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Full Length Research Article

Magnetic Lineaments of the Kuri River Basin, Western Part of the Younger Granite Province, Central Nigeria

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ABSTRACT
A ground magnetic survey of the Kuri River Basin located within some parts of Lere and Kauru Local Government Areas of Kaduna State, Nigeria was carried out with the aim of studying the magnetic lineaments of the basin. Measurements were carried out on 62 base stations and 352 detailed stations using the Proton Magnetometer and employing the leap-frog sequence of field observations. From the contoured magnetic maps, magnetic lineaments were obtained based on magnetic susceptibility contrast. These lineaments and/or geologic features appear as thin elliptical closures and nosings. The trend of the magnetic lineaments on the average is on the North to South direction, which is in agreement with the structural trend and magnetic lineaments observed by other researchers in and around the area.

Keywords: Ground magnetics, Magnetic Lineaments, Magnetic susceptibility, Kuri River Basin.

INTRODUCTION
Magnetic lineaments or fracture patterns in magnetic studies are obtained from information based on magnetic maps. Magnetic susceptibility contrast is generally recorded or observed across a fracture zone, this can be due to the filling of the fracture planes by bodies whose susceptibilities are different from those of the host rocks (Nsikak, *et al.* 1999). Generally, geophysical methods have found useful applications in geological mapping. These include bedrock determination, determination of superficial deposits, structural mapping, lithological boundary differentiation and determination of structural trends among others (Early and Dyer, 1964; Zohdy, 1974; Van-Overmeeran, 1981; Dogara, 2003). In most parts of the lowland area, the basement rocks are not exposed. Hence, the geology and the lithological boundaries are in most cases, inferred (Oyawoye, 1972) and unexposed rocks are sometimes identifiable using geophysical measurements (Dobrin and Savit, 1988). It is the aim in this work to unravel the magnetic lineation within the Kuri River Basin in parts of Lere and Kauru Local Government Areas of Kaduna State, Nigeria.

The area investigated in this work covers parts of the topographic map sheets 146 (Geshere) and 147 (Lere). The area lies between latitudes 10.05^{o}N and 10.34^{o}N and longitudes 8.30^{o}E and 8.70^{o}E. The total area covered in this work measures about 745km^2. The study area falls within the Younger Granite Province of Central Nigeria (Fig. 1).

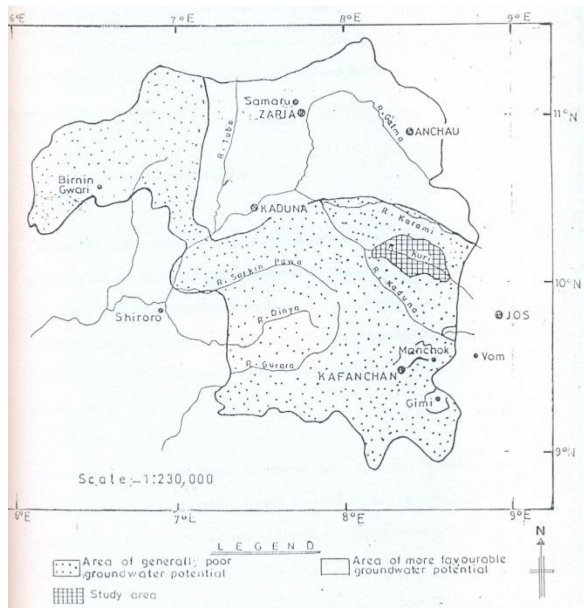

Fig. 1: Map of Kaduna State showing the Location of the Study Area (Adapted from KSWB/RWS/34)

Geology of the Area
Nearly fifty Younger Granite massifs are known, varying greatly in size, many of the large ones being made up of two or more overlapping ring complexes (Turner, 1969). They occur in a broad N-S zone, 400x150 km, centered on the Jos Plateau where the greatest concentration of ring complexes is found (McCurry, 1989). The Nigerian Younger Granites are part only of a much larger igneous province extending far to the north in Niger Republic (Black and Girod, 1970, Turner, 1969). The basement rocks appear to have exerted some control over the Younger Granite emplacement. A large part of the Nigerian basement is made up of ancient crystalline rocks that were re-deformed and re-metamorphosed in the Pan-African orogeny. Rocks belonging to a phase of sedimentation within this orogenic cycle probably occur in the schist belts that lie to the west of the area containing the Younger Granite complexes (McCurry, 1989). In this region, orogenic deformation was intense but metamorphic temperatures were only moderate and pervasive migmatization did not take place. In contrast, the basement in the Younger Granite region, mainly migmatites, gneisses and granites show gradational boundaries between rock types and widespread migmatisation which accompanied the emplacement of the Pan African granites (Wright and McCurry, 1970). The study area comprises Precambrian to Lower Palaeozoic basement complex rocks into which the Jurassic Younger Granites are intruded. In fact the Kuri

River Basin is in the basement complex of Nigeria and is bound by the Rishuwa Younger Granite in the west, Saiya-Shokobo Younger Granite Complex in the north east, the Amo and the Buji Younger Granite Complex in the south east and the Kerku Younger Granite Complex in the southwest.

Magnetic Data Acquisition and Reduction

The magnetic data was collected on a total of 62 base stations and 352 detail stations within the project area (Fig.2) using the MP-2 portable proton precession magnetometer. The leap frog sequence was used where A_1, A_2, A_3, B_2, B_3 and C_2 were repeated readings at those base stations, while a_1, a_2, a_3, b_1, b_2, b_3 are readings at the intermediate stations (Fig.3).

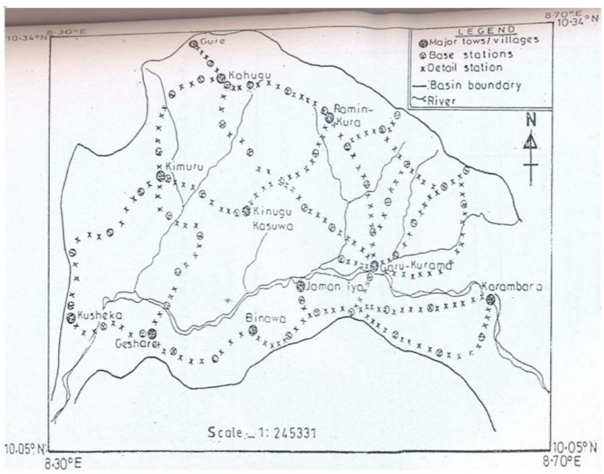

Fig.2: Map Showing the Magnetic Data Points

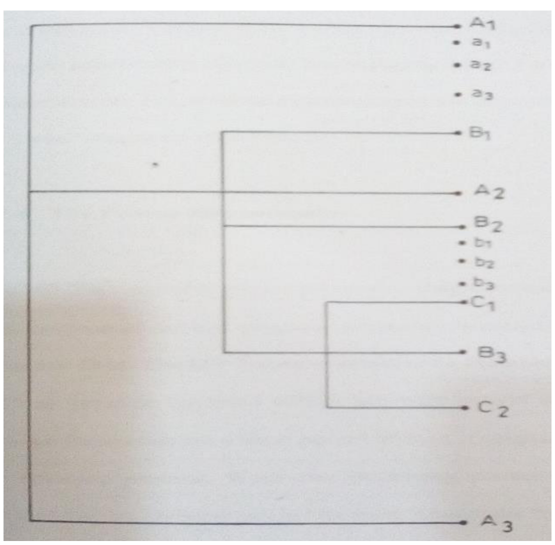

Fig. 3: Leapfrog Sequence of Magnetic Data Collection

The cascade method of drift correction was used to reduce the magnetic data. In this reduction, the quasi-inner loops were first reduced. A linear drift was assumed during the correction. Although, this assumption may not be absolutely correct, it is however, the best in a situation where the exact trend of the magnetic field variations is not exactly known (Osazuwa, 1988). The mathematical model on which the computation was based is derived from a simple linear drift assumption for each complete loop. For the linear drift condition, the drift rate is given as

$$U = -\frac{(B_1 - A_1)}{t_2 - t_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..1$$

Where B_1 and A_1 are the observed magnetometer readings at base stations B and A at times t_2 and t_1 respectively. The terminating stations are obviously the base stations in this case. Every intermediate observation at time t_s was referred to time t_1, the required drift correction to the observed value ds, at a station s was given as

$$d_s = U(t_s - t_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..2$$

The computation using equation (2) was done for all base stations established. The error d_s was distributed over the detailed stations with time, and was added or subtracted depending on whether there is an increase or decrease in magnetic reading within the time the two base stations were re-occupied and hence corrected for drift for all the magnetic stations established in the area of study. The magnetic field observed and reduced over an area can be taken as a combination of a regional component and a residual component. The regional component is that due to deep-seated and distant variations in the internal state of the earth while the residual component is that due to relatively local variations in magnetic inhomogeneuities in the earth's crust. In processing magnetic data in this work, the regional magnetic field values over the area of study were estimated, the residual field was obtained by subtracting the regional component form the total field values. In this work, it was assumed that the regional field is a first degree polynomial surface (Dobrin and Savit, 1988, Kangkolo, 1996). Suppose that it is desired to fit M data points (T_i; x_i; y_i); i = 1,2,…, M to a model which has N adjustable parameters C_j; j = 1,2,…N. The model predicts a functional relationship between the measured independent and dependent variables:

$$T(x,y) = T(x, y; c_1, \ldots, c_N) \ldots\ldots\ldots\ldots(3)$$

Where the dependence on the parameters is indicated explicitly on the right-hand side. For example, the functions could be 1, x, y, xy, x^2, y^2, x^2y, …, in which case their general linear combination

$$T(x,y) = c_1 + c_2x + c_3y + c_4x^2 + c_5xy + c_6y^2 + \ldots\ldots(4)$$

is a general polynomial of degree N – 1

The general form of this kind of model is

$$T(x,y) = \sum_{j=1}^{N} CjPj(x,y) \ldots\ldots(5)$$

Where $p_1(x,y)$ … $p_N(x,y)$ are arbitrary functions of x and y called the basis functions.

Note that the functions $p_N(x,y)$ can be wildly nonlinear functions of x and y.

In this discussion "linear" refers to the models dependence on its parameters c_j. In the general least squares techniques, to obtain the fitted values for the c_js we minimize over c_1 … c_n the merit function

$$X^2 = \sum T_i - T(x_i, y_i, c_i, \ldots c_n) \ldots\ldots(6)$$

The minimum value occurs where the derivatives of x^2 with respect to all N parameters c_j vanishes.
The model representing the first degree surface, is a two dimensional first order polynomial of the form

$$T(x,y) = c_1 + c_2x + c_3y \qquad (7)$$

This is the special case of equation (3) for which:
$N = 3$; $p_1(x,y) = 1$; $p_2(x,y) = x$; $p_3(x,y) = y$.
Substituting these into some relevant equations will produce an equation that can be written in matrix form represented as
A.C = B.
The elements of the matrices A and B are known. Since it is a low order system of equations, the elements of the matrix of unknowns C and be rapidly evaluated by the Cramer's method (Pennington, 1965, Kangkolo, 1996; Dogara, 2003).
The values evaluated from the determinants define the form of the first degree surface fit (equation. 5). Thus, the equation of the regional field over the river basin becomes:

$$T(x,y) = 240.9283 + 270.6440.x + 412.4054y \qquad (8)$$

The regional field map based on equation (8) is shown in figure 4 while the residual field map is shown in figure 5.

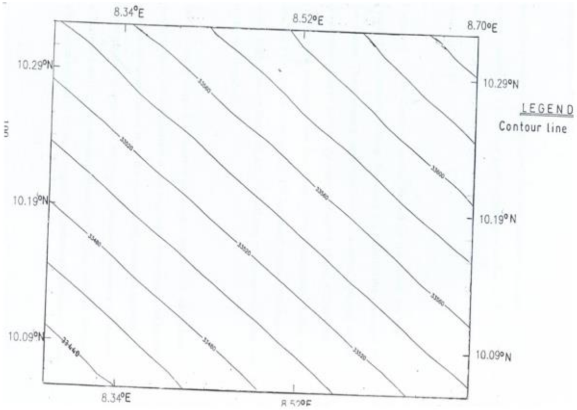

Fig.4: The Regional Magnetic Field Map of Kuri River Basin (values in nT)

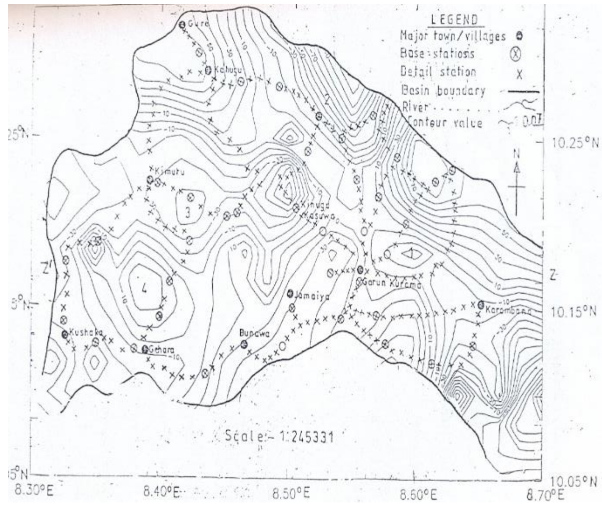

Fig.5: The Residual Magnetic Field map of Kuri River Basin (values in nT)

RESULTS OF QUALITATIVE INTERPRETATION AND DISCUSSION

The total magnetic magnetic intensity map of the study area is shown in figure--. The dynamic range of the total intensity magnetic field is 914gamma, the contour levels range from 33179nT to 34093nT. An examination of the contour map (Fig.5) reveals some clustered areas with mainly short wavelength anomalies from near surface geology. These short wavelength anomalies are elliptical and mostly oriented along N-S and E-W direction, thus defining a fabric that is commonly found on the basement complex of Nigeria (McCurry, 1971; Ball, 1980; Dogara, 2003).
The most prominent feature evident on the map is the large scale NW-SE trending magnetic anomaly (marked ZZ' in Figure 6) beginning from the northeast of Karambana and ending northeast of Gure. The lineament ZZ' shows a continuous narrow belt with nearly parallel contours indicative of a shallow magnetic source (Dobrin and Savit, 1988).

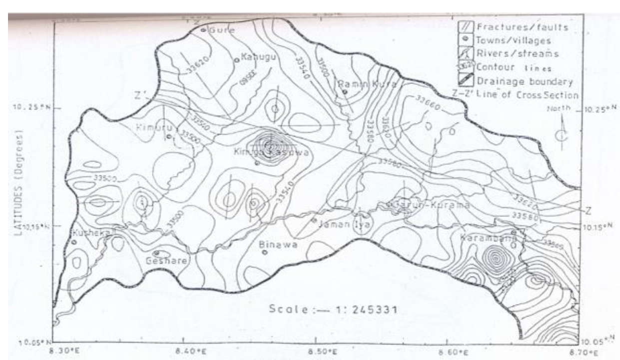

Fig.6: The Residual Magnetic Map of Kuri River Basin Showing Possible Lineaments/Fractures

To understand the tectonic history of the study area, the characterization of the magnetic lineament either as faults, fractures, etc, are of vital importance. Ajakaiye *et al.* (1991) showed that the magnetic lineations of the Younger granite Province are parallel to structural trends in the oceanic crust of West Africa and other parts of West Africa. Also in their work on the magnetic anomalies in the Nigerian continental mass based on aeromagnetic surveys, it supports the existence of the Nigerian portion of a suggested continent-wide megashear system hypothesized to pass onto the continents from the sea floor and through Nigeria as deduced fromlandsat imagery (Neev *et al.* 1982; Ajakaiye *et al.*, 1985) The works on aeromagnetic surveys and landsat imagery showed prominent coincidence in magnetic anomalies with the st. Paul's and chain fault zones offshore from West Africa. Ajakaiye *et al*. (1985) further showed that many of the ring complexes in the Younger Granites area lie on the magnetic lineations. These lineations were considered to be magnetic expressions of fracture systems through which the ring complexes were intruded. In this connection, prominent closures or nosings of contours were identified on the residual magnetic field map as they express geologic lineaments according to Nsikak, et al. 1999 and Grauch, *et al.* 2001. In the residual magnetic map, figure 6, the positions of such lineaments are represented by lines drawn parallel to the elongation and through the centre of the anomalies. The lineaments shown in figure are reproduced for clarity in figure 7. It could be seen that the trend of magnetic lineament, on the average is on the N-S direction, which is in agreement with the structural trend in the area.

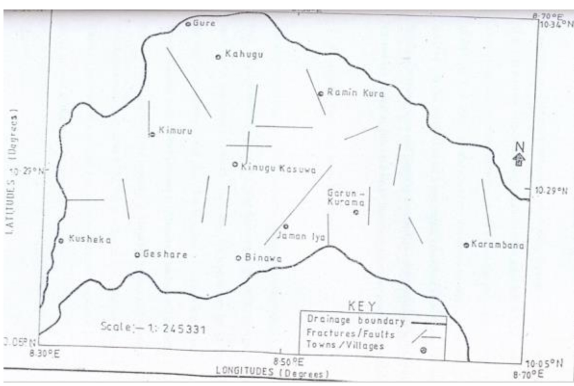

Fig.7: Deduced Magnetic Lineaments/Fractures in the Kuri Basin Based on the Residual Magnetic Map

Thus, the existence of the major lineament trend (ZZ') identified in the present study is in agreement with the general tectonic framework of the study area. The prominent lineament probably represents pre-existing line of weakness in the continental crust, which was rejuvenated during the tectonic phase of the Pan African orogeny (Sykes, 1978). The lineament probably provides zones of weakness along which basic intrusives were intruded. The lineament observed on the magnetic map passes North of Kinugu Kasuwa around one of the major anomalies identified from geoelectrical investigation results (Dogara and Ajayi, 2001). It is the view in this work that this lineament represents a major fracture system through which ring complexes are intruding in isostatic equilibrium. This fracture is most probably a zone of weakness inherited from the Pan African orogeny (Sykes, 1978). Thus, lineament ZZ' could be considered to be part of a signature of shear, fracture or zones of weakness that probably resulted from the readjustment of the shape of the Younger Granites during a search for isostatic equilibrium. This deduction lay credence to the suggestion by Schoeneich *et al*., (1990) that the Younger Granites may not likely be made up of acidic igneous rocks only but may also have some that are likely of basic igneous but less dense than the surrounding rocks. If they are less dense than the surrounding rocks then the isostatic concept of the origin of the Younger Granite, that the Younger granitic materials isostatically protrudes upwards (and may still be protruding upward) in heavier granitic gneisses is a great possibility in this work as shown in figure 8.

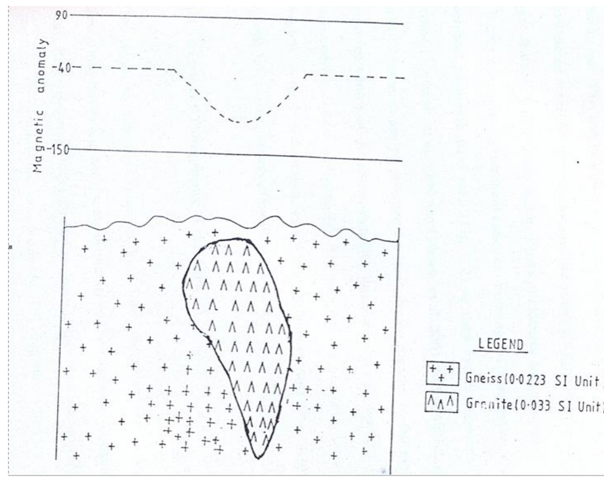

Fig.8: A model of a Granitic Material Isostatically Protruding Upwards In a Granitic Gneiss (after: Schoeneich, *et al*. 1990)

The character of the topography of the whole basin is presented in a 3-D surface plot (Fig.9) with the deepest and shallowest zones indicated. The arrows in figure 9 show a ridge-like structure with a trough and crest that approximates the direction of the river. From the above and earlier researches, it could be said that the entire basin is structurally controlled with some possible major lineations between Gure and Geshere, Ramin-Kura and Jaman'Iya and also around Karambana. However, there is a major basement elevation around Kinugu Kasuwa in line with the works of Dogara and Ajayi (2001) and Chii *et al* (2008).

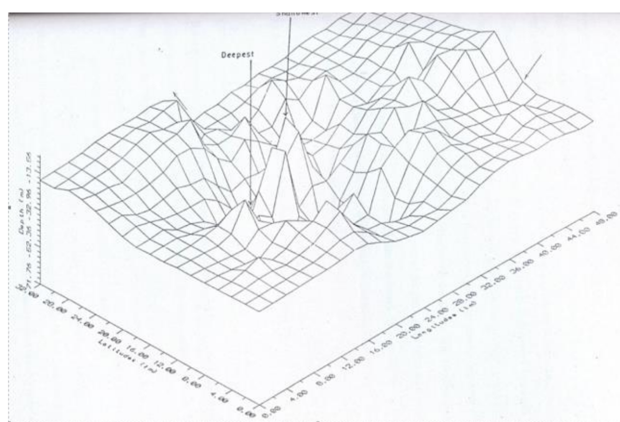

Fig.9: 3-D Surface Plot of the Basement Surface Underlying the Kuri River Basin Showing Deep and Shallow Zones

CONCLUSION

The Kuri River Basin in Lere-Kauru areas of Kaduna State, Nigeria was investigated using ground magnetics to unveil the possible magnetic lineaments or signatures of the basin. From the magnetic maps, it was revealed that there are lineaments and/or geologic features that appear as thin elliptical closures and nosings. On the average it was found that the lineaments trend on the N-S direction, which is in agreement with the structural trend and magnetic lineaments observed by earlier researchers on gravity, magnetics and electrical methods

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