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Determination of Magnetic Basement Depth over Guzabure and Its Environs Chad Basin, North Eastern Nigeria

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Abstract: *The aeromagnetic data of Guzabure and its Environs within the Chad Basin, Northeastern Nigeria have been interpreted qualitatively and quantitatively. The total magnetic intensity and residual intensity field showed range of magnetic anomalies which reveal that the study area is magnetically heterogeneous. The horizontal derivatives map showed the occurrence of subsurface linear structures which suggests the presence of faults in the study area. Spectral analysis technique was employed in quantitative interpretation with the aim of determining depth/thickness of the sedimentary basin and basement topography.The result from spectral analysis shows that the depth to the magnetically deep sources ranges from 2.5 to 6.9 km with an overall average depth of 4.069km while the depth to the shallow sources ranges from 0.87 to 1.47 km with overall average depth of 1.086 km.*

Keyword: *Aeromagnetic data,spectral analysis,horizontal derivatives, basement depth, Chad basin*

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I. Introduction

Airborne geophysical survey is an important aspect of modern geophysics, it allows faster and usually cheaper coverage of large areas. It involves measuring the variation of different physical or geophysical parameters of the earth such as distribution of magnetic minerals, density, electric conductivity and radioactive element concentration (Sunmonu and Alagbe, 2014**)**. Aeromagnetic survey is one of the most widely used airborne geophysical surveys in terms of line length survey, and is a rapid and cost-effective technique (Kearey and Brooks, 1984). It is carried out using a magnetometer aboard or towed behind an aircraft. The aircraft typically flies in a grid-like pattern with height and line spacing determining the resolution of the data. As the aircraft flies, the magnetometer measures and records the total magnetic field intensity at the sensor. The measured intensity is a combination of the desired magnetic field generated in the Earth as well as little variations due to the temporal effects of the constantly varying solar wind and the magnetic field of the survey aircraft. The aeromagnetic method has a unique advantage when compared with other geophysical methods in its rapid rate of coverage and low cost per unit area explored. More so, it can be used over water and in regions inaccessible for ground work (Telford *et al.*, 1990).The method has remained a powerful tool in modern geological mapping and mineral exploration purposes. In this study,we considered the use of spectral analysis to determine the depth to magnetic source rocks in the study area. Spectral analysishas been successfully applied in the interpretation of aeromagnetic data for depth to basement determination (Spector,1968,Hahn *et al.,Onwumesi,1997*,Ikumbur et al.,2013,Bonde et al.,2014.Abdulahi et al.,Ikeh et al.,2017,Alasi et al.,2017).Aeromagnetic investigation for depth to basement determination utilizes the principle that the magnetic field measured at surface can be considered an integral of the magnetic signatures from all depths. The power spectrum of the surface field can then be used to estimate the average depth to basement over the geological area of interest. The study area lies within latitude 12° 00' to 13° 00' North and longitude 12° 30' to 14° 00' East .

II. Geology of the Study Area

The Chad Basin lies within a vast area of central and west Africa at an elevation of between 200 and 500m above sea level and covering approximately 230,000km^2 (Ajana *et al.*, 2014). It is the largest area of inland drainage in Africa (Barber, 1965;Matheis, 1976;Avbovbo*et al.*,1986). It extends into parts of the republic of Niger, Chad, Cameroon, Nigeria and Central Africa. The Nigerian Chad Basin (Figure.1) is about one tenth of the Basin (Wright, 1976; Falconer, 1911). This Bornu-Chad Basin is a broad sediment-filled depression spanning northeastern Nigeria and adjoining parts of the Republic of Chad. The stratigraphy of Bornu-Chad Basin has been reported by several workers (Avbovbo *et al.*, 1986; Obaje, 2009; Nwankwo and Ekine, 2009). The stratigraphic sequence shows that Chad, Kerri-kerri and Gombe formations have an average thickness of 130 to 400 m. Below these formations are the Fika shale which is a dark grey to black in color, with an average thickness of 430 m. Others are Gongila and Bima formations with an average thickness of 320 m and 3500m, respectively.

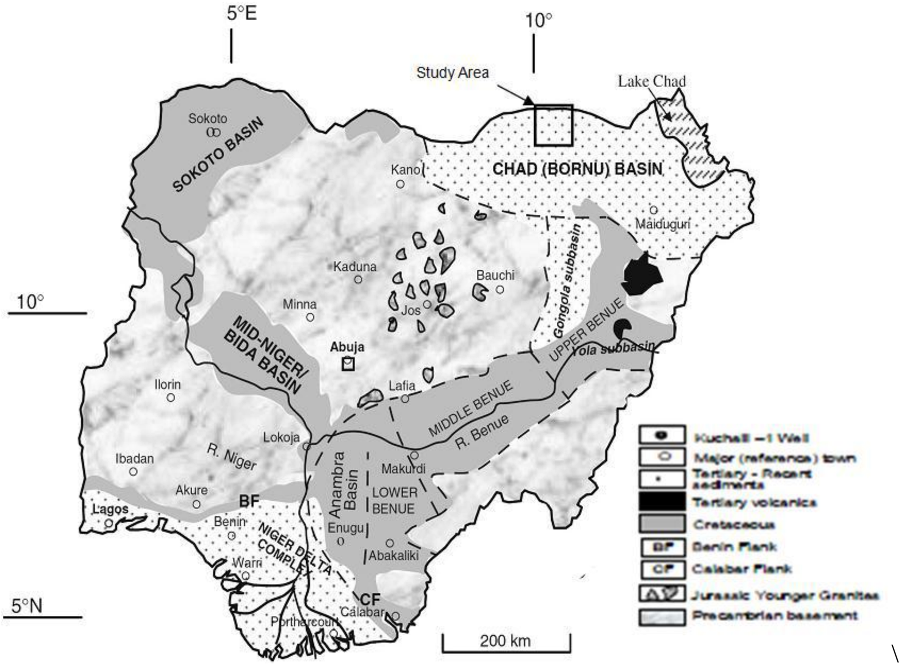

Figure: 1.Geological map of Nigeria showing the study area

III. Materials and Method

Six aeromagnetic maps were acquired from National Geological Survey Agency (NGSA), Abuja. These sheets are sheets 44, 45, 46 ,66, 67 and 68. The aeromagnetic data were obtained as part of a nationwide aeromagnetic survey sponsored by geological survey of Nigeria. The data were acquired along a series of NW – SE flight lines with a spacing of 5km and an average flight elevation of about 80m while tie lines occur at about 2km interval. The geomagnetic gradient was removed from the data using the international geomagnetic reference field (IGRF). The six sheets were merged into a single composite sheet which formed the study areausing Ms Excelsoftware. Other data reduction techniquesapplied include : the regional – residual separation and the horizontal derivatives calculations.

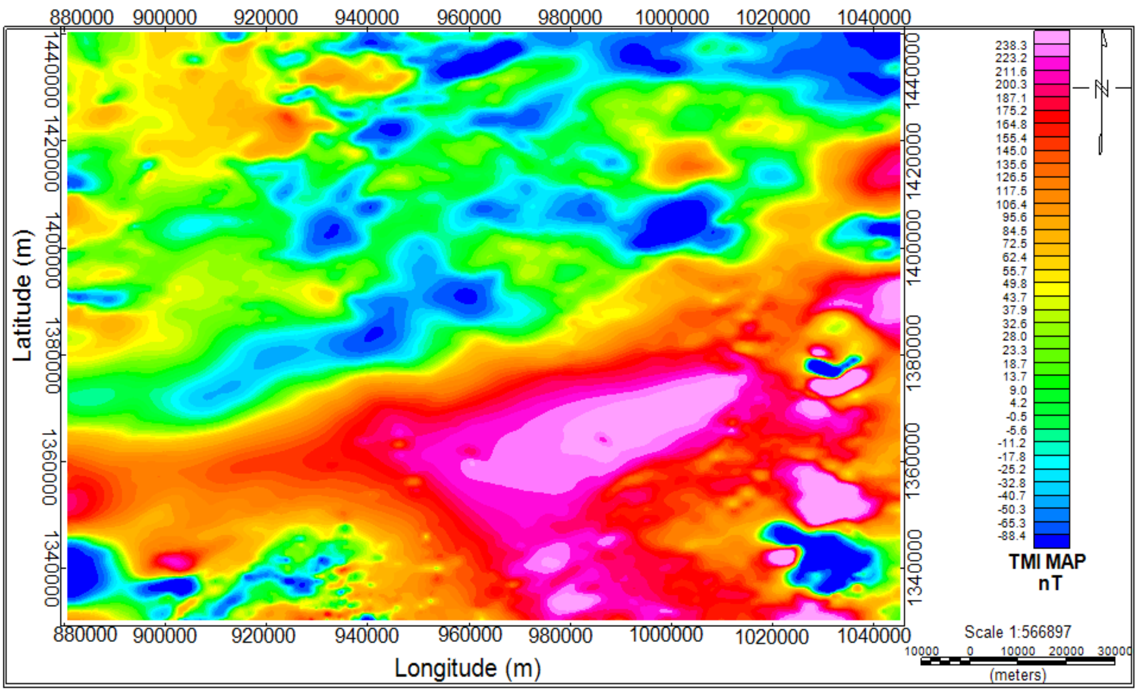

Figure 2: Total magnetic intensity (TMI) map of the study area.

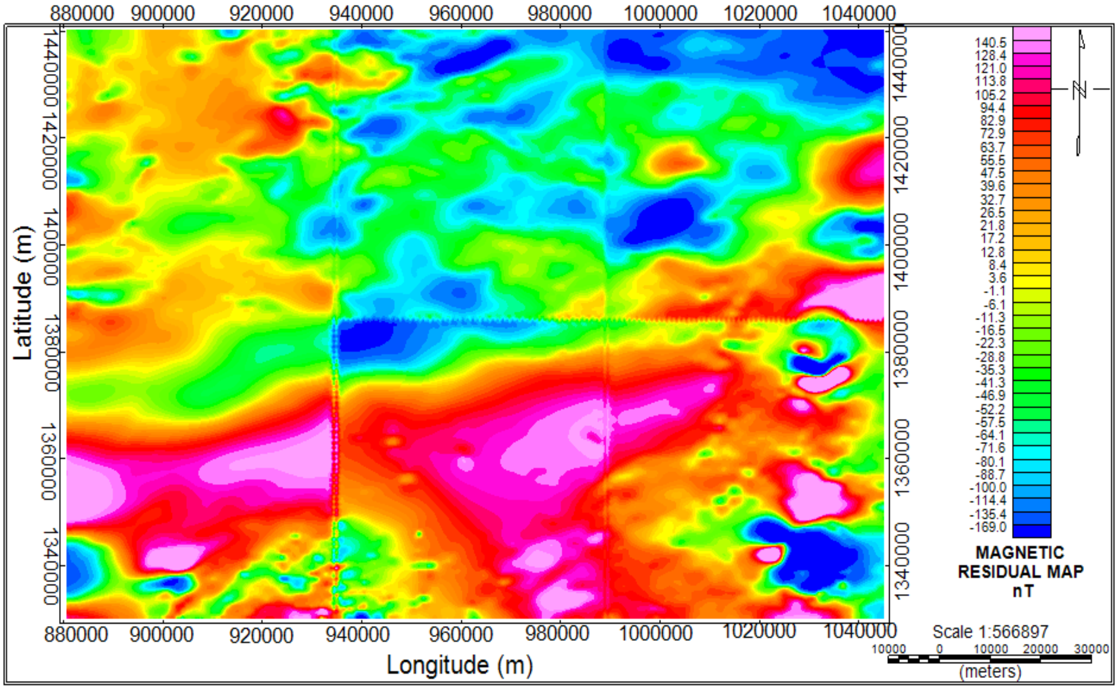

Figure:3 Residual anomaly map of the study area.

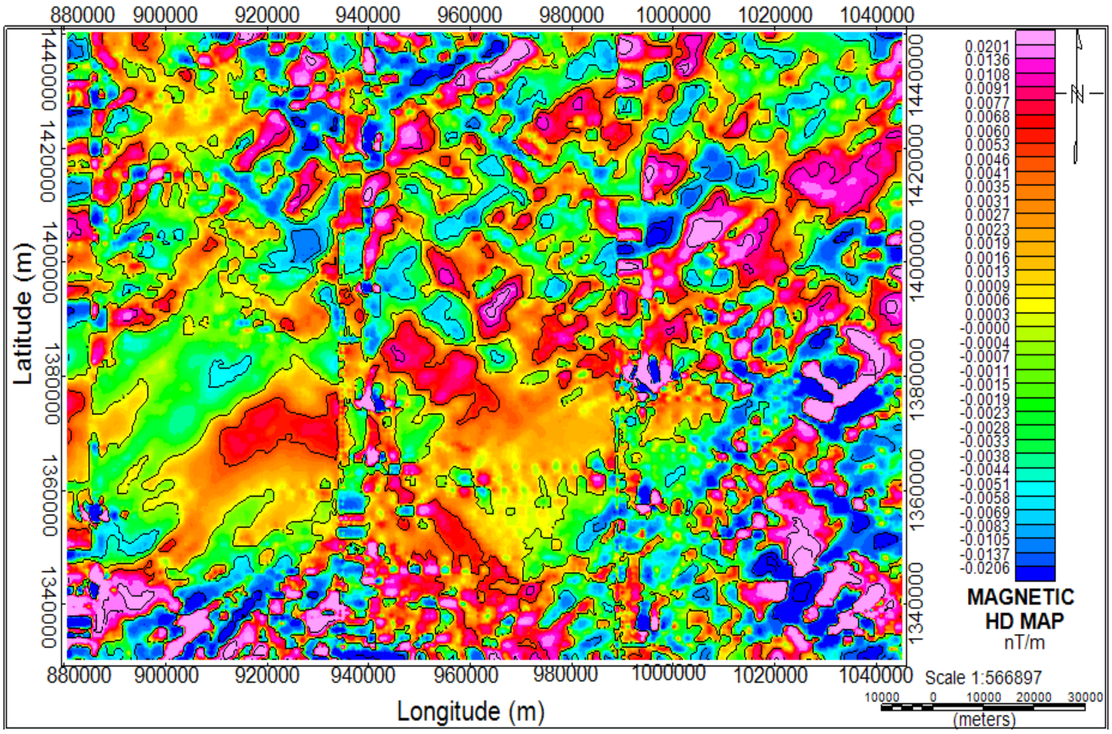

Figure 4: Horizontal derivative map of the study area.

Spectral Depth-Determination Method:

Spectral analysis is the process of calculating and interpreting the spectrum of potential field data. Spectral analysis of potential field data has been used extensively over the years to derive depth to certain geological features (Spector and Grant, 1970) or the Curie isotherm (Shuey *et al.*, 1977; Blakely, 1988). The Discrete Fourier Transform is the mathematical tool for spectral analysis and applied to regularly spaced data such as the aeromagnetic data. A Fast Fourier Transform (FFT) algorithm computes the Discrete Fourier Transform (DFT) of a sequence, or its inverse. The Fourier Transform is represented mathematically (Onwuemesi, 1997) as:

$$Y_i(x) = \sum_{i=1}^{N}\left[a_n \cos\left(\frac{2\pi n x_i}{L}\right) + b_n \sin\left(\frac{2\pi n x_i}{L}\right)\right] \quad 1.$$

Where $Y_i(x)$ is the reading at x_i position, L is length of the cross-section of the anomaly, n is harmonic number of the partial wave number, N is number of data points, a_n is real part of the amplitude spectrum and b_n is imaginary part of the amplitude spectrum; for $i = 0,1,2,3,\dots,n$.The entire study area was divided into twenty four (24) windows or cells of 27.5km × 27.5km in order to accommodate longer wavelength so that the deep depth to the basement up to about 7 km could be investigated. Using the Magmap extension of Oasis Montaj the grid for each section was Fast Fourier transformed and radial average spectrum was run for each section; this produced a column for logs of spectral energy and the corresponding frequencies.These logs of spectral energies were plotted against the corresponding frequencies, and two trend lines were imposed on linear segment. The gradient of each segment of the straight line was evaluated and the depths to basement were determined using the equations,according to Negi*et al.*(1983);Ikumbur *et al.*(2013);Bonde *et al.*(2014).

$$D_1 = -\frac{m_1}{4\pi} \quad 1.$$

$$D_2 = -\frac{m_2}{4\pi} \quad 2.$$

Hence the two gradients corresponding to the linear segments were evaluated, with the steep gradient related to the deep sources (D_1) and the low gradient related to the shallow sources(D_2). M_1 and M_2 are the gradients of the first and second segments respectively.

IV. Results

Four representative plots of spectral energy against frequency from the analysis are shown in figures 5(a-d).From the computed values of spectral depths, the magnetic basement depth was plotted and contoured using surfer 32 software. The deep magnetic sources vary from 2.5 to 6.9 km (Figure 6), whereas the shallow magnetic source varies from 0.87 to 1.47 km (Figure 7). The deep magnetic sources suggest depth to Precambrian basement while the shallow magnetic sources depict depths to basic intrusive and/or magnetized bodies. The deep depth to basement is shallowest (purple color) in the north eastern part of the study area, while it is deepest (black color) in the south western part.

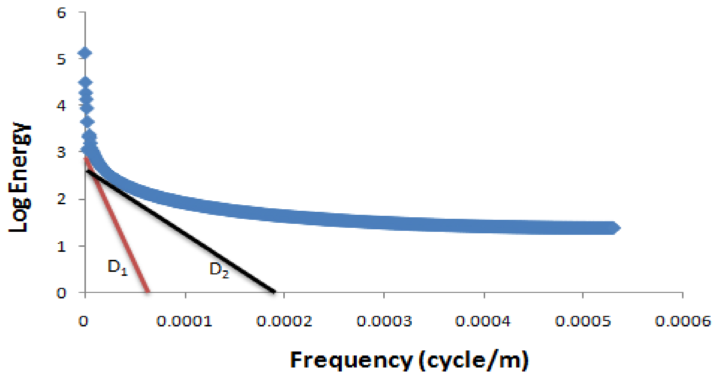

Fig:3a. Spectral Plot of log of energy against frequency for cell 4

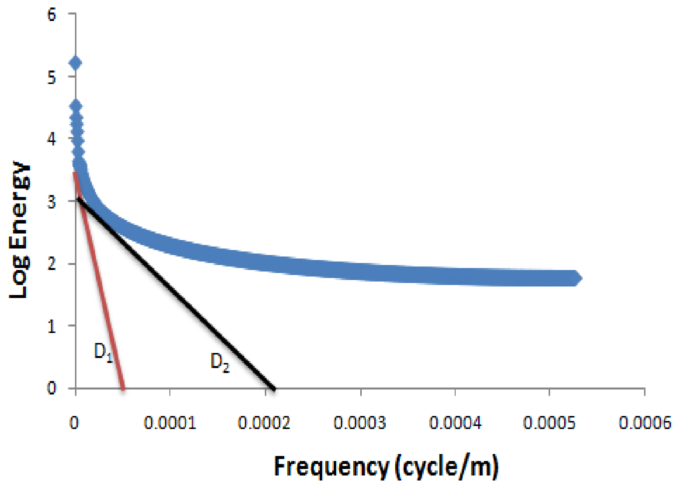

Fig :3b. Spectral Plot of log of energy against frequency for cell 9

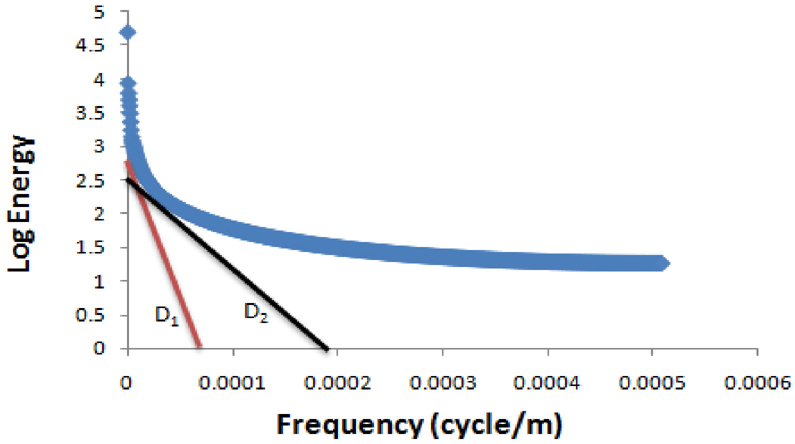

Fig :3c. Spectral Plot of log of energy against frequency for cell 17

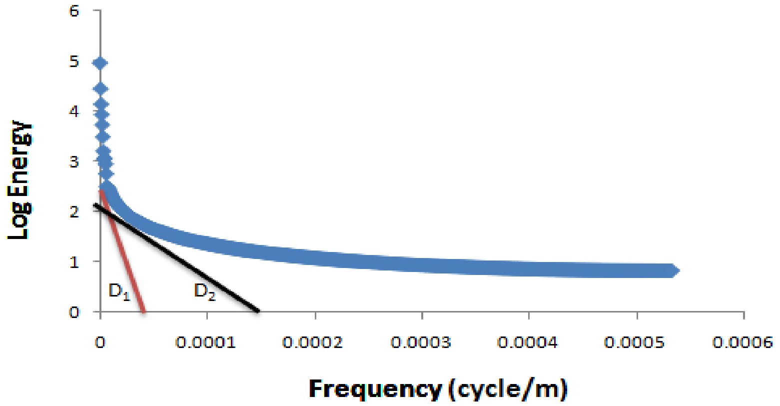

Fig :3d. Spectral Plot of log of energy against frequency for cell 22

Table 1: Summary of Spectral analysis result.

S/N	SPECTRAL BLOCKS	CO-ORDINATES (m)		DEPTH SOURCE VALUE (km)	
	SECTIONS	X(Longitude)	Y(Latitude)	DEEP(D_1)	SHALLOW(D_2)
1	1	894110.3	1344026	3.946	1.159
2	2	921456.0	1344026	3.185	1.087
3	3	948802.0	1344026	3.298	1.106
4	4	976148.0	1344026	4.343	0.955
5	5	1003494.0	1344026	4.255	1.256
6	6	1030840.0	1344026	3.494	0.910
7	7	894110.3	1371412	6.923	1.468
8	8	921456.0	1371412	6.941	1.393
9	9	948802.0	1371412	5.246	1.082
10	10	976148.0	1371412	3.069	1.035
11	11	1003494.0	1371412	3.901	1.053
12	12	1030840.0	1371412	4.379	0.943
13	13	894110.3	1398798	3.649	1.054
14	14	921456.0	1398798	4.632	1.152
15	15	948802.0	1398798	3.462	1.109
16	16	976148.0	1398798	4.777	1.076
17	17	1003494.0	1398798	3.488	1.075
18	18	1030840.0	1398798	3.120	1.106
19	19	894110.3	1426183	3.920	1.103
20	20	921456.0	1426183	3.764	0.923
21	21	948802.0	1426183	4.204	1.124
22	22	976148.0	1426183	4.514	1.120
23	23	1003494.0	1426183	2.541	0.893
24	24	1030840.0	1426183	2.612	0.874
AVERAGE DEPTH				4.069	1.086

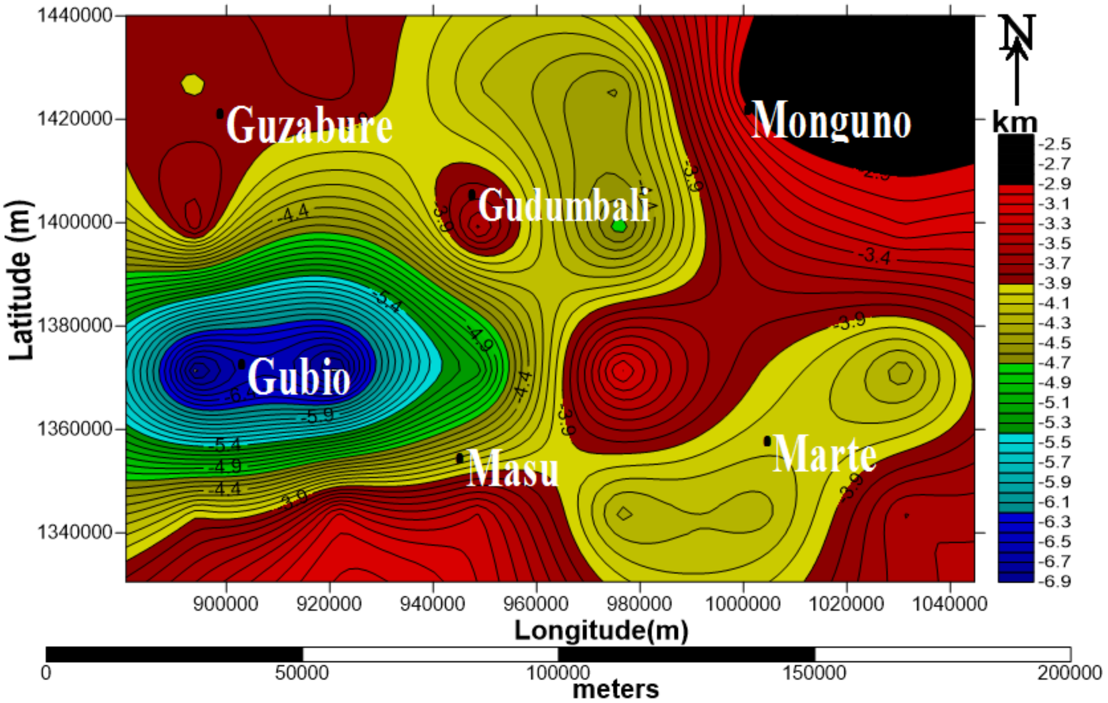

Figure 6: Deep depth to basement map (contour interval 0.1km)

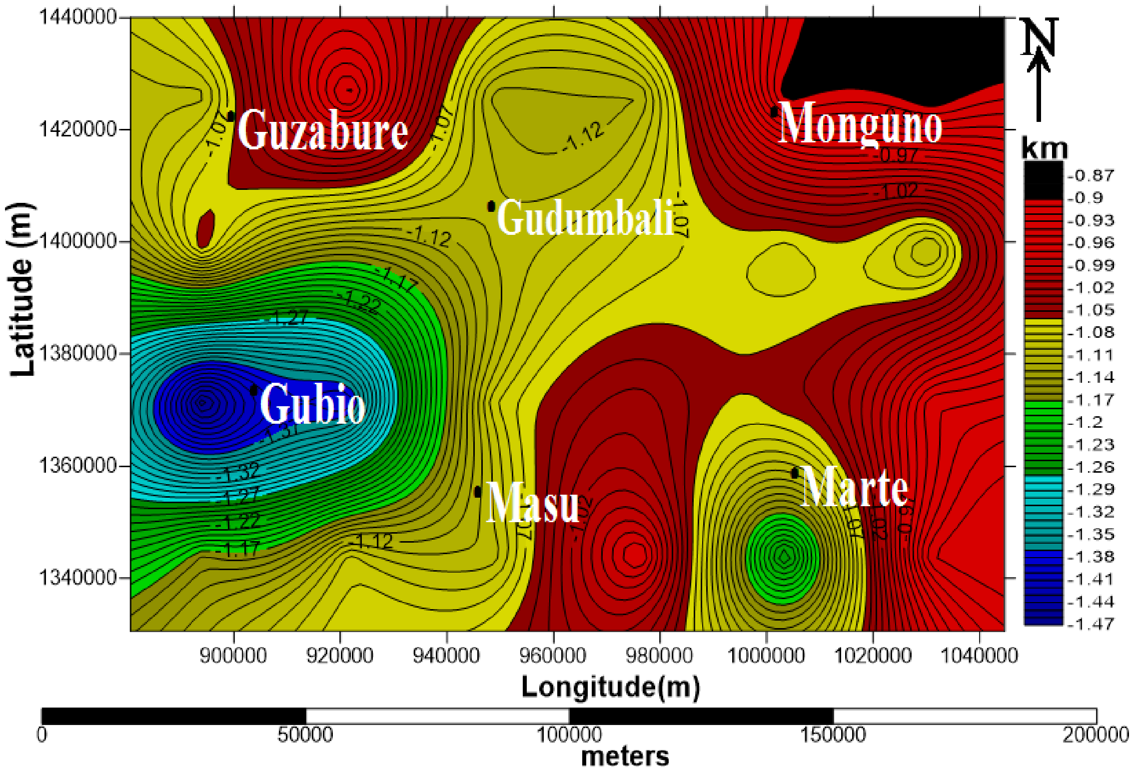

Figure 7: Shallow depth to basement map (contour interval 0.01km).

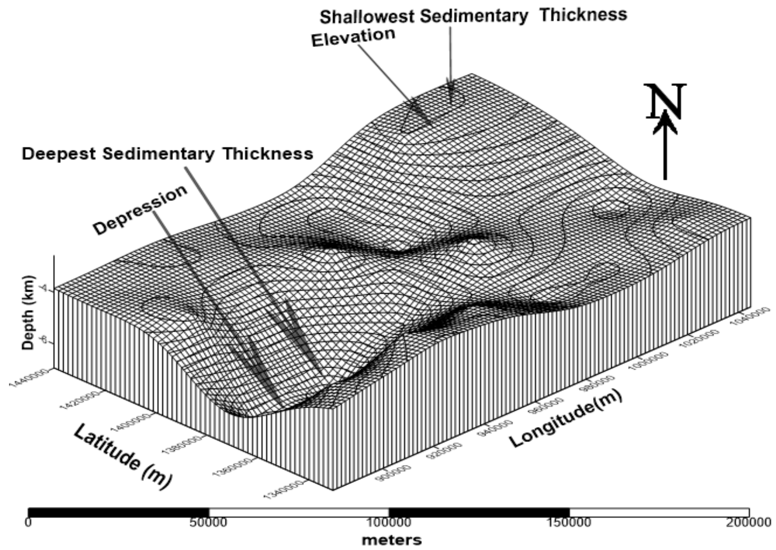

Figure 8: 3D map of the study area showing magnetic basement topography.

V. Discussion Of Results

The total magnetic intensity of the study area shows range of magnetic anomalies which vary from -88.4nT to 238.3nT while the residual magnetic anomaly values are from -169.0nT to 140.5nT. The residual magnetic field was used to bring into focus local features which tend to be obscured by the broad features of the regional field. The areas of strong positive anomalies likely indicate a higher concentration of magnetically susceptible minerals while areas with broad magnetic lows are likely areas of lower susceptibility minerals. Horizontal derivative enhancement technique was applied on the total magnetic intensity field to reveal subtle geophysical features. The horizontal derivative map shows the occurrence of subsurface linear structures which could be the presence of faults in the area; the fault lines are visible on the lineament map . The lineament could be a favourable structure for the control of mineral deposits in the area. This agrees with Awoyemi *et al.* (2016) who investigate the basement fault propagation into the overlying sedimentary cover in parts of the Nigerian sector of Chad Basin. They asserted that faults constitute potential structural traps for oil accumulation or conduit for oil migration.The result from spectral analysis shows that the depth to the magnetically deep sources ranges from 2.5 to 6.9 km with an overall average depth of 4.069km while the depth to the shallow sources ranges from 0.87 to 1.47 km with overall average depth of 1.086 km. This depth is found to be within the range of depths predicted by earlier researchers that worked in Chad Basin. Lawal *et al.* (2007) got a sedimentary thickness range of 2.47 km to 5.40 km from aeromagnetic data of Chad Basin North Eastern Nigeria. The 3D basement topographic map(figure 8) presents irregular nature of the basement which is possibly associated with faults that aid the migration and entrapment of hydrocarbon and other mineralized deposits. The 3D map shows a linear depression with thickest sediments at the south western region of the study area and an elevation with shallowest sediments at the north-eastern part of the study area.The maximum depth obtained from this work show thick sediment that could be feasible for hydrocarbon accumulation which agrees with the work of Wright *et al.* (1985) that the minimum thickness of the sediment required for the commencement of oil formation from marine organic remains would be 2.3 km.

VI. Conclusion

The aeromagnetic data of Guzabure and its environs within the Nigeria Chad Basin have been interpreted qualitatively and quantitatively. The Horizontal derivative map showed the occurrence of subsurface linear structures which suggest the presence of faults in the study area. Spectral analysis was employed in quantitative interpretation with the aim of determining depth/thickness of the sedimentary basin and basement topography,The 3D basement topographic map presents irregular nature of the basement which are possibly associated with faults that aid the migration and entrapment of hydrocarbon and other mineralized deposits. The sedimentary thickness obtained in this work indicate the possibility of hydrocarbon accumulation in the study area.

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