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FAULT PATTERNS WITHIN PART OF BORNU BASIN, NORTH-EASTERN NIGERIA, USING SEISMIC DATA

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ABSTRACT

Two seismic base maps were first merged into a single map. It was from this single seismic base map that analysis was made. Three horizons and six faults were mapped. The study area lies within the North-east end of Nigeria between latitude 12^0 $19^/$ N and longitude 13^0 $14^/$ E and 13^0 $25^/$ E. The thrust of this work was to identify major faults and its patterns displayed in the seismic section. From analysis six faults were mapped to include two regional, one antithetic, two normal and one growth faults. The faults are located within longitudes 13^0 $15^/$ E to 13^0 $24^/$ E and latitudes 12^0 $21^/$N and 12^0 $27^/$ N. The trend of the faults indicated both a northwest-southeast and northeast-southwest trend. The presence of faults and its trend show that the basin is a rifted basin capable of having hydrocarbon accumulation.

Keywords: Fault Patterns, Seismic Base Map, Seismic Data, Horizons. Vertical Displacement.

INTRODUCTION

Seismic wave is an acoustic energy transmitted by vibration of rock particles. Low energy waves are approximately elastic, leaving the rock mass unchanged by their passage, but close to a seismic source the rock may be shattered and permanently distorted (Milsom, 2003). Seismic waves are generated by both natural uncontrollable earthquake sources and artificial sources at or near the earth's surface. Seismic data are series of reflected and refracted pulses, scaled in amplitude according to the distance traveled and the reflection coefficients/head wave production capability of the various layer boundaries (Okwueze, 2007).

The Bornu Basin is the Nigeria sector of Chad Basin which extends into parts of the Republics of Niger, Chad, Cameroon, Nigeria and Central Africa. The Bornu Basin is about one-tenth of the entire Chad Basin and lies approximately between latitudes 10^0N and 13^0N and longitudes 10^0E and 13^0E. It is one of the seven sedimentary basins in Nigeria and it is the most explored with the exception of the Niger Delta. So far, 23 wells have been drilled and about 2500km of seismic data have been acquired in the Bornu Basin with virtually no commercial discovery of hydrocarbon. Such exploration failures call for more efficient exploration and interpretation of available data (Adepulumi, et al, 2010). Truthfully, the search for hydrocarbon in the Nigerian Chad Basin has really been intensified with NNPC and other oil companies going back to acquire 3-D seismic data after the initial 2-D seismic data previously acquired. However, an in-depth study as being conceived in this work would give an adequate technical knowledge to one vital area of exploration – the fault pattern of the Basin.

A fault is a large crack in the earth's crust where one part of the crust moved against another part (Wikipedia, 2010). Four parts of faults include the fault plane, the fault trace, the hanging wall and the footwall. Based on the sense of slip four types of faults are seen. They are normal faults, reverse fault, strike-slip fault (Wikipedia, 2010). Faults play a vital role in hydrocarbon exploration. They create oil traps when permeable reservoir rocks break and slide next to impermeable rocks. This helps the buoyant hydrocarbon to be trapped within a structural fault block (Wikipedia, 2012).

GEOLOGY

The geology of the study area according to Mathais (1976), is largely part of the Chad Basin. This was confirmed by Ajakaiye and Ajayi (1981). Ayoola et al, sedimentation controlled by transgressive and regressive movements in a geotectonic setting related to rifting. The structural evolution of the basin is represented by NE – SW trending fault. The faulting occurs as a result of rifting which is associated with the opening of the Benue and South Atlantic.

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The sediments of the regressive sandstones of Aptain Cenomonian forms the topmost part of the Bima sandstones formation (Nwaezeapu, 1992). The Bima represents the upper part of the continental intercalaire in Niger (Adepelumi et al; 2010). Another formation, the Gongila formation is regarded as transitional deposit that accompanied the onset of marine incursions into the basin (Carter et al; 1963). The minimum thickness recorded for Gongila formation is 1410m. Yet, the Fika Shale formation was deposited till late Cenomonian. The source of marine water during the period is believed to be through the Trans Sahara way. A maximum thickness of 890m has been penetrated by boreholes in Maiduguri.
Volcanic intrusive which occur as diorite sills are also present at several horizons of the formation (Okosun, 1995). The regressive phase that followed the end of the cretaceous resulted in the deposition of deltaic estuarine, clastic sediments of Gombe formation. This clastic sediments must have been derived from the uplift margin of the trough after Satonian folding episode which affected major basins in Nigeria (Carter et al; 1963; Peter, 1981 and Avbovbo et al; 1986). The remnant basin that succeeded the folding episode formed the site for the deposition of the tertiary kerri-kerri formation which rest over the Gombe formation. The sediments are lacustrine and deltaic in origin and have a maximum thickness of over 200m (Adepelumi et al; 2010). The Chad formation is the youngest strategic unit in the Basin. The lower Chad has been dated as Paleocene (Peter and Ekweozor, 1982; and Avbovbo et al; 1986). It is estimated to be about 800m thick. See figure 1.
The Bornu Basin has an approximate sediment thickness of more than 10km (Ananaba and Ayakaiye, 1983; and Avbovbov et al; 1983).
The study area lies within the Northeast end of Nigeria between latitude 12^0 $19^/$ N and 12^0 $28^/$N and longitudes 13^0 $10^/$ E and 13^0 $25^/$ E covering an area of about 20 by 40 kilometers square.

MATERIALS AND METHOD

The study area is covered with many seismic reflection lines. Thirteen dip lines and ten strike lines trending northwest-southeast and northeast-southwest directions respectively were considered. Most of these seismic lines were shot around 1955 to 1994. Two base maps were used for this work.
The acquisition parameter and the quality of the seismic data supplied were studied by critically examining the seismic section information boxes. They were then visually studies to see whether faults can easily be seen. Qualitative and quantitative techniques were adopted in the analysis of the data.
In order to facilitate structural interpretation from the available seismic sections, the two seismic base map were first merged into a single map. It is on the resulted seismic base maps that the analyses were made. Faults were picked in all the dip lines and correlated with the strike lines. At where faults intersect, the line is folded so that the fault is concealed and horizons correlated. The traced horizons and faults were tied on other profiles around a loop using parameters such as event strength, amplitude and coherency as guides. This is to ensure continuity of the same structural information in all the profiles noting the points of misties which can help to locate hidden faults (Grant and West, 1965). Telford et al; (1979), Kearey and Brooks, (1984); McQuillin, et al; (1984) and Dobrin and Savit, (1988).
Identification and marking of faults on the available seismic section was based on the following criteria;
(i) Reflection discontinuity at fault plane (ii) Vertical displacement of reflection (iii) Disclosures in tying reflections around loops (iv) Deterioration of data below such suspected fault. (v) Distortion of dips as seen through section. However, all these criteria were never completely employed in any single case, but the presence of one, more of these were always apparent in each seismic section.
The throws of each of the marked faults was computed using the relation

$$Tr = \frac{1}{2}(t_d - t_u)\, Vrms$$

The intersections of seismic events with fault surfaces at different travel times were marked with their corresponding upthrow and downthrow positions on the reflection section (Nelson, 1983). Fault plane map was then generated from a plot of the events at corresponding shot points location on the map linked together with reference to their dip direction. Well log data could also be used in the construction of fault plan maps (Tearpock and Bischike, 1991).

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RESULTS AND DISCUSSION

Results of the fault patterns are presented as fault plane maps. The faults cut across the three horizons mapped in each horizon, fault plane map was drawn.

In horizon 1, one regional growth fault F_1, was mapped. The trend of this fault is northwest-southeast with a minimum throw (figure 2). The fault is located at longitude 13^0 $22^/$ $59^{//}$E to 13^0 $23^/$ $05^{//}$E and latitude 12^0 $25^/$ $39^{//}$N to $12^0 23^/$ $45^{//}$N. Two regional faults F_1 and F_2 were mapped in horizon II (figure 3). The trend of the two faults are still northwest-southeast. Here F_1 is located along longitude 13^0 $21^/$ $59^{//}$E to 13^0 $23^/$ $04^{//}$E and latitude 12^0 $25^/$ $23^{//}$N to $12^0 23^/$ $21^{//}$N while F_2 is located along longitude 13^0 $21^/$ $02^{//}$E to 13^0 $23^/$ $02^{//}$E and latitude 12^0 $25^/$ $23^{//}$N to 12^0 $22^/$ $32^{//}$ N. In horizon III, six faults $F_{1,}F_{2,}$ $F_{3,}$ $F_{4,}$ F_5 and F_6 were mapped. $F_{1 \text{ and}}$ F_2 still maintained their northeast-southwest trend. $F_{3,}$ a secondary antithetic fault dips in the direction of northeast-southwest. Close to F_3 is another normal fault F_4 with a minimum throw. At the lower part of the map is another fault $F_{5.}$ Both F_4 and F_5 are northeast-southwest in trend. Another fault F_6 is a growth fault, trending northwest –southeast (figure 4). F_1 in this horizon is located along 13^0 $21^/$ $40^{//}$E to 13^0 $23^/$ $59^{//}$E and latitude 12^0 $25^/$ $19^{//}$N to 12^0 $23^/$ $03^{//}$N. F_2 is along longitude 13^0 $20^/$ $48^{//}$E to 13^0 $22^/$ $04^{//}$E and latitude 12^0 $25^/$ $01^{//}$N to 12^0 $23^/$ $48^{//}$ N. The location of F_4 is between longitude 13^0 $24^/$ $19^{//}$E to 13^0 $13^/$ $02^{//}$E and latitude 12^0 $24^/35^{//}$N to 12^0 $23^/30^{//}$N. F_5 is along longitude 13^0 $13^/$ $02^{//}$E to $13^0 13^/$ $03^{//}$E and latitude 12^0 $22^/$ $04^{//}$N to 12^0 $20^/$ $48^{//}$N. F_6 is located along longitude 13^0 $10^/$ $14^{//}$ E to 13^0 $10^{//}$ $45^{//}$E and latitude 12^0 $21^/$ $34^{//}$N and 12^0 $19^/$ $33^{//}$N.

CONCLUSION

The trend of the faults in the study area indicated both northwest-southeast and northeast-southwest trend. This variation shows that the basin is a rifted basin common in other petroliferous basins of the world. However, the availability of faults in the basin shows the possession of traps for accumulation of hydrocarbon.

We hereby recommend that continuous basinal analysis and interpretation techniques be carried out which will help enhance seismic data quality and possible detection of better productive oil and gas reservoirs.

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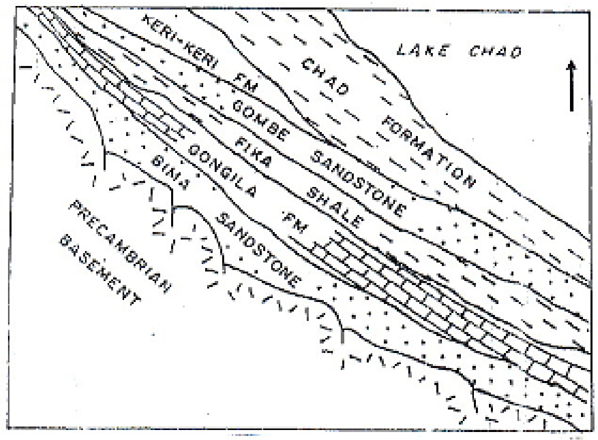

(Fig. 1) Bornu Basin Formation

(After Avbovbo, Ayoola and Osahon, 1986)

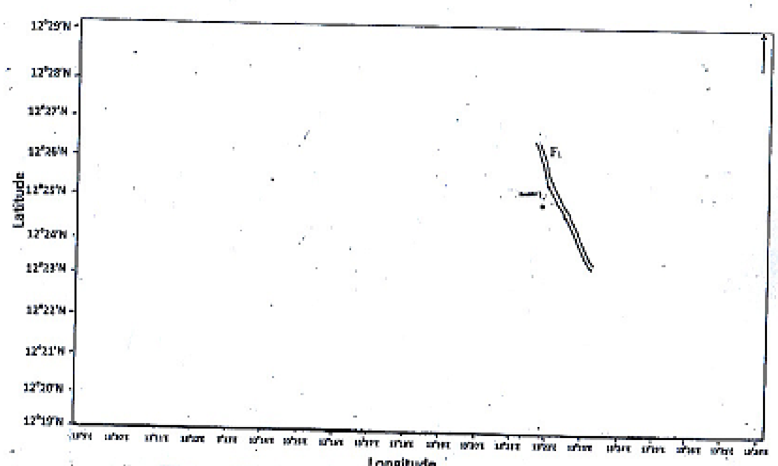

FIG - 2: Fault Plane Map of Horizon I

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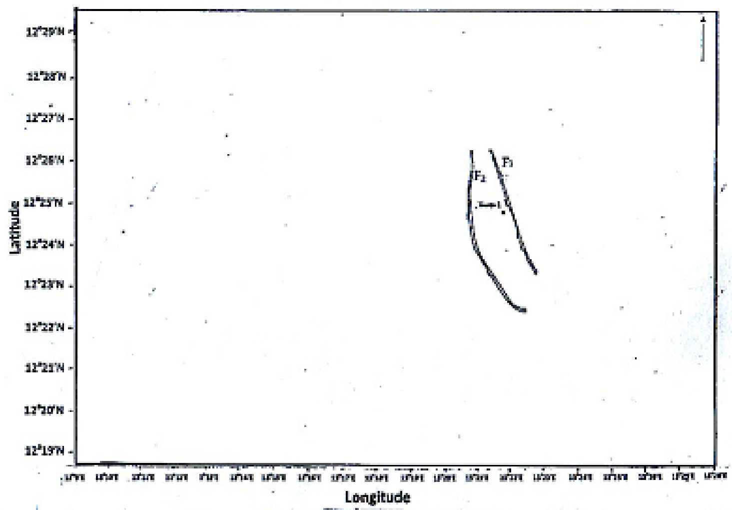

FIG 3: Fault Plane Map of Horizon II

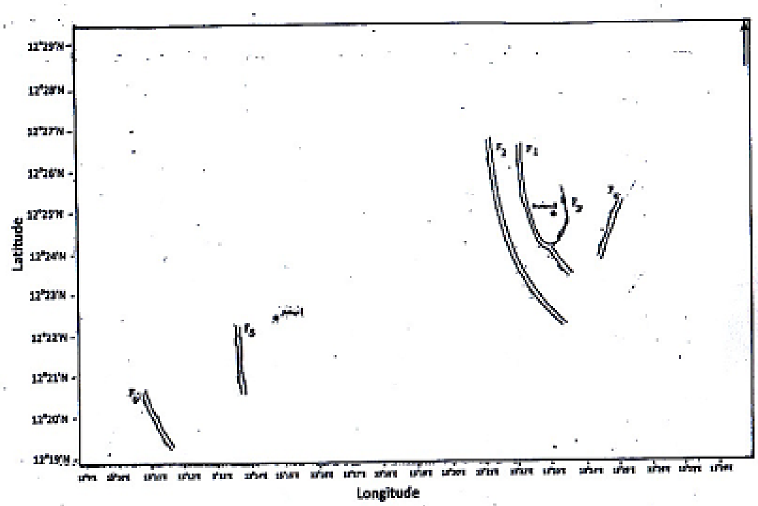

FIG 4: Fault Plane Map of Horizon III