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A reconnaisance study to delineate the potential mineral zones around the schist belt areas Of Kano State, Nigeria using airborne magnetic data

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This work presents a reconnaissance study to delineate potential mineral zones in the schist belt areas of Kano State. These parts of the state have received little or no attention for a long time and activities of artisanal miners suggest that the area is of economic mineral value. Airborne magnetic data acquired from Nigerian Geological Survey Agency (NGSA) were first reduced to the equator before subjecting them to first and second vertical derivatives. The short wavelength anomalies recorded in the study area, ranging from -99.182 to 88.338 nT indicate that the area is characterized by crystalline basement complex rocks. The results of the vertical derivatives show that lineaments (depicting faults, fractures and contacts) which represent veins of possible mineralization exist in the study area. The trend of these lineaments is in the NE-SW and E-W directions with the NE-SW trend dominating. Location with high mineral favorability is bounded within longitudes 7°51ʹ E to 8° 12ʹ E and latitudes 11° 46ʹ N to 12° 30ʹ N in the NE – SW directions. The trend cuts through Gwarzo, Shanono, Bagwai, Tsanyawa, Bichi and Kunchi.

Key words: Airborne magnetic data, Lineament, Mineralization, Schist Belt and Vertical derivatives.

INTRODUCTION

The importance of solid minerals to every country in the areas of revenue generation, industrialization, employment creation etc. cannot be overemphasized. The commercial value of Nigeria's solid minerals has been estimated to run into hundreds of trillions of dollars, with 70 percent of these buried in the bowel of Northern Nigeria (Udegbe, 2014).

Specifically, the solid mineral resources in Kano State include gold, chromite/nickel, silver, cassiterite (tin ore), and columbite (Obaje, 2009).

Few geophysical studies in relation to mineral prospecting have been carried out in Kano State and information about the distribution of the minerals can be said to be inadequate. Regional gravity survey was done

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by Ajakaiye and Verheinjen (1979) in Southern Kano and they reported the presence of a residual anomaly around Rano. A detailed follow up gravity survey was carried out by Ojo et al. (1993), and Muhammad (1998) confirmed some of their results in his own aeromagnetic study. A much more recent geoelectric study was carried out by Bagare (2018) at Alajawa artisanal mining site in Shanono area (western Kano). This study however focused on just one site. More so, it is very difficult to carry out a regional survey using electrical method, hence the need for other geophysical methods, such as magnetic method, where a regional study can be done using available aeromagnetic data.

Magnetic method, a potential field method has been successfully used over the years by geophysicist/ geologists for mineral prospecting (Biswas, 2018). This is due to the fact that minerals and rocks have different permittivities (and by extension, susceptibilities) thereby causing disturbances in the earth's magnetic field. These disturbances, often referred to as anomalies, are analyzed and interpreted to gain information about the subsurface with regard to the mineral contents. Aeromagnetic surveys (like other airborne surveys) are the most rapid methods for finding geophysical anomalies. They are also the most inexpensive for covering large areas and hence often used for reconnaissance; anomalies of interest are later investigated using more detailed ground techniques (Telford et al, 1990).

Aeromagnetic survey has been a powerful tool for geological mapping and mineral exploration purposes. This method of investigating the subsurface geology is based on the magnetic anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks. Measurements of the total gradient of the magnetic field may also be made (Biswas et al., 2017). The shape dimensions, and amplitude of an induced magnetic anomaly are a function of the orientation, geometry, size, depth, and magnetic susceptibility of the body as well as the intensity and inclination of the earth's magnetic field in the survey area (Biswas, 2018, 2016; Biswas and Acharya, 2016).

For the exploration purposes, both land and aero-magnetic data have been used to investigate the presence of mineral deposits in combination with gravity. In the mining industry, both magnetic and gravity method is still widely used as an exploration tool to map subsurface geology and estimate ore reserves for some massive ore bodies (Biswas and Sharma, 2016; Biswas et al., 2014a, b). Aeromagnetic survey for determining the depth to magnetic source of anomaly over an area utilizes the principle that the magnetic field measured at the surface can be considered an integral of the magnetic signatures from all depths. The power spectrum of the surface field can be used to estimate the average depth to basement (sedimentary thickness) across the geological area.

This study is an attempt to delineate the potential mineral zones in the entire western parts of Kano State, using airborne magnetic data, by enhancing the magnetic signatures of shallow geologic features. It is a reconnaissance study upon which a more detailed ground investigation would be based.

The study area

The study area is bounded within latitudes 11°30' N to 12°30' N and longitudes 7°30' E to 8°30' E. It covers western parts of Kano and eastern parts of Katsina States (Figure 1). Geologically, the area comprises gneiss-migmatite-granite complex rocks with an intrusion of schist rocks which lies between the Karau Karau and Kazaure Schist Belts, and quaternary sediments all belonging to Northern Nigerian Basement Complex (Obaje, 2009) (Figure 2).

METHODOLOGY

Data

The aeromagnetic data used for this work were obtained from Nigerian Geological Survey Agency (NGSA), who acquired the digital data for the entire country between 2006 and 2007 by Furgro airways services (ngsa.gov.ng, 2018). The data were published in form of grid on half-degree sheets. Four sheets numbering 56, 57, 79 and 80, representing the study area, were assembled for this work. Each square block is 55 x 55 km^2 making the total area covered to be 12,100 km^2. The four sheets were merged as a unified block to give the Total Magnetic Intensity (TMI) map (Figure 3) of the study area, and the data were extracted using Oasis Montaj Software.

Method

Generally, data enhancement is a routine in potential field studies; the type of enhancement carried out depends on the information needed. The main aim is to subdue some features of the data and accentuate others not too apparent in the original map. In aeromagnetic studies, reduction to pole/equator, regional/residual separation, continuations, derivatives and depth estimation are the common techniques used (Telford et al., 1990). Interpretation of aeromagnetic data can be carried out both quantitatively and qualitatively. Quantitative interpretation involves making numerical estimates of the depth and dimensions of the sources of anomalies and this often takes the form of modeling of sources which could, in theory, replicate the anomalies recorded in the survey (Biswas et al., 2017; Singh and Biswas, 2016; Biswas, 2016, 2015).

In this study, we employed reduction to the equator and vertical derivatives.

Fourier Transform (FT)

Since late 1950s, specifically after the work of Dean (1958), Fourier analysis has become an acceptable technique for the processing of potential field data.

Generally, potential field data e.g. magnetic field data can be represented using two-dimensional discrete Fourier transform

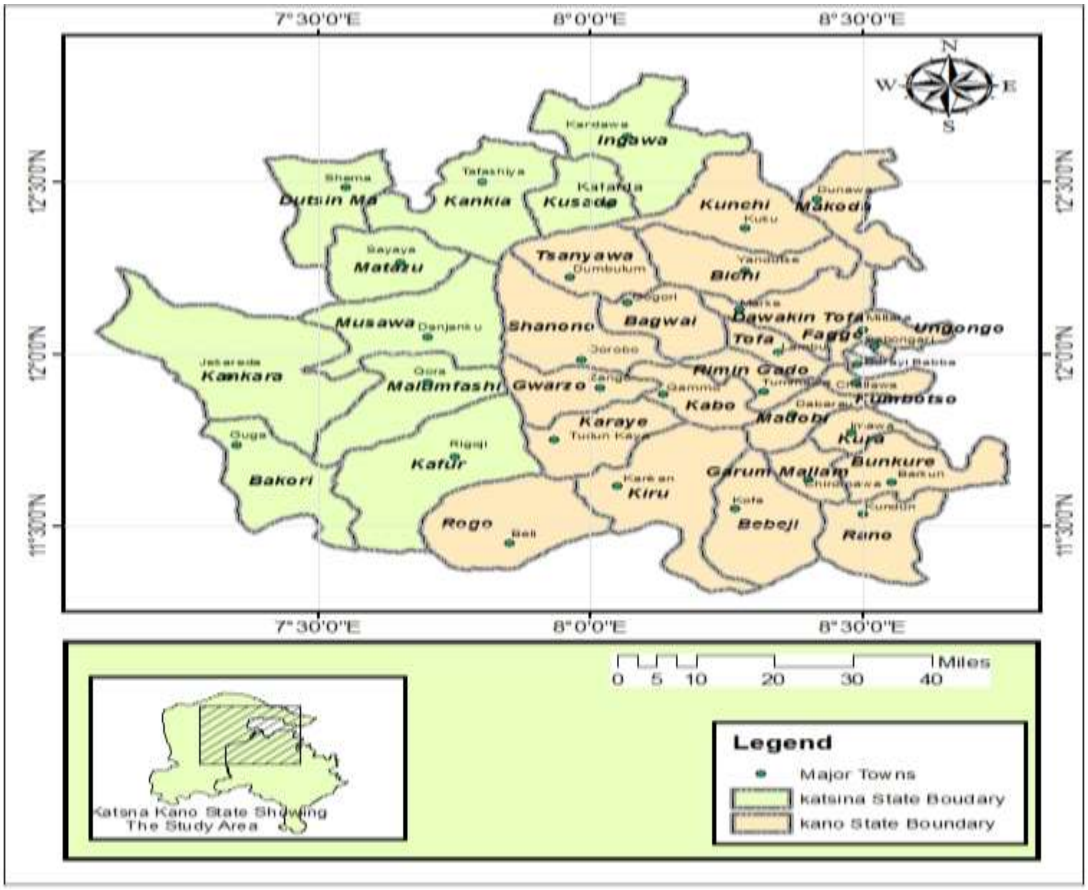

Figure 1. Administrative Map of the Study Area (Source: Cartography Lab, Bayero University, Kano, 2018).

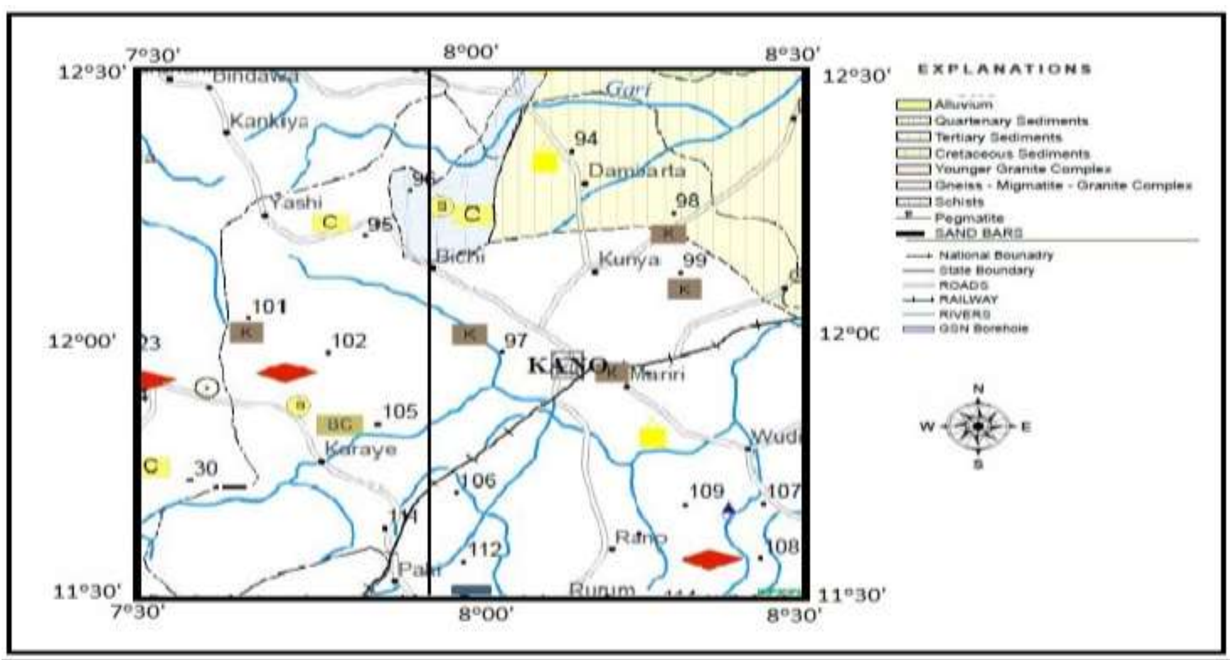

Figure 2. Geological Map of the Study area (Adapted from Mineral Resource Map by Geological Survey of Nigeria Agency, 2006).

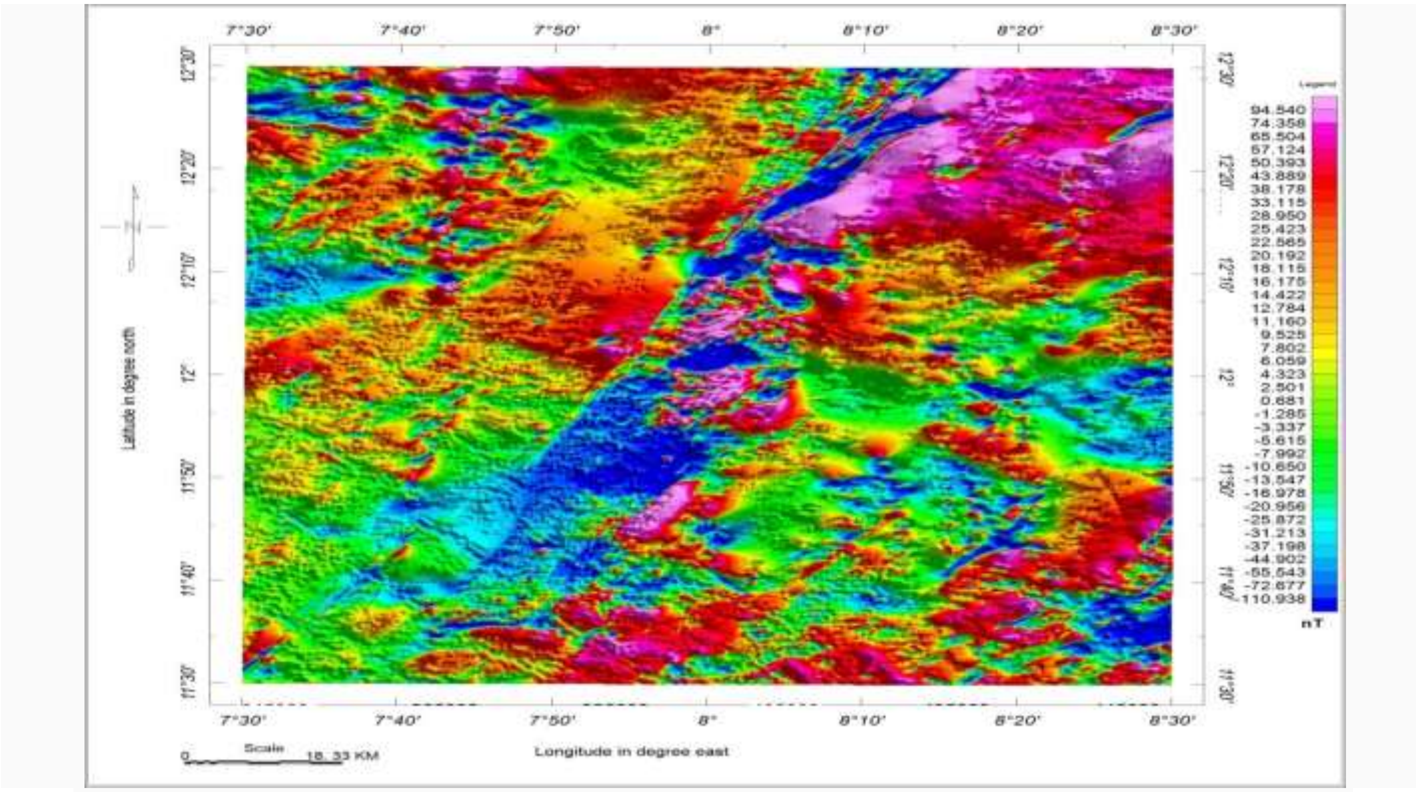

Figure 3. Total Magnetic Intensity (TMI) Map.

(DFT) given by equation 1

$$F(k,l) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n) exp\left\{-j2\pi\left[\left({}^{mk}/_{M}\right)+\left({}^{nl}/_{N}\right)\right]\right\} \quad (1)$$

and the inverse transform is

$$f(m,n) = \frac{1}{MN}\sum_{k=0}^{M-1}\sum_{l=0}^{N-1} F(k,l)\, exp\left\{+j2\pi\left[\left({}^{mk}/_{M}\right)+\left({}^{nl}/_{N}\right)\right]\right\} \quad (2)$$

$0 \leq k \leq M-1$ and $0 \leq l \leq N-1$. Where $f(m,n)$ is the observed field data, k and l are called frequency numbers, M and N represent total number of data points in x and y directions respectively while m and n are the positions of each data point in x and y directions respectively and j is $\sqrt{-1}$.

In this study, we computed the Fourier transform of the observed field with M and N being 1,217,640 each, multiplied the transformed field by the desired filter equation and computed the inverse Fourier transform. This computation was done using Fast Fourier Transform (FFT) Algorithm package available on Oasis Montaj Software.

Reduction to pole/equator (RTP/RTE)

Magnetic data, unlike gravity data, are often difficult to interpret because anomalies do not take place at the apex of the disturbing bodies. This is due to the inclination of the magnetizing vector. A transformation, called 'reduction to pole' developed by Baranov (1957), is often carried out whereby the anomaly is transformed to one which would be obtained if the causative body is taken to the pole. At the pole, the magnetizing vector has an inclination of 90° and so, the anomaly is located symmetrically above the body.

However, RTP operator is highly unstable if the transformation is from low latitude, as it is the case in this study. Jain (1988), following the formulation of Gunn (1975), gave the equation for the reduction of magnetic data from low latitudes. This is called reduction to the equator operator O_E and it is given in Equation 3.

$$O_E = -(lu+mv)^2\left[\{n^2(u^2+v^2)-(lu+mv)^2\}+2jn(u^2+v^2)^{1/2}(lu+mv)\right]\left[(lu+mv)^2+n^2(u^2+v^2)\right]^2 \quad (3)$$

Where, l, m, n are direction cosines of the earth's field vector, u and v are wave numbers in x and y directions respectively and j is $\sqrt{-1}$. The wavenumbers u and v are related to frequency numbers k and l by $u = 2\pi k/M$ and $v = 2\pi l/M$. The direction cosines are obtained from each component of the earth's field (F_x, F_y, F_z) related to the angle of inclination i and declination d by (Telford et al, 1990) $H = F\cos i$, $F_x = H\cos d$, $F_y = H\sin d$, $F_z = F\sin i$. Where, H represents the total horizontal components.

So, we computed the FT of the observed field, multiplied the result by O_E and then, computed the inverse FT to obtain the magnetic field reduced to equator. The RTE map is shown in Figure 4.

First and second vertical derivatives (FVD and SVD)

Derivatives are frequently used in potential field studies for isolating anomalies (Telford et al., 1990). Vertical derivative enhances shallow sources, suppressing deeper ones and gives a better resolution of closely spaced sources (Reeves, 2005). The principle of vertical derivative for anomaly isolation lies on the fact that

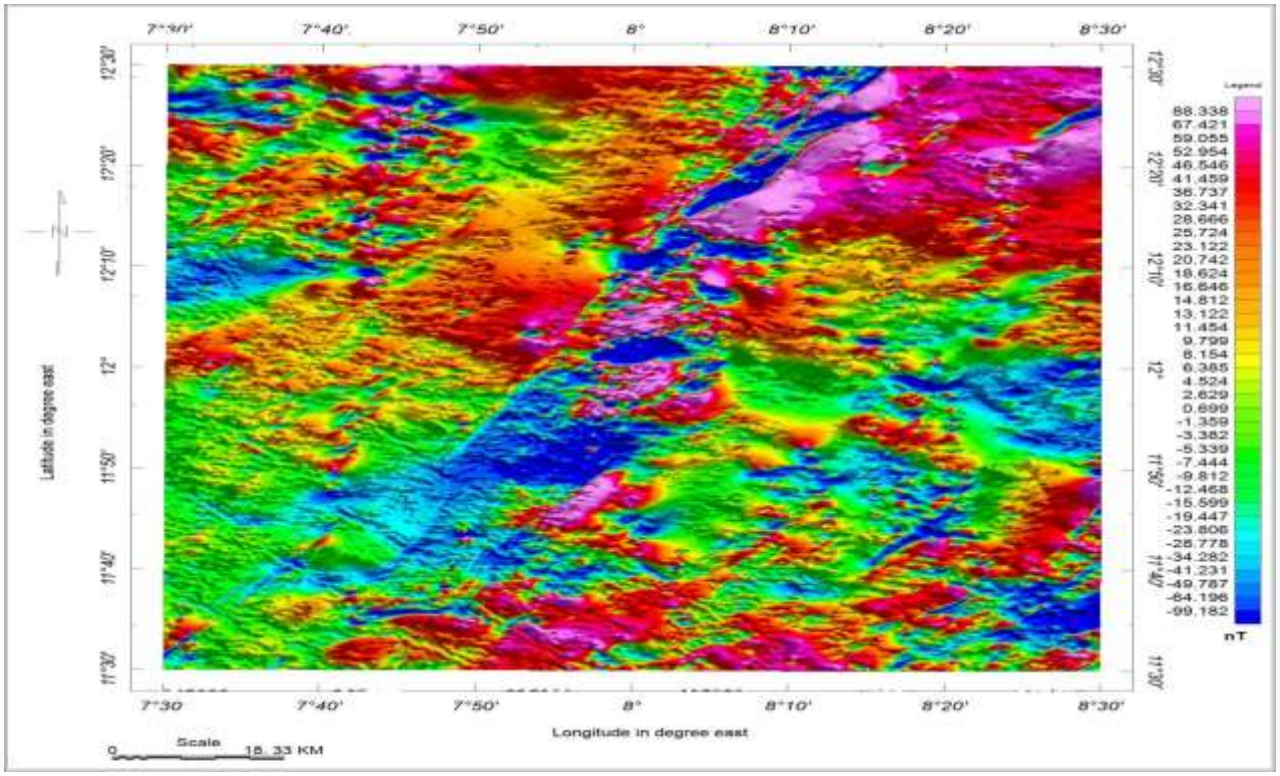

Figure 4. TMI Map reduced to equator.

magnetic field $F \propto 1/r^2$, r being distance. So, first and second derivatives vary as the inverse of the third and fourth powers respectively. SVD maps are of much use in approximately delineating the boundaries of the bodies causing magnetic anomalies (Bhattacharyya, 1965). These boundaries are called lineaments.

In wavenumber domain, the equation for the filter to produce nth derivative is (Naidu and Mathew, 1998),

$$A(u,v) = s^n \tag{4}$$

Where, A is magnetic field, $s = (u^2 + v^2)^{1/2}$ while u and v remain as defined before.

Again, we multiplied first and second vertical derivative filters by the computed FT of the observed field in Equation 1 and thereafter, computed the inverse FT to obtain the first and second vertical derivatives of the observed field. Figure 6 is the FVD and SVD maps.

The lineaments from FVD and SVD were automatically traced out using the CET module available on Oasis Montaj Software. The CET module was developed by the Center for Exploration Targeting in the University of Western Australia to provide automated lineament detection of gridded data (CET 2018).

RESULTS AND DISCUSSION

Figures 3 and 4 show the TMI and TMI-RTE maps respectively. By mere observation, there exists a negligible difference between the two maps due to small angle of inclination recorded generally in the study area (average of 1.9). It is evident in the TMI-RTE map that the area is marked by both high and low magnetic signatures, which could be attributed to factors such as variation in depth, difference in lithology, difference in magnetic susceptibility etc. The anomalies range from -99.182 nT to 88.338 nT. Short wavelength anomalies recorded indicate that the area is generally characterized basement complex rocks. The positively high anomalies are concentrated around the north-eastern parts of the area (Makoda, Kunchi and Bichi) with quartzite and schist being the major rock types. Some positively high anomalies were also found around the north western part (Kankia) of the study area. The rock type here is majorly biotite granite. However, low signatures are recorded in different locations of the area with the lowest around the central region with major trend in the NE-SW directions.

A further enhancement of the short wavelength trends in the data set is achieved in the first and second vertical derivative (FVD and SVD respectively) maps as shown in Figures 5a and b. A system of NE-SW trending negative anomalies which are rimmed by positive anomalies is observed. The lineament map (Figure 6) from the CET clearly shows the lineaments with a major trending of NE-SW and minor trending of E-W directions. These lineaments, depicting faults, fractures and contacts represents veins of possible mineralization.

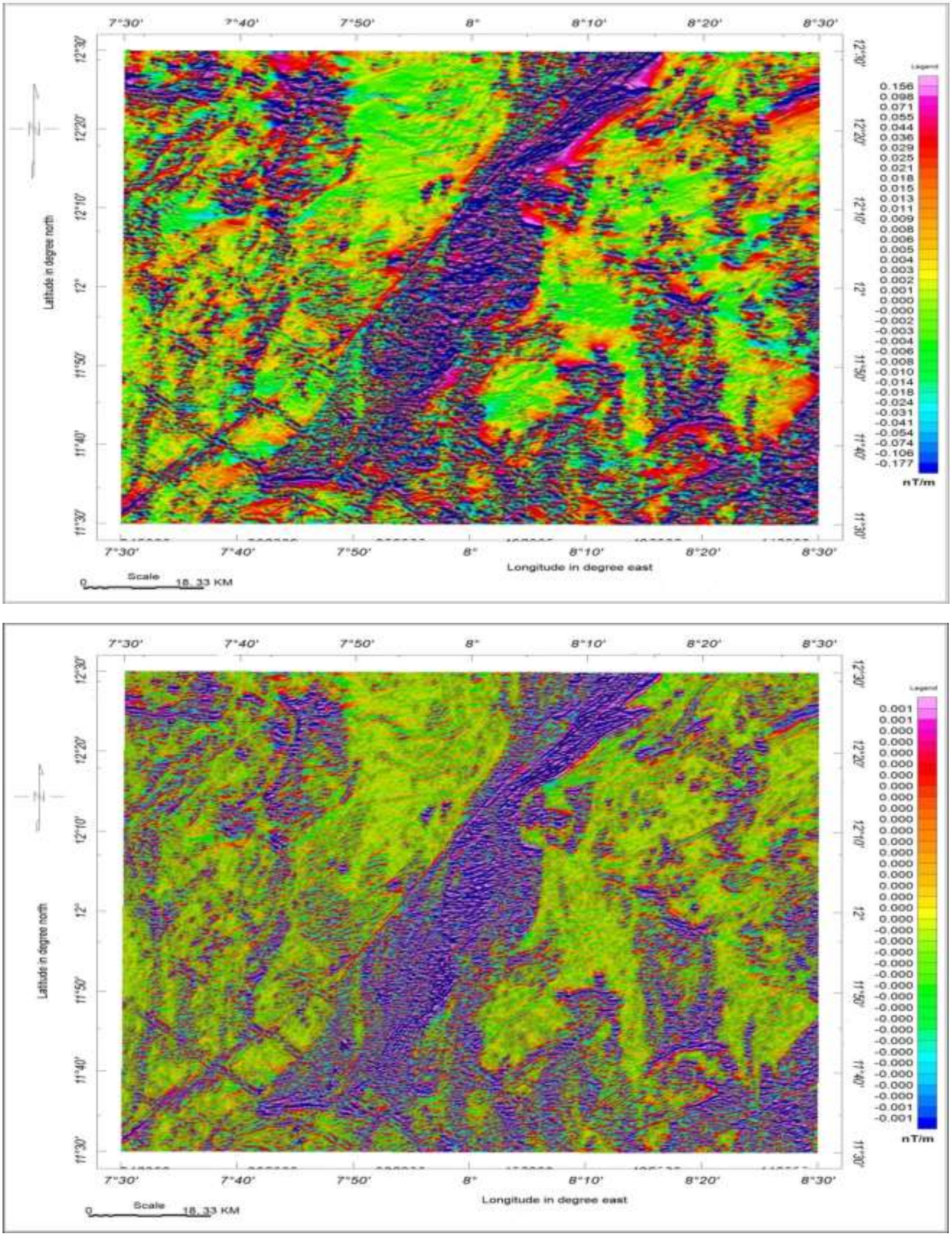

Figure 5. (a) First vertical derivative map. (b) Second Vertical Derivative Map.

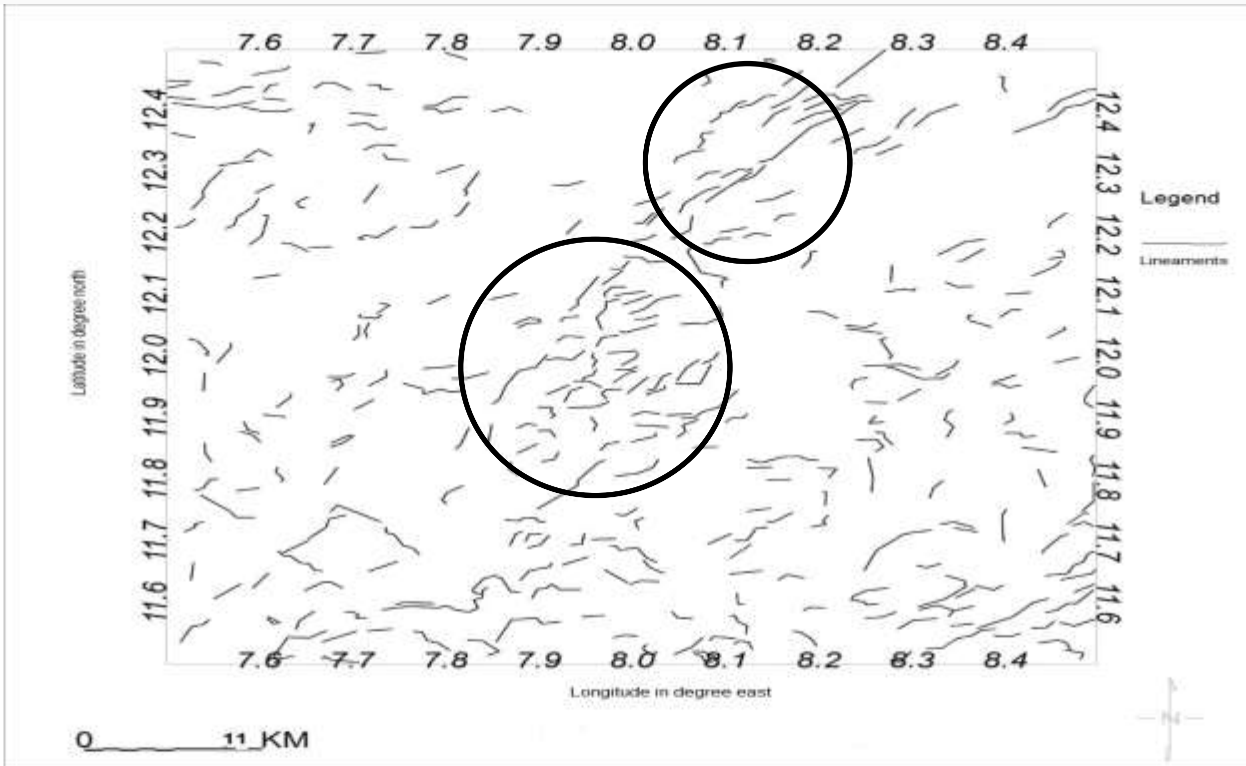

Figure 6. Lineament Map showing the Locations of Dominating Trend in Circles.

Table 1. The locations of the Major Lineament.

S/N	East Longitude	North Latitude
1	8° 03′ – 8° 15′	12° 20′ – 12°30′
2	7° 59′ – 8° 09′	12° 12′ – 12° 19′
3	7° 53′ – 8° 07′	11° 59′ – 12 °12′
4	7° 49′ – 8° 05′	11° 52′ – 11 ° 59′
5	7° 49′ – 8° 01′	11° 42′ – 11° 52′
6	7° 43′ – 8° 55′	11° 33′ – 11° 42′

Table 1 shows the locations of the Major Lineament.

The observed lineaments are in agreement with Muhammad (1998) who also obtained NE-SW and E-W trending in his aeromagnetic studies of southern parts of Kano; they are also in agreement with Adetona (2018) who observed similar trends in eastern parts of lower Benue trough. The lineaments could be traced to the shear stress created when the American plate was separated from the African plate (Ajakaiye et al., 1991) during the plate tectonics processes.

Conclusion

A reconnaissance study to delineate potential mineral zones in the Schist belt areas of Kano state has been carried out using airborne magnetic data acquired from Nigerian Geological Survey Agency.

Due to the obliquity of the magnetizing vector, a characteristic that complicates interpretation of magnetic data, the data were first reduced to the equator before subjecting them to regional/residual separation and vertical derivatives.

Short wavelength anomalies ranging from -99.182 to 88.338 nT were recorded in the study area indicating that the area is characterized by crystalline basement complex rock. These rocks include biotite and quartzite.

First and second vertical derivatives were carried out since they give a better resolution of closely spaced sources. Lineaments (depicting faults, fractures and contacts) which represent veins of possible mineralization exist in the study area. The trend of these lineaments is in the NE-SW and E-W directions with the NE-SW trend dominating.

Location with high mineral favorability is bounded within longitudes 7° 51' E to 8° 12' E and latitudes 11° 46' N to 12° 30' N in the NE – SW directions. The trend cuts through Gwarzo, Shanono, Bagwai, Tsanyawa, Bichi and Kunchi.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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