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Spectral analysis on aeromagnetic data to determine sedimentary thickness over part of Bornu Basin, Northeast, Nigeria

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Abstract: *Quantitative interpretations of aeromagnetic anomalies to estimate the thickness of sediments over parts of Bornu Basin of Nigeria have been carried out using spectral analysis so as to identify possible areas of hydrocarbon potential. The study area covers an area of approximately 12,100 km^2 located within latitude 12°0' to 13°0' North and longitude 12°30' to 13°30' East. Aeromagnetic data in grid format containing four sheets were analyzed and interpreted. First order polynomial fitting technique was used to separate the regional anomaly from the total magnetic intensity map to obtain the residual anomaly data that corresponds to the target source for further processing. The residual data was analyzed spectrally to obtain 12 spectral blocks for sedimentary depth estimates (deep and shallow depths). Spectral depth determination method reveals a maximum depth of about 4.5 km around Masu and Gubio areas. Shallow sources also exist around Gazubure and Dububali areas with depths ranging from 0.74 km to about 1.25 km. The 3-D basement topography map of the study area shows linear depression with deepest sedimentary thickness at the southeastern region of the study area, which implies that the feasibility of hydrocarbon potential will be higher in Masu area than in Dububali. The deepest depths obtained from spectral analysis is sufficient for hydrocarbon maturation. Further research using seismic reflection should be carried out in the areas where maximum depths were obtained.*

Keywords: *Aeromagnetic anomaly; spectral analysis; sedimentary thickness; hydrocarbon potentials*

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I. Introduction

Airborne magnetic survey has been employed in delineating geological structures for exploration of mineral and for other geological purposes. This technique investigates the subsurface geology based on the magnetic disturbances in the earth's magnetic field resulting from the magnetic properties of the underlying causal rocks. The shape dimensions, and amplitude of an induced magnetic signature is a function of the orientation, geometry, depth, size, and magnetic susceptibility of the body as well as the intensity and inclination of the earth's magnetic field in the survey area (Biswas, 2016). In many sedimentary basins, anomalies of magnetic fields resulting from secondary mineralization along fault planes, are often imaged on aeromagnetic maps as surface linear features (Raina, 1989; Glenn and Badgery, 1998) For exploration and mining purposes, both ground and aero-magnetic data have been combined with gravity data to map surface geology and investigate ore reserves for some massive ore bodies (Mandal *et al.*, 2013).

The present study focuses on the analysis of a total field aeromagnetic data over parts of Bornu Basin to estimate depth to magnetic basement rock for hydrocarbon maturation. The outcome of this analysis will provide more information on the geophysical and other linear features of the area and add to the geophysical history of the area. The new high resolution aeromagnetic data obtained in the year 2009 were used for this analysis which reveal more structural features that could not be captured using the old data, and so this study throw more light on this peculiarity and further provide base-line information for further studies and correlation. This study is relevant to the national need because it will further provide information (geophysical) through the processed total field aeromagnetic data on the structural styles of the area.

Over recent years, the economy of Nigeria has turned more attention towards searching for earth embedded minerals and hydrocarbon (oil and gas) which has contributed to the greater part of the nation's income whereupon over 200 millions of its growing population relies. Hence the need to exploit the sedimentary basins, particularly the Bornu Basin, an inland basin, presumed to contain high hydrocarbon potential (Anakwuba and Chiwuko, 2012; Salako and Udensi, 2013). The Federal government of Nigeria has directed the Nigerian National Petroleum Corporation (NNPC) to heighten hydrocarbon prospecting in the Northeast (Bornu

Basin), thereby expanding Nigeria's oil and gas hold, boosting the economy of the nation and also creating many new employment opportunities in Nigeria.

Spectral analysis of aeromagnetic data acquired over the area would be used to determine the sedimentary thickness (depth to basement) and hence delineate the basement topography of the study area. The result from the spectral analysis could be used to suggest areas of potential hydrocarbon presence.

Spectral analysis method of basement depth determination has been successfully used by researchers (Okonkwo *et al*., 2012; Adewumi *et al*., 2017; Nwobodo *et al*., 2018), whose results showed that a sedimentary thickness of 3 km and above is sufficient for hydrocarbon maturation.

Location and geology of the study area

The area of study is located between latitude 12 and 13 °N and longitude 12°30' and 13°30' E occupying an estimated area of 12,100 km^2 within parts of the Nigerian sector of the Chad Basin, locally known as the Bornu Basin which is one of the Nigerian inland basins occupying the north-eastern part of the country (Fig. 1). It represents about one-tenth of the total area of the Chad Basin, which is a regional large structural depression common to five countries, namely; Central African Republic, Cameroun, Niger, Chad, and Nigeria (Obaje, 2009). The main structures are basement detached faults and symmetrical folds trending NE-SW, NW-SE and E-W directions (Aderoju, *et al*., 2016). The basin contains marine and continental sediments comprising the Bima Sandstone at the bottom, Fika Shale, Gongila, Kerri-Kerri and Chad Formations. The Chad, Kerri-Kerri and Gombe Formations have an average thickness of 130 to 400 m. Beneath these formations are the Fika shale with an average thickness of 430 m and exhibiting a dark grey to black in colour. Others are Gongila and Bima Formations with average thickness of 320 m and 3,500 m respectively (Odebode, 2010). The Bima Formation unconformably overlies the Precambrian Basement and contains continental sediments varying in age from Albian to Cenomanian. The Gongila Formation represents transitional calcacerous deposits marking the onset of marine incursions into the Bornu Basin. The Fika Formation was assigned the Coniacian to Santonian age. There lies an uncomformity between the Gombe and Kerri-Kerri Formations. The Kerri-Kerri and Chad Formations overlying the Cretaceous formations constitute the Tertiary sediments of the Bornu Basin (Okusun, 1995).

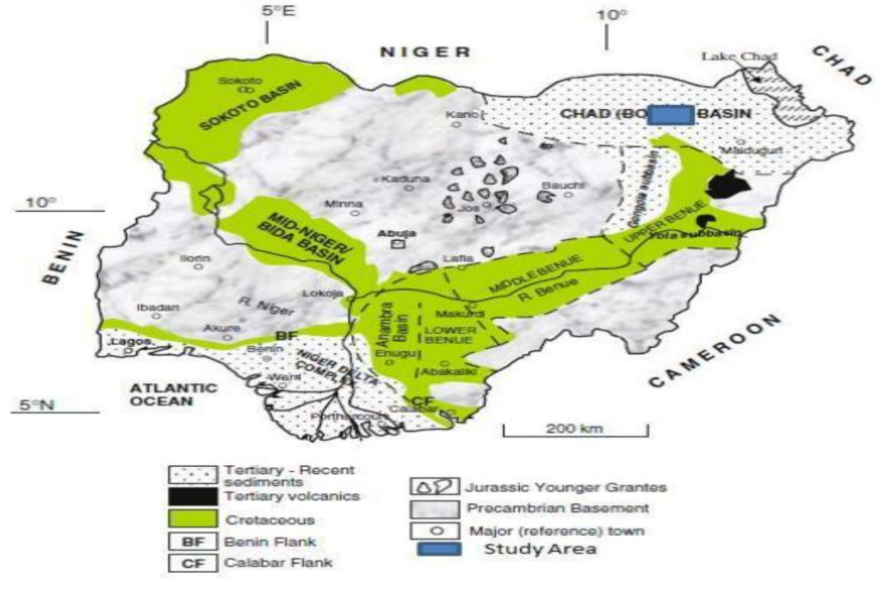

Fig. 1 Geological Map of Nigeria showing the Bornu Basin **(**Adapted from [Obaje, 2009]).

Geologically, the Bornu basin has been described as a sediment-filled broad depression straddling North-eastern Nigeria and adjoining parts of the Republic of Chad. The Borno State where the area of study is located is endowed with rock mineral-based resources such as limestone, clay, kaolin, salt, iron ore, uranium and mica. The sedimentary rocks of the area have a cumulative thickness of over 3.6 km and rocks consisting of thick basal continental sequence overlaid by transitional beds followed by a thick succession of Quaternary Limnic, fluviatile and eolian sand and clays (Odebode, 2010).

II. Materials and Methods

The high resolution aeromagnetic data of Guzabure (sheet 44), Dububali (sheet 45), Gubio (sheet 66) and Masu (sheet 67) used for this study were obtained from the Nigerian Geological Survey Agency (NGSA). Fugro Airborne Surveys Limited carried out the airborne geophysical work in 2009 for NGSA. The data were obtained at an altitude of 100 m along a flight line spacing of 500 m oriented in NW-SE and a tie line spacing of 2000 m in NE-SW direction. The maps are on a scale of 1:100,000 and half-degree sheets contoured mostly at 10 nT intervals. The geomagnetic gradient was removed from the data using the International Geomagnetic Reference Field (IGRF).

Data processing

The four digitized aeromagnetic sheets were merged together using Oasis Montaj to form the study area (Fig. 2). The total magnetic intensity map was contoured and colour-filled to show the high and low total magnetic intensity of the study area. To get the actual magnetic intensity value at a given point, a value of 33,000 nT must be added to the data. First order polynomial fitting was applied on the data set in order to remove the regional anomalies from the total magnetic intensity, to obtain the residual anomaly (Fig. 3). The extracted residual anomaly was used for qualitative interpretation based on visual inspection of the data.

Spectral depth analysis

Spector and Grant (1970) developed a 2-D spectral depth determination method. Their model assumes that an uncorrelated distribution of magnetic sources exists at a number of depth intervals in a geologic column. The Fourier transform of a potential field as a result of prismatic body has a wide spectrum whose upper location is a function of the depth to the up and down surfaces and whose maximum displacement (amplitude) is determined by its density or magnetization (Salako and Udensi, 2013).

The peak wave number (ω) can be related to the geometry of the body according to the following expression:

$$W' = \frac{In(hb/ht)}{hb-ht} \qquad (1)$$

where W' is the peak wave number in radian/ground–unit, ht depth to the top and hb is the depth to the bottom. For a bottomless prism, the spectrum peak at the zero wave number according to the expression:

$$f(\varpi) = e^{-h\varpi} \qquad (2)$$

where ω = angular wave number in radians/ground-unit; h = depth to the top of the prism.
For a prism with up and down surface, the spectrum is:

$$f(\varpi) = e^{-ht\varpi} - e^{-hb\varpi} \qquad (3)$$

where ht and hb are the depths to top and bottom surface respectively. The log spectrum of this data can be used to determine the depth to the top of a statistical ensemble of sources using the relationship:

$$Log\ E(k) = 4\pi h\mathrm{k} \qquad (4)$$

where h=depth in ground–units, and k=wavenumber in cycles/ground–unit. Dividing the slope of the energy (power) spectrum by 4π gives the depth of an 'ensemble'; a deep source depth, a shallow source depth and a noise component.

III. Results and Analysis

The Total Magnetic Intensity (TMI) map (Figure 2) of the study area consists of both the regional anomaly (from deep magnetic bodies) and the residual anomaly (from shallow magnetic sources). The total magnetic intensity map (TMI) map is produced in different colours, with green to blue colour depicting low magnetic anomalies while red to pink colour depicts low anomalies. The total magnetic intensity map of the study area exhibits both high and low anomalies ranging from -70.4 to 228.1 nT.

The separation of the regional anomaly from the TMI anomaly to obtain the residual anomaly was carried out using polynomial fitting of order one. The residual field data corresponds to the target source for further processing. The residual map (Figure 3) shows high and low magnetic field values ranging from -77.6 to 65.6 nT.

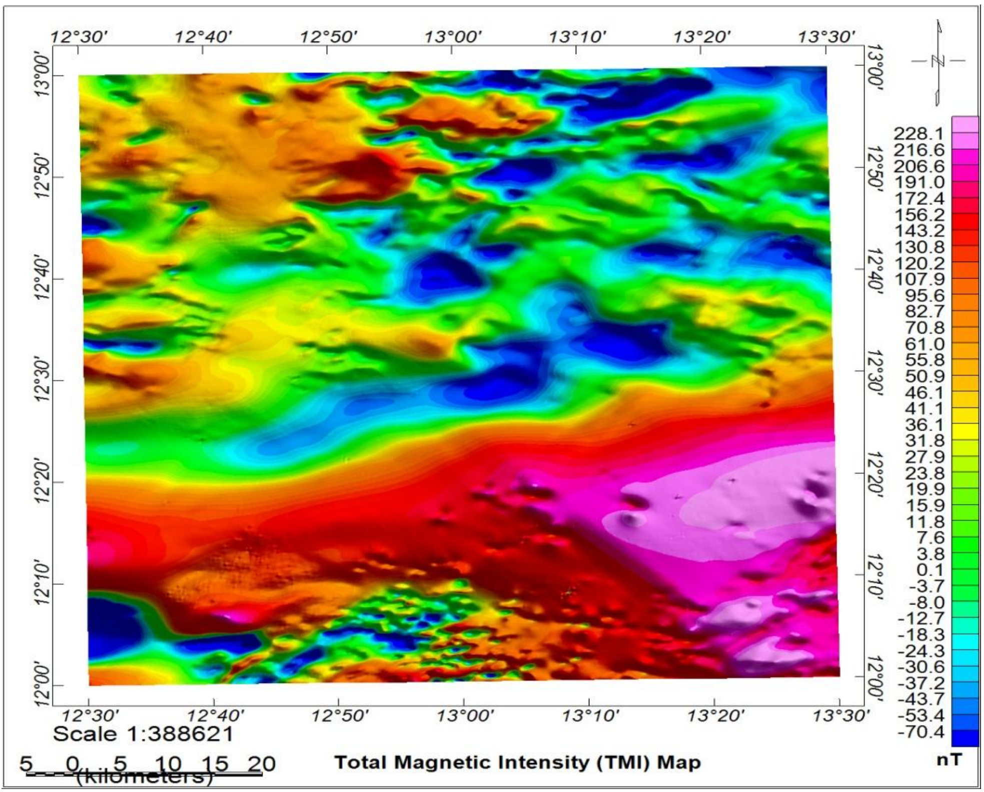

Fig. 2 Total Magnetic Intensity (TMI) map of the study area.

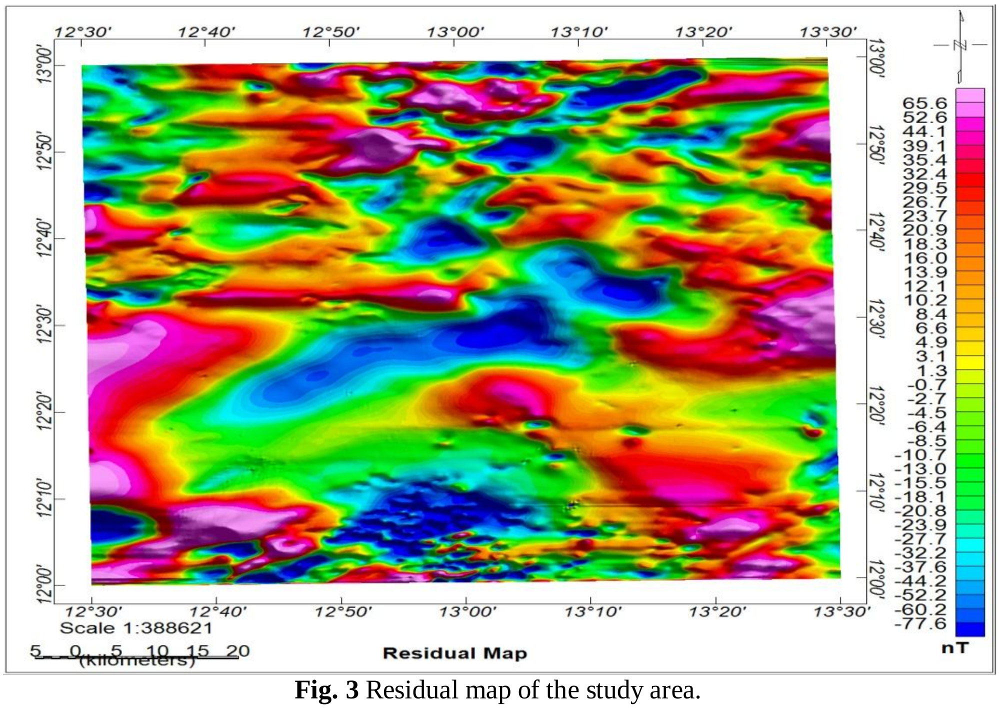

Fig. 3 Residual map of the study area.

The residual anomaly map was divided into twelve (12) overlapping magnetic sections or blocks (A-P) using an algorithm in Oasis Montaj (Figure 4). Each profile covers a square area of 65 km by 65 km in order to accommodate longer wavelengths. Spector and Grant (1970) has shown that the Log-energy spectrum of the source have a linear gradient whose magnitude is dependent upon the depth of the source. A Matlab program was used to obtain the graph of energy against frequency in cycle/km of the twelve blocks (A-L). The slope of each of the line segments for the twelve spectral blocks were first evaluated. The average depth of buried ensemble was also calculated. The coordinates and the two depth estimates (deep depth) and (shallow depth) for each of the twelve spectral blocks were then determined.

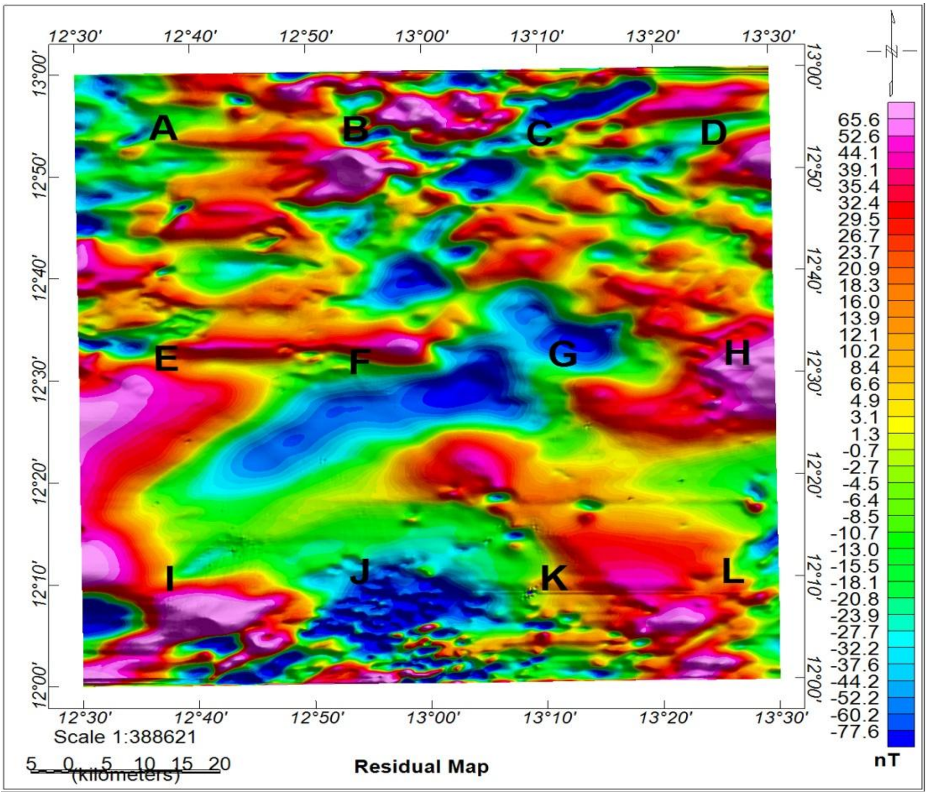

Fig. 4 Residual map of the study area showing spectral blocks.

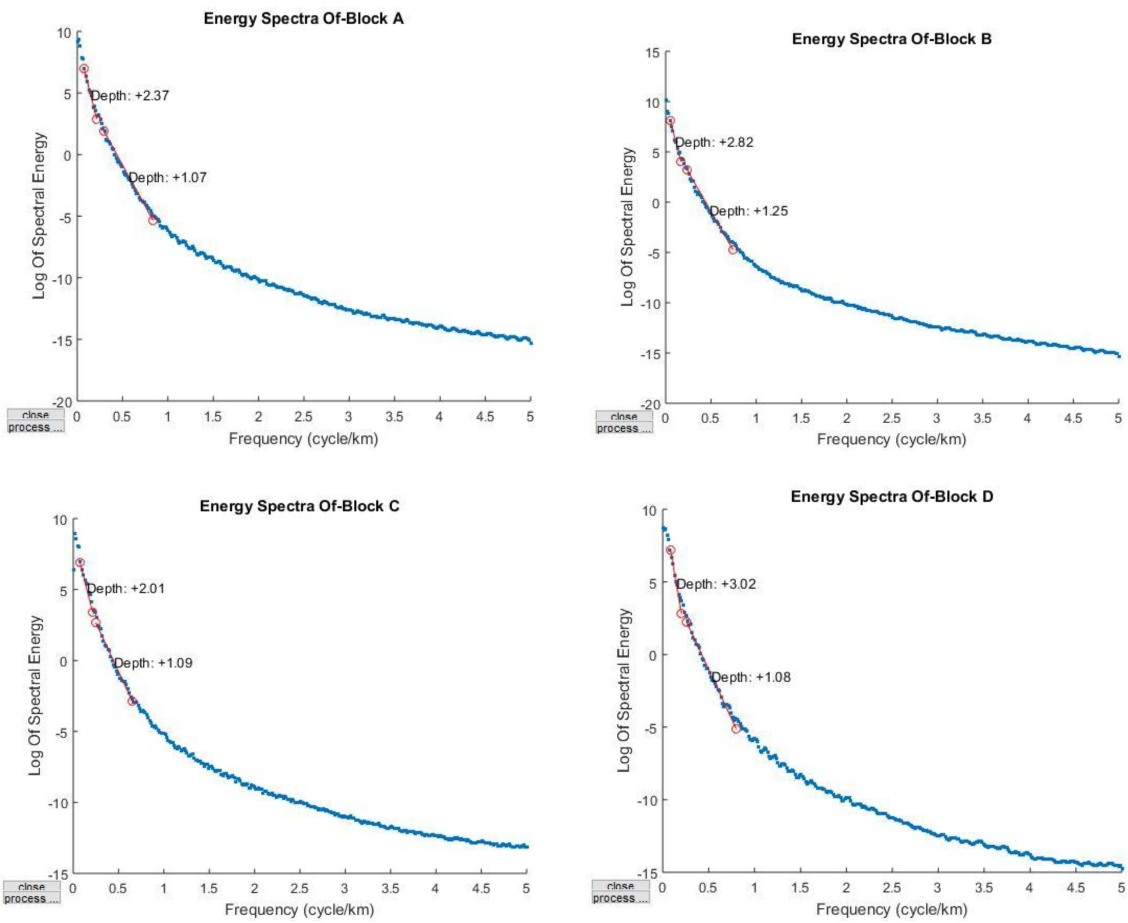

Fig. 5 Typical plots of energy spectrum against frequency (Section A-D).

Table 1 Summary of estimates of depth to maximum and minimum magnetic sources

Block	Long. (Deg.)	Lat. (Deg.)	Z_1 (Km)	Z_2(Km)
A	12.75	12.75	2.27	1.07
B	12.92	12.75	2.82	1.25
C	13.08	12.75	2.01	1.09
D	13.25	12.75	3.02	1.08
E	12.75	12.58	3.11	0.99
F	12.92	12.58	3.96	1.23
G	13.08	12.58	4.7	1.2
H	13.25	12.58	4.54	1.01
I	12.75	12.25	3.13	0.78
J	12.92	12.25	2.88	0.79
K	13.08	12.25	4.58	0.74
L	13.25	12.25	2.77	0.84
Av. Depth			3.32	1.01

IV. Discussion of Results

The TMI anomaly varies from -70.4 to 228.1 nT while the residual anomaly varies between -77.6 and 65.6 nT. From the TMI and residual maps, the maximum and minimum magnetic intensity values shows variations in the study area and marked by both low and high magnetic signatures. Such variations may be attributed to factors like; magnetic susceptibility, depth, difference in lithology and degree of strike.

The lower portion of the area is predominantly of high anomaly while the upper part is dominated by low magnetic anomalies. Short wavelength anomalies with high frequency of occurrence are observed to dominate the North-eastern corner. Major anomalous structures observed on the map exhibit E-W trends. The presence of magnetic bodies in the area of study is revealed by the elliptically closed contours on the map(Figure 6).

The residual map produced from this study was divided into twelve (12) cells (A-L) of overlapping magnetic sections. Energy spectrum of each section was plotted against frequency wave number) with a Matlab program designed to estimate the deep and shallow magnetic source depth using the following equation:

$$Z_1 = -\frac{m_1}{4\pi} \quad (5a)$$

$$Z_2 = -\frac{m_2}{4\pi} \quad (5b)$$

where m_1 and m_2 are gradients (slopes) of the first and second line segment of the plot, and Z_1 and Z_2 are first and second depths respectively.

A summary of the result of the estimates of the depth to basement for the deep (Z_1) and shallow (Z_2) depths are presented in Table 1. Four representative plots of log of spectral energy versus frequency for the twelve spectral blocks are shown in Figure 5. The deep magnetic sources vary from 2.01 to 4.7 km in the study area, with an average depth of 3.32 km. While the shallow magnetic sources vary from 0.74 to 1.25km, having an average depth of 1.01 km. The deepest basement depths were found at the southeastern part of the study area which corresponds to Masu Town. The computed depths to basement were used to construct the 3D surface map for the basement topography of the area (Figure 7). The 3D surface map shows a linear depression with deepest sedimentary thickness at the southeastern part (Masu area) of the study area.

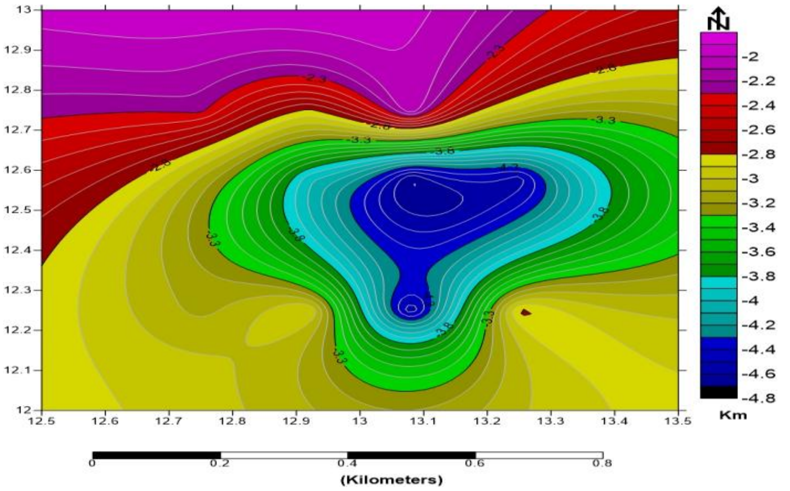

Fig. 6 2D spectral magnetic depth to basement contour map of the study area (contour interval 0.1).

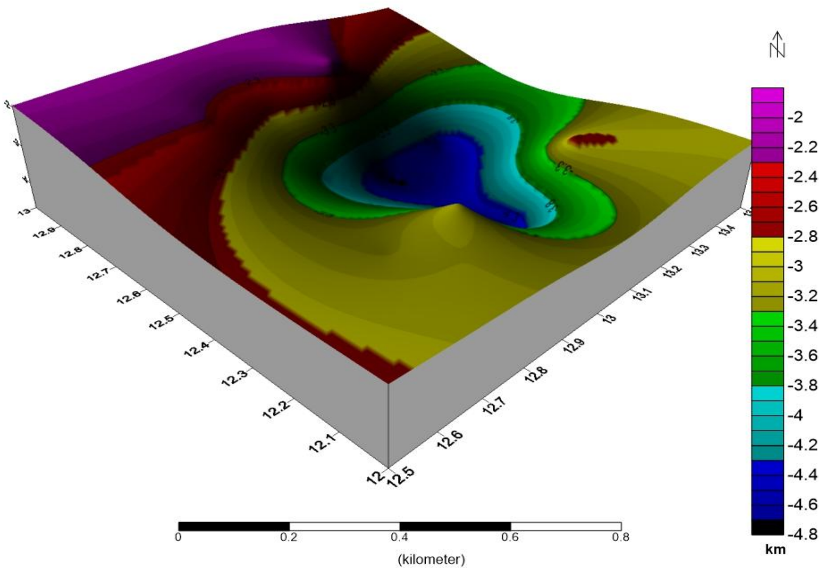

Fig. 7 3D surface map of magnetic depth to top of basement of the study area from spectral depths.

V. Conclusion

The aeromagnetic data of Guzabure, Dububali, Gubio and Masu areas have been interpreted quantitatively. The 2D residual anomaly map revealed that the area is magnetically heterogeneous. The irregular pattern of the basin suggests areas with faults which can aid in mineral entrapment and accumulation. The results of spectral analysis show clearly the variation along profiles in the surface of magnetic basement across the study area. Based on the average sedimentary thickness of 3.3 km, there is possibility of hydrocarbon presence in the study area. Further research using seismic data is suggested.

References

[1]. Adewumi, T., Salako, K. A, Salami, M. K., Mohammed, M. A., Udensi, E. E. (2017). Sedimentary Thickness using Spectral analysis of Aermagnetic data over part of Bornu Basin, Northeast, Nigeria. *Asian Journal of Physical and Chemical Science* 2(1):1-8.

[2]. Aderoju, A. B., S. B. Ojo, A. A. Adepelumi, and F. Edino (2016). A reassessment of hydrocarbon prospectivity of the Chad Basin, Nigeria, using magnetic hydrocarbon indicators from high resolution aeromagnetic imaging, *Ife J. of Sci.*, 8(2), 503-520.

[3]. Anakwuba, E., and A. Chinwuko (2012). Re-evaluation of hydrocarbon potentials of Eastern Part of the Chad 13 Aeromagnetic data for hydrocarbon exploration Figure 10. Sedimentary basin thickness map showing region with thick sediment delineated for further exploration. Basin, Nigeria: An aeromagnetic approach. Extended abstract prepared in conjunction with poster presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012.

[4]. Biswas, A. (2016). Interpretation of gravity and magnetic anomaly over thin sheet-type structure using very fast simulated annealing global optimization technique. *Model. Earth Syst. Environ.* 2(1):30.

[5]. Glenn, W.E. and Badgery, R.A. (1998): High resolution aeromagnetic surveys for hydrocarbon exploration: prospect scale interpretation. *Canadian journal of exploration geophysics*, 34(1), 97-102.
[6]. Mandal, A., Biswas, A., Mittal, S., Mohanty, W. K., Sharma, S. P., Sengupta, D., Sen, J., Bhatt, A.K. (2013). Geophysical anomalies associated with uranium mineralization from Beldih mine, South Purulia Shear Zone, India. *J. Geol. Soc. India* 82(6):601-606.
[7]. Nwobodo, T., Ezema, P., Ugwu, G. (2018). Determination of Magnetic Basement Depth over Guzabure and Its Environs Chad Basin, North Eastern Nigeria. *IOSR Journal of Applied Physics*. 10. 10.9790/4861-1001022330.
[8]. Obaje, N. G. (2009). Geology and mineral of Nigeria (Germany: Springer Verlag);2009.
[9]. Odebode, M. O. (2010). A handout on geology of Bornu (Chad) Basin, Northeastern Nigeria.
[10]. Okonkwo, C. C., Onwuemesi, A. G., Anakwuba, E. K., Chinwuko, A. I., Ikumbur, B. E., Usman, A. O. (2012). Aeromagnetic interpretation over Maiduguri and environs of Southern Chad Basin, Nigeria. *Journal of Earth Sciences and Geotechnical Engineering* 2(3):77-93.
[11]. Okosun, E. A. (1995).Review of Geology of Bornu Basin. Journal of Mining and Geology, 31, 113-122.
[12]. Raina, B. (1989): Landsat exploration of Hilmalayan and peninsular regions. Remote sensing and mineral exploration pergamon press, Newyork, 10(2), 66.
[13]. Salako, K. A, Udensi, E. E. (2013). Spectral Depth Analysis of part of upper Benue Trough and Bornu Basin, Northeast Nigeria, using Aeromagnetic data. International Journal of Science and Research 2(8).
[14]. Spector, A., Grant, F. S. (1970). Statistical models for interpreting aeromagnetic data. Geophysics 35:293-302.

Gladman Goteh Bright, et. al. “Spectral analysis on aeromagnetic data to determine sedimentary thickness over part of Bornu Basin, Northeast, Nigeria.” *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 9(4), (2021): pp 45-52.