Nigerian Journal of Physics (NJP)
ISSN online: 3027-0936
ISSN print: 1595-0611
DOI: https://doi.org/10.62292/njp.v33i3.2024.289
Volume 33(3), September 2024

Delineation of Mineralized Zones in Parts of University of Abuja Main Campus, Abuja Nigeria from Aeromagnetic Data

***[1]Abdulsalam, N. N., [1]Jegede, A., [1]Egbelehulu, P. and [2]Ibeneme, S. I.**

[1]Department of Physics, University of Abuja,
[2]Department of Geology Federal University of Technology, Owerri

[*]Corresponding author's email: nassnaeem@gmail.com; abdulsalam.naeem@uniabuja.edu.ng

ABSTRACT
Every country's industrial and economic growth is based on its mineral resources. The precise mode of occurrence and unique chemical and mineralogical composition of any identified mineral ore can be determined by a deliberate and thorough evaluation of mineral deposits. Aeromagnetic data was interpreted to delineate structures for sulphide ore exploration within longitude 07˚ 08′30′′E 07˚ 08′15′′ E and Latitude; 08˚ 57′30′′N- 08˚ 57′45''N of the University of Abuja main campus, Abuja Nigeria for its mineral potentials. Based on structural interpretation of aeromagnetic sheet 207, regional and local faults were identified. Various tectonic events have given rise to fractures zones aligned in the three main directions, E-W, N-S, NW-SE system, as opposed to main structural lineament trending NE-SW of the area. The overall pattern of structural form lines and geological formations is congruent with the NE-SW trend. The Gbesa village, located within the University area, is where the distinct areas are most noticeable.

Keywords:
Aeromagnetic,
Derivative filters,
Lineament,
Faults.

INTRODUCTION

The role of solid mineral exploration in the history of our nation's economic development cannot be overemphasised. Every country's industrial and economic growth is based on its mineral resources. Humans obtain the materials they utilize from two main sources: mining and agriculture (FMARD, 2002). Except in rare cases, minerals are the most stable chemical element known to science. They are the building blocks of rocks, ores, and meteorites. Nigerian (NGSA, 1995). An intentional or thorough investigation of mineral deposits yields details about the true mechanism of occurrence of any mineral ore found, its unique chemical and mineralogical makeup, and the reserve. Investment planning for national economic development is made simpler with the inclusion of this data in a national database. The capacity to map structures such as faults, folds, contacts, shear zones, intrusions, and suitable locations of ore deposits makes magnetic method valuable in the mineral exploration process. This is because the method response to ferromagnetic material and ideal in the detections of metallic objects (Bit.ly/2utzzns, 2019).

Possibility of fault-bound mineral occurrences and the detection of such structural styles (faults, dykes, lineaments and folds and other intrusive bodies), palaeo-landscape features (buried volcanic flows and palaeochannel) offers important clues to the existence of formations that host minerals within the study area (Verduzco et al.2004). This study is pertinent to the needs of the country since it offers previously unresearched geological information on the area's structural settings through processed total field aeromagnetic data, thus providing useful scholarly information for readership. The objectives of the study is to delineate the subsurface structures (such as lineaments) which are likely to host potential minerals in the study area from the qualitative analysis of aeromagnetic data, to acertain the trend of mineralization and general trends of the target, as well as estimate depth of emplacement of the deposits and to estimate the lateral extent and depth of the causative bodies.

Location and Geology of study area

The area of study is bounded by longitude 07˚ 08′30′′E to 07˚ 08′15′′ E and Latitude; 08˚ 57′30′′N to 08˚ 57′45''N within University of Abuja main campus (Figure 1). About 85% of the research area is made up of Precambrian rocks from the Nigerian Basement Complex, and the remaining 15% is made up of cretaceous sedimentary rocks from the Bida Basin.

According to Offodile's (2003) geological mapping, the primary lithologic units discovered include migmatite-gneiss, earlier granites, meta-sediments (mostly schist, phyllite, and quartzite), and Bida sandstones. The majority of mineralization occurs in structural lineaments such folds, veins, fractures, and dykes in most basement complex terrain, including the research region. Therefore, the study of mineralization within the area implies studying lineaments within the area.

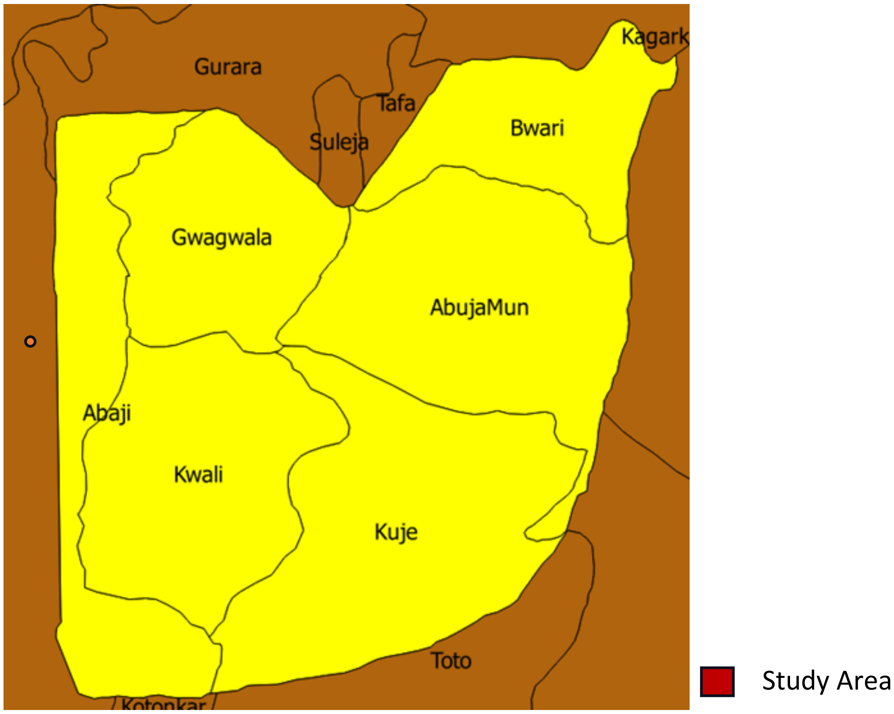

Figure 1: Map of Abuja showing the study area Source: bit.ly/2utzzns (2019)

MATERIALS AND METHODS

The Nigerian Geological Survey Agency (NGSA) provided the aeromagnetic data (Sheet 207) in digital/grid format for this study. Between 2003 and 2009, Nigeria undertook a high-resolution Airborne Geophysical Survey that included magnetic, radiometric, and restricted electromagnetic surveys with the goal of supporting and encouraging mineral exploitation. There were 500 meters between flight lines, 80 meters of terrain clearance, a flight direction of NW to SE, two kilometers between the lines, and a direction of NE to SW. Multi-channel radiometric and magnetic gradient were the measured parameters.

Aeromagnetic Data Processing

The aeromagnetic data of the study area was analyse using the following digital filters an algorithm in Oasis Montaj; First and Second vertical derivative, Tilt derivative and Analytic signal.

Vertical derivative filters

The vertical derivative, which can be computed in the frequency or space domain, is frequently used to highlight the shallowest geological source in total magnetic field data. A cause structure can be more clearly imaged thanks to the enhancement, which tends to reduce anomaly complexity and sharpen anomalies over bodies. Since the transformation would boost noise at short wavelengths, it may be loud. First vertical derivative (FVD) data are now practically required for projects involving magnetic interpretation. Compared to the first vertical derivatives, the second vertical derivative (SVD) has a greater capacity for resolution (Telford et al. 1990).

$$L(r) = r^n \qquad (1)$$

with: n = order of differentiation.

The FVD of the magnetic field is often computed by using the relation.

$$FVD = \frac{\partial T(x,y,z)}{\partial z} \qquad (2)$$

Where T $\quad 1\,\mathrm{VD} = \frac{\mathrm{dA(x,y,z)}}{\mathrm{dt}}$ is the total magnetic field at (x, y, z)

The SVD of magnetic field can be calculated by the equation given below (Mohammed et al. 2019)

$$SVD = \frac{\partial^2 T(x,y,z)}{\partial z^2} \qquad (3)$$

where T $\quad 1\,\mathrm{VD} = \frac{\mathrm{dA(x,y,z)}}{\mathrm{dt}}$ (3.2) is the total magnetic field at (x, y, z)

Tilt derivative filter

One excellent edge-detection filter is the tilt derivative filter (TDR), which highlights short wavelength anomalies and indicates the existence of magnetic lineaments. According to Miller and Sing (1994), the tilt derivative filter also functions as an automatic-gain-control (AGC) filter, which attempts to balance the response to strong and weak anomalies. As a result, the filter offers a useful method for following startling abnormalities. The tilt angle is defined as (Nabighian, 1972).

$$\mathrm{TDR} = \tan^{-1}\left(\frac{VDR}{THDR}\right) \quad (4)$$

where VDR and THDR are the first vertical total horizontal derivatives, respectively, of the total magnetic intensity T.

$$\mathrm{VDR} = \frac{dT}{dx} \quad (5)$$

and

$$\mathrm{THDR} = \sqrt{\left(\frac{dT}{dx}\right)^2 + \left(\frac{dT}{dy}\right)^2} \quad (6)$$

The total horizontal derivative of the tilt derivative is defined as:

$$HD\_THDR = \sqrt{\left(\frac{dTDR}{dx}\right)^2 + \left(\frac{dTDR}{dy}\right)^2} \quad (7)$$

By substituting (3.12) and (3.13) into (3.11), we have:

$$\mathrm{VDR} = \tan^{-1}\left(\frac{\frac{dT}{dz}}{\sqrt{\left(\frac{dT}{dx}\right)^2+\left(\frac{dT}{dy}\right)^2}}\right) \quad (8)$$

Analytic signal

This filter is applied to magnetic data with the intention of simplifying the fact that magnetic bodies typically have a positive and negative peak connected with them, which often complicates the process of pinpointing the precise location of the causal body (Debeglia and Corpel, 1997).

It has been demonstrated by Nabighian (1972) that a bell-shaped symmetrical function can be obtained for two-dimensional entities, and that this function maxima precisely above the top of the magnetic contact. In 1984, the three-dimensional case was developed. This function is the amplitude of the analytical signal. The only assumptions are that all causative bodies have uniform magnetization and that polygons with finite or infinite depth extent can depict their cross section

(Egbelehulu et al. 2021). Thus, strike, dip, magnetic declination, inclination, and remanent magnetization have no effect on this function or its derivatives (Abdulsalam et al. 2022).

One can define the potential field anomaly's 3-D analytical signal, A.,

$$A(x,y) = \left(\frac{\partial M}{\partial x}\right)\hat{x} + \left(\frac{\partial M}{\partial y}\right)\hat{y} + \left(\frac{\partial M}{\partial z}\right)\hat{z} \quad (9)$$

with M: magnetic field

The analytical signal amplitude can now be calculated as: (Abdulsalam et al. 2022)

$$|A(x,y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \quad (10)$$

RESULTS AND DISCUSSION

Figure 2 displays the research area's total magnetic intensity map. Positive anomalies are shown by the color pink to red on the map, whereas negative anomalies are represented by the color green to blue. The Total Magnetic Intensity map of the study area exhibits both magnetic highs and lows anomalies. The value of 33000nT has been removed from the data at the point of correction for handling. To obtain the actual value at any point, 33000nT must be added to it. Positive magnetic signatures predominate in the southern to south-western regions of the research area, whereas negative (low) magnetic anomalies predominate in the northern region. Mixtures of both high and low short wavelength closures with a high frequency of occurrence dominate the central part of the research area. The study area is slightly overlain with shallow sediments because the study area is predominantly made up of crystalline rocks.

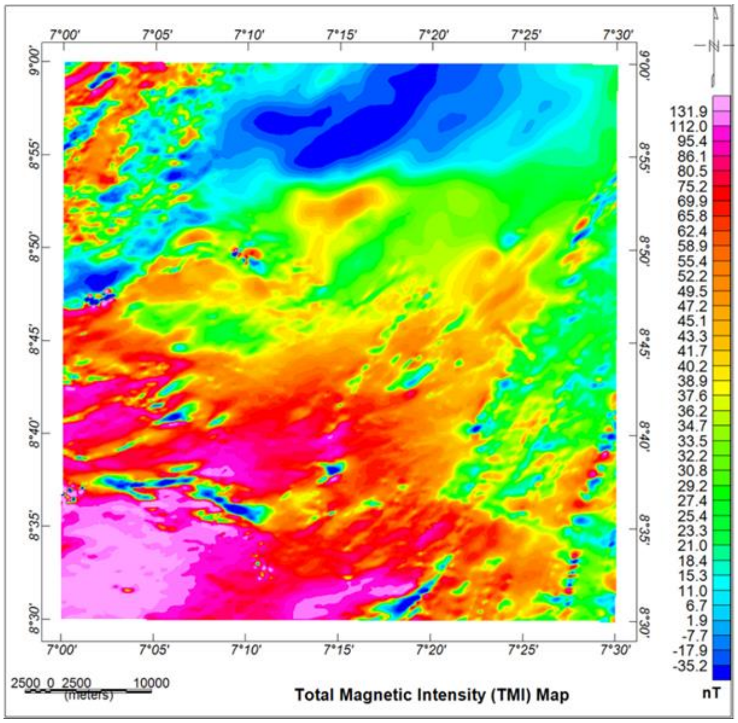

Figure 2: Total Magnetic Intensity Map of the Study Area

Application of The First Vertical Derivative Filter

The shallow geologic sources such as structural lineaments and igneous intrusions that may be related to the local mineralization systems are enhanced by the first vertical derivative filter. The near-surface magnetic lineaments that trend NE-SW have been made visible with the use of the filter. The sedimentary region and basement comprise the first vertical derivative (Figure 3), with the basement occupying a significant amount of the research area. It covers the NW, SW, and S regions, with an extreme concentration in the SW, and the sedimentary region covers the northern portion of the research area.

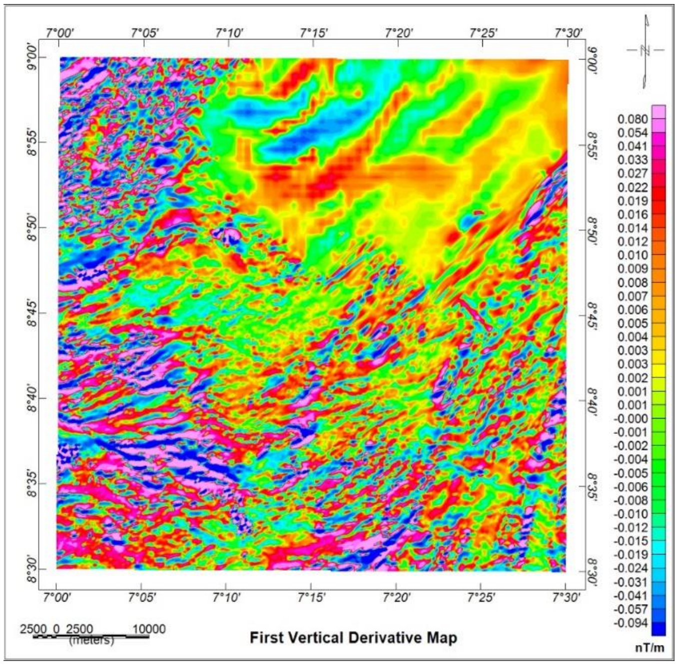

Figure 3: First Vertical derivative map

Second Vertical Derivative

Significant anomalies or regional influences are eliminated by the second vertical derivative, which highlights local feature expressions (Figure 4). The main benefit of this improvement is that the zero value for the magnetic data, in particular, very nearly corresponds to the edges of suprabasement disturbances or faults, or the sub-vertical edges of intrabasement blocks. Consequently, highlighting the near-surface characteristics that have been left out of the regional data, such as late-stage dykes, veins, connections, and cultural origins. Additionally, it shows where shear zones and faults are. The structures (lineaments) depicted on the first vertical derivative map and the second vertical derivative map show a trend that is consistent with each other.

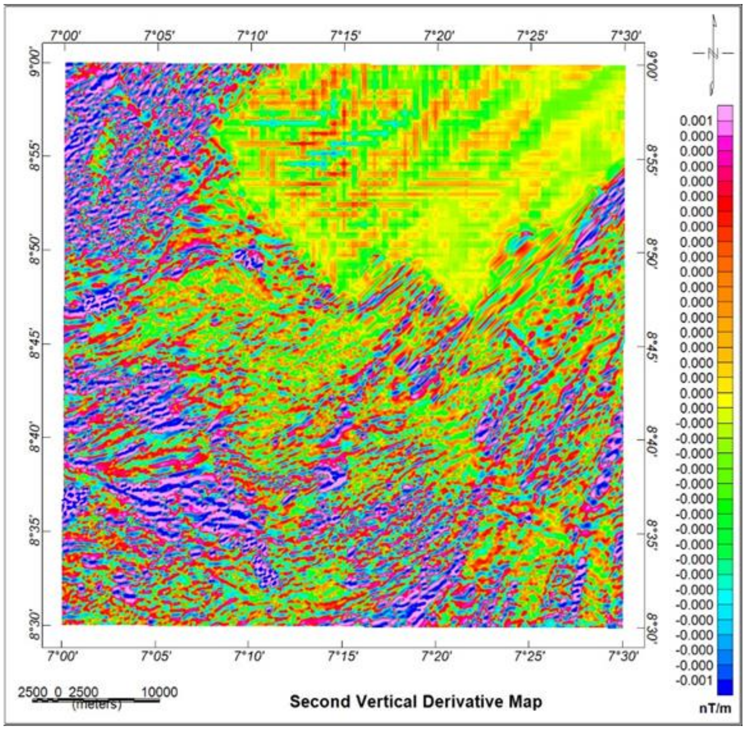

Figure 4: Second vertical derivative

Tilt Derivative Map (TDR)

When mapping out shallow near-surface structures, the tilt derivative map comes in handy (figure 5). The purpose of this improvement is to examine contact and fault features. It enhances the first vertical derivative in a complementary manner (Figure 3). Generally speaking, it yields a more precise fault location than the first vertical derivative. By enhancing the short wavelength anomalies, the tilt derivative map (Figure 5) was able to map shallow basement features and potential mineral development targets. The structures delineated are in agreement with those mapped out in the application of the first derivative filter. The structures (Lineament) delineated on the map which could host minerals in the study area trends NE-SW, E-W and NW-SE.

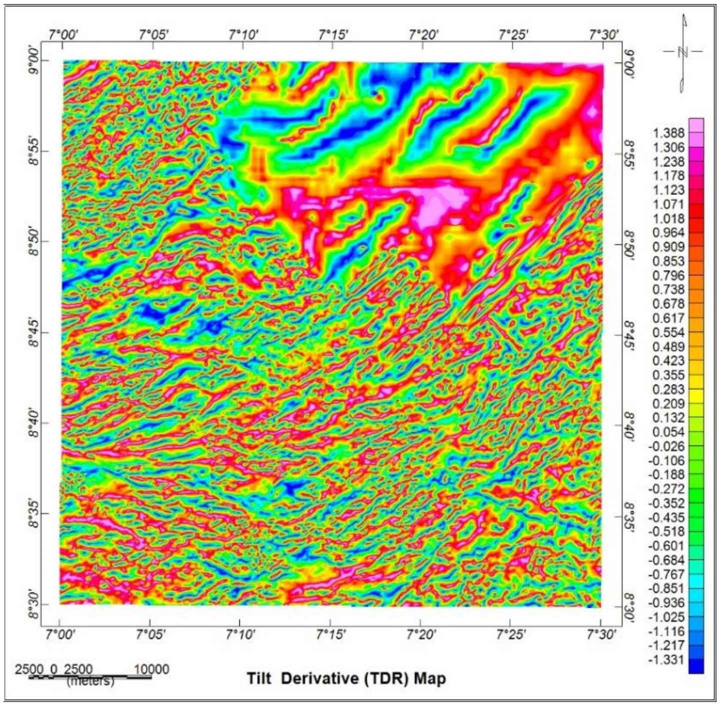

Figure 5: Tilt Derivative Map of Study Area

Analytic Signal Map

The research area can be divided into zones of outcrop, intermediate structures, and basement under the impact of thick sedimentation by using the analytical signal map, which displays fluctuations in the amplitudes of the magnetic anomalies. Figure 6 clearly shows two main regions: areas with low amplitude responses, which represent areas with relatively good sedimentation in the western part of the study area, and areas with high amplitude responses, which are primarily basement outcrops with varying degrees of deformations at the northeastern, eastern, southeastern, and extreme southwestern parts of the area.

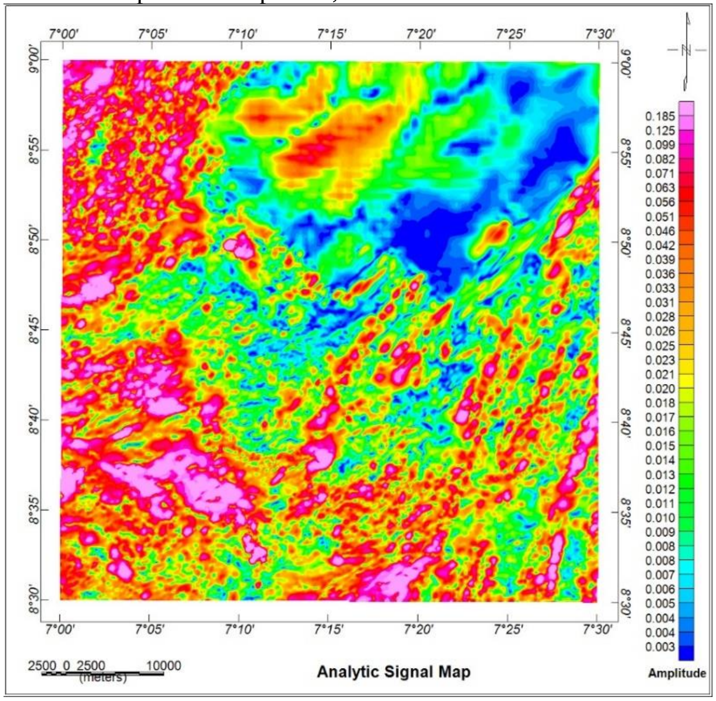

Figure 6: Analytic Signal of the Study Area

Lineament Map

The lineament map of the study area (figure 7) was produced using ArcGIS using Arc Map software. Structural information such as lineament, contacts, faults or discontinuities that are on the surface or near surface structures were digitised from processed magnetic data. Both minor and major structures were delineated. The structures such as lineaments, faults and discontinuity trends NE-SW, E-W and NW-SE which agrees strongly with Figure 3, 4, and 5 while the minor structure also trends in the same manner.

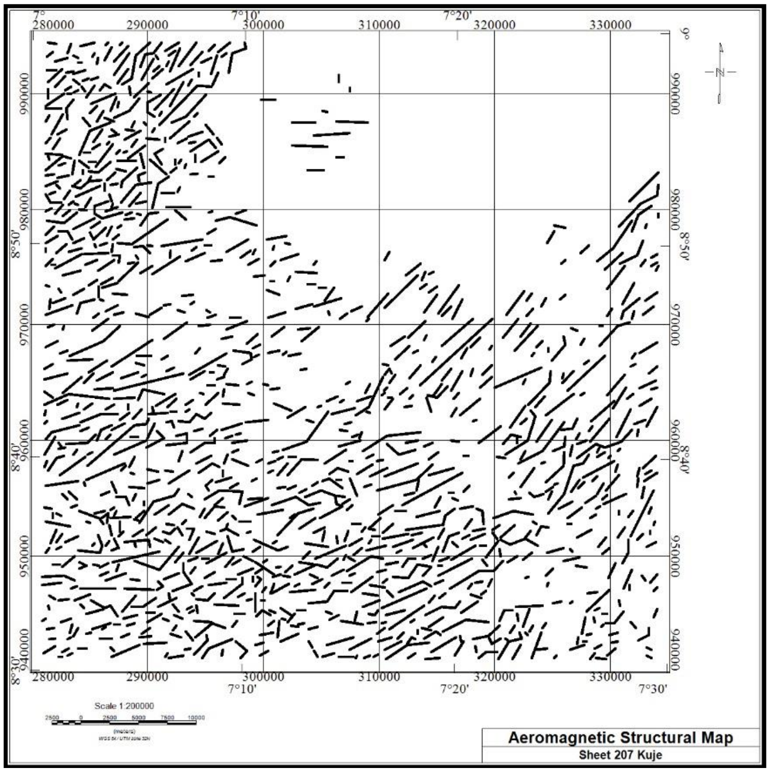

Figure 7: Lineament of study area

The research area's first derivative map showed that the region's predominant lineaments trend was NE-SW Pan-African. More line segments with NE-SW, E-W, and NW-SE trends were found by the tilt derivative. The minor trends in lineaments were NW-SE and E-W. Within the study area, the Pan-African deformational episode was the most prevalent (Figure 7). These lines in the research area were previously reported by Bala et al., Obaje (2009), and Braide (1992b).

(2017) and Anudu et al. (2020), Egbelehulu et al.(2021a&b). The collision between the westward-moving plate and the West African craton produced the E-W lineaments. According to McCurry (1971, 1976; Onyeagocha 1984; Toteu et al., 1990), the E-W movements are widely repeated as a highly deformed set of multidirectional orientations that are common in folds, lineaments, and faults over the entirety of the Nigeria basement complex and northern Cameroun. Pre-Pan African structures in the basement are oriented in opposition to these directions, but the NE-SW structures are most likely connected to the Pan African orogeny.

The application of the 1VD technique to the study area's residual magnetic data yielded results indicating, as shown in Figures 3, 5, and 7, polyphase deformation was ubiquitous throughout the region in the form of joints, fractures, faults, and folds.

CONCLUSION

This research work aimed at delineating subsurface structures and probable areas within the study area for both economic and industrial minerals using magnetic method. The aeromagnetic data was analysed and interpreted qualitatively to delineate subsurface structures that might host potential minerals (most importantly, gold mineralization) in the study area since minerals are structurally control. From the research area, a number of notable potential mineralization zones were found. The zones are rather broad, trend NE-SW and NW-SE, and are continuous as they go from one survey line to the next (figure 3-7). The overall tendency of structural form lines and geological formations is congruent with the NE-SW trend. The Gbesa neighborhood on the university campus is where the zones are most noticeable.

REFERENCES

Abdulsalam Nasir Naeem, Ene Kate Ogoh and Oluwatoyin Ologe (2022). Evaluation of Structural Framework and Depth Estimates Using High Resolution Airborne Magnetic Data over Some Parts of Middle Benue Trough, Nigeria. International Journal of Geosciences, 13, 557-575

Abdulsalam Nasir Naeem**,** John Florence Oluwabukola and Ologe Oluwatoyin. (2023). The effects of magnetic and radiometric responses on hydrothermal zones and its implication in minerals characterization over part of Nasarawa, North Central Nigeria. Journal of Tropical Resources and Sustainable Science, Vol. 11 (1). Home page jtss.org

Anudu, G. K., Stephenson, R. A., Ofoegbu, C. O., & Obrike, S. E. (2020). Basement morphology of the middle Benue Trough, Nigeria, revealed from analysis of high-resolution aeromagnetic data using grid-based operator methods. Journal of African Earth Sciences, 162, 103724

Bala. B., Lawal, K. M., Ahmed, A. L., Umar, M., Mohammed, A. A., & Adamu, A. (2017). The use of analytic and first vertical derivative techniques to gain insight into aeromagnetic anomaly patterns in part of Ikara, Nigeria. FUW Trends in Science and Technology Journal, 2(2), 684-690.

Bit.ly/2utzzns (2019). Map of Abuja showing the local government area.

Braide, S. P. (1992b). Syntectonic fluvial sedimentation in the central Bida Basin. Journal of Mining Geology, 28, 55-64.

Debeglia, N., & Corpel, J. (1997). Automatic 3-D interpretation of potential field data using analytic signal derivatives. *Geophysics*, *62*(1), 87-96.

Egbelehulu Priscillia, Abu Mallam Abel. U. Osagie (2021a). Interpretation of Aeromagnetic Data of Part of Gwagwalada Abuja Nigeria for Potential Mineral Targets. Journal *of Geological Research* 03 (4).

Egbelehulu Priscillia, Abu Mallam, Abel. U. Osagie and Adewumi Taiwo (2021b). Structural exploration of aeromagnetic data over part of Gwagwalada, Abuja for mineral targets using derivatives filters. Journal of Geological research 03(3), 2021

McCurry, P. (1971). Pan-African Orogeny in Northern Nigeria. Geological Society of America Bulletin 82, 3251-3262.

McCurry, P. (1976). The geology of the precambrian to lower paleozoic rocks of Northern Nigeria. A review, in Geology of Nigeria, Edited by C.A. Kogbe. Published by Elizabethan Co. Lagos. Pp. 15-39

Miller, H. G., & Singh, V. (1994). Potential field tilt—a new concept for location of potential field sources. *Journal of applied Geophysics*, *32*(2-3), 213-217.

Mohammed Adama, Mallam, A. and Abdulsalam, N.N. (2019). "Investigation of Magnetic Structures within the Chad Basin, Nigeria, Using High Resolution Aeromagnetic Data" International Organization of Scientific Research, Vol. 21(3) pp.27-36.

Nabighian, M. N. (1972). The analytic signal of two-dimensional magnetic bodies with polygonal cross-section - Its properties and use for automated anomaly interpretation: Geophysics, **37,** 507-517.

Nabighian, M. N. (1984). Toward a three-dimensional automatic interpretation of potential field data via generalized Hilbert transforms - Fundamental relations: Geophysics, 49, 780-786.

Obaje, N. G. (2009). Geology and mineral resources of Nigeria. Springer Berlin

Offodile, M. E. (2003). The development and management of groundwater in Nigeria. *Contributions of Geosciences and Mining to National Development, (NMGS)*, 1-7.

Telford, W. M., Geldart L.P. and Sheriff R.E. (1990). Applied Geophysics. Cambridge University Press, London.

Toteu, S. F., Garoua, J. M., Bertrand, J. M., & Dautel, D. (1990). Metamorphic zircons from North Cameroon; implications for the Pan-African evolution of Central Africa. Geologische Rundschau, 79(3), 777-788.

Verduzco, B., Fairhead, J. D., Green, C. M., & MacKenzie, C. (2004). New insights into magnetic derivatives for structural mapping. *The leading edge*, *23*(2), 116-119.