FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 7 No. 5, October, 2023, pp 192 - 197
DOI: https://doi.org/10.33003/fjs-2023-0705-1968

EVALUATION OF UPWARD CONTINUATION AND REDUCTION TO MAGNETIC EQUATOR ON AIRBORNE MAGNETIC DATA

[1]Oladejo, O. P., *[2]Ogunkoya, C. O.

[1]Department of Physical Sciences Education, Emmanuel Alayande University of Education, P.M.B. 1010, Oyo, Oyo State, Nigeria.
[2]Department of Physics, Ajayi Crowther University, P.M.B 1066, Oyo Town, Oyo State, Nigeria.

*Corresponding authors' email: co.ogunkoya@acu.edu.ng

ABSTRACT
This research work is aimed at interpreting the airborne magnetic data of the study area for mapping the basement geologic structures using magnetic image enhancement filters. It focus on performing filtering techniques to expose and identify the magnetic properties of the basement structures at various continuation distances. The procedure applied to Total Magnetic Intensity (TMI) data of the study area using Oasis Montanj^{TM} software were Reduction to Magnetic Equator (RTME) to remove the inclination effect as well as positioning the peak of the anomalies over their sources so as to improve the orientation of the magnetic sources, separation of regional and residual magnetic anomalies. These was followed by application of upward continuation at 500 m, 1000 m, 2000 m and 3000 m height. The results of the RTME shows the amplitude of the magnetic anomalies ranging from -37.577 nT to 27.398 nT. High magnetic anomaly is dominated in the northwest, southeast through southern part of the study location. Furthermore the results of the Upward Continuation (UC) revealed a wider wavenumber anomalies as well as height above the near surface. Hence the results of this research has displayed an enhanced geological magnetic structures located in the study area and also shows an improved quality of magnetic anomalies as the continuation distances increases.

Keywords: airborne magnetic data, Igboho, upward continuation, magnetic equator

INTRODUCTION
Airborne magnetic survey is a powerful tool in geophysical prospecting, it is distinguished in the areas of its large area coverage, and low cost per unit area and has made its application around the globe increased (Ozebo *et al.*, 2014). It provides accessibility of geophysical data even in the remote areas. This magnetic survey can be employed to delineate the lithology and geological structures of the subsurface for mineral concentration, faults/joints detection, oil exploration among other applications.
Literatures have shown various researches being carried out in the area of aeromagnetic surveying such as; qualitative interpretation of high resolution aeromagnetic data of Abeokuta, Ogun state for geological characterization (Edunjobi *et al.*, 2023). Mohamed *et al.*, (2022) investigated mineral potential zone in Egypt's Eastern Desert area using Analytic Signal (AS), Total Horizontal Gradient (THG), First Vertical Derivative (FVD) and Tilt Derivative (TD) on aeromagnetic data of Egypt's Eastern Desert area. A depth determination of magnetic sources were also carried out using aeromagnetic data of some part of Benue trough (Nuraddeen and Ibrahim, 2020). Ahmed *et al.*, (2021) interpreted the aeromagnetic data of Shilman area of south eastern desert in Egypt for structural analysis and depth determination.
However direct interpretation of aeromagnetic maps with a small coverage areas can sometimes be difficult or showing indistinctive anomalies as a result of small range of anomalies generated from low magnetic susceptibility contrast to low density between the host and fault rock minerals (Okpoli and Akinbulejo 2022). Hence the applicability of enhancement techniques would increase the quality of aeromagnetic map for detailed interpretation of the study area.
There are varieties of anomaly enhancement techniques used in aeromagnetic survey (horizontal derivatives, vertical derivatives among others), that will generate a more meaningful geological results (which were initially difficult to know) for better interpretation. One of the earliest enhancement techniques was Enhanced Horizontal Derivatives introduces by Fedi and Flori (2001), the technique was used to determine the locations of the source boundaries horizontally. But nowadays, there are other enhancement techniques available for facilitating the geophysical data interpretation because most data acquired are now digitized data. The purpose of this research is to perform enhancement techniques on the filtered aeromagnetic data (TMI) to expose the magnetic properties of the basement structures at different continuation distances and to also identify the location of the magnetic structures of the study location.

Geology of the Study area
Nigeria Basement belongs to part of Pan-African mobile belt known as Trans-saharan mobile belt. It is about 1000 km wide and 3000 km long north-south trending belt bounding in the eastern side of the West African craton, it has a boundary with the eastern part of the circum-West Africa belt of gravity heights which marks an eastward dipping suture comprising of dense mafic and ultramafic structures. There are three major rocks units in the basement rocks in Nigeria. The migmatite complex which made up high grade granulite facies and Tonalitic composition of Archean to early Proterozoic age along with interbedded schist and meta-quartzite known as older metasediments of early Proterozoic age. Then we have late Proterozoic (Neoproterozoic) low grade supercrustal pellitic and Psammitic metasediments which occurs in what is known as unconformable syncline schist belts. Lastly we have Syn-Tectonic and Late-tectonic granitoids bodies (the old Granites) which intrudes into the migmatite complex and the schist belts. Oyo state which host Orelope local government area is within the basement complex of southwestern Nigera and Orelope Local Government area that host the study area is geologically dominated by basement rocks beneath the oldest stratified rocks types in southwestern Nigeria Basement (figure 1). The study area lies within Eastings 3^{o}30'N and 4^{o}00'N and between northings 8^{o}30'N and 3^{o}00'N

with average elevation of 425 m above the mean sea level. It is about 162 km northwest of the state capital. The quartzite schist complex, older granites, undifferentiated meta-sediments and undifferentiated basement complex outcrop in different part of Oyo state underlain the Basement rocks of the study area

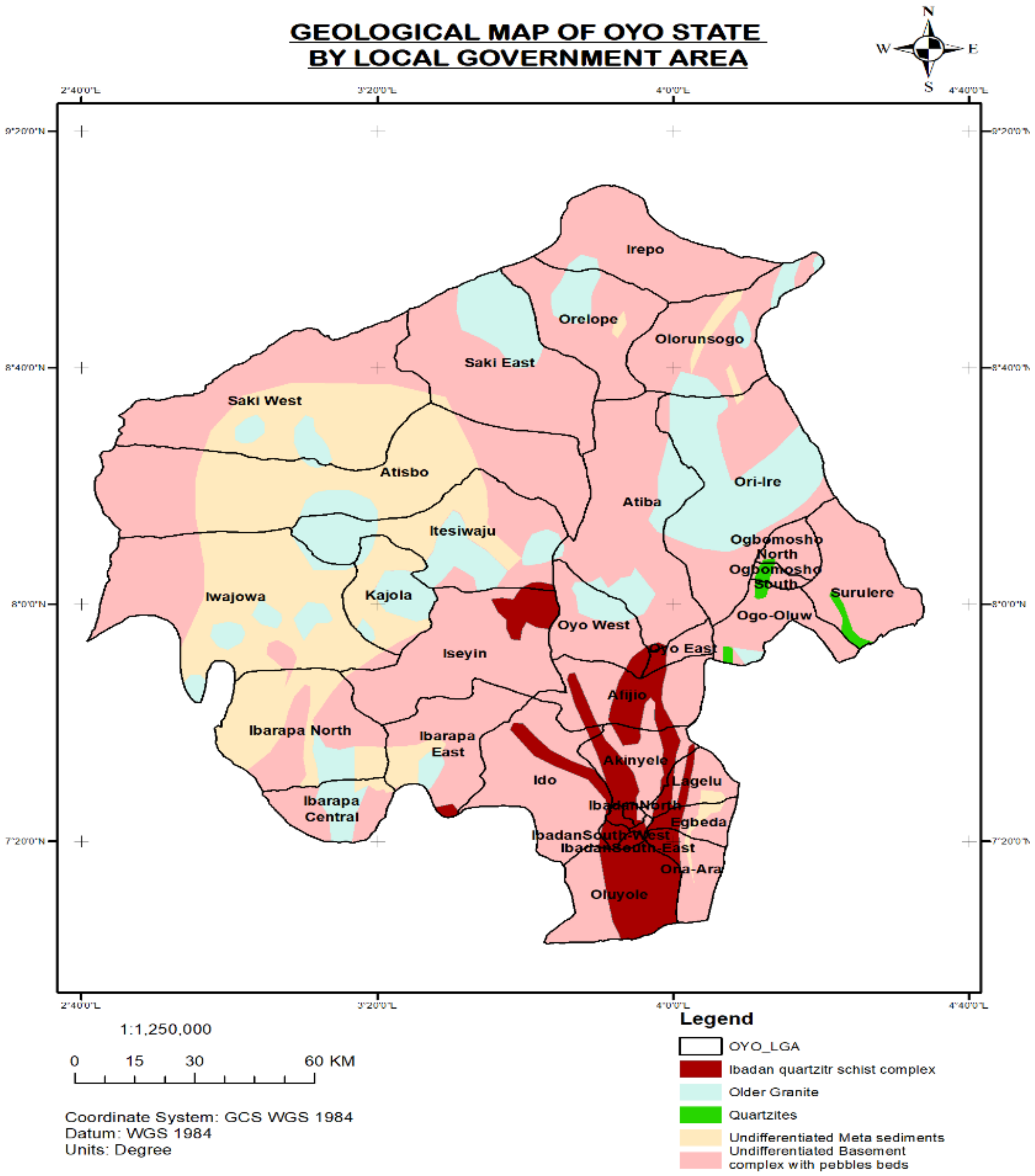


Figure 1: Geology of the study area

MATERIALS AND METHODS

The methodology adopted for this research described the acquisition of airborne dataset and discussed the processing techniques in transforming the original data into data with direct relation to the subsurface geology for easy interpretation. The airborne dataset used for this research was acquired from Nigeria Geological Survey Agency (NGSA) as part of the dataset obtained by Fugro Airborne surveys. Oasis montaj^{TM} software was used to process the data and then generate the Total Magnetic Intensity (TMI) map of the study location (Figure 2) in a grid cell at an interval of 5000 m. The International Geomagnetic Reference Field (IGRF) was calculated and removed from TMI to obtain figure 3 which is the Total Magnetic Anomaly (TMA) connoting the real magnetic distribution of the anomalies in the study area.

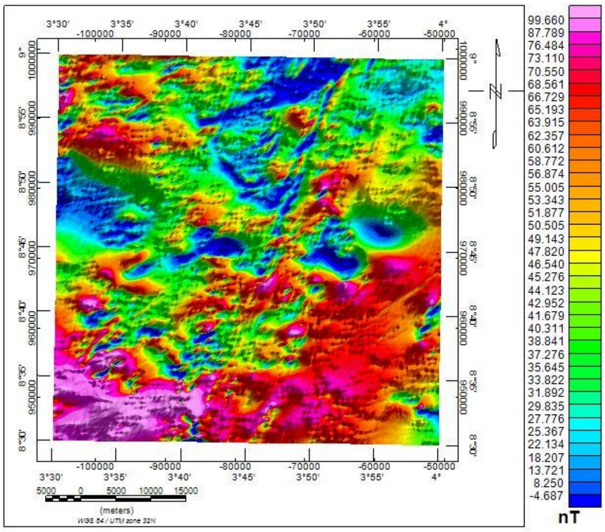


Figure 2: Total Magnetic Field Intensity (TMI) Map of Igboho

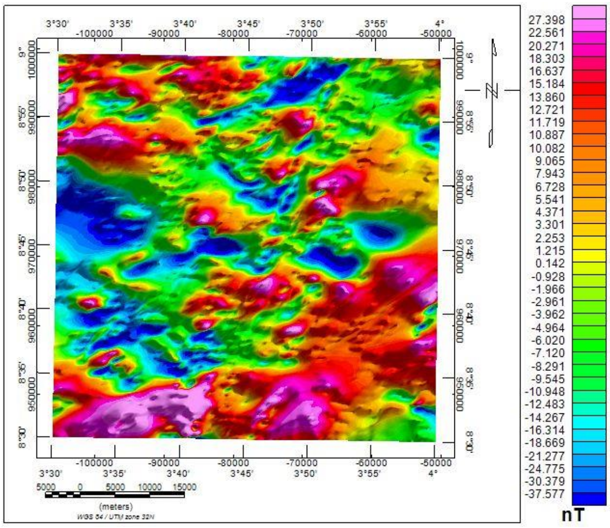


Figure 3: Total Magnetic Field Anomaly Map of Igboho

Reduction to Magnetic Equator.

The shape of any magnetic signals is dependent upon the shape and size of the causative body, depth and magnetic inclination (Ogunkoya *et al.,* 2023). The magnetic field of the earth is parallel (horizontal) to the surface at magnetic equator which indicate the magnetic compass needle is located horizontally at the inclination angle 0^o. However the anomaly become difficult as its peak begins lying on their corresponding sources at the middle of the south or north poles. Therefore to simplify anomalies and ensure that anomalies lie directly above the causative body, Reduction to Magnetic Equator (RTME) is usually required. RTME placed the observed magnetic anomalies upon the magnetic bodies (Ogunkoya *et al.,* 2023; Rajagopalan 2003; Ndousa Mbarga *et al.,* 2012).

Upward Continuation (UC)

Upward continuation (UC) is an enhancement technique that attenuates the magnetic anomalies of shallow structures with respect to long wavelength anomalies and enhances the anomalies of large features (Olomo *et al.,* 2022; Ganiyu *et al.,* 2013). It has application in reducing the effect of small scale features closer to the surface and reduction of topographic effects. The total upward continuation filter is given as:

$$\Delta F(x, y, z) = \sum_{n=0}^{n} \sum_{m=0}^{m} F(x, y, 0)\, e^{-2\pi z h}$$

Where $h = \sqrt{\left(\frac{m}{L_x}\right)^2 + \left(\frac{n}{L_y}\right)^2}$

$\Delta F(x, y, z)$ is the measured field at $z = 0$ (horizontal axis), z is the height to which the field is continued, $m\ and\ n$ are wavenumber in the direction of x and y axis, $L_x\ and\ L_y$ are fundamental wavelength in the direction of x and y axis.

The upward continued field is determined by taken the product of the upward continued filter in the frequency domain and the Fast Fourier Transform magnetic data. The multiplication result is the inverse Fast Fourier Transform to the space domain in obtaining upward continuation data (Suleiman *et al.,* 2018). However, the residual airborne magnetic data of the study area were upward continued to a height of 500 m, 1000 m, 2000 m and 3000 m (figure 5a-d) so that the short wavelength signals were minimized for enhancement of deeper anomalies effect (i.e. the transformation highlights the longer spatial wavelength anomalies at the expense of the shorter wavelength anomalies).

RESULTS AND DISCUSSIONS

The result of the Reduction to Magnetic Equator (RTME) on the gridded data (figure 4) displayed significant difference from figure 3, the Total Magnetic Anomaly (TMA) map with low magnetic angle of inclination. Figure 4 displays high and low centers better than TMA map, transforming the magnetic sources to be horizontal and remove the effect of magnetic inclination in the low latitude region through positioning the peaks of the magnetic anomalies over their sources to improve orientation of magnetic source. The map (figure 4) also denote the representation of output of the TMA map of the study location with two different categories of intensities (high and low magnetic values) identified. The amplitude of magnetic values is from -37.577 nT to 27.398 nT. The high amplitude range of magnetic anomalous values is dominated in northeastern, southern and southeastern regions while the low amplitude magnetic intensity values (-37.577 nT – 6.728 nT) is observed dominant in the study location with the exception to high magnetic value regions. This variance in the lithology distribution may be attributed to different magnetic content in the study location.

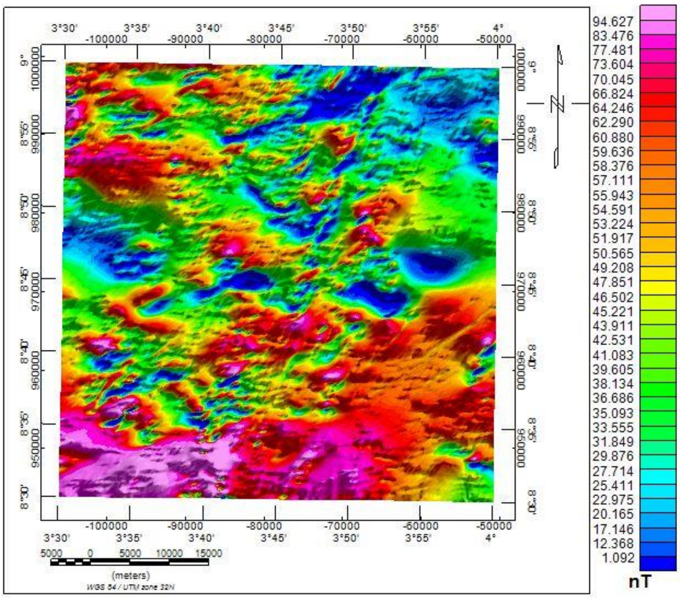
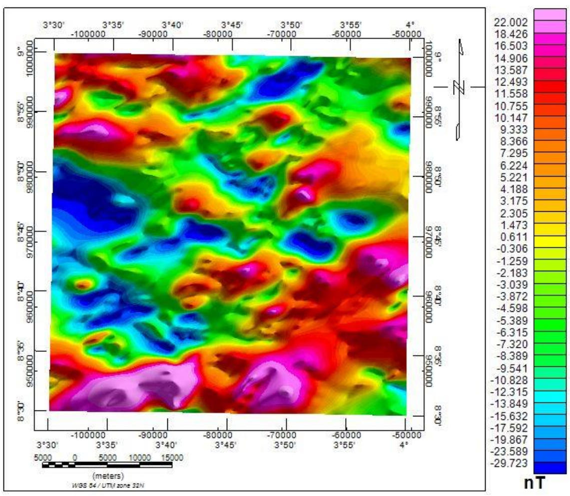
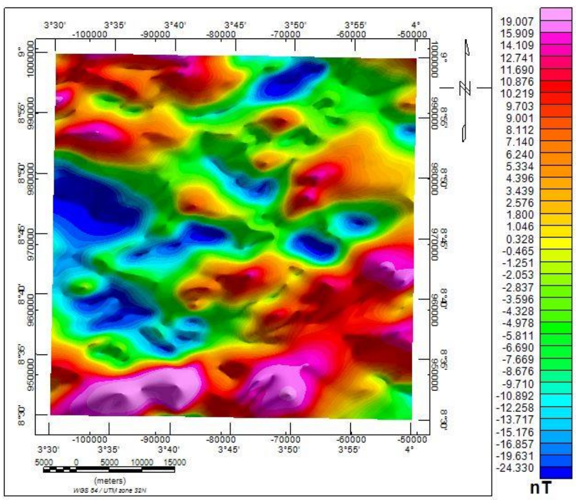


Figure 4: Reduced to Equator Total Magnetic Field Intensity (RTE-TMI) Map of Igboho.

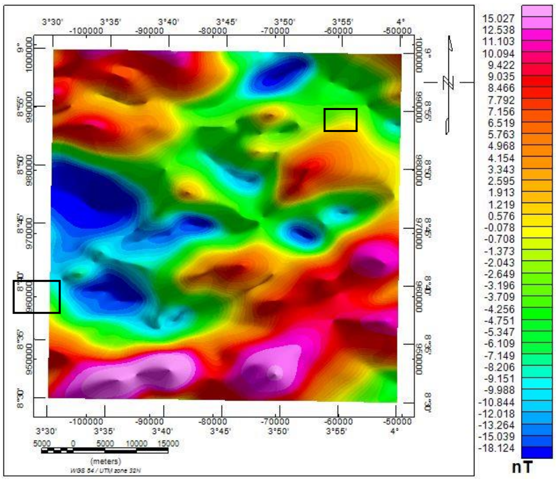
Continuation filtering is the second enhancement operation performed. The filtering operation was applied on RTME-TMI map of the study area at continuation distance of 500 m, 1000 m, 2000 m, and 3000 m to expose the properties of the basement magnetic structures at these various levels as shown in figure 5a-d. By visual inspection of these maps, the effect of smaller magnetic structures with respect to the effect of larger, thicker magnetic bodies (of considerable depth) disappeared as the upward continuation distance increases. These UC map revealed a wider and increase attenuation of high wave number anomalies, as well as a rise in the amplitude above the near surface. The larger the continuation distance, the lower the effect of thinner magnetic structures thereby reducing the effect on larger magnetic bodies in the study area. The result of UC therefore provides the main tectonic and crustal blocks in the study location.



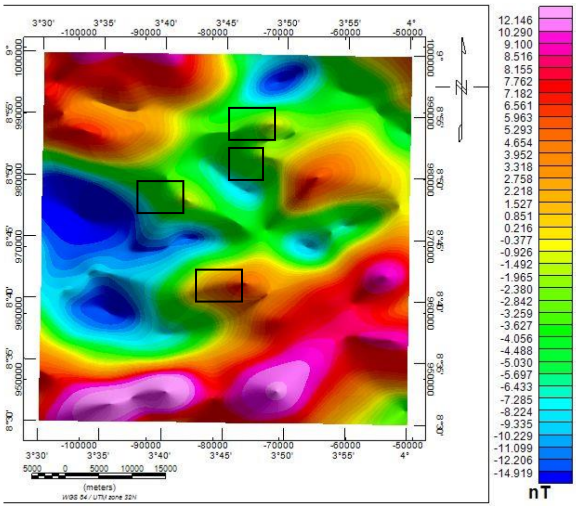
(a) 500 m Depth



(b) 1000m Depth



(c) 2000 Depth



(d) 3000 m Depth

Figure 5: Upward continuation process of RTE-RMI map of Igboho at depth: (a) 500 m; (b) 1000 m; (c) 2000 m; (d) 3000 m; obtained from upward continuation

CONCLUSION

In this research the geologic structures of the study location were mapped out using magnetic enhancement filters (reduction to magnetic equator (RTME) and upward continuation) applied to TMI data of the location using Oasis Montaj^{TM}. The RTME results visually revealed the magnetic source bodies (in spherical form) and their locations better than TMI (unfiltered magnetic data). The upward continuation at 3000 m clearly defines lithological edges and geological magnetic structures in the location. Hence the enhancement filters improves anomalies related with deeper magnetic bodies and deteriorate the dominated shallow magnetic sources. The RTME and UC can therefore regarded as an effective data enhancement techniques for improve magnetic anomalies structure interpretation

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