

Full Length Research Paper

Forward and inverse modelling of aeromagnetic anomalies over Abakaliki and Nkalagu areas of the Lower Benue Trough, Nigeria

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Aeromagnetic data over Abakaliki and Nkalagu areas of the Lower Benue Trough of Nigeria were interpreted by forward and inverse Modelling techniques. A highly interactive 3-D modelling software (Potent V4:10:02) of the Geophysical Software Solutions was used for the modelling exercise. The anomalies over the study area were modelled by spherical, prismatic or dyke-like bodies. These bodies are emplaced at various depths of between 2km and 22km, either within the Cretaceous sediment or in the basement. The magnetic susceptibility of most of these bodies, as revealed by the model results, indicate that the bodies are igneous rocks. The igneous intrusions in the study area account for the mineralization in the area. Although depth extents of 10-22km obtained for some anomalies in the study area could be favourable sites for accumulation of hydrocarbons, the presence of large number of intrusions makes this part of the Benue Trough incapable of holding any significant hydrocarbon potentials.

Keywords: Aeromagnetic, intrusions, anomalies, hydrocarbons, mineralization.

INTRODUCTION

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. The origin and evolution of the Benue Trough is now well documented (Wright, 1968, 1976; Grant, 1971; Nwachukwu, 1972; Olade, 1975, 1978; Petters, 1978; Ofoegbu, 1985). The major component units of the Lower Benue Trough include the Anambra Basin, the Abakaliki Anticlinorium and the Afikpo Syncline.

The study area which is within the Abakaliki Anticlinorium is characterized by a zone of lead-zinc mineralization, pyroclastic rocks and brine. The occurrence of these mineral deposits has generated a lot of interest on the re-examination of the economic potentials of this mineral belt. Intense geological and geophysical investigations have been carried out in the

Abakaliki Anticlinorium at different times in search for these mineral deposits (Uzuakpunwa, 1974; Olade, 1976; Hoque, 1984; Ofoegbu and Onuoha, 1991; Obi et al, 2010).

In order to contribute to the understanding of geology and hydrocarbon potentials of the Lower Benue Trough, we have considered the use of aeromagnetic survey to delineate the subsurface structures which control the anomalous mineralization zones. Forward and inverse modelling techniques have been employed for this purpose. This is with a view to delineating the areas of possible magnetic intrusions and their lateral and vertical extents. The hydrocarbon potentials of the area is also assessed.

Geology of the study area

The geology of the southern portion of the Benue Trough has been described by several authors (Olade, 1975; Nwachukwu, 1972, Ofoegbu,1985). The oldest sediments belong to the Asu River Group (Figure 1) which

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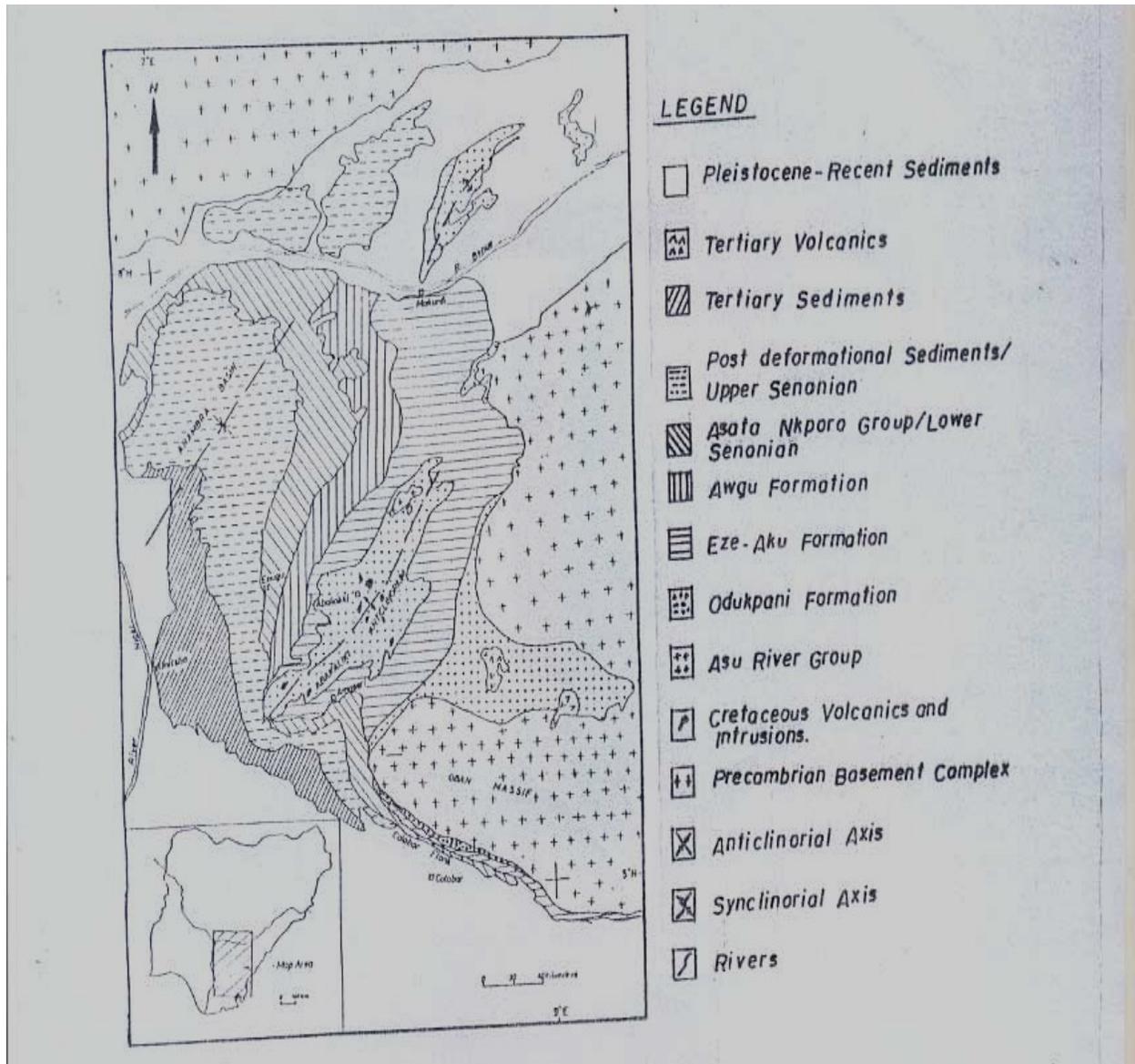


Figure 1. General geology of the southern portion of the Lower Benue Trough (after Olade, 1976).

uncomfortably overlies the Precambrian basement complex that is made up of granitic and migmatic rocks. The Asu River Group, whose type section outcrops near Abakaliki has an estimated thickness of 2000m (Ofoegbu, 1985) and is of Albian age. It comprises of argillaceous sandy shales, laminated sandstones, micaceous sandstones and minor limestones with an interfingering of mafic volcanics (Nwachukwu, 1972). The shales are fissile and highly fractured and are associated with pyroclastic rocks, especially around Abakaliki and Ezillo areas (Uzuakpuwa, 1974; Olade, 1976, Hoque, 1984). Deposited on top of these Asu River Group sediments in the area were the Upper Cretaceous sediments, comprising mostly the Ezeaku Shales. The Ezeaku Shales consist of nearly 1000m of calcareous flaggy

shales and siltstones, thin sandy shaley limestones and calcareous sandstones (Reyment, 1965). They are Turonian in age and are overlain by younger sediments of the Awgu Shale (Coniancian). The Awgu Shales consist of marine fossiliferous grey bluish shales, limestones and calcareous sandstones. They are overlain by the Nkporo Shales (Campanian) which are also mainly marine in character and has sandstone members.

Data acquisition and interpretation

Digitized aeromagnetic data was obtained from the Nigerian Geological Survey Agency, NGSA, Abuja. The data was acquired from the airborne geomagnetic survey

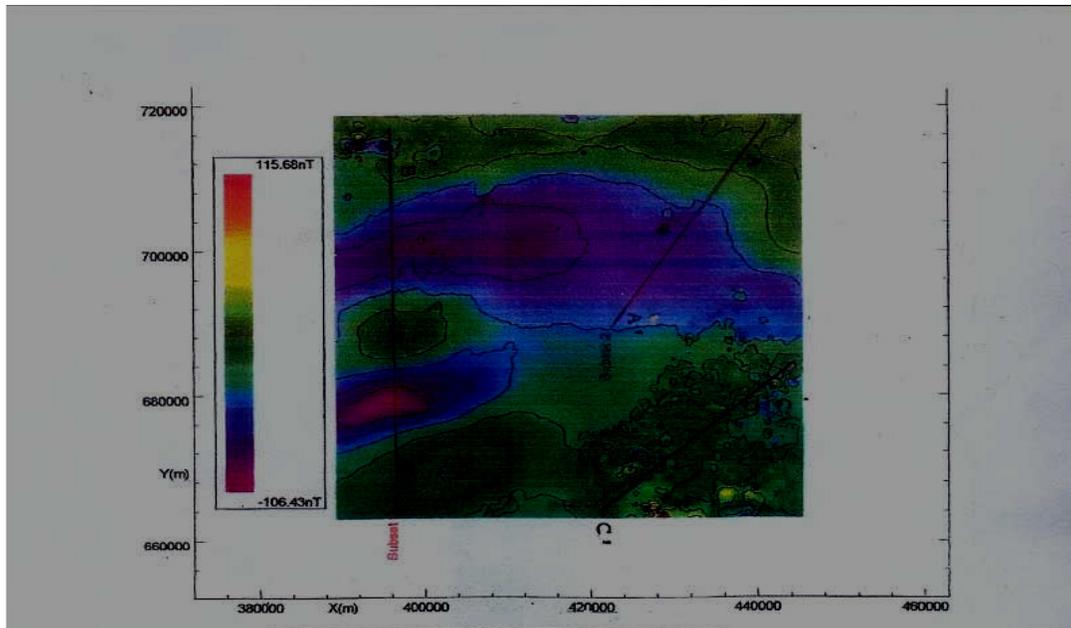


Figure 2. Profiles taken on Abakaliki field image.

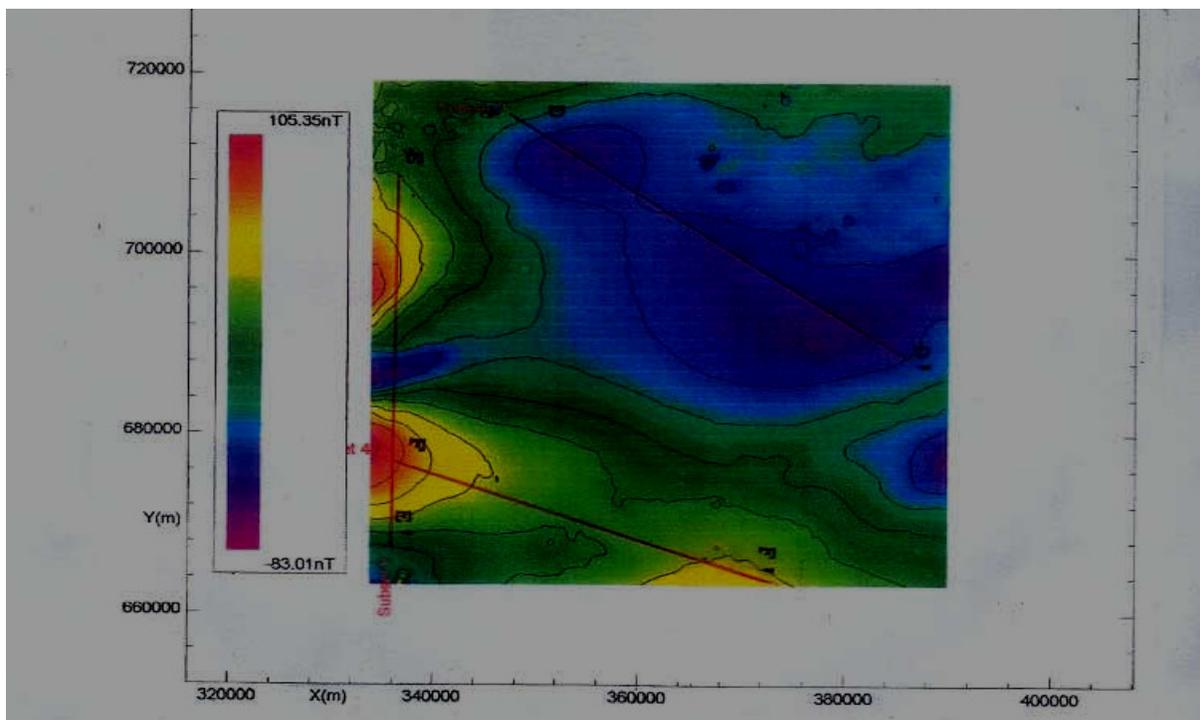


Figure 3. Profiles taken on Nkalagu field image.

carried out in 2008 by Fugro Surveys Limited for the Nigeria Geological Survey Agency. The data was acquired at a flight altitude of 80m above the ground surface. The nominal flight line spacing was 500m while the tie line spacing was 2km.

Sheets 302 (Nkalagu) and 303 (Abakaliki) on a scale of 1:100,000 were used for this study. These cover the

area within latitude 6°N and $6^{\circ} 30'\text{N}$ and longitude $7^{\circ} 30'\text{E}$ and $8^{\circ} 30'\text{E}$.

Interpretation of the acquired data was by forward and inverse modelling techniques. The software used for the modelling techniques was the Potent Version4 (Geophysical Software Solutions, 2010). Interpretation of the data using Potent begins with the observation of the

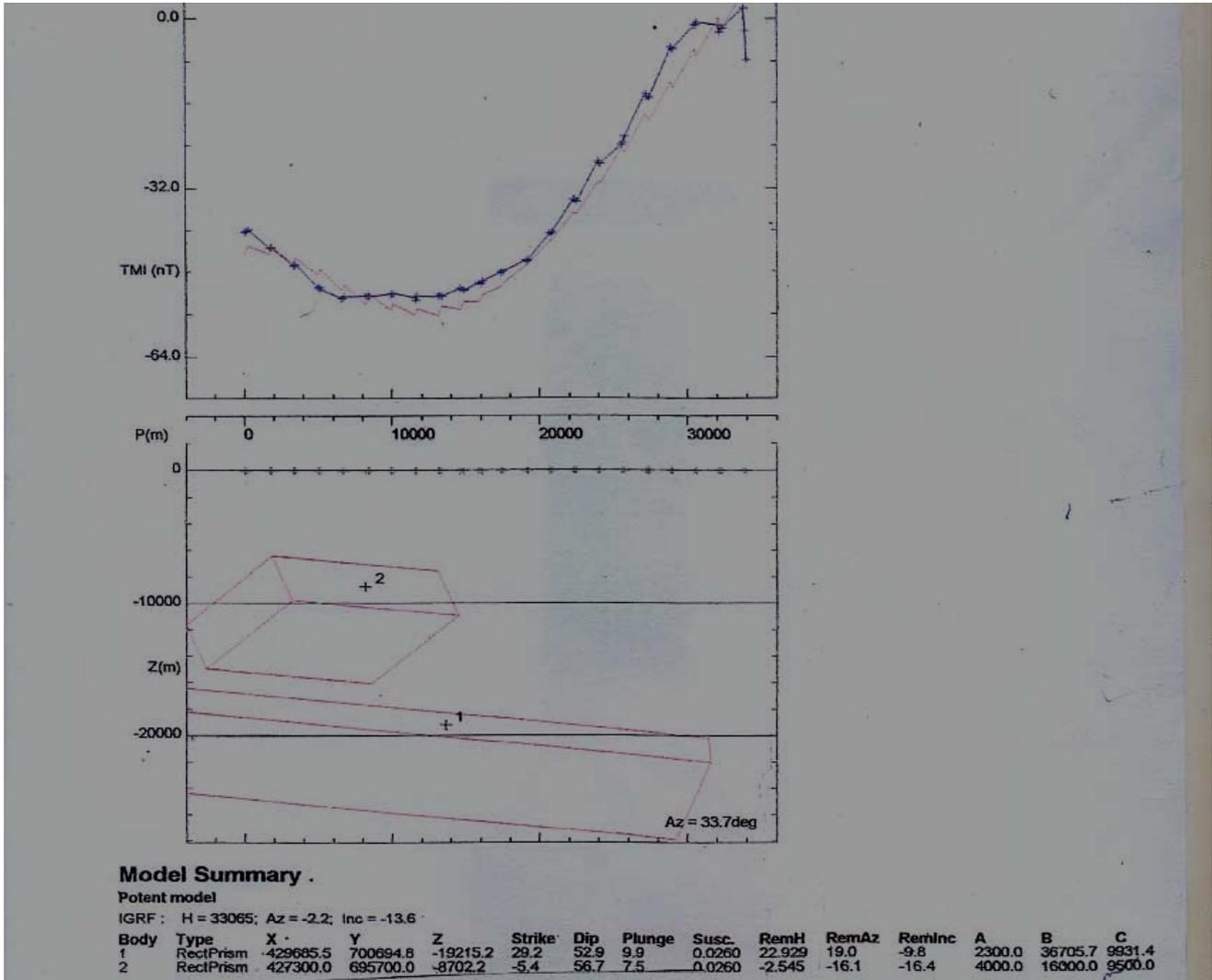


Figure 4a. Model result of subset 2 of Abakaliki Field.

image of the acquired data. The field image shows contours of the observed total magnetic intensity over the area. The regional field was first removed from the observed field by choosing a first degree polynomial in the regional tool of the Potent software. The first – degree polynomial surface, r , is given by:

$$r = a_0 + a_1 (x - x_{ref}) + a_2 (y - y_{ref})$$

where X_{ref} and Y_{ref} are the co-ordinates of the geographic centre of the dataset and a_0 , a_1 and a_2 are the polynomial coefficients. The International Geomagnetic Reference Field (IGRF) was also removed from the observed data by putting the latitude, longitude and year (2008) into the Potent IGRF software to obtain the residual fields needed for forward and inverse modelling.

Three profiles were taken on the Abakaliki field and are given by lines AA', BB' and CC' (Figure 2) while the three profiles taken on the Nkalagu field are given by lines DD', EE' and FF' (Figure 3).

RESULTS

The result of the forward and inverse modelling of the anomalies over the study area are given in Figures 4 and 5. In the model results shown, the blue curves represent the observed fields while the red curves represent the calculated fields due to the model.

DISCUSSION

Profile 2 taken around Alebo area in the northeastern part of the Abakaliki field was modelled by two rectangular prisms (Figure 4a) emplaced at depths of 8.7 – 19.2km in the basement. These bodies have magnetic susceptibility of 0.0260 which is typical of basic igneous rocks (Telford et al, 1976). Profile 3 taken in the N-S direction and passing across Aba – Omega was modelled by two

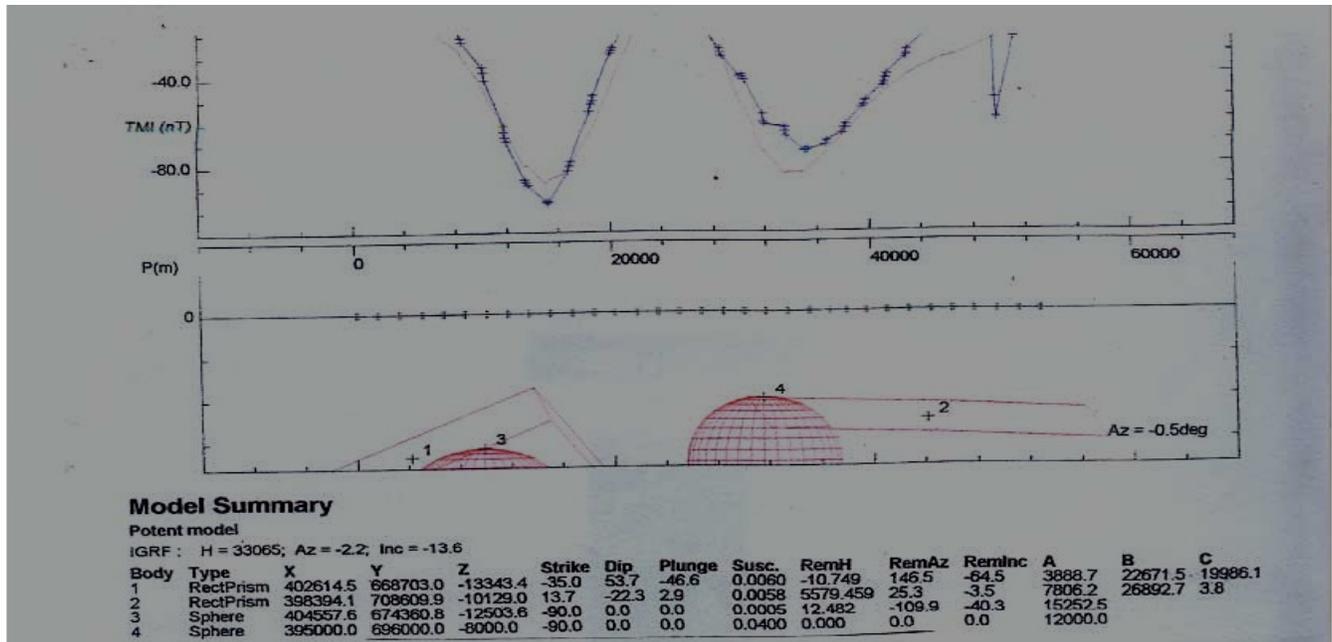


Figure 4b. Model result of subset 3 of Abakaliki Field.

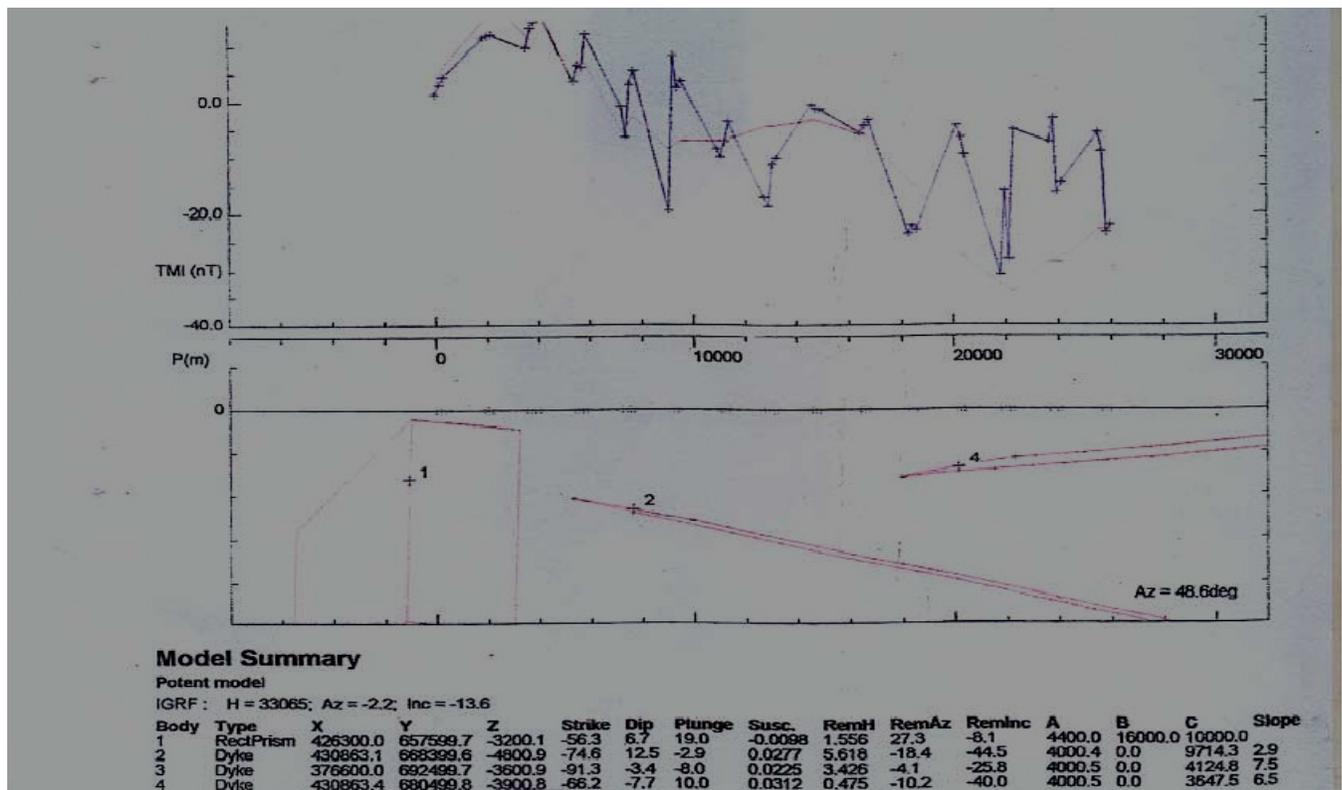


Figure 4c. Model result of subset 4 of Abakaliki Field.

spherical bodies and two rectangular prisms (Figure 4b). These bodies were estimated to be at depths of about 8.0 – 13.3km also in the basement. Profile 4 taken on the

southeastern part of the Abakaliki field was modelled by three dykes and one rectangular prism (Figure 4c). The dykes have magnetic susceptibility of about 0.0277 –

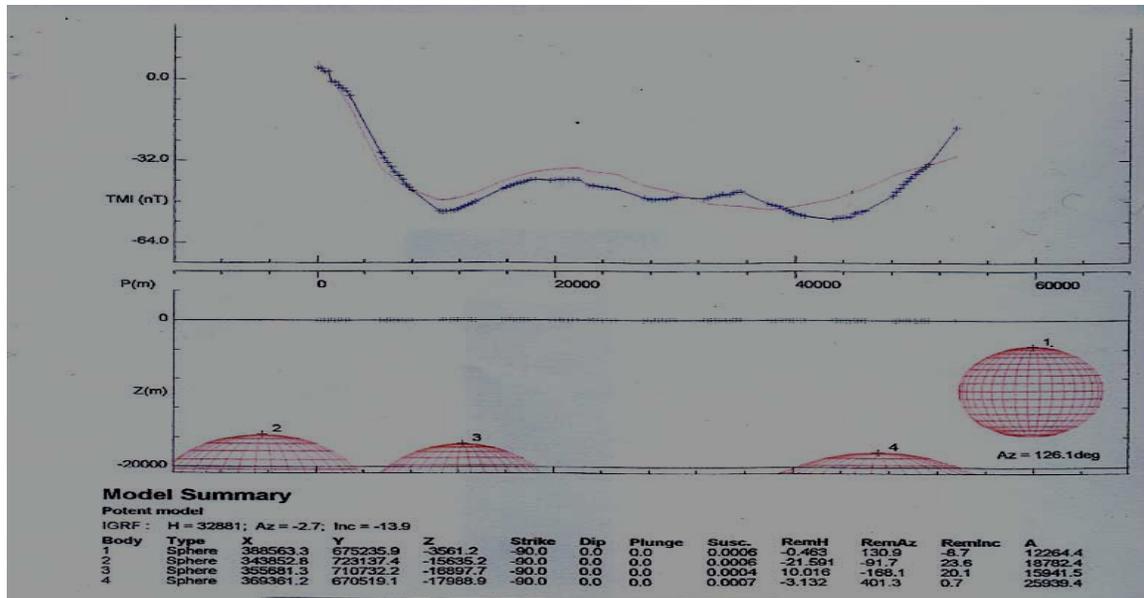


Figure 5a. Model result of subset 3 of Nkalagu Field.

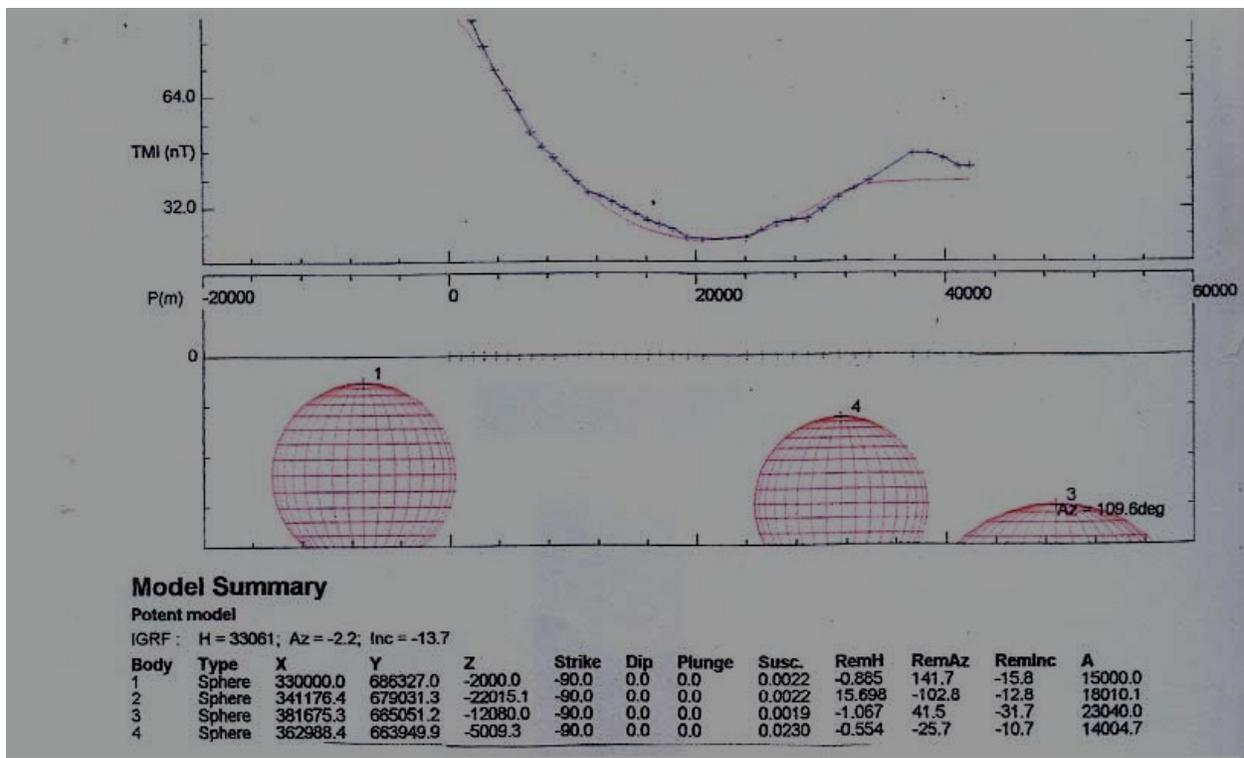


Figure 5b. Model result of subset 4 of Nkalagu Field.

0.0312 (typical of granite, dolerite, basalt and rhyolite). These bodies were modelled to have been emplaced at depths of about 3.2 – 3.9km within the Cretaceous sediments. This result is in agreement with that obtained by Ofoegbu and Onuoha (1991) on the analysis of magnetic data over the Abakaliki Anticlinorium. The

authors noted the occurrence of numerous intrusive bodies which were modelled in terms of dyke-like bodies using non-linear optimization techniques.

All the profiles taken on the Nkalagu field (Figure 5) were modelled by spherical bodies at various depths of between 2.0km and 22.0km. The magnetic

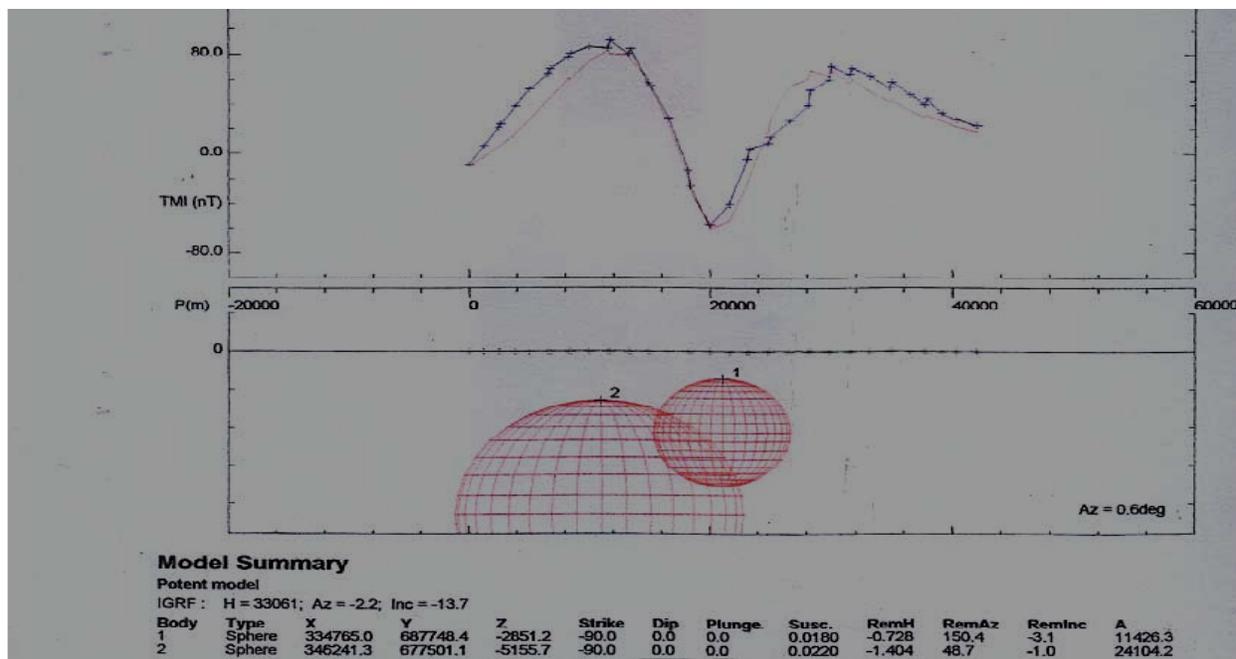


Figure 5c. Model result of subset 6 of Nkalagu Field.

susceptibilities of all the bodies of subsets 4 and 6 (Figure 5b and 5c) are mostly igneous rocks (typical of rhyolite, granite and diabase).

Anomalous depths of 10-22km obtained at some parts of the study area may be potential sites of hydrocarbon accumulation. However, the occurrence of a large number of igneous intrusions in the area indicates an exceedingly high temperature history capable of destroying any hydrocarbons that might have been formed in the area. Temperatures of 100 – 160°C were estimated to have prevailed at the time of formation of these minerals in the area (Nwachukwu, 1975).

CONCLUSION

Forward and inverse modelling of aeromagnetic anomalies over Abakaliki and Nkalagu areas of the Lower Benue Trough show that the anomalies over the areas can be interpreted in terms of spherical, prismatic or dyke-like intrusive bodies. The bodies are emplaced at various depths, either within the Cretaceous sediments or in the basement. The magnetic susceptibilities of most of these bodies indicate that they belong to igneous rocks of basic to intermediate composition. The intrusive bodies identified in the present study include granite, diabase, dolerite and rhyolite. These intrusions account for the mineralization in the study area.

The occurrence of a large number of igneous intrusions in the area indicates an exceedingly high temperature history capable of destroying any

hydrocarbons that might have been formed in the area. This area of the Benue Trough might therefore not hold any significant hydrocarbon potentials.

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