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Coherence Seismic Attribute, A Better and Most Effective Attribute in Delineating Structural Trend in Bornu Basin

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***Abstract-** Seismic interpretation plays a pivotal role in subsurface characterization, particularly in the identification of structural discontinuities such as faults, fractures, and stratigraphic boundaries. Among the numerous seismic attributes employed for structural interpretation, curvature has long been recognized for its ability to enhance subtle geological features by measuring changes in reflector geometry. However, curvature is highly sensitive to seismic noise, data quality, and processing artifacts, which can reduce its effectiveness in complex geological settings. This study investigates coherence as a more robust and effective seismic attribute for structural interpretation and evaluates its performance relative to curvature. Coherence measures the similarity of adjacent seismic traces, making it particularly effective in detecting discontinuities caused by faults, fractures, channels, and other geological features. Through comparative analysis of seismic datasets. The evaluation considers the clarity of fault imaging, continuity of seismic events, sensitivity to data quality, and overall interpretational reliability. The results demonstrate that coherence consistently provides sharper imaging of fault planes and structural discontinuities while exhibiting greater resistance to noise and acquisition-related artifacts than curvature. Although curvature remains valuable for highlighting subtle flexures and fold geometries, its susceptibility to noise often leads to ambiguous interpretations in structurally complex areas. In contrast, coherence offers clearer visualization of discontinuities and enhances interpreter confidence by preserving the integrity of geological features. The findings suggest that coherence is a more reliable seismic attribute for fault and fracture mapping.*

The coherence attribute analysis of Bornu Basin in Nigeria is carried out with the aim of identifying, analyzing and interpreting Structural Trends in the Bornu Basin Optimally. Firstly 3-D seismic data of the basin was integrated with well data. Hence lithostratigraphic interpretation, seismic structural analyses, seismic attributes analyses and prospects identification at the Basin were carried out using Schlumberger`s petrel 2017 interpretation software. The lithostratigraphic interpretation showed that the study area is characterized by sand- shale interbedding. Lithologic correlation carried out showed the presence of a basin and intra-reservoir seals. The Structural analysis revealed various types of faults such as normal faults, also fold such as the anticline where older rocks are formed, which also help in hydrocarbon trapping

I. INTRODUCTION

Chad Basin is a sedimentary basin which extends into parts of Niger, Chad, Central African Republic, Cameroon and Nigeria known as Bornu basin. (Avbovbo, Ayoola, and Osahon, 1986). Shown in figure 1.0. For more than three decades, researchers and scholars on petroleum potentials in Nigeria have concentrated in Southern part, such as in the Niger Delta, Anambra Basins, and recently in Benue Trough, while little geophysical and geological works have been carried out in the Nigerian portion of the Chad Basin. Nigerian Government has demonstrated renewed efforts in its search for hydrocarbon accumulation at Chad basin in order to increase its oil and gas reserve. (Mohammed, and Tela, 2012). This is because several wells drilled in the Nigerian sector of the Chad basin over the years have not encountered commercial quantity of hydrocarbon, whereas commercial hydrocarbon deposits have been discovered at some other parts of West Africa contiguous to the Bornu Basin and bearing similar geology with it (Obaje, Wehner, and Scheeder, 2004). This is the Nigerian sector of the Chad basin also known as “Bornu Basin”. which Shows that major source and reservoir rocks in Termit Basin has occurred from continental Aptian to Cenomanian deposits of Abu Gabra and Bentiu formations respectively and these could be correlated with the Bima Sandstone in the Bornu basins (Hamza and Hamidu, 2012).

Researchers are increasingly employing more geophysical techniques on three dimensions (3-D) data to review, and gain further understanding of both

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geophysical and geological characteristics of the Bornu Basin in recent times. Seismic attributes have been used by researchers to interpret reflection geometry, amplitudes, and continuity of seismic trace to analyzed subsurface geologic features.

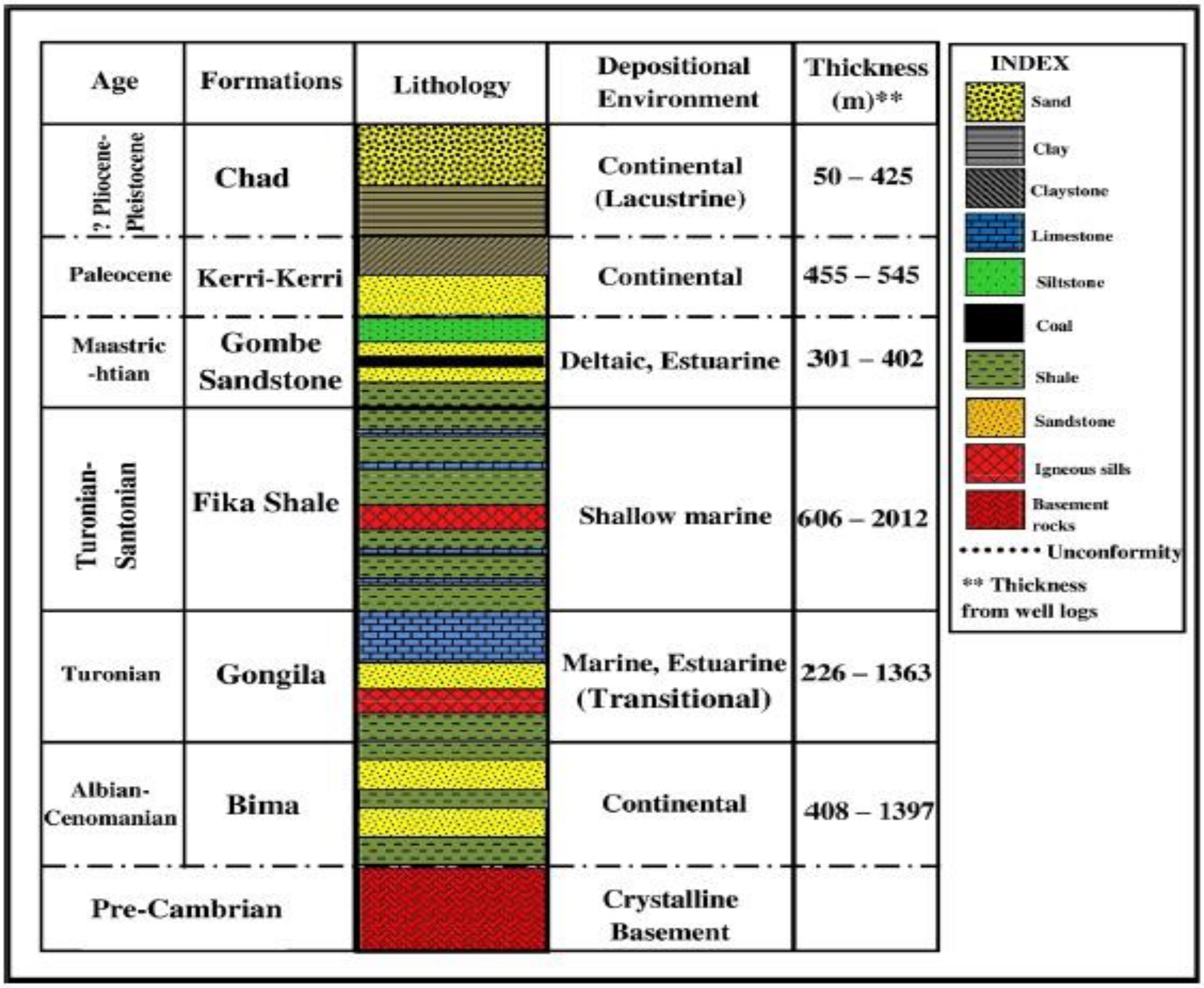

Figure 1.0: Stratigraphic Succession of Bornu Basin (After Avbovbo et al., 1986)

II. MATERIALS AND METHODS

The data utilized for this work are 3D-seismic volume in SEG-Y format, four well logs suits in LAS file format, check shot data, formation tops and the field map showing the location of each well. The seismic volume in 3D window shown in figure 2.1. The well log suite includes Gamma ray (GR) log ranging from 0 -160 API (American Petroleum Institute), Resistivity Log (LLD) ranging from 0.2 – 2000 Ωm, Neutron Porosity (ΦN) in the range of 1.83 – 2.67, Sonic log (DT) ranging from 40 – 240 µs/ft and density (RHOB) in the range of 1.9 – 2.9 g/cm3. The data were obtained from Nigerian National Petroleum Corporation (NNPC) in line with the Department of Petroleum Resources (DPR) and the Federal government's policy on education. Petrel ® E&P software platform 2017, was used for the 3D seismic interpretation, attribute analyses, and well logs data display. Four wellheads (Kasade, Kinasar, Bulte and Kanadi) were utilized for this study, Figure 2.2, is the geologic map showing the locations of the wells, the coordinate of the wells are; Kasade (14250000N, 3280000E), Kinasar (14500000N, 3640000N), Bulte (14450000N, 3280000N), Kanadi (14400000N, 3600000E).

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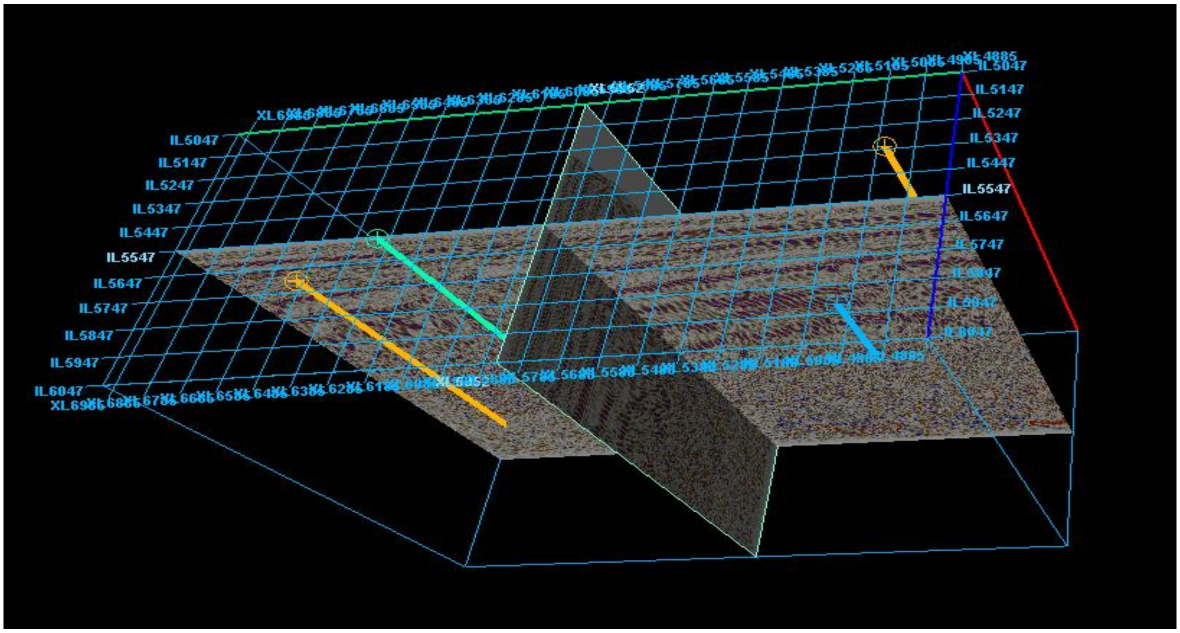

Figure.2.1

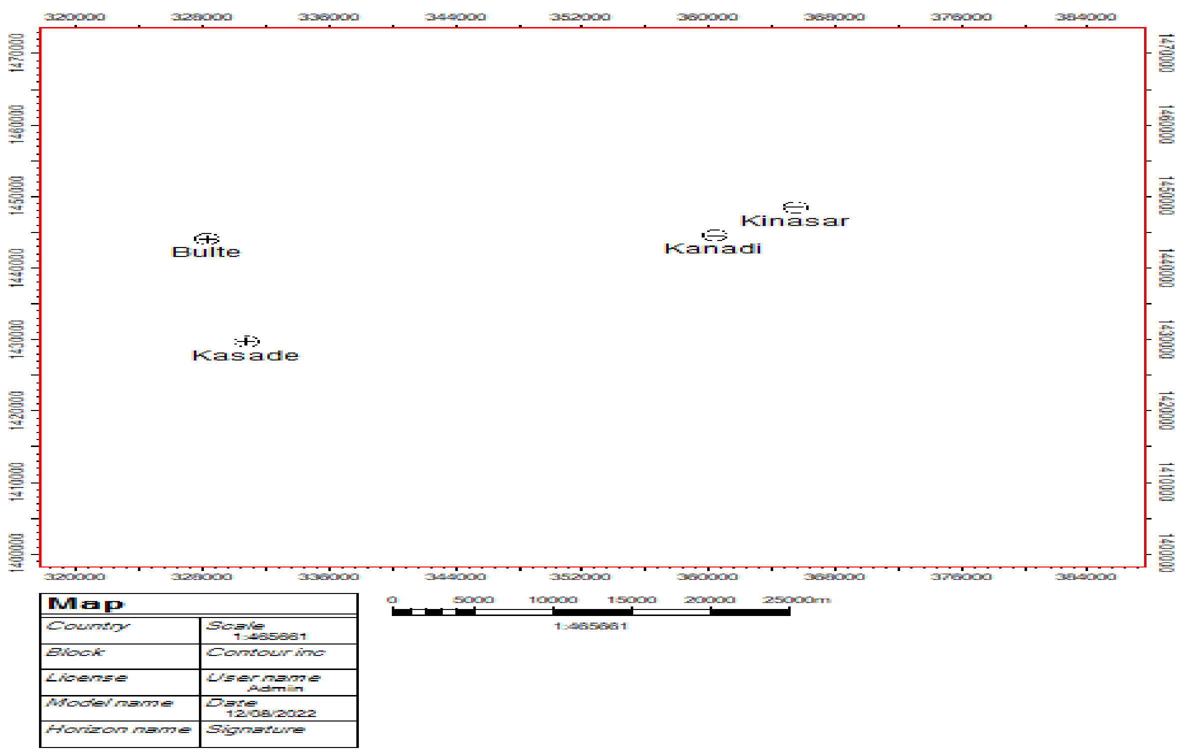

Figure 2.2: Base Map of the Study Area Showing the location of wells

III. METHOD

The 3D seismic data and the well logs were imported into the petrel environment and displayed in various windows such as interpretation window, well section window and 3D window for data quality check (Data QC). The data with their respective coordination reference system was loaded into the Petrel Software. The well data was used for lithological interpretation and stratigraphic correlation. The log data was

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integrated with the seismic data using time-depth data which is the check shot data to generate a synthetic seismogram and as well initiate a relationship between the well log data and the seismic data, (seismic to well tie). The seismic data was used for subsurface fault interpretation and horizon mapping. Gamma ray log which has a scale of 0 to 160 API (America Petroleum Institute) was used for lithology determination and lithostratigraphic correlation. Shale baseline of 60 API was adopted, thus zones with gamma ray reading less than 60 API were marked as sand zones and vice versa. The resistivity log is of the scale of 0.2 to 2000Ohms meter and was used to identify potential hydrocarbon zone. The sonic log was also used for the seismic to well tie process.

IV. RESULTS AND DISCUSSION

4.1. Fault Mapping

Faults were interpreted on the seismic volume based on the discontinuity of reflectors, displacement of reflectors, abrupt termination of reflectors, and rollover reflectors. These faults were mapped along the inline and cross line with the help of a software known as petrel, some of the faults are shown in (Figure 4.1a), and as well mapped in time slices with the help of coherence attribute in comparison with curvature attributes in 3D windows. Normal faults were interpreted, which is an evidence of extensional tectonic regimes. It was observed that the dip of most of the faults, has a dip of almost 90 degrees (Figure 4.1a), there are also some listric faults observed. Listric faults are faults whose dip decreases with angle. The listric faults form the major structures within the study area and could act as traps and migration pathways for hydrocarbon. From the horizon mapping of Gongila and Bima formation indicated by pink horizontal lines respectively, the Fika, Kierri – Kierri and Chad formation overlaying the Gongila formation is not much disrupted by faults except few basement involved faults that run deep into the basement. The most tectonically affected top is the Bima formation that has series of normal and listric faults across it.

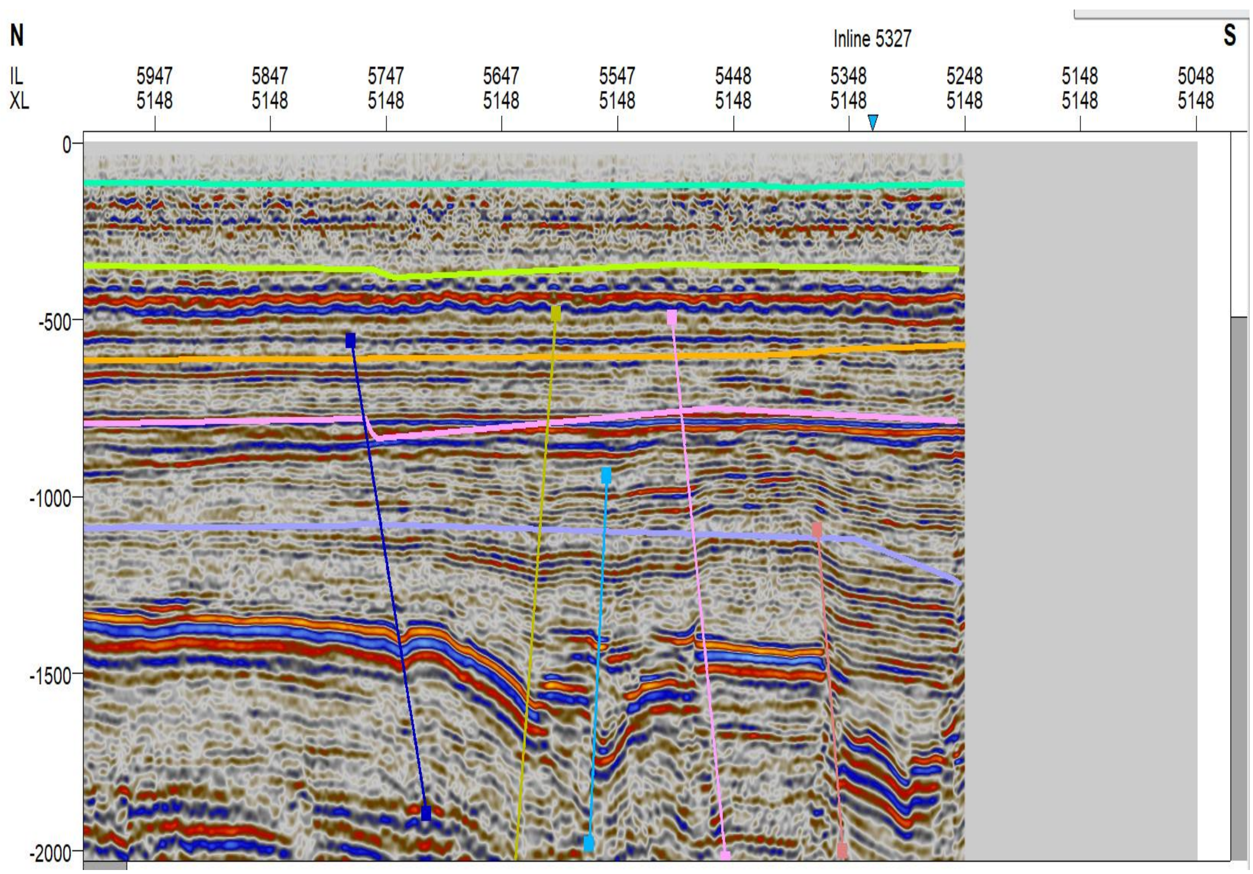

Figure 4.7a. Mapped Faults at Crossline 5148

4.2. Fault Extraction Using Coherence and Curvature Volume

Coherence attribute used for faults extraction depends on the variation of frequency. Wave is said to be Coherence, if they have the same frequency, wavelength and a constant phase difference. The areas with high coherence anomaly (incoherent, not having the same frequency, wavelength and constant phase) shows evidence of fracture, therefore, the faults mapped across the seismic volume were better visualized using the coherence seismic attribute. The dark red coloration on the coherence time slice 1700/ms indicate a red arrow line which shows area of high anomaly. (Figure 4.2a), the red coloration represents coherence anomaly which could be as a result of faults. The faults mapped across the seismic volume fall within the defined zone of higher coherence anomaly. The curvature attribute measures gradient or the rate of change of dip in the maximum dip direction, the higher the gradient the higher the fractures are identified. The curvature attribute in (Figure 4.2b) shows that the area of high gradient was indicated by red arrow, the zone of high gradient readings are found in white discontinuous coloration against the dominant gray continuous coloration. The contrasts in gradient values helped in identification of fracture zone within the study area, hence, the interpreted faults across the seismic volume passed through the zone white discontinuous coloration.

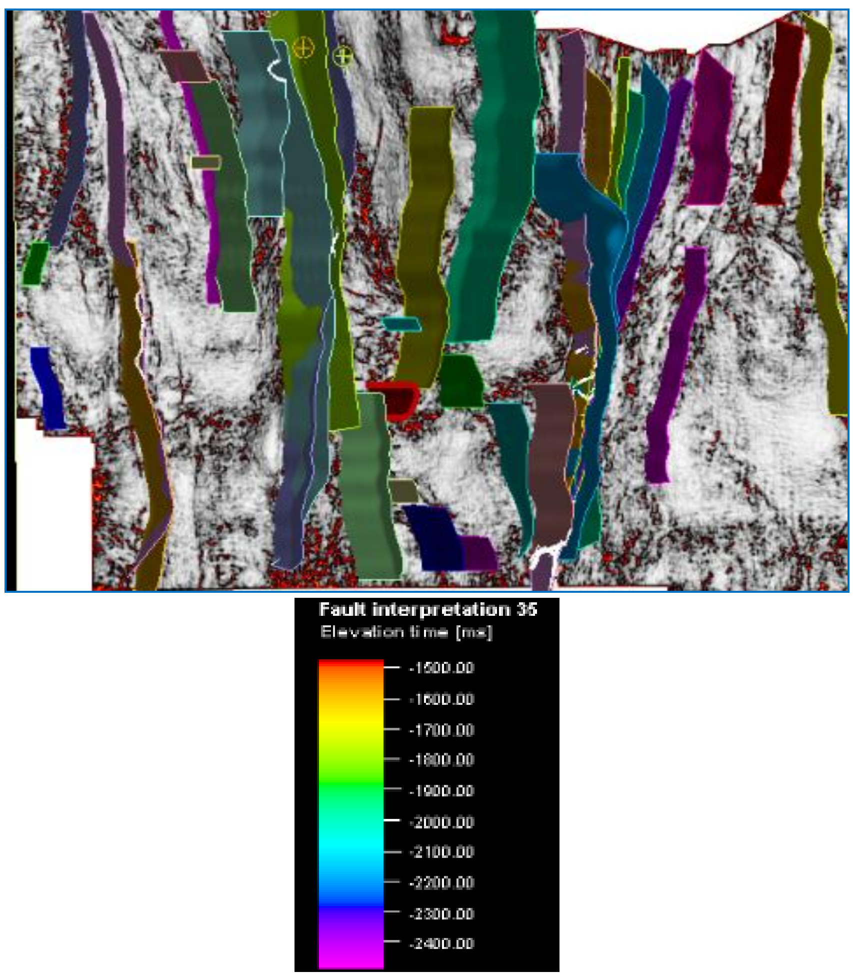

Figure 4.2a. Coherence Attribute at Time Slice 1700ms, Showing Mapped Faults

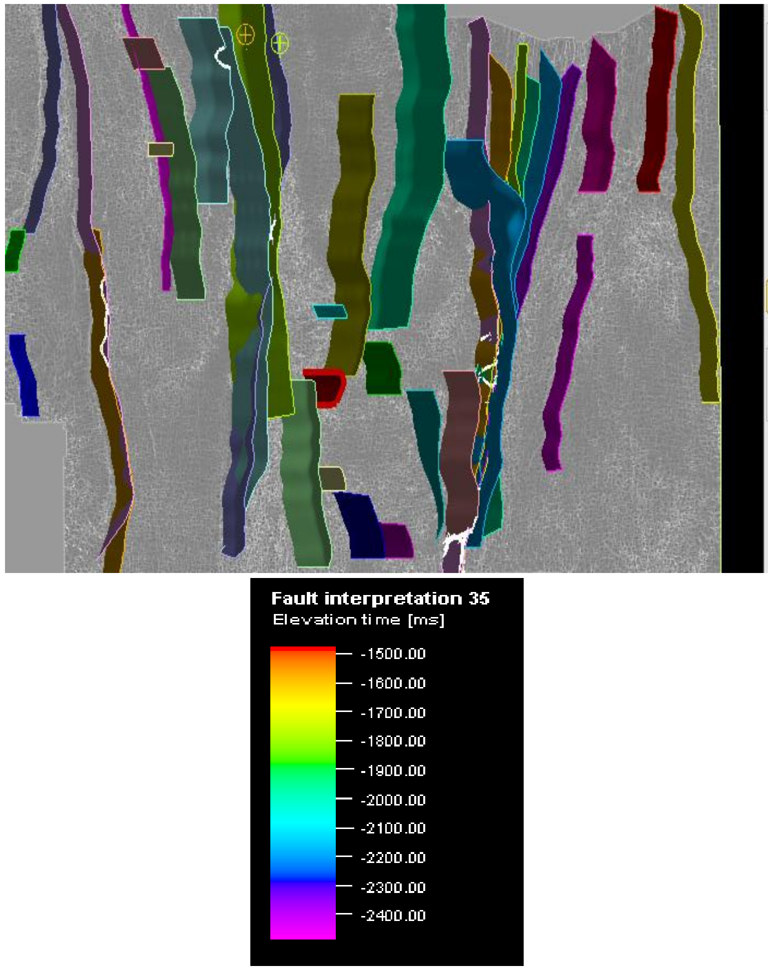

Figure 4.2.b. Curvature Attribute at Time Slice 1700ms, Showing Mapped Faults

Comparing Coherence and Curvature Attribute

Coherence volume attribute anomaly depends on change in frequency while curvature attribute anomaly depends on dip gradient. Both attributes are good in mapping out subsurface structures like faults but coherence attribute is better than curvature attribute because coherence attribute has more defined resolution and clarity in detecting fractures, it also outline all the minor and major faults. Figure 4.2c shows coherence volume attribute at time slice 1700ms, indicating interpreted faults across the seismic volume, while (Figure 4.2d) is curvature attribute along with the interpreted faults in the 3D window. The use of these attributes which are the Coherence and Variance, shows that Coherence attribute have better resolution and hence significance in optimization of structures.

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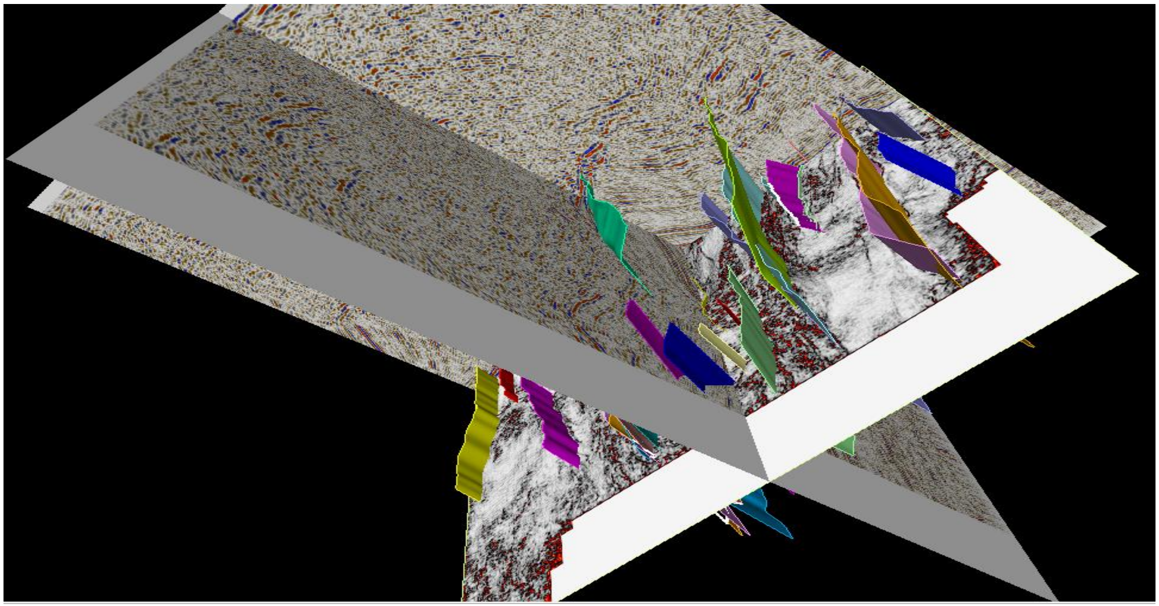

Figure 4.2c. Coherence Attribute at Time Slice 1700ms Showing Interpreted Faults in the Seismic Volume

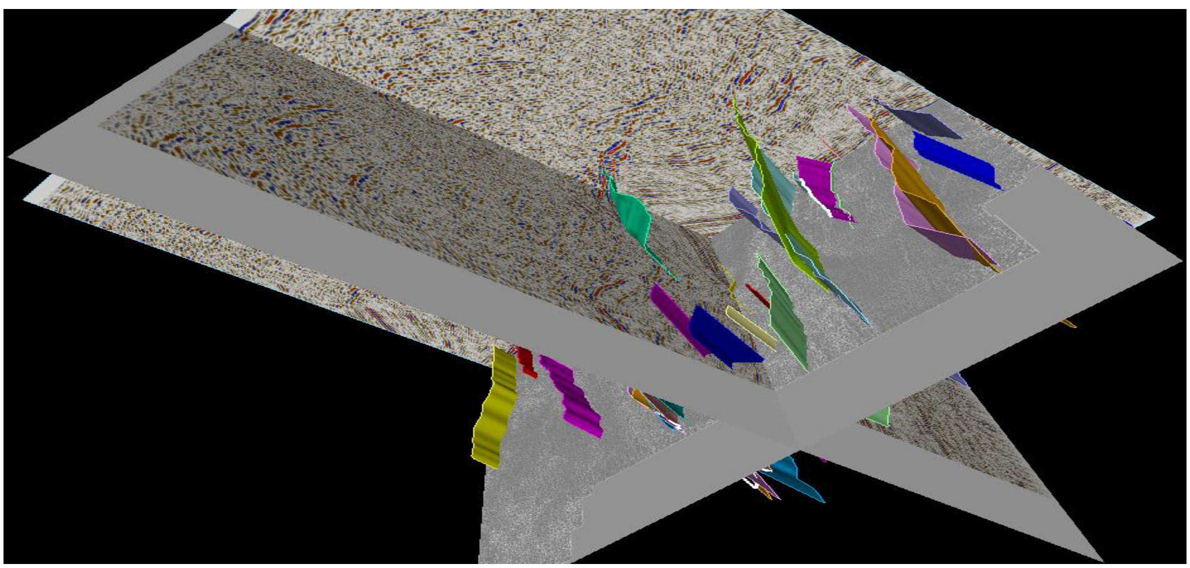

Figure 4.2d. Curvature Attribute at Time Slice 1700ms with Interpreted Faults in the Seismic Volume

V. CONCLUSIONS

Based on the interpreted results obtained, it can be concluded that coherence, and curvature attributes are more efficient in the analyses of structural and fractural trends in sedimentary basins. Coherence attribute when compared with curvature attribute simultaneously gave the same results based on frequency and gradient reading respectively. However, the coherence attributes are preferred to curvature attribute because they show higher resolution of structures. Micro and macro geological structures can be mapped by coherence attribute. The lithological analysis revealed that Bornu basin contains the two major rock types that could generate and store hydrocarbon which are shale and sand formation respectively.

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5.1 Contribution to Knowledge

This work has led to structural analyses in Bornu basin using coherence, variance and curvature attributes. It has contributed immensely to proper location of future wells in the basin for efficient hydrocarbon production. It has also given information on the size of hydrocarbon reserve, and has determined the trap integrity (e.g., Fault). Which gives information where wells should be drilled, in those area of identified anticline for more exploration activities.

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