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Structural Interpretation of Akos Field, Coastal Swamp Depobelt, Niger Delta, Nigeria

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ABSTRACT

Structural interpretation from information of detailed geologic formations (well logs), well checkshot survey, directional survey, reservoir tops and high resolution 3D seismic data has been effectively done to map the structures and hydrocarbon trapping potential of Akos field, coastal swamp depobelt, Niger Delta. The research methodology involved horizon and fault interpretation to produce subsurface structural maps. Time and depth structure maps were extracted to show further details on the structures. Three major horizons were mapped based on the clarity and uniqueness of their features namely; Sand 1, 2 and 3 respectively. Major faults were also delineated on the 3D volume and other minor faults, formed by post depositional process. The presence of these faults in the study area is a possible indication that there is a possibility of hydrocarbon accumulation. From the horizon and fault interpretations, depth structure maps were produced. Structural highs are stretched over the field areas coloured with purple while structural lows are the goldish/yellowish coloured region. The northern part forms a large closure against the fault. Some dark stripes were seen on the semblance attribute and shows discontinuities which is synonymous to fault cutting through the seismic time slice, the most inclined fault defines the largest closure which is the prospect zone. The application of the results from this study will help the Exploration and Production industry to identify with utmost certainty hydrocarbon potentials of a field and identification of new prospects and also to make better economic decisions.

Keywords: Structural Interpretation, Faults, Horizon, Seismic, Well logs.

1.0 INTRODUCTION

The ultimate purpose of seismic (structural) interpretation is to aid in constructing the most accurate earth model or reservoir description possible, this entails identifying and describing structural and stratigraphic traps appropriate for economically exploitable accumulations. This can best be accomplished when the seismic data are merged with petrophysical, geological and engineering databases (Ameloko and Omali, 2013). Hydrocarbons reservoirs are found in geologic traps (any combination of rock structure that will keep oil and gas from escaping either vertically or laterally). (Wan Qin, 1995). These traps can either be structural, stratigraphic or a combination of both. Structural traps can serve to prevent both vertical and lateral migration of the connate fluid (Coffen, 1984). Examples of these include rollover anticlines and flanks of salt domes (Adeoye and Enikanselu, 2009). Stratigraphic traps include sand channels, pinch outs, unconformities and other truncations (Folami et al, 2008). The onshore Niger Delta has history of proven unexplored hydrocarbon deposits due to its structural and stratigraphic complexities resulting from its formation stages. This has resulted in the search of oil and gas increasingly complex and challenging. To overcome these challenges in the delta, a comprehensive examination of the stratigraphic and structural architecture, as well as the trapping mechanisms due to its large hydrocarbon potential is necessary.

Several researchers have made enormous contributions based on structural interpretations within the Niger Delta basin to investigate the potentiality of hydrocarbon deposits (Hooper et al, 2002; Aizebeokhai and Olanyinka, 2011; Emujakporue and Ngwueke, 2013; Ameloko and Omali, 2013; Ameloko and Owoseni, 2015; Horsfall et al, 2015). Ameloko and Owoseni (2015) in their study on hydrocarbon reservoir evaluation of X-field in the Niger

Delta using seismic and petrophysical data deduced from their results on structural interpretations that localized normal faults exist in the study area, the presence of the faults is an indicator of possible accumulations of hydrocarbon deposits. Aizebeokhai and Olayinka (2011) also delineated horizons and series of growth faults which serves as migratory paths for hydrocarbons into structural closures and the reservoir unit at large.

The objectives of this study were to delineate the geologic structures and hydrocarbon trapping potential by integrating 3D seismic data with well logs in the study area. In addition, amplitude attributes analysis that indicates bright spot which is a direct hydrocarbon indicator (DHI) was carried out. The bright spot is a valuable mapping tool because it allows visual identification of features related to the presence of hydrocarbons directly on seismic traces.

2.0 LOCATION AND GEOLOGY OF THE STUDY AREA

The study area falls within the coastal swamp of Southeast of Port Harcourt Niger Delta Basin of Nigeria.(Fig.1). The base map of the study area is shown in (Figure 2). The field is located in the Niger Delta sedimentary basin of Nigeria. The Niger Delta forms one of the world's largest hydrocarbon provinces and it is situated on the Gulf of Guinea and extends through the Niger Delta provinces (Klett et al. 19780). It covers an area within longitude 4°E - 9°E and latitudes 4°N - 9°N. It is composed of an overall regressive clastic sequence, which reaches a maximum thickness of about 12km (Evamy et al, 1978). From Eocene to the present, the Delta has prograded southwards, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of about 300,000 km2 (Kulke, 1995) a sediment volume of about 500, 000 m3 [10] and a sediment thickness of over 10 km in the basin depocenter (Kaplan et al, 1994).The Niger Delta province has been identified to have only one petroleum system referred to as the tertiary Niger Delta (Akata – Agbada) petroleum system (Ekweozor and Daukoru, 1994).

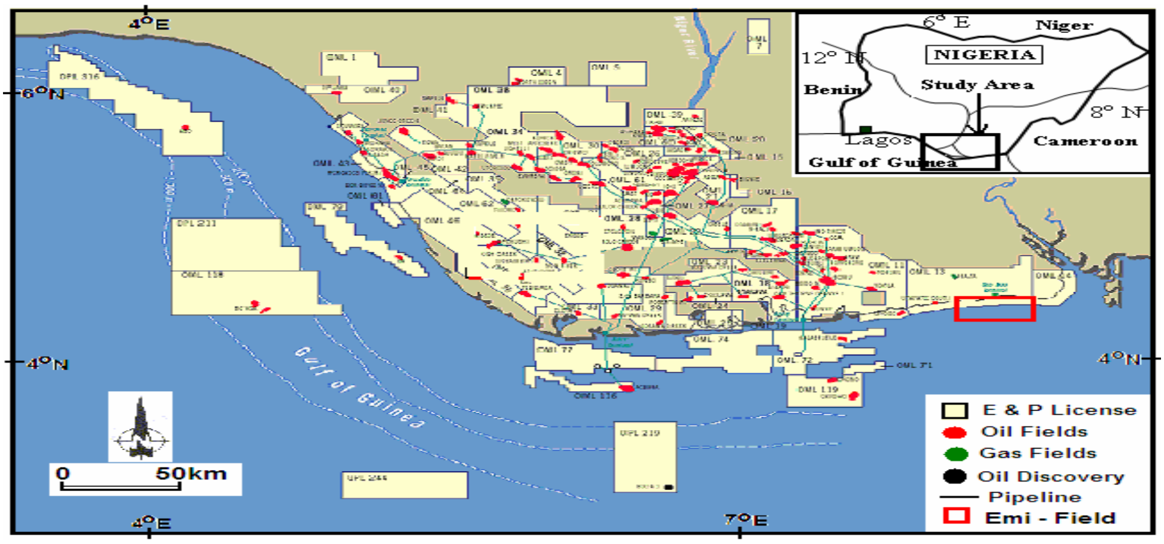

Figure 1: Location of the Field in the Niger Delta [18]

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3.0 METHODOLOGY

The methodology consists of using 3-D seismic sections spanning over 28 sqkm on a scale of 1: 12500m. the seismic section comprises of five survey lines (crosslines XL) running approximately 7249m that is shot parallel to the dip direction and seven survey lines (in-lines IL) running approximately 1325m. The spacing between the seismic section for both the in-lines and cross-lines is 100m. (Figure 2). Other data used include well log data, well checkshots surveys, directional Survey, reservoirs tops The study is basically structural interpretation and seismic attribute analysis by interpreting horizons and faults to produce subsurface structural map Structural interpretation entails visually inspecting the seismic section for reflection discontinuities, vertical displacement of reflection events and abrupt termination of events, overlapping of reflections and changes in pattern and strength of reflection events across the seismic section. It usually begins with correlating well logs information to the 3D seismic volume in order to ensure the continuity of events both on the seismic sections and wells. Horizons and faults were mapped. A horizon is a surface separating two different rock layers. Manual picking of horizons were done on inlines and crosslines. Also, identification of faults networks (synthetic faults and other related secondary faults) on the seismic sections. Faults were recognized from the seismic section by distinct discontinuity or abrupt jump of seismic reflection events. The interpreted faults were quality checked on the variance time slice and corrected/assigned. The time structure maps were generated from the horizons and the mapping range on the seismic section. In addition, the depth structure maps were generated from them which were used to make interpretations. The RMS amplitude attribute was extracted for each horizon. Time structure maps were produced using the interpolated seismic seed grids for each horizon. The time maps were then converted to depth maps using a simple velocity model.

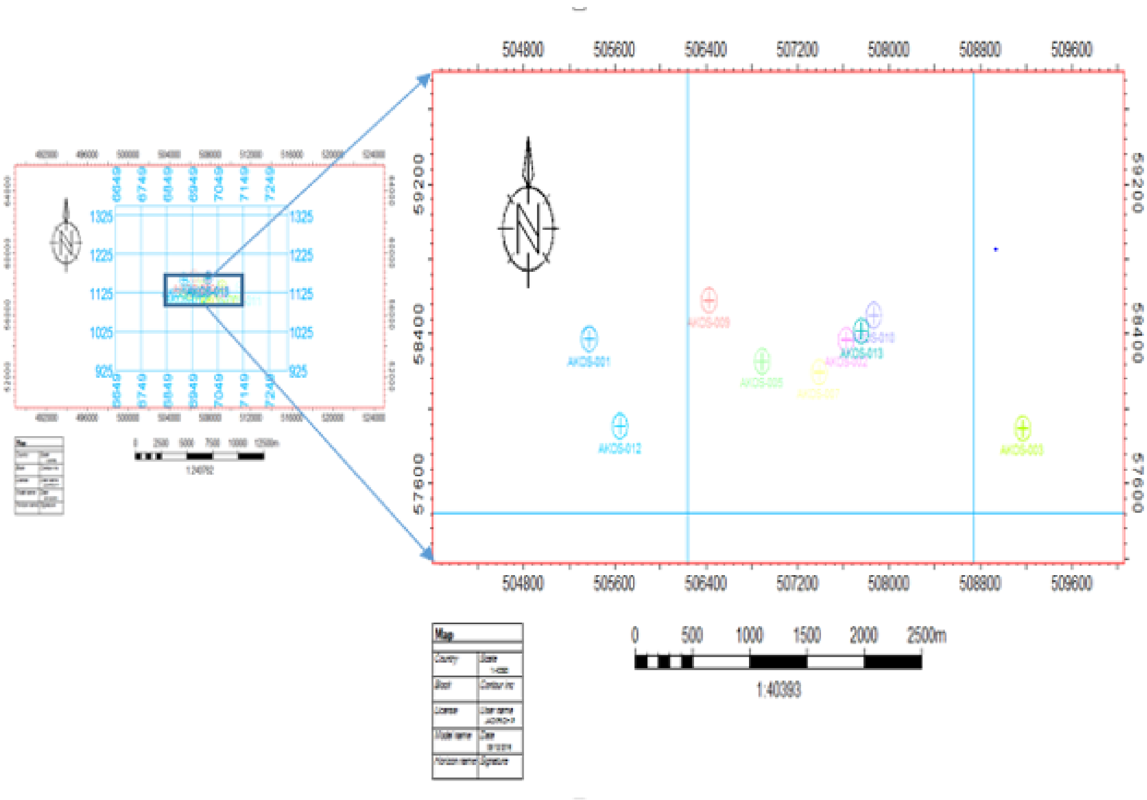

Fig. 2 Base Map of Study Area Showing Well locations and seismic Lines

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4.0 RESULTS AND DISCUSSION

This results of the detailed study on the structural interpretations of the study area is presented in the following sub headings below:

4.1 Structural Framework and Modeling

The structural modelling was achieved using the 3D seismic section. Horizons and faults interpretations were made from the seismic sections to enhance the structural modelling. Depth structure map and Time contour maps were also generated. The results of the structural interpretation generated from the seismic sections is presented in different figures below. Figures 3 and 4 shows crossline 1297(3D cross section) with un-interpreted and interpreted (picked) horizons respectively. The seismic volume also reveals the presence of patterned reflection discontinuities which are identified and interpreted as faults.. Figures 5 and 6 shows inline 6969 with un-interpreted and interpreted faults cross-sections respectively. Also figure 7 shows the combined interpretation of the fault and horizon. Figures 8, and 9 also showed the depth structure map for horizon H1with fault polygons, time slice with fault interpretations (semblance attribute) and gridded fault and event showing structural framework of study area on plan and dip sections

4.2 Horizon Interpretation

Horizon/events were mapped, interpreted and correlated all through the study area. Horizon picks were done iteratively in in-line and cross-line directions, and corrected for mis-ties. In areas where reflection quality and characteristics are of good quality, lines are picked at larger intervals while at areas where reflection quality is relatively poor and characterized by discontinuities, lines were picked at closer intervals in order to reduce mis-ties to acceptable minimum. Fig. 4 shows crossline 1297 with picked horizons. The Crosslines display the horizons and top of shale diapir delineated. The crossline displays less structure inferring strike lines**.** Three major Horizons were mapped based on the clarity and uniqueness of their features namely; Sand 1, 2 and 3respectively. Seed grids were generated across mapped/picked faults (Fault-sticks) and horizon line. This was gridded using the appropriate module in Petrel interface to produce structural and stratigraphic framework and also generate horizon maps of selected regional markers.

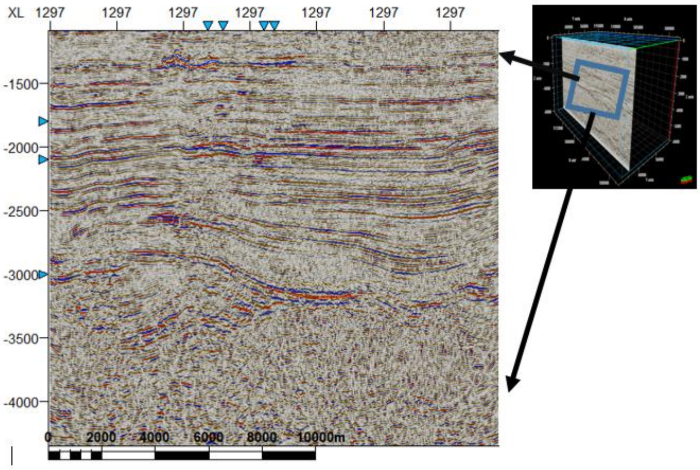

Figure 3: Crossline 1297 Showing 3D Cross Section with Uninterpreted Horizon

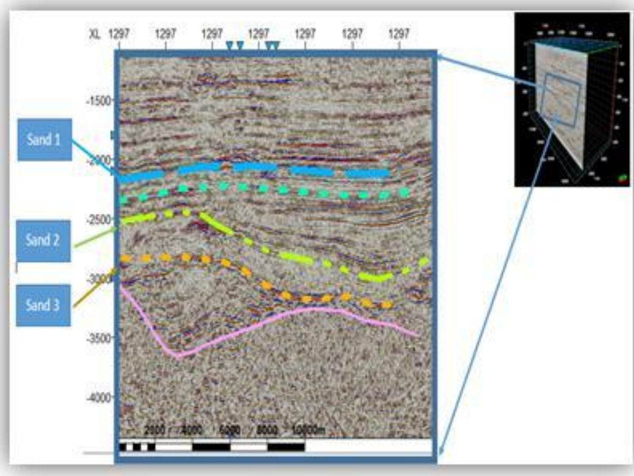

Figure 4: Crossline 1297 Showing 3D Cross Section with Interpreted Horizons

4.3 Fault Interpretation

Seismic volume reveals the presence of patterned reflection discontinuities which are identified and interpreted as faults. Interpreting fault plane geometry was quite difficult in most areas due to poor reflection characteristics around fault – a seismic acquisition and processing artefact. Also mapping faults detachments at depth was difficult and sometimes impossible as data quality deteriorates greatly with depth. However simple extrapolations were made to constrain interpretation picks. Figure 6 shows the inline 6969 with interpreted cross sections. Apart from the major faults seen on the section in figure 6, there are other minor faults, 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. (Weber and Daukoru 1975) described faults as good migration pathway for hydrocarbon into the reservoir rocks. The normal faults also make local scale horst and graben geometries favourable for the accumulation of oil. Figure 7 shows a section of both fault and horizon interpretation.

The northern part of the study area is controlled by first major faults dipping north and striking east-west forming a rollover anticline characterized with smaller faults such as a negative flower structure or tulip structure on one side of the horst block. The other side of the horst block is characterized with second major fault and series of smaller faults all dipping southwards antithetic to the first major fault. The basin encountered series of extensional tectonic forces leading to the formation of rollover anticline faults. The inline displays more structures and faults perpendicular to the fault plane inferring dip lines. The Northern part of the study area can be recognized as more prospect zone compared to the southern region because of anticlinal closure against the listric fault forming a good structural trap.

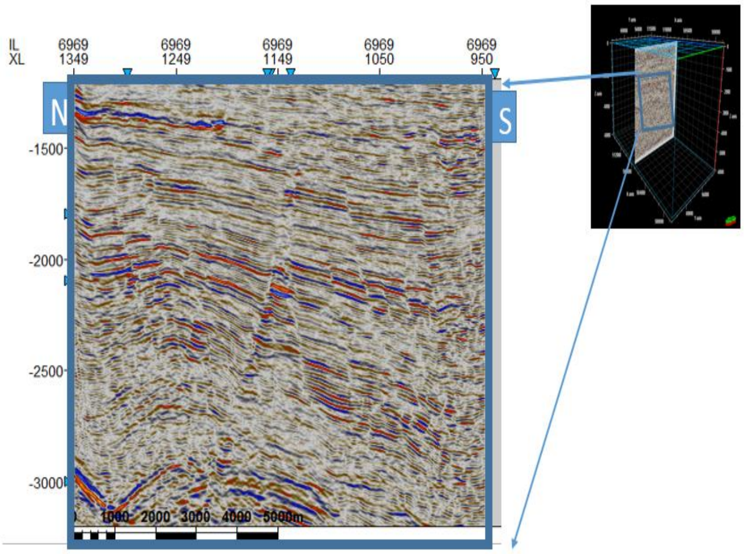

Figure 5: Inline 6969 Showing 3D Cross Section with Uninterpreted Fault

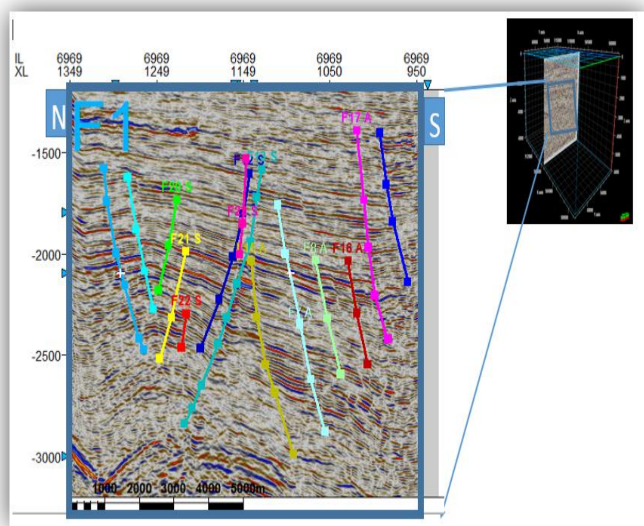

Figure 6: Inline 6969 with Faults (3d Cross Section) showing Fault Interpreted

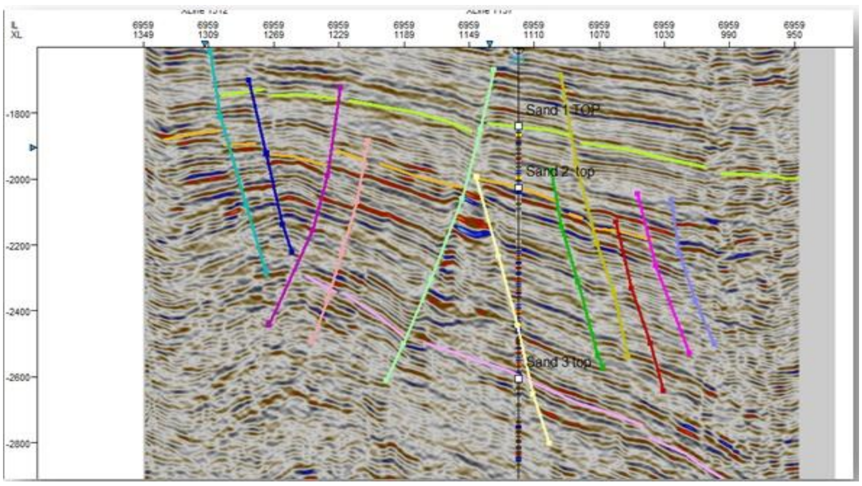

Figure 7: Fault and horizon combined interpretation

4.4 Depth Structure Map

From the horizon and fault interpretation, depth structure maps were produced. Structural highs are stretched over the field areas coloured with purple while structural lows are the goldish/yellowish coloured region.The northern part forms a large closure against the fault. Figure 8 shows the depth structure map for horizon h1 with fault polygons. The colour key is displayed.

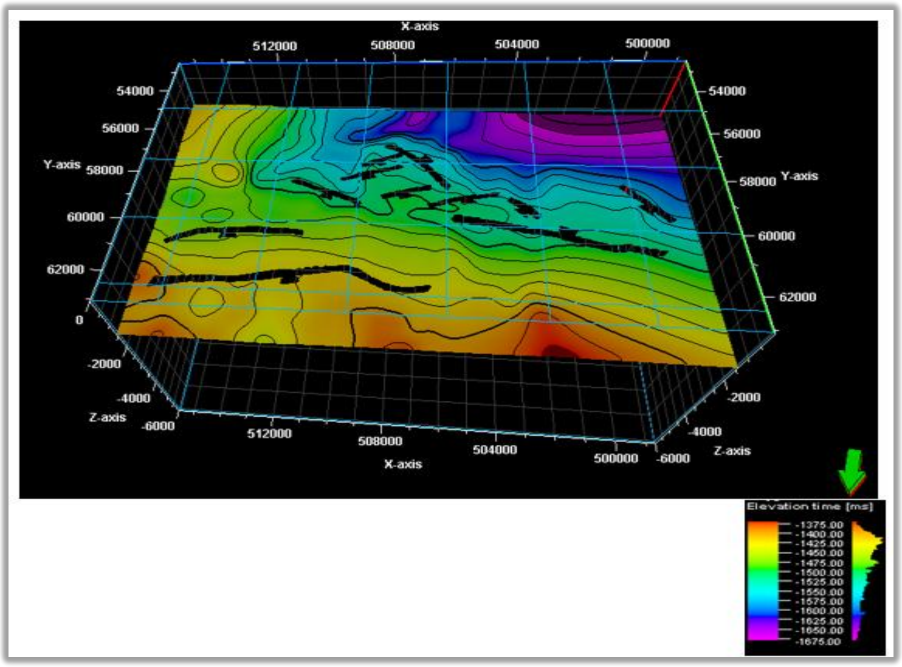

Figure 8: Depth structure map for horizon h1 with fault polygons. The colour key is displayed.

4.5 Time Structure Map

Mapped horizons and the generated fault polygons were used to generate time structural maps for the three reservoirs, the time structure maps of the three horizons generated are shown in figure 9. Time Structure map were generated to aid in the data interpretation. These maps also give an interpreter a 3D perspective of the mapped surfaces. The corresponding time values of the horizons on all the cross-lines were picked with the use of the in-lines to generate the time map.

The main faults seen on the seismic section is also displayed on the surfaces. Although a time map is compressed in its deeper parts and stretched out in its shallow areas because of the general increase in velocity with depth, the highs and lows are normally in the right places. This is particularly true when the geology is in the form of a layer with near horizontal formations of fairly uniform thickness (Amigun and Bakare, 2013).

The dark stripes on the semblance attribute shows discontinuities which is synonymous to fault cutting through the seismic time slice. The slantest fault defines the largest closure which is the prospect zone.

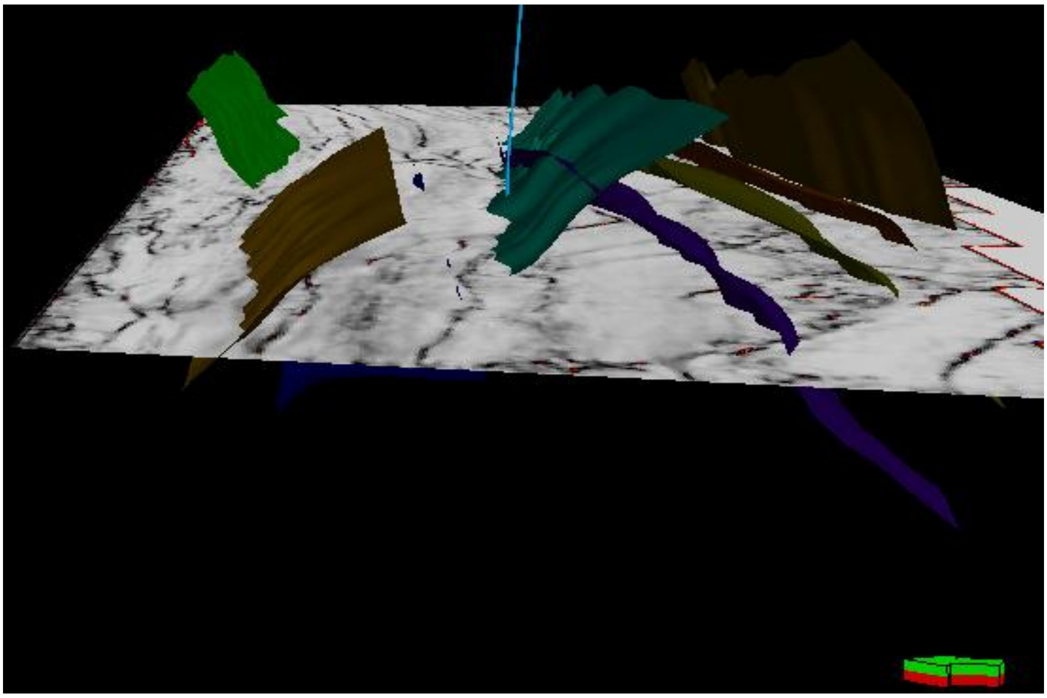

Figure 9: Time Slice with fault interception (Semblance attribute)

4.6 Structural Framework

This involves Fault Modelling, Pillar Gridding and Horizon Making. Fault Modelling involved definition of the various faults in the model which formed the basis for generating the 3D Grid. The figure 10 is a gridded Fault and Event showing Structural Framework of study area on Plan and Dip section. The faults and horizons picked can be clearly seen in 3D view.

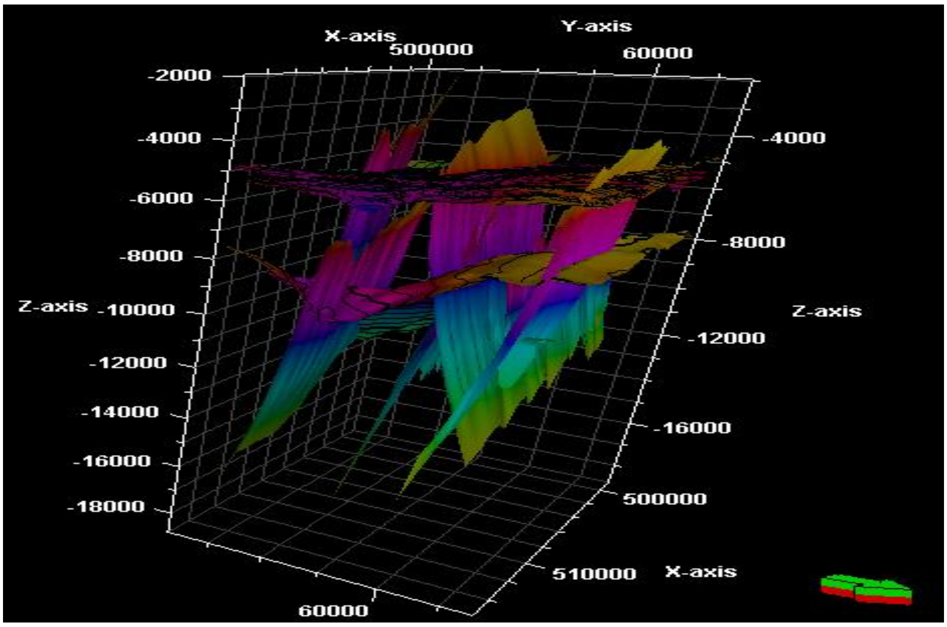

Figure 10: Gridded Fault and Event showing Structural Framework of study area on Plan and Dip section.

5.0 CONCLUSION

Structural interpretation has been effectively done to map the structures and hydrocarbon trapping potential of Akos field, coastal swamp depobelt, Niger Delta. Time and depth structure maps were extracted to show further details on the structures. The results reveal three major horizons were mapped based on the clarity and uniqueness of their features namely; Sand 1, 2 and 3 respectively. Major faults were delineated on the 3D volume and other minor faults, formed by post depositional process. The presence of these faults in the study area is an indication that there is a possibility of hydrocarbon accumulation. From the horizon and fault interpretation, depth structure maps were produced. Structural highs are stretched over the field areas coloured with purple while structural lows are the goldish/yellowish coloured region. The northern part forms a large closure against the fault. Some dark stripes were seen on the semblance attribute and shows discontinuities which is synonymous to fault cutting through the seismic time slice. The most inclined fault defines the largest closure which is the prospect zone. The results also show that the trapping mechanisms in the field are favourable for hydrocarbon accumulation based on the anticlinal structure inherent in the field.

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