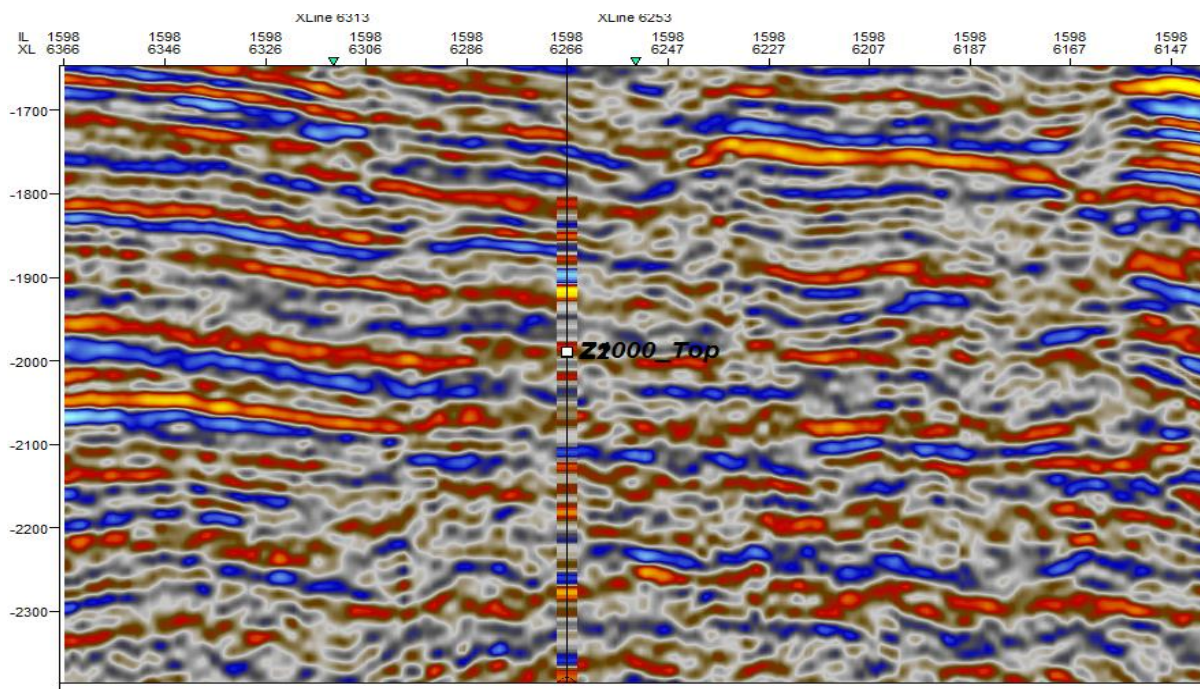


Fig.4: Well to seismic tie on inline 1598

This was achieved through mapping of seismic horizon, locating structural trap and placing them on the base with a view of developing time horizon map (Fig.5).

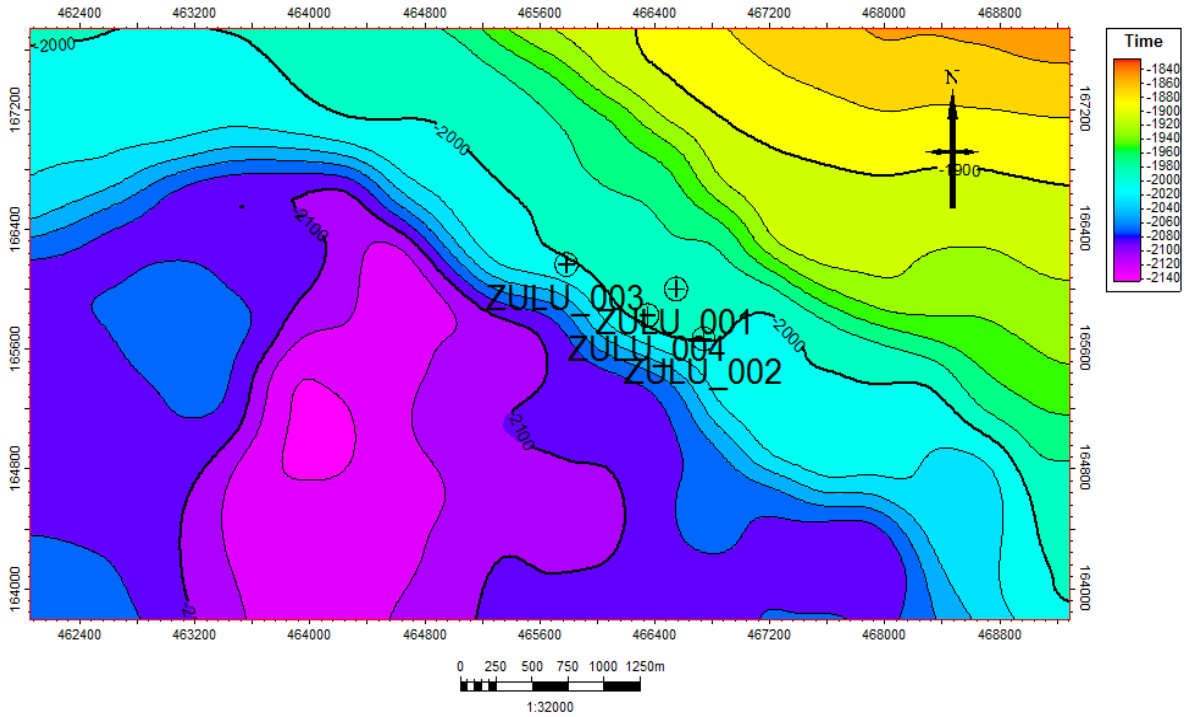


Fig.5: Time map of Horizon Z1000-top

On the time map Z1000_top was located at 2000ms which is equivalent to 2331.1m on the depth map, thus all reservoirs were delineated between 2,250m and 2,375m. For a better interpretation, the time map was converted to structural depth map (Fig. 6 and 7).

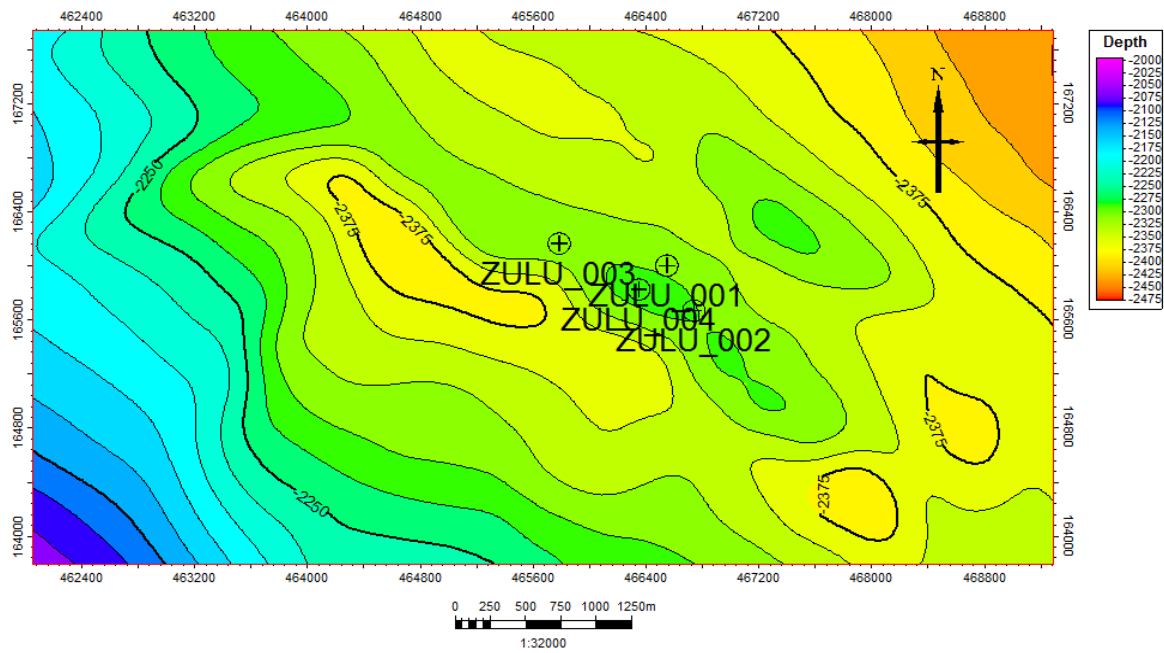


Fig.6: Depth map of Z1000-top

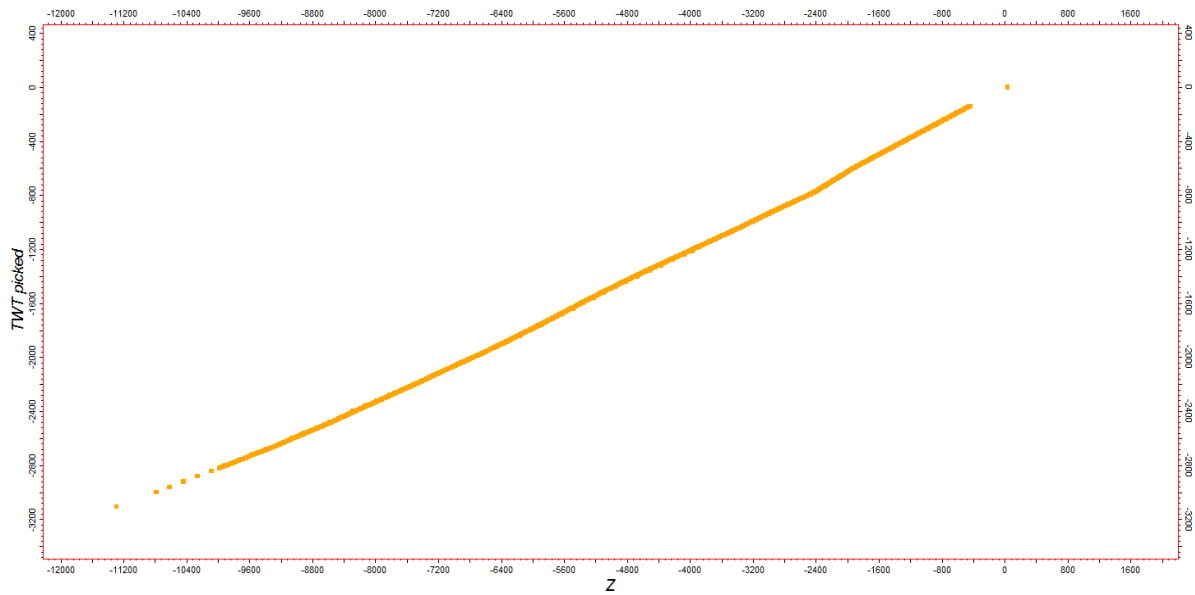


Fig. 7: Time –Depth map

Considering the lateral reflection, we observe discontinuity of the horizon at the fault boundary caused by the weight of the overlying strata after the fault have pushed the underlying strata downward. Vertical

discontinuity of the reflectivity depicted fault trends, which were traced on the inline from North to South direction; hence this gave a better resolution of the fault trends (Fig.10).

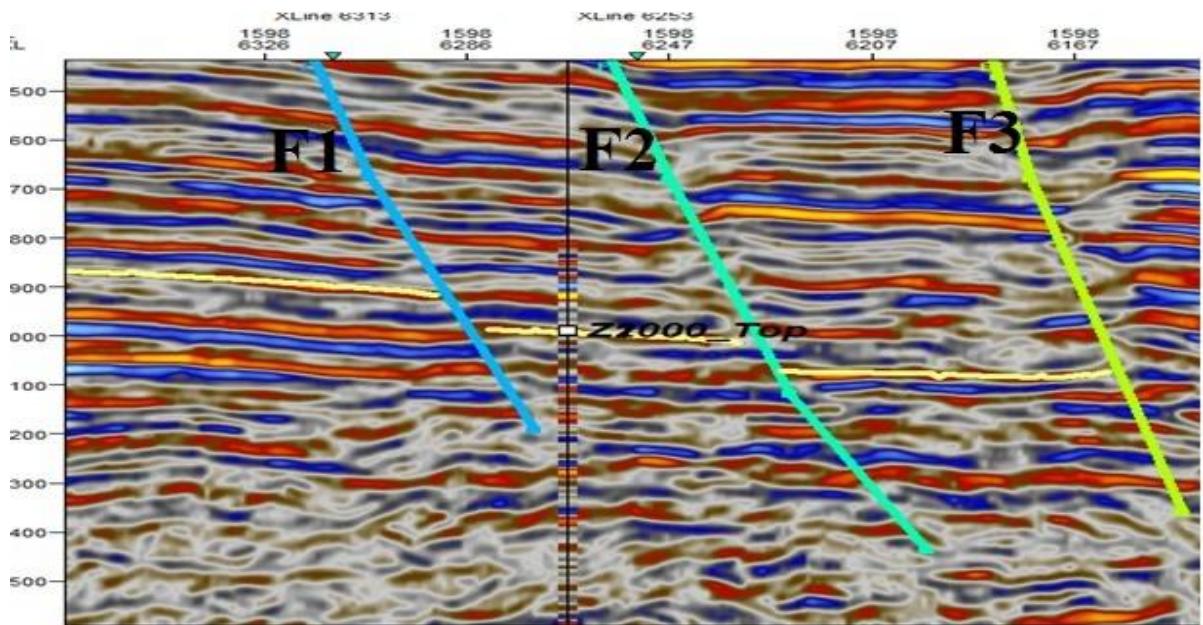


Fig.8: Interpretation fault sticks and wells

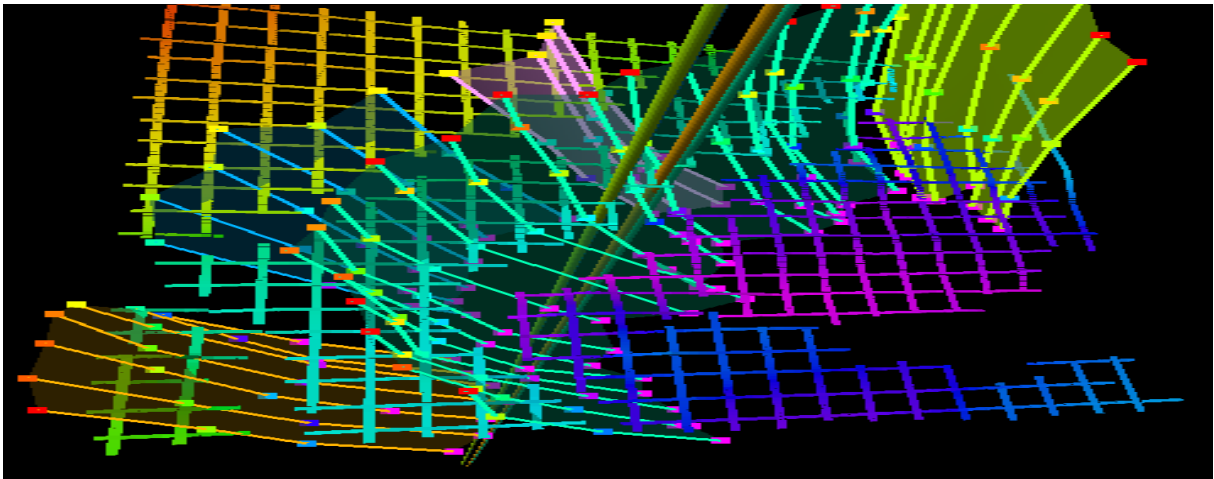


Fig.9: Horizon Interpretation

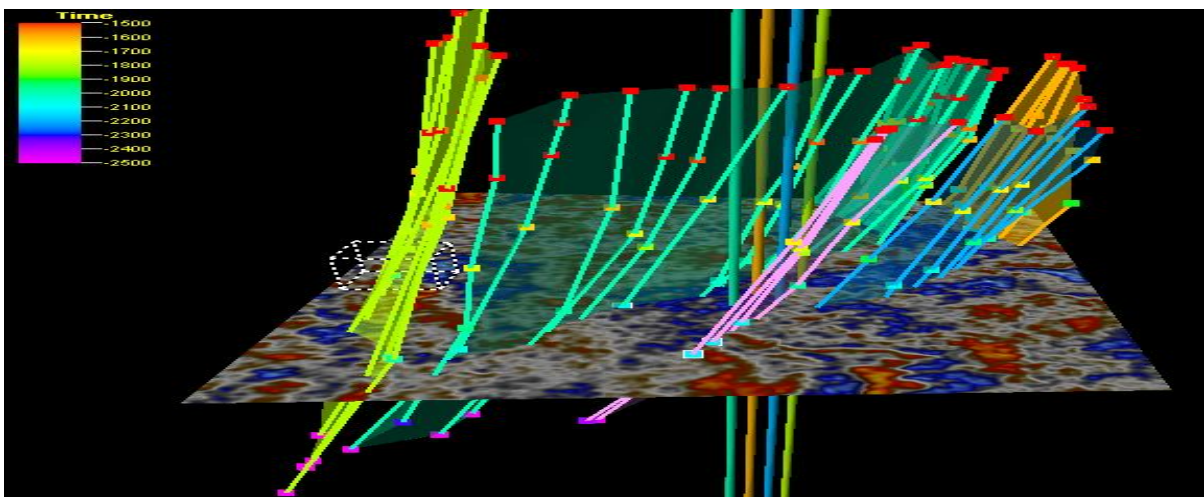


Fig.10: Interpreted fault sticks and wells.

From the observations, all the wells are located within the fault assisted anticline closures, this is an evidence from roll over structures seen on the seismic sections; which is a typical hydrocarbon accumulation traps in Niger Delta.

DISCUSSION

The map of Niger Delta showing the possible location of the study area and base map of the study area is shown in (Fig. 1 and 2). The representative reservoir structural analysis based on Geology and Petrophysical properties was developed using 3D seismic data and well log. The lateral extent of Zulu oil reservoir was

delineated using seismic data while the possibility of deriving its depth resolution depended on the well logs.

Vertical discontinuity of the seismic reflection was used to trace the fault plane on inline and interpretation was done in accordance with horizon delineated at 2,000ms (Fig. 4). The enthusiasm to obtain a high resolution structural interpretation led to reservoir delineation from the depth map generated from the study area. Since the total study area might not possess the hydrocarbon potential structural style, it was necessary to identify the potential areas; so as to avoid abnormal well placement. The

synthetic seismogram generated from the well log was linked to correspond with event of the seismic section; it was done by considering reflectivity trace being differential acoustic impedance which when moved down by greater wavelet, it looks similar to reflectivity trace. As a result of seismic shift caused by shallow event, the seismic event shifted by not matching with the synthetic. While comparing the seismic and synthetic by matching up each loop, static shift was applied to the synthetic so as to match up with the seismic at Z1000-top and Z1000-base of Zulu-01 well log. These points form the formation top and base were tied with the synthetic (Fig.3), the essence was to provide more confidence in seismic interpretation.

Analysis has shown that accurate structural interpretation can be done in depth but not only time alone. Contour map which shows a two way time to a reflector as picked on the seismic section can be converted to depth map using the average velocity (Olabode and Enikanselu, 2008). The predicted average velocity away from the wells were used to develop the time average velocity map which was used to convert Z1000-top to depth; the time structural map (Isochron map) (Fig.5), was used to generate depth structural map using the velocity model. On the time map Z1000-top was located at 2,000ms which is equivalent to 7,777ft approximately 2,331.5m on the isopach map (Fig.6 and 7). On the depth structural map, Zulu -001 is located in a closed contour; Zulu-003 touches the contour enclosing Zulu-001 while Zulu-004 is a bit further from the contour. All the reservoirs were delineated between 2,250m and 2,375m; the wells are located within the fault assisted anticlinal closures. This is evident from roll over structures seen on the

seismic map, which exemplifies hydrocarbon accumulation traps in Niger Delta.

From seismic section as observed in (Fig.8), reflectivity is some what clearer from the beginning to 2,100ms. The amplitude of reflectivity reduced from 2,100ms and got blurred from 2,400ms to the end of the seismic section. Considering lateral reflection, we observe discontinuity of the horizon at the fault boundary caused by the weight of the overlying strata after the fault push of the underlying downward strata; vertical discontinuity of the reflectivity depicts fault trends. Fault traces were traced on the inline seismic section; the inline run from North to South and give better resolution of the fault trends. Interpretation of faults was done by digitizing the fault trends (Fig.10), this process used fault sticks to pick the trends of the faults; there by giving room for fault skeleton generation. Although several faults were interpreted, but three major faults are conspicuous (Fig. 8 and 10). From well to seismic tie, horizon was identified at 2000ms of the line of the seismic section; but picking of the horizon was done on the cross line using the intersection of the line and cross line since it runs from East to West (Fig.9).

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