SPECTRAL DEPTH ANALYSIS OF PARTS OF BIDA BASIN, NORTH CENTRAL NIGERIA, USING AEROMAGNETIC DATA

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Abstract

Spectral depth analysis of aeromagnetic data covering latitude 8.50^0N to 10.00^0N and longitudes 5.00^0E to 6.00^0E which corresponds to part of central Bida Basin, North Central Nigeria, was carried out for the purpose of investigating the sedimentary thickness beneath the subsurface. The study area was covered by six aeromagnetic maps. The aeromagnetic maps were digitized on a 37 by 37 grid and later compiled to produce a combined aeromagnetic data file for the area. The data file comprised 1369 data points. The polynomial fitting method was applied in the regional-residual separation. The residual map was later sub-divided into 16 spectral sections. The result of the study shows that the first layer depth was 1.8km while the second layer depth was 2.85 km with an average thickness of 2.0km. The maximum depth of 2.8km could be found at the South- Eastern part while the minimum depth of 1.8km could be found at North–Western part. Several depressions or variations in thickness have been observed in some parts of Bida Basin, particularly around Egbako and Pategi areas. These deeper sections of the Bida sedimentary basin identified in this study might be possible potentials sites for hydrocarbon deposits and is therefore recommended to be subjected to further geophysical method like seismic reflection/refraction, so as to ascertain its hydrocarbon potential.

Keywords: Aeromagnetic data, Spectral, Depth, Sedimentary depth, First and Second layer depth

1. Introduction

Up to 90% of Nigeria economy depends on crude oil from the south, but this has greatly affect the potential stability of the country, as this (Crude oil) is today only found in the southern part of the country, in order to resolve the political in-balance there is need to explore our inlands basin in the country for possible presence of crude oil resources, of which Bida Basin is one of those Basins being suspected to have high hydrocarbon potential as reported recently in the media. This study will be very useful on a reconnaissance basis for oil. The Spectral analysis of aeromagnetic fields over the area would differentiate and characterize regions of sedimentary thickening from those of uplifted or shallow basement and also to determine the depths to the magnetic sources. The results could be used to suggest whether or not the study area has the potential for oil/gas concentration. This study area is bounded by latitude 8.50^0N to 10.00^0N and longitudes 5.00^0E to 6.00^0E located within the North Central part of Bida Basin, Nigeria (Figure 1). It is covered by 6 aeromagnetic maps. The data from each digitized map is stored in a 37 by 57 coding sheet and later compiled to produce a combined aeromagnetic data file for the area.

2. Geology of the Study Area.

The study area covers extensively the central part of Bida Basin (Northern part of Bida Basin). Map of Nigeria shows the location of the study Area and the geological map of the area, Figure 1 and Figure 2. The study area covers Fashe, Akerre, Mokwa, Egbako, Lafiagi and Pategi. All the rocks in the study area belong either to the upper Cretaceous or to the Precambrian rocks of the Basement complex (Russ, 1957; Adeleye, 1973 and 1976; Udensi *et al.,* 2003). The Nupe sandstones consist of slightly cemented fine to coarse-grained sandstones and siltstones with interbedded thin beds of carbonaceous shales and clays. The Nupe sandstones appear to lie directly on the Basement (Adeleye, 1976).

3. Materials and Method

The aeromagnetic dataset used for the study was obtained from the Nigerian Geological Survey Agency between 1974 and 1980. The magnetic data were collected at a nominal flight altitude of 154.2m along approximately N-S flight lines spaced at 2 km apart. The study area is covered by six aeromagnetic maps of total-field intensity in ½ ° by ½ ° sheets. These are numbers 161, 162, 181, 182, 203 and 204 on a scale of 1:100, 000. The magnetic values were plotted at 10nT (nano Tesla) interval. The actual magnetic values were reduced by 25,000 gammas before plotting the contour maps. This means that the value of 25,000 gammas should be added to the contour values so as to obtain the actual magnetic field at a given point. A correction based on the international Geomagnetic Reference Field, IGRF, and epoch date

January 1, 1974 was included in all the maps. The data used were digitized on a 19 by 19 grid systems and later compiled to produce a combined aeromagnetic data file for the area (Figure 3a). The data file comprised 1369 data points. The polynomial fitting method was applied in the regional-residual separation. The residual map (Figure 4) was later sub-divided into 16 spectral sections.

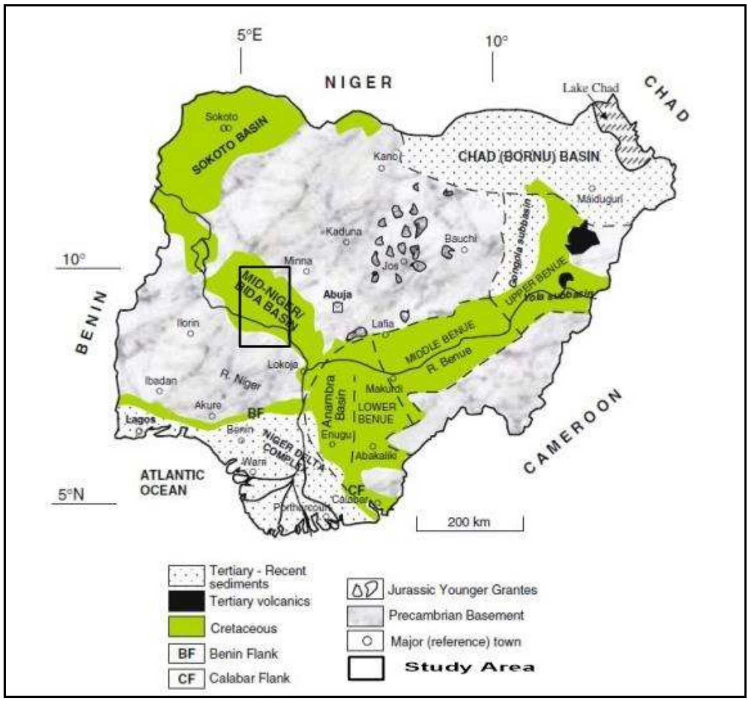


Figure 1: Location of the Study Area on Generalized Geological Map of Nigeria (Adopted from Obaje, 2009)

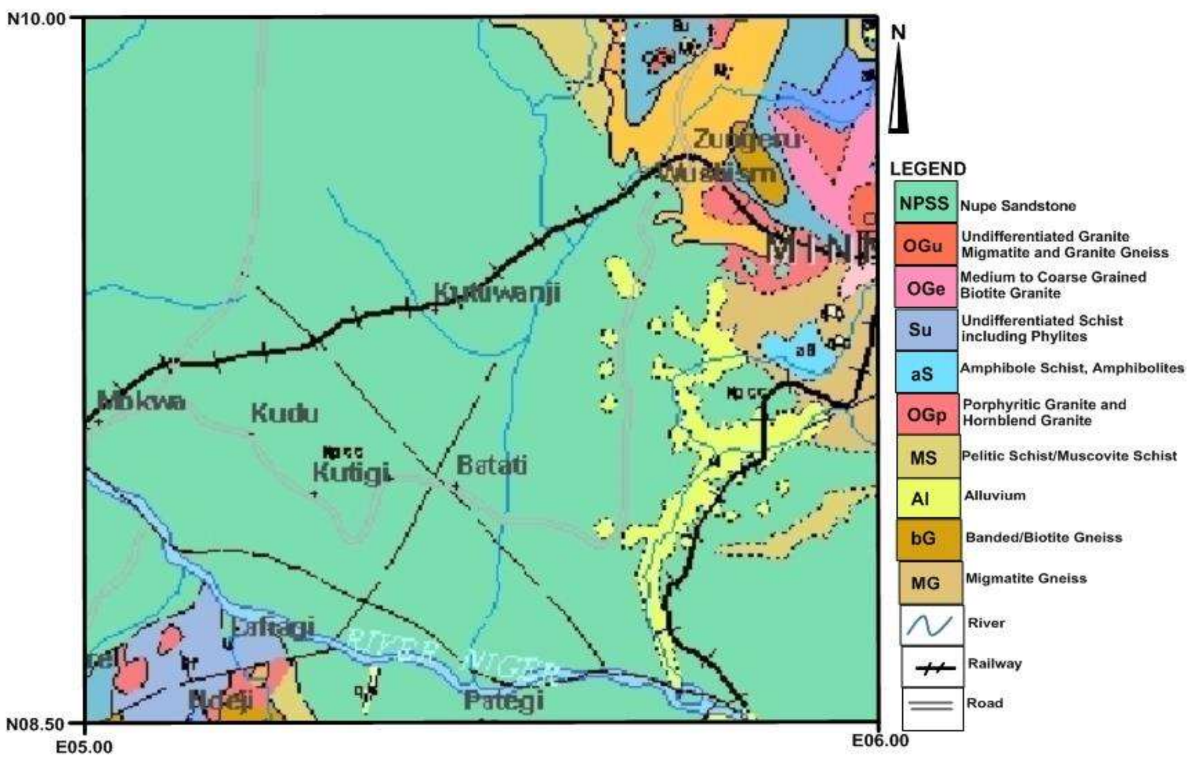


Figure 2: Geological Map of the Study Area (Adapted from Nigeria Geological

Survey Agency, 2006)

4. Spectral Analysis

The Fourier transform of the potential field due to a prismatic body has a broad spectrum whose peak location is a function of the depth to the top and bottom surfaces and whose amplitude is determined by its density or magnetization.The peak wave- number (ω') can be related to the geometry of the body according to the following expression.

$$\omega' = \frac{In\left(^{h_b}/_{h_t}\right)}{h_b - h_t} \qquad (1)$$

where,

ω' is the peak wave-number expressed in radian /ground

h_t is the depth to the top

h_b is the depth to the bottom.

For a bottomless prism, the spectrum peak at the zero wave – number, is given according to the expression:

$$f(\omega) = e^{-H\omega} \qquad (2)$$

where ω is the angular wave - number expressed in radians/ground – unit and h is the depth to the top of the prism. (Bhattacharyya, 1996) for a prism with top and bottom surface, the spectrum is:

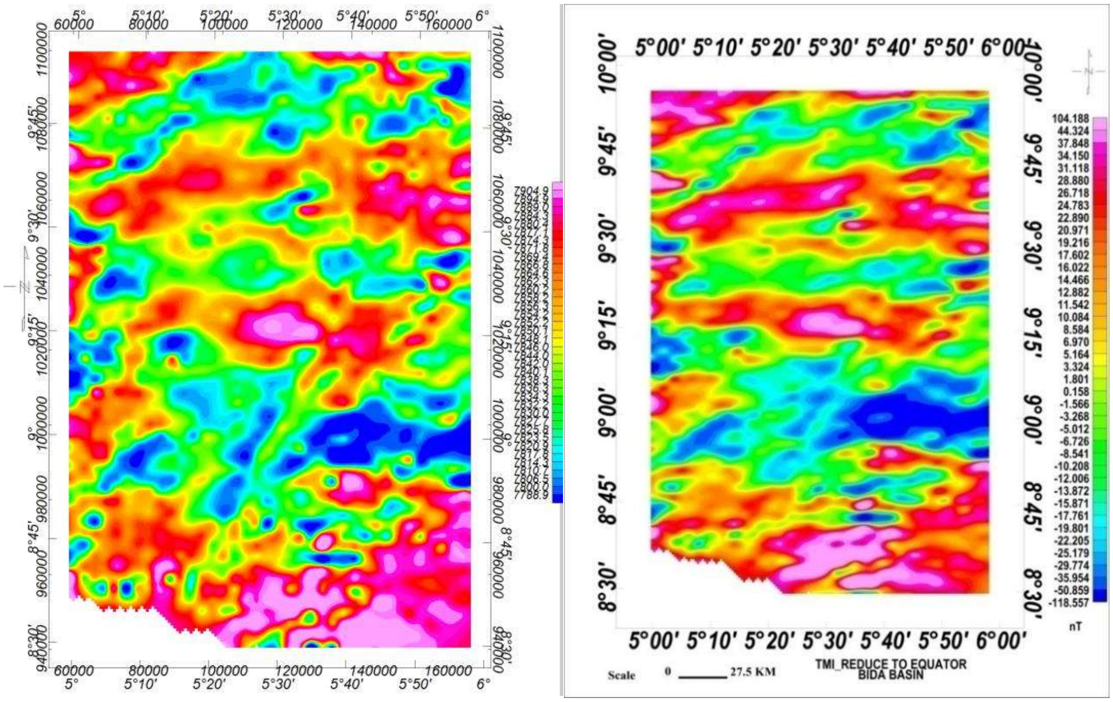
$$f(\omega) = e^{-h_t\omega} - e^{-h_b\omega} \qquad (3)$$

where h_t and h_b are the depths to top and bottom surface respectively. As the prism bottom moves closer to the observation point at surface, the peak moves to a higher wave number. When looking at the spectrum, it is important to note that the amplitude of a deep prism does not exceed the amplitude of the same prism at shallow depth at any wavenumber. The effect of increasing the depth is to shift the peak to lower wavenumbers.

Because of this characteristic, there is no way to separate theeffect of deep sources from shallow sources of the same type by using wavenumber filters. The sources can only be distinguished if the deep sources have greater amplitude or if the shallow sources have less depth extent. When considering a line that is long enough to include many sources, the log spectrum of this data can be used to determine the depth to the top of a statistical ensemble of sources using the relationship.

$$LogE(k) = 4\pi hk \qquad (4)$$

where h is the depth in ground – units and k is the wavenumber in cycles / ground – unit. The depth of an'ensemble' of source can be determined by measuring theslope of the energy



(a) **(b)**

Figure 3: (a) Total Magnetic Intensity Map of the Study Area after 25,000nT have been Removed (b) TMI Reduced to Equator Map of the Study Area

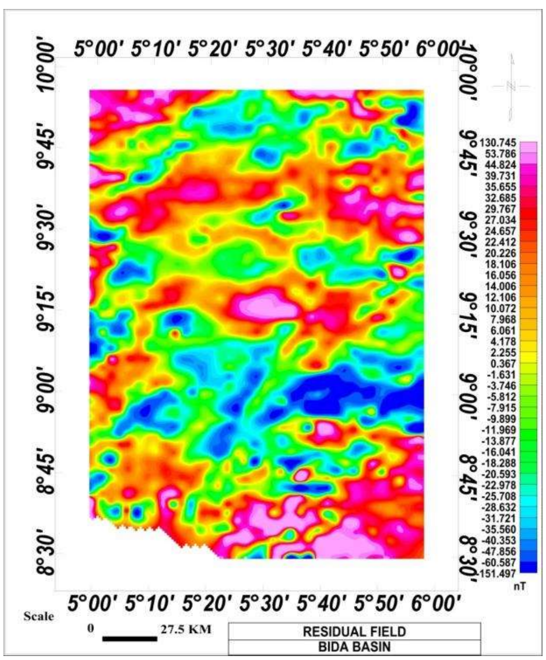


Figure 4: Residual Field Map of the Study Area

(power) spectrum and dividing by 4π. A typical energy spectrum for magnetic data may exhibit three parts – a deep source component, a shallow source component and a noise component and a noise component. The residual map of the study area was divided into sixteen (16) blocks of overlapping magnetic sections. The divisions of residual data/map into 16 spectral sections was done with Oasis Montaj and the spectral energies were plotted within it,*. SPC file obtained were later exported into the Microsoft Excel worksheets one after the other until the total number of 16 spectral (*SPC) energy files were exported. The Microsoft Excel worksheets file obtained was later used as an input file into a spectral program plot (SPP) developed with Matlab. The total numbers of 16 spectral energies were plotted in Matlab with the developed program. Atypical plot of energy against frequency (wavenumber) is as shown in Figure 4. From the slopes of the plot, the first and second magnetic source depth was respectively estimated using the relations below:

$$Z = -\frac{m}{4\pi} \qquad (5)$$

where m and z is the slope and the depth respectively

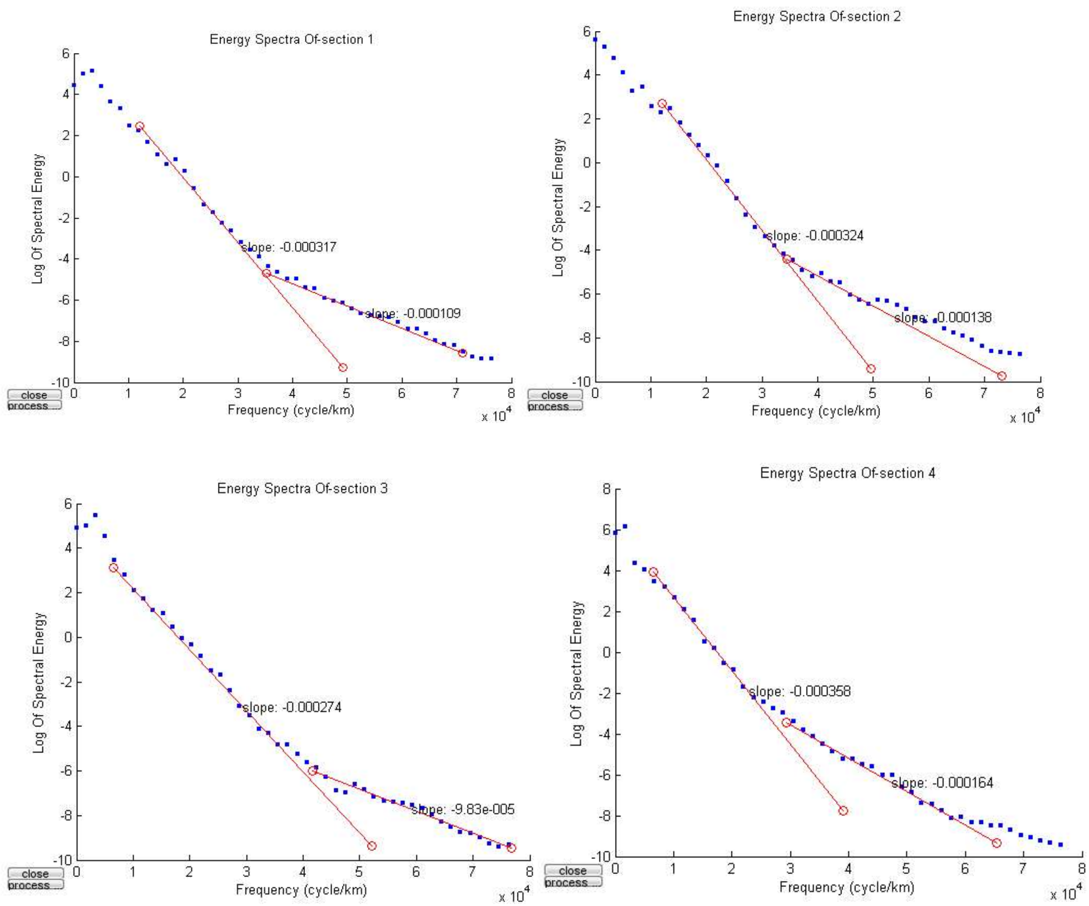


Figure5: Atypical plot of energy spectrum against frequency for sections 1-4

The coordinates of each spectral block were obtained by summing the values of the bounding latitude and longitude and averaging it. This was used in plotting the spectral energy against frequency as presented in Figure 5.

5. RESULTS

Equation (5) shows the relationship between the depth (h) to the basement and the decay slopes (m) of the energy spectrum. Table 1 shows the estimated magnetic sources for both the shallow source (depth 1) and deeper sources (depth 2). The primary sources that account for the first layer depth derived from the statistical spectral analysis are the magnetic rocks that intrude the sedimentary formation.The Second layer depth may be attributed to magnetic rocks that are emplaced or intruded into the basement underlying the sedimentary basin. Intra basement features like fractures and faults are other sources of the second layer depth.Result of spectral analysis of the aeromagnetic data over the Bida area revealed two depth source models.

The first layer (h1) varies from a thickness of1.8 km to 2.85 km with an average thickness of 2.0km. The maximum depth of 2.85km could be found at the South- Eastern part while the minimum depth of 1.8km could be found at North–Eastern part of Figures5a and 5b.Figure 5(b) is the 3D view of the depth to basement within the subsurface, the map is contoured with the depth values inverted by multiplying the depth values in Figure 5a by (-1).Several depressions or variations in thickness have been observed in some parts of Bida Basin, particularly around Egbako, Pategi and Mokwa areas. The highest sedimentary thickness observed from Figure 5b is the depression seen at the south-eastern part of the study area which corresponds to Egbako and Pategi areas. These areas correspond to areas with highest magnetic values of total magnetic intensity (TMI) map of Figure 3 and residual map of Figure 4. These deeper sections of the Bida sedimentary basin identified in this study might be possible potentials sites for hydrocarbon deposits and is therefore recommended to be subjected to further investigations.

The spectral depth value of 2.8 km agreedat large with the views of Kogbe (1989) thatthe total thickness of Cretaceous sediments in the eastern portion of southern Nigeria basins is about 3.3km.Similarly, Udensi and Osazuwa (2003) got the depth estimate of about 3.3 km for the entire Bida Basin.

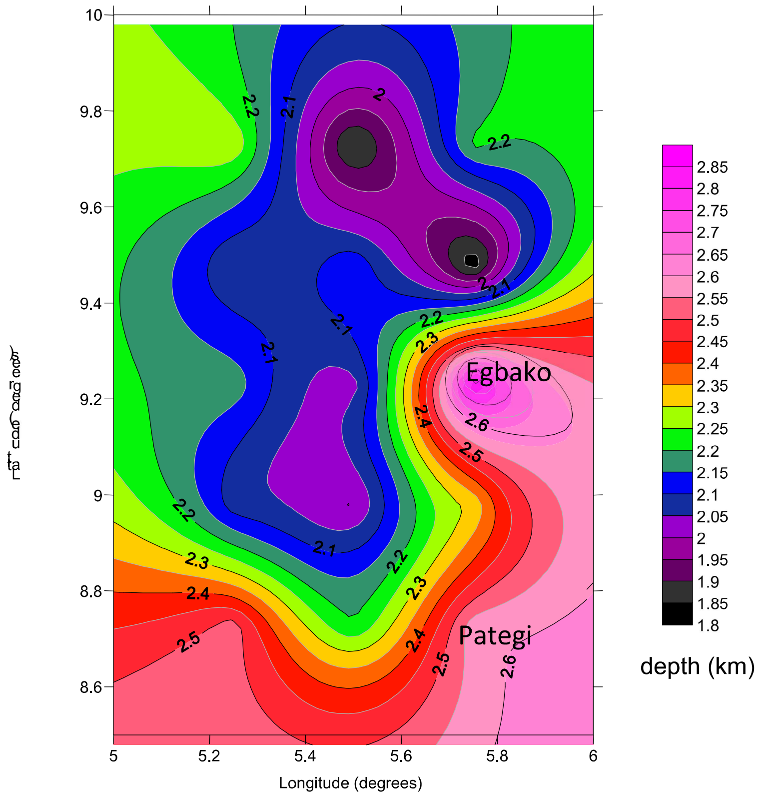
Table 1: Estimated depth to the shallow (depth 1) magnetic sources and deep (depth 2) magnetic sources in km

S/ No	Spectral Section	Longitude	Latitude	M1	M2	h_1(km)	h_2(km)
1	SPT1	5.25	8.75	-0.000317	-0.000109	2.521	0.867
2	SPT2	5.75	8.75	-0.000324	-0.000138	2.577	1.097
3	SPT3	5.25	9.25	-0.000274	-0.000146	2.179	1.161
4	SPT4	5.75	9.25	-0.000358	-0.000164	2.847	1.304
5	SPT5	5.25	9.75	-0.000288	-0.000172	2.290	1.368
6	SPT6	5.75	9.75	-0.000278	-0.000148	2.211	1.177
7	SPT7	5.5	8.75	-0.000277	-0.000153	2.203	1.217
8	SPT8	5.5	9.25	-0.000255	-0.000159	2.028	1.264
9	SPT9	5.5	9.75	-0.000231	-0.000143	1.837	1.137
10	SPT10	5.25	9.0	-0.000261	-0.000158	2.076	1.256
11	SPT11	5.25	9.5	-0.000258	-0.000148	2.052	1.177
12	SPT12	5.75	9.0	-0.000291	-0.000162	2.314	1.288
13	SPT13	5.75	9.5	-0.000228	-0.000178	1.813	1.415
14	SPT14	5.5	9.0	-0.000251	-0.000162	1.996	1.288
15	SPT15	5.5	9.5	0.000269	-0.000143	2.139	1.137
16	SPT16	5.5	9.25	-0.000283	-0.000165	2.251	1.312

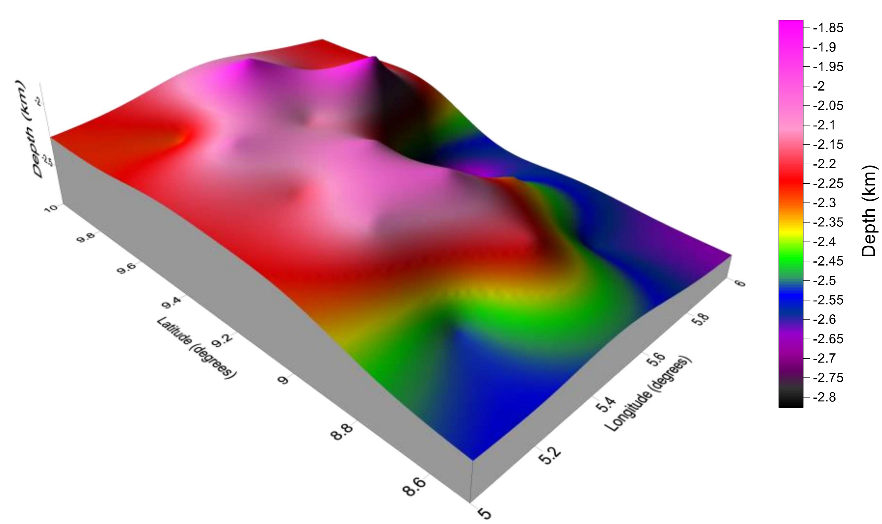
M_1 and M_2 are slopes of the first and second of the plot while Z_1 and Z_2 are first and second depths respectively (Table 1).

6. Summary and Conclusion

Presence of hydrocarbon and its potential is enhanced by the thickness of the sediments of the basin, and also by the kind of geological structure existing within the basement that forms traps for oil and gas.The highest sedimentary thickness obtained with spectral analysis is 2.8 km, located at the south-eastern part of the study area around Egbako and Pategi. This thickness may be sufficient for hydrocarbon (gas) presence in the area.


Egbako
Pategi
depth (km)
Longitude (degrees)
2.85
2.8
2.75
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8

(a)


Depth (km)
Latitude (degrees)
Longitude (degrees)
-1.85
-1.9
-1.95
-2
-2.05
-2.1
-2.15
-2.2
-2.25
-2.3
-2.35
-2.4
-2.45
-2.5
-2.55
-2.6
-2.65
-2.7
-2.75
-2.8

(b)

Figure 5: **(a)** Contour map of first layer magnetic source contour interval is 0.05km **(b)** 3D of deeper magnetic sources

References

Adeleye, D.R. (1973). Origin of Ironstones: An Example from Middle Niger Valley, *Nigerian Journal of Sedimentary Petrology, 43, 709-727.*

Adeleye, D.R. (1976). The Geology of Middle Niger Basin. In: C.A.Kogbe (editor), *Geology of Nigeria,* Elizabethan, Lagos, pp. 283-287

Bhattacharyya, B.K. (1966). A method for computing the total magnetization vector and the dimensions of a rectangular block-shaped body from magnetic anomalies.*Geophysics, 31, 74-96*

Obaje, N.G. (2009) *Geology and Mineral resource of Nigeria* Berlin: Springer-Verlag Heidelberg, Pp. 221.

Kogbe, C. A. (1989(b)): The Cretaceous and Paleogene Sediments of Southern Nigeria. In: Kogbe C. A. (Ed.) Geology of Nigeria(2nd Ed.). Rock View (Nig.) Ltd, 325-334.

Russ, W. (1957).The Geology of part of Niger, Zaria and Sokoto Province.*Geological Survey of Nigeria Bulletin, 27, 1-42.*

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

Udensi, E.E, Osazuwa, I.B., and Daniyan, M.A. (2003). Trend Analysis of the Total Magnetic Field over the Bida Basin, Nigeria. Nigerian Journal of Physics 15(1), 143-151