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Research Article

Spectral Re-Evaluation of the Magnetic Basement Depth over Yola arm of Upper Benue Trough Nigeria Using Aeromagnetic data

***1Emberga TT and 2Chigbu Timothy**

[1]Department of Physics/Electronics, Federal Polytechnic, Nekede –Owerri Imo State, Nigeria
[2] Department of Physics/Electronics, Abia state Polytechnic, Aba Abia state

*Corresponding Author E-mail: terhemba4sure@yahoo.com

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Abstract

The aeromagnetic data have been used to re-evaluate parts of the Upper Benue Trough Nigeria using spectral analysis technique in order to appraise the mineral accumulation potential of the area. The regional field was separated with a first order polynomial using prolific program. The residual data was subdivided into 24 spectral blocks using OASIS MONTAJ software program. Two prominent magnetic depth source layers were identified. The deeper source depth values obtained ranges from 1.56km to 2.92km with an average depth of 2.37km as the magnetic basement depth while for the shallower sources, the depth values ranges from -1.17km to 0.98km with an average depth of 0.55km. The shallow depth source is attributed to the volcanic rocks that intruded the sedimentary formation and this could possibly be responsible for the mineralization found in parts of the study area.

Keywords: Spectral analysis, Upper Benue Trough, OASIS, MONTAJ, Magnetic basement depth, shallow depth source

INTRODUCTION

This data was used to re-evaluate the basement depth of some parts the Upper Benue trough using the spectral analysis technique. Among the major previous studies using old aeromagnetic data in Nigeria include Ofoegbu (1984, 1985, 1986), Ahmed (1991), Ofoegbu and Onuoha (1991), Onwuemesi (1996) and so on. Nwachukwu(1985) using geochemical technique considered the Middle Benue Trough to have high prospects for hydrocarbon within the trough. Mapping of magnetic basement depth beneath sedimentary cover is one of the key functions of aeromagnetic survey and its interpretations. This study therefore aims to appraise the mineral potential of the study area by accomplishing the following objectives: determination of sedimentary thickness within the study area, and magnetic basement topography through surface plots.

The Benue trough is part of the long stretch arm of the Central African rift system originating from the early Cretaceous rifting of the central West African basement uplift (Samuel et al.,2011). The trough has been categorized into three different zones and they are: the Lower Benue Trough at the southern part, the Middle Benue Trough at the center while the Upper Benue Trough at the Northern part. The geology of the Middle Benue Trough is characterized by the presence of thick sedimentary cover of varied composition whose age ranges from Albian to Maastrichtian (Obaje, 2004). The Asu-River Group of marine origin is the oldest deposited sediment in this area followed by Ezeaku Formation, keana/Awe Formation, Awgu Formation and Lafia Sandstone which is the youngest sediment (Obaje, 2004). More on this geology could be found in the work of Cratchley and Jones (1965), Burke *et al.* (1970); Offodile (1976), Osazuwa *et al.* (1981) and Offoegbu (1985).

LOCATION AND GEOLOGY OF THE STUDY AREA

The study area is located within the Upper Benue Trough. Benue Trough is defined as an intercontinental Cretaceous basin about 1000km in length stretching in a NE-SW direction and resting unconformably upon the Pre- Cambrian Basement. In the Yola, the oldest sediments belong to the Bima sandstone and Yolde Formation which outcrop in the major part of the study area Eze Aku Shale Group and Yola Formation are also present in the study area. The Bima Sandstone and Yolde Formation are variable sequence of sandstones and shale which mark the transition from Continental to Marine sedimentation. The Upper part of the formation (Bima sandstone and Yolde) contain blue-black shales (Carter et al., 1963). From the map of the study area (Figure 1), it is observed that on the southern part of the area, the basement complex outcrops on the surface. The basement rocks are mainly quartz, feldspathic, biotite, hornblende, gneisses, quartzites, marbles and calc-silicate rocks

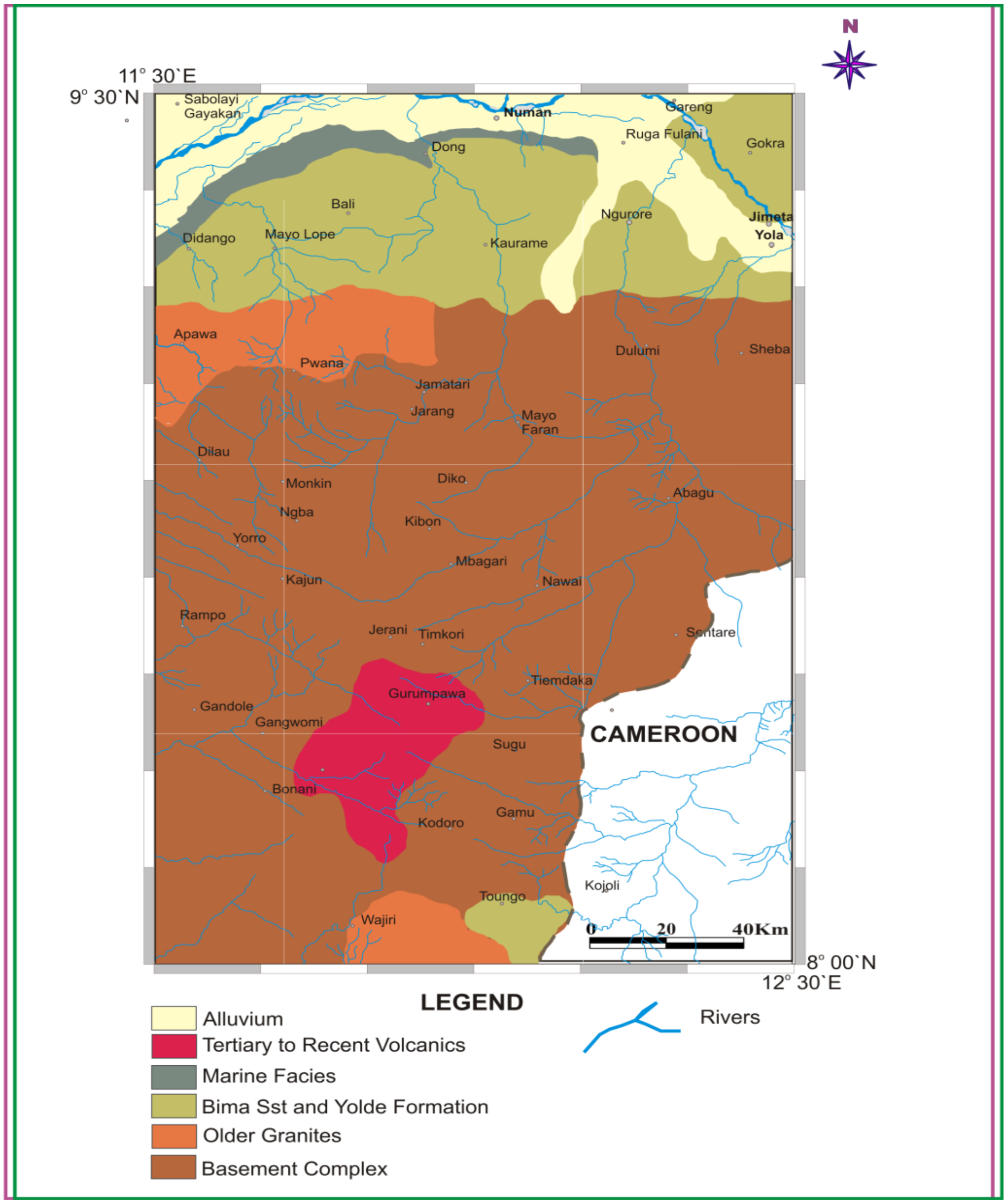


Figure 1. Geology map of Upper Benue Tough

MATERIALS AND METHOD

The data used for the study were compiled using the geological map of the study area comprising Numan (sheet 196), Dong (sheet 195), Jada (sheet 217), Kiri (sheet 237),Monkin (sheet 216) and Toungo (sheet 236) ,each at a scale of 1:100,000 and satellite image - Landsat 5 TM, Bands 432 with wavelengths 0.76-0.90µm (near – IR), 0.69 µm (Red) and 0.52-0.60µm (green). It has high spatial resolution of 30mx30m ground area..

Filtering – (High pass filtering): A local contrast enhancement method for the purpose of highlighting linear features or edges – faults, fractures and joints, drainage patterns, and geological boundaries. Filtering is a way of separating signals of different wavelength to isolate and hence enhances any anomalous feature with a certain wavelength. A rule of thumb is that the wavelength of an anomaly divided by three or four is approximately equal to the depth at which the body producing the anomaly is buried. Thus filtering can be used to enhance anomalies produced by features in a given depth range. Traditional filtering can be either low pass (Regional) or high pass (Residual). Thus the technique is sometimes referred to as Regional-Residual Separation. Bandpass filtering isolates wavelengths between user-defined upper and lower cut-off limits.

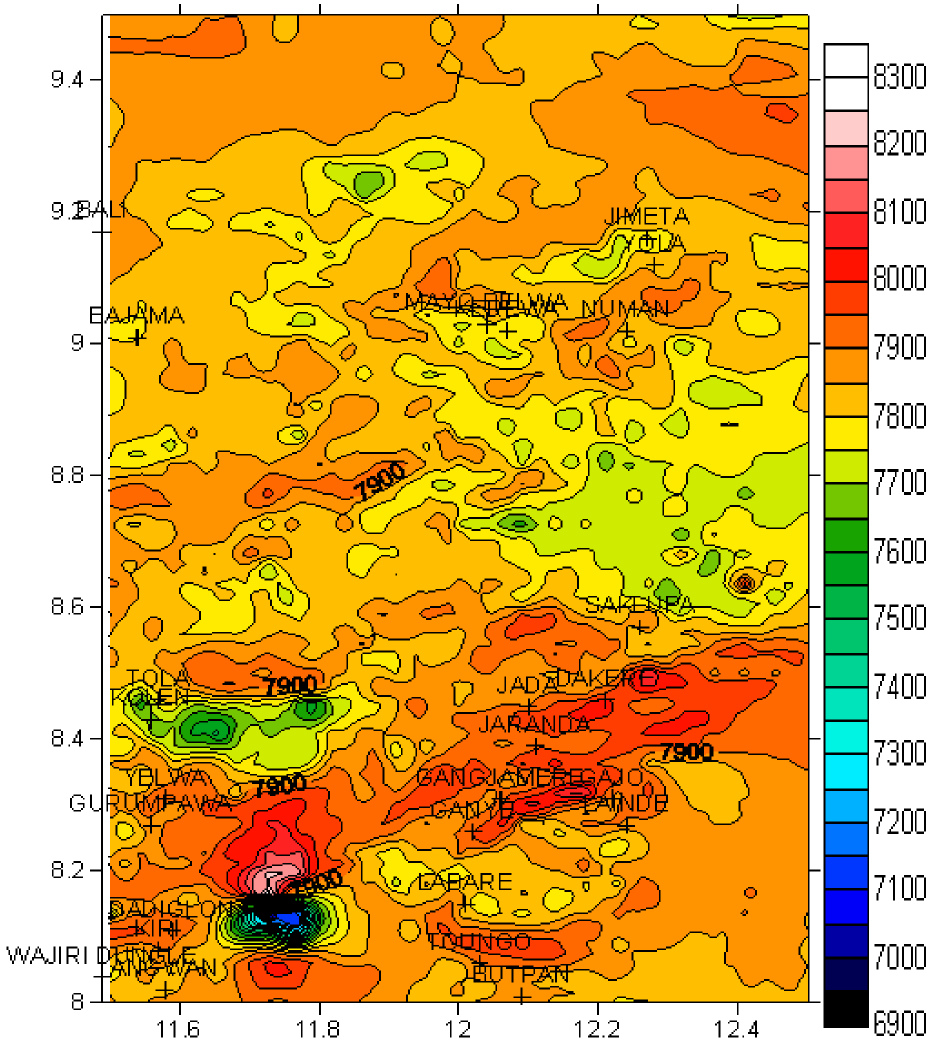


Figure 2. Total magnetic amomaly map of Upper Benue Trough

THE THEORETICAL BACKGROUND OF SPECTRAL ANALYSIS

The power spectrum computes the thickness of the sedimentary basin and that of the crustal Moho depth (Spector and Grant, 1970). The spectral depth method is based on the principle that a magnetic field measured at the surface can therefore be considered the integral of magnetic signatures from all depths. The power spectrum of the surface field can be used to identify average depths of source ensembles (Spector and Grant, 1970). This same technique can be used to attempt identification of the characteristic depth of the magnetic basement, on a moving data window basis, merely by selecting the steepest and therefore deepest straight-line segment of the power spectrum, assuming that this part of the spectrum is sourced consistently by basement surface magnetic contrasts. A depth solution is calculated for the power spectrum derived from each grid sub-set, and is located at the centre of the window. Overlapping the windows creates a regular, comprehensive set of depth estimates. This approach can be automated, with the limitation however that the least squares best-fit straight line segment is always calculated over the same points of the power spectrum, which if performed manually would not necessarily be the case.

Depth results are generated for the entire dataset using different wave number ranges and window sizes. A potential field grid may be considered to represent a series of components of different wavelength and direction. The logarithm of the power of the signal at each wavelength can be plotted against wavelength, regardless of direction, to produce a power spectrum. The power spectrum is often observed to be broken up into a series of straight line segments. Each line segment represents the cumulative response of a discrete ensemble of sources at a given depth. The depth is directly proportional to the slope of the line segment. Filtering such that the power spectrum is a single straight line can thus enhance the effects from sources at any chosen depth at the expense of effects from deeper or shallower sources. It is a data-adaptive process involving spectral shaping. As such, it performs significantly better than arbitrary traditional filtering techniques described above.

The application of spectral analysis to the interpretation of aeromagnetic anomalies is now sufficiently well established (Bhattacharyya, 1966, 1968; Spector and Grant, 1970; Mishra and Naidu, 1974; Nahn et al., 1976). The method allows an estimate of depth of magnetized blocks of varying depth, width, thickness and magnetization. Most approaches used involve Fourier transformation of the digitized aeromagnetic data to compute the energy (or amplitude) spectrum. This is plotted on the Logarithmic scale against frequency. The plot shows the straight line segments which decrease in slope with increasing frequency. The slopes of the segments yield estimates of depths to magnetic sources.

Given a residual magnetic anomaly map of dimension L×L digitized at equal intervals, the residual intervals, the residual total intensity anomaly values can be expressed in terms of double Fourier series expansion:

$$T(x,y)=\sum_{n=1}^{N}\sum_{m=1}^{M}P_m{}^n\cos(\frac{2\pi}{L})(nx+my)+Q_m{}^n\sin[(\frac{2\pi}{L})(nx+my)]\ldots\ldots\ldots\ldots(1)$$

Where L dimension of the block, $P^n{}_m$ and $Q^n{}_m$ are Fourier amplitude and N, M are the number of grid points along the x and y directions respectively.

Equation (1) can be combined into a single partial wave thus:

$$p_m^n\cos[(\frac{2\pi}{L})(nx+my)]+Q_m^n\sin[(\frac{2\pi}{L})(nx+my)]=C_m^n\cos[(\frac{2\pi}{L})(nx+my)-\delta_m^n\ldots\ldots(2)$$

Where $(P_m^n)^2+(Q_m^n)^2=(C_m^n)^2\ldots\ldots\ldots\ldots(3)$

and δ_m^n is the appropriate phase angle.

Each (C_m^n) is the amplitude of the partial wave. The frequency of this wave is given by: $F_m^n=\sqrt{n^2+m^2}$ is called the frequency of the wave. Similarly, using the complex form, the two dimensional Fourier transform pair may be written (Bhattacharryya, 1966; Bath, 1974; Oppenheim and Schafer, 1975)

$$G(U,V)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}g(x,y)e^{-j(ux+vy)}dxdy\ldots\ldots\ldots\ldots(4)$$

$$g(x,y)=\frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}G(U,V)e^{-j(ux+vy)}dxdy\ldots\ldots\ldots\ldots(5)$$

Where u and v are the angular frequencies in the x and y directions respectively.
G (u,v) when broken up into its real and imaginary parts is given by

$$G(u,v) = P(u,v + jQ(u,v) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The energy density spectrum or simply the energy spectrum is

$$E(u, v) + \left| G(u,v) \right|^2 = P^2 + Q^2 \ \ldots\ldots\ldots\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The Analysis (Quantitative interpretation)

The following operations were performed on the acquired digitized aeromagnetic data leading to the quantitative determination of depth to magnetic sources

Regional-Residual separation

The regional field was removed from the total magnetic intensity data (observed data) to obtain the residual data with a first order polynomial using prolific program. The residual data was subdivided into 16 spectral blocks allowing spectral probe of 12.5km by 12.5km area for 15minute by 15minute windowing.

Divisions into Spectral cells and Windowing

For the purpose of easier handling of the large data involved, the four residual blocks of the study area was subdivided into 24 spectral cells (labeled in table 1) of 12.5km by 12.5km in order to accommodate longer wavelength so that depth up to about 12km could be investigated. Each signal was then widowed 15 minutes by 15 minutes.

Table 1. Twenty four (24) spectral cells

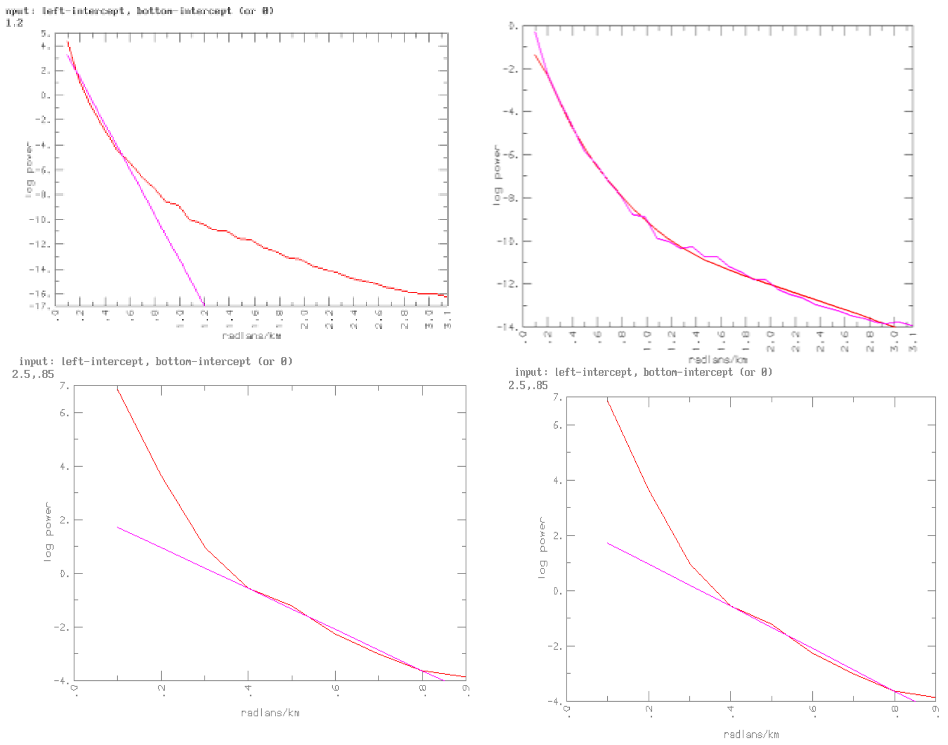
TOUNGO A	NUMAN A	MONKIN A	KIRI A	JADA A	DONG A
TOUNGO B	NUMAN B	MONKIN B	KIRI B	JADA B	DONG B
TOUNGO C	NUMAN C	MONKIN C	KIRI C	JADA C	DONG C
TOUNGO D	NUMAN D	MONKIN D	KIRI D	JADA D	DONG D

Generation of radial energy spectrum:

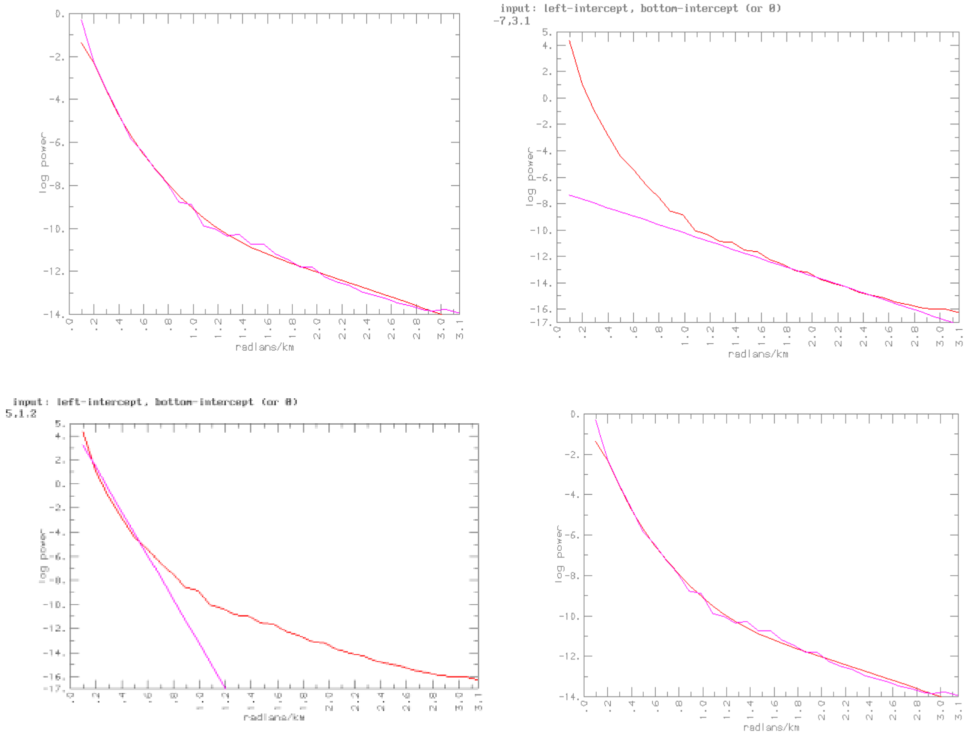
Digital signal processing software (OASIS MONTAJ) program employing the fast Fourier transform technique was used to transform the residual magnetic data into the radial energy spectrum for each block. The average radial power spectrum was calculated and displayed in a semi-log figure of amplitude versus frequency.

Plots of Log of Energy and the frequency:

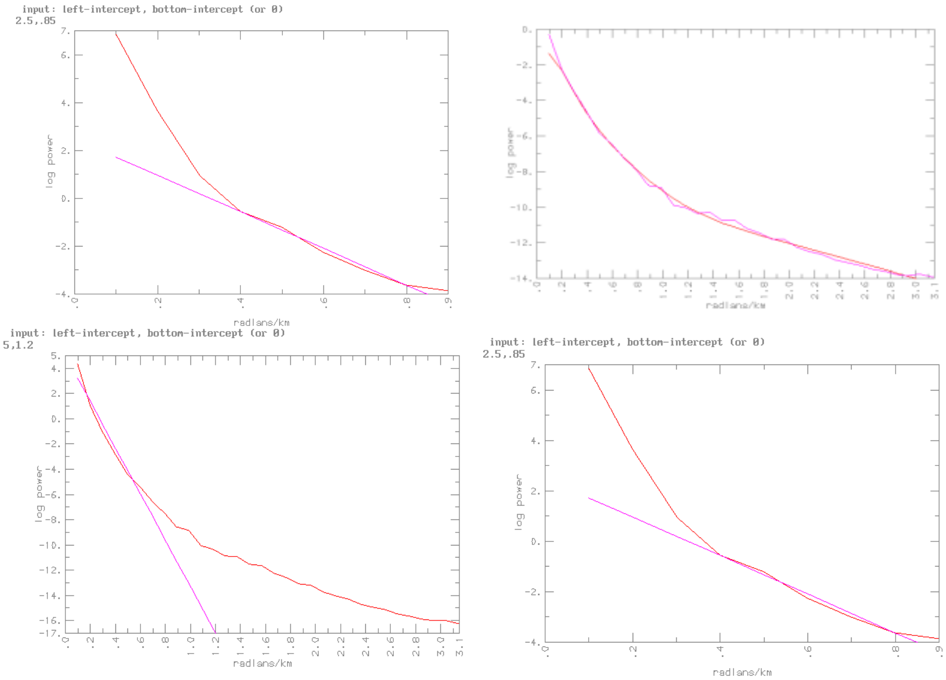
Spector and Grant (1970) have shown that the Log-power spectrum of the source have a linear gradient whose magnitude is dependent upon the depth of the source. Graphs of logarithm of the spectral energy against frequencies for the 24 spectral cells was plotted and shown on figure 3



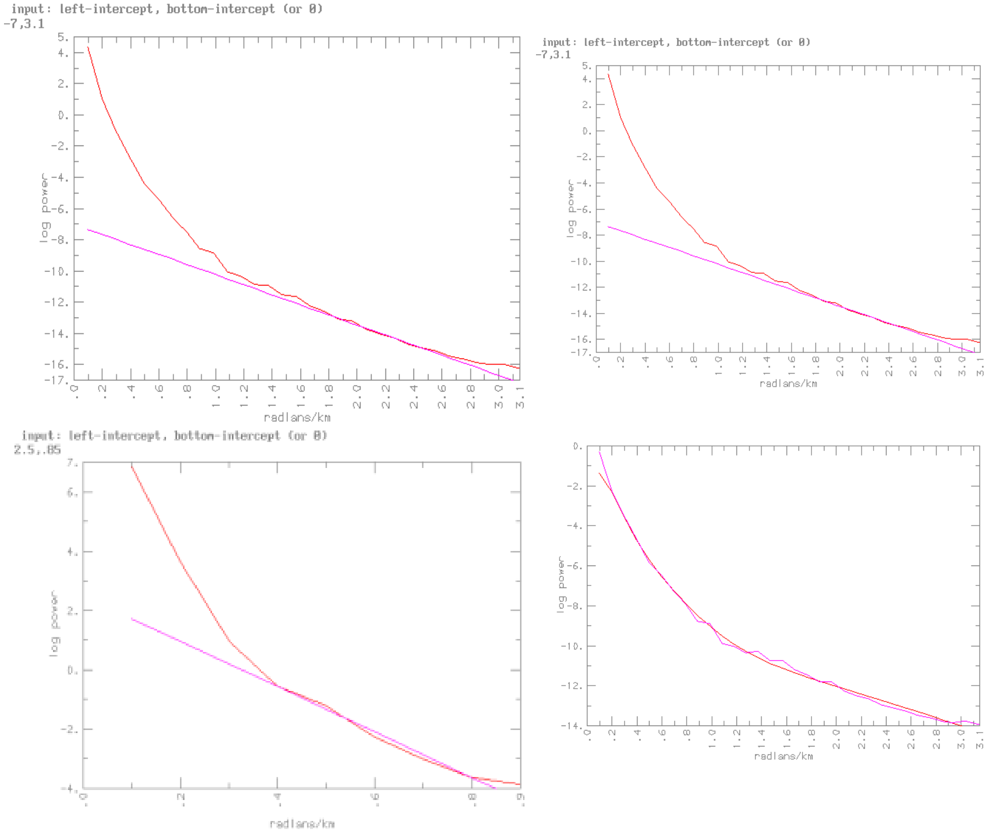
Power spectrum plots of Dong sheet



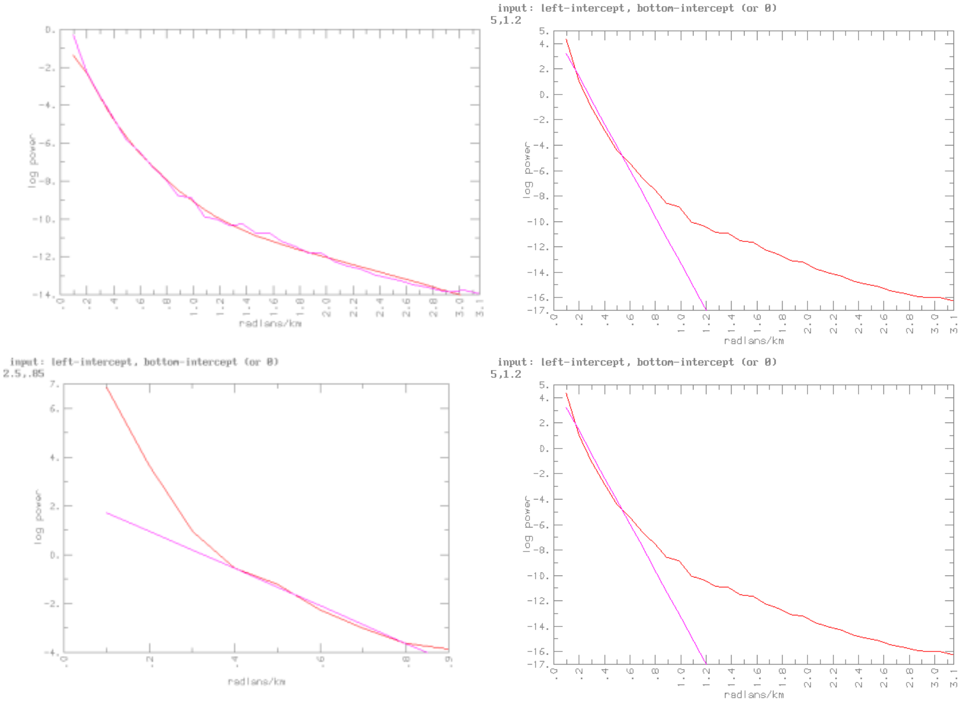
Power spectrum plots of Numan sheet



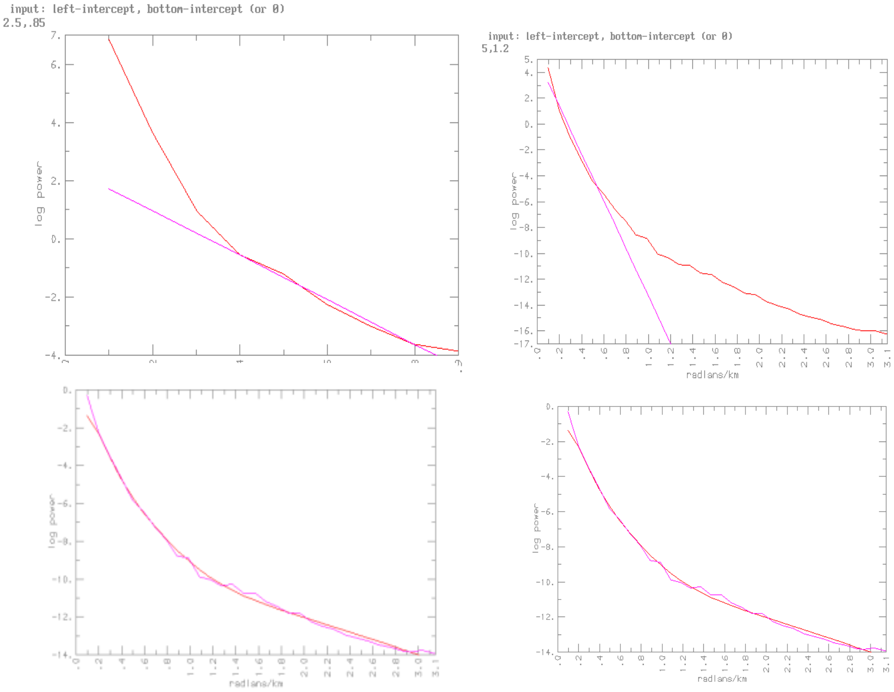
Power spectrum plots of Jada sheet



Power spectrum plots of Toungo sheet



Power spectrum plots of Monkin sheet



Power spectrum plots of Kiri sheet

Figure 3. Spectral plots of log (E) against Frequency (rad/sec)

For each cells two linear segments could be identified which implies that there are two magnetic source layers in the study area. Each linear segment group points are due to anomalies caused by bodies occurring within a particular depth range. The line segment in the higher frequency range is from the shallow sources and the lower harmonics are indicative of sources from deep - seated bodies

Table 2. Depth estimates of the first and second magnetic layers for the 24 spectral blocks and their coordinates

SPECTRAL BLOCK	LONGITUDE		LATITUDE		DEPTH KM	
	X_1	X_1	Y_1	Y_1	D_1	D_2
Kiri A	11.5	11.75	8	8.25	0.6	1.98
Kiri B	11.5	11.75	8.25	8.5	0.9	2.1
Kiri C	11.75	12	8	8.25	0.8	1.89
Kiri D	11.75	12	8.25	8.5	0.92	2.06
Monkin A	11.5	11.75	8.5	8.75	0.57	2.9
Monkin B	11.5	11.75	8.75	9	0.66	2.6
Monkin C	11.75	12	8.5	8.75	0.11	2.7
Monkin D	11.75	12	8.75	9	0.94	2.92
Jada A	12	12.25	8	8.25	0.67	2.75
Jada B	12	12.25	8.25	8.5	0.598	2.61
Jada C	12.25	12.5	8	8.25	-1.174	2.67
Jada D	12.25	12.5	8.25	8.5	0.88	2.78
Dong A	11.5	11.75	9	9.25	0.35	2.52
Dong B	11.5	11.75	9.25	9.5	0.2	2.41
Dong C	11.75	12	9	9.25	0.98	2.38
Dong D	11.75	12	9.25	9.5	0.67	2.255
Toungo A	12.25	12.5	8	8.25	0.54	2.06
Toungo B	12.25	12.5	8.25	8.5	0.98	2.05
Toungo C	11.5	11.75	8	8.25	0.62	1.98
Toungo D	11.5	11.75	8.25	8.5	0.28	1.575
Numan A	12.25	12.5	9.0	9.25	0.2	2.45
Numan B	12.25	12.5	9.25	9.5	0.9	2.39
Numan C	11.5	11.75	9.0	9.25	0.2	2.58
Numan D	11.5	11.75	9.25	9.5	0.9	2.34
AVERAGE DEPTH					0.5539	2.3729

The deep anomaly source depth averaging 2.373km deep could possibly represent the magnetic basement surface of the study area while the other depth averaging 0.554km could possibly represent the shallow source

DISCUSSIONS

Spectral analysis of the aeromagnetic data of the Upper Benue trough has revealed two main magnetic anomaly sources depth as shown on table 2. These are the deep magnetic anomaly sources and the shallow magnetic anomaly sources. The deep source anomalies vary between 2.373km and 0.554km and this represents the magnetic basement depth. The shallow anomaly sources with an average of 0.554km and this may be regarded as the magnetic intrusions into the sediment, probably through the magmatic activities and could be responsible for the lead-Zinc mineralization found in the area. Active magmatisms have been reported in the Benue Trough with Ofoegbu and Odigi (1989) confirming the close associations between magmatisms, mineralizations and fractures in the area.

CONCLUSION

These results obtained from the use of the new high resolution data have shown some similarities with those from the previous old data. However, they could be more dependable and exacts owing to the high resolution nature of the 2009 data more than the 1970s data in terms of terrain clearance, line spacing and improvement in technology since then. Also the stressful work of digitizing a map and the likely error that could be introduced during the process have all been eliminated because the 2009 data is in a digitized format. The depth values estimated from spectral analysis over part of the Upper Benue is an indication that mineral prospecting should be intensified.

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