# Structural Analysis and Interpretation of Airborne Magnetic Data of Part of Middle and Lower Benue Trough, Nigeria

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## Abstract
*This study presents the results of the analysis and interpretation aeromagnetic data over part of Middle and Lower Benue Trough, Nigeria. The Middle and Lower Benue Trough, Nigeria, is a region of significant geological interest due to its complex tectonic history and potential for mineral and hydrocarbon resources. The study aimed at delineating geological structures that might support mineralization and hydrocarbon exploration in the study area. The Total Magnetic Intensity (TMI) of the study area was analyzed and interpreted by employing various magnetic filtering techniques to delineate lineaments and depth of the structural features. The filtering methods used includes vertical derivatives, analytical signal, Rose diagram, and Euler deconvolution. The results reveal a complex structural pattern, with several faults, fractures, and fold axes that related to tectonic evolution of the region. The lineament analysis showed two principal trends namely: NE-SW and NW-SE with varying degrees of minor lineaments directions. The first vertical derivative and the analytic signal showed structural trends oriented in the NE-SW directions confirming the trends of the three mega shear zones in the area. Result of the Euler deconvolution reveal a depth range of 1.194 – 6.512 km. Since minerals are structurally controlled, these structures delineated might host the economic minerals in the study area.*

**Keywords:** Aeromagnetic data, Analysis, Benue Trough, geological structures, lineaments, Mineralization, Exploration

## Introduction
The main purposes of geophysical techniques are to identify the type of subsurface, explore the earth's subsurface layers and structures that may facilitate the exploration of hydrocarbons, identify the heat flow from the earth's interior for geothermal exploration, identify minerals and other valuable materials found in the earth, and offer an integrated approach to certain geological issues (Reynolds, 2011).

Investigating subsurface geology using anomalies in the Earth's magnetic field caused by the magnetic characteristics of the underlying rocks is the main goal of a magnetic survey. It is possible to conduct magnetic surveys in the air, on land, and at sea. As a result, the method is often used, and the speed at which aircraft surveys can be conducted makes it a particularly appealing approach for finding ore deposits that include magnetic minerals. The ability of aeromagnetic data to investigate the earth's subsurface depends on the rocks' magnetic susceptibility in the target areas.

Throughout the years, research has demonstrated that aeromagnetic data can be used to locate magnetic minerals and determine the depth of geothermal reservoirs located at the bottom of magnetic rocks. These geologic features include faults, folds, shear zones, contacts, and intrusions. (Paterson et al., 1985; Airo, 2002, 2010; Adewumi et al., 2019; Ravat et al., 2007).

Nigeria's Benue Trough, which stretches more than 1,000 kilometers from the Chad Basin in the north to the Gulf of Guinea in the south, is a significant geological feature. The upper Benue Trough, middle Benue Trough, and lower Benue Trough are the three main sections of the trough. The Middle and Lower Benue Troughs, which are distinguished by their substantial geological activity and intricate tectonic history, are the subject of this investigation.

In order to identify geological features that might facilitate mineralization in the research region, this study aims to examine and interpret the aeromagnetic data across a portion of the Middle and Lower Benue Trough in Nigeria. It is anticipated that the analysis's findings will provide more insight into the lineaments, or structures, that may include certain possible minerals in the research region.

**Location and Geology Settings of the Study Area**

The study area is square shaped bounded by longitudes $7^{o}$ 00′E - $9^{o}$ 30′E and latitudes $7^{o}$ 00′N - $9^{o}$ 30′N. This covers an area of about 22500 square meters (77,006.25 $km^2$) on the equatorial scale of $1^{o}$ to 111 km. The study area and the entire Benue Trough generally has a low relief. The elevations above sea level along the river Benue are usually in the range of 60 to 70 m towards the northern and southern boundaries of the trough, the elevations are as high as 250 m. in between these two extremes. Elevations increase gradually in form of rolling hills with elevations increasing toward the through boundaries. The area of study is dissected by high lands to the north and SW and low lands typical of plains to the southeast, which mostly drain to the west in the River Benue. It is evident from the distribution of drainage pattern that the trends of the main valleys and their tributaries may be structurally controlled. The general outline of the topography of the area under investigation shows that the northern part of the area is mainly covered by basement complex of relatively high rugged terrains with a number of prominent peaks, mostly formed of the NE-SW trending schist belts, migmatite - gneiss complexes and granitic rocks. Sedimentary rocks mainly cover the southern and the eastern part of the study area, which is less rugged and less complex than its western part.

Geologically, the Benue Trough (study area) is bounded both to the north and to the south by the basement rocks. These rocks form part of the undifferentiated basement complex of Nigeria (Oyawoye, 1970; NGSA, 2004) which belongs to the Pan-African orogeny (Oyawoye, 1977). Gneisses and migmatites are the major components in the northern basement and other major formations are rhyolites which are located as dykes in the Younger granites, quartzite, dolerites, and quartz veins (Oyawoye, 1977). Wright (1971) reported that the basement complex comprises five distinct rock units, viz: granulitic gneisses, intermediate rocks, migmatites, granite-gneiss and magmatic granite-gneiss and the older Granites (Figure 1).

However, Younger Granites occur within the Precambrian basement complex; while recent volcanic rocks are found both within the Precambrian basement complex as well as the sediments. The granulitic gneisses are fine-grained rocks with a sugary texture, grey to brown in colour, distinctly foliated and composed largely of quartz, feldspar and biotite. Small outcrops are widely distributed among the migmatites. The migmatites occupy a large area but in general, exposure is limited and the outcrops are of low relief. The main areas in which weakly migmatised gneisses occur, include the northern part of the Maijuju sheet and the western Kurra sheet. The Migmatitie-Gneiss Complex also termed by some workers as the‶migmatite-gneiss-quartzite complex″ makes up about 60% of the surface area of the Nigerian basement (Rahaman & Ocan, 1978). The gneisses are predominantly of granodiorite composition but subordinate granitic phases also occur. The general texture is medium-grained and granoblastic with coarse porphyroblastic feldspar showing a variable and frequently localized occurrence. The Mesozoic Younger Granite ring complexes of Nigeria (Figure 1) form part of a wider province of alkaline anorogenic magmatism. They occur in a zone 200 km wide and 1,600 km long extending from northern Niger to south central Nigeria. Rubidium – Stratium whole rock dating indicates that the oldest complex of Adrar Bous in the north of Niger Republic is Ordovician in age, with progressively younger ages southwards. Volcanic rocks in the study area are of two types viz: extrusives and intrusives. The latter are more abundant in the Albian sediments (Wright, 1975) and are closely associated with anticlinal structures (Cratchley and Jones, 1965; Wright, 1975). Offodile (1976) also reported that the anticlines seem to have provided the centres for the Cretaceous volcanic activities in the area. The Lafia formation within the study area encompasses intrusives which are mainly sills, domes and dykes, (Offodile, 1976). On the other hand the volcanics encountered in Upper Benue are mainly in the form of plugs, hills and plateau (Cratchley and Jones, 1965). The volcanic rocks types are the diorites and gabbros with their hyperbasal equivalents (Wright, 1975). In the Awe area, the extrusives are vessicular basalts which are present in the highly laterized zones (Offodile, 1976).

**Figure 1: Geological map of the Study area**
**(Extracted from the geological map of Nigeria)**

## Materials and Methods

The airborne magnetic data used in this study was procured from Nigeria Geological Survey Abuja (NGSA). The survey was carried out by Hunting Geology and Geophysics Ltd, Fairey Survey Ltd, and Polservice PPG on behalf of the government of Nigeria between 1974 and 1976. The data were collected at a nominal flight altitude of 500 ft (152.4 m) along NNW – SSE flight lines spaced approximately 2 km apart and NE – SW trending tie lines of 20 km. The maps are on a scale of 1:1,000,000 and half degree sheets contoured mostly at 10 nT intervals. The corrections carried out on – board on the total-field aeromagnetic intensity for this area was diurnal correction, magnetic compensation, micro-levelling, corrugation removal and tie leveling (Luyendyk 1998). A correction (regional) based on the International Geomagnetic Reference Field (IGRF) epoch date January 1974 using DGRF 1975 model was applied on all the data. Each map sheet was digitized on a $19 \times 19$ grid point with an interval of 2.895 km (approximately 3 km). This introduces a Nyquist frequency of 1/6 and a wavelength of 6 km (Hall, 1968; 1974). The minimum magnetic anomaly wavelength detectable by present study is 6 km, which is adequate for regional surveys (Ajakaiye, 1985). The interpolated data recorded on the coding sheets for each map were merged together column by column and row by row. The Total Magnetic Intensity (TMI) was analysed to delineate geological structures within the study area from First vertical derivative map, Rose diagram, lineament maps, and Euler Deconvolution.

## The First Vertical Derivative

The first derivative of the function $f(x)$, which we write as $f'(x)$ or as , is the slope of the tangent line to the function at the point $x$. To put this in non-graphical terms, the first derivative tells us how whether a function is increasing or decreasing, and by how much it is increasing or decreasing. This information is reflected in the graph of a function by the slope of the tangent line to a point on the graph, which is sometimes described as the slope of the function. Positive slope tells us that, as $x$ increases, $f(x)$ also increases. Negative slope tells us that, as $x$ increases, $f(x)$ decreases. Zero slope does not tell us anything in particular: the function may be increasing, decreasing, or at a local maximum or a local minimum at that point. Writing this information in terms of derivatives, we see that:

1. if , then $f(x)$ is an increasing function at $x = p$.
2. If , then $f(x)$ is a decreasing function at $x = p$.
3. If , then $x = p$ is called a critical point of $f(x)$, and we do not know anything new about the behavior of $f(x)$ at $x = p$.

The first derivative of the total field as applied to the total is used in the detection of lineaments.

(1)

The first vertical derivative is commonly applied to total magnetic field data to enhance the shallow geologic sources in the data by showing the degree of curvature of nonlinear TMI field. It also tends to reduce anomaly complexity, allowing a clearer picture of the causative body. The transformation can be noisy since it will amplify short wavelength noise (GETECH Group, 2007). Low-pass filters are often also applied to remove high-wavenumber noise (Oasis Montaj, 2008). Computation of the first vertical derivative in an aeromagnetic survey is equivalent toobserving the vertical gradient directly with a magnetic gradiometer and has the sameadvantages, namely enhancing shallow sources, suppressing deeper ones, and giving abetter resolution of closely-spaced sources (Reeves, 2005).

Analytic Signal

This filter applied to magnetic data is aimed at simplifying the fact that magnetic bodies usually have positive and negative peak associated with it, which may make it difficult to determine the exact location of causative body. For two dimensional bodies a bell shaped symmetrical function is derived and for three dimensional bodies the function is the amplified analytic signal. This function and it derivatives are independent of strike dip magnetic declination, inclination and remanent magnetization (Debeglia and Corpel 1997).

The 3D analytic signal A of a potential field anomaly can be defined (Nabighian, 1984).

$$|\vec{A}| = \left\{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2\right\}^{\frac{1}{2}} \tag{2}$$

Where $M$ = magnetic field anomaly

**Euler Deconvolution**

Any homogeneous field, including the analytical signal of magnetic data, can be subjected to Euler deconvolution, a technique for estimating the depth of subsurface magnetic anomalies. When it comes to defining the subsurface connections, it excels. When employing the pole-reduced magnetic field instead of the magnetic data alone, it has been shown that the depth estimations using the magnetic data are more accurate. In exploratory geophysics, Euler deconvolution was first created to quickly estimate the depth and position of magnetic or gravity sources. It is predicated on the observation that Euler's homogeneity equation is obeyed by the potential field generated by several simple sources (Hood, 1965).

If a given component of the magnetic anomalous field $\Delta T(x, y, z)$ satisfies the following equation:

$$\Delta T(x, y, z) = \text{tn}\, \Delta T(x, y, z) \tag{3}$$

where $n$ is the degree of homogeneity, then differentiating Equation 8 with respect to $t$ gives Equation 9:

$$\mathrm{x}\frac{\partial \Delta T}{\partial \mathrm{x}} + \mathrm{y}\frac{\partial \Delta T}{\partial \mathrm{y}} + \mathrm{z}\frac{\partial \Delta T}{\partial \mathrm{z}} = \mathrm{n}\Delta T \tag{4}$$

where $x$, $y$, and $z$ are the coordinates of the field observation points and assumed to be at the origin.

According to Thompson, (1982), considering the potential field data, Euler's deconvolution equation can be expressed as

$$(\mathrm{x} - \mathrm{x}_0)\frac{\partial \Delta T}{\partial \mathrm{x}} + (\mathrm{y} - \mathrm{y}_0)\frac{\partial \Delta T}{\partial \mathrm{y}} + (\mathrm{z} - \mathrm{z}_0)\frac{\partial \Delta T}{\partial \mathrm{z}} = \mathrm{N}(\mathrm{B} - T) \tag{5}$$

The position of a magnetic source whose total magnetic field T is measured at (x, y, z) is denoted by (x0, y0, z0). N is the degree of homogeneity (structural index), which is equal to n in Equation (9), and the whole field has a regional value B. The least squares approach is used to solve a given system of linear equations with a prescribed value for N in order to estimate the unknown coordinates (x0, y0, z0). And by utilizing several approximations for N, a solution with the lowest standard deviation is discovered.

The depth to the top of the magnetic basement was ascertained in this investigation using the Euler deconvolution.

**Results and Discussion**

**Total magnetic Intensity Map**

The total magnetic intensity map of the study area (TMI) (Fig. 2) is displayed in colour level values ranging from 32733.1 to 32942. 1 nT. The northern part of the study area is characterized by an NE-SW trending alternating of high and low magnetic intensity signatures; with the magnetic highs dominant. On the map as a whole, the magnetic trend is essentially NE – SW. However, E – W trend is seen at the southern flank of the study area. There seems to be a magnetic boundary south of the basement – sedimentary boundary indicated in thick grey colour shade. However, the correspondence between the magnetic boundary and the basement – sedimentary boundary is obscure. The magnetic boundary most probably marks the geologic contact between the sedimentary basin of the Benue Trough to south and the basement complex to the north. This corroborates the works of Ajakaiye *et al.,* (1985). The SW part of the study area is dominated by an alternating magnetic highs and lows. On the other hand southeast part of the study area is characterized by a NW-SE trending magnetic low. The lineament trend directions found from this study are in good agreement with the lineament a direction found in the Nigerian basement complex and agrees with others (Ajakaiye *et al.,* 1991; Ajakaiye and Ajayi, 1977; Ajayi *et, al.,* 1991).

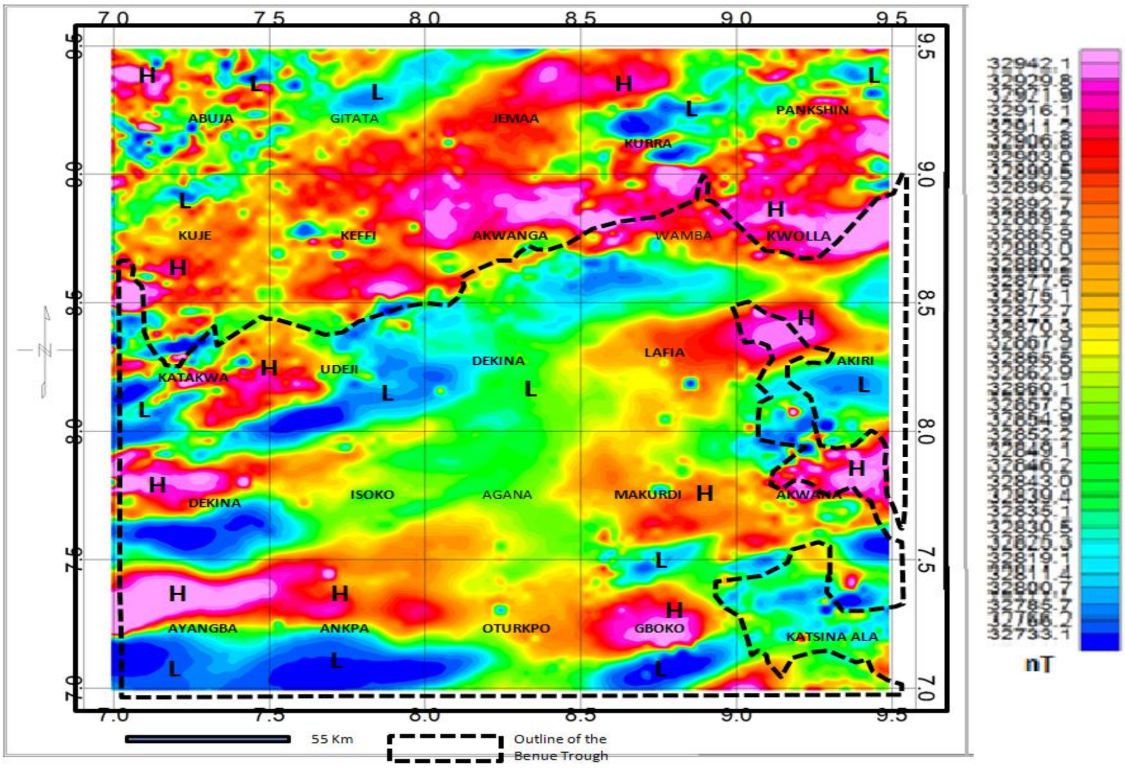



**Figure 2: Total Magnetic Field Intensity Map of the Study Area showing areas of Magnetic Highs and Lows**

## Structural Maps

The lineament analyses in this section are resultant of the lineaments extracted from the landsat imagery, the real faults and the inferred faults based on their respective rose diagrams. Both the latter and the former are maps obtained from the Nigerian Geological Survey Agency, (NGSA, 2004)**.**

## Rose Diagram (RD) and Lineament map from the Landsat Image

The rose diagram (Fig. 3a) and lineament map (Fig. 3b) were extracted from the Landsat image covering the study area. Structural analysis analysis as applied to mineral exploration attempts to define the most favourable location for mineral concentration, these zones forms channels for easy passage of mineralizing fluids. The RD reveal major structures trending NNE-SSW, NE-SW, and NW-SE. while the minor structures trend E-W. The lineament map (Fig. 3b) of the study area suggests that there are 4 zones of lineament density anomaly namely: (i) there is a NE-SW trending anomaly centre to N – E part of the study area, (ii) E-W trending to the SE part of the study area, (iii): the NE part of the study area is characterized by cluster contours and (iv): in the southern portion lies a NE-SW trending centre of anomaly. Olashehinde *et al.,* (2012) working within Pankshin area observed that many of the lineaments mapped onthe Landsat imagery when examined, consisted in part of linear segments of drainage, many of which were also aligned with linear scarps and that the drainage pattern of the study area were controlled by the River Benue. Those lineaments which outcrop are observed to be joints, quartz-veins and dykes that parallel the lineaments (Olashehinde *et al.,* 2012). This suggests that most of the lineaments mapped are fracture zones.

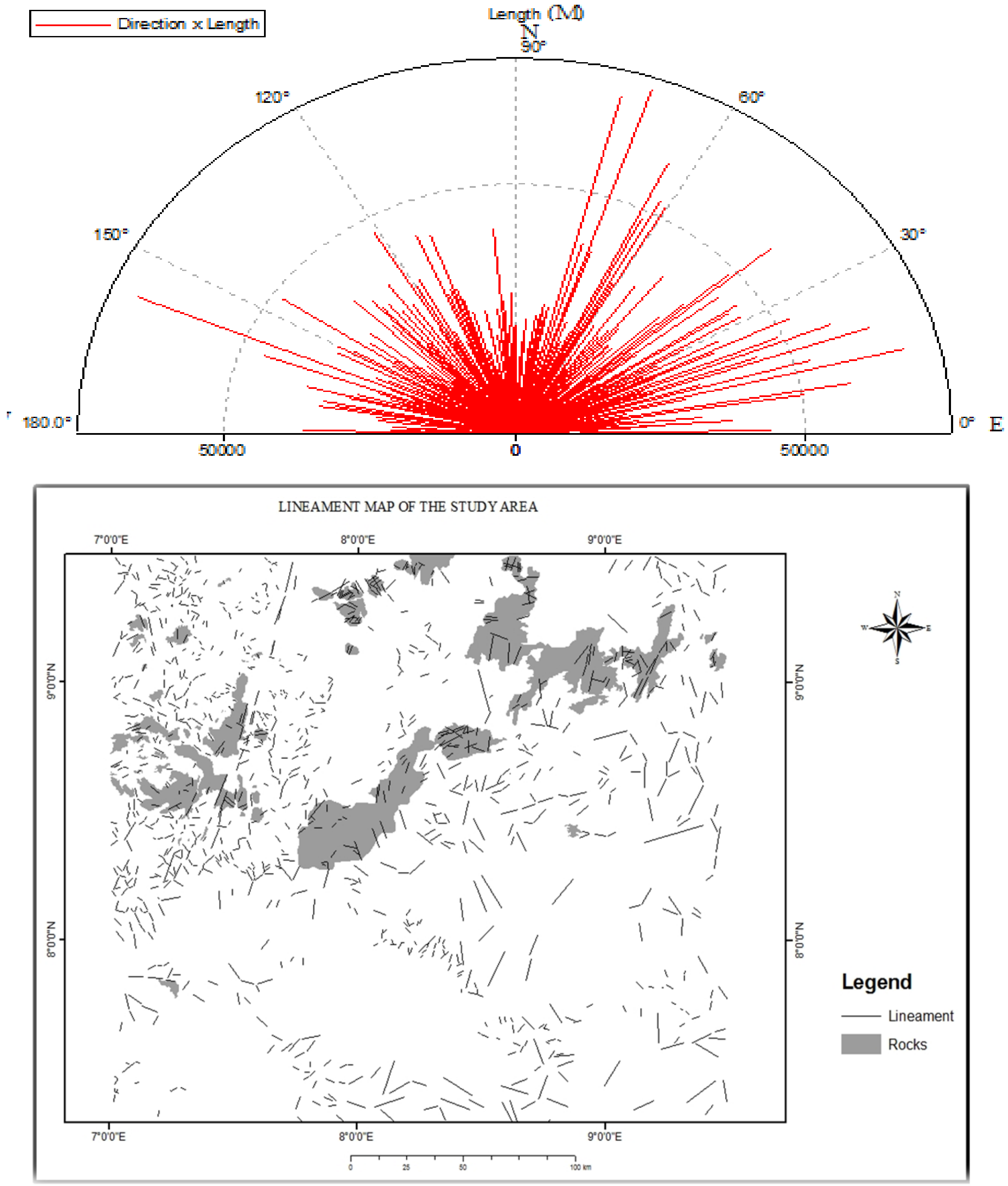


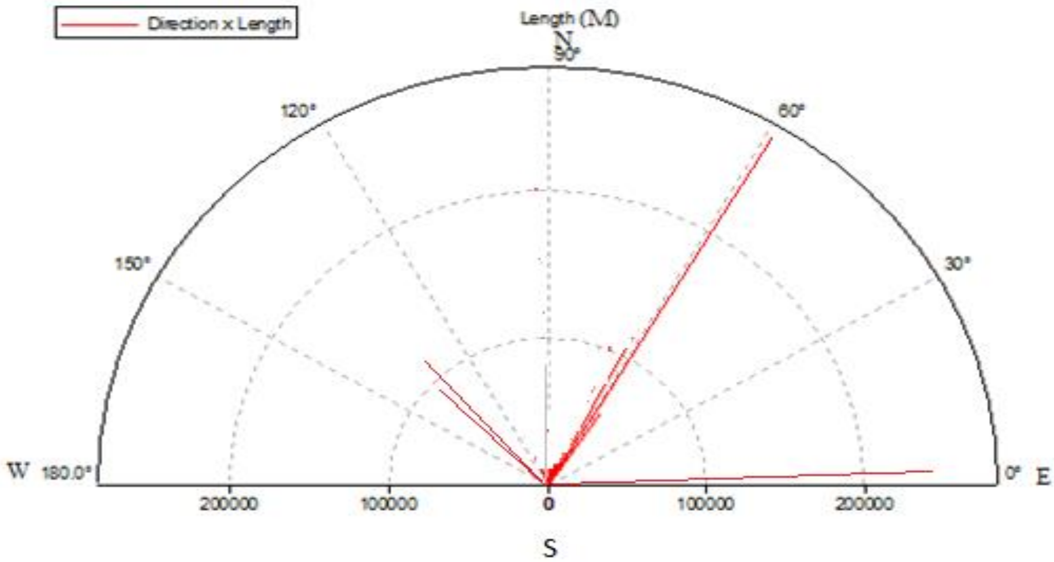

**Figure 3: (a): Rose Diagram (b) Lineament Map extracted from the Landsat imagery of the Study Area.**

Rose Diagram (RD) and Lineament extracted from the Magnetic Field

RD and the lineaments map and the rose diagram extracted from the magnetic field are presented in Fig. 4a and 4b, respectively. The lineaments range in length from 33 to 110 km. The Two (2) dominant lineament directions are: NE-SW and E – W, with minor NW-SE directions. These are lineament expressions from deep seated intra-basement structures. Structures (which are generally considered as evidence of deformation left as imprints on rocks) in the Basement Complex include joints, veins, dykes, foliations and faults, trend mainly in the NE-SW direction. Olashehinde *et al.,* (2012) identified a major shear zone trending NE-

SW cutting across the Basement Complex and this zone is also identified (also confirmed from field mapping) from twenty separate location (exposures) along the general trend.

Most of the mapped trends agree with previous work carried out in the Benue Trough and parts of the adjoining basement complex by Ajakaiye *et al.*, (1986), Olashehinde *et al.* (2012) and Anudu *et al.* (2012). Structural trends (fractures, faults, shear zones, veins and foliations) mapped on the Landsat image reflect crustal adjustment of tectonic blocks following the separation of African and Latin-American plates at the surface of the Earth (Ajakaiye *et al*, 1985; Likkason, 2004). Their directions may not necessarily be the same as those of the lineaments extracted from the residual magnetic field. The latter may reflect the directions of deep seated fault zones such as the Pelusium Line.



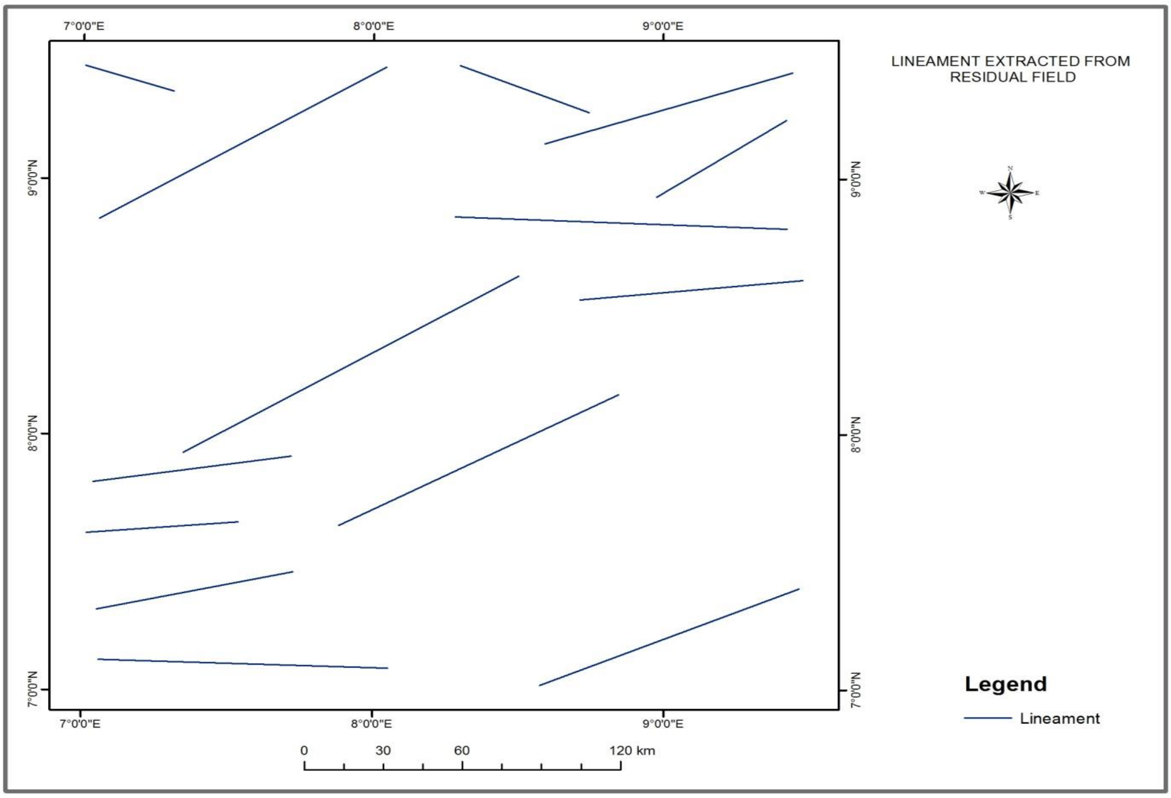



**Figure 4: (a) Rose Diagram (b) Lineaments extracted from the Magnetic field Map**

Rose Diagrams (RD) from the Real and Inferred Faults

The rose diagrams for both of real and inferred faults are shown in Fig. 5a and Fig. 5b, respectively. Likewise, the lineament map of both the real and inferred faults is shown in Figure 5c. The real faults in the study area have dominant NE-SW, NW-SE and E-W, N-S and minor NEE-SWW directions and range in length from 4 to 145 km. On the other hand, the inferred faults have dominant NE-SW and NW-SE directions with minor N-S, E-W, NEE-SWW and NWW-SEE directions. All of the lineament directions are included into the rose diagram of the real as well as the inferred faults. This corroborates the results of the faults as well as the inferred faults (NGSA, 2004).On the whole, both trends are inconformity with the trends observed in the Nigerian Basement, which indicate some major structural control. These structures are believed to have resulted from intense regional tectonism that preceded and accompanied the emplacement of Older Granites during the Pan-African orogeny that produced a very extensive N-S trend in northern Nigeria, including the study area. Joint systems are observed largely in the granitic outcrops, some of which bear quartz veins in the range of a few centimeters in width. Thousands of these lineament streaks will combine/align to produce lineaments of regional scale. This is in agreement with cluster of contours to the NE part of our study area. To this end lineament density analysis is the stock in trade in mineral exploration and if substantial weathering exists the high density values may be targets for hydrogeological investigations.

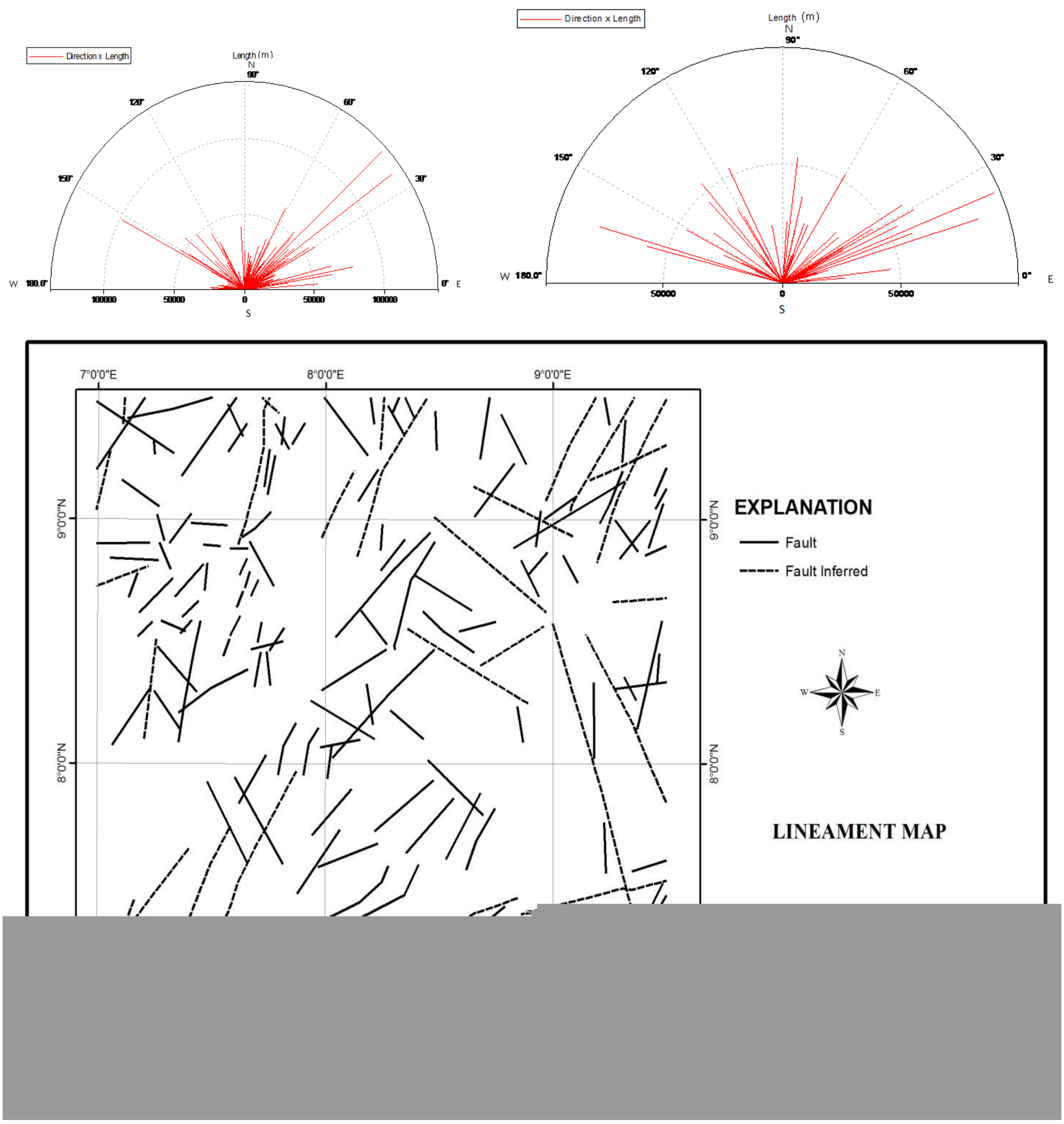



**Figure 5: (a) Rose Diagram of the Real Faults (b) Rose Diagram of the Inferred Faults (c) Lineament Map of the Real and Inferred Faults**

The structural lineaments (fractures, faults, shear zones, veins and foliations) orientations obtained from the rocks can be used to date the events that produced the rocks. Obiora (2009) reported that, NNE-SSW/N-S trends are Pan-African, while E-W, NNW-SSE trends are pre-Pan-African. Hence the NE-SW, NW-SE and NNE-SSW trends in the study area may probably have been Pan-African (younger than 800Ma), whereas the NNW-SSE and E-W trends may have been pre-Pan-African (over 800 Ma).
The First Vertical Derivative (FVD) Map.

The FVD map (Fig. 6) can be categories into four (4) lineament directions, namely: NNE-SSW, NE-SW, NW-SE and N-S. This map shows that dominant lineament directions within the study area are oriented NE-SW. The lineaments directions revealed by this map are in inconformity with the trend directions found in the lineaments map extracted from the residual field, landsat based lineament map and the lineaments from the real and inferred faults. These are the lineament directions found within the Nigerian basement complex and corroborates the studies of Ajayi *et al.*, (1991); Ajakaiye *et al.,* (1985); Likkason *et al.*, (2005); Umego, (1990) and Ekine *et al.*, (2008).

**The Analytic Signal (AS) Map**

The AS map (Fig. 7) is used in delineating the edges of magnetic structures. The structural index (SI = 1) of contact or step (Colin, 2005; Reid *et al.*, 1990) window size of 10 and flight height 150 m, were used in the application of the ASA as the objective is to map out is to map out structures. The values of the analytic signal amplitude vary from +191.6 nTto +4812.7 nT. Structurally, the study area can be categorized into three (3) geologic units based on the visual inspection of the dynamic range in terms of standard colour shades. The area is marked by both high and low magnetic closures, which could be attributed to several factors such as (1) variation in depth (2) difference in magnetic susceptibility (3) differences in lithology and (4) degree of strike. The pink colour shade represents three types of geologic structures; and listed as follows: basement outcrop and, the basement intrusive and the intrusive within the sediments.

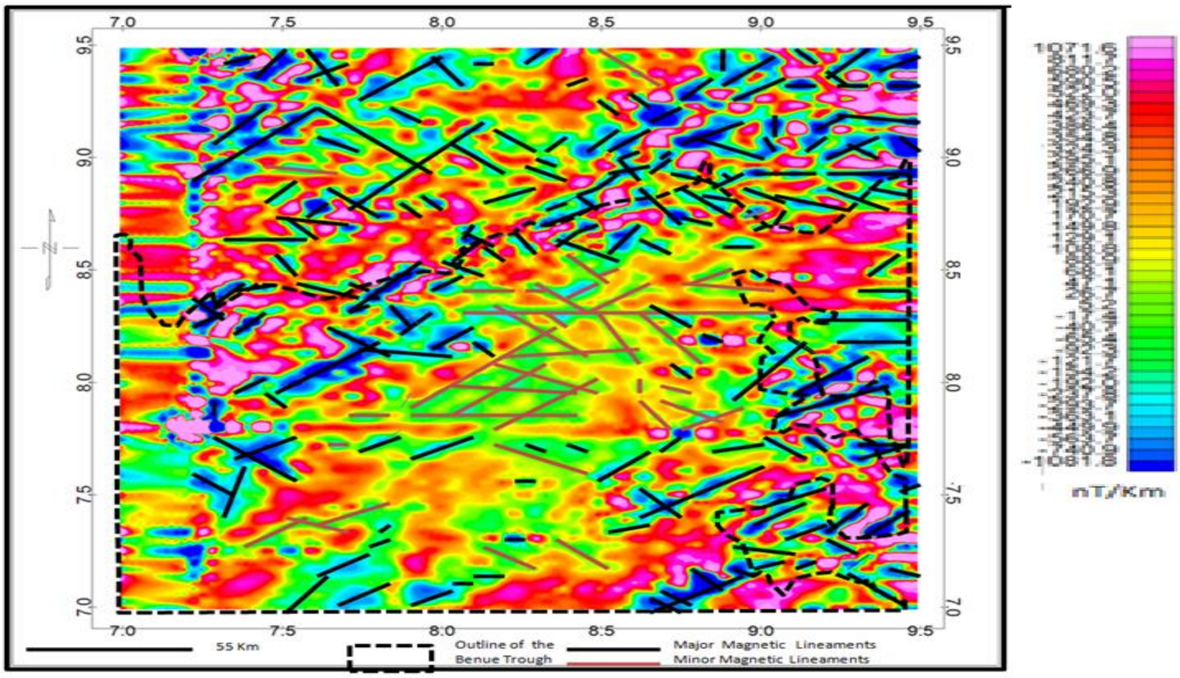



**Figure 6: FVD map of the study area**

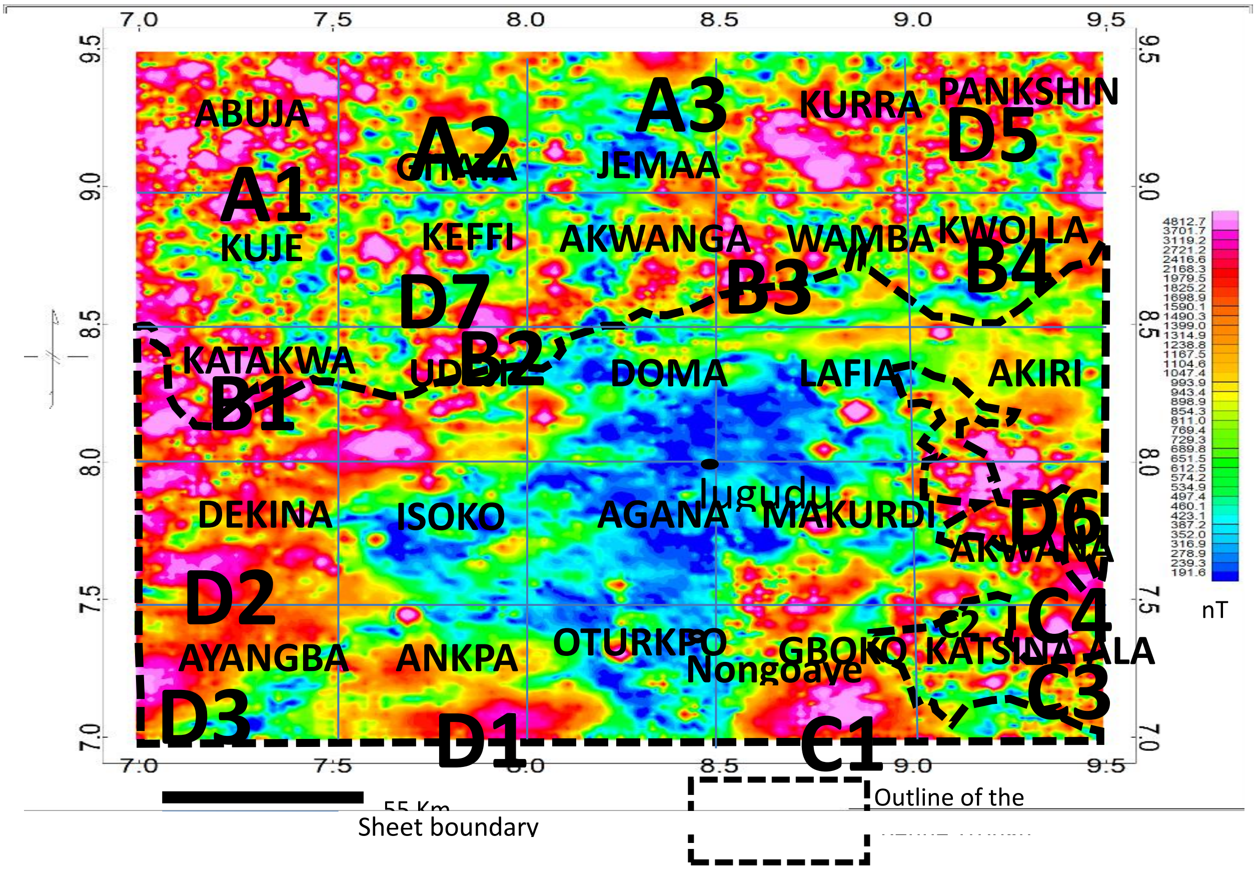



Figure 7: AS map of the Study area

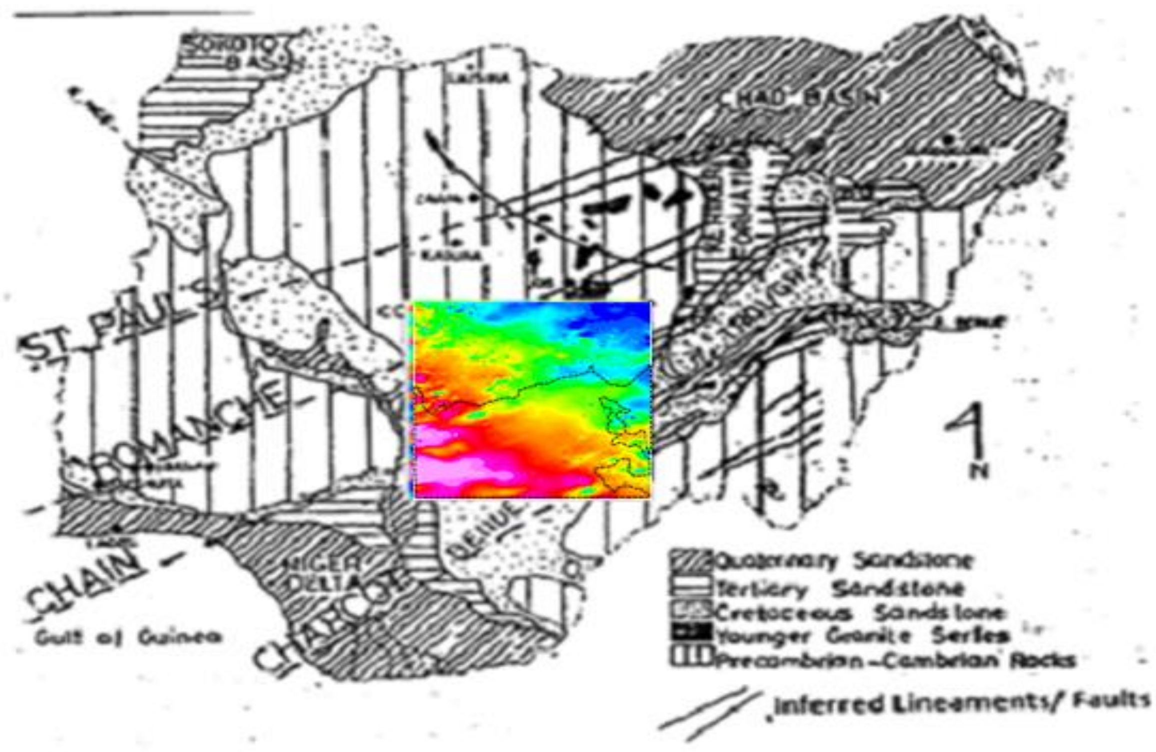
The basements outcrops are represented by areas A1 - A3, B1 - B4, D5, and parts of D6 within the basement complex D7 (Fig. 7). Igneous structures denoted by anomaly centres A1 –A3, B2 – B4, C1, D1 and D2 trend in the NW-SE directions while areas of anomaly denoted by A2, A5 and D3 and D6 trend in the NE-SW directions. On the other hand, the generic representations for intrusive either within the sedimentary formations are B1, C1 – C4, D1 – D3 and D6 respectively. The analytic signal amplitude shows from this study that the Benue is underlain by near - surface intrusive rocks. However, Adetona and Abu (2013), who studied parts of the anomaly centers (B1 - B3 and west of longitude 7° 00′) reported an E-W oriented swarm of basement intrusive. Anomaly centers B1 and D2 represent basement seated intrusive bodies at the saddle of the basement-sedimentary contact to the north. There is a swarm of intrusive rocks to the south of the demarcation line between the basement complex and the sedimentary area. There is a detailed correspondence between the sedimentary and basement boundary.

This is an improvement over the findings of Ajakaiye *et al.*, (1985) who reported that the correspondence at the basement-sedimentary boundary is not detailed. Last but not least are the yellow to light blue colour shades. These represent magnetic amplitude typical of metamorphic rocks (within the basement complex) and the sedimentary areas (NGSA, 2004). These two distinct geologic formations have a dominant NE-SW direction. They are characterized by long wavelengths and occupy most of the study area. Another colour band is the area represented by light blue. These areas of weakest amplitude are to the deepest because the amplitude of the analytic signal falls off as the square of the depth from the source. On the basement complex, one of the deepest portions is east of Akwanga and locates the depth to roots of the migmatite complex underlying the granite gneiss of the Pan- African granitoids. The locations of Yogbo and Nongoaye represent some of the deepest areas within the Awgu-Ndeaboh and Ezeaku formations respectively. The results of the analytic signal are in line with the results of the lineament studies carried out so far in this work. The lineament directions obtained from the first vertical derivative map is oriented along the directions of the intrusive revealed by the analytic signal map. The main structural trends within the survey area are igneous outcrops trending in the NW – SE and NE –SW directions superimposed on a central N- S trending magnetic low. The magnetic low within the study area represents the sediments within the Benue Trough and the overburden within the basement complex. In a nutshell the regional trends of the igneous intrusive and extrusive is oriented NE –SW and conforms with the orientations (NE – SW) of the magnetic lineament swarms obtained from the first vertical derivative.

**Paleo-structures of the Study Area**

Fig.8 shows the residual magnetic field superimposed on the simplified geological map of Nigeria. The map suggests that the continental extensions of intracratonic faults which are the Romanche, the Chain and the Charcot, fault zones pass through the study area. The results of the first vertical derivative and the analytic signal amplitude together suggest that the northwest part of the study area, the boundary of the Trough to the north and the southeast part of the study area are characterized by swarms of short - segments of magnetic lineaments/structures. From results of the first vertical derivative and the analytic signal confirmed the existence of NE – SW trending paleo-fracture zones. The three fault zones are paleo-fractures that resulted from the separation of the American and African plates and had been identified to be a system of faults from what is known as the Pelusium line. They extend right from the Atlantic Ocean at the Bight of Benin up to Turkey (Burser, 1966; Neev, *et al.,* 1982). These fault systems have been equally identified by many researchers in Nigeria (Offodile, 1976; Ajayi,1979; Osazuwa, 1982; Olatunji, 2005; Udensi, 2000 and Ajakaiye *et al.,* 1991).

The Fig. 8 shows that the Charcot fault zone passes through Akwana, Gboko and Katsina Ala sheets, while the Chain fault zone passes through Wamba, Kwolla, Udeji, Doma, Lafia, Dekina and Isoko sheets. The Romanche fracture zone is probably passing through Abuja, Gitata,



Jemaa, Kurra, Kuje, Keffi and Akwanga sheets. The figure also shows boundaries between structures are not sharp, however, they are gradational.

Figure 8: Residual Magnetic Field Intensity illustrating the passage of the Romanche, the Chain and the Charcoat Fault zones through the study area: (Geological Map, after Ajakaiye, 1974)

The Euler deconvolution map result from the research region is shown in Fig. 9. The Euler depth with structural index 1 was computed using the residual map's pre-processed grids (dx, dy, and dz). The depth to magnetic sources (anomalies) varies between 1.194 and 6.512 km, according to the Euler Depth map. The study's maximum depth of 6.512 km is enough for the maturation and accumulation of hydrocarbons and serves as a reliable indication for petroleum exploration in the region under investigation. There are several structures on the Euler depth map that match the structures shown on the RD and FVD maps.

The picture can't be displayed.

**Figure 9: Euler Deconvolution map of the study area**

## Conclusion

The structural analysis and interpretation of aeromagnetic data of Middle and Lower Benue Trough has been successfully carried out in this present study. The study highlights the complex structural geology of the region and identifies several potential mineral and hydrocarbon targets. The results of this study provide new insights into the tectonic evolution of the Benue Trough and have significant implications for mineral and hydrocarbon exploration in the region. The depth to the top of magnetic basement obtained from this study is sufficient for hydrocarbon maturation and accumulation within the study area. It also identifies several potential mineral and hydrocarbon targets, including sedimentary basins, fault-controlled structures, and igneous intrusions. The targets require further investigation to determine their potential for mineral and hydrocarbon resources.

## References

Adetona, A. A., & Abu, M.(2013) Investigating the structures within the lower benue and upper anambra basins, Nigeria, using first vertical derivative, analytic signal and (CET) centre for exploration targeting plug-In. *Earth Science,* 2(5), 104-112. doc: 10.11648/j.Earth.20130205.11.

Airo, M. (2002). Aeromagnetic and aeroradiometric response to hydrothermal alteration. *Surveys in Geophysics*. 23. 273-302. 10.1023/A: 1015556614694.

Airo, M., Marit W., (2010). Application of regional aeromagnetic data in targeting detailed fracture zones. *Journal of Applied Geophysics,* 71, (2–3). 62-70. https://doi.org/10.1016/j.jappgeo.2010.03.003.

Ajakaiye, D. E., Hall, D. H., & Miller, T. W. (1985) Interpretation of aeromagnetic data across the central crystalline shield area of Nigeria. *Geophysics J.R. Astron. Soc.* (83) 503 – 507.

Ajakaiye, D. E., Hall, D. H., Ashiekaa, J. A. & E. E. Udensi (1991). Magnetic anomalies in the Nigerian basement continental mass based on aeromagnetic surveys. *Tectonophysics,* (192) 211-230.

Ajayi C O, Ikpokonte A E and Ike E C (1991) Structural pattern in the Lower Benue trough, Nigeria: Deductions from Ground Magnetic Data: *Nigerian Journal of Geology and Mining,* 7(2).

Ajayi, C. O. (1979) *A* Detailled gravity survey of the middle Benue trough, Nigeria. Unpublished Ph. D. Appl. Geophys. Thesis, Depart. of Phys. ABU-Zaria, pages 245.

Ajayi, C. O. and Ajakaiye, D. E. (1979) *The origin and peculiarities of the Nigerian Benue trough: Another look from recent gravity data obtained from Middle Benue Trough*. Paper presented at the International symposium of Rift zones of the Earth-the Dead Sea Rift, Jerusalem.

Anudu, G. K, Onuba, L. N., Onwuemesi, A. G., & Ikpokonte, A. E. (2012). Analysis of aeromagnetic Data over Wamba and its adjoining areas in North-central Nigeria. *Earth Sci. Res. SJ.16 (1), 25 – 33.*

Colin, R. (2005). Aeromagnetic Surveys: Principle, practice and interpretation, Section 2, 1-22.

Cratchley, C. R., & Jones, G. P. (1965). An interpretation of the geology and gravity anomalies of the benue valley, Nigeria – *Overseas Goelogical survey,* Geophysics Paper No. 1.

Ekine, A. S. (2008). Magnetic anomalies trends and spacing patterns in parts of the lower Benue trough, Nigeria, *Nigeria. Journal. of Physics,* 20(1), 155-162.

Hall, D. H. (1968). Regional magnetic anomalies, magnetic units and crustal structure in the Kenora district of Ontario/ *Canadian J. of Earth Sci., 5: 1127-1296*.

Hall, D. H. (1974). Long wavelength aeromagnetic anomalies and deep drustal magnetization in Manitoba and Northwestern Ontatiro. *Canadian Journ. of Geophysics. 40: 403 – 430.*

Likkason, O. K., Ajayi, C. O., Shemang, E. M., & Dike, E. F. C. (2005). Indication of fault expressions from filtered and werner deconvolution of aeromagnetic data of the middle Benue trough, Nigeria. *Journal of Mineral and Geology. 41(2), 205-227.*

Lowrie, W. (1997). *Fundamentals of Geophysics.* First Edition, Cambridge University Press, 374.

Luyendyk, A. P. J. (1998), Processing ofairborne magnetic data, AGSO *J. Australian Geol. Geophys*. 17, 31-38.

NGSA, (2004) Geological map of the federal republic of Nigeria, Nigerian Geological Survey Agency (NGSA), Kaduna.

Obiara, S. C. (2009). Field measurements in descriptions of igneous andmetamorphic rocks. In Lambert-Aikhionbare, D.O. and Olayinka,A.I. (eds.) Proceedings of Field Mapping Standardisation Workshop, Ibadan University Press, 105-125.

Offodile, M. E. (1976). A review of the geology of the cretaceous of the Benue Valley, *in* C. A. Kogbe, ed. *Geology of Nigeria*. Surulere, Lagos Elizabethan Publishing Company, p. 319-330.

Olashehinde, A., Ashano E. C., & Singh G. P. (2012). Structural analysis the Ropp Complex, North Central Nigeria, using Magnetic Anomaly and Landsat ETM Imagery, *Continental J. Earth Sciences 7 (1): 1 – 8.*

Oyawoye, B. A. (1977). Geology of nassarawa eggon area and the distribution and contact *relationship of Dolerite Dykes* in S. W. Wamba District, Plateau State - a B. Sc. Dissertation in Geology, A. B. U. Zaria.

Oyawoye, M. O. (1970). *The basement complex of Nigeria - in African Geology*. University Press, Ibadan.

Reid, A. B., Allsop, J. M., Granser, H., Millet, A. J., & Somerton, I. W. (1990). Magneticinterpretation in threedimensions using Euler deconvolution. *Geophysics,* 55, 80-91.

Umego, M. N. (1990) Structural interpretation of gravity and magnetic anomalies over Sokoto Basin, Northwestern Nigeria. Unpublished PhD Thesis, Ahmadu Bello University Zaria.

Umego, M. N.. (1978). *Gravity investigations around the ribi salt springs* – an M.Sc. Thesis of the A. B. U., Zaria

Wright, J. B. (1975). *Volcanic rocks in Nigeria – in geology of Nigeria*, Elizabethan Press, Lagos.

Wright, J. B. (1971). Basement complex: *The Geology of Jos Plateau.*1(32), 12-47.