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Analysis Of Aeromagnetic Data For Magnetic Susceptibility Distribution In Eastern Niger Delta, Nigeria: Implications For Magnetic Mineral Potential

Righteous Ombu And Alvan Kigigha
Department Of Physics With Electronics, School Of Applied Sciences, Federal Polytechnics Ekowe, Bayelsa State, Nigeria

Abstract
This study, Analysis of Aeromagnetic Data for Magnetic Susceptibility Distribution in Eastern Niger Delta, Nigeria: Implications for Magnetic Mineral Potential was aimed at determining magnetic susceptibility distribution and its implications for magnetic mineral potential in the region. Magnetic susceptibility is the degree to which a material becomes magnetized in response to an applied magnetic field. Its distribution in a sedimentary basin is vital in understanding the presence of magnetic mineral deposits in the sedimentary sequence. A high-resolution aeromagnetic data was obtained from the Nigeria Geological Survey Agency (NGSA), Abuja. The data was processed and interpreted using oasis montaj software by using the following steps: gridding of data to obtain the total magnetic intensity (TMI) base map, contouring, and reduction to pole, regional – residual anomalies separation and standard Euler deconvolution. The results from the TMI map colour contoured TMI map and regional RTP map shows that the area is magnetically heterogeneous with magnetic susceptibility range from -46.2nT to 174.9nT. There are areas with low and high magnetic susceptibilities in the study area. The areas with low magnetic susceptibility (blue to green) in the south, southeast and southwest parts are indicative of sediments with presence of low magnetic mineral deposits. The areas of high magnetic susceptibility (red to magenta) in the north, northeast and north-central parts are indicative of sediments with presence of high magnetic mineral deposits. The contoured TMI map revealed pockets of depression and elevation typifying areas of sediment deposits and basement intrusions. The regional TRP map also revealed a signature of dyke, spherical, cylindrical but elongated and tampered shaped magnetic anomalies which corresponds to faulted anticline, syncline and faulted synclines structures. Similarly, result from the standard Euler deconvolution map x-rayed sediment thickness range of 96.5m to 6601.5m. This variation in the sediment thickness depicts the undulated nature of the basement topography. Therefore, further geological and geophysical investigation is recommended to unravel the type's magnetic mineral deposits in the study area.

Keywords: *Aeromagnetic, Analysis, Data, Magnetic Susceptibility, Mineral and Niger Delta*

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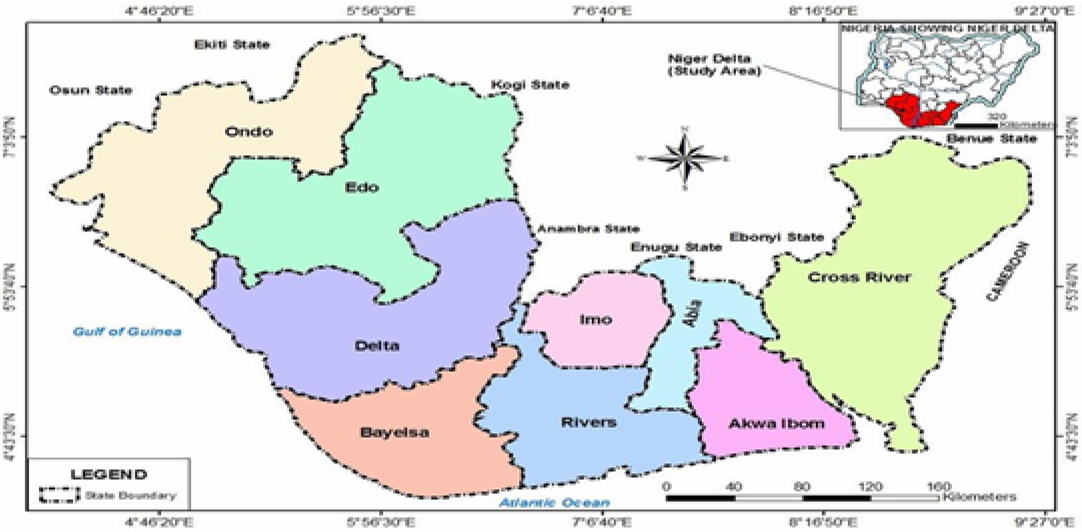
I. Introduction

Magnetic susceptibility is the degree to which a material becomes magnetized in response to an applied magnetic field (Roest et al, 2001). Its distribution in a sedimentary basin is vital in understanding the presence of magnetic mineral deposits in the sedimentary sequence. An aeromagnetic data obtained from aeromagnetic can be used to determine magnetic susceptibility distribution of a location. Aeromagnetic survey is the investigation of the subsurface geology on the basis of the anomalies in the earth's magnetic field resulting from the variation of the magnetic properties of the underlying rocks using a magnetometer mounted in an aircraft in a continuous parallel flight lines that are equally spaced covering the area under investigation (Telford et al., 2001). The aeromagnetic survey is similar to the land magnetic survey where the magnetometer is held with hand but it permits more surface areas of the earth to be covered more quickly. The aircraft flies in a grid pattern with height and line spacing which determine the resolution of the data. The magnetometer records minute difference in the ambient magnetic field intensity due to temporal effects of the frequently fluctuating solar wind and spatial differences in the earth's magnetic field as the aircraft flies. The spatial changes of the earth's field are due to the regional magnetic field and the local effect of the magnetic minerals in the earth's crust (corridor et al., 2005). The removal of the solar wind and regional effects delineates the magnetic susceptibility distribution, relative abundance of magnetic minerals, sediment thickness map geological boundaries between lithologies of different of different magnetic contrasts including faults (Telford et al., 2001). Therefore, in this study, analysis of aeromagnetic data for magnetic susceptibility distribution in eastern Niger Delta with implication for magnetic mineral deposit will be achieved through a series of the application of magnetic data enhancement attributes and interpretation based on qualitative and quantitative analysis.

II. The Location Of The Study

The location of study is the eastern flank of the tertiary Niger Delta that lies within latitudes $5^0 00$ to $8^0 00E$ and longitudes $4^0 00$ to $8^0 00N$ (Opufunso, 2007) as in Figure1. The Eastern Niger Delta sedimentary basin is the area marked in red which lies within Latitude $60^0 00$ to $80^0 00E$ and longitude $43^0 00$ to $60^0 00N$. This region is located within the oceanic section of the Abakilike – Benue suture zone of the much larger southern Nigerian basin. On its west boundary, it is separated from the Benin Basin by the Okitipupa basement high and on the east by Cameron Volcanic fine. The northern boundary is the Anambra basin, Abakilike uplift; Afikpo Syncline and Calabar flank (Heinio & Davis 2006). The tertiary Niger Delta covers an approximate area of 75,000sqkm and consists of a regressive classic succession, which attains a maximum thickness of 12,000m with the siliciclastice system prograding across pre-existing continental slope into the deep-sea during the late Eocene and still active today (Odumodu, 2011).



Where F_m is magnetic force of attraction or repulsion, $P_1 \& P_2$ are magnetic strengths of the magnetic poles, R is the distance of separation and ar $\mu_0 \& \mu_r$ are magnetic permeability in free space and relative magnetic permeability respectively. The force is attractive if the poles are of different signs and negative if they are of like signs.

III. Materials And Method

The data used for this study was a high resolution secondary aeromagnetic data acquired by the Fugro Airborne Survey and Nigeria Geological Survey Agency. It contains a total of twelve (12) magnetics sheets as Olobiri (Sheet 327), Degema (Sheet 328), Port-Harcourt (Sheet 329), Opobo (sheet 330), Patani (Sheet 319), Ahoada (Sheet 320), Abo (Sheet 321), Ikot-Ekpene (Sheet 322), Kwale (Sheet 310), Abo (Sheet 311), Okigwe (Sheet 312) and Afikpo (Sheet 313) as in table 3.1 and was presented in XY Geosoft format for analysis and interpretation. The Oasis Montaj software was used for the analysis and interpretation.

Methods of Data Interpretation

The analysis of the high resolution aeromagnetic data was done using the following data filtering techniques; gridding of data to obtain the total magnetic intensity (TMI) base map, contouring, reduction to pole, regional – residual anomalies separation and data enhancing magnetic attribute of standard Euler deconvolution were applied respectively to obtain the desired results.

Gridding of Data

Gridding of aeromagnetic data is the first step for data analysis and interpretation. This is because the imaging, processing and interpretation of potential field data require the data to be converted to an equally spaced two dimension (2D) grid (Ugwu et al., 2020). This will aid to generate a composite or base map of the survey that is a superposition of regional and residual anomalies and to enhance a three dimensional interpretation of the data. Similarly, in a typical aeromagnetic survey, the sampling of aeromagnetic data is several anisotropic because of closely spaced samples along wide spaced flight lines (Cordell, 2006). This sampling can result in a spatial aliasing of short-wavelength magnetic anomalies in between the flight lines (Dill et al., 2010). Therefore, to reduce the spatial aliasing effects, the flight line spacing is recommended to be less than twice the mean height of the sensor (magnetometer) above the magnetic sources (Cooper & Cowar, 2006). The grid spacing is normally selected to be a third to a fifth of the flight line spacing. Therefore, procedure of gridding involves interpolation of the data using a minimum curve gridding algorithm provided in the Geosoft Oasis Montaj software. In principle, it fits a minimum curvature surface or smoothest possible surface to the data points (Nasuti et al., 2019). The gridding of data produces the total magnetic intensity map. Furthermore, to minimize magnetic distortions of aeromagnetic data which is a normal consequence of sampling at grid points only and enhances the application of Fast Fourier Transform base method, the total magnetic intensity base map will be emptied into the Cartesian coordinate system using universal transverse Mercator (UTM) projection parameters of the study area (zone 32 UTM) with WGS84 datum.

In this study, the high resolution aeromagnetic data was gridded using the maximum curvature method to generate total magnetic intensity (TIMI) base map and the contoured (TMI) map respectively.

Reduction to Pole (RTP)

After Transforming the data from space domain to frequency domain using Fast Fourier Transform (FFT), the reduction to pole the north magnetic pole (RTP) map was obtained using inclination and declination values of 44.3^0 and 2.45^0 respectively (Rob, 2005). The reduction to pole transforms an anomaly into the anomaly that would have been observed if the magnetization and regional field were vertical. That is, as though the normally was measured as the magnetic north pole. Furthermore, symmetric anomaly generates asymmetric anomaly at the magnetic poles. Hence, reduction to the pole usually removes the asymmetrics caused by a non-vertical magnetization or regional field, and to produce a simpler set of anomalies to interpret (Cooper & Cowar, 2006). Therefore, the RTP technique is the best method and commonly used to remove magnetic distortion. The resulting map depicts a direction correlation between areas of high magnetic concentration and their causative sources.

Regional – Residual Separation

The Gaussian Regional – Residual separation was carried out on the generated total magnetic intensity (TMI) base map or total magnetic intensity composite map reduced to pole. That is, the residual magnetic data was produced by subtracting the regional field from the total magnetic field using the polynomial fitting of the second order of Least Square according to (Ugwu et al., 2020):

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

Where r is the regional field, a_0, a_1 & a_2 are the regional polynomial coefficients, and X_{ref} & Y_{ref} are the X and Y coordinates of the geographic center of the data set respectively. For the purpose of this study, the regional anomaly map was used for the analysis and interpretation for lineament features and trends in the sub region.

Standard Euler Deconvolution

According to Verdusco et al., (2019), the level of anomalous point and depths to the basement are determined and estimated via Euler deconvolution method. The standard Euler deconvolution is a well established depth estimation technique that uses gradients to determine potential field edges and calculate their corresponding depths. It is a three dimensional (3D) semi-automatic interpretation technique employed in depth estimation and delineation of different geologic structures. It generates a two-dimensional (2D) grid map that shows the locations and related depths of the geologic units recorded. The Euler homogeneity solution is the foundation of this method. The coefficient of homogeneity, which can be seen as the fundamental index, is what essentially connects the potential field and its gradient constituents to the source region in the model (Telford, 2001). For a specific geometry source, the framework index is a hyperbolic factor that represents the rate during which the fields diminish with distance.

Applying the Euler homogeneity formula, which can be stated as follows, and the 3D Euler menu of the Geosoft Oasis Montaj software, this method was utilized to the total magnetic flux map in this investigation for estimating the depths to exceptional bodies.

$$x\frac{\partial T}{\partial x} + y\frac{\partial T}{\partial y} + z\frac{\partial T}{\partial z} + \eta T = x_0\frac{\partial T}{\partial x} + y_0\frac{\partial T}{\partial y} + z_0\frac{\partial T}{\partial z} + \eta b \qquad 2$$

Where x, y, z represents coordinates of estimated points, were the initial location's geographic coordinates, and the complete field is identified at x_0, y_0, z_0, where b is the fundamental level. η is the structural index and T is the potential field. Generally, the record of the structural index relies on the nature of initial body under study. For this study, structural index of one (1), $\eta = 1$ was used. It represents the height of a upward dyke or edge of a sill.

IV. **Results Presentation**

Total Magnetic Intensity (TMI) Map

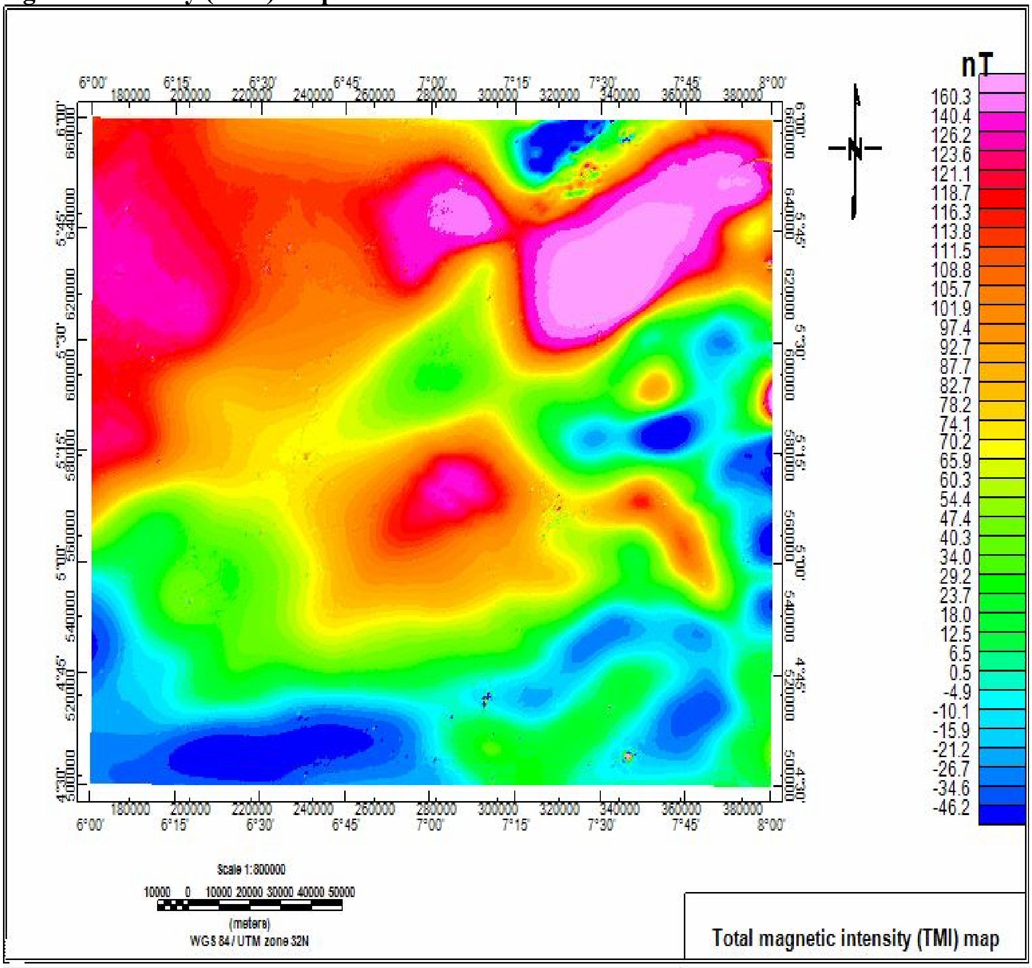


Figure 2: Result of Total Magnetic Intensity Map

Contoured TMI Map

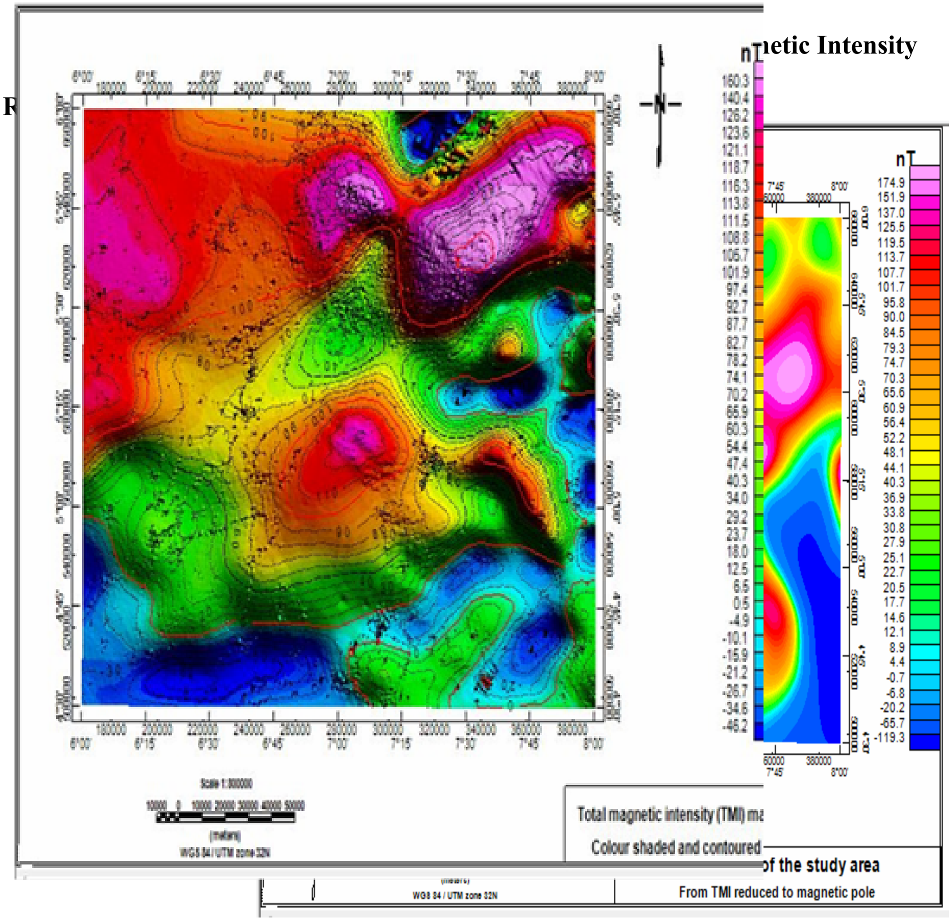
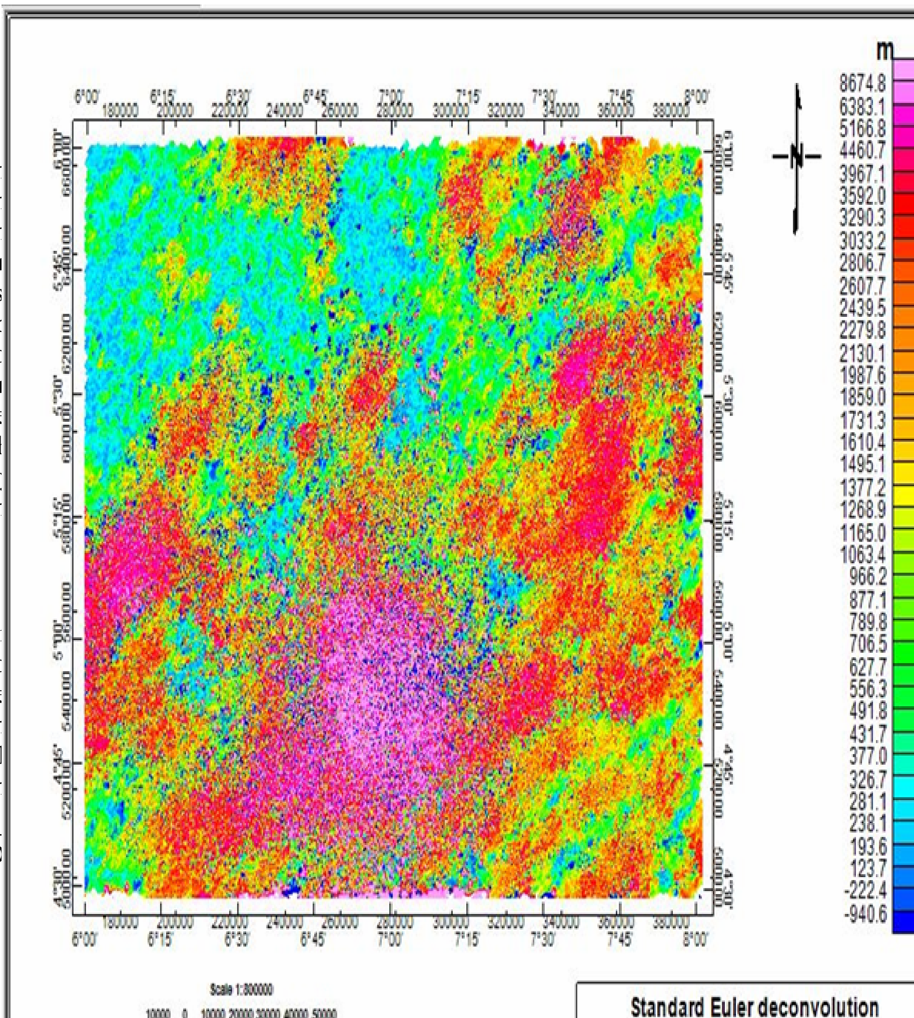


Figure 4: Result of RTP map

Standard Euler Deconvolution Map



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elevations in the northern

region are suggestive of the presence basement intrusions. The regional TRP map also revealed a signature of spherical, cylindrical but elongated and tampered shaped magnetic anomalies. The spherical, elongated and tampered shaped bodies in the north-central, south, south-east and south regions of the study area is characteristics of sediment pockets while the cylindrically elongated and tampered bodies in the north, north-east, south-east and south-west regions depicts of basement intrusions. The variations of depths were x-rayed using SED magnetic attribute. They are characterized as shallow depths, intermediate depths and deep depths corresponding to (98.6m to 681.1m), (734.6m to 1547.0m), (1604.4m to 6601.5m) respectively. The areas described as shallow depth areas are suggestive of river alluvium, deltaic and clay sediments while areas described as intermediate and high depth areas are suggestive of localized magnetization with baked ferruginous sediments.

Therefore, from these results it is recommended that further investigation applying both geological and other geophysical techniques be carried out to identify the types of magnetic minerals and possible hydrocarbon potential in the study area for exploration and exploitation.

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