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An Aeromagnetic Data Analysis and Interpretation over Middle Benue Trough, Nigeria.

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Abstract: *High Resolution Aeromagnetic data (HRAM) interpretation and analysis over parts of Benue Trough (Gboko, Makurdi, Katsina –Ala and Takum) was carried out to determine the depth to basement and appraise its hydrocarbons accumulation potentials using spectral analysis and source parameter imaging. Delineating the basement morphology and structural features within the basin using vertical derivative method and upward continuation was performed. Oasis montaj 6.42 and MATAB software were used as a tool to obtain some results presented in graphical format for energy spectral. The Qualitative results revealed lineaments with trend directions in the N-S, NE-SW, NWSE and E-W directions, with the NE-SW been dominant. In addition, the qualitative results of the depths to basement within the trough were established to be at 3.72 to 0.85km. The Source Parameter Imaging (PSI) plot generated showed the estimated average depth of 3.42km for depth magnetic basement and an average of 0.80km for the shallow depth.*

Keywords: *Aeromagnetic data, Benue Trough, Spectral depth, Energy spectral, Sedimentary thickness,*

1. INTRODUCTION

Mineral deposits and hydrocarbon (oil and gas) has been a major business challenge in Nigeria since the pre-colonial era and the 1960s. Over 80 percent of the country's revenue comes from export and domestic sales of the oil and gas upon which over 140 million growing population depends on [1]. As the hydrocarbon potential of the prolific Niger delta becomes depleted in the near future may be exhausted due to continuous exploration, attention needs to be shifted to other sedimentary basins. Recent interest in the inland basins in Nigeria for petroleum and mineral deposits necessitated the need to study one of the prominent basins the "BENUE TROUGH" which has received little attention from researchers for some time now [2].

The Benue Trough is a linear NE- SW trending rift system originated as a result of tectonic evolution from the separation of the African Continent from the South American Continent in the Aptian and the opening of the South Atlantic Ocean during the Cretaceous period.This separation led to the development of the triple junction characterized by South Atlantic Margin, the Gulf of Guinea, and the Benue Trough. However, The Benue Trough failed to develop into rift thereby creating an aulacogen [3] and [4]. The location of the Middle Benue Trough, Nigeria lies within Latitude 08.50°N– 09.50°N and Longitudes 09.00°E and 10.0°E.

Increased efforts to explore new reserve via high resolution aeromagnetic data over part of Middle Benue Trough has been the main drive behind this study because this research work is expected to increase the Nigeria oil and gas reserves and add values to the hydrocarbon potentials of the Nigerian inland basins, thereby provide investment opportunities, boost the economy and as well create of new jobs opportunities that will reduce unemployment in Nigeria. This study will be very useful on a reconnaissance basis for oil and mineral prospecting areas.

Some methods are used to measurethe variation of different physical or geochemical parameters of the earth such as gravity, electromagnetic, gamma ray spectrometry, density, electric conductivity and radioactive element concentration[5] and [6].

1.1. Magnetic Method

The method used in this work involves the measurement of the earth's magnetic field intensity, and theaim of magnetic surveying is to investigate subsurface geology on the basis of anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks [7], the measurement of vertical or horizontal gradient of the magnetic field is also achievable. TheAeromagnetic give rise to fast coverage of large and inaccessible areas for subsurface reconnaissance; thereby making magnetic data analysis an extremely important tool for geophysical exploration. Generally, magnetic surveying has been used in different studies to map out mineral and hydrocarbon potential zones.

Magnetic anomaly is a local variation in the earth's magnetic field resulting from variations in the chemistry or magnetism of the rocks.Mapping of variation over an area is valuable in detecting structures obscured by overlying material [8],the magnitude of magnetic anomalies is related to the magnetic intensity, the size and position of the disturbance. The high magnetization of the rock is mostly due to the presence of strongly magnetic minerals such as magnetite, titan magnetite, hematite and pyrrhotite. Thus, in oil prospecting the principal use of the magnetic method is in the determination of the thickness of non-magnetic sedimentary section or structural features on the basement surface that might influence the structure of overlying sediment. It is usually assumed that the structure of the sediment is controlled by basement topography; as a result, variations in the depth of the basement can suggest the possible location of oil deposit [9] and [10].

This research work is aimed at analyzing and interpreting the Aeromagnetic data over parts of Middle Benue Trough in Nigeria by:

i. Analyzing and interpreting the Total Magnetic Intensity (TMI) map.

ii. Estimating the position, depth and nature of anomaly sources present in the area.

iii Identifying zones of high potential of hydrocarbon prospecting within the study area.

2. Literature Review

Several research work have been done on the geology and economic mineralization of the study area and beyond using different parameters and methods.

[11] carried out qualitative and quantitative interpretation on aeromagnetic data of Maiduguri and environment of southern Chad basin to identify the nature and estimate depth of magnetic sources. The study revealed that, the depth to basement of the basin structures ranges from about 0.5 km in the southern part of the study area and deeper towards the northern part is up to 3.0 km. The spectral analysis employed in depthand temperature calculations helped in revealing the possible subsurface structure of the area that assisted in delineating of promising area for hydrocarbon exploration.

[12] carried out re-evaluation of hydrocarbon potentials of Eastern part of the Chad basin using aeromagnetic approach. The study revealed that the sedimentary thickness of the area ranges from 1.0 km to 5.5 km and obtained two sources depth; the shallow source with an average value of 1.5km and the deeper source with an average value of 3.97 km.

[13] evaluated the Magnetic Basement Depth over Parts of Middle Benue Trough Nigeria by Empirical Depth Rule Based on Slope Techniques Using the HRAM. The result of the study area showed an average depth to basement of 3.70 km and the oldest geological formation being marine sediment of Albian age, may be promising for hydrocarbon accumulation if other conditions are met, in the middle Benue using the 1970s data which showed that the magnetic basement depth vary from 1.513 km and 4.936 km.

[6]presenteda 2-D spectral analysis and Land sat Imagery of the adjacent lower Benue trough by equally revealed a two-layer depth model and predominant NE-SW lineament trend. The shallow magnetic source depth has an average depth of 1.041km while the deeper magnetic source bodies have an average depth of 3.574km.

[14]used spectral analysis to estimate the depth of subsurface structural in part of Bornu Basin. The result of his study reveals that the first layer depth estimated a range between 0.18 km and 1.9 km

while the second layer ranges from 2.9 km to 4.2 km and the highest sedimentary thickness was 4.2 km. The result shows the presence of hydrocarbon potential in the area.

[15]worked on the interpretation of high resolution aeromagnetic data over southern Benue Trough in south-eastern Nigeria which shows the maximum depth to basement values for 3D Euler and SPI to be 4.40 km and 4.85 km showing the area possesses high potential for large accumulation of base metal mineralization.

[16]worked on the determination of depth to basement rocks over parts of Middle Benue Trough in North Central Nigeria by using high resolution aeromagnetic data. The high resolution aeromagnetic data over part of middle Benue trough was interpreted quantitatively using Spectral depth analysis. The study area has been considered to be the most prospective area for hydrocarbon within the trough because depths to the mature zones are moderate 2km to 4km.

[17]analyzed the Aeromagnetic Data across Kebbi State, Nigeria. The study was aimed at extracting the magnetic anomalies of geologic interest from the residual magnetic data and to determine the depth to magnetic sources giving rise to magnetic anomalies using spectral analysis. The research work used selected aeromagnetic map sheets 26, 27, 28, 48, 49, 50, 71, 72, 73, 94, 95 and 96; which were published by the Nigerian Geological Survey Agency (NGSA). The data were collected at a nominal flight altitude of 152.4 m along N-S flight lines spaced approximately 2 km apart. The maps are on scale of 1:100,000 and half-degree sheets, and the maps were digitized on a 1.5 x 1.5 km grid system and SPT 98 software was used to obtain the spectral plots from which the depths were determined using D = -M/2. The results revealed clearly two magnetic depth layers. The depth to the shallow magnetic layer D1 varies from 0.22 km to 0.95 km with an average depth of 0.67 km while the deeper magnetic layer D2 varies from 0.80 km to 1.72 km with an average depth of 1.25 km.

[18]worked on an Aeromagnetic Mapping for Lithostructural Delineation for Iwo Region, Nigeria and to estimate depth to basement thickness. In the work, the filtered Aeromagnetic data over Iwo was subjected to reduction to magnetic equator filtering, residual filtering, upward and downward continuation filtering, automatic gain control filtering, tilt angle derivative, second vertical derivative, analytical signal and Euler deconvolution; this reveals the geologic information such as structural trend. The Result obtained showed that the total magnetic intensity map, reduction to equator map, analytical signal map and residual magnetic intensity map. The rocks in the study area have a trend of approximately northeast- southwest direction as seen on the upward continuation map. Most of the delineated lineaments found within the study area strike mostly in NNE-SSW, NE-SW and NW-SE with minor trend of E-W and ENE-WSW direction.

[19]investigated to determine the depth to the bottom of magnetic source across Sokoto basin, Nigeria or evaluate the sedimentary thickness of the Basin using source parameter imaging and 3D Euler deconvolution techniques. The Study employed fifteen number aeromagnetic sheets covering longitude 4°30'E - 6°00E and latitude 11°00'N - 13°30'N. The total magnetic intensity of the area was subjected to reduction to magnetic equator using a geomagnetic inclination angle of 1.4°, declination of 1.7° and a standard deviation of 0.1. The results from 3D Euler deconvolution revealed depths of 1.38, 2.14, 2.58 and 2.80 km for structural indexes of 0, 1, 2 and 3, respectively. Finally, the source parameter imaging result revealed a maximum depth of 1.65 km and aminimum of 0.1 km in the study area.

[20]employed a High-Resolution Aeromagnetic (HRAM) data covering the Dahomey Basin Nigeria have been interpreted to map the basement structural configuration and to identify mini-basins favorable for hydrocarbon prospect. The work was focused on detailed structural interpretation of high-resolution aeromagnetic data to provide additional insights on the basement block pattern, basin architecture and determine how the basement structure have affected the distribution of mini-basins and petroleum systems developed in the study area. The total magnetic intensity grid was reduced to the equator and edge detection filters including First Vertical Derivative (FVD), Total Horizontal Derivative (THDR), tilt derivative and total horizontal derivative of upward continuation were applied to the RTE grid to locate the edges and contacts of geological structures in the basin. Depth to magnetic sources were estimated using the source parameter imaging (SPI) method. Data interpretation results revealed shallow and deep-seated linear features trending in the NNESSW, NE-SW, NW-SE and WNW-ESE directions.

3. METHODS AND MATERIALS

3.1. Data Source

Four high resolution aeromagnetic maps (HRAM) having sheet numbers 251, 252, 271, and 272 with their locations Makurdi, Takum, Gboko and Kastina Ala respectively were acquired, assembled and interpreted. These maps were obtained as part of the nationwide airborne survey carried out by Fugro and sponsored by the Nigerian Geological Survey Agency in the year between 2003 and 2009.

The data were obtained at an altitude of 80m a flight line spacing of 500moriented inNorth West – South East (NW-SE) and a tie line spacing of 2km. The maps are on a scale of 1:100,000 and half-degree sheets ($1/2^o$ by $1/2^o$) contoured mostly at 10nT intervals. The geomagnetic gradient was removed from the data using the International Geomagnetic Reference Field (IGRF), the total area covered was about 12,100 km^2. The actual magnetic intensity value of 33,000 nT which was reduced for handling purpose must be added so as to get the actual value of the magnetic intensity at any point. The first step taken was to assemble the four maps covering the study area which was in a different sheets and the next step was to re-grid the maps using Oasis Montaj software (version 6.4.2) to produce the total magnetic intensity map (TMI) of the study area. The TMI was subjected to regional/residual separation using polynomial fitting with order one. The residual map shows both positive and negative magnetic intensity values and it ranges from -45.512 to 46.709 nT, and Figure 1 shows the residual magnetic intensity map of the study area.

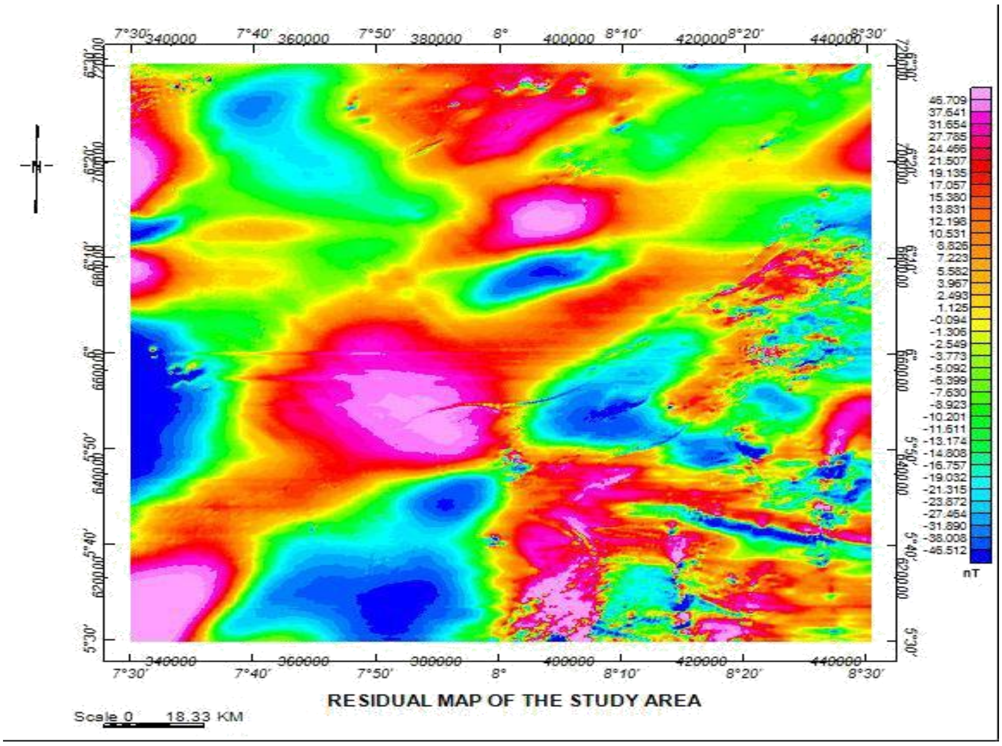


Figure1. *Residual Magnetic Intensity Map (A value of 33000nT is added to get the actual Total Magnetic Value).*

3.2. Materials

Materials used for this work includes:

I. Geosoft Oasis Montaj (6.4.2)

II. Surfer 11

III. Arc GIS

IV. Total magnetic Intensity (TMI) - Data

V. Geological map of the study area

The data collected at the Nigerian Geological survey Agency (NGSA) were subjected to the following corrections:

a. Magnetic Compensation

b. Noise Removal

c. Micro levelling

d. IGRF removal of 33,000 nT

Thus, the data for this interpretation which range in values from -45.512 nT to 46.709 nT are mostly of residual origin and were subjected to:

1. Regional residual separation using polynomial fitting method to establish the regional trend within the field.
2. Reduction to the equator to observe if there is any shift in anomaly position as a result of removal of data dependence on the angle of inclination.
3. Horizontal derivatives Δx, Δy, Δz to observe the relative changes in the direction ofmajor anomaly trending and as an input value for other analysis.
2. First and Second Vertical Derivatives to delineate the major structures and lineamentin the study area.
3. Analytical Signal helped in delineating the area into regions of magnetic boundaries, intermediate structures and basement under the influence of thick sedimentation.
4. Upward continuation which enhances the deep-seated anomaly thereby suppressing the shallow ones.
5. Source Parameter Imaging to also establish the depth of sedimentary rocks within the study area.
6. Spectral Analysis to establish the depth of sedimentary rocks.

3.3. Total Magnetic Intensity Map (TMI)

The total magnetic intensity (TMI) of the study area as shown in Figure 2 was contoured at 10 nT contour interval. The actual magnetic intensity value was reduced by 33,000 nT before plotting the contour maps. This means that a value of 33,000 nT should be added to produce the contour map and colour-shaded map of the total magnetic intensity using Surfer package of Golden Software Incorporation and Oasis Montaj software of Geosoft Technology (version 6.4.2) respectively.

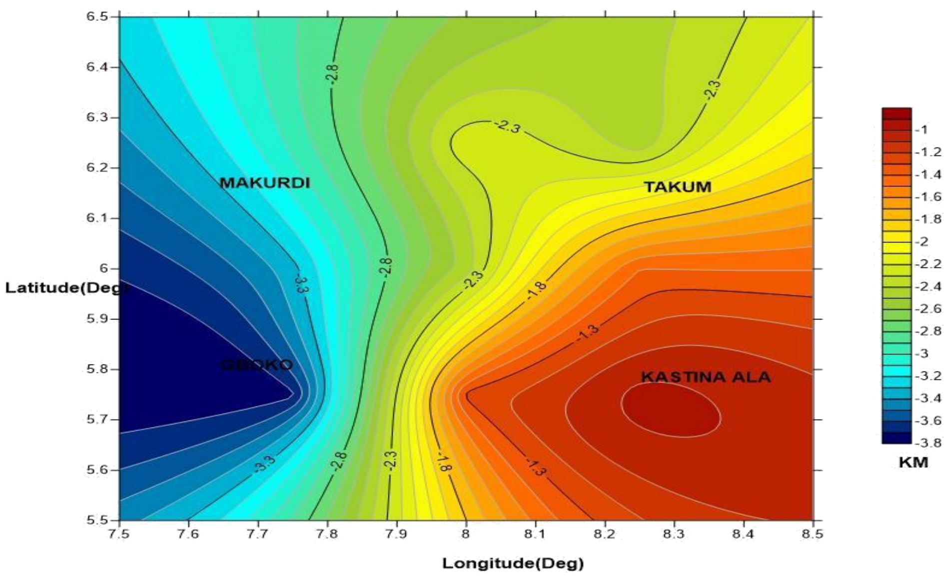


Figure2.*TMI Contour Map of the Study Area.*

3.4. Regional Residual Separation using Polynomial fitting

The effects of shallow masses (near-surface noise) are usually of short wavelength. They are removed largely by filtering out (smoothing) long wavelength anomalies. The effects of deep masses are called the regional,the magnetic field after near-surface noise and regional was removed called the residual; it presumably represents the effects of the intermediate zone of interest. Residual separation attempts to remove the regional so as to emphasize the residual. The Oasis Montaj software was used for the residual separation via wave length filtering scheme, various methods of separating residuals from the regional are based on the degree of smoothness (or wavelength) of anomalies. Filtering can also be done in the wave number domain using a 2D Fourier transformation to transform the data to wave number domain and then removing certain wave number components after which an inverse transformation is transformed to reconstitute the map, but with certain wavelengths removed. What are removed are usually the small wave numbers (long wavelengths) of the regional, so that the number components involved in the inverse are the large ones which correspond to short wavelengths of the residual. Wave number filtering encounters the same problem as other residualizing schemes. The wave number of most spectral features are broadband, so spectral features at different depths overlap and consequently the features cannot be separated completely by filtering.

3.5Upward Continuation

The proliferation of local magnetic anomalies often obscures the regional features with an overabundance of detail. Upward continuation thus smoothens out these disturbances without impairing the main regional features. The main purpose of upward continuation is to view the magnetic field intensity at a height above flight level so as to eliminate short wavelength anomalies by emphasizing longer ones reflecting regional features [21].

The equation of the wave number domain filter to produce upward continuation is given by:

$F = e^{\wedge}(-hw)$ (1)

where:

h is the continuation height.

For this research work, upward continuation will be carried out for height of 2 km, 5 km, 10 km, 15 km, 20 km, 25 km, 30 km ,32 km, 40 km and 50 km to enhance the deep seated magnetic features.

3.6. Depth to Source Estimation Techniques

Using the first aeromagnetic surveys, the recognition of the largest magnetic anomalies was produced by sources near the top of the crystalline basement, and the wavelengths of these anomalies increased as the basement rocks becomes deeper. Techniques such as the Source Parameter Imaging (SPI) technique were devised to estimate the depths to the magnetic sources and thus, the thickness of the overlying sedimentary basins. Mapping basement structure became an important application of the new aeromagnetic method. Below are the depth estimation techniques employed in this work.

3.6.1 Source Parameter Imaging

This technique is based on the complex analytic signal, which computes source parameters from gridded magnetic data. The technique is sometimes referred to as the local wave number method. The local wave number has maxima located over isolated contacts, and depths can be estimated without assumptions about the thickness of the source bodies. Solution grids using the SPI technique show the edge locations, depths, dips and susceptibility contrasts. The local wave number map more closely resembles geology than either the magnetic map or its derivatives. The technique works best for isolated 2D sources such as contacts, thin sheet edges, or horizontal cylinders.

The SPI method [22] estimates the depth from the local wave number of the analytical signal.

In this study, data were transformed to its analytical signal from which basement texture and depths were determined.

The analytical signal $A_1(x, z)$ [23] is given by:

$A_1(x,z)=[\partial M(x,z)/\partial x]-j\partial M(x,z)/\partial z$ (2)

where:

M(x,y) is the magnitude of the anomalous total magnetic field.

j is the imaginary number, z and x are Cartesian coordinates for the vertical direction and the horizontal direction respectively.

The horizontal and vertical derivatives comprising the real and imaginary parts of the 2D analytical signal and are related as follows:

$\partial M(x,z)/\partial x \Leftrightarrow \partial M/(x,z)\partial z$ (3)

where:

⇔ denotes a Hilbert transformation pair.

3.6.1.1 Analytic Signal

The concept of analytic signal for magnetic interpretation shows that its amplitude yields a bell-shaped function over each corner of a 2D body with polygonal cross-section [23] and [24]. For an isolated corner, the maximum of the bell-shaped curve is located exactly over the corner, and the width of the curve at half its maximum amplitude equals twice the depth to the corner. The determination of these parameters is not affected by the presence of ruminant magnetization. Horizontal locations are usually well determined by this method but depth determinations are only reliable. For polyhedral bodies [25]the use total magnetic gradient which they called the “3-D analytic signal” to approximately estimate positions of magnetic contacts and obtain some depth estimates from gridded data. Their results however, are strongly dependent on the direction of total magnetization in sharp contrast with the 2D case

The 3D analytic signal A of a potential field anomaly (Nabighian, 1984) is given by:

$A(x,y,z)= [\partial M/\partial x]x+ [\partial M/\partial y]y+ [\partial M/\partial z]z$(4)

where:

M = Magnetic field.

3.6.2. Spectral Analysis

The statistical spectral analysis of the residual field data was used to determine the depths to the buried magnetic sources within the subsurface of the study area. Amodel developed[4] for 2-D spectral depth determination method assumes that an uncorrelated distribution of magnetic sources exists at a number of depth intervals in a geologic column. The Fourier transform of the potential filed 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) is related to the geometry of the body according to the following expression.

$W'= \ln(h_b/h_t)/(h_b-h_t)$(5)

where:

W' is the peak wave number in (radian / ground).

$ht$is the depth to the top.

h_b is the depth to the bottom.

3.6.2.1 Spectral Cells Division

In otherto control the large data involved, the four residual blocks of the study area of the middle Benue trough was subdivided and pre-sectional into nine spectral cells. Each section (A-I) was subjected to spectral analysis using Oasis Montaj (6.4.2) software andMATLAB software as a tool was employed to plot the energy spectral graph.

4. Results

4.1. Total Magnetic Intensity (TMI)

The Total Magnetic Intensity map of the study area in Nano Tesla (nT) and the contour intervalin 10 nT is shown in Figure 3. The colour image shows the variation of High (H) and Low (L) of the magnetic anomaly ranging from minimum value of -0.36 nT to maximum value of 177.19 nT. Magnetic. The regions with pink colour marked ‘H’ are closures with high magnetic signatures and while the regions with blue colour marked ‘L’ are the lows. The reddish part also predicates high magnetic signature while the yellowish colour indicates an intermediary between low and high magnetic signature. The greenish colour represents alluvium deposition. The magnetic field data is small because it’s been reduced by 33000 nT for simplicity.

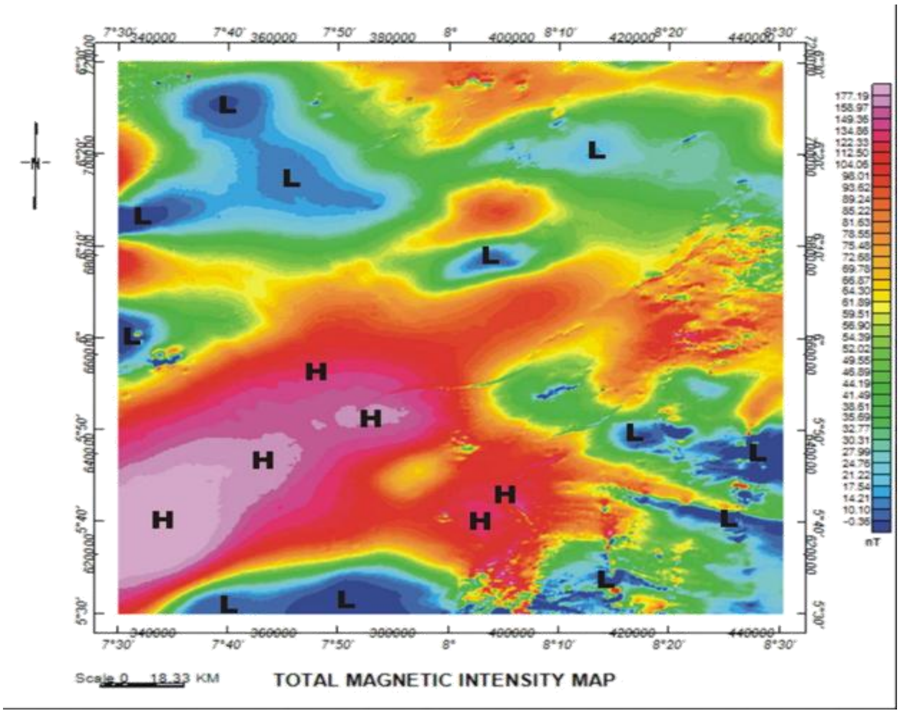


Figure3. *Total Magnetic Intensity Map (A value of 33000 nT is added to get the actual Total Magnetic value).*

4.2. Residual Magnetic Intensity Map

The Residual magnetic intensity map produced in this study using polynomial fitting via Montaj software is as shown in Figure 4which shows the magnetic intensity values ranging from 46.512 nT to 46.709 nT. Magnetic intensity with negative values are scattered in the study area but are more prominent in the northeast-southwest and north central of the study area, while positive magnetic intensity values are more pronounced in the southern and western part of the study area. There is also an occurrence of the positive magnetic intensity value in the eastern part.

The positive magnetic intensity values trend NE-SW while the negative magnetic intensity values trends SE Part of the study area. The high magnetic intensity values are as a result of an intrusive body into the sedimentary structurewhile the low magnetic intensity values were associated with the sedimentary region.

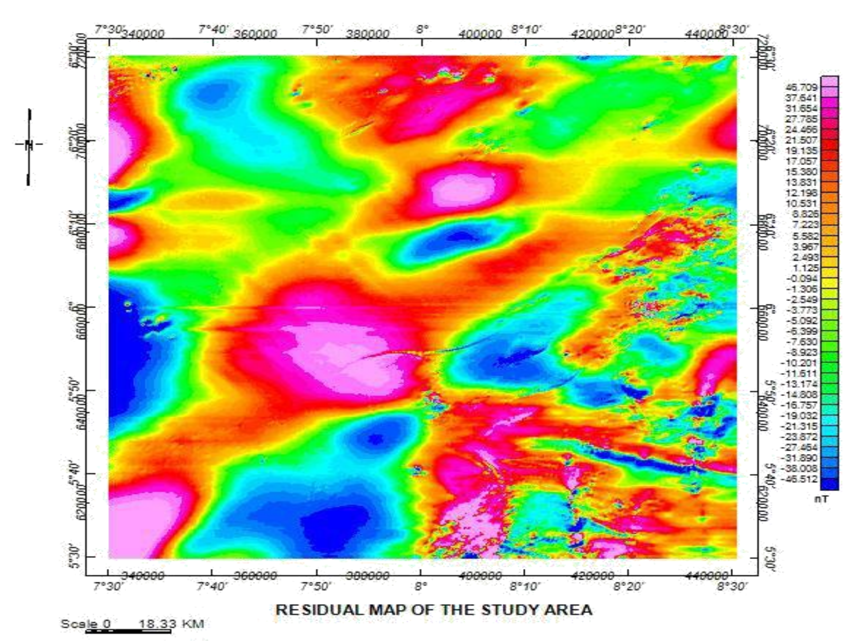


Figure4. Residual Magnetic Intensity Map*(A value of 33000 nT is added to get the actual Total Magnetic value).*

4.3Analytical Signal Map

Figure 5 shows the variation in the amplitude (both high and low) of the anomalies. It was observed that the high amplitude anomaly is as a result of intrusive bodies into the sedimentary structure, and the high amplitude anomaly is attributable to wide variation in susceptibility of rock-units in zones of fracturing, shearing and faulting. While the low amplitude anomaly was associated with sedimentary region which is the area of interest in this study. The high amplitude anomaly trends North East – South West(NE-SW) while the low amplitude anomaly trends East-West (EW). This distinguishes the area into regions of magnetic boundaries, intermediate structures and basements under the influence of thick sedimentation, it shows the types of outcrops present.

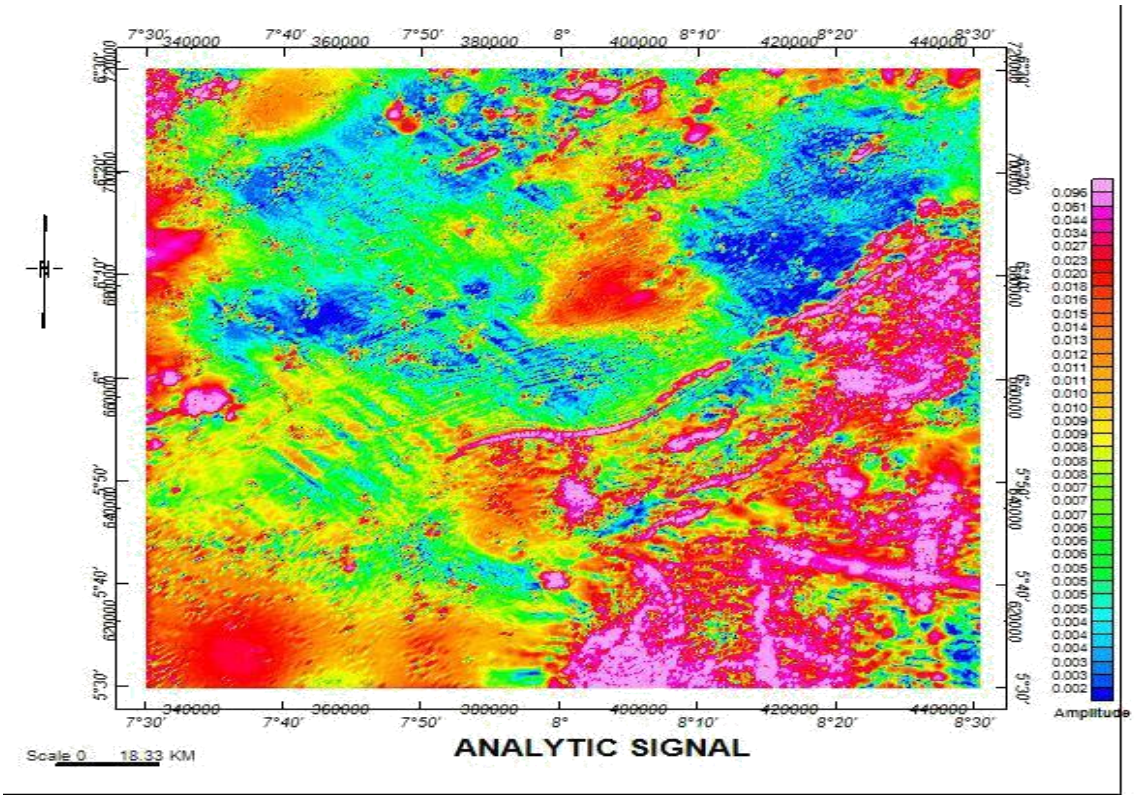


Figure5. *Analytic Signal Map.*

4.4. Upward Continued Filter Control

These are Total Magnetic Intensity (TMI) results obtained from filtering process using upward continuation filter control at certain height interval above flight level.

4.4.1 Upward continued at 2 km

Figure 6 below shows the TMI map at the height of 2 km above flight level, here the shorter wavelength anomalies are visible. At the southeast part of the map, the pink colour is more conspicuous while the blue colour and green colour are spread all over the map. The yellow-pink colour dominates the northern and the western part of the map. This means that the effect of near surface magnetic anomalies could still be noticed on the map.

4.4.2Upward continued at 5 km

Figure 7 shows the height at 5 km above flight level revealing the short wavelength anomalies have started disappearing thereby unifying longer wavelength, enhancing deep seated anomalies. The map also shows that basement features are more prominent than the shallow sedimentary structures.

4.4.3 Upward continued at 10 km

At the height of 10 kmabove flight level as shown in Figure 8, the basement structures occupy more portion of the study area. The sedimentary structures appear at the southern region and small portion appears at the east part of the study area.

4.4.4Upward continued at 15 km

The basement structures appeared quite distinct from the sedimentary region as shown in Figure 9 at 15 km above flight level. Areas of lowest magnetic values, (such as areas of thicker deposits of sediment) found to be at southern region of the study area.

4.4.5 Upward continued at 20 km

At this heightabove flight level as shown on the map in Figure 10, the thicker deposits of sediment trend towards the extreme south of the study area while the basement structures still occupy east part of the study area. There is no significant difference from the upward continuation at the height of 15 km because the thicker deposits of sediments suddenly disappeared at the southern part of the study area.

4.4.6 Upward continued at 25 km

Figure 11 is the upward continuation at 25 km above flight level which is the same with that at 20 km with small variation in the basement structures which tends towards the extreme eastern part of the study area while the sedimentary structures also appears at the extreme south of the study area.

4.4.7 Upward continued at 30 km

As shown in Figure 12 at 30 km height above flight level the basement structures appeared at the extreme eastern part of the study area and the areas of low magnetic values appeared at the extreme southern part of the study area.

4.4.8 Upward continued at 35 km

It was observed that the upward continuation at 35 km above flight level asshown in Figure 13, the upward continuation at 40 km as shown in Figure 14 and the upward continuation at 45 km as shown in Figure 15 are the same showing the basement structures appearing at the extreme eastern part of the study area and the areas of low magnetic values appeared at the extreme southern part of the study area. In the three cases the shallow anomaly is almost invisible.

4.4.9 Upward continued at 50 km

The upward continuation at this heightabove flight level as shown in Figure 16 shows that the basement structures occupied the extreme eastern part of the study area while the areas of low magnetic values also occupied the extreme southern part and the extreme southern part of the study area is generally characterized with low magnetic values, an indication of either thicker sediment in the region, or deep-seated anomalies. The map conspicuously reveals the regional effects, and trends southeast-northwest.Therefore, Figure 16 can be called the regional map produced from this study.

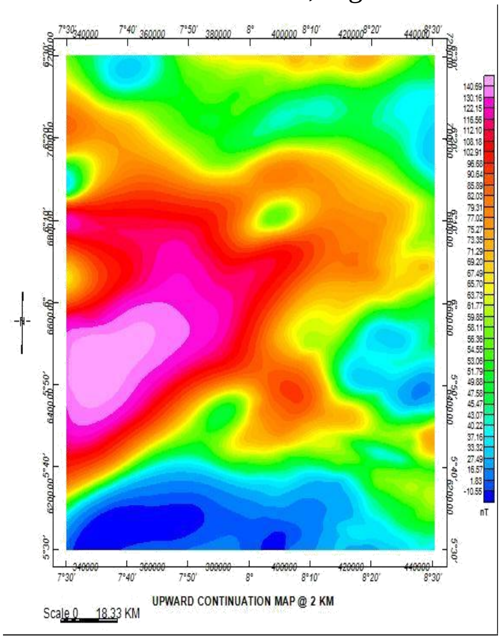


Figure 6.*Upward continuation Map at 2 km.*

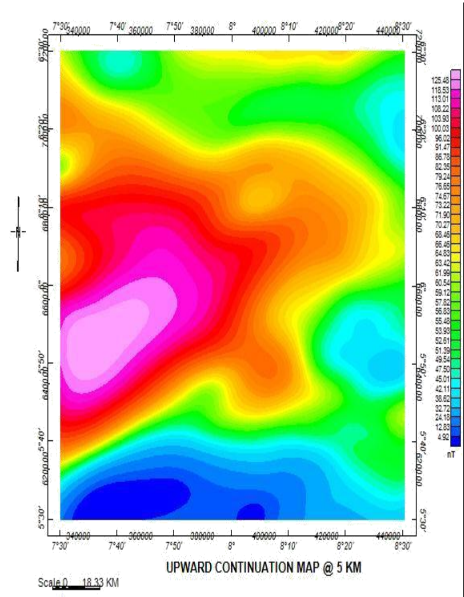


Figure 7.*Upward continuation Map at 5 km.*

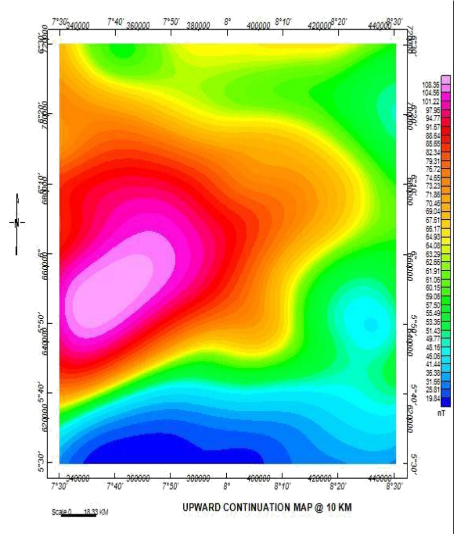


Figure 8.*Upward continuation Map at 10 km.*

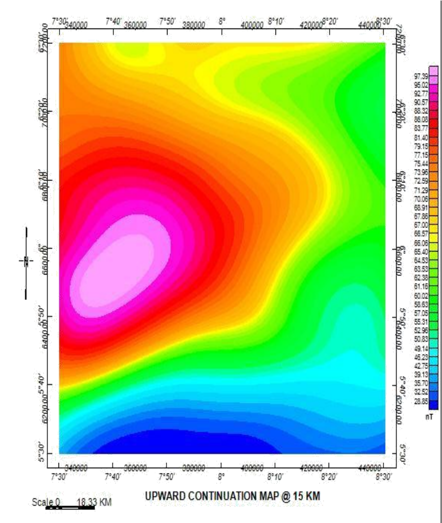


Figure 9.*Upward continuation Map at 15 km.*

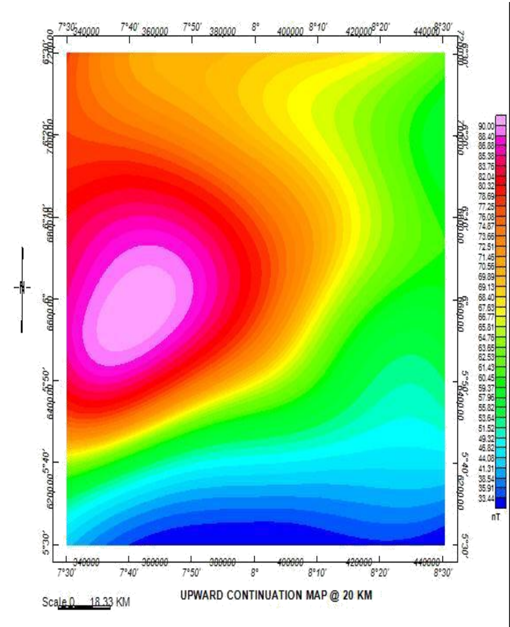


Figure 10.*Upward continuation Map at 20 km.*

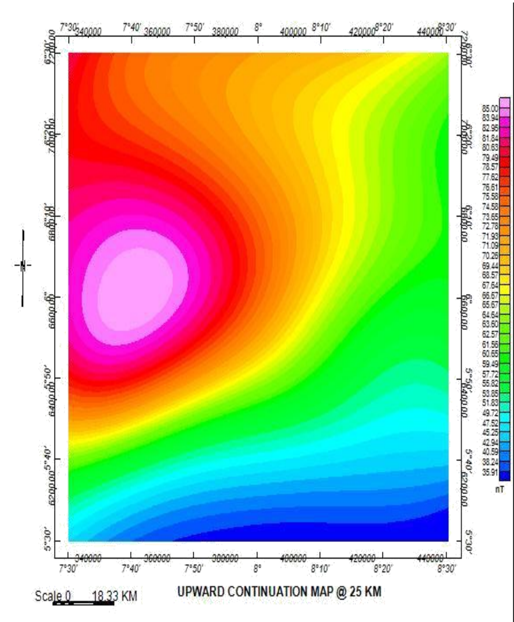


Figure 11.*Upward continuation Map at 25 km.*

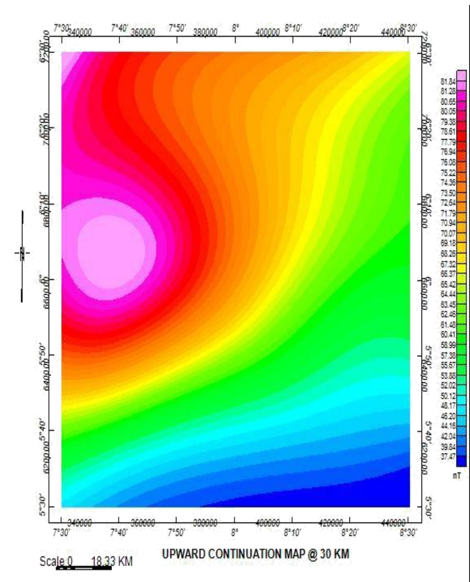


Figure 12.*Upward continuation Map at 30 km.*

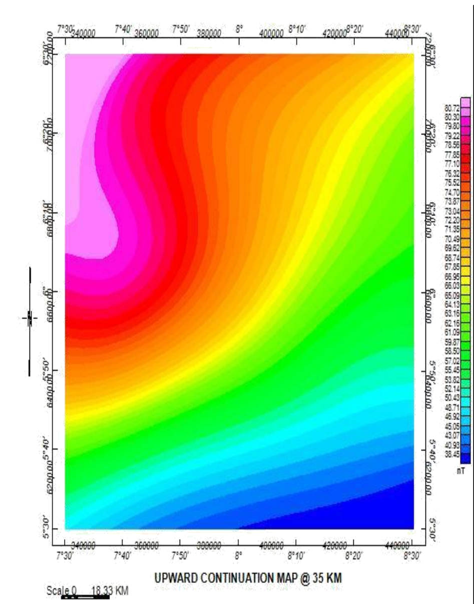
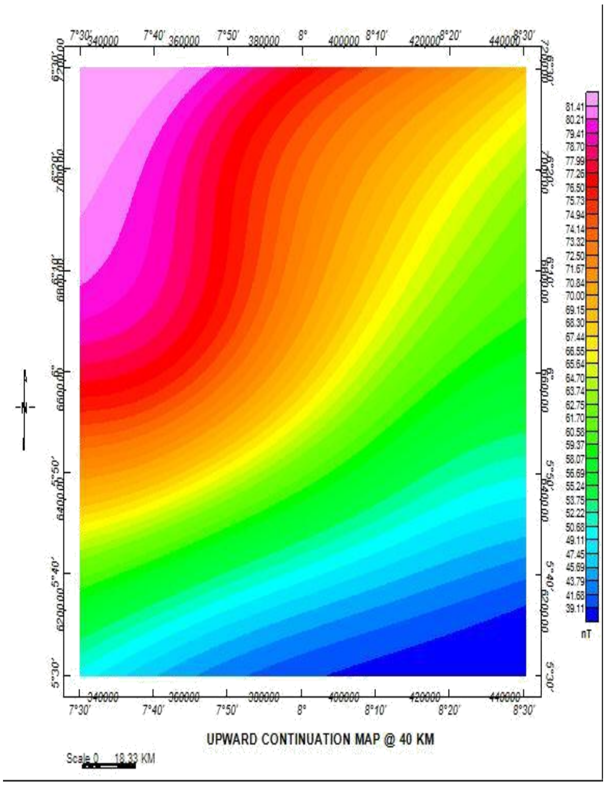


Figure 13.*Upward continuation Map at 35 km.*



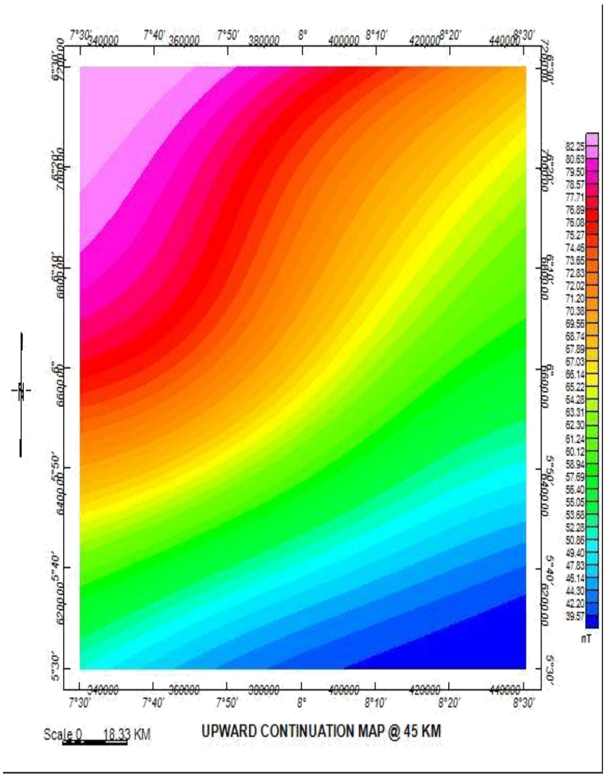


Figure 14.*Upward continuation Map at 40 km.*

Figure 15.*Upward continuation Map at 45 km.*

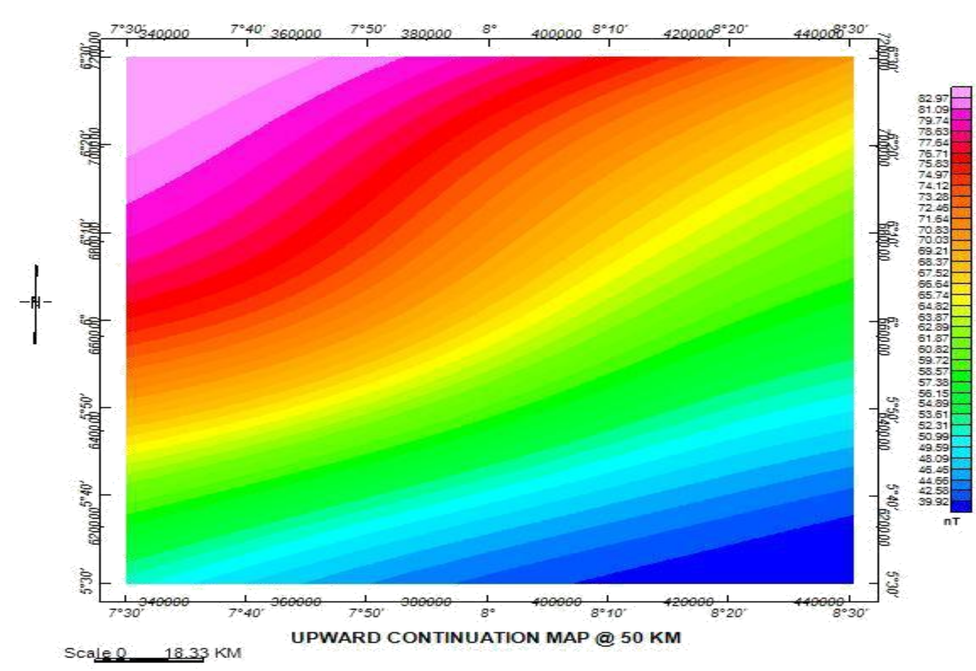


Figure 16.*Upward continuation Map at 50 km.*

4.5 Depth Determination from Source Parameter Imaging (SPI) Method

Figure 17 shows the source parameter imaging map produced from this study using Oasis Montaj software. The pre-processed grids dx, dy and dz from the residual grid of the study area was used as input grid to produce the source parameter imaging. The map reveals two depth source; shallow depth and deeper depth. The areas with pink colour depicts the shallow depth and the areas with blue colour depicts the deeper source which is the area of interest that can accommodate presence of hydrocarbon potential.

The shallow depth source ranges from 0.085 km to 0.148 km, and the are more pronounced at the South East (SE) and extreme eastern part of the study area which corresponds to Kastina Ala and Takum respectively with the maximum sedimentary thickness of 3.42km, this area Gboko might be a good region for hydrocarbon potential.

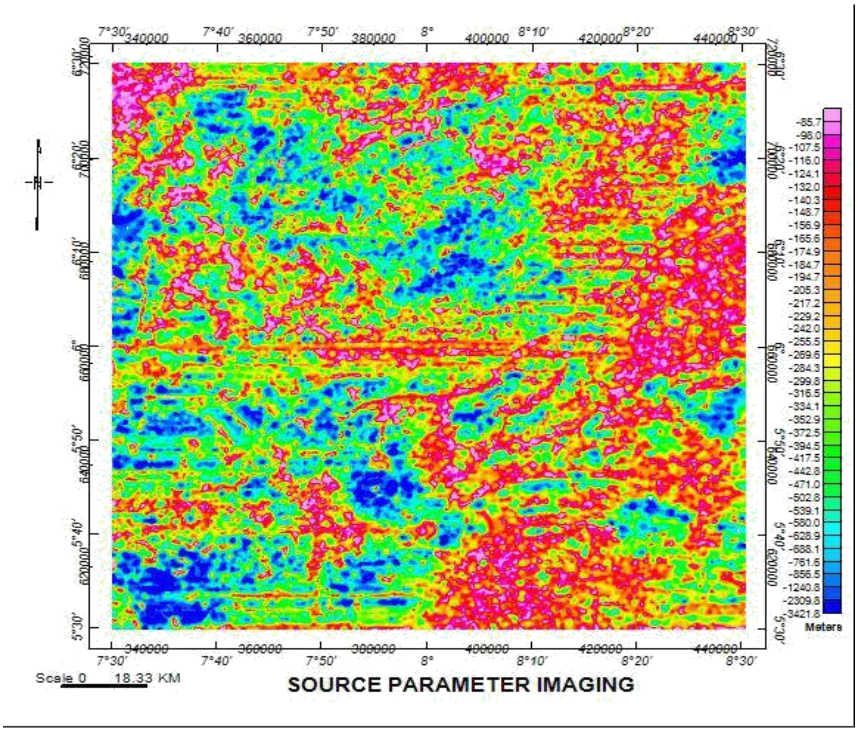
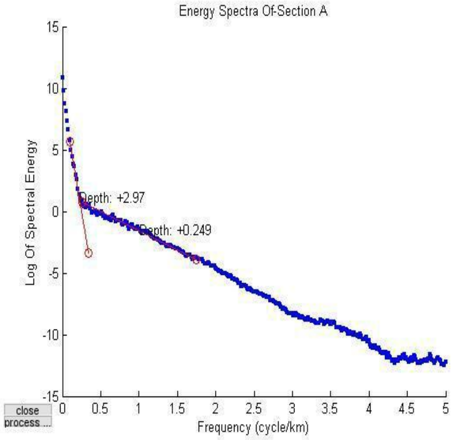


Figure17. *Source Parameter Imaging (SPI) Map.*

4.6 Spectral Depth Estimation

The residual map produced from this study was divided into nine (9) spectral sections (A-I) of overlapping magnetic sections using the 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 number of nine (9) spectral energies were plotted using MATLAB. A plot of energy spectrum against frequency (wave number) is shown in Figure (18 A-I), and the highest depth was seen in plot C.

The spectral depth of 3D modelling and contour map is also shown in Figures 19 and 20 respectively. The shallow depth sources from Figure 19 is 0.72 km while the deeper depth source is 3.72 km. The spectral table is shown below in Table 1, the shallow depth source ranges from 0.25 km to 0.85 km, while the deeper depth source ranges from 1.27 km to 3.42 km.



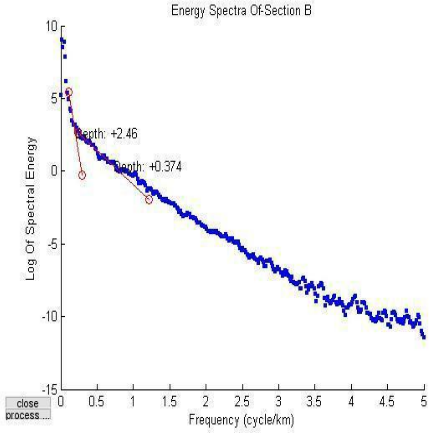


Figure18a.*Energy against Frequency of SectionA.* **Figure18b.***Energy against Frequency of Section B.*

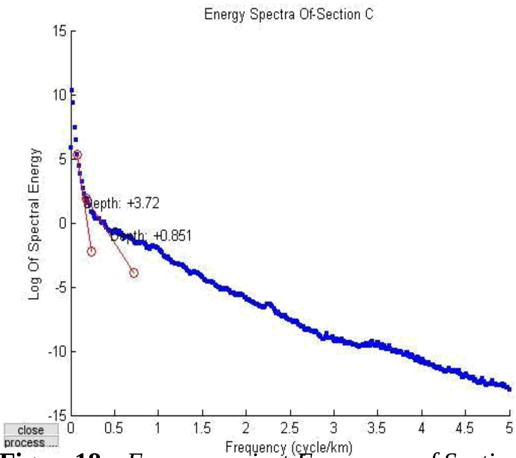


Figure18c. *Energy against Frequency of Section C.*

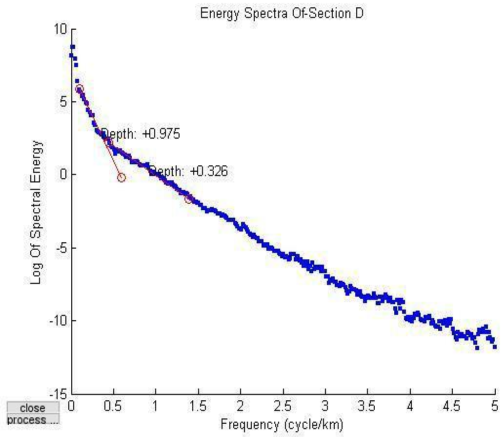


Figure18d. *Energy against Frequency of Section D.*

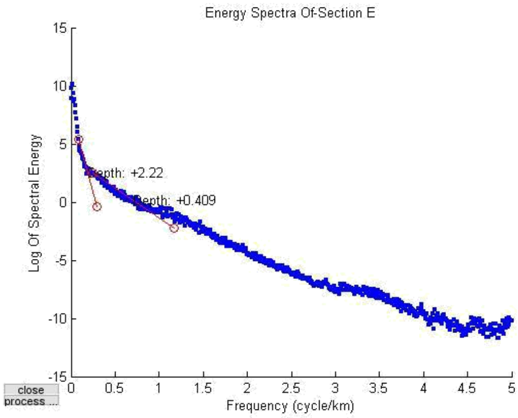


Figure18e. *Energy against Frequency of Section E.*

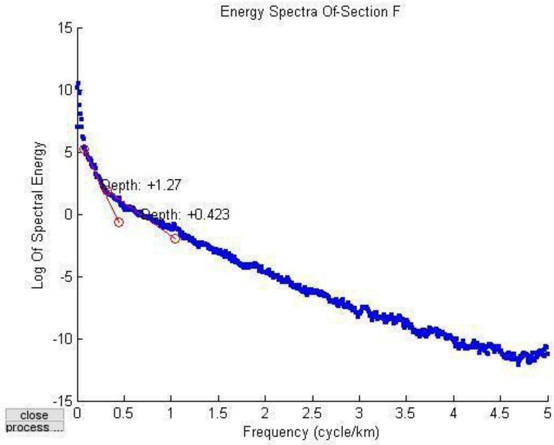


Figure18f. *Energy against Frequency of Section F.*

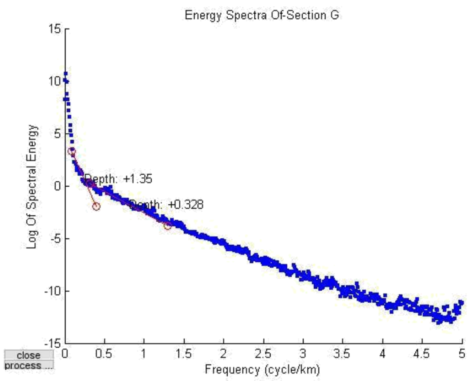


Figure18g. *Energy against Frequency of Section G.*

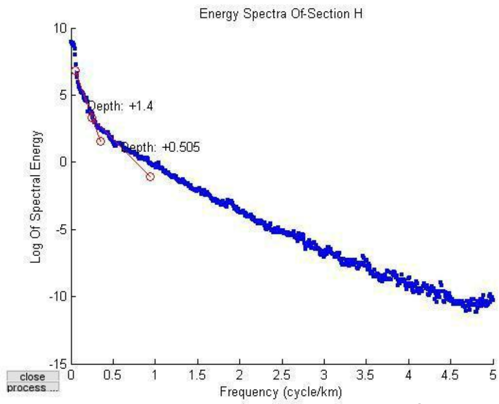


Figure18h. *Energy against Frequency of Section H.*

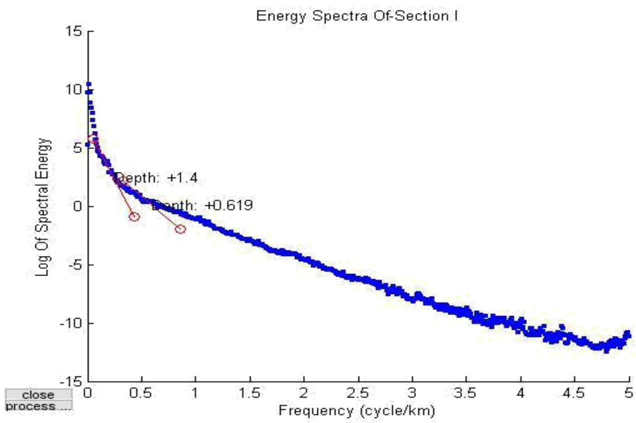


Figure18i. *Energy against Frequency of Section I.*

Table1. *Estimated Depth of Deeper and Shallow Magnetic Source Rock of part of Benue Trough.*

	Longitude(x) (Degree)	Latitude(Y) (Degree)	Z_1 (km)	Z_2 (km)
A	7.75	6.25	2.97	0.25
B	8.25	6.25	2.46	0.37
C	7.75	5.75	3.72	0.85
D	8.25	5.75	0.97	0.33
E	8.0	6.25	2.22	0.41
F	8.0	5.75	1.27	0.42
G	7.75	6.0	3.33	0.39
H	8.25	6.0	1.40	0.05
I	8.0	6.0	2.25	0.61

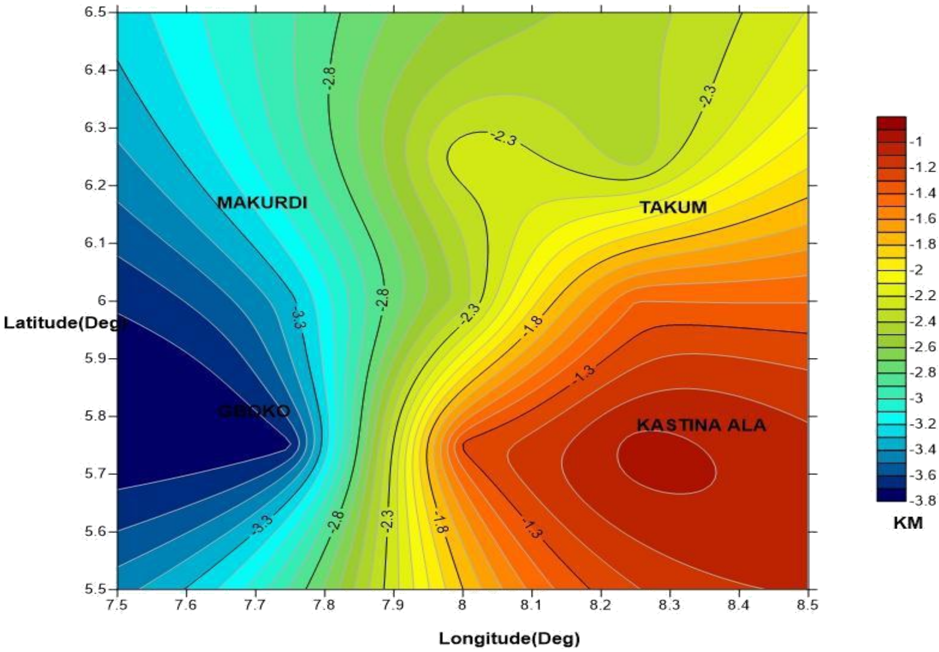


Figure19. *3D Map of Depth to Top Magnetic Basement of Study Area.*

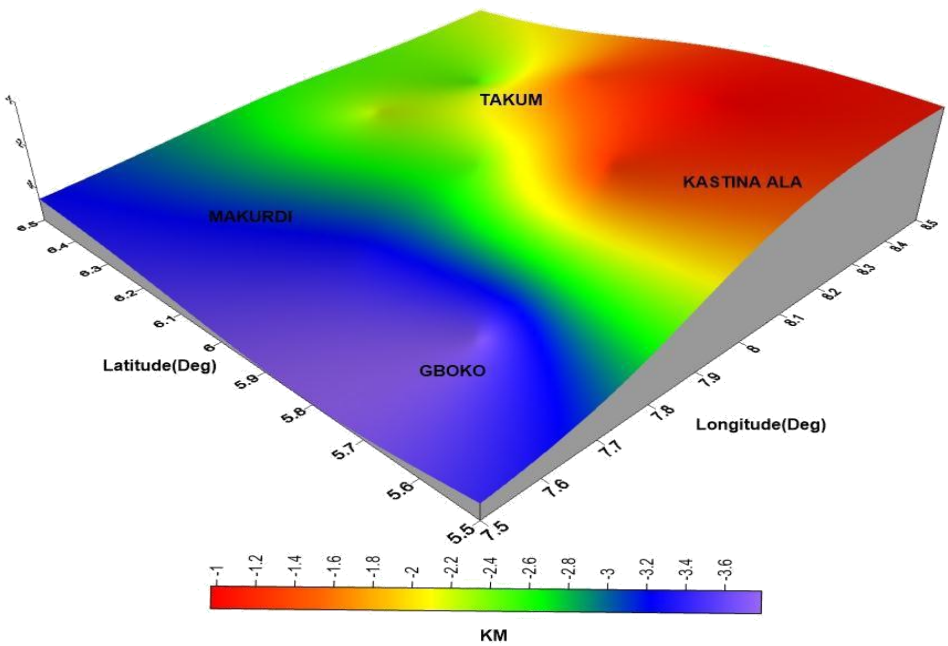


Figure20. Contour Map of Depth to Top Magnetic Basement of Study Area.

4.7Vertical Derivative of Total Magnetic Intensity

Figure 21 shows the first vertical derivative of total magnetic intensity map produced from this study,which reveals the anomaly texture of the total magnetic intensity. It is applicable in finding magnetic lineament and to determine the border between lithological units more precisely. The lines drawn on the map indicate the lineament like fault and fractures and their orientations.

Figure 22 shows the second vertical derivative of total magnetic intensity produced from the study. The second vertical derivative of magnetic field gives the rate of change of the vertical gradient in the vertical direction. It measures the size of curvature of the magnetic field and it is used for resolution of anomalies in magnetic field to aid geological mapping, for delineation of geological discontinuities in the subsurface.

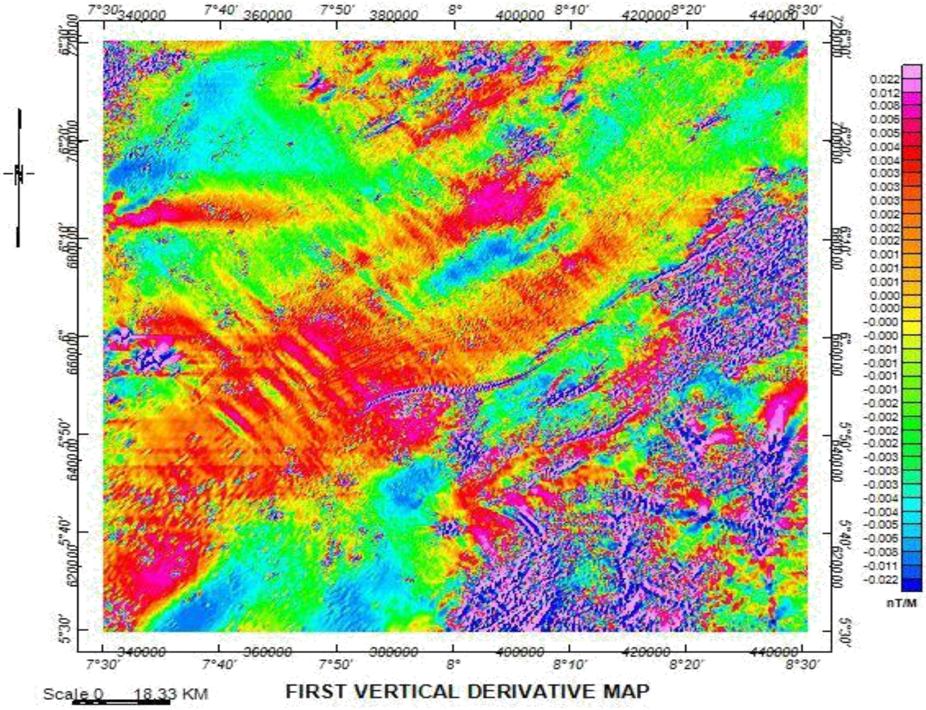


Figure21. *First Vertical Derivative of Total Magnetic Intensity.*

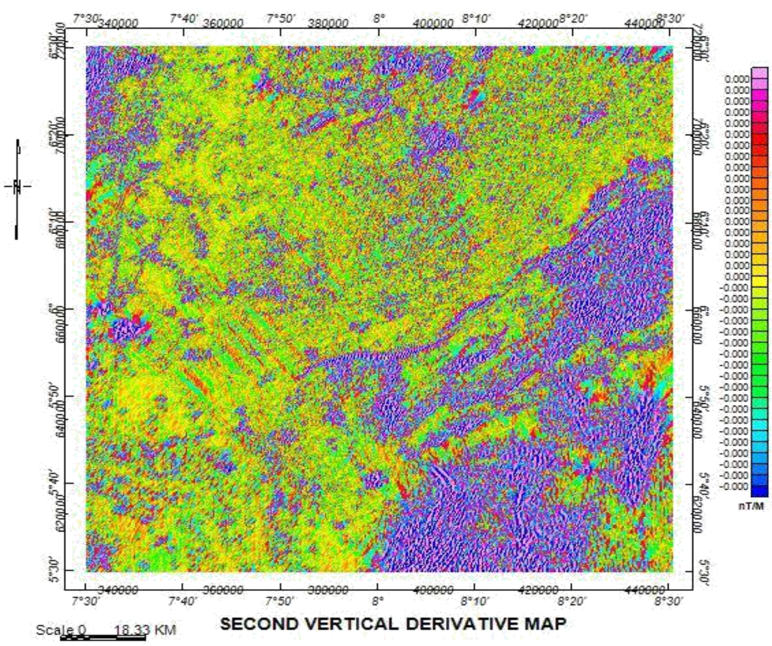


Figure22. *Second Vertical Derivative of Total Magnetic Intensity.*

5. CONCLUSION

Analysis and Interpretation of Aeromagnetic data over over part of Middle Benue Trough (Gboko, Makurdi, Katsina –Ala and Takum) has been presented in this study. The Total Magnetic Intensity was analyzed and interpreted, an estimation of the position and depth of the study area was also carried out to identify region of high hydrocarbon potentials, since the presence and the magnitude of minerals, oil and gas can only be ascertained by geophysical investigations of the subsurface geologic structures.

The study of sedimentary basins for hydrocarbon potential depends on 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, 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 source parameter imaging with highest sedimentary thickness of 3.42 km and the spectral analysis with highest sedimentary thickness of 3.72 km is sufficient enough for hydrocarbon maturation therefore, the study area has favourable prospect for oil accumulation.

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