A Gradient Analysis-Based Study of Aeromagnetic Anomalies of Some Dikes in the Nupe Basin, Central Nigeria.

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Abstract

An aeromagnetic intensity contour map of a part of Nupe Basin of Nigeria was acquired, digitized and analysed. This work was carried out for a better understanding of the study area using the Gradient analysis-based technique to calculate depth to basement and to interpret the aeromagnetic anomaly map of the area. Statistical method of Ajakaiye *et al.(1989) was employed to produce a magnetic facies map of the area. Regional-residual separation of the total intensity map was done to produce a residual aeromagnetic intensity data. Depths to the magnetic source bodies were estimated from the profiles obtained from residual data using Pal's (1985) gradient analysis method. The estimated depths ranged from 0.44km to 1.67km which agrees with those predicted by some earlier workers on the Nupe Basin. These depths fall within the lithospheric layer of the earth and the causative magnetic anomalies body are likely basic intrusives. While this approach appears cheap, accurate and cost-effective, it is recommended that other ground geological and geophysical techniques be applied to further strengthen the assertions made in this work.*

Keywords: Gradient, Digitized, Aeromagnetic, Intensity, Regional, Residual, Intrusive.
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Introduction

The Nupe Basin is a NW-SE trending embayment perpendicular to the main axis of the Benue trough and the Niger Delta Basin of Nigeria (Fig.1). It is frequently regarded as the North-Western extension of the Anambra Basin, both of which were major depocentres during the transgressive cycle of Southern Nigeria in the Late Cretaceous times (Murat, 1972). It has rocks of sedimentary basin being flanked by both the basement complex rocks of South-Western and North-Central Nigeria.

The Basement complex rocks include migmatites, granites and pelithic schist while the sedimentary rocks consists of Upper Cretaceous sediments (sandstone, ironstone and siltstone) which are believed to be between 300 to 1000 m thick (Adeleye, 1989). A contact zone exists between the basement and sedimentary environments in this basin and this area is rich in mineral deposits (Akande *et. al.*, 2005; Garba, 2011; Arogundade, *et. al.* 2007) and characterized by controversial tectonic history, hence the need for proper assessment of the structural/tectonic nature of this study area (Udensi, *et. al.*, 2003) (Fig. 1).

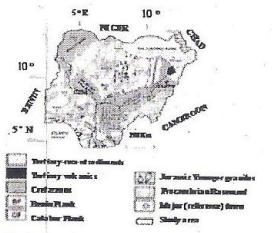


Fig.1: Geological sketch map of Nigeria showing the study area (After Obaje, 2009).

Using gravity data, central positive anomalies flanked by negative anomalies have been confirmed for this basin as shown for the adjacent Benue trough and typical of rift structures (Ojo and Ajakaiye, 1989). The basin has also been confirmed to be bounded by a system of linear faults trending NW-SE, using geophysical data (Kogbe *et. al.*, 1983).

The Aeromagnetic Anomalies

The magnetic data used in this study was compiled from aeromagnetic maps supplied by the Nigerian Geological Survey Agency. The maps, which are on a scale of 1:100,000 were compiled from data collected at a nominal flight altitude of 152.4m along N-S flight lines spaced approximately 2 km apart. A correction based on the International Geomagnetic Reference Field (I.G.R.F., epoch date January 1, 1974) was included in all the maps (Ojo, 1990). The total field aeromagnetic map of Share (Sheet 202), Lafiagi (Sheet 203) and Patigi (Sheet 204), (Fig. 3) which is about 55.74 by 55.74km each in dimension were hand digitized at an equal spacing of 1.85km yielding 961 values. Crustal anomalies are much wider than 3.7km (Hall, 1974) imposed by the above spacing, and therefore lie in a frequency range for which computation errors arising from aliasing do not occur with a 1.85km digitizing grid. Previous works with crustal magnetic anomalies (Ajakaiye *et. al.*, 1989) show that this spacing is suitable for interpretation of magnetic anomalies arising from regional structures.

A statistical method was used for the production of facies map (Fig. 2). It is cheaper,

more rapid and less cumbersome than the conventional method used in MAGMAP (Patterson *et. al.,* 1980). A mean value was subtracted instead of fitting a surface to the aeromagnetic map's data. Magnetic intensities in the map area vary from 7000 to 8000nT. The "Facies" map was obtained by contouring the data set using three contour intervals; 7780, 7820 and 7860nT in order to cover the data evenly. The first and the third of these levels are two standard deviations below and above the mean respectively, while the second is the mean. Contour levels 7780nT lies at the boundary between green and light green colours while 7860nT lies between light green and brown colours. The magnetic "facies" map used as continuation map in this study is very useful in interpreting the geology of an area.

The magnetic values were grouped as follows:

High > (M + 2S)
Intermediate = (M – 2S) to (M + 2S)
Low < (M – 2S)

Where

M = mean
S = Standard deviation.

The upward continued map was obtained by shading, according to the scheme of Ajakaiye *et al.,* (1986), as follows:

High > 7860nT
Intermediate = 7780 – 7860nT
Low < 7780nT

The map produced from this method gave the first insight into the segregation of the aeromagnetic data into three regions; Sedimentary area, intermediate and Basement area. The three regions can be distinguished on the basis of the variations in intensity of aeromagnetic data. A concentration of high magnetic anomalies is seen on the basement part of the surveyed area (Fig. 2).

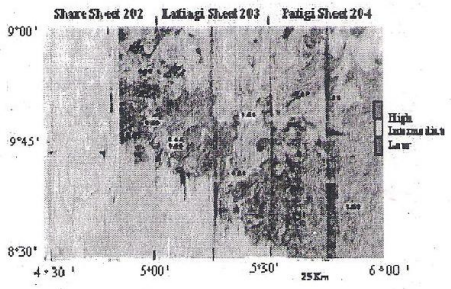


Fig.2: The magnetic intensity map of Share, Lafiagi and Patigi divided into three regions.

Magnetic Depth Estimates:

A variety of methods have been used for depth estimates from magnetic data: the earliest methods include those of Peters (1949) and Vacquier *et. al.* (1951). However, emphases are now on more automated techniques like those described by Reid *et al.,* (1990), Zhang *et. al.*, (2000), Rapolla *et. al.*, (2002), Claerabout (2003) and Ravat *et. al.*(2003). For this study the gradient analysis-based method (Pal, 1985) has been modified and employed because of its ease of application and efficiency.

Gradient Analysis-Based Method (Pal, 1985)

From the fact that the appearance of oscillations in the proximity of the source can be directly used in depth prediction, Pal (1985) developed a simplified inversion strategy employing the profile and its horizontal gradient to determine depth to magnetic sources giving rise to observed magnetic inversion along profiles. In this work the inclined thick dike extending infinitely in the direction of its dip has been used. The procedure used for depth estimates is as follows:

-On each profile, region(s) having magnetic inversion(s) is located. In any region of inversion, ΔF (residual total magnetic intensity) has characteristic maxima (M:X_M) and minima (m:x_m) points and $\Delta F(0) = M + m$ is computed.

-The horizontal gradient $\Delta F_X = (\Delta F_2 - \Delta F_1)/\Delta X = (\Delta F_2 - \Delta F_1)/1.85$ nT/Km observing, that $\Delta F_X = 0$ at $x = X_M$ or x_m. $u = (-X_M x_m)^{1/2}$ is computed and a plot of ΔF and ΔF_X against distance (x) is made.

$-\Delta F_X(0)/\Delta F_X(u) = [(X_M + x_m)/u]\tan^2\theta_f$ and the depth h is obtained from the relation

$h = (X_M + xm)\tan\theta_f$.

$\theta_f = 2I' - 0 - 90^0$ (for total magnetic intensity)

Where:

I′ is the effective inclination of the local geomagnetic vector in the direction of the profile.

θ = the dip angle of the dike measured clockwise from the positive x-axis ($180 \geq \theta \geq 0^0$).

Here segments of total magnetic intensity data were processed to obtain residual data. The segments were chosen such that each segment contained several anomalies and do not terminate or start in the midst of anomalies. The profiles available in each segment were then plotted and the anomalies with good magnetic inversions were chosen for depth calculations (Figs. 3, 4, 5, 6, and 7).

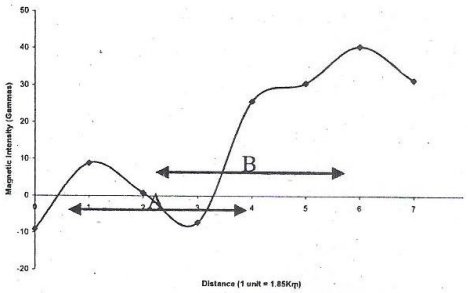


Fig. 3: Residual magnetic intensity profile 202a (2). A and B are regions of magnetic inversion.

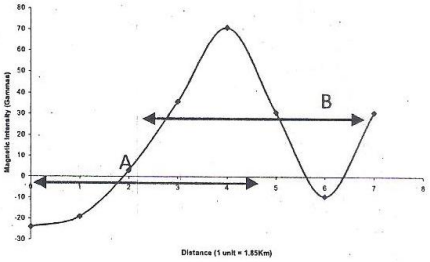


Fig. 4: Residual magnetic intensity profile 202a (4). A and B are regions of magnetic inversion.

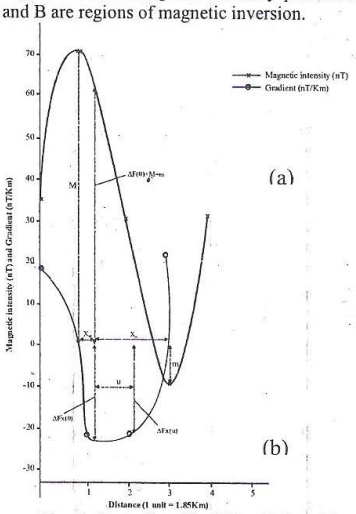


Fig. 5: Part of profile 202a (4B) and its horizontal gradients

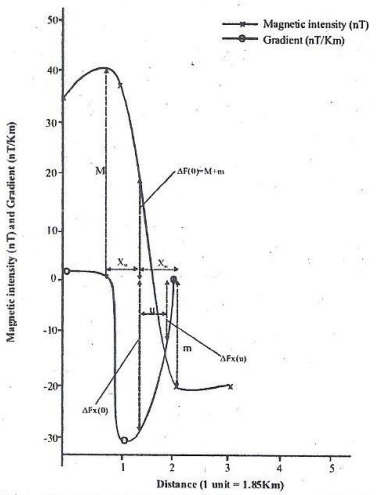


Fig. 6: Part of profile 202b (5A) and its horizontal gradients

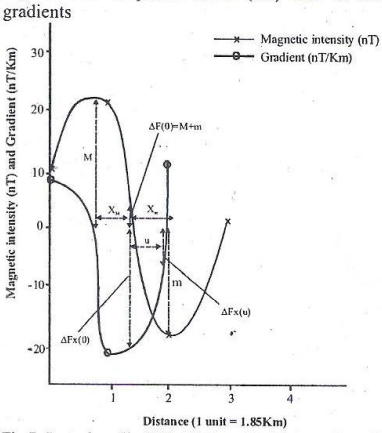


Fig.7: Part of profile 203b (16A) and its horizontal gradients.

Discussions

Models for the origin of the Middle Niger (Nupe) Basin have centered mainly on the isostatic subsidence and rift models (Ojo, 1990). Using gravity measurements and interpretation, Ojo and Ajakaiye (1976) concluded that the general indication was that the basin is an area of local subsidence. However, they did not totally rule out a rift origin because of the limited data and the ambiguity inherent in gravity interpretation. Based on magnetic data interpretation, Ojo (1990) assumed that the basin is underlain by granite gneiss, the dominant rock types of the Nigerian basement complex. He also observed that the sediments are flat lying with a maximum thickness of about 2 km.

In this study, the gradient based-analysis of Pal (1985) has been used to corroborate the depth determination over this basin. The results obtained from the analysis of magnetic data showed a sediment thickness variation across the study area (Fig. 8). There is a general increase in depth from the western part to the eastern part of the study area and from basement to sedimentary environment. The calculated values range from 0.44 to 1.67km. These depths, agree with those suggested Adeleye (1989) that a thickness of more than 300m for the Nupe Basin and Ojo and Ajakaiye (1976) who indicated a thickness of 1.0 to 2.0 km for the Nupe Basin.

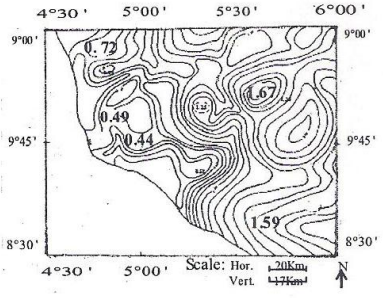


Fig.8: Isopach map of Share, Lafiagi and Patigi inferred from gradient analysis-based depth values.

The depths obtained from the gradient-based analysis calculations in this study (Fig. 8) agree with those suggested by early workers on the Nupe Basin as stated earlier.

Conclusions

The Gradient based-analysis technique of Pal's (1985) has been employed in this work. The approach has given depth values ranging from 0.44 to 1.67km for the sediments thickness in the study area of the Nupe Basin of Nigeria (Fig. 8). The statistical method which is a cheaper, more rapid and less cumbersome way of grouping magnetic data into corresponding rock types was used instead of the conventional method used in MAGMAP for interpreting the geology from aeromagnetic data. Magnetic facies map of the magnetic anomalies and their corresponding rocks shown in this study strengthens the assertions made through the Gradient based-analysis technique depth to source calculations.

Observed magnetic anomalies show that the shallow depth of the overburden in the major part of this area must have resulted from basic intrusive while the remaining parts are characterized by the moderately deep sedimentary areas at the central part of this area while the very deep sedimentary areas are found towards the eastern part of the study area.

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