AEROMAGNETIC DATA INTERPRETATION OF THE TRIPLE JUNCTION AREA OF THE UPPER BENUE TROUGH, NORTHEASTERN NIGERIA

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ABSTRACT

Airborne magnetic anomaly data over the triple junction of the upper Benue Trough, Northeastern Basement complex Nigeria, shows complicated arrangement of long wavelength anomalies, with significant magnetic low. These features are interpreted in terms of deep geologic structures and/or susceptibility variations within the basement rocks or ascribed to rocks of thick cretaceous sediments or both. The NE-SW trending of the lineament map identifies the same trending of the Benue Trough presumed they have the same structural control. The residual magnetic anomaly map indicates that Dong and Numan is smoother, which is masked off by the effect of the stronger magnetic basement likely to be sedimentary basin. The NE-SW revelation shows that this basement region is polygenetic, and has experienced magmatism, metamorphism and structural deformations. Consequently, the effects of the results to Chad Basin and Tenere Rift evolution and the relationship with dominant anomalies in the residual field are rather sporadic with values ranging from between -20 to 60 nT with the area characterized by faults. It is clear from the interpretation of the regional field that there is an uplift of the mantle and a corresponding thinning of the crust in the study area. Later mantle activity caused basalt flow or basic igneous intrusion along the transform faults.

Key Words: Geologic map, Composite map, Regional field, Residual field, 3-D Residual field

INTRODUCTION

Until recently, rather scanty geological and geophysical information about the entire Benue Trough was available. For example, only a part of the area is covered by geological survey carried out in the Benue Trough was done by.1 The results of their work revealed that the Benue Trough is characterized by central gravity ‘high’ over Amar, Awe, Gboko in the middle Benue Trough and Kaltungo in upper Benue Trough. The result also revealed that the central gravity ‘high’ are flanked on both sides by gravity ‘low’. Cratchely and Jones interpreted the ‘low’ as areas of thickest cretaceous sediments. Due to lack of subsurface geological data, they could not uniquely resolve the source of the central gravity high but after considering several models, they subjected that the positive anomalies could be a zone of igneous intrusion of intermediate to basic composition located within the oldest cretaceous rocks of Albian age and basement which underlines them.

AIMS AND OBJECTIVES

The purpose of the present geophysical survey is therefore to investigate the structural features of the upper Benue Trough which, hitherto, has not been covered by any detailed geophysical survey.

MATERIAL AND METHODS

To achieve the above objectives, magnetic survey was carried out at Numan, Guyuk,
Dong and Shelleng of the upper Benue Trough. The area lies between latitude 9°30’N and 10°00’N longitude 11°30’E and 12°30’E, which are Numan, Guyuk, Dong and Shelleng in the Northeastern part of Nigeria. Less than half of the upper Benue Trough is hilly with a relief which hardly exceeds 300m. The part of the area covered by the present work is in the low plain of the upper Benue Trough. The drainage pattern in the area is dominated by river Benue which flows westward to join the River Niger. The main tributary of the river Benue in the area is Gongolar River which joins Benue River near Numan.

Study area
Rocks in the area had been presented on the 2005 edition of the geological map of Nigeria and published by the Geological Survey of Nigeria (GNS).² Important geological features of the region comprise of upper cretaceous/ quaternary sedimentary rocks and Tertiary volcanic rocks. These overlie the Precambrian crystalline basement consisting of mainly granitoids and gneisses.³

Basement complex
The basement rock units in the north and south parts of the study area are made up of older granites, gneisses and migmatites. Basic extrusives (basalt) and intrusive also occur. Whilst sedimentary rock units comprising mainly sandstones, limestone, clays and shales outcrop within the central portion of the study area.³

The volcanic rocks and igneous intrusion
The extensive igneous activity which took place on the lower cretaceous of Nigeria and was probably most intense during the late Albian time.⁴ The intrusions are widely distributed through the area, and the younger intrusive are represented by volcanic plugs, dyke, silts in the study area. Smaller dykes are of basic masses, occasionally produce contact metamorphism in the sediments, as well as characteristics suggestive of a close interval of time between segmentation, folding and intrusion.¹ The plugs outcrop in the area occurs as circular to oval features entirely surrounded by the Alluvium and Bima sandstones. Generally, they show sharp contact with the surrounding sedimentary deposits.

Quaternary-alluvium
The Quaternary alluvium is a superficial deposit, comprising mainly argillaceous stuff called Benue valley alluvium. The soil is black to dark gray clayey sediment formed by the weathering of volcanic (basaltic) and shaley rocks. It is marshy and covered by shrubs. They form stripes of 500m to 1km radius range, beyond which they are intercalated with poorly sorted sands and gritty clays (typical of the Benue valley Alluvium). In the study area, the Quaternary Alluvium unconformably overlies the Bima formation and obscures it in most sections. The Bima sandstone is classified into three layers: the lower, middle and upper bima.

The upper bima (B3)
It consists of medium to coarse grained feldspathic sandstone. In the Lamurde anticline, the maximal thickness reaches up to 1,700m but may vary considerably elsewhere. The sequence was deposited under fluvial to deltaic environment.³ A late Albian/Cenomanian age was assigned to such event.

Middle bima (B2)
It composed of very coarse grained, feldspathic sandstone with these bands of clay, shale and occasional calcareous sandstones. In the Lamurde anticline, the thickness is 800m but may vary elsewhere. This sequence was laid down in fluvial and the deltaic environment.³ A tentative middle Albian age has been assigned to it.

Lower bima (B1)
It is the oldest sediment known in the area which appear in the core of the Lamurde anticline which consist of coarse grained feldspathic sandstone alternating with red, purple shale and occasional band of calcareous sandstones and silts stone. The visible thickness in the Lamurde anticline is 390m.³ This basal sequence was deposited in lacustrine environment with a brief marine incursion.⁷ An upper Aptian/Albian age has been recently assigned to this part of Bima sandstone on the basis of palynological date. Fig. 1 shows the geologic map of the study area.
Data acquisition
The datasets used in this study were compiled from four aeromagnetic maps with index numbers of 174, 175, 195 and 196, for Numan, Guyuk, Shelleng and Dong. These maps were obtained from Geological surveys Agency, Kaduna, Nigeria. The contour lines in all the maps were dense; therefore it was easy to adopt the flight line digitization used with very minimal errors of human judgment. The magnetic values were plotted at 10nT (gamma) interval. The maps were numbered and named according to the places covered for easy reference. A total of 340 maps covered the entire country. The actual magnetic values were reduced by 25,000 gammas before plotting the contour maps. This means that the value of 25,000 gammas should be added to the contour values so as to obtain the actual magnetic field at a given point.

The maps were digitized on a 1x1 system. This spacing imposed a Niquisit Frequency of ½ km⁻¹ so that the narrowest magnetic feature that can be defined by the digitized data has a width of 2 km. The anomalies are much wider than 2 km and therefore lie in a frequency range from aliasing which do not occur with a 1km digitizing grid.

Having digitized each aeromagnetic map, the data were stored in 55x 55 coding sheets, each of which contains records of the boundary longitudes and latitudes, the map number and name of the town overflow. The data were entered into a computer file, thereafter became the input file for a computer program, which picked all the data points row by row, calculate their longitude and latitude and the magnetic value for coordinates respectively. Each output file for this operation was given a meaningful name for easy identification. The three dimensional coordinates from x, y, z, is made to be acceptable to a contouring package “SURFER 7.0”. The SURFER is a menu-driven interactive computer programme, which places each magnetic data point according to their longitude and latitude bearing and thereafter produces contour maps to ensure that they correspond with their respective original maps. (Fig. 2 to Fig. 5) The compilation of the aeromagnetic maps of Numan, Dong, Guyuk and Shelleng form a composite map. The composite aeromagnetic map of the study area was produced by joining the four maps covering the study area together. The computer program used to determine the longitude and latitude for each small map was also used to determine the longitude and latitude for the composite map was also used to determine the longitude and latitude of the composite map. This map would be the subject of analysis and interpretation in other section of this work. Fig. 6 shows the total magnetic field map of the study area.

Fig. 6: Geologic map of the study area after Nigeria Geology Survey Agency : 2005
Fig. 2: Aeromagnetic map of Numan (contoured at 10nT)

Fig. 3: Aeromagnetic map of Dong (contoured at 10nT)

Fig. 4: Aeromagnetic map of Guyuk (contoured at 10nT)
Regional-residual separation

The polynomial fitting method

In this work, the polynomial fitting method which is the most flexible and most applied of the analytical methods for determining regional magnetic field\(^6\,7\) was used. In this method, marching of regional by a polynomial surface of low order express the residual features as random error. This treatment is also based on statistical theory. The observe data are used to compute, usually by least square, which is the mathematical describable surface giving the closest fit to the magnetic field that can be regional field and the residual field is the difference between the magnetic field values as actually mapped and the regional field thus determined.

The least-square method

The least square method was applied to the study area. Because the study area seemed adequate and reasonable to assume that the regional field is a first polynomial surface. All the regional were therefore calculated as a two dimensional first – degree polynomial surface. To eliminate the regional field, a plane surface was fitted to the data by multiple regression least-squares

Fig. 5: Aeromagnetic map of Shelleng (contoured at 10nT)

Fig. 6: Total aeromagnetic field of the study area (contoured at 10nT)
criteria established by the mathematical concept of \(^7,6\). The polynomial coefficients were used to compute the regional map of the study area. The resultant map is shown in Fig. 7. A computer program was used to subtracting values of the regional filed from the total magnetic field value at grid points. The residual values were contoured using computer software (SURFER 7.0). The data were inputted into the contouring software programme, which automatically generated the residual field map of the area. The residual magnetic anomaly contour map is shown in Fig. 8(a) and the magnetic high and low in Fig. 8(b). Further analyses of the residual field map in Fig. 8a with the help of software (Surfer 7) generated 3-D residual anomaly field in Fig. 9.

Fig. 7 : Regional map of the study area (contoured at 5nT)

Fig. 8(a) : Residual map of the study area (contoured at 10nT)
RESULTS AND DISCUSSION

The qualitative analyses of the composite map using polynomial fitting method in regional - residual separation produced the residual magnetic anomaly map. The result of the regional separation exercise revealed that the area is underlain by a NE-SW regional trend, which shows that they are in agreement with Benue trough, presumed that they have the same structure control. The result of the trend analysis also showed that the area is characterized by faults. The residual magnetic anomaly map and the 3-D version (Fig. 8(b) and Fig. 9) show the
areas of significant positive residual anomalies. They occur to the N-W Guyuk and few parts of S-E of Numan. The maximum amplitude of the anomalies is between -20 to 60 nT. The residual anomalies are largely truncated, found at the SE boundary of Numan and NE of Dong with maximum amplitude between 40 to 60 nT. Northern part of Guyuk also has maximum amplitude of 60 nT. These residual anomalies can be explained in the light of available regional geological reports on the adjoining basement regions (Adamawa massive Nigeria and the northern Cameroon basement). These regions have widespread occurrence of basalts, trachytes and trachybasalts. The positive residual anomalies are attributed to these basic and intermediate rocks. Areas of occurrence of zero or negative residual anomalies in the study area are interpreted in terms of the presence of granite and gneiss. They may also be due to the susceptibility variation in lithologies or combination of both.

From the 3-D residual magnetic anomaly map, Dong and Numan are likely to be sedimentary basin, which is W-E trending. It shows that the magnetic field there is smoother which is masked off the affects of the stronger magnetic basement. High amplitude of the anomalies which outcrop at N-W part of Guyuk shows the presence of Lunguda basalts. High amplitude of the anomalies which outcrop across Shellelg are presumed to be basic intrusion in the area which is termed Mesozoic basalt. The high amplitude of the anomaly along the S-W features of the Numan area presumed to be Ngurore Basalts. The study area has experienced polyphase thermo tectonic events involving magmatism, metamorphism and structural deformations. From the regional structural field, the oldest deformation features trend NE-SW. These features are foliation, shear zones and joints. The NE-SW lineaments are among the longest and inverably are of deep crustal origin. Other geophysical evidences (gravity and seismic) exist to show these lineaments continue beneath the Chad basin into Niger Republic, where they have surface expression as the Tenere Rift. The NE-NW structures are next to NW-SE in relative age. The structures are found to be faults and foliation. This structural direction is related to the West African Rift system made up of the northerly Benue Trough and Cameroon Volcanic line. By inference, it is also related to NE trending Chad shear zone in Chad Republic, (Regional field). An ENE-WSW trend as foliation direction produced as a Late Pan African event.

CONCLUSION

The regional field has thrown some light on the geology and structure of this part of Nigeria basement complex. The study revealed NE-SW trending which correlate with the geology of the area showing that the Benue trough trends NE-SW, indicating that they have the same structural control. The study which revealed NE-SW structures as the youngest in the Nigerian Basement. The major lineaments observed have been accounted for in terms of faults and foliation. The lineaments have regional extension into Niger, Chad and Cameroon. The residual shows that the area is characterized by residual positive anomalies ranging from -20 to 60 nT. In this study, it is assumed that the anomalous magnetic field of the crustal rocks is due to induced magnetization in the area. It could be the fact that some locations have a high component of remnant magnetism in the anomalies field. High-sensitivity aeromagnetic data over the area contain both low-amplitude, linear anomalies produced by structurally deformed magnetized layers near the top of the sedimentary section and high amplitude, broad anomalies produced within the basement. Matched-filtering has been successful in separating the anomalies produced by these two source regions. Finally, further study for geochrological dating of rocks and structural events in the area for a better understanding of the geologic history and the rock susceptibility is needed.

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REFERENCES

2. Geological Survey of Nigeria, Geological