STRUCTURAL PATTERNS WITHIN THE KURI RIVER BASIN, CENTRAL NIGERIA: DEDUCTIONS FROM GROUND MAGNETIC SURVEY.

Chii E.Chii*, K.M Lawal, M.D Dogara** and S.O Adetola*****

*Dept. of Mathematical Sciences, Adamawa State University, Mubi, Nigeria.

**Dept. of Physics ,Ahmadu Bello University, Zaria, Nigeria.

***Dept. of Physics, Federal University of Technology, Yola, Nigeria.

(Submitted: 30 September, 2007; Accepted: 11 June, 2008)

Abstract

Magnetic field data of the Kuri River basin were obtained from a ground magnetic survey using an MP-2 proton precision magnetometer. The data were obtained randomly at 425 statioris at an average spacing of 0.5km. A regional - residual separation was performed on the data, by fitting a first degree polynomial. The residual field was upward continued by one grid interval and the resulting field was interpreted for structural boundaries using the Analytical Signal technique. Results obtained reveal the presence of two major faults which trend along the same direction as the regional field. Also boundaries obtained from the analytic signal solutions showed the presence of elliptically buried structures which are likely related to unexposed Younger Granite intrusions,

Keywords: *Magnetic, regional field, upward continuation, structural boundaries, Analytic*

Introduction

Magnetic measurements can be used for geologic mapping due to the response to the variations of magnetic susceptibility of soil and rock. Generally, total field measurements are used for geologic mapping primarily, for mineral exploration and for characterizing geologic structure such as fault, fractures, intrusions, contacts and other geological boundaries (Ajakaiye et al., 1991; Verduzco et al., 2004 and Salem et al., 2007). Previous related works carried out around the Kuri river basin are: study of aeromagnetic anomalies across the Nigerian Younger Granite province (Ajakaiye et al.. 1985) which reveals the trend of lineaments in the Younger Granite ring-complex indicating a relationship between these and structural features of the Benue Trough. Kangkolo (1984) did an interpretation of the aeromagnetic anomalies over the younger granite of Jos Pankshin area and concluded that most of the significant magnetic anomalies correlate with known geological features. Kangkolo (1984) also showed from models of buried structures that they were at an average depth of 1 km below the surface extending between 3 km and 14 km with vertical sides and polygonal cross section. These shapes conform to the concept of the origin of the Younger Granites from cauldron subsidence in magma chambers within the crust. Dogara and Ajayi (2001) deduced from geoelectric investigation the presence of three to four major geoelectric layers within the basin. They also indicated the probable presence of unexposed Younger Granite suites intruding the basement. This work is intended to ooiain a better insight of the structural patterns of the basin based on the analytical signal and Werner deconvolution techniques which are used to delineate structural boundaries, depth to and nature of magnetic sources.

The Kuri River Basin is of interest because of its strategic location and possible tectonic relation to some younger granite complexes of central Nigeria some of which are made up of two or more overlapping ring complexes.

Geology of the Study Area.

The study area lies between latitudes 10000' N and 10028' N and longitudes 8018' E and 80 55' E covering a total land mass of 745km2 (Fig. 1). The area is underlain by crystalline rocks of Precambrian to probably Palaeozoic basement complex into which the Jurassic Younger Granite are intruded. The Basin is bounded by the Rishuwa Younger Granite in the northwest, Saiya-Shokobo Younger Granite complex in the north east, the Amo and Rukuba Younger Granite complex in the south east and the Kerku Younger Granite Complex in the South west (Fig. 1). The Younger granite province had been famous for its huge deposit of cassiterite and columbite which have been exported in commercial quantities before the advent of petroleum.

Theory of methods used

The analytical signal amplitude of a potential field (in three-dimensions) is defined as the square root of the squared sum of the vertical and the two derivatives of the field. This signal exhibits maxima over magnetization contrasts, which are independent of the ambient magnetic field and source magnetization directions. Locations of these maxima thus determine

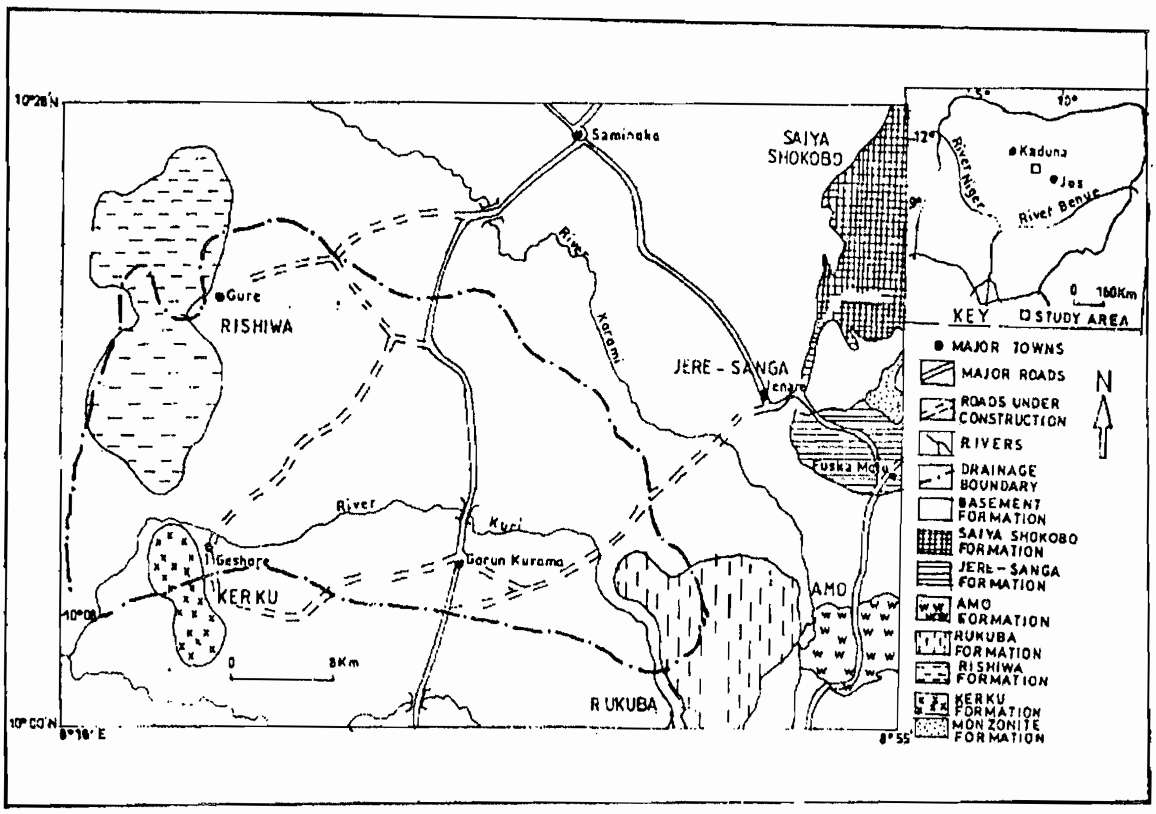


Fig. 1 : Geological map of the study area (Kinnaird et al. , 1981)

the outlines of magnetic sources. This concept of analytical signal has been explained in Nabighian (1972, 1974) and Salem (2005) for two dimensional cases and used in three-dimensional magnetic interpretation by Roest et a., (1992). As this method is not frequently used, it is worthwhile giving a brief summary of its basic theory: Defining $\hat{x}$, $\hat{y}$ and $\hat{z}$ as unit vectors in x, y and z directions respectively, the three-dimensional analytic signal
field anomaly 'of a potential given by Roest et al (1992) is

$$A(x,y) = \frac{\partial T}{\partial x}\hat{x} + \frac{\partial T}{\partial y}\hat{y} + i\frac{\partial T}{\partial z}\hat{z} \qquad (1)$$

where $i = \sqrt{-1}$

Equation (1) satisfies the basic requirement of the analytcal signal (Nabighian, 1972, 1984), that is, its real and imaginary parts form a Hilbert transform pair.

Werner Deconvolution (Werner, 1953; Hartman et at., 1971; Ku and Sharp, 1983; Ojo, 1990) is a technique for determining the depth to source bodies along a magnetic profile and, with large density contrasts, gravity profiles as well. Werner Deconvolution assumes that the source bodies are either dikes or contacts with infinite depth extent and uses a least-squares approach to solve for the source body parameters in a series of moving windows along the profile. The user specifies both the range of window sizes and the increments between window placements, thereby maximizing solution accuracy.

An edge or contact can be referred to as an interface, and in geological terms an interface is simply a dipping contact. The magnetic anomaly for a dipping dyke is precisely the same as the derivative of the magnetic anomaly for a similarly positioned interface. Therefore, if interface-type anomalies are present in the total field data, they can be converted (transformed) to thin dykestype anomalies simply by calculating the derivative of the total field. This derivative profile, or gradient, can then be subjected to the Werner deconvolution analysis, resulting in depth, horizontal position, susceptibility and dip calculations for the interface. Solutions from the Werner deconvolution are plotted using different * symbols, one type representing solutions obtained using the horizontal derivative of the field (useful for resolving contacts), and another type representing the solutions obtained using the total field (useful for dyke-like bodies), The sizes of the symbols are a measure of the significance of the solutions. The clustering signifies the presence of more than one solution, and reinforces the interpretation of the presence of a source.

Data Acquisition and Interpretation

A total of 425 stations were covered using an MP-2 portable proton processing magnetometer, and station interval of about 1.8 km was used between consecutive observations. More data points were generated by using the gridding method of interpolation along a regular grid of 48 by 32. with grid intervals of 0.00910. The total magnetic field was separated into its residual and regional component by a first degree polynomial fit. Figure 2 shows the regional field while Figure 3 is the residual field. It can be seen in Figure 3 that most of the anomalies tend to strike along the northwest-southeast direction, and there also seem to be a lineament which runs from the eastern part of the map towards the northwestern part. This is in close agreement with the direction of the regional field (figure 2) which trends along the northeast-southwest direction. Before applying the analytical signal technique the residual field was upward continued by a height of a grid interval to reduce the effect of noise. Using the procedure described in the above section a Fortran 77 program was developed to carry out the analyticalsignal operation on the upward continued field, and the result is shown in Figure 4. The dots in Figure 4 indicate the solutions obtained from the analytical signal technique while

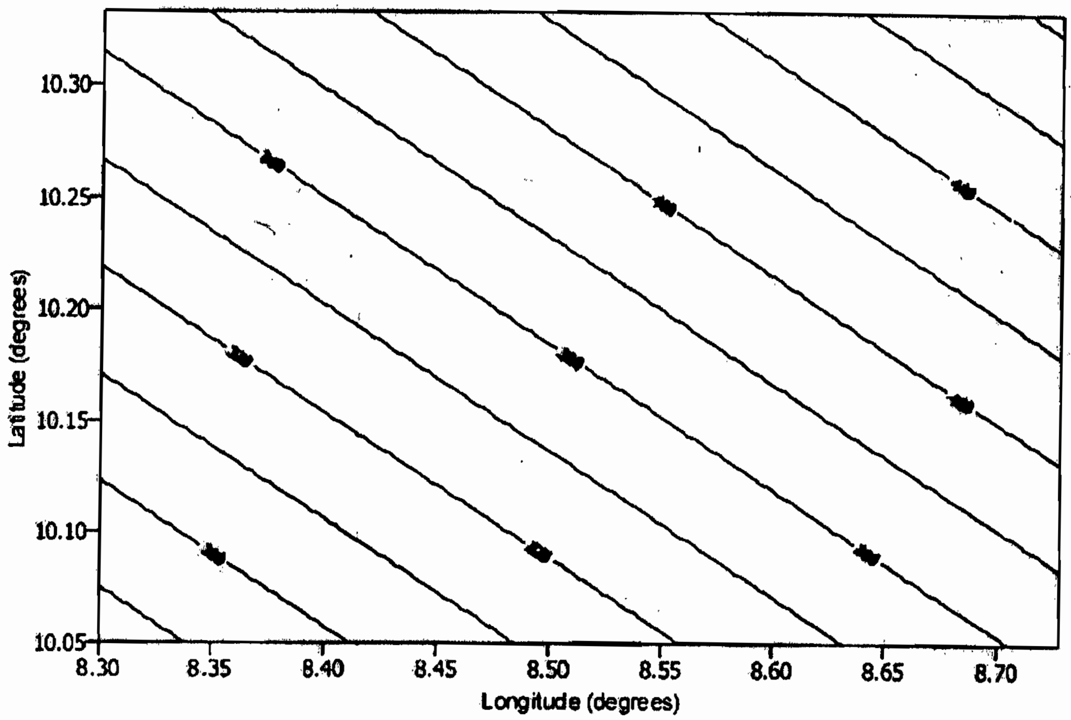


Fig. 2: Regional field map of the study area. A value of 33750nT Has been subtracted and contour interval is 2nT.

the dashed blue lines represent the inferred boundaries. As can be seen, four major sources or bodies have been mapped out (A, B, C and D) and also the suspected lineament which runs across from the eastern to the northern part of the area has been confirmed (L1). The other lineament (L2) which is close and parallel to L1 is an indication that the region is probably a fractured zone, These lineaments have probably guided the intrusions occurring around the northern part of the area. The boundary L3 corresponds to the boundary of the Rukuba Younger granite formation. In order to investigate further the nature of this subsurface structures, the Werner deconvoiution technique is run along two profile perpendicular to the general structural trends within the area (see profile XX and YY in figure 4). Figure 5 shows the results of applying theWerner technique. The triangles represent solutions for contact-like bodies which have been obtained using the horizontal gradient field while the squares indicate dike-like structures obtained using the total field. In figure 5a (Werner solutions for profile xx) the presence of dike-like structures is seen at distances of 5.2 km with depth of 2.5 km (which corresponds to body A), 8 km with depth 4.5 km and at 16.5km with depth of 3.0 km (which corresponds to body B). The solutions forcontact-like bodies occur at a distance of about 17 km on the profile and with an average depth of about 2 km. In figure 5b the Werner solution also confirms the presence of a contact at a distance of 16 km along profile YY this is followed with a strong confirmation of the presence of a dyke or intrusion at about 20 km along the profile and these corresponds to body C. The presence and positions of the contacts in figure 5a and 5b supports the proposition that the lineament extends towards the northern part.

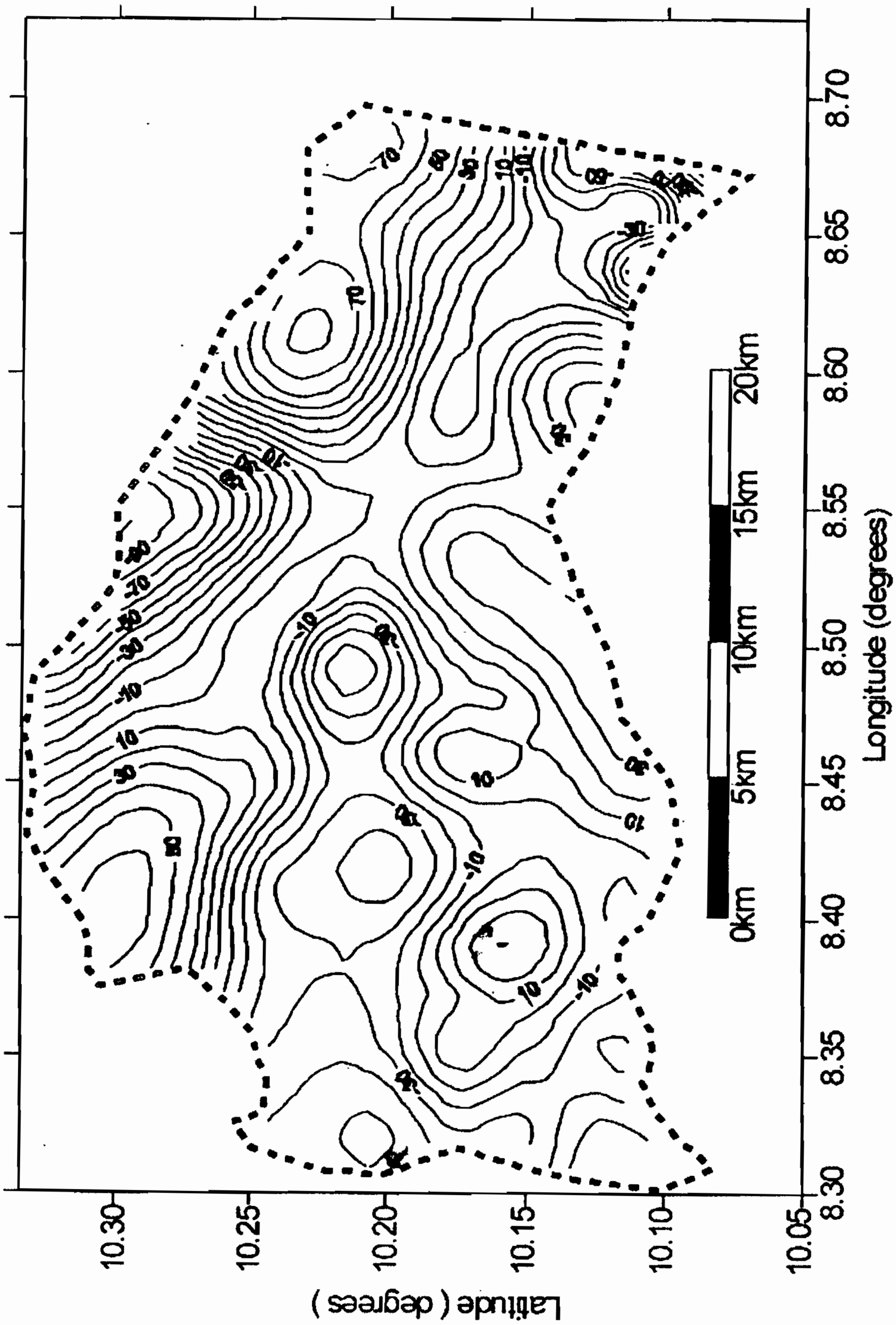


Fig. 3: Map showing the residual field for the area of study. Contour interval 10nT

.Discussion and Conclusion

Ground magnetic data have been obtained within the Kuri river basin North central Nigeria. A regional/residual operation was performed on the data and the residual field has been interpreted using the analytical signal technique and the Werner deconvolution technique. The regional field obtained has a northwest - southeast trend which corresponds to the general trend of the anomalies in the residual field. This is an indication that the emplacement of subsurface

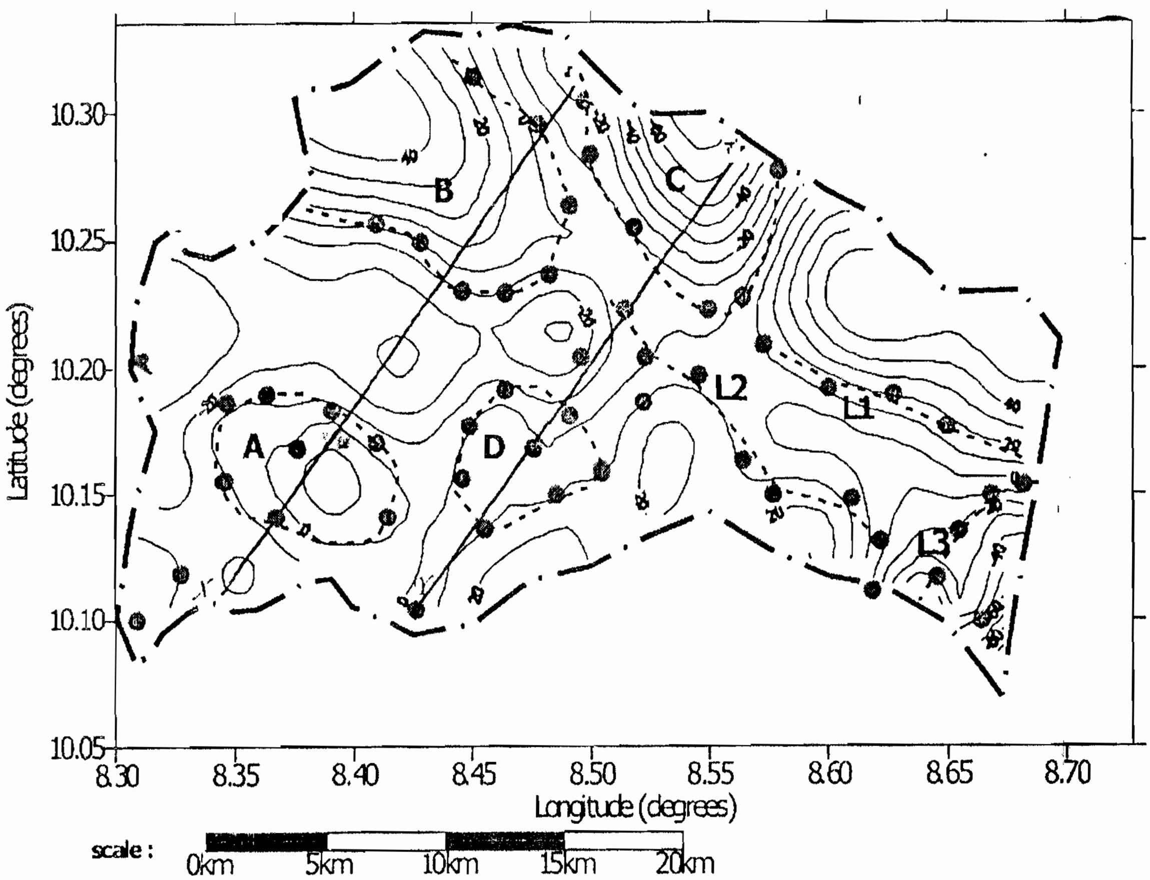


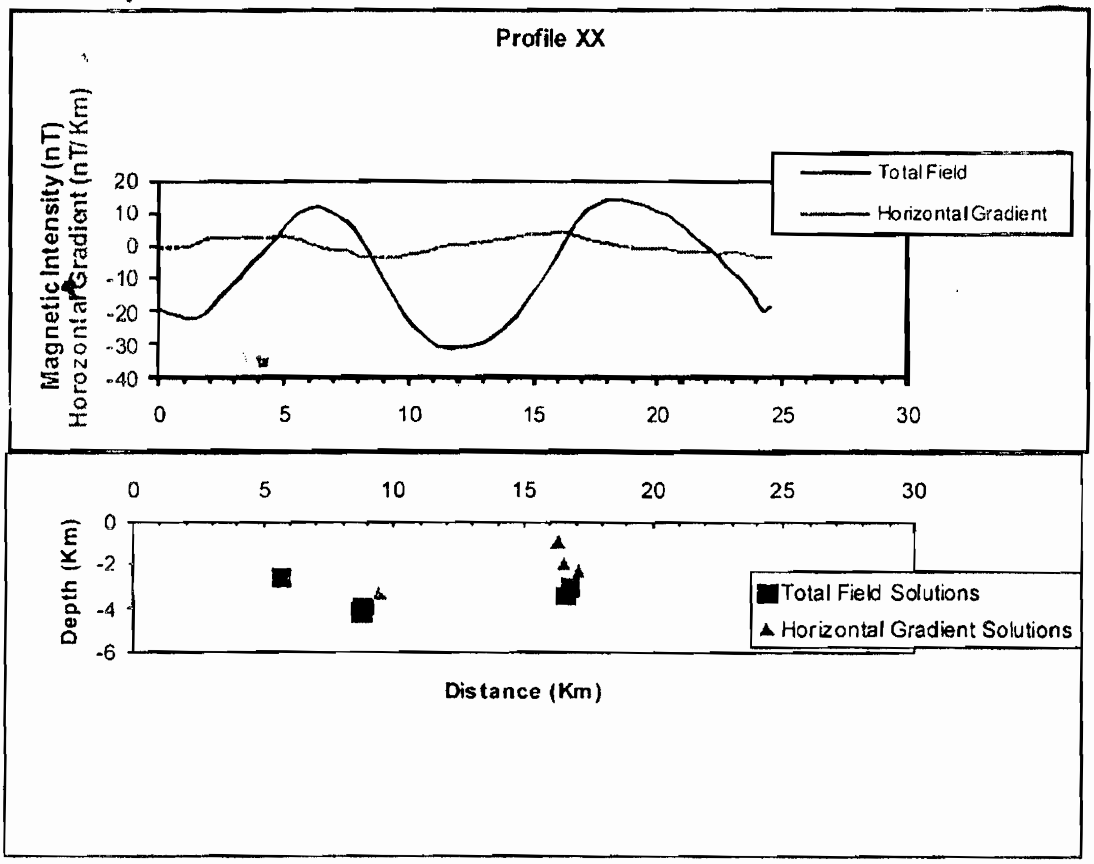
Fig. 4: Upward continued residual field showing the inferred boundaries (dash lines) obtained from the Analytical Signal solutions (dots). The height of continuation is 1 grid interval and the contour interval is 10nT

structures within the basin is regionally influenced. Results obtained from the analytical signal technique indicate the presence of four intrusions, some of which are probably extensions of the Rishiwa younger granite complex in the northwest and the Rukuba Younger granite formation in the south east. Combined analysis of the Analytical signal and Werner deconvolution techniques indicate the presence of a long linearment or fractured zone which trends along southeast to northwest of the area of study. Dogara and Ajayi, 2001, proposed the existence of some unexposed younger granites within the area. These fracturing could probably have influenced the formation of the unexposed younger granite. In view of the close association of mineralisation with regional tectonics, it is also possible that these anomalous belts could be loci of economic mineralisation. This work has proven that Werner deconvolution technique could serve as a vital complement to the analytical signal technique in delineating structural boundaries especially in situations where there is difficulty in inferring the boundary as a result of criss crossing of the solution points

.References

Ajakaiye, D.E., Hall, D.H., Ashiekaa, J.A. and Udensi, E.E. (1991): Magnetic Anomalies in the Nigerian Continental Mass Baled on

(A)



(B)

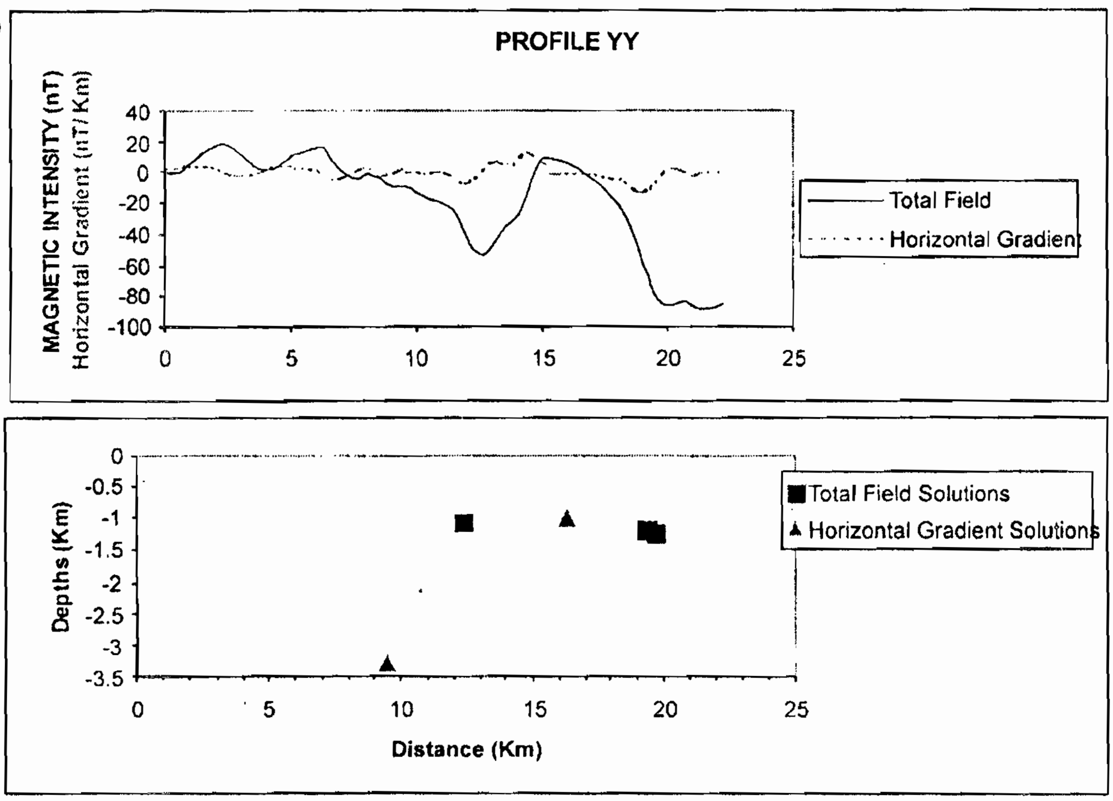


Fig. 5: Werner profiles

Aeromagnetic Surveys, Tectonophysics, 192, 211-230.

Ajakaiye, D.E.; Hall, D.H. and Millar, T.H, (1985): Interpretation of Aeromagnetic Data Across the Central Crystalline Shield Area of Nigeria, Geophvs. J.R. Astron.Soc.. 83, 503-517.

Dogara, M.D and Ajayi C.O. (2001): Unexposed Younger Granite Suites of Central Nigeria: Deductions rom Geoelectrical Investigation, Nig. Journ. of Phys.. 13, 11-15.

Hartman, R.R., Tesky, D.J. and Freidberg, J. (1971): A System for Rapid Digital Aeromagnetic Interpretation, Geophysics, 36, 891- 918.

Kangkolo, R. (1984): Interpretation of Aeromagnetic Data Over a Portion of the Nigerian Younger Granite Ring Complexes (MSc. Theses Ahmadu Bello University Zaria).

Kinnaird, J.A., Bowden, P., Bennett, J.N., Turner D.C., Ike E.C., Abaa S.I., Moyes A.B., Badejoko T.A., Weir J., Martin R.F., Barriere M., (1981): Geologic Map of the Nigerian Anorogenic Ring Complexes. John Bartholomew and Sons Ltd.

Ku, C.C. and Sharp, J.A. (1983): Werner Deconvolution for Automated I Magnetic Interpretation and its Refinement Using Marquadt's Inverse Modeling, Geophysics. 48, 754-774.

Nabighian, M.N., (1972): The Analytic Signal of Two-Dimensional Magnetic Bodies with Polygonal Cross-section: It's Properties and Use for Autom ated A nom aly Interpretation. Geophysics, 37, 507- 517.

Nabighian, M.N., (1974): Additional Comments on the Analytical Signal of Two-Dimensional Magnetic Polygonal Bodies with Cross-section. Geophysics. 39, 85-92.

Nabighian, M.N., (1984): Towards a Three-Dimensional Automatic Interpretation of Potential Field Data Via Generalized Hilbert Transforms; Fundamental Relation. Geology, 49, 957-966.

Ojo, S.B. (1990): Origin of a Major Aeromagnetic Anomaly in the Tectonophysics, 85, 153-162.

Roest, W.R., Verhoef J., and Pilkington, M, (1992): Magnetic Interpretation Using the 3-D Analytic Signal. Geophysics. 57, 116-125.

Salem A., Williams S., Fairhead J. D., Ravat D and Smith R. (2007): Ttilt- deptn Method: a simple Ctepth Estimation Method Using Rirst Order Magnetic Cerivatives. The Leading Edge, 26i 1502-1505.

Salem, A. (2005): Interpretation of Magnetic Data using Analytic Signal Derivatives, Geophysical Prospecting, 53, 75-82.

Verduzco B., Fairhead J. D., Green C.M., Mackenzei C. (2004): New

Insights into Magnetic Derivatives for Structural Mapping, The leading Edge, 2, 116-119.

Werner, S. (1953): Interpretation of Magnetic Anomalies at Sheet-Like Bodies, Sver. Geol. Unders. Ser: E, No. 508.