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Investigation of Mambila Plateau In North Central Part of Nigeria For Potential Minerals Using Aeromagnetic Method

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Abstract: *Aeromagnetic data of Mambila plateau have been interpreted qualitatively and quantitatively using two methods: standard Euler deconvolution and forward and inverse modeling methods. The area is marked by both high and low magnetic signatures (which range from -129.9nT to 186.6nT) which could be associated to several factors like difference in magnetic susceptibility, variation etc. 3D Euler deconvolution depth estimation for structural index (SI = 0.3 and 0.5) ranges from -213.9 m to -2112.0 m and -239.9 m to -2374.9 m, respectively. Depth estimate of forward and inverse modeling for profiles P1, P2, P3, and P4 are 2372m, 2537m, 1621m, and 1586m, with susceptibility values of 0.0754, 0.0251, 0.0028, and 0.001 respectively. This suggests that the bodies causing the anomaly are typical of igneous rocks; basalt and olivine, intermediate igneous rock; granites, and rocks mineral (qaurtz).*

Keywords: *Mambila plateau, Aeromagnetic interpretation, forward and inverse modeling, 3D Euler deconvolution.*

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I. Introduction

Geophysical exploration in all parts of the world is concerned with the composition, form, and structure of the crustal rocks, search for minerals, oil and gas, problems of civil engineering and construction. Each of these problems is addressed using geophysical exploration methods suited for it. Over the years, different methods of exploration both ground and airborne geophysical techniques have been developed to assist in mineral and hydrocarbon exploration. These methods include gravity method, electrical method, well logging, radiometric method, seismic method, magnetic method among others.

In this work, magnetic method was used to investigate some parts of Mambilla Plateau in Taraba State, Nigeria for mineral deposits. Magnetic prospecting maps or measures variations in the magnetic field of the earth that is attributable to changes of structure, magnetic susceptibility, or remanence in certain near-surface rocks. These anomalous magnetizations might be associated with local mineralization that is potentially of commercial interest, or they could be due to subsurface structures that have a bearing on the location of oil deposits (Dopamu et al., 2011). The difference between the observed and expected values is a magnetic anomaly (Lowrie, 2007). Magnetic surveying is a rapid and cost effective technique and represents one of the most widely used geophysical methods (Paterson & Reeves, 1985). Magnetic surveys are used extensively in the search for metaliferous mineral deposits. Airborne methods are usually the most cost effective tools available for both large regional reconnaissance surveys used as aids in geological mapping and for locating target areas for more detailed follow-up (reconnaissance survey) using helicopter borne instruments.

Mambilla plateau (Gashaka and Mayo Daga) is part of Upper Benue Trough, though, many aeromagnetic surveys have been done in the Upper Benue Trough (Abubakar et al., 2010; Bonde et al., 2014; Emberger and Chigbu, 2014; Salako, 2014; etc), which the Mambilla plateau is part of, no documented work on aeromagnetic survey has been carried out in the Mambilla plateau area precisely. The purpose of this work is to study the magnetic anomalies of Mayo Daga and Gashaka areas, by interpreting qualitatively and quantitatively the aeromagnetic anomalies of the areas with the aim of estimating the depth to the basement, determining the magnetic susceptibility and type of mineralization predominant in the area.

1.1 Location and geology of the study area

The study area (Mambilla plateau) is made up of Mayo Daga and Gashaka areas. In order to encompass the two areas at once, we shall take the description of the Mambilla plateau.

Mambilla plateau is located between latitude 5˚ 30' to 7° 18′ N and longitude 10° 18′ to 11° 37′ E with a total land mass of 3,765.2 km^2 (Tukur et al., 2005). The study area falls under the Sardauna local government area in Taraba State, Nigeria which is bounded in the southern, eastern and almost half of its western part by Cameroon. Mambilla plateau has the highest elevation in West Africa (Frantz, 1981) and about one-third of the area (Kakara, Nguroje, Maisamari, Gurgu, Yelwa, Mayo Ndaga and Lekitaba) is covered with volcanic rocks. About two-third of the study area is underlain by basement complex rocks which are of Precambrian to early Paleozoic era (Mubi & Tukur, 2005). The remaining part of the plateau is made up of volcanic rocks of the upper Cenozoic to tertiary and quaternary ages (Jeje, 1983). The rocks are of volcanic origin and are made up of basalts suite, olivine basalt and trachyte basalt containing a mixture of pyroxenes, amphiboles with some free quartz minerals (Moulds, 1960). The tertiary basalts found in the Mambilla Plateau are mostly formed by trachytic lavas and extensive basalts (Du Preez and Barber, 1995).

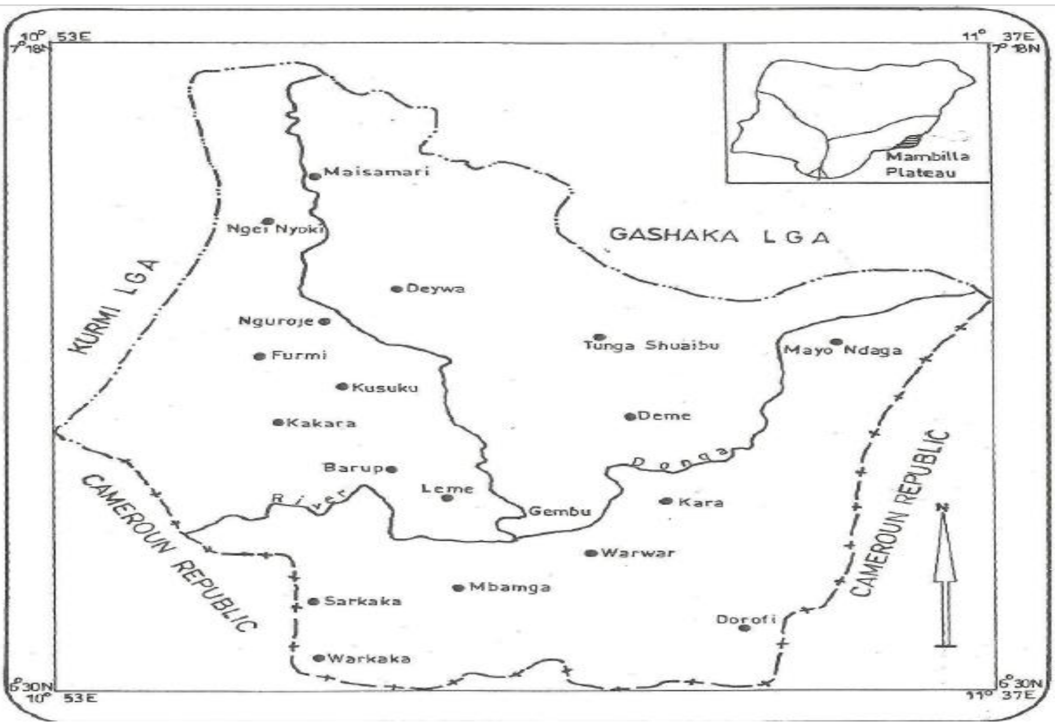

Fig. 1: Map of Nigeria showing the study area (Ahmed & Oruonye; 2016)

II. Materials And Methods

Once a complete magnetic data set is obtained from measurements in the field, an initial data processing normally starts with the removal of extraneous data, such as spikes present in essentially all raw data. The common early stage of interpretation involves the application of mathematical operations (enhancement) or filters to the observed data in order to enhance anomalies and to gain basic information on magnetization of the area. Aeromagnetic data can be enhanced by so many filtering algorithms, which enhance some features of data such as the edges of magnetic bodies, shallow magnetic feature, magnetic features at depth, subtle magnetic anomalies etc (Milligan and Gunn, 1997). Mathematical operations such as Fourier transforms are particularly useful in magnetic interpretation for resolution of specific anomalies by downward or upward continuation, changing the effective field inclination (reduction to pole) or conversion of total field data to vertical-component data, calculation of derivatives, general filtering separating anomalies caused by sources of different size and depth and modeling (Bhattacharyya and Navolio, 1976).

Regional anomaly was separated from the residual anomaly by applying first order polynomial fitting using least square method to the data. Different orders of polynomial were tried, but first order polynomial fitting was found to be the best for our data as it reflected the geological formation of the area. According to Ugwu *et al*. (2013) algorithm for removal of regional data is given as:

$$r = a_0 + a_1(X - X_{ref}) + a_2(Y - Y_{ref}) \quad (1)$$

where r is the regional field, X_{ref} and Y_{ref} are the X and Y coordinates of the geographical center of the dataset respectively. They are used as X and Y offsets in the polynomial calculation to prevent high order coefficients in becoming very small and a_0, a_1 and a_2 are the regional polynomial coefficients.

The polynomial fitting method is an analytical method for determining regional magnetic field. The regional field values were subtracted from the observed data to obtain residual values which formed the input data for this study.

Reduction to magnetic pole is confined to magnetic anomalies. It helps to transform data as if it was obtained at the pole and centers the anomaly, but in the process it distorts the shape of the anomaly. This change in the shape of the anomaly is because the shape of magnetic anomaly depends on the inclination and declination angle of the earth's main magnetic field. By implementation of filters on both the amplitude and phase spectra of the original TMI grid, the shapes of the magnetic anomalies may be simplified so that they appear like the positive anomalies located directly above the source expected for induce magnetized bodies at the magnetic pole where the angle of inclination is 90^o. Reduction to magnetic pole makes the delineating of magnetic sources considerably straight forward.

A potential field measured on a given observation plane at a constant height can be recalculated as though the observation were made on a different plane either higher or lower the original datum plane. Upward projection is known as upward continuation, this operation smoothen the anomalies obtained at the ground surface by projecting the surface mathematically upward above the original datum. This was done using Magmap suite in Oasis Montaj software. Detection depends on the amount of magnetic material present and its distance from sensor. The anomalies are presented on color contour maps.

Derivatives help to sharpen the edges of anomaly and enhance shallow features. This includes first and second vertical derivatives and horizontal derivative. Computation of the first vertical derivative in an aeromagnetic survey is equivalent to observing the vertical gradient with a magnetic gradiometer with advantages of sharpening the edges of magnetic anomalies, enhancing shallow magnetic sources, suppressing deeper magnetic sources and giving a better resolution of closely-spaced sources. The equation of the wave number domain filter to produce n^{th} derivative is given (Reeves, 2005) as

$$F(w) = w^n, \qquad (2)$$

where *F(w)* is the function of the wave number, *w* is the wave number and *n* is the nth order of the derivative. Gridding is a process of interpolating data unto an equally spaced grid of cells in a specified coordinate system. To produce the grids, "minimum curvature" method was used (Briggs, 1974). This method called the random gridding method fit a minimum curvature surface (the smoothest possible surface that will fit given data values) to data points. The method was used because the data were sparely sampled over wide area and continuous between data points.

Euler deconvolution is an inversion method for estimating location and depth to magnetic anomaly source. It relates the magnetic field and its gradient components to the anomaly source with the degree of homogeneity expressed as a structural index and it is the best suited method for anomalies caused by isolated and multiple sources (El Dawi *et al*., 2004). The structural index (SI) is a measured fall-off of the field with distance from the source. Considering potential field data, Euler's equation can be written as (Hood, 1965):

$$(x - x_o)\frac{\partial T}{\partial X} + (y - y_o)\frac{\partial T}{\partial y} + (z - z_o)\frac{\partial T}{\partial z} = N(B - T) \qquad (3)$$

where $\frac{\partial T}{\partial X}, \frac{\partial T}{\partial y}$ and $\frac{\partial T}{\partial z}$ represent first-order derivative of the magnetic field along the x-, y- and z- directions, respectively, and (x_o, y_o, z_o) is the source position of a magnetic source whose total field T is measured at x, y, z. B is the regional value of the total field. *N* is known as a structural index and related to the geometry of the magnetic source. Oasis montaj software was used in computing the Euler 3D image and depth.

Forward modeling involves the comparison of the calculated field of a hypothetical source with that of the observed data; the model is adjusted in order to improve the fit for a subsequent comparison. The technique is used to estimate the geometry of the source or the distribution of magnetization within the source by trial and error approach. Inverse modeling involves direct determination (as opposed to the trial and error or indirect determination) of some parameters of the source from the measured data. In this method, it is customary to constrain some parameters of the source in some way, realizing that every anomaly has infinite number of permissible source leading to infinite number solutions. Potent suite in Oasis software was also used in the modeling and inversion of the data. Potent is a program for modeling magnetic and gravitational effects of subsurface. It provides a highly interactive 3-D environment that, among other applications, is well suited for detailed ore body modeling for mineral exploration. Interpretation of magnetic field data using potent starts with observation of the image of the observed data (Obiora *et al*., 2016).

III. Sources of Data

The aeromagnetic data of Mayo Daga and Gashaka areas (sheets 295 and 276, respectively) were produced by an aeromagnetic survey conducted by Nigerian Geological Survey Agency (NGSA) Abuja, in 2009. The aeromagnetic data was obtained using a 3x Scintrex CS3 cesium vapour magnetometer. Fugro Airborne Surveys carried out the airborne geophysical work. Aeromagnetic surveys were flown at 500m line spacing and 80m terrain clearance. The average magnetic inclination and declination across the survey area was -10.854^0 and -0.223^0 respectively. The geomagnetic gradient was removed from the data using International Geomagnetic Reference Field (IGRF) in 2009 and the data was collected in digitized form (X Y Z). The X and

Y represent the Northing's in meters (longitude in meters) and Easting's in meters (latitude in meters) respectively, Z represents the magnetic intensity measured in nanoTesla (nT). It should be noted that the various corrections as described above have been applied to the data collected.

IV. Results

Interpretation of the data set for this work followed a qualitative and quantitative interpretation approach. Qualitative interpretation describes the survey results and the explanation of the major features revealed by the survey in terms of the types of likely geological formations and structures that cause the evident anomalies. It deals with the description of anomalies, especially their symmetry, strike, extension, width, amplitude and gradients (Ofoegbu, 1985). It shows shallow subsurface structures (faults and dykes), basaltic intrusions, as well as the basement control of the considered area. It also involves the measurement of total magnetic intensity. In this work, qualitative interpretation was done by applying mathematical operations or filters to the observed data aimed at enhancing the anomalies of interest. Total magnetic intensity (TMI) map of the study area was produced using magmap suite in Oasis Montaj software. Quantitative interpretation involves making numerical estimates of the depth and dimension of the sources of anomalies and this often takes the form of modeling of sources which could, in theory, replicate the anomalies recorded in the survey. Quantitative interpretation of aeromagnetic data can be carried out by employing different methods which includes the source parameter imaging (SPI) method, standard Euler deconvolution method, analytical signal method, spectral analytical method, graphical interpretation method, forward and inverse modeling e.t.c. Two methods were used in this work: standard Euler deconvolution, and forward and inverse modeling methods.

4.1 Qualitative interpretation

Qualitative interpretation of aeromagnetic data was first carried out by producing the total magnetic intensity map (Figure 2) of the study area. The total magnetic intensity was produced from digitized data (XYZ data) collected from Nigerian Geological Survey Agency (NGSA) using Oasis montaj software. The magnetic intensity of the area ranges from a minimum value of -129.9nT to a maximum value of 186.6nT. The area is marked by both high and low magnetic signatures which could be attributed to several factors such as; difference in magnetic susceptibility, variation in depth, degree of strike and difference in lithology. The closely spaced linear sub-parallel orientation of contours in the northern and southern parts of the study area suggests that faults or local fractured zones may possibly pass through these areas. Most of the anomalous features trend in the East-West direction, while minor ones trend Northeast-Southwest. The elliptical contour closures seen in the study area suggest the presence of magnetic bodies. The main trend of the lineaments is East-West, while few trend Northeast-Southwest.

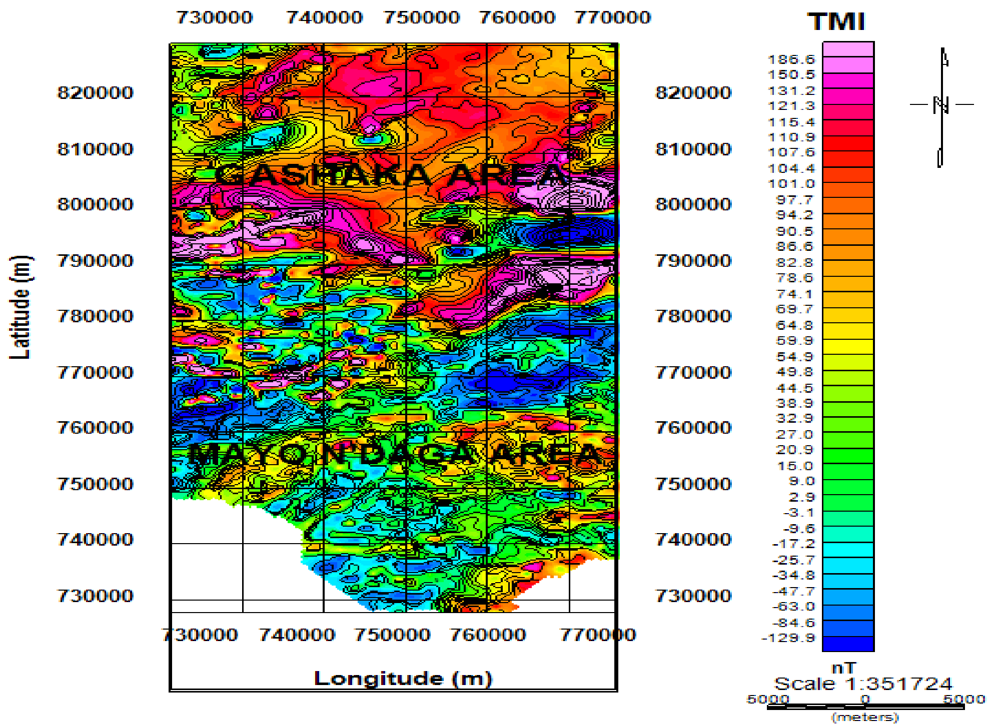

Figure 2: Total magnetic intensity map of the study area.

4.1.1 Residual magnetic values

The residual magnetic values was obtained by subtracting regional field from the total magnetic value at the grid cross points using Oasis montaj software. The negative residuals area (Figure 3) reflects zone of low magnetization while the positive residual anomalies reflect area of high magnetization. The 2D residual map of the study area (Figure 3) revealed that local magnetic field variation whose magnitude varies between -145.1 nT and -44.0 nT (blue colour) appearing mostly in the south and western part of the map and those ranges between -37.8 nT and -1.7 nT (green colour) are observed spreading across the area. Very dominant in the study area and appeared to be well distributed almost in equal proportion throughout the entire study area are the anomalies ranging between 30.3 nT and 129.1 nT (red and purple colour). Residual anomalies with magnetic intensity ranging between 1.3 nT and 26.9 nT (yellow colour) are observed spreading from the north to the southern parts of the study area in a large proportion. Local positive residual anomalies observed in the parts of the study area are suspected to be some outcrops of cretaceous rocks and perhaps concentrations of sand stones within the study area. These could also be associated with volcanic and ophiolitic rocks. Negative anomalies are suspected to be greater thickness of cretaceous rocks contained within the fault-bounded edges and depicting isolated basinal structures. These are well distributed across the study area.

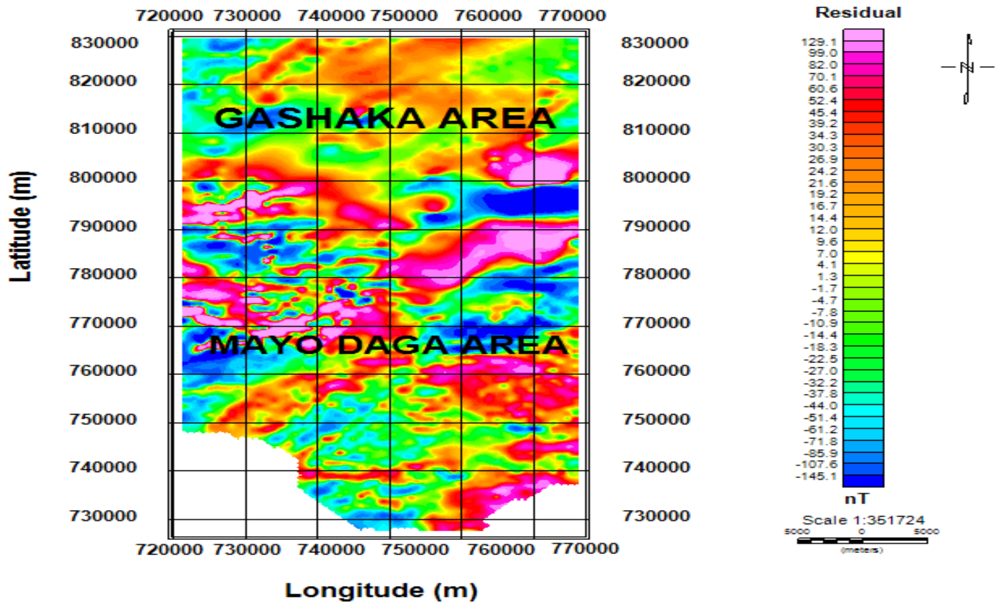

Figure 3: Residual map of the area

4.1.2 Reduction to the pole

Reduction to the pole filter reproduces the magnetic field of a data set as if it were at the pole. This means that the data could be viewed in map form as a vertical magnetic field inclination with a declination of zero. This makes interpretation of the data easier as vertical bodies will produce induced magnetic anomalies that are centered on the body symmetrically. By implementation of Reduction to Pole (RTP), filters on the residual magnetic intensity grid and the shapes of magnetic anomalies were simplified, and they appeared like the positive anomalies located directly above the expected magnetized bodies at the magnetic poles (Figure 4).

4.1.3 Upward continuation

In upward continuation, magnetic field data from one datum surface were mathematically projected upward to level surfaces above the original datum (Figure 5). Upward continuation is a straightforward operation since the surfaces are in field-free space. In projecting to a higher plane, we are effectively smoothing the anomalies obtained at the ground surface.

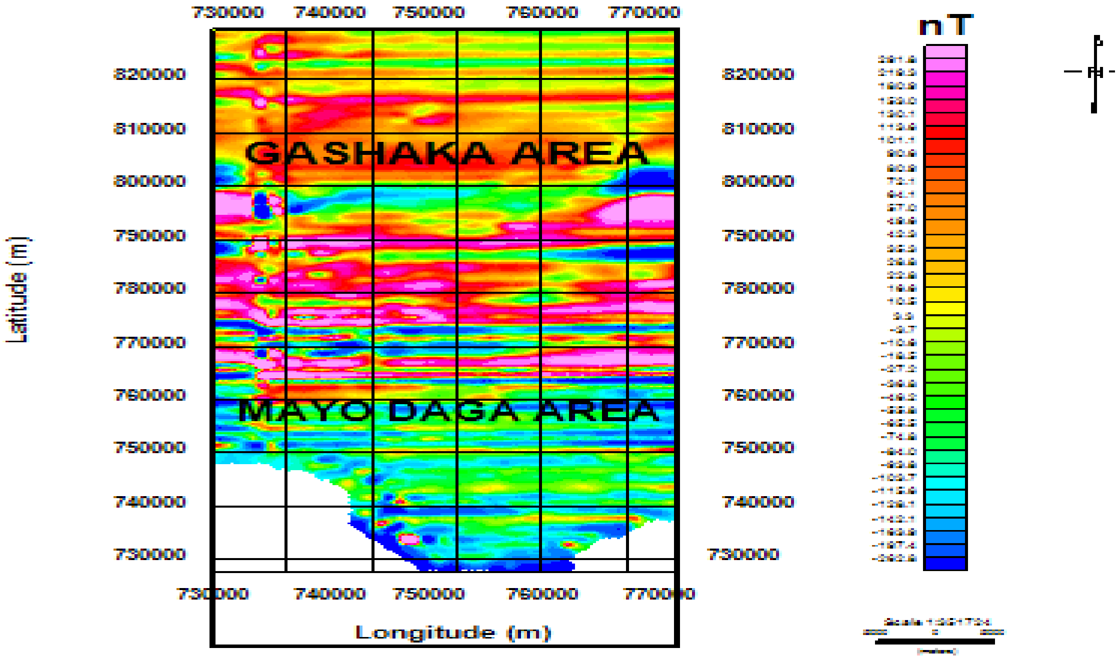

Figure 4: Reduction to Pole produced from residual magnetic map.

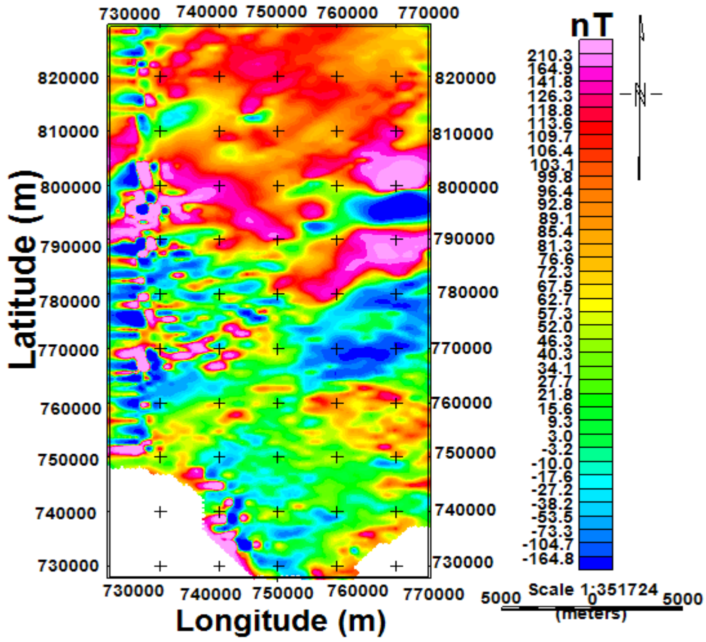

Figure 5: Upward continuation produced from residual magnetic map.

4.1.4 First vertical derivative

First vertical derivative helped to reveal near surface anomalies. In other words, the first vertical derivative filter computes the vertical rate of change in the magnetic field. Derivative filter suppresses the long wave lengths. Figure 6 shows the shape of the filter and results of the first derivative filter. The shape of any magnetic anomaly depends on the inclination and declination of the main magnetic field of the earth. Thus the same magnetic body will produce an anomaly of different shape depending on its position and orientation.

4.2 Quantitative interpretation
This involves making numerical estimates of the depth and dimensions of the sources of anomalies and this often takes the form of modeling of sources which could, in theory, replicate the anomalies recorded in the survey. Some quantitative methods of aeromagnetic data interpretation are employed and these include 3D Euler deconvolution method, and forward and inverse modeling method.

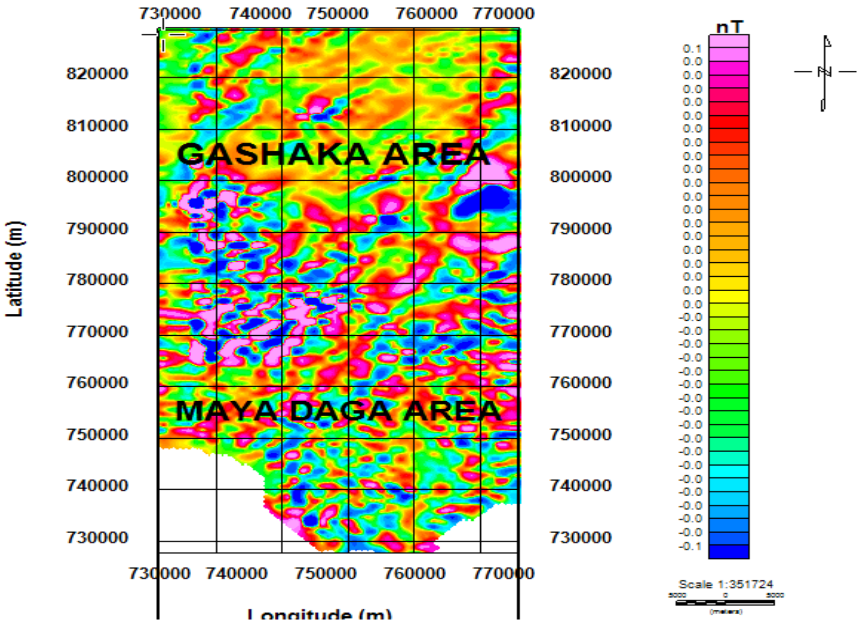

Figure 6: First vertical derivative produced from residual magnetic map.

4.2.1 Result of 3D Euler deconvolution method
The Oasis Montaj software was employed to compute Euler 3D image and depth. The results were achieved using structural indices (SI = 0.3 and 0.5), which represent vertical contact in geological model. This was done to locate depths to the lithologic contacts on the gridded map. The derived solutions were windowed to reduce uncertainty to the minimum by constraining the obtained Euler Deconvolution solutions to accept depth (dz) 15%, window size of 10. Figures 7a and 7b show varied colours of different magnetic susceptibilities contrast within the study area, and also portrayed the undulations in the basement surface. The negatives in the numbers on the legend signify depth. The blue colour in the legends shows area of deep lying magnetic bodies. The pink, purple and orange colours in the legends show areas of shallower sediment or near surface lying magnetic bodies. From the result of 3D Euler deconvolution method shown in Figures 7a and 7b respectively, the depth for the structural index (SI = 0.3) ranges from -213.9 m to -2112.0 m and for structural index (SI = 0.5) the depth ranges from -239.9 m to -2374.9 m.

4.2.2 Model Results and Interpretations of Forward and Inverse Modeling
Figure 8 shows the profiles taken on residual magnetic map of the study area and the subsets are shown in Figure 9 (a-d).
Figure 9 (a-d) shows the model profiles of the study area. In the result, the blue curves represent the observed field while the red curves represent the calculated fields due to the model.

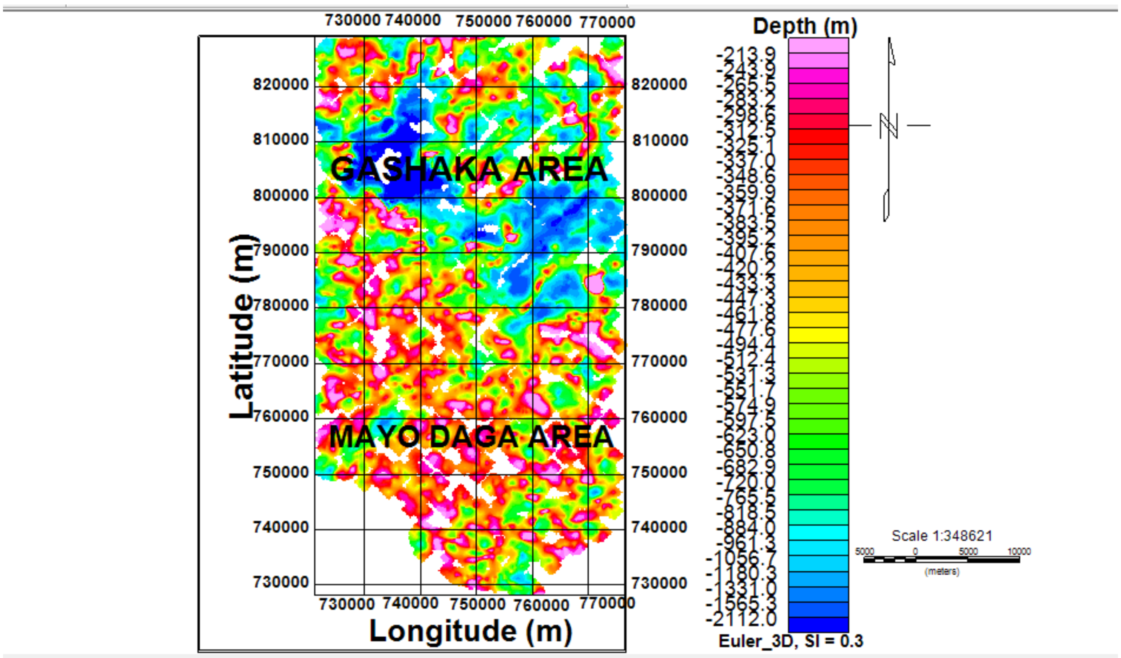

Figure 7a: Depth estimation by Euler deconvolution for structural index of 0.3.

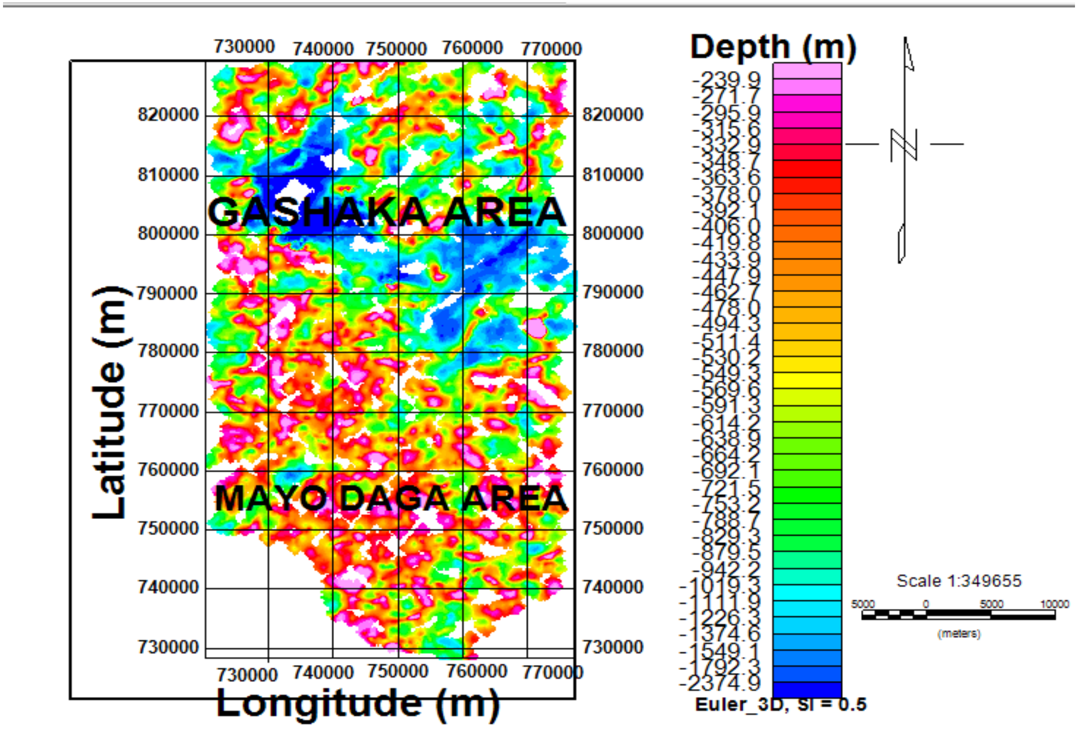

Figure 7b: Depth estimation by Euler deconvolution for structural index of 0.5.

During forward modeling session, the shape, position and physical properties of the model were adjusted in order to obtain a good correlation between the calculated field and the observed field. The field was calculated by potent at the actual observation points (the only points where the observed field is known). Potent therefore automatically calculated the field from the model in response to the changes made to the model. The observed values are depicted as an image and as a single N-S and E-W profile. Their fit is measured by their visible superposition and the root mean square (RMS) values. The inversion algorithm then attempts to minimize the root-mean-square (RMS) difference between the observed and the calculated values. The RMS value was then displayed at the end of each inversion exercise. As the fit between the calculated field and observed field continued to improve, the RMS value continued to decrease until a reasonable inversion result was achieved. The RMS value of less than twenty one was set as acceptable error margin for the inversion results.

The sub profiles in each model show the variations of the field values with distance at the area or points modeled. Profiles P1 and P2 taken around north-western and north-eastern parts of the study area were modeled by a Cylinder shapes emplaced at depths of 2372 m and 2537 m respectively (Figures 9a and 9b). The bodies have magnetic susceptibilities of 0.0754 and 0.0251 respectively suggesting that the bodies causing the anomaly are typical of igneous rocks; basalt and olivine (Telford et al., 1990).

Profile P3 taken in the south eastern part, was modeled by Ellipsoid shape emplaced at depth of 1621 m with susceptibility value of 0.0028 (Figure 9c), suggesting that the bodies causing the anomaly are typical of intermediate igneous rock; granites (Telford et al., 1990). Profile P4 taken in the south western part of the study area, was modeled with Lens shape emplaced at depth of 1586 m with magnetic susceptibility value of 0.001 (Figure 9d), reveals rock mineral (qaurtz) Telford et al. (1990). The summary of the modeling result is shown in Table 1.

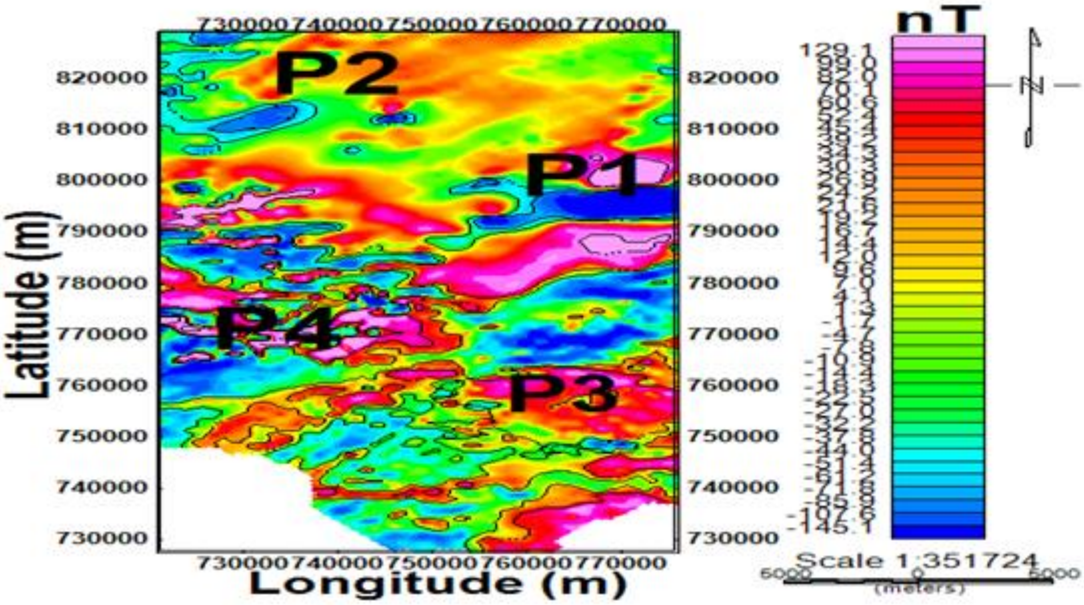

Figure 8: Residual magnetic contour grid map showing four profiles.

V. Discussions

Qualitative interpretation was done by visual inspection of the total magnetic intensity map, residual magnetic map, regional magnetic map, upward continuation, first vertical derivative and reduction to the pole.

The total magnetic field ranges from -129.9 nT to 186.6 nT. Higher values of total magnetic intensity are found in the north central and eastern parts of the study area, and lower values in the southern region (Figure 2). The closely spaced linear sub-parallel orientation of contours in the northern and southern parts of the study area suggests that faults or local fractured zones may possibly pass through these areas. Most of the anomalous features trend in the East-West direction, while minor ones trend Northeast-Southwest. Chinwuko et al. (2012) believed there would always be a magnetic susceptibility contrast across a fracture zone due to oxidation of magnetite to hematite, and/or infilling of fracture planes by dyke-like bodies whose magnetic susceptibilities are different from those of their host rocks. Such geologic features may appear as thin elliptical closures or nosing on an aeromagnetic map. The elliptical contour closures seen in the study area suggest the presence of magnetic bodies. The main trend of the lineaments is East-west, while few trend Northeast-Southwest.

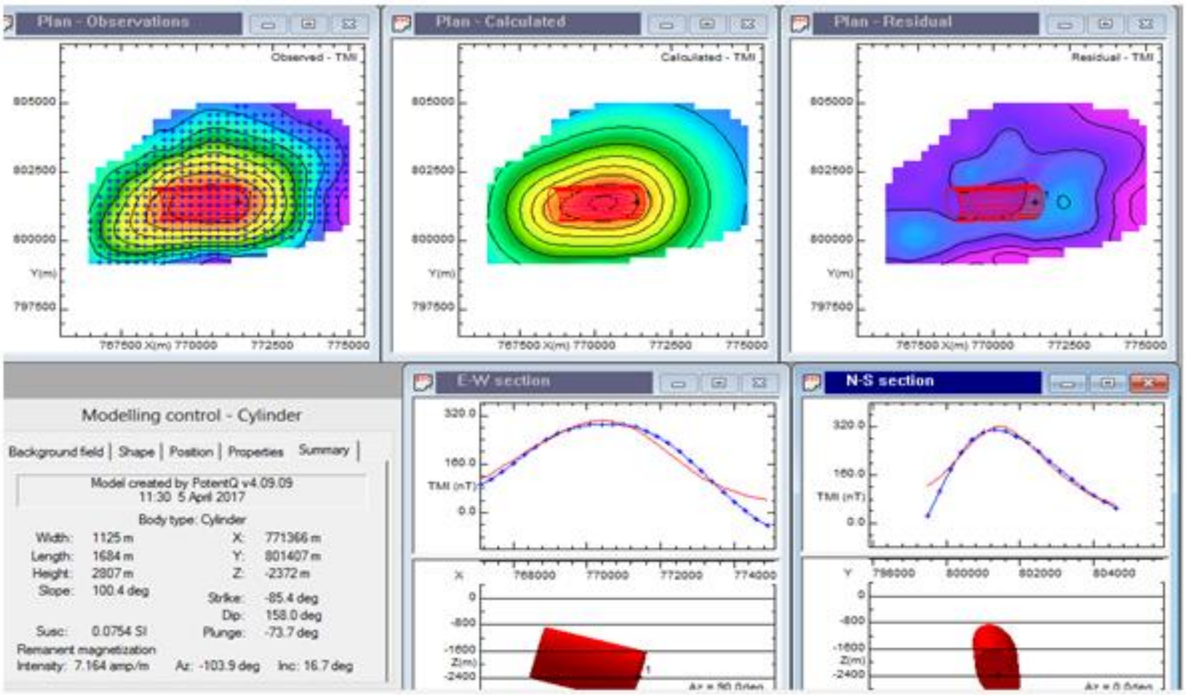

Figure 9a: Model (Cylinder) result of profile 1.

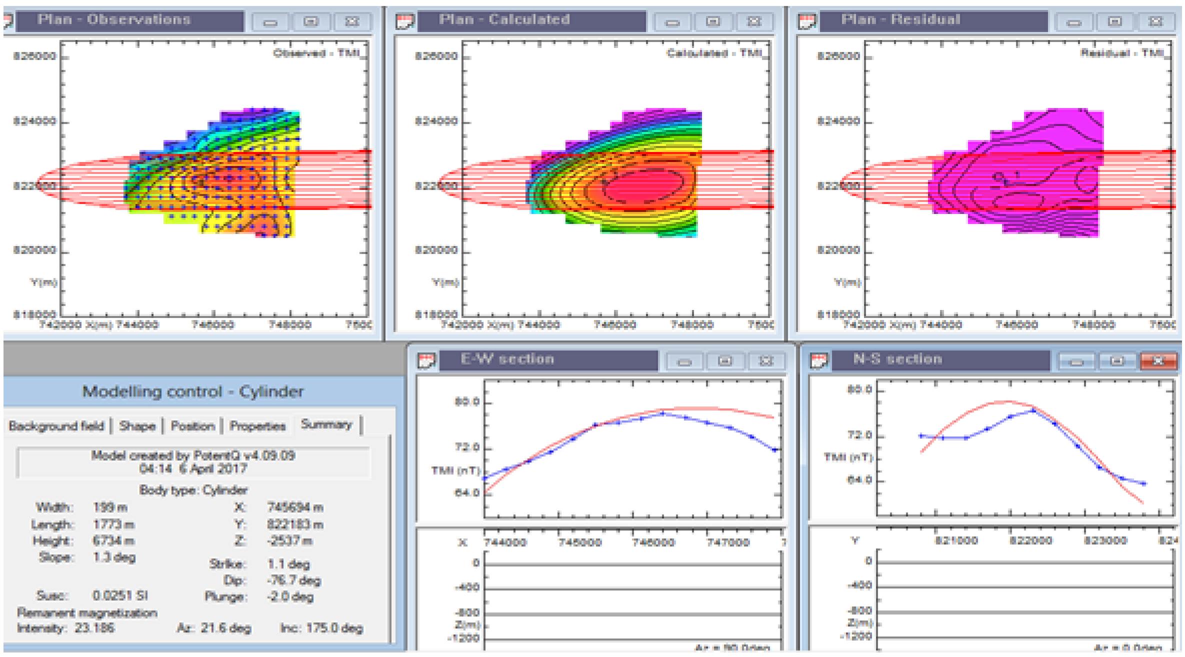

Figure 9b: Model (Cylinder) result of profile 2.

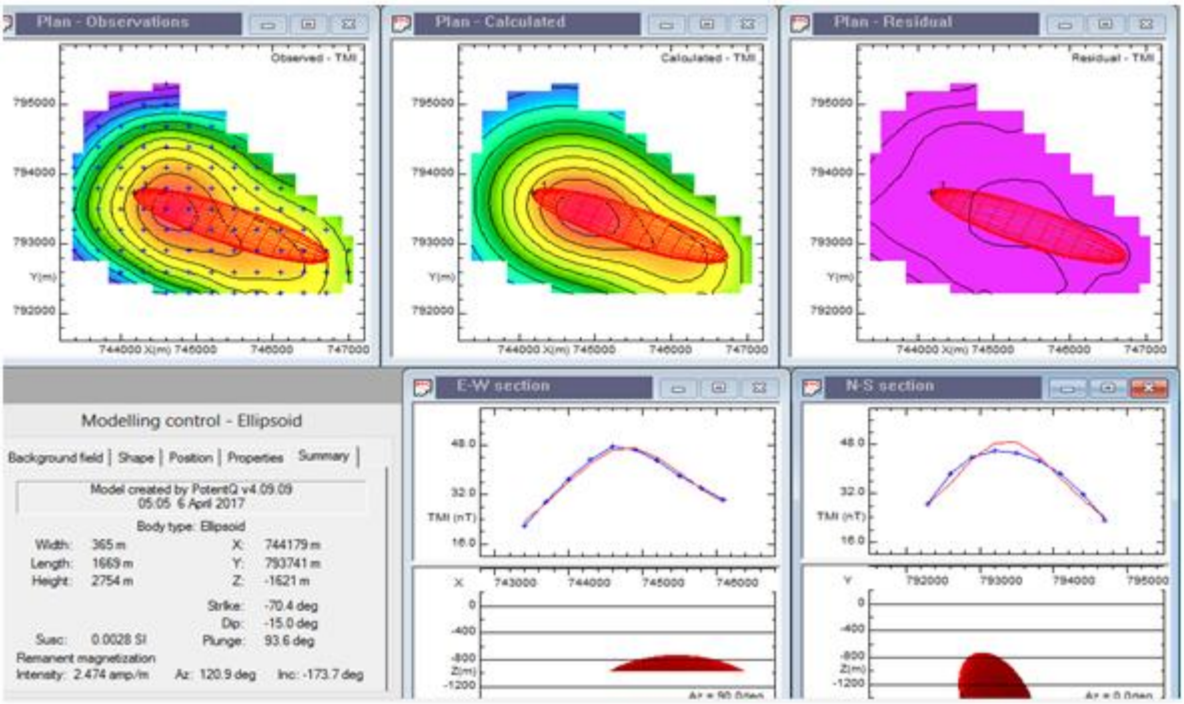

Figure 9c: Model (Ellipsoid) result of profile 3.

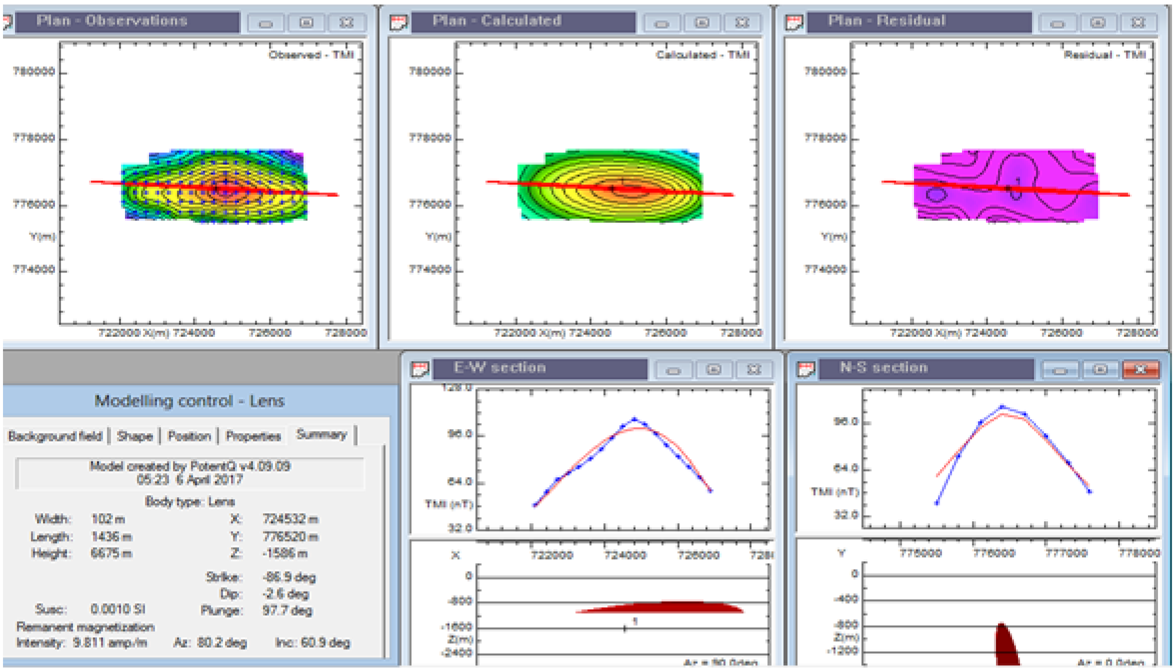

Figure 9d: Model (Lens) result of profile 4.

Table 1: Summary of modeling results

Profile	X(m)	Y(m)	Depth (m)	Types of body	Dip (deg.)	Plunge (deg.)	Strike (deg.)	K value	Possible cause of anomaly
1	771366	801407	-2372	Cylinder	158.0	-73.7	-85.4	0.0754	Basalt
2	745694	822183	-2537	Cylinder	-76.7	-3.0	1.1	0.0251	Olivine
3	744179	793741	-1621	Ellipsoid	-15.0	93.6	-70.4	0.0028	Granite
4	724532	776520	-1586	Lens	-2.6	97.7	-86.9	0.001	Qaurtz

The negative residual anomalies (Figure 3) reflects zone of low magnetization while the positive residual anomalies reflect area of high magnetization. 2D residual map of the study area (Figure 3) revealed that local magnetic field variation whose magnitude varies between -145.1 nT and -44.0 nT (blue colour) appearing mostly in the south and western part of the map and those ranging between -37.8 nT and -1.7 nT (green colour) are observed spreading across the area. Very dominant in the study area and appeared to be well distributed almost in equal proportion throughout the entire study area are the anomalies ranging between 30.3 nT and 129.1 nT (red and purple colour). Residual anomalies with magnetic intensity ranging between 1.3 nT to 26.9 nT (yellow colour) are observed spreading from the north to the south parts of the study area in a large proportion. Local positive residual anomalies observed in the parts of the study area are interpreted or suspected to be some outcrops of cretaceous rocks and perhaps concentrations of sand stones within the study area. These could also be associated with volcanic and ophiolitic rocks. Negative anomalies are ascribed to greater thickness of cretaceous rocks contained within the fault-bounded edges and depicting isolated basinal structuring and these are well distributed across the study area. Ajayia and Ajakaiye, (1981) suggested the existence of near-surface intrusion, vocanic plugs, basement rocks and basalt flow which could be deeply rooted, which agrees with the results of this work.

First vertical derivative map (Figure 6) shows areas of higher intensity (high signal) in the north central, west and east of the study area, while the south region has lower intensity (low signal). In addition, the reduction to pole map (Figure 4) shows some elliptical bodies, indicating the shapes of magnetic anomalies that are centered on the body symmetrically. The upward continuation map (Figure 5) shows the smoothened anomalies obtained at the ground surface of the study area and the boundary each anomalous body.

The depths estimated for shallow magnetic bodies and deep lying magnetic bodies using Standard 3D Euler deconvolution and forward and inverse modeling methods are within the same range. For Euler deconvolution, Figure 7(a & b) shows the depth estimates by standard Euler deconvolution for each structural index (SI); the depth for the structural index (SI = 0.3) ranges from -213.9m (shallow magnetic bodies) to -2112.0m (deep lying magnetic bodies) and for structural index (SI = 0.5) the depth ranges from -239.9 m (shallow magnetic bodies) to -2374.9 m (deep lying magnetic bodies). This maximum depth obtained using Euler deconvolution method agrees with the work of Emberger and Chigbu (2014), which from their work showed that the deep source anomalies of the Yola arm of upper Benue trough vary between 2.373km and 0.554km and this represents the depth to the magnetic basement. While the shallow anomaly sources have an average of 0.554km and this may be regarded as the magnetic intrusions into the sediment.

The modeling result shown in Figure 9(a-d) (forward and inverse modeling), the blue curves represent the observed field while the red curves represent the calculated fields due to the model. Profiles P1 and P2 taken around north-western and north-eastern parts of the study area were modeled by a Cylindrical shapes emplaced at depths of 2372 m and 2537 m respectively (Figures 9a and 9b). The bodies have magnetic susceptibilities of 0.0754 and 0.0251 respectively suggesting that the bodies causing the anomaly are typical of igneous rocks; basalt and olivine (Telford *et al*., 1990). Profile P3 taken in the south eastern part, was modeled by Ellipsoid shape emplaced at depth of 1621 m with susceptibility value of 0.0028 (Figure 9c), suggesting that the bodies causing the anomaly are typical of intermediate igneous rock; granites (Telford *et al*., 1990). Profile P4 taken in the south western part of the study area, was modeled with Lens shape emplaced at depth of 1586 m with magnetic susceptibility value of 0.001 (Figure d), reveals rocks mineral (qaurtz) Telford *et al*. (1990).

VI. Conclusions

The magnetic anomalies of Gashaka and Mayo Daga areas were studied by employing qualitative and quantitative interpretation of aeromagnetic data of the area. Euler deconvolution and modeling methods were used as part of quantitative interpretation. The maximum depths obtained from each method are approximately 2.3 km. The depths obtained from Euler and forward and inverse modeling is good for hydrocarbon accumulation in the study area. This agrees with the assertion of Wright *et al*. (1985) that the minimum thickness of the sediment required for the commencement of oil formation from marine organic remains would be 2300 m (2.3 km), if other factors are satisfactory.

The results obtained from the qualitative and quantitative interpretation of this study show some agreement with those of other researchers (Chinwuko *et al*., 2012, Wright *et al*., 1985 and Ajayia and Ajakaiye, 1981). This study has helped to delineate the geological structures of Gashaka and Mayo Daga areas which are of great benefits to the solid mineral sector of Nigeria economy.

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