

Interpretation of Aeromagnetic Data over Ankpa and Nsukka Areas of Lower Benue Trough Nigeria

Udegbe S.U¹, Ezema .P.O² Chima,A.I³, Ikechukwu.A⁴. and Chime P.I⁵.

^{1,2,3,4}Department of Industrial Physics, Enugu State University of Science and Technology Nigeria.

⁵Department of Physics Coal City University Enugu, Nigeria

Corresponding Author: Udegbe Stanley (Abraham.chima@esut.edu.ng).

ABSTRACT: The aeromagnetic data of Ankpa and Nsukka areas have been interpreted qualitatively and quantitatively. The total magnetic intensity and residual intensity field showed range of magnetic anomalies which reveal that the study area is magnetically heterogeneous. The Horizontal derivative showed the occurrence of subsurface liner structure which could be the presence of faults in the study area. Oasis Montaj, Microsoft and surfer 10 software were employed in the data analysis. This research work is based on high resolution of aeromagnetic data interpretation of Ankpa and Nsukka using Spectral Analysis, Source Parameter Imaging, Euler Deconvolution, forward and inverse modelling in order to obtain the residual magnetic data, estimate the depth to basement and determine the feasibility for hydrocarbon potential in the area, determine the magnetic susceptibility and possible solid minerals in the area. The result from spectral analysis shows that the depth to the magnetically deep source ranges from 2.4 to 6.6km with an overall depth of 3.953km while the depth to the shallow source ranges from 0.66 to 1.7km with overall average depth of 0.979km. The depth result from SPI ranges from -367.9m (shallow magnetic bodies) to -6412.7m (deep lying magnetic bodies). The depths of the magnetic source bodies estimated from Euler deconvolution for the three different structural index (SI=0, 1 and 2) ranges from 1036.4m (out cropping magnetic bodies) to -7613.0m (deep lying magnetic bodies). The estimated depths from the forward and inverse modelling method are 522, 1289, 5766, 710 and 1828m for profiles 1-5 with susceptibility values of 0.0146, 0.0045, 0.0200, 0.0001 and 0.0240 SL respectively which indicate dominance of minerals like shale, pyrite, sandstone, dolomite and limestone

Keywords: Aeromagnetic Data, Magnetic Intensity, Residual Intensity field, subsurface liner structure, Trough

I. INTRODUCTION

Aeromagnetic survey is one of the most important tools used in modern geological mapping. It is a rapid and cost effective technique for locating both hidden ores and structures associated with mineral deposits. Roughly about 60% of magnetic surveys are carried out for regional geological mapping and mineral exploration purposes while the remainder being mainly for petroleum exploration [1]. In many countries of the world including Nigeria, government agencies and private interests have employed aeromagnetic method to survey most of their countries in search for oil and gas and for mapping strongly magnetic basements at regional scale and for delineating weakly magnetic sedimentary contacts at local scale [2]. Large scale aeromagnetic surveys have been used to locate faults, shear zones and fractures and lineaments which could be possible host to varying earth resources such as minerals, oil and gas [3]. Aeromagnetic survey is carried out using a magnetometer aboard or towed behind an aircraft. The aircraft typically flies in a grid-like pattern with height and line spacing determining the resolution of the data. As the aircraft flies, the magnetometer measures and records the total magnetic field intensity at the sensor. The measured intensity is a combination of the desired magnetic field generated in the Earth as well as little variations due to the temporal effects of the constantly varying solar wind and the magnetic field of the survey aircraft. After removal of the solar wind, regional, and aircraft effects, the resulting aeromagnetic map shows the spatial distribution and relative abundance of

magnetic minerals [4]. This project work covers interpretation of aeromagnetic data over Ankpa and Nsukka area. Spectral analysis, source parameter imaging (SPI), forward and inverse modelling and Euler deconvolution are the methods that will be adopted in this study for solid minerals and hydrocarbon exploration in Nigeria.

1.1 LOCATION AND GEOLOGY OF THE STUDY AREA

The geology of the Lower Benue Trough has been described by several authors [5],[6],[7]. The Lower Benue Trough is underlain by a thick sedimentary sequence deposited in the Cretaceous. The study area lies between latitudes 6°30' and 7°30' North and longitudes 7°00' and 7°30' East. It covers a total surface area of approximately 6050 kilometer square. Nsukka is a sedimentary unit within the Anambra Basin underlain by rocks which range in age from Coniacian to Paleocene. Anambra Basin consists of six major rock units namely Enugu shale, Agwu shale, Mamu formation, Ajali formation, Nsukka formation and Imo shale formation. These rocks are grouped into four formations namely: Mamu formation, Ajali Sandstone, Nsukka Formation, and Imo Shale Formation [8];[9] The geology of Nsukka and Ankpa areas are composed mainly of Imo Formation of Paleocene, Nsukka Formation, Ajali Formation of Maastichtian and Mamu Formation [8];[9]

II. MATERIAL AND METHODS

The materials used for this study include two sheets of aeromagnetic data of Ankpa and Nsukka area (227 and 268 respectively) which will be obtained from the Nigerian Geological Survey Agency (NGSA). Software applications that will be used include: Oasis Montaj 6.4.2, Potent Q, Microsoft excel, and Surfer10. While the aeromagnetic quantitative analysis techniques we adopted in this study are;

- (i) Spectral analysis
- (ii) Source parameter imaging (SPI)
- (iii) Euler deconvolution
- (iv) Forward and Inverse modelling

2.1. SPECTRAL ANALYSIS (ESTIMATION OF DEPTH TO BASEMENT)

The study area was subdivided into eighteen equal spectral blocks Fig. 1 using the filtering tool of the Microsoft Excel software. Each block covers a square area of 18.3km by 18.3km in order to accommodate longer wavelength so that the deep depth to the basement up to about 8km could be investigated.

From the computed values in TABLE 1, the magnetic basement depth was plotted and contoured using surfer 10 software. The deep magnetic sources vary from 2.4 to 6.6km (fig. 2), whereas the shallow magnetic source varies from 0.66 to 1.7km (Fig.3). The deep depth to basement is shallowest (purple colour) in the north eastern part of the study area (Ankpa area), while it is deepest (blue colour) in the south western part (Nsukka area).

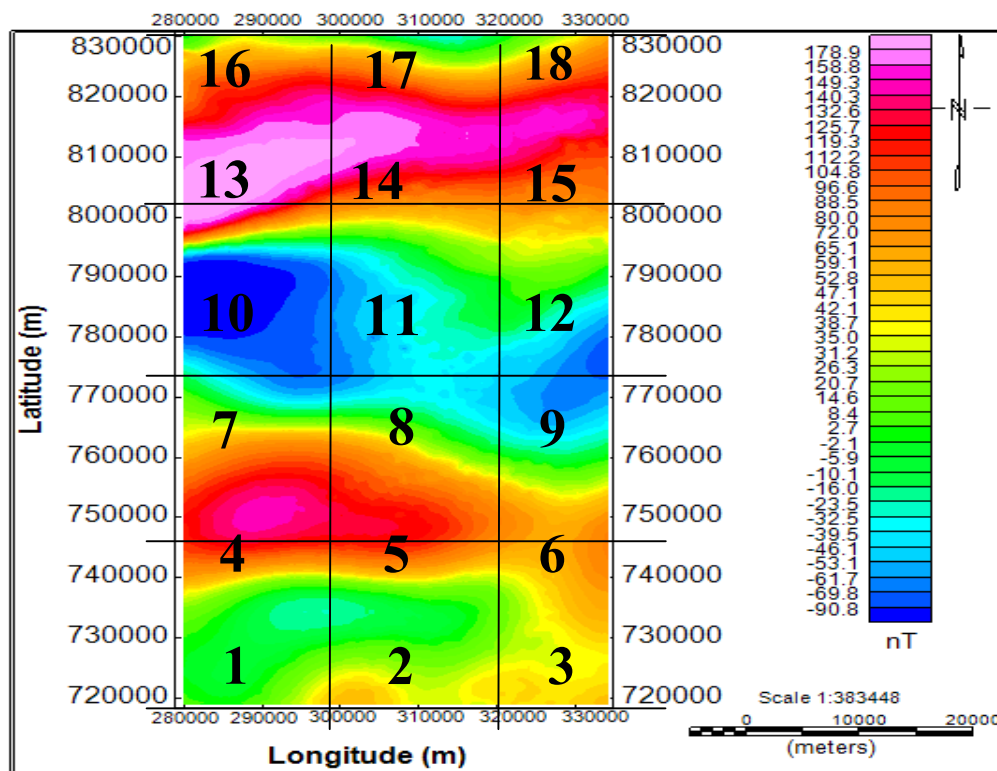


Fig. 1: division into 18 spectral blocks for estimation of the depth to basement.

Table 1: Depth Estimates of the First and Second Magnetic Layers for the 18 Spectral Blocks and their Coordinates.

S/N	SPECTRAL CELLS	CO-ODINATES (m)		DEPTH SOURCE VALUE (km)	
	SECTIONS	X(Longitude)	Y(Latitude)	DEEP(D_1)	SHALLOW(D_2)
1	1	288900.4	728218.1	6.513	1.694
2	2	306900.4	728218.1	3.411	1.012
3	3	324900.4	728218.1	4.212	0.796
4	4	288900.4	746684.0	5.010	0.741

Research Article

5	5	306900.4	746684.0	3.341	0.923
6	6	324900.4	746684.0	3.114	1.256
7	7	288900.4	765149.9	3.550	0.955
8	8	306900.4	765149.9	3.016	0.904
9	9	324900.4	765149.9	4.321	1.114
10	10	288900.4	783615.8	4.682	0.884
11	11	306900.4	783615.8	3.254	1.167
12	12	324900.4	783615.8	3.345	0.995
13	13	288900.4	802081.7	5.034	1.061
14	14	306900.4	802081.7	4.112	0.747
15	15	324900.4	802081.7	2.407	0.663
16	16	288900.4	820547.6	3.753	1.077
17	17	306900.4	820547.6	3.971	0.763
18	18	324900.4	820547.6	4.105	0.865
AVERAGE DEPTH				3.953	0.979

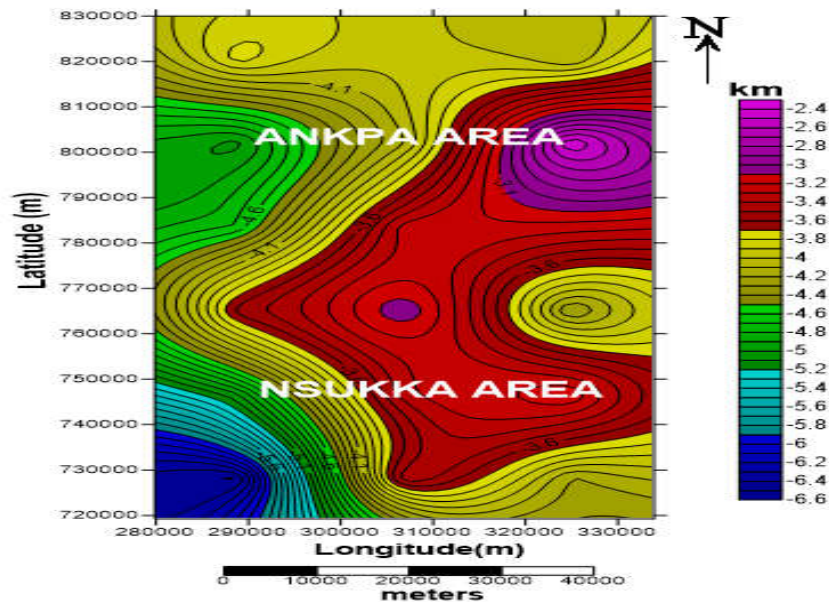


Fig. 2: deep depth to basement map (contour interval 0.1km).

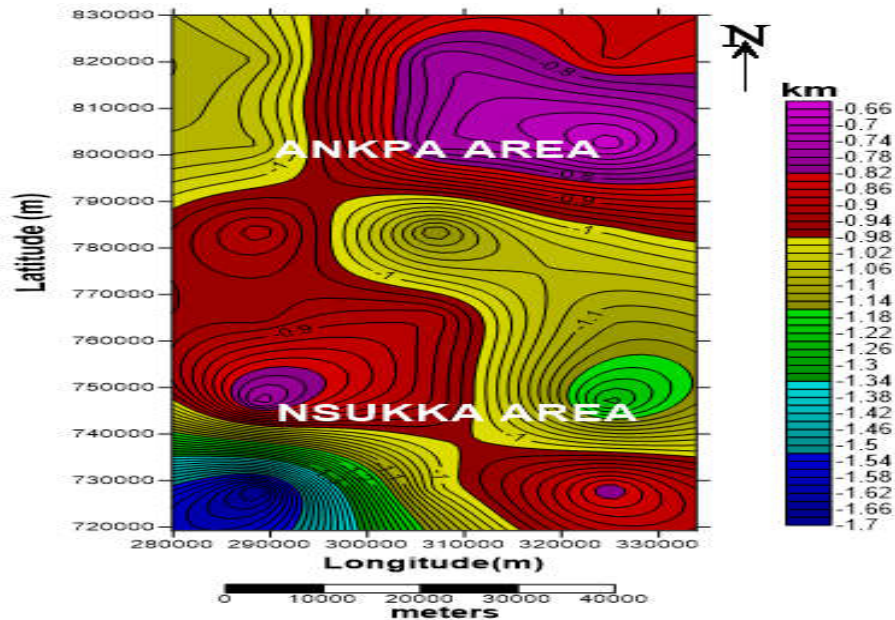


Fig. 3: shallow depth to basement map (contour interval 0.02km).

1.2. BASEMENT TOPOGRAPHY

Research Article

The computed deep depth to basement was used to construct the three dimension (3D) basement topography map of the study area (Fig. 4). The topographic map generated using Surfer 10 software shows the undulating nature of the basement surface with thickest sediments at the south eastern region of the study area (Nsukka area) and an elevation with shallowest sediments at the north-western part of the study area (Ankpa area).

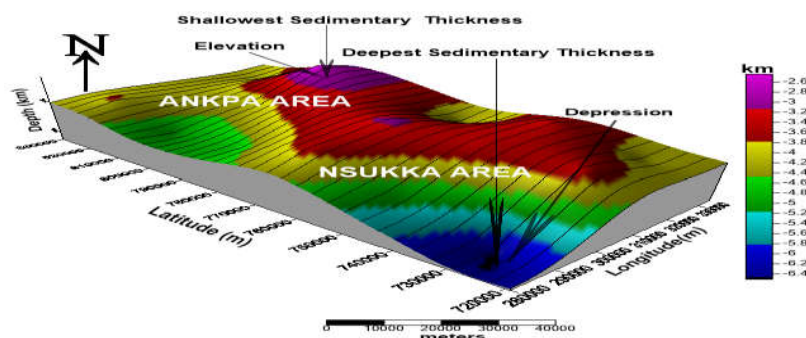


Fig. 4: 3D map of the study area showing magnetic basement topography

2.3 APPLICATION OF SOURCE PARAMETER IMAGING (SPI)

In computing the SPI depth of the magnetic data, Oasis Montaj software was employed. Using the first vertical derivatives and horizontal gradient, the SPI depth was computed. In Fig. 5, the negative depth values shown on the SPI legend depicts the depths of buried magnetic bodies, which may be deep seated basement rocks or near surface intrusive. The pink colour generally indicates areas occupied by shallow magnetic bodies, while the blue colour depicts areas of deep lying magnetic bodies. The SPI depth result ranges from -367.9m (shallow magnetic bodies) to -6412.7m (deep lying magnetic bodies).

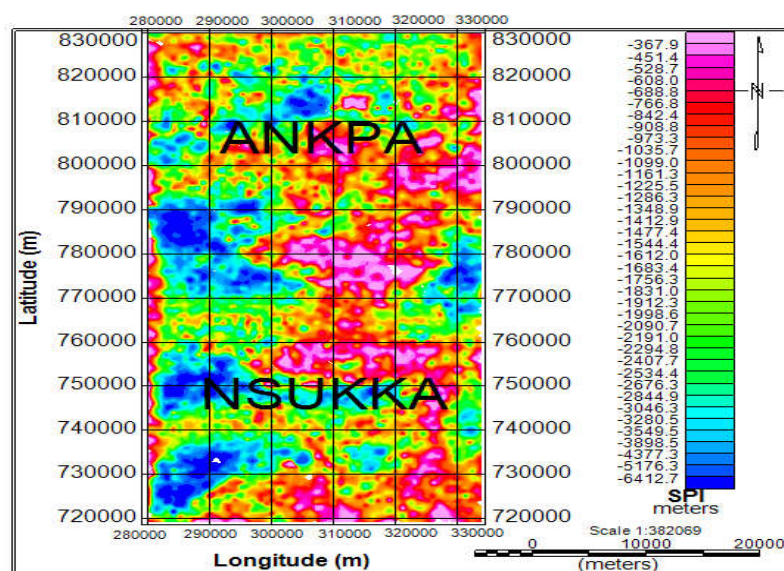


Fig 5: Source parameter image (SPI) map of the study area.

2.4APPLICATION OF EULER DECONVOLUTION

Oasis Montaj software was employed in computing the Euler depth. The Euler depths were estimated using vertical derivatives in three dimensions (x, y, and z). Vertical derivatives enhance shallow magnetic bodies. Hence, depths of shallow magnetic anomalies for different structural index are displayed by Euler method. Different structural index numbers were tried but it was found that the index number 0, 1 and 2 were the best for the data as it reflected the geological information of the area. Two Euler deconvolution maps were generated as shown in Figure 9(a, b and c). The pink colour indicates shallow magnetic bodies, while the blue colour indicates deep lying magnetic bodies. The Euler depth result ranges from 1036.4m (outcropping magnetic bodies) to -7613.0m (deep lying magnetic bodies). The results of Euler 3D depths are summarized in TABLE 2.

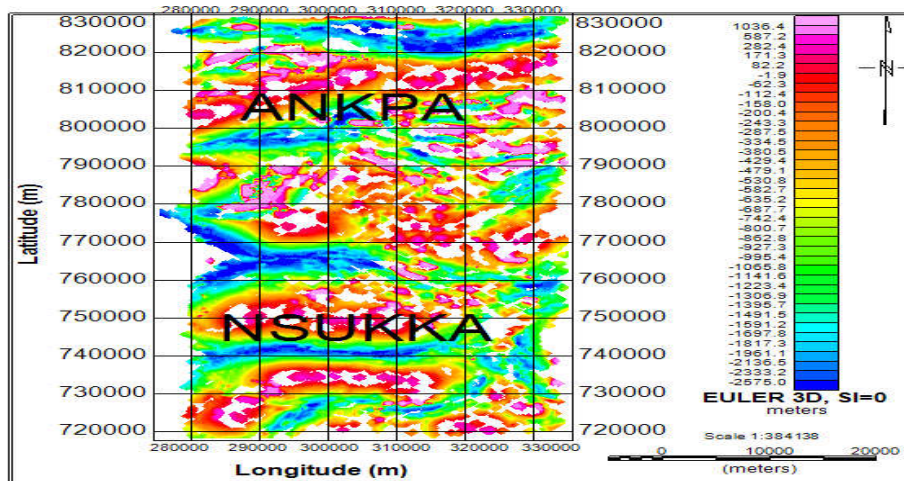


Fig. 6(a): Euler 3D depth map, SI=0.

Table 2: Summary of Euler Depths

Structural index, SI	Depth ranges (m)
0	From 1036.4 to -2575.0
1	From 331.3 to -5108.5
2	From -447.4 to -7613.0

2.5APPLICATION OF FORWARD AND INVERSE MODELING

Five profiles were taken on the residual magnetic grid (Fig. 7) and modeled. Each profile produced a degree of strike, dip and plunge where the observed values matched well with the calculated values. The blue curves in

Fig. 8 (a, b, c, d and e) represent the observed field values while the red curves represent the calculated field values. The forward modeling being a trial and error method, the shape, position and physical properties of the model were adjusted in order to obtain a good correlation between the calculated field and the observed field data. Using PotentQ 3D tool of the Oasis Montaj software, the field of the model was calculated. The root mean square (RMS) difference between the observed and calculated field values was attempted to be minimized by the inversion algorithm. At the end of the inversion, the RMS value was displayed. The RMS value decreased as the fit between the observed and calculated field continues to improve, until a reasonable inversion result was achieved. Less than 5% of root mean square value was set as the error margin.

The results of the forward and inverse modelling are summarized in TABLE 3. The susceptibility values obtained from the model profiles 1, 2, 3, 4 and 5 are 0.0146, 0.0045, 0.0200, 0.0001 and 0.0240SI respectively, with respective depths of 522, 1289, 5766, 710 and 1828m. These susceptibility values indicate the presence of minerals like Shale, Pyrite, Sandstone, Dolomite and Limestone.

Table 3: Summary of Forward and Inverse modelling results

Model	Model shape	X(m)	Y(m)	Depth to anomalous body (m)	Plunge (deg)	Dip (deg)	Strike (deg)	K-value (SI)	Possible cause of anomaly
P1	Ellipsoid	301596	720128	522	-121.7	-77.7	112.1	0.0146	Shale
P2	Rectangular Prism	288035	751693	1289	82.9	107.3	-46.0	0.0045	Pyrite
P3	Rectangular Prism	320312	787907	5766	58.1	133.7	165.0	0.0200	Sandstone
P4	Rectangular Prism	282800	806081	710	-122.7	-98.3	172.3	0.0001	Dolomite
P5	Ellipsoid	322890	822969	1828	10.7	70.8	-44.3	0.0240	Limestone

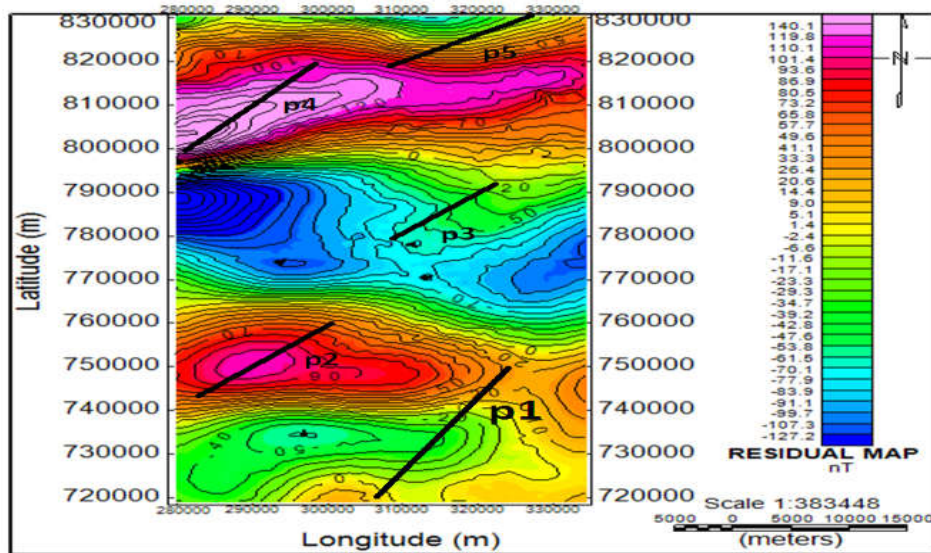


Fig. 7: Residual contour map of Ankpa and Nsukka.

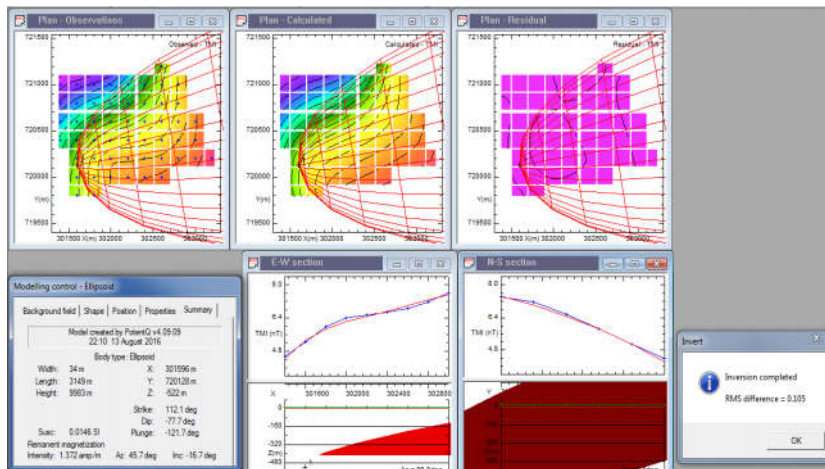


Fig. 8 (a): Profile 1 (P1) modelled.

Research Article

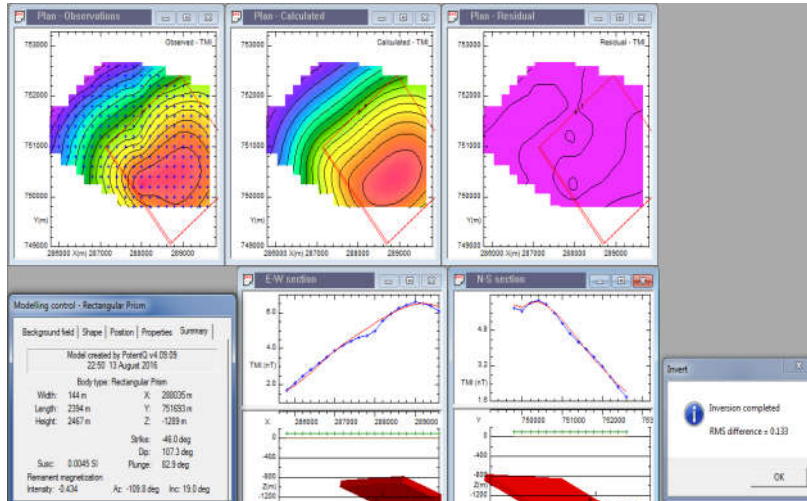


Fig. 8(b): Profile 2 (P2) modelled.

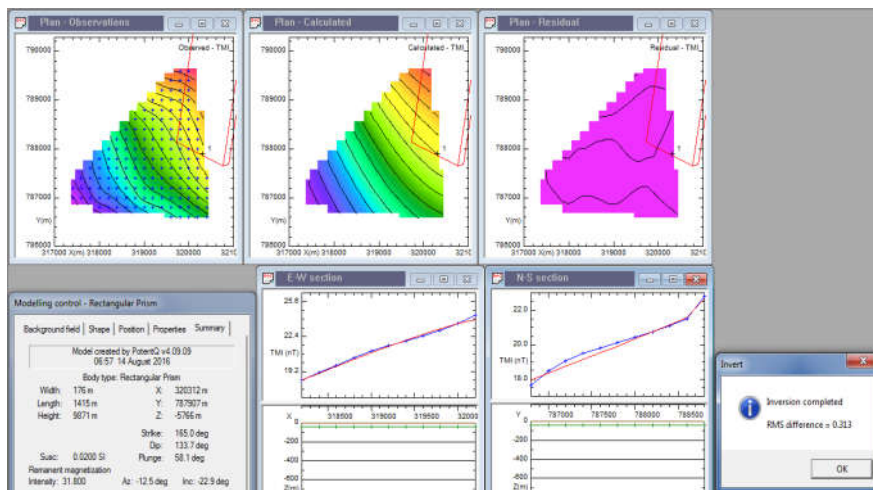


Fig. 8(c): Profile 3 (P3) modelled.

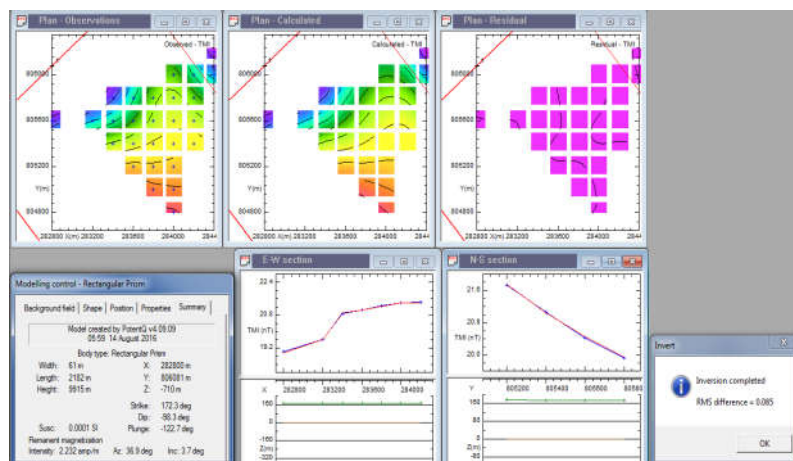


Fig. 8 (d): Profile 4 (P4) modelled.

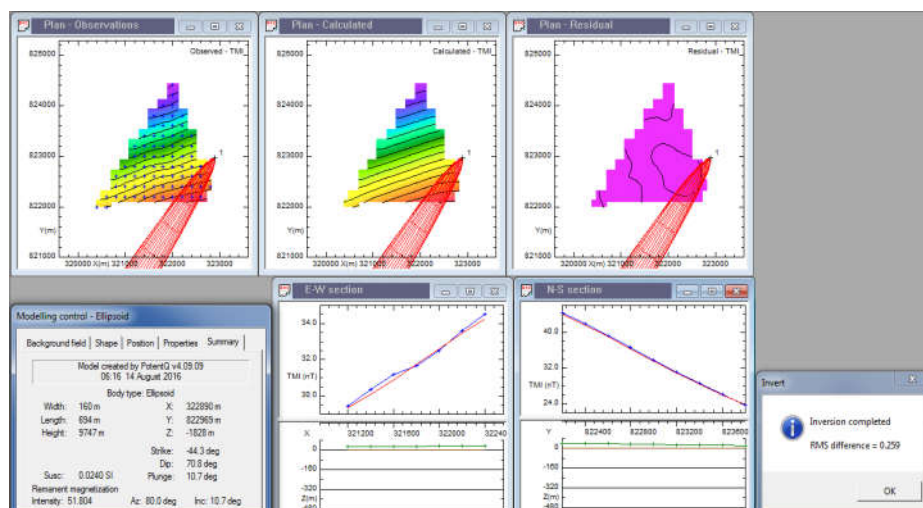


Fig. 8(e): Profile 5 (P5) modelled.

II. DISCUSSION OF RESULTS

The total magnetic intensity of Ankpa and Nsukka shows range of magnetic anomalies which vary from -90.8nT to 178.9nT while the residual values are from -127.2nT to 140.1nT. The residual magnetic field was used to bring into focus local features which tend to be obscured by the broad features of the regional field. The areas of strong positive anomalies likely indicate a higher concentration of magnetically susceptible minerals while areas with broad magnetic lows are likely areas of lower susceptibility minerals. Horizontal derivative enhancement technique was applied on the residual intensity field to reveal subtle geophysical features. The horizontal derivative map (Fig. 9) shows the occurrence of subsurface linear structures which could be the presence of faults in the area; the fault lines are visible on the structural trend map (Fig. 10). The structural trend could be a favourable structure for the control of mineral deposits in the area. This agrees with the work done by earlier researchers that worked in the Basin [7],[10],[11],[12],[13],[14],[15]. The result from spectral analysis shows that

the depth to the magnetically deep sources ranges from 2.4 to 6.6km with an overall average depth of 3.953km while the depth to the shallow sources ranges from 0.66 to 1.7km with overall average depth of 0.979km. The depth result from SPI ranges from -367.9m (shallow magnetic bodies) to -6412.7m (deep lying magnetic bodies). These depths are found to be within the range of depths predicted by earlier researchers that worked in the Basin. [13] got a deep depth range of 1.16 to 6.13km with average of 3.03 km and depth to the shallower magnetic source ranging from 0.016 to 0.37km with average of 0.22 km from spectral analysis of aeromagnetic data over some part of Lower Benue Trough using Spectral analysis. [11] estimated that the depths to the magnetic source bodies in the lower Benue Trough and some adjoining areas vary from 0.518 to 8.65 km with a mean depth of 3.513 km (for deeper magnetic source bodies) and 0.235 to 3.91 km with a mean depth of 1.389 km (for shallower magnetic source bodies).

The 3D basement topographic map presents irregular nature of the basement which is possibly associated with faults that aids the migration and entrapment of hydrocarbon and other mineralized deposits. The 3D map (Fig. 5) shows a linear depression with thickest sediments at the south-western region of the study area (Nsukka area) and an elevation with shallowest sediments at the north-eastern part of the area (Ankpa area).

The depths of the magnetic source bodies estimated from Euler de-convolution for the three different structural index ($SI = 0, 1$ and 2) ranges from 1036.4m (out cropping magnetic bodies) to -7613.0m (deep lying magnetic bodies). The estimated depths from the forward and inverse modelling method are 522, 1289, 5766, 710 and 1828m for profiles 1, 2, 3, 4 and 5, with susceptibility values of 0.0146, 0.0045, 0.0200, 0.0001 and 0.0240SI respectively which indicate dominance of minerals like shale, pyrite, sandstone, dolomite and limestone. The study area has revealed potentials for mineral deposit, which could serve as raw material(s) for many factories and industries in Nigeria. The presence of Sandstones can be used in cement manufacture, road construction and as petroleum reservoir. The depth obtained from spectral analysis, forward and inverse modelling, Euler de-convolution and Source parameter imaging are in close agreement. The maximum depths obtained from different methods in this work show thick sediment that could be feasible for hydrocarbon accumulation. Such that the minimum thickness of the sediment required for the commencement of oil formation from marine organic remains would be 2.3km. Some previous work done in the Basin show similar results. It was noted that that sedimentary thickness of 1644 to 3082.7m in Nsukka area show sufficient thick sediments suitable for hydrocarbon accumulation.

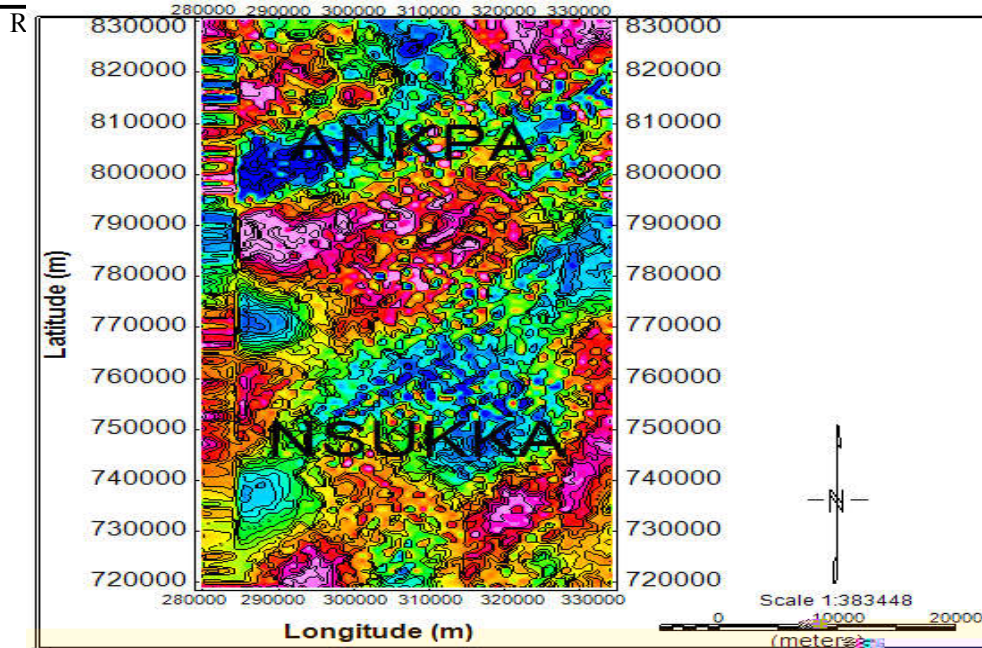


Fig. 9: Horizontal derivative map of the study area.

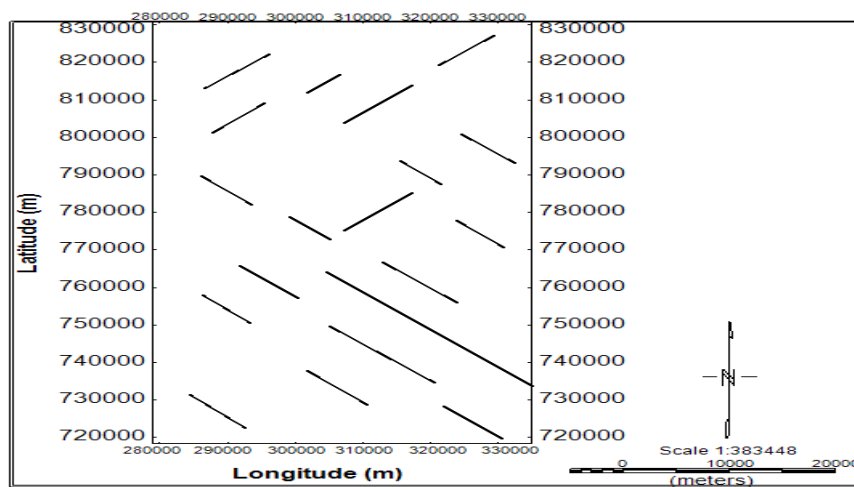


Fig. 10: Magnetic lineament map showing the lines of the faults in the study area (derived from horizontal derivative).

CONCLUSION

The aeromagnetic data of Ankpa and Nsukka areas have been interpreted qualitatively and quantitatively. The total magnetic intensity and residual intensity field showed range of magnetic anomalies which reveal that the study area is magnetically heterogeneous. The Horizontal derivative showed the occurrence of subsurface linear structures which could be the presence of faults in the study area. The depths from spectral analysis, Source parameter imaging, forward and inverse modelling and Euler de-convolution are in close agreement. The highest depth of the deep sources is 7.613km and is believed to correspond to the surface of the magnetic

Research Article

basement in the study area. The modelling of the residual map revealed some minerals in the study area, which are; shale, pyrite, sandstone, dolomite and limestone.

The study area has revealed potentials for mineral deposit, which could serve as raw material(s) for many factories and industries in Nigeria. The 3D basement topographic map presents irregular nature of the basement which are possibly associated with faults that aids the migration and entrapment of hydrocarbon and other mineralized deposits. The sedimentary thickness obtained from different methods indicates the possibility of hydrocarbon accumulation in the study area.

REFERENCES

- [1]. Sharma, P. V. Magnetic Method Applied to Mineral Exploration. *Ore Geology Review*, 2: 1987, 323-357
- [2]. Folami, S. L. Interpretation of Aeromagnetic Anomalies in Iwaraja Area, South-Western Nigeria. *Journal of Mining and Geology*, 28(2): 1992, 391-396.
- [3]. Anudu, G. K., Onuba, L. N., Onwuemesi, A. G. and Ikpokonte, A. E. Analysis of aeromagnetic data over Wamba and its adjoining areas in north central Nigeria, *Earth Science Research Journal* 16(1): 2012. 25-33.
- [4]. Kearey, P. and Brooks, M. An Introduction to Geophysical Exploration. *Blackwell Scientific Publications*, 1984, 296.
- [5]. Olade, M. A. Evolution of Nigeria's Benue Trough (aulacogen): a tectonic model. *Geol. Mag.*, 112: 1975, 575-583
- [6]. Nwachukwu, S. O. The tectonic evolution of the southern portion of the Benue Trough, Nigeria. *J. Min. Geol.*, 11: 1972, 45-55.
- [7]. Ofoegbu, C. O. A review of the geology of the Benue Trough, Nigeria. *J. Afr. Earth Sci.*, 3: 1985, 293-296.
- [8]. Nwajide