

Original Research Article**Estimation of Sedimentary thickness Using Spectral Analysis of Aeromagnetic Data over part of Bornu Basin, Northeast, Nigeria****ABSTRACT**

The aeromagnetic data (High resolution) over part of Bornu Basin NE was interpreted using spectral analysis to estimate the sedimentary thickness of the study area. The study area is covered by four aeromagnetic data sheets covering latitude 12°N and 13°N and Longitude 12°E and 13°E with an estimated total area of 12, 100 km². Polynomial fitting method was adopted for the regional-residual separation of the total magnetic intensity. The residual map was divided into nine spectral sections. The result of the study shows a sedimentary thickness that ranges between 0.54 km and 3.35 km. The sedimentary thickness of over 3 km could be found around the South-eastern part of the study area which corresponds to Gubio town while the minimum sedimentary thickness could be found around North-western part of the study area which also corresponds to Borgo town area. The maximum sedimentary thickness of 3.35 km may be sufficient for hydrocarbon presence.

Keywords: Aeromagnetic data, Spectral analysis, Polynomial fitting, Sedimentary thickness and Hydrocarbon maturation

1. INTRODUCTION

Over the years, searching for earth embedded minerals and hydrocarbon (oil and gas) has become a bone of contention in the economy of Nigeria. The bigger part of the nation's income (80%) is gotten from hydrocarbon (oil and gas) profit whereupon more than 160 million overflowing populace relies on upon. As the hydrocarbon potential of the prolific Niger delta becomes depleted or exhausted in the nearest future due to continuous exploitation and inherent crises in the Niger delta region which had led to excessive reduction in oil production for export and domestic use, it is of necessity to shift attention to other sedimentary Basins. In particular, the Bornu Basin which is one of the inland Basins in Nigeria presumed to have high hydrocarbon potential aside other earth minerals with high economic values ²⁰. The Nigerian government have directed one of its Oil-regulating Agency (NNPC) to heighten hydrocarbon prospecting in the Northeast (Bornu Basin). As this will expand Nigeria's oil and gas holds, add qualities to the hydrocarbon potentials of the Nigerian inland basins, in this way, give speculation open doors, help the economy of the nation and also provide many new employments to lessen unemployment definitely in Nigeria. This

36 research will be very useful on a reconnaissance basis for oil and mineral prospecting in the
37 area.

38 Spectral analysis of aeromagnetic data over the area would be used to determine the
39 sedimentary thickness of the study area. The result from the spectral analysis could be used to
40 suggest areas of potential hydrocarbon presence.

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42 **2. GEOLOGY OF THE STUDY AREA**

43 The area of study is part of the Nigerian sector of the Chad Basin, known locally as the Bornu
44 Basin (Figure 1). It is one of the Nigerian inland Basins occupying the north-eastern part of
45 the country. It represents about one-tenth of the total area extent of the Chad Basin, which is
46 a regional large structural depression common to five countries, namely, Cameroon, Central
47 African Republic, Niger, Chad, and Nigeria¹⁴. The Bornu Basin (Study area) falls between
48 latitudes 12°N and 13°N and longitudes 12°E and 13°E with an estimated area of 12,100 km².
49 The Borno State where the area of study is located is endowed with rock mineral base
50 resources such as clay, salt, limestone, kaolin, iron ore, uranium and mica.

51 Geologically, the Bornu basin has been explained as a broad sediment-filled broad depression
52 straddling North-eastern Nigeria and adjoining parts of the Republic of Chad. The
53 sedimentary rocks of the area have a cumulative thickness of over 3.6 km and rocks consist
54 of thick basal continental sequence overlaid by transitional beds followed by a thick
55 succession of Quaternary Limnic, fluvial and eolian sand and clays⁷. The stratigraphy
56 sequence (Figure 2) shows that Chad, Kerri-Kerri and Gombe Formations have an average
57 thickness of 130 to 400 m. Below these formations are the Fika shale with a dark grey to black
58 in colour, with an average thickness of 430 m. Others are Gongila and Bima Formations with
59 an average thickness of 320 m and 3,500 m, respectively¹⁵.

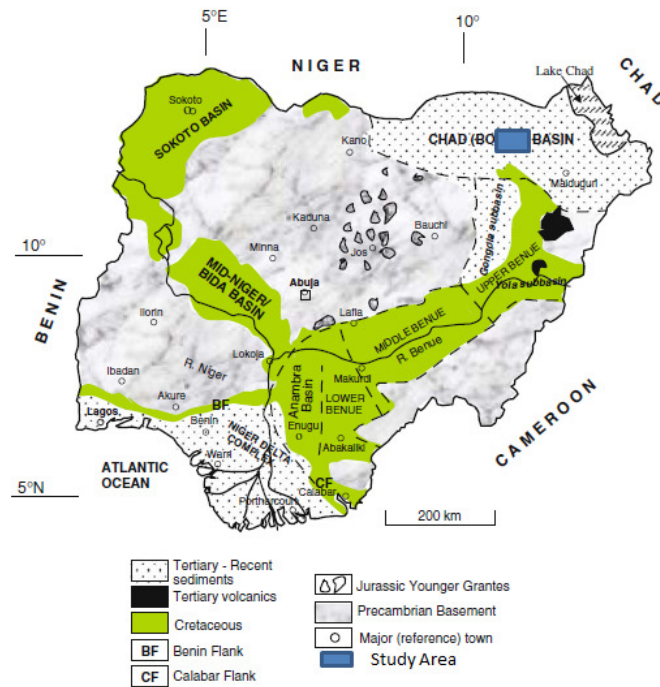


Figure 1: Geological Map of Nigeria showing the study area. (Adapted from ¹⁴)

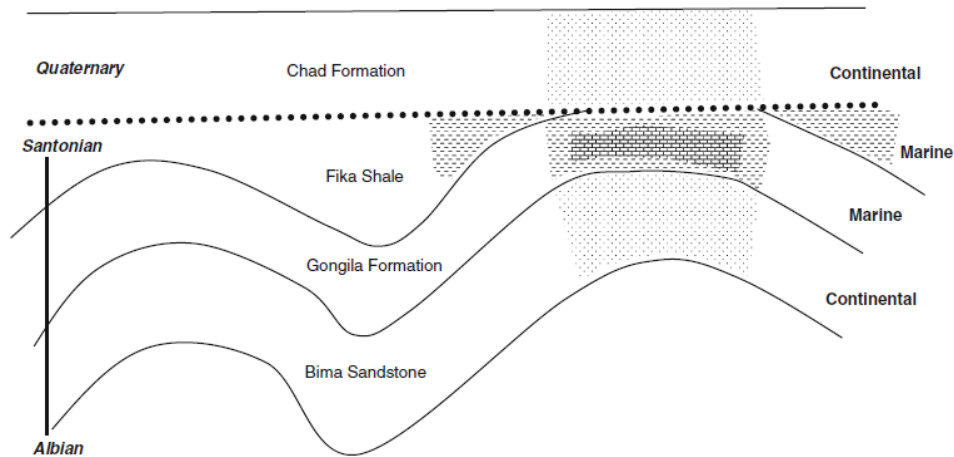


Figure 2: Generalized stratigraphic Sequence of Bornu Basin, Nigeria (Adapted from ¹⁴).

3. MATERIALS AND METHOD

The study area is covered by four aeromagnetic data sheets of total-field intensity in $1/2^\circ$ by $1/2^\circ$ procured from Nigerian Geological Survey agency (NGSA). The sheets are 43 (Borgo), 44 (Bazabure), 65 (Chungulbulturi) and 66 (Gubio). The sheets were merged together to

71 generate the study area using Oasis montaj software. The aeromagnetic data were obtained as
 72 part of the aeromagnetic survey carried out between 2003 and 2009 sponsored by Geological
 73 survey of Nigeria. The data were obtained at an altitude of 100 m along a flight line spacing
 74 of 500 m oriented in NW-SE and a tie line spacing of 2000 m. The maps are on a scale of
 75 1:100,000 and half-degree sheets contoured mostly at 10nT intervals. The geomagnetic
 76 gradient was removed from the data using the International geomagnetic Reference Field
 77 (IGRF). The total area covered was about 12,100 km².

78 The actual magnetic intensity value was reduced by 33,000 nT for handling before the
 79 contour map was plotted. As a result, 33,000 nT must be added to the data so as to get the
 80 actual magnetic intensity at a given point. The total magnetic intensity was contoured and
 81 colour filled to show the high and low total magnetic intensity of the study area (Figure 3).
 82 Polynomial fitting (order one) method was used for the regional-residual separation, Figures
 83 4 and 5 shows the contoured and colour filled regional map and residual map respectively.
 84 The magnetic values found on figure 4 trend northeast-southwest and the lines observed
 85 indicate faults. Since minerals are structurally controlled, minerals present in the study area
 86 like gypsum can be found along the fault lines.

87 **3.1.Spectral Analysis**

88 The statistical spectral analysis of the residual field data was used to determine the depths to
 89 the buried magnetic sources within the subsurface of the study area. Spector and Grant
 90 developed a 2-D spectral depth determination method. Their model assumes that an
 91 uncorrelated distribution of magnetic sources exists at a number of depth intervals in a
 92 geologic column. The Fourier transform of the potential field due to a prismatic body has a
 93 broad spectrum whose peak location is a function of the depth to the top and bottom surfaces
 94 and whose amplitude is determined by its density or magnetization²¹.

95 The peak wave number (ω) can be related to the geometry of the body according to the
 96 following expression.

$$97 \quad W' = \frac{\ln(h_b/h_t)}{h_b - h_t} \quad (1)$$

98 Where W' is the peak wave number in radian / ground – unit, h_t the depth to the top and h_b
 99 is the depth to the bottom.

$$100 \quad f(\omega) = e^{-h\omega} \quad (2)$$

101 Where ω is the angular wave number in radians/ground-unit and h is the depth to the top of
 102 the prism. For a prism with top and bottom surface, the spectrum is:

$$103 \quad f(\omega) = e^{-h_t\omega} - e^{-h_b\omega} \quad (3)$$

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

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

$$115 \quad \text{Log } E(k) = 4\pi h k \quad (4)$$

116 Where h is the depth in ground – units and k is the wavenumber in cycles / ground – unit. The
 117 depth of an ‘ensemble’ of source can be determined by measuring the slope of the energy
 118 (power) spectrum and dividing by 4π . A typical energy spectrum for magnetic data may
 119 exhibit three parts – a deep source component, a shallow source component and a noise
 120 component.

121 In this study, the graph of each energy spectral was obtained with Matlab software purposely
 122 designed to accept the longitude and latitude values alongside with its respective magnetic
 123 values for each of the nine spectral sections label (A –I) where the log of spectral energy
 124 plotted against frequency.

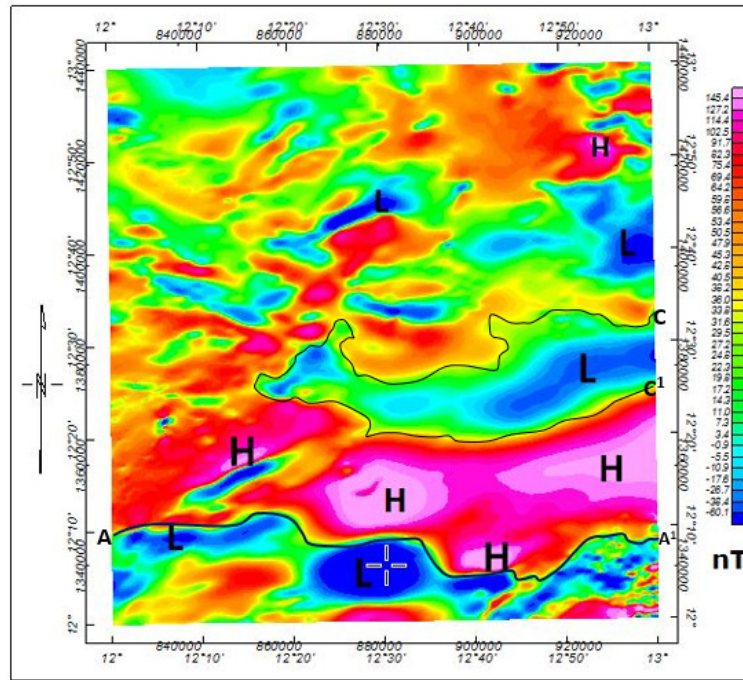


Figure 3: Total Magnetic Intensity Map over part of Bornu Basin. Magnetic 'Lows' are represented by 'L' and magnetic 'Highs' are represented by 'H'. AA¹ and CC¹ are the identified paleo-structures in the study area

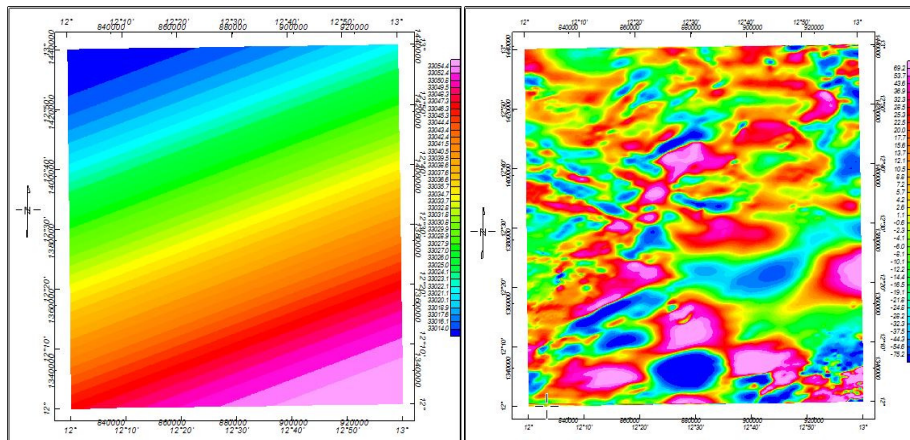


Figure 4: Regional Map of the Study Area

Figure 5: Residual Map of the Study Area

4. RESULTS AND DISCUSSION

The residual map (Figure 4) produced from this study was divided into nine (9) blocks (A-I) of overlapping magnetic sections. Six of the divisions (section SPTA, SPTB, SPTC, SPTD, SPTE, and SPTF) covered 55km² and three others (SPTH, SPTG, and SPTI) covered 110km². The divisions of residual map into nine (9) spectral sections was done with Oasis

Montaj and the spectral energies were plotted, the *.SPC file obtained were later exported into Microsoft Excel worksheets one after the other until the total number of nine (9) spectral (*.SPC) energy files were later used as an input file into a spectral program plot (SPP) developed with Matlab. The total numbers of nine (9) spectral energies were plotted in Matlab with the developed program. A typical plot of energy against frequency (wavenumber) is shown in Figure 6.

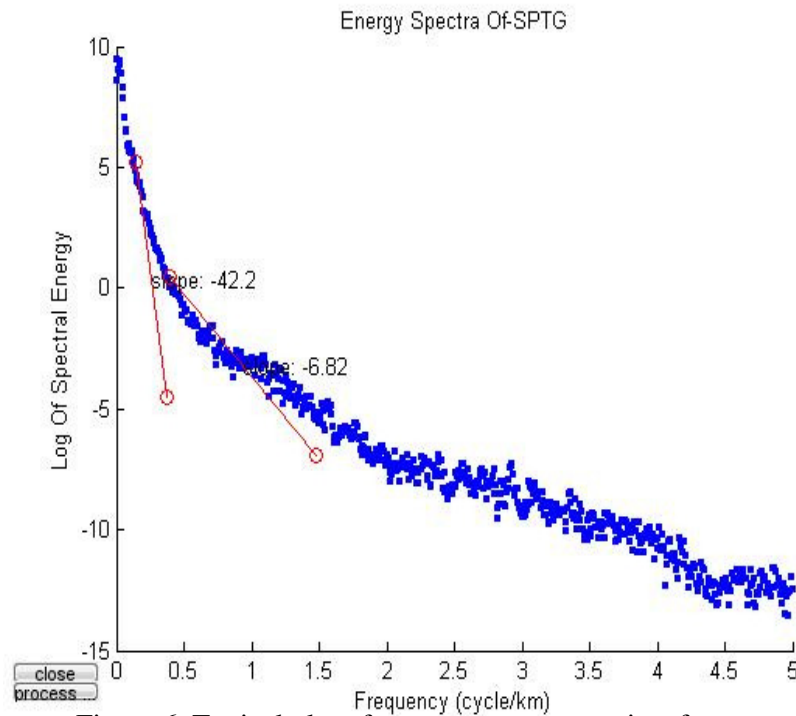


Figure 6: Typical plot of energy spectrum against frequency

The program has been designed to determine the first slope (m_1) and the second slope to calculate for the first and second magnetic depth source using the equations below.

$$Z_1 = -\frac{m_1}{4\pi} \quad (5)$$

$$Z_2 = -\frac{m_2}{4\pi} \quad (6)$$

Where m_1 and m_2 are slopes of the first and second segment of the plot while Z_1 and Z_2 are first and second depths respectively (Table 1).

Substituting for $m_1 = -42.2$ and $m_2 = -6.82$ (Figure 6) into the equation (5 & 6)

Therefore,

$$Z_1 = -(-42.2/4 * 3.142) = 3.35 \text{ Km}$$

Similarly,

155 $Z_2 = -(-6.82/4 * 3.124) = 0.54 \text{ Km}$

156 Figure 6 shows a typical plot of energy spectrum against frequency of section SPTG, two
 157 layers can be observed with their respective depths and magnitude values. The minimum
 158 depth is 0.54 km while the maximum depth source is 3.35 km (Figure 6). Table 1 shows that
 159 the shallow depth source (Z_2) ranges from 0.39 km to 0.64 km while the deeper depth source
 160 (Z_1) ranges from 1.32km to 3.35 km. Figure 7 and 8 shows that the maximum sedimentary
 161 thickness of 3.35 km is more pronounced around Gubio town.

162 Table 1: Estimated depth to deeper magnetic and shallow source in Km

S/N	Sections	Longitude (Degrees)	Latitude (Degrees)	Depth Z1(km)	Depth Z2 (km)
1	SPTA	12.15	12.65	1.32	0.39
2	SPTB	12.65	12.65	1.54	0.53
3	SPTC	12.15	12.15	2.10	0.54
4	SPTD	12.65	12.15	2.77	0.47
5	SPTE	12.5	12.65	1.48	0.29
6	SPTF	12.5	12.15	3.32	0.35
7	SPTG	12.15	12.5	3.35	0.54
8	SPTH	12.65	12.5	3.06	0.46
9	SPTI	12.5	12.5	3.12	0.64

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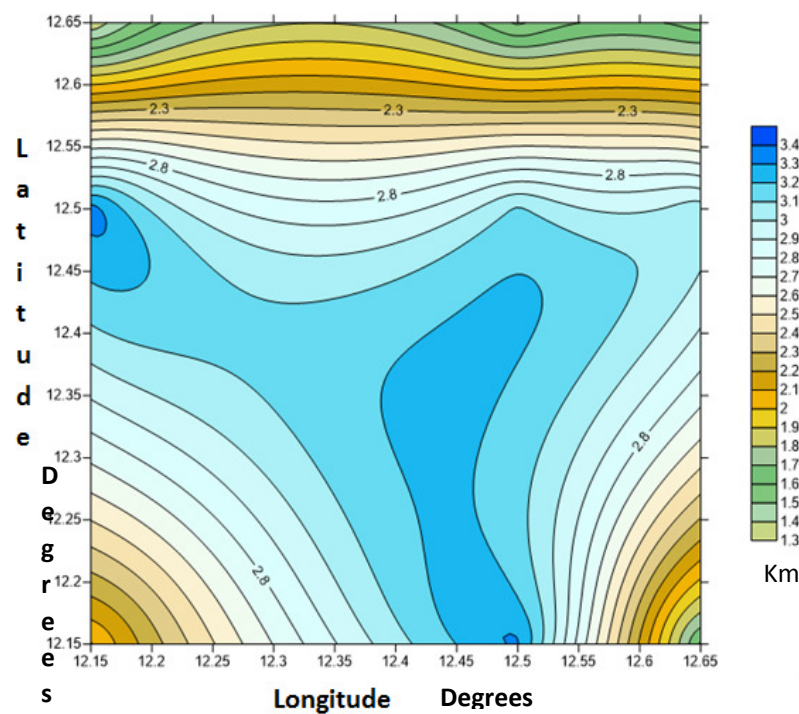


Figure 7: Contour Map of Spectral magnetic depth to top of basement over part of Bornu Basin.

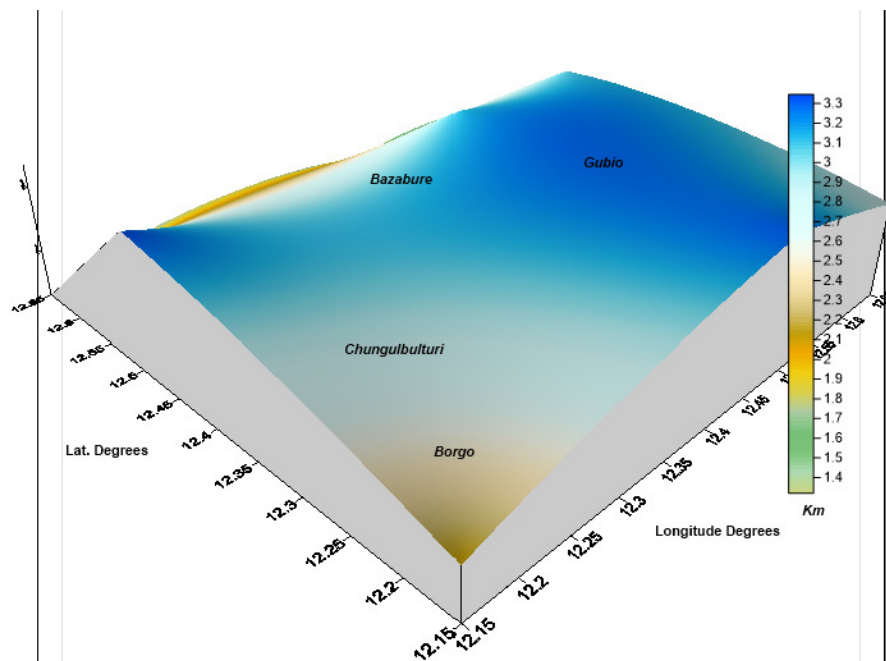


Figure 8: 3D Surface map of magnetic depth to top of basement over part of Bornu Basin.

5. CONCLUSION

Since the nearness and magnitude of minerals, oil and gas must be learned by geophysical investigations of the subsurface geologic structures and the investigation of sedimentary basins for hydrocarbon potential relies upon the sedimentary thickness of the basin for hydrocarbon maturation, it can therefore be concluded that the results from the depth estimation techniques used in this study, spectral analysis with highest sedimentary thickness of 3.35 km is sufficient enough for hydrocarbon maturation and the results also concur with those obtained by other researchers in some part of the Bornu Basin; notably are results of studies by ² and ¹⁷.

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