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Spectral Analysis of Aeromagnetic Data over Some Parts of Central Benue Trough, Nigeria

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Abstract: *The spectral analysis of the magnetic anomalies over some part of Central Benue Trough, Nigeria, has been carried out in order to determine the magnetic source depths and the variability of basement structures. The aeromagnetic maps of the study area was digitized at two kilometer (2km) intervals and were subjected to multi-regression-least-squares analysis in order to obtain the residual field values. Two-dimensional (2-D) spectral analyses were then carried out to determine the average magnetic source depths. The results of the analysis reveal that the thickness of the sedimentary cover in the area varies between 1.25km and 5.60km; and 0.13km and 1.53km for deeper and shallower sources respectively. The results of this study are indicative of the basement overlain being irregular in shape and is associated with faulted structures.*

Key words: *spectral, magnetic, basement, Central Benue Trough, Nigeria*

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I. Introduction

The Benue Trough being a unique rift feature in the African continent has a tectonic evolution that aroused a lot of interests amongst geoscientists [1, 2, 3, 4, 5, 6]. The economic mineral potential of the trough has made it a focus of geologic and geophysical activities. Not many studies have been carried out on the analysis of aeromagnetic anomalies in the Trough. At present, magnetic studies have been localized and have mainly involved the search for minerals in some parts of the trough. This research involves the preparation of aeromagnetic data fit for spectral analysis which would enhance the determination of basement variability within the sedimentary cover in some parts of the Central Benue Trough. The results of this work can aid in geologic mapping.

STUDY AREA AND ITS GEOLOGY

The Benue Trough lies within Latitude 07.50° - 08.50°N and Longitudes 08.00° and 09.30°E (Fig. 1). It is an intra-cratonic rift structure, which extends from the Northern limit of the Niger Delta to the Southern margins of Chad Basin. The valley which is occupied by up to 600m of marine and fluviodeltaic sediments, that have been compressionally folded in non-orogenic shield environment has been subdivided geographically into the Lower, Middle (Central) and Upper Benue Trough for the ease of mapping. The Middle Benue Trough which is of particular interest in this project work encompasses the study area located in the central part of Nasarawa State. The geology of Nigeria is made up of three major litho-petrological components, namely, the Basement Complex, Younger Granites, and Sedimentary Basins [7, 8]. The Basement Complex, which is Precambrian in age, is made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The Younger Granites comprise several Jurassic magmatic ring complexes located in Jos and other parts of north-central Nigeria. They are structurally and petrologically distinct from the Older Granites. The linear NE-SW trending Benue Trough (Fig. 1) has a length of approximately 800km and open into the Gulf of Guinea where the Cenozoic Niger Delta has built out upon oceanic crust [9]. The Benue Trough was terminated by a Late Santonian episode of compressional folding. Subsequent sedimentation was centred on basins developed on the North-Western flank of the resultant deformed sediments.

The area of focus in the present study falls within Latitudes $7^0$00'N-$8^0$8'N and longitudes $8^0$00'E-$9^0$8'E of Central Benue Trough (Fig. 2). The Central Benue Trough links the Lower and Upper Benue Trough. The Benue Trough of Nigeria is an elongated rift (or fault-bounded) megastructural depression trending north-eastwards to a length over 1,000km extending from the Niger Delta in the South-West to the Chad Basin in the North-East with a width of about 130-150km [10]. The Trough is believed to have developed along pre-existing major lineaments as failed arm of an RRR triple junction during the opening of the Gulf of Guinea in the Aptian-Albian times (104Ma) [11, 12, 8].

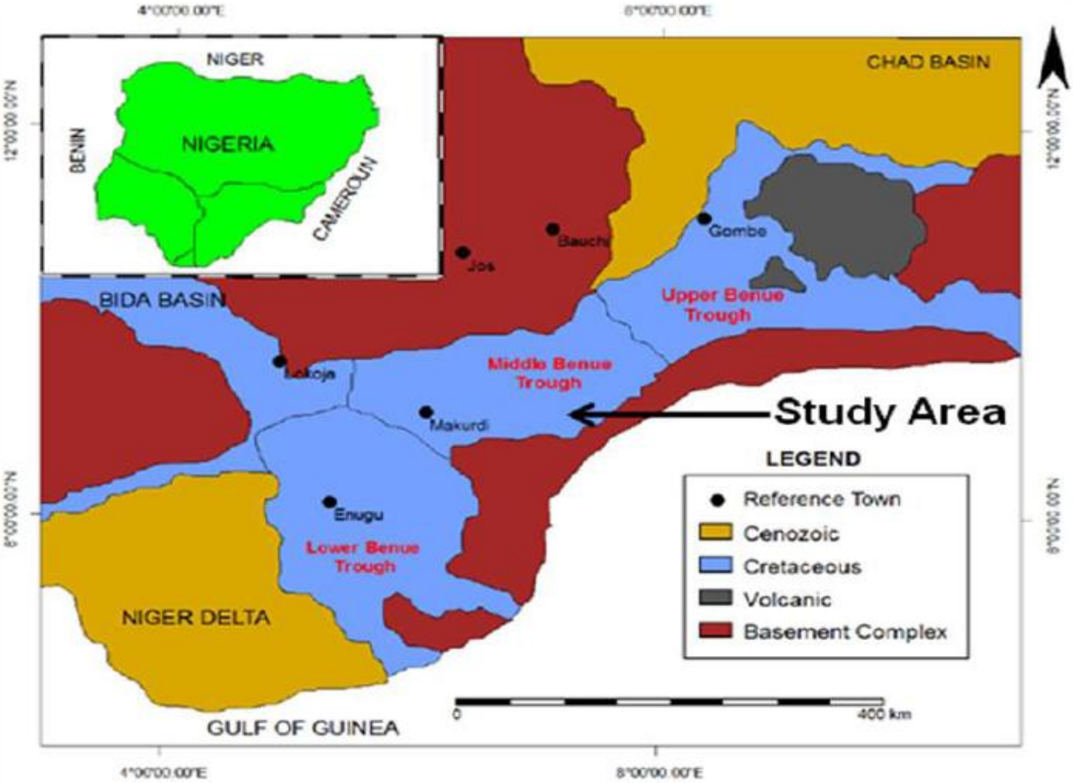

Fig. 1: Map of Nigeria showing Central Benue Trough

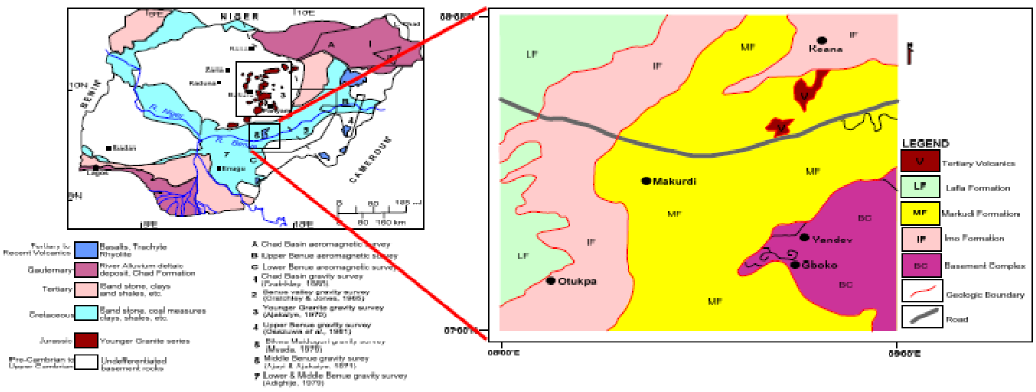

Fig. 2: Geological map of the Benue Trough showing the Study Area [4].

The Cretaceous and Tertiary sediments (Albian-Palaeozoic) filled the trough with thicknesses estimated from gravity data to vary from 5-6km in the lower and middle Benue Trough [13, 14, 15] to about 2km in the Upper Benue Trough (Osazuwa, 1978). The Santonian period of the Cretaneous was dominated in folding, uplift and erosion which led to the extensive deformation of the Albian-Turonian sediments in a north-easterly trending fold axis [16, 12].

II. Materials And Methods

Data Acquisition

The actual field work was done by the Geological Survey of Nigeria during a nationwide aeromagnetic survey. For this study, the contoured maps were collected and digitized horizontally by hand at interval of 2km to obtain a total magnetic field anomaly for the purpose of magnetic source depths determination. The sheets were 231, 232, 251, and parts of sheets 233, 253, 271, 272 and 273.

The research area of 64 x 64 data points of the observed field was reduced to sixteen blocks containing 16 x 16 data points of the residual field in order to carry out the Fourier analysis. In doing this, the following suggestions pointed out by Hahn *et al.* [17] were considered:

(i) Each square of the digitized map should contain more anomalies than one maximum-minimum pair or more than maximum or minimum in an area of high or low geomagnetic latitudes.
(ii) The square's sides should not cut through the essential parts of anomalies of single bodies.
(iii) The difference between field values along opposite sides should be smaller than the difference between maxima and minima inside the square.

To achieve this, a few of the blocks were made to overlap each other. The spectral obtained for the 16 blocks making up the area are shown in Figs. 5, 6, 7 and 8. A summary of the slopes of the spectral is given in Table 1. Two – depth models have been estimated for all the blocks and these values are summarized in Table 2 which gives the computed average magnetic source depths for each block of 16 x 16 data points.

Data Analysis

The collected data were reduced for drift and other corrections, plotted and contoured to give the total magnetic field map (Fig. 3). A regional field was removed from the total field anomaly map using a multiple least squares regression curve fitting program which uses a first order polynomial of the form:

$$T(R) = B_0 + B_1 x + B_2 y \quad (1)$$

where T(R) is the regional field at locations x and y and B_0, B_1 and B_2 are coefficients that give a minimum regional.

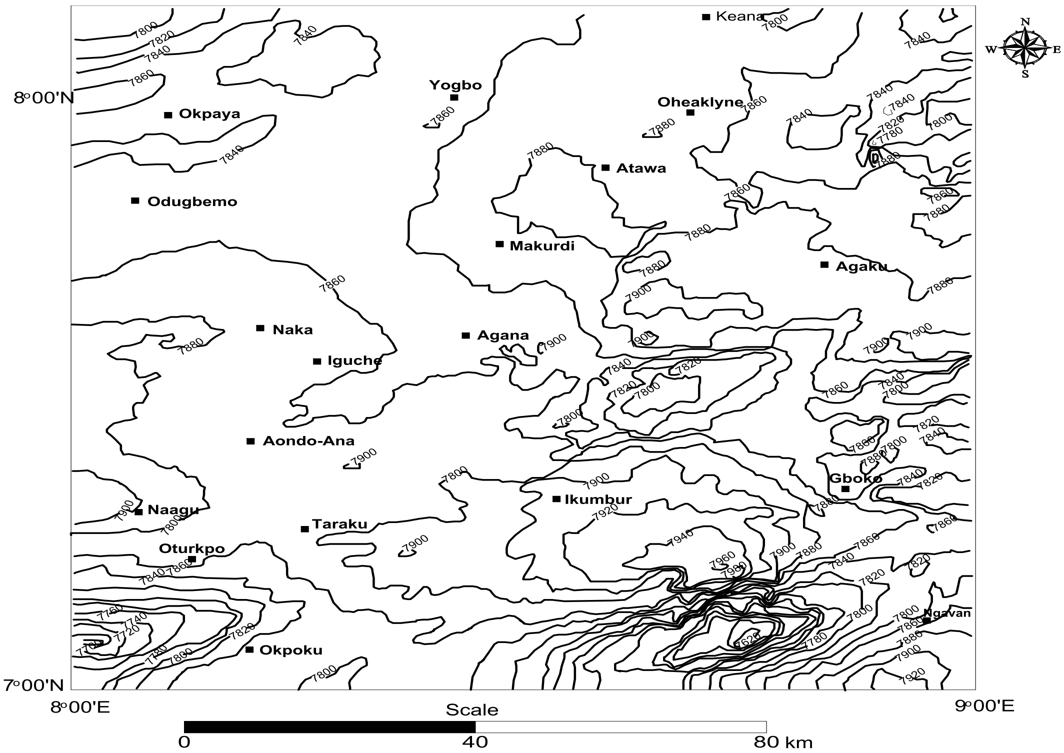

Fig. 3: Total Magnetic Field over the Study Area as Contour Map (Contour interval = 20nt)

A simple inclined plane surface [18] was assumed and the result appropriate within a linearly increasing regional geomagnetic total intensity field ranging from 32,000 to -35,000 nT from IGRF85 model, 1985 epoch. The expression obtained for the regional T (R) is as follows:

$$T(R) = 7861.871 + 0.051x - 0.115y \quad (2)$$

where x and y are units of spacing. The regional field values were subtracted from the observed data to obtain the residual field values. The residual values were contoured by hand at 20nT intervals on a scale 1: 200,000 (Fig 4).

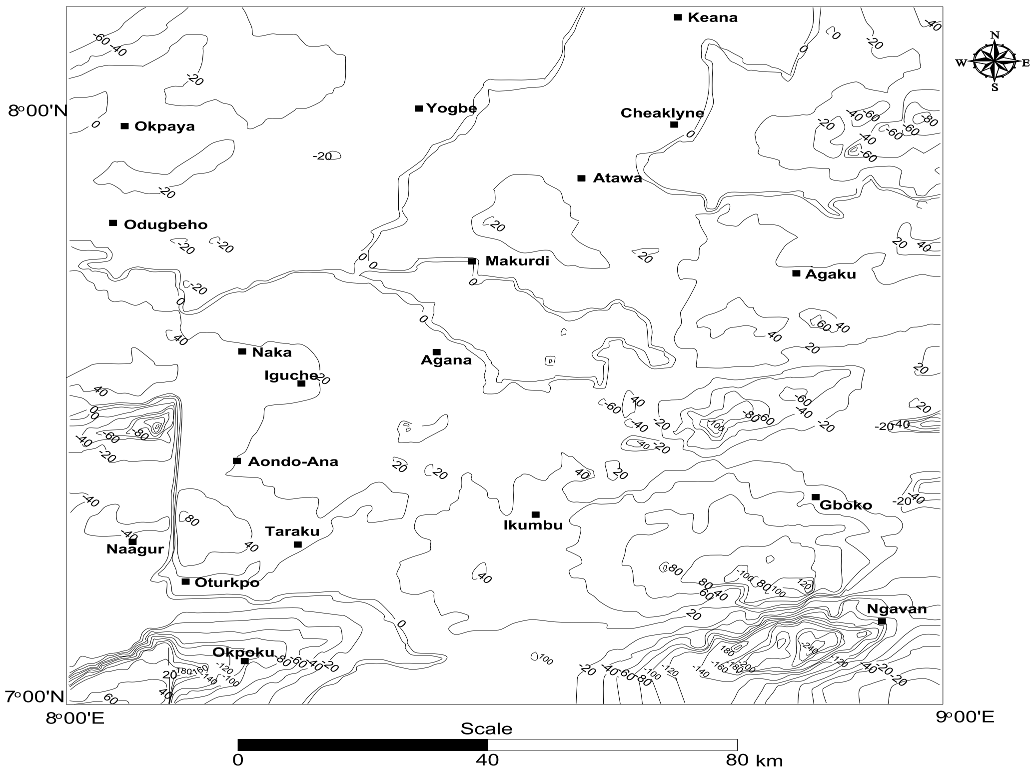

Fig.4: Residual Field over the Study Area as contour Map (Contour interval = 20nt)

III. Results And Discussions

Table 1: Summary of the slopes of the Spectral for 16 x 16 blocks (All slopes S_1 and S_2 are in km

1 S_1=0.90 S_2 =0.17	2 S_1=1.10 S_2 =0.57	3 S_1=0.25 S_2 =4.33 x 10^{-2}	4 S_1=0.60 S_2 =3.33 x 10^{-2}
5 S_1=0.57 S_2 =0.30	6 S =-5.50 x 10^{-3}	7 S_1=0.60 S_2 =0.13	8 S_1=0.88 S_2 =2.5 x 10-2
9 S=0.48	10 S= 0.32	11 S =9.71 x 10^{-2}	12 S_1=0.18
13 S_1=0.26 S_2 =0.03	14 S_2 =0.64	15 S_1=0.53 S_2 =3.75 x 10^{-2}	16 S_1=0.65 S_2 =9.33 x 10^{-2}

Table 2: Summary of the Magnetic Source depths for the different 16 x 16 blocks obtained (Depths of D_1 and D_2 are in km).

1 D_1=4.58 D_2 =0.85	2 D_1=5.60 D_2 =2.88	3 D_1=1.25 D_2 =022	4 D_1=3.06 D_2 =0.17
5 D_1=2.88 D_2 =1.53	6 D=-0.03	7 D_1=3.06 D_2 =0.66	8 D_1=4.46 D_2 =0.13
9 D=2.08	10 D=1.64	11 D=-0.49	12 D=-0.92
13	14	15	16
D_1=1.34 D_2 =0.15	D =3.25	D_1=2.71 D_2 =0.19	D_1=3.31 D_2 =0.48

The total magnetic map (Figure 3) shows the existence of high and low magnetic features. There is a large magnetic intensity of 7980n T at Southeast of Ikumbur. It has an extension of about 9km Southeast of Ikumbur and about 8.5km Northwest of Ngavan. This represents the largest in area extension on the map. About 13km Southeast of Ikumbur, there exists the smallest sized intensity of 7620nT. The several magnetic features are mostly different in sizes. The continuation of these features is interrupted by fractures. The prominent fractures on the map have NE-SW and NW-SE directions. One of such major fractures passes horizontally on the map from Okpokwu and extends through the basement which outcrops west of the study area. There exists a diagonal fracture at about 5km North of Ikumbur and extends through a distance of about 7km Eastwards. The West and North ends of the study area have scanty intensities which range from Taraku through Iguche and up to Yogbe and Keana. At the Nortwest of the study area that is between Okpaya and Odugbeho, there exists a magnetic intensity of 7840nT which opens at the boundary line. A similar intensity is closed adjacent to it and another started and opened at the sharp corner with an intensity of 7800nT.

On the residual field map (Figure 4), the highest positive magnetic intensity is about 5km Northwest of Ngavan with a value of 120n T. In contrast, other intensities vary below 100nT on the map. One such intensity is seen around Gboko. It is noteworthy that the highest and lowest values are found between Ikumbur and Ngavan. There are several negative intensities throughout the area. There exist closely packed contours at the corners of the study area. Considering the central part of the map, the North and South ends have sparsely spaced contours varying from - 20n T to 20n T and few intensities of 40nT and 100nT at the Southwest of Ikumbur. The lowest magnetic intensities are in some places enclosed within the high intensities. By comparison, it is observed that faults exist on small shifts in direction relative to those identifiable ones on the total magnetic field map. However, magnetic sources of shallow origin which appear on the residual map were absent from the total field map. Hence, some anomalies not evident on the observed field were now seen on the residual field map.

The results of the spectral analysis of aeromagnetic data over the area of study, suggest the existence of two main source depths under the area except blocks 6, 9, 10, 12 and 14 where one source depth was obtained (Table 1). The deeper sources represented by the first segment of the spectral of Figures 5a, b, c, d; 7a, d; 8a, b, d reflect the Precambrian Basement. The magnetic horizon represented by the second segment of the spectral of the Figures 5a, b, c, d; 6a, d,; 8a b, d reflect magnetic sources shallower than the basement. Figure 7b whose slope gave a negative value resulted to a negative depth which compares with the area as shown on the residual field map, having no contour passing through the area. The deeper source lies at a depth varying between 1.25km and 5.60km; while the shallower source lies at a depth varying between 0.13km and 1.53km. The estimated single sources lie between 0.92km and 3.25km with an anomalous single sources lie between 0.92km and 3.25km with an anomalous single source of depth -0.03km in block 6.

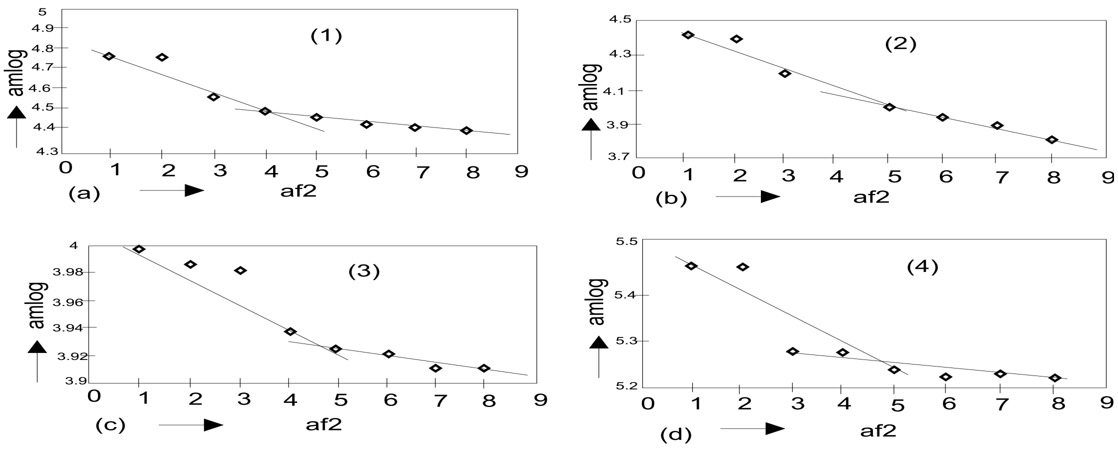

Fig. 5: Graphs of the Spectral of Blocks 1, 2, 3 and 4

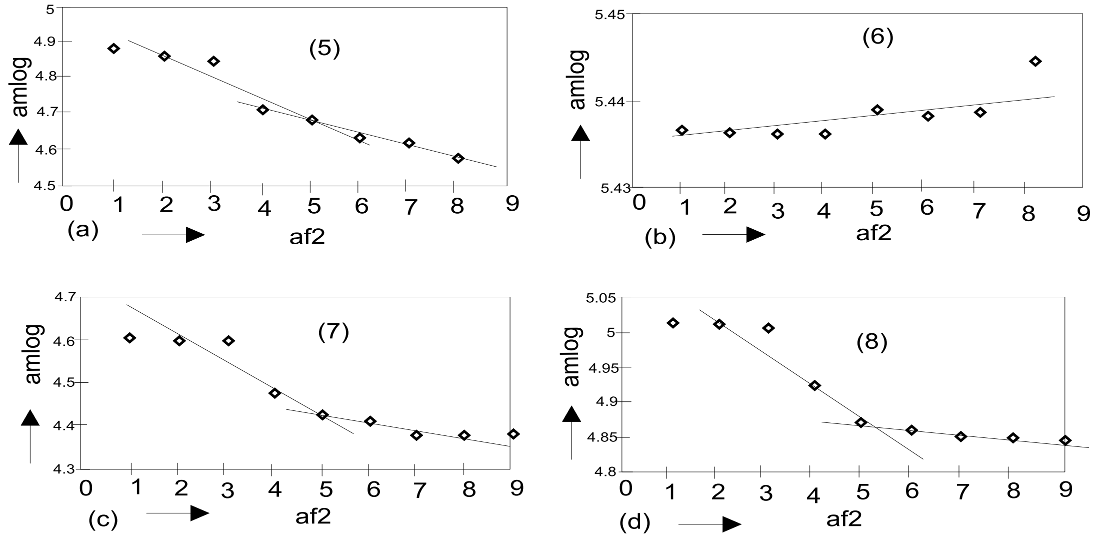

Fig. 6: Graphs of the Spectral of Blocks 5, 6, 7 and 8

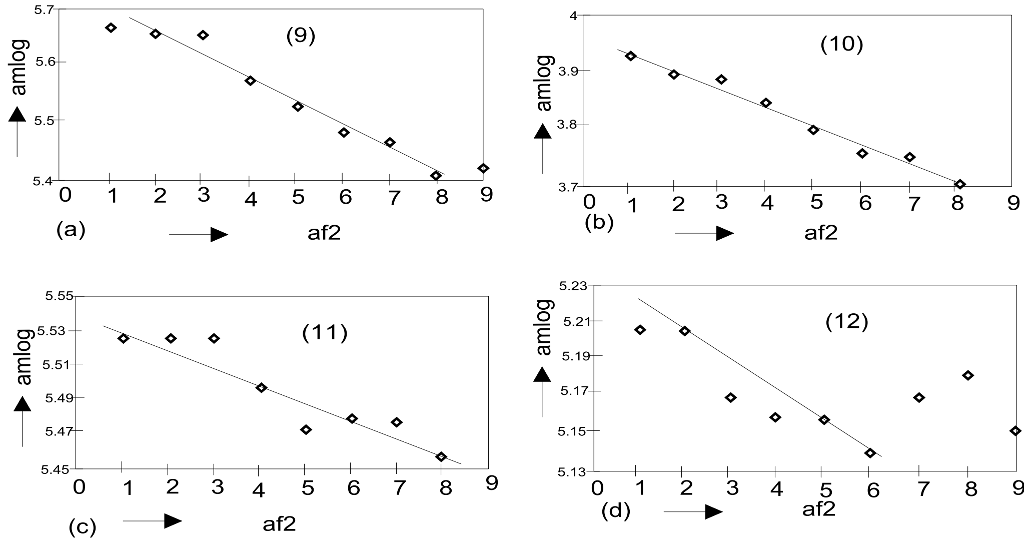

Fig. 7: Graphs of the Spectral of Blocks 9, 10, 11 and 12

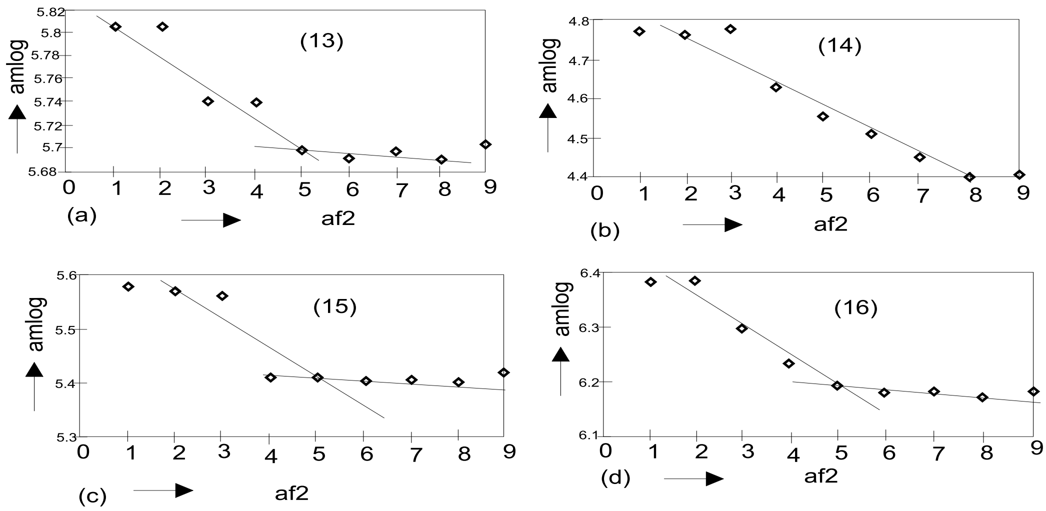

Fig. 8: Graphs of the Spectral of Blocks 13, 14, 15, and 16.

It is observed that the magnetic contours cluster together in blocks 4, 9, 12, 13 and 16 with depths varying between 1.34km and 3.31km; 0.15km and 0.48km for deeper and shallower sources respectively. There is also a single source depth of 2.08km in block 9 where contours cluster. These estimated depths represent the depths at the centers of each block due to the fact that there were overlaps during the Fourier analysis of the residual fields' data.

IV. Conclusion

The results of this research suggest that the depth to the basement underlying the study area and consequently the thickness of the sedimentary cover in the area varies between 1.25km and 5.60km; and 0.13km and 1.53km for deeper and shallower sources respectively. In addition to this, single source depths varying between 0.92km and 3.25km were obtained. An anomalous source depths varying of -0.03km was also obtained which needs further investigation. The study confirms that the basement area overlain by sediments is irregular in shape which may have been associated with faulted structures. The major sub-basin has NE-SW directions. From the depths calculated so far, the sedimentary thickness compares well with previous works [19, 4, 20]. The thickness is possible for mineral accumulation but may be too thin for oil accumulations.

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