

QUALITATIVE ANALYSIS OF AEROMAGNETIC DATA OF BASHAR AND ENVIRONS, NORTH-CENTRAL NIGERIA

¹Zumji, J. J., ²Odewumi, S. C. and ¹Akanbi, E. S.

¹Department of Physics, University of Jos, Nigeria ²Department of Science Laboratory Technology, University of Jos, Nigeria **Corresponding email**: scodewumi@gmail.com

ABSTRACT

This study focuses on Qualitative Analysis of Aeromagnetic Data of Bashar and environs, North-central Nigeria. Software used for the analysis include: Oasis Montaj Version 8.4, Matlab Version R2010a, Grapher 5, SUFER 11, Georient and Microsoft Excel. The Total Magnetic Intensity (TMI) map has intensity values that range from 32876.4 to 33189.7 nT, showing significant magnetic high and low signatures. The Reduce-to-Equator (RTE) map has an intensity range of -732.6 to -405.5nT. The Upward Continuation analysis of 15 km distance which shows more of the deep regional trend with a range of -616.7nT to -457.6nT. The First Vertical Derivative (FVD) map has an intensity value ranges from -0.123 to 0.102nT/m. The magnetic high regions could be said to be regions with fresh basement outcrops while the regions with low magnetic intensity could be said to be region with old weathered outcrops. The lineaments observed were basic dykes, alpite, felsite and quartz veins which the host minerals. The dominant trend of lineament is NE-SW while minor trend of lineament is NW-SE direction. The rose diagram plot shows the lineaments trending NE-SW, NW-SE, and NNE-SSW directions, with the NE-SW being the dominant trend. The mineralization map shows positive magnetic intensity which ranges from 0.2 to 129.8. The region characterized by high magnetic anomalies intensity (36.7 - 129.8) is associated with rocks having higher content of ferromagnetic minerals and could be attributed to underlying igneous and metamorphic rocks while the region with low magnetic intensity (0.2 - 26.6) corresponds to the sedimentary bedding of sandstones, siltstones and claystone within the study area.

Keywords: Lineaments, Magnetic intensity, Mineralization, Dykes, Rose diagram

INTRODUCTION

The magnetism of the interior part of the earth is made up of three parts; Core, Mantle and Crust. The core is further divided into inner and outer core. Our planet's magnetic field is believed to be generated deep down in the Earth's core (Reynolds et al., 1990). Some



materials become magnetized when in the presence of a magnetic field and develop an induced magnetic field, while others posses their own intrinsic magnetic fields. The interaction of such fields with the Earth's primary field gives rise to the field at the Earth's surface (Reeves, 2004). The causes of magnetic anomalies include dykes, faults and lava flows. The anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Magnetic surveys can be conducted from the air (airborne), sea (marine) and ground (land) with a magnetometer (Richard and Stephen, 2015) (*remove italics*). An airborne survey can be used to map out a broad structural framework over a large exploration area both quickly and effectively, it is a powerful means available to the earth scientist for investigating very large areas rapidly. This study focuses on Qualitative Analysis of Aeromagnetic Data of Bashar and its environs, north central Nigeria with the aim of determining the magnetic intensity, upward continuation, First Vertical Derivatives, lineaments and magnetic sources.

Location and Geological Setting of the Study Area

The study area is located on Latitudes $9^{0}00$ to $9^{0}30$ N, and Longitudes $9^{0}30$ to $10^{0}30$ E with an approximate area of 6,050 km². The study area comprises of the Precambrian Basement rocks, Younger Granite ring complexes and part of the Middle Benue Trough in Northcentral Nigeria. The study area has two distinctive relief features: lowlands and highlands as shown in the Digital Elevation Map of the study area (Figure 1). Generally, the area is characterized by a rugged relief (hills and undulating plains).

The geological map of the study area is shown in Figure 2. The Precambrian Basement Complex is unconformably overlain by the Bima Bandstone which is the oldest and the most extensively outcropping formation in the Benue trough (Carter *et al.*, 1963). According to Oyawoye (1964), the area consists of gneiss migmatites, and the Older Granite. Jacobson *et al.* (1963) also reported that the rock found within the study area comprises of migmatites, granite-gniesses and older granite. This group of rock is believed to be as a result of



remobilization during the Pan-African Orogeny. The Younger Granite occurs largely as distinct pluton often batholitic size ranging in composition from quartz-hypersthenes diorite through leucocratic granites, porphyriticbiotite Granite, granodiorite and pegmatite.

In the eastern part of the study area, the Precambrian to lower Paleozoic basement gneisses and migmatite were overlain by alternating shale, limestone, shelly sandstones and clay. The sandstones consist of slightly cemented fine coarse grained sandstone and clay with interbeded thin beds of carbonaceous shale and clays.



Figure 2: Geological Map of Wase Sheet 191 and Bashar Sheet 192

MATERIALS AND METHODS

The software used include the following: Oasis Montaj version 8.4 (2015); MatLap (2015); grapher5 (2004); ILWIS 3.3 (2005); Surfer11 (2011) and Micro soft excel (2016).



Magnetic data acquisition and processing

A high resolution aeromagnetic survey over some parts of Nigeria was conducted by Fugro Airborne Survey between 2003 and 2009 and overseen by the Nigeria Geological Survey Agency, NGSA. Scintrex CS3 Caesium Vapor magnetometer was used for scalar measurement of the Earth's magnetic field.

Aeromagnetic Data Analysis

Interpretation of the aeromagnetic survey data aims to map the surface and subsurface regional structures (e.g., faults, contacts, bodies and mineralization). Aeromagnetic data are mostly analyzed in these processes: Aeromagnetic data filtration (upward and/ or downward continuation, Reduction to pole, Reduction to equator, vertical derivatives, etc.), Regional-Residual Separation, and Depth estimation analysis.

Total Magnetic Intensity Map from High Resolution Aeromagnetic Data

The minimum curvature methods include the following: The high resolution aeromagnetic data sheet of the study area were first imported into the software (Oasis Montaj) and the data were then digitally merged to obtain a composite data set of the study area. The aeromagnetic data was then, geo-referenced where it was converted from projected. Universal Transverse Mercator (UTM) to geographic longitude-latitude form. This was done by using the coordinate menu, setting the new projected coordinate and set projection to achieve the conversion. To produce the TMI, the data was now gridded using the minimum curvature method, which is the smoothest possible surface that fit the given data values as described by (Briggs 1974). This was done by using the grid menu and scrolling to gridding and then to minimum curvature display panel. Then, click Ok in order to run the program and obtain the TMI map.



The Regional-Residual Separation

The distinction between the regional (main) and residual (crustal) field is somewhat arbitrary but the regional component can be thought of as the response of bodies large and/or deep compared with respect to the study area and, therefore, not readily interpretable within the bounds of the study area. To separate the regional field (main field), a regional (or low pass) filter could be multiplied point-by point with the spectrum where low wave numbers are passed, high wave numbers rejected, with an approximately Gaussian roll-off between them to minimize ringing (also known as Gibb's phenomena) when the output is reversetransformed to the space domain.

The complement of the low-pass regional filter is the high pass or residual filter. The residual grid may be obtained either by applying such a filter in the wave number domain, or by subtracting the regional field from the original data grid. In practical cases, the residual filter would usually be designed to roll-off again at wave numbers corresponding to noise so that noise could be eliminated simultaneously.

The filter then becomes a band-pass filter, retaining only information from a range of wave numbers considered important for the study of the residual anomalies at hand.

For this study, the regional gradients of the aeromagnetic data were removed by polynomial fitting, this involved fitting a plane surface to the data by using multi-regression least squares analysis. The expression obtained for the regional field T(R) is given as:

 $T(R) = 76122.158 + 0.371x \ 0.248y$

(1)

where x and y are units of spacing.

The regional field values are subtracted from the observed data to obtain the residual anomaly values. The technique is carried out on the aeromagnetic data of the study area to produce the first to fourth residual and regional trend surfaces.



Lapai Journal of Science and Technology, Vol. 9, No. 1 (2023) Reduction to Magnetic Equator (RTE) Map

To produce anomalies, this depends on the inclination and declination of the body's magnetization, inclination, and declination of the local earth's field and orientation of the body with respect to the magnetic north, it is usually necessary to perform a standard phase shift operation known as Reduction-to-Pole (RTP) on the observed magnetic field. In magnetic equatorial regions where inclination is less than 15°, RTP is generally unstable and cannot be derived because such data introduces north – south alignment of the anomalies into the data, thereby making the data unstable. A similar effect is seen when a magnetic field is Reduced-to-Equator (RTE) instead of to the pole depending on the latitudinal position of the study area. Once the field has been reduced to the equator, the regional magnetic field will be horizontal and most of the source magnetizations will be horizontal. For the vital purpose of accurate positioning, the total magnetic intensity map was reduced to equator prior further processing to correct for effect of latitude and to make the magnetic anomalies to be symmetrically centered over their corresponding sources because the study area is closer to the equator.

RESULTS AND INTERPRETATIONS

The total magnetic intensity (TMI) value ranges from 32876.4 to 33189.7 nT (Figure 3) and shows a colour range with pink colour as high, pale green to yellow as intermediate and blue colour as low. The high and low magnetic signatures could be attributed to either difference in lithology, variation in depth, susceptibility contrast or the degree of geological strike. The amplitude of a magnetic anomaly is directly proportional to the magnetization which depends on magnetic susceptibility of the rocks (Gunn *et al.*, 1997).

The short-wavelength components are attributed to shallow magnetic sources associated with intrusive bodies such as dykes and plutons. The high magnitude of strong amplitude magnetic anomaly could be due to the presence of outcrops such as Migmatite-Gneiss Complex or the rocks existing at shallow depths (source). The high magnetic anomalies



correspond to regions with high magnetite content which in the study area could be associated with Migmatite-Gneiss Complex. The low magnetic anomaly characterized regions with relatively low magnetite content which could be associated with Younger Granite and thick sediments in the study area. The pink and red colours depict high anomalies suggesting higher concentration of magnetic materials (e.g. magnetite). The green to blue depicts low anomalies while pale green and yellow colours indicate intermediate. High magnetic values which according to Dahiru et al (2016) indicate high concentration of magnetic minerals (magnetite). However, high magnetic anomalies may have been associated with the presence of magnetic materials (magnetite) or other metalliferous deposits within the crystalline rocks in the area.

Visual studies of the residual aeromagnetic intensity map (Figure 4) of Wase and its Bashar area revealed variations in magnetic field intensity throughout the area. The result of the residual separation exercise revealed that the area is underlain by a NE-SW regional trend which shows similarity with structure control of Benue trough. The magnetic intensity values of the residual map ranges from -732.6 to -405.4nT as shown in Figure 4. Negative magnetic intensity values are observed throughout the study area which shows that the study area is located at the southern part of the magnetic equator. The residual map is also an indicative of local trend variations giving clues on structures for possible hydrocarbon, mineral or ore emplacement.

Magnetic field intensity usually increases from the east towards the southern part of the area, such variation is a function of the rock types and their lithologies. The northern and southwestern parts of the study area constitute part of the Middle Benue Trough which is underlain by Cretaceous Sedimentary rocks (Awgu shale and Lafia formation) and thus exhibited predominantly low (highly negative) magnetic intensity. Therefore, depressions or variations in thickness observed in some parts ofWase and Bashar around Rimi, Ganua,



Bashar, Makibufala, Kula, Dawaki and Dungun might be probable potential sites for hydrocarbon deposits.

The magnetic intensity of RTE map ranges from -732.6to - 405.5nT as shown in Figure 5 and shows similar features with the TMI map except for realignment of anomalies. The RTE map is characterised by high frequencies, short wavelengths, small size-high and weak intensities, sharp low amplitude and nearly regular-shaped anomalies which are associated with near-surface sources such as shallow geologic units and geological features.

The area under study shows variation in the magnetic field of the earth and this variation occurs as a result of local changes in the geological properties of underlying sub-surface rocks. The variation also reflects the presence of considerable amounts of magnetic bodies in the area. The differences in magnetic anomaly could be attributed to the rock types and mineral compositions of the various rocks The low intensity (green and blue colours) anomalies with magnetic intensity ranges from -732.6to -526.5nT (Figure 5) observable around Rimi, Garua, Gubuk, Bashar and Makibufala.

The region with low intensity magnetic value in Bashar sheet is made up of hornblende biotite granite, shale, limestone, and feldspathic sandstone which are formed within the earth's crust. The low iron content of the minerals within the rocks in this region could be responsible for the low magnetic intensity value observed. The high intensity (pink to red colour) anomalies range from -507.2 to -405.4nT and the rocks types underlying the area include: migmatite, basalt, fine to-medium grained biotite, coarse porphyritic granite and hornblende biotite granite. Migmatite could be the reason for high magnetic values observed in this region due to the iron rich content in the rock since migmatite is formed from dark colored gneiss or schist and light coloured felsic band.



FVD was applied on the residual map in order to sharpen-up anomalies and allows clearer imaging of the shallow causative structures vertically. The FVD has an intensity ranges from -0.123to 0.102nT/m as shown in Figure 6. Magnetic high (red and pink) was observed with magnetic intensity ranges from 0.006 to 0.102 nT/m which indicates high magnetic anomaly area while slightly low (blue and green) anomaly of -0.123nT/m to -0.001nT/m was observed covering some part of the region. From the map, regions with fresh basement are outlined in magnetic highs (red and pink) with an intensity range of 0.006 to 0.102 nT/m while regions with magnetic lows (blue and green) indicate older weathered outcrops.

Fractures were observed all over the map and predominant in regions with mixtures of high and low intensity values. The FVD map also show geologic structures presents in the study area as clearly confirmed in the lineament map (Figure 7) with NE-SW direction as the dominant trends and NW-SE as minor trends summarized in the rose diagram (Figure 8).



Figure 3: Total Magnetic Intensity (TMI) map of the Study Area





Figure 4: Residual Map (Crustal Field) of the Study Area



Figure 5: Reduced-to-Equator Map of the study area





Figure 6: First Vertical Derivative (FVD) Map of the study area

ure 7) suggests that the dominant lineaments orientation is NE-SW and can be related to the main structural direction. The second lineaments trend in NW-SE as minor trends which shows cross folding or shear zones in the study area. The rose diagram (Figure 8) shows the dominant trend of NE-SW and minor trend of NW-SE. The RTE data of Wase and Bashar sheets 191 and 192 were upward continued for elevation of 15km with magnetic anomaly intensity ranges from -616.7 to -457.6nT (Figure 9). The RTE (grid) continued upward to 15km i.e. to show image of the magnetic intensity that would be obtained assuming the data were at a height of 15km than the original datum the data was collected. As a result, upward continuation maps give the indications of the main tectonic and crustal blocks in an area. It



is apparent that the attenuation of the shallow source anomalies in the upward continuation process permits a clearer or enhanced view of the deeper anomaly sources (Jacobson, 1987). Figure 10 shows the magnetic intensity with values ranging from 0.2 to 129.8 and the boundaries of the anomalies are clearly defined. High magnetic anomalies zones are associated with highly rich ferromagnesian-bearing rocks with minor felsic minerals (Telford et al., 1990). The mineralization is observed along the northeastern and southeastern part of Bashar trending in the NE-SW direction which is in agreement with the structural trend in figure 7. This is because the structures actually host the mineralization but in a small quantity trending NW-SE direction in the Northwestern part of Wase. Subsurface linear structures were identified in the study area as observed from the lineament maps (Figure 7), which revealed the lineation trending in NE-SW and NW-SE directions. The NE-SW trend is the most dominant orientation and believed to have played a major role in the control of the geodynamic evolution of the study area.

The mineralization map (Figure 10) generated from the high resolution aeromagnetic data exhibits positive magnetic intensity which ranges from 0.2 to 129.8 and depicts contrasting lithology of the sedimentary and Basement Complex rocks in the study area. The northeastern parts of Bashar, and SE and NW regions of Wase are characterized by high magnetic anomalies intensity ranges from 36.7 to 129.8 (Figure 10). The NE - SW trending of the anomalies is associated with rocks of higher content of ferromagnetic minerals and could be attributable to underlying igneous and metamorphic rocks. The magnetic low anomalies range from0.2 to 26.6 which correspond to the sedimentary bedding of sandstones, siltstones and claystone within the study area. The intermediate positive magnetic anomalies with intensity rangingfrom28.8 to 33.4 coincides the undifferentiated Basement Complex rocks consisting predominantly NE - SW quartz-mica schist.



Lapai Journal of Science and Technology, Vol. 9, No. 1 (2023)



Figure 7: Lineament Archs extracted from FVD map of the study area



Figure 8: Rose Diagram Depicting Strike of Lineament of the Study Area (Sector Angle =150; Dominant Trend = NE-SW; Minor Trend=NW-SE; No of data plotted=87)





Figure 9: Upward Continued Aeromagnetic Field over the Study Area (15) Km



Figure 10: Aeromagnetic Map Showing mineralized Zones



The aeromagnetic data of Wase and Bashar was qualitatively produced into a map consisting of aggregate of colours called the Composite Total Magnetic Intensity (CTMI) map (Figure 3). These colour variations show the magnetic intensity values at various point of the map. The contrast in colour are possibly due to the presence of faults, fractures, dykes, seals, undulations in the basement, differences in lithology and geologic contact as well as magnetic susceptibility contrast of minerals present in the sedimentary section. The aeromagnetic map comprises of the violet, yellow, red, green, blue and the light blue colours (Figure 3).

In respect to the CTMI map, the magnetically subdued areas are the magnetic low points within the study area and this is typical of a sedimentary terrain while the magnetic responsive areas are the magnetic high regions which was believed to be due to either igneous or metamorphic rocks (Onuba *et al.*, 2011). The Composite Total Magnetic Intensity map shows TMI values ranging from 32876.4 to 33189.7 nT and is similar to TMI values of 32796 to 32895 nT reported from Birnin-Kebbi area by Bashar *et al.* (2017). However, lower TMI values of -171.647 to 188.405 nTwas reported by Ayodeji and Dare (2015) from Ado-Ekiti area while TMI values of -17.297 to 128.757 nT was reported by Cyril and Victor (2017) from Ibadan area, southwestern Nigeria.

There are noticeable NE-SW trending features in the residual map as shown in Figure 4. Generally, the entire study area revealed negative residual magnetic intensity, indicating that the area is located along the magnetic equator. Also, series of magnetic highs and lows were observed in the area. The residual map intensity values range from -732.6 to 406.4nT (Figure 4) which are higher than the residual intensity value of -220 to 220 nT obtained from Wamba area, northcentral Nigeria (Anudu *et al.*, 2012) and residual intensity value of -40 to 25nT from Upper Benue Trough Basin, northeastern Nigeria (Alagbe and Sunmonu, 2014).



The reduced-to- equator (RTE) map shows anomalies in form of circular, long-narrow features and dislocations, with high and low magnetic values (Figure 5). This shows similar features with the TMI map (Figure 3) except for realignment of anomalies when viewed closely. The RTE intensity values ranges from -732.6nT to - 405.5nT (Figure 5). The First Vertical Derivative (FVD) map (Figure 6) shows smoothened shallow and deeper magnetic bodies with anomalous trend of NE-SW and NW-SE. Unlike the residual map, high magnetic values indicate magnetic intrusions that occur at the southeastern and southwestern portion of the map when the enhancement technique was applied. However, zones with high aeromagnetic values were also observed in the northern and slightly at the southern portions of the map (Figure 6). Magnetic high (red and pink) was observed with magnetic intensity of 0.006 to 0.102nT/m which indicates high magnetic anomaly area while slightly low (blue and green) anomaly of -0.123 to -0.001 nT/m covering some part of the region.

The FVD map has an intensity value ranges from -0.123 to 0.102nT/m. The magnetic high regions could be said to be regions with fresh basement outcrops while the regions with low magnetic intensity could be said to be region with old weathered outcrops. The FVD shows an intensity value of -0.123 to 0.102 nT/m which is higher than the intensity value of -0.03997 to 0.04004 nT/m reported by Udochukwu *et al.*, (2019) and intensity value of 0.803 to 0-015nT/m (Ngama and Akanbi, 2017).

The subsurface linear structures were identified in the study area as observed from the lineament maps (Figure 7), which revealed lineation with trend directions in NE-SW and NW-SE. The NE-SW trend is the most dominant orientation in the study area while NW-SE being the minor trend as shown in the Rose diagram (Figure 8). The NE-SW linear trends are believed to have played a major role in the control of the geodynamic evolution of the study area.



The Upward continuation map (Figure 9) shows the deep regional basement trending in the area. Five (5) possible mineralization zones marked in the study area were isolated, that is areas where the magnetic intensities are at their peak. This was seen along the northeastern and southeastern part of Bashar trending in the NE-SW direction which is in agreement with the structural trend as shown in Figure 8. Structures actually host the minerals and minor trend occurs in NW-SE direction particularly in the northwestern part of Wase.

The northeastern of Bashar while the southeastern and northwestern portions of Wase regions are characterized by low magnetic anomalies with intensity ranging from -732.6 to -639 nT. The NE-SW trend of the anomalies is associated with rocks of the lower content of ferromagnetic minerals and could be attributed to underlying igneous and metamorphic rocks. The positive high magnetic anomaly ranges from -611.3 to -515.0 nT which corresponds to the sedimentary bedding of sandstones, siltstones and claystone within the study area. The intermediate positive magnetic anomalies having intensity ranging from - 611.0 to -515.0 nT coincide with undifferentiated Basement Complex rocks with predominantly NE – SW trending quartz-mica schist.

The mineralization map of the study area (figure 10) generated from the high resolution aeromagnetic data was used to determine the rock lithology of the study area. It exhibits positive magnetic intensity which ranges from 0.2 to 129.8 and depicts contrasting lithology of the sedimentary and Basement Complex rocks in the study area. The regions are characterized by high magnetic anomalies intensity ranges from 36.7 to 129.8. The NE-SW trending of the anomalies is associated with rocks having higher content of ferromagnetic minerals and could be attributed to underlying igneous and metamorphic rocks while the magnetic low anomalies range from 0.2 to 26.6 and corresponds to the prevalent sedimentary bedding of the sandstones, siltstones and claystone within the study area.



The First Vertical Derivative (FVD) has an intensity value ranges from -0.123 to 0.102nT/m with magnetic highs and lows. The magnetic high regions could be said to be regions with fresh basement outcrops while the regions with low magnetic intensity could be said to be region with old weathered outcrops.

The Lineaments direction are mostly NE-SW and is in agreement with previous work suggesting that Nigeria has a complex network of fractures and lineaments with dominant trend directions of NE-SW, NW-SE and N-S directions. The rose diagram plot shows that the lineaments trending NE-SW and NW-SE directions, with the NE-SW being the dominant trend.

The mineralization map shows positive magnetic intensity which ranges from 0.2 to 129.8. The region characterized by high magnetic anomalies intensity ranging from 36.7 to 129.8 is associated with rocks having higher content of ferromagnetic minerals and could be attributed to underlying igneous and metamorphic rocks while the region with low magnetic anomalies ranging from 0.2 to 26.6 corresponds to the prevalent sedimentary bedding of the sandstones, siltstones and claystone within the study area.

REFERENCES

- Alagbe, O. A. and Sunmonu, L. A. (2014). Interpretation of aeromagnetic data from upper Benue basin, Nigeria, using automated techniques. *Journal of Applied Geology and Geophysics*, 2 (5), 22-40.
- Anudu, G. K, Onuba, L. N, Onwuemesi, A. G., and Awajiakan, E. I. (2012). Analysis of aeromagnetic data over Wamba and it adjoining areas in North-Central Nigeria. *Earth Science Research Journal*, 16(1): 25-33.
- Ayodeji. J. and Dare, O. (2015). Geological and Structural Interprtation of Ado-Ekiti Southwest and it adjoining Area Using Aeroamgnetic Data.*AAPG*,*SEG and SEPG Joint Technical Conference, AAPG Oxnard, California*



- Bashar, M. G., Sanusi, Y. A. and Udensi, E. E. (2017). Interpretation of Aeromagnetic Data Over Birnin-Kebbi and Its adjoining areas Using First Vertical Derivative and Local Wavenumber Methods. *IOSR Journal of Applied Geology and Geophysics* 5(5):44-53
- Briggs, I. C. (1974), Machine contouring using minimum curvature: Geophysics, 39: 39-48
- Carter, J. D., W. Barber, E. A. Tait and Jones, G. P. (1963). The geology of parts of Adamawa, Bauchi and Borno provinces in North-eastern Nigeria. Bull. *Geological Survey of Nigeria.* 30: 109-109.
- Cyril, N. N. and Victor, S. E. (2009). Geothermal gradients in Chad Basin, Nigeria, from bottom hole temperature Logs. *International Journal of Physical Sciences*. *4*(12).
- Dahiru, D., Yusuf, A.S., and Emmanuel, E. U, (2016). Analysis of aeromagnetic data over Wase and it adjoining area. *Journal of Applied Physics*, 8(4): 57-66.
- Gunn, P. J., Maidment, D. and Milligan, P. R. (1997) Interpreting aeromagnetic data in areas of limited outcrop. *AGSO Journal of Geology & Geophysics*, 17(2): 175-185.
- Jacobson, B. H. (1987). A case for upward continuation as a standard separation filter for potential-field maps. *Geophysics*, 52, 1138-1148.
- Jacobson, R. R. E., Snelling, N.J. and Truswell, J. F. (1963). Age determination in the Geology of Nigeria with special references to the Older and Younger Granites. *Overseas Geological and Mineral Resource* 9: 168–182
- Ngama, E. J. and Akanbi, E. S. (2017). Qualitative Interpretation of Recently Acquired aeromagnetic data of Naraguta area, northcentral Nigeria. *Journal of Geography, Environmental and Earth Science International,* 11(3): 1-14
- Onuba, L. N, Anudu, G. K, Chaiaghanam O. I. and Anakwuba E.K. (2011). Evaluation of aeromagnetic anomalies over okigwe area South-Eastern Nigeria. *Journal of Enviromental and Earth Sciences.*, 3: 498-507.
- Reynolds, R. L., Rosenbaum, J. G., Hudson, M. R., and Fishman, N. S. (1990). Rock magnetism, the distribution of magnetic minerals in the Earth's crust, and aeromagnetic anomalies: U. S. Geological Survey Bulletin 1924: 24-45



- Reeves, C. (add period after C) (2005). Aeromagnetic Survey, Principles, Practice and Interpretation. *Pp. 56-100*
- Richard, C. S. and Stephen, A. S. (2015). *Elements of Petroleum Geology (Third Edition)*, Pp. 28-36
- Telford, W. M., Geldart L.P., Sheriff, R. E. and Key, S. D. (1990). Applied Geophysics. *Cambridge University Press, London.* P.107-110.
- Udochukwu, B. C., Akiishi, M. and Tyovenda, A. A. (2019). Estimation of Geothermal Gradient and Heat flow for Determination of Geothermal Energy Resources in Monguno area of northeastern Nigeria. *Journal of Geography, Environmental and Earth Science International*, 20(1): 1-8.