INTERPRETATION OF HIGH RESOLUTION AEROMAGNETIC DATA OVER NSUKKA AND UDI AREAS OF ENUGU STATE, NIGERIA

Supported by tetfund TERTIARY EDUCATION TRUST FUND

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Received: November 11, 2016 **Accepted:** March 16, 2017

Abstract: Aeromagnetic data analysis and interpretation of Udi sheet and that of Nsukka sheet in Enugu State, Anambra Basin was carried out. The data which were obtained by Nigeria Geological Survey Agency (NGSA) were interpreted qualitatively and quantitatively.Source Parameter Imaging and Forward and Inverse Modeling methods were employed to interpret the data quantitatively to obtain the intrusive bodies and their respective depth to basement. The depths to the magnetic bodies' estimated using Source Parameter Imaging (SPI) method after some data processing like first order derivative ranges from 0.4723 km – 6.0518 km, In the forward and inverse modeling techniques seven profiles were taken on the residual map and were modeled, thus revealing some special features of the study area. These results show six intrusive bodies: pyrryhotite, ironstone, sandstone in some parts of Nsukka area and granite, gabbro or basalt, sandstone and olivine in some parts of Udi area with their respective depths and susceptibilities. The depths of the minerals obtained ranges from 0.835 km to 5.321 km.

Keywords: Aeromagnetic, imaging, modeling, potent, residual, Nsukka, Udi

Introduction

Geophysics is the application of principle of physics to the study of the earth's interior. These principles of the study of the earth's crust vary in accordance with the physical properties of rock.Magnetic surveying investigate the subsurface of the earth based on the variations in the earth magnetic field which result from the magnetic properties of the underlying rock. The purpose of magnetic surveying is to identify and describe regions of the earth's crust that have unusual (anomalous) magnetization. It can be carried out on land (ground survey), at sea (marine borne) and in air (air borne).

Aeromagnetic survey is a common type of geophysical survey carried out using magnetometer attached behind an aircraft. The principle is similar to a magnetic survey carried out with a hand-held magnetometer, but allows much larger area of the earth's surface to be covered quickly at little interval of time. As the aircraft flies, the magnetometer records the variation in the intensity of the ambient magnetic field due to the temporal effect of the constant varying of solar wind and spatial in earth magnetic field (Robinson and Coruh, 1998). The aim of the research is to analyze and hence interpret the aeromagnetic data sheets of Nsukka and Udi areas of Enugu state, South East of Nigeria, so as to delineate the minerals and estimate the depth to the basement.

Some scholar such as Ofoegbu, (1984), Ugwu and Ezema (2012), Ugwu *et al.* (2013), Ezema *et al.* (2014) carried out studies based on aeromagnetic data interpretations in the lower Benue trough and Anambra basin using various methods.

Materials and Methods

Location and geology of the study area

The study areas, Udi and Nsukka are within Benue Trough of Nigeria which is a major geological formation in West Africa. It is a basin originated from the early cretaceous rifting of the central West Africa basement (Samuel *et al.*, 2011) that extends NE-SW for about 1000 km from bight of Benin to Lake Chad. Benue Trough is believed to have been formed when South America was separated from Africa (Petters, 1978). Nsukka is a town in Enugu state that lies between latitude 6°30' and 7°00' North and longitude 7°00' and 7°30' East. It covers a total surface area of approximately 3,961 km^2 with total population of about 309,633 people as at 2006 census (Federal Republic of Nigeria Official Gazette, 2007) while Udi is also an area in Enugu state which is about 897km^2 and has a total population of about 234,002 people as at 2006 census (Federal republic of Nigeria official Gazette, 2007). It is bounded by latitude 6°11' and 6° 19' North and longitude 7° 15' and 7° 25' East. Geographical map showing thelocation of the study areas and geological map of the study areas are shown in Figs. 1 and 2, respectively.

Fig 1: Geographical map of the study area showing Nsukka and Udi areas in Enugu State

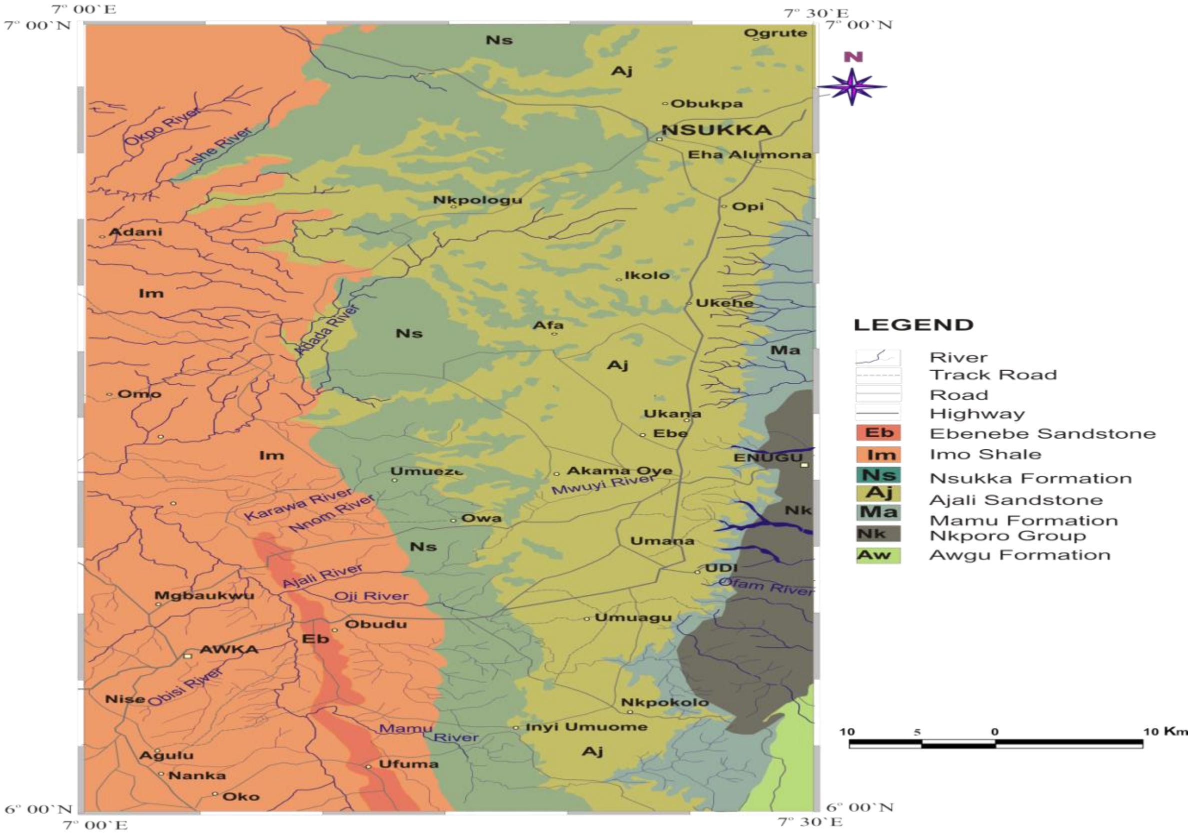


Fig 2: Geological map of the study area with legend bar

The Aeromagnetic dataset used for this study was obtained from Nigerian Geological Survey Agency (NGSA). Data of Udi was obtained in the year 2008 with flight height of 80 m spacing of 500 m and tie lines at 2000 m, after removing geomagnetic potential the data was recorded in X, Y and Total magnetic intensity, (TMI) and that of Nsukka was also obtained by the same Survey Agency in the year 2010 as part of a major project known as the Sustainable Management for Mineral Resources. The survey has Tie-line spacing of 500 m, the flight line spacing of 100 m in East-West direction, flight height of 80 m and terrain clearance of 100 m. The data was recorded in digitized form (Easting X, Northing Y and TMI) after removing the geomagnetic gradient from the raw data using International Geomagnetic Reference Field (IGRF), 2010 with intensity of 33095nT.

Methods used for the study

Aeromagnetic interpretation commonly involves qualitative and quantitative analyzes that are integrated to arrive at geological interpretation of the surface. Qualitative analysis involves examination of anomaly patterns to determine the characteristic of a particular geological unit in other to infer their presence in the subsurface (Reeves, 2005). Qualitative interpretation of the field data was first carried out by inspecting the total magnetic intensity (TMI) grid of the study area. The total magnetic intensity map of the area was produced into maps which are in colour aggregate (Obiora *et al.*, 2015). TMI map of the gridded data was produced using oasis montaj software as shown in Fig. 3.

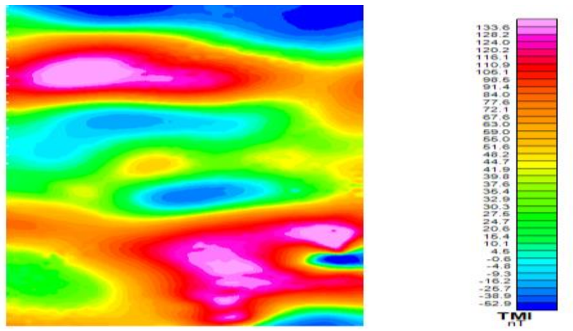


Fig 3: TMI map and the colour legend bar

Source parameter imaging (SPI) method

The Source Parameter Imaging (SPI) function is a quick, easy and powerful method for calculating the depth of magnetic sources. Its accuracy has been shown to be +/– 20% in tests on real data sets. This accuracy is similar to that of Euler Deconvolution; however, SPI has the advantage of producing a more complete set of coherent solution points and it is easier touse than other methods (Salako, 2014).

A stated goal of the SPI method (Thurston and Smith, 1997) is that the resulting images can be easily interpreted by someone who is an expert in the local geology. The SPI method (Thurston and Smith, 1997) estimates the depth from the local wave number of the analytical signal. The SPI depth of magnetic data was determined using oasis montaj software and employing the first vertical derivatives and horizontal gradient. This model was displayed on an image and correct depth for each anomaly is determined.

Forward and inverse modeling method

Interpretation of aeromagnetic field data using Oasis montaj for forward and inverse modeling begins with the observation of the image of the observed data. The field image shows contours of the observed total magnetic intensity (TMI) of the study area as show in Fig. 9. The potent in the Oasis montaj software (6.4.2) version was used for the modeling and inversion of the anomalies after getting preliminary information about anomaly causative sources. The software which was written by Geophysical Software Solution (GSS) in Australia is a program that consists of an assemblage of 2D and 3D geometric bodies such as sphere, ellipsoid, slab, lens, dyke, rectangular prism, polynomial prism, and cylinder. It is use for modeling the magnetic and gravitational effects of subsurface to provide a highly interactive 3D and 2D environment for some application like mineral exploration. By trial and error approach, these bodies were attempted in modeling the observed data in order to obtain the best fit model. In trying to model the observe data, potent assigns the body default parameter (shape, position and physical properties). Agiven body model is created by varying any or all the parameters of the body. The main concepts in the potent modeling include: Observation, inversion, model, visualization and calculation.

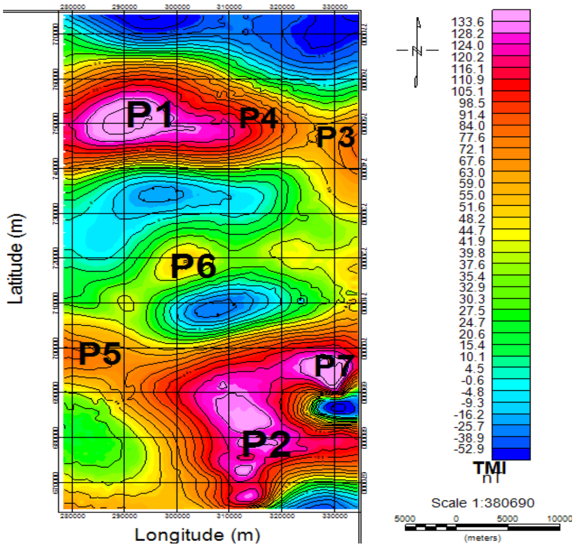


Fig 4: Profile portions in TMI map of the data

Modeling of some selected profiles

The first step in interpreting the observed data was to take profiles on the residue of the area and model in order to obtain a close match between the observed data and the calculated data to produce a variation in dip, plunge, susceptibility (k) and depth (Z). In the TMI map of the area seven profiles were taken along different parts in the map. Using a single component data (TMI) for multiple bodies, the inversion procedure was performed and they provided the observed field value against which the calculated field values were compared. The root mean square (RMS) between the observed and calculated field was expected to be minimized by the inversion algorithm.

Results and Discussion

The interpretation of the results of the aeromagnetic data of the study area commenced with the qualitative analysis of the total magnetic intensity map of the area as shown in figure 3. It shows that intensity of the anomalies in area ranges from -52.9 to 133.6 nT, the area marked by the (pink colour) is the place with high magnetic signatures while the place marked with (blue colour) indicates low magnetic intensity for the anomalous bodies. The variation in the magnetic intensity could be as a result of degree of strike, variation in depth, difference in magnetic susceptibility, difference in lithology, dip and plunge.

The depth to the basement estimated using Source Parameter Imaging (SPI) as shown in Fig. 5 ranges from the minimum depth of 472.3m (0.4723km) which is indicated with pink colour to the maximum depth of 6051.8m (6.0518km) with deep blue colour.Some representatives of the results from the Forward and Inverse Modeling of the anomalies over the area are displayed in Figs. 6 – 8.In the graphs of the modeled result, blue curves represent the observed fields while the red curves represent the calculated fields due to the model. The summary of the result with the corresponding minerals (according to Telford *et al.*, 1990) is shown in the Table 1.

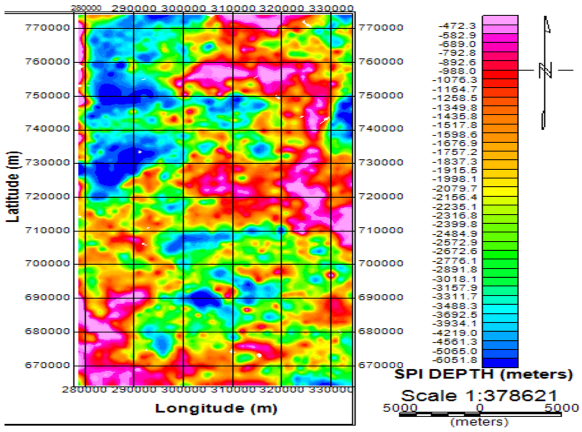


Fig 5: Source parameter image (SPI) showing the estimated depths

The 3-D forward and inverse modeling technique was used to model some places to obtain the minerals with their respective susceptibilities and depth. These include pyrrhotite (1.4490), granite (0.0251), ironstone (0.0015), sandstone (0.0037), gabbro or basalt (0.0753), sandstone (0.0038) and olivine (0.0251), with 4956, 5321, 1950, 5117, 4807, 835, 4122m as their depths respectively. Figs. 6 – 8 displayed representative of the results obtained from Forward and Inverse Modeling method, the 'plan observation' is the portion marked out from the main TMI map to model, the 'plan calculated' is the calculated portion of TMI after the modeling**,** while**'**plan residual' is the residua TMI of the minerals causing the anomalies in the area after modeling to get the best fit of the observed curve (with red colour) and calculated curve (with blue colour) in both the E-W section and N-S section graphs.

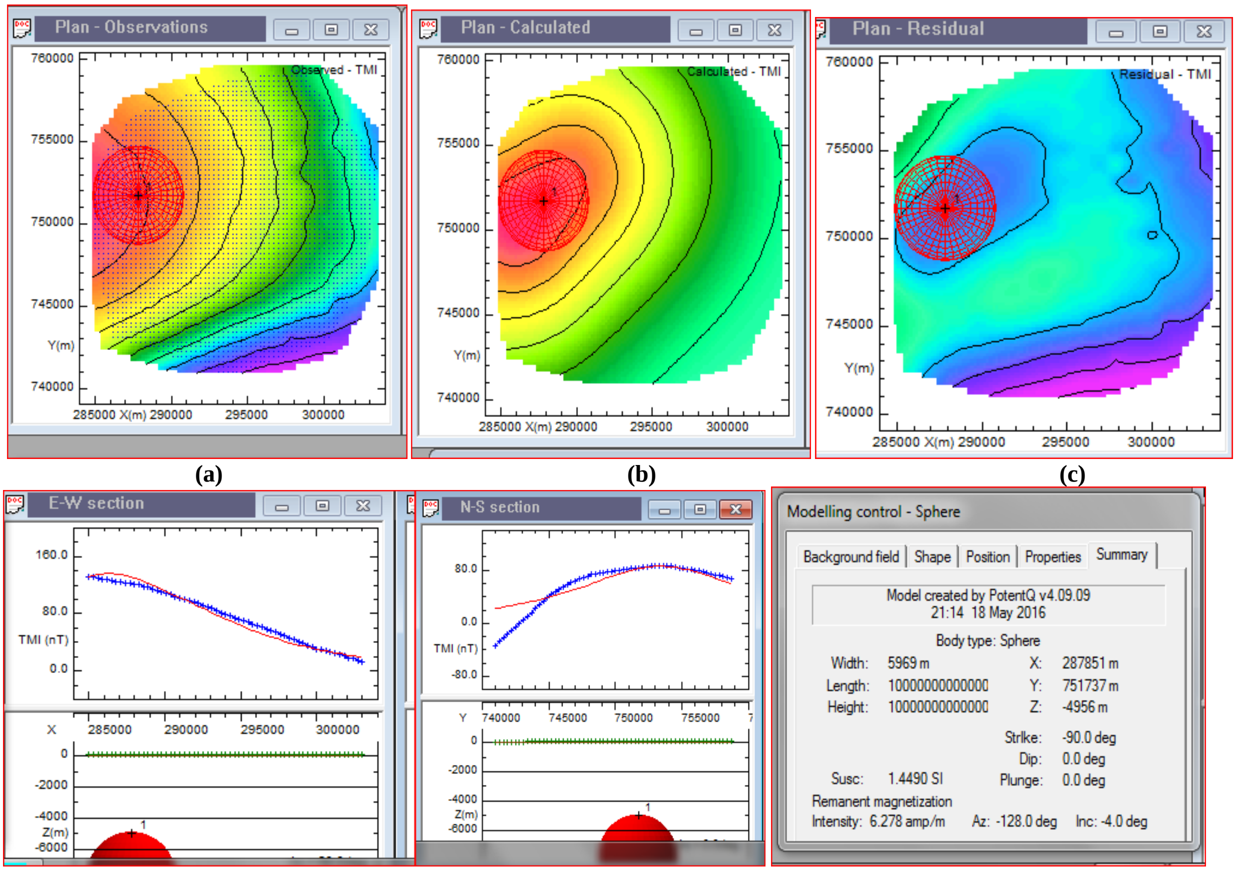
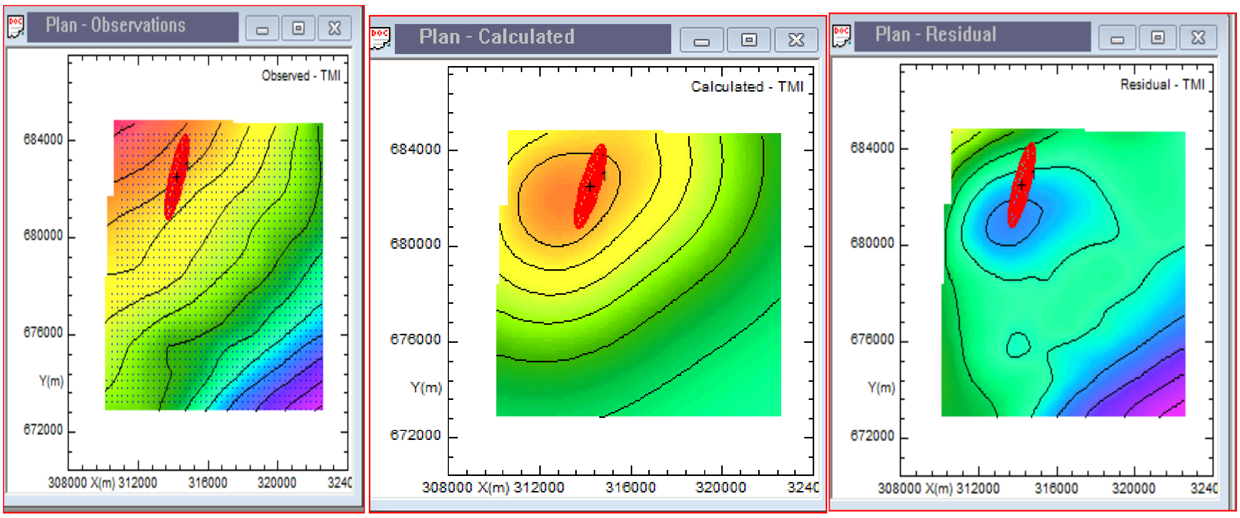
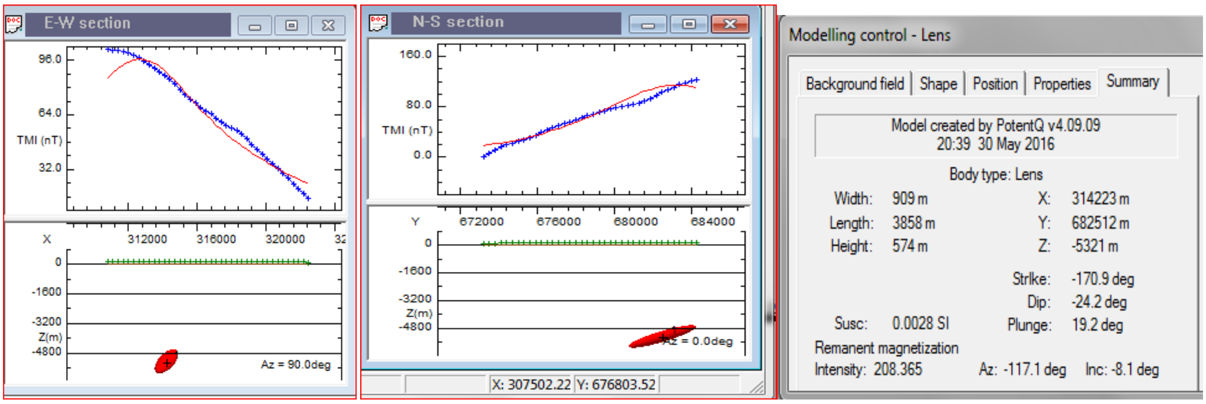


Fig. 6(a – f): The complete Results from Profile 1(a) Observed plan, (b) calculated plan, (c) Residual Plan, d. Graph of E-W section, (e) Graph of N-S section, (f) Summary of the modeling

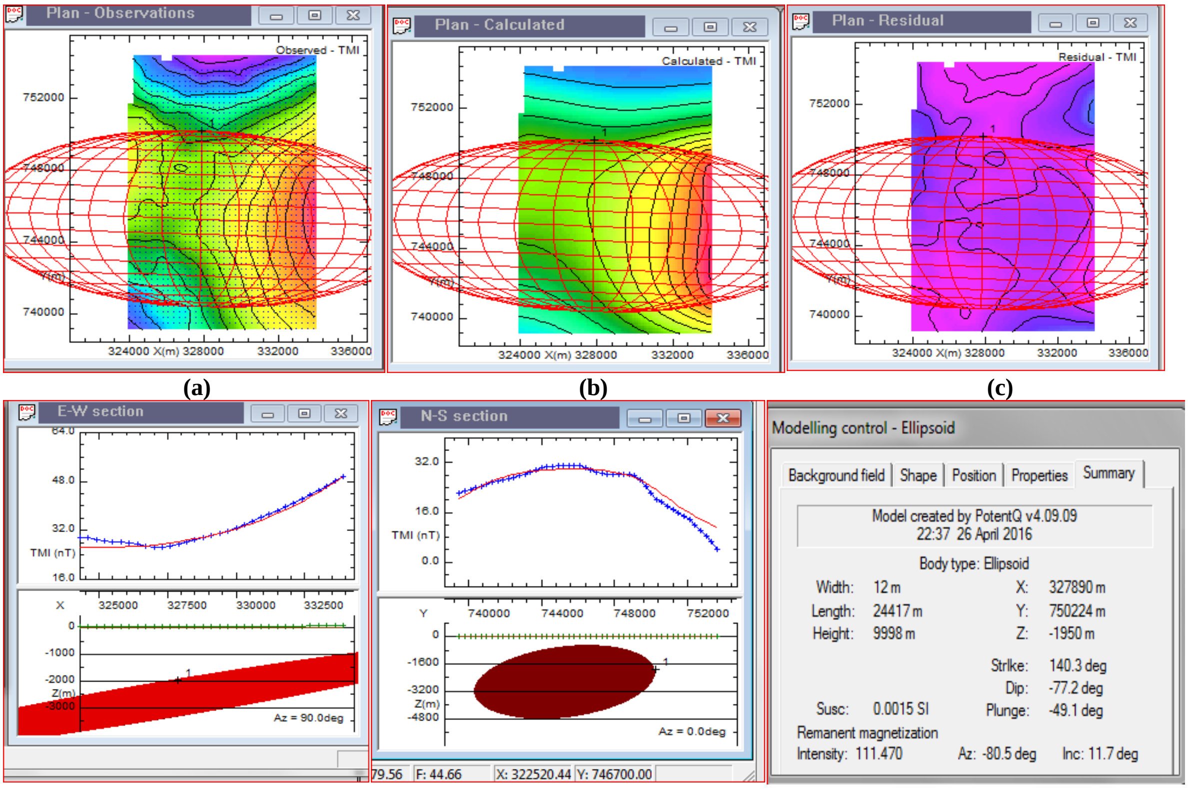


(a) (b) (c)



(d) (e) (f)

Fig 7(a – f): The complete results from profile 2(a) Observed plan(b) calculated plan (c) ResidualPlan (d) Graph of E-W section (e) Graph of N-S section (f) Summary of the modeling



(a) (b) (c)

(d) (e) (f)

Fig 8(a – f): The complete results of profile 3(a) Observed plan (b) Calculated plan (c) Residual Plan (d) Graph of E-W section (e) Graph of N-S section (f) Summary of the modeling)

Table 1: Summary of forward and inverse modeling method on the TMI map

Modeling profiles	X(m)	Y(m)	Depth Z (m)	Dip (deg)	Plunge (deg)	Strike (deg)	Body shape	K value (SI)	Possible mineral
Profile 1	2878851	751737	-4956	0.0	0.0	-90.0	Sphere	1.4490	Pyrrhotite
Profile 2	314223	682512	-5321	-24.2	19.2	-170.9	Lens	0.0028	Granite
Profile 3	327870	750224	-1950	-77.2	-49.1	140.3	Ellipsoid	0.0015	Ironstone
Profile 4	311175	748779	-5117	0.0	0.0	-90.0	Sphere	0.0037	Sandstone
Profile 5	281982	696893	-4807	0.0	0.0	-90.0	Sphere	0.0753	Gabbro or Basalts
Profile 6	302971	719563	-835	30.7	0.0	-1.4	Slab	0.0038	Sandstone
Profile7	330219	697074	-4122	82.7	81.6	71.9	Ellipsoid	0.0251	Olivine

The E-W section represents the graph of TMI in horizontal axis against longitude (X) while the N-S section represents the graph of TMI in vertical axis against latitude (Y). The red bodies in all the plans indicate the type of body used during the modeling which could be ellipsoid, lens, sphere etc. The summary displayed all the necessary information after the best fit of the modeling such as the longitude, latitude, depth, susceptibility of such particular mineral in that portion of the area.

The estimated depth from source parameter imaging (SPI) ranges from 0.4723km to 6.0518km. The estimated depth from forward and inverse modeling method are 4956, 5321, 1950, 5117, 4807, 835 and 4122 m for profiles 1, 2, 3, 4, 5, 6 and 7, respectively. The susceptibility values obtained from the model profiles are 1.4490, 0.0028, 0.0015, 0.0037, 0.0753, 0.0038 and 0.0251, respectively which indicate dominance of iron rich minerals in form of pyrrhotite, granite, ironstone, sandstone, gabbro, sandstone and olivine etc. This is in line with basic rock units or minerals that characterized the study area. Their respective depth still lies within the range of depths obtained from source parameter imaging and spectral analysis methods.
This depth range obtained from each method is sufficient for hydrocarbon accumulation since it agrees with the work of Wright *et al*. (1985) which asserts that the minimum thickness of the sediment required for the commencement of oil formation from marine organic remains would be 2300m (2.3km).

Conclusion
Interpretation of aeromagnetic data of the study area (Nsukka and Udi) has been done qualitatively and quantitatively. Source parameter imaging (SPI) and forward and inverse modeling methods were employed in quantitative interpretation. Some intrusive bodies responsible for the anomalies in the study area were identified to include Pyrrhotite, Gabbro or Basalt, Ironstone, Sandstone, Granite and Olivine and their depths to the basements were also estimated. The study also revealed that sufficient hydrocarbon accumulation is possible in the Nsukka axis of the study area, as it has the required minimum thickness of the sediment for the commencement of oil formation from marine organic remains.

Acknowledgement
The authors are grateful to the Nigerian geological survey agency for the data used in this study.

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