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# Forward and Inverse Modelling of Aeromagnetic Anomalies over Parts of Middle Benue Trough, Nigeria

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#### **Abstract**

The aeromagnetic data over Lafia, Akiri, Makurdi and Akwanga, of the Middle Benue Trough of Nigeria were interpreted by forward and inverse modelling techniques in order to determine the depth to basement and the type of mineralization prevalent in the area. Oasis Montaj and PotentQ software were used for the data reduction and interpretation. The regional anomalies were separated from the total magnetic intensity (TMI) to obtain the residual fields using first order polynomial fitting. The magnetic anomalies were modelled by prismatic and ellipsoid bodies. The magnetic susceptibility of the bodies after forward and inverse modelling of profiles 1-5 were respectively 0.0400, 0.0003, 0.0002, 0.0001 and 0.0250; with respective depths of 4650, 1160, 2420, 980 and 3420 m. The indicated magnetic susceptibilities of these bodies suggest that they are igneous or metamorphic intrusions of basic to intermediate composition. These magnetic susceptibilities are associated with occurrence of minerals such as pyrite and graphite and rocks such as granite, limestone, schist, gnesis and marble. Maximum depth to basement was recorded around Akiri in the north-eastern part of the study area. The prospect for hydrocarbon accumulation is higher around the north-eastern part of the study area than at the other parts.

#### **Keywords**

Aeromagnetics, Forward and Inverse Modelling, Intrusions, Magnetic Susceptibility, Basement Depth and Mineralization

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### 1. Introduction

Aeromagnetic geophysics has remained am important method of modern geophysics, haven widely gained preeminence, especially as a reconnaissance tool. The method guarantees faster and usually cheaper coverage of the exploration area compared to other geophysical methods. This method of investigating the earth subsurface is based on the magnetic anomalies in the earth's magnetic field due to the magnetic properties of the underlying rocks/minerals. The shape, dimensions and amplitude of an induced magnetic anomaly is a function of the orientation, geometry, size, depth and magnetic susceptibility of the body as well as the

intensity and inclination of the earth's magnetic field in the survey area.

Rocks differ in their magnetic mineral content hence the magnetic intensity map of a survey area depicts the geological structures of the area. The main purpose of magnetic survey is therefore to detect rocks or minerals possessing unusual magnetic properties that reveal themselves by causing disturbances or anomalies in the intensity of earth's magnetic field.

Following the renewed calls for diversification of Nigeria's economy and re-investigation of the hydrocarbon potentials of other inland basins, there has been increasing interest in the search for the abundant solid minerals in the country as

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well as the hydrocarbon prospects of other basins. Identification of these minerals or oil and gas deposits in the country will yield increased revenue to the economy while increasing the national reserves.

The Benue Trough has been reported by so many authors to possess a unique economic importance due to the mineralization along the belt. Intense geological and geophysical investigations have been carried out along this belt by so many researchers in search of these minerals [1-5]. Other successful geophysical investigations carried out in the Benue Trough using forward and inverse modelling techniques include [6-9]. This paper reports the result of geophysical interpretation of high resolution aeromagnetic

data of Lafia, Akiri, Makurdi and Akwana areas of the Middle Benue Trough of Nigeria using forward and inverse modelling techniques. This is with a view to delineating areas with magnetic intrusions and their lateral and vertical extents. The hydrocarbon potential of the study area is also investigated.

# 2. Geology of the Study Area

The study area lies within longitude  $8^0$  30' to  $9^0$  30' East and latitude  $7^0$  30' to  $8^0$  30' North. This covers an area of about  $12100 \text{ km}^2$ .

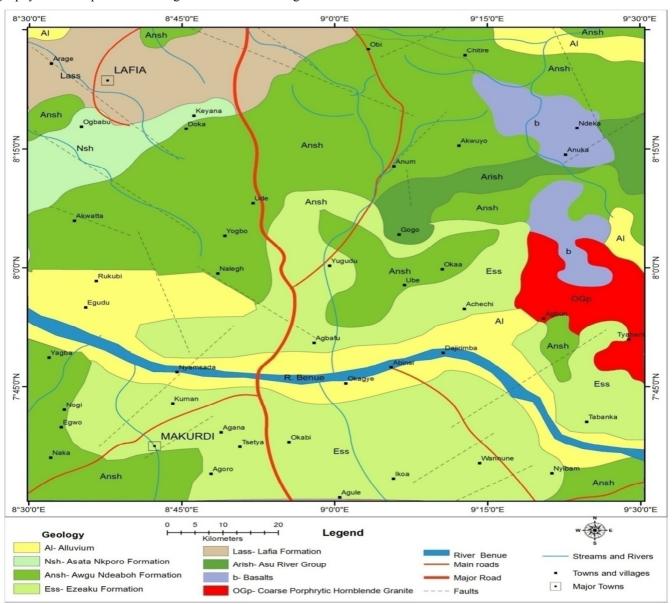


Figure 1. Geological map of the study area [15].

The stratigraphic succession in the Middle Benue Trough started with the Asu River Group whose age ranges from Middle Albian to Late Albian [10, 11]. The Asu River Group whose type section outcrops in the Asu River near Abakaliki consists of dark shale, siltstones, fine grained sandstones and limestones [12, 13]. Typical exposures of this formation have

been reported east of Keana and near Arufu, where it overlaps the older sediments to rest unconformably on the crystalline basement rocks [11-13]. The Asu River Group is overlain by the Turonian Ezeaku Formation which consists mainly of shale, clay, siltstones and limestones. The Eze-Aku Formation has an estimated thickness of 95 m [10]. The Keana/Awe Formation overlies the Ezeaku Formtion. The thickness of the Keana/Awe Formation has been estimated at 800 m around Keana – Awe area [10, 11]. In the Keana- Awe area, the overlying Keana/Awe Formation consists of flaggy whitish coarse to medium grained sandstones, inter-bedded with carbonaceous shale, clay and sandy limestones [12-14]. The thickness of Keana/Awe Formation which can be traced

over large areas of the Benue Trough has been put at about 1000 m [11]. Overlying the Keana/Awe Formation are the marine deposits of the Turonian–Santonian Agwu Formation. The Agwu Formation whose thickness was estimated at 290 m [10] composed mainly of black shale, sandstones, seams of coal and subordinate limestones. The Lafia Formation is the youngest formation in the Middle Benue and consists of coarse grained ferruginized sandstones, loose sand, flaggy mudstones and clay [10-13]. The type locality is seen around Lafia. Its thickness is estimated to be about 500 to 1500 m [10]. Figure 1 shows the geological map of the study area while Figure 2 shows the stratigraphic sequence of the Benue Trough.

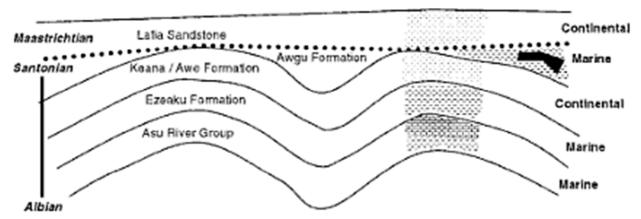


Figure 2. Stratigraphic sequence of the Middle Benue Trough [16].

#### 3. Materials and Method

#### 3.1. Source of Data

Aeromagnetic data of Lafia (sheet 321), Akiri (sheet 232), Makurdi (sheet 251) and Akwana (sheet 252) were obtained from the Nigeria Geological Survey Agency (NGSA). The data were acquired for NGSA by Fugro Airborne Surveys Limited in 2008 using proton precession magnetometer at a flight altitude of 80m above the ground surface. The nominal flight line spacing was 500 m while the tie line spacing was 2 km apart. The flight line direction was 135° while the tie line direction was 225°. The digitized data were recorded in (X, Y, Z) format on a scale of 1: 100,000. The X and Y value respectively represents the longitude and latitude of each data point (in meters) while the Z value represents the magnetic field intensity (in nanoTesla) at that point

#### 3.2. Data Reduction

The four digitized aeromagnetic data sheets were first merged into a single composite sheet which formed the study area using Oasis Montaj Software. The regional geomagnetic gradients were first removed from the data using the international geomagnetic reference field (IGRF). This was followed by polynomial fitting for regional-residual separation.

#### 3.3. Forward and Inverse Modelling

Interpretation of the acquired data after all the data reduction was by forward and inverse modelling techniques. Forward modelling technique involves making numerical estimates of the depth and dimensions of the anomalous source body recorded in the survey. The modelling technique is a trial-and- error approach where the shape, position and physical properties of the model are adjusted in order to obtain a good fit between the calculated field and the observed field [7, 8]. The inverse modelling technique is a mathematical process that automatically adjusts the forward model parameters so as to improve on the fit between the calculated and the observed fields. The software used for the modelling of the data was PotentQ (v4.09.09).

Five profiles were taken on the residual field image (map) at different portions of the map. Each profile at the end of the modelling session produced the best fit model for the given type of body with the model parameters displayed.

# 4. Results and Discussion

Figure 3 shows the 2-D map of the TMI of the study area while Figure 4 shows the 2-D map of the residual magnetic field intensity with the five profiles taken on the map. The TMI of the area ranges from -46.6 to 109.4 nT (Figure 3) while the residual magnetic intensity ranges from -85.7 to 69.4 nT (Figure 4). The model results of profiles 1 to 5 are shown in Figures 5 to 9 respectively. The red curves represent the calculated field due to the model while the blue curves represent the observed field. Profiles 1 and 2 where modelled by rectangular prisms at depth of 4650 m and 1160 m respectively. The bodies have magnetic susceptibility of 0.0400 and 0.0003 respectively. Profiles 3, 4 and 5 were modelled by ellipsoid bodies at depths of 2420, 980 and 3420 m respectively. The magnetic susceptibility of the anomalies are 0.0002, 0.0001 and 0.0250 respectively. Each model result produced a degree of Strike, Dip, and Plunge where the observed field matches well with the calculated field. Other parameters of the bodies such as Remanent magnetization, Azimuth and Inclination are as indicated on the model

results. The deep depths are associated with sources arising from the basement while the shallow depths are due to sources arising likely from igneous intrusions in the sediment. The indicated magnetic susceptibilities of these bodies [17] suggest that they are igneous or metamorphic intrusions of basic to intermediate composition, typical of minerals such as pyrite and graphite and rocks such as granite, limestone, schist, gnesis and marble. This is in agreement with the results obtained by other researchers in the Middle Benue Trough [18, 19]. Using spectral analysis, the depth to deep sources in the Middle Benue Trough (identified with the basement) was found to vary from 1600 to 5000 m while the depth to shallow sources (identified with igneous intrusions) varied from 60 to 1200 m [18]. Also using source parameter imaging (SPI) technique, a depth range of 2000 to 6291.5 m in the Middle Benue Trough was obtained [19]. The maximum depth of 4650 m recorded at the north-eastern part of the study area (around Akiri) shows thick sediment capable of holding hydrocarbon potential, if other structural features of hydrocarbon accumulation are favourable.

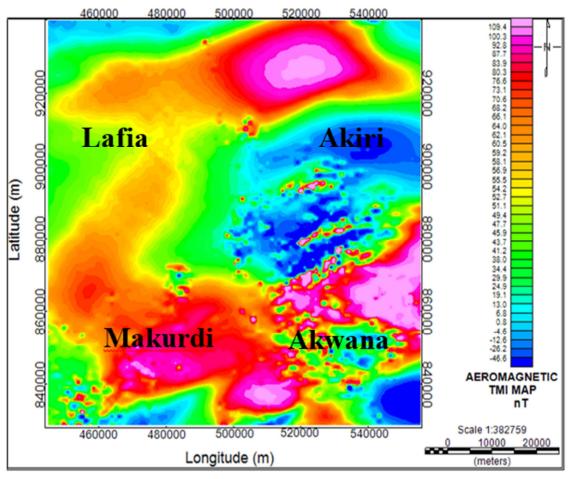


Figure 3. TMI map of the study area.

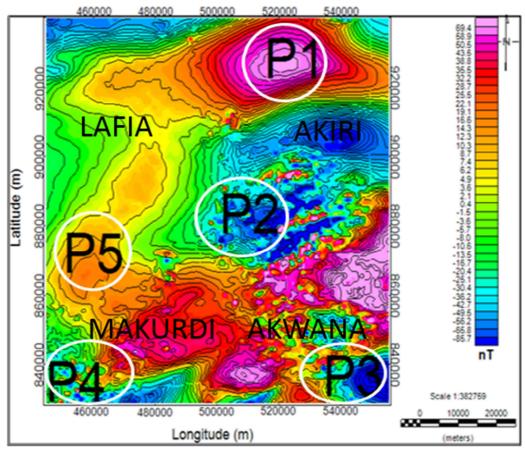


Figure 4. Residual magnetic intensity map showing profiles taken.

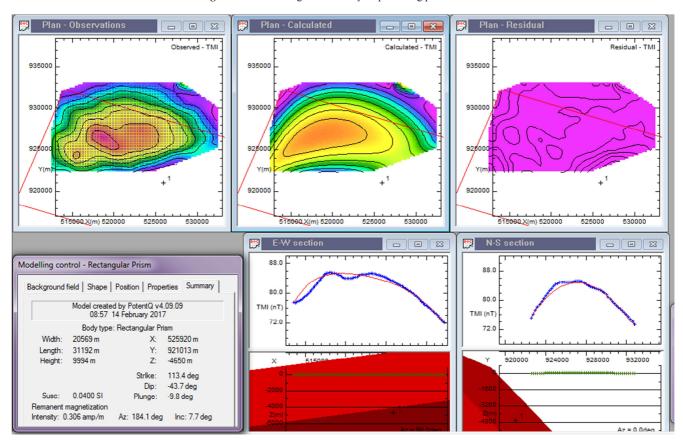


Figure 5. Model result of Profile 1 (P1).

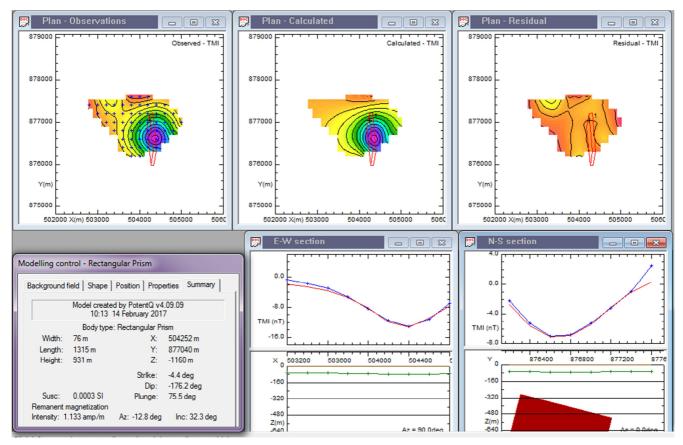


Figure 6. Model result of Profile 2 (P2).

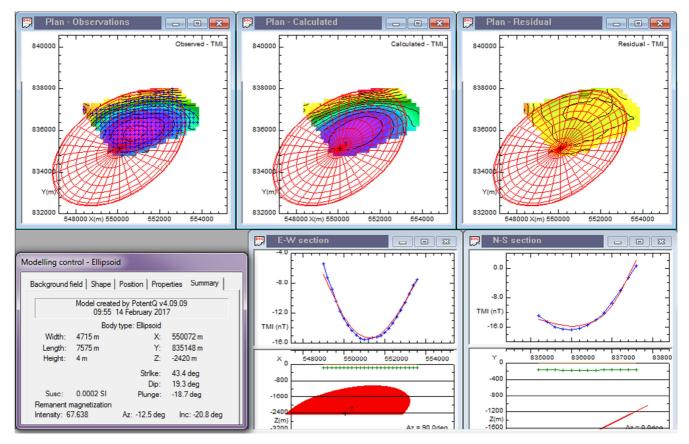


Figure 7. Model result of Profile 3 (P3).

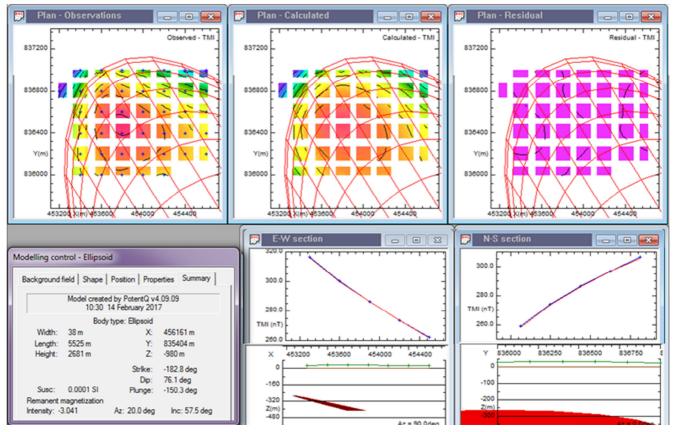


Figure 8. Model result of Profile 4 (P4).

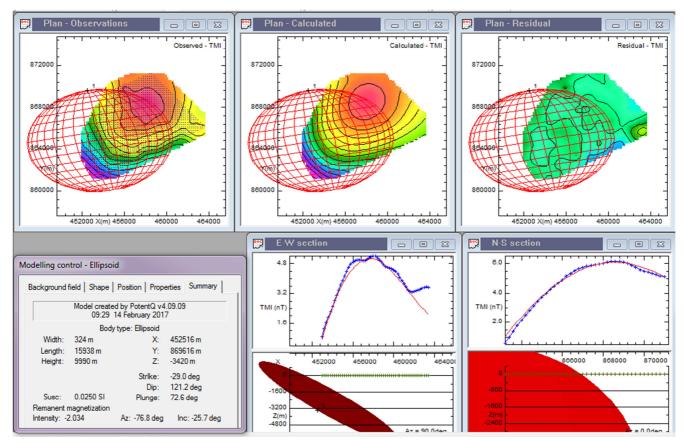


Figure 9. Model result of Profile 5 (P5).

# 5. Conclusion

The aeromagnetic data over some parts of Middle Benue Trough of Nigeria have been quantitatively interpreted by forward and inverse modelling techniques to determine the depth to the magnetic sources (sediment thickness) as well as the type of mineralization prevalent in the area. The magnetic susceptibilities of the modelled bodies suggest the presence of minerals such as pyrite and graphite as well as rocks such as granite, limestone, schist, gnesis and marble. These minerals and rocks depicted by magnetic intrusions are more prevalent around Akwana area. The north-eastern part of the study area (near Akiri) with maximum sediment thickness of 4650 m holds more hydrocarbon accumulation prospect. These minerals can be exploited to diversify the economy of the country while the hydrocarbon exploration around the area will increase the oil and gas reserves of Nigeria.

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