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Interpretation of Lineaments Using High Resolution Aeromagnetic Data of Parts of Benue Trough, Nigeria

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A B S T R A C T

This study, analyzed the high resolution aeromagnetic data within Benue Trough in order to depict structural complexity related to the basin, delineate the structural lineaments according to their spatial and directional attributes as well as deduce the mineral potentials of the study area. The aeromagnetic data was subjected to different enhancement techniques to enhance the signal-to-noise ratio. Lineaments identified in the study area have principal trend directions in NE – SW, NW – SE, and E – W with prevalent orientation in the NE – SW. This suggests that these areas are sites of intense tectonic/magmatic activities and may therefore be strongly deformed. The rose diagram plot revealed lineament trend structures predominantly in NE – SW, NW – SE, and E – W direction, having predominant trend in the NE – SW direction which is similar to the major lineament trend of the study area. The E-W, and NW-SE depict the older and deeper tectonic directions. The NE-SW exhibit the younger tectonic occurrence, this is because the younger event primarily leaves no trace of the older event. These lineaments are believed to have controlled mineralization across the study area.

Keywords: **Aeromagnetic, Magnetic Intensity, Lineaments, Tectonics, Benue Trough.**

1. Introduction

The study of geologic structures such as lineaments which include faults, joints and fractures cannot be overemphasized. The reason for this is because, they do not only act as zones for ores and minerals deposits, but also act as reservoirs for oil, gas and water storage. Several authors have defined lineament. According to (Hung et al., 2005), Lineaments are straight or nearly straight-line features, visible on the earth's surface as faults, folds and fractures which exposes the underlying geologic structure. O'Leary *et al.* 1976, defined lineament as a mappable linear or curvilinear surface, whose parts are aligned in a rectilinear or slightly curvilinear relation and differs from the patterns of adjacent features and presumably reflects a subsurface phenomenon. Magnetic survey as an efficient potential field technique has the capability of revealing lineaments and geological structures especially for mineral prospecting. For mineral investigation, aeromagnetic data interpretation involves depicting feasible structures, rocks and zones that may serve as potential region of mineral deposits. In view of this, geologic structures like faults, fractures, domed strata, folds, contacts and intrusive play important role as mineral indicators. Rubin 1979, defined mineral indicators as physical /chemical phenomenon which correlates with known mineral occurrences. Several studies involving aeromagnetic data have been used to delineate near-surface geologic features, estimated sediment thicknesses, reveal existence of block faulting and presence of intrusive within Benue Trough (Ofoegbu, 1984; Ananaba et al., 1987; Ajakaiye *et al.*, 1991; Ofoegbu and Onuoha, 1991; Anudu *et al.*, 2014; Oha *et al.*, 2016; Opara et al., 2015; Abdullahi *et al.*, 2019; Osinowo and Taiwo, 2020; Ekwok et al., 2021). A good knowledge of lineaments has been effectively used in the study of structural geology, petroleum, mineral exploration, nuclear energy facility sittings, water resource investigations and groundwater studies. The present study analyzed the high resolution aeromagnetic data to delineate the structural features of the study area and information obtained will serve as a guide for mineral exploration.

2. Location and Geology of the study area

The study area is located within the Benue Trough, Nigeria and is defined by Latitudes 6° 00^{1}N - 8° 00^{1}N and Longitudes 7° 30^1 E - 9° 30^{1}E. The Benue Trough (Figure 1.1) is a significant geological structure that underlies a huge extent of Nigeria. It is a rift basin in the central West Africa that trends north – easterly for about 800 km in length and about 130- 150 km in width (Cratchely and Jones, 1965). The studies carried out by (Nwachukwu, 1972; Agagu and Adighije, 1983) has evidenced several tectonic architectures that has given rise to the structural features within the basin. Extensional and compressional sequence produced for the geometry as well as the orientation of the trough were identified (Fairhead, 1988). Major deformational structures include the Abakaliki Anticlinorium and the Afikpo Syncline in the Lower Benue, the Giza anticline and the Obi syncline in the Middle Benue, and the Lamurde anticline and the Dadiya syncline in the Upper Benue Trough. The Benue Trough is subdivided into a lower, middle and upper portion (Obaje et al., 1999).

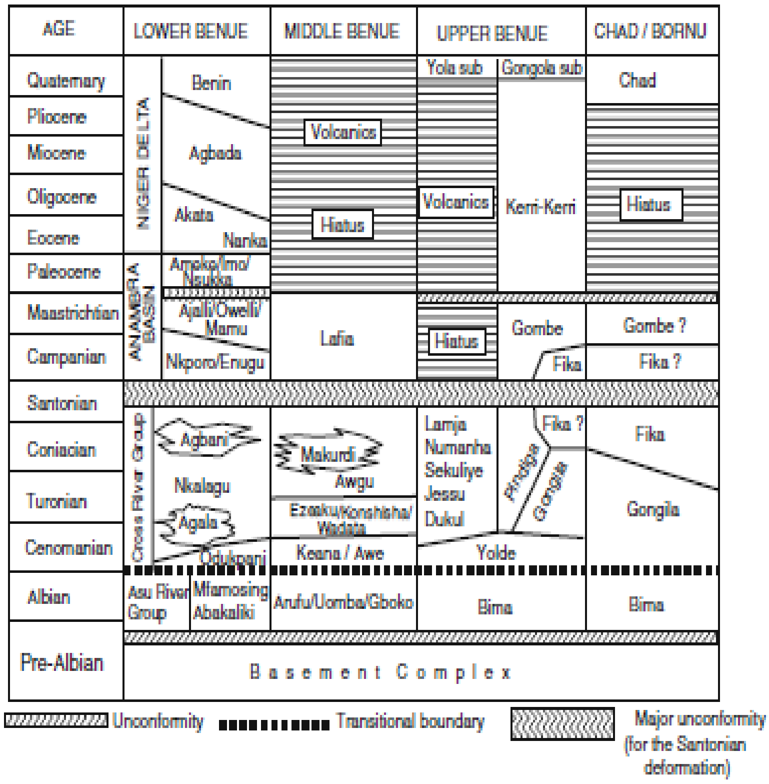

Figure 1: Stratigraphic successions in the Benue Trough and the Nigerian sector of the Chad Basin (Adapted from Obaje, 2009)

3. Materials and Method

The set of data used in this work form part of the high resolution aeromagnetic data obtained from the Nigerian Geological Survey Agency (NGSA) and acquired by Fugro Airborne Surveys. The digital airborne data were collected as a result of nationwide survey conducted between the period of 2005 and 2009. The survey was flown at a nominal flight height of 80m along NW – SE flight lines spaced at 500m interval. The geomagnetic gradient was removed from the data using the International Geomagnetic Reference Field (IGRF) formula for 2005. Data processing, including editing and initial filtering, was performed by Paterson, Grant & Watson Limited (PGW). Diurnal variations in the airborne magnetometer data were corrected. Leveling procedure was adopted to take record of effects including data differences at intersection of tie and traverse line recording. For this study, several techniques such as total magnetic intensity, first vertical derivative and tilt derivative were applied to analyze, enhance the signature of hidden faults.

First vertical derivative (FVD)

The first vertical derivative estimates the rate of change of magnetic field in the vertical direction. First vertical derivative (FVD) is frequently employed to sharpen, enhance shallow magnetic anomalies and effectively locate source bodies more accurately (Cooper and Cowan, 2006). It has more influence to local than regional or regional effects and provides a sharper image than the total field intensity map (Feumoe et al. 2012).

The FVD filter is expressed as:

$$\mathrm{FVD} = \frac{\partial T}{\partial z} \qquad (1)$$

Where, T is the potential field anomaly. dz = is the derivative in vertical direction

Tilt derivative

The tilt derivative (TDR) technique is usually employed for edge detection and location of the magnetic anomalies. The method suppresses lower amplitude section at the expense of higher amplitudes. The filter, highlights short wavelength signatures and reveal the presence of structural lineaments. According to (Miller and Singh, 1994) the tilth angle is given by:

$$Tilt = tan^{-1}\left\{\frac{\partial f/_{\partial z}}{\sqrt{\left(\partial f/_{\partial x}\right)^2 + \left(\partial f/_{\partial y}\right)^2}}\right\} \qquad (2)$$

4. Results and Discussion

The result of the aeromagnetic data is presented and discussed. The airborne magnetic data generated high resolution images that exhibited major lithologies and structural features present in the study area. The Interpretation was carried out visually to identify and delineate geological structures. Figure 2 is the Total Magnetic Intensity (TMI) map of the study area. It reveals magnetic intensity values ranging from

-89.5 nT to 112.0 nT. The study area is characterized by low magnetic intensity values ranging from -89.5 nT to -22.9 nT and high magnetic intensity values ranging from91.9nT to 112.0 nT. Several magnetic closures were observed trending in the NE-SW direction.

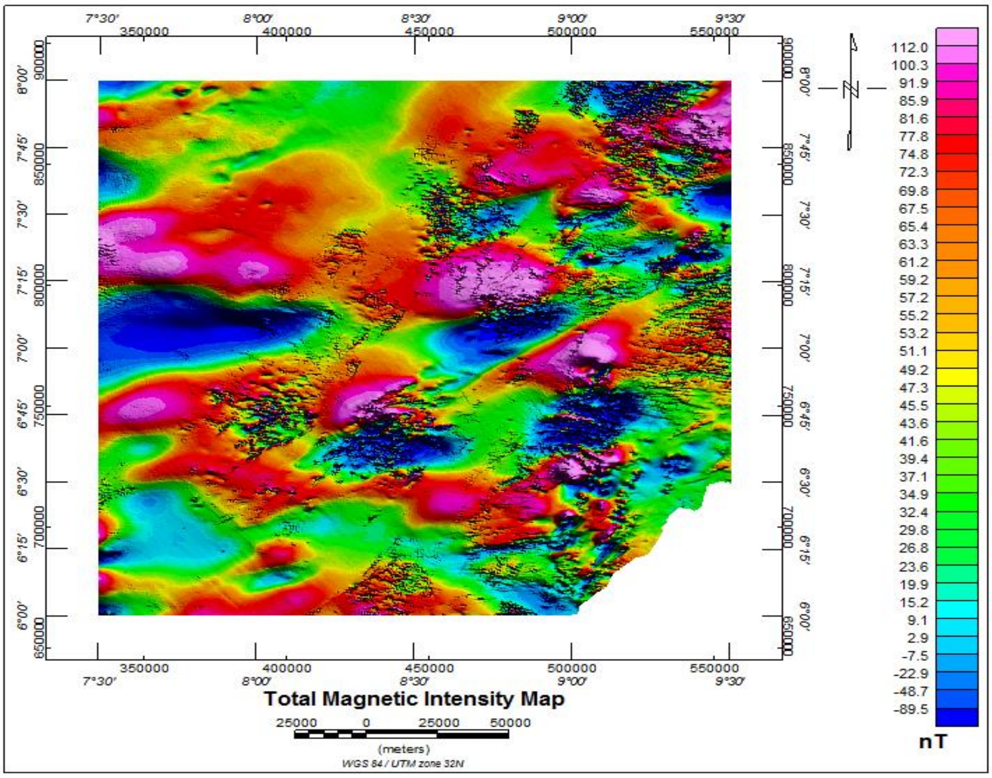

Figure 2: Total Magnetic Intensity (TMI) Image of the study area.

The first vertical derivative map (Figure 3) reveals near surface structure such as lineaments (faults and joints), intrusive that could be associated with mineralization of the area and determines boundaries between lithological units (Adewumi and Salako 2017). The FVD values range from -3.60677 to 3.26137nT/Km. Regions with positive magnetic values displays regions having high magnetic intensity (anomaly) which could suggest the subtle magnetic structures (high fracture density and faults). The major magnetic features trending NE-SW with Minor NW-SE trend. Since minerals are structurally controlled, the structures found in the study area might host the minerals present in the study area.

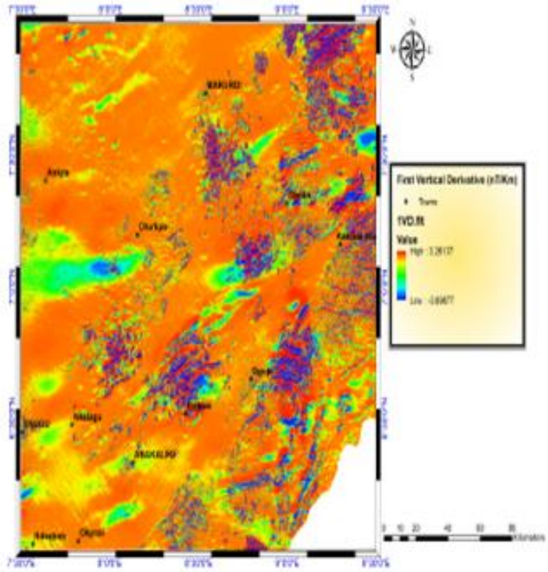

Figure 3: First vertical derivative map

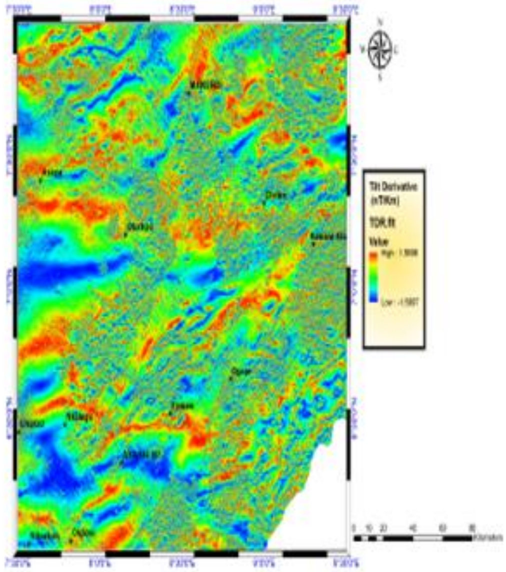

Figure 4: Tilt derivative map

Tilt derivative map

The tilt derivative map (Figure 4), was employed to determine structures (fault and folds), contacts, edges of magnetic sources and to enhance short wavelength anomalies which could be used to map shallow basement structures and mineral exploration targets. The region showing red to yellow colour depicts positive anomalies, while the blue colour depicts negative anomalies. The magnetic anomalies values range from − 1.5697 to 1.5696nT/Km. The map agrees with the first vertical derivatives map. It reveals the structures (lineament) that host minerals that could be found at the north-western part of the study area. The structures trends northeast-southwest.

Structural trend

Figure 5 shows different lineaments with different intensities and lengths. A total of 326 lineaments were identified and delineated to generate a lineament map for the study area using the ArcGis software of Oasis Montaj. The lineament map revealed two groups of linear features in the NE-SW, NW-SE, with the dominant structural trends being in the NE-SW direction. The map reveals high concentration of lineaments around Markudi, Oturkpo, Gboko, Katsina Ala, Ogoja, Ejekwe. This suggests that these areas are sites of intense tectonic/magmatic activities and may therefore be strongly deformed. It also shows evidence of increase in rock fracturing, shearing, intense deformation and presence of minerals. This is in agreement with the work of Ananaba et al. 1987.

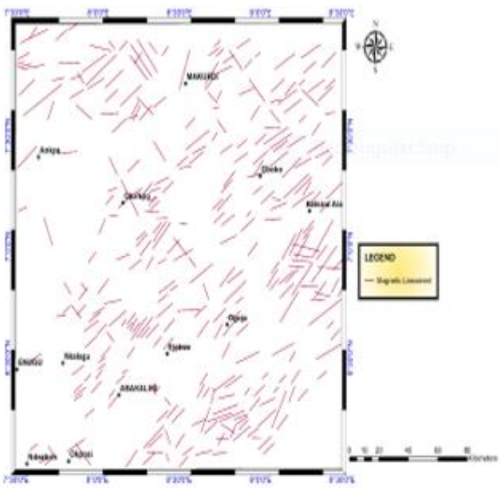

Figure 5: Lineament map

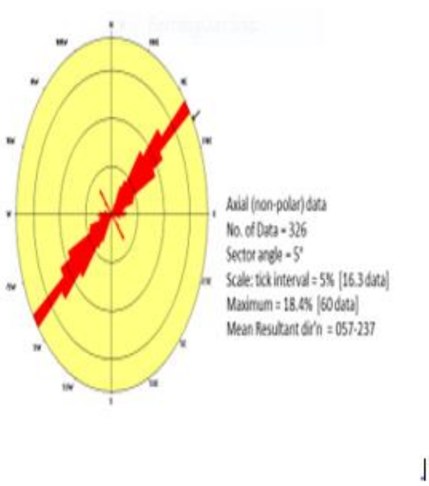

Figure 6: Rose diagram

Statistical analysis using the Rose diagram (Figure 6) was carried out to identify the orientation and frequency of lineaments. It revealed lineament trend directions of NW – SE, NE – SW and E – W with the prevalent trend being in the NE – SW which corresponds to the major lineament trend of the study area. NE-SW exhibits the younger tectonic occurrence, this is because the younger events are more prominent and leaves no trace of the older event. The maximum is 18.4% of the delineated lineaments and trending in the Northeast - Southwest direction.

5. Conclusion

This study presents the analysis and interpretation of high-resolution aeromagnetic data of the study area, in order to delineate the structural lineaments and distribution of magnetic sources. The enhancement filters were applied to the data. The lineament map exhibited two groups of linear features in the NE-SW, NW-SE, with the dominant structural trends being in the NE-SW direction. The map reveals high concentration of lineaments around Markudi, Oturkpo, Gboko, Katsina Ala, Ogoja, Ejekwe. This suggests that these areas are sites of intense tectonic/magmatic activities and may therefore be strongly deformed. It also reveals greater degree of rock fracturing, shearing, intense deformation and have provided suitable hosts for different kinds of economic minerals.

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Disclosure of conflict of interest

There is no conflict of interest to declare by the authors.

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