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Evaluation of Depth to Basement Complex and Cenozoic Unconformity from Seismic Profiles and Boreholes in the Nigerian Sector of the Chad Basin

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Abstract

Knowledge of basement relief, overburden thickness and depth to different sedimentary units within the Chad basin are essential information for geothermal studies and update of geologic information of the basin. This study entails the interpretation of twenty seismic profiles with focus on the key marker horizon separating the major sedimentary sequences of Nigeria sector of the Chad basin to deduce the depth to the Cenozoic unconformity and base of Cretaceous/top of the Basement complex. The results of this work showed that depth to the Cenozoic unconformity range from about 100m b.g.l. around southern outskirts of the Basin to about 1700m b.g.l. around Lake Chad. In the middle of the study area around Gubio, a depth of 800m b.g.l. was obtained and in the depression between Maiduguri and Bida is was found to be 1100m b.g.l.. The depth to base of Cretaceous/top of Basement in this study was found to range between 500m b.g.l. to 6500m b.g.l. north of Maiduguri and 5000m b.g.l. around Gubio area which indicate thickness less than 8000m and 10000m as reported by earlier works on the basin.

Keywords: Basement, Cenozoic, Chad basin, Seiemic profile, Gubio, Bida

1 Introduction

The Chad Basin with an area of about 2,335,000km^2 [1] occupies a vast area at an altitude of between 200m and 500m above sea level [2]. According to [3] strata that fill the Chad Basin attained a thickness of approximately 10 km. From spectral analysis of gravity data, [4] revealed sediment thickness ranging from 420 m to 8000 m in the Southwest of the

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Chad Basin. [5] produced an Isobath map of Jurassic basement which indicated the sedimentary column in Borno basin to have a maximum thickness of about 6000m. [6] indicated the Kanadi well as bottoming in basement rocks. Kanadi well is one of the wells drilled by the NNPC in the Nigeria sector of the Chad basin in search of Hydrocarbon, Kanadi well reached a depth of 3048m according to the NNPC logs. [7] also reported only the Kinasar well as penetrating the full thickness of the Bima Group and "Pre-Bima" beds . Kinasar reached total depth of 4663 m according to the NNPC logs.
The present work involves interpretation of about twenty seismic profiles with focus on the key marker horizon separating the major sedimentary sequences in order to obtain the depth to the Cenozoic unconformity and base of Cretaceous/top Basement complex.

1.1 Regional Geology

The origin of the Chad Basin is generally attributed to the Rift systems that develop in the early Cretaceous when the African and South American lithospheric plates separated and the Atlantic opened. The Chad Basin covers an area of approximately 230,000 km^2. It extends into parts of Nigeria, Niger, Chad, Central African Republic and Cameroon. The Bornu Basin (Nigerian sector of the Chad Basin) makes up approximately 10 percent of the basin and lies between latitude 11˚N and 13˚45'38''N and longitudes 8˚ $21^{1}49^{11}$ and 14°40'22"E in north-eastern Nigeria [7].
The history of the Chad Basin according to [8], began before the beginning of Upper Cretaceous, when continental sediments consisting of Bima Sandstones were deposited uncomformably on the Pre-Cambrian basement probably during Albian. The Gongila Formation, which is mixed limestone / shale, was deposited by marine transgression on the Bima Sandstone in early Cenomanian. Marine Fika shale of Cenomanian to Turonian age overlies these beds. Towards the end of the Cretaceous an estuarine deltaic environment prevailed, and the Gombe Sandstones were deposited with intercalations of siltstones, shales and ironstones. The Paleocene marked the period of deposition of grits, sand and clay of continental Kerri- Kerri Formation. The Chad Formation of Pliocene to Recent age overlies these sediments in the basin.
According to [3], strata that fill the Chad basin attain a thickness of approximately 10 km. Combining gravity data with seismic refraction studies [2] identified a "Maiduguri trough" thought to contain some 3000 m of Cretaceous and Quaternary sediments running NNE from near Maiduguri and connecting with Termit rift. From spectral analysis of gravity data [4] revealed sediment thickness ranges from 420 to over 8000m in the southwest of the Chad Basin (Nigerian Sector of the Basin).
The most important formation as far as groundwater resources is concerned are the Chad and the Kerri-Kerri Formations. Fresh potable water some 1713km^3 or 15% of all Nigerian fresh water is confined only to the uppermost part about 500 m of Chad Formation [1] The whole of sedimentary fill of the Chad Basin estimated on basis of gravimetry at over 7,000 metres with an exception to the Pindiga Formation is highly porous, moderately permeable and contains 9,530km^3 of salty and fresh water, about 27% of all fresh and salty water in Nigeria. [9, 10].

2 Materials and Methods

About twenty 2D seismic profiles acquired by National Petroleum Investment Management Services (NAPIMS) of the Nigerian National Petroleum Corporation (NNPC) where obtained for this research. All the seismic profiles together with the study wells were located on the map of the study area (Figure 1).

2.1 Seismic Data Analysis

The scope of the interpretation done on the available 2-D seismic data is limited to identification of the key marker horizons separating major sedimentary sequences and the main faults within the Nigerian sector of the Chad Basin. The identification of these features is based on a reference interpreted line (CHD-88-924) which was obtained from previous seismic interpretation done by past works on the Chad Basin (Figure 2).

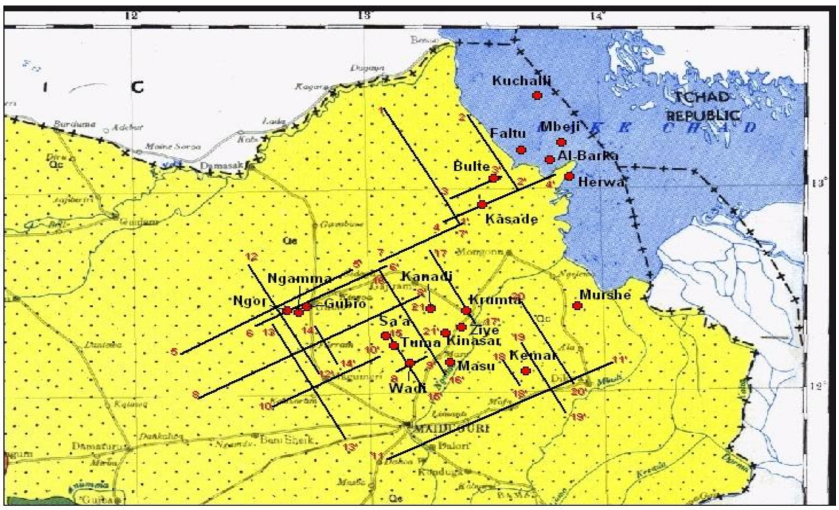

Figure 1: Map of the study area with the location of the seismic profiles (black lines) along with the study wells

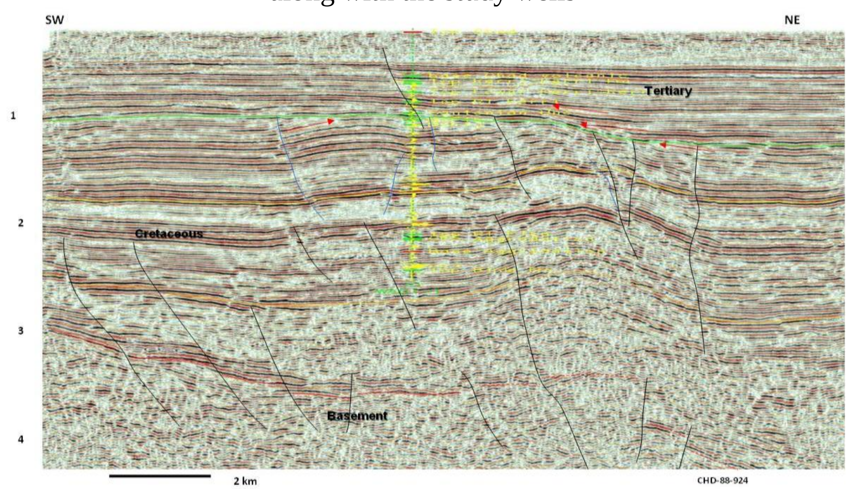

Figure 2: Reference seismic section (CHD-88-924)

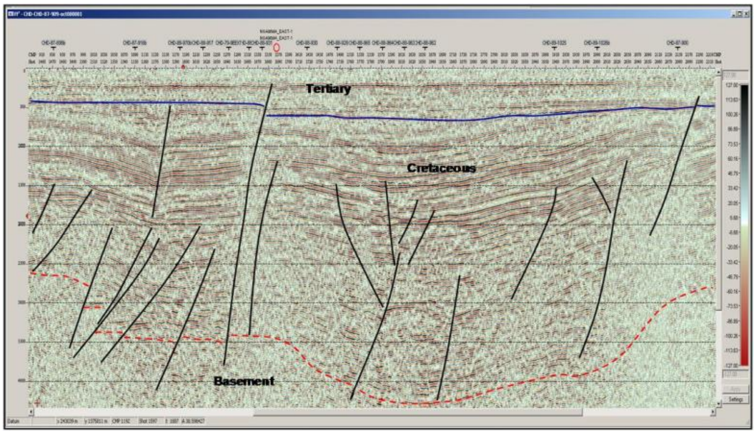

Figure 3: Interpreted seismic profile clearly showing major horizons (Cainozoic, Cretaceous and Basement) and faults

Faults have been indentified and picked as lines of discontinuities along the seismic events which displaces the regular seismic layering within each given seismic section (Figure 3).

The key markers have been picked by seismic correlation with an existing reference interpreted seismic line section (CHD-88-924). In the reference line, the key markers have been picked based on stratigraphy of the Chad Basin from the well that has been drilled along the seismic line. This well and the markers have been superimposed on the seismic section by a process of seismic-to-well tie (calibration) using the time depth relationship for the well and a synthetic seismogram generated from the well logs. This enabled picking of the appropriate seismic signature (event) that corresponds to the stratigraphic markers.

The reference interpreted line section was used as an analogue to comparing the raw seismic sections to the reference line section; it was possible to select the equivalent key markers on the raw seismic sections by correlation. Two key stratigraphic markers were then picked;

i. The base Tertiary – top Cretaceous marker (which is an unconformity surface as can be seen on the seismic sections) (Figure 4).
ii. The approximate base Cretaceous - top of the Precambrian Crystalline Basement (characterized by regular seismic layered events representing the sediments of the Cretaceous above the Crystalline Basement rocks and the chaotic/irregular seismic event typical for the Basement rocks) (Figure 4).

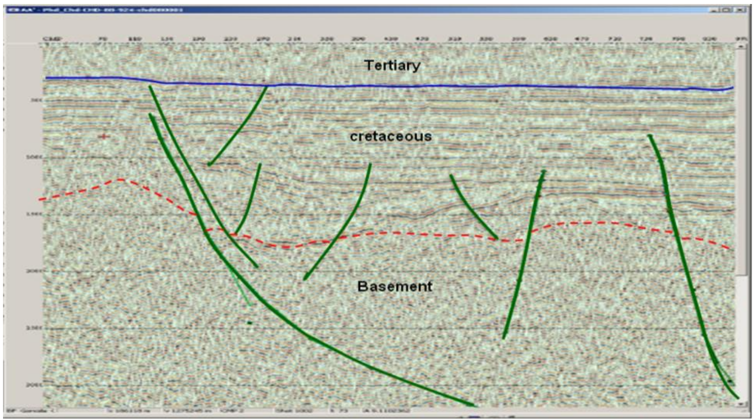

Figure 4: Interpreted seismic profile showing the base Tertiary - top Cretaceous marker and base Cretaceous - Top of the Precambrian Crystalline Basement.

2.2 Professional Computer Software

Professional mapping and calculating programs were used for presenting location of data within the research area, processing the data and constructions of structural and geothermal maps, integrating of data among others. Professional software used includes the Geographix, Surfer, MapInfo and Global Mapper.

In this study Geographix software was utilized to manipulate, interpret and analyses most of the geophysical data obtained. It was used for distinguishing the major geological formations in seismic profiles as well as to analyze digital information of well logs which was obtained from NNPC in LAS format and was converted to normal conventional signature logs which led to interpretation of the lithology and porosity of rocks in wells.

Surfer is used extensively for terrain and underground surface modeling, bathymetric modeling, landscape visualization, surface analysis, contour mapping, 3D surface mapping, gridding and volumetric. It gives a possibility to do the calculations based on the databases and created grids, and the results are obtained in form of a report wits values (Figures) or in form of new grid and map.

3 Main Results

Integration of the interpreted seismic profiles together with information from the studied exploration oil wells located on the map of the Nigerian sector of the Chad Basin culminated into construction of maps of depth to Cretaceous/Cenozoic Unconformity and depth to the Basement Complex. Depth to the Basement Complex obtained range from less than 500 m b.g.l. on the south and west of the study area to about 5000-6500 m b.g.l. – north of Maiduguri area and medium depth - about 3000-3500 m b.g.l. is observed around Gubio and south-east from Bida area (Figure 6).

Depth to the Cenozoic Unconformity in the study area generally increases from south to the north of the area with depth of about 1500-1700 m b.g.l. around Lake Chad. In the middle of the area there is some additional deep zone recorded around Gubio and SE from Gubio, where the depth to the Unconformity reaches 800 and 1100 m b.g.l. (Figure 5).

Thickness of the sediment which also indicates the depth to the Basement Complex from the present study varies from about 500m b.g.l. to about 6500m b.g.l. around Gajiram area.

3500m b.g.l. was recorded around Gubio area. The maximum thickness of about 6500m in the Borno Basin obtained in the present study corresponded to 6000m of [5] but less than that of [3] thickness of 10,000m and [4] thickness of 8,000m. Although both the present study, that of [3] and [5] utilized seismic data to arrive at the thickness and some structures, [4] applies two-dimensional analysis and Hilbert transform of gravity data. [2] identified a "Maiduguri Through" containing about 3000m of Quartenary and Cretaceous sediments, this result coincide with the present study's Map of Depth to Basement which indicates a trough as well, with a little greater depth of about 3500-4500m in some part of Maiduguri (Figure 6)

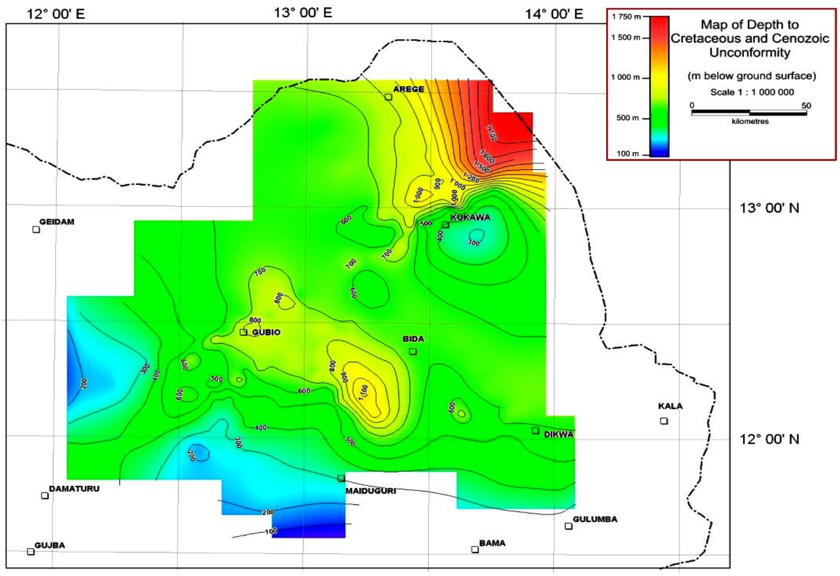

Figure 5: Map of depth to Cretaceous and Cenozoic Unconformity

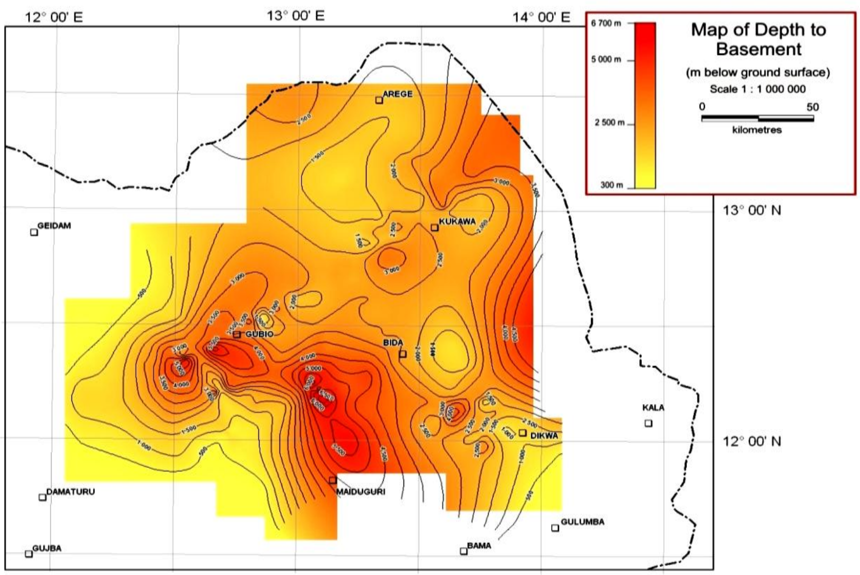

Figure 6: Map of depth to Basement

5 Conclusion

Seismic profile interpretation of the key marker horizon led to the determination of depth to Cenozoic unconformity and depth to the bottom of Cretaceous. Map of the depth to the Unconformity which indicates about 300m bgl to 1700m bgl may be new information and the map will also help in determining the thickness of the Chad Formation in different areas of the region. The depth to Basement which gives 6500m b.g.l. also indicate a lesser thickness of the Basin than the ones reported by some authors 8000m and 10000m, by Nur (2001) and Avbovbo (1986) respectively.

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