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Analysis of High Resolution Aeromagnetic Data over Isah and Environs, Northwestern Nigeria

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Abstract

The analysis of high resolution aeromagnetic data over Isah and environs was carried out to determined depth to magnetic sources and potentials of the study area for hydrocarbon generation using the spectral analysis. The study area is located between longitude 6° 00"E and 6°30"E and latitude 13°00"N and 13"30°N. The results showed that the total magnetic intensity of the study area varies from -78.0nT to 147.7nT. The residual magnetic map shows the magnetic intensity of -98.2nT to 74.7nT. Magnetic anomalies observed on both total magnetic intensity map and residual map indicate that most of the anomalies are trending in the NE-SW direction, with others in NW-SE, N-S and E-W directions. The result of the spectral analysis shows deeper magnetic source depth, varying from 1.06 km to 2.08 km with shallow magnetic source ranging from 0.653 km to 0.98 km. This study indicates that the areas with depth of 2 km and above are the potential area for hydrocarbon generation.

Keywords: Aeromagnetic Data; Spectral Analysis; Magnetic Sources; Hydrocarbon Potentials and Isah and Environs.

Introduction

Magnetic method is one of the best geophysical techniques used for determining depth to magnetic sources and delineating sub-surface structures. Large-scale aeromagnetic surveys have been used to locate faults, shear zones and fractures. Such zone may serve as potential host for a variety of minerals and may be used as guidance for exploration of the epigenetic, stress-related mineralization in the surrounding rocks (Paterson and Reeves, 1985). Sediment thickness required for hydrocarbons (oil and gas) to form or generated varies from place to place. The minimum sediment thickness required for hydrocarbon generation usually varies from 2km to 4km, for oil and 3km to 7km for gas (Dow, 1978; Cornfort, 1990; Gluyas and Swarbrick, 2005).

Aeromagnetic maps usually reflect variations in the earth's magnetic field resulting from the magnetic susceptibilities of rocks. Sedimentary rocks have the lowest magnetic susceptibility, whereas metamorphic and acidic igneous rocks intermediate and basic igneous rocks have the highest magnetic susceptibility (Kearey *et al.*, 2004). The largest proportion of a magnetic signal or anomaly is thus generated at crystalline (igneous or metamorphic) basement level (GETECH, 2007). Magnetic anomalies are caused by magnetic minerals contained in rocks; such anomalies are usually caused by underlying basement (igneous and/or Metamorphic) rocks or by igneous features such as intrusive plugs, dykes, sills, lava flows and volcanic centres when magnetic anomalies are observed over sedimentary terrain (Gunn, 1997). Nevertheless, high sensitivity measurements could also be associated with cultural iron contamination and authigenic alterations in sedimentary rocks, possibly caused by hydrocarbon migration (Costanzo-Alvarez *et al.*, 2000; Adelana *et al.*, 2003). The high demand of hydrocarbon in the world has drawn the attention of every nation to explore for more potentials, and Nigeria is one of the countries that potentials for hydrocarbon. Sokoto Basin is one of the sedimentary basins of Nigeria that is drawing attention for hydrocarbon exploration. Isah and environs is also part of the Sokoto basin. In view of that, the analysis of s aeromagnetic data over this area will serve as a guide for detail exploration in the area. This study will be very useful on a reconnaissance basis for hydrocarbon potentials in the area. The analysis of aeromagnetic data over the area will differentiate and characterize regions of sedimentary thickness through the determination of depths to the magnetic sources. The results will be used to suggest whether the study area has the potentials for hydrocarbon generation.

The study area is part of the Illummeden embayment in Nigeria, known locally as Sokoto basin and lies between longitudes 6°00´E and 6°30´E and latitudes 13°00´N and 13°30´N (Fig.1) with an estimated area of 3014 km^2. It consists predominantly of a gently undulating plain with an average elevation varying from 250 m to 400 m above sea level. Occasionally the plain is interrupted by low Mesas. A low Escarpment known as the "Dange Scarp" is the most prominent feature in the basin. The area to the east of the escarpment consists of mainly an undulating sandy plain, which extends south-westwards to the outcropping basement complex. The basin falls within the hottest parts of Nigeria, belonging to the Sahel region of Africa. The temperatures of the area are generally high, with average daily minimum of 16°C, during cool months of January and December, and the hottest months of April to June with an average maximum of 38°C and minimum of 24°C. The average minimum temperature throughout the year is about 36°C and average daily minimum is 21°C. Rainfall is generally low with mean annual rainfall ranging from 600mm to 1000mm across the Basin (Affodile, 2002).

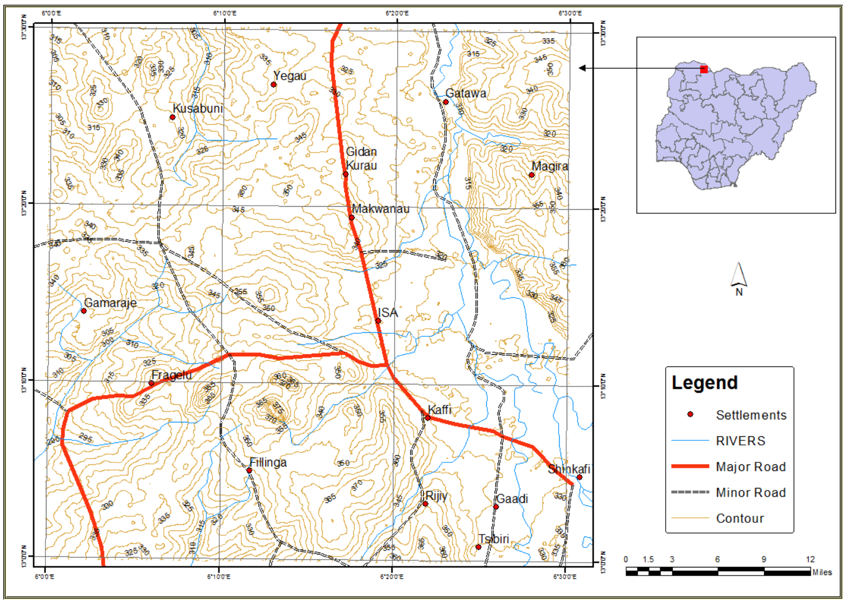

Figure 1: Topographic Map of the Study Area (After Digital Elevation Model (DEM), 2006)

The geology of the Sokoto basin is very well documented by several authors such as Bonde *et al*. (2014), Obaje *et al*. (2013) and Kamba *et al.*, (2016). According to the geology of Nigeria 2006, the study area (Fig. 2) is unified into Rima Group and Gundumi formation. The Rima group consists of the Wurno formation, Dukamaje formation and Taloka formation. The Wurno formation marks the top unit of the Rima Group and consists of about 25m to 50m of pale fine sand and some silt. Towards the southern part of the study area the lithology changes from the typical fine grained sands and clays to medium and coarse sands with less abundant clays. The Dukamaje formation consists of shale, some limestone and mudstones. It contains some shally bone beds with numerous fragments of fossil vertebrae, limbs and skulls which lie near the base. The thickness of the formation varies from 23m at the type area, to less than 0.5m in places. Good exposures are found on the valley of the Rima River near Wurno. The Taloka formation is the oldest of the group, with a maximum thickness of 180m. It consists of essentially sandstones and mudstones. Good exposures are found at Guronyo, Taloka and Shinaka. It consists of white fine- grained friable sandstones and siltstones with intercalated mudstone and shales. The Gundumi formation consists of clays, sandstones and pebble beds, seems to be lacustrine and fluvitile in origin. The maximum thickness of the formation is found to be up to 300m near the Niger border. The base is mark by conglomeritic beds which are well preserved and exposed by the road side at Tureta and Ruwan

Kalgo (Kogbe 1976). These basal beds contain rounded quarts cobbles and pebbles and attain a thickness of about 3m. The formation is the oldest sedimentary rock in the northern part of the study area and it lies uncomfortably on the Basement Complex.

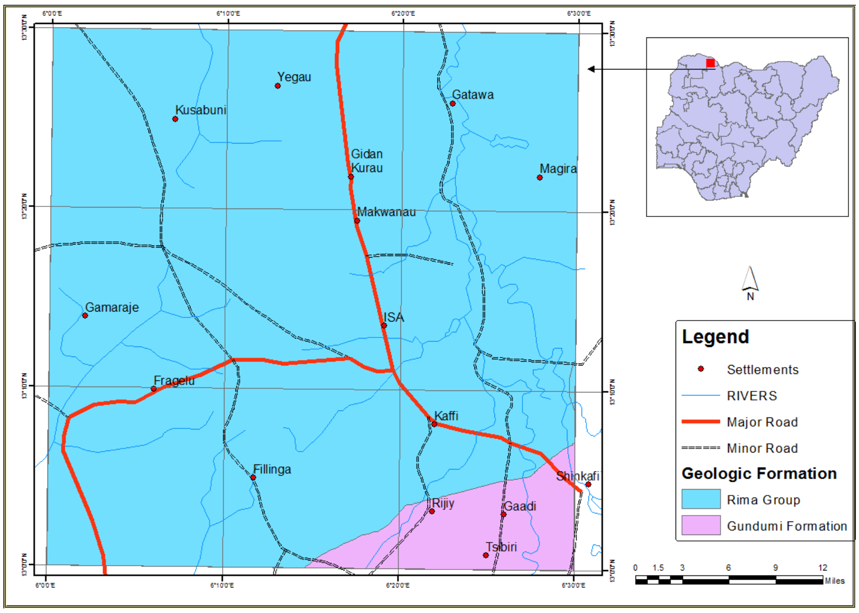

Figure 2: Geologic Map of the Study Area (After Nigerian Geological Survey Agency, 2006)

Materials and Methods

Data Acquisition

The high resolution Aeromagnetic data that was used for this study consist of one sheet of 30'x30' with sheet number 12, which was obtained from Nigeria Geological survey Agency Abuja (NGSAA). The high resolution Aeromagnetic geophysical surveys were carried out throughout the whole country in phases from 2003 to 2009). The study area (Sokoto basin) is part of the Phase II of the Geophysical Surveys which covers about 56% of the country. The country was divided into five geologic blocks. The blocks are D1, D2, D3, D4 and D5. The study area falls in D5, which has 388,518 line kilometers, Flight line spacing of 500 m, Terrain clearance of 80 m, flight line direction of NW-SE, Tie line spacing of 2 km and Tie line direction of NE-SW.

Data Analysis

The processing of the Aeromagnetic data involves the use of various filters that enhanced certain features for interpretation. The higher resolution aeromagnetic data was subjected to high resolution filtering techniques such as polynomial filtering to obtain the regional and the residual maps, and spectral analysis to determine average thickness. All these were carried out using the Oasis montaj, math lab and sufer 11software.

In polynomial fitting the regional is matched with a mathematical Polynomial of low order to expose the residual features as random errors, and the treatment is based on statistical theory. The observed data are used to compute, usually by least square method, the mathematically described surface is given the closet fit to the magnetic field that can be obtained within a specified degree of detail. This surface is considered to be the regional field and the residual is the difference between the magnetic field value thus determined (Udensi, 2001). The simplest approach is to fit a polynomial of first order to the magnetic data over a large area as possible around the zone of interest and to subtract the polynomial surface from the observed surface. If the regional field were a simple inclined plane it will be a first order surface. Thus

$$Z = A x + By + C \text{……..1}$$

The next stage of complexity is the representation of a second order polynomial where,

$$Z = A x^2 + By^2 + CxyDx + Ey + F \text{………2}$$

Determination of depths to buried magnetic rocks is among the principal applications of an aeromagnetic data. The depths are commonly computed from measurement made on the widths and slopes of an individual's anomaly of the aeromagnetic profiles. The statistical approach has been found to yield good estimates of mean depth to basement underlying a sedimentary basin (Hahn *et al*., 1976, Udensi, 2001).

In this work, the characteristics of the residual magnetic field were studied using statistical spectral methods. This is done by first transforming the data from space to the frequency domain and then analyzing their frequency characteristics. In the general case the radial spectrum may be conveniently approximated by straight line segments the slopes of which relate to depths of the possible layers, (Spector and Grant, 1970, and Hahn *et al*., 1976). The residual total magnetic field intensity values are used to obtain the two dimensional Fourier Transform, from which the spectrum is to be extracted from the residual values T(X, Y) consisting of M rows and N columns in X -Y. The evaluations will be done using an algorithm that is a two dimensional extension of the fast Fourier transform (Oppenheim and Schafer, 1975). Next, the frequency intervals are subdivided into sub-intervals, which lie within one unit of frequency range. The average spectrum of the partial values together constitutes the radial spectrum of the anomalous field (Hahn *et al*., 1976, Kangkolo, 1996 and Udensi, 2001). If the z is the mean depth of the layer, the depth factor for this ensemble of anomalies is exp (-2zk). Thus the logarithmic plot of the radial spectrum would give a straight line whose slope is -2z.

The mean depth of the burial ensemble is thus given as:

$$Z = \frac{m}{2} \ldots\ldots\ldots\ldots\ldots 3$$

Where (m) is the slope of the best fitting straight line.

Equation (4) can be applied directly if the frequency unit is in radian per kilometer. If however, the frequency unit is in circle per kilometer, the corresponding relationship can be expressed as:

$$Z = \frac{m}{4\pi} \ldots\ldots\ldots\ldots\ldots 4$$

In this study the aeromagnetic data set was divided into a block of 7.5" x 7.5" data points totaling 16 blocks which were subjected to Fast Fourier transformation (FFT) to compute the power spectrum of the magnetic data using Oasis Montaj software.

Results and Discussion

The result of the analysis of high resolution aeromagnetic data of Isah and environs shows that, the total magnetic intensity map of the study area can be grouped into low magnetic intensity areas, which vary from -78.0nT to 60.6nT, moderate magnetic intensity areas with values of 64.2nT to 93.0nT and high magnetic intensity areas with susceptibility values ranging from 95.4nT to 147.7nT. Low magnetic intensity areas are prevalent in the southern part, northeastern part and pockets orienting diagonally in the northwest to southeast. The moderate magnetic anomalies dominate the central eastern part and smaller portions in the northern, southern and eastern parts of the study area. High magnetic intensity areas are dominant in the eastern part and northwestern parts. Figure 3 shows the Total Magnetic Intensity Map of the study area.

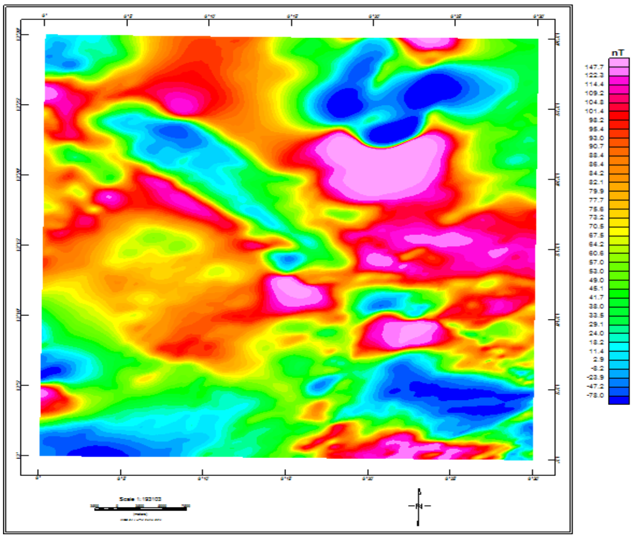

Figure 3: Total Magnetic Intensity Map of Study Area

The residual magnetic intensity map was also classified into low, moderate and high susceptibility areas. The result shows that, low magnetic areas ranges from -89.2nT to -0.5nT, which occur in the almost in every part of the study area, moderate magnetic intensity areas are the second to the low magnetic intensity areas and align diagonally from the northwest to southeast. It has values ranging from 1.5nT to 25.0nT. High residual magnetic intensity areas have values varying from 28.0nT to 74.7nT. It is dominant in the northern and southern parts of the study area with disseminations aligning from the northwest to southeast (Fig. 4).

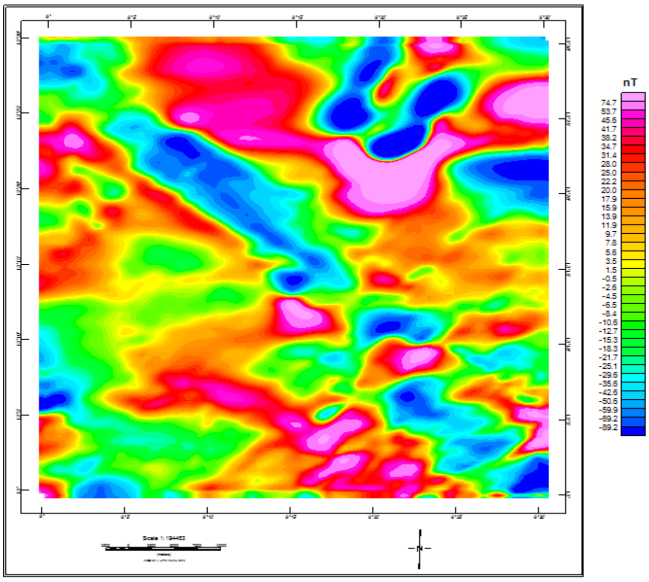

Figure 4: Residual Magnetic Map of the Study area

The result of the total magnetic and residual magnetic maps shows that, areas with low susceptibility could be sediments that have very low magnetic properties or non-magnetic sediments, while moderate to high susceptibility areas could be sediments of sandstones, ironstones etc., which have been reported in the studies of kogbe, 1976 and Bonde *et al.*, 2014, or probably areas that have igneous intrusions near the surface.

The spectral analysis of the study area was carried out to determined depth to magnetic sources. The examples of some of the graphs of the logarithms of spectral energies against frequencies are shown in Figure 5. Two linear segments were drawn from almost each graph. The depth to the deeper magnetic sources (D1), from the slope of the longest part of the wave length spectrum and the depth to the shallow magnetic sources (D2) of that distribution from the slope of the second longest wave length segment was calculated. The deeper sources ranges from 1.06 km to 2.08km, while the shallow sources ranges from 0.653 km to 0.98 km respectively. Table 1 shows the summary of the depths (D1 and D2). The results of D1and D2 were contoured to produce contoured maps of D1 and D2 (Fig. 6i and 7i). Also 3D surface maps of D1 and D2 were produced (Fig. 6ii and 7ii).

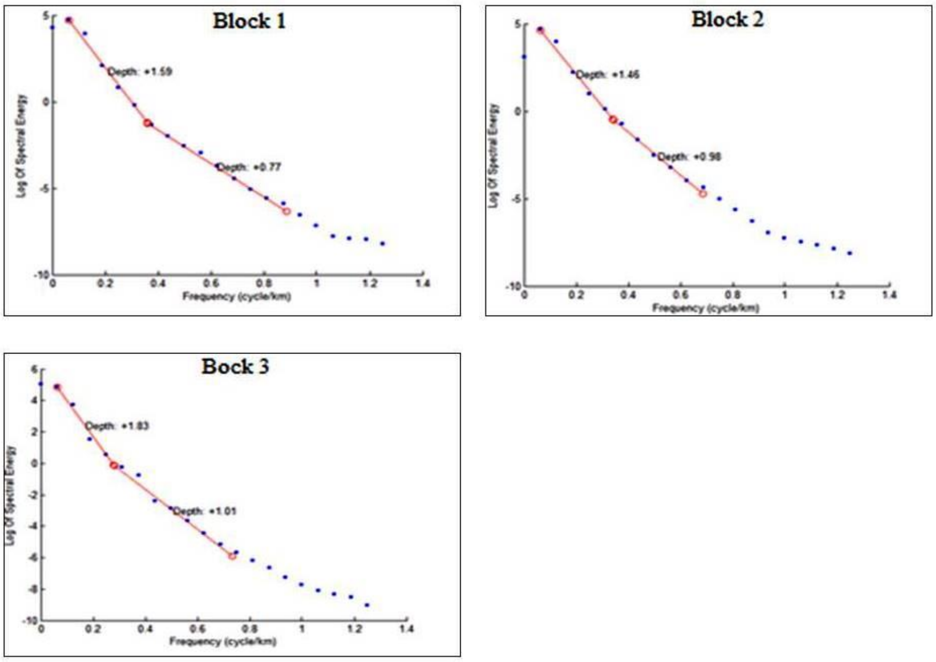

Figure 5: Examples of Graphs of Spectral Blocks 1 to 3 Obtained in the Study Area.

Table 1: Deeper (D1) and Shallow (D2) Magnetic Source depths obtained from Spectral Blocks of the Study area

BLOCK 1 D1 = 1.59 D2 = 0.77	BLOCK 2 D1 = 2.08 D2 = 0.967	BLOCK 3 D1 = 1.52 D2 = 0.967	BLOCK 4 D1 = 1.46 D2 = 0.98
BLOCK 5 D1 = 1.53	BLOCK 6 D1 = 1.83 D2 = 1.01	BLOCK 7 D1 = 1.18 D2 = 0.956	BLOCK 8 D1 = 1.58 D2 = 0.694
BLOCK 9 D1 = 1.62 D2 = 0.938	BLOCK 10 D1 = 1.43 D2 = 0.958	BLOCK 11 D1 = 1.96 D2 = 0.834	BLOCK 12 D1 = 1.21 D2 = 0.761
BLOCK 13 D1 = 1.06	BLCOK 14 D1 = 1.48 D2 = 0.67	BLOCK 15 D1 = 1.21 D2 = 0.766	BLOCK 16 D1 = 1.49 D2 = 0.653

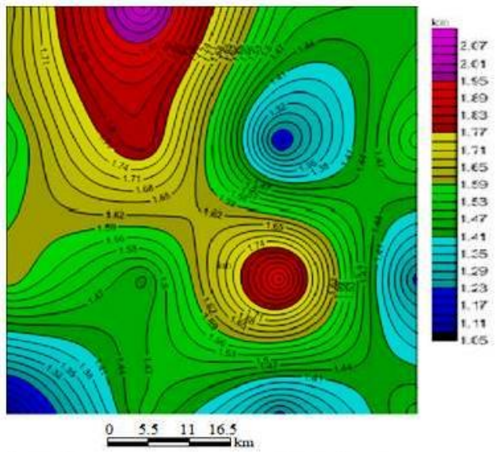

Figure 6i: Contoured Deeper (D1) Magnetic Source Depth of the Study area (Cont. Int. 0.03km),

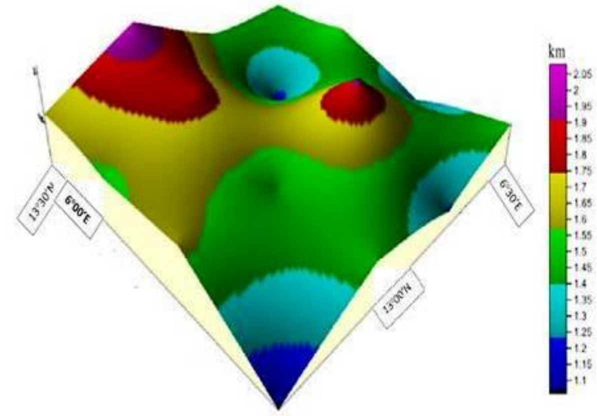

Figure 6ii: Three Dimension (3D) Surface Map of Deeper (D1) Magnetic Sources of the Study Area.

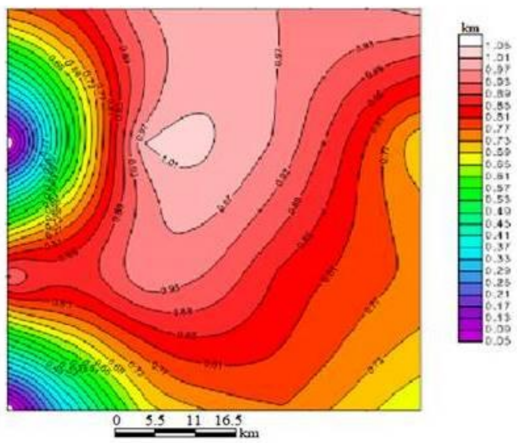

Figure 7i: Contoured Shallow (D2) Magnetic Source Depth of the Study area (Cont. Int. 0.04km)

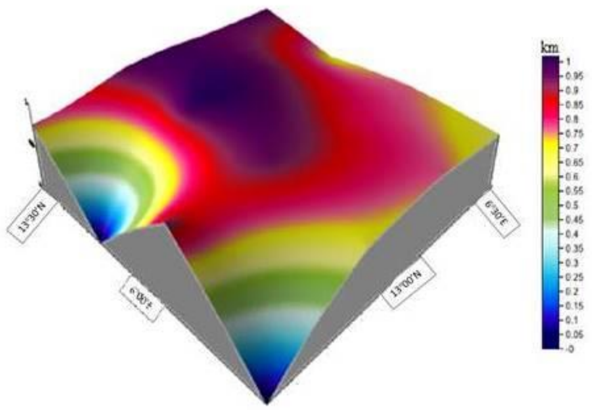

Figure 7ii: Three Dimension (3D) Surface Map of Shallow (D2) Magnetic Sources of the Study Area.

An area with high sediment thickness of 2.08km, was observed at the NNW part of the study area with an aerial extent of 8.5km. According to Nwanko, (2007) and Olasehinde, (2009)), opined that areas with sediment thickness from 2km and above are potential areas for hydrocarbon generation. Therefore, the area with sediment thickness of 2.08km with an aerial extent of 8.5km could be a potential area for hydrocarbon generation, if other conditions are mate. Other areas that have moderate depth, from 1.53km to 1.85km occur in the northwestern part and south eastern part of the study area. This indicate that that 95% of the study area do not have the potentials for hydrocarbon generation but could have potentials for magnetic minerals and mostly non-magnetic minerals due to low susceptibility of the study area. Shallow magnetic source depth (Fig. 7i and 7ii) areas could be potential areas for ground water exploration. Areas with lowest depth of 0.05km occur in the south eastern and northwestern part of the study area. Values above 0.05km, dominate the entire area. These could be igneous intrusions of late magmatic deposits and thus potential areas for mineral exploration.

Conclusion

The analysis of high resolution aeromagnetic data, over Isah and environs northwestern Nigeria was carried out to determined depth to magnetic sources and the potentials for hydrocarbon generation. The finding of the analysis shows that the study area has deeper magnetic sources ranging from 01.06km to 2.08km, while shallow magnetic sources vary from 0.653km to 0.98km. This result shows that, a particular area located in the NNW part of the study area has a depth above 2km. Therefore, this area is a potential area for hydrocarbon generation and thus a potential area for hydrocarbon exploration. Based on the result obtained from the analysis of high resolution aeromagnetic data, part of the study area is said to have the potentials for hydrocarbon generation. Therefore, further detail investigation, using other geophysical methods such as seismic and geochemical studies are recommended.

References

Adelana, S. M. A., Olasehinde, P. I. and Vrbka, P. (2003). Isotopes and geochemical characterization of surface and subsurface waters in the semi-arid Sokoto Basin, Nigeria. *African Journal of Science and Technology,* 4; 76–85.

Affodile, M.E, (2002). *Ground water study and development in Nigeria*: 2nd Edition; Mecon Geology and Eng., Services Ltd., Jos Nigeria, 453p.

Bonde, D. S., Udensi E. E. and Rai J. K. (2014). Spectral Depth Analysis of Sokoto Basin. *IOSR Journal of Applied Physics*, 6(1): 15-21.

Hahn A., Kind E. G., and Mishra, D. C. (1976). Depth estimation of magnetic sources by means of Fourier amplitude spectra. *Geophysical Prospecting* 24, pp.287-308.

Kamba, A. A. Bonde, D. S. and Udensi, E. E. (2016). Spectral Depth Analysis of some Part of in Lower Sokoto Basin, North-West Nigeria, Using Aeromagnetic Data. *Standard Global Journal of Geology and Explorational Research:* 3(5); 226 – 236.

Kangkolo, D. E. Ojo, and S.B. (1996). The Influence of Outlier Points and their Suppression in the Determination of Regional Fields by Polynomial Fitting. Proceedings of the 31st Annual Conference of the Nigerian Mining and Geosciences Society.

Kearey, P., Brooks, M. and Hill, I. (2004). *An Introduction to Geophysical Exploration*. Third Edition, Blackwell Pub.

Kogbe, C. A., (1976). *Outline of the geology of Illummeden Basin, Basin Geology of Nigeria*. Elizabethan Publishing Co. pp. 331-338.

Nigerian Geological Survey Agency Abuja (2006). Geological Map of the study area.

Nwanko, L.I., (2007). Spectral evaluation of aeromagnetic anomaly map for geothermal exploration in part of Nupe basin, west central Nigeria. Ph.D Thesis University of Ilorin.

Olasehinde, O.D. (2009) Investigation of the Geothermal Source Potential of part of the Niger-Delta Nigeria using Aeromagnetic Data. Unpublished M. Tech Thesis, Federal University of Technology, Minna, Niger, Nigeria. Pp. 34-44.

Oppenheim A. V. and Schafer, R. W. (1975). *Digital signal processing practice*. Hall International Inc. New Jersey. Pp. 1227-1296.

Reeves, C. (2005). Aeromagnetic Surveys; Principles, Practice and Interpretation, Training Programme, NGSA, Nigeria.

Spector, A., and Grant, F.S. (1970), Statistical Models for interpreting aeromagnetic data. *Geophysics,* 35:293-302.

Udensi, E. E., Osazuwa, J. B. and Daniyan, M. A. (2001). Production of a Composite Aeromagnetic Map of the Nupe Basin, Nigeria. Jour. of Sci. Tech. and Maths Educ.,Vol. 3(2) Pp 150 -159