Interpretation of gravity anomaly of Parts of Lower and Middle Benue Trough, Nigeria

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ABSTRACT - The airborne gravity anomalies interpretation of the lower and middle Benue Trough of Nigeria have carried out. The early cretaceous sedimentary rocks of the study area and the outcropping and intruded basaltic rocks are considered to be the primary source of the mineral potential of the study area. Depth to the subsurface structures has been carried out using spectral analysis and the Euler deconvolution technique. The minimum depth to anomalous sources of 0.80 km was recorded while a maximum depth of 3.0 km was recorded by the Euler deconvolution technique and minimum depth of 0.83 km and maximum of 3.4 km were recorded using the spectral analysis method. The depth estimate by the two methods is in good agreement as well as with result of the previous depth estimate by some researchers.

Key words -Benue Trough, gravity anomalies, Precambrian, cretaceous sediments, basalts, spectral analysis, Euler deconvolution.

1 Introduction

The Nigerian Benue Trough is located on the West Coast of Africa. It is a rift that was developed during the second phase of the rifting of Gondwana supercontinent which resulted in the opening of the South Atlantic Ocean, Gulf of Guinea and the separation of South America in the Late Jurassic to Early Createaceous[7]; [3].

As can be seen in figure 1, the Benue Trough is an integral of the West and Cental African Rift System [8]; [10], starting from the northern end of the Niger Delta Basin in the southern Nigeria and extends in the north-east direction to the Bornu Basin in the east to join the other African intra-continental rift system of Chad, Niger, Cameroon and Sudan. [4], stated that the structural evolution of the Trough may be attributed to the extension of the Atlantic Ocean fractures on the continent through the transcurrent movement along the deep seated basement faults. It is approximately 1050 km long and 250 km wide in the southern (Niger Delta Basin) to a width of 120 km in the eastern part (Bornu Basin) with Createaceous thickness of around 4-6 km and trends NE-SW direction unconfromably resting on the Precambrian crystalline basement [5]. The Nigerian Benue Trough was divided into three sub Troughs viz; the Lower Benue Trough (LTB), the Middle Benue Trough (MBT) and the Upper Benue Trough (UBT) on the basis of their tectonic and sedimentary characteristics [14] (figure 1).

In this paper we intent to interpret the new airborne gravity data obtained from the Nigerian Geological Survey Agency (NGSA) in association to the geological map in order to understand to causative sources of the anomalies.

2Geological Settings of the Study Area

The study area is composed of metamorphic rocks of Neo-Proterozoic age[2]; [13]. The crystalline basement rocks are mainly Biotite Gneiss, Porphroblastic Gneiss and Granite Gneiss (Migmatitic_Gneiss complex) and coarse porphyritic granites (Pan-African older granitoid) with thin dykes of intermediate-basic intrusive (figure 3). The basement rocks are said to be grouped into two; the migmatite-Gneiss complex and the Pan-African older granitoids. The coarse porphyritic granite of around Gboko area can be seen to be cross-cut by the rhyolitic (of the Pan-African younger granitoid) dyke.

The Early Cretaceous sedimentary rocks of this area include; the Neocomian – Cenomanian Asu River Group, the early to late Turonian Eze–Aku Group, the Coniacian – Santonian Awgu-Ndeaboh formation, the Nkporo formation and the Nsukka formation (figure 2). The Asu River Group represents the earliest clastic fill of the Lower Benue Trough. It consists of upper marine shale and limestone with sandstone intercalations. The Asu River Group is overlain by the Turonian Eze–Aku Group which consists of fossiliferous calcareous sandstones, shale and siltstones of unknown thicknesses. Overlying the Turonian Eze–Aku Group is the Awgu Group consisting of the thick black shale and limestones. Overlying the Awgu formation is the Nkporo formation consisting of shale and mudstone.

3Analysis of the airborne gravity anomalies

Airborne gravity data is collected for the study area from Nigerian Geological Survey Agency (NGSA). The data is acquired at a terrain clearance of 80 m, along NE-SW oriented flight lines with 4000 m flight line spacing. The data is available in digitized sheet maps. The data is then analyzed to obtain the complete Bouguer anomaly map (figure 7) of the study area using geophysical survey software (Geosoft).

The gravity anomalies H1, H2, H3, H5, H6, L1, L2, L3 and L4 are related to the underlying cretaceous sedimentary rocks. The large variations between these anomalies within the cretaceous sedimentary rocks may be due large density variations in the constituent’s sediments and/or other geological bodies like the barite ores, gypsum, lead-zinc sulphide deposits, sills, dykes, pyroclasts, volcanic rocks and basaltic lava intruded into the sedimentary strata. The low anomalies may be related to the basin and sub-basins in the study area. The anomalies H4 and H8 may be associated to the near-surface high density bodies like basalts with some of which intruded into the overlying the sedimentary rocks and others exposed on the surface (figure 2). The anomalies of H7, H9 and H10 and adjoin area which are relatively complex varying in amplitude from 15 mGal to above 33 mGal. These anomalies are associated to the Precambrian crystalline basement rocks (biotite-gneiss, porphroblastic-gneiss and the granite-gneiss).

Figure 4 below shows the anomaly (residual) map of the Bouguer anomaly. This gives the anomalies due to the subsurface buried bodies. This is obtained through low-pass filter at 7.0 km cut-off wavelength.

4Spectral Analysis

Spectral analysis is a useful technique based on the statistical analysis method using the Fourier Transform for the estimation of basement depth [6]; [15]; [9]; [11]. We applied the spectral analysis technique on the residual gravity anomaly map (figure 3). The radial average power spectrum method was deployed in the calculation of the basement depth. Fast Fourier Transform (FFT) was applied to the airborne gravity anomaly map to calculate the power energy spectrum. The energy decay curves include linear sections with slope distinctions which are attributed to the deeper and shallower sources. The method depends on the logarithmic plot of the power spectrum against the wavenumber and the depth is estimated on the basis of moving data window. That is, by selecting the steepest straight line segment of the power spectrum. Figures 6 shows the radially average power spectrum of the gravity anomaly which showed different segments of straight line that decreases in slope with increasing wavenumber. The slope of each section yields the averaged estimates of the depth to the sought causative sources. In the figure we have showed the average depth of the deeper sources as 3.4 km while that of the shallower sources as 0.83 km.

5Euler deconvolution

Euler deconvolution is based on homogeneity equation. The homogeneity equation relates the magnetic field and the components of its gradient to the location of the sources with a degree of homogeneity been N. N is known as the structural index [16]. This parameter is defined as the rate of change of the field with distance.

To calculate the basement depth, the residual anomaly grid was processed and then the euler deconvolution using a range of structural indices from 0.0 (thin sheet edge/dyke), 1.0 (pipe/cylinder/thin bed fault), and 2.0 (for sphere). The Euler solution of the residual anomaly map was calculated to fit a dyke model (N = 0.0) at window size of 10x10. Figure 5, shows the clustering of circles with linear shape, indicating the depth ranges of anomalous soures from 0.80 km to over 3.0 km.

The result of the depth estimates by the spectral analysis and the Euler deconvolution technique showed a sharp agreement. Maximum depth of about 3.5 km was recorded by [1] around this area.

6Conclusion

The airborne gravity anomalies of the parts of Lower and the Middle Nigerian Benue Trough have been analyzed and interpreted in line with the geological formations that are probably the causative sources of the anomalies. The area is found to be intruded by basaltic rocks with some of them been exposed to the surface as seen from the geological map. The anomalies of the area is also been characterized by a basin and sub-basins which may be separated by a horst like structure. Depth to the subsurface structures has been carried out using spectral analysis and the Euler deconvolution technique. The minimum depth to anomalous sources of 0.80 km was recorded while a maximum depth of 3.0 km was recorded using Euler deconvolution technique and a minimum depth of 0.83 km and the maximum of 3.4 km using the spectral analysis method. The depth estimate by the two methods is in good agreement as well as with result of the previous depth estimate by some researchers.

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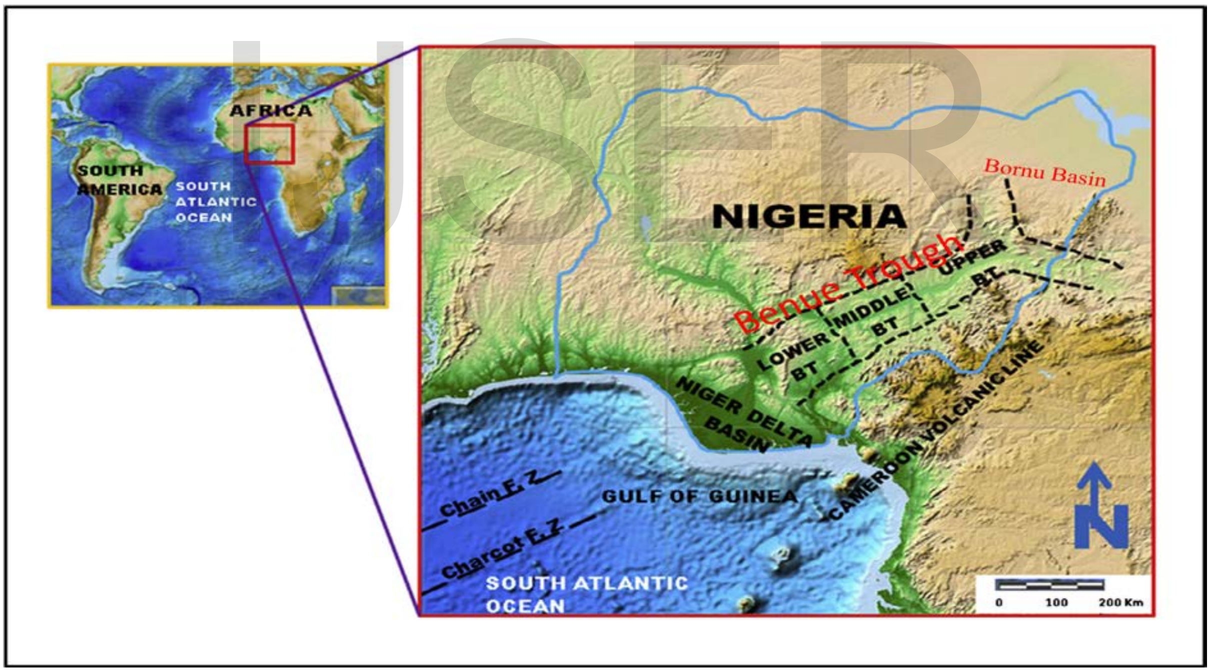

Figure 1 Relief map of Nigeria and adjoin; showing the Benue Trough and its sub-divisional Troughs, modified after [3].

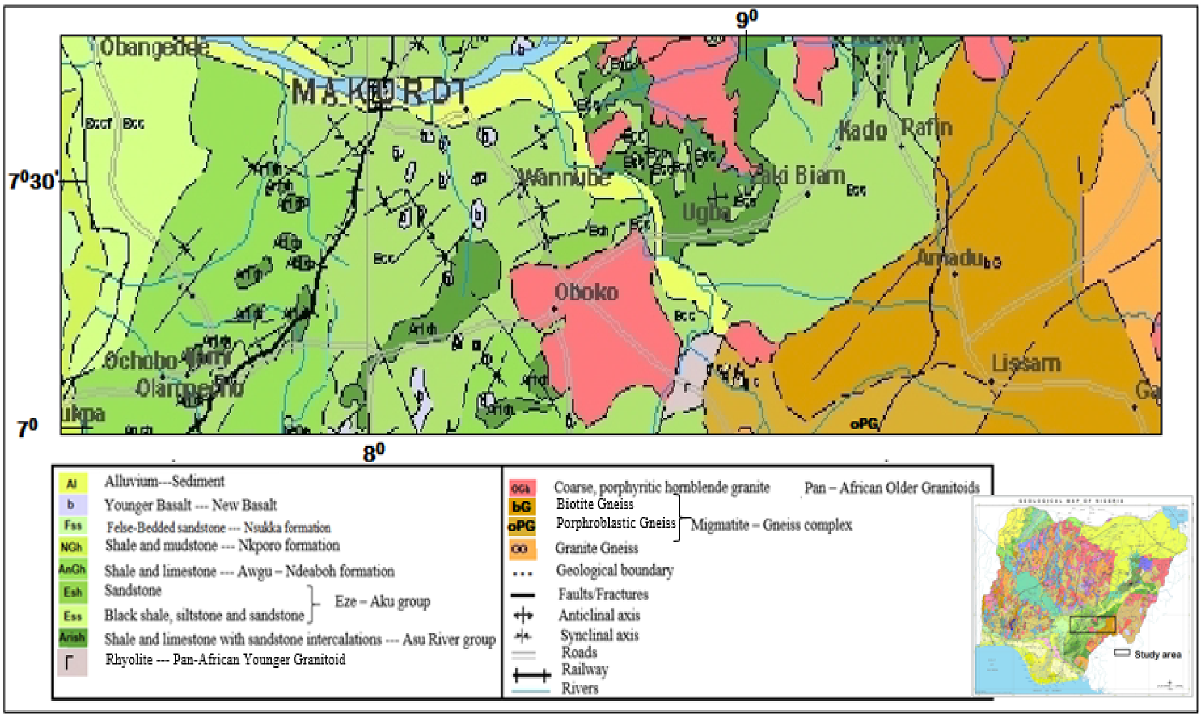

Figure 2 Geology of the study area modified after [12].

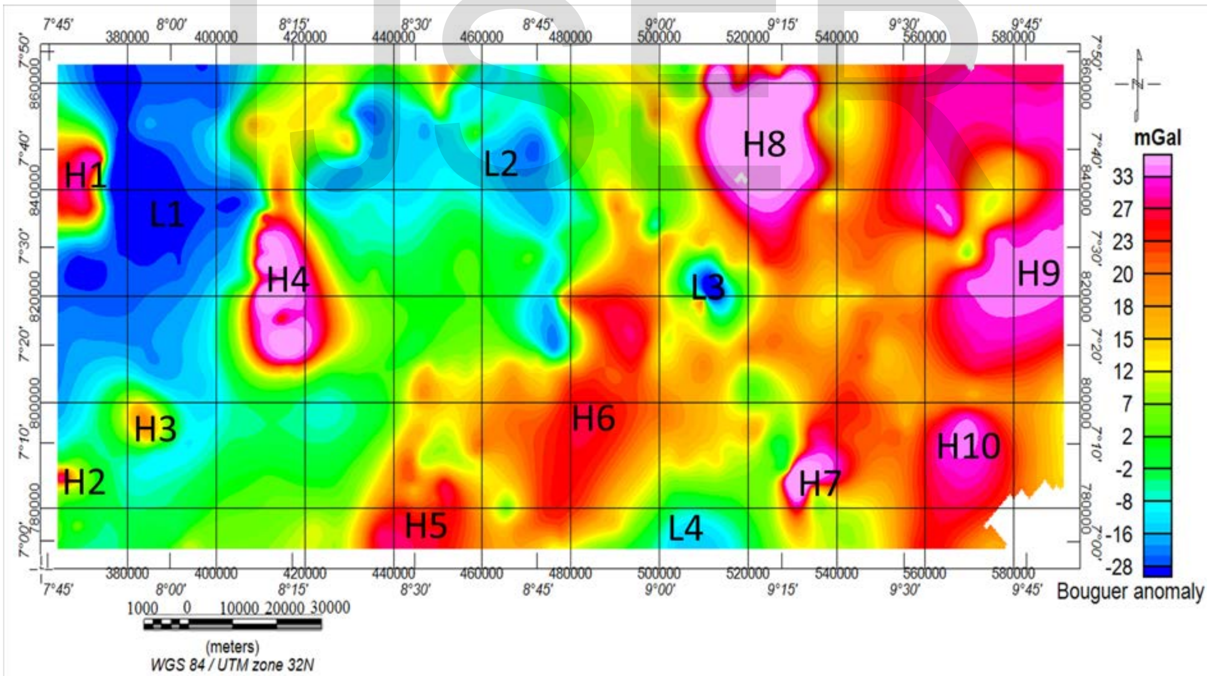

Figure 3 complete Bouguer anomaly map of the study area.

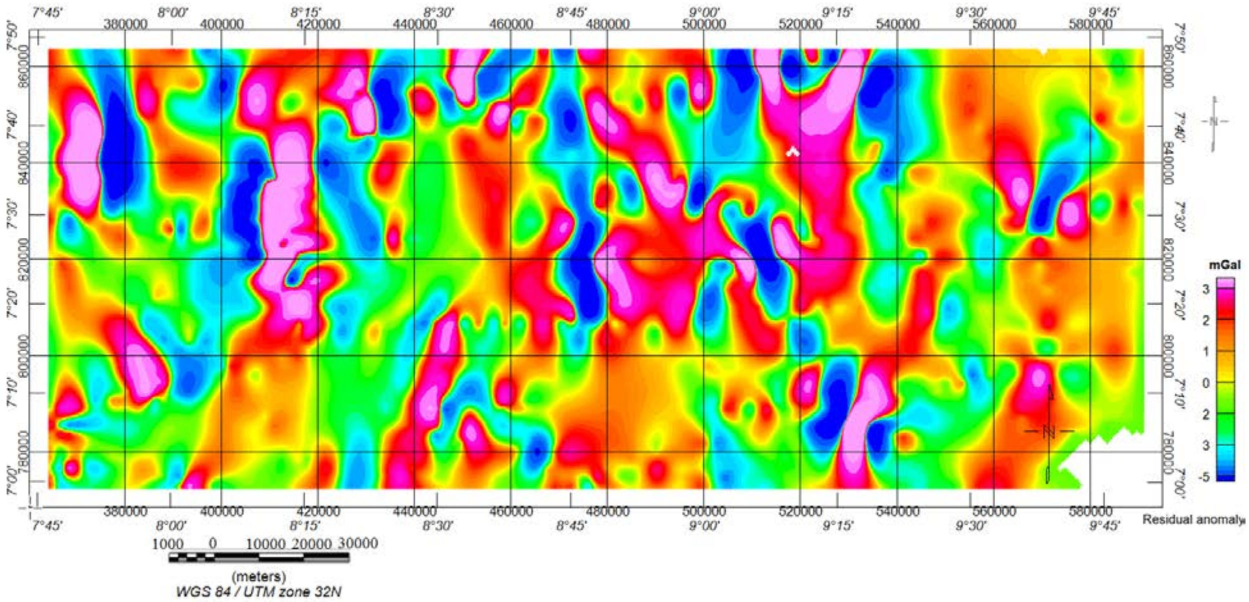

Figure 4 residual anomaly map of figure 3.

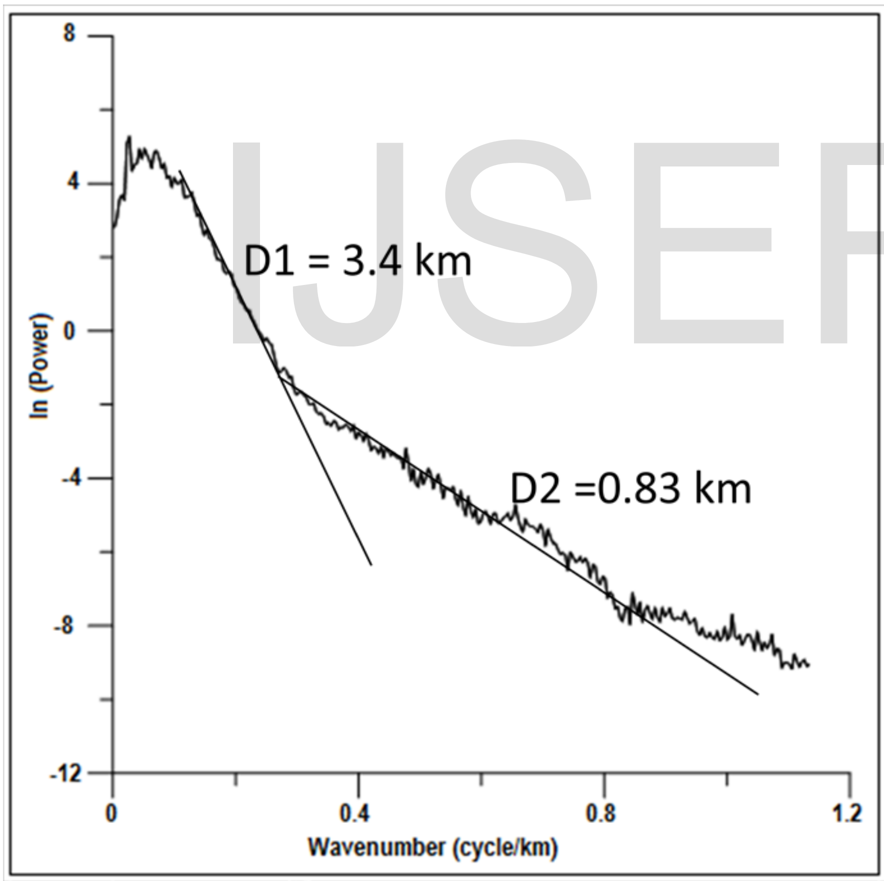

Figure 5 spectral analysis estimates of the residual sources in the study area.

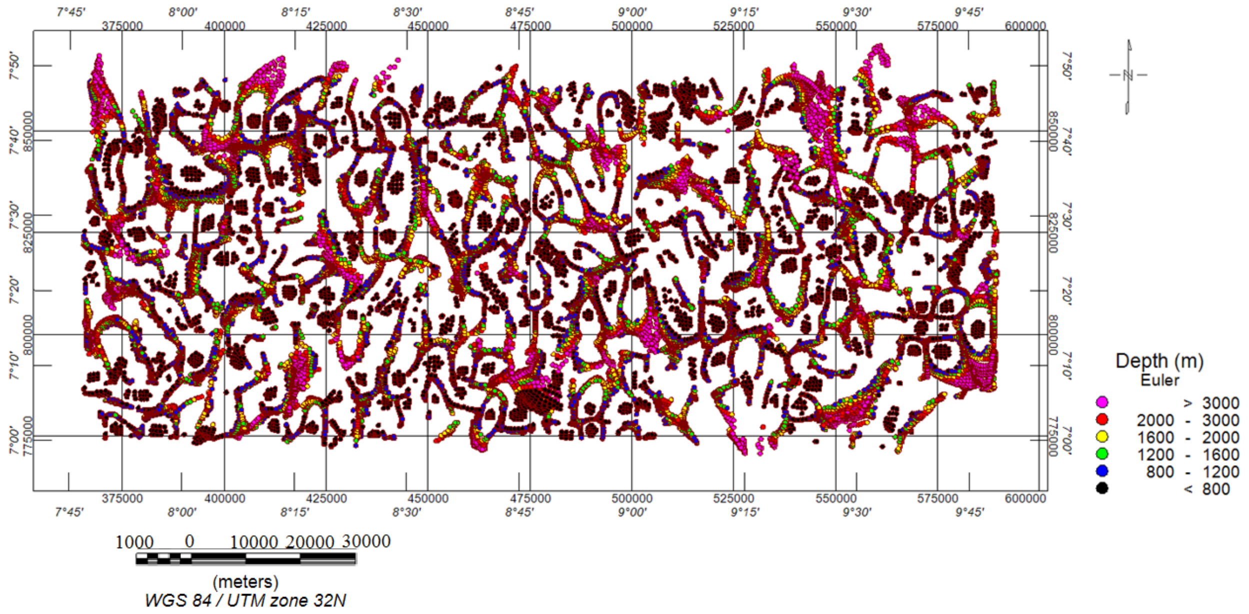

Figure 6 Euler deconvolution depth estimates of the residual anomaly map (figure 4).

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