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Evaluation and Structural Interpretation of Aeromagnetic Anomalies over Parts of Monguno and Environs, Northeastern Nigeria Using 3-D Euler Deconvolution

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Abstract. Evaluation and structural interpretation of aeromagnetic anomalies over parts of Monguno and environs, northeastern Nigeria was carried out using 3-D Euler deconvolution to determine the presence, distribution and depth of intrusives in the area. Analysis of maps and images provided the basis for qualitative as well as quantitative interpretations of the aeromagnetic data so as to obtain information on the presence, depth and distribution of intrusives in the area. Results from the 3-D Euler deconvolution of the aeromagnetic data showed predominantly geologic sources of magnetic anomalies for horizontal cylinder and pipe, spheres, sills and dykes, in order of decreasing magnitude, having structural indices (SI) of 2, 3 and 1 respectively. To a lesser degree are sources of magnetic anomalies for contact, having SI of 0, which may be interpreted to be deep seated faults, which have significantly affected the basement rocks surface configuration. The average depth to which magnetic intrusions occur within the sedimentary formations across all SI is less than 500m. Mineralization may be prevalent in the study area as indicated by the presence of these intrusives, some of which occur at favourable depths that allow for economic extraction.

Keywords: Aeromagnetic anomalies, Euler deconvolution, intrusives, Monguno and Chad Basin.

1 Introduction

The study area is bounded by latitudes 12°00´N and 13°00´N; and longitudes 13°00´E and 14°00´E, and has an area of about 12,100km^2. The study area falls within the Borno Basin occupying the northeastern part of the country. Major towns within the area include Gudumbali, Marte, Masu, Gajiram and Monguno.

The application of the 3D Euler deconvolution process in this study is to generate maps that show the locations and the corresponding depth estimations of geologic sources of magnetic anomalies in a two-dimensional grid. Aeromagnetic data presented in grid form may be interpreted rapidly for source positions and depths by deconvolution using Euler's homogeneity relation (Reid *et al.*, 1990).

This method is applicable to all geologic models and it is insensitive to magnetic remanence and geomagnetic inclination and declination. However, an initial assumption of the source type has to be made. A structural index that is dependent upon the potential source type is chosen (Thompson, 1982). The structural index and depth estimates combine to potentially identify and calculate depth estimates for a variety of geologic structures such as faults, magnetic contacts, dykes, sills, etc.

The expected results of the analyses will contribute to a better understanding of the general geology of the area and serve as a tool for hydrocarbon and mineral wildcat preliminary investigations.

2 Geological Setting

The Chad Basin lies within a vast area of Central and West Africa, containing marine and continental sediments of the Bima Sandstone, Gongila Formation, Fika Shale, Kerri Kerri and Chad Formations (Okosun, 2000). Its origin has been generally attributed to the rift system that developed in the early Cretaceous (Burke, 1976; Genik, 1992) when the African and South American lithospheric plates separated and the Atlantic opened. Pre-Santonian Cretaceous sediments were deposited within the rift system (Nwankwo *et al.,* 2009). The study area is covered by sand and lack good outcrops (Fig. 1).

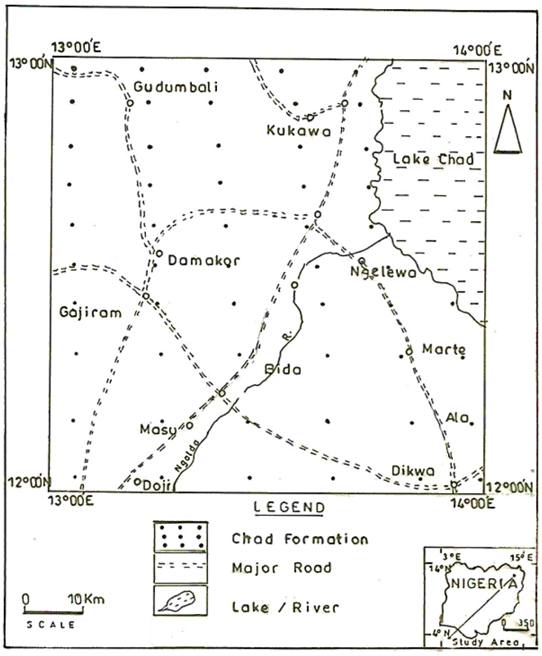

Figure 1. Location map showing geology of the study area (adapted from NGSA, 2011).

Bima Sandstone is the oldest stratigraphic unit in the area. It was deposited under continental environments and lies unconformably on the Basement Complex (Okosun, 1995). The Gongila Formation is a transitional sequence between the underlying continental Bima Sandstone and the overlying fully marine unit of the Fika Shale, and consists of a sequence of sandstone, clay, shale and limestone layers. The Gombe Sandstone formation has not been penetrated by wells used variously in the past for the study of the Chad Basin and its occurrence in any significant proportion in the basin is doubtful (Obaje *et al.*, 1999). Kerri-Kerri Formation consists of loosely cemented, coarse to fine-grained often cross bedded sandstone, massive claystone and siltstone; bands of ironstone and conglomerate occur locally. Chad Formation is the youngest stratigraphic unit in the area. This consists of yellow, grey clay, fine to coarse-grained sand with intercalations of sandy clay and diatomites (Wright *et al.*, 1985). The formation varies considerably in thickness and on the western shore of Lake Chad (Moumouni *et al.*, 2007).

3 Data and Methodology

Digitized airborne magnetometer survey maps of total magnetic field intensity were used in this study. Availability of the data was made possible by Fugro Airborne Surveys. It included a total of 1,930,000 line-km of magnetic surveys flown at 500m line spacing and 80m terrain clearance using Fugro's GENESIS EM system.

The objective of the 3-D Euler deconvolution process is to produce a map showing the locations and the corresponding depth estimations of geologic sources of magnetic or gravimetric anomalies in a two-dimensional grid (Reid *et al.*, 1990).

The Standard 3-D Euler method used in this study is based on Euler's homogeneity equation, which relates the potential Field (magnetic or gravity) and its gradient components to the location of the sources, by the degree of homogeneity N, which can be interpreted as a structural index (Thompson, 1982). The method makes use of a structural index in addition to producing depth estimates. In combination, the structural index and the depth estimates have the potential to identify and calculate depth estimates for a variety of geologic structures such as faults, dykes, sills, etc.

Thompson (1982) showed that for any homogenous, three-dimensional function f(x; y; z) of degree n:

$$f\left(tx;ty;tz\right)=t^{n}f\left(x;y;z\right) \tag{1}$$

It can be shown that, the following equation, which is known as Euler's homogeneity relation can be satisfied:

$$x\frac{\delta f}{\delta x}+y\frac{\delta f}{\delta y}+z\frac{\delta f}{\delta z}=nf \tag{2}$$

In geophysics, the function f(x, y, z) can have the general functional form:

$$f\left(x,y,z\right)=\frac{G}{r^{N}} \tag{3}$$

where $r^2 = (x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2$, N a real number (1,2,3...) and G a constant (independent of x, y, z). The parameter N is dependent on the source geometry, a measure of the fall-off rate of the field and may be interpreted as the structural index (SI).

Considering potential field data, Euler's equation can be written as:

$$\left(x-x_{0}\right)\frac{\delta T}{\delta x}+\left(y-y_{0}\right)\frac{\delta T}{\delta y}+\left(z-z_{0}\right)\frac{\delta T}{\delta z}=N\left(B-T\right) \tag{4}$$

With B the regional value of the total magnetic field and (x_0; y_0; z_0) the position of the magnetic source, which produces the total field T measured at (x; y; z).

Table 1. Structural indices for simple magnetic models used for depth estimations by 3-D Euler deconvolution (modified after Reid *et al.*, 1990).

Geologic Model	Number of Infinite Dimensions	Magnetic Structural Index
Sphere	0	3
Pipe	1 (z)	2
Horizontal cylinder	1 (x-y)	2
dyke	2 (z and x-y)	1
sill	2 (x and y)	1
contact	3 (x, y, z)	0

Thompson (1982) showed that simple magnetic and gravimetric models are consistent with Euler's homogeneity equation. Thus Euler Deconvolution provides an excellent tool in aeromagnetic surveys for providing good depth estimations and locations of various sources in a given area, assuming that appropriate parameter selections are made. It is applicable to all geologic models and is insensitive to magnetic remanence and geomagnetic inclination and declination.

Table 1 summarizes the structural indices (SI) for given geologic models. The number of infinite dimensions describes the extension of the geologic model in space.

The results of the Euler method are displayed in ordinary maps as point solutions combining the location (position of solution) and the depth (colour range). Given the choice of an appropriate structural index, 3-D Euler Deconvolution will lead to a clustering of solutions, which can be interpreted.

4 Result Presentation and Interpretation

Digitized airborne magnetometer survey maps of total magnetic field intensity (sheets 45, 67, 46 and 68 representing Gudumbali, Masu, Monguno and Marte respectively) were acquired, assembled and interpreted. The total magnetic field intensity map derived from the data digitization and enhancement is presented as a colour shaded pixel map, total field intensity map and 3-D wireframe map of the total magnetic field intensity of the study area respectively (Figs. 2, 3 and 4).

The resultant total magnetic field map obtained from the digitized aeromagnetic data shows a very complex pattern of magnetic anomalies of both short and long wavelengths. These wavelengths are represented as magnetic low and high anomalous bodies. The anomalies have a regional gradient with increasing field intensity from north to south, with positive magnetic intensity values generally ranging between 7650 to 8500 nT.

Variation in magnetic intensity across the study area showing increase in magnetic intensity from the northern to the southern part indicates that the higher frequency anomalies are concentrated mainly within the southern part of the study area with a conspicuous elongated NE − SW anomaly directional preference in the southern part of the area. Areas of high magnetic intensity values could therefore be as a result of igneous intrusion in the area.

The 3-D Euler deconvolution process was used to produce maps showing the locations and the corresponding depth estimations of geologic sources of magnetic anomalies, as well as identify and calculate depth estimates for a variety of geologic structures such as magnetic contacts, dykes, sills, etc. with remarkable accuracy using a number of structural indexes. The results of the Euler method are displayed in ordinary maps as point solutions combining the location (position of solution) and the depth (colour range).

The study area is characterized by sharp contacts (Fig. 5a − b) that may be interpreted to be deep seated faults, which have significantly affected the basement rocks surface configuration/relief. Real faults are typically complex structures however, and slightly higher indices are often appropriate in properly defining them (Reid *et al.*, 1990). The study area is dominated more by the presence of sills and dykes (Fig. 6a − b), horizontal cylinders and pipes (Fig. 7a − b) and spheres (Fig. 8a − b), and less by the presence of contacts at various depths as seen on the maps showing the locations and the corresponding depth estimates of geologic sources of magnetic anomalies. As these geologic sources of magnetic anomalies are attributed to various forms of intrusions from the magnetic basement to the sediment pile towards the surface, they may serve as potential mineralization zones.

The depth to which magnetic intrusions occur within the sedimentary formations is at an average of 500m. This therefore constitutes the average depth to which magnetic intrusions to the sedimentary cover are expected. The nature of geologic structures formed from magnetic intrusions across the study area may constitute potential mineralization zones.

One primary factor considered in the exploitation of minerals is that it must be economically extracted at a profit. Hence if the ratio of overburden to the location of the mineralization is very high, and the market value of the mineral in question is relatively low, it therefore means that exploitation of the mineral may not be profitable. In other words the ratio of overburden to the location of the mineralized zone and the type of mineral deposit determines how profitable exploitation of the mineral deposit is.

Certain non-magnetic ore bodies can become significantly magnetic due to its association with certain magnetic minerals. In such a case this association may be used as a path-finder for the ore.

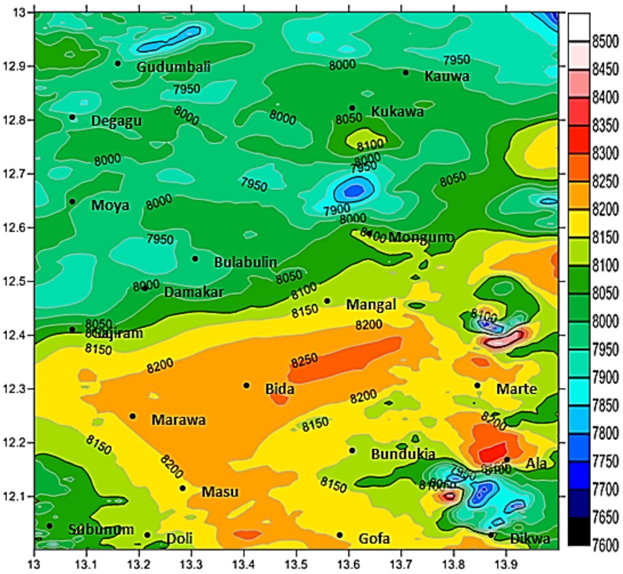

Figure 2. Colour shaded pixel map of the total magnetic field intensity of the study area.

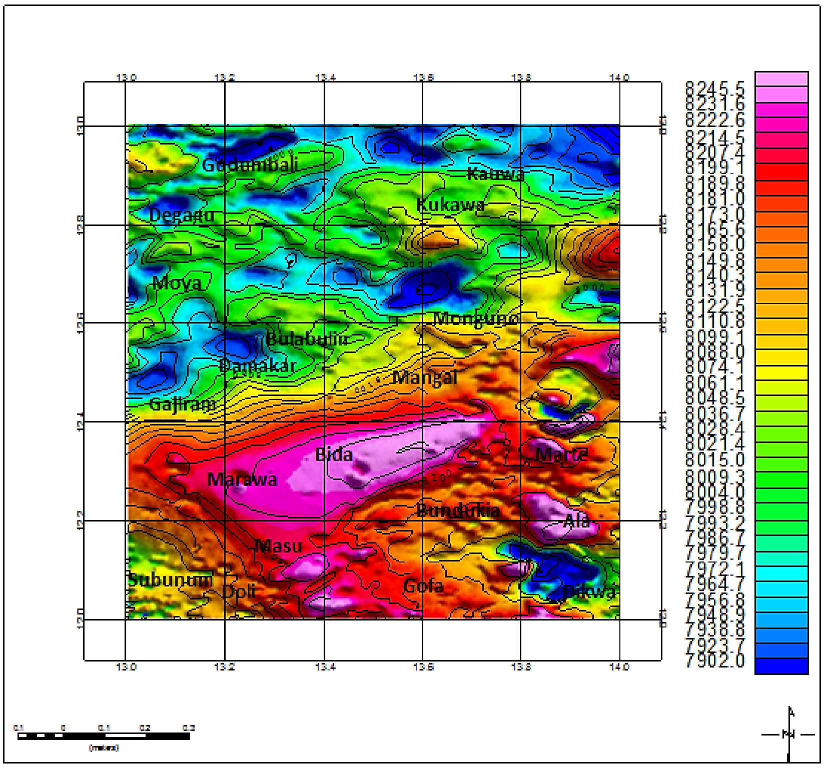

Figure 3. Total magnetic field intensity map of the study area (contour interval 20nT).

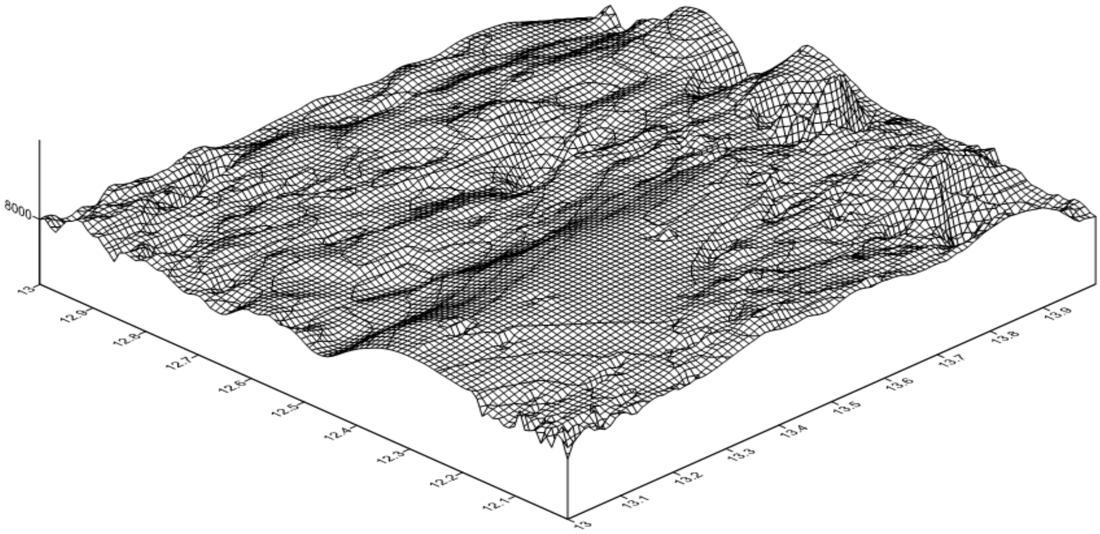

Figure 4. 3-D wireframe map of the total magnetic field intensity of the study area.

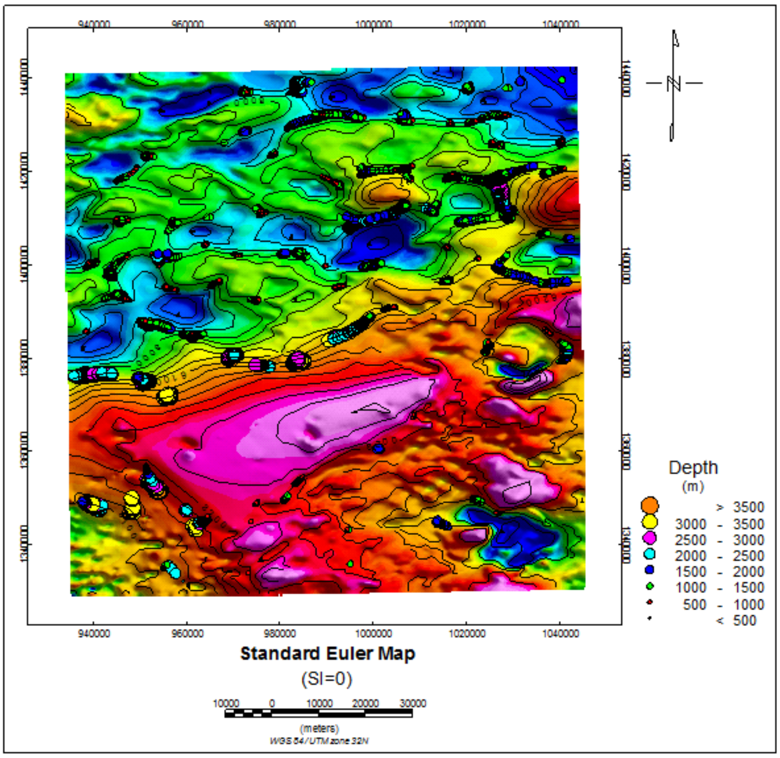

Figure 5a. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for contact.

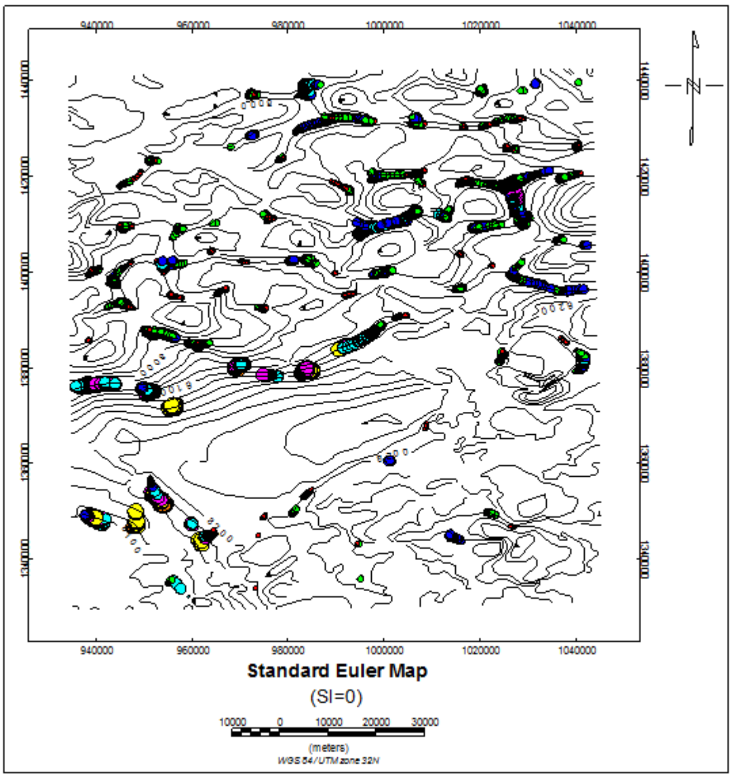

Figure 5b. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for contact.

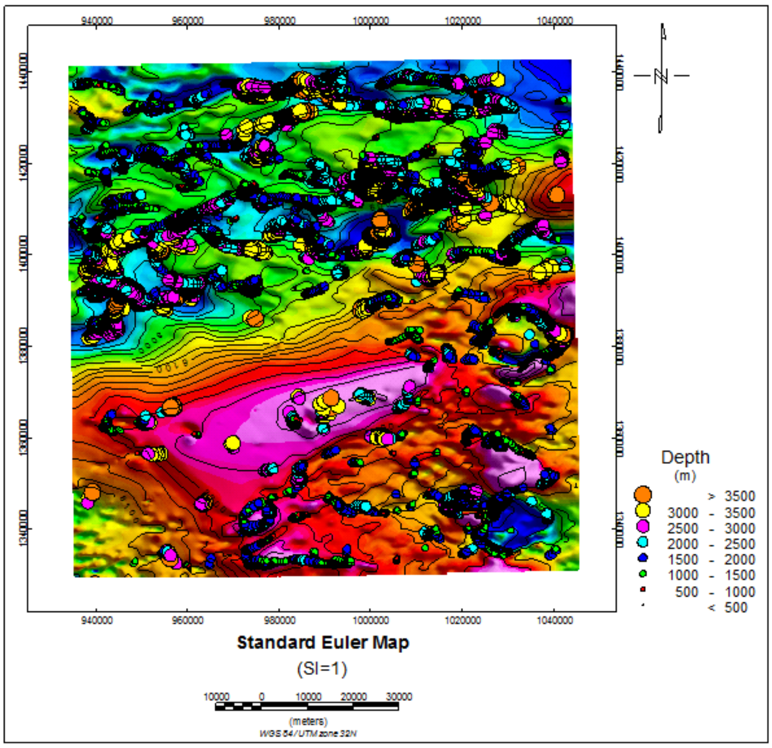

Figure 6a. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for sill and dyke.

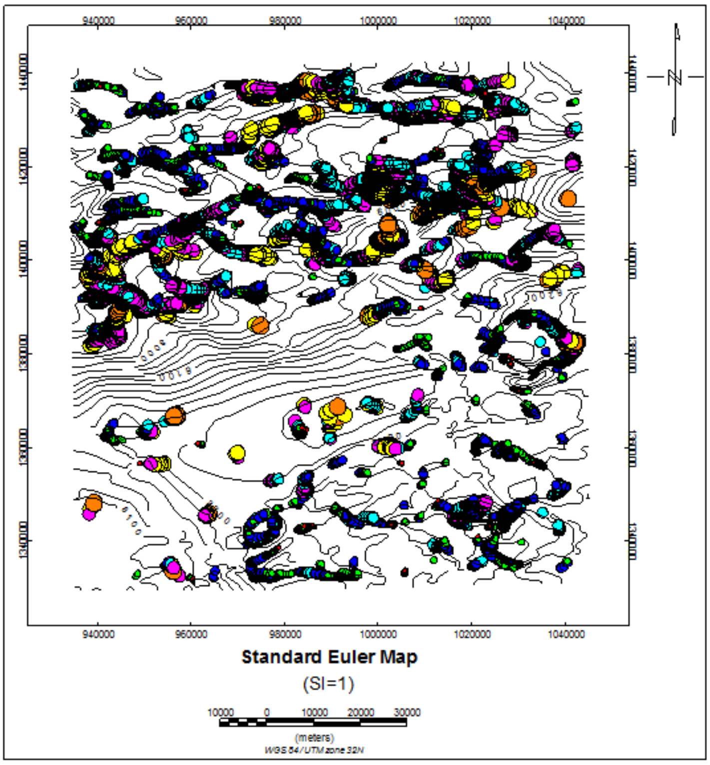

Figure 6b. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for sill and dyke.

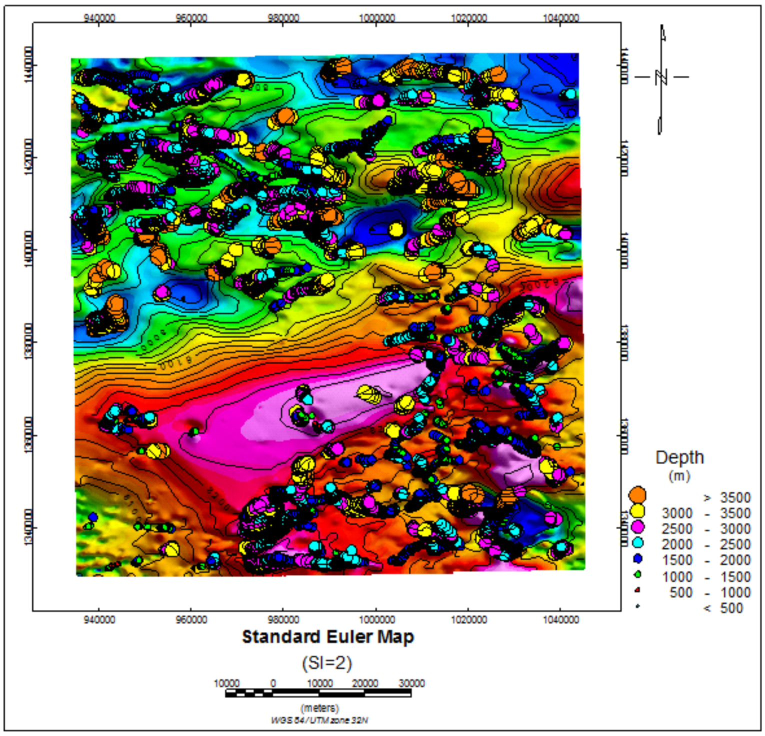

Figure 7a. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for horizontal cylinder and pipe.

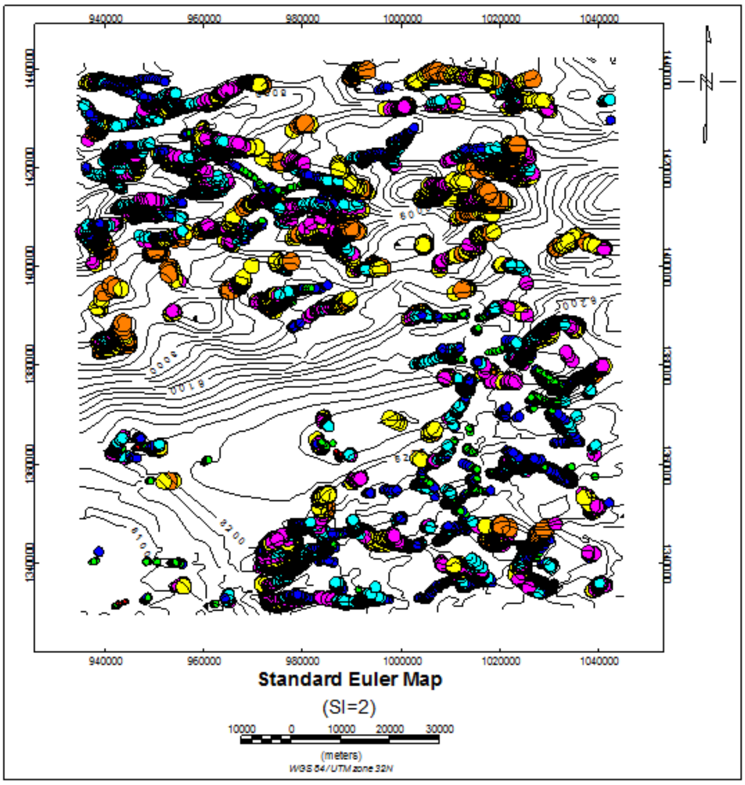

Figure 7b. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for horizontal cylinder and pipe.

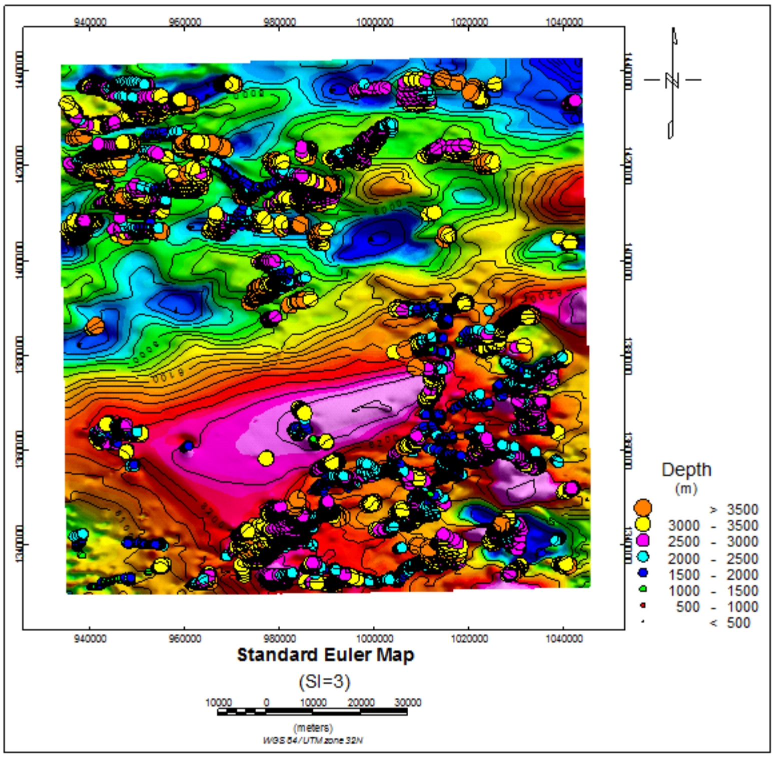

Figure 8a. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for sphere.

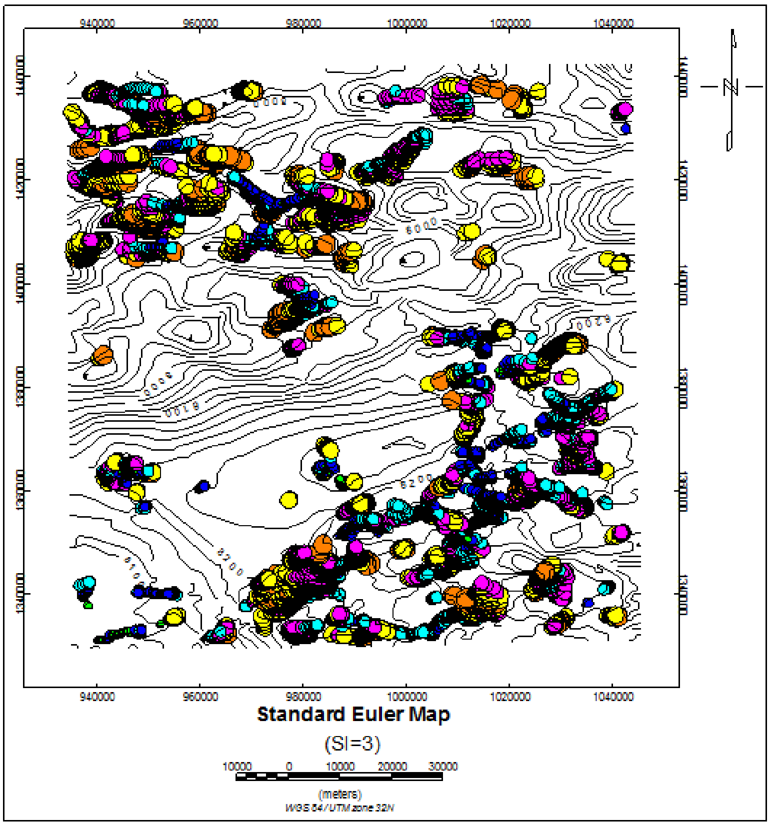

Figure 8b. Locations and corresponding depth estimations of geologic sources of magnetic anomalies for sphere.

5 Conclusion

Euler deconvolution methods have been applied to a set of aeromagnetic data over part of Monguno and environs in the Borno Basin, northeastern Nigeria through the extraction of information that would have been relatively difficult to interpret in a contour map.

Mineralization may be prevalent in the study area as indicated by the presence of intrusives, some of which occur at depths that allow for economic exploitation at a profit. Detailed mineral investigation should be carried on the southern areas because of the high magnetic values while detailed geophysical and geological investigations should be carried out around the area that houses the intrusion as the resident rocks maybe associated with economic grades minerals.

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