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ANALYSIS OF HIGH RESOLUTION AEROMAGNETIC DATA OF SOME PARTS OF BENUE TROUGH, NIGERIA

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ABSTRACT

This work is aimed to determine the depth to basement of magnetic sources in the study area. Four aeromagnetic sheets were acquired from the Nigerian Geological Survey Agency which includes (sheet 131,132,152 and 153). The study area covers an estimated area of about 12100 km^2 between latitude 9^0N-11^0N and longitude 11^0E-13^0E. The total magnetic field of the study area have been evaluated. In order to determine the basement depth, spectral analysis technique was applied. Detailed analysis of the aeromagnetic data for the study area was performed. The procedure involved in the analysis include reduction to equator to remove the effect of inclination, contouring of the total magnetic intensity, separation of the regional and residual anomalies using polynomial fitting of first order, qualitative interpretation and quantitative interpretation. The residual field of the study area composes of low magnetic anomalies reaching a minimum value of -158.6 nT as observed in the northern and southern parts and high magnetic anomalies reaching a maximum value of 178.1 nT as observed in the western part of the study area. The result from the spectral analysis for each block shows that the depths to the magnetic source are 5.20 km for block 1, 5.74 km for block 2, 7.59 km for block 3 and 3.56 km for block 4. The average depth to magnetic source in the study area was found to be 5.52 km. From an economic view point, the depth obtained in the study area show the possibility of mineralization in the area.

Keywords: Aeromagnetic data, Basement, Magnetic source, Spectral analysis

INTRODUCTION

Aeromagnetic survey is a kind of geophysical prospecting which makes use of airborne geophysical surveying instruments installed in an aircraft at a certain flight height range to acquire magnetic field strength from the subsurface. The main purpose of the aeromagnetic survey is to detect minerals and rocks that have unusual magnetic properties which reveal them by causing anomalies in the earth magnetic field (USGS, 1997). Aeromagnetic survey is one of the most important tools used in modern geological mapping, determining depth and structure of crystalline basements rock underlying sedimentary basin (Onuba et al., 2012; Ikumbur et al., 2019). Previous studies were carried out in the study area in order to determine the basement depth. Such works includes that of Olawale and Yusuf (2019) who applied Euler Deconvolution for basement configuration and lineament mapping from aeromagnetic data of Gongola arm of upper Benue trough, North-eastern Nigeria. The result obtained by Olawale and Yusuf shows that the basement depth in the study area is 5 km below the surface; Muhammad et al., (2014) applied Stanley method to evaluate magnetic basement depth over Bajoga and environs. The result from the analysis using Stanley method shows that the depth of 2.4 km, 2.23 km, 0.9 km and 1.6 km for profile AA',BB',CC' and DD' respectively; While Abubakar et al., (2010) applied spectral analysis for the evaluation of Gongola Basin upper Benue trough, North-eastern Nigeria. The result from the analysis shows that the first layer depth has an average of 1.19 km; the second layer depth has an average depth of 3.16 km and the third layer depth with an average depth of 5.39 km. The present study involves reduction to equator of the high resolution aeromagnetic data in order to determine the approximate depth to the basement in the study area.

Location and Geology of the Study Area

The study area is located at Latitude 10°N-11°N and Longitude 11°E-12°E. The areas are Bajoga (Sheet 131); Gulani (Sheet 132); Gombe (Sheet 152) and Wuyo (Sheet 153), and it falls within the Upper Benue Trough (Fig. 1). The trough is filled with sediment whose ages range from middle Albian to Maestrichtian and whose thickness generally decreases from the lower and middle Benue to the upper Benue region (Charles, 1985; Abraham et al., 2019; Ayuba and Ahmed, 2019). The basement complex within the study area includes;

The Migmatites – Gneiss Complex which is generally considered as the basement complex (Rahaman, 1988), and it is the most widespread of the component units in the Nigerian basement. It has a heterogeneous assemblage comprising migmatites, orthogenesis, paragneisses, and a series of basic and ultra basic metamorphosed rocks. The Schist Belts comprise low grade, Meta sediment-dominated belts trending N–S which are best developed in the western part of Nigeria (Onwuemesi, 1997; Mukaila et al., 2019; Alabi et al., 2019; Akusika et al., 2020). These belts are considered to be Upper Proterozoic supra crustal rocks which have been infolded into the migmatites-gneiss-quartzite complex. The term "Older Granite" was introduced to distinguish the deep-seated, often concordant or semi-concordant granites of the Basement Complex from the high-level, highly discordant tin-bearing granites of Northern Nigeria (Petters, 1982).

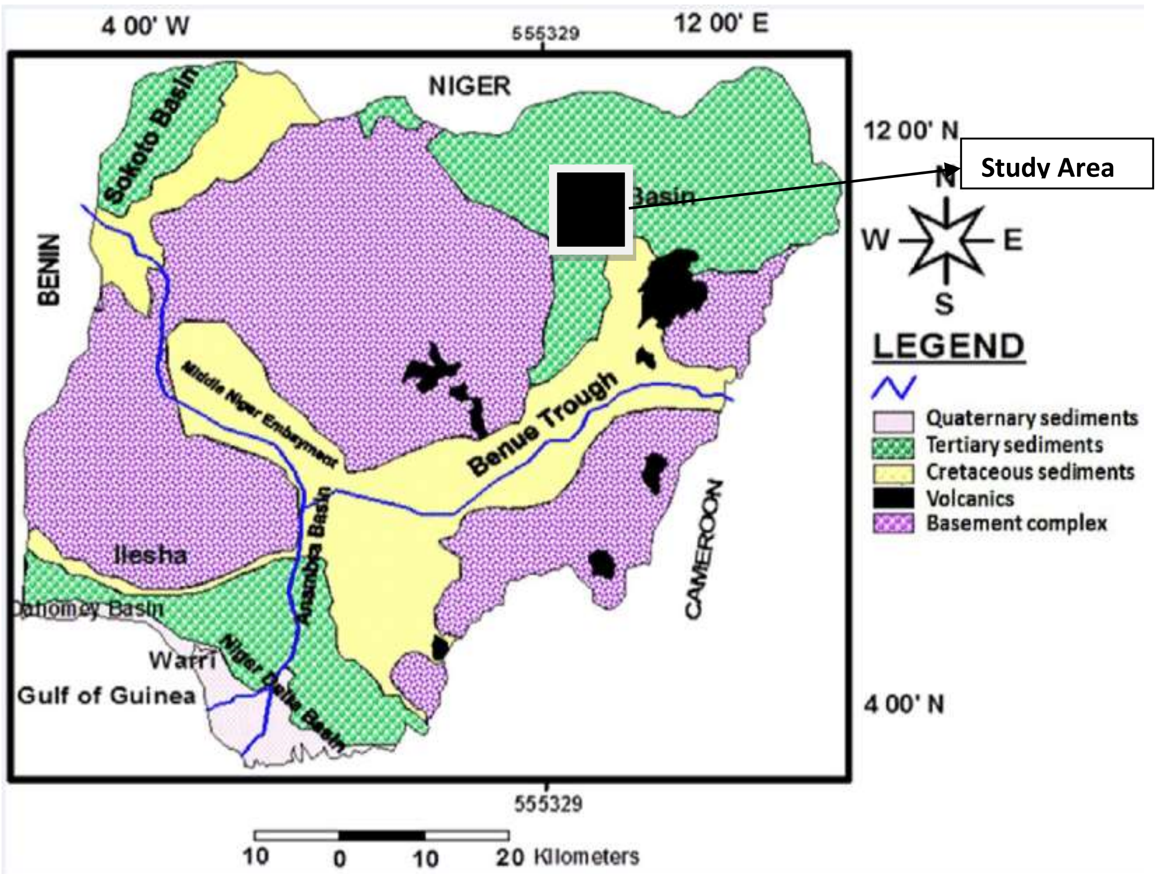

Figure 1: Geological Map of Nigeria showing the study area

MATERIAL AND METHODS

The Geological survey of Nigeria in 2005 carryout an Aeromagnetic survey of some parts of the country. Four of these maps (sheet 131, 132, 152, and 153) were acquired by the kind of approval of Nigeria Geological Survey Agency (NGSA) and are used in this research. The grid file comprises of three parameters which are the Easting, Nothing and total magnetic field intensity (nT). The direction of the flight line and tie line are NW-SE and NE-SW respectively. The line spacing of the profile is 500 m and the flight height is 100 m. The data was re-interpolated and the new spacing was 200 m. The inclination and declination of the area was estimated using International Geomagnetic Reference Field (IGRF) model. The data was collected in 2005, using the coordinates of the study area. The procedure involved in this study include reduction to equator, contour of the total magnetic field map, regional residual separation of the magnetic data, division of the study area into four blocks, and the analysis of the magnetic data amongst others.

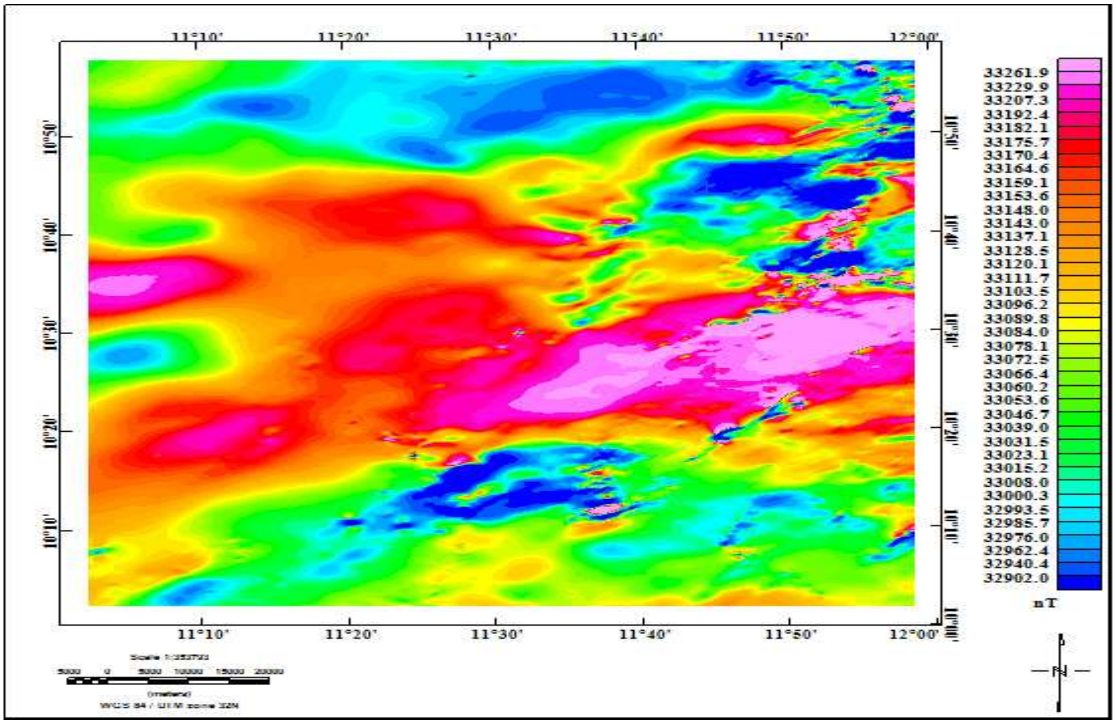

Fig. 2.Total field intensity map of the study area

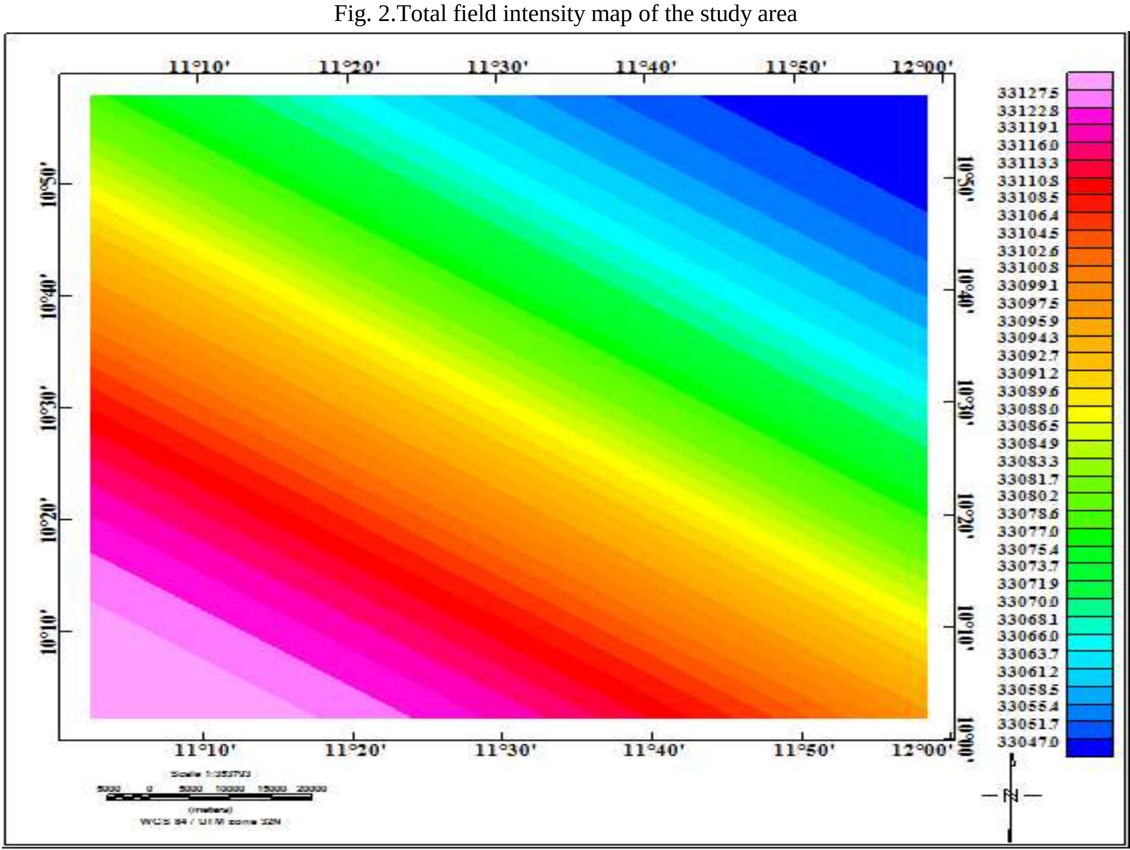

Fig. 3. Regional field map of the study area

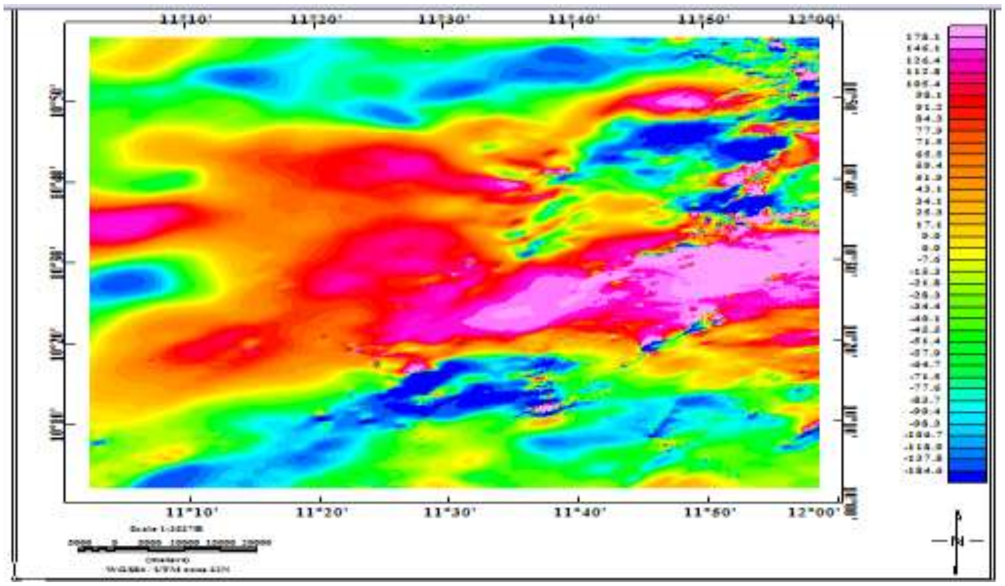

Fig. 4. Residual field intensity map of the study

Spectral Analysis

Spectral analysis employing Fast Fourier transform is the mathematical tool used in the research. The Fast Fourier transform is applied to regular spaced data such as aeromagnetic data. It is represented mathematically (Khalid et al., 2020; Pascal, 2019; vahid, 2017).

$$Y(x) = \sum_{n=1}^{N} \left(a_n \cos\frac{2n\pi x}{L} + b_n \sin\frac{2n\pi x}{L}\right) \qquad 1$$

Where Y(x) is the reading at x position

L is length of the cross section of the anomaly

n is the harmonic number of the partial wave

N is the number of the data points

a_n is the real part of the amplitude spectrum

b_n is the imaginary parts of the amplitude spectrum.

The graph of the natural logarithm of the amplitude against frequency plotted and the linear segment from the low frequency portion of the spectral drawn from the graph. The gradient of the linear segment is computed and the depth to the basement is determine using the equation 2 according (Negi, 1983; Chifu et al., 2019; Ikumbur et al., 2019; Anudu et al., 2020; Lucic, 2019) given as

$$z = -\frac{ML}{2\pi} \qquad 2$$

Where

Z is the depth to the basement

M is the gradient of the linear segment

L is the length of cross section of the anomaly.

RESULT AND DISCUSSION

Fourier mathematical algorithm was used to compute the fast Fourier transform magnitude and fast Fourier transform frequency. The energy which is in logarithm scale was plotted against frequency to produce a decay curve segment which decreases in slope with increasing frequency (Khalid et al., 2020). The depths to magnetic sources using spectral analysis of high resolution aeromagnetic data of the study area are represented in (Fig. 5-8).

Figure 5 shows the power spectrum of plot of logarithm of spectral power (energy) against wave numbers (frequencies) for block 1. The plot shows that a group of sources has the same depth and they fall onto line of constant slope indicating a magnetic source in the area.

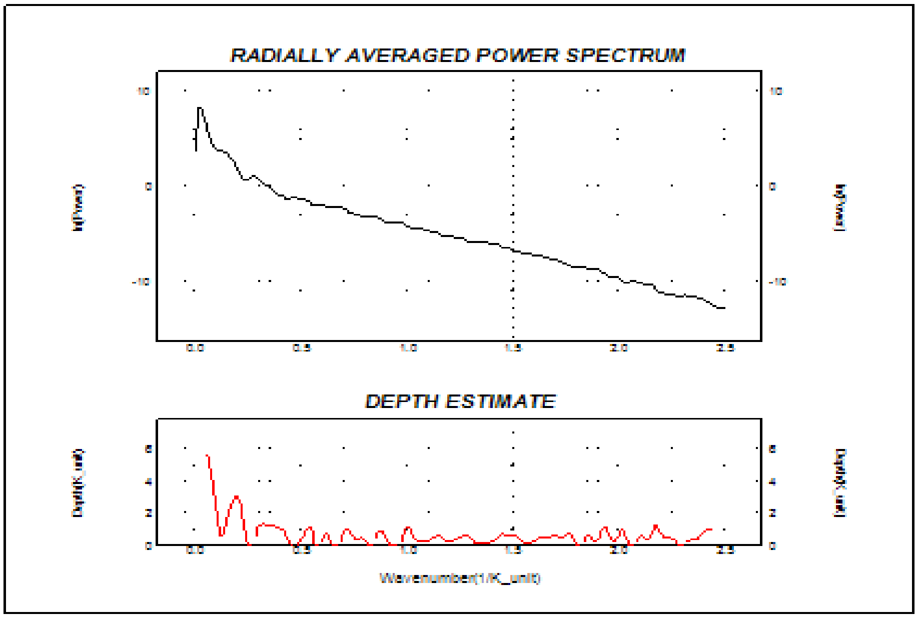

Fig. 5. Radial energy spectrum for **Block 1**

Figure 6 shows the power spectrum of plot of logarithm of spectral power (energy) against wave numbers (frequencies) for block 2. The plot shows that a group of sources has the same depth and they fall onto line of constant slope indicating a magnetic source in the area.

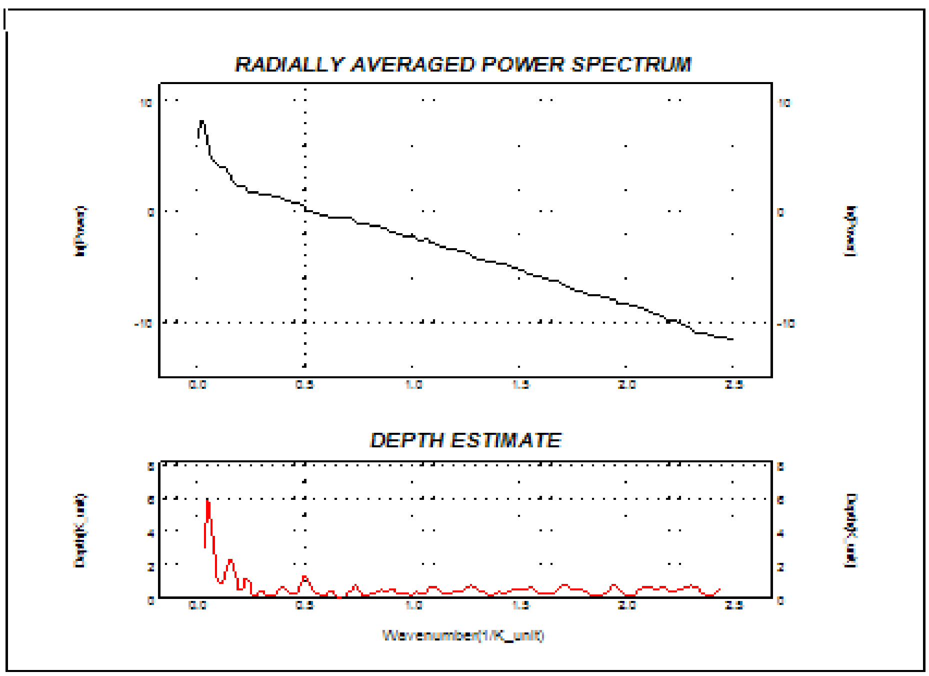

Fig. 6. Radial energy spectrum for **Block 2**

Figure 7 shows the power spectrum of plot of logarithm of spectral power (energy) against wave numbers (frequencies) for block 3. The plot shows that a group of sources has the same depth and they fall onto line of constant slope indicating a magnetic source in the area.

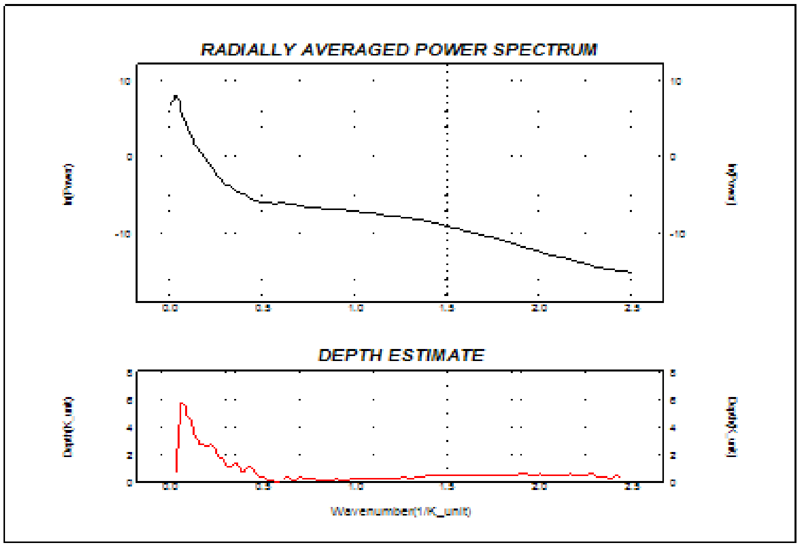

Fig. 7. Radial energy spectrum for **Block 3**

Figure 8 shows the power spectrum of plot of logarithm of spectral power (energy) against wave numbers (frequencies) for block 4. The plot shows that a group of sources has the same depth and they fall onto line of constant slope indicating a magnetic source in the area.

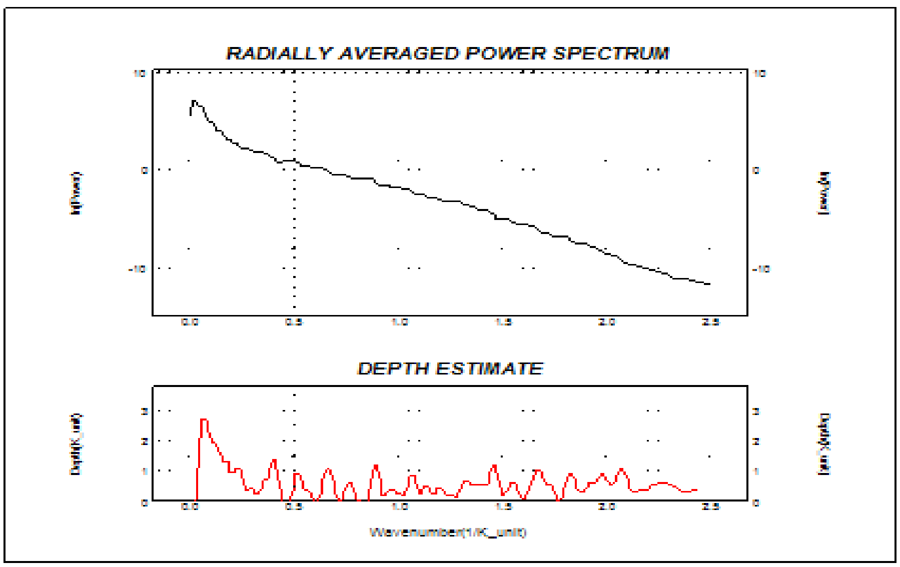

Fig. 8. Radial energy spectrum for **Block 4**

Figure 9 shows the spectral plot of Ln of power against frequency for block 1. The graph energy decreases with increase in frequency and the slope obtained from the plot indicate the average depth of the source bodies. A depth value of 5.2 km was obtained for the block.

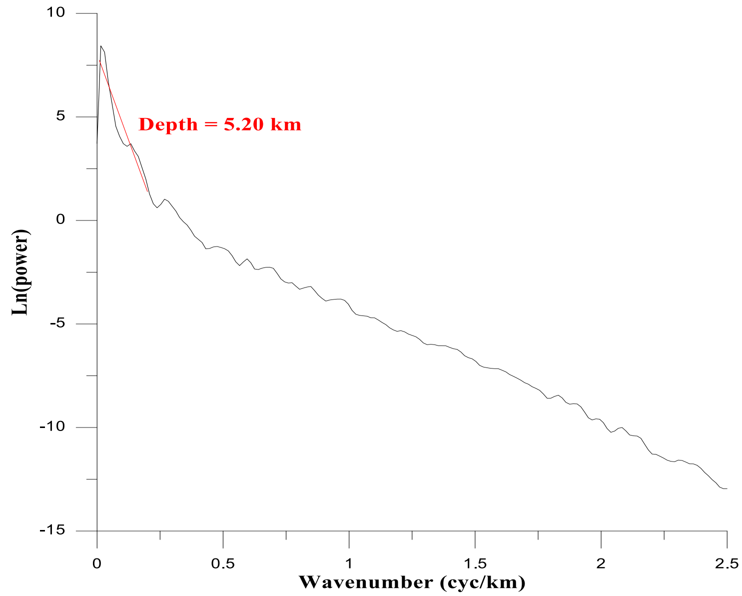

Fig. 9. Spectral plot of Ln power against Frequency for **Block 1**

Figure 10 shows the spectral plot of Ln of power against frequency for block 2. The graph energy decreases with increase in frequency and the slope obtained from the plot indicate the average depth of the source bodies. A depth value of 5.74 km was obtained for the block.

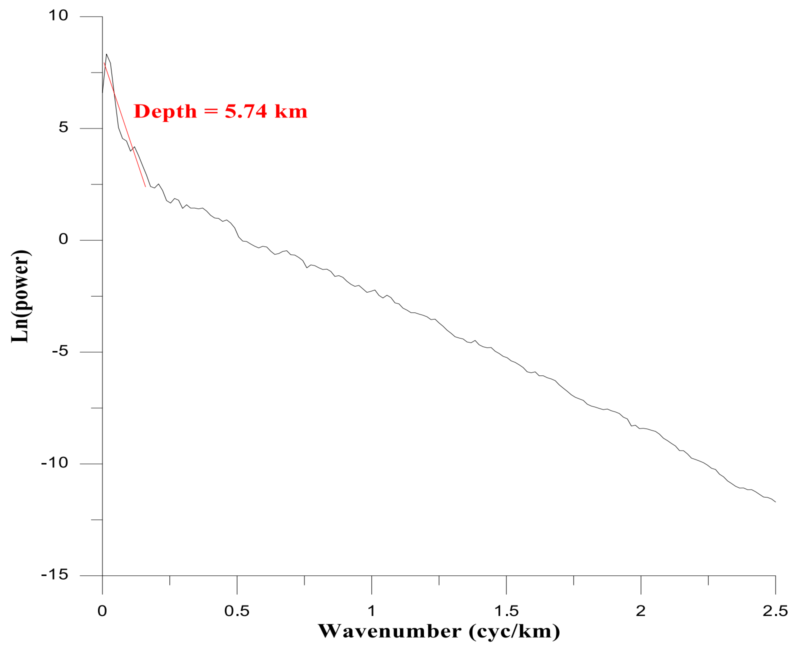

Fig. 10. Spectral plot of Ln power against Frequency for **Block 2**

Figure 11 shows the spectral plot of Ln of power against frequency for block 3. The graph energy decreases with increase in frequency and the slope obtained from the plot indicate the average depth of the source bodies. A depth value of 7.59 km was obtained for the block.

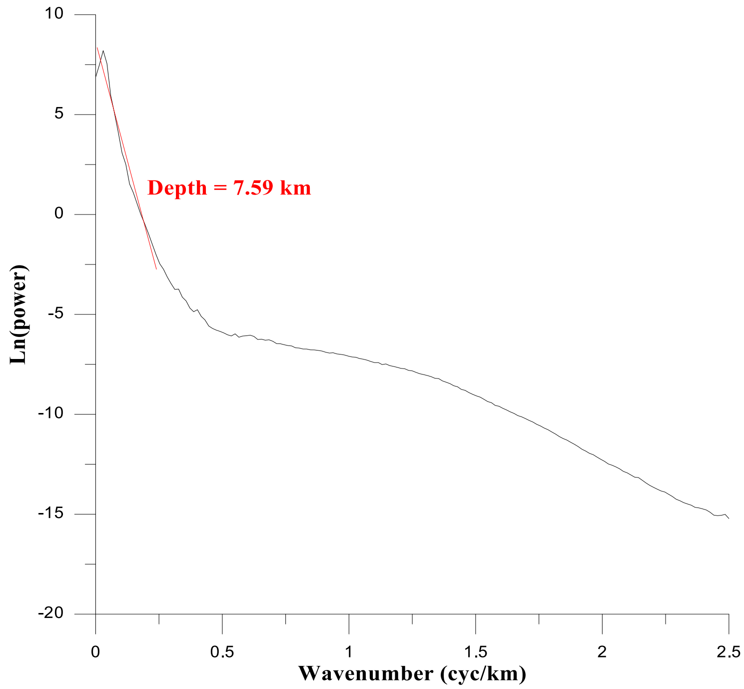

Fig.11. Spectral plot of Ln power against Frequency for **Block 3**

Figure 12 shows the spectral plot of Ln of power against frequency for block 4. The graph energy decreases with increase in frequency and the slope obtained from the plot indicate the average depth of the source bodies. A depth value of 3.56 km was obtained for the block.

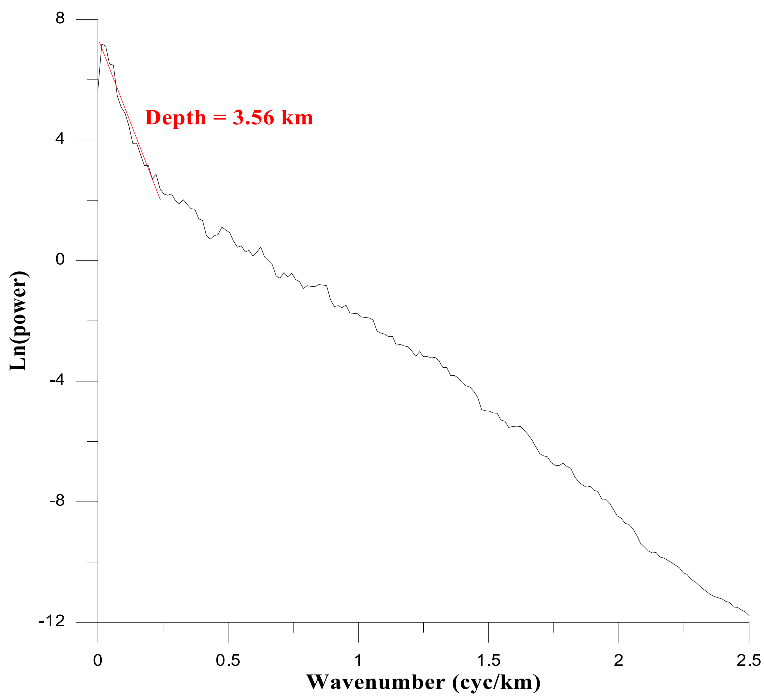

Fig. 12. Spectral plot of Ln power against Frequency for **Block 4**

Examining both the total magnetic intensity and residual map of the study area (Fig. 2 and Fig. 2), it is observed that, the study area is made up of magnetic high and magnetic low signatures. The magnetic high observed on the residual magnetic field ranges between 0.7 nT to 178.3 nT, and magnetic low observed in the residual magnetic field ranges between-154.6 nT to -7,6 nT. Therefore, the high could be as a result of basic intrusive within the study area while the magnetic low could be as a result thick sedimentary cover, the variation in the magnetic intensity can be related to the differences in depth in the study area as obtained. The magnetic source depth determinations through spectral analysis in the study area are shown by the spectral blocks (Fig.5-8). The result also suggests the existence of depth under the study area. The graphs of the Ln of power against frequencies for the blocks are also shown (Fig.9-12). The depth value of 5.2 km was found in block 1, 5.74 km in block 2, and 7.95 km in block 3 and 3.56 km in block 4 respectively. The average depth in the study area was found to be 3.1km. In comparison with the depths (sedimentary thickness) in the study area with those previously estimated from magnetic data analysis shows good agreement. For example Bello (2018) obtained average sedimentary thicknesses (depths) of 3.81 km, and Muhammad (2014) obtained sedimentary thickness of 2.23 km from data interpretation over the Upper Benue Trough. The difference in the depth values obtained in the present work and that of the previous work may be as a result of difference in the techniques used.

CONCLUSION

Geophysical investigation of some parts of Benue Trough was carried out using aeromagnetic data. The aeromagnetic data of Bajoga (sheet 131), Gulani (sheet 132), Gombe (sheet 152) and Wuyo (sheet 153) were interpreted qualitatively and quantitavely. Spectral analysis technique is employed in quantitative interpretation with the aim of determining the depth to magnetic basement in the study area. Oasis montaj, Microsoft excel and Grapher software was employed in the data analysis.. The total magnetic field intensity values of study area ranges from 32902.0 nT to 33261.9 nT while the residual magnetic field intensity ranges from -154.6 nT to 178.1 nT. These values show that the study area is magnetically heterogeneous. The average depth to basement (sedimentary thickness) in the study area was found to be 3.1 km. However, based on the computed sedimentary thickness, the possibility of hydrocarbon generation in the study area is feasible.

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