Asian Journal of
Earth Sciences

ISSN 1819-1886

Academic
Journals Inc.

www.academicjournals.com

Asian Journal of Earth Sciences 5 (3): 70-78, 2012
ISSN 1819-1886 / DOI: 10.3923/ajes.2012.70.78

Estimation of Magnetic Basement Depths Beneath the Abeokuta Area, South West Nigeria from Aeromagnetic Data Using Power Spectrum

[1]J.A. Olowofela, [1]O.D. Akinyemi, [2]O.A. Idowu, [1]O.T. Olurin and [1]S.A. Ganiyu
[1]Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria
[2]Department of Water Resources Management and Agro-Meteorology, Federal University of Agriculture, Abeokuta, Nigeria

Corresponding Author: O.T. Olurin, Department of Physics, Federal University of Agriculture, Abeokuta, P.M.B 2240, Ogun State, Nigeria

ABSTRACT

This study presents the result of spectral analysis of aeromagnetic data of Abeokuta area, a basement complex of South-western Nigeria. Aeromagnetic survey is a powerful tool in delineating the regional geology of buried basement terrain. The purpose of magnetic surveying is to investigate the subsurface based on the variation in the observed magnetic field result from the differences in the magnetic properties of the underlying rocks, or in some cases cultural sources. In order to achieve the aim of this study, matched pass filtering operation was performed on digitised aeromagnetic data of the area under consideration to separate magnetic anomalies produce by shallow features and cultural features separated from anomalies produced by deeper geologic unit. Two-dimensional spectral analysis revealed that the magnetic sources are mainly distributed at two levels. The shallow source is depth 0.467 km below ground level is inferred to be due to the intrusions within the region. The deeper sources depth, which is 2.797 km below ground, is attributed to the underlying basement. The mean shallow depth and deeper depth are 0.467 km and 2.797 km, respectively. The shallow depth of 0.467 km might probably due to intrusive within the sediment while deeper depth of 2.797 km is attributed to underlying basement. Variation in magnetic depth values reveals the general trends in the magnetic basement surface.

Key words: Aeromagnetic data, complex basement, regional, residual, spectral analysis

INTRODUCTION

The early use of potential field methods in petroleum was to map sedimentary basin thickness Airborne geophysical surveys are an extremely important aspect of modern geophysics. Compared with ground surveys airborne surveys allow faster and usually cheaper coverage, of large areas. At the largest reconnaissance scale, the most common airborne surveys are aeromagnetic surveys, as used in government reconnaissance surveys. Until the last couple of decades the other primary application of airborne surveys was in mineral exploration (Nabighian *et al.*, 2005). Over the last decade there has been increase in the use of airborne magnetic and more recently, gravity in the petroleum exploration industry but high-resolution surveys are used to investigate basement trends and intra-formational structures. High resolution methods are now being applied in the groundwater, environmental and engineering studies (Nabighian *et al.*, 2005; Grauch *et al.*, 2006).

Magnetic method is one of the most economical geophysical techniques to delineate the subsurface structures. Generally, aeromagnetic anomaly maps reflect the lateral variations in the earth's magnetic field. These variations are related to changes of structures, magnetic susceptibility or remanent magnetization. It was observed that sedimentary rocks have low magnetic properties compared to metamorphic and igneous rocks, which have greater magnetic properties (intensity and susceptibility). Therefore airborne magnetic surveys are useful to map geologic structure on or inside the basement rocks or to detect magnetic minerals directly. Previous study has shown that Abeokuta is underlain by Precambrian rocks typical of the basement Complex of Nigeria (Rahaman, 1976). Some of the main rock types found in this area are granite-gneiss. This study deals with an estimation of shallow (residual) and deeper (regional) depth from the observed digitized aeromagnetic data of Abeokuta area using power spectral techniques. Thus, spectrum is a transformation of data from time or space domain to frequency or wave number domain respectively (Igboama and Ugwu, 2004).

Location of the study area: The study was carried out in Abeokuta area of Ogun State, South western Nigeria. The area is located within longitude 3°00 ‘E to 3° 30 ‘E and latitude 7°00 ‘N to 7°30‘ N covering an area 55×55 km, which is 3,025 km^2. Ogun state is bounded in the west by Benin Republic, in the south by Lagos, in the north by Oyo/Osun and in the east by Ondo State.

Abeokuta is one of the most prominent urban settlements in the South-western Nigeria. The gneiss-migmatite complex is the most widespread rock formation within the study area. It comprises gneisses, quartzite, calcsilicate, biotite-hornblende schist and amphibolites (Rahaman, 1976). The older granites and around the Abeokuta, are of late Precambrian to early Palaeozoic in age and are magmatic in the origin (Jones and Hockey, 1964).

Abeokuta falls within the basement complex of the geological setting of south-western Nigeria (Fig. 1). The basement complex rocks of Pre-Cambrian age are made up of older and younger granites, with the younger and older sedimentary rocks of the both tertiary and secondary ages. The area is underlain by basement rocks, which cover about 40% of landmass in Nigeria (Fig. 2) (Obaje, 2009).

Aeromagnetic data: Abeokuta area is covered by an aeromagnetic survey conducted by Nigeria Geological Survey Agency of Nigeria in 2006. The aeromagnetic data were obtained using a proton precession magnetometer with a resolution of 0.01 nT. Fugro Airborne Surveys carried out the airborne geophysical work. Aeromagnetic surveys were flown at 500 m-line spacing and 80 m-terrain clearance. The flight line direction was in the direction 135 azimuths while the tie line direction was in 45 azimuths. The average magnetic inclination and declination across the survey was 9.75^0 and 1.30^0, respectively. The geomagnetic gradient was removed from the data using International Geomagnetic Reference Field (IGRF).

Power spectrum: Spectral analysis of potential field data has been used extensively over the years to derive depth to certain geological features (Spector and Grant, 1970; Hahn *et al.*, 1976; Connard *et al.*, 1983; Gracia-Abdeslem and Ness, 1994) or the curie-temperature isotherm, (Okubo and Matsunaga, 1994; Shuey *et al.*, 1977; Blakely, 1988). Spectral analysis is the process of calculating and interpreting the spectrum of the potential field data. The spectral depth method is based on the principle that a magnetic field measured at the surface can be considered as an integral of magnetic signature from all depths (Rabeh, 2009). The power spectrum of a surface field can be used to identify average but maximum depth of source ensemble (Spector and Grant, 1970).

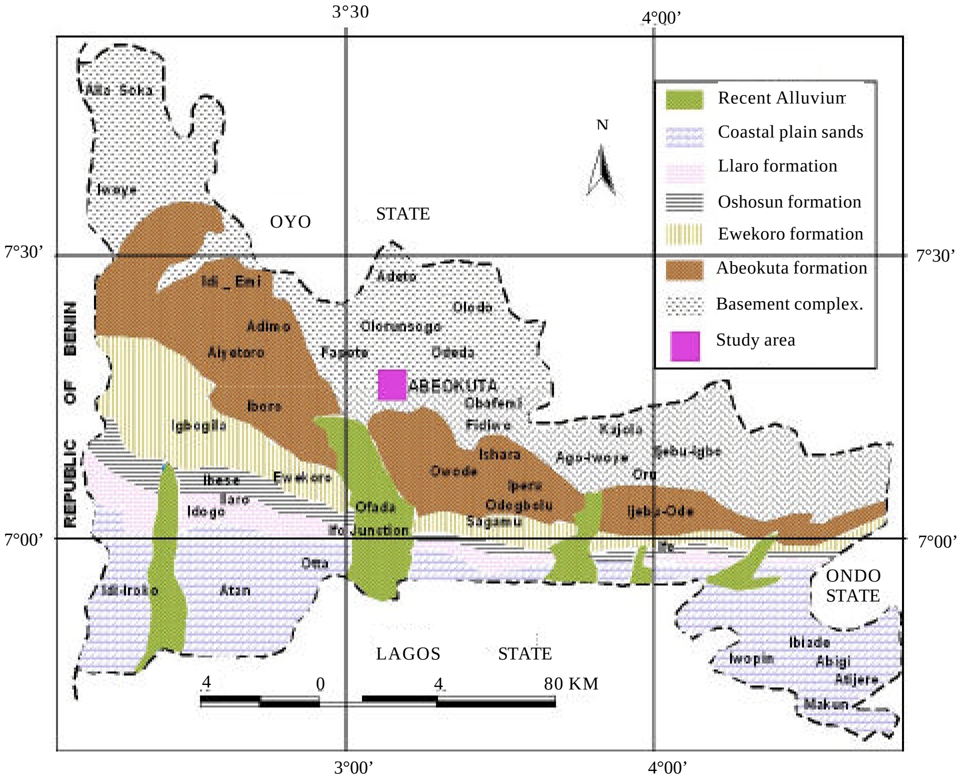

Fig. 1: Geological map of Ogun State showing the study area

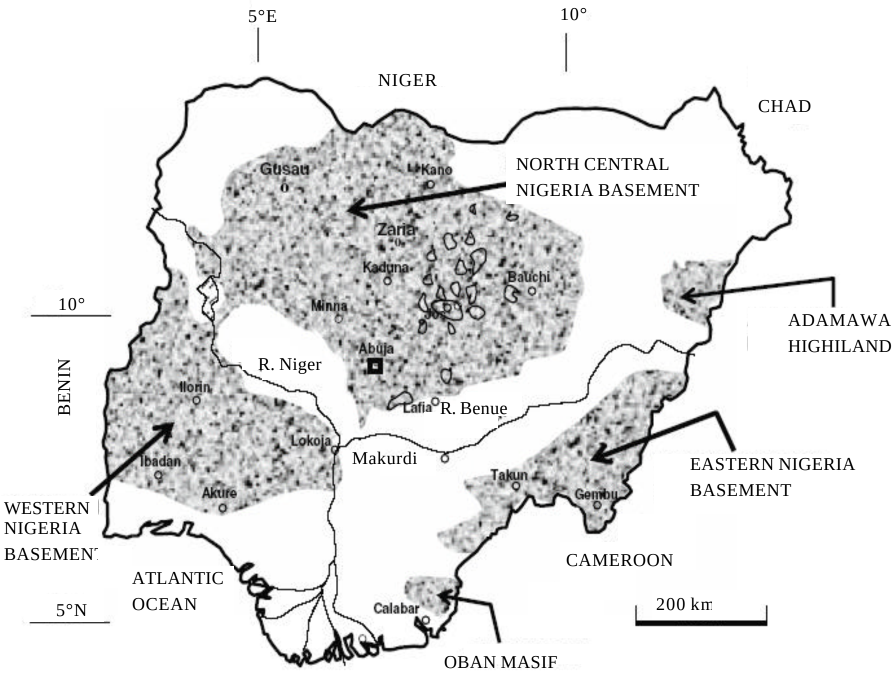

Fig. 2: Basement geological map of Nigeria, (Obaje, 2009) geological setting

Hence, spectral analysis method is suitable in providing the average depth value to the top of statistical ensemble of blocks of anomalous bodies. These anomalous sources can be interpreted in terms of subsurface structures.

Indirect interpretation, the information such as the maximum depth at which the body could lie and depth estimates of the centre of the body is obtained directly from the magnetic anomaly map. Inherent ambiguity may lead to infinite number of different configurations that may result in identical magnetic anomalies at the surface. Many researchers have used the calculation of the power spectrum from the Fourier coefficients to obtain the average depth to the disturbing surface or equivalently the average depth to the top of the disturbing body (Spector and Grant, 1970). It is necessary to define the power spectrum of a magnetic anomaly in relation to the average depth of the disturbing interface. It is also important to point out that the final equations are dependent on the definition of the wave number in the Fourier transform. For an anomaly with n data points the solution of Laplace equation in 2-D is:

$$M\left(X_j z\right)=\sum_{j=0}^{n-1} A_k e^{-i2\pi k x_j} e^{\pm\pi kz} \tag{1}$$

where, wave number k is define as k = 1/λ and A_k is therefore the amplitude coefficient of the spectrum:

$$A_k=\sum_{j=0}^{n-1} M\left(x_j, z\right) e^{-i2\pi k x_j} e^{\pm\pi kz} \tag{2}$$

for z = 0 Eq. 2, can be written as:

$$\left(A_k\right)_0=\sum_{j=0}^{n-0} M\left(x_j, 0\right) e^{-i2\pi k x_j} \tag{3}$$

Then Eq. 2 can be rewritten as:

$$A_k=\left(A_k\right)_0 e^{2\pi kz} \tag{4}$$

Then the power spectrum P_k is defined as:

$$P_k=\left(A_k\right)^2=\left(P_k\right)_0 e^{4\pi kz} \tag{5}$$

$$\log_e P_k=\log_e\left(P_k\right)_0+4\pi kz \tag{6}$$

The plot of log P against frequency reflects the average depth to the disturbing interface. The interpretation requires the best-fit line through the lowest frequency of the spectrum.

Therefore, the average depth can be estimated from the plot of Eq. (6) as:

$$m = \frac{\Delta \mathrm{LogP}}{\Delta K} \tag{7}$$

$$4\pi Z - m$$

$$h = Z = -\frac{m}{4p} \tag{8}$$

where, h = Depth to the magnetic source (Albora and Ucan, 2008).

RESULTS AND DISCUSSION

The total magnetic intensity (Fig. 3) over Abeokuta Area showed magnetic signature ranging from-10 nT to 102 nT. The magnetic high of magnitude 102 nT observed in some part of Northwestern and Northeastern part of the study area which could be as a result of presence of gneiss-migmatite complex is the most widespread rock formation in the area under consideration. These compared favorably well with geologic map on Fig. 1. The variation in the magnitude of the earth's magnetic field (Fig. 3) is to detect local changes in the properties of the underlying

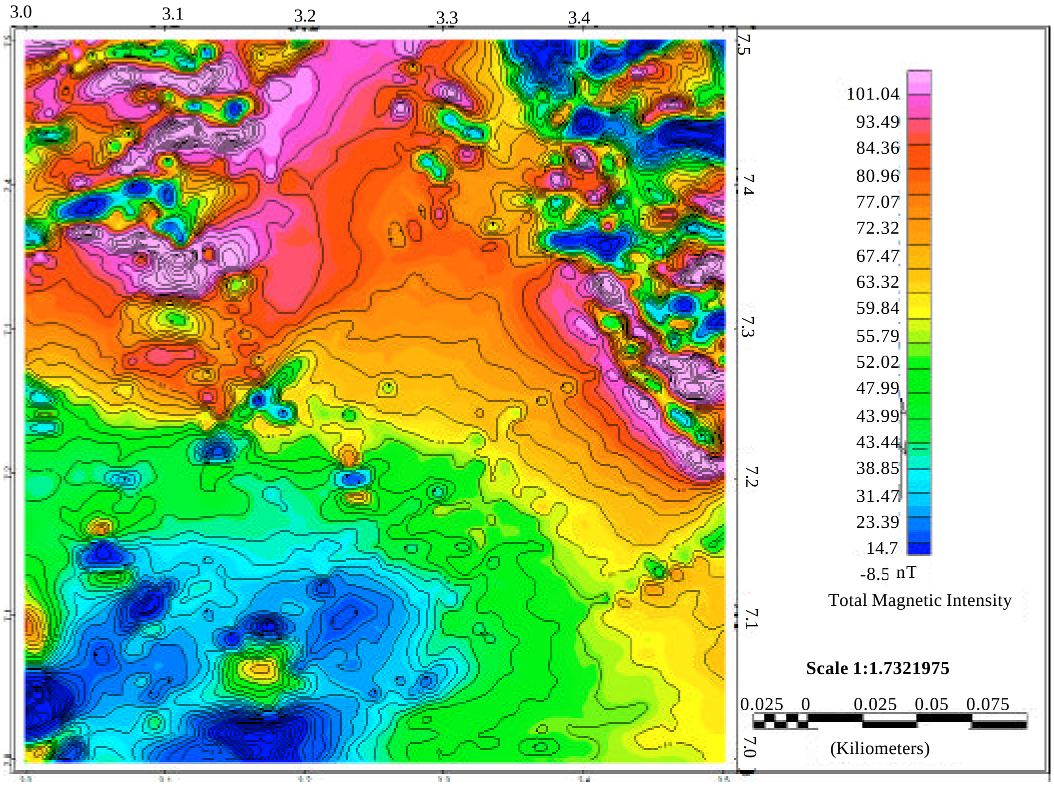

Fig. 3: Total intensity magnetic map of the study area (Long-wavelength magnetic anomalies are produced by regional geologic sources, cultural features and shallow geologic sources produce short-wavelength anomalies)

geology and also show that there is sizeable quantity of different magnetic deposit structures on the location. Figure 3 shows combination signals of regional, residual and noise but with the help of matched filtering, separation of signals was made possible as can be seen from Fig. 4 and 5, respectively.

In Fig. 4 there is a "noise" layer containing low-amplitude, very short-wavelength magnetic noise largely unrelated to geologic sources, a layer corresponding to near-surface magnetic sources, and Fig. 6 is an excellent representation of the field without the noise and contains the magnetic anomalies from the deepest and broadest features of the geology.

Graphs of the logarithms of the spectral energies against frequencies were plotted as in Fig. 6, from which depths were computed. This shows that the magnetic anomalies originate at two distinct mean depth levels. Two linear segments can be drawn from each graph: regional and residual components. The gradient of each linear segments were evaluated using equation 8 (Albora and Ucan, 2008) and was used to calculate the depth to the causative bodies (deep and shallow sources); where h and m are the depth and gradient, respectively.

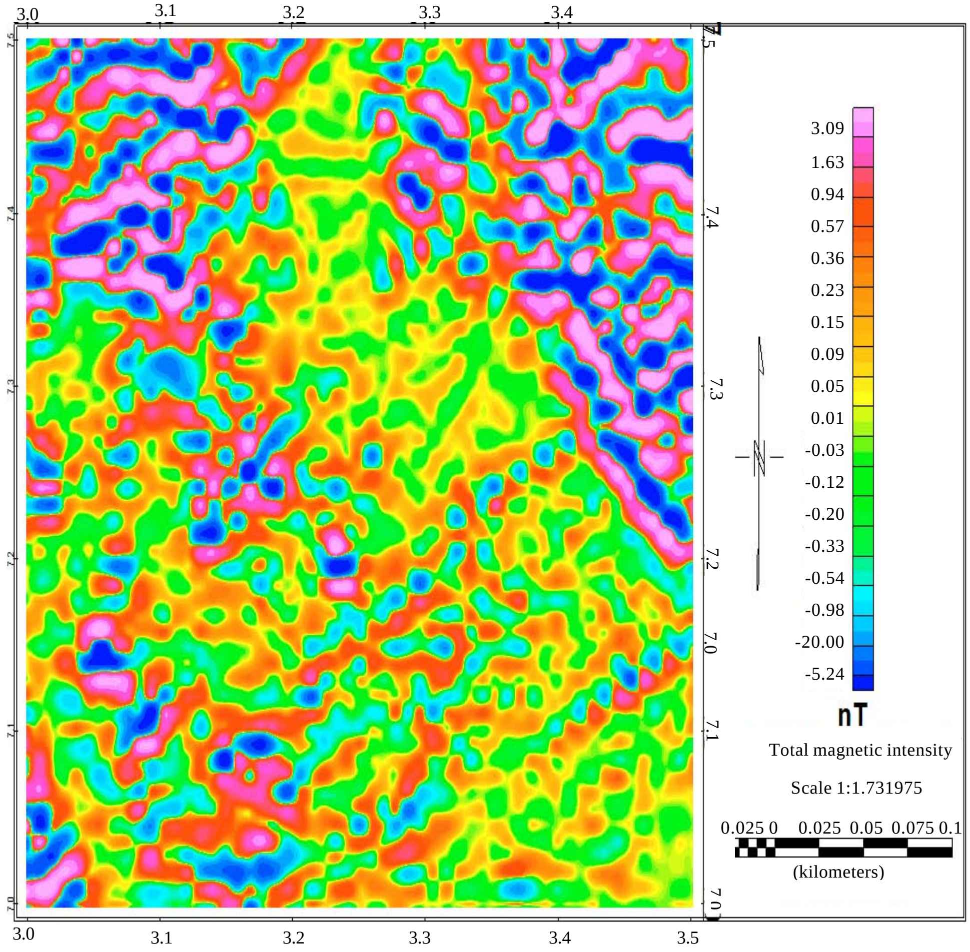

Fig. 4: Residual field of the total magnetic intensity map of Abeokuta (contains magnetic anomalies produced by shallow geologic sources and cultural sources)

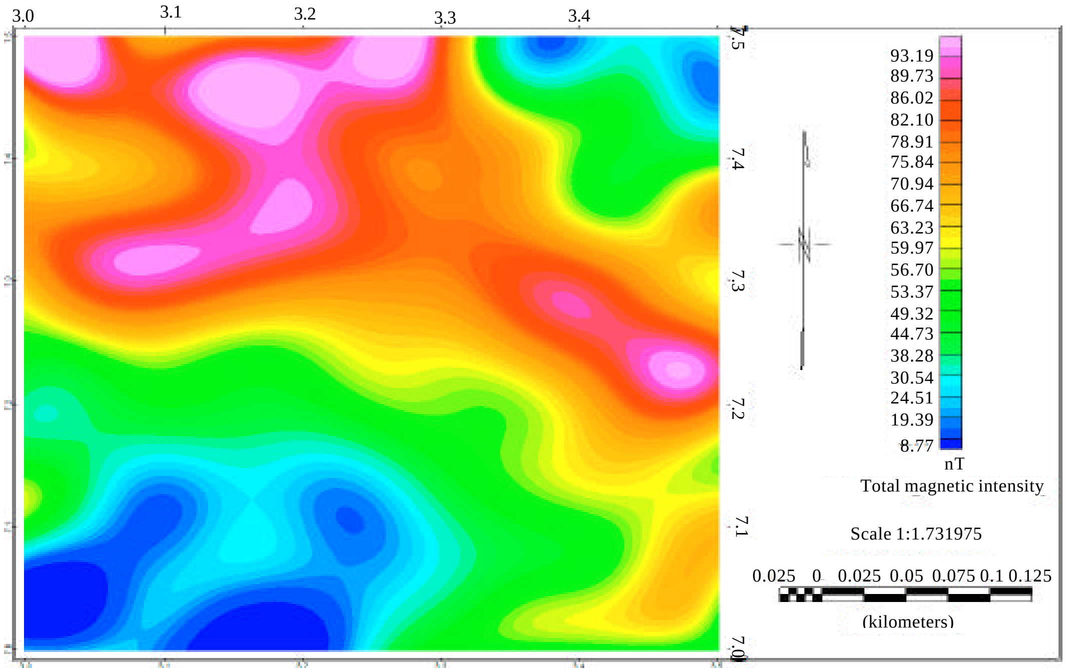

Fig. 5: Regional field of the total magnetic intensity map of Abeokuta (contains the magnetic anomalies from the deepest and broadest features of the geology)

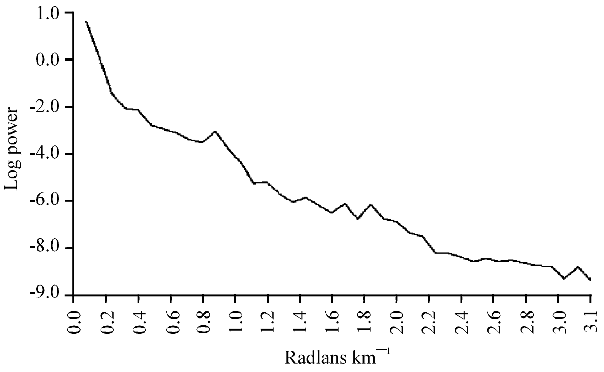

Fig. 6: Radially averaged power spectrum for the magnetic data (curves representing the power spectra of simple equivalent magnetic layers)

Depth estimates from spectral analysis of magnetic data along the profile indicate a two-depth source model. This is in agreement with earlier study by Bansal *et al.* (2010), where the application of scaling spectral method on Bouguer anomaly of Kucth indicates variation in the depth of anomaly sources. The mean depth of the deeper sources (2.797 km) could be identified with the basement while the mean depth of the shallower sources (0.426 km) could be identified as near surface intrusive and local changes on the earth surface. The magnetic basement depth range from 0.467-2.797 km compare well with what obtained within Ibadan area by Olowofela *et al.* (2011) because airborne magnetic data of Abeokuta dovetail into part of Ibadan. The result obtained is in support with the earlier study by Kasidi and Ndatuwong, 2008 on aeromagnetic data over Longuda plateau and environs where the mean depth of shallow sources was 0.591 and 2.26 km for the depth to deeper magnetic sources. Hassanein (2001) used Filon Fourier spectral analysis and obtained 0.7 and 6.0 km for residual and regional anomalies, respectively.

However, the study carried out by Nwankwo *et al.* (2008) on Sedimentary Formation of Northern Nupe basin found depth to magnetic basement to vary from 0.52-4.38 km while depth range of 0.24-1.74 km was attributed to shallow sources. Also, Onuba *et al.* (2011) evaluate aeromagnetic anomalies over okigwe Area, South-eastern Nigeria using Half-slope method to obtained on the average depth of the deeper magnetic sources ranging from 2.0-4.99 km while the shallow magnetic sources ranges from 0.4-1.99 km.

CONCLUSION

The results of this spectral analysis show clearly the variation along profiles in the surface of magnetic basement across the study area. The depth of the deeper sources 2.797 km and is believed to correspond to the surface of the magnetic basement in the study area. The shallower depth, 0.426 km, may refer to some major magnetic units, uplifted basement surface as well as to some local magnetic features.

These results therefore demonstrate the applicability of the spectral method of magnetic interpretation in estimating depths to the surface of magnetic basement in a basement complex.

ACKNOWLEDGMENT

The authors appreciate the Nigerian Geological Survey Agency, Abuja Nigeria for providing the Aeromagnetic data for this research work.

REFERENCES

Albora, A.M. and O.N. Ucan, 2008. Gravity anomaly separation using 2-D wavelet approach and average depth calculation. Geophysics, 58: 395-404.

Bansal, A.R., V.K. Rao, V.P. Dimri and K.K. Babu, 2010. Heterogeneity in kutch (India) an intraplate seismic region from gravity data. Proceedings of the EGM International Workshop, April 11-14, 2010, Capri, Italy.

Blakely, R.J., 1988. Curie temperature isotherm analysis and tectonic implications of aeromagnetic data from Nevada. J. Geophys. Res., 93: 11817-11832.

Connard, G., R. Couch and M. Gemperte, 1983. Analysis of aeromagnetic measurements from the cascade range in central oregon. Geophysics, 48: 376-390.

Gracia-Abdeslem, J. and G.E. Ness, 1994. Inversion of power spectrum from anomaly. Geophysics, 59: 381-401.

Grauch, V.J.S., M.R. Hundson, A.M. Scot and J.S. Caine, 2006. Source of along-strike variation in magnetic anomalies related to ultra sedimentary faults: A case study from Rio Granda Rifts, USA. Explor. Geophys., 37: 372-378.

Hahn, A., E. Kind and D.C. Mishra, 1976. Depth Estimation of magnetic source by means of fourier amplitude spectral. Geophys. Prospect., 24: 287-305.

Hassanein, H., 2001. Using filon fourier spectral analysis technique for filtering of aeromagnetic data and outlining subsurface structures of helma-madrakah area kingdom of Saudi Arabia. JKAU: Earth Sci., 12: 105-125.

Igboama, W.N. and N.U. Ugwu, 2004. Basement depths in the anambra basin determined by one-dimensional spectral analysis of aeromagnetic data. J. Applied Sci., 7: 4411-4418.

Jones, H.A. and R.D. Hockey, 1964. The geology of parts of south western Nigeria. Bull. Geol. Surv. Nigeria, 31: 101-101.

Kasidi, S. and L.G. Ndatuwong, 2008. Spectral analysis of aeromagnetic data over longuda plateau and environs North-Eastern Nigeria. Continental J. Earth Sci., 3: 28-32.

Nabighian, M., V. Grauch, R. Hansen, T. Lafehr and Y. Li *et a.*, 2005. The historical development of the magnetic method in exploration. Geophysics, 70: 33ND-61ND.

Nwankwo, D.I., T.I. Owoseni, D.A. Usilo, I. Obinyan, A.C. Uche and I.C. Onyema, 2008. Hydrochemistry and plankton dynamics of Kuramo lagoon. Life Sci. J., 5: 50-55.

Obaje, N.G., 2009. Geology and Mineral Resources of Nigeria. Springer, Heidelberg, Pages: 221.

Okubo, Y. and T. Matsunaga, 1994. Curie point depth in Northeast Japan and its correlation with regional thermal structure and seismicity. J. Geophys. Res., 99: 22363-22371.

Olowofela, J.A., B.S. Badmus, S.A. Ganiyu, O.T. Olurin and P. Babatunde, 2011. Source location and depth estimation from digitized aeromagnetic data acquired from a basement complex formation. Earth Sci. India, 4: 136-142.

Onuba, L.N., G.K. Anudu, O.I. Chiaghanam and E.K. Anakwuba, 2011. Evaluation of aeromagnetic anomalies over Okigwe area South-Eastern Nigeria. Res. J. Environ. Earth Sci., 3: 498-507.

Rabeh, T., 2009. Prospecting for the ferromagnetic mineral accumulations using the magnetic method at the Eastern Desert, Egypt. Geophys. Eng., 6: 401-411.

Rahaman, M.A., 1976. A Review of the Basement Geology of South Western Nigeria. In: Geology of Nigeria, Kogbe, C.A. (Ed.). Elizabethan Publication Co., Lagos, Nigeria, pp: 41-58.

Shuey, R.T., D.K. Schellinger, A.C. Tripp and L.B. Alley, 1977. Curie depth determination from aeromagnetic spectra. Geophys. J. Int., 50: 75-101.

Spector, A. and F. Grant, 1970. Statistical models for interpreting aeromagnetic data. Geophysics, 35: 293-302.