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Sediment thickness and depth to magnetic sources computations from high-resolution aeromagnetic data over Yola arm of the upper benue and adjoining basement regions, Northeastern Nigeria

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Abstract

The study of high-resolution aeromagnetic data was carried out over Yola arm (Upper Benue) and adjoining basement regions of northeastern Nigeria, so as to determine the sediment thickness and depths to magnetic sources using radially average power spectrum and depth to basement topographic map. Data processing by polynomial fitting was done on the total magnetic intensity mapso as to expose the residual features. Oasis Montaj software (7.0.1) was used to generate radially average power spectrum and basement topography for depth computation. Results show that these diment thickness over the region as showed by the power spectrum is in the range of 0.5-1.8km for the shallow sources and 1.8 – 4.5km for deep sources. The depth to basement of the region is in the range of 0.2-2.2km for shallow sources and 1.2-3.8km for the deeper sources. The two results agrees to some extent, the numerical values are very much in agreement but they differ in some places. Areas of thick sediments accumulation as shown in this work should be targeted for further exploration as such could possibly harbor petroleum. This suggestion is made in the light of the present move by the federal government to explore for petroleum in the country's inland Basins.

Keywords: Magnetic data, power spectrum, polynomial fitting, sediment thickness.

Introduction

This work attempts to analyze high-resolution airborne magnetic data over the Yola Trough and adjoining sectors of the basement blocks (Figure-1) for spectral depths and sediment thickness computations. The area is located between longitude $12^0$00' - $13^0$30'E and Latitude $8^0$00' – $10^0$00'N, which is the Yola trough a division of the Upper Benue Trough which is also a sub set of the Benue trough a Cretaceous sedimentary basin, trending in E-W direction. The Benue trough is generally said to have formed from aridge- ridge-ridge structure which existed at the site of the present Niger Delta in the early Cretaceous times[1,2] with arms as the Gulf of Guinea (R) the South Atlantic (R) and the Benue Arm (R).

The drainage feature of this region is characterized by two major rivers, the Benue River which takes it source east of the Cameroon Mountains and for the other one the Gongola River which source is from the north central high lands composed of crystalline rocks. The area is bounded by the Hawal Massif to the north and the Adamawa Massif to the south. Both Massifs extend into Cameroon Republic. Major towns in the area are Yola, Sugu, Song, Ganye and Toungo.

Geology of the region: The area is part of the Yola trough a division of the Upper Benue Trough which is also a sub set of the Benue trough with some sectors of the adjoining basement terrain which are contiguous to the Yola trough. The trough is a Cretaceous sedimentary basin with structures that forms a restricted band of rock formations which stretches eastward and splits into small isolated basins in Cameroon. Sedimentary rocks in the area are mainly shales, sandstones, lime stones, siltstone and clay. Tertiary basalts which are part of the Cameroun Volcanic Line extrusive rocks are found within the sedimentary basin and in the basement. Basement rocks of Precambrianage together with, basic intrusions and metamorphic rocks were also present.

Previous studies: Studies undertook by Haruna et al.[3] on the basinal framework and basement structuring of lower Benue Trough, based on regional magnetic field data. Their work showed sediment thickness of 7-10 kilometers, N-S, NNW-SSE and E-W are the structural trends of the area.

Studies on the basement depth over the Yola arm of the upper Benue trough Nigeria, by Emberga et al.[2] from 3-D euler deconvolution and spectral inversion of high resolution aeromagnetic data (HRAM) and conclude that the area is characterized by NE-SW and N-S trending lineaments with spectral depth ranging from 1.56-2.92 kilometers and euler depth range from 0.5-2 kilometers.

Working on the high-resolution aeromagnetic data of the triple junction structure of the Upper Benue Trough, Northeastern Nigeria, by Omeje et al.[1] demonstrated that the area is characterized by NE-SW trending lineaments and there was tectonic activity that lead to uplift of the mantle, thinning of the crust and a later mantle activity which causes a basaltic lava flow or basic igneous intrusions along transform fault.

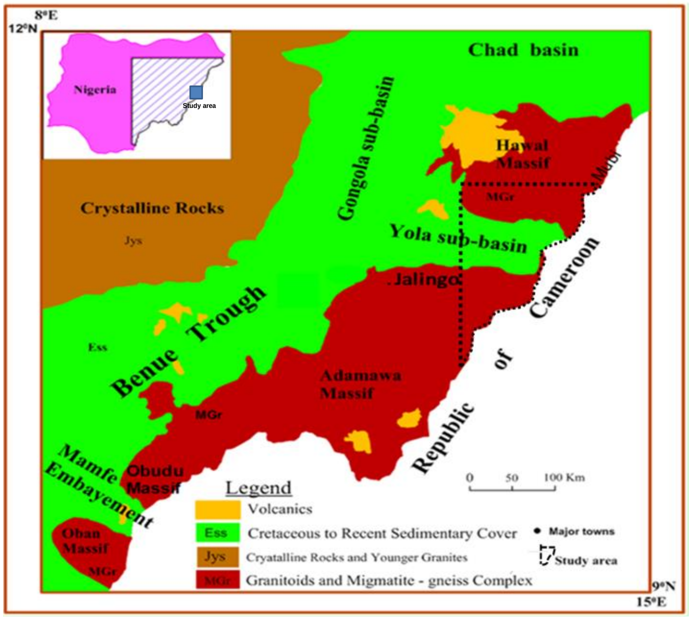


Figure-1: Regional geological map of Nigeria's eastern sector showing location of study area[3].

Investigation of $2^{1/2}$ dimensional modeling of the significant structures underlying Dong and Shelleng regions of the upper Benue trough, by Omeje[5] using GM-SYS computer modeling. Their discoveries revealed that sediments thickness is in the region of 0.9km to 2.9km.

Studies on Landsat imagery and aeromagnetic data under took by[6] form applying of linear structures over Yola arm (upper Benue trough), Nigeria. The authors posit that the area under investigation is controlled by NE-SW trending lineament, with two-source depths namely the deep and shallow sources.

Working on ground magnetic survey on the tectonic and structural pattern of part of southern margin of Hawal basement complex, northeast Nigeria[7] showed that the magnetic anomalies have short wavelengths and are of positive polarity, originating from shallow/superficial sources. Their outcome showed two dominant trends the NE – SW and NW – SE directions.

Methodology

The high resolution aeromagnetic data utilized in this research were acquired for Nigeria Geological Survey Agency (NGSA) in 2010 as part of a country wide geological survey. The high resolution aeromagnetic data has the following specifications, terrain clearance of 80m, flight line spacing of 500m and a tie line spacing 5000m. The following sheets with index numbers were used for this study: 175,176,177,196,197,217 and 218.

The results obtained from the high resolution data would be more precise (due to its high resolution nature) compared to results obtained by the defunct Geological Survey of Nigeria which is analog in nature. Secondly manual digitizing of data (with possible introduction of errors) which was the practice with earlier data (before processing) this was not done because the present data is in digital format.

The total intensity magnetic (Figure-2a) map was processed using the *Oasis Montaj*™ software. The main objective of filtering data is to condition the data set and to render the result presentable in such a way as to make it easier for the geoscientist to comprehend and interpret the significance of anomalies in terms of their geologic causes and settings. Using filters in data processing always enhances the data and help define features that were not easy to detect before filter application. Polynomial fitting was done to produce the residual anomaly map from the total intensity map (Figure-2b).

Radial average power spectral and depth to basement computations were done in other to determine the sediment thickness and depths to magnetic sources. The radially average power spectrum plots are presented in Figure-3.

Polynomial fitting: Here a low order polynomial was used to expose the residual features as random errors. This treatment depends on measurable hypothesis (statistical theory) whose details can be obtained in the literature. This method was used by Nwosu and Onuba[8] to produce the residual data from where all other filtering operations were applied.

Radially Averaged Power Spectrum: A potential magnetic field of a newly acquired data may be taking as representing a series of interfering waves of contrasting wavelengths and directions. The force of every wavelength can be plotted against wave number regardless of direction to produce a power spectrum. The spectrum plot can be broken into series of straight-line section, each section describe the results that increase in strength that represent an ensemble of sources at a given depth.

The slope of the line section is directly increasing or decreasing to the depth of ensembles, and Kivior and Boyd[9] states that magnetic bodies provide information about the source depth to the top of ensemble of these magnetic bodies.

To carry out spectral analysis the data set was divided and windowed into blocks of 16 data points, which were then processed using *Oasis montaj* software to compute the spectra of the magnetic data. This filter was applied in determining the sediments thickness and depths to magnetic sources.

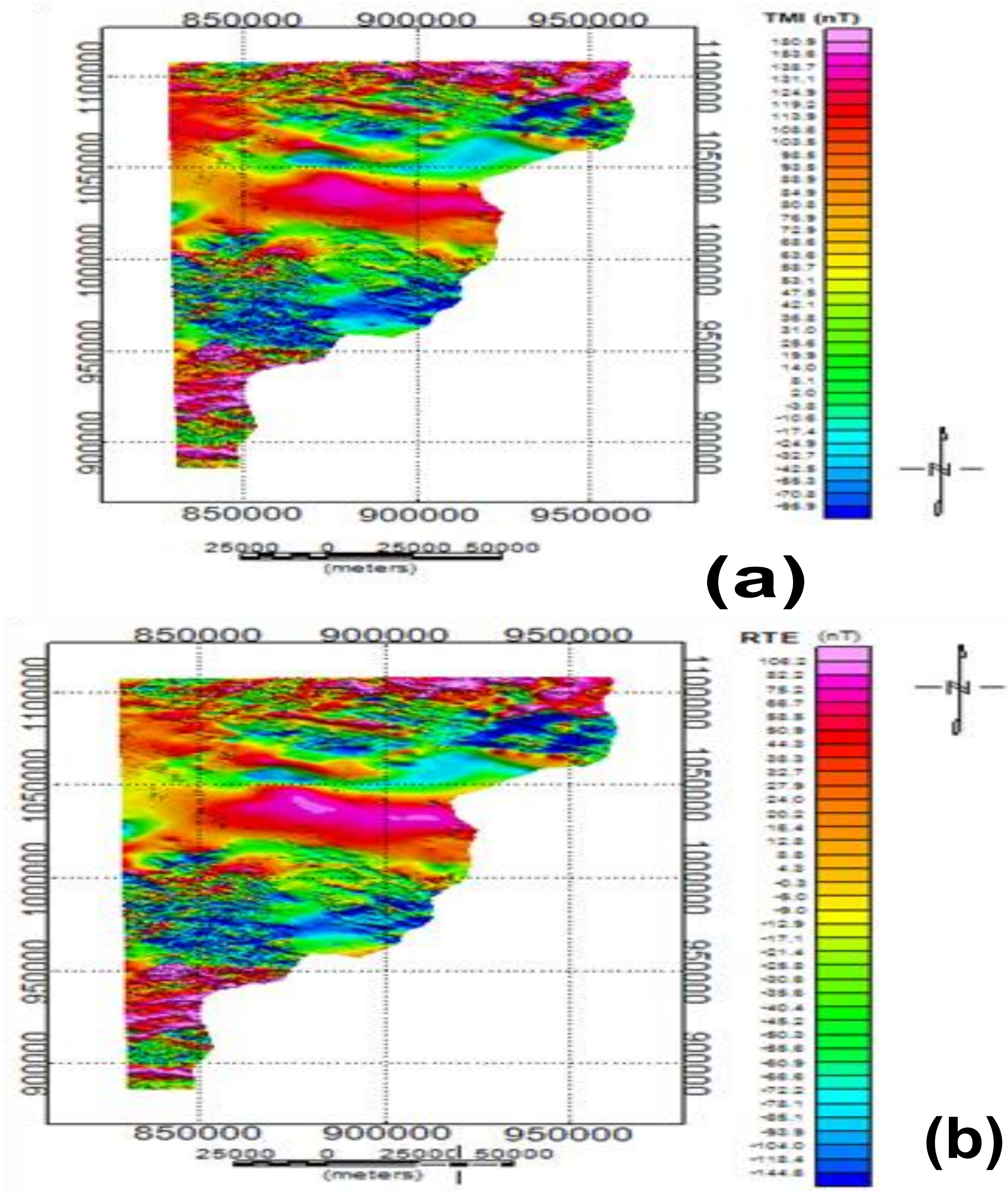


Figure-2 (a and b): Total magnetic intensity and residual maps of the study area respectively.

Results and discussion

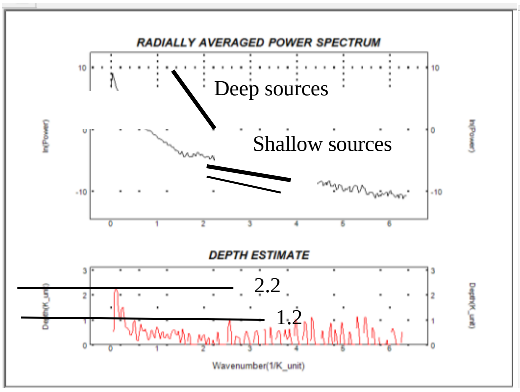
Figure-2b shows residual magnetic anomaly map which has some similarity with the total magnetic intensity map of Figure-2a. The long wavelength features are of regional nature and are credited to deep seated sources.

Low amplitude, short wavelength features that are different from expected are superimposed on these large regional features.

Anomalies of 177.2 to -79.6 nT (Figure-2a) exist as a sequence of areas of magnetic highs and lows. These areas are not continuous according to Bassey[10] but appear as several elongated lobes extending over varying distances before interruptions by short wavelength anomalies which may be due to near surface intrusive, volcanic plugs, basement rocks or thin basaltic flows. The sediment thickness over the area as revealed by the power spectrum is in the range of 0.5-1.8km for shallow depths and 1.8-4.5km for greater depths.

The spectral analysis of the total intensity magnetic field, as indicated by Oladele et al[11] shows the dispersion of short to long wave number over-all series of interfering magnetic responses of contrasting wave number and direction. The result of this study is in agreement with those of other workers such as Alagbe[12] who worked on the same area and got sediment thickness in the range of 1.22-3.45km., sediment thickness of 2.33-5.86km were gotten by Nwosu et al.[13] who worked in the middle section of the Benue trough. Also, Salako K.A.[14] worked in the northern section of the Benue trough and some section of Borno Basin, N.E. Nigeria utilizing source parameter imaging and got sediment thickness of 5.0 kilometers in the area. Working on the Gongola trougha division of the Upper Benue Trough[15] posits that the sediment thickness in the area is around 4 - 4.5km.

The magnetic basement depth of the region from the basement topographic map (Figure-4) shows the results in the scope of 0.2-2.2 km for shallow sources and 1.2-3.8km for the deeper sources (Figure-5 and 6). The result of the average power spectrum and the depth to basement topographic map are genuinely reliable.



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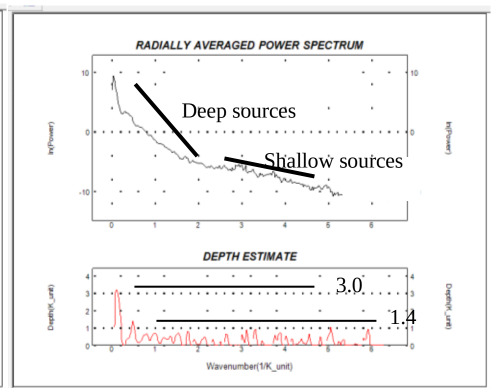

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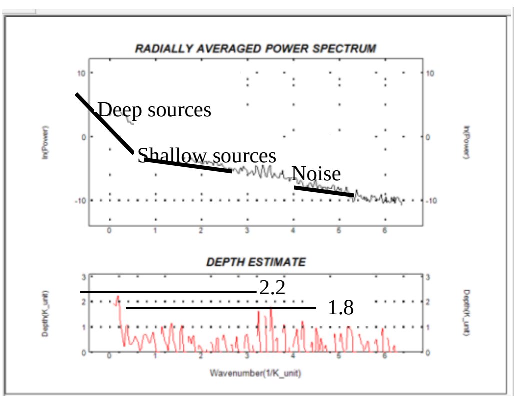

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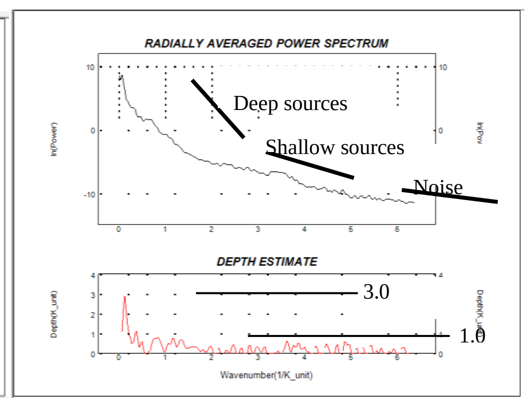

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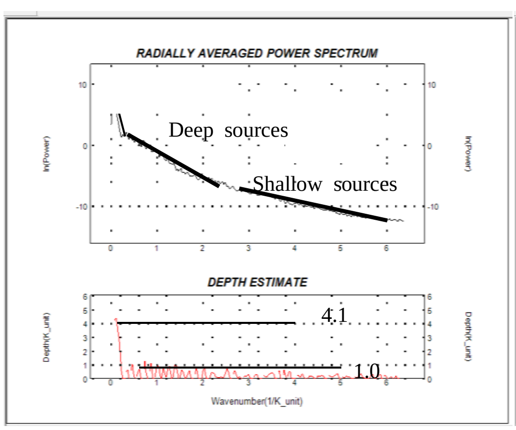

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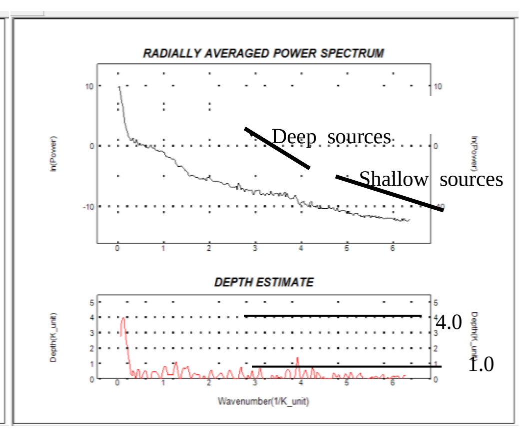

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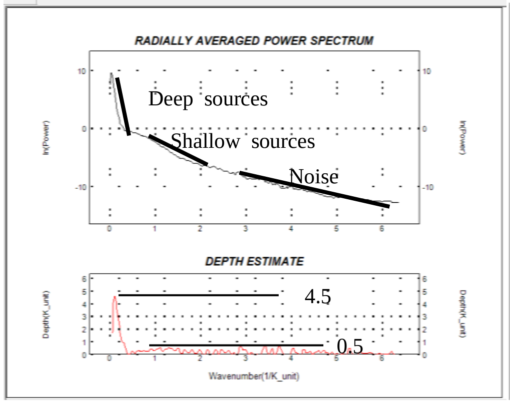

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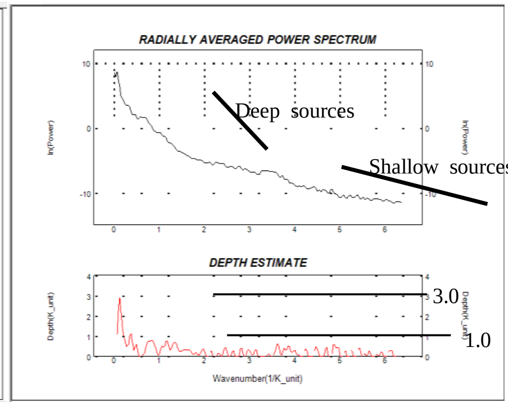

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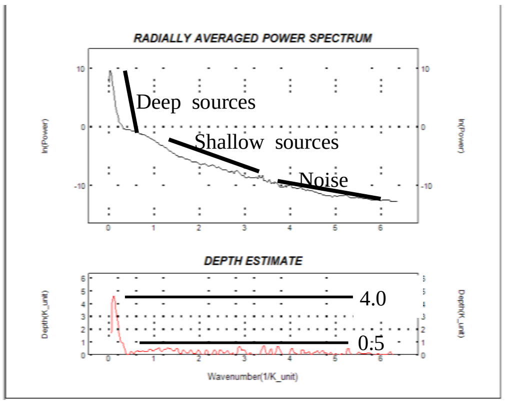

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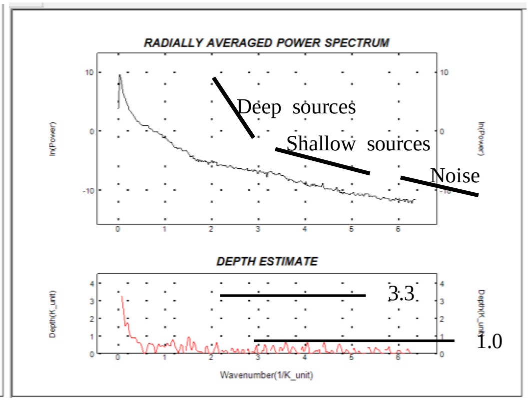

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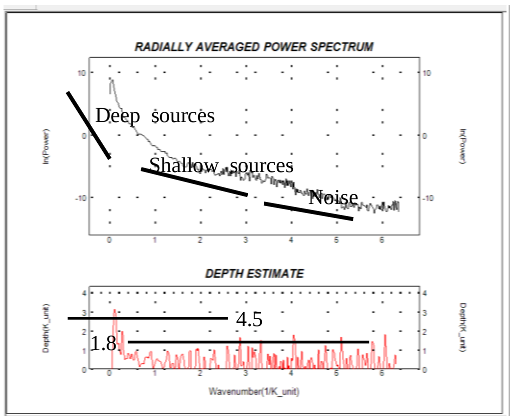

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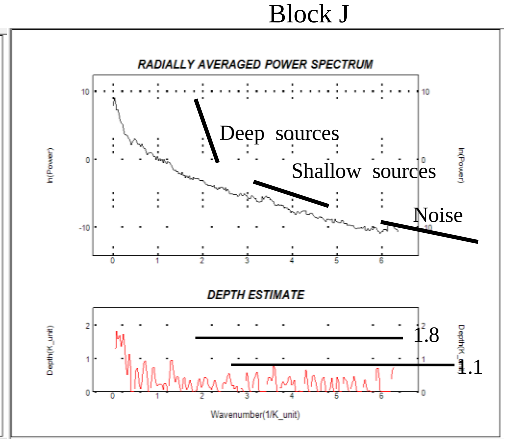

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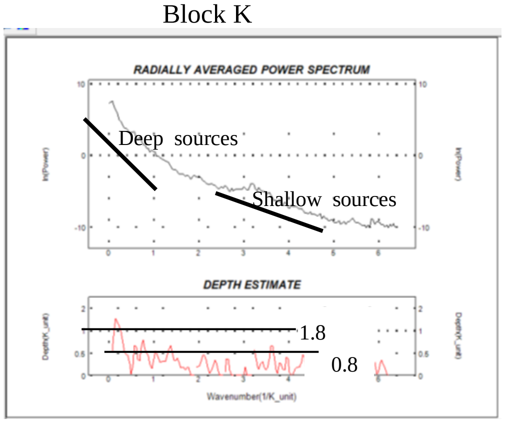

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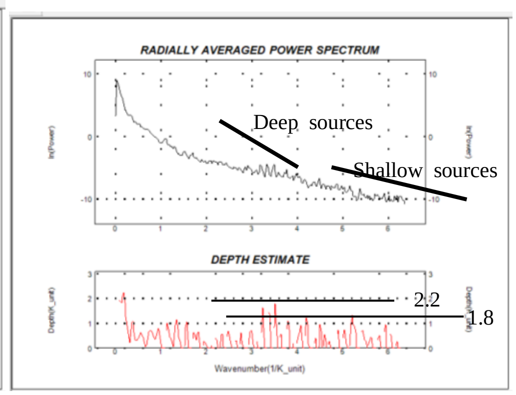

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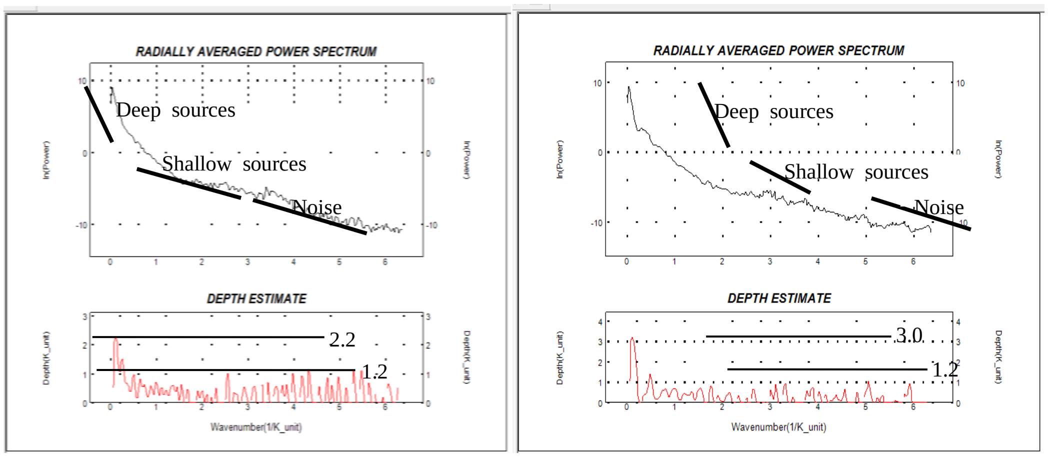

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Figure-3(A-P): Radially average power spectral plots of the study area.

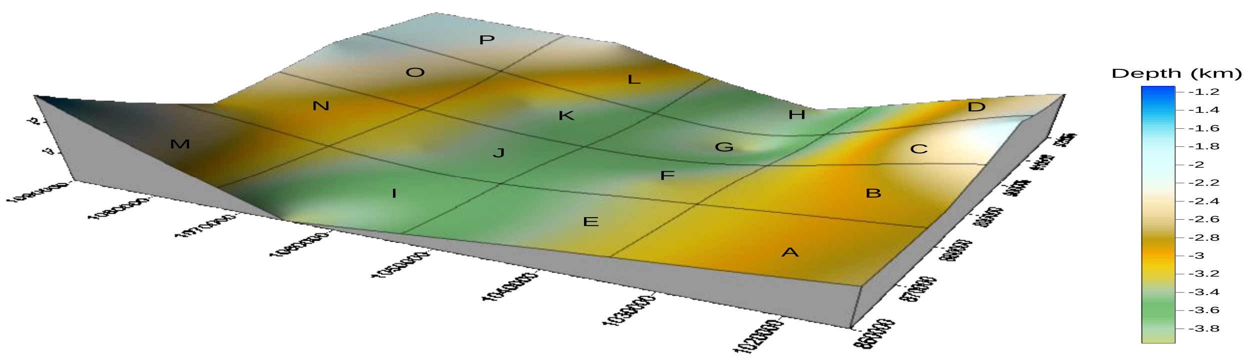

Figure-4: A 3-Dimension basement topographic map of the area divided into 16 blocks, power spectral operation was performed for each block. The greater depths are between -3.4 to -3.8 km and are within the Yola Trough.

Table-1: Deep and shallow sources from the power spectrum of the study area.

Blocks	Deep sources (km)	Shallow sources (km)
A	2.2	1.2
B	3.0	1.1
C	2.2	1.8
D	3.0	1.0
E	4.1	1.0
F	4.0	1.0
G	4.5	0.5
H	3.0	1.0
I	4.0	0.5
J	3.3	1.0
K	4.5	1.8
L	1.8	1.1
M	1.8	0.8
N	2.2	1.8
O	2.2	1.2
P	3.0	1.2

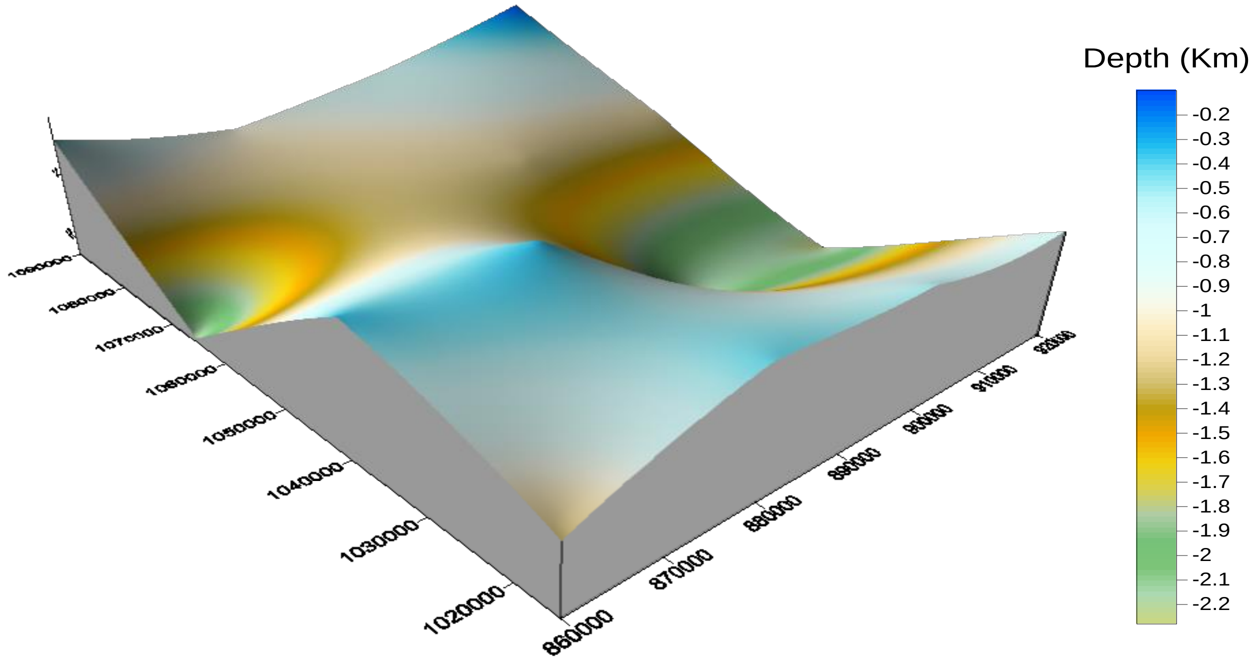

Figure-5: Shallow source depth to basement topographic map of the study area.

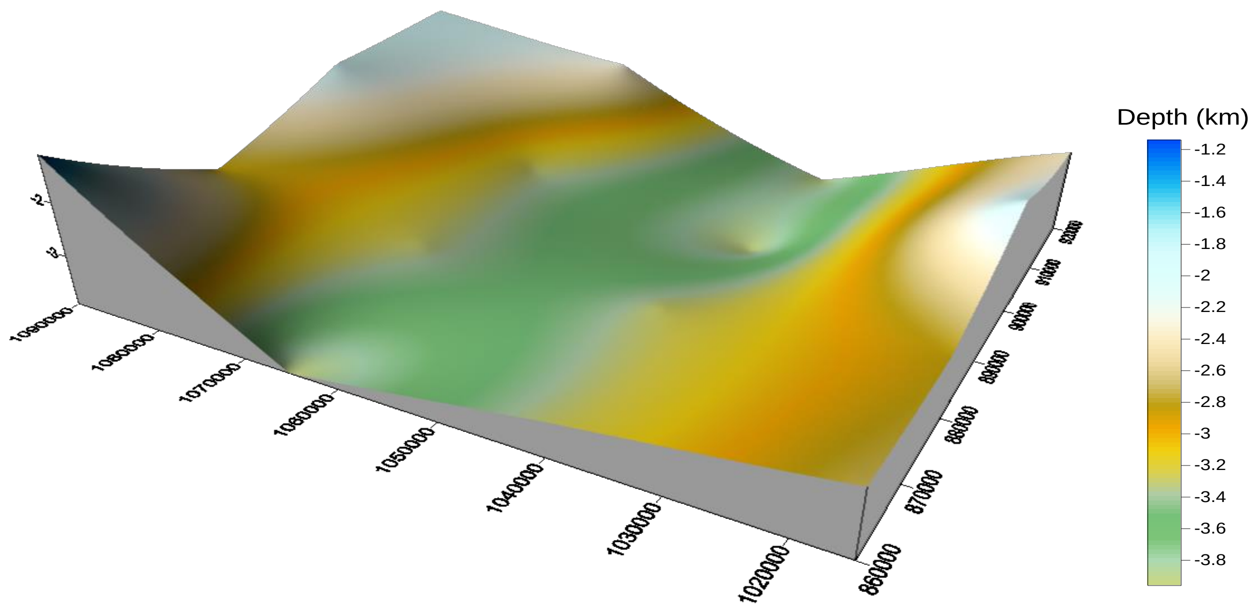

Figure-6: Deep source depth to basement topographic map of the area.

Table-2: Comparison of the sediment thickness by various workers.

Area	Results	Reference
Upper Benue trough.	1.22 – 3.45 Km	12
Middle Benue trough.	2.33-5.86	13
Upper Benue / Borno basin.	5.0 Km	14
Gongola basin, Upper Benue trough.	4 - 4.5 km	15
Upper Benue trough and adjoining basement areas	1.8 – 4.5 Km	Present work

Conclusion

The result of the average power spectrum and the depth to basement topographic map are genuinely reliable. These depths range from 0.5–1.8km for the shallow sources and 1.8–4.5km for deeper sources. The depth to magnetic basement of the area from the basement topographic map gives a range of 0.2-2.2km for shallow sources and 1.2-3.8km for the deeper sources. Areas with high sediment thickness (>1.8km) should be further studied using seismic survey. They could be probable zones for hydrocarbon accumulation. However such conclusion can only be drawn after comprehensive and integrated exploration activities are undertaken over the area. This suggestion is made in the light of present day petroleum exploration activities in Nigeria's inland Basins. The significance of this study is that there are no literatures in the areas around Ganye and Sugu areas of the basement complex, most of the studies are on regional scale.

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