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AEROMAGNETIC INVESTIGATION OF GEOLOGIC STRUCTURES ASSOCIATED WITH GOLD MINERALIZATION ALONG DANJA, NORTHWESTERN NIGERIA

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ABSTRACT

The discovery of petroleum led to a subsequent shift of the Nigerian economy, leading to a lack of attention to gold exploration, despite the widespread potentials. Gold production declined during the Second World War period and never recovered as mines were abandoned by mostly colonial companies, hence the need to study the aeromagnetic field over the study area. the interpreted aeromagnetic data delineate structures associated with mineralization of gold along Danja, North Western Nigeria. This was achieved by first determining depth to basement and then producing a magnetization map showing susceptibility range across the entire area of study, and to model the shape, location and depth of structures in the study area. The anomalies on the aeromagnetic map were defined by fitting a first order polynomial to the total fields, by the method of least squares to obtain the residual field data. First vertical derivative and analytic signal anomalies computed, defined distinct pattern of the magnetic signatures. Euler deconvolution applied produced solutions at different location of the area of study, this shows that the solution plotted clustered around the region where the geological structures are located with average depths range of 200.2 m to 2229.1 m, with very few solutions having depths less than 300 m, the most prominent lineament and all major subtle lineament have a depth range of 200 m to 600 m. Most of the solutions within the mining site are between 200.2 m to 618.4 m which shows that the structure is deep seated. The possible flow of fluid that produced the emplacement of Gold mineralization in the area is believed to be related to the Kalangai fault which trends NE-SW along Malumfashi in the study area. The susceptibility values obtained from the magnetization map ranges from -0.000666 to 0.000996SI.

Keyword: Werner Deconvolution; Euler Deconvolution; Analytic Signal; Model; Magnetization; Vertical derivatives.

INTRODUCTION

In the absence of any systematic exploration and development, the Nigerian gold fields have experienced intense artisanal workings which target both the primary gold-quartz reefs and their associated alluvial occurrences. Officially, recorded gold production in Nigeria started by 1913 and peaked in the period of 1933. The gold production declined during the Second World War period and never recovered as mines were abandoned by mostly colonial companies. In Northern

Nigeria, the most prominent occurrences are found at Maru, Anka, Malele, Tsohon-Birnin Gwari, Kwaga and Gurmana (Garba, 2000; 2002). The discovery of petroleum led to a subsequent shift of the Nigerian economy, leading to a lack of attention to gold exploration, despite the widespread potentials. This development has prompted a need to map out regional structural features which might serve as the conduits for the mineralizing gold fluids in areas where such mines were abandoned. As a result, this research was aimed to delineate structures responsible for the emplacement of gold mineralization in Rafin Gora, of Katsina state Northwest Nigeria, and other possible mineralization zones across the entire study area. In this study, aero-magnetic geophysical method was used due to the large extent of the study area and its ability to estimate the depth to basement, faulting, hydrothermal alteration and geologic mapping. Magnetic method have been successfully applied to locate buried faults in south eastern Cameroun (Theophile *et al.*, 2012), it is also applied in geothermal exploration and in the investigation of unexposed granitic plutons, unexposed ring complex (Raimi *et al.*, 2014) and investigation of subsurface continuity of a particular rock unit (Bello, 2015) to mention a few.

Location and geology of the study area

The study area is situated in Rafin Gora, Tandama Village of Danja Local government Area of Katsina State, Nigeria. It lies within the Northern Nigerian Basement complex between longitudes 007^{0} 00^{I}E – 007^{0} 35^{I} E and latitudes 11^{0} 27^{I}N – 11^{0} 31^{I}N. An area of approximately 12000 Sq Km of Precambrian to lower Paleozoic rocks around Zaria in Northern Nigeria the

Geological Survey of Nigeria degree sheet 21, was mapped for the first time (McCurry, 1970). Reconnaissance techniques of photo-geological interpretation and selected field traverses were used to compile four geological maps in the scale of 1:100,000, it lies within the Northern Nigerian Basement Complex between longitudes 007^{0} 00^{I}E - 008^{0} 00^{I}E and latitudes $11^{0}00^{I}$N – 12^{0} 00^{I}N (Figure 1). The Rafin Gora Mine is located in Tandama Village of Danja Local Government Area of Katsina State, it is accessible via the Bakori and Danja roads.

Data acquisition

Four High Resolution Aeromagnetic data o f Funtua (sheet 78), Malumfashi (sheet 79, Maska (sheet 101) and Zaria (sheet 102), w hich lies from longitude 007^{0} 00^{I}E - 008^{0} 0 0^{I}E to latitude 11^{0} 00^{I}N – 12^{0} 00^{I}N. This da ta which covers the entire study area were p urchased from Nigerian Geologic Survey A gency, which are on a scale of 1:100,000. T his data was collected at a flight altitude of 80m, along NE-SW flight lines spaced app roximately 500m apart.

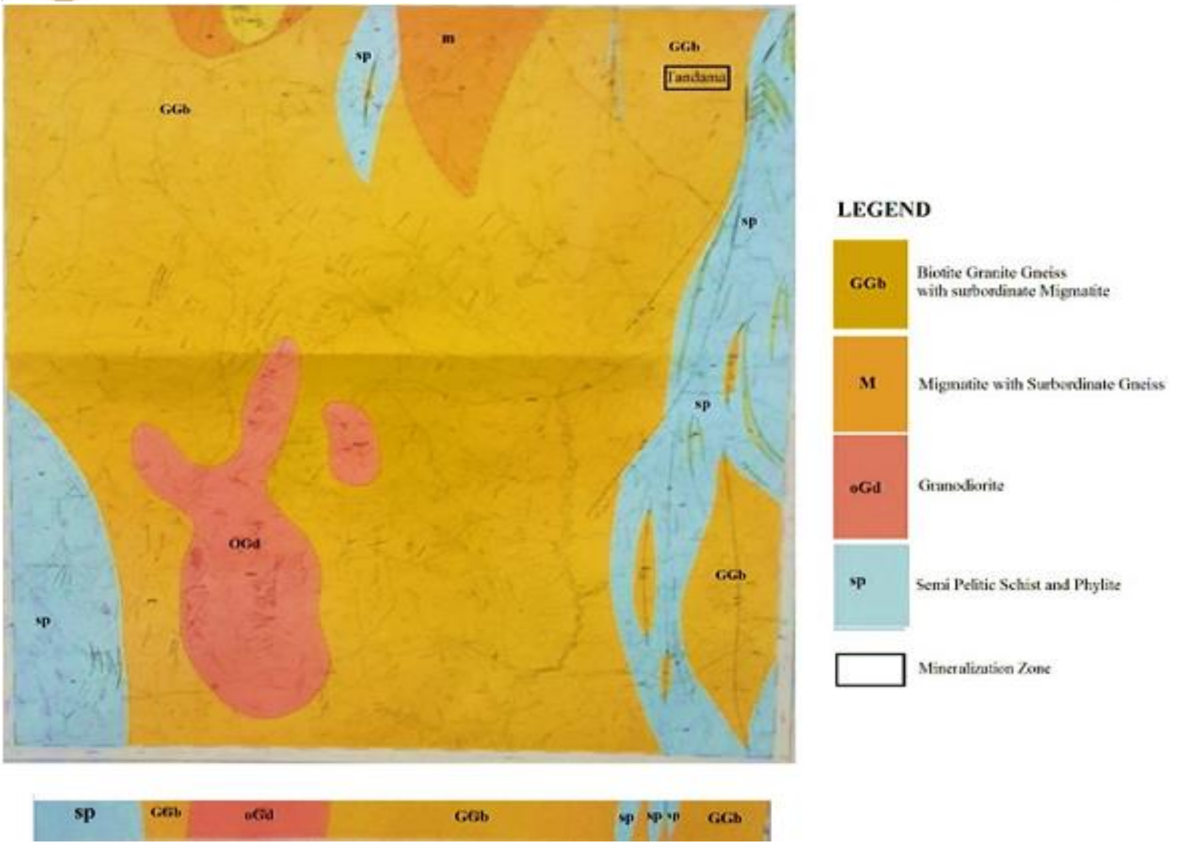


Figure: 1: Geological Map of the study area showing geological Features Courtesy (NGSA)

MATERIALS AND METHODS

Data enhancement

Enhancement of magnetic data is very important in the study of structural features because it enhances the edges of anomalies. The first vertical derivative (FVD) is given as:

$$FVD = \frac{\partial M}{\partial z}, \quad (1)$$

Where M is the potential field anomaly. The vertical derivative was computed from the upward continued data. This is very important to this research as it brings out the lineaments of interest more obvious.

Upward continuation of residual field

This is a mathematical technique that projects data taken at a particular elevation to a higher elevation. It is a filtering technique that removes noise caused by high frequency (i.e. short wavelength) anomalies which usually arise from near surface cultural features in the survey area (Mekonnen, 2004). The upward continued ΔF (the total field magnetic anomaly) at higher level (z = - h) is given by:

$$\Delta F\ (x, y, -h) = \frac{h}{2\pi} \iint \frac{\Delta F(x,y,0)dxdy}{((x-x^0)^2+(y-y^0)^2+h^2)} \quad (2)$$

The empirical formula (Henderson, 1960) gives the field at an elevation h, above the plane of the observed field (z = 0) in terms of the average value ΔF at the point (x, y, o).

The Analytic Signal Technique

The analytic signal is a complex function formed through a combination of the horizontal and vertical derivatives of the magnetic anomaly. In 3D, the analytic signal of the magnetic anomaly field T is defined as:

$$A(x, y, z) = \frac{\partial T}{\partial x}\hat{x} + \frac{\partial T}{\partial y}\hat{y} + i\frac{\partial T}{\partial z}\hat{z} \quad (3)$$

Where $\hat{x}$, $\hat{y}$ and $\hat{z}$ are unit vectors in the x, y and z directions, respectively $\frac{\partial T}{\partial z}$ is the vertical derivative of the magnetic anomaly field intensity, $\frac{\partial T}{\partial x}$ and $\frac{\partial T}{\partial y}$ are the horizontal derivatives of the magnetic anomaly field intensity.(Blakely, 1995).

The amplitude of the analytic signal in 3D is given by:

$$|A(x, y, z)| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \quad (4)$$

Depth estimation of magnetic source using Euler deconvolution method

To obtain the approximate depth to the source of the anomalies, Euler deconvolution method was applied to the upward continued data. This technique provides automatic estimates of source location and depth. Therefore, Euler deconvolution is both a boundary finder and depth estimation method. Euler deconvolution is commonly employed in magnetic interpretation because it requires only a little prior knowledge about the magnetic source geometry, and more importantly, it requires no information about the magnetization vector (Thompson, 1982; Reid et al., 1990). Euler deconvolution is based on Euler's homogeneity equation. Thompson (1982) showed that Euler's homogeneity relation could be written in the form:

$$(x - x_0)\frac{\partial T}{\partial x} + (y - y_0)\frac{\partial T}{\partial y} + (z - z_0)\frac{\partial T}{\partial z} = N(B - T), \quad (5)$$

Where *B* is the regional value of the total magnetic field and x_0,y_0, and z_0 is the position of the magnetic source, which produces the total magnetic field *T* measured at x,y,z. *N* is called structural index. For each position of the moving window, an over-estimated system of linear equations are solved for the position and depth of the sources (Thompson, 1982; Reid et al., 1990).

2D Forward Modeling

A model, particularly as it concerns earth sciences and Physics, can be described as a geological representation of geophysical data. In order to create or predict a geologic model for an area, measurements are taken so that a set of desired parameters such as location or size of a body or distribution of physical properties might be inferred. After these parameters have been inferred, the goal therefore is to arrive at a representative model which is a best estimate of the parameters in question. The Oasis montaj GM-SYS (5.1) module, which is based on the algorithm described by Won and Beris (1987), and Rasmussen and Pedersen (1979), was used for this research.

Magnetization (Susceptibility) Map

The magnetic susceptibility is a measure of the magnetic properties of a material. The susceptibility indicates whether a material is attracted into or repelled out of a magnetic field, and is simply the degree of magnetization. Mathematically it is the ratio of magnetization *I* (magnetic moment per unit volume) to the applied magnetizing field intensity *H.* The susceptibility map filter includes a downward continuation to the source depth. Because a downward continuation filter magnitude increases with wavenumber, it tends to also amplify high-wavenumber noise in the data. To prevent this noise arising from susceptibility map filter, an optimum depth filter was applied to help remove high wave number that is considered noise in the data.

RESULTS

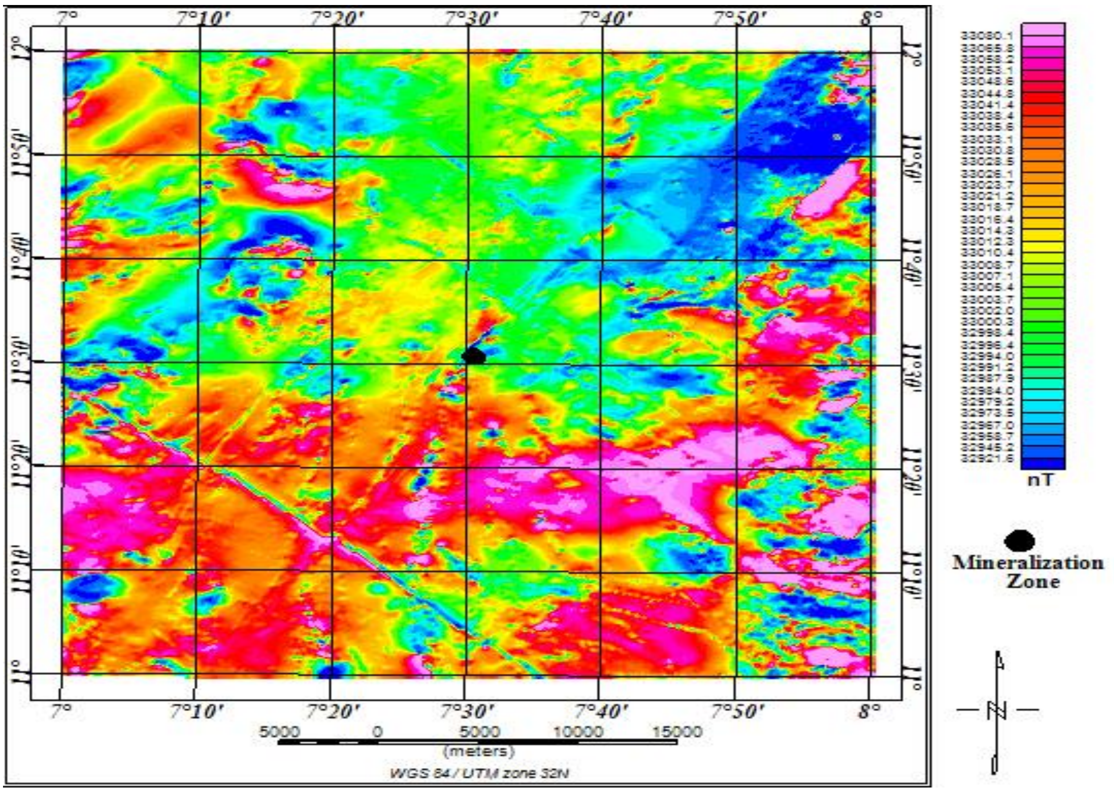
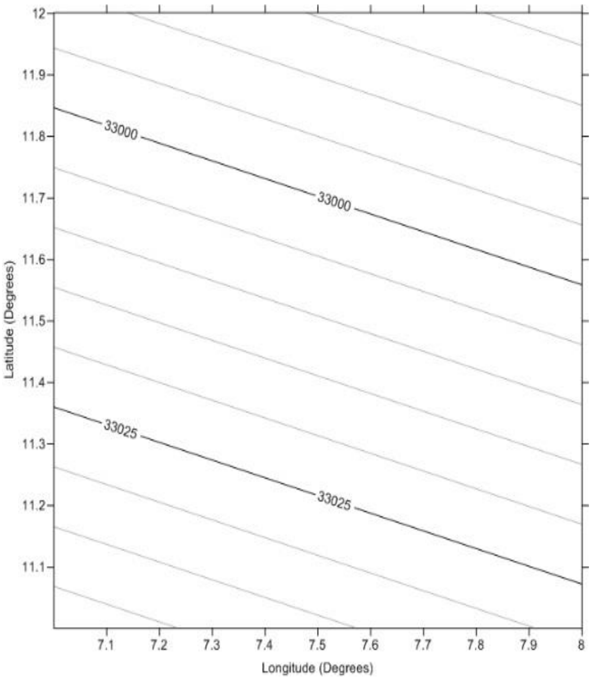


Figure 2: Showing the Total Magnetic Intensity Map of the Area



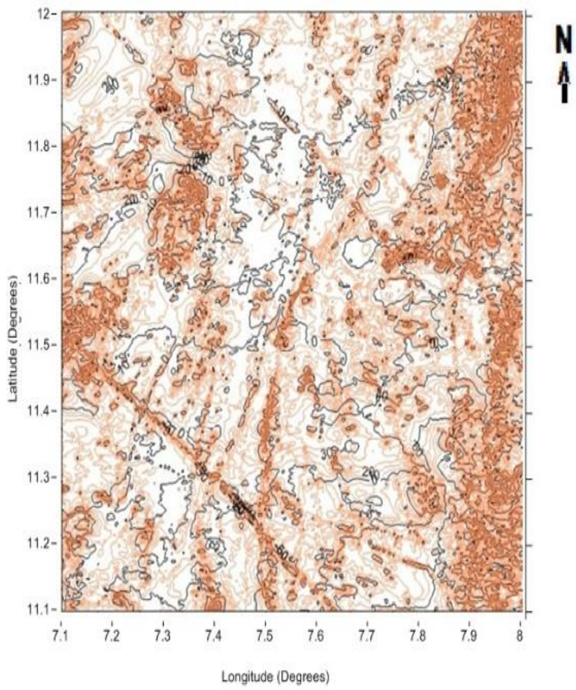


Figure 3: Regional Magnetic Field Map

Figure 4: Residual contour map

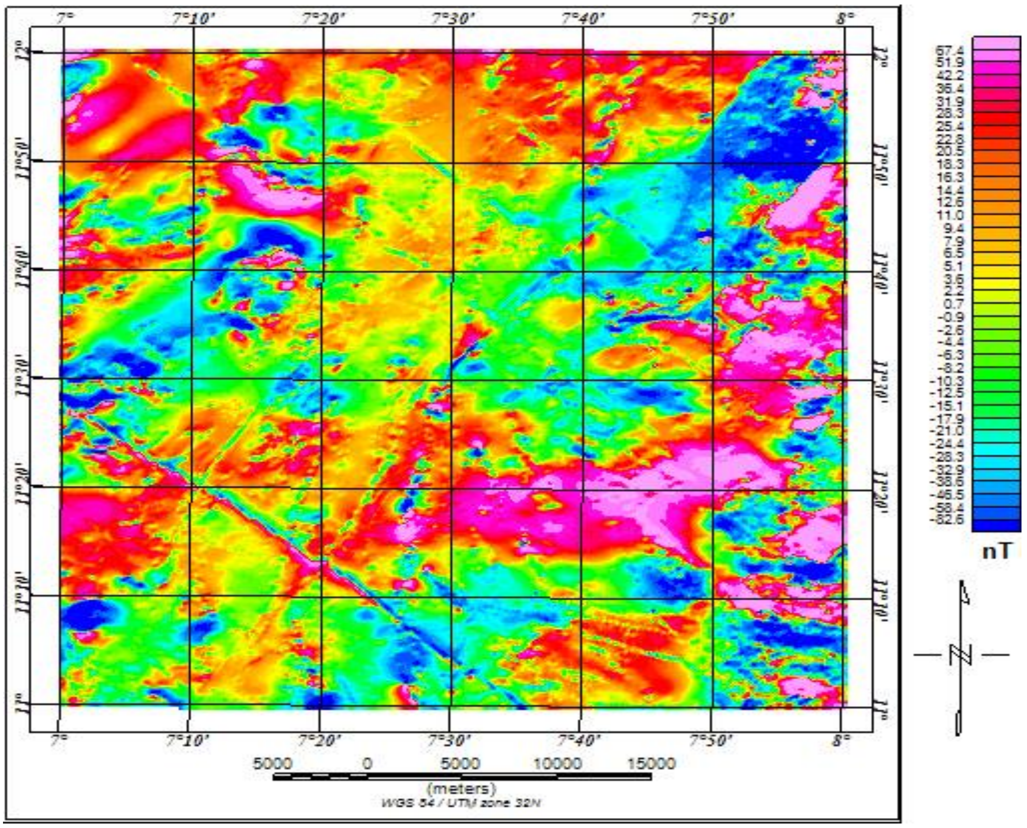


Figure 5: Residual Magnetic Intensity grid

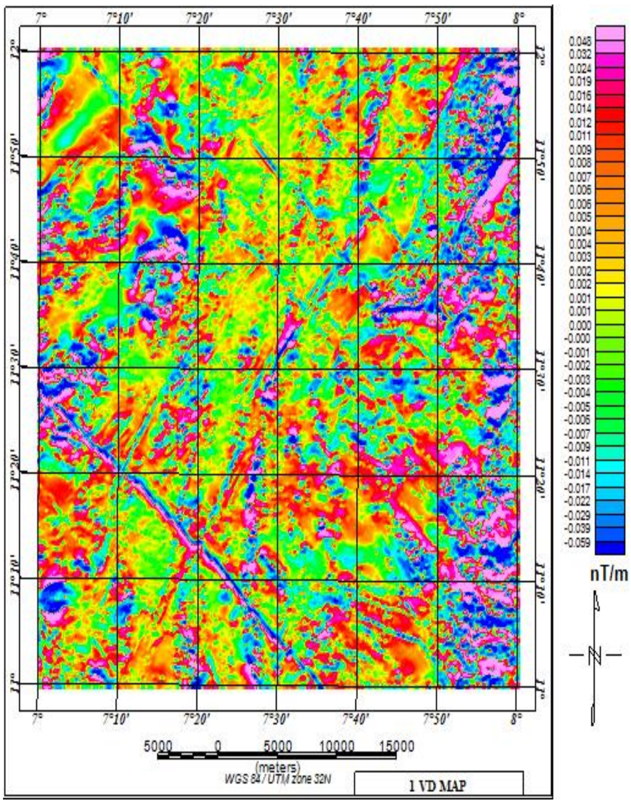


Figure 6: The first vertical derivative map

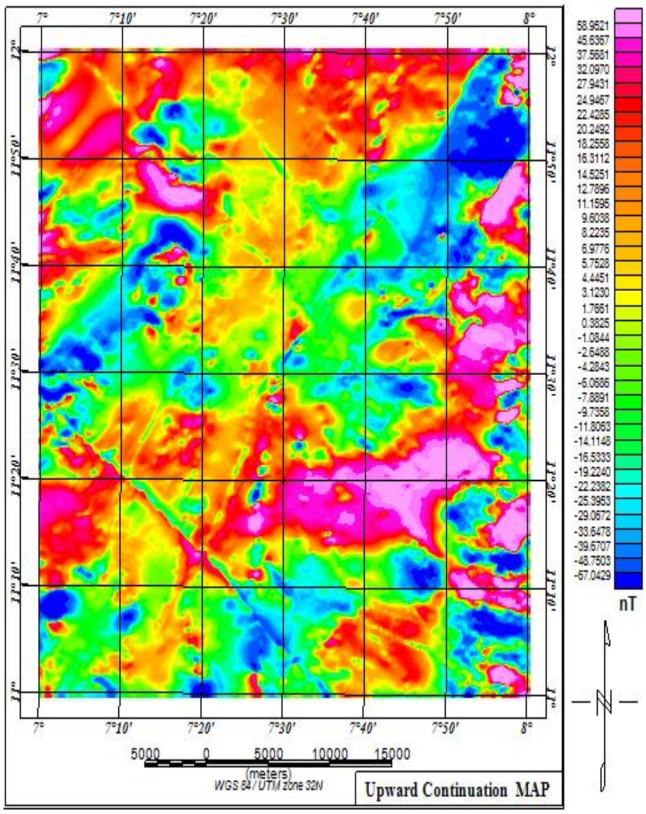


Figure 7: The upward continued map

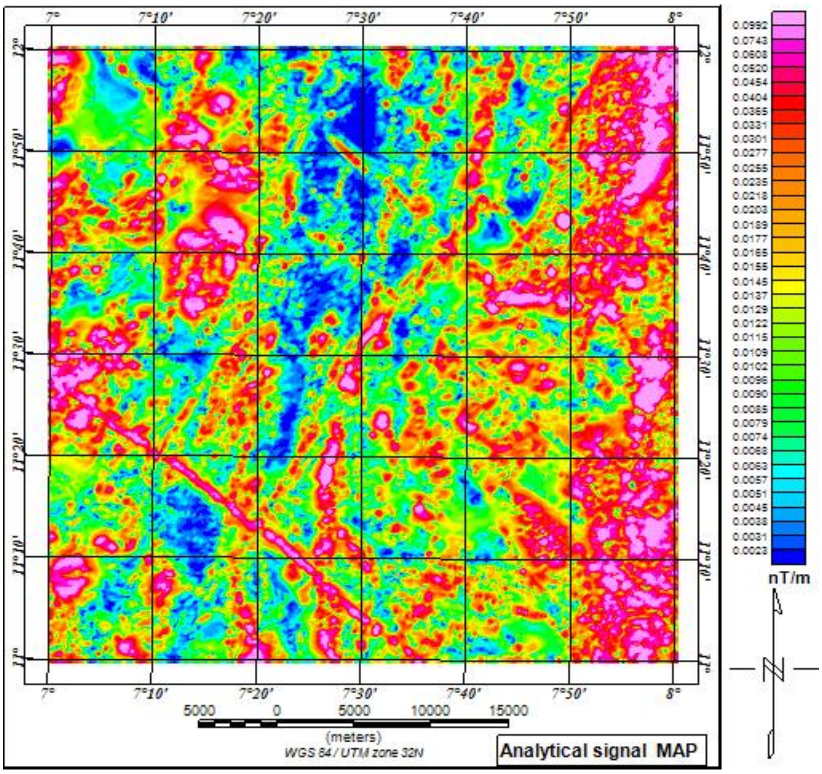


Figure 8: Analytic Signal map of the area.

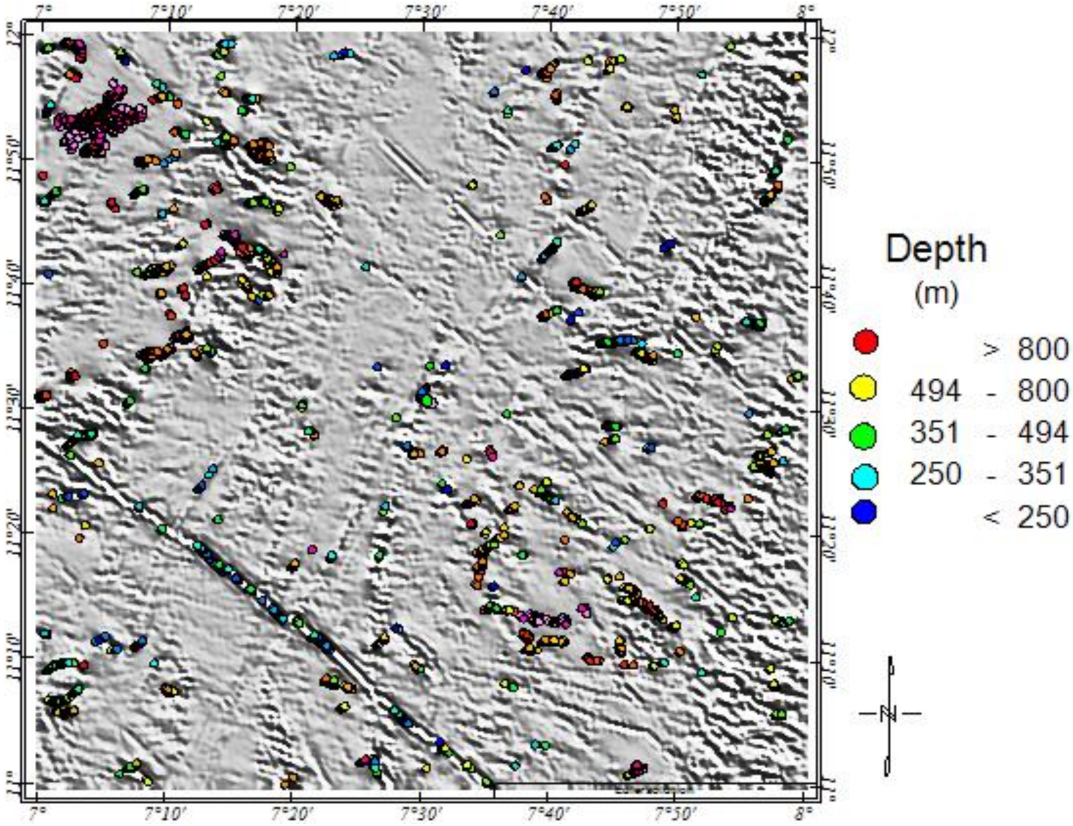


Figure 9: Plot of Euler depth solution.

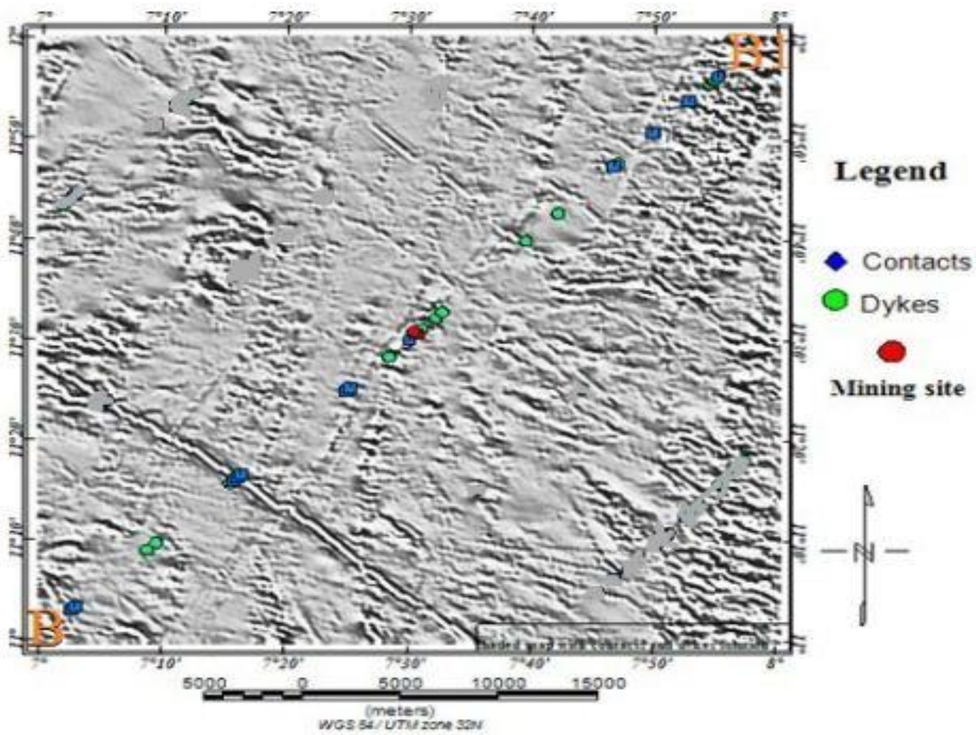


Figure 10: A map of profile BB1 (Modeled profile).

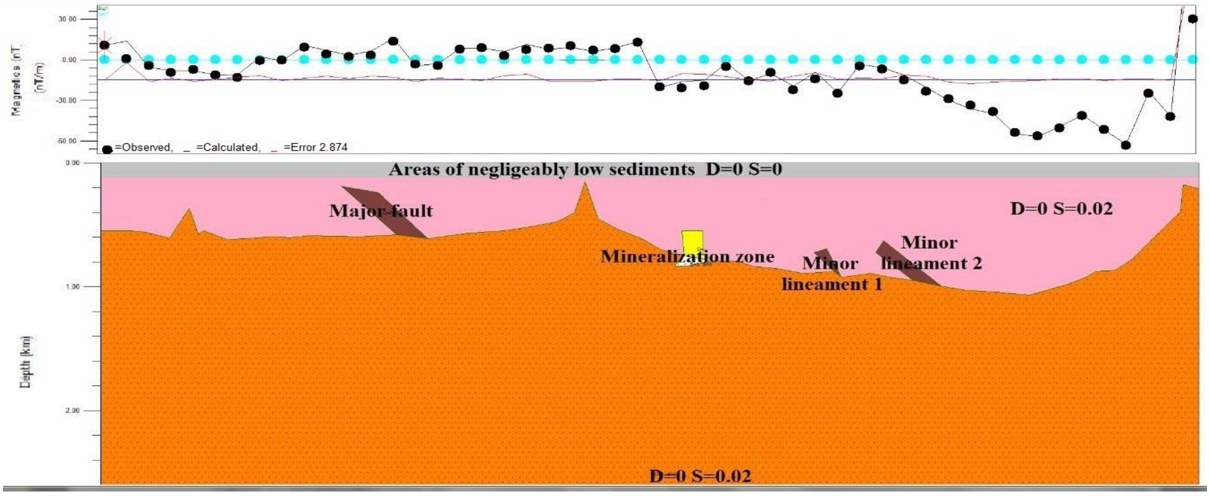


Figure 11: Modeled field of profile BB1, showing calculated and Observed magnetic field readings with depth in km

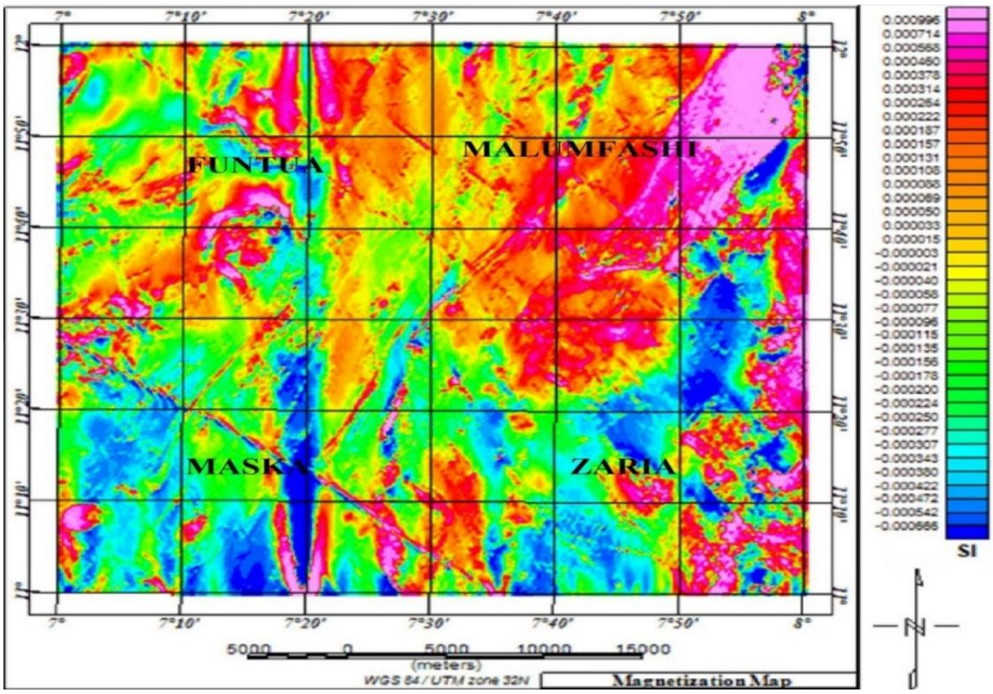


Figure 12: Magnetization map of the study area.

DISCUSSION

Regional and Residual Separation of Magnetic Anomalies

Magnetic data interpretation usually commences with some procedure that separates the smooth, presumable deep-seated regional effects from the observed field so as to obtain the residual effects, which are the anomalies of geological interest. The regional magnetic fields are large features which generally show up as trends and continue smoothly over very considerable areas, and they are caused by deeper homogeneity of the earth's crust (Nettleton, 1976). The regional magnetic field contour map is shown in figure 4 the magnetic field intensity values in figure 4 show the trend from NW-SE direction, the residual magnetic intensity map is illustrated in figure 5, this was done using SURFER 12 and Oasis Montaj software.

Data enhancement

First vertical derivatives were used in this research to enhance the upward continued field data, the first vertical derivative map is shown in figure 6 which shows the response of the target structures. The residual field was upward continued to 150m which is about one third the inter profile spacing used in collecting the data. This helps remove noise caused by high frequency shallow anomaly. The upward continued field map is shown in figure 7.

The analytic signal maps

The analytic signal map produced gives distinct pattern of structural and magnetic signatures in the area. the result obtained shows very clearly the orientation of the Kalangai fault which cut across Malumfashi in the study area, this shows that the mineralization might be as a result of the continuity of the Kalangai fault in the study area. McCurry (1970) Kalangai fault is poorly exposed along its southern end, and is marked by quartz ridges and is probably an ancient fault which has reactivated several times during the Pan African orogeny. Figure 8 shows the computed analytic signal map of the study area.

Euler depth estimation

In this work, we applied the Euler method on the Residual Magnetic Intensity grid using the Euler 3D extension module of the Oasis Montaj software. The best clustering solution was obtained by selecting a structural index of one (i.e. SI = 1) and the depth estimates from the Euler analysis which are presented as "Elevation" in the database was plotted on the first vertical derivative shaded relief map for effective correlation (Figure 9). shows that the solution plotted clustered around the region where the geological structures (lineaments) are located on the first vertical derivative shaded relief map with average depths range of 200.2 m to 2229.1 m, with very few solutions having depths less than 300 m, the most prominent lineament and all major subtle lineament have a depth range of 200 m to 600 m Most of the solutions within the mining site are between 200.2 m to 618.4

m which shows that the structure is deep seated.

Modeling

Profile (BB1) Figure 10 is the modeled profile; it is a 150-km section of a flight line. The choice of this profile is based on observations from Figure 10 which depicts that profile (BB1) is perpendicular to a major lineament trending NW-SE along the southern part of the study area at a distance of 36-km, the strike of mineralization zone in the study area at a distance of 73-km, and perpendicular to other two minor lineament trending NW-SE along the northeastern part at a distance of 97.4-km and 125.4-km respectively as shown in Figure (3.9). The depth estimate, magnetic susceptibility and dip of the source body obtained from profile (BB1) are 217.8m, -24.9 degrees and 0.0004238SI respectively. Furthermore, a rock sample collected from the mining site was measured and found to have a magnetic susceptibility of 0.02 SI. These parameters were used as guide to produce a 2D forward model Figure 11 of the area.

Magnetization Map

The map figure 12 revealed that there were three major magnetic regions in the area, these are regions of positive magnetic susceptibility which could be due to the rock rich in ferromagnetic minerals, and are predominantly found around Malumfashi. Region of intermediate (medium to high magnetization) which are found to be lying over Funtua, Gusau and Dutsenma. Concordant lenses of mafic rocks northeastern part of the study area around Zaria. Are also regions of high magnetization. Regions of negative magnetic susceptibilty around the southern part of the study area around Maska and some part of Zaria with low Magnetization.

CONCLUSION

The aeromagnetic data proved valuable in the delineation of most of the structures in the area and estimating the depth to basement of the magnetic body. The depth estimate, magnetic susceptibility and dip of the source body obtained from the model are 217.8m, -24.9 degrees and 0.0004238SI respectively. The magnetization map of the entire study area showing areas of high and low magnetic susceptibility was also produced. The susceptibility values obtained from the magnetization map ranges from -0.000666 to 0.000996SI.

REFERENCE

Hall M. Jr. (1959),” The Theory of Groups” Macmillan Company New York.

Garba, I. (2000 & 2002). *The variety and the possible origin of Nigerian gold mineralization: Okolom-Dogondaji and Waya veins as case study*. Journal of African earth sciences, 981-986.

Henderson., (1960) *Models of Interpreting Aeromagnetic Data.* Geophysics,Vol 26, pp 132- 143.

Ku, C.C., and Sharp, J.A. (1983). *Werner deconvolution for automated interpretation and its refinement using Marquardt’s inverse modeling:* Geophysics, 28, 754-774.

McCurry, P., (1970) *The geology of degree sheet 21 (Zaria)* [MSc thesis] Zaria, Nigeria, Ahmadu Bello University.

Mekonnen, T. K. (2004). *Interpretation and Geodatabase of Dukes using Aeromagnetic data of Zimbabwe and Mozambique.* M. Sc. Thesis, International Institute for Geoinformation science and Earth Observation, Enschede, the Netherlands.

Nettleton, L.L. (1976). *Regionals, residuals and structures.* Geophysics 19 (1): 1 – 22.

Raimi, J. Dewu B. B. M. and Sule P. (2014). *An Interpretation of Structures from the Aeromagnetic Field over a Region in the Nigerian Younger Granite Province.* International Journal of Geoscience, 5, 313-323.

Reid, A.B., J.M. Allsop, H. Granser, A.J. Millett and I.W. Somerton, 1990, *Magnetic interpretation in three dimensions using Euler deconvolution. Geophysics*, **55**, 80-90.

Telford, W.M., L.P. Geldard, R.E. Sherriff and D.A. Keys, (1990) *Applied Geophysics.* 2nd edition, Cambridge University Press, Cambridge, GB, 860.

Theophile N., Feumoe A. N., Eliezer M. and Fairhead J. D. (2012). *Aeromagnetic Data Interpretation to Locate Buried Faults in South East Cameroun.*Geophysica 48 (1-2), 48-63.

Thomson, D.T. (1982). EULDPTH: *A new technique for making computer-assisted depth estimates from magnetic data: Geophysics*, 47; 31–37.

Won, I.J. and Bevis M. (1987) computing the gravitational and magnetic anomalies due to a Polygon, algorithms and fortran sub-routines. Geophysics, Pp 232-238.