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Seismic Interpretation and Attribute Analysis of WABI Field, Onshore Niger Delta, Nigeria

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Abstract: *The objectives of this paper are to evaluate the geological and structural elements, identify and evaluate the prospects in WABI field. The field studied is located in the Niger Delta Basin. An appropriate understanding of the structural families and hydrocarbon trapping systems in any field will lead to a more effective field development planning. An integrated iterative 3-D seismic interpretation, time and depth structural analysis, seismic attribute analysis and structural modelling techniques were employed in this study. Network of faults were interpreted and labelled F1 (orange), F2 (blue), F3 (green) and F4 (red). Three blocks were observed in the semblance time slice resulting from the faults. Two major horizons were mapped which are; Horizon A (light green) and Horizon Deep (red) reservoirs. The structural maps obtained showed fault-assisted anticlinal structures which match up with the crest of the rollover anticlines on the seismic sections. Bright spots seen on the root mean square (RMS) amplitude attribute shows anticlinal structure which mean the field is prolific and contain economic hydrocarbon accumulations.*

Keywords: *Seismic Attribute, Fault and Horizon Interpretation, Hydrocarbon, WABI*

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I. Introduction

The absolute purpose of oil and gas discovery is to recognize and describe structural and stratigraphic traps appropriate for cost-effectively exploitable hydrocarbon accumulations. Hydrocarbon reservoirs are found in geologic traps, which are described as any combination of rock formation that is porous with the capability to store and produce oil and gas when penetrated by wells and also prevent the escape of hydrocarbon in either vertically or laterally (Qin, 1995). Hence, geological trap consists of structural, stratigraphic or a blend of both. Structural traps are capable of preventing vertical and lateral migration of the connate fluid (Coffen, 1984). Rollover anticlines and flanks of salt domes are some examples of these traps (Adeoye and Enikanselu, 2009). Pinch outs, sand channels, unconformities and other truncations are some examples of Stratigraphic trap (Folami et al., 2008). Commonly found traps in the Niger Delta province are structural (Doust and Omatsola, 1990).

In order to locate them, horizons are picked and faults mapped on the seismic in-lines and cross-legged. It is obviously done so as to produce the time structure maps. This has the potential to reveal structural capability that can serve as traps for hydrocarbons accumulation (Adeoye and Enikanselu, 2009). However, carrying out accurate delineating of prolific reservoirs is not as simple as it seems. This is basically because they have to go through rigorous development planning process before they become a fully funded project. Several decisions and plans are dependent on the final possible models of the earth's subsurface with so many uncertainties attached to their input data. It is, therefore, paramount to apply robust methods that can reveal commercially viable prospects before drilling and production commences. This present study incorporates 3-D seismic data and well logs to map, identify and evaluate the prospects in WABI field. The method of amplitude attributes analysis was employed. Bright spot is one of the direct hydrocarbon indicators and a valuable mapping element used by geoscientists because it allows for visual recognition of features related to the presence of hydrocarbons directly on seismic traces.

II. Regional Geologic Setting of Niger Delta

The area of the study is WABI field (Figure 1) located in the Greater Ughelli Depositional Belt of the Niger Delta Basin Nigeria. The Niger Delta contains a thick, net progradational succession of sediments and sedimentary rocks that are composed of three diachronous siliciclastic units. The Akata Formation (marine shale) at the base of the Niger delta complex is composed mainly of marine shale, which is of the Late Cretaceous to Paleocene age. Its thickness ranges from 2,000 m at the most distal part of the delta to 7,000m thick beneath the continental shelf (Doust and Omatsola, 1990). The reservoir rock (Agbada Formation) is more than 3,500 m thick and is made up of a mixture of sand or sandstone and shale, which is of Eocene to Pliocene age. The topmost part of Benin Formation is made up of Late Eocene to Holocene continental sand deposits, plus alluvial and coastal plain deposits that are up to 2,000 m (Avbovbo, 1978). Growth faults produced by quick sedimentation load and gravitational variability of the Agbada sedimentary pile accruing on the moveable undercompacted Akata shales, which are the major structural features in the Niger delta. On the other hands, the youngest Tertiary depobelt at the continental slope of the Niger Delta Basin is associated with shale diapirism (diapirism structures) such as Toe thrusting zones formed at the edge of the prograded delta. lateral flow and extrusion of the Akata shales which occur during growth faulting and related extension, all account for the diapiric structures on the continental slope of the Niger Delta (Doust and Omatsola, 1990). _

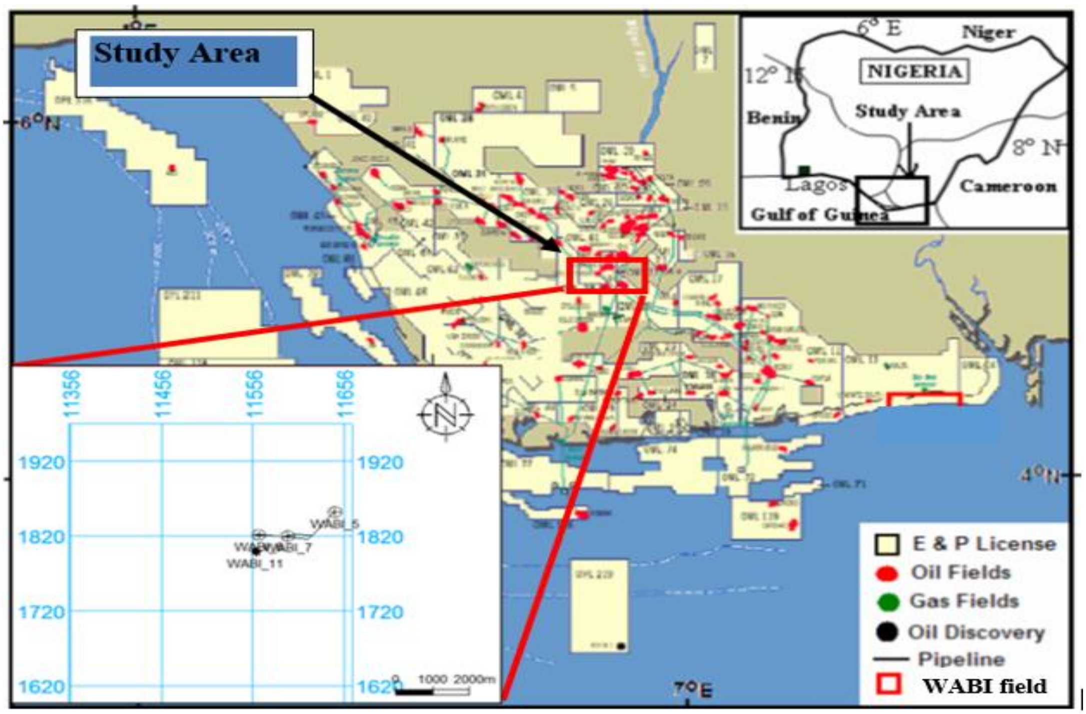

Figure 1: Map of WABI field, Niger Delta (modified from Nton and Estan, 2010)

III. Data Sets And Methodology

The data consists of suites of well logs from four wells (WABI 05, 06, 07 and 11), deviation survey data, checkshot data and 3-D velocity data.

Integrated iterative 3-D seismic interpretation, Time and depth structural analysis, Seismic Attribute Analysis and Structural Modelling techniques were employed in this study. Prior to the actual interpretation, well-to-seismic tie constituted the first step in selecting seismic reflection events corresponding to the tops the reservoir sands for interpretation.

Well-to-seismic tie was achieved by copying the updated checkshots from their respective wells and the original checkshots into wells without checkshots data. This was done under the assumption that lateral velocity variation is minimal or non-existent for wells lying within the same compartment.

IV. Results And Discussions

4.1 WELL CORRELATION

Well tops (horizons) were selected based on the potential well tops recognized from petrophysical analysis of well logs. The horizon tops and bases were identified using gamma-ray and resistivity logs. They were also linked across the four wells as seen in figure 2. Two sand bodies marked Reservoir A and Reservoir Deep were correlated across four wells. The results revealed that each of the identified horizons (sand unit) spreads over the field, varying in thickness and some horizons occurring at greater depth than their adjacent unit which is possibly an evidence of faulting. The sand layers were observed to decrease with depth along with a corresponding increase in shale layers.

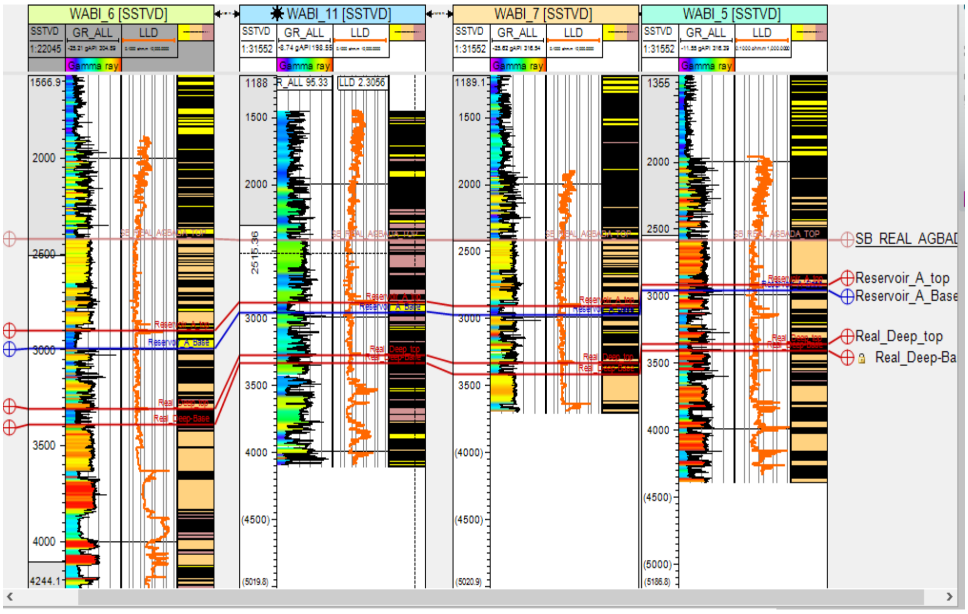

Figure 2: Lithologic Correlation Panel of Delineated Reservoirs across WABI field

4.2 STRUCTURAL ANALYSIS

4.2.1 Horizon and fault interpretation

The 3-D seismic interpretation of WABI field involved fault picking and correlation, which was done to establish the regional structural framework of the field. Figure 3 shows the fault and horizon interpretation along line and trace. It was quality-controlled using the combination of seismic time slices, coherency cube generated from the seismic volume and variance cube from Petrel. Two reservoirs were mapped which are; HORIZON A (light green) and HORIZON DEEP (red) reservoirs. Identified faults were assigned names, colour-coded and correlated as revealed in figure 3. The faults were labelled F1 (orange), F2 (blue), F3 (green) and F4 (red). Figure 4 shows the Semblance time slice of WABI field captured at 2.212 second, showing the three blocks. Fault picks correlate well with fault traces.

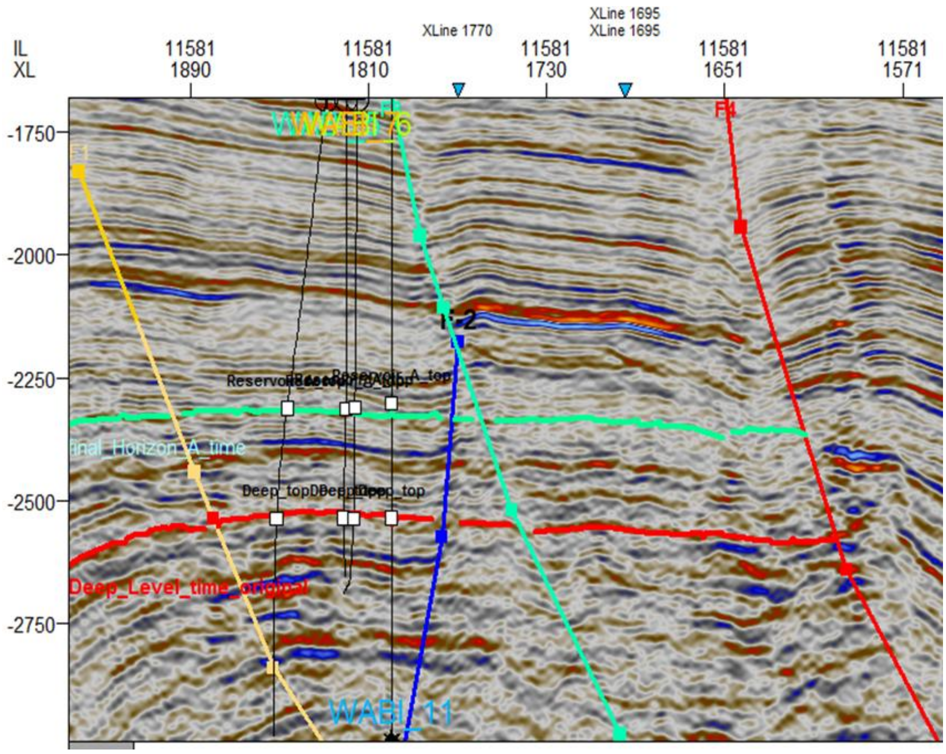

Figure 3: Interpreted Alpha horizon across field done on Petrel

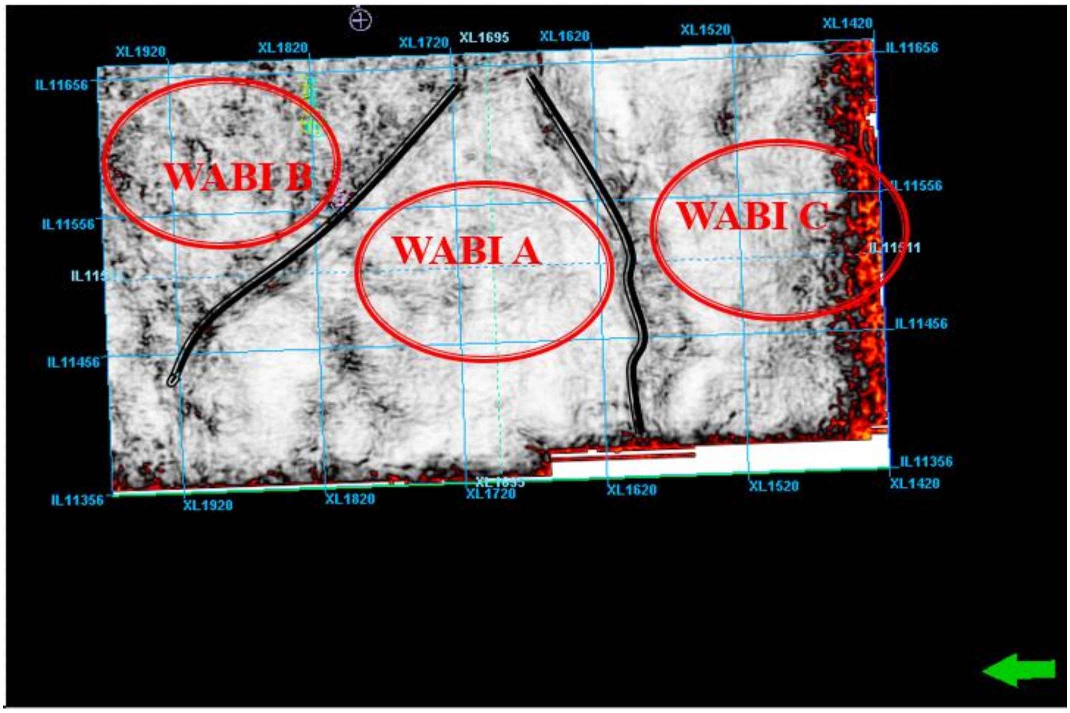

Figure 4: Semblance time slice of the study area for the three blocks

4.2.2 Time structural map

Mapped horizons and the generated fault polygons were used to generate time structural maps for the two reservoirs. The time structure maps of the two horizons generated are shown in Figures 5 and 6 respectively.

The contoured map has contour interval of 10 ms and the values range from 2520 (orange/yellow) to 2740 ms (purple/blue). Points of equal time are identified by same colour. In figure 5, areas with very high times are seen to the west and North eastern part of the field. However, in the case of the deep reservoir (figure 6), regions of extremely high times appear in the north eastern and western parts of the field.

The two growth faults seen on the seismic section is also displayed on the surfaces in both cases. A time map is usually compressed in its deeper parts and stretched out in its shallow areas because of the general increase in velocity with depth.

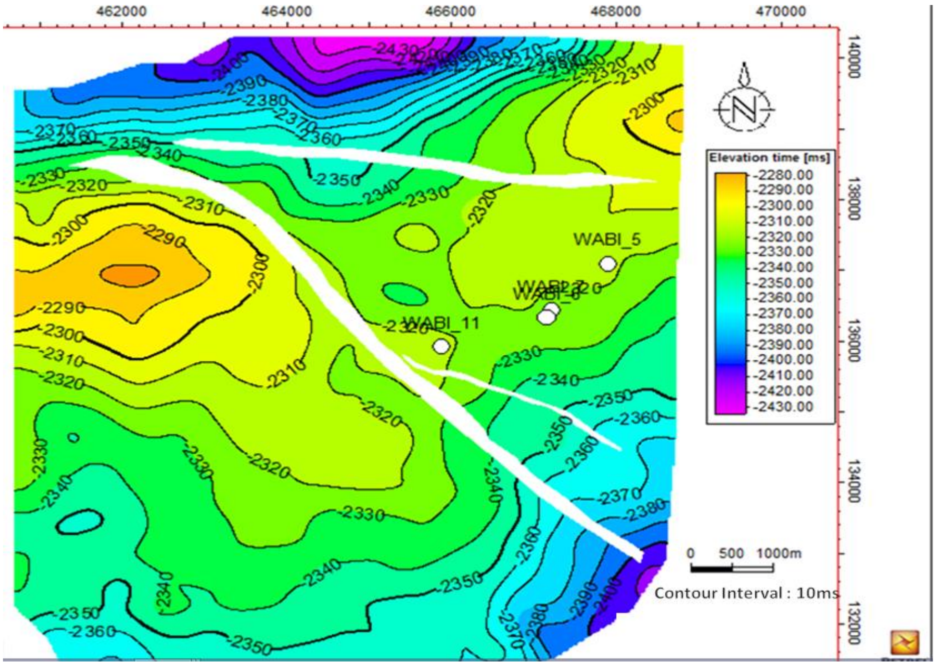

Figure 5: Time Structure map of "A Reservoir".

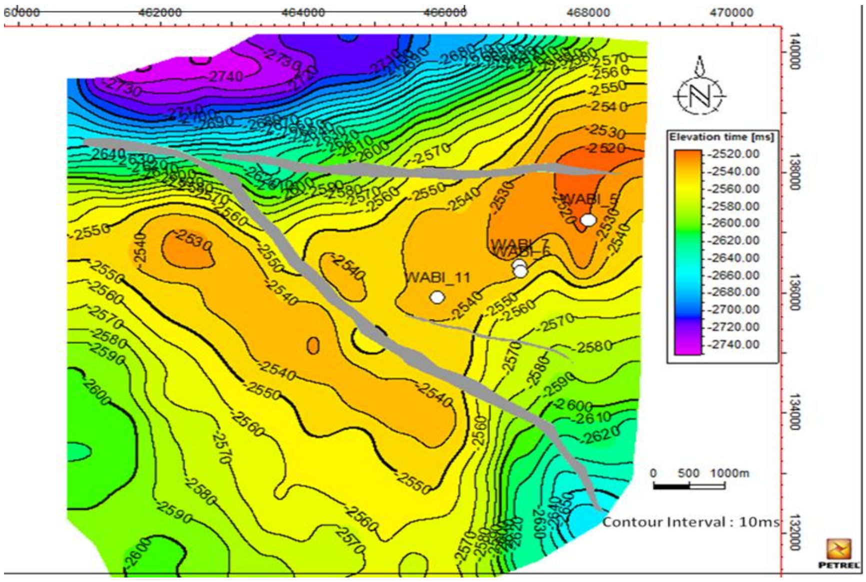

Figure 6: Time Structure map of "Deep Reservoir".

4.2.3 Depth Structure Map

The time structure maps were then converted into depth maps as seen in Figures 7 and 8 using the checkshot data obtained from the area. The depth structural maps also showed the anticlinal structure and two faults. The contouring was actually done by joining points of equal depth going around the data with contour interval of 10m for each surface.

Points of equal depth are identified by having the same colour and the depth of each colour is shown in the colour bar in Figures 7 and 8. Depth structural map of Reservoir A is shown in Figure 7. The contoured map has values ranging from 2840m to 3040m. Structural highs are observed at the North western and central part of the field.

This area forms a good trapping system, thereby increasing retentive capacity for hydrocarbons. The hydrocarbon trapping system in the central part of the field where the wells are located is a faulted rollover anticline. The low faults throw in the area is responsible for outstanding retentive volume of hydrocarbons.

Structural lows are seen in the north and south-eastern region and the area obviously has no prospect. Figure 8 is structural map for the deep reservoir. The contoured interval value ranges from 3275m to 3600m. Structural highs observed in the North-Western part and the central part serves as good traps for the hydrocarbon accumulation.

The hydrocarbon trapping system is still faulted rollover anticlines. In the North-West and central region of the field, structural lows are observed.

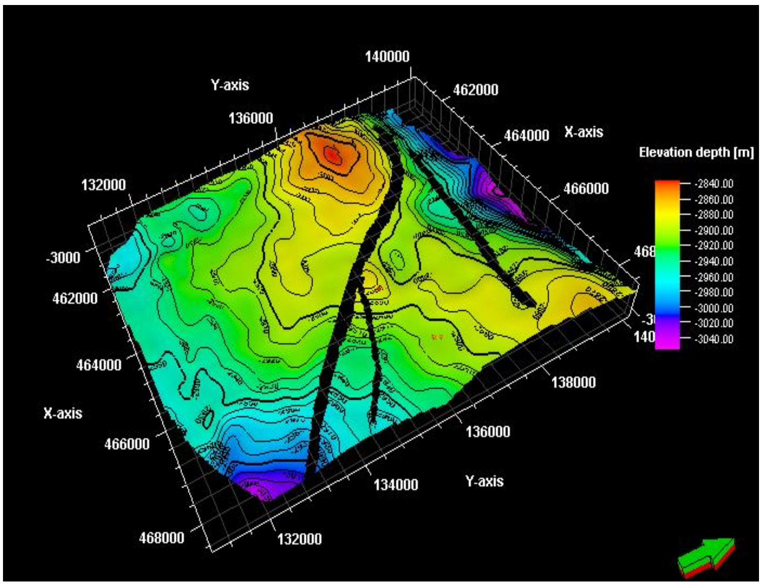

Figure 7: Depth structure map of "A reservoir" with Fault Polygons

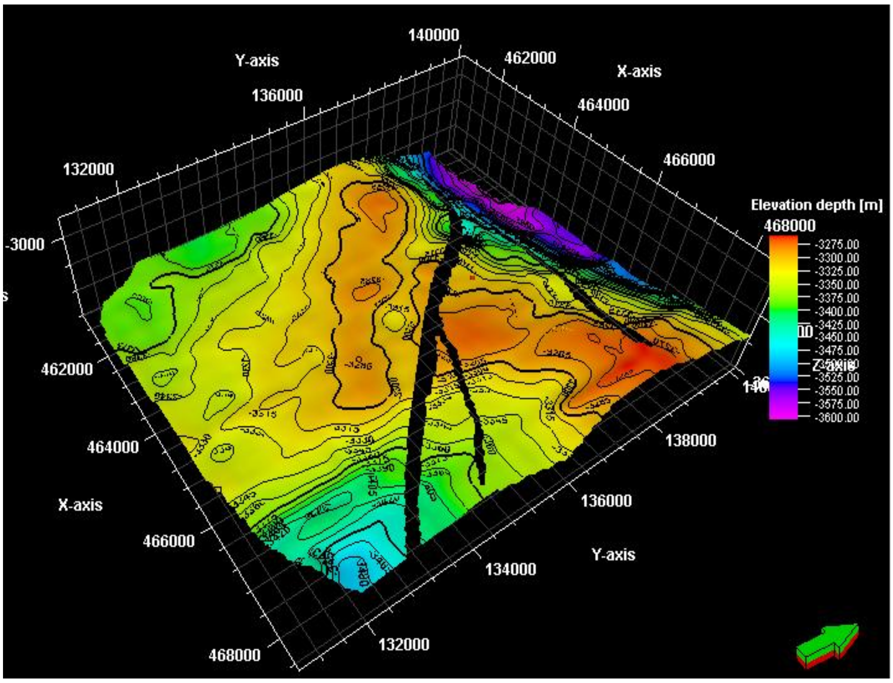

Figure 8: Depth structure map of Deep Reservoir with Fault Polygons

4.3 SEISMIC ATTRIBUTE MAPPING

Seismic attribute analysis involves extracting seismic information from the seismic interpreter-specified structured surface, and allows a quick look at amplitude anomalies and/or structural/ stratigraphic changes in the zone of interest, and also provides direct hydrocarbon indicators.

Series of attributes were extracted to constrain hydrocarbon extent in the field by the use of attributes that give indication of fluid and facies distribution. Root-mean-square seismic attributes were extracted from the seismic data at the deep and shallow reservoirs (figure 9 and 10 respectively). Figure 9 shows an evidence of RMS amplitude (anomaly) within "Reservoir A", indicating hydrocarbon (DHI).

This was validated in well logs where high resistivity values were seen at the same reservoir. RMS amplitude attributes correlates strongly with formation porosity and/or liquid saturation (oil/water versus gas). Figure 10 shows a new prospect delineated within Block A. The observed high amplitude is seen to conform to structure using seismic amplitude analysis.

This should, however, be validated by applying other methods for further analysis. No significant amplitude anomaly is seen within Block B. Hence, there is the presence of low pay contrast.

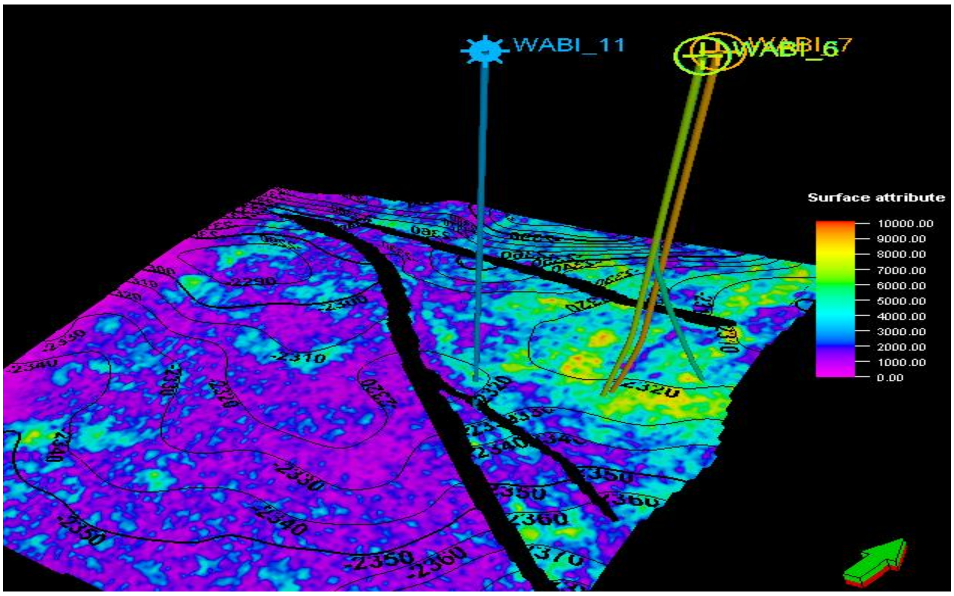

Figure 9: RMS Attribute Map of shallow reservoir A

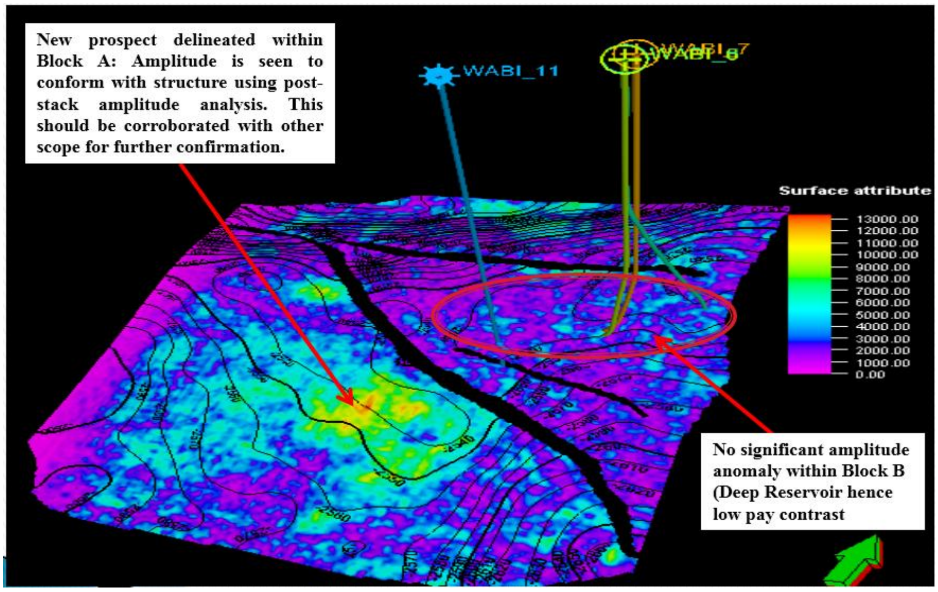

Figure 10: RMS amplitude map of Deep Reservoir

4.4 STRUCTURAL MODELLING

The depth structural model shown in figure 11 has confirmed the compartmentalization of reservoirs into two units from the fault model. These blocks are labelled "A" and "B". Block C is outside the area of operation; hence, not considered for modelling. It was also plagued with poor data quality. Further analysis like prestack inversion should be done on Block A. Modelling was on block B, owing to the fact that Block A has no well control.

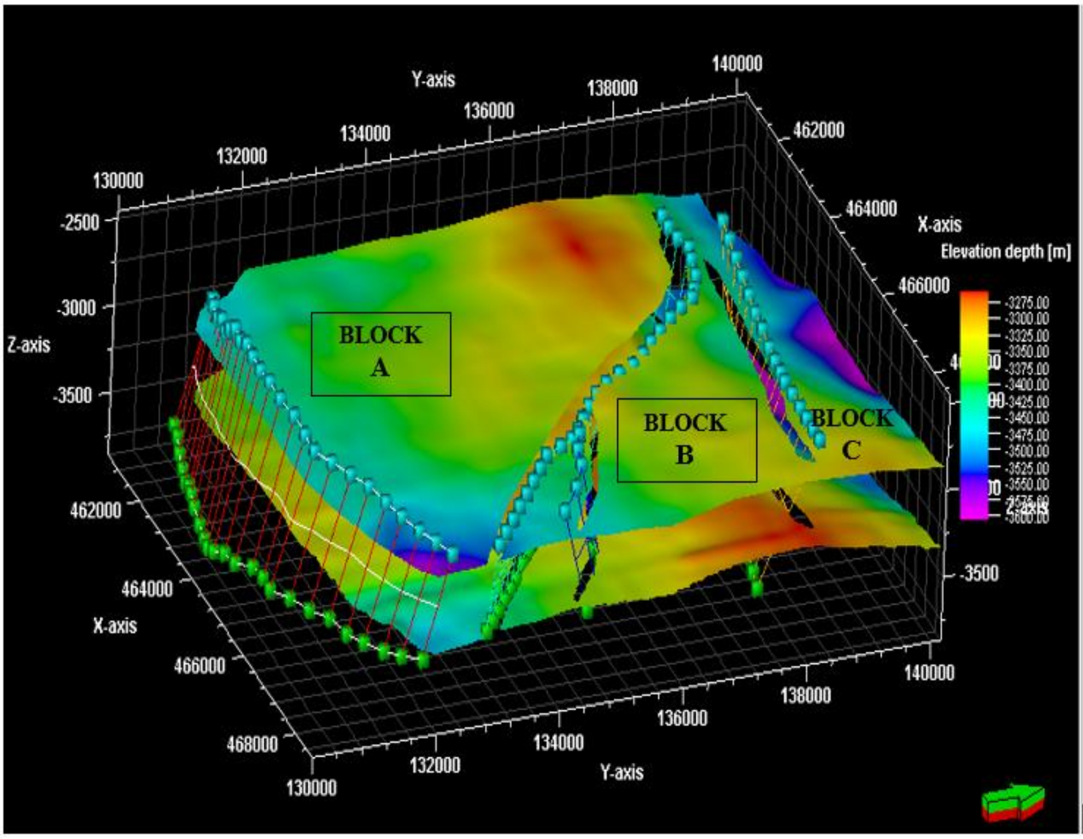

Figure 11: Structural Model of WABI field showing compartmentalization of reservoirs into two units.
Figure 11: Structural Model of WABI field showing compartmentalization of reservoirs into two units. 5.0

V. Conclusion

3-D structural analysis and seismic attribute analysis have been successfully carried out to evaluate the subsurface structures and hydrocarbon trapping potentials of WABI Field, which is located in the Niger Delta, using 3-D seismic and well log data. Through detailed interpretation and analysis of the 3-D seismic, the study provided an insight into the structural architecture of the field via horizon and fault interpretation. Two major horizons were mapped which are: HORIZON A (light green) and HORIZON DEEP (red) reservoirs. Identified faults were assigned names and colour-coded. The faults were labelled F1 (orange), F2 (blue), F3 (green) and F4 (red). The major faults separate the field into three blocks as observed in the semblance time slice. Faults seen on seismic section is a suggestion of the presence of hydrocarbon accumulation. Mapped horizons and the generated fault polygons were used to generate time structural maps for the two reservoirs. The horizons identified were used to produce the structural maps. The structural plots of the tops of the reservoirs revealed that the hydrocarbon structures are fault-assisted anticlinal structures; and they match the peak of the rollover anticlines on the seismic slices. Bright spots seen on the root mean square (RMS) amplitude attribute show anticlinal structure which means the field is prolific and contain economic hydrocarbon accumulations.

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