Delineation of the Subsurface Geological Structures over Shani Basement and Environs, North-East Nigeria, Using Aeromagnetic Data

Bello Sani and Hassan U. Msheliza

Physics Department College of Education Waka – Biu , Borno State, Nigeria

Abstract: - **Qualitative analysis of aeromagnetic data over Shani and its environs had been carried out with the aim of delineating mineral potential zone. The study area is bounded by 9° 30′ N and 10° 30′ N, and longitudes 11° 30′ E and 12° 30′ E. N with an estimated total area of 12,100 km^2. Different enhancement techniques were used to filter the short wavelength anomalies which could give preliminary information about the magnetic minerals present in the study area. The total magnetic intensity map shows variation of both highs and lows magnetic signature ranges from – 31.9.2 nT to 220.8 nT and -29.5 nT to 213.4 nT after the removal of IGRF value of 33,000 nT; the highs which is basement dominates the north- and north-east part of the study area which corresponds to Wuyo, Walama and part of Shelleng; these are areas with promising minerals of economic potentials like, Uranium, porphyritic granite etc. The low magnetic values on the other hand, which is made up of sediment deposition also dominates the southern part of the study area, this area corresponds to southern part of Wuyo, Bargu, Kire and Shelleng and Guyuk host some industrial minerals like limestone, Clay, glass Sands, gypsum and Coal. The greenish part of the study area indicates alluvium deposition. The filters used are vertical derivatives, and horizontal derivative. The first and second vertical derivatives; shows structures like lineament that could be the host to minerals present in the study area and it trends NE-SW. The horizontal derivative map shows that magnetic amplitude highs could be found at the northern end with most lineaments delineated also conform to other filter used which could be used to mapped shallow basement structures and mineral exploration targets. Lineament map obtained from CET shows linear structures that trend in the NE-SW and E-W directions these could be interpreted as veins that are host for minerals within the area, they are predominant around Wuyo and Shani in Borno State and Shelleng in Adamawa State The results of these filters agreed largely and since most magnetic minerals are structural controls, it is expected that those lineaments identified, most especially at the northern and north east portions, could play host to those minerals aforementioned.**

Keywords: **Aeromagnetic, Shani, Derivatives, CET and Geological.**

I. INTRODUCTION

The subsurface structure of the earth crust at point is conceals with lot of different natural resources which function of geological time that when discovered and harnessed, could be of economic and scientific importance. Different economic minerals such as, solid minerals, oil, gas, groundwater and so on lie beneath the earth crust and the presence and magnitude of these resources can be revealed by geophysical investigations of the subsurface geologic structures in the area. As this will create a productive environment for business opportunities, boast the nation's economy and provide raw materials for industrial uses which might in turn reduce the level of unemployment thereby eradicating poverty in Nigeria. Several geophysical methods exist and for each, there exist physical property to which the method is sensitive. The type of physical property to which a method responds clearly determines its range of application. Several geophysical works have been carried out in different geological formations across the globe using gravity, magnetic, seismic, electrical, and other geophysical methods.

Exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria. Nigeria is endowed with abundant mineral resources, which have contributed immensely to the national wealth with associated socioeconomic benefits. Mineral resources are of important source of wealth for a nation but before they are harnessed, they have to pass through the stages of exploration, mining and processing (Ajakaiye *et al.*, 1985 and Adekoya, 2003).

Magnetic method of geophysical prospecting is very vital in investigating subsurface geology and identifying anomaly resulting from the magnetic properties of the underlying rocks. It is found to be very successful in delineating various subsurface formations due to relatively high susceptibility contrast between basement rock and sedimentary unit (Emujakporue *et al*., 2017). Several works were carried out for the purpose of delineating basement structural pattern and topology using aeromagnetic data (Osinowo *et al*., 2013; Emujakporue *et al*., 2017 etc). Information about subsurface geometry, depth, thickness and lateral extent of the basement is very crucial for accurate characterization of certain target of a given formation.

Location and Geology of the Area

The area of study is the Shani area of Borno State, north eastern part of Nigeria. The area is located between geographic latitudes 9° 58′ 12″ N and 10° 37′ 11″ N, and longitudes 11° 38′ 59″ E and 12° 38′ 24″ E. It is part of the Precambrian Basement Complex of northeast Nigeria, called Hawal massif.

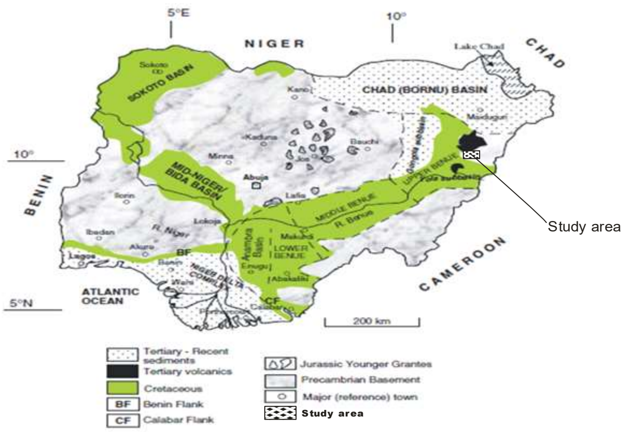

Figure 1 Geology map of Nigeria showing study area

The area is bounded to the south by the Cretaceous E-W trending arm of the Benue Trough (Yola Rift), to the west by the N- trending arm (Gongola Basin). Northwards it is bounded by the Chad Basin of Quarternary age and basalts rocks of Biu plateau. The basement extends into the neigbouring Cameroun Republic. The geology of the area is made up of the Precambrian basement complex rocks which are considered to be undifferentiated basement complex (McCurry 1979 and Bassey *et al.*, 1999), mainly gneisses, migmatite and granites outcropping in different parts of the study area which include, Garkida, Shani, Zumo, Chibok and even in Girei. Cretaceous sediment belonging to Bima sandstone and Yolde formation outcrops at the northern part of the study area (Figure 2).

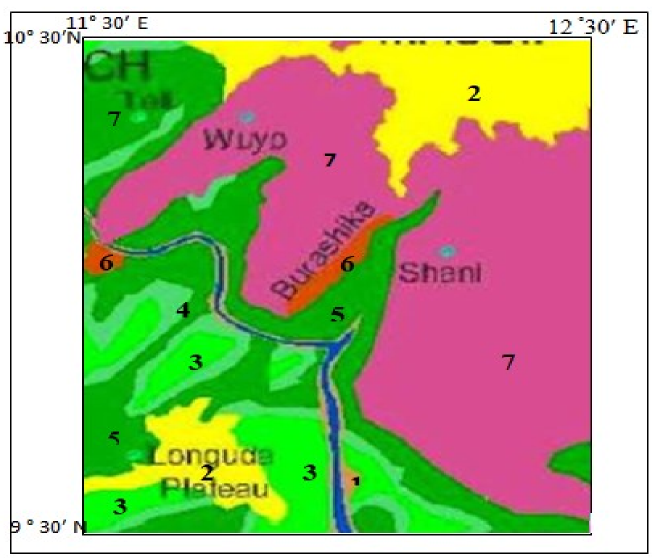

Figure 2: Geology of the study area: 1, quaternary alluvium: 2, tertiary to recent volcanism: 3, pindiga formation: 4, yolde formation: 5, Bima sandstone: 6, burashika group (Mesozoic volcanism): 7, granitoids precambrian (modified after Maurin *et al*., 1985).

The tertiary to recent Volcanics (Biu basalt) are third most widespread rocks in the study area belonging to northern arm of Cameroon volcanic line. The Volcanics vary in composition from basalt to trachyte and rhyolite.

The Pan-African older granites are the second wide-spread group of rocks in the study area. They intruded into the Gneiss-migmatite complex. The gneiss-migmatite complex is the most widespread and occupies more than half of the area and is the oldest rock here. They are heterogeneous rock group, which is composed gneiss migmatite of various origin and series of metamorphosed basic and ultra basic rocks (Grant, 1971).

The Tertiary- Recent volcanic rocks in the study area consist of the Basalts, Trachyte, Rhyolite, and newer basalts of eastern arm of Cameroon volcanic line.

II. MATERIALS AND METHOD

Four aeromagnetic maps consist of Wuyo, Shani, Guyuk and Shelleng were acquired from NGSA and interpreted the total magnetic intensity (TMI) grids. The aeromagnetic survey was conducted by Fugro Airborne Surveys, on behalf of the Nigerian Geological Survey Agency (NGSA) between 2003 and 2009. The main purpose of these surveys has been to assist in mineral and groundwater development through improved geological mapping. The magnetometer system used for the aeromagnetic data survey is 3 scintrex CS-2 Cesium vapour. The output from the magnetometer was sampled at 0.2 s to a resolution of 0.01 nT with noise envelope of 0.1 nT The geomagnetic gradient was removed from the data using the International geomagnetic Reference Field (IGRF). The actual magnetic intensity value of 33,000 nT which was reduced for handling must be added to the value of magnetic intensity at any point so as to get the actual value of the magnetic intensity of the study area (Figure 3). The aeromagnetic data of the study area was process for enhancement using the Geosoft package software, Oasis montaj.

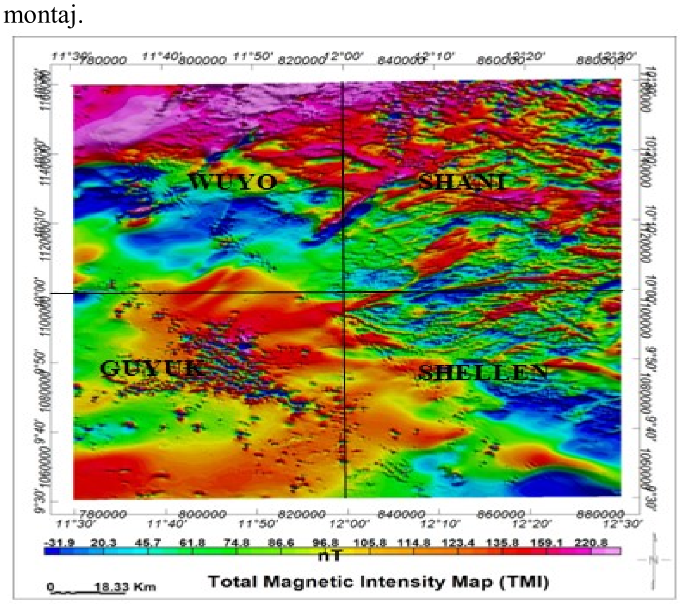

Figure 3: Total Magnetic Intensity Map of the Study Area.

Thus, the magnetic feature that can be defined by the digitised data has a narrowest width of 3.0 km. This gridding system was supported by previous studies with crustal magnetic anomalies (Ajakaiye *et al.,* (1985), Udensi (2001) and Udensi and Osazuwa (2002), which shows that the spacing is suitable for the portrayal and interpretation of magnetic anomalies arising from regional crustal structures. The magnetic values found on Figure. 5 trend northeast-southwest and the lines observed indicate faults. Figures 4 and 6 are the total magnetic intensity map reduced to equator and the residual magnetic map of the study area respectively.

Reduction to Magnetic Equator (RTE)

The Reduction to Magnetic Equator (RTE) filter was used to produce the RTE_TMI image (Figure 4) in order to centre structures and anomalous bodies over their exact positions. To produce anomalies depend on the inclination and declination of the body's magnetization, inclination, and declination of the local earth's field and orientation of the body with respect to the magnetic north (Baranov, 1957). The RTE_TMI gridded data (Figure 4) was adopted as our new processed data for other images to be produced.

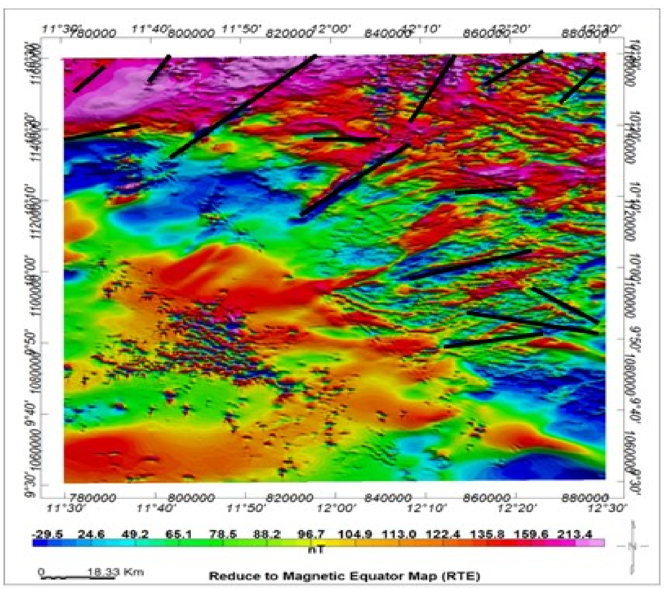

Figure 4: Total Magnetic Intensity Map_RTE of the Study Area.

$$L(\theta)=\frac{[\sin(I)-i.\cos(I).\cos(D-\theta)]^2 * \left(-\cos^2(D-\theta)\right)}{\left[\sin^2(I_a)+\cos^2(I_a).\cos^2(D-\theta)\right] * \left[\sin 2(I)+\cos^2(I).\cos^2(D-\theta)\right]} \quad 1$$

If $(|I_a|\langle|I|)$, $I_a = I$

Where $L(\theta)$ is the TMI reduction to equator (RTE), I is the geomagnetic inclination, I_a is the inclination for amplitude correction and D is the geomagnetic declination.

Vertical derivatives

Derivatives tend to sharpen the edges of anomalies and enhance shallow features. The derivative maps are much more responsive to local influence than broad or regional effects and therefore tend to give sharper pictures than the map of the total field intensity. Thus the smaller anomalies are more readily apparent in cases of long regional disturbances. In fact, the first derivatives (both horizontal and vertical) are used to delineate high frequency features more clearly where they are shadowed by large amplitude, low frequency anomalies. The derivatives in the frequency domain are represented by the following equation:

$$L(r)=r^n \quad 2$$

Where n is the order of differentiation, and r is the wavenumber (radians/ground unit).

The first vertical derivative (FVD) is used to delineate high frequency features more clearly where they are shadowed by large amplitude, low frequency anomalies.

The second vertical derivative is the vertical gradient of the first vertical derivative. First vertical derivative data have become an important tool in magnetic interpretations. Second vertical derivative has even more resolving power than the first vertical derivative, but its application requires high quality data because of its greater enhancement of noise (Fig. 4). It was shown by Hood and McClure (1965) that second vertical derivative is zero and rapidly changes sign at a point vertically over a contact. In magnetic data interpretation, second vertical derivatives are used to delineate the plain-view boundaries of intra-basement anomaly sources and are also found to be effective for enhancement of magnetic anomalies (Sharma, 2002).The zero-point (of the second vertical derivative) of the image map indicates the spatial locations of the magnetic source edges which in effect outline anomalous areas. Theoretically, from the Laplace's equation, if H is a potential so $\nabla^2 H$ is equal to 0 (Elkins, 1951).

$$\frac{\partial^2(\Delta H)}{\partial z^2}=-\frac{\partial^2(\Delta H)}{\partial x^2}+\frac{\partial^2(\Delta H)}{\partial y^2} \quad 3$$

Horizontal Derivative

Horizontal derivative of the potential field is a measure of the horizontal derivative tendency of the magnetic field (Cooper, 2009). This process involves a phase transformation as well as an enhancement of high frequencies. Horizontal gradient method is least susceptible to noise in the data. The phase transformation generally has the result of producing anomaly peaks approximately located over the edges of wide bodies and the enhancement of the high frequencies sharpens these peaks to increase the definition of the body edges. This quality of horizontal derivatives is used to map body outlines. (Grauch and Cordell, 1987 and Elkins, 1951). The mathematical expression of this filter is written as:

$L(U) = (ui)^n$ (Horizontal derivative in x direction) 4

$L(V) = (vi)^n$ (Horizontal derivative in y direction) 5

The resultant horizontal derivative filter can then be mathematically expressed as:

$$L(u,v) = \sqrt[n]{(ui)^n + (vi)^n} \qquad 6$$

Where n = order of differentiation, u = x components of wave number, v = y components of wave number and $i = \sqrt{-1}$. Horizontal gradient of the TMI was carried out in order to identify contact areas (lateral variation), infer faulted areas, and enhance the high frequency, short wavelength anomalies.

III. RESULTS AND DISCUSSION

The qualitative interpretation is done by visual assessment of the Total Magnetic Intensity reduce to equator (TMI), vertical and horizontal derivatives maps Biswas 2016, and Biswas et al., 2017. The maps show that the RTE map show no significant modification of the original magnetic anomalies on total magnetic intensity (TMI) map (Figure 2a), show both positive and negative anomalies. The amplitude of anomalies range from -29.5 nT to 213.4 nT (Figure 4) which were consistent in pattern, trend and amplitude of the total magnetic anomalies within – 31.9 nT to 220.8 nT shows that the data has been well filtered. The amplitude of a magnetic anomaly is directly proportional to the magnetization which depends on magnetic susceptibility if the rocks (Gunn et al., 1997). The north western, north east and the south west sections of the RTE map is characterized by positive (high) magnetic intensity value range between 96.7 nT to 213.4 nT, the north west, north central and south east regions of the study area host intermediate magnetic value range within 49.2 to 96.7 nT while the north west and south east area have negative (low) anomalies range between - 29.5 nT to 49.2 nT.

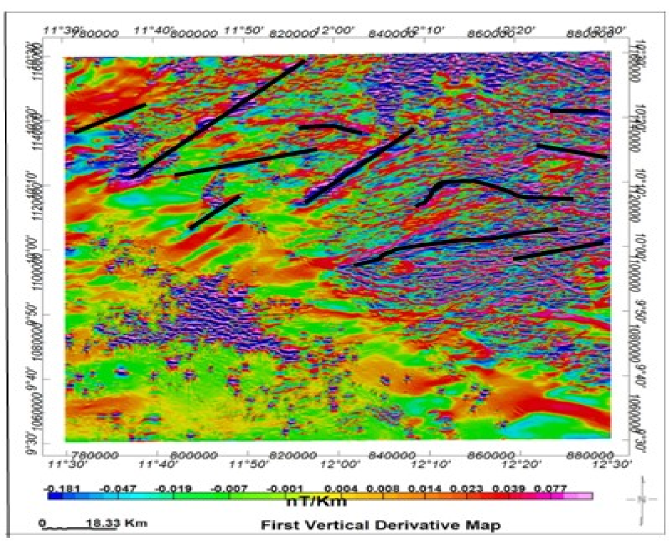

Figure 5: First vertical derivative of the Study Area.

High magnetic values were observed which may be attributed to the presence of moderately high magnetic rocks (Granite, Migmatite Gneiss complex, quartzite). Negative magnetic values were observed in the area which may be due to the present of low magnetic rocks (e.g sandstone, schist, weathered sediments) in the area, that are noted for low magnetic signatures. Magnetic highs mostly trend in the NE-SW and E-W directions. The high magnetic anomalies correspond to regions with high magnetite content which in the study area is the crystalline basement rocks of north east Nigeria. Low magnetic anomaly characterized regions with relatively low magnetite content.

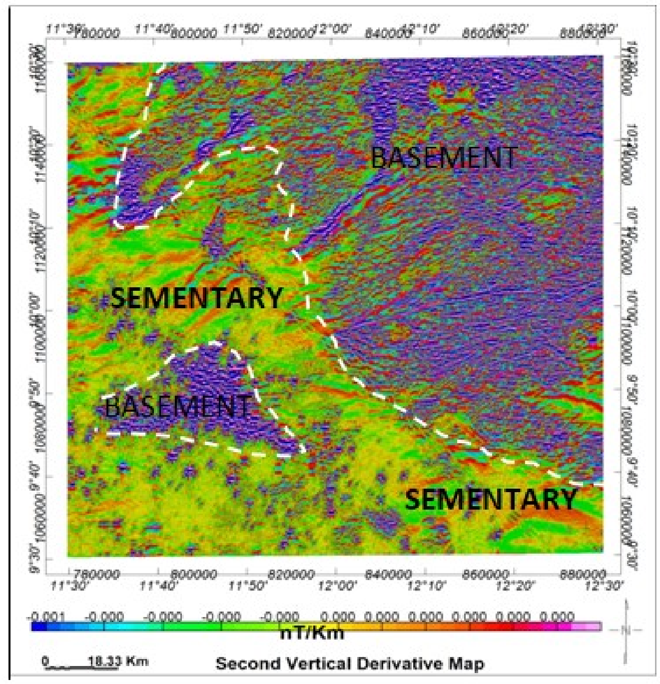

Figure 6: Second vertical derivative of the Study Area.

The first vertical derivative (FVD) map (Figure 5) clearly revealed the sharpened edges of anomalies and shallow features, trending NE-SW and few NW – SE and E-W. Magnetic intrusions having high magnetic values and narrow magnetic anomalies are evenly distributed within the map. Also the FVD map reveals shallow geologic features with less noise and which are prominent at the north west, north east, south west and south east part of the study area. Structural variations are similar to the structures observed on the TMI_RTE map.

Figure 5 clearly defines the basement and sedimentary section of the area; the basements occupy the northern part while the sedimentary region occupies the southern part of the study area. It reveals the types of structures like lineament present in the study area. One of the important applications of first vertical derivative is finding magnetic lineament and determine the border between lithological units more precisely. The major magnetic features (lineament) found on the study area aligned northeast-southwest at the northern part of the study area. Since minerals are structurally controlled, the structures found in the study area might host the minerals present in the study area.

To correlate FVD with geologic map, The FVD zero contour map was superimposed on the geologic map of the study area shown in Figure 6. The high density of contours at SE and NE parts of the study area, correspond to Quartz feldspathic granulite and gneiss and also migmatitic Gneiss complex respectively. The NE-SW and E-W trend of the anomalies in the image map of the FVD superimposed on geologic map also correlated with the trend of the geologic map.

The second vertical derivative (SVD) map (Figure 6), like the FVD map enhanced shallow features with respect to deep seated long wavelength regional effect though with the SVD map consisting of noise which makes the anomalies inconspicuous. Like the FVD map, magnetic intrusive bodies are distributed within the map.

It is used for resolution of anomalies in magnetic field to aid geological mapping; for delineation of geological discontinuities in the subsurface. The trend of structures found on the FVD map agrees with the trending of the structures (lineaments) found on the SVD map. The SVD map shows the trend of structures like faults in the area. Since minerals are usually structurally control, the trend of faults on the second vertical derivative map may indicate the alignment of minerals that could be found in the study area. The major structures delineated on the second vertical derivative map trends both northeast-southwest and northwest-southeast.

The horizontal derivative of the field shown in Figure 7 enables us to locate and map the major anomalies within the study area as it is illustrated in the degree of distortion to the magnetic signatures. Rock type at the north western through north east portions of the study area is identified as undifferentiated Older granite, mainly porphyritic granite granitized gneiss with porphyroblastic granite.

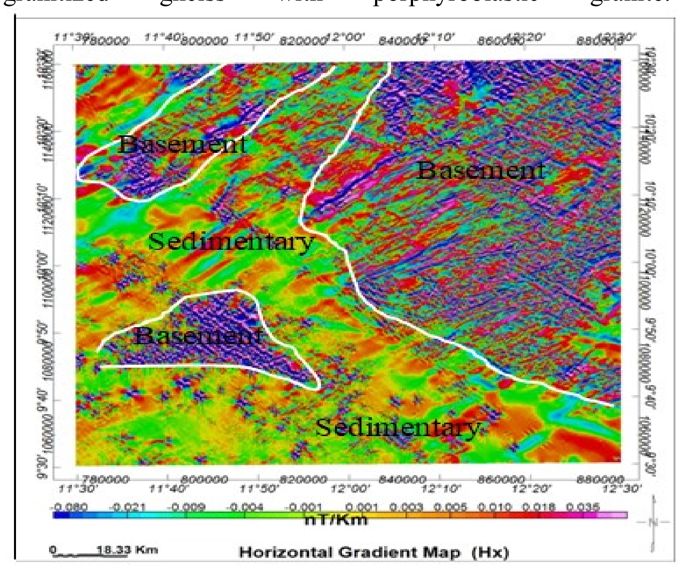

Figure 7: Horizontal derivative of the Study Area.

Rock type at the Northern portion is identified as Biotite gneiss. False bima, coal, and sandstone are the lithologic units at the surface within the sedimentary basin. River Alluvium deposition identified along the river channel above and below the river Gongola. Undifferentiated granite mainly porphyritic granite granitized gneiss with porphyroblastic granite covers Wuyo and Shani in Borno State. Part of Wuyo in the south, Shalleng and Bargu are covered by false bedded sandstone of Bima Formation.

The horizontal derivative map (Figure 7) attenuates long wavelength and provides contact locations that are continuous and thin and linear when compared to the TMI_RTE, and the vertical derivatives maps (Ndougsa-Mbarga *et al.,* 2012). The horizontal gradient values ranges from 0.080 to 0.035 nT/m and shows a large contrast in magnetic susceptibility along geologic contacts. The HD map (Figure 7) revealed prominent NE – SW structural trend which is in agreement with the generally known deformation trend the Pan-African older granites in the basement complex rock of Nigeria. The anomalies, trending, correspond to the geological contact zone with little or no magnetic susceptibility like the anomalies in the first and second vertical derivative map.

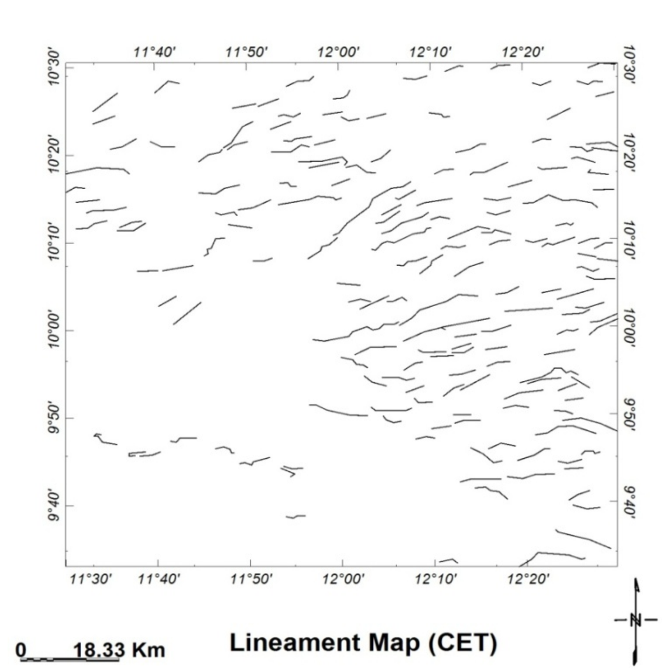

Figure 8: Lineament Map of the Study Area.

From Figure 6, magnetic lineaments within the area of study where automatically extracted using the CET and the result is shown on Figure 8. The result (Figure 8) shows the occurrence of several deep source criss crossing lineaments predominantly trending in the NE-SW direction. This gives further evidence of the extent of deformation that occurred within the area during the Pan African Orogeny. The few NW – SE and E – W lineaments is in agreement with the magnetic anomalies (Figure 4) indicating deformation which could reveal structural features such as faults and fractures.

IV. CONCLUSION

Qualitative analysis of aeromagnetic data of Shani and it's environ was processed, enhanced and interpreted using Oasis Montaj geo-software in order to map geologic structures related to mineral exploration in the area. The IGRF Total Magnetic Intensity data was reduced to the pole so as to reduce the effect of angles of inclination and declination and to remove the effect due to dipolar nature in magnetic data. This operation enabled us to obtain perfect symmetry and to place the magnetic signature directly above the causative body. The result is mapped as shown in Figure 4. The result is further subjected to First, Second and Horizontal Derivative which revealed two main regions, the first showing short wavelength magnetic signatures that are a mixture of both high and low magnetic susceptibility, which is the characteristic features of basement/outcrop and or regions of intrusive bodies at shallow depth.

Interpretation of the first and second vertical derivative maps reveals the major fault systems within the study area, with dominate trend in the NE-SW direction and with few NW-SE and E – W trends. The horizontal derivative map gives better enhanced faults and fractures in the study area. The results from this study shows the presence of minerals of economic potential and the areas where the minerals Figure 8. At the northeastern and northwestern part of area which is made up of basement complex that corresponds to Wuyo, Shani and the northern section of Shelleng host magnetic minerals like Uranium, Gemstone and granites etc. while the southern and to some extent north west portion which is made up of sedimentary rocks that corresponds to Guyuk and southern part of Wuyo and Shelleng, host industrial minerals like limestone, Clay, glass Sands and coal. The results of the filters used in this study agreed largely and since most magnetic minerals are structural controls, it is expected that those lineaments identified, most especially at the northern part, could play host to those minerals aforementioned. These minerals, if harnessed will help in provide a lot of jobs and thereby eradicating poverty in Nigeria.

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