



INTERPRETATION OF HIGH RESOLUTION AEROMAGNETIC DATA OVER PART OF NORTHWESTERN, NIGERIA

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Abstract

Interpretation of HRAM data over part over part of Northwest Nigeria has been carried out with the aim of delineating lineament structures such as faults, contacts, joints etc. and estimating the depth to the top of the magnetic basement (which is equivalent to the sedimentary thickness). This research work makes use of a Total Magnetic Intensity (TMI) acquired from Nigerian Geological Survey Agency which was part of the recent nationwide airborne magnetic survey carried out in 2010. The map was gridded into eighteen non-overlapping blocks (20 x 20 km) and each of the blocks was analysed using Spectral analysis which reveals two source depths, depth to shallow magnetic sources which ranges from 0.12 km to 0.30 km and depth to deeper magnetic sources which ranges from 0.98 km to 1.81 km. Also, the study area reveals parallel contour lineament trending NE – SW and subordinate E-W direction which are suggestive of fault and joint in the area. The result obtained from the study which reveals the depths to basement structures and delineation of lineament structures would complement the existing geophysical information of the area.

Keywords: HRAM data, Spectral Analysis, depth estimates and lineament structures.

Introduction

Magnetic survey is one of the geophysical survey that exploit the considerable differences in the characteristics of magnetic minerals on the foundation of anomalies in the Earth's magnetic field resulting from the properties of magnetic rocks beneath earth surface (Ross, 2002; Reeves 2005). These anomalies can be analyzed to estimate depth to magnetic basement and when the magnetic depth to the basement is contoured, it will provide an illustration of the spatial variation about the sedimentary thickness of the area under consideration and these illustrations correlate meaningfully to the known sedimentary activities in the region of

study. Among the well know mathematical techniques used in analyzing the depth to magnetic basement (2D forward modelling, characteristic curves, Euler deconvolution, Naudy method, Werner deconvolution, CompuDepth, Analytic signal etc.) spectral analysis has proved to be a powerful tool in interpreting magnetic data and this is because it seeks to describe the frequency content of a signal based on a finite set of data (Nwankwo *et al.*, 2008; Lawal, 2014). Generally, a mathematical basis for the application of power spectrum analysis to aeromagnetic data interpretation has been developed by (Spector and Grant 1970) and several other researchers have applied to all

potential field data. They studied the relationship between the power spectrum of aeromagnetic anomalies and the average depth of source bodies using some statistic assumption. This provides a foundation for anomaly source parameter estimation of depth to magnetic sources. The power spectrum of aeromagnetic anomalies can be written as (Lawal 2014).

$$\langle P(k) \rangle = 4\pi^2 M^2 \langle e^{-2hk} \rangle \langle 1 - e^{-tk} \rangle \langle S^2(k) \rangle \quad [1]$$

where $\langle \rangle$ stands for ensemble average, M is the magnetic moment/unit volume, h is the depth of the top of the source body, t is the thickness of the source body, k is the radial wave number and $\langle S^2(k) \rangle$ which is defined in equation (1) represent the horizontal size of the source body.

$$\langle S^2(k) \rangle = \frac{1}{\pi} \int_0^\pi \langle S^2(k, \theta) \rangle d\theta. \quad [2]$$

Spector and Grant, (1970) found that the $\langle e^{-2hk} \rangle$ term which is the depth factor is invariably the dominating factor in the power spectrum and that the effect of the extension factor $\langle 1 - e^{-tk} \rangle$ and the horizontal factor $\langle S^2(k) \rangle$ is comparatively small, especially in low-frequency bands. From equation (2), the third and the last are relatively small, therefore it becomes

$$P(r) \approx C e^{-2hk}. \quad [3]$$

Taking the log of equation (3), we have

$$\ln(P(r)) \approx -2hk + C'. \quad [4]$$

Where C and C' are constant coefficients and h is the average depth of the source body.

From equation (4), the plot of log power spectrum against the radial wave number

gives results of different spectrum segments. The slopes obtained from the above plot indicate the average depth to the source bodies. Previous research work carried out in Sokoto basin where the study area is located includes the work of (Adetona *et al.*, 2007) where they determined the depth to buried magnetic rocks using aeromagnetic data of lower of Sokoto basin and obtained depth to magnetic basement ranging from 0.46 km to 1.96 km. Also, the thickness of the underlying sediments was obtained by (Chikwelu and Ogbuagu 2014) in the interpretation of aeromagnetic data of Sokoto basin with their result varying between 0.6 km and 1.83 km. Shehu *et al.*, (2004) and Taufiq *et al.*, (2014) analyzed and interpreted aeromagnetic data of upper Sokoto basin and Kebbi State respectively. They obtained values ranging from 0.80 km to 1.72 km, and 0.4 km to 2.0 km respectively and recently, Nwankwo *et al.*, (2016) determine the depths to buried magnetic rocks from the aeromagnetic data of Gandi (Eastern part of the study area) in the upper Sokoto basin and they obtained depths ranging from 0.04 km to 2.68 km. Hence, this research work is aimed at delineating lineament structures and estimating the depth to the top of the magnetic basement which would supplement the available geophysical information within the area and also contribute immensely in understanding the geophysical information of entire the Sokoto basin.

Location and the Geology of the Study Area

The area of study, which is a part of the sedimentary Sokoto basin (also known as lullemeden basin), Nigeria, is bounded by latitudes 12°30' N and 13°00' N and longitudes 3°28' E and 5°00' E. (Figure.1). It covers area like Kaingiwa, Lema, and Argungu and situated in the North-Western part of Nigeria. Geologically, the basin which houses the study area has been described by many authors (Kogbe, 1981; Odebode 2010; Obaje *et al.*, 2013 etc.).

Odebo 2010 stated that the basin is an intracratonic epeirogenesis basin which extends from the crystalline areas of Niger Republic in the north to the Gusau-Kano area (Nigeria) in the south. It covers a total land area of over 700,000km². The basin has been described as one of the three important sub-Saharan inland basins consisting of a broad syncline with gently dipping flanks with the syncline axis trending North-South and the overlying sedimentary sequences become progressively younger from the NE to the

SW, which is an indication of the directions of successive cretaceous marine transgressions. Three principal fault, namely north-northeast south-southwest (NNE-SSW), north-northwest south-southeast (NNW-SSE) and east-west (E-W) are said to have dominated the entire basin. Nwankwo et al (2016) also reported that Sokoto basin is located in the dry Sahel and surrounded by sandy savannah and isolated hills with an annual average temperature of 28.3 °C.

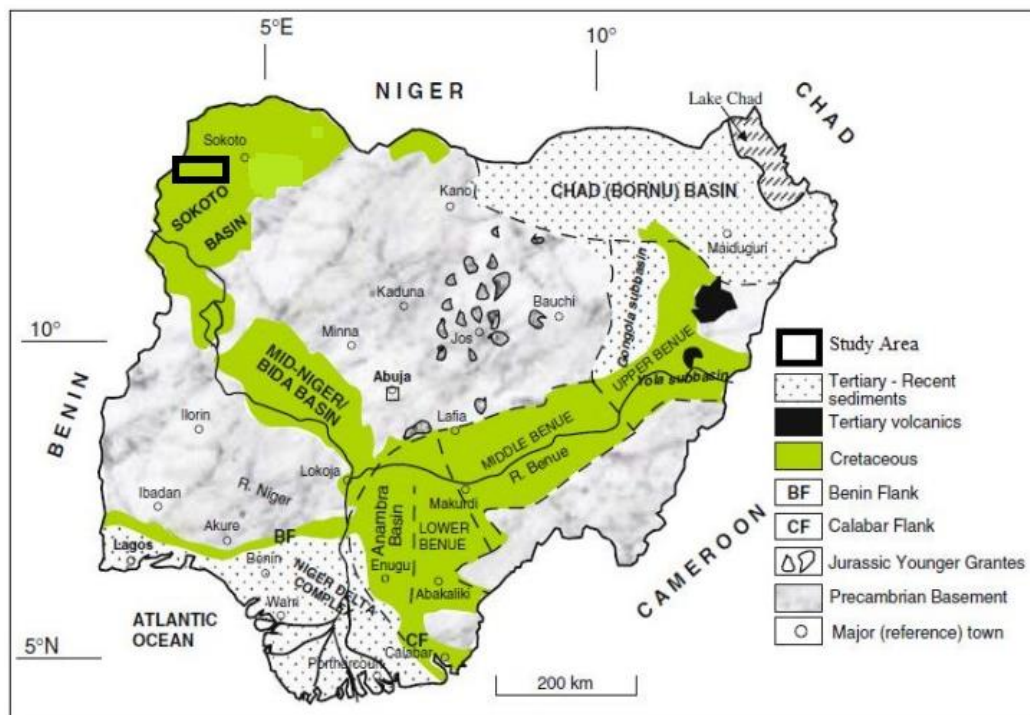


Figure 1: Geological map of Nigeria showing the study area.

Materials and Methods

Three (3) HRAM maps (sheet number: 26, 27 and 28) contours of Total Magnetic Intensity (TMI) published by the Nigerian Geological Survey Agency (NGSA) airborne geophysical series flown between 2004 and 2010 on a scale of 1:1000,000 were acquired. The survey was carried out by Fugro Airborne Services Limited, Johannesburg along a series of NW - SE flight lines with a spacing interval of 500 m and an elevation of about 80 m while tie lines occur at about 2 km interval. The Regional field was removed from the data

by NGSA using the International Geomagnetic Reference Field (IGRF). For the purpose of this analysis, the HRAM sheets listed above were merged in to a composite map (Figure. 2) with the magnetic values ranging between - 36.9 nT and 134.3nT. The composite HRAM maps were carefully gridded into eighteen (18) blocks (Figure. 3) covering 20 km by 20 km cutting across various geological structures, and each of the blocks were analyzed for source depth using Spectral analysis described in (equation 1 to 4).

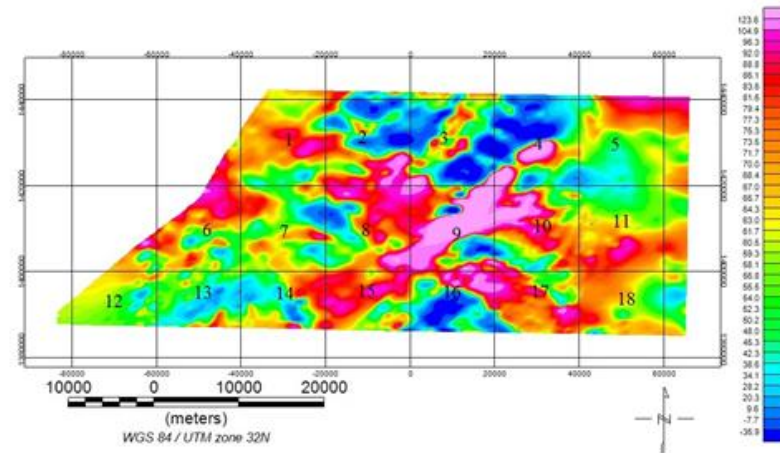


Figure 2: Merged composite HRAM maps of the study area

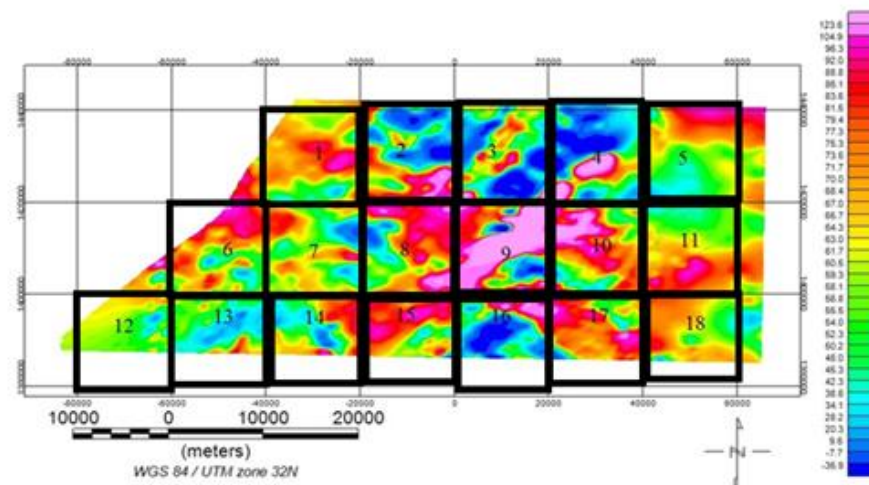


Figure 3: Gridded composite HRAM maps of the study area

Results and Discussion

The Total magnetic intensity map (Figure 2) shows that the study area is divided into regions of positive ($>9.6\text{nT}$) and negative magnetic values ($< -7.8\text{nT}$). These regions of positive values are characterized as high magnetic anomalies while regions of negative values are characterized as low magnetic anomalies. These high magnetic anomalies are more prominent in the central part of the map trending NE-SW and NW-SE of the study area. Few of these anomalies are also noticeable in the N-W, N-E and S-E respectively. The low magnetic anomalies are prominent in the northern part while few of them were noticed in the southern part of the area and

they all trends in the NE-SW direction. The high magnetic anomalies found in the area are felsic igneous intrusive rocks because of their high magnetite content and they may have resulted from several tectonic activities events which occurred in the formation of the basement complex, while the low anomalies in the area are mafic sedimentary rock because of their low magnetite content. These anomalies are reflections of the down-faulted blocks of the Precambrian basement complex which controls the sediments above it. For the purpose of quantitative interpretation, plots of some of the spectral analysis performed on 18 eighteen blocks are shown in Figure 4 for blocks 2, 7 and 11 respectively. The figure 4 (i.e. block 2, 7 and 11) is a plot of

natural logarithm of power spectral against the wave number and the slopes (m_1 and m_2) of the straight line = segments for each block was determined while depths for deeper and shallow source were calculated (Table 1). The power spectral of the anomaly is mainly concentrated in the low frequency band and the linear segment from the low wavelength band (m_1) represent contributions from the deep-seated causative bodies while high wavelength band (m_2) represent the shallow bodies which were obtained from each block. The result obtained from the deeper sources varies from a thickness of 0.98 to 1.81 km (Figure 6) while the shallow source depth varies from a thickness of 0.12 to 0.30 km (Figure 5). Two magnetic sources account for the first depth obtained from the spectral analysis. The first is the shallow magnetic source which can be found on the sub-surface of the area which bound the

Sokoto basin while the second and more important sources are the magnetic rocks which intrude the sedimentary formation and sometimes extrude on the surface. The second layer may be attributed to the magnetic rocks e.g. Dange and Gambaformations which extrude to the surface. The estimated depth obtained from this study agrees with the results of Adetona *et al* (2007) a varying depth of 0.46 km to 1.96 km, (Chikwelu and Ogbuagu, 2014) where they in the interpretation of aeromagnetic data of Upper Sokoto basin with their result varying between 0.6 km and 1.83 km. Others are (Taufiq *et al.*, 2014), result varying between 0.40 km and 2.0 km, (Nwankwo *et al.*, 2016), they interpreted aeromagnetic data of Gandi using Euler deconvolution and obtained maximum sedimentary thickness of 2.68 km.

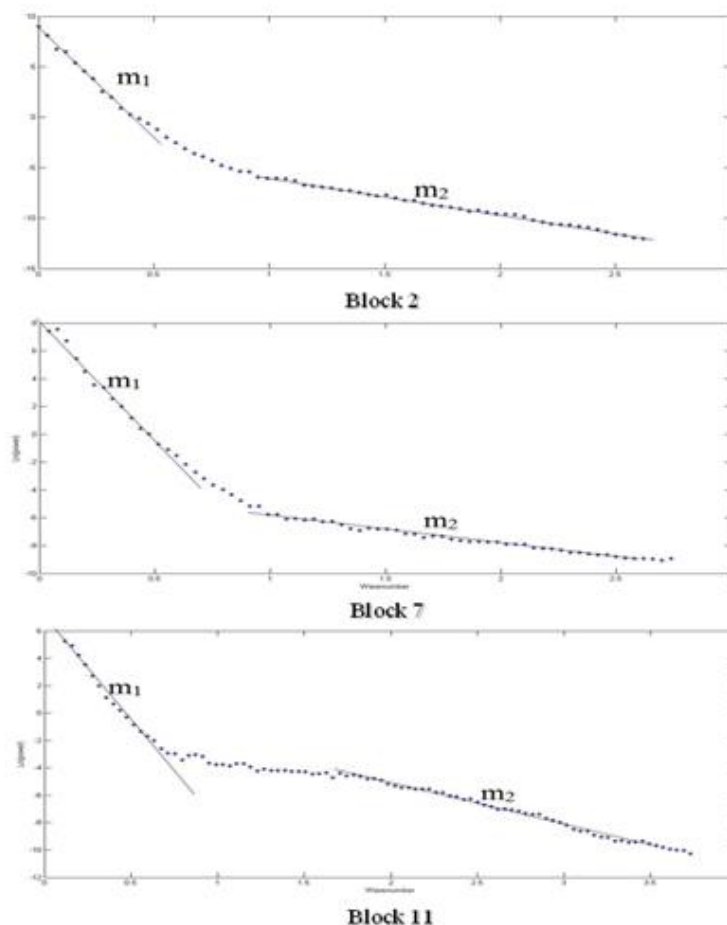


Figure 4: Plots of power against the wave number for Block 3, 7 and 11
Table 1: Summary of Shallow and Deeper Depth of the study area

Blocks	Shallow depth (km)	Deeper depth (km)
1	0.16707	1.40046
2	0.28805	1.76315
3	0.29704	1.6521
4	0.17109	1.59994
5	0.24474	1.81733
6	0.12596	1.18917
7	0.15766	1.35854
8	0.20716	1.6568
9	0.12438	1.39261
10	0.26101	1.27565
11	0.24123	1.19942
12	0.24523	0.98366
13	0.25836	1.21426
14	0.14918	1.56363
15	0.27882	1.36802
16	0.22972	1.39337
17	0.16849	1.14481
18	0.15782	1.77543

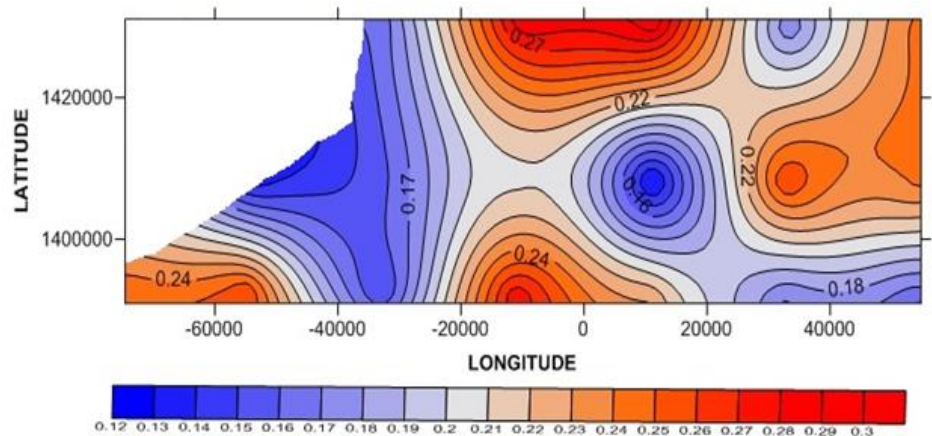


Figure 5: Contour Map of the study area for shallow depths (km).

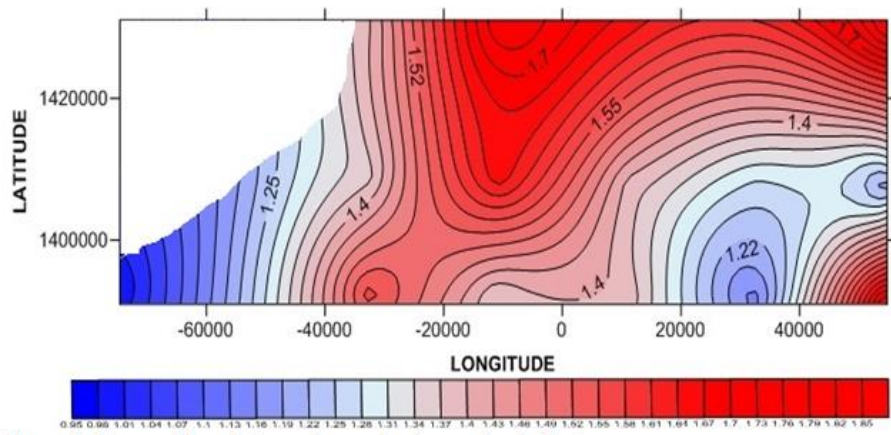


Figure 6: Contour Map of the study area for deeper depths (km).

Conclusion

Interpretation of HRAM data over part over part of Northwest Nigeria has been carried out with the aim of delineating lineament structures and estimating the sedimentary thickness. It will be observed that depth to shallow magnetic sources ranges from 0.12 km to 0.30 km and depth to deeper magnetic sources ranges from 0.98 km to 1.81 km. Also, the study area reveals parallel contour lineament trending NE – SW and subordinate E-W direction which are suggestive of fault and joint in the area. The maximum sedimentary thickness obtained from this study is about 1.81 km. It has been argued that the minimum thickness for hydrocarbon formation is 2.3km (Wright *et al.*, 1985). In view of these estimated depths, the area may not be plausible for petroleum exploration but results obtained will complement the existing geophysical information in the study area.

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