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Integrated Approches to Depth to Basement Enhancement of Ijebu Ode, a Location in Sothwestern Nigeria Using Aeromagnetic Data

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Abstract

The depth to basement enhancement using a singular method is not sufficient enough to ascertain and determine the true depth to anomalies of aeromagnetic survey work carried out. This work adopted different approaches to locate the depth to magnetic basement of Ijebu Ode. The high resolution aeromagnetic data acquired was subjected to downward continuation filtering, Euler deconvolution at different spectral indices and the radial power spectrum analysis to determine the depth to underground vault. The various values gotten for the depth using these different methods were compared and this shows that there were similarities in the results of the depth estimation using all these approaches. For the downward continuation filtering, the depth to basement was estimated at 500 m, and using spectral analysis technique, it was found out to be in the range of 5m and 410 m and using the Euler deconvolution at various spectral indices the values ranges between 6m and 502 m. The depth to basement was confirmed to be at shallow depth using these different approaches.

Keywords: Aeromagnetic data, Anomalies, Depth, Enhancement, Filtering.

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1. Introduction

Depth to basement determination is one of the objectives of using aeromagnetic survey method in the discovery of spot of magnetic minerals and geological features of a study area. Okpoli and Eyitoyo (2016), in the mapping of inland extension of Chain Fault zones of Okitipupa, south western part of Nigeria, using aeromagnetic survey data used the Euler Deconvolution and the radial power spectrum to determine depth to basement. Olurin et al., (2016) interpreted aeromagnetic data over Abeokuta and its environs, Southwest Nigeria, using spectral analysis. Bello (2017) interpreted the aeromagnetic anomalies over Abeokuta, Southwest Nigeria, using spectral depth technique. Onwuemesi (1997) used one-dimensional spectral analysis of aeromagnetic anomalies and curie depth isotherm in the Anambra Basin of Nigeria. Attention should be drawn to the fact that spectral depths are in general average depths and individual depth projected may have values which is at variance from one another. Therefore, the need for emphasis on integration of different methods to delineate the possible depth to basement in order to reduce the chances of errors especially the use of downward continuation filtering technique as a tool for depth determination in order to give more precise value to depth estimation.
The work is aimed at depicting depth to basement using aeromagnetic data and the sole objective is to use integrated approaches to delineate depth to basement of the study area introducing downward continuation filtering technique.

1.1 Geological Setting of the Study Area

Ijebu Ode is located in Ogun state, south western Nigeria within latitude 6^0 40N and 7^0 00’N and longitude 3^0 00E and 3^0 30’E. It is positioned on a geological switch zone from the Precambrian migmatite gneiss rocks and Cretaceous sedimentary rock units of Abeokuta group. It is a basement crystalline rocks region which includes gneiss complex, migmatite biotite gneiss, biotite granite gneiss and quartz schist (Oyawoye 1964, McMurry and Wright 1977, Rahaman 1988)

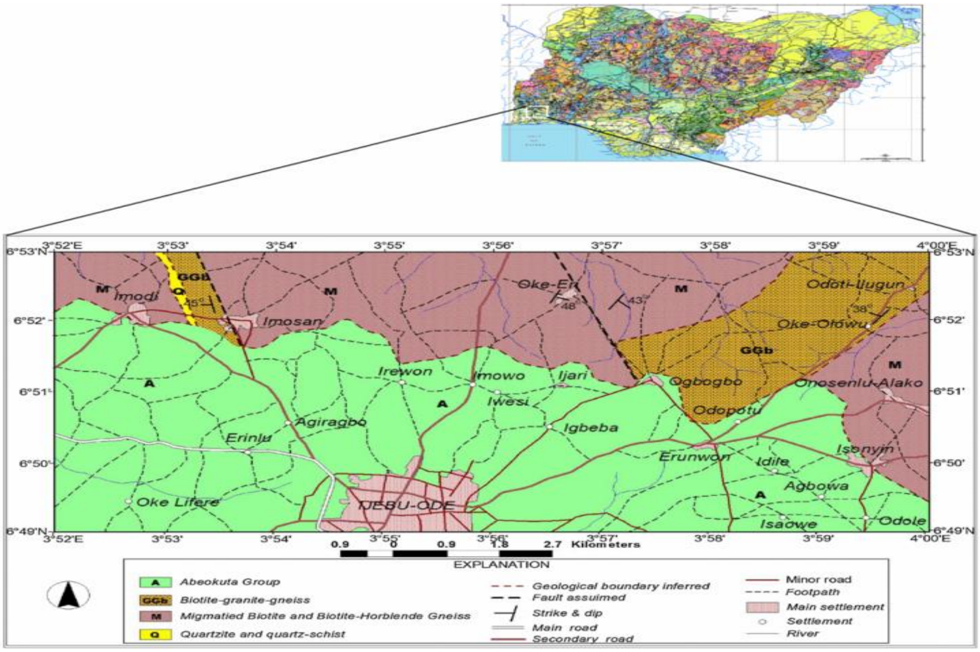

Figure 1: Geological Map of Ijebu Ode (Osinowo, O.O and. Olayinka, A.I, 2012)

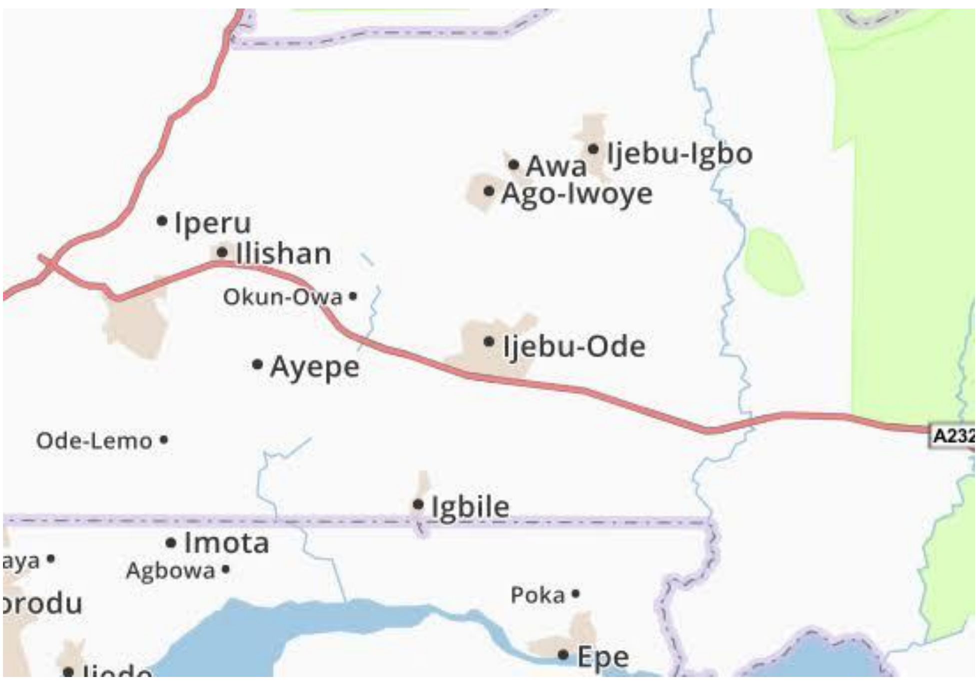

Figure 2: Road and Accessibility map of Ijebu Ode

2. Material and Method

Aeromagnetic sheets of the survey area labelled sheet 280 were acquired during the high resolution airborne geophysical surveys of Nigeria between 2003 and 2009 by Fugro Airborne Survey Limited for the Nigeria Geological Survey Agency (NGSA, 2009). This sheet is the sheet for, Ijebu Ode. To interpret the local field, the data were corrected for International Geomagnetic Reference Field, gridded at an appropriate cell size that enhances anomaly details and reduces possible noise and latitude effects (Patterson and Reeves, 1985). This sheet was assembled and analyzed. The data are made available in the form of contoured maps. The residual aeromagnetic intensity map of the study area was subjected to series of data filtering and processing tools involving Gaussian filter, downward continuation, Analytical signal, and Euler Deconvolution at different spectral indices.

Gaussian filter is a smooth filter that is often used for low pass or high pass application to remove blur images and noise.

$$\boldsymbol{L(k) = [1 - e^{-(\frac{k^2}{2k_0{}^2})}]} \tag{1}$$

For downward continuation,

$$\boldsymbol{g(x, y, 0) = \frac{h}{2\pi}\int_{-\infty}^{\infty}\int \frac{\Delta g(\xi, \eta, h)}{((x-\xi)^2 + (y-\eta)^2 + h^2)^{3/2}} d\xi} \tag{2}$$

Downward continuation concept is to adjust altitude of the observations to a set of data as an aid to the interpretation of a survey and also to increase the resolution of anomalies and their sources by continuing the field that are least severely compromised due to the quality of data. The procedure includes smoothening the original data by attenuating the long wavelength or low frequency anomalies relative to their short wavelength of high frequency (Feumoe et al. 2012; Langenheim and Jachens, 2014), in order to categorize if the anomalies are coming from deeper source of shallow depth.

Extended Euler deconvolution was adopted to establish the depth to the magnetic basement from profiles at predictable level of certainty (Reid et al., 1990). This method is more complex, and more rigorous in determining the depth to magnetic sources. Euler's homogeneity relation can be written:

$$\boldsymbol{(x - x_0)\frac{dT}{dx} + (y - y_0)\frac{dT}{dy} + (z - z_0)\frac{dT}{dz}} = \mathrm{N(B\text{-}T)} \tag{3}$$

Where (x_0, y_0, z_0) is the location of a magnetic source, whose total field magnetic anomaly at the point (x, y, z) is T and B is the regional field. N is the Euler's Structural Index (SI) which characterizes the source geometry (Reid, 1990).

2.1 Geological Model Table

Geological model	Number of dimensions	Structural Index (SI)
Sphere	0	3
Pipe	1(Z)	2
Horizontal cylinder	1(X or Y)	2
Dyke	2(Z and X or Y)	1
Sill	2(X and Y)	1
Contact	3(X,Y and Z)	0

Table 1: Structural Indices for various geological models Adapted from Amigun et al. 2012b. Olasehinde et al. 2012. Yaghoobian et al. 2009. GETECH, 2007 and Reid et al. 1990.

3. Results

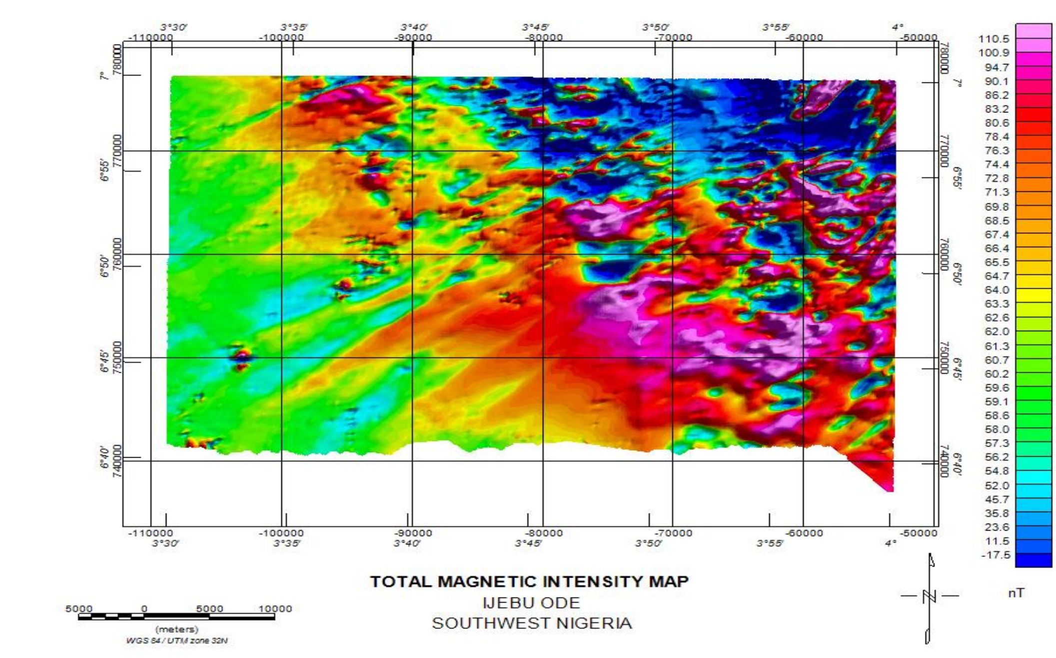

Figure 3: The Total Magnetic Intensity Map of Ijebu Ode

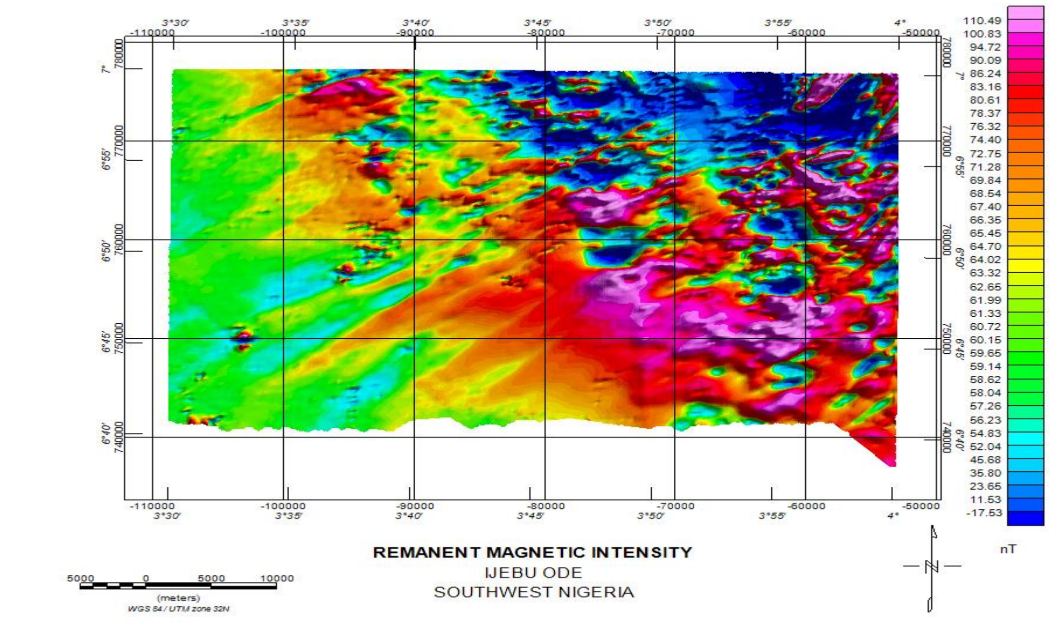

Figure 4: The Remanent Magnetic Intensity Map of Ijebu Ode

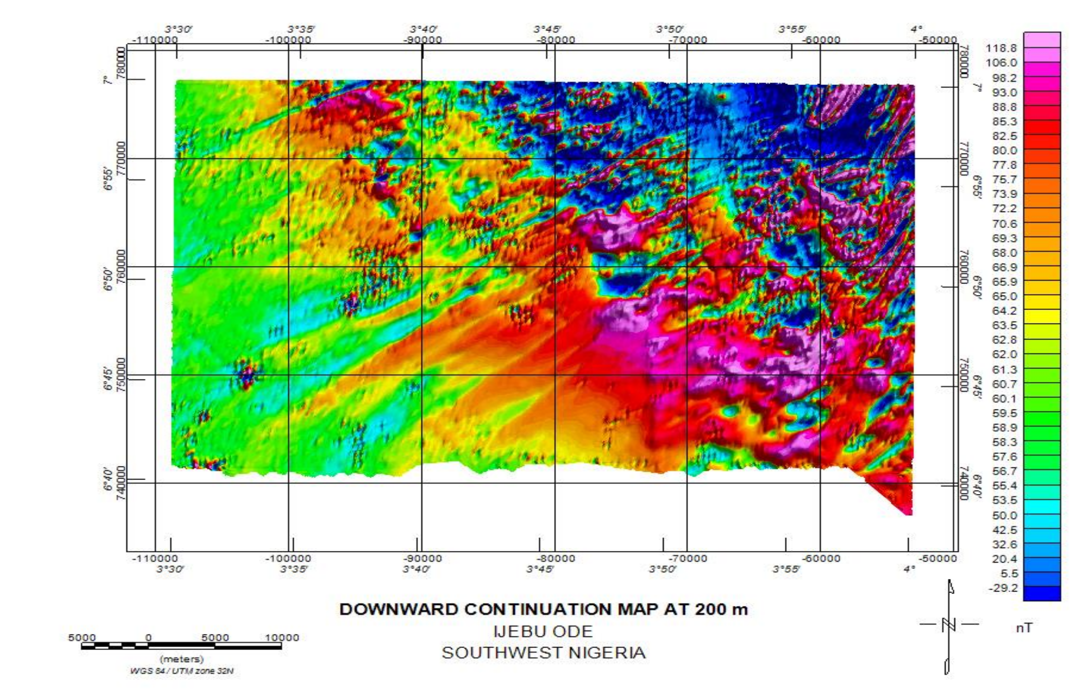

Figure 5: The Downward Continuation Map at 200 m depth

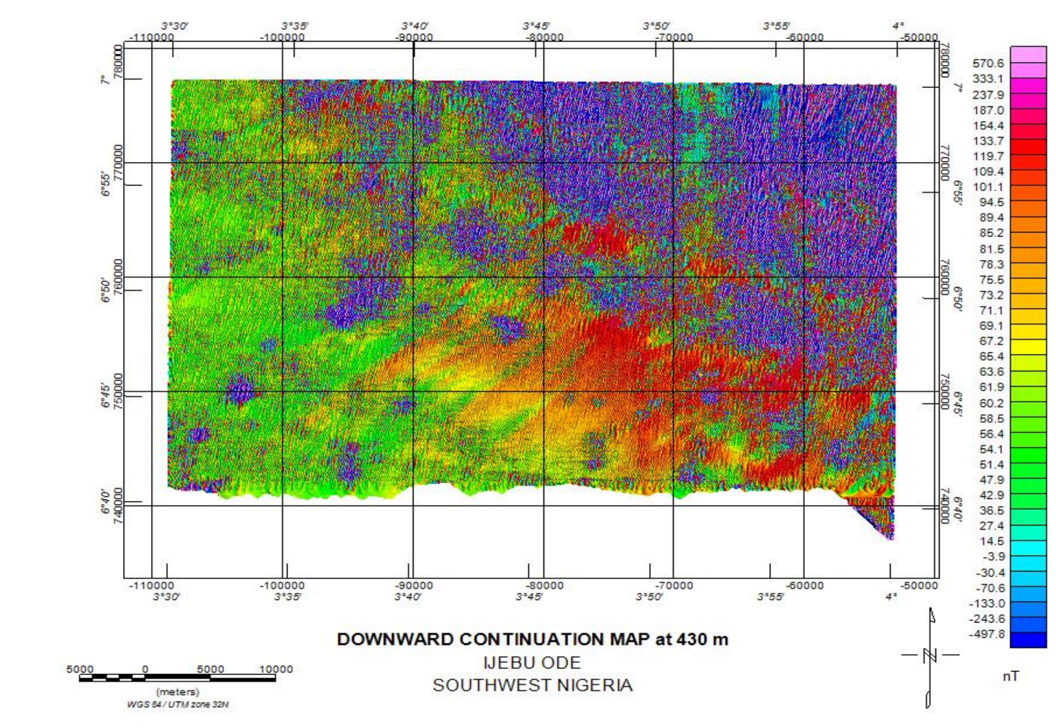

Figure 6: The Downward Continuation Map at 430 m depth

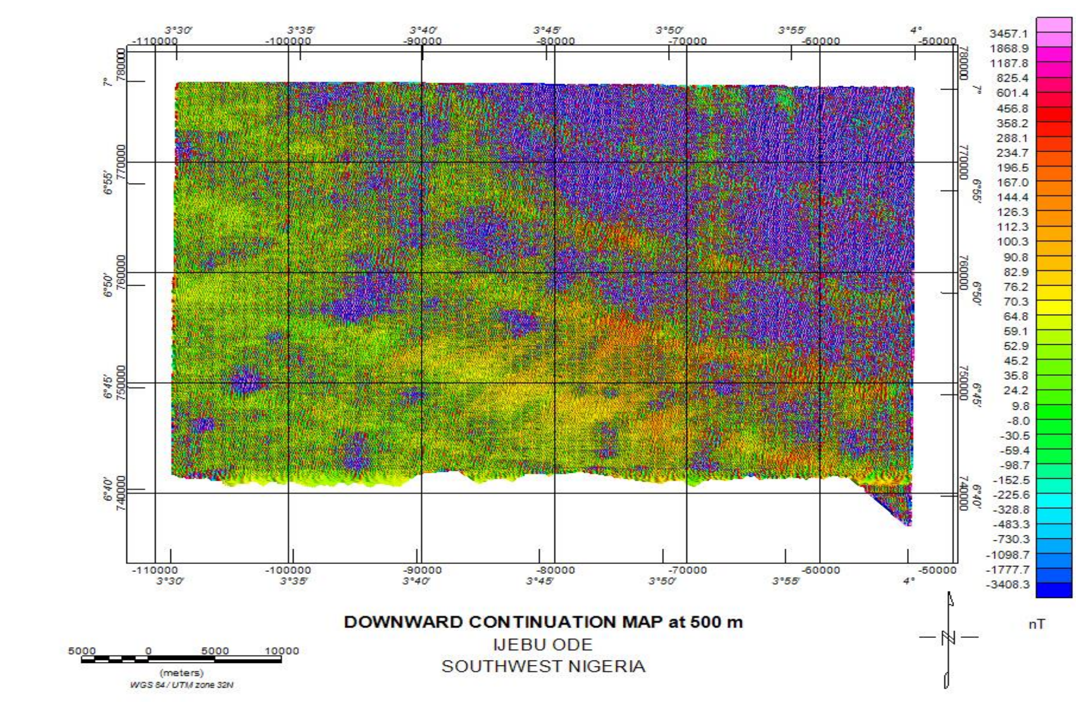

Figure 7: The Downward Continuation Map at 500 m depth

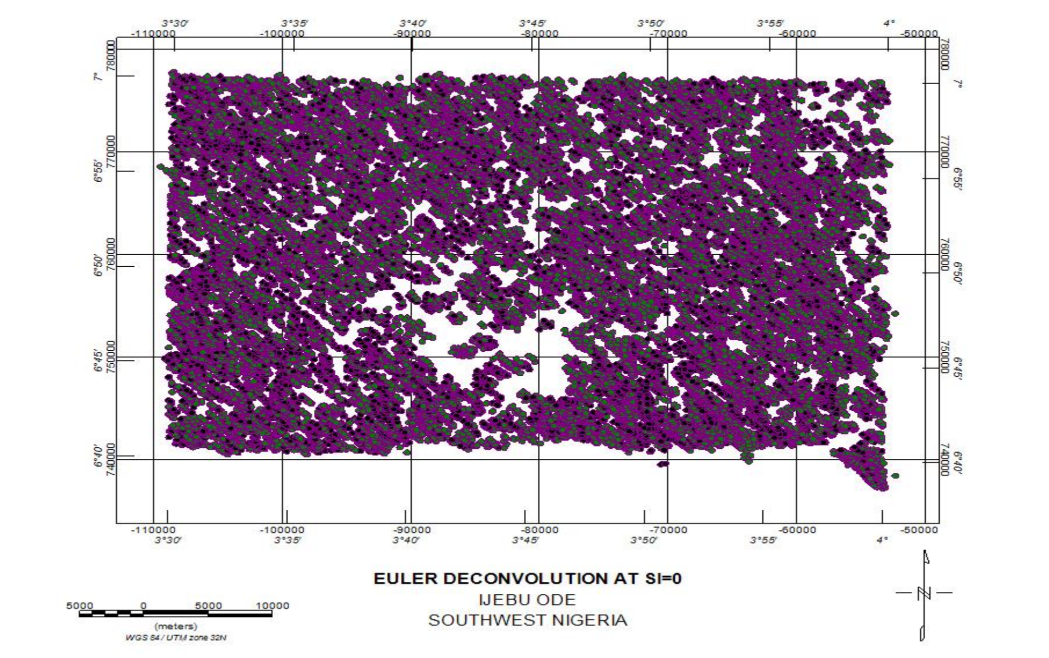

Figure 8: The Euler Deconvolution at Structural Index of 0

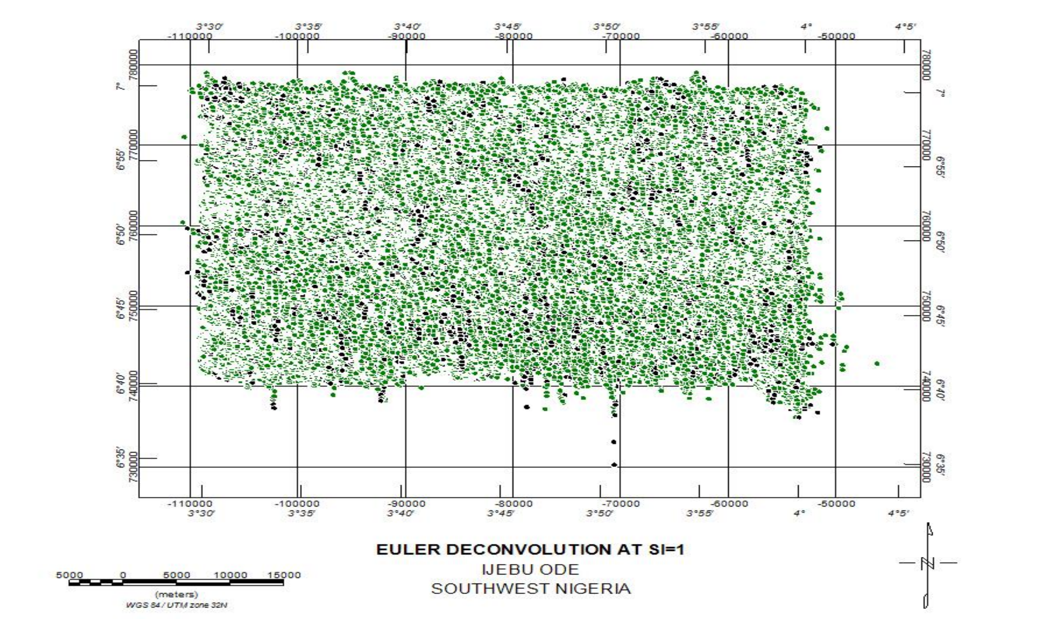

Figure 9: The Euler Deconvolution at Structural Index of 1

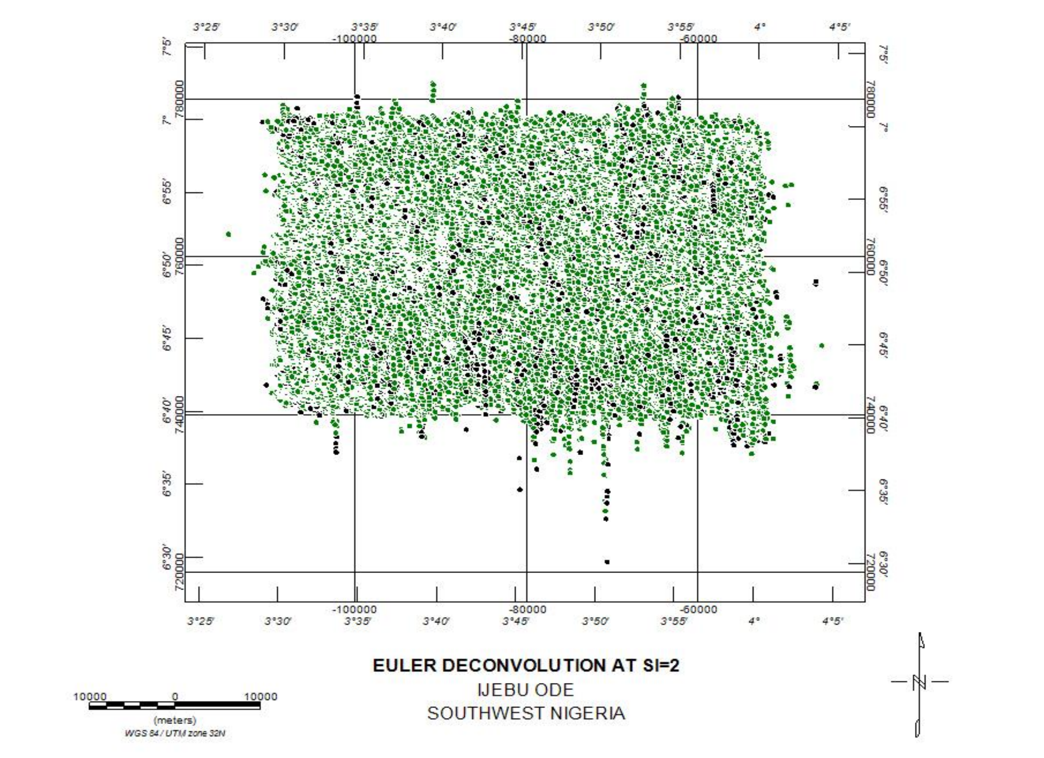

Figure 10: The Euler Deconvolution at Structural Index of 2

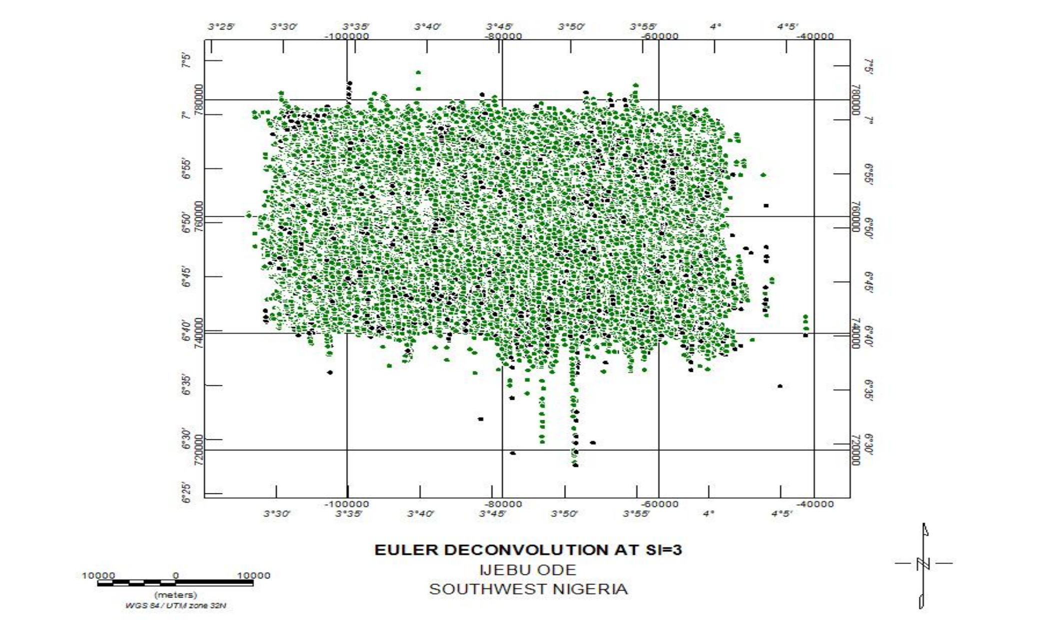

Figure 11: The Euler Deconvolution at Structural Index of 3

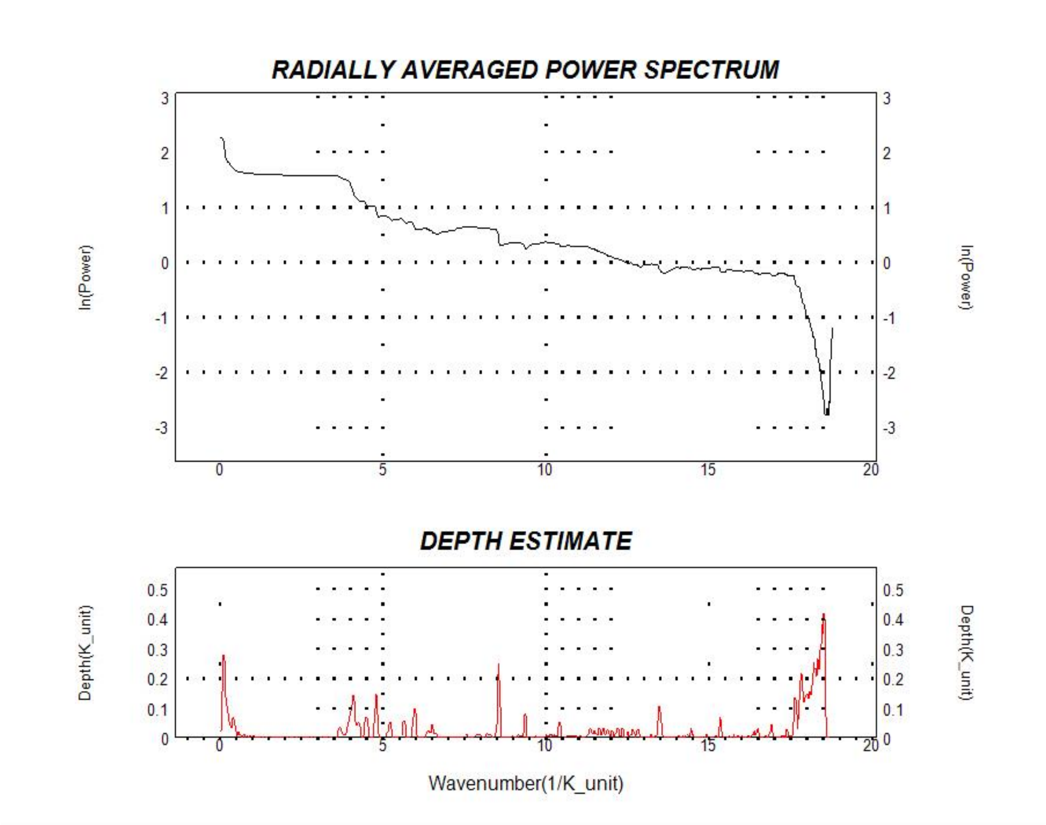

Figure 12: The Power Spectrum Analysis of the depth to basement

4. Discussion of Results

The total magnetic intensity of the study area (Ijebu Ode) is depicted above (Figure 3). The coloured maps (TMI) aided the visibility of a wide range of anomalies in the magnetic map and the ranges of their intensities. The strong positive anomalies areas (pink) indicate a higher concentration of magnetically susceptible minerals. The strong magnetic regions (86.2nT to 110.5nT) contain minerals which brings about the major anomalies and this corroborates (Sunmonu et al., 2014). Similarly, areas with extensive magnetic lows (blue) are likely areas of low magnetic concentration and hence a lower susceptibility and also it coincides with an existing fault (Mattsson and GeoVista 2010). The magnetic anomaly of magnitude between 23.6 nT and -17.5 nT appears as the lowest point with relatively low magnetic intensity (blue colour). It is predominant in the Northeastern and little traces in the Northwestern and Southeastern part of the study area.

For the Remanent Magnetic Intensity, the low-pass Gaussian filtering technique was adopted for this case to smoothen the input data by the application of convolution filter (depth-dependent linear filtering) data so that all data is treated by the filter equally and to remove regional anomalies from the magnetic data. The filter is called low-pass because it allows low wave numbers (low frequencies) to pass to the output channel. Features in the data that are shorter than the short wavelength cut off were removed.

The magnetic zone with high intensity of 0.13 nT to 0.07 nT which are basically the pink region from north towards the east and south while the low intensity of 0.002 nT at the centre and towards the southwest.

When the Total Magnetic Intensity map was downward continued at a depth of 200 m, there was presence of magnetic anomalies and further to a depth of 430 m (figure 5 and 6) until it reaches a depth of 500 m (figure 7) where the the anomalies disappear. This suggests that the depth to basement is estimated at around 500 m and probably a little above.

The solutions obtained from the estimated values of Euler deconvolution using various structural index values ranging from 1 to 3 were depicted (Table 1). The values for structural index (SI) of 0, gives a range of 7 m to 573 m, structural index(SI) for 1 gives range of 10 m to 545 m, structural index (SI) for 2 gives a value between 6 m and 530 m and structural index (SI) for 3 gives 10 m to 560 m. The SI numbers from 0, 1, 2 and 3 was adopted and this matches in relation to the geological results and hence accepted as solution because it is a good match as there are clusters around some notable anomalies in Ijebu Ode.

From figure 13, the depicted radially power spectrum of the study area shows a depth of a little above 400 m. The depth obtained from Euler deconvolution when compared with the power spectrum graph (Salem and Ali, 2014) shows little variation in the value of the depth to basement.

5. Conclusion

This work examines the comparison of various approaches to investigating the depth to basement using the Euler Deconvolution method (ED), Power Spectrum Analysis (SPA) and downward continuation filtering technique which corroborate the results obtained from the ED and SPA using aeromagnetic sheet labelled 280 of Ijebu Ode. The data obtained was processed using Oasis Montaj 6.4.3.(HJ). The results obtained showed that there were similarities in the values obtained by each method and hence more information on the depth to basement is depicted. These depths specify obviously the extent of variations in depth of both the basement topography and other intrusive in this area and these values of depth to basement spread over the study area. The accepted Euler Deconvolution structural index for 0, 1, 2 and 3 indicate contact, sill, sill/dyke, horizontal cylinder, horizontal cylinder/pipe and sphere geological model respectively and these are the solutions to the Euler deconvolution technique.

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