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Spectral Analysis of Aeromagnetic Data over Part of the Southern Bida basin, West-Central Nigeria

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ABSTRACT

Qualitative and quantitative interpretations of aeromagnetic map over part of the Southern Bida Basin, West-Central Nigeria have carried out using spectral analysis. The aeromagnetic maps digitized along flight lines of 2km interval. The qualitative interpretation of the magnetic anomaly and first vertical derivative maps revealed that the area is intensely faulted with major faults trending East-West (E-W) and minor ones Northeast-Southwest (NE-SW) directions. The result obtained using the spectral method reveals two depth sources in the area, the deeper sources range from 2.81 to 3.24km, while the shallower sources range from 0.45 to 1.49km.The result also shows a linear depression with sedimentary accumulation trending E-W. The average sedimentary thickness in the region is about 2.90km.

Keywords: Aeromagnetic data, basement topography, depths to basement, linear trend surface, Bida Basin,Spectral Analysis
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INTRODUCTION

The aim of a magnetic survey is to investigate the subsurface geology based on magnetic anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks. The aeromagnetic survey has applied in mapping the magnetic anomalies in the earth's magnetic field and correlated with the underground geological structure (Anakwuba, Onwuemesi, Chinwuko, & Onuba, 2011). In addition, aeromagnetic surveys traditionally applied at the early stage of petroleum exploration to determine depth and structure of crystalline basement rocks underlying sedimentary basins (Abdulsalam, Mallam, & Ologe). Previous studies on spectral analysis of aeromagnetic data carried out in other parts of Nigeria. Such works include that of (Onwuemesi, 1997) who applied 1D spectral analysis to aeromagnetic anomalies in the Anambra basin, (Anakwuba et al., 2011) used spectral methods to interpret aeromagnetic anomalies over Maiduguri-Dikwa depression of Chad basin. (Chinwuko, Onwuemesi, Anakwuba, Onuba, & Nwokeabia, 2012) also applied spectral analysis to evaluate aeromagnetic anomalies over parts of Upper Benue Trough / Southern Chad basin, Nigeria. The present study involves the spectral analysis of aeromagnetic data over part of the Southern Bida basin, West-Central Nigeria. The spectral method has an advantage over other geophysical methods because it has the ability to filter all the noise away from the data, information is not lost during the process, and in many cases, operations are easier to perform in the transform domain(Telford, Geldart, & Sheriff, 1990). The application of spectral analysis to the interpretation of potential field data is a method that can be us to determine the basement depth, and is now sufficiently well established(Spector & Grant, 1970). The procedures involved in this study include digitization of the aeromagnetic maps, separation of magnetic data and production of magnetic anomaly map, production of the first vertical derivative of the total field and analysis of magnetic anomaly data amongst others. The objectives of this study are to determine depths to basement (sedimentary thickness) and model the magnetic anomalies found in the area. The study further attempts the delineation of the basement topography and structural features such as faults within the study area.

LOCATION AND GEOLOGY

The area of study is the southern part of Bida basin and bounded by latitudes $08^0 00'$N, $06^0 00'$E and $09^0 00'$N, $07^0 00'$E. It is an area of about 12,000 km^2 situated at the West-Central Nigeria (Fig.1).The Bida Basin (also known as the Nupe Basin or the Middle Niger Basin) is an elongated NW-SE trending depression perpendicular to the main axis of the Benue Trough of Nigeria. The entire basin is bounded by latitudes and longitudes $08^{o}00'$N, $04^{0}30$E and $10^{0}30'$N, $07^{0}30'$E. It covers an area of about 90,760 km^2. The basin is a gentle down-warped shallow trough filled with Campanian-Maastrichtian marine to fluviatle strata believed to be more than 300m thick (Adeleye, 1976; Jones, 1955). The Basin might be regarded as north-western extension of Anambra basin, which is found in the southeast, both of which were major depocenters during the second major sedimentary cycle of southern Nigeria in the Upper Cretaceous time (N. G. Obaje, 2009). The original rock of the area, subjected to considerable erosion before the Upper Cretaceous beds have laid down. The sandstones consist of unfossiliferous shallow water sandstones and beds. It is possible that these sandstones could have covered a large area (continuous to the Sokoto Basin) than now (Russ & Russ, 1957). Both surface and subsurface information available is suggestive of Post-Santonian origin as sediments in Bida basin are generally undisturbed (Agyingi, 1991). Maximum sedimentary thickness of up to 3.30km recorded in the basin from aeromagnetic interpretation (Agyingi, 1991). The geological map of the southern part of Bida basin shown in Fig.1 consists of Lokoja, Patti and Agbaja Formations. According to (Akande, Ojo, & Ladipo, 2005), the Patti Formation, which is the only stratigraphic unit containing carbonaceous shale in the Bida basin is sandwiched between the order Campanian-Maastrichtian Lokoja Formation (conglomerates, sandstones and claystones) and younger Agbaja Formation, which is mainly ironstones.

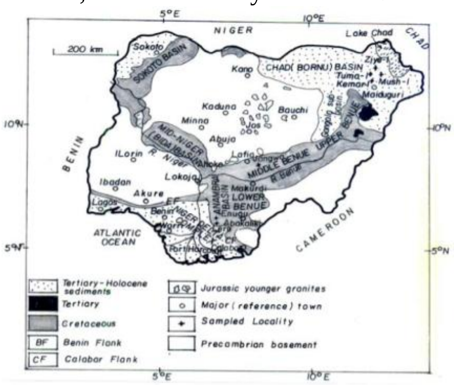

Fig.1 Geologic map of Nigeria showing the study area within Bida Basin (N. Obaje, Wehner, Scheeder, Abubakar, & Jauro, 2004)

MATERIALS AND METHODS

Four digitized aeromagnetic maps (sheets 205, 206, 226 and 227) acquired, assembled and interpreted. These maps obtained as part of the nationwide aeromagnetic survey sponsored by the Geological Survey Agency of Nigeria. The data were acquired along a series of NW-SE flight with a spacing of 2km and an average flight elevation of about 150m while tie lines occur at about 20km interval. The geomagnetic gradient removed from the data using the International Geomagnetic Reference Field (IGRF). The data made in form of contoured maps on a scale of 1:100,000. The area covered was about 12,100km^2. The first step in the present study was to assemble the four maps covering the survey area. The next was to re-contour the map using contouring software (Surfer Version 32) in order to produce the total field aeromagnetic intensity map (Fig.2) which contains both the regional and residual anomaly. The regional gradient removed from the map by fitting a linear surface to the digitized aeromagnetic data using a multiple regression technique. The surface linear equation on the data selected according to Likkason (1993) as;

$$p(x,y) = ax + by + c \quad (1)$$

Where, a, b and c are constants; x and y are distances in x and y axes; $p(x,y)$ is the magnetic value at x and y co-ordinates. The Least squares method of statistical analysis was used to obtain the constants (a, b and c) and the trend surface equation (regional gradient) becomes;

$$p(x,y) = 1.8013x - 0.4575y + 7989.78 \quad (2)$$

The trend surface equation (Eq.2) subtracted from the aeromagnetic (observed) data and the resultant residual aeromagnetic anomaly data obtained and contoured (Fig.3).

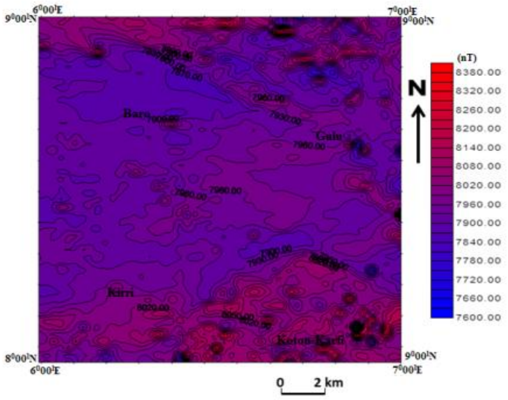

Fig.2 Total Magnetic Intensity Map of the Study Area (Contour interval ≈ 30nT)

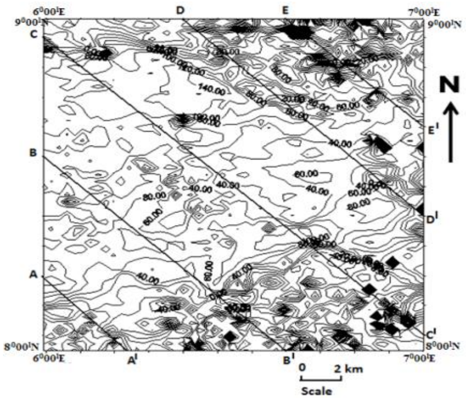

Fig.3 Residual Anomaly Map of the Study Area with Profile lines (Contour interval ≈ 30nT)

In order to estimate depths to basement (sedimentary thicknesses) across the study area using spectral methods, five profiles taken cutting across anomalous features for the interpretation of the geophysical anomalies in the area under study (Fig.3). The anomalies identified on these profiles subjected to the spectral analysis. The Discrete Fourier Transform is the mathematical tool for spectral analysis and applied to regularly spaced data such as the aeromagnetic data. The Fourier Transform represented mathematically in (Onwuemesi, 1997) as:

$$Y_{i(x)} = \sum_{n=1}^{N}\left[a_n \cos\left(\frac{2\pi n x_i}{L}\right) + b_n \sin\left(\frac{2\pi n x_i}{L}\right)\right] \quad (3)$$

Where $Y_i(x)$ is reading at x_i position, L is length of the cross-section of the anomaly, n is harmonic number of the partial wave N, number of data points, a_n real part of the amplitude spectrum and b_n is imaginary part of the amplitude spectrum; for $(i = 0, 1, 2, 3, \dots, n)$. Graphs of the natural logarithms of the amplitude (A_n) against frequency (n) plotted and the linear segments from the low frequency portion of the spectral drawn from the graphs. The gradient of the linear segments were computed and the depths to the basement were determined using the equation according to(Negi, Agrawal, & Rao, 1983), given as;

$$Z = -ML/2\pi \qquad (4)$$

Here Z is depth to the basement, M gradient of the linear segment and L defined as length of the cross-section of the anomaly.

RESULT AND DISCUSSION

The qualitative interpretation has done by visual inspection of the total magnetic intensity, residual magnetic anomaly, first vertical derivative and magnetic lineament maps. The total magnetic field is from 7600 to 8380 nanotesla (nT). Higher values found in the northern and southern parts, and lower values in the central region (Fig.2). The closely spaced linear sub-parallel orientation of contours in the northern and southern parts of the study area suggests that faults or local fractured zones may possibly pass through these areas (Fig.2 -3). Most of the anomalous features trend in the East-West direction, while minor ones trend Northeast-Southwest. (Chinwuko et al., 2012) generally believed there would always be a magnetic susceptibility contrast across a fracture zone due to oxidation of magnetite to hematite, and/ or infilling of fracture planes by dyke-like bodies whose magnetic susceptibilities are different from those of their host rocks. Such geologic features may appear as thin elliptical closures or nosing on an aeromagnetic map. The elliptical contour closures seen in the study area suggest the presence of magnetic bodies. These features represent geologic lineaments and their positions indicated by lines drawn parallel to the elongation and through the centre of the anomalies (Fig.4). The main trend of the lineaments is East-West, while few trend Northeast-Southwest. Also, the aeromagnetic map over the study (Figs. 2 and 3) area shows that the contour lines are widely spaced in the central part which shows thicker sediments in the region indicating that the depth to basement is higher compared to the closely spaced contours in the northern and southern parts which suggest shallow sedimentary thickness. The first vertical derivative map (Fig.5) shows areas of higher intensity (high signal) in the north and south of the study area, while the central region has lower intensity (low signal). In addition, the residual anomaly map (Fig.3) shows positive magnetic anomaly and larger sedimentary thickness indicating deeper depths at the central region, while the northern and southern portions show negative anomaly with smaller sediment thickness indicating shallower depths. In the south-eastern part of the study area (Koton-Karfi), there is a dome-shaped linear feature. The general indication is that this linear feature is of intermediate depth and seems to hosted in the basement structure and is thought to be a major divide (fault or fracture) making a boundary (Abdulsalam et al.). Several contour closures found south of this lineament, which indicate shallow basement. This may be due to this fact that the Niger-Benue River confluence is an uplifted area, similar to a model earlier proposed by (Wright, 1976) and (Abdulsalam et al.).

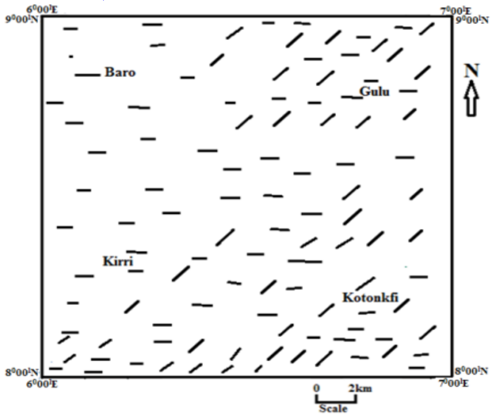

Fig.4 Magnetic Lineament map of the study area

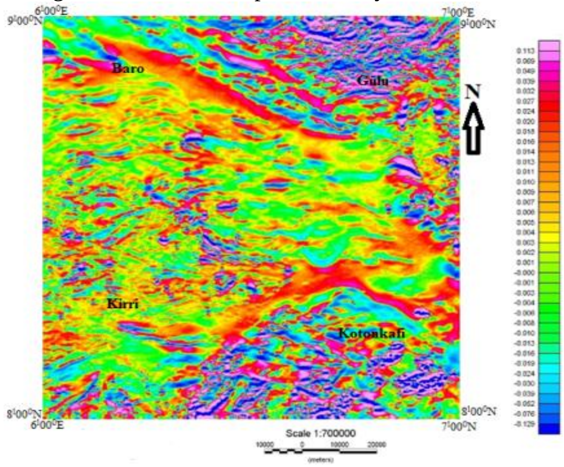

Fig.5 First Vertical Derivative Map of the Study Area

The natural logarithms graphs of the amplitude against frequencies for the selected profiles obtained (Fig.6). The gradient of the graph computed and used to estimate the depth to magnetic sources.

Table.1 Basement Depths obtained from Spectral Analysis

Profile name	Profile direction	Anomaly	Depth
A-A Along Kirri	NW-SE	1	0.45
	NW-SE	2	0.88
	NW-SE	3	1.31
	NW-SE	4	0.45
B-B (Kirri-kotonkarfi)	NW-SE	5	1.08
	NW-SE	6	0.9
C-C (Baro Kirri & Kotonkarfi)	NW-SE	7	3.07
	NW-SE	8	2.81
	NW-SE	9	3.24
D-D (Baro & Gulu	NW-SE	10	2.82
	NW-SE	11	0.62
	NW-SE	12	1.49
	NW-SE	13	0.67
E-E (Gulu)	NW-SE	14	0.56
	NW-SE	15	0.76
	NW-SE	16	1.1

The depths to magnetic sources range from 0.45 to 3.24km (Table 1). Geological model of sections, generated for the profiles (see Fig.7). Profile A-A[1] passes through the south-western part of the study area. The maximum magnetic value along the profile is 100nT and the minimum is - 40nT. The depth values along this profile range from 0.45km to 1.31km while Profile D-D[l] passes through the northern part of Baro and the southern part of Gulu respectively. The magnetic intensity in this area is very high as shown in the curve. The maximum magnetic intensity value along the profile is 125nT, while the minimum is – 22nT. The depth values range from 0.62km to 2.82km.

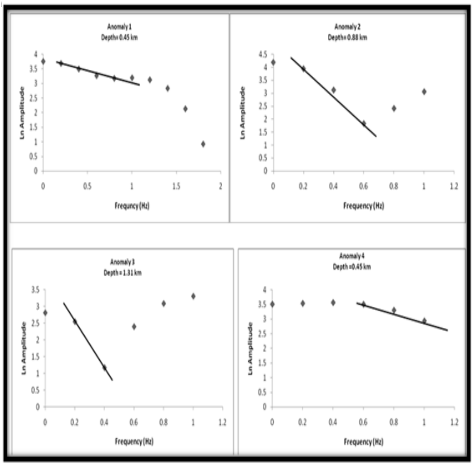

Fig.6 Representative of Amplitude spectral for various anomalies within the study area

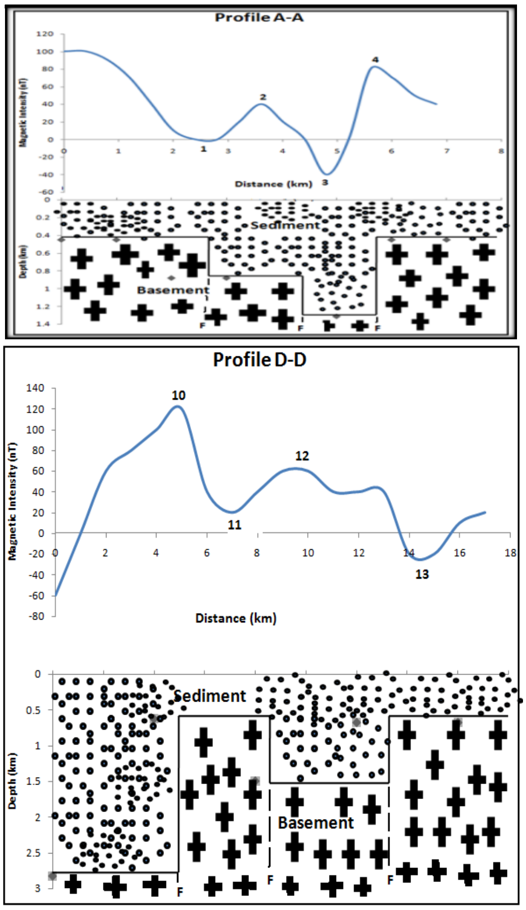

Fig.7 Representative of Geologic modelling of anomalies along various Profiles

The computed depths to basement used to construct both the basement map and 3-D surface map for the basement topography of the area (Figs. 8 and 9). The two maps show that the depth to basement is deeper in the central region and shallower in the northern and southern parts of the study area. The 3-D surface map (Fig.9) also shows a linear depression with thicker sediments at the central region of the study area trending E-W direction. Based on the sedimentary thicknesses (0.45-3.24km) obtained from this study and the geochemical analysis carried out in the area by (N. Obaje, Musa, Odoma, & Hamza, 2011) and (N. G. Obaje, 2009) indicates that the possibility of hydrocarbon generation in the central part of the study area is feasible.

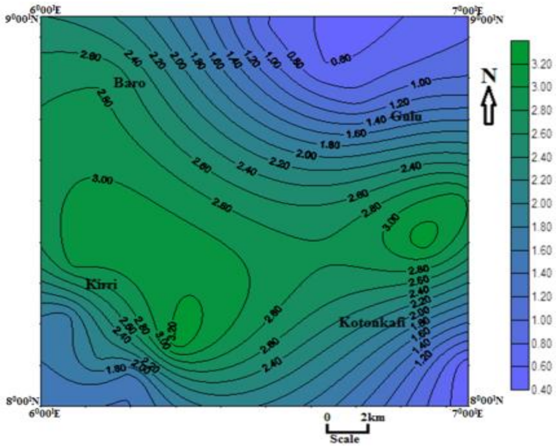

Fig.8 Depth to basement map of the study area

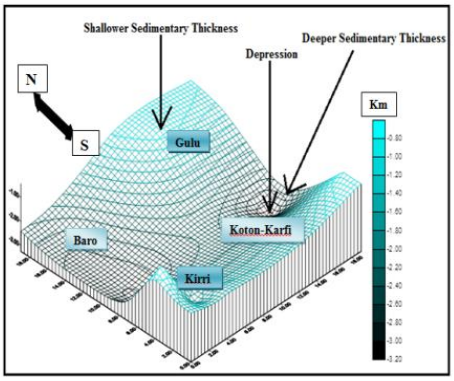

Fig.9 3D Surface Plot for the basement topography of the study area

CONCLUSION

The aeromagnetic anomaly data over part of the Southern Bida basin, West-central Nigeria was subjected to both map and profile analysis using Discrete Fourier Transform method. The procedure involved in this study includes separation of the magnetic data, production of the residual anomaly map, and estimation of depths to magnetic sources and modelling of the anomalies. The results reveal two depth source models in the study area. The deeper sources range from 2.81 to 3.24km, while the shallower sources range from 0.45 to 1.81km. The deeper magnetic sources identified with the crystalline basement, while the shallower magnetic sources could be associated to near surface magnetic sources, which may be magnetic rocks that intruded into the sedimentary formations or magnetic bodies within the sedimentary cover. The results also show a linear depression with thicker sediment accumulation trending E-W.

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