

## Structural trends and spectral depth analysis of the residual magnetic field of Naraguta area, North central, Nigeria.

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### Abstract

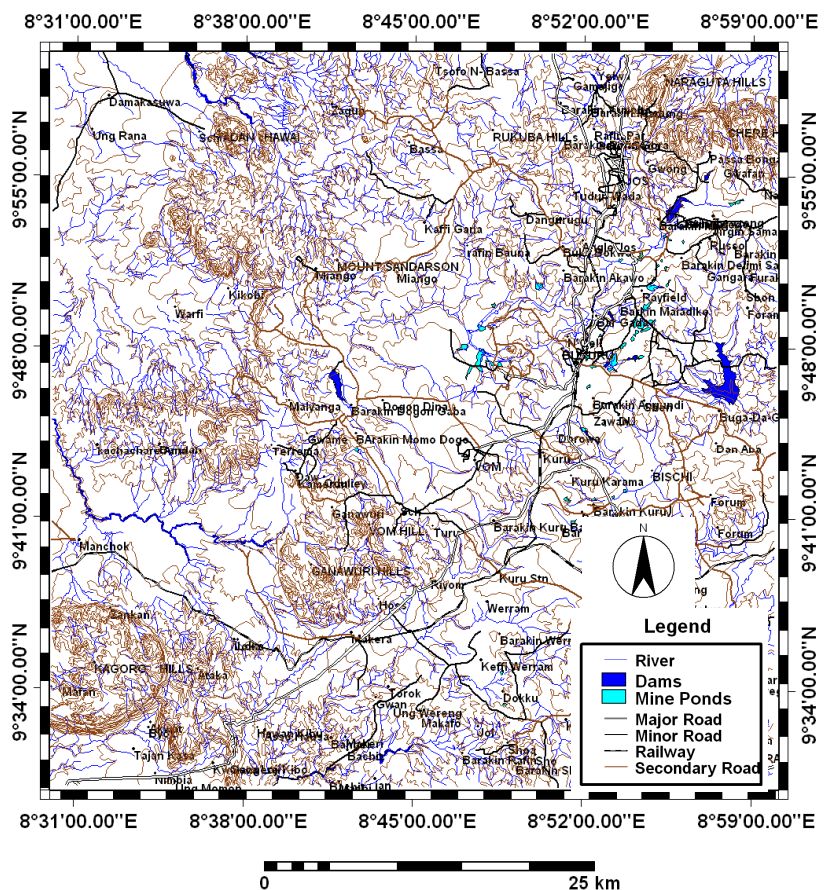
The results of a magnetic study of the Naraguta area, North Central Nigeria are presented here. Regional-residual separation was carried out using Least Square method. The resultant regional map revealed a regional trending in a NW-SE direction. The magnetic residual values range from  $-487.828\text{nT}$  to  $+405.447\text{nT}$ . Short to moderately long dislocations were found in the residual magnetic map. Several magnetic closures of various sizes were also noticed. While the discontinuities indicate the presence of minor to moderately long geologic fault in the area, the closures depict the type and size of the anomalies that lie beneath the area. Magnetic lineaments trending in a NE-SW direction has been identified to pass through the study area. This concentration of magnetic lineaments may be connected with the occurrence of younger granites in the study area since almost all known younger granite complexes lie within the region dominated by this trends. Also a prominent ENE-WSW anomaly low has been identified in the Jos-Bukuru complex. The trend of the anomaly is believed to be roughly parallel to that of the main structural feature of the Benue trough indicating the probability that the Benue trough and the younger granite intrusive are related considering the stress, which initiated the formation of these features. 2-D spectral analysis of the magnetic anomalies over the area has been carried out in an effort to estimate the depth to magnetic sources. The result shows that the deeper sources have an average depth of 2.03 Km while the shallower sources have an average depth of 265m.

**Keywords:** Lineaments, Trend, Magnetic Anomalies, Younger Granites.

### Introduction

The study area is situated in North Central Nigeria and covers an area of about  $2970.25\text{km}^2$  and it is bounded by latitudes  $9^{\circ}30'$  and  $10^{\circ}00'$  and longitude  $8^{\circ}30'$  and  $9^{\circ}00'$ . It includes Jos area and surrounding towns such as Bukuru, Bassa, Hoss, Vom, Barakinladi etc. This area covers Naraguta topographic map (sheet 168) published by the Federal Survey Department on scale 1:100 000 (Fig.1). The study area has high relief features and elevation ranges from 1800m-5300m above sea level. The highland area is affected by weathering and erosion with laterite covering most parts. The scenery of the area varies from level plain and plateau surfaces almost devoid of exposed rock to rugged, deeply dissected massifs developed on the more resistant rock types. Throughout the area, there is a close relationship between rock type and scenery. The Jos - Plateau owes its preservation largely to the close concentration of resistant younger and older granites, and indeed almost all the upland areas coincide with outcrops of one of these two rocks (Macleod *et al.*, 1971). The younger granites in particular with their sharp contrast to basement rocks, are generally marked by an abrupt break of slope at their margins. The older granites with their widely spaced jointing are characterized by smooth rounded inselbergs. The younger granites generally give rise to a more rugged topography with steep rocky hills and joint

Fig.1. Topographical Map of study Area (modified from GSN map series)



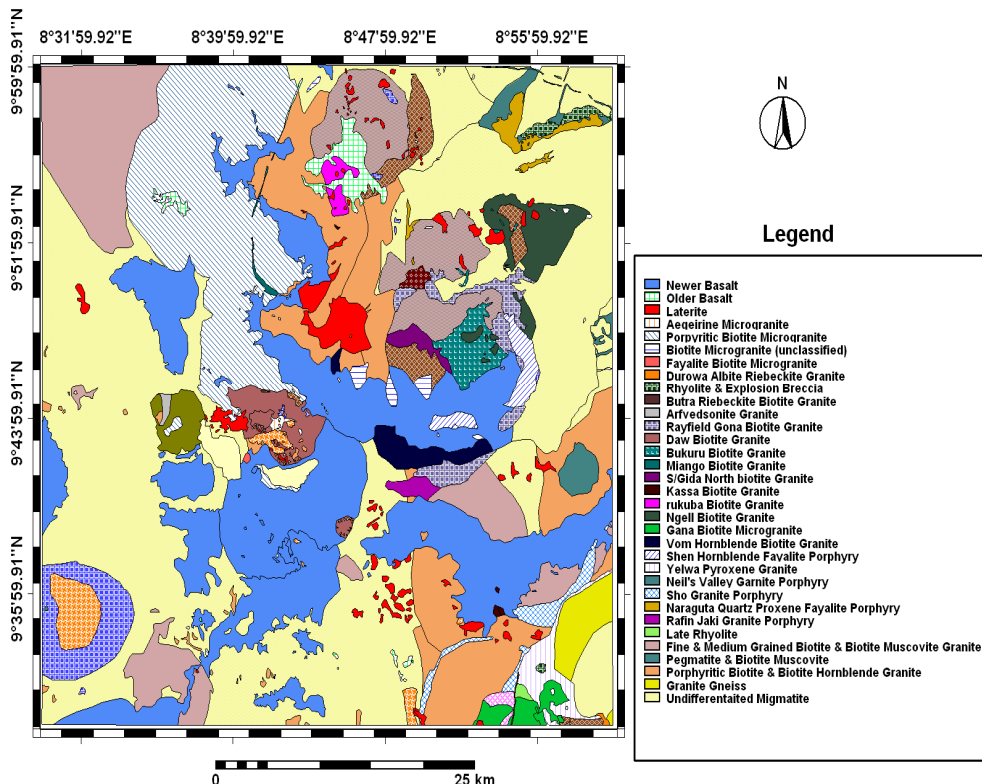
controlled valleys. Apart from the granites, basement rocks generally form low-lying, poorly exposed areas except where dissected around the plateau margins. The basalts produce some of the most prominent landscape features of the Plateau, especially the laterite- capped mesas of decomposed older basalt and the newer basalt volcanoes with their steep sides scored by shallow gullies. A general succession according to Macleod *et al.* (1971) is shown in Table 1; also vide geological map (Fig 2).

Table 1. Geologic sequence of study area

Geologic time	Rock type	Occurrence
Tertiary-Quaternary	Newer basalts	Lava flows and volcanic cone, lava flows now largely decomposed, overlying alluvium
Jurassic	Younger granite	Granites, porphyries and rhyolites
Precambrian to lower Paleozoic	Crystalline basement	Migmatites, Gneisses & older granite

The most common mineral in the area is cassiterite. Other minerals in the area include columbite, wolfram, pyrochlore, fergusonite, thorite, zircon, monazite, xenotime, beryllium minerals, molybdenite, cryolite and other minor minerals such as topaz, gelana, pyrite, arsenopyrite, bismuthinite, and chalcopyrite. In this paper the trends of the Residual magnetic field map are analyzed qualitatively and depths to magnetic sources are calculated by statistical spectral analysis methods.

Fig. 2. Digitized geological map of the study (Modified from G.S.N)



**Theory**

*Least square method*

The least square method (LSM) is usually used in estimating the residual component of Bouguer (Abdelrahman *et al.*, 1989), magnetic (Abdelrahman *et al.*, 1996; Akanbi & Udensi, 2006) and self-potential (Abdelrahman *et al.*, 1997) anomalies. In this study the LSM approach by Nettleton (1976) was applied. The method consists of matching the regional field by a polynomial surface of low order. The treatment is based

on statistical theory. Assuming that the equation for the surface that best fits the data is

$$T(x,y)=A_0+A_1x+A_2y \quad (1)$$

Where T would be computed value of the regional for the coordinates x, y. A<sub>0</sub>,A<sub>1</sub>and A<sub>2</sub> are constants which are to be determined.

The residual(R) would be

$$R = B - T \quad (2)$$

With B being the observed total magnetic field value and T the regional surface value.

**Statistical spectral depth analysis**

Spector (1968) and Spector & 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 the geologic column. The evolution of spectral analysis has some important precursor, by which one tried to present data only in a simple 2-D format. The most important of these precursors is the harmonic analysis or Fourier series expansion of a given time series of data. According to Fourier's theorem, any function f (t) satisfying certain restrictions can be expressed as a sum of infinite number of sinusoidal terms.

In the general case, f(t) can stand for any function such as displacement, particle velocity, acceleration, temperature, rainfall, wind velocity, geomagnetic field intensity etc. The phenomenon e.g. geomagnetic field can also be a function of f(x). To study the characteristics of the residual field, the data is first transformed from space to the frequency domain and then their frequency characteristics are analyzed. For the purpose of analyzing aeromagnetic maps, the subsurface is assumed to consist of a number of independent ensembles of rectangular,

vertical sided parallelepiped. If there are two sets of sources then they can be recognized by marked change in spectra decay rate. The energy spectrum of the double ensemble will then consist of two parts. The first, which relates to the deeper sources, is relatively strong at low frequencies, and decays away rapidly. The second, which arises from the shallower ensemble of sources, dominates the high frequency end of the spectrum (Spector & Grant, 1970). In general case, the radial spectrum may be conveniently approximated by straight line segments, the slopes of which relate to depths of the possible magnetic layers (Spector & Grant, 1970; Hahn *et al.*, 1976). The power spectrum derived from a two-dimensional dataset such as a grid of residual magnetic data, also has inherently a two-dimensional form. If the frequency unit is in radians per kilometer the mean depth of burial of the ensemble is given by

$$z = -\frac{m}{2} \quad (3)$$

Where m is the slope of the best fitting straight line. If, however, the frequency unit is in cycles per kilometer, the corresponding relation can be expressed as

$$z = -\frac{m}{4\pi} \quad (4)$$

The use of the Discrete Fourier Transform introduces the problem of aliasing and the truncation effects (Gibb's phenomenon). In this study, aliasing was reduced by the digitizing interval used. The map was digitized on a 1km x 1km grid system. The spacing imposes a Nyquist frequency of  $\frac{1}{2} \text{ km}^{-1}$ . Thus, the narrowest magnetic anomaly that can be defined by the digitized data has a width of 2km. Previous studies with crustal magnetic anomalies (Hall, 1968 & 1974) show that this spacing is suitable for the portrayal and interpretation of magnetic anomalies. The truncation effect arises when limited portion of an aeromagnetic map is subjected to Fourier synthesis; it is difficult to reconstruct the sharp edges of the anomaly with a limited number of frequencies. This truncation leads to the introduction of spurious oscillation around the region of discontinuity. This means that false frequencies will be introduced into the spectrum. The truncation effect was reduced by applying a cosine taper to the observed data before Fourier transformation (Kangkolo, 1996; Akanbi & Udensi, 2006). It has been found (Pal *et al.*, 1978) that in the use of spectral approach to magnetic source depth determinations, the error in depth prediction increases with the depth of source and is also related to the map size. The map size required for adequate results should be much larger

(about 10 times) the required target depth. The low frequency components in the energy spectrum are generated from the deepest layers whose locations are most likely in error thus, it is advisable in the general method here to ignore the first few points in the energy spectrum.

**Materials and method**

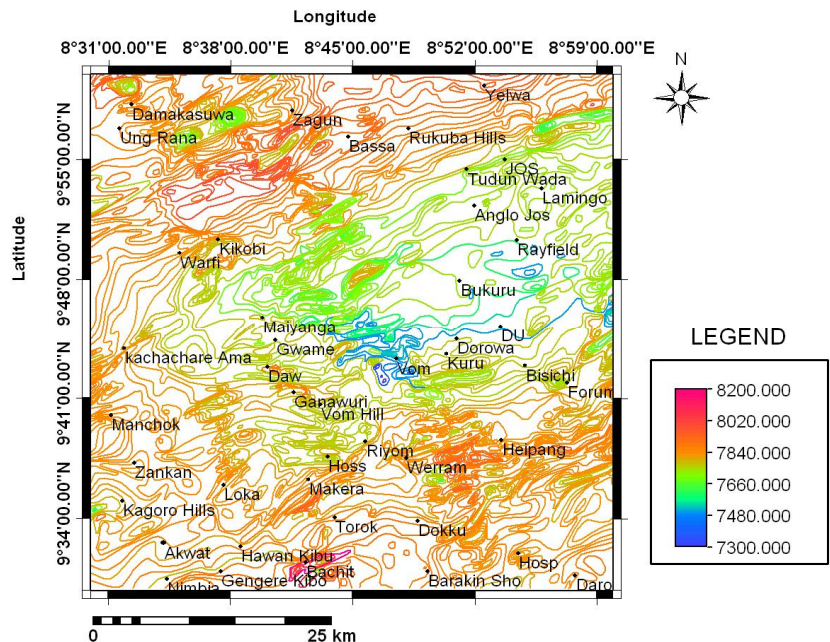
The data sets used for this research are: 1. Aeromagnetic map covering Naraguta sheet 168 (1: 100 000), 2. Geologic map covering Naraguta sheet 168 (1: 100 000) and 3. Geologic report covering the area by Macleod *et al.* (1971).

The software used include: ILWIS 3.2(academic), SURFER 8, REGRES.FOR and SPEC.FOR.

The following procedure was adopted for the study:

- (i) The Naraguta (sheet 168) aeromagnetic map was digitized and reproduced using ILWIS 3.2 (Academic)
- (ii) The regional magnetic field was determined by fitting a 2 dimensional first degree polynomial surface to the total data using the least square method. This was achieved using REGRES.FOR which is based on the least squares technique.
- (iii) The residual magnetic field was obtained by subtracting the regional field values from the total magnetic field values at grid cross points.
- (iv) Depths to the magnetic layers of the residual magnetic field were determined using SPEC.FOR a FORTRAN program which is based on statistical spectral analysis.
- (v) The resultant maps were interpreted qualitatively and quantitatively.

Fig. 3. Digitized total aeromagnetic field map of Naraguta Sheet, 168.(modified from G.S.N)



**Result presentation and discussion**

*Structural trend analysis*

The picture that emerges from a magnetic contour map such as Fig.3 is one that shows the superposition of disturbances of notably different order of sizes. Larger features produce magnetic anomalies that are smooth over considerable distances and are caused by the deeper heterogeneity of the earth's crust. These smooth trends are referred to as regional trends, regional fields or simply regionals. Smaller, more local sources account for sharper anomaly shapes of more restricted areal extent. These are superimposed on the regional fields but frequently camouflaged by them. Though they are smaller local disturbances which are secondary in size, they are of primary importance. These are the residual anomalies, residual field or simply residuals which may provide evidence of the existence of mineral ore bodies or reservoir-type structures. For potential field data (such as magnetic or gravity) to be interpreted and or used for further analysis, the residual anomalies must be separated from the regional background field. Least squares method was used for regional-residual separation and the equation of the regional obtained in this work is

$$T(x,y) = 32851.98 - 0.00148x - 0.00013y \quad (5)$$

From this relation the regional gradients along any line were calculated. The resultant map is shown in Fig.4. The regional trends in an approximate NW-SE direction. A program was used to derive the residual

Fig. 4. Regional magnetic map of study area.

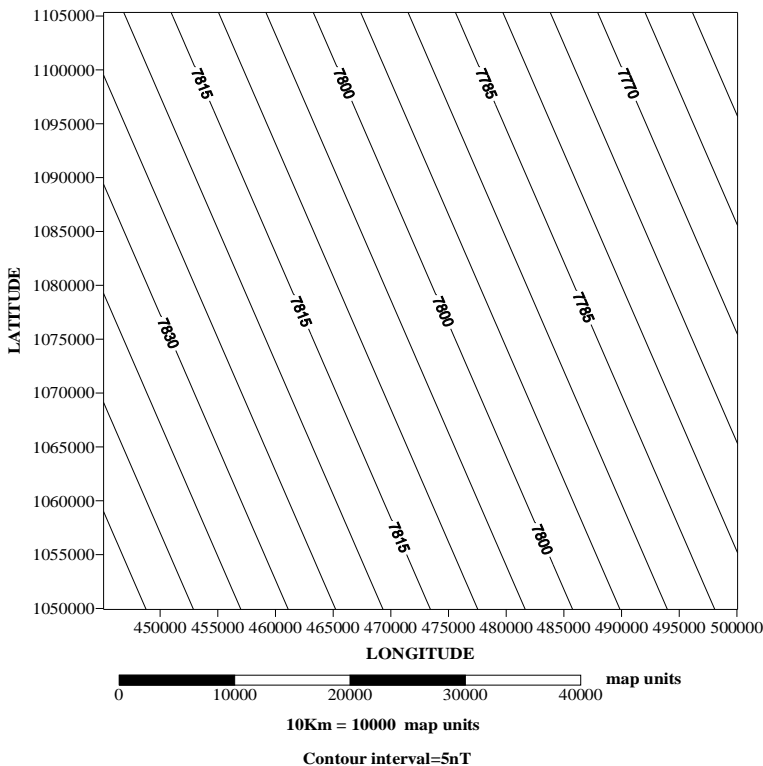
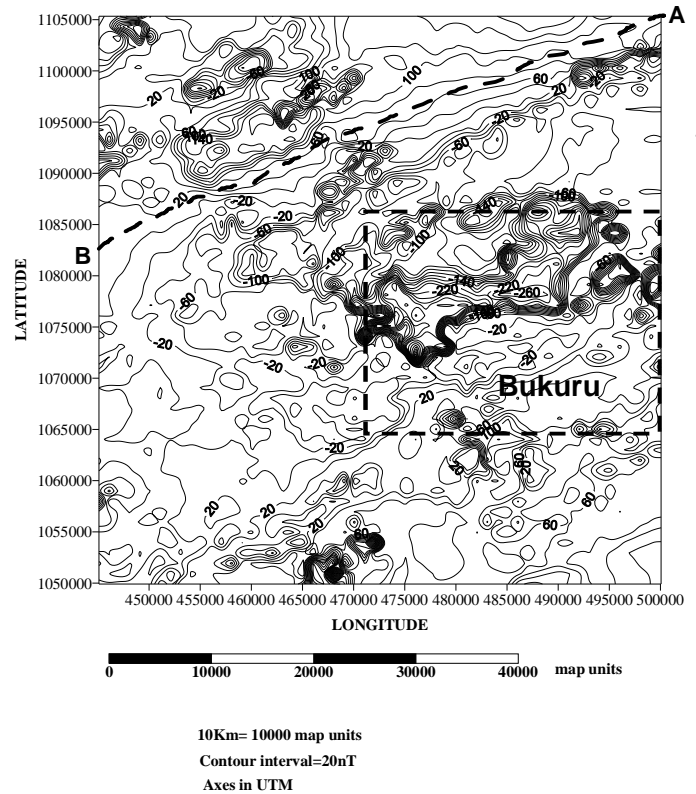


Fig. 5. Airborne magnetic residual anomaly map of study area



magnetic values by subtracting the values of the regional field from the total magnetic field values at grid cross points. The contour map of the residual values (Fig.5) shows that the magnetic residual values range from -487.828nT to +405.447nT. Negative residuals dominate the study area because the study area is close to the magnetic equator. The features on the map are not linear i.e. we have closures on the map which indicates the anomalous conditions in the subsurface. Circular pattern on Fig.5 could be associated with the presence of ore bodies, granitic as well as basic ore bodies while the long narrow patterns seen more in the North to the North-Central portion of the map could probably be due to dikes, tectonic shear zones, isoclinically folded strata with magnetic impregnation or long ore bodies. The nature of the closure depicts the depth of burial and size of intrusions that are within the basement underlying the area. Short to moderately long dislocations were also noticed in the magnetic map which is indicative of short to moderately long geologic faults. Long narrow anomaly features known as magnetic lineaments trending in NE-SW direction (A-B) has been identified to pass through the study area. The work of Buser (1966) in the study which covers Nigeria and its surrounding countries,

established the existence of paleostructures, which have directed events like tectonic movements, intrusions, metamorphism, sedimentation, mineralization, volcanism and drainage. He identified them as striking in a NNE-SSW direction. These structures are in the form of culminations (crests) and depressions. They influence the major tectonic features in these regions to an approximate NE-SW direction. Ajakaiye *et al.* (1991) in their interpretation of aeromagnetic data across the Nigerian continental mass identified the NE-SW trending anomalies as dominant magnetic features of most of this shield area. They deduced that these lineaments coincide with major structural trends such as the Benue trough in Nigeria, fractures in the oceanic crust of the West African coast, Eburnean syncline in the Cote-D'ivoire and can be traced to the lineaments in Guyana and Eastern Brazil. They showed that on the shore lineaments in West Africa are the extensions of the St Paul's, Romanche, Chain and Charcot fracture zones. These fracture zones are believed to be part of the major zones of weakness in the crust that predate the opening of the Atlantic Ocean and were reactivated during the early stage of continental rifting. These authors further pointed out this concentration of magnetic lineaments appeared to be connected with the occurrence of Younger Granites since almost all known Younger granite complexes lie within the region dominated by this trends. Also from fig.5 most of the anomalies in the area trend largely in NE-SW direction while a few trend E-W, N-S direction. An ENE-WSW anomaly low has been identified in the Jos-Bukuru complex. This agrees with the study carried out by Ajakaiye (1982). In their study, a prominent ENE-WSW anomaly low is centred at the Jos -Bukuru complex with a trend which is roughly parallel to that of the main structural feature of the Benue trough. They suggest that the origins of two major structural features in Nigeria that is the Benue trough and the Younger Granite intrusive are related considering the stress, which initiated the formation of these features. Also from Fig.5 it can be seen that the low magnetic anomaly values dominate the study area probably because the biotite granites which are the major rock type forming the plutons in the ring complexes are characterized by very low magnetic anomalies since they are poor in iron.

**Statistical spectral analysis**

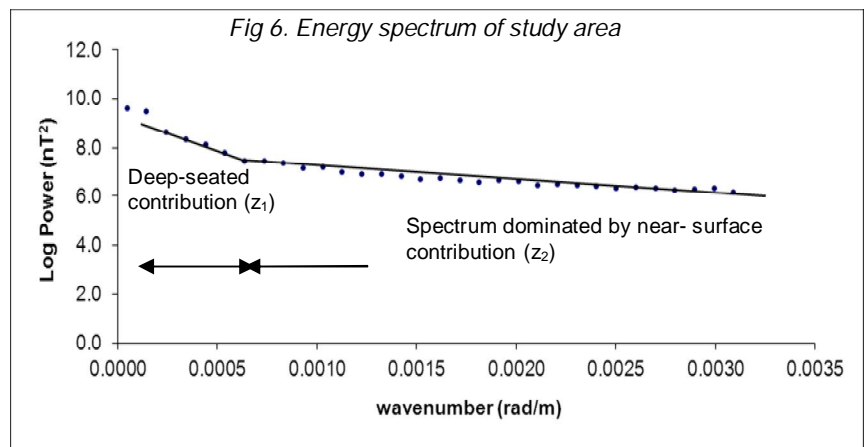
The residual total magnetic field of Fig.5 was used to determine the depth to magnetic sources within the Naraguta area using statistical spectral analysis. Graph of the logarithm of the spectral energies against frequencies obtained for the area is shown in Fig.6. Two linear segments were drawn from the graph. The gradients of the linear segment was

evaluated and used to calculate the depth to the causative bodies. The result shows that the first segment has an average depth ( $Z_1$ ) of 2.03 Km while the second segment has an average depth ( $Z_2$ ) of 265m.

We may attribute the first segment to the deeper sources to and the second segment to the surface rocks. The deeper sources are probably thought to be caused by the crystalline metamorphic basement rocks of the area which consists of migmatites, gneisses and Older Granites. While the shallower sources are probably due to the rhyolitic rocks that directly overlie the metamorphic basement, Pleistocene cassiterite bearing alluvium and/or Quaternary to Recent basalt lava flows have filled the broad Pleistocene valleys.

**Conclusion**

The Residual aeromagnetic map over Naraguta in central Nigeria has been interpreted in this study. Circular patterns on the map could be associated with the presence of ore bodies, granitic as well as basic ore bodies while the long narrow patterns seen more in the North to the North-Central portion of the map could probably be due to dikes, tectonic shear zones, isoclinically folded strata with magnetic impregnation or long ore bodies. Short to moderately long dislocations were also noticed in the magnetic map which is indicative of short to moderately long geologic faults. Magnetic lineaments have been identified to pass through the area. Low magnetic anomaly values dominate the study area probably because the study area is close to the magnetic equator and that the biotite granites which are the major rock type found in the area are characterized by very low magnetic anomalies since they are poor in iron. Also an ENE-WSW anomaly low has been identified in the Jos-Bukuru complex with a trend which is roughly parallel to that of the main structural feature of the Benue trough. The result shows that the first layer has an average depth of 265 m while the second layer has an average depth of 2.03Km.





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