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ESTIMATION OF THE MAGNETIC DEPTH FROM QUANTITATIVE INTERPRETATION OF AEROMAGNETIC ANOMALY OVER ILORIN, NORTHCENTRAL NIGERIA

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ABSTRACT

Total field aeromagnetic anomalies over Ilorin (bounded by longitude $4^0$30'- $5^0$30' E and latitude 8^0 - $8^0$30' N) have been interpreted using Fast Fourier Transform method in order to estimate the sedimentary thickness. Aeromagnetic data of the area (sheet 223) were acquired, digitized and analyzed. The result obtained reveals two depth sources in the study area: the depth to the shallow magnetic sources which is averagely 0.415 km and the depth to the deeper magnetic sources which is averagely 1.294 km. These depths are relatively shallow; hence, hydrocarbon exploration is not recommended in the area owing to the low thickness of sediment on the average. The shallower sources are probably due to the presence of igneous intrusives and/or magnetized bodies within the sedimentary cover. The lithology of the basement structure was also modelled in contour and 3D surface map. All deductions made from this study were reached after due consideration of the quantitative interpretations supported by geological information of the area.

1. Introduction

Ilorin, the capital city of Kwara State, lies within the crystalline basement rocks of western part of central Nigeria [1]. The area is a semi-arid region of Nigeria with vegetation mainly guinea savannah, with shrubs and undergrowth [2]. The area is drained by rivers and streams such as Oyun River and river Ile-Apa as a tributary of river Niger [3].

Geophysics is the application of physics to study the Earth, oceans, atmosphere and near-Earth space. It is a broad subject that encompasses many of the major sciences [4]. The science of geophysics applies the principles of physics to the study of the Earth. Geophysical investigations of the interior of the Earth involve taking measurements at or near the Earth's surface that are influenced by the internal distribution of physical properties [5]. Analysis of these measurements can reveal how the physical properties of the Earth's interior vary vertically and laterally [6].

Aeromagnetic applications are well known in a wide variety of geological studies and they play an important role in tracing lithological contacts and also to detect and recognize magnetic structures such as the basement rocks. Aeromagnetic data can be used along with conventional geological maps for various earth resource

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evaluation applications ([7] and [8]). The regional aeromagnetic study of anomaly map brings out the regional geological pattern and structural features and provides an exceptional background for interpretation for specific purposes [9].

This study is aimed at estimating the depths to the basement rock in the study area by carrying out quantitative interpretation of the aeromagnetic data over the area which lies between Longitude 4.30°E and 4.60°E and Latitude 5.00°N and 5.30°N. It falls within the Nigerian Precambrian basement complex (Figure 1), a suite of crystalline rocks exposed in over nearly half of the country extending west into the Dahomeyan of Benin Republic [10].

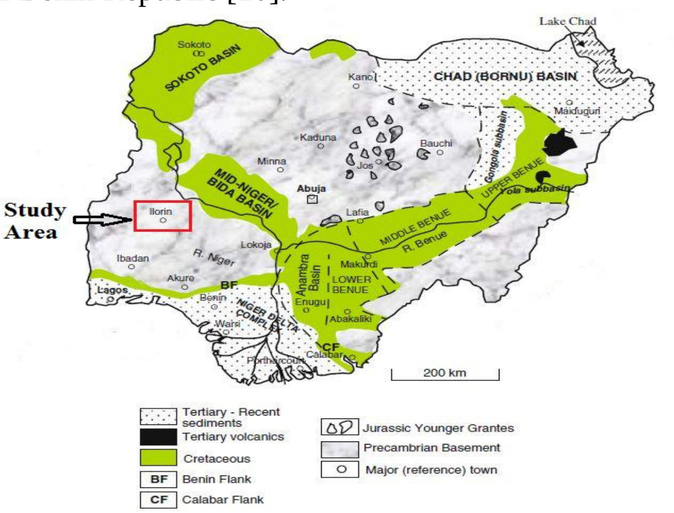

Figure 1: Geologic Map of Nigeria indicating the Study Area (after [11]).

Regional and Geological Setting of the Study Area

The dominant lithologic units of the study area are gneisses of migmatite, biotite and granite which are regionally emplaced; the ferruginous quartzite is the source of the iron ore mineralization in the area [12]. The area falls under the banded iron Formation of Nigeria, generally they occur in metamorphosed folded bands, associated with Precambrain basement complex rocks which included low metasediments, high grade schist, gneisses and migmatites [13]. The dominated lithologic units in the area are gneisses of migmatite, biotite and granite. [12] pointed out that the ferruginous quartzite is the source of the iron ore mineralization. The south eastern part of the study area is more sedimentary.

Methodology

Aeromagnetic datasheet/map with sheet number 223 (Ilorin) was used for this study. The square map is about 55 X 55 km^2 covering an area of 3, 025 km^2. The new high resolution aeromagnetic survey carried out for the Nigerian Geological Survey Agency (NGSA) by Furgo Airborne Services in 2009 which was flown at 500 m line spacing and 80 m terrace clearing using various survey parameters, softwares and errors which were corrected during surveys. This created a higher resolution data in digital form too as shown in Figure 2 and eliminated many errors associated with the old map.

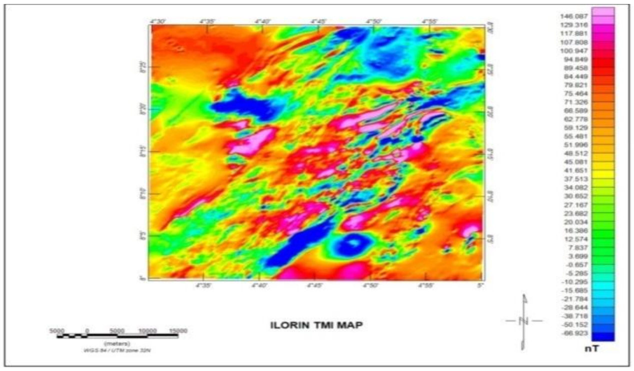

Figure 2: Total Magnetic Intensity (TMI) Map of Study Area

The aeromagnetic map was acquired NGSA, Abuja. The aeromagnetic data was obtained as part of a nationwide aeromagnetic survey sponsored by geological survey of Nigeria. The geomagnetic gradient was removed from the data using the international geomagnetic reference field (IGRF). Digitization of data is followed by separation of aeromagnetic data. Here, a linear trend surface (equation 1) was fitted on to the digitized aeromagnetic data by a multiple regression technique for the purpose of removing the regional magnetic gradient. The linear surface so fitted was removed from the digitized data so as to obtain the residual anomaly data which was used to construct residual anomaly map. The data were then transformed into regular grid using computer software Surfur-32 which iteratively carries out interpolation of data and contoured the anomalies (total magnetic field intensity and residual).

The trend surface equation (regional gradient) becomes

$$T(x, y) = -11177 - 147.26x + 217.38Y \quad (1)$$

Where

$T(x, y)$ is the Magnetic value at x and y coordinates x and y are units of spacing along the latitude and longitude. The residual anomaly was subjected to slope method analysis and geologic modeling. Slope method has been widely used by several authors ([14] and [15]) to determine the depths of magnetic anomalies. The slope method is mostly used as a quick check on the validity of depth estimates. The method gives reasonable results and it is very suitable for anomaly of aeromagnetic data.

Quantitative Interpretation

The most important parameter in quantitative interpretation is the depth of the anomalous body. Depth to source is contained in the shape of the anomaly. Because of the obvious importance of the depth to basement in mineral exploration, the depth to the source usually referred to as the depth to the magnetic basement is of great importance [13].

The general mathematical basis for the application of power spectrum analysis to aeromagnetic map interpretation has been developed by Spector and Grant [15]. They studied the relationship between the power spectrum of aeromagnetic anomalies and the average depth of source bodies using some statistical assumption. This provides a foundation for anomaly source parameter estimation of depth to magnetic sources ([16] and [17]). The plot of log power spectrum against the radial wave number gives results of different spectrum segments. The slope obtained from the above plot indicates the average depth to the source bodies [18].

The study area is covered by aeromagnetic map of total-field intensity in sheet 223 on a scale of 1:100,000. The data used were gridded into 11 overlapping windows using Oasis montaj. In this study, Fast Fourier Transform (FFT) filter was used to calculate the depth. The data was transformed from space domain to frequency domain using FFT. A Matlab program was developed to separate the high and low frequency signal zones and to calculate their slopes. The database of the study area was gridded and then used to contour the total intensity map. The total magnetic field intensity value Z was stripped of 33,000nT for ease of processing. A simple arithmetic addition of 33,000nT to each value of Z therefore gives the Z-Total (NGSA).

Results and Discussion

The depth to magnetic sources within the study area was determined from the total magnetic field data using statistical spectral analysis. Figure 3 shows selected power spectrum blocks of the plot of logarithm of spectral power (energies) against wavenumbers (frequencies) obtained.

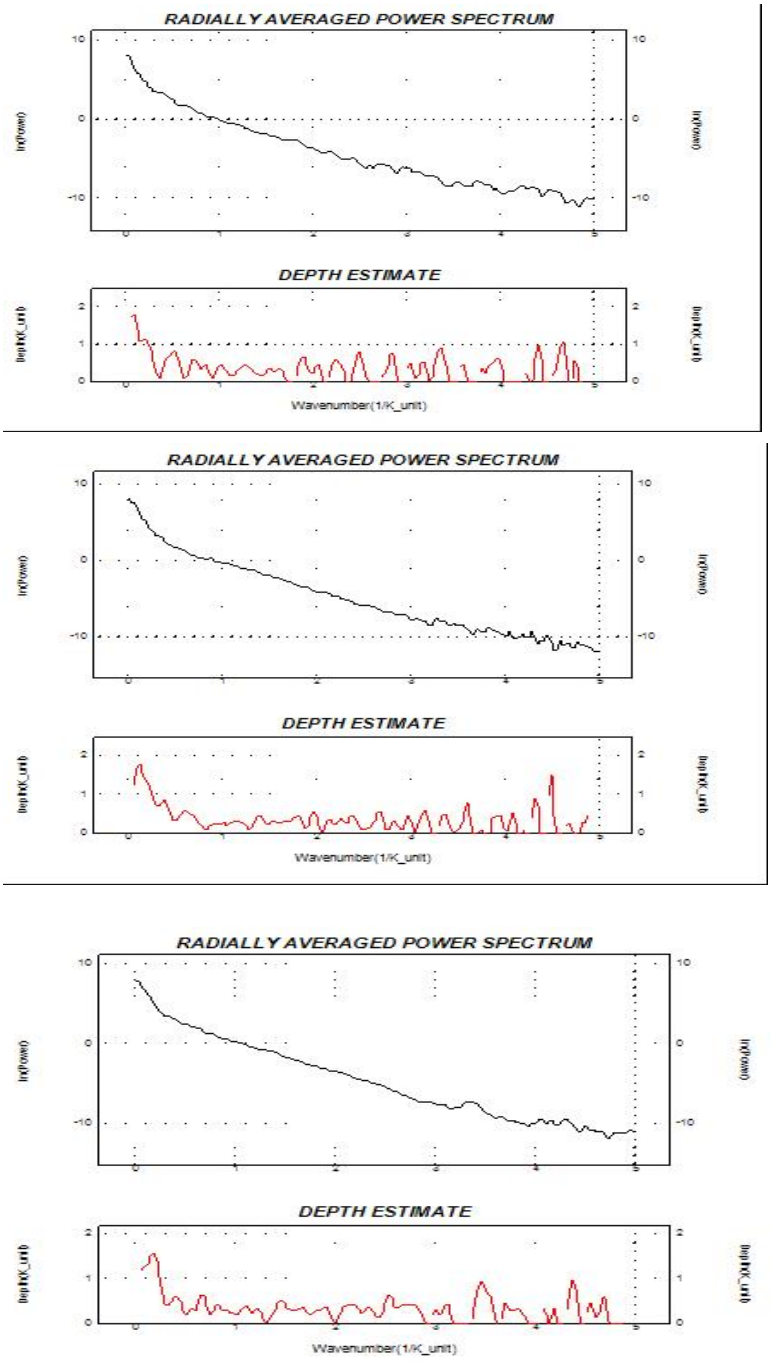

Figure 3: Selected Power Spectra Plots

Two linear segments were drawn from the graph of each window. The data were deployed to plot the logarithm of the radially averaged power spectrum against the wavenumber using MATLAB. Figure 4 shows selected plots for depth estimation, for each of the window, from which the slope of the two linear segments (deeper and shallow) were obtained.

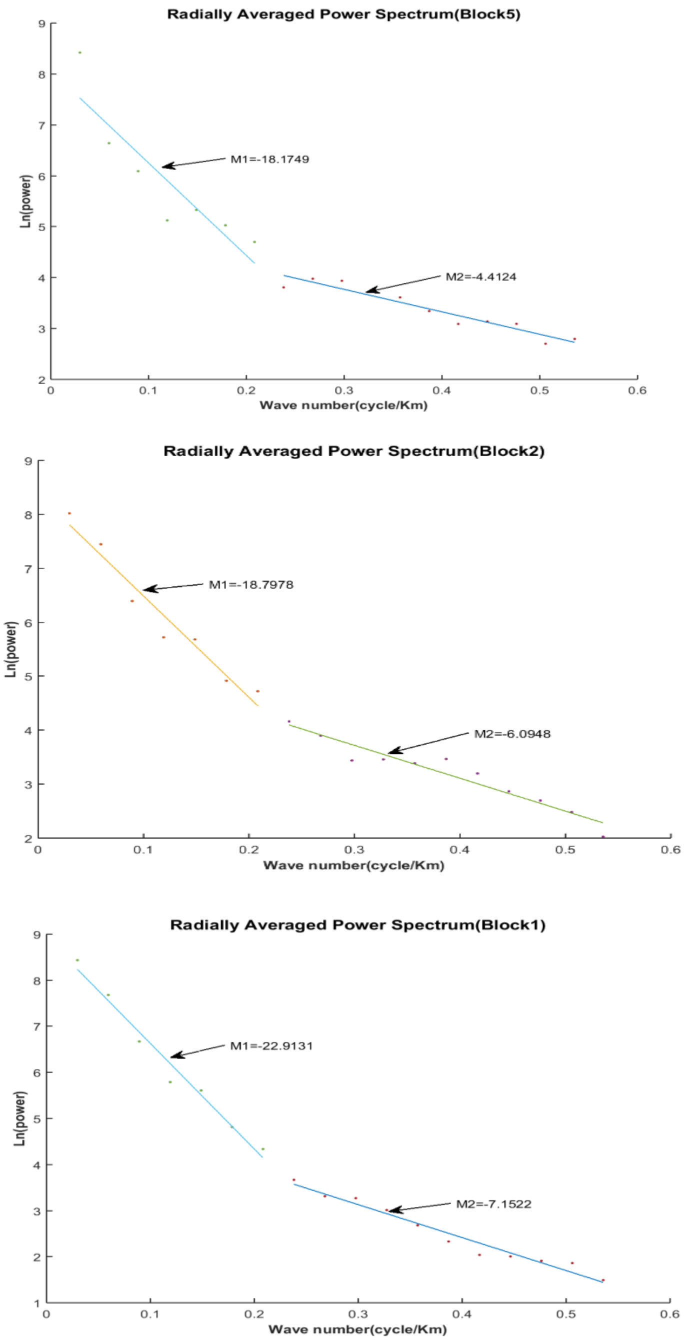

Figure 4: Selected Plots of Ln(power) against wavenumber

The slope obtained was used to calculate the depth to causative body as

$D_1 = -M_1/4\pi$ (2)

$D_2 = -M_2/4\pi$ (3)

Where M_1 = slope of the deeper source, M_2 = slope of shallow source, D_1 = depth to deeper source, and D_2 = depth to shallow source.

The maximum depth that can be probed in this research work is about 2.30 km in line with the relation

$$D = L/2\pi \tag{4}$$

Given by [18], where L is window length (15 km in the present study).

Table 1 below shows the estimated magnetic sources for both the shallow source (D_2) and deeper sources (D_1).

Table 1: Depth estimations from spectral analysis of aeromagnetic data of the study area.

WINDOW	NORTHINGS (km)	EASTINGS (km)	M_1	M_2	DEEP SOURCE	SHALLOW SOURCE	ERROR
1	29.891	930.163	-19.807	-6.094	1.501	0.514	±0.02
2	59.859	930.163	-14.497	-5.515	1.154	0.439	±0.01
3	74.842	930.260	-17.175	-4.421	1.546	0.315	±0.05
4	10.384	930.007	-19.772	-4.298	1.574	0.343	±0.02
5	29.890	915.084	-14.948	-5.658	1.190	0.451	±0.01
6	44.875	915.084	-11.023	-5.240	0.877	0.416	±0.02
7	74.841	915.084	-19.411	-4.425	1.545	0.321	±0.11
8	10.375	915.084	-16.801	-2.295	1.337	0.183	±0.03
9	59.858	900.196	-14.173	-6.228	1.218	0.494	±0.14
10	75.745	900.196	-14.484	-8.366	1.145	0.655	±0.05
11	90.921	900.196	-14.894	-6.144	1.184	0.488	±0.02
12	10.471	900.196	-15.154	-5.527	1.253	0.358	±0.06

The primary sources that account for the first layer depth derived from the statistical spectral analysis are the basement (magnetic) rocks that intrude the sedimentary formation. The first layer magnetic source's depth as estimated using FFT ranges from 0.183 to 0.655 km, while the range of the second (deeper) magnetic source depth is from 0.877 to 1.574 km. The maximum depth of 1.574 km could be found at the south-western part while the minimum depth of about 0.183 km could be found roughly at the central part of the total intensity map. Contour and surface maps of the shallow sources in the study area as shown in Figure 5.

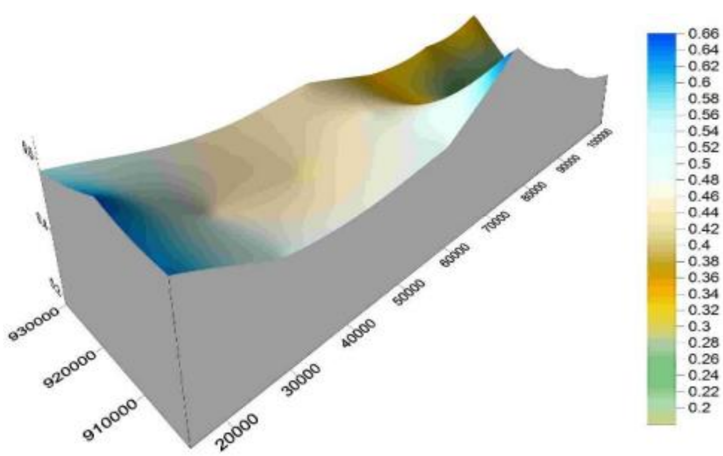

Figure 5: 3D Surface Map of the Shallow Depth Sources

The second layer depth may be attributed to magnetic rocks that are emplaced into the basement underlying the sedimentary cover. Also, intra-basement features such as fractures could equally contribute to sources that accounted for the second layer depth. The second layer depth invariably represents the average sedimentary thickness (1.304 km) of the study area, that is, the depth to the underlying basement complex rocks. The 3D surface map is shown in Figure 6.

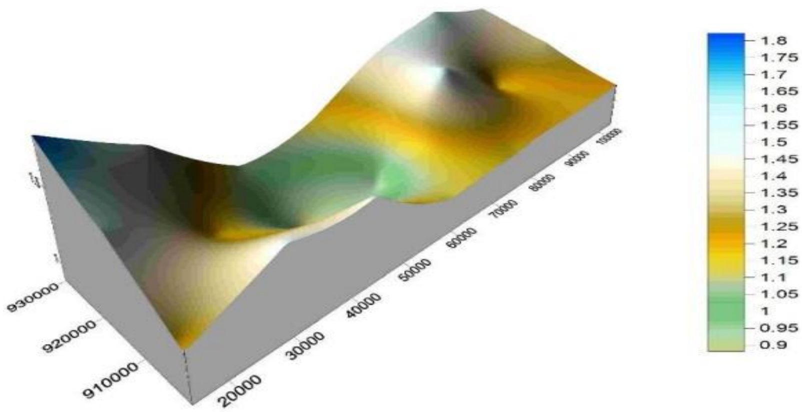

Figure 6: 3D Surface Map of the Deeper Depth Sources

This depth approximation correlates previous works and geology of the study area which is a basement complex. The depth to magnetic source is actually expected to be shallow in the study area with inferences drawn from the geology of the area.

Conclusion

Quantitative analysis of high-resolution aeromagnetic data of Ilorin using Fast Fourier Transform method was carried out. The procedure involved includes gridding of the magnetic data, production of the frequency domain map, and estimation of depths to magnetic sources. The results reveal two depth source models in the study area. The deeper sources range from 0.877 to 1.574 km, while the shallower sources range from 0.183 to 0.655 km. The deeper magnetic sources identified with the crystalline basement, while the shallower magnetic sources could be associated to near surface magnetic sources, which may be magnetic (igneous or metamorphic) rocks that intruded into the sedimentary formations or magnetic bodies (e.g., laterite) within the sedimentary cover. The average depth obtained from the spectral analysis of high-resolution aeromagnetic data to determine depth to magnetic basement is shallow and this correlates to previous geological work which pointed out that the area is a basement complex; hence hydrocarbon exploration is not recommended in the area owing to the low thickness of sediment on the average.

References

[1] Sunday, J. A., Usman, A., Ologe, O. and Lawal, T. O. (2019). Detection of Fracture Zones for Groundwater Investigation from Interpretation of VLF-EM Anomalies of Kwara State Polytechnic Ilorin and its Environs. Global Journal of Human-Social Science; (19) 27-41.

[2] Nwankwo, L. I (2011). 2D Resistivity Survey for Groundwater Exploration in a Hard Rock Terrain: A Case Study of MAGDAS Observatory, UNILORIN, Nigeria. Asian Journal of Earth Sciences; pp. 1-3. [3]Nwankwo*et al.*, 2004

[4] Gadallah, M. R. and Fisher, R. (2009). Exploration Geophysics: Berlin Germany: Springer.

[5] Telford, W., Geldart, L., Sheriff, R. and Keys D. (1976). Applied Geophysics (2nd edition). New York. Cambridge University Press.

[6] Keary, P., Micheal, B. and Hill, I. (2002). An Introduction to Geophysical Exploration (3rd Edition). Willey Blackwell Science.

[7] Reeves, A. (1990). Olympic Dam Copper-Uranium- Gold-Silver Deposit; in Geology of the Mineral Deposits of Australia and Papua New Guinea, the Australasian Institute of Mining and Metallurgy, Hughes, F.E., Editor, pp: 1009-1035.

[8] Sheriff, R. E. and Geldart, L. P. (1995). Exploration Seismology (2nd Edition). University of Houston. Cambridge University Press. [9] Mohammad, A. (2009). Aeromagnetic Data Interpretation to Locate Buried Faults in Yazd Province-Iran; World Applied Sciences Journal 6 (10) ISSN 1818-4952: 1429-1432.

[10] Amigun, J. O. and Ako, B. D. (2009). Rock density-A tool for mineral prospection: A case study of Ajabanoko iron ore deposit, Okene SW Nigeria. The pacific journal of science and technology, vol.10, pp.733-744.

[11] Obaje, N. G. J (2009). The Bornu Basin – Nigerian Sector of the Chad Basin. Journal of Geology and mineral, Vol. 120/2009, pp.69 – 76.

[12] Olade, M. A. (1975). Evolution of Nigeria's Benue Trough. African Lithosphere and their Geodynamic Significance. Journal of African Earth Science, Vol. 3, pp.437 – 442.

[13] Chinwuko, A. I., Usman, A. O., Onwuemesi, A. G, Anakwuba, E. K., Okonkwo, C. C. and Ikumbur, E. B., (2014); Interpretations of aeromagnetic data over Lokoja and environs, Nigeria; International Journal of Advanced Geosciences, 2 (2): pp.66-71.

[14] Onuba, L. N., Anudu, G. K., Chiaghanam, O. I. and Anakwuba, E. K. (2011). Evaluation of aeromagnetic anomalies over Okigwe area, Southeastern Nigeria. Research journal of environment and earth sciences.pp.498 -506.

[15] Spector, A. and Grant, F. S. (1979). Statistical model for interpreting Aeromagnetic data Geophysics. 25, pp.293-302.

[16] Lawal, T. O., Nwankwo, L. I. and Akoshile, C. O. (2015). Wavelet Analysis of Aeromagnetic Data of Chad Basin, Nigeria. The African Review of physics, 10 (16).

[17] Nwankwo, L. I., Olasehinde, P. I, and Sunday, A. J. (2018). Fractal Revaluation of Bottom Depth of Magnetic Sources in Bida Basin, Nigeria from High-Resolution Aeromagnetic Data. J. Ind. Geophys. Union; v.22, no.2, pp: 143-150.

[18] Shuey, R. T., Schellinger, D. K., Tripp, A. C. and Alley, L. (1977). Curie depth determination from aeromagnetic spectra. Geophysical Journal. 50(1), 75-101.