BAJOPMAS JOURNAL 16(1): 33 – 45
Printed in Bayero University, Kano - Nigeria.

DETAILED GROUND MAGNETIC SURVEY FOR MINERAL POTENTIAL IN SHANONO LOCAL GOVERNMENT AREA KANO STATE NIGERIA.

[1]Lawan, M. S.; [1]Saleh, M.; [1]Aku, M. O.; [1]Maitama, A.and [2]Ibrahim, H. S.
[1]Department of physics, Bayero University, Kano, Nigeria
[2]Department of physics, Aliko Dangode University of Science and Technology, Wudil

ABSTRACT
The study deployed high resolution ground magnetic survey to explore the mineral resource potential of Shanono Local Government Area Kano State Nigeria. Measurements of the magnetic field were performed with a GSM-19 portable Overhauser magnetometer with sensitivity of about 0.022nT, with all readings georeferenced using GPS receivers. The survey was composed of parallel profiles which were oriented perpendicular to the strike of the topography and the mining sites. The acquired data were corrected, reduced, enhanced and interpreted using standard soft wares in correlation with the geology of the area. Structural interpretation revealed three dominant lineament trends NE–SW, E–W, NW–SE and three major fracture zones northwestern, central, and southwestern, characterized by dense and intersecting structures. These structurally complex zones are interpreted as favorable conduits for mineralizing fluids, making them prime exploration targets. Depth to magnetic source estimations using Euler Deconvolution, yielded minimum values of 5m and maximum depths of about 1.7km. The identification of such depth and structurally favorable targets presents significant investment opportunities for the mining sector and provides actionable insights for policymakers to develop sustainable mining strategies in the region.

Keywords: Magnetic, Potential, Ground, Mineral, Lineament

1.0 INTRODUCTION

Nigeria is widely recognized for its substantial mineral endowments, having over 40 types of solid minerals distributed at about 450 locations [1]. Research findings further demonstrate that abundant mineral resources are distributed across various regions of the nation [2]. Current evidence suggests that the demand for mineral resources is reaching historically unprecedented levels, largely driven by accelerating global industrialization and the growing material needs associated with expanding populations [3]. In economic terms, the concept of a “resource” refers to any item that can generate actual or potential wealth; accordingly, a mineral resource is understood as that component of a region’s mineral endowment from which economic value can be derived [4]. Minerals are defined as naturally occurring substances in solid, liquid, or gaseous states that are found in or on the Earth’s crust [5].

Nigeria’s complex and diverse geological framework promotes the presence of numerous economically valuable mineral deposits throughout the country [6]. Mineral resources can be broadly categorized into two principal groups based on their physical occurrence: solid minerals and liquid fuels. Solid minerals are further subdivided into metallic minerals (e.g., iron ore, gold, copper), non-metallic minerals (e.g., phosphate, salt, glass sand), and energy-bearing minerals (e.g., coal, bitumen/tar, uranium), whereas liquid fuels encompass petroleum and natural gas [1]. Despite Nigeria’s substantial endowment of solid mineral resources, the sector has attracted relatively limited foreign investment, largely attributable to factors such as insufficiently proven and bankable mineral reserves, inadequate geological data, and associated uncertainties that deter external investors [6]. Before the 1960s, mining constituted a foundational pillar of the Nigerian economy, contributing as much as half of the nation's Gross Domestic Product [1]. Currently, the contribution of the mining sector to Nigeria's Gross Domestic Product remains relatively low—estimated at around 0.2 % of GDP—which is markedly lower than the shares observed in several other African economies such as Botswana, Ghana, and South Africa, where the mining sector accounts for substantially larger proportions of national output [7].

In March 2017, Dr. Kayode Fayemi, then Nigeria's Minister of Mines and Steel Development, characterised the nation's minerals sector by asserting that "we are a mineral nation but we are not a mining nation," highlighting that although Nigeria possesses extensive mineral occurrences, it has not realised substantial commercial mining comparable to its West African peers. Unlike countries such as Ghana (notably gold, manganese, and bauxite), Guinea (iron ore, bauxite), Sierra Leone (gold, diamond), Liberia (iron ore, diamond) and Burkina Faso (gold), Nigeria has yet to discover or develop major world-class metallic mineral deposits that could underpin a robust mining industry [1]. Several factors have been identified to explain why Nigeria has yet to identify major mineral deposits, chief among them being the absence of comprehensive and detailed geophysical exploration of known mineral occurrences—a deficiency that has resulted in limited subsurface data and hindered the accurate delineation of potential deposits necessary for attracting significant investment [1]. However, much of the existing geological information remains outdated, with foundational data and maps largely produced in the 1950s and early 1960s by the Geological Survey of Nigeria, limiting the availability of modern, high-resolution subsurface information for current mineral exploration [4] with the most recent comprehensive geological data having been collected during the 2006–2007 airborne geophysical surveys, indicating a lack of updated, high-resolution national datasets since that period [8].

Shanono Local Government Area in Kano State is geographically situated between approximately 11.962° N and 12.264° N latitudes and 7.979° E and 8.980° E longitudes, and is underlain by the crystalline rocks of the Northern Nigerian Basement Complex—predominantly comprising gneisses, migmatites, and associated metasedimentary units characteristic of this Precambrian geological terrain [9]. Geologically, the area is underlain predominantly by a migmatite–gneiss–granite complex that has been intruded by schistose rocks, and this assemblage is situated between the Karau Karau and Kazaure Schist Belts—reflecting the typical juxtaposition of high-grade basement complex lithologies and lower-grade supracrustal units characteristic of Northern Nigerian Basement geology [8]. Detailed geological mapping and studies of schist belts in Nigeria have been conducted in numerous localities—including Maru, Anka, Zuru, Kazaure, Zungeru, and Ilesha, where these supracrustal belts are widely documented as being generally associated with gold mineralisation [4]. *In typical gold-bearing quartz vein systems, the mineralised quartz is accompanied by a suite of sulphide minerals, with pyrite generally predominating and galena commonly present as significant accessory phases* [10]. Previous studies have demonstrated that primary gold mineralization in the Nigerian Basement Complex is structurally controlled, with geological features such as faults, shear zones, and fractures serving as pathways for hydrothermal fluid flow and acting as focal points for ore deposition [11]. The study area exhibits numerous lineaments interpreted as faults, fractures, and lithological contacts that serve as potential conduits for mineralisation. These structural features predominantly trend in the northeast–southwest and east–west orientations, with the northeast–southwest direction being most prevalent. The mapped lineament trends extend through the localities of Gwarzo, Shanono, Bagwai, Tsanyawa, Bichi, and Kunchi, reflecting dominant tectonic fabrics that may influence mineral prospectivity in the region [8].

[9] also reported that, In their study, interpretation of high-resolution aeromagnetic data delineated structural lineaments that intersect known gold mineralisation zones and identified principal structural anomalies trending predominantly in the northeast–southwest and northwest–southeast directions within the Shanono Local Government Area of Kano State and its environs; these tectonic trends are inferred to control subsurface fluid pathways and the localisation of mineralisation.

In this work, ground magnetic survey using GSM-19 portable high-sensitivity Overhauser Magnetometer was used for the Measurement of the Earth's total magnetic field and the collected magnetic data were corrected, reduced and processed using golden surfer and oasis montaj software for locating the areas with higher mineral potential in Shanono local Government area of Kano State Nigeria.

1.1 Geomagnetic field and magnetic Susceptibility of Geologic Materials

According to the classical description of magnetostatic interactions, when two magnetic poles with strengths m_1 and m_2 are separated by a distance r, a force of interaction exists between them that is proportional to the product of their pole strengths and inversely proportional to the square of the separation. This force is repulsive for poles of like polarity and attractive for poles of opposite polarity, acting along the line connecting the two poles [12], [13].

$$F = \frac{m_1 m_2}{4\pi\mu r^2} \quad (1)$$

where μ is the magnetic permeability of the medium separating the poles; m_1 and m_2 are pole strengths and r the distance between them [12].

The Earth's magnetic field, or geomagnetic field, is generated predominantly by electric currents induced within the convecting, electrically conducting fluid of the outer core, a process known as the geodynamo. In addition to this core-generated main field, contributions to the overall geomagnetic field arise from external current systems in the ionosphere and magnetosphere, as well as from magnetisation within the Earth's crust—both induced by the main field and retained as permanent (remanent) magnetisation in crustal rocks. Together, these internal and external sources combine to produce the complex magnetic field observed at and near the Earth's surface [12], [13]. The magnetic fields produced by geological bodies are superimposed upon the Earth's principal geomagnetic field, and spatial variations in the intensity and orientation of this main field affect both the amplitude and geometric expression of localized magnetic anomalies observed at the surface. In other words, changes in the magnitude and direction of the background field modulate the strength and morphology of anomalies attributable to subsurface magnetic sources [13]. The relationship between magnetic flux density (B) and magnetic field strength (H) can be expressed in terms of a diagnostically significant parameter known as magnetic susceptibility (κ), which quantifies the extent to which a material becomes magnetized in response to an applied magnetic field; essentially, susceptibility represents the proportionality between the induced magnetization within a substance and the strength of the external field acting upon it [12].

Magnetic susceptibility is a key physical property of rocks that reflects the abundance and types of magnetic minerals they contain. Rocks with relatively high concentrations of ferro- and ferrimagnetic minerals, such as those found in basic and ultrabasic lithologies, typically exhibit the greatest magnetic susceptibilities; in contrast, acidic igneous and many metamorphic rocks generally display intermediate to lower susceptibility values, while most sedimentary rocks have very low susceptibilities due to limited magnetic mineral content

[12]. A body placed in a magnetic field acquires a magnetization which, if small, is proportional to the field.

$$M = kH \tag{2}$$

Where M is the material magnetization, k is the magnetic susceptibility and H is the magnetizing field [13].

The total magnetic field B, which include the effect of magnetization can be written as

$$B = \mu_r \mu_0 \mathrm{H} \tag{3}$$

where B is the total magnetic field, H is the magnetizing field, μ_0 is the permeability of free space and μ_r is the permeability of material [14]

1.2 Location and Geology of the Study Area

The study area (Figure 1) is situated within the Shanono Local Government Area of Kano State, Nigeria, between latitudes 12.02° N and 12.13° N and longitudes 7.95° E and 8.07° E, and it lies within the northern sector of the Nigerian Basement Complex—a Precambrian crystalline terrain. The geology of the region is dominated by a migmatite–gneiss–granite assemblage intruded by schistose units, reflecting supracrustal rocks that occupy the structural corridor between the Karau-Karau and Kazaure schist belts characteristic of northwestern Nigeria's metamorphic framework [8].

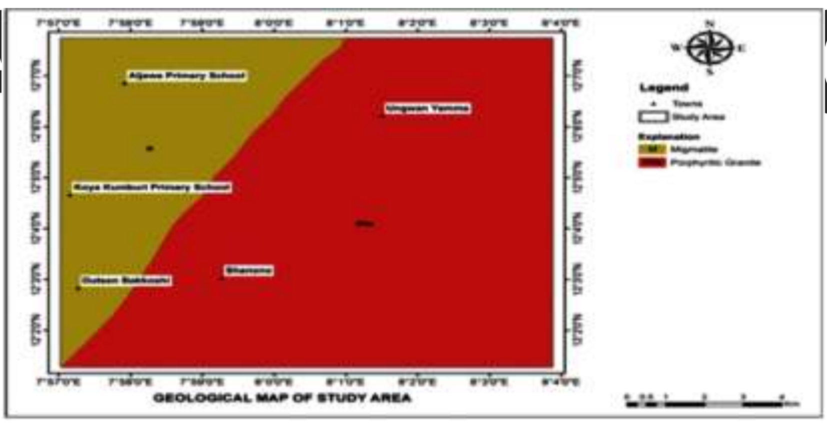

Figure 1 Geology of the Study Area

2.0 MATERIAL AND METHOD

2.1 Data Collection

A ground magnetic survey was conducted within the first two weeks of the month of July, 2025 to measure the total magnetic-field in Shanono Local Government Area Kano State Nigeria using a GSM-19 portable, high-sensitivity Overhauser magnetometer with sensitivity of about 0.022nT, which was paired with GPS receivers to geolocate each reading. The survey comprised a series of parallel profiles, spaced approximately 50m apart, and oriented perpendicular to the terrain and local mining features. A base station was established in a magnetically quiet, fixed location to record instrument drift and diurnal variations, and these corrections were applied to the field data. The acquired data were corrected, reduced, enhanced and interpreted using standard soft wares in correlation with the geology of the area.

2.2 Reduction to the Equator (RTE)

One common approach to facilitate the interpretation of Total Magnetic Intensity (TMI) data involves applying a mathematical transformation to the gridded TMI values to reduce or eliminate the influence of geomagnetic latitude. This processing generates a filtered anomaly map that approximates the magnetic field response that would be observed if the survey area were located at the magnetic pole or the magnetic equator, thereby simplifying the geometry of the magnetic anomalies for subsequent geological interpretation [12]. The Reduction to Equator (RTE) filter is applied to magnetic data to mathematically reposition the observed magnetic anomalies so that their peaks are aligned directly over the causative sources, thereby centering the anomaly maxima over geological bodies and facilitating clearer interpretation of subsurface structures in regions of low magnetic latitude. The RTE filter is mathematically expressed as Equation 4 [15].

$$RTE = \sin I + i\cos I(D-\theta)^2 \quad (4)$$

Where I is the geomagnetic inclination, D geomagnetic declination, sin I is the amplitude component, and i cos I $(D-\theta)^2$ is the phase component.

2.3 Regional Residual Separation

Regional–residual separation refers to the analytical procedure by which the long-wavelength, broad-scale component of a dataset (the regional field) is distinguished from the shorter-wavelength, localized component (the residual field). The principal objective of these filtering operations is to transform and partition the data in a manner that facilitates the geological interpretation of magnetic anomalies, thereby clarifying their significance with respect to underlying geological structures and sources [16]. The total magnetic field observed at the Earth's surface is composed of both a broad-scale regional component and a shorter-wavelength residual magnetic anomaly component. The regional field primarily reflects the influence of deep-seated sources, such as the Earth's core and large-scale geological structures, whereas the residual anomaly field is attributed mainly to magnetic effects arising from variations in the magnetic properties of crustal rocks. which can be express as Equation 5 [15].

$$Residual\ Field = Total\ Field - Regional\ Field\ (IGRF) \quad (5)$$

2.4 Derivative Filters

Derivative operations applied to magnetic data tend to emphasise high-frequency components associated with near-surface features and accentuate the boundaries of anomaly responses, thereby sharpening the edges of magnetic anomalies and improving the delineation of shallow geological structures. Among such filters, the first vertical and higher-order derivative maps are commonly generated because they enhance the representation of shallow sources relative to deeper regional effects, facilitating more precise structural interpretation [14]. Deriving meaningful geological information from magnetic field measurements necessitates the application of specialised filtering techniques to emphasise the magnetic responses generated by subsurface sources while attenuating extraneous noise and background trends; these filters enhance the detectability of signals associated with magnetised geological bodies and facilitate more accurate interpretation of the underlying structures [17]. These filters include First vertical derivative, second vertical derivative, total horizontal derivative, tilt derivative etc.

2.4.1 Vertical Derivative (VD)

Application of the First Vertical Derivative (FVD) operator to magnetic field data effectively attenuates the long-wavelength responses generated by deeply buried causative bodies, thereby enhancing the resolution of near-surface features. This filtering improves the clarity of the magnetic image by highlighting important structural and lithological elements that are not readily apparent on Total Magnetic Intensity (TMI) or Reduction to the Equator (RTE) maps [18]. Many advanced filtering techniques used in magnetic data interpretation rely fundamentally on first and higher-order vertical derivatives of the anomaly field to qualitatively delineate characteristics of the causative sources. These derivative-based filters accentuate the high-frequency, short-wavelength components of the signal that are typically associated with the edges, centres, or subtle features of near-surface bodies, while attenuating the longer-wavelength components derived from deeper regional sources. Consequently, vertical derivatives serve to enhance shallow magnetic anomalies and define structural boundaries, thus aiding in the interpretation of geological features [17]. The first vertical derivative is given in Equation 6

$$FVD = \frac{\partial T}{\partial z} \tag{6}$$

where, T is the potential field anomaly and z is the vertical depth.

2.4.2 Total Horizontal Derivative (THD)

The Total Horizontal Derivative (THD) (Equation 7) of magnetic data serves as an effective edge-detection tool by computing the combined horizontal gradient of the field, and it is widely employed to delineate the boundaries of source bodies. This technique accentuates anomaly discontinuities and reliably defines lateral contrasts in magnetisation while exhibiting relatively low sensitivity to variations in source depth and data noise compared to some other derivative filters [17].

$$THD = \sqrt{(\frac{\partial T}{\partial x})^2 + (\frac{\partial T}{\partial y})^2} \tag{7}$$

where, x and y are horizontal length

2.4.3 Tilt Derivative (TD)

In magnetic data interpretation, a geophysical enhancement technique known as the tilt-derivative (TD) filter is widely applied to delineate subsurface structural features during mineral exploration. This method is particularly valued for its capacity to accentuate subtle characteristics and trace the boundaries of causative magnetic bodies—expressed as lineaments—thereby improving the visualization of geological contacts and structural discontinuities in the magnetic anomaly field [18]. In magnetic data analysis, the tilt derivative (TD) is widely employed to aid in the identification of mineralised zones and to delineate shallow basement structural features. The tilt angle itself is mathematically defined as the arctangent of the ratio between the first vertical derivative and the total horizontal derivative of the magnetic field, producing a dimensionless angle that enhances the detection of geological boundaries and subtle anomaly trends in potential field data and can be express in Equation 8 [16].

$$TD = \tan^{-1}(VD/THD) \tag{8}$$

2.5 Depth Estimation

Depth estimation is a principal objective in magnetic data interpretation. Empirical “rule-of-thumb” techniques provide approximate depths to the tops of causative bodies that are generally accurate to within about ±30 %, which is considered sufficient for the preliminary evaluation of field results before undertaking more detailed quantitative analyses [13]. Estimating the depth of magnetic sources remains a fundamental objective in magnetic data interpretation. An approximate depth to a causative magnetic body can often be inferred directly from the geometric characteristics of the observed anomaly—specifically, the shape and wavelength of the anomaly can provide a first-order estimate of the depth to the source in preliminary analyses [12].

2.5.1 Euler Deconvolution

Estimating depths to magnetic sources has long been recognised as a central objective in magnetic survey interpretation. Since Peters' seminal work in 1949, a continuous succession of studies has introduced new and refined methods for determining source depths from potential field data. During the 1980s, an influential technique known as Euler deconvolution was developed, providing a computational means to process magnetic data and infer the depths and positions of causative sources by mathematically collapsing the observed field to equivalent point sources at depth [12]. The Euler deconvolution technique operates directly on the observed magnetic data and yields a mathematical solution (equation 9) without requiring a predefined geological model, which is advantageous because the resulting interpretation is not constrained by prior geological assumptions and can be used as an independent test of structural and geological hypotheses. In this method, the strength of the magnetic field at any point is related to the gradients of the total magnetic field expressed in Cartesian coordinates, and these gradients are linked to different types of magnetic sources through a parameter known as the structural index N [12].

$$(X - X_0)\frac{\delta T}{\delta x} + (Y - Y_0)\frac{\delta T}{\delta Y} - Z_0\frac{\delta T}{\delta Z} = N(B - T) \quad (9)$$

where X_0, Y_0, Z_0 are the coordinates of a magnetic source whose total field intensity T and regional value B are measured at a point (X, Y, Z); N is the degree of homogeneity and is referred to as the Structural Index [12]. We applied standard Euler deconvolution. This method solves Euler's homogeneity equation over moving data windows, using an assumed structural index to infer the positions and depths of source bodies.

2.6 The Centre of Exploration Target (CET) Technique

The Centre for Exploration Targeting (CET) grid analysis is an advanced geophysical image-processing technique commonly applied in mineral exploration to assess the textural characteristics of gridded datasets in order to delineate structurally complex zones and evaluate the potential for mineralisation. In practice, this method initially identifies magnetic discontinuities within the data, determines their spatial positions, and subsequently examines the structural relationships among these features such as intersections, contacts, and changes in strike direction to highlight areas of structural complexity that may correspond to favourable mineralised targets. The sequential process of discontinuity detection, spatial positioning, and structural linkage analysis facilitates the identification of geological features that are potentially conducive to gold deposit occurrence [16]. The Centre for Exploration Targeting (CET) grid analysis method applies advanced image texture analysis to geophysical grids in order to delineate zones of structural complexity that may be favourable for the occurrence of mineralisation, particularly gold. In this approach, magnetic discontinuities are first detected and their spatial locations identified; structural relationships among these discontinuities such as intersections, junctions, and variations in strike direction—are then examined to characterise lineaments and structural networks. By highlighting structurally complex areas, the technique facilitates the identification of prospective targets for further exploration [17].

3.0 RESULT AND DISCUSSION

3.1 Total Magnetic Field

The colour gradations in (Figure 2) delineate marked spatial variations in total magnetic field intensity, spanning from approximately 3,395nT to 34,553nT. These variations are interpreted to reflect differences in lithology within the study area. The red, pink, and orange shades correspond to zones of elevated magnetic intensity, likely indicative of magnetite-rich or strongly ferromagnetic rocks proximal to the surface. Conversely, the regions shaded in blue and green represent lower magnetic intensity, which may denote non-magnetic lithologies or zones of advanced weathering. Moreover, a distinct, diagonally oriented boundary trending NW–SE across the map defines a sharp magnetic gradient, this feature is interpreted as representing a lithological contact, fault, or other structural discontinuity. However, the regions of elevated magnetic intensity in the southern and northern portions of the study area may signify strongly magnetized anomalous zones, which could correspond to potential mineralization zones.

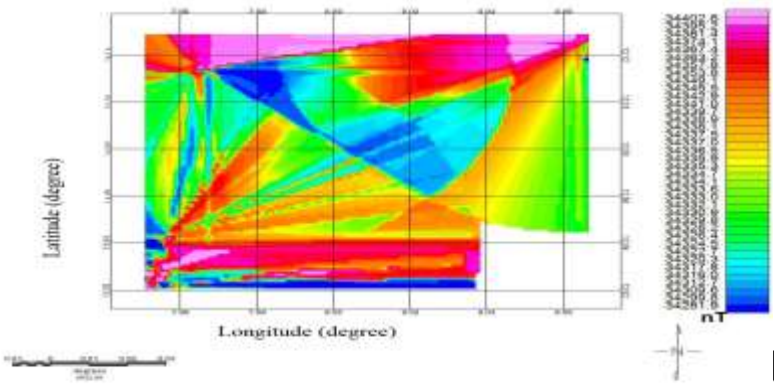

Figure 2 Map of Total Magnetic Intensity

3.2 Reduce to Equator (RTE) Residual Magnetic Field

The reduction-to-equator (RTE) map (Figure 3) for the study area preserves a spatial pattern broadly analogous to that of the total magnetic intensity map, although with modest deviations in colour intensity. In the RTE representation, negative amplitude values span from dark blue through to red, whereas positive amplitude values range from red to pink, with magnetic field magnitudes varying from approximately **–88.156nT to +32.393nT**.

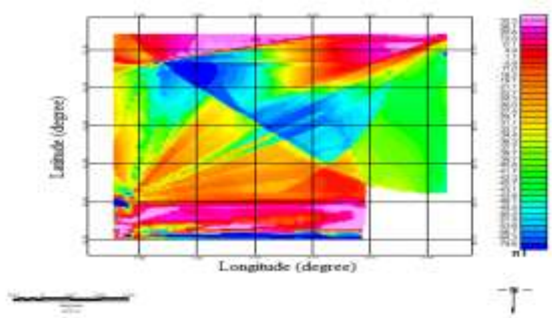

Figure 3 Map of Reduce To Equator (RTE) Residual Magnetic Field

3.3 The First Vertical Derivatives (FVD)

The First Vertical Derivatives (FVD) map (Figure 4) of the study area exhibits magnetic field intensities ranging from –0.29nT to +0.289nT. It reveals distinct lineaments, predominantly oriented in a northeast–southwest (NE–SW) direction, with additional trends in the southern and northwestern sectors showing east–west (E–W) alignment. These structural features are most strongly expressed in the southwestern and northwestern parts of the region, while a diagonal geological contact, delineating a lineament, bisects the study area in a northwest–southeast (NW–SE) direction.

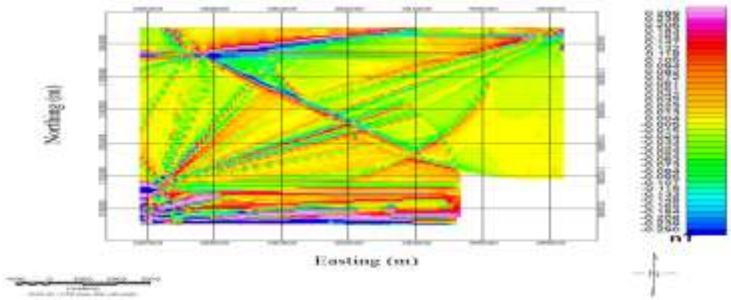

Figure 4 Map of First Vertical Derivative (FVD)

3.4 Total Horizontal Derivative (THD)

Total Horizontal Derivative (THD) map (Figure 5) presents a narrower amplitude range (–0.002nT to +0.002nT) and is dominated by NE–SW trending lineaments, with a few diagonal features trending NW–SE. The NE–SW lineaments are interpreted as fractures, whereas the NW–SE trending structures likely correspond to the principal geological fault or contact in the area.

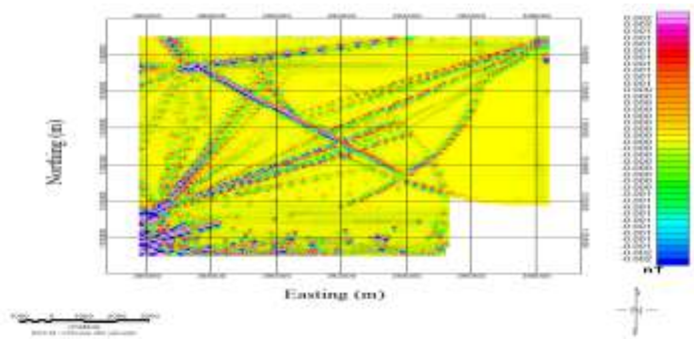

Figure 5 Map Total Horizontal Derivatives (THD)

3.5 Tilt-Derivative (TD)

Tilt-Derivative (TD) map (Figure 6) reproduces the dominant NE–SW lineament trends observed in the FVD and SVD, while also delineating additional dashes and contacts, likely major faults. Magnetic values on the TD map vary from –1.5nT to +1.5nT, with negative anomalies (depicted in blue–green) concentrated in the eastern and north-central sectors; positive anomalies (orange–red) predominate in the northern, western, southern, and central parts of the study area, suggesting structural discontinuities such as contacts or faults.

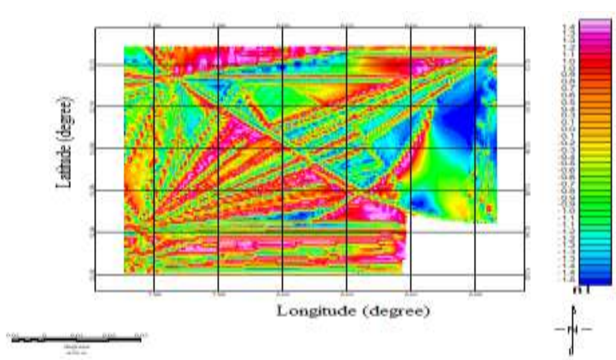

Figure 6 Map of Tilt-Derivative (TD)

3.6 Euler Deconvolution

Euler deconvolution (Figure 7) provides location and depth constraints, revealing source depths ranging from 5.2m to as deep as 1,713m. The shallow Euler solutions corroborate the very near-surface features inferred by spectral analysis, reinforcing the interpretation that some of these sources may be associated with localized mineralization zones exploited by artisanal miners. Meanwhile, the deep Euler estimates point to profound magnetic bodies or basement structures, potentially indicating major litho-tectonic features or intrusive complexes.

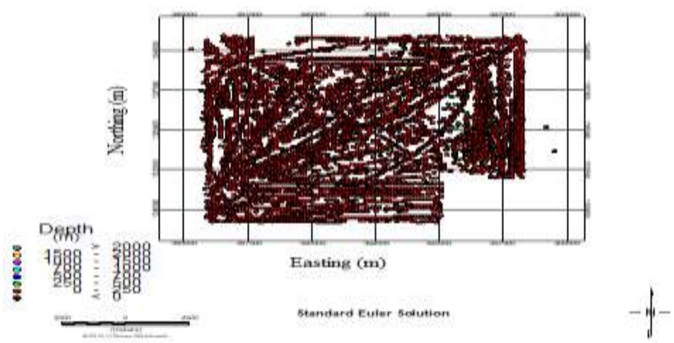

Figure 7 Map of Euler Standard Solution

3.7 Depth Estimation

The estimated maximum depths of the magnetic-source to mineralization zones, as determined by standard Euler deconvolution, solution was found to be approximately **1.7km**. This maximum depth is broadly consistent with previous studies in the same area, notably [9], who reported a maximum depth of **1,436m** (Euler), and [19], who estimated a depth of **700m** (Euler). However, the minimum depths derived in our work, **5.18m** (Euler) diverge from those earlier findings, which reported minimum depths of **244.5m** (Euler) [9] and **100m** (Euler) (Mohammed & Jimoh). The shallowest solutions we observe, nonetheless, align more closely with the very near-surface mining activities of local artisanal miners operating in the study area.

3.8 Integrated Geological Interpretation

The shallow magnetic sources of 5m that was delineated may likely correspond to surficial lithologies or highly magnetized zones within the weathered layer. Given their correspondence with artisanal mining depths, these may reflect near-surface mineralization or high-susceptibility fragments exposed or accessible to local miners.

The deepest sources of 1,700m reflect significant crustal structures. These could be deep-seated intrusions, basement highs, or consolidated magnetic basement rock. Their spatial clustering suggests that they may define the major tectonic framework of the region and could be associated with long-lived structural features.

The Centre of Exploration Target (CET) technique **(**Figure 8A &B), the FVD **(**Figure 4), the THD **(**Figure 5) and the TD **(**Figure 6), presents the lineament maps for the study area, revealing several dominant structural trends. The majority of lineaments exhibit a **NE–SW** (northeast–southwest) orientation, while a secondary subset in the northern and southern zones trends **E–W** (east–west). Additionally, a distinct population of lineaments aligns **NW–SE** (northwest–southeast), which may indicate the presence of a major fault or a contact zone. This feature likely delineates a significant geological boundary, consistent with the two geological formations identified in the geological map (Figure 1). Notably, the lineament density increases markedly in the **northwestern, central**, and **southwestern** sectors of the study area. These high-density zones, characterized by a convergence of intersecting lineaments, suggest regions of enhanced structural complexity and extensive fracturing. Such structural domains may constitute preferential pathways for mineralizing fluids and therefore offer elevated prospectivity for mineral exploration. This interpretation aligns with previous work by [9], [19] and [8] who similarly identified these areas as prospective targets.

The spatial distribution and orientation of lineaments provide critical insights into the tectonic framework and structural controls on mineralization. The **NE–SW** and **E–W** trends may reflect regional extensional or compressional stresses, whereas the **NW–SE** trend likely defines a principal fault or contact. The intersection of these structural systems in the high-density zones underscores their potential as structurally controlled mineralization sites.

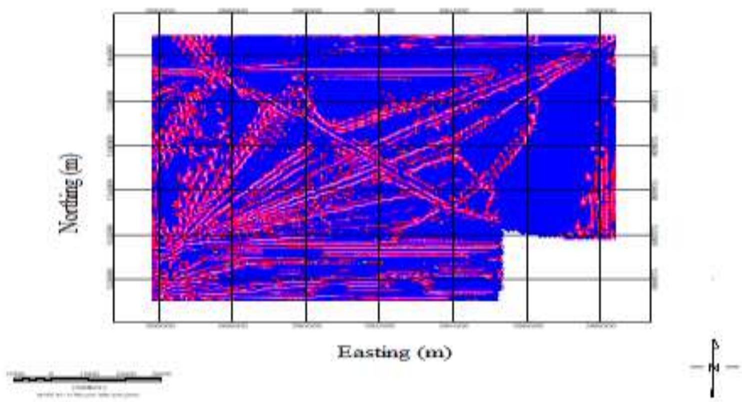

Figure 8A Map of Lineaments

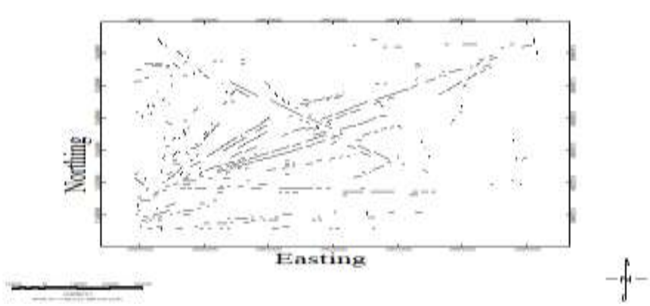

Figure 8B. Map of Lineaments

4.0 Conclusion

This ground magnetic survey of the Shanono Local Government Area in Kano State has successfully delineated structurally favorable zones for mineralization within the basement complex terrain. The high-precision magnetic measurements and detailed data processing identified three major structural lineament trends NE–SW, E–W, NW–SE and three dense fracture domains such as northwestern, central, southwestern, which likely act as conduits for mineralizing fluids. Depth to magnetic source estimations yielded minimum depth value of 5.18m, and maximum depths of 1,713m. This suggests that the study area hosts a multi-level mineralization system, making it a promising target for further exploration. The results provide strong evidence for significant mineral resource potential, supporting the case for increased investment in regional mining. Additionally, the structural framework and mineralization model developed through this study can inform strategic planning and policy formulation by relevant regulatory authorities.

RECOMMENDATION:

To facilitate a more comprehensive investigation and rigorous validation of the present findings, it is recommended that an integrated suite of complementary geophysical techniques be applied, including three-dimensional (3D) modeling. In addition, subsequent high-resolution ground-based magnetic surveys and strategically targeted drilling campaigns should be conducted to improve subsurface characterization and to substantiate the geophysical interpretations

REFERENCES

[1] Olade, M. A. (2019). Solid mineral deposits and mining in Nigeria : - A sector in transitional change. *Achievers Journal of Scientific Research*, *2*(1), 1–16. http://www.achieversjournal.org/

[2] Elton, M., Mike, E., & Taiwo, I. (2020). Problems and Strategies for Exploration of Solid Mineral Resources in Nigeria. *International Journal of Research and Innovation in Social Science*, *4*(7), 485–489. https://ideas.repec.org/s/bcp/journl.html

[3] Molua, C., & Edobor, M. (2024). Geophysical Exploration for Solid Mineral Deposits : A Key to Sustainable Mining Practices. *Fupre Journal of Scientific and Industrial Research*, *8*(1), 117–123. https://journal.fupre.edu.ng/index.php/fjsir/article/download/258/219/

[4] NEITI. (2020). A SURVEY OF THE SOLID MINERALS LANDSCAPE & ENDOWMENTS IN NIGERIA. *NEITI Occasional Paper Series*, *5*, 1–168. https://neiti.gov.ads/2021/08/NEITI-OPS6

[5] Shasore, O. (2016). Nigeria ' s Solid Minerals as a source of Economic Development - Tapping a latent resource ? *African Law Practice*, *December*. https://www.alp.company/resources/energy-and-natural-resources/nigerias-solid-minerals-source-economic-development-tapping

[6] Ahmed, H. A. (2022). Overview of Nigeria ' s Solid mineral Potentials , Challenges and Prospects. *FUTY Journal of the Environment*, *16*(1), 76–91. http://creativecommons.org/licenses/by/4.0/

[7] Adekanmbi, A. O., & Wolf, D. (2024). Solid Mineral Resources Extraction and Processing Using Innovative Technology in Nigeria. *JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION*, *12*(January). https://doi.org/10.13140/RG.2.2.16610.91840

[8] Shehu, S. J., Musa, O. A., Muhammad, S., Abdulrahim, A. B., & Salihu, B. S. (2019). A reconnaisance study to delineate the potential mineral zones around the schist belt areas Of Kano State, Nigeria using airborne magnetic data. *Journal of Geology and Mining Research*, *11*(2), 14–21. https://doi.org/10.5897/jgmr2018.0307

[9] Daniel, E., Jimoh, R., & Lawal, K. (2019). Delineation of Gold Mineral Potential Zone Using High Resolution Aeromagnetic Data Over Part of Kano State , Nigeria. *Journal of Geology & Geophysics*, *8*(4), 1–9.

[10] Obaje, N. G. (2009). Geology and Mineral Resources of Nigeria. *Springer Science & Business Media*, *120*, 1–222. https://doi.org/10.1007/978-3-540-92685-6

[11] Usman, A., Sani, M. A., Lawal, K. M., & Magaji, S. S. (2019). Aeromagnetic Investigation of Geologic Structures Associated with Gold Mineralization along Danja, Northwestern Nigeria. *Journal of Geology & Geophysics*, *3*(1).

[12] Reynolds, J. M. R. (2011). *An Introduction to Applied and Environmental Geophysics*

(Second Edi, Issue 606). John Wiley. www.wiley.com/go/reynolds/introduction2e

[13] Milsom, J. (2003). Field geophysics. The Geological Field Guide Series. In *univesity college london* (Third Edit, Vol. 27, Issue 06). wiley. https://doi.org/10.5860/CHOICE.27-3322

[14] Telford, W.M. and L. P. G. R. E. S. (2001). *APPLIED GEOPHYSICS* (second edi). Cambridge university press. https://doi.org/10.1017/CBO9781139167932

[15] Nda, A., & Bello, M. M. (2022). Aeromagnetic Data Analysis and Interpretations to Investigate Solid Mineral Potential in Part of Northwest Nigeria. *Afropolitan Journals of Advaances Science Technology Research*, *4*(1), 125–138. https://publications.afropolitanjournals.com/index.php/ajastr/article/view/171

[16] Saleh, A., & Gabr, S. S. (2024). Application of magnetic data and satellite spectral imaging in identifying gold mineralization zones and its associated subsurface structures at Fawakheir - Attala area , Central Eastern Desert , Egypt. *Environmental Earth Sciences*, *83*(17), 1–33. https://doi.org/10.1007/s12665-024-11776-y

[17] Gobashy, M. M., Allah, E., Abbas, S., Soliman, K. S., & Abdelhalim, A. (2022). Mapping of gold mineralization using an integrated interpretation of geological and geophysical data — a case study from West Baranes , South Eastern Desert, Egypt. *Arabian Journal of Geosciences*. https://doi.org/10.1007/s12517-022-10955-0

[18] Abdelrady, M., Moneim, M. A., Alarifi, S. S., Abdelrady, A., Othman, A., Mohammed, M. A. A., & Mohamed, A. (2023). Geophysical investigations for the identification of subsurface features influencing mineralization zones. *Journal of King Saud University - Science*, *35*(7), 102809. https://doi.org/10.1016/j.jksus.2023.102809

[19] Osumeje, J. O., Oniku, A. S. and, & Meludu, O. C. (2021). ANALYSIS OF LINEAMENT MAP OF PART OF MARU SCHIST BELT, NORTHWEST, NIGERIA AND ITS IMPLICATION FOR MINERAL EXPLORATION. *FUDMA Journal of Sciences (FJS)*, *5*(3), 355–362.