DETERMINATION OF DEPTH TO BASEMENT OF KALTUNGO AND GUYOK AREA USING HIGH RESOLUTION AIRBORNE GRAVITY DATA

Nwobodo, A. N[1]. Chima ,A. I[2]. Anih, J. O[3] and Onyia, A. I[4]

[1,2,4] Department of Industrial Physics Enugu State University of Science and Technology
[3]Department of Physics, Federal College of Education Eha – Amufu. Enugu State

Correspondence author's email: anthonia.nwaobodo @yahoo.com, ngenendidi@yahoo.com anthonia.nwaobodo@esut.edu.ng

ABSTRACT
The airborne gravity data of Kaltungo and Guyok, Upper Benue Trough, Nigeria which covers an area of approximately 6050 km^2 in the north-eastern part of Nigeria between latitudes 9°30' and 10°00' North and longitudes 11°00' and 12°00' East have been interpreted qualitatively and quantitatively. Regional anomaly was removed from the Bouguer gravity map to obtain the residual anomaly using polynomial fitting. The Bouguer gravity anomaly map identifies regions of gravity high which corresponds to region with high density contrast and gravity lows which correspond to regions of low density contrast. The structural trend map showed the occurrence of subsurface linear structures which could be the presence of faults in the study area. Spectral analysis was employed in the quantitative interpretation in order to determine the depth to basement and basement topography of the area. The result from spectral analysis shows that the depth to the bouguer gravity deep sources ranges from 1.587 to 4.365 km while the depth to the shallow sources ranges from 0.610 to 1.117 km. The sedimentary thickness obtained in this work indicate the possibility of hydrocarbon accumulation in the study area but the real possibility of that and potential assessment needs further research.

INTRODUCTION

Geophysics is the application of principle of physics to the study of the earth's interior. The study of geophysics has helped man to locate buried materials usually of geophysical interest in the earth's sub-surface. These materials usually manifest as anomalies which could be sensed by different geophysical survey methods. Airborne geophysical survey is an important aspect of modern geophysics; it allows faster and usually cheaper coverage of large areas. It involves measuring the variation of different physical or geochemical parameters of the earth such as distribution of magnetic minerals, density, electric conductivity and radioactive element concentration (Kasidi and Ndatuwong, 2008; Sunmonu and Alagbe, 2014). Airborne geophysics, form a critical component of geological mapping and mineral resource inventory programmes in many countries. The data they provide, aid better geological knowledge within a country or region and also form part of a larger initiative that helps to attract investments in the mining sector and grow gross domestic product (GDP). The principle of airborne gravity survey is similar to land gravity survey carried out with a hand-held gravimeters but airborne gravity survey allows much larger areas of the Earth's surface to be covered quickly for regional reconnaissance. The aircraft typically flies in a grid-like pattern with height and line spacing determining the resolution of the data. As the aircraft flies, the gravimeters measures and records the bouguer gravity anomaly at the sensor but in airborne gravity spacecraft satellite survey, the Grace Gravity Model Sensor is mounted onboard two satellites and the bouguer gravity anomaly is measured at the sensor.

No geophysical work on determination of depth to basement using spectral analysis technique of airborne satellite gravity data has been carried out in Kaltungo and Guyok areas, though some work have been done in Upper Benue Trough in which the study area falls. Some of them are Salako and Udensi (2013), Sunmonu and Alagbe (2014), Alagbe (2015) and Salako (2014). Therefore, in contribution to the understanding of geology and hydrocarbon potentials of the upper Benue Trough, we have considered the use of airborne space satellite gravity survey to determine the depth to basement of Kaltungo and Guyok upper Benue Trough, Nigeria.

GEOLOGY OF THE STUDY AREA

This study covers an area of approximately 6050 km^2 in the north-eastern part of Nigeria between latitudes 9°30' and 10°00' North and longitudes 11°00' and 12°00' East covering Kaltingo and Guyok which are located in the Upper Benue Region The Upper Benue Trough is part of the Benue Trough of Nigeria and is comprised of three basins: the east–west trending Yola Basin (Yola Arm), the north– south trending Gongola Basin (Gongola Arm) and the northeast– southwest trending Lau Basin (Main Arm). The geological map of Nigeria for the Upper Benue is shown in Figure 1. Stratigraphic relationships in the Upper Benue Trough are depicted in Figure. 2. The earliest Cretaceous sequence is the continental Bima sandstone, which rests unconformably on the undulating PreCambrian Basement. The unit is a thick and widespread series of continental grits, sandstones and clays. In the north, these beds are wholly continental, but in the south, marine shales occur in the lower part of the formation (Carter *et al.*, 1963). Overlying the Bima Formation is the paralic Yolde Formation (Early Turonian), comprising alternating sandstones and shales. Thesandstones are fine- to medium-grained and light-brown, with shale and limestone intercalations. Thick marine Turonian shales with limestones at their base overlie the transitional deltaic-to-marine Yolde Formation in many localities. These shales, called the Pindiga Formation in the Upper Benue Trough, are found in the south to be laterally equivalent to the Jessu Formation, consisting of interbeds of shales, sandstones and limestones, the gypsiferous Numanha Formation and the Sukuliye Formation (shales and limestones). The type localities of the Sukuliye and Numanha Formations occur at Sukuliye and Lamja Kasa, respectively (Carter *et al.*, 1963). These two units succeed the Jessu Formation.

ISSN 2229-5518

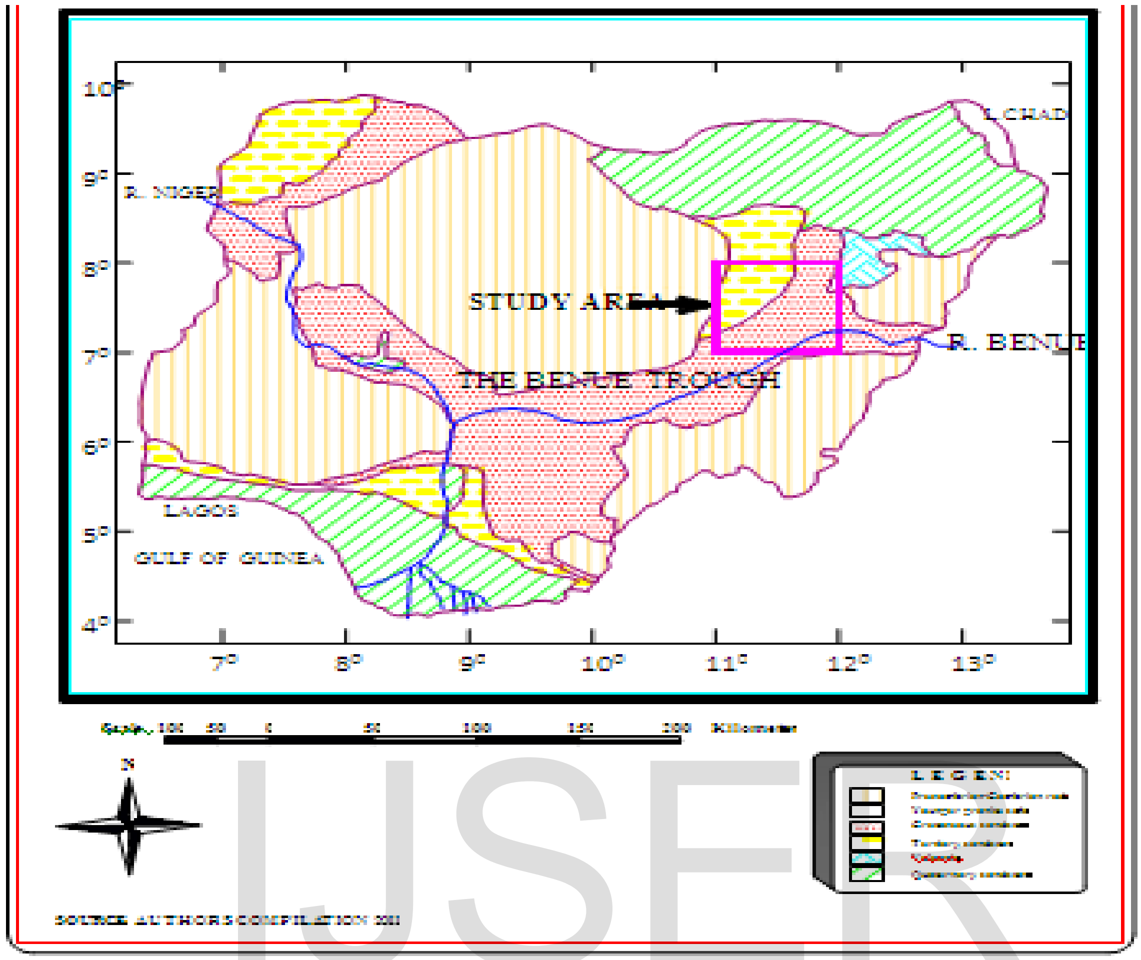

Figure 1. Map of Nigeria showing the study area

MATERIALS

The high resolution airborne magnetic data of Kaltungo (sheet 173) and Guyok (sheet 174), used for this study, were obtained from the Nigerian Geological Survey Agency (NGSA). The airborne gravity data were obtained using GRACE GRAVITY MODEL Sensor onboard 2 satellites by National Aeronautics and Space Administration (NASA) and German Aerospace Center in 2013. The airborne gravity Bouguer anomaly data (gravity data) were obtained in XYZ format; X and Y are distance in meters measured along east and north direction respectively. While Z is the Bouguer anomaly values measured in miligal.

METHOD

The digitized airborne gravity data of Kaltungo and Guyok were merged together to produce one single sheet which forms the study area. The merged data was gridded in order to produce the Bouguer gravity map of the study area. First order polynomial fitting was used for the regional – residual separation using Oasis Montaj software. The residual data was further divided into 18 different cells(windows) using Microsoft-excel sort and filter for spectral analysis.

The spectral depths are usually computed from measurement made on the widths and slopes of individual anomalies of the aerogravity profiles. The method uses the principle that a gravitational field measured at the surface can be considered to be the integral of gravity signatures from all depths. The Fourier integral transform of a function that varies continuously along a profile of observation, such as potential field, transforms the function from the space to the frequency domain. In its complex form, the two dimensional Fourier transform pair may be written as

$$G(u,v) = \iint_{-\infty}^{\infty} g(x,y)e^{i(u_{x-v_y})}\ dxdy \quad 1$$

and

$$G(x,y) = \frac{1}{4\pi^2}\iint_{-\infty}^{\infty} g(u,v)e^{i(u_{x-v_y})}\ dudv \quad 2$$

where *u* and *v* are the angular frequencies in *x* and *y* directions respectively.

For depth estimations for magnetic field data, this is usually expressed according to (Spector and Grant,1970) as

$$E(u,v)=exp(-4\pi hr) \quad 3$$

The exp $(-4\pi hr)$ term is the dominant factor in the power spectrum. The average spectrum of the partial waves falling within this frequency range is calculated and the resulting values constitute the radial spectrum of the anomalous field. If we replace *h* with *Z* and *r* with *f*; then

$$Log\ E = -4\pi Zf \quad 4$$

*w*here *Z* is the required anomalous depth; and *f* the frequency. Therefore the linear graph of logE against *f* gives slope $m = -4\pi Z$. The mean depth (*Z*) of the magnetic source is thus given by

$$Z = -\frac{m}{4\pi} \quad 5$$

The following procedure was employed in the use of this method:

i) *Division of the study area into spectral cells*: The two residual blocks of the study area were subdivided into 18 spectral blocks, each covering a square area of 18.3 km by 18.3 km using the filtering tool of Microsoft Excel software (Figure 6) for easy handling of the large data involved.

ii) *Generation of radial energy spectrum*: The Microsoft Excel analysis tool pack was used to transform the residual air borne gravity data into the radial energy spectrum for each block.

iii) *Plots of Log of Energy vs the frequency*: The Log-power spectrum of the source has a linear gradient whose magnitude is dependent upon the depth of the source. Graphs of spectral energy against frequencies for the 18 spectral cells were plotted. These series of points which fall on one or more straight line segments represent 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. The slopes of these graphs in the higher and lower portions of the graphs reveal two depth source models: h_1 and h_2 for shallow and deeper sources respectively. A sample of one of the plots is shown in Figure 7.

iv) *Estimation of the depth to magnetic sources:* The slopes of each of the line segments were first evaluated. The mean depth (*h*) of burial of the ensemble was then calculated using equation (5).

RESULTS AND DISCUSSION

The Bouguer anomaly of the study area varies from -67.4 mGal to -25.8 mGal (figure 2). The colour legend bar identifies regions of gravity high (red and pinks) which corresponds to region with high density contrast beneath the surface; intermediate values (green and yellow) and gravity lows (blue colour) that correspond to regions of low density contrast.

ISSN 2229-5518

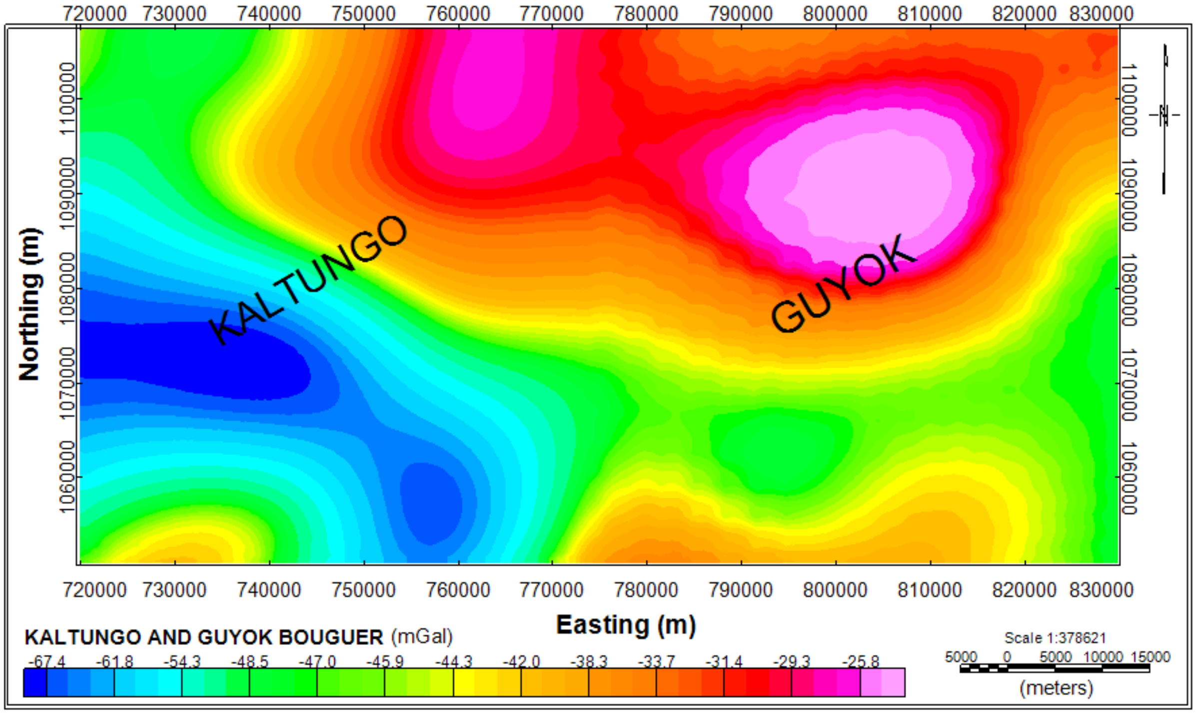

Figure. 2: Bouguer gravity map of the study area.

The residual Bouguer anomaly of the study area varies from -15.4 mGal to 18.3 mGal (Figure. 3). The colour legend bar identifies regions of gravity high (red and pinks) which corresponds to region with high density contrast beneath the surface; intermediate values (green and yellow) and gravity lows (blue colour) that correspond to regions of low density contrast. Figure 3 is the regional Bouguer anomaly map. The values range from -56.1 mGal to -29.4 mGal.

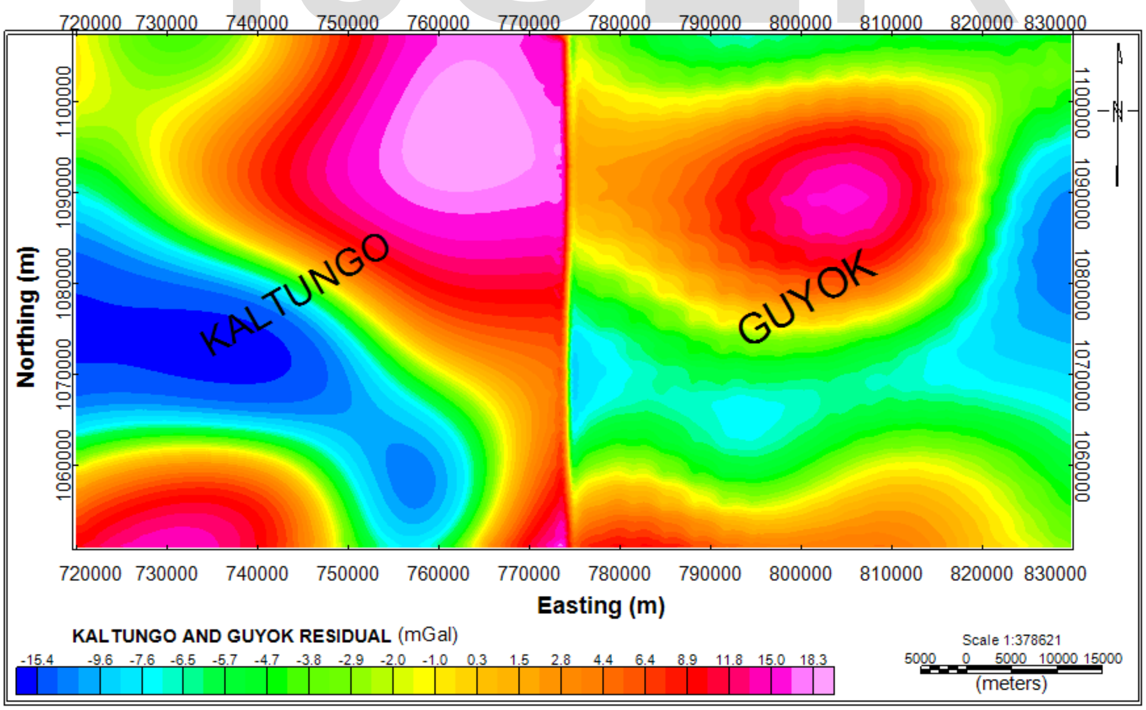

Figure. 3: Residual gravity map of the study area

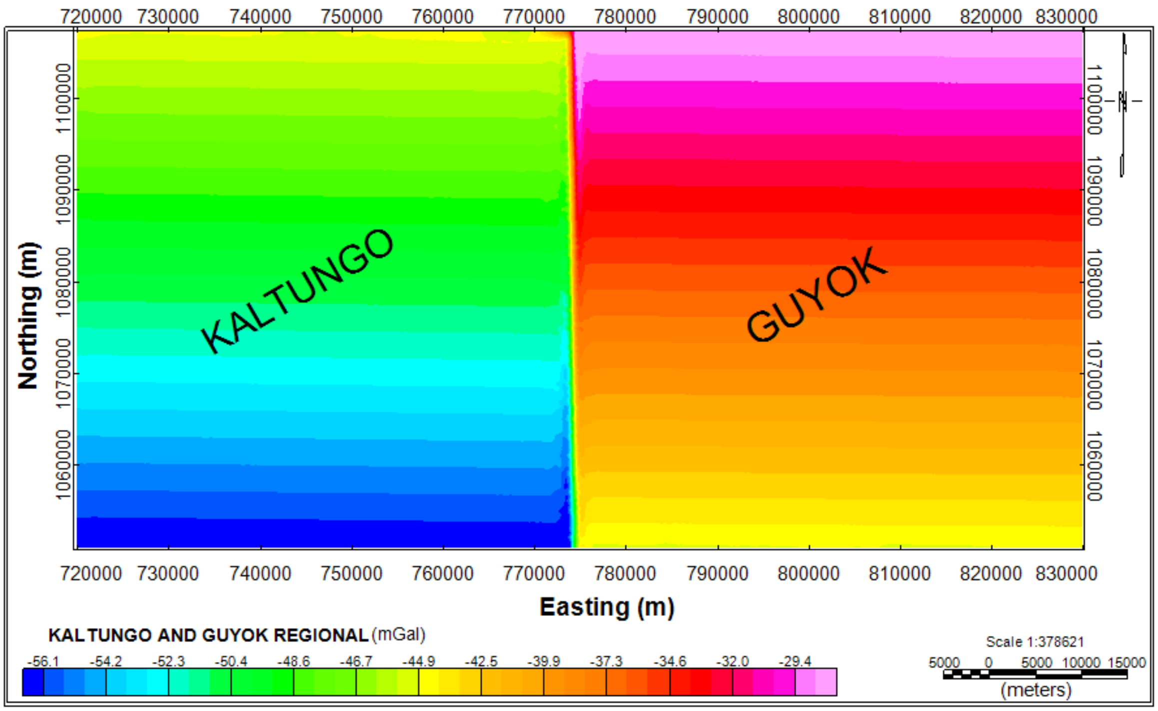

Figure. 4: Regional Gravity Map of the study area

The first vertical derivative computed on the residual data of airborne gravity of the study area enhanced the shallow sources by suppressing the effect of the deeper ones, this helped to reveal near surface intrusions (Figure 5). The second vertical derivative sharpens the effect of the first vertical derivatives and helps to determine the edge of the anomalous body (Figure. 6). The horizontal derivative shows more exact location for faults (figure. 7).

Figure .8 is the structural trend map showing the lines of faults within the study area. The most dominant trend are seen in Kaltungo area. This could be a favorable structure for the control of mineral deposits in the area and it could also serve as reservoir for the suspected minerals in the study area (Sunmonu and Alagbe, 2014; Alagbe, 2015). The structural trend map was obtained from the residual grid using Oasis Montaj software.

ISSN 2229-5518

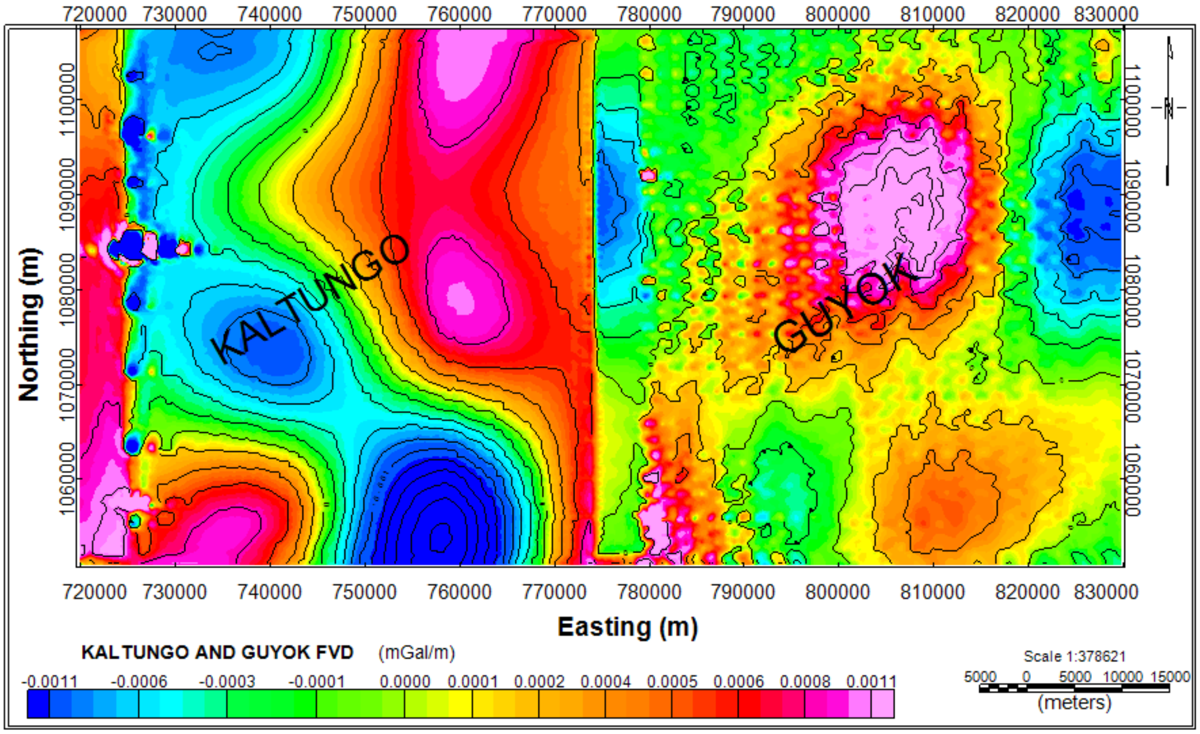

Figure. 5: Airborne gravity first vertical derivative map of the study area.

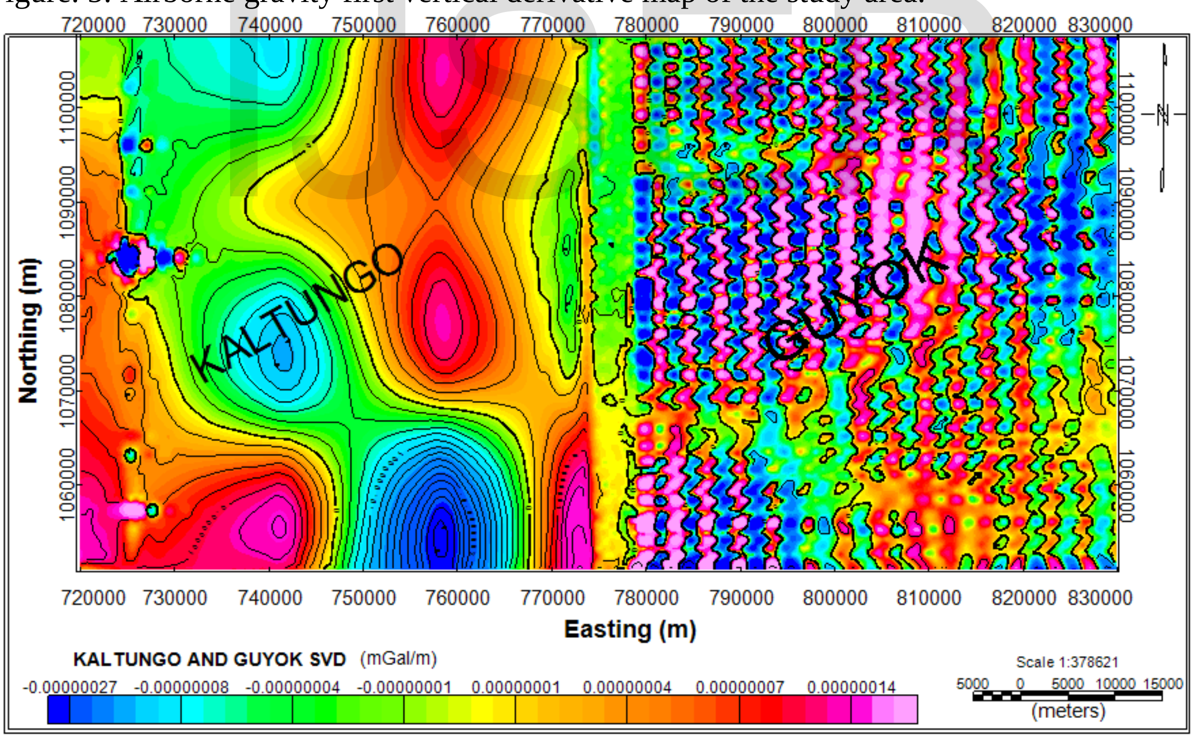

Figure. 6: Airborne gravity second vertical derivative map of the study area.

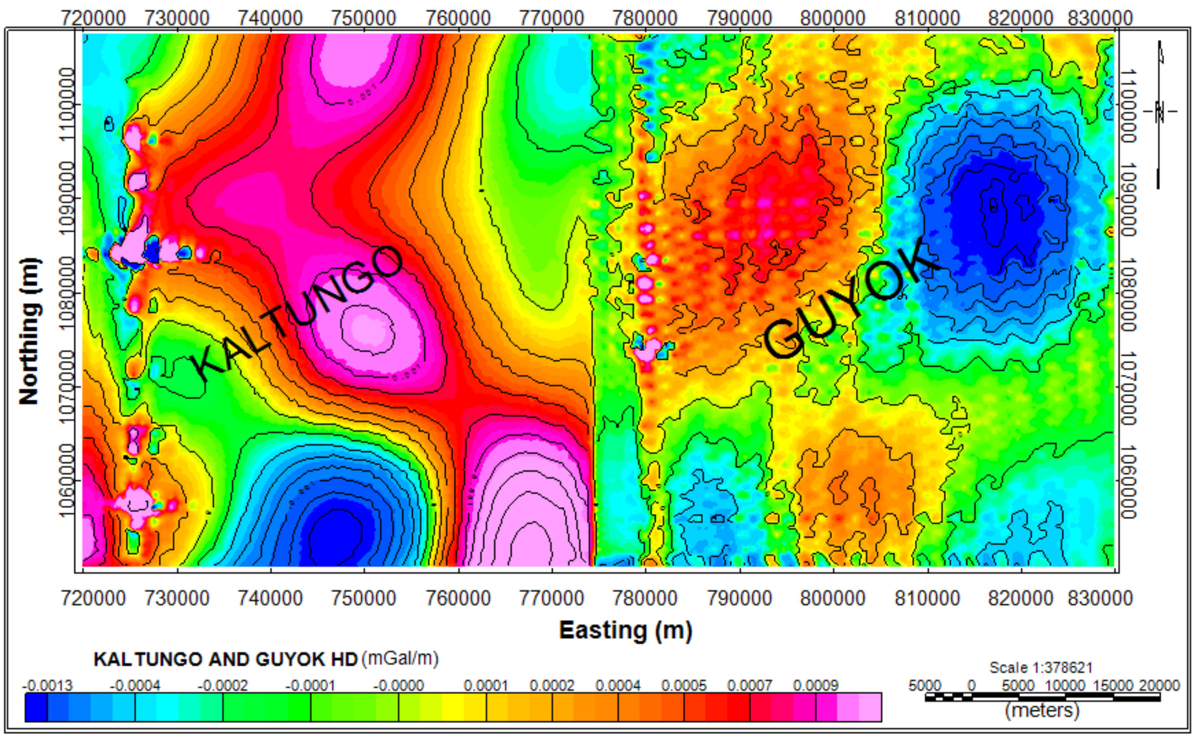

Figure. 7: Airborne gravity horizontal vertical derivative map of the study area.

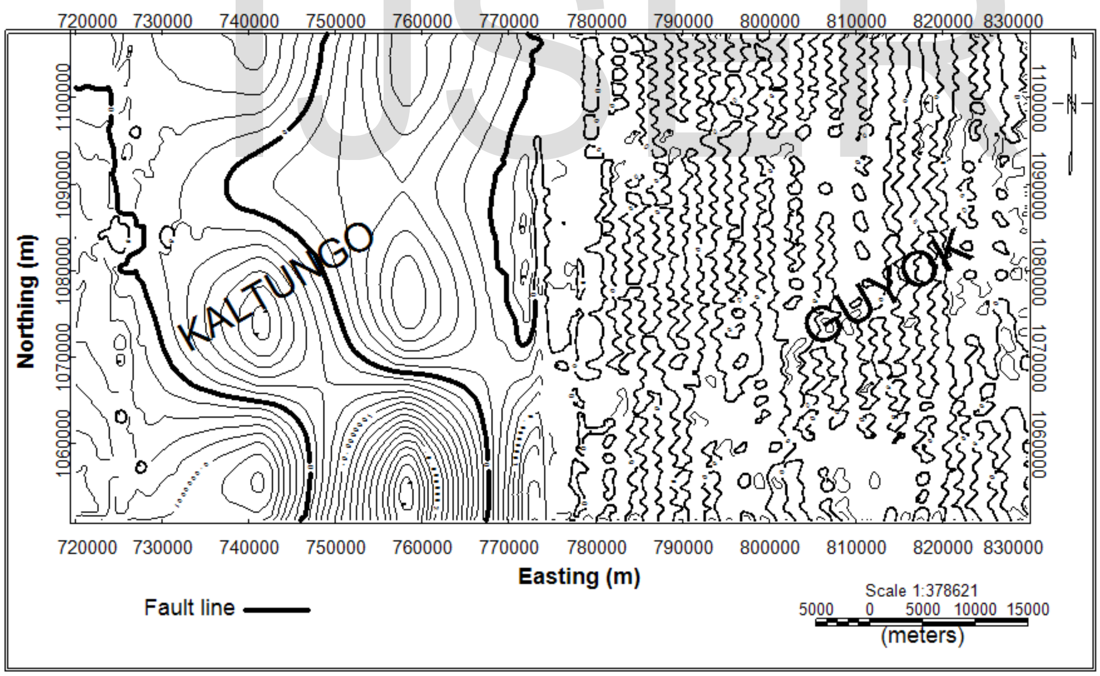

Figure. 8: Structural trend map showing the line of the faults in the study area

From the graphs of the 18 spectral profiles (figure. 9.) the gradient of each of the line segments in figure.10(a,b) were evaluated. The depth of buried ensemble was then calculated.

From the calculated values for the 18 spectral blocks, the gravity basement depth were plotted and contoured using surfer 32 software. The deep bouguer sources vary from 1.587 to 4.365 km (Figure. 11), whereas the shallow bouguer source varies from 0.610 to 1.117 km (Figure. 12).

The deep bouguer sources suggest depth to precambrian basement while the shallow bouguer sources depict depths to basic intrusive bodies. The result from spectral analysis shows that the depth to the bouguer gravity deep sources ranges from 1.587 to 4.365 km while the depth to the shallow sources ranges from 0.610 to 1.117 km. The deep depth to basement is shallowest (purple colour) in the Guyok part of the study area, while it is deepest (blue colour) in the Kaltungo part of the study area. These depths are found to be within the range of depths predicted by earlier researchers that worked in Upper Benue Trough. Sunmonu and Alagbe (2014) deduced a deep source magnetic depth ranging between 5 km and 8.5 km, intermediate depths between 2 km to 4.5 km and shallow magnetic source depth between 0.01 km and 2.5 km from aeromagnetic data of Upper Benue Trough using spectral analysis. The calculated deep depth to basement for the 18 spectral plots was used to construct the 3D basement topography map of the study area (Figure.13). The topographic map generated using Surfer 32 software shows the undulating nature of the basement surface with thickest sediments at the Kaltungo region of the study area and an elevation with shallowest sediments at the Guyok part of the study area. The irregular nature of the basement presented by the 3D basement topographic map could be possibly associated with faults that aids the migration of hydrocarbon and other mineralized deposits.

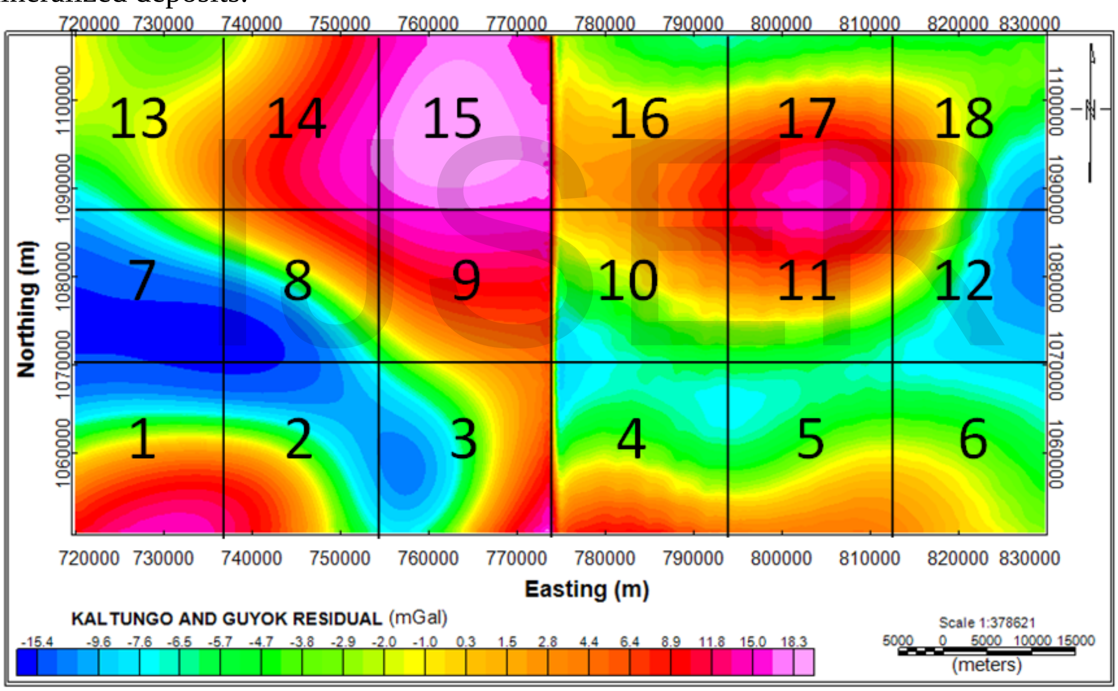

Figure. 9: Division into 18 spectral blocks for estimation of the depth to basement.

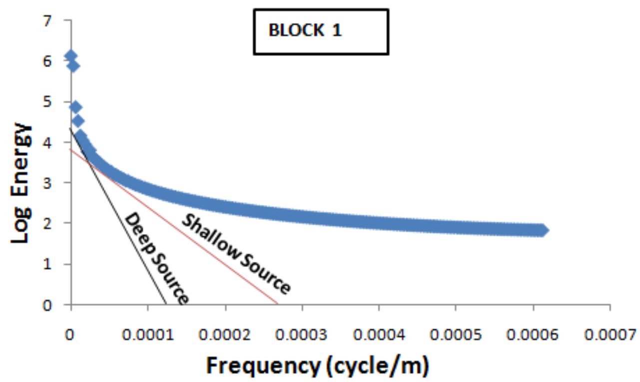

Figure.10(a): Spectral plots of logarithm of Energy against Frequency (cycle per meter)

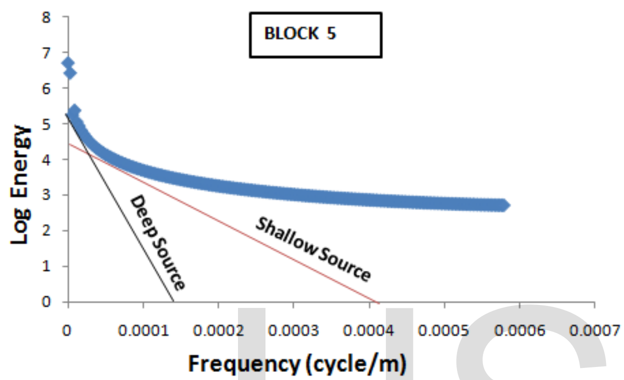

Figure.10(b): Spectral plots of logarithm of Energy against Frequency (cycle per meter)

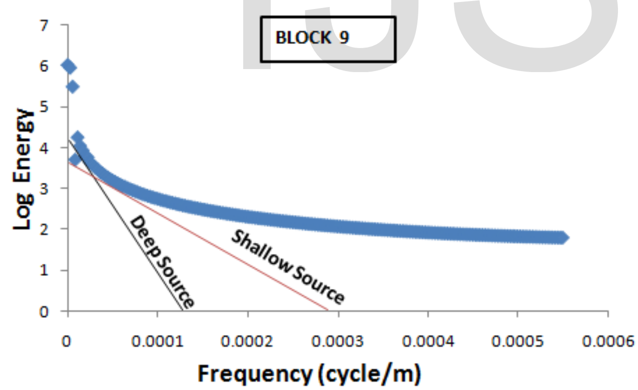

Figure.10(c): Spectral plots of logarithm of Energy against Frequency (cycle per meter)

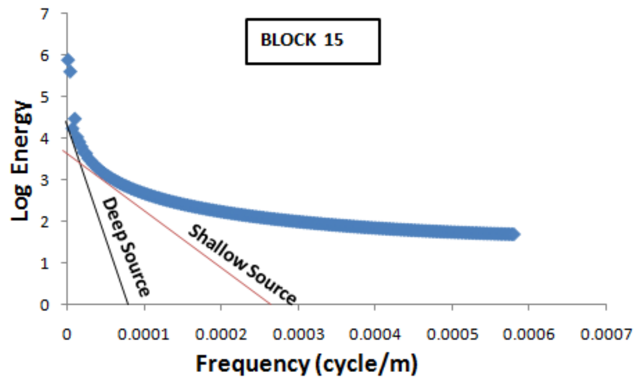

Figure.10(d): Spectral plots of logarithm of Energy against Frequency (cycle per meter)

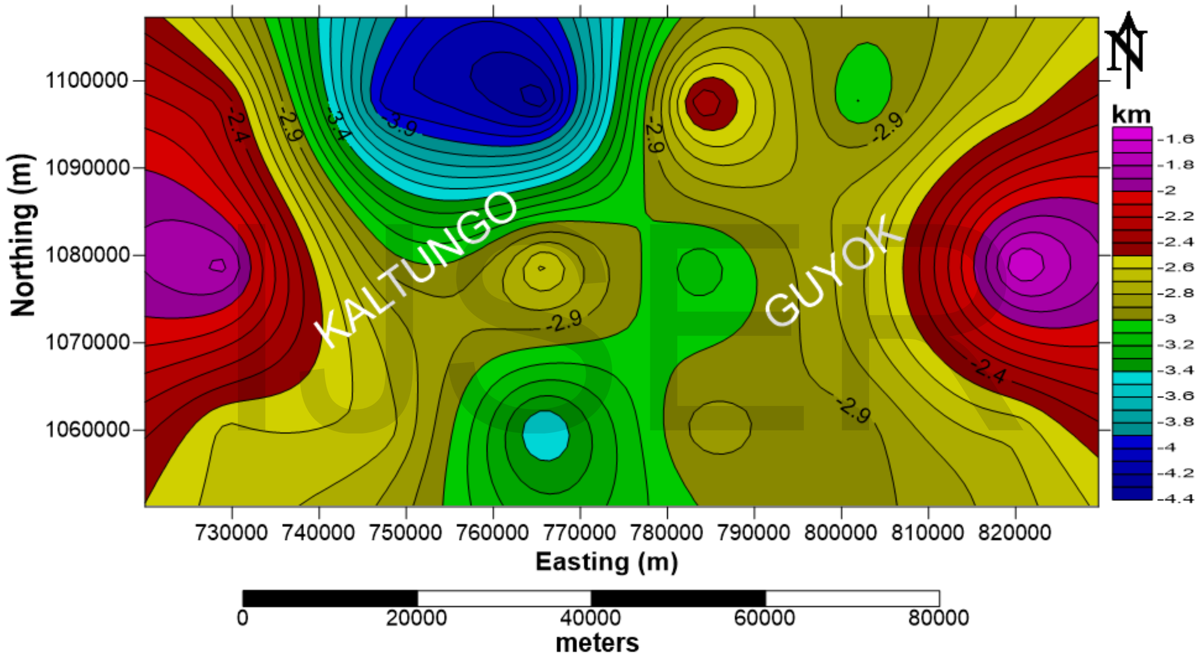

Figure.11 : Deep depth to basement map.

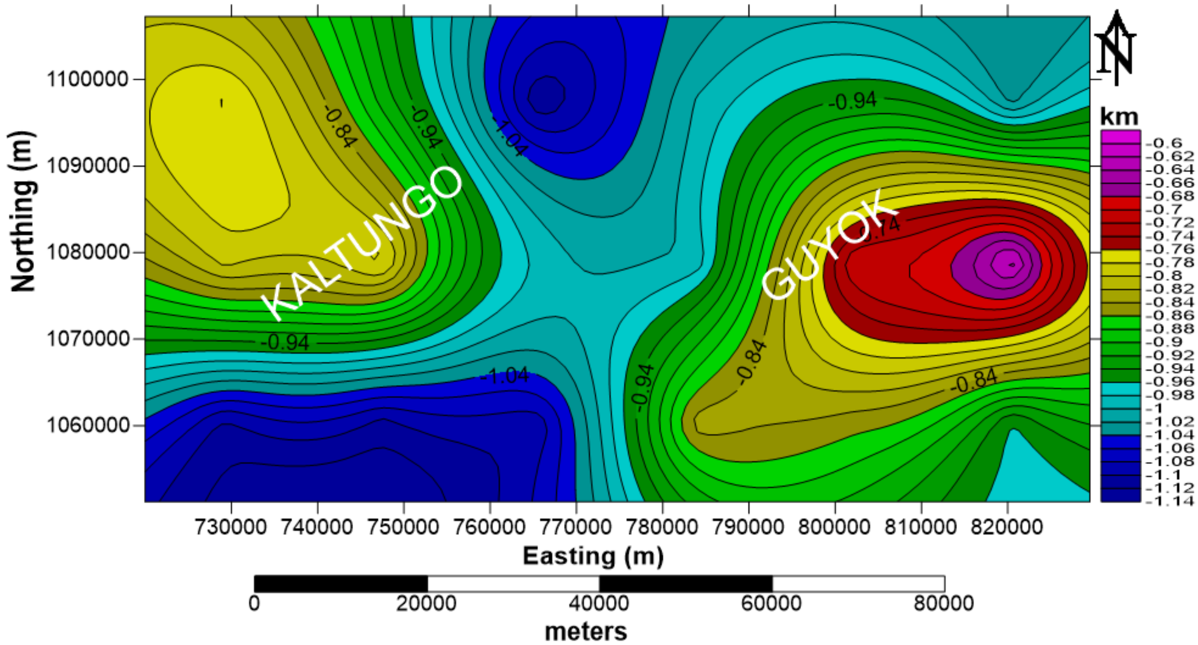

Figure.12: Shallow depth to basement map.

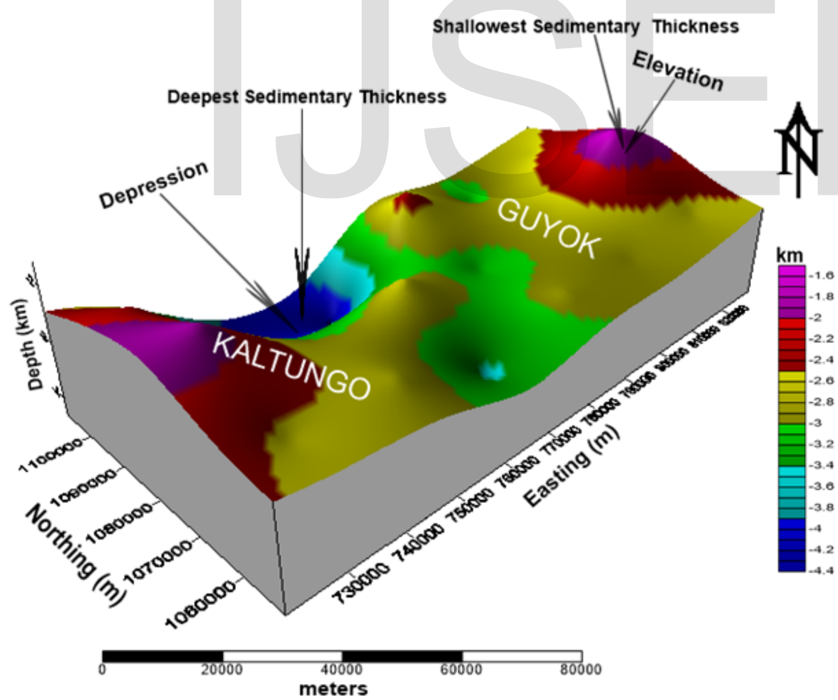

Figure.13: 3D map of the study area showing the basement topography.

CONCLUSION

The airborne gravity data of Kaltungo and Guyok, Upper Benue Trough, Nigeria have been interpreted qualitatively and quantitatively. The Bouguer gravity anomaly map identifies regions of gravity high which corresponds to region with high density contrast and gravity lows which correspond to regions of low density contrast. The structural trend map showed the occurrence of subsurface linear structures which could be the presence of faults in the study area.The sedimentary thickness obtained in this work indicate the possibility of hydrocarbon accumulation in the study area but the real possibility of that and potential assessment needs further research.

ACKNOWLEDGEMENT

We are grateful to Nigerian Geological Survey Agency for providing the data used for this research

REFERENCES

Alagbe, O. A. (2015). Depth Estimation from Aeromagnetic Data of Kam. *International Journal of Advanced Research in Physical Science (IJARPS)*, 2(1): 37-52.

Kasidi, S. and Ndatuwong, L.G. (2008). Spectral Analysis of Aeromagnetic data over Longuda plateau and Environs, North-Eastern Nigeria. *Continental J. Earth sciences*, 28 – 32.

Salako, K. A. (2014). Depth to Basement Determination Using Source Parameter Imaging (SPI) of Aeromagnetic Data: An Application to Upper Benue Trough and and Borno Basin, Northeast, Nigeria. *Academic Research International*, 5(3): 74-86.

Salako, K. A. and Udensi, E. E. (2013), Spectral Depth Analysis of Parts of Upper Benue Trough and Borno Basin, North-East Nigeria, Using Aeromagnetic Data: *International Journal of Science and Research (IJSR)*, 2(8): 2319-7064.

Sunmonu, L. A. and Alagbe, O. A. (2014). Interpretation of Aeromagnetic Data of Kam, Using Semi-Automated Techniques. *International Research Journal of Earth Sciences*, 2(2): 1-18.

Spector, A. and Grant, F. (1970). Statistical models for interpreting aeromagnetic data.
Geophysics, 35(2): 293-302.

Carter, J.D., Barber, W., Tait, E.A. and Jones, G.P. (1963). The geology of parts of Adamawa, Bauchi and Borno Provinces in Northeastern Nigeria. Geol Surv Niger Bull 30:108