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ESTIMATION OF SOURCE PARAMETERS IN IBADAN, SOUTH – WESTERN NIGERIA USING DIGITIZED AEROMAGNETIC DATA

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ABSTRACT

Airborne magnetic data covering geographical latitudes of 7⁰00'N to 7⁰30'N and longitudes of 3 30'E to 4 00'E within Ibadan area were obtained from Nigeria Geology Survey Agency. The data were analyzed to map the sub surface structure and the source parameters were deduced from the quantitative and qualitative interpretation of magnetic data. The upward continuation technique was used to de-emphasize short – wavelength anomaly while the depth to magnetic sources in the area was determined using local wavenumber technique, the analytic signal was also employed to obtain the depths of the magnetic basement. Analysis involving the local wavenumber, upward continuation and apparent magnetic susceptibility techniques significantly improves the interpretation of magnetic data in terms of delineating the geological structure, source parameter and magnetic susceptibility within Ibadan area.. These depth ranges from 0.607km to 2.48km. The apparent susceptibility map at the cut-off wavelength of 50 m ranges from -0.00012 to 0.00079 which agree with the susceptibility value of some rock types; granite gneiss, migmatite biotite gneiss, biotite muscovite granite, hornblende granite, quartz and schists. The result of the local wavenumber suggests variation along the profiles in the surface of magnetic basement across the study area.

Keywords: Aeromagnetic, Local wavenumber, upward continuation, Geological structure, Magnetic susceptibility

INTRODUCTION

Geophysical investigation of the earth involves the study of physical properties of the ground, thereby providing vital information on subsurface material conditions by taking measurements at or near the earth's surface that are influenced by the internal distribution of physical properties (Fadele *et al.,* 2013). The main source of the magnetic field and the cause of the circular variation remained a mystery since rapid fluctuations seemed to be the odds with the rigidity of the Earth, and until this century an external origin of the field was seriously considered. In 1838, Gauss was able to prove that the entire field has to be of internal origin. Gauss used spherical harmonics and showed that the coefficients of the expansion, which he determined by fitting the surface harmonic to the available magnetic data at that time. To acquire the variation in the earth magnetic field, there is need to carry out magnetic survey. Magnetic method is a geophysical technique that exploits the appreciable differences in the magnetic properties of minerals within the main objective of characterizing the earth's subsurface. In order to cover a large expanse of land, airborne magnetic survey is required. Aeromagnetic data allow fast coverage of large and inaccessible areas for subsurface reconnaissance, which makes magnetic data analysis an essential tool in geophysical exploration. Airborne magnetic data is the gathering of magnetic data by small aircraft over a large expanse of land (which may be or not be accessible) and interpreting the data using several interpretation techniques. It is a means of arriving at ore deposit within a geographic area (Reeves, 2007). Aeromagnetic data records variation in the magnitude of the earth's magnetic field in order to detect local changes in the properties of the underlying geology. Airborne magnetic data collected over region under study becomes a potential source of valuable information containing signal related to hidden magnetic lithology and subsurface structure of area under consideration. Astier and Paterson (1987) have shown, in crystalline basement complex in some parts of West Africa a direct correlation between the yield of bore wells and their proximity to faults and dykes determined from aeromagnetic data. In this study, a digitized airborne magnetic data of Ibadan area, southwestern part of Nigeria as obtained by Nigerian Geological Survey Agency in 2009 were employed to estimate source parameters associated with the area under consideration using source parameter imaging (SPI) methods. The aim of this research work was to study enhancement and depth estimation of total magnetic data of the study area using local wave number technique.

Location and geology of the study area

The study area is Ibadan and its environs, an inland town in Oyo state, southwestern Nigeria. It is bounded in the north by Kwara State, in the east by Osun State, in the south by Ogun State and in the west partly by Ogun State and partly by Republic of Benin. Ibadan is bounded by latitude $7^o 00' N$ to $7^o 30' N$ and longitude $3^o 30' E$ to $4^\circ 00' E$ with an area of about 3,025 square kilometers situated in southwestern Nigeria (Fig.1). Ibadan falls within the basement complex of geological setting of southwestern Nigeria characterized by basement complex rocks of Precambrian age consisting of older and younger granites and metasedimentary rocks (Okunlola *et al.,* 2009). Ibadan area is composed of biotite, granite gneiss, migmatite biotite gneiss, biotite muscovite granite, hornblende granite and schists (Obaje, 2009). The schistose rock occurrence around Ibadan area constitutes the southern extension of the north south trending Iseyin Oyan belt. This is shown in Fig.2.

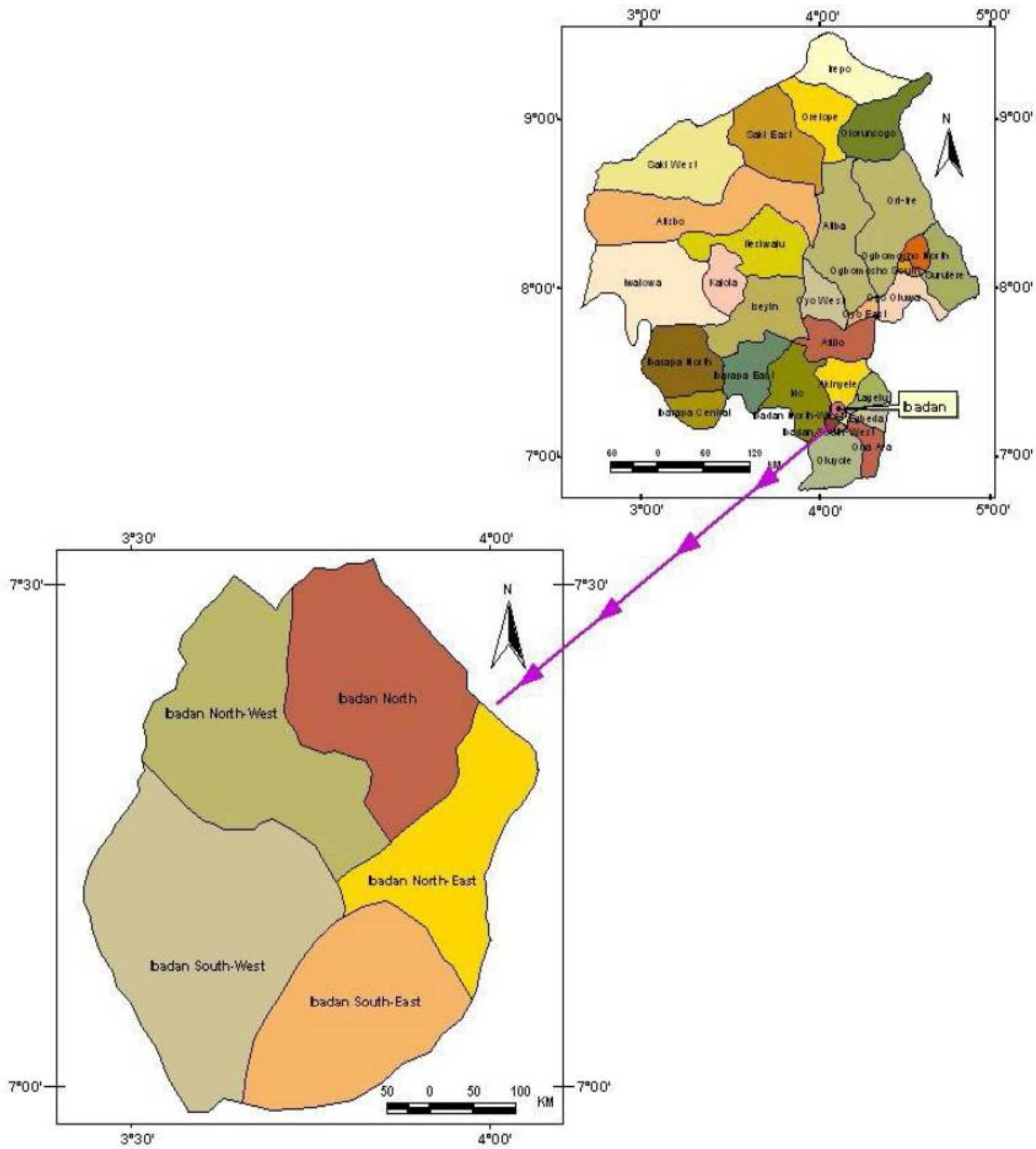

Figure 1: Administrative map of Oyo State showing the study area

Data source and analysis of airborne magnetic data

Ibadan area is covered by an aeromagnetic survey conducted by Geological Survey Agency of Nigeria. The aeromagnetic data (Sheet No. 261) were obtained using a proton precession magnetometer with a resolution of 0.1nT. The airborne geophysical work was carried out by Fugro Airborne Surveys in 2009. Aeromagnetic surveys were flown at 500m line spacing and 80m terrain clearance. The flight line direction was in the direction 135 azimuths while the tie line direction was in 45 azimuths. The average magnetic inclination, declination and field strength across the survey was 9.75^0, 1.30^0 and 32,742.556 *nT* respectively. The geomagnetic gradient was removed from the data using International Geomagnetic Reference Field (IGRF).

METHOD

Upward Continuation

Upward continuation is a transformation whereby the potential field anomaly is calculated at an altitude higher than the measured field. This is the reason why magnitude of magnetic anomalies decreases with the cube of the distance from the source. Jacobsen (1987) likened upward continuation to a low pass filter because high frequency components are attenuated while low frequency components are enhanced. $A(x, y, z)$ is assumed to be a potential field at location x, y, z and to be harmonic outside the source. In the absence of a source in the upper half space, A is given by Gibert and Galdeano (1985) as equation 1

$$\Delta A = |(x, y, z)| = 0 \qquad 1$$

If values of A are known on the surface where $z = 0$, the function can be continued upward (Gibert and Galdeano, 1985). Schwartz, (1950) stated that utilizing Green's integration and convolution theorem $A(x, y, z)$ at $z > 0$. The potential field A can therefore be expressed as equation 2,

$$A_z^{'}(u, v) = A_0^{'}(u, v)e^{-kz} \qquad 2$$

Local Wavenumber Method

The local wavenumber method is a magnetic interpretation technique for estimation of sources parameters such as depth, source location, dip and apparent magnetic susceptibility from magnetic data. This method is based on the extension of complex analytic signal to estimate magnetic basement depth and other source parameters.

From the analytic signal amplitude, the determination of the local phase and local wavenumber for grid based data have been made easier using the methods reported by Thurston and Smith (1997), Smith *et al.,* 1998, Miller and Singh (1994), Bracewell (1965), Fairhead et al. (2004) and Verduzco *et al.,* (2004). Considering 2 – D source in which the dimension in the y direction extends to infinity, then the analytical signal associated with total magnetic field intensity in x and z direction $T(x, z)$ of the anomaly is given in complex function form as,

$$A(x, z) = |A|e^{j\theta}$$

Where $|A|$ = Amplitude of the analytic signal and is given by Equation 3

$$|A| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \qquad 3$$

j is the imaginary number $\sqrt{-1}$ and θ is local phase which is the ratio of the vertical component of magnetic gradient to horizontal component of magnetic gradient.

$$\theta = \tan^{-1}\left[\frac{\partial T/\partial z}{\partial T/\partial x}\right] \quad 4$$

$$T_z = 2sFc\sin d\,\frac{x\cos(2I-d-90) - h\sin(2I-d-90)}{h^2+x^2} \quad 5$$

$$T_x = 2sFc\sin d\,\frac{h\cos(2I-d-90) - x\sin(2I-d-90)}{h^2+x^2} \quad 6$$

Considering sloping contact, the expressions for the vertical and horizontal gradients as defined by Nabighian (1972) are given by Equation 5 and Equation 6

The amplitude of analytic signal and local phase are defined in Equations 3 and 4 respectively. The other source parameters such as local depth to the top of the contact, local dip of the contact and susceptibility contrast are given by Equations 7, 8, and 9 respectively.

$$h = 1/k \quad 7$$

where k = Apparent susceptibility contrast,

$$d = \theta + 2I - 90 \quad 8$$

$$s = \frac{|A|}{2kFc\sin d} \quad 9$$

where, $c = 1 - \cos^2 I \sin^2 \alpha$ and

$$\tan I = \frac{\tan i}{\cos\alpha}$$

α = the angle between the positive x -axis and magnetic north,

i = ambient field inclination.

RESULTS AND DISCUSSION

The total magnetic intensity grid was created using a minimum curvature gridding algorithm with a grid cell size of 50 meter. The grid values fit the profile data to within 1nT for 99.98% of the profile data points. The average gridding error is below 1nT. The output for a gridding of sheet 261of the study area is shown in Fig.3

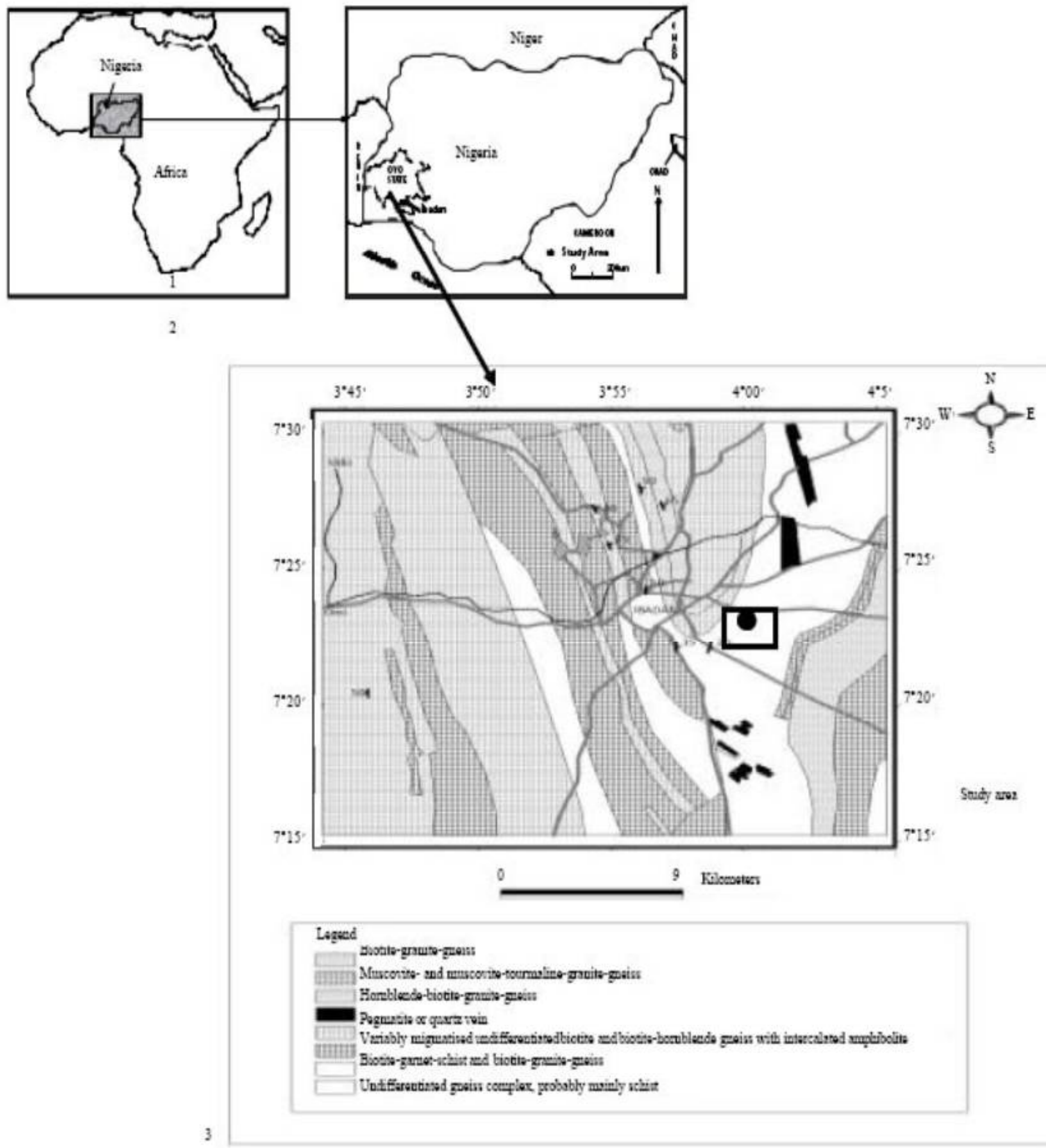

Figure 2: Geological map showing the study area (adapted from Okunlola *et al.,* 2009)

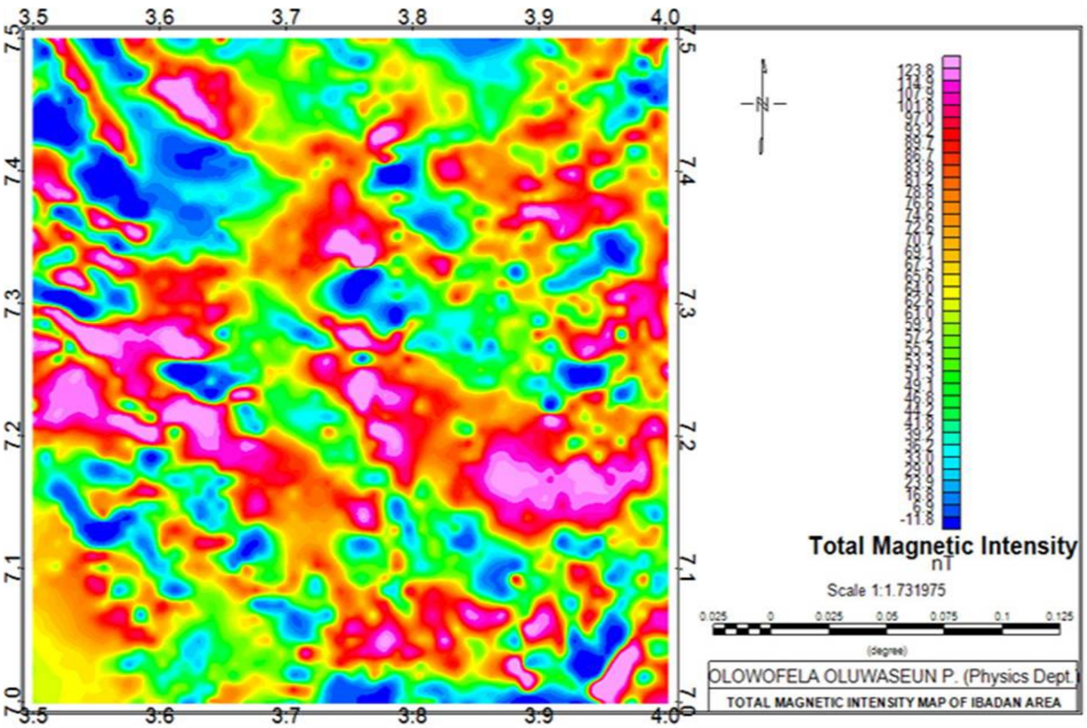

Figure 3: Total Magnetic Intensity Aeromagnetic Map of Ibadan

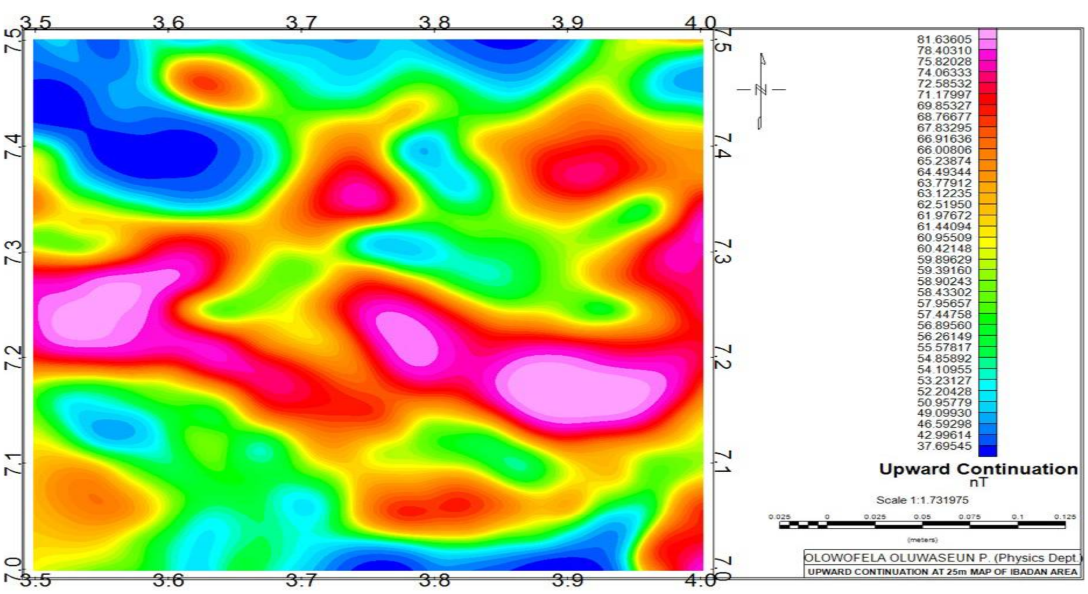

Figure 4: Upward Continued Magnetic Data of Ibadan at cut off wavelength of 25 Meter

In Fig.3, the total magnetic intensity values ranges from -11.76 *nT* to 114.88 *nT* suggesting contrasting rock types in the basement complex of the study area. The survey area is characterized by cluster short wavelength anomalies in the entire area. The short wavelength components may be attributed to shallow magnetic sources. Inspection of Fig.3 reveals that the entire study area is basement complex which agrees with the geological map of study area and an earlier work by Olowofela *et al.,* 2011. Continuation filtering was also performed on the data using MAGMAP FILTER control file in OASIS MONTAG Version 6. 7. The upward continuation process was applied on airborne magnetic Sheet Number 261 at 25m, 50m, 75m and 100m, to expose the basement at these various levels as shown in Fig. 4, 5, 6 and 7 respectively. The upward continuation results reveal increasing attenuation. These upward continued maps illustrate the change in anomaly character with increasing observation to magnetic source distance. It is apparent that the attenuation of the shallow source anomalies in the upward continuation process enhanced view of the deeper anomaly signature.

In Fig.4, the upward continuation value continued at the cut – off wavelength of 25m ranges from 37.69545nT to 81.63605nT reveals the pattern of short wavelength magnetization but with broader attenuation than that of the total magnetic intensity map in Fig.3. The total magnetic intensity of Ibadan which originally range from -11.8nT to 123.8nT drop in intensity from 123.8nT to 81.63605nT in the more basement complex region and increased from -11.8nT to 37.69545nT in the sedimentary magnetization region.

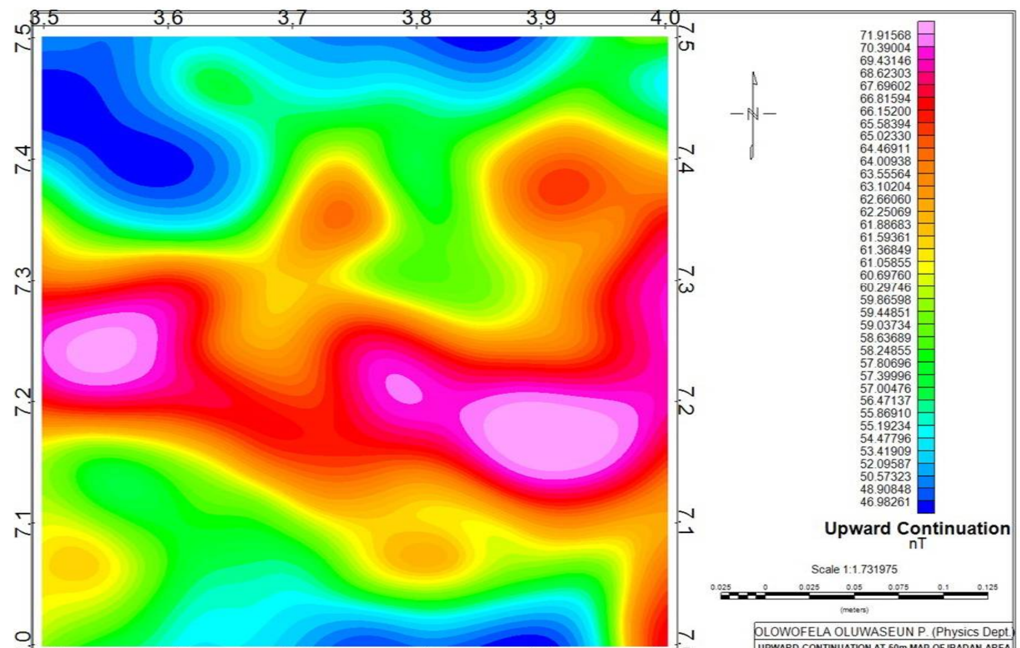

Figure 5: Upward Continued Magnetic Data of Ibadan at cut off wavelength at 50 Meter

In Fig.5, the upward continued values at cut -off wavelength of 50m ranges from 46.98261nT to 71.91568nT. There is presence of short wavelength anomaly with more broader and clearer attenuation of the long wavelength anomaly in the upward continued value at 50m. Thus the short wavelength observed in fig.5 was not closely space and there was also drop in total magnetic intensity from 81.63605nT to 71.91568nT

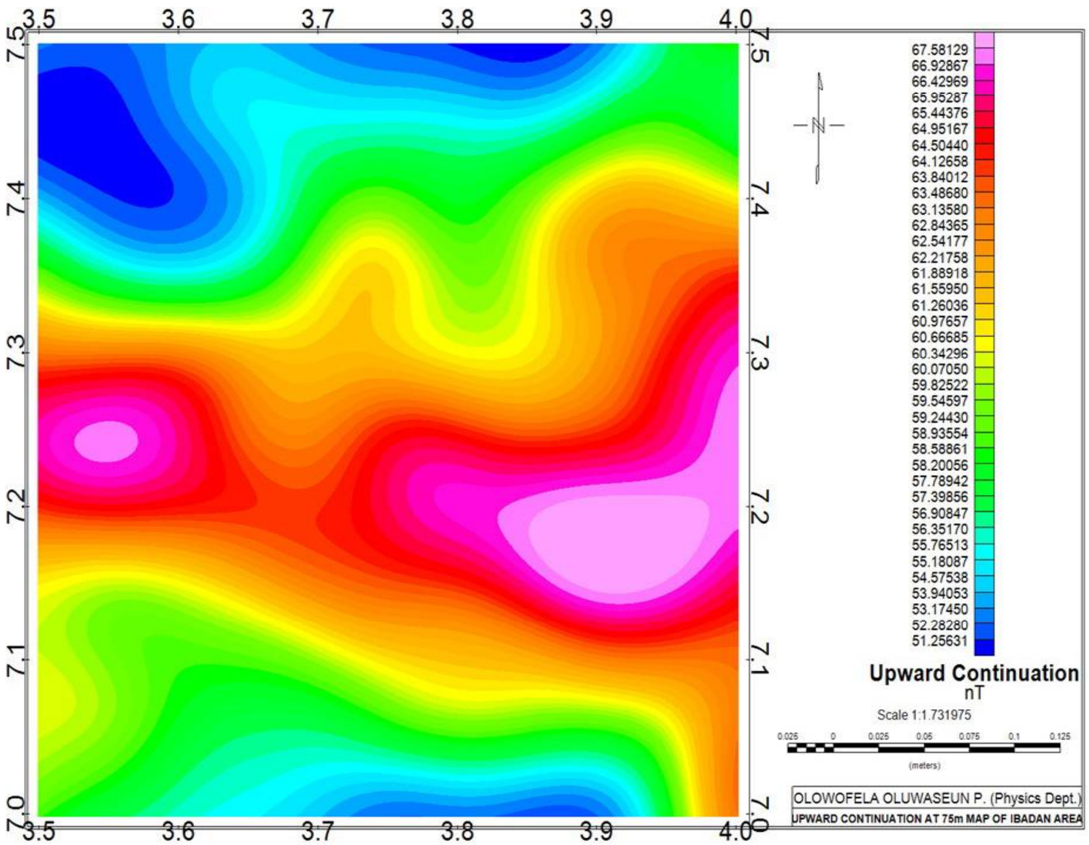

Figure 6: Upward Continued Magnetic Data of Ibadan at cut off wavelength at 75 Meter

In Fig.6, the upward continued value at cut – off wavelength of 75m ranges from 51.25631nT to 65.95287nT. Fig.6 shows that there are few short wavelength anomaly and is almost dominated by the long wavelength anomaly, the upward continued value at 75m have a broad attenuation but the magnetic signature is not perfectly pronounced. At upward continued value at 75m, there is also a drop in intensity in the more basement complex magnetization which drop from 71.91568nT to 65.95287nT and there is increased in intensity in the more sedimentary magnetization complex which rises from 46.98261nT to 51.25631nT.

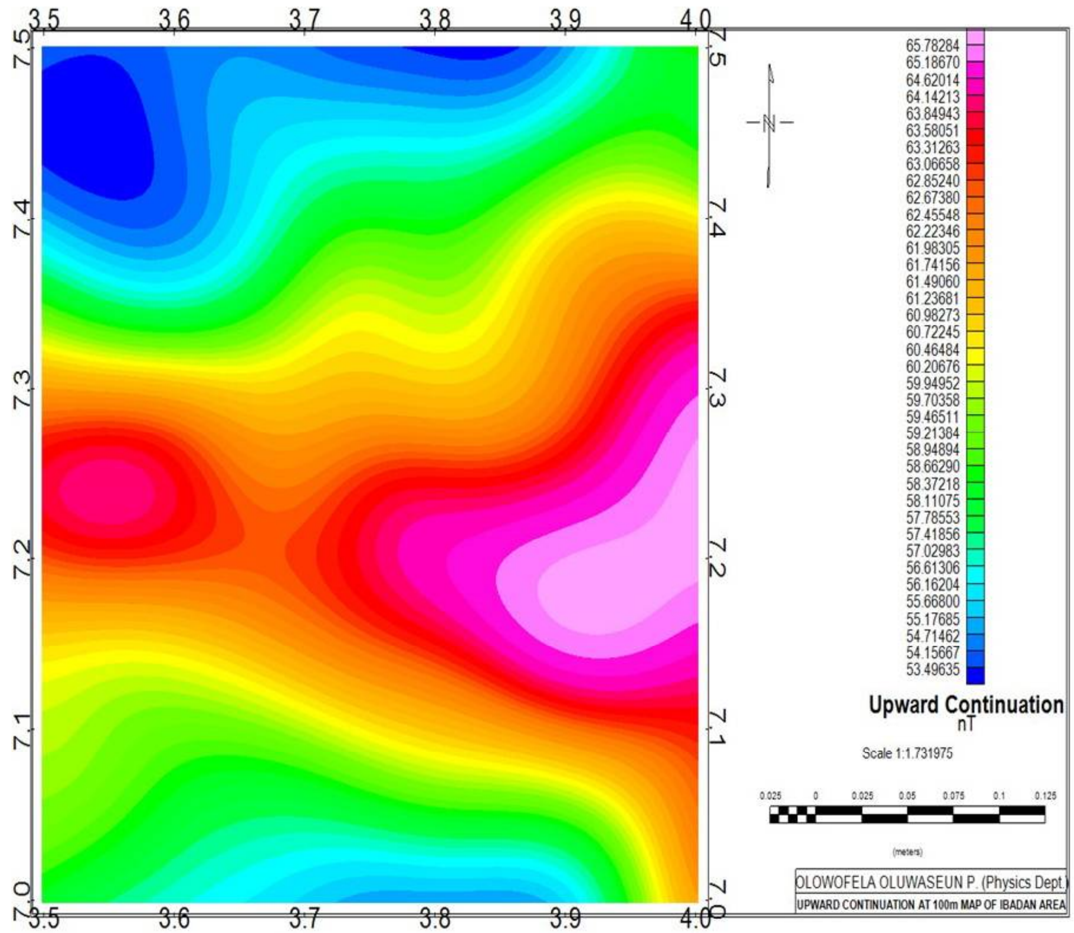

Figure 7: Upward Continued Magnetic Data of Ibadan at cut off wavelength at 100 Meter

In Fig.7, the upward continuation value at 100m ranges from 53.49635nT to 65.78284nT the upward continued value at cut-off wavelength of 100m reveals increased attenuation and broadening of long wave length anomalies with increasing height above the ground level. It was observed that as cut-off wavelength increases, the upward continued magnetic intensity value decrease. These upward continued maps illustrate the change in anomaly character with increasing observation to source distance.

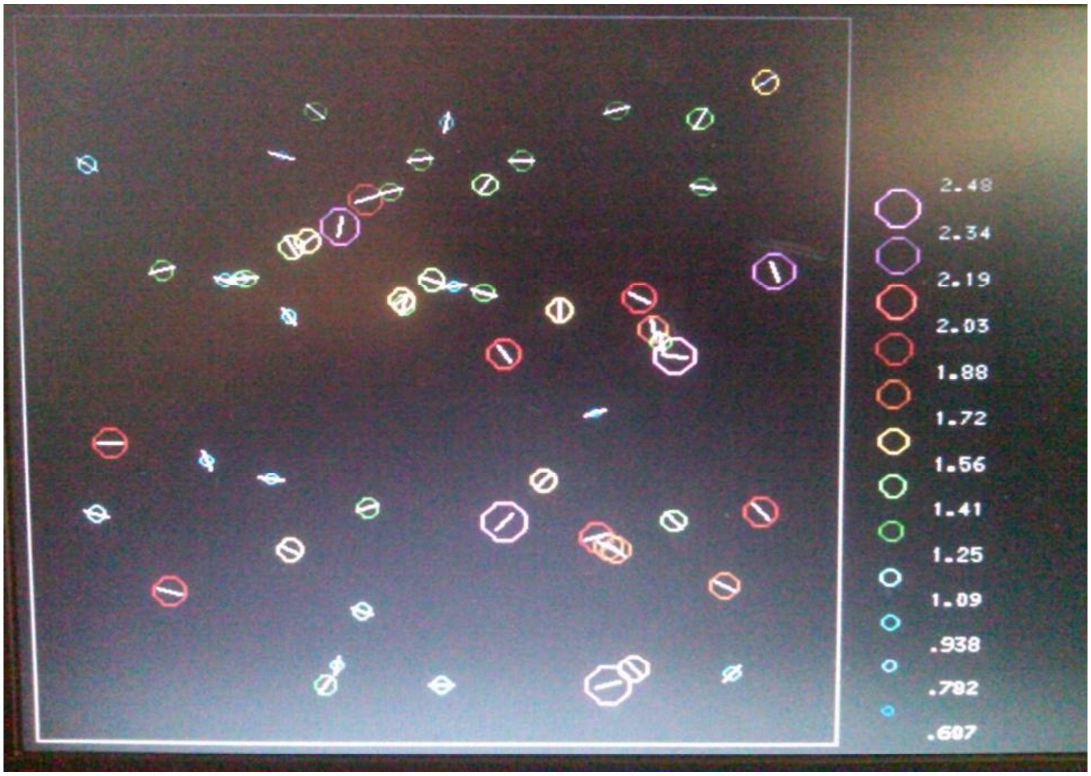

Figure 8: Local Wavenumber Depth of Ibadan Area which ranges from 0.607km to 2.48km

In Fig.8, the result obtained using Local wave number method shows that the estimated depth ranges from 0.607km to 2.48km. The result also revealed that the limit to shallow source depth is 0.607km and limit to deep source depth is 2.48km. The inspection of the map further shows that the shallow depths are at the southern and the north central part of the study area. However, the deepest depths are located at the western and eastern part of the area under consideration.

The apparent susceptibility map at 50m (Fig.9) which ranges from -0.00012nT to 0.00079 was used to define the magnetization domains within Ibadan area and rock types were inferred based on the range of susceptibility values within these domains i.e. relative high magnetic susceptible and conductivity zones (0.00030 – 0.00079) could be inferred as area where the magnetite type iron ore are concentrated in the deposit which also agrees with the susceptibility value of the following minerals; augite, granite, haematite and schists, columbite.

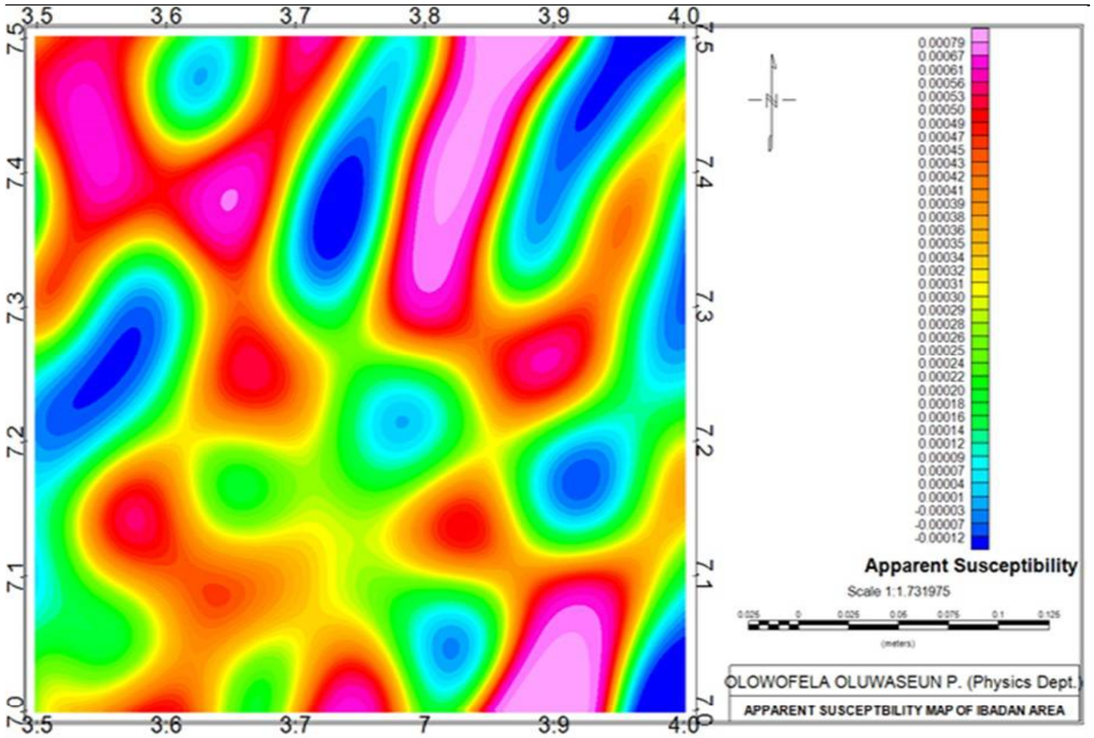

Figure 9: Apparent Susceptibility Map of Ibadan at cut – off frequency of 50 Meter

CONCLUSION

Analysis of aeromagnetic data provides valuable geological information about the area under study. The results obtained from this study show that the study area is dominated with basement rocks and have considerable variations both in the physical characteristics of rocks and structural geometries. In general, the prominent features in the study area are the high magnetic zones believed to be region where magnetic anomalies are likely to be fully deposited.

Upward continuation filtering and Local wavenumber were used to analyze aeromagnetic data of Ibadan area. Result of Upward -continuation emphasized long-wavelength anomalies as this helps to be a suitable method in bringing out subtle features in terms of discriminating between the shallow source and deep source while retaining long-wavelength anomalies. The result of the local wavenumber showed clearly the variation along the profiles in the surface of magnetic basement across the study area. The limit depth of the deep sources is 2.48km and is believed to correspond to the surface of the magnetic basement across the study area. The shallow depth limit ranging from 0.607km may refer to some major magnetic units, uplifted basement surface as well as to some local magnetic features. This result therefore demonstrates the applicability of Upward Continued treatment and Local wavenumber method of magnetic interpretation in estimating source location and depths to the surface of magnetic basement in basement complex. The apparent susceptibility of the Ibadan and its environs obtained range between – 0.00012 and 0.00079 which reveals that major rock types found in Ibadan area are granite, gneiss and quartzit.

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