Indication Of High Frequency Structures Using Derivative Filters Over Koton Karifi Area, Nigeria, Modelled From Aeromagnetic Data

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Abstract: An aeromagnetic map of the Koton-karifi area, (sheet 227) was purchased from the Geological survey of Nigeria (GSN).The area is located between latitudes 8°.00’N and 8°.30’N and longitudes 6°.30’E and 7°00’E.Six profiles were established. The map was digitised with a spacing of 1KM.The anomaly map with values ranging from -200nT to 250nT, Shows a central linear belt which runs from the western to the eastern ends. The southern end is dominated by convolutions and the Northern end is dominated by smoothed network of contours. The derivative filters were designed and used to quantify the spatial rate of the magnetic field in vertical and horizontal directions and so capable of enhancing higher frequency anomalies relative to the lower ones.

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Key words: Derivative filters, vertical directions, horizontal directions, high- frequency, convolutions.

1. Introduction

The aim of a magnetic survey is to investigate subsurface geology on the basis of magnetic anomalies in the Earth’s magnetic field resulting from the magnetic properties of the underlying rocks. Magnetic surveys can be performed on land, at sea and in air. The speed of operation and cost make airborne magnetic surveys very attractive, where the principal objective has been to assist in mineral and groundwater development through improved geologic mapping. In addition, aeromagnetic surveys have traditionally been applied at the early stage of petroleum exploration to determine depth and major structure of crystalline basement rocks underlying sedimentary basins. The methodology for acquiring and compiling data appears to be keeping pace with modern technology so that presently the magnetic method is by far the most widely used of all geophysical survey; both in terms of line-kilometres surveyed annually and in total line-kilometres (Paterson and Reeves, 1985). Thus compared to other geophysical methods, the aeromagnetic data are always readily available and so it is important to exploit the potentialities of these data. This has been the aim of this work. This paper focuses on the analyis of a total-field aeromagnetic data using derivative filters over the Koton Karifi area, central Nigeria. The outcome of the analysis is expected to throw more light on the geology and other linear features of the area.

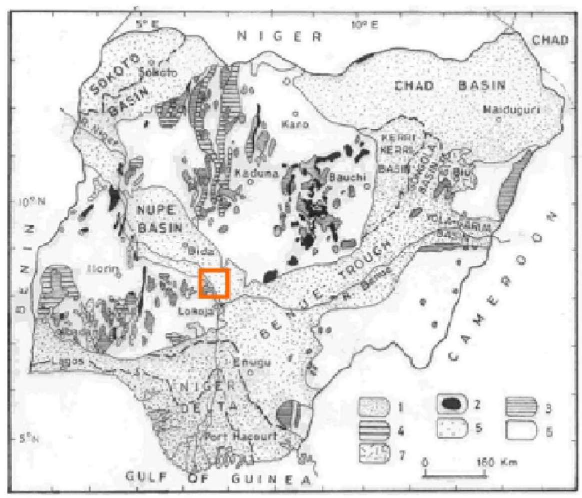


Fig. 1.0 Geological map of Nigeria

1 = Cretaceous-Recent sediments; ***2***=Younger Granites; ***3*** = Older Granites; ***4*** = Undifferentiated Metasediments; ***5*** = quartzite and quartzite schist; ***6*** = Undifferentiated basement complex and ***7*** = Tertiary volcanics (From Geological map of Nigeria 1994: compiled by the Geological Survey of Nigeria). Inset is the study area: the Koton Karifi Area of the Nupe Basin, Nigeria.

2. Geology of the Koton Karifi Area

The Koton-karifi area of Nigeria (Figs. 1.1 & 1.2) is part of the entire Nupe basin, Nigeria and is the SE edge of this basin lying between latitudes

8^0:00'N and 8^0:30'N and longitudes 6^0:30'E and 7^0:00'E.

This trough is filled with Upper Cretaceous sediments and is mainly occupied by the sandstones. The original rock of the area could have been subjected to considerable erosion before the Upper Cretaceous beds were laid down. The sandstones consist of unfossiliferous shallow water sandstones and pebble beds. It is possible that these sandstones could have covered a larger area (continuous to the Sokoto Basin) than now (Russ, 1957). Tertiary earth movements could have impacted low dips to this formation leading to erosion over wider areas. The youngest rocks of the area are laterites and alluvial, terrace and terrestrial deposits of tertiary and recent age (Russ, 1957).

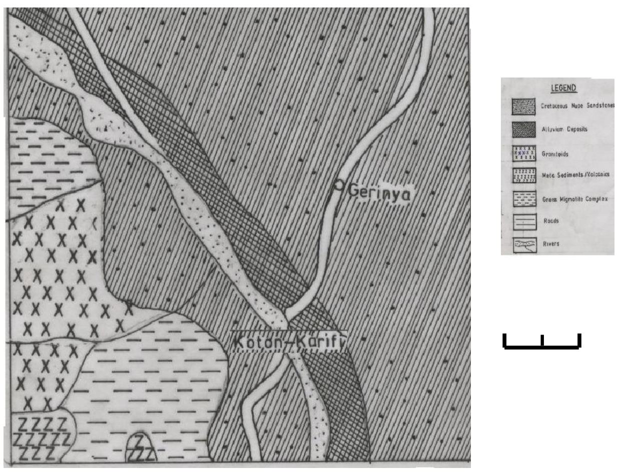


FIG: 1.0 Geology map of Koton – Karifi (From Geological) Map of Nigeria 1994

The general stratigraphy and sedimentation processes consist of the lithologies overlying the Precambrian Basement complex. The sequence is divided into a number of formations and lithologies characteristics of the age group. The Precambrian to probably Palaeozoic rocks are the oldest rocks and form the basement complex (Adeleye, 1976). During the upper cretaceous times, depositional cycle started with overlying of the Nupe Group (undifferentiated sandstones) in the Santonian. Adeleye (1976) gave the remaining sedimentary succession as follows. Sandstone formations of Bida and Lokoja followed in succession up to the end of Santonian. During this period, there were no severe crustal movements to alter the geometry of the layers at the end of each depositional cycle. Thus these formations overlie conformably on one another. At the beginning of the Maastrichtian, the Agbaja (around Niger/Benue confluence) and Batati (around Bida) formations were deposited conformably over the Mamu formation. The Agbaja and Batati formations comprise ironstones of the minnette-type of iron ores (Adeleye, 1976). These ironstones have identical properties to the iron ores of minnette-type of Europe and America, which contain 1.3 – 0.8% phosphorus, small percentage of alumina, sulphur and silica (Adeleye, 1976). The depositional sequence is followed by Ajali sandstones and the coal seams and sandstones making the Nsukka formation. The Quarternary deposits are the recent alluvium, laterites, terrace and terrestrial gravels and sands (Russ, 1957).

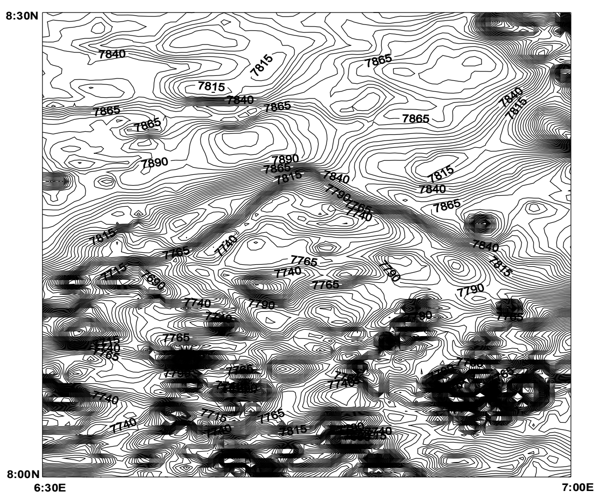
The sedimentary facies of the area and the description of the major formational lithologies and structural expositions of the area have been given by Adeleye (1976), as a gently down-warped trough whose buried Basement Complex has a high relief with sedimentary formations of more than 300m thick. The epeirogenesis responsible for the basin genesis seems closely connected with crustal movements of the Santonian orogeny of South-eastern Nigeria and the nearby Benue Valley (Adeleye, 1976). The earlier periods of sedimentation and instrusion in the Precambrian represent a complex vast period of history in the area (Russ, 1957). These earlier sediments and some minor intrusion must have been subjected to several periods of metamorphism.

3. Materials and Methods

Total field aeromagnetic anomaly data obtained for the Koton-Karifi area, Nigeria were used for the present study. The original data were part of the aeromagnetic map of the total magnetic field intensity in half-degree sheet acquired from the Nigeria Geological Survey Agency (NGSA). These surveys were conducted by consultants on behalf of NGSA between 1974 and 1976 covering nearly the entire country. The main aim of these surveys was to assist in mineral and ground water development through improved geological mapping. Flight line direction was NNW-SSE at profile spacing of 2km and flight line spacing of 20km at an altitude of about 152 m. The lines were flown in an ENE-WEW (N60E).

The first step in the present analysis was to digitize the map covering the survey area with a digitizing space of 1km. Digitizing was done manually, reading values at intersections of north-south and east-west profiles. The next step was to recontour the map to check for any misreading and to produce the total – field aeromagnetic intensity map (Fig. 2a). The contouring was done using the Golden Software 2D Surface Mapping Program (Surfer

Version 7.0). The main corrections applied during post-processing of the total-field aeromagnetic intensity for this area were diurnal correction, estimation of regional correction from component gradients and crossover tie leveling (Luyendyk 1998). The resulting anomaly map for the study area, after the International Geomagnetic Reference Field (epoch 1 January 1974, using IGRF 1975 model [Cain 1968]) removal, is displayed in Figure 2b. The map (Fig. 2b) shows values ranging from –200 to 250 nT. The map shows a central linear belt which runs from the western to the eastern ends and apparently separating the area into two: with the southern dominated by convolutions and the northern dominated by smoothed network of contours. This prominent belt is likely very significant in the area and will be further investigated.



Total Field Aeromagnetic Map (Sheet 227) of Koton Karifi. Contour interval is 5 nT. Actual values are obtained by adding 25000 nT to contour values. Regional correction based on IGRF (epoch date 1st January 1974) has not been made.

FIG: 2a

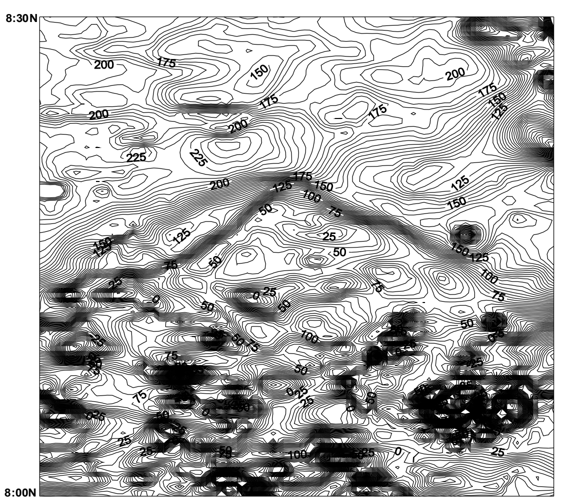


FIG: 2b Total field aeromagnetic anomaly map of koton- karifi area(sheet 227). The main field in form of igrf (igrf model 1975 of epoch date 1 jannuary 1974) has been removed. Contour interval is 5nT.

4. Theory of Vertical Derivative Filters

First and second vertical derivatives emphasize shallower anomalies and can be calculated either in the space or frequency domains. These operators also amplify high-frequency noise, and special tapering of the frequency response is usually applied to control this problem. Derivatives quantify the spatial rate of change of the magnetic field in vertical and horizontal directions.

The expression for the magnetic force $\vec{F}(r)$ is obtained from Coulomb's law for magnetic poles m_1 and m_2 separated by a distance r as

$$\vec{F}(r) = \frac{m_1 m_2}{\mu r^3}\vec{r} \qquad (1.0)$$

The poles are somewhat of a fiction, since they cannot exist isolated, but only in pairs: if we assume two very long bar magnets with two poles close together and the other two apart, the situation is fulfilled in practise. The value μ is the permeability of the medium surrounding the magnets and is dimensionless.

The magnetic field strength $\vec{H}(r)$ is expressed as

$$\vec{H}(r) = (F^{\to}(r)) \,/\, m' = \left(\frac{m}{\mu r^3}\right)\vec{r} \qquad (1.1)$$

And the magnetic induction $\vec{B}(r) = \mu\vec{H}(r)$.

The magnetic field vector $\vec{B}(r)$ can be derived from a scalar potential function A (r) as

$$\vec{B}(r) = -\vec{\nabla}A(r) \qquad (1.2)$$

This potential may be defined as the work done in moving a unit pole against the magnetic field as

$$A(r) = -\int_{\infty}^{r}\vec{B}(r).\overrightarrow{dr} = m/\mu r \qquad (1.3)$$

Though a single magnetic pole is a pure fiction, the scalar potential is somewhat complex and more details can be found from Telford et al. (1990).

The first and second vertical component of the field $\vec{B}$ are the derivatives of the potential in the direction of the vertical axis. They are respectively $\frac{\partial B}{\partial z} = -\frac{\partial^2 A}{\partial z^2}$ and $\frac{\partial^2 B}{\partial z^2} = -\frac{\partial^3 A}{\partial z^3}$. Note that the magnetic potential A, like gravity potential satisfies the Laplace's equation: $\nabla^2 A = 0$ for a homogeneous region outside the volume V of the magnetic body. Similarly the magnetic potential everywhere within a region containing magnetic material satisfies the Poisson equation $\nabla^2 A = 4\pi\vec{\nabla}.\vec{M}(r)$, where the magnetic body is a continuous distribution of dipoles resulting in a vector dipole moment per unit volume, $\vec{M}(r)$.

Many modern methods for edge detection and depth-to-source estimation rely on horizontal and vertical derivatives (Nabighian et al. 2005). Derivatives essentially enhance high frequency anomalies relative to low frequency anomalies; the derivative maps however, cannot be interpreted quantitatively but are only useful as enhancement tools for high-frequency structures.

5. Results and Discussion

The residual anomaly over this area was subjected to first and second vertical derivative filters. The results are displayed in Figures 3.0 and 3.1 respectively. Figures 3.0 and 3.1 show contour values ranging from -70000nT/km to 60000nT/km and -24000000nT/km to 19980000nT/km respectively. Numerous convolutions are observed in the southern ends (Figs. 3.0 & 3.1) indicating enhancement of high-frequency structures and/or noise. Generally, vertical and horizontal derivatives quantify the spatial rate of the magnetic field in vertical and horizontal directions and so derivatives enhance high frequency anomalies relative to low frequencies.

The FFTFIL (Hildenbrand 1983) was used to accomplish these computations.

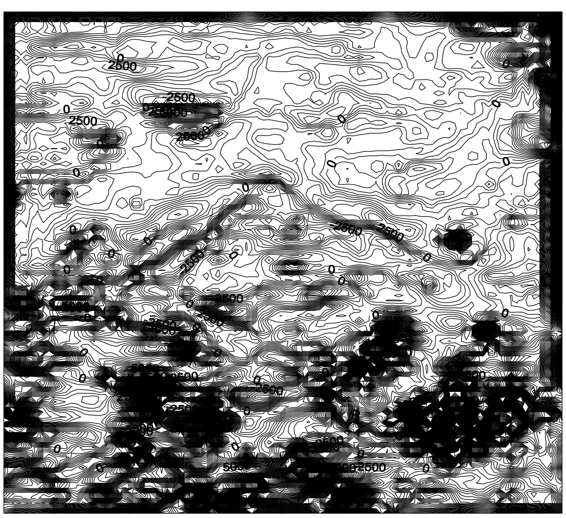


Fig. 3.1: The total field magnetic anomaly map of Koton Karifi area subjected to first vertical derivatives.

(Contour interval is 5nT)

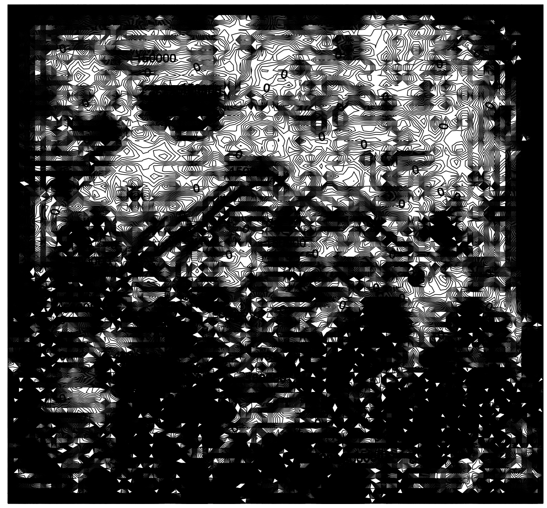


Fig. 3.0: The total field magnetic anomaly map of Koton Karifi area subjected to first vertical derivatives.

(Contour interval is 5nT)

6. Conclusion

The aeromagnetic anomaly data over Koton-Karifi area, Nigeria after the IGRF removal was subjected to map analyses using derivative filters. Derivative filters involved the use of first and second derivatives filters. These are enhancement filters and application gives a new unit to the data (either nT/km or nT/km2). However, the analyses results indicate that high- frequency structures or noise may have been enhanced (Figs. 3.0 & 3.1) and hidden features were better highlighted. These features may help much in forward or inverse modelling of the field in this area. The present study did not consider the interactive modelling of the magnetic data.

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