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SPECTRAL DEPTH ANALYSIS OF PARTS OF BORNO BASIN, NIGERIA, USING AEROMAGNETIC DATA

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Abstract
Statistical spectral analysis of the residual magnetic field values was employed in this research to determine the depth to the magnetic basement rocks of parts of Borno Basin. The area of study lies between latitude 12^{0}N to 13.5^{0}N and longitude 12^{0}E to 13.5^{0}E. The first magnetic layer from spectral depth analysis was attributed to lateritic ironstone, ferruginous sandstone and effect of surrounding basement rocks with an average value of 0.283 km. The second layer was attributed to magnetic rocks that intruded onto the basement surface, lateral discontinuities in basement susceptibilities and inter-basement features like faults and fractures. The second layer thus represents the depth to basement in the area and this depth has an average value of 2.99 km. This represents the average thickness of the sedimentary formation overlying the Basement Complex over the area under investigation. The generalized depth to basement map produced reveals that the basin is relatively shallow with a maximum depth (thickness) of 5.34 km at the northeastern part of the study area. This increases the possibility of hydrocarbon accumulation in the area.

Keywords: Spectral depth, magnetic layer, sediments, basement and aeromagnetic data.

Introduction
The study area covers parts of the Borno Basin- Latitude 12^{0}N - 13.5^{0}N and longitude 12^{0}E - 13.5^{0}E, of square block 24,200 km^2, the Schist belt (Kerikeri formation). This area is situated at the north-eastern part of Nigeria, as shown in Figure 1. The Borno Basin (or "Maiduguri Sub-basin" of Avbovbo *et al.,* 1986) makes up the south-western part of the Chad Basin (Figure 1). The Cretaceous sediments in the Borno Basin are almost entirely concealed by the continental Pliocene to Pleistocene Chad Formation (Carter *et al.,* 1963; Barber, 1965; Miller *et al.,* 1968) which reaches a thickness of over 1500 m (Olugbemiro, 1997). Descriptions of the Borno Basin have been given by Raeburn and Jones (1934), Matheis (1976), Avbovbo *et al.* (1986), Okosun (1995a) and Olugbemiro, (1997). Those parts of the Chad Basin to the north and east were reviewed by Bellion (1989) with important subsequent accounts given by Genik (1992, 1993). The latter provided detailed descriptions of the concealed east Niger, Bongor, Doba, Dosco and Salamat rifts. The southern part of the Borno Basin is covered by the Geological Survey of Nigeria 1/250,000 Series map sheets 25 (Potiskum). Raeburn and Jones (1934), Barber (1965) and Miller *et al.* (1968) produced the geological maps of parts of the area to the north.

The present term "Gongola Basin", correspond to the "Chad Basin" of Carter *et al.,* (1963). A series of N-S to NNE-SSW trending faults controls the trend of the Gongola Basin (Zaborski *et al.,* 1998). The thickest sedimentary successions occur in the western part of the Gongola Basin to which Campano-Maastrichtian and Cenozoic deposits are restricted. Over 5km of sediments occur in the "Dukku", "Ako" and "Bashar" sub-basins; thinner successions occur in the "Lau" and "Numan" sub-basins of the Yola arm (Benkhelil, 1988, 1989). The Yola arm extends eastwards into Cameroun where it is known as the Garoua Basin.

Similarly, Cratchley (in Avbovbo *et al.,* 1986) recognized an ovoid-shaped negative Bouguer gravity anomaly north of Maiduguri. Combining the gravity data with seismic refraction studies, Cratchley *et al.,* (1984) identified a "Maiduguri Trough", thought to contain some 3000m of Cretaceous and

Quaternary sediments, running NNE from near Maiduguri and connecting with the Termit rift. A positive regional gravity anomaly of about 45 mgal amplitude was associated with the Maiduguri Trough, by comparison with the Benue Trough, this anomaly being interpreted in terms of crustal thinning. Seismic reflection data of Avbovbo *et al.,* (1986) inferred a total thickness of over 10 km of Cretaceous to Quaternary sediments in the "Maiduguri depression". The Chad Formation has been attributed to a thermal sag stage of basin development subsequent to rifting in the WCARS (Fairhead, 1986, 1988a and 1988b; Fairhead and Okereke, 1987, 1990). Sahagian (1993) and Hartley and Allen (1994) believed that uplift of its periphery, notably that of the Hoggar, Air, Tibesti and Darfur domes, was the most important control on Neogene-Recent sedimentation in the Chad basin.

In this study, spectral analysis of the residual magnetic field map of the aeromagnetic data covering part of Borno Basin has been estimated and the upward continuation of the total field map of the study area was analyzed to corroborate the results of the spectral depth analysis.

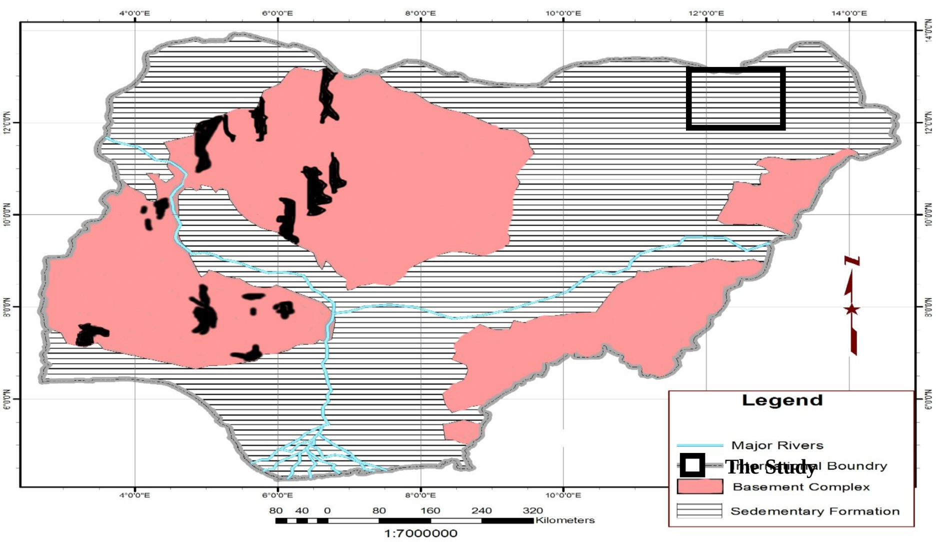


Figure 1: General geology Map of Nigeria Showing the Sedimentary Formation and Location of the Study Area

Data Collection

Aeromagnetic survey of a substantial part of Nigeria was carried out by the geological survey of Nigeria between 1974 and 1980. The magnetic information consists of profiles or flight lines plotted on continuous strip chart or tape records. To achieve this, the Nigeria landmass was divided into blocks. The magnetic data were collected at a nominal flight altitude of 152.4 m along N-S flight lines spaced approximately 2 km apart. The aeromagnetic survey measured only the total field, F. The data were later published in the form of $^1/_2{}^o$ by $^1/_2{}^o$ aeromagnetic maps on a scale of 1: 100, 000. The magnetic values were plotted at 10nT (gamma) interval. Eight (8) aeromagnetic maps i.e. maps numbers 22, 23, 24, 43, 44, 45, 65 and 68 were used for the study area. Each map was digitized on a 1.5 x 1.5 km^2 grid system.

After digitizing each aeromagnetic map, the data were collected and recorded in 38 by 38 coding sheets. The values obtained were then re-contoured and the resulting map was compared with the original map. Figure 2 is the method of eliminating edge effect as it was done in this work to obtain the super map.

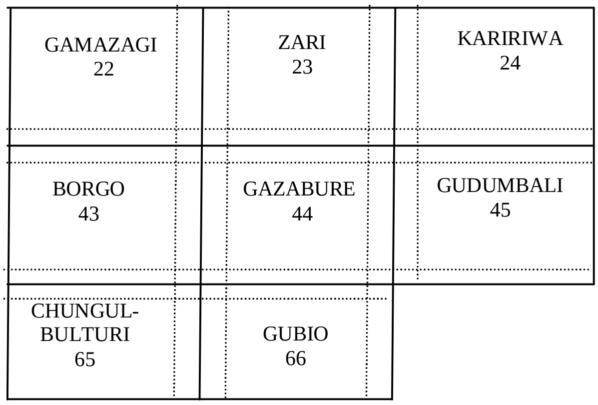
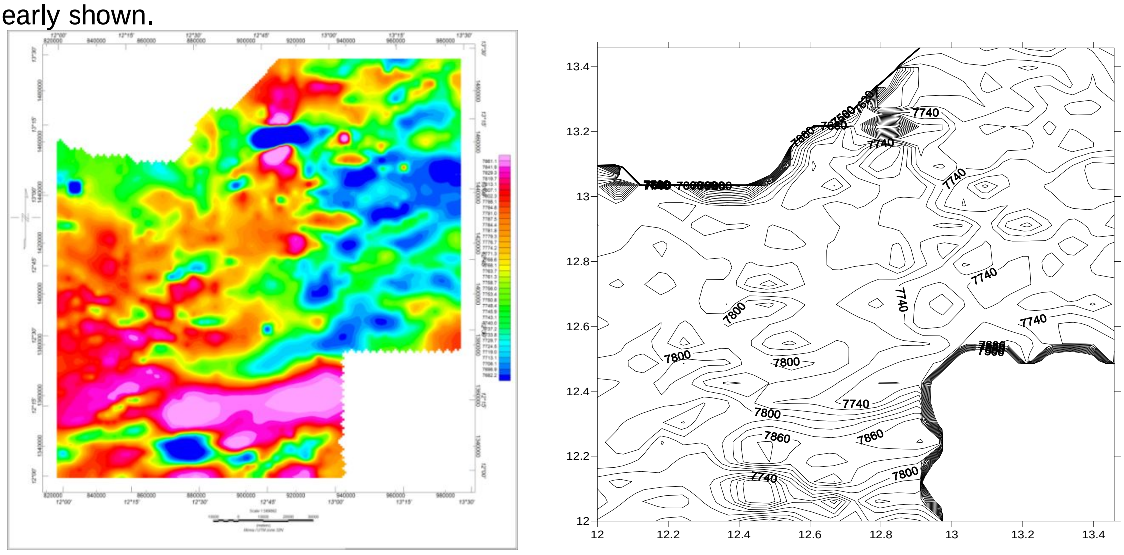


Figure 2: Method of Eliminating Edge Effect in Super Map.

Figure 3 is the Total Magnetic Intensity map of parts of Borno Basin, which was later produced at a lower gridding and contoured at 20nT intervals. This was done so that the contour lines would be clearly shown.



(a) (b

Figure 3: Total Magnetic Intensity Map of the Study Area, (a) Using Oasis Montaj and (b) Using Surfer8 Package. Vertical and Horizontal Axes are in Degrees.

The contour values shown in Figure 3 ranges from 7740nT to 7800nT after the base value of 25,000nT have been removed from all data points. Figure 3 is the Total Magnetic Intensity map of parts of Borno basin. For potential field data to be interpreted, the residual anomalies must be separated from the regional (background) field. The polynomial fitting method is about the most flexible and most applied of the analytical method for determining regional magnetic field (Skeels, 1967; Johnson, 1969 and Dobrin, 1976). In this method, the matching of regional by a polynomial surface of low order exposed the residual features as a random error. The treatment is based on statistical theory. The observed data were used to compute, usually by least squares, the mathematically describable surface giving the closest fit to the magnetic field that can be obtained within a specified degree of detail. It was assumed reasonably that the regional field is a first degree polynomial surface. All the regional fields were therefore calculated as two dimensional (2-D) first degree polynomial surfaces. A computer program was used to derive the residual magnetic values by subtracting values of the regional fields from the total magnetic values at the grid cross point. Figure 4: (a) and (b) shows the regional magnetic map and the residual map of the study area respectively

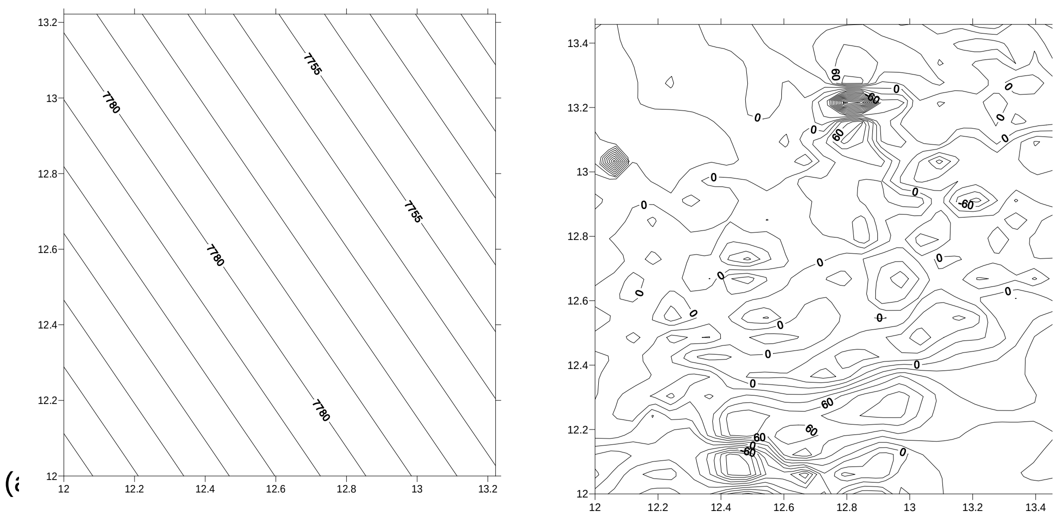


Figure 4: (a) Regional Magnetic Map of the Study Area showing the NW-SE trend (b) Residual Magnetic Map of the Study Area (contour intervals is 10nT). Vertical and Horizontal Axes are in Degrees.

Spectral Analysis

Spectral analysis involves a plot of a radially-averaged power spectrum on a natural logarithmic scale. In general, it is found that potential field anomalies analyzed in this way display something approaching a natural power-law spectrum, such that, much energy comes from large, deep sources (at a low wavenumbers) and relatively little (orders of magnitude less) from small, shallow ones (high wavenumbers) with an approximately exponential decay with wavenumber. Beyond the Nyquist wavenumber, the spectrum is meaningless, (any energy originally here will be aliased or folded-back into lower wavenumbers), but usually noise predominates at wavenumbers approaching the Nyquist wavenumber if a sound sampling regime was established for the survey. The research area covering latitude 12^0N - 13.5^0N and longitude 12^0E - 13.5^0E was subdivided into sixteen sections for the purpose of spectral depth determination. A sample of the logarithm of the spectral energies against frequencies obtained for the various sections are shown in Figure 5.

When considering a line that is long enough to include many sources, the log spectrum of this data can be use to determine the depth to the top of a statistical ensemble of sources using the relationship.

$$Log\ E(k) = 4\pi hk$$

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 the slope of the energy (power) spectrum and dividing by 4π.

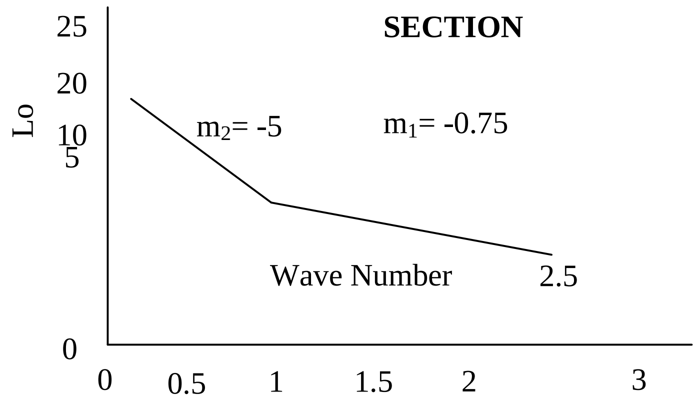


Figure 5: A Sample of the Logarithm of the Spectral Energies against Frequencies

Data Analysis

For this analysis, the study area is divided into sixteen (16) sections allowing spectral depth determination at every 15 km by 15 km interval of the field. These depths were shown as H_1 and H_2 in Table 1.

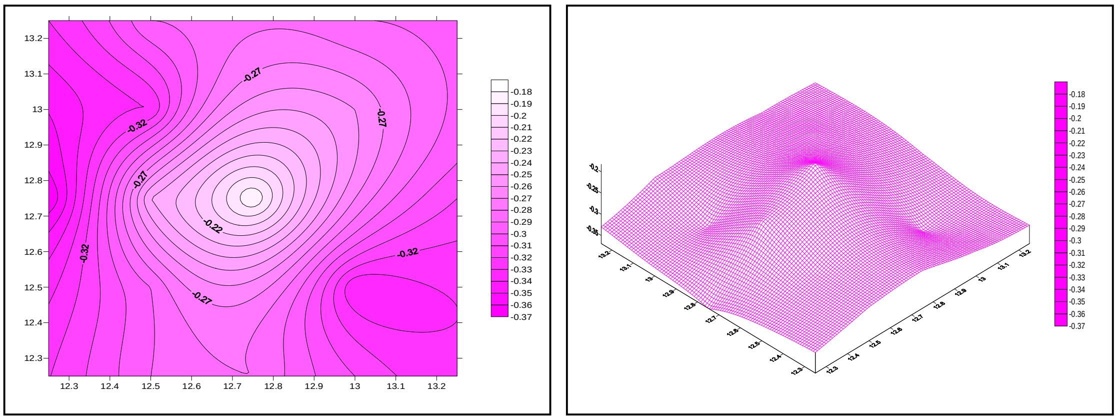
From the table, the first layer depth (H_1) varies in thickness from 0.18 km minimum to 0.37 km maximum, and has an average thickness of 0.283 km. The second layer (H_2) depth varies from a thickness of 1.79 km minimum to 5.34 km maximum and has an average depth of 2.99 km.

Table 1: Depth Estimate: Location for the First and Second Layers

SECTION	LONGITUDE	LATITUDE	H_1 (km)	H_2 (km)
1	12.5	12.5	0.29	2.5
2	12.5	13	0.33	1.79
3	13	12.5	0.34	3.75
4	13	13	0.26	5.34
5	12.75	12.25	0.28	2.82
6	12.75	12.75	0.18	2.43
7	12.75	12.25	0.22	3.75
8	12.25	12.75	0.37	2.5
9	12.75	12.75	0.25	5
10	13.25	12.75	0.31	1.82
11	12.5	12.25	0.29	3.09
12	12.5	12.75	0.24	3.5
13	12.5	13.25	0.29	2.11
14	13	12.25	0.31	2.73
15	13	12.75	0.27	2.5
16	13	13.25	0.29	2.13

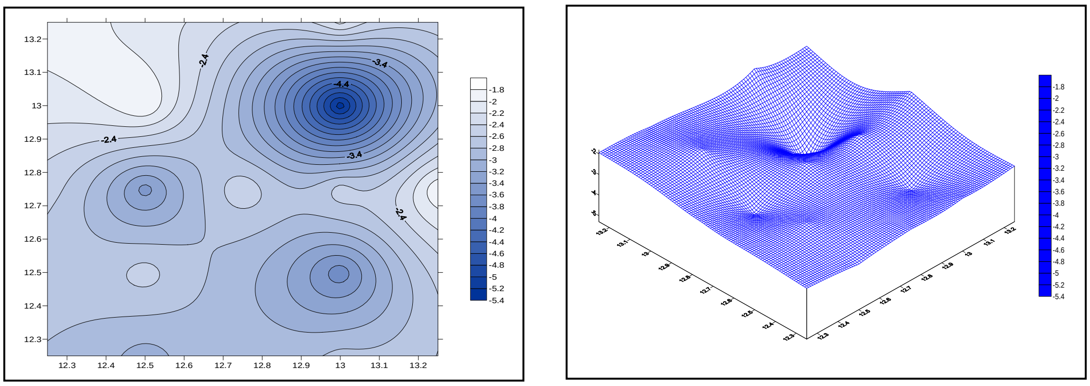
Data Interpretation

Figure 6(a) depicts first layer H_1 depth contoured at an interval of 20 meters vertical and horizontal axes in degrees. The high depth is at the central region which is, area on the map with light pink colour, while the low depths with deep pink colour are at the surrounding edges of North, South and Eastern part of the map. Figure 6(b) depicts the Surface plot of first magnetic layer. Figure 7(a) depicts second layer H_2 depth contoured at an interval of 50 meters vertical and horizontal axes in degrees. The high depths with light blue colour are seen in the North and Southern region, while the low depths with deep blue colour are found at the Eastern and central part of the map. Figure 7(b) depicts the Surface plots of second magnetic layer.



(a) (b)

Figure 6: (a) First Layer H_1 Depth Contoured at an Interval of 20metres (b) Surface Plots of First Magnetic Layer



(a) (b)

Figure 7: (a) Second Layer H_2 Depth Contoured at an Interval of 50metres
(b) Surface Plots of Second Magnetic Layer

The most promising region where the depth of 5.34 km could be found lies between latitude12^{0}45' to 13^{0}15'N and longitude 13^{0}00' to13^{0}30'E of figures 7(a), which corresponds to the northeastern part of Figure 7(a). This area has the sedimentary thickness (or highest depth to basement).

Conclusion

A critical examination of Figure 7(a), Second layer (H_2) depth contour map, shows that the Northeastern of the study area, around Kaririwa, contains the highest accumulation of sediments (5.34 km). This depth could infer the presence of hydrocarbon.

Summary

The spectral depth estimation of the depth to basement on the parts of Borno basin had shown a maximum depth estimate or sedimentary thickness of over 5 km which could be obtain around Kaririwa area of the study area.

Recommendations

The accumulation of sediments in the northeastern part of the Borno basin, could suggests the presence of hydrocarbon. We wish to recommend that bore hole be sunk and the well log be done to confirm further, this findings. However seismic reflection survey could be done around the area found to have a depth estimate of over 5 km.

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