

# **Structural analysis of high resolution aeromagnetic data. A case study of Akko and environs, Gongola basin upper Benue trough Northeastern Nigeria. Implication for mineralization and groundwater potentials.**

## **Abstract**

Magnetic method had proved very effective in the area of subsurface anomaly studies and structural delineation worldwide. Sheet number 151(Akko sheet) of the high resolution digital airborne magnetic data was obtained from the Nigerian Geological Survey Agency (NGSA). Analysis of the data was done using first horizontal and first vertical filters while the residual field was obtained using the polynomial fitting method. Lineaments of the study area were generated from SRTM (shuttle radar thematic mapper) and DEM (digital elevation model) by producing four shaded relief images at solar altitude of 45°, 50°, 60° and 90°. The first horizontal and first vertical derivative filters exhibited magnetic trend consistent with the lineament trend of the study area, which showed major trends in NE-SW and NNW-SSE direction and minor trends along NW-SE.

**Keyword: Airborne magnetic data, Akko, Horizontal derivatives, Lineament, Vertical derivatives,**

## **Introduction**

Magnetic method had proved very effective in the area of subsurface anomaly studies and structural delineation worldwide. The Earth could be thought of as a large and spherical magnet surrounded by a variable magnetic field. Dipole magnet at the center of the Earth with North and South Pole generates the field (Suleiman et al., 2018). Measured magnetic field at a point is from the superimposition of the magnetic field of geological bodies at the point on the Earth's background magnetic field. Thus the Earth's magnetic field varies with location and time, the implication of which is that every subsurface material has characteristic magnetic susceptibility (Revees, 2007). It then means that when aeromagnetic data is well analyzed the anomalies are capable of giving good information about the subsurface structures including lithological formations, mineral deposition, archeological findings etc. (Biswas and Sharma, 2016; Nabighian et al., 2005). Subsurface studies using magnetic survey could be done on land, it could also be marine or air borne. Apart from the fact that it is capable of covering large survey areas within a short time, it also allows data acquisition from inaccessible areas. These make magnetic data analysis very effective and essential in the area of geophysical exploration. Nigeria Geological Survey Agency (NGSA) is the government agency among other things saddled with the responsibilities of acquiring important environmental data in the country. A good number of geophysical survey, which are mostly airborne are being carried out by the agency. For example, exploration for crude oil in the northern part of the country using airborne aeromagnetic survey has been on since 2008.

## **Location and Geology of the Study Area**

The study area, Akko southern Gombe lies between latitudes  $10^{\circ}3'6''\text{N}$  and  $10^{\circ}8'8''\text{N}$ , and longitude  $11^{\circ}17'38''\text{E}$  and  $11^{\circ}24'13''\text{E}$ . Located within the Gongola basin upper Benue trough Nigeria, about 30 km away from Gombe town along the A345 Gombe-Adamawa road, Akko is bounded by Billiri to the south, Kaltungo and Balanga, to the south-east, Kwami to the North, Dukku to the North-west, Yamaltu Deba to the East and by Bara (Bauchi state) to the West (Figure 1). Akko has total area of 2,627 km square and has a population of 337,853 (2006 census). Akko local government consists of six geological units: (i) sandstone, siltstone and shale (ii) sandstone, siltstone, shale, coal and ironstone unit of the Maastrichtian age, located in the Gombe sandstone formation, (iii) shale and minor sandstone of upper Turonian Pindiga formation, (iv) shale sandstone and limestone of the Albian - late Cenomanian age in Yolde formation (v) sandstone, siltstone and shale of Albian to early Cenomanian age in the Bima formation (Ikusemoran et al., 2018). The climate is known with wet season, which run between May and October and dry season that comes up between November and April (Mustapha et al., 2011).

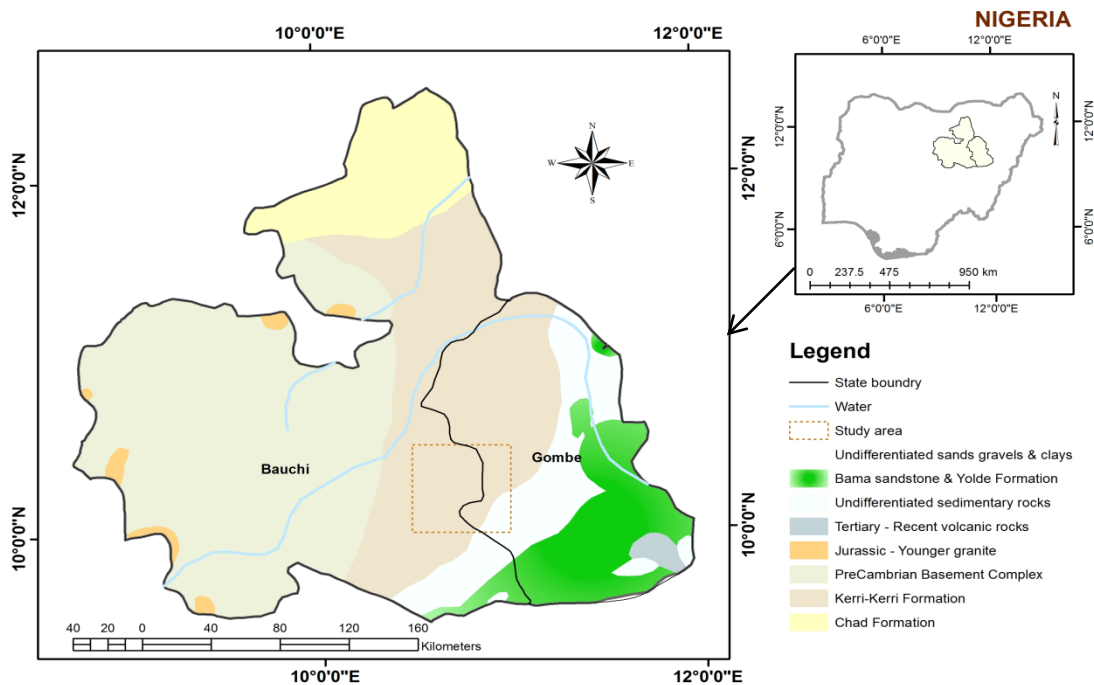


Figure 1: Location and Geological Map of the Study Area

## Materials and Method

Digitized aeromagnetic data obtained from the Nigeria Geological Survey Agency (NGSA) Abuja has been used in this investigation. The data is a part of the data set of aeromagnetic survey acquired by (NGSA), which was aimed at re-invigorating solid mineral sector in Nigeria. The study area (Akko and environs) falls within the sheet designated 151 of the gridded aeromagnetic data of the country acquired by Fugro Airborne Surveys. Series of NW – SE flight lines were defined and with flight line spacing of 500 m and sensor average terrain clearance of 80 m magnetic data were acquired. With the removal of geomagnetic gradient (employing IGRF), the data were produced as digitized data in form of coordinates and intensity (X,Y,Z).

Oasis Montaj (Geosoft) software was used for data processing, analysis and interpretation. Lineaments of the study area were generated from SRTM and DEM by producing four shaded relief images at solar altitude of 45°, 50°, 60° and 90°. Lineament density map was plotted using Arc GIS 10.5 and the related values were calculated and used to generate the rose diagram in Rockworks17.

### **Regional – residual separation**

The main Earth's magnetic field, which is the regional field values were modeled and removed from the total magnetic value (TMI) values. This is to analyze the magnetic effects of the crustal rocks.

**First Horizontal derivative (FHD)** Horizontal derivative is a useful filter in enhancing the edges of magnetic bodies of a potential field (Phillips 2002). The technique detects how much the geomagnetic field data changes with respect to horizontal direction. In form of maximum value of FHD, the changing anomaly shows a sharp characteristic. Thus the anomaly border is well indicated (Rosid and Siregar, 2016). FHD values could be obtained using equation 1.

$$\text{FHD} = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2} \quad (1)$$

where  $\frac{\partial M}{\partial x}$  and  $\frac{\partial M}{\partial y}$  are two horizontal derivatives of the field.

### **First vertical derivative (FVD)**

Vertical derivatives enhance shallow source and suppress deeper ones (Reeves, 2007). Fourier transformed data is multiplied with the filter of the  $n$  power of the wavenumber,  $k$  (i.e.  $k^n$ ) to estimate the first vertical derivative in the frequency domain.

## **RESULTS AND DISCUSSION**

### **Total Magnetic Intensity (TMI)**

The TMI map characteristically comprises of positive and negative magnetic anomalies produced as colorful map with pink down to blue colors representing high and low magnetic intensities. The TMI map of the study area (Figure 2) exhibited anomalies of high and low values ranging between -0.017 and 0.012 nT. The high values (color pink and red) predominantly found in the northwestern and southeastern part of the study area running diagonally along northeast-southwest direction (NE- SW) with an intermediate value (color green) clustering around it. The low values (color blue) are dominant at the center of the study area but also in the (NE- SW) direction. The color green forms a background for the entire study area.

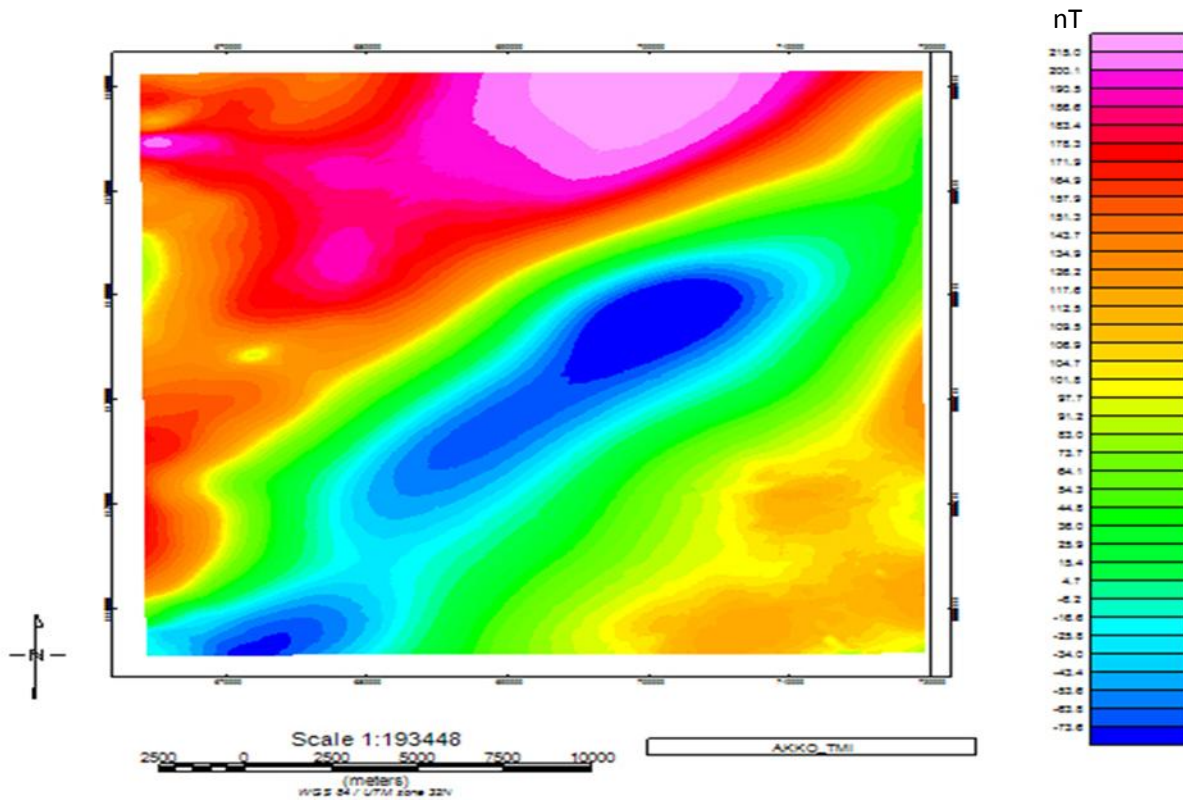


Figure 2: Total magnetic intensity Map of the Study Area.

### Regional -Residual Separation (RRS)

When magnetic residual map is employed, it is capable of revealing detailed subsurface features. For the analysis of the magnetic effects of the crustal rocks in the study area, the regional magnetic field (Earth's internal field) were modeled and subtracted from the TMI values. Multi-regressional analysis was adopted for the modeling of the regional magnetic field as a plane surface. The residual map of the study area reveal areas of high magnetic intensity ranging between 199.4 and 215.0 nT. This is highly dominant in the northwest, southwest and far northeastern region of the study area. Areas with low magnetic intensities between -96.6 and 199.4 nT are predominant along the NE-SW direction and occurs at the middle of the map (Figure 3).

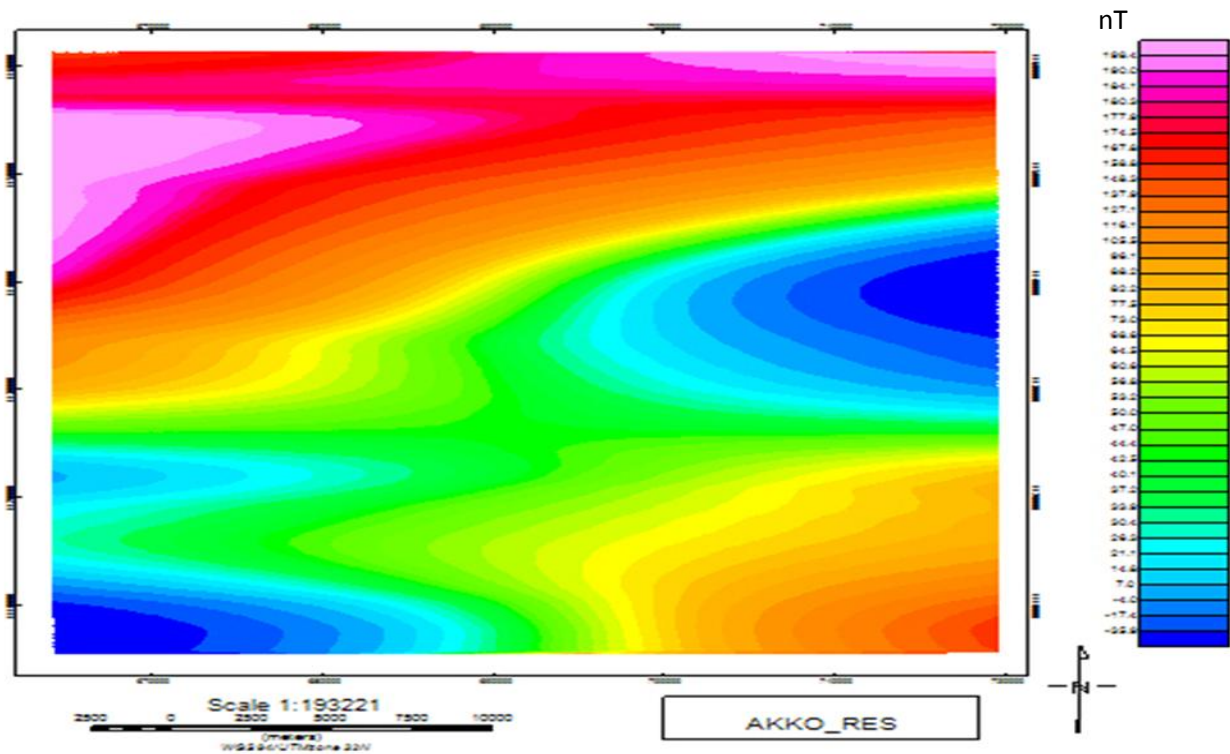


Figure 3: Residual Map of the Study Area

### First Horizontal Derivative (FHD)

The horizontal derivative in X direction exhibits high magnetic intensity values ranged up till 199.0 nT in the entire northern part of the study area. The areas of highs are located northwest and southeast while the low values are dominant in the central and southwestern part of the study area with minimum value of -25.5 nT (Figure 4). The horizontal derivative map demonstrates anomalies of high and low values with dominant NE-SW trend. The dominant long wavelength components with spatial scales of several kilometers are undoubtedly due to deep basement under the basin. The linear structures which frequently present contrasting magnetic signatures that fluctuate significantly from that of the rocks that host them (may be due to recrystallization of existing rock minerals across the fracture or due to infilling of fracture with younger material) were extracted to express the structural framework of the study area, Musa *et al.*, (2021). The horizontal derivatives results give contact locations that are continuous and thin and display major structures in the NE-SW direction as shown in figure 4, it can be widely used to map out the margins of susceptibility differences. It exploits the detail that the horizontal derivative of the magnetic field caused by a tabular body tends to have maximum values over the edges of the anomalous body in case the edges are vertical and well-separated from each other, it is not only less sensitive to the noise in the data, but also robust in exposing shallow magnetic sources. It has high amplitude over the edge of the magnetic source, Musa *et al.*, (2021).

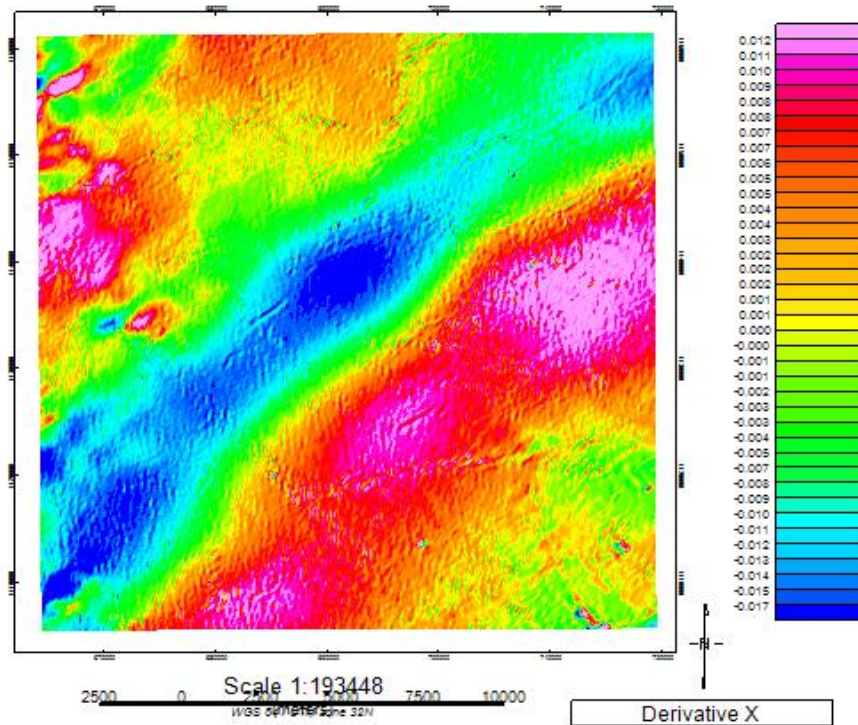


Figure 4: First Horizontal Derivative Map of the Study Area

### First Vertical Derivative (FVD)

The FVD map of the study area is given in Figure 5 where the magnetic intensity values ranges from -0.019 nT to 0.015 nT. Areas with high magnetic intensity values are located in northwest and the northeast-southwest direction of the study area. Whereas the low magnetic intensity values are randomly scattered in the northwest and southeastern part of the study area. The intermediate values are widespread across the entire study area with no dominance noticed. The vertical derivative was first applied to outline edges of magnetic bodies. It is usually applied to the data to focus near-surface geological features and further improve the high wavenumber constituents of the spectrum where the zero values of vertical derivatives of the magnetic field generally correspond to the geological boundaries. It is also applied to the data to further enhance the shallowest geological source and can be calculated either in space or frequency domain. Musa et al., (2021). The enhancement improves anomalies over features and inclines to decrease anomaly complexity, permitting a perfect imaging of a causing structure. The change can be piercing since it will amplify short wavelength noise. The vertical derivative also expresses major structures in the NE-SW direction. Both the horizontal and vertical derivatives maps trend in the NE-SW direction and are related to the pre pan African and pan African orogenic activity.

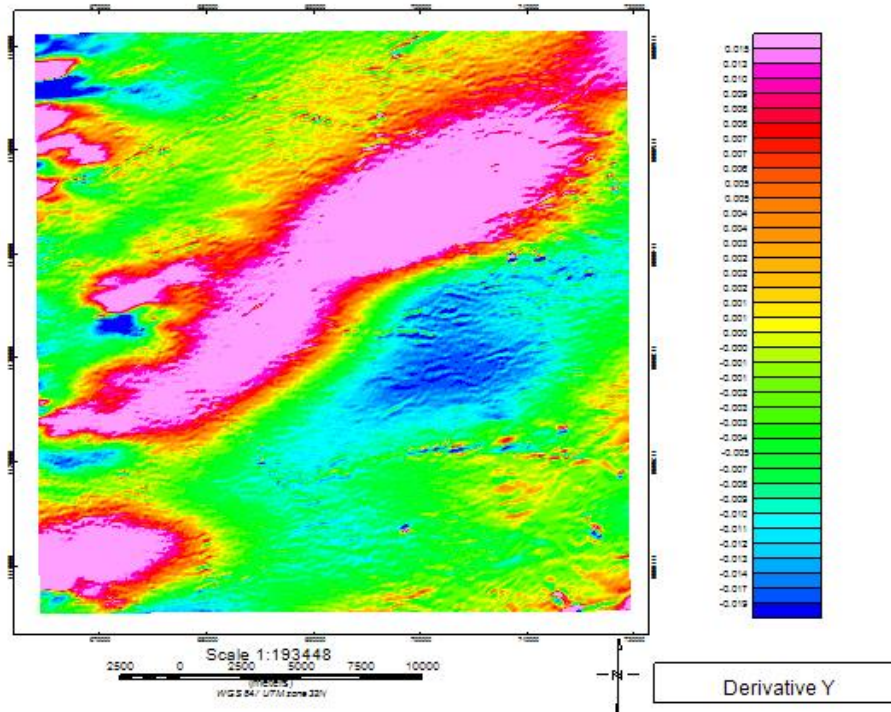


Figure 5: First Vertical Derivative Map of the Study Area

### Lineament Study of the Study area

Lineament mapping of the study area was done and superposed on the FVD map figure 6. Although the lineament trend exhibited various orientations, the two major orientations of the lineaments beneath the surface of the study area as shown in Figure 6 are NW-SE and NE-SW directions. Lineaments in NE-SW direction are noticeably dominant. The NW-SE and NE-SW lineament trends is a good hint about the pre Pan African and Pan African orogenic activities  $650 \pm 150$  Ma (Genik, 1992). The lineament density map and the rose diagram of the study area are shown in Figure 7. There is consistency in the lineament hereby inferred and the previously inferred lineaments in the region (Suleiman et. al., 2018; Raimi *et al.*, 2014; Salau *et al.*, 2016).

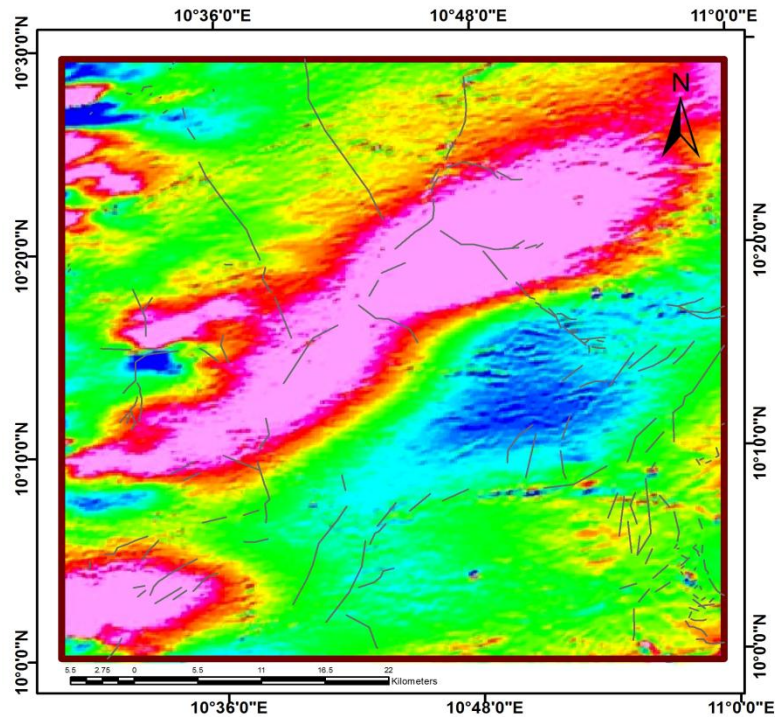
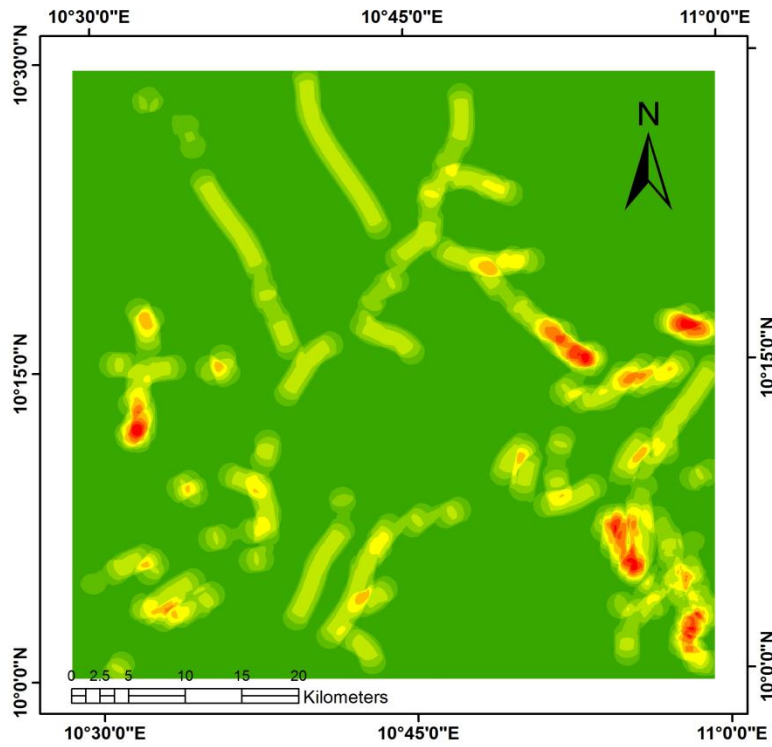
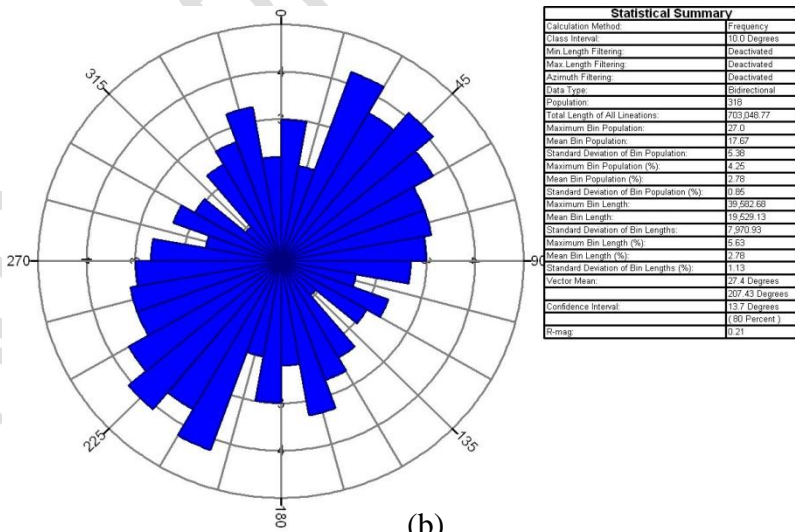


Figure 6: Lineament of the Study Area superposed on the FVD Map

Two major zones of high density of lineaments have been observed in this research (Fig.7a), and they all fall at the fringes of the study area. The map also gives good evidence of the general characteristics of the fracture pattern, showing in particular, its great homogeneity over the area independent of the various geologic formations therefore these areas should be targeted for mineral exploration, Bello et al., (2020). In the central part of the study area there was low fracture density, this may also be indicative of considerable thickness. Also, a considerable intensification of the fracturing in the border zones seems to have derived directly from the formation of the Gongola basin study area inclusive. The lineament density map and areas where lineaments intersect are particularly advantageous in modern exploration geosciences in that they offer a quick glance at the spatial distribution of the density of lineaments and thus provide a useful data base in mineral and groundwater explorations, these should be targeted for both mineral and groundwater explorations in the area. The significance of lineament studies lies in its applicability to groundwater and mineral explorations, Odeyemi *et al.*, (1999) states that same or similar condition exist for ore bearing fluids in basement areas of the world. The trend of the lineament extracted from this research work that may be related to deep seated structures.



(a)



(b)

Figure 7: Lineament Study of the Study Area (a) Lineament Density Map and (b) Rose Diagram

## Conclusion

Analysis of High resolution aeromagnetic data over Akko and environs, Gombe state were analyzed using first horizontal and first vertical derivatives and lineament methods. It is concluded from the results that there less deformation of the basement rocks of the area, which usually occurs due to stress regimes of different geologic phases. Both the horizontal and vertical derivatives maps trend in the NE-SW direction and are related to the pan African orogenic activity. Areas of high density lineaments were observed in this study. The rocks were controlled structurally to run majorly in NW-SE and NE-SW directions. The lineament density map and areas where lineaments intersect are particularly advantageous in modern exploration geosciences in that they offer a quick glance at the spatial distribution of the density of lineaments and thus provide a useful data base in mineral and groundwater explorations, these research will be very useful for both mineral and groundwater explorations in the area.

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