ASSESSMENT OF MAGNETIC ANOMALIES OVER ABAKALIKI AREA OF THE LOWER BENUE TROUGH, SOUTH EASTERN NIGERIA, USING HIGH RESOLUTION AEROMAGNETIC DATA

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Abstract: Aeromagnetic data of Abakaliki area of south eastern Nigeria was analyzed qualitatively and quantitatively. For the qualitative analysis, the various enhancement processes such as regional/residual separation, TMI and analytic signal were performed using Oasis Montaj software version 6.4.2. For the quantitative interpretation, Oasis Montaj software was used to generate the SPI map and 3D SPI map while the modelling was carried out using Potent Q, an extension of the Oasis Montaj software. The total magnetic intensity map shows magnetic intensity values ranging from 21.2 – 92.7 (nT), therefore indicating that the study area has very high tendencies of producing magnetic minerals since the intensity values are all positive. The regional map depicts magnetic intensity values ranging from 36.7 – 82.7 (nT) which is a clear indication that the regional indicates a completely magnetic basement trending with the east –west tectonic trends. The modelling results indicate that the north central region and parts of the south eastern region marked A and C are sediment filled and they are suspected of having limestone and rock salt/anhydrite, respectively with an average depth of about 3 km while the regions marked B and D are more of shallow sources as their depth is less than 1 km below the subsurface. The average depth to sediment is about 4 km as seen in the 3D SPI map, hence the possibility of hydrocarbon accumulation is not ruled out.

Keywords: Magnetic anomalies, susceptibility, modelling, basement, residual, sediments

Introduction

Magnetic method is one of the most widely used geophysical techniques for investigating the subsurface of the earth, thereby, reducing ambiguity and enhancing accuracy. The main purpose of magnetic survey is to detect minerals or rocks that have unusual magnetic properties which reveal themselves by causing anomalies in the intensity of the earth's magnetic field (Onuba *et al*., 2011). Of all the magnetic minerals that occur in nature, magnetite is the most abundant, hence Aeromagnetic surveys reflect almost exclusively the distribution of magnetite and pyrrhotite in rocks (Abbas & Mallam, 2013).

The Benue Trough of Nigeria is an elongated rifted depression that trends NE – SW from the South, where it merges with the Niger Delta, to the north where its sediments are part of the Chad Basin successions (Ugwu & Ezema, 2012). Over 80 percent of the Nigeria's revenue comes from export and domestic sale of the oil and gas upon which over 140 million growing population depends on (Salako, 2014).

Abakaliki has a lot of potentials for hydrocarbon and minerals such as lead, zinc, silver, salt, limestone, dolerite which constitute quarries, thereby boosting the economy Abakaliki.

Based on the above, it is necessary to embark on more robust assessments of Abakaliki and its environs in order to ascertain the hydrocarbon prospects that abound as well as the economic minerals present, hence this work. This work is aimed at qualitatively and quantitatively interpreting the magnetic anomalies over Abakaliki area using high resolution aeromagnetic data in order to ascertain the depth to basement, hydrocarbon potentials as well as the presence of other economic rich minerals.

Taufiq *et al*. (2014) carried out the Analysis of Aeromagnetic data across Kebbi State, Nigeria. The results of their work revealed clearly two magnetic depth layers; the depth to the shallow magnetic layer d1 which 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. they concluded that these values obtained are too small to allow any accumulation of hydrocarbon in the study area. They however recommended that other geophysical techniques such as seismic and resistivity should be used in the area.

Chinwuko *et al*. (2012) carried out the Interpretation of Aeromagnetic Anomalies over parts of Upper Benue Trough and Southern Chad Basin, Nigeria. By using Discrete Fourier Transform method, they interpreted a two depth source model; Depth to the deeper magnetic sources which ranges from 1.5 to 2.5 km, representing the sedimentary cover in the study area and the depth to the shallower magnetic source model which ranges from 0.5-1.4 km, representing intrusive bodies within the area. Based on the sedimentary thickness of 1.5 - 2.5 km and the temperature at depth of 81-1150°C, they concluded that the possibility of hydrocarbon generation in the northeastern part of the study area is feasible

Geology of the study area

Abakaliki area falls within the lower Benue Trough and it is located between latitude 6° 35' N and 6° 45' N and Longitude 8° 42'E and 8° 47'E (Fig. 1), with average elevation of 117 m (Obiora *et al*., 2018). The Benue Trough was formed as a result of series of tectonics and repetitive sedimentation in the Cretaceous time when South American continent separated from Africa and the opening of the South Atlantic Ocean (Okpoli, 2019). Abakaliki falls within the Anambra basin in the lower Benue Trough and geologically, it is known for the famous Abakaliki anticlinorium which is flanked by two synclines; one of which coincides with the Anambra valley and the other one passes through Afikpo, forming the Afikpo syncline. The Abakaliki area is mostly underlain by the Abakaliki shale of the Albian Asu River group (Omoha & Aghamelu, 2016). The sediments that occur in the Abakaliki Anticlinorium belong to four geological formations: Awgu shale(Caniacian); Nkporo shale(Campanian); Eze-Aku shale(Turonian); and Asu River Group (Albian) (Ezema *et al*., 2014).

Sedimentary order in Abakaliki was influenced by major tectonic activities which eventually culminated in the folding of the sediments during the Santonian; thereby forming the Abakaliki Anticlinorium.

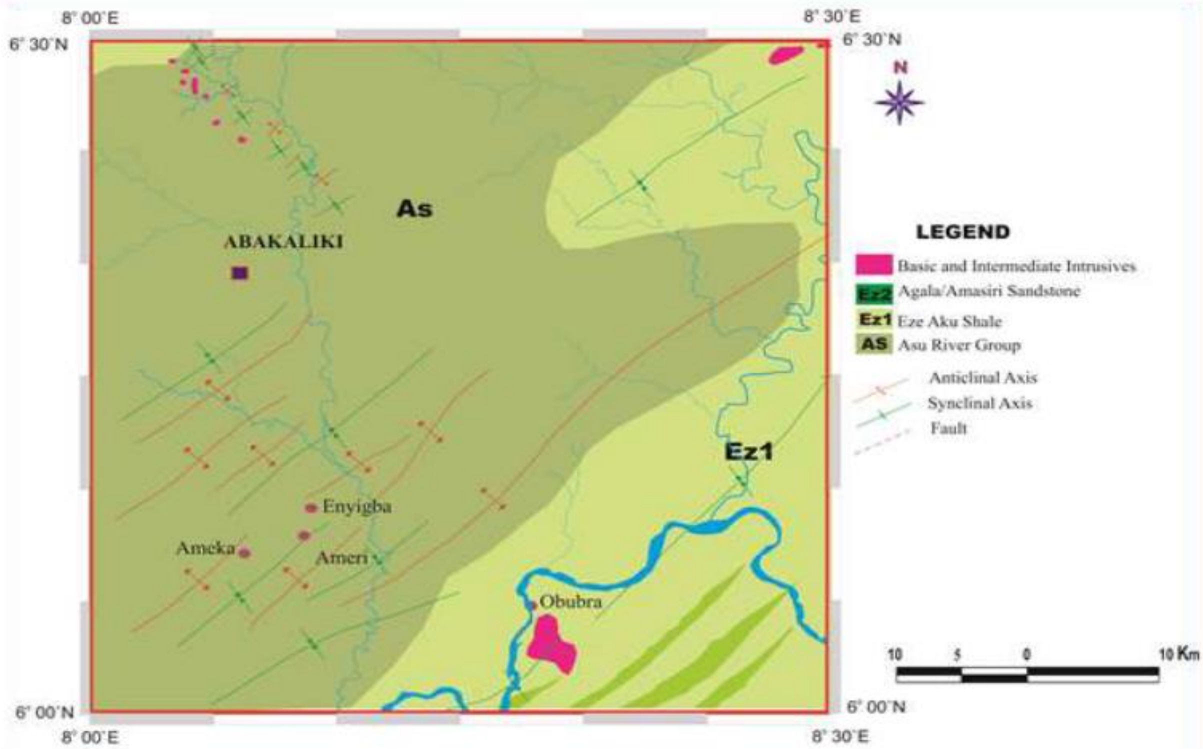

Fig. 1: Geologic map of Abakaliki (Obiora *et al*., 2018)

Materials and Methods

The data used for this work was obtained from the Nigerian Geological Survey Agency (NGSA). This data was part of the aeromagnetic data obtained by NGSA during the nationwide aeromagnetic survey. The data was analyzed using qualitative and quantitative methods. For the qualitative analysis, the various enhancement processes such as regional/residual separation, total magnetic intensity (TMI) and analytic signal were performed using Oasis Montaj software version 6.4.2. For the quantitative interpretation, Oasis Montaj software was use to generate the SPI map and 3D SPI map while the modelling was carried out using Potent Q, an extension of the Oasis Montaj software.

Agabi *et al*. (2020) worked on ‘’Depth Analysis and its Implications on Hydrocarbon Prospectivity in Part of The Lower Benue Trough of Nigeria Using High Resolution Aeromagnetic Data’’ with the aim of determining the hydrocarbon potentials of the study area. Qualitative and quantitative analysis were carried out using Oasis Montaj software version 6.4.2. Two depth regions were identified; the shallow basement of about 280 m which was suspected of having mineral potentials and the sedimentary regions with depth ranging between 2477 to 3386 m which they concluded to be a prospect for hydrocarbon accumulation. They however recommended further investigations into the above stated prospects.

Chukwunonso *et al*. (2012) carried out ‘Aeromagnetic Interpretation over Maiduguri and Environs of Southern Chad Basin, Nigeria’ with the aim of identifying the nature and depth of the magnetic sources in the study region. They used the Spectral analysis method to delineate lithology and mapping of the depths of subsurface geologic structures. They discovered that the Depth to the basement of the basin structure ranges from about 0.5 km in the southern part of the study area and gets deeper towards the northern part up to 3.0 km. They also noted the most significant structural trends (NE-SW) affecting the distribution of magnetic anomalies in the study area hence revealing the possible subsurface structure of the area that assisted in delineation of promising areas for hydrocarbon exploration.

In this work, the application of the TMI /Residual map were carried out in order to show the general overview or the distinction between areas with low and high magnetic intensities as well as areas with sedimentary cover or intrusions. The regional map from the Oasis Montaj software gave an overview of the nature of the basement while upward continuation at higher depth enhanced the basement and revealed the nature of rocks therein as well as their orientation. In order to obtain information about the depth and thickness of sediments, the SPI and 3D SPI maps were employed while the Potent Q extension of the Oasis Montaj software was used to model selected portions with a view to obtaining physical quantities/parameters of the subsurface, thereby leading to a prediction of the underlying causes) of anomalies.

Results and Discussion

TMI/Residual map

Figure 2 shows the total magnetic intensity map with magnetic intensity values ranging from 21.2 – 92.7 (nT). This shows that the study area has very high tendencies of producing magnetic minerals since the intensity values are all positive. The highest intensities (pink colour) are found in the south-east, south-west, west and slightly at the north west. The most magnetic minerals/rocks could be found in the above mentioned areas. The TMI also shows fault zones trending in the north-east to south-west direction. Also, the TMI map shows regions of least magnetic susceptibility found around the north central region with an elongation extending towards the right and on the south western region trending east-west (the blue colours) indicating the presence of thick sediments. Also, areas indicating the presence of intrusive rocks can be found in the north west extending towards the north east, the Midwest, the south west and parts of the south-south and south east with pink colours as confirmed from the Residual map (Fig. 4). These areas show potential areas/zones of high magnetic deposits. On the other hand, with the elimination of the short wavelength components, the Residual map (Fig. 4) also shows the presence of thick sediments of least susceptibility on the south west (deep blue) and a slightly more magnetic and loose sedimentary region in the north central region (deep – light blue colour)

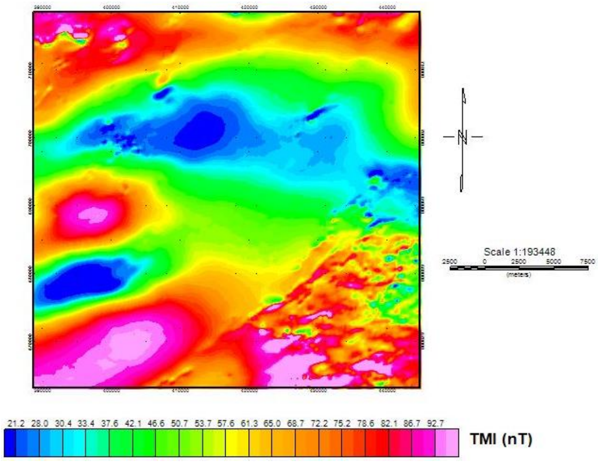

Fig. 2: TMI map

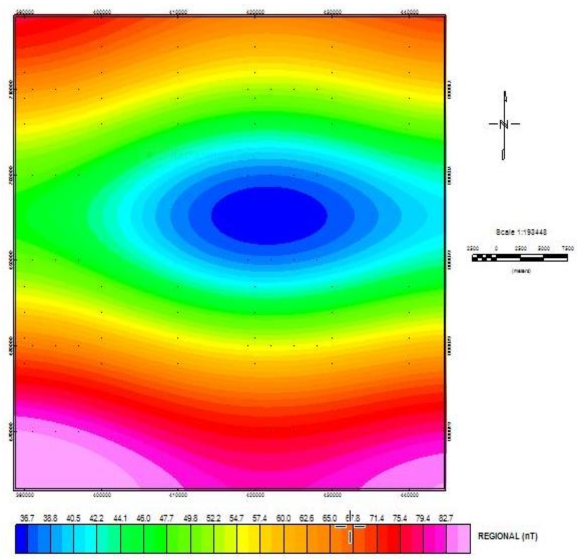

Fig. 3: Regional map

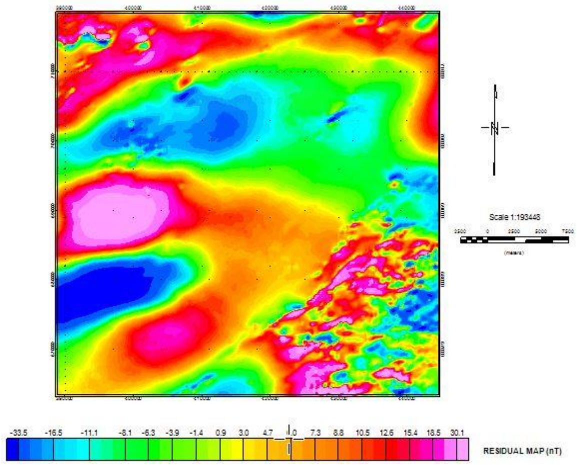

Fig. 4: Residual map

Regional map

From Fig. 3, the regional map depicts magnetic intensity values ranging from 36.7 – 82.7 (nT). It is however clear from the map that the regional indicates a completely magnetic basement trending with east –west tectonic trends. The southern portion is more magnetic which is followed by the northern region and the least magnetic region being the central portion. The circular anomaly in the central region (deep blue) is suspected to be a fault. The regional map shows long wavelength (short frequency) features. It is actually a magnetic basement.

Analytic signal map

The analytic signal map (Fig. 5) divides the area into areas of various degrees of magnetization. The south eastern region and parts of the western regions have the highest susceptibility (pink and red colours) indicating high mineralization. The south eastern region shows the anomalies trending in the North-East to South –West direction. The middle region (deep-light blue colours) are indications of low magnetization showing huge deposits of low magnetic minerals.

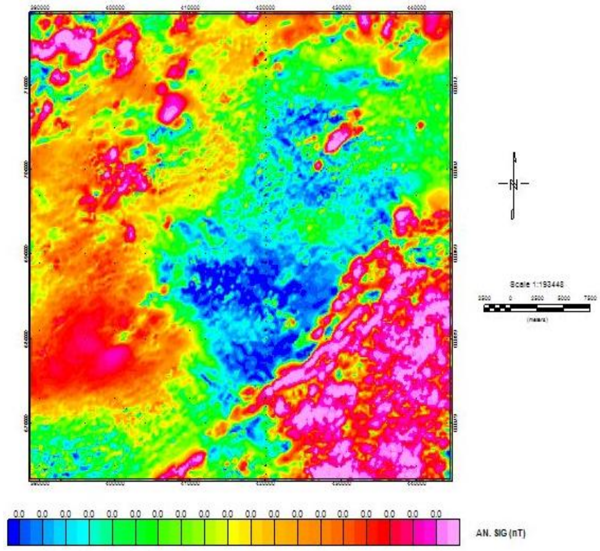

Fig. 5: Analytical signal map

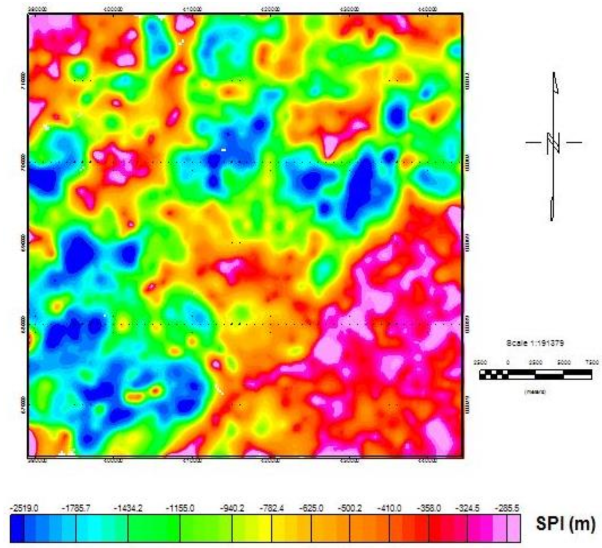

Fig. 6: SPI map

SPI Map

The Source Parameter Imaging (SPI) is a technique using an extension of the complex analytical signal to estimate magnetic depths (Nwosu, 2014). The SPI map (Fig. 6) represents a partially even distribution of various magnetic materials in the study area with respect to their depths. The depth range to these magnetic sources varies between 285.5 m (for shallow sources) and 2519 m (for deep sources) below the sub surface. The shallow magnetic sources represented by pink and red colours are found in the entire south east and parts of the north west and a few scattered around the north central and north east. They indicate the intrusion of magnetic materials from the basement into the sediments.

The variation of depth as seen in the SPI map can be visualized using the 3D SPI view (Fig. 7). From the 3D view, it can be clearly seen that the regions with the least magnetic susceptibility (deep blue and light blue) are indicative of huge deposits of sediments as the susceptibilities and the depths are clearly seen as being least and highest, respectively. The shallow magnetic sources are clearly visible as their layers are thinner (pink and red colours). These regions indicate the presence of intrusives, hence, their minimum depths.

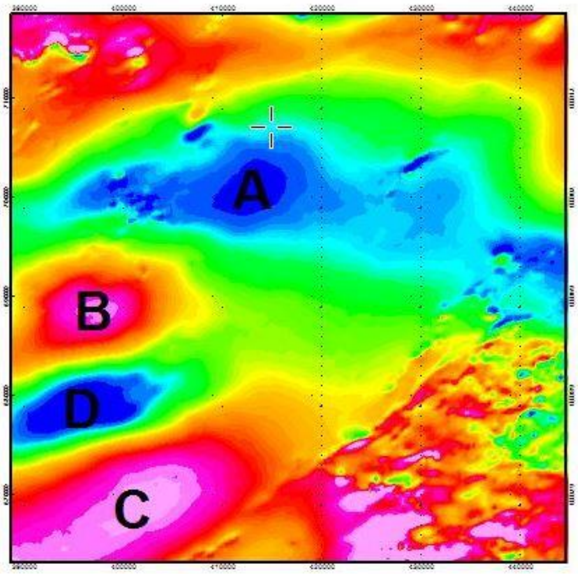

Fig. 8: Map showing modelled areas

Figure 8 is a map of the study area showing the modelled regions, while Figs. 8(A – D) represent the modelling outcomes from the modelled areas A – D on the map.

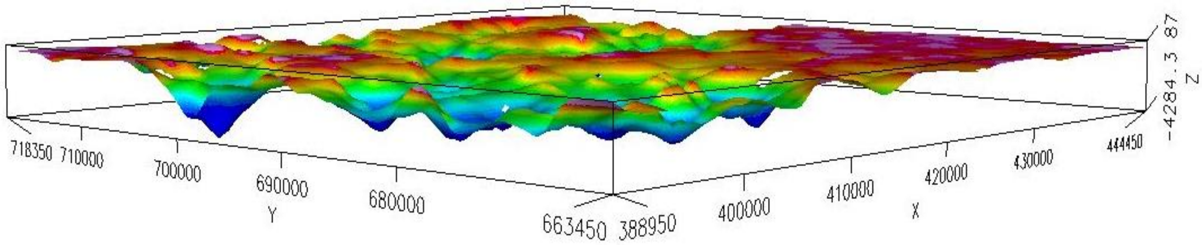

Fig. 7: 3D SPI view

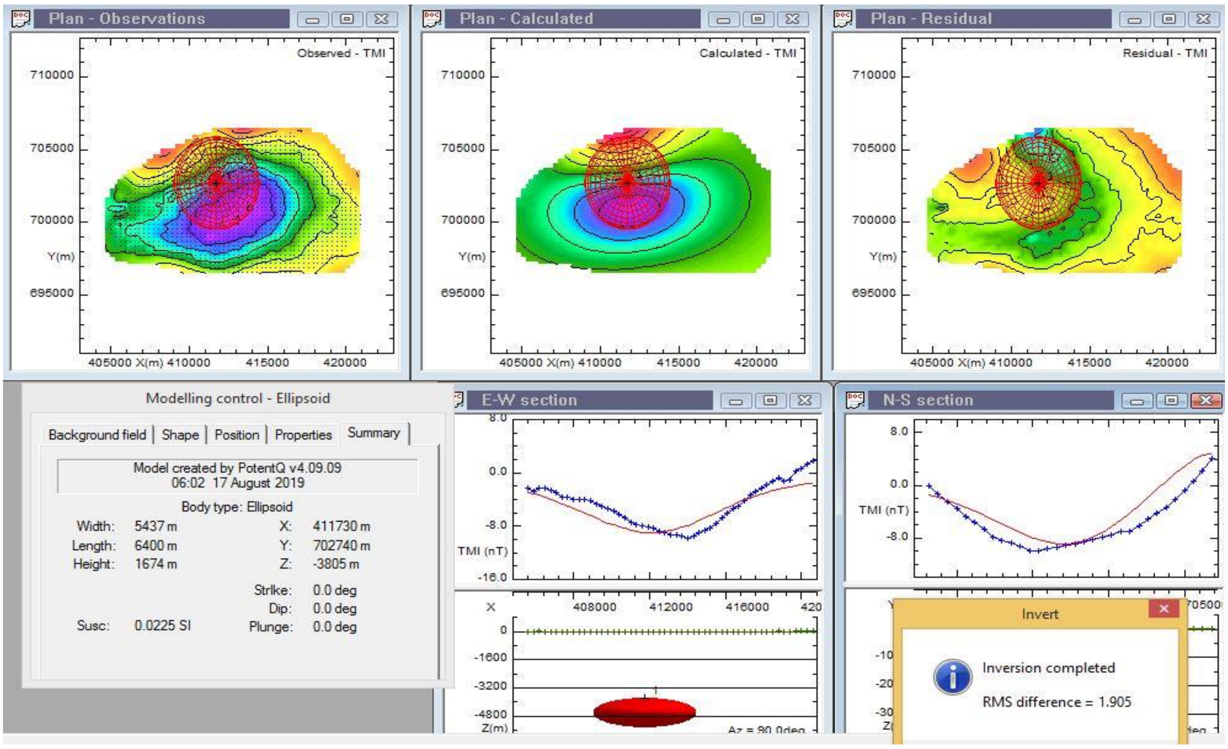

Fig. 8A: Diagram showing model A

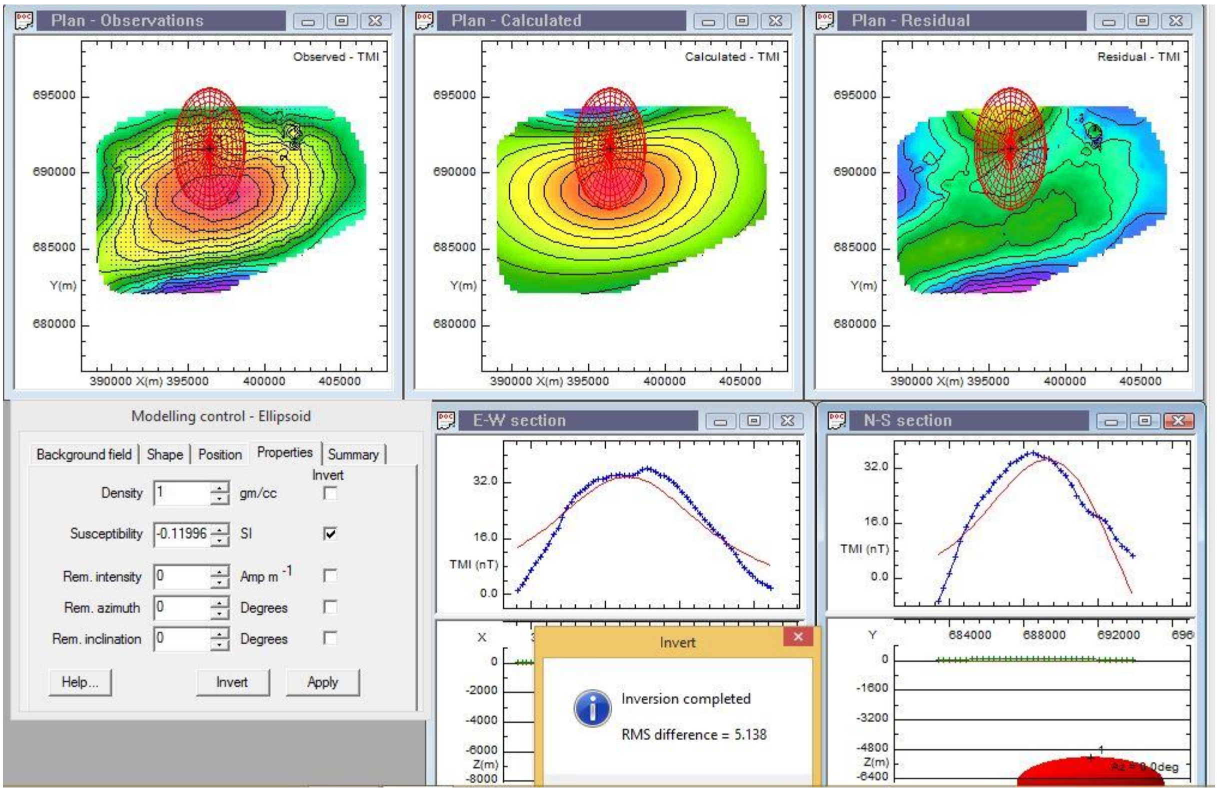

Fig. 8B: Diagram showing model B

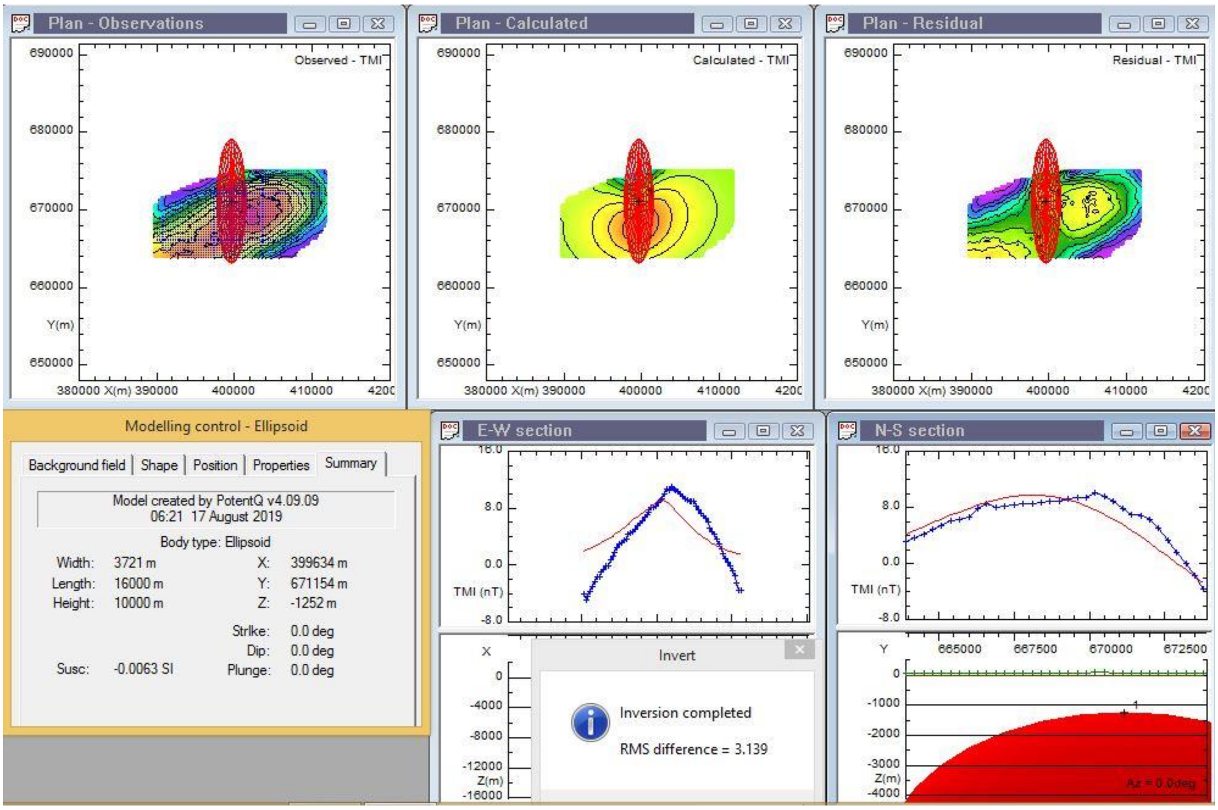

Fig. 8C: Diagram showing model C

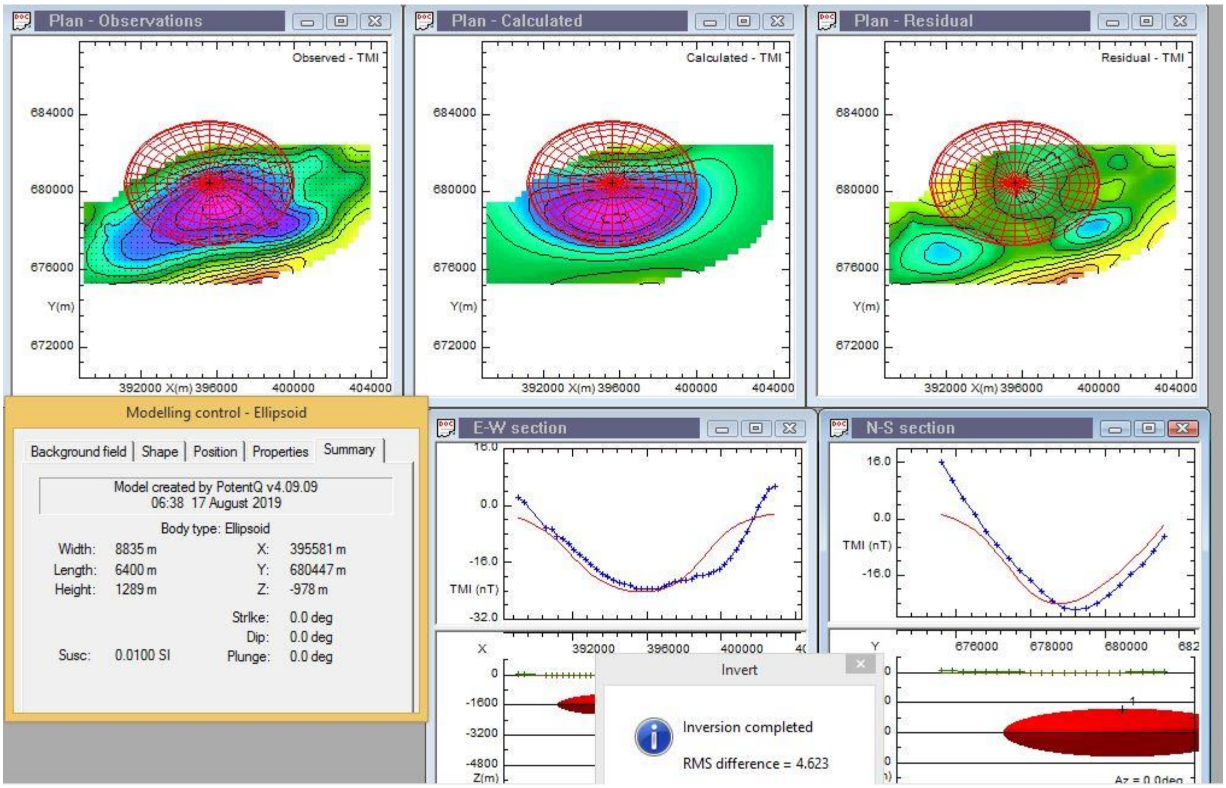

Fig. 8D: Diagram showing model D

Table 1: Table showing summary of modelled results

S/N	Model	X(m)	Y(m)	Depth (m)	Body used	K-value	Possible cause(s) of anomaly
1	A	411739	702740	-3805	Ellipsoid	0.0225	Limestone/shale
2	B	396710	690810	-920	Ellipsoid	-0.0582	Calcite
3	C	399634	671154	-1252	Ellipsoid	-0.0063	Rock sat/anhydrite, gypsum
1	D	395581	680447	-978	Ellipsoid	0.01	Shales

The result obtained from the modelling is as tabulated in Table 1. From Table 1, the north central portion of the map (model A) consists mostly of low magnetic susceptibility depicting the presence of sediments similar to model D in the south western region. The regions in model A (blue colour) have the thickest sediment thickness as seen from the 3D SPI map and from the Table. On the other hand, regions within models B and C are indications of shallow sources of higher magnetic content. From the range of values of susceptibility on Table 1, model A has susceptibility value of 0.0225, B has susceptibility value of –0.0582, C has susceptibility value of –0.063 and D has susceptibility value of 0.01. The above k values represent the presence of limestone/shale, calcite, rock salt/anhydrite/gypsum and shales respectively (Doo *et al.*, 2009).

Conclusion

From the results obtained, it can be seen that the north central and south western regions of the study area are more prolific and viable for the exploration of mineral resources as well as for further investigations. The region in profile A suspected of containing limestone should be investigated further to ascertain the possible extent of the suspected rock (limestone) because of its economic importance. Similarly, profiles A and D which are mainly sedimentary should be investigated further for possible hydrocarbon content since the average depth to basement is about 4 km which is suitable for the accumulation of hydrocarbon as seen in Fig. 7. The regions marked B and C suspected of calcite and rock salt/anhydrite/gypsum should be well targeted for the exploration of these minerals since they are of shallow depth of less than 1.5 km as seen from the Table. The regions marked D and C form intrusives which dominate the eastern part of the 3D SPI map.

Conflict of Interest

Authors declare there is no conflict of interest related to this study.

References

Adetona A, Abbass L & Abu M 2013. Estimating the Thickness of Sedimentation within Lower Benue Basin and Upper Anambra Basin, Nigeria, Using Both Spectral Depth Determination and Source Parameter Imaging. Hindawi Publishing Corporation 1.

Agabi DA, Ijeh BI, Chukwu GU, Odong PO & Udo AA 2020. Depth analysis and its implications on hydrocarbon prospectivity in part of the lower Benue Trough of Nigeria using high resolution aeromagnetic Data. *Global Scientific Journal*, 8(1): 275.

Chinwuko AI, Onwuemesi AG, Anakwuba EK, Onuba LO & Nwokeabia NC 2012. Interpretation of aeromagnetic anomalies over parts of upper Benue Trough and Southern Chad Basin, Nigeria. *Advances in Appl. Sci. Res.*, 3(3): 1757.

Chukwunonso OC, Onwuemesi AG, Anakwuba EK, Chinwuko AI, Ikumbur EB & Usman AO 2012. Aeromagnetic interpretation over Maiduguri and environs of Southern Chad Basin, Nigeria. *J. Earth Sci. and Geotech. Engr.*, 2(3): 77.

Doo W, Hsu S, Tsai C & Huang Y 2009. Using analytic signal to determine magnetization/density ratios of geological structures. *Journal J. International*, 179(8).

Ezema PO, Eze ID, Ugwu GZ & Abdullahi U 2014. Hydrocarbon and mineral exploration in Abakaliki, South Eastern Nigeria. *Int. J. Engr. and Sci.* (IJES), 3(1): 24.

Nwosu OB 2014. Determination of magnetic basement depth over parts of Middle Benue Trough by source parameter imaging (Spi) technique using HRAM. *J. Scientific and Techn. Res.*, 3(1); 262.

Obiora DN, Idike JI, Oha AI, Soronnadi-Ononiwu CG, Okwesili NA & Ossai MN 2018. Investigation of magnetic anomalies of Abakaliki area, Southeastern Nigeria, using high resolution aeromagnetic data. *J. Geol. and Mining Res*., 10(6): 58 & 60.

Okpoli CC 2019. Delineation of high-resolution aeromagnetic survey of lower Benue Trough for lineaments and mineralization: Case study of Abakikili sheet 303. *Malaysian Journal of Geosciences,* 51.

Omoha AS & Aghamelu OP 2016. Foundation properties and stability of some bridge construction sites in southeastern Nigeria: Results from preliminary geophysical investigation. *FUNAI J. Sci. & Techn*., 2(1): 51.

Onuba LN, Anudu GK, Chiaghanam OI & Anakwuba EK 2011. Evaluation of aeromagnetic anomalies over Okigwe area, southeastern Nigeria. *Res. J. Envtal. and Earth Sci.*, 3(5): 498.

Salako KA 2014. Depth to basement determination using source parameter imaging (SPI) of aeromagnetic data: An application to upper Benue Trough and Borno Basin, Northeast Nigeria. *Academic Research International,* 5(3): 74.

Taufiq S, Udensi EE & Muhammed SB 2014. Analysis of aeromagnetic data across Kebbi State, Nigeria. *Int. J. Marine, Atmospheric & Earth Sci.*, 2(1): 41.

Ugwu GZ & Ezema PO 2012. Forward and inverse modelling of aeromagnetic anomalies over Abakaliki and Nkalagu areas of the Lower Benue Trough, Nigeria. *Int. Res. J. Geol. and Mining* (IRJGM), 2(8): 222.