



## ANALYSIS OF LINEAMENT MAP OF PART OF MARU SCHIST BELT, NORTHWEST, NIGERIA AND ITS IMPLICATION FOR MINERAL EXPLORATION

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### ABSTRACT

Lineament are extended mappable linear or curvilinear feature of a surface which can be utilized in mineral, oil, gas, and underground water studies. They are obvious in satellite images, aerial images or aerial photographs. The aim of this study is to analyse an automatically generated lineament from part of the Maru schist belt using a combination of Digital Elevation Model (DEM) data and Aeromagnetic data. The area of study is within the Maru schist belt in Zamfara State. A shaded relief map was produced from the two data sources and the lineament was extracted automatically from them. The extracted lineament was combined to obtain a final lineament map of the area. Trends such as N-S, NW-SE, ENE-WSW and NW-SE, with very little E-W were all present. The areas of very high, high, moderate and low population of lineaments was delineated. Regions with very high lineament intersections and lineament concentration, covers an area of 153.6 km<sup>2</sup> and accounts for 16.1% of the study area, these regions are known to harbour gold and iron ores from literature reviews. These target regions are located at the Northern and South part of the study area. Also, the gold artisan miners have dominated these same regions and they have only started from exposed vein of gold mineralization. With this rather fast and easier approach of obtaining such a map, it could be used as a start point for planning a more detailed geophysical or geological survey.

**Key Words:** Aeromagnetic, Lineaments, Mineral, Remote sensing, and Schist-Belt

### INTRODUCTION

Lineaments have been defined as extended mappable linear or curvilinear features of a surface whose parts align in straight or nearly straight relationships that may be the expression of folds, fractures or faults in the subsurface. These features are mappable at various scales, from local to continental, and can be utilized in mineral, oil and gas, and groundwater exploration studies (Prabu, and Rajagopal, (2013)). Fracture zones, shear zones and igneous intrusions such as dykes can also give rise to lineaments. Lineaments are often apparent in geological, geophysical or topographic maps and can appear obvious on aerial or satellite images or aerial photographs. Lineaments are necessary for understanding the geological structures and mineral content for prospectivity in an area.

Prospectors and mining geologists have long recognized the importance of regional and local fracture patterns as controls on ore deposits. Structurally, Kushake schist belt which is very similar to Maru schist belt has revealed subsurface geologic structures that have inferred orogenic mineralization. Sanusi and Amigun (2020) have shown that the gold mineralization in the basement complex are located at regions of high populated lineaments with conjugate faulting system. Major fault trends are, N-S, NW-SE, ENE-WSW and NW-SE, with very little E-W trend.

It has been proven that mineralization is positively correlated with photo lineaments populations and photo-lineament intersection populations (Alizadeh, and Arian, (2015)). Hardcastle, (1995), has used photo-lineaments to explore for groundwater in fractured bedrock because they are good in delineating fractured bedrocks. His classification of the potential of an area was based on; the population of the photo-lineaments,

the direction of the lineament families and the population of the intersection of the lineaments. Chernicoff, et al., (2002), analysed regional aeromagnetic surveys, Landsat images, and geological information. Their results revealed that mineralization occur near the intersections of major lineament zones and these structural intersections serve as facilitators for magma ascent and volatile exsolution. Lineament density map constitutes a useful base map that can aid the development of the solid mineral sector of Nigeria.

Rowan and Wetlaufer (1975) used a Landsat mosaic of Nevada to interpret regional lineaments. Literatures have shown that mining districts exist mainly alongside lineament strips and particularly at major intersection points of lineaments. Rowan and Bowers (1995) have been able to positively correlate the geological linear structures and existing mineralization in Western Nevada. The extraction and analysis of lineaments from digitally enhanced satellite images and shaded relief maps derived from DEMs has been a valuable sources for regional and tectonic structural studies (Masoud and Koike, 2006; Solomon and Ghebreab, 2006). The detection and treatment of lineaments have great application for mineralization, hydrological, structural and tectonic purposes in limited areas (Seleem, 2013). However, Adekoya (1996) had tried to delineate some part of the Maru Schist belt to be of Banded Iron Formation (BIF) type.

In this study area, (which has arid and semiarid terrains) well-exposed bed rocks are present and brittle structures can be easily observed on satellite images. According to Haruna (2017), Nigerian is majorly divided into two mineral belts, the Pan African mineral belts and the Mesozoic to Cenozoic belts. The Maru schist belt which falls under the Pan African

Mineralisation belts is known to include the Gold schist belts, the Chromite belt, the Banded Iron Formation (BIF) belt and the Sn-Ta Pegmatite belt. Areas of gold mineralisation in Nigeria are associated with the regional NE-SW and NNE-SSW fault systems and gold veins are hosted by various rock types ranging from gneisses, schists, phyllites, quartzites to amphibolites and granitic intrusions. The Nigerian schist belts structures are known to be regionally and locally controls by systems of transcurrent and subsidiary faults patterns of Pan African age (Obaje, 2009). Primary minerals alike iron, gold, lead-zinc, etc, occur in major areas of high lineament density and has been

recovered by artisanal miners who follow mineral veins, through excavation of several pits of various dimensions and depths (Oke, et al., 2014). The aim of this research work is to analyse lineament map and delineate possible zones for mineral exploration in part of Maru schist belt. The whole of Maru schist belt covers an area of 6,200 square km between latitude  $12^{\circ}10' N$  and  $13^{\circ}10' N$  and longitude  $6^{\circ}00' E$  and  $6^{\circ}50' E$  (Ibrahim, 2012), but the research work is carried out in part of the Maru Schist belt as shown in Figure 1 and is bound by longitude  $6^{\circ}15' E$  to  $6^{\circ}30' E$  and latitude  $12^{\circ}10' N$  to  $12^{\circ}30' N$ .

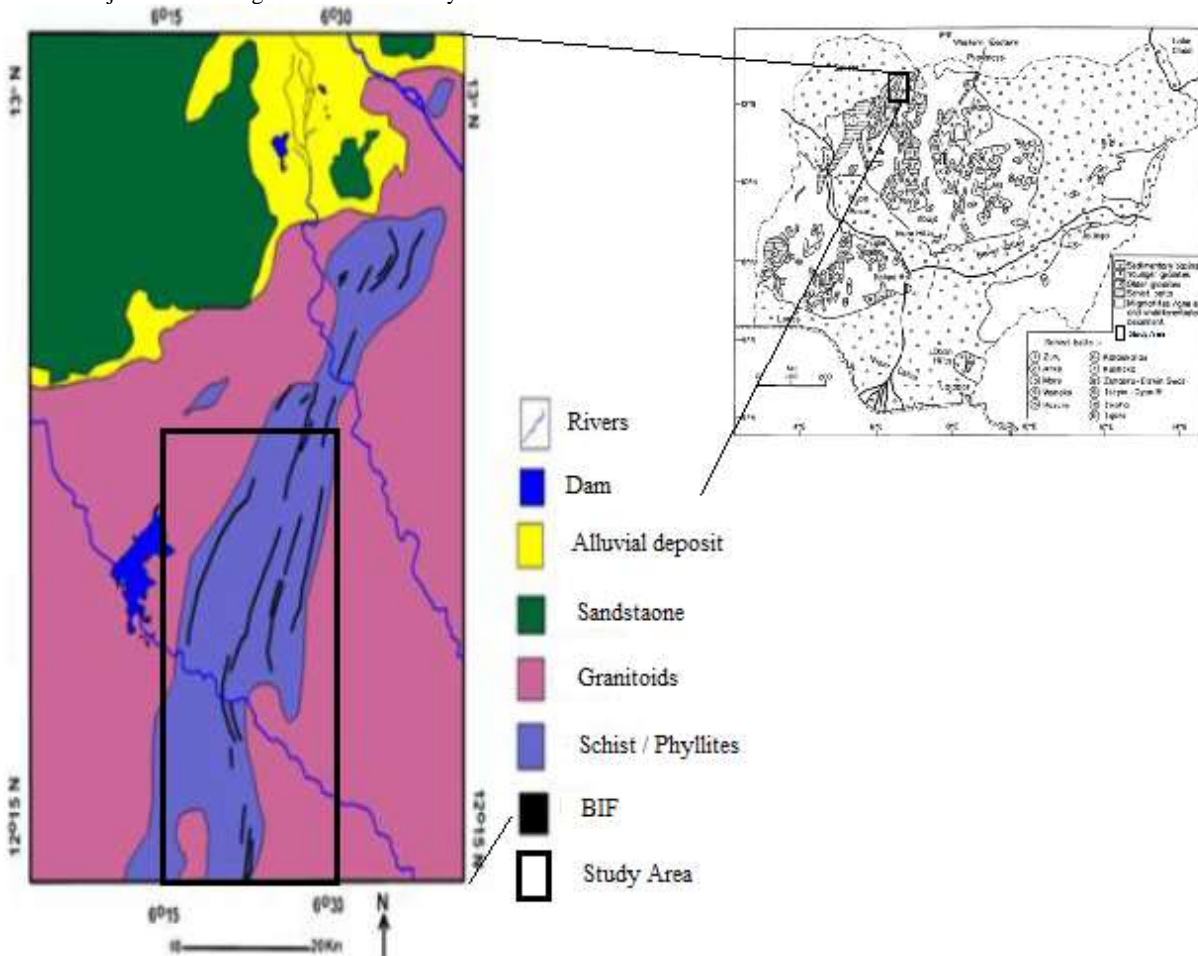


Figure 1: Geological Map of Maru Schist belt showing study area (Source: Kudamnya, *et al.*, 2014)

## MATERIALS AND METHODS

The Digital Elevation Model (DEM) is the remote sensing data obtained from the USGS website and the Aeromagnetic data obtained from Nigerian Geological Survey Agency was used for this study. The flight line spacing was 500 m, the sensor mean terrain clearance was 80 m, the flight line trend was  $135^{\circ}$ , the magnetometer used for the survey was 3X Scintrex CS3 Cesium Vapour. The DEM is a better reflection of the geomorphology of a terrain unlike the satellite because it has the ability of suppressing non-structural lineaments. The aeromagnetic map was added because it exposes deep seated lineaments. Using the ERDAS IMAGINE (Version 2015) software, we were able to create various shaded relief images of the study area by varying the positions (azimuth and elevation) of the sun's illumination, this uncovers the various different structural lineaments that are

trending in all the directions and ignoring all other non-linear structures. This Shaded relief images created from digital elevation models (DEMs) are helpful in identifying lineaments in different distinct relief and topography (Seleem, 2013). The Aeromagnetic data was also filtered and a shaded relief image of the second vertical derivative was created using PCI Geomatica software (version 10), the lineaments were extracted from both shaded relief images of the DEM and Aeromagnetic image.

The final lineament map of the study area produced from the DEM and the Aeromagnetic data from which the rose diagram was produced from.

## RESULTS AND DISCUSSION

The following results were obtained from the processed data for the study area. The raw data for the DEM is shown in Figure 2 (a) and 2 (b) in shaded relief form with its automatically extracted lineament beside. The aeromagnetic raw data of total magnetic intensity is shown in Figure 3 (a) and 3 (b) in shaded relief form and the automatically extracted lineament beside.

The final lineament map of the study area produced from the combination of the DEM and the Aeromagnetic data is shown in Figure 4 (a). The lineament orientation and the rose diagram are shown in Figure 4(b) and Figure 5 respectively. The lineament density properties are shown in Table 1.

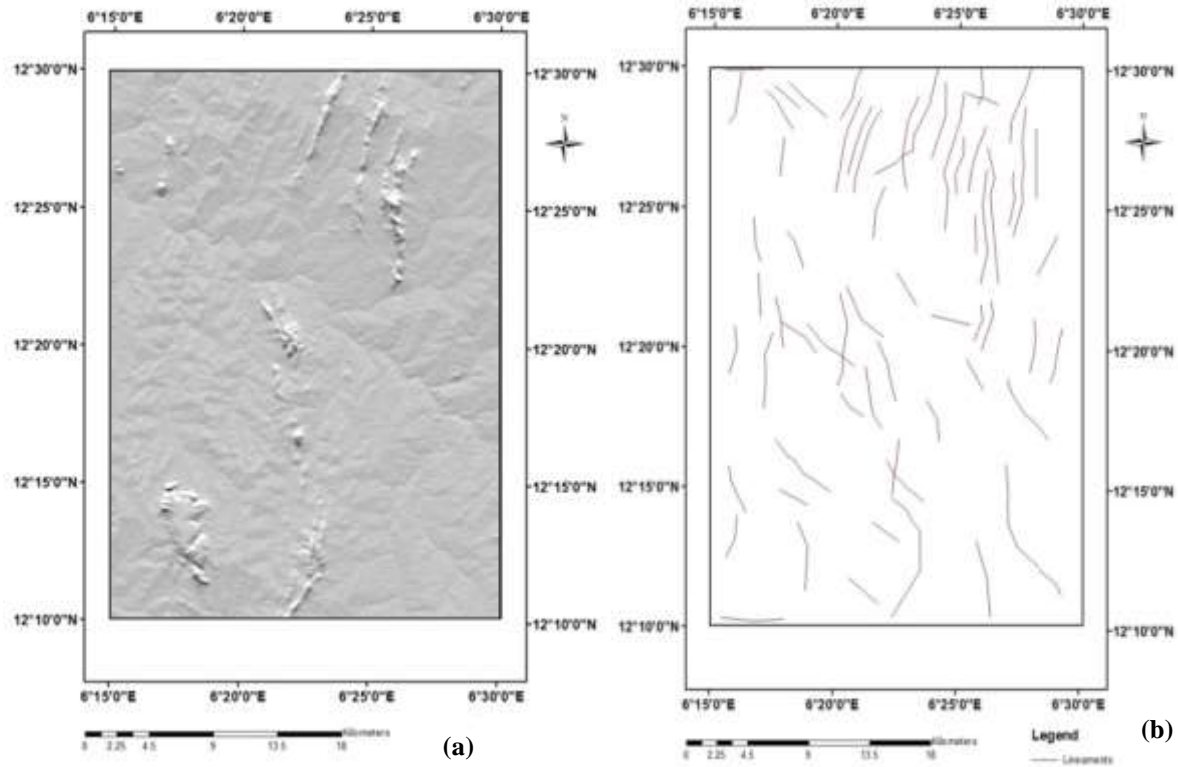


Figure 2: (a) DEM Shaded relief image and (b) Automatically extracted lineament map from DEM

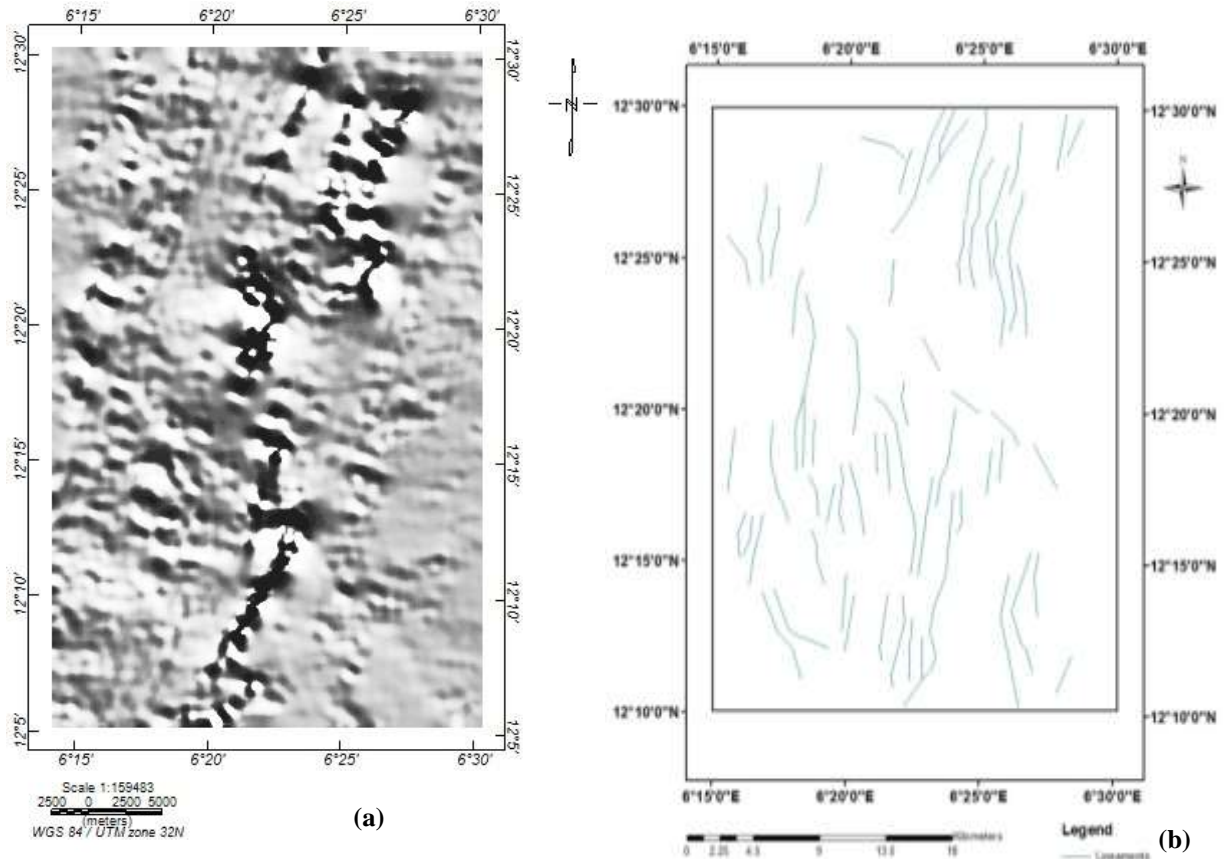


Figure 3: (a) DEM Shaded relief image and (b) Automatically extracted lineament map from DEM

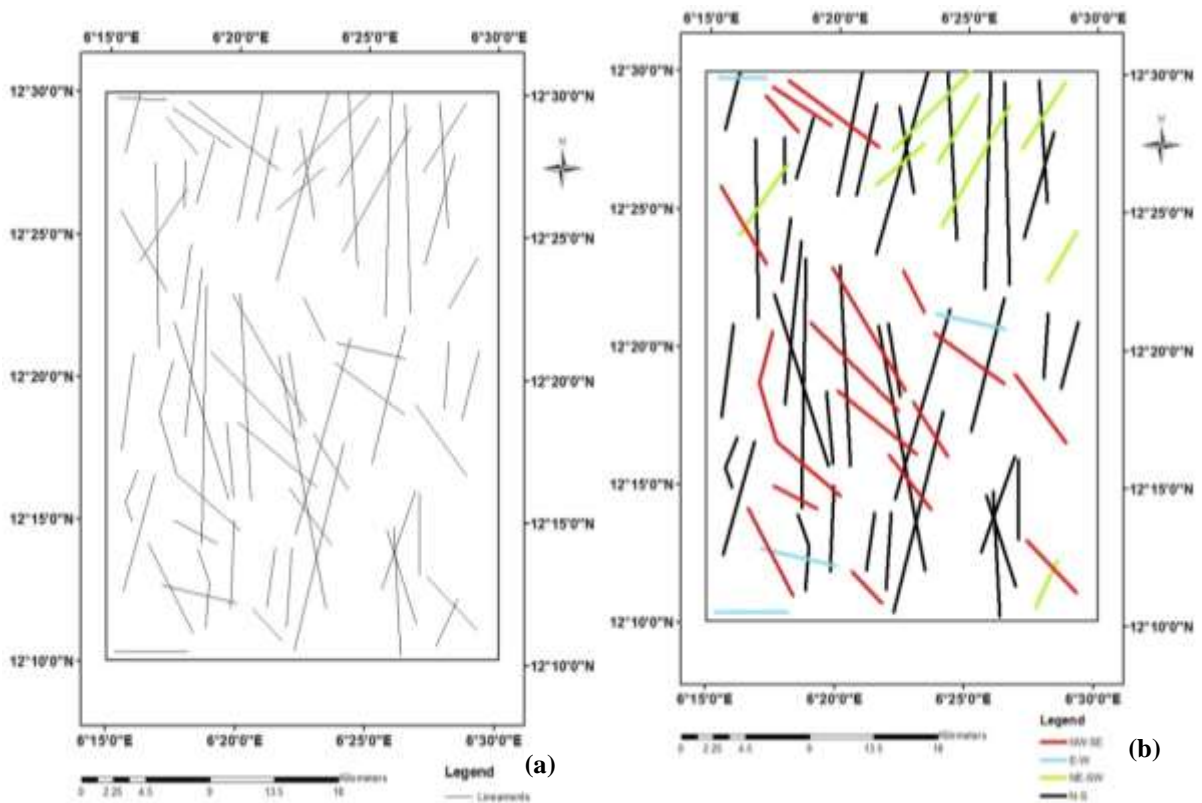


Figure 4: (a) Lineament map for the study area (b) Lineament orientation map of the study area

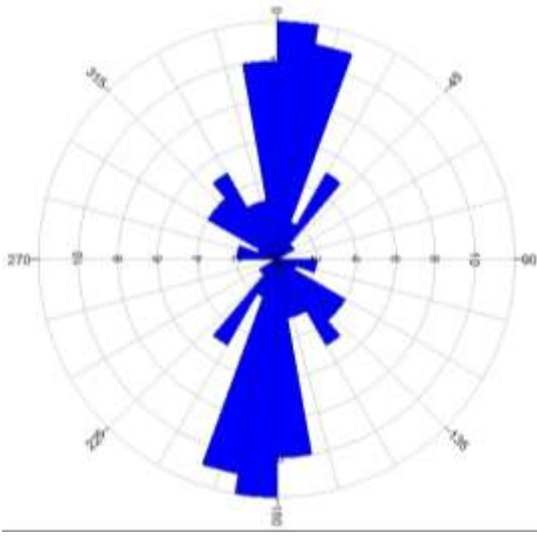


Figure 5: Rose diagrams of the study area showing majority trending N-S.

**Table 1: Lineament density properties for the study area**

S/N	Class	Range (km)	Area Cover (km <sup>2</sup> )	Percentage Cover (%)
1	Low	0.00173-0.22972	196.1	19.3
2	Moderate	0.00972-0.459267	348.5	34.3
3	High	0.459267-0.688814	308.8	30.4
4	Very High	0.688814-0.918361	163.6	16.1

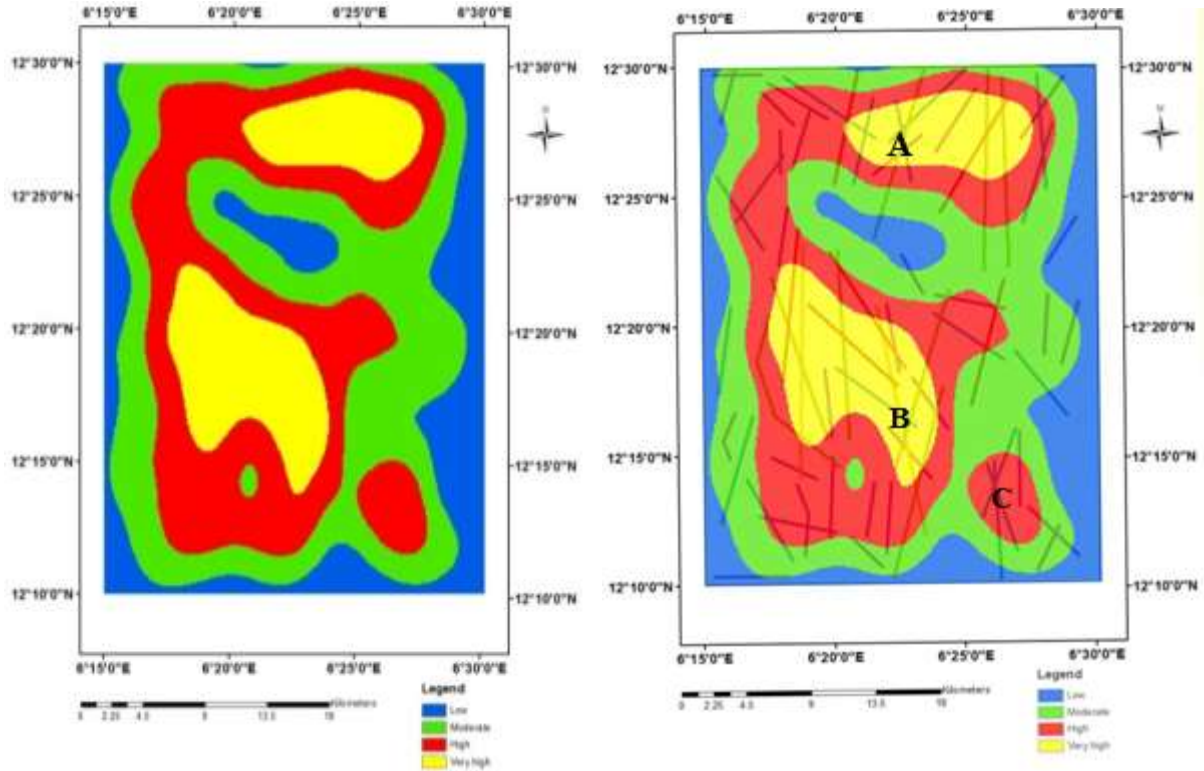


Figure 6: (a) Lineament density map (b) Combined map of lineament and its density

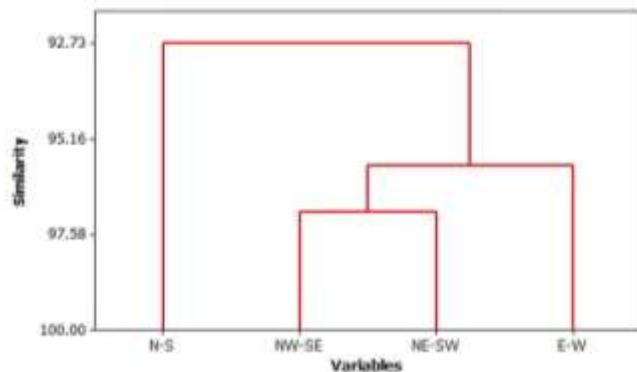


Fig 7: Dendrogram for Lineament Orientation

**DISCUSSION**

The principal fracture directions in the Nigerian basement complex are the N-S, NNE-SSW, NE-SW, NNW-SSE and NW-SE and to a lesser extent, the E-W, all of these trends had been established in the lineament map of the study area as shown in Figure 4 (a) and Figure 4(b). The E-W lineaments are usually very few and difficult to recognize in the field and in aerial/satellite images because they have been annealed by mineral fillings and/or have been rotated North or South away from their original E-W directions (Haruna, 2017). The N-S fractures are easily identified in the lineament map as prominent scarp surfaces and depressions that are controlled by the major N-S fracture system in Nigeria. These fractures are also marked by considerable shearing and brecciation features attributable to brittle deformation. They are

fragmented due to deformation and hence they appear to be comparably short in dimension. Other structural trending includes the NE-SW and the NW-SE conjugate species are distinguished from the NNE-SSW and NNW-SSE species (shown in Figure 4(b) and Figure 5). According to Kolawole, F. and Anifowose, (2011), both are probably strike-slip faults but the Northeasterly ones are being characterized by a dextral sense of movements. These pattern of faults, as established in the study area, may be as a result of the transient movements system during the Pan-African orogeny. The Anka-Yauri-Iseyin (AYI) regional fault system has traverses the Maru schist belt, the longer NNE-SSW lineaments in the study area are considered a very deep strike-slip lineament (Haruna, 2017; Oke, et al., 2014; Danbatta, 2008).

The rose diagram in Figure 5 shows that the longest and the dominant lineaments are in the N-S direction and in both the NNE-SSW and NNW-SSE direction. This implies that the structures within the study area have tectonic signatures of the Pan African Orogeny (Haruna, 2017). The Figure 5 also shows the less dominant and shorter lineaments species are in the NW - SW and NE - SW directions. These are dextral wrench faults with locally developed conjugate sinistral wrench faults (Danbatta, 2008). This conjugates system of lineaments supports greatly the existence of mineralization and this can be inferred by the works of Oke et al., (2014) where he was able to identify some primary minerals like iron, gold, lead-zinc, etc, occur in major areas of high lineament density and has been exposed by artisanal miners who just go after exposed viens.

Lineament density for the study area (Figure 4 (a) and 4 (b)) has a minimum of 0.0017 lineaments per unit area, a maximum of 0.9184 lineaments per unit area, with a mean of 0.4447 lineaments per unit area and a standard deviation of 0.2190 lineaments per unit area Table 1. Lineament density was segregated into five classes' base on the number of lineaments per unit area (Low, Moderate, High and Very High) as shown in Table 1. The table shows the range of the individual classes which was used for the segregation. This table was used to create the lineament density map of the study area as shown in Figure 4 (a) and 4 (b).

From the lineament density map in Figure 4 (a) and 4 (b), areas of low lineament density have area coverage of 196 km<sup>2</sup> and account for 19.3% of the study area and this zone is represented by the blue colour in the lineament density map. Areas of moderate lineament density covers an area of 348.5 km<sup>2</sup> accounting for 34.3% of the study area and this zone is represented by the green colour of the lineament density map. Areas of high lineament density have an area coverage of 308.8 km<sup>2</sup> accounting for 30.4% of the study area, this zone is represented by the red colour in the lineament density map. Areas of very high lineament density covers an area of 153.6 km<sup>2</sup>, accounting for 16.1% of the study area, this zone is represented by the yellow colour. The yellow and the red coloured zones of the density map are areas that support high mineral exploration; this is evidence from the number of lineaments population in the area and the number of lineament intersections present in these areas. A combination of the lineament map and the lineament density map is shown in

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Figure 6 (a) and 6 (b) the areas marked A, B and C. The artisan miners have dominated these areas and they have only started from exposed vein of gold mineralization. In all these areas, there are presences of interception of lineaments which is a good tracer path for mineral exploration. From the geology of the schist belt and according to Chernicoff, et al., 2002 and Obaje, 2009 and Oke, et al., 2014, primary minerals like iron, gold, lead, zinc, exist in this intersection points. In general, the relationship between different lineament orientation species reveals a close correlation between NW-SE and NE-SW lineaments species. This is evident from the Dendrogram plot in Figure 7, where two lineaments species (NW-SE and NE- SW) are more correlating to the E-W lineaments than the N-S lineaments?

## CONCLUSIONS

The presence of geological or geophysical features (like lineaments) are of importance in any exploration activity. However, the presence of clusters of lineaments and intersection of lineaments goes a long way to infer the geological importance of that location. Various trends of lineaments were observed as N-S, NW-SE, ENE-WSW and NW-SE, with very little E-W trend. Lineaments are known to be conduit for mineral transport and eventual deposition. The result of this study has shown that areas of large numbers of lineaments can support the existence of mineral in this area. From previous literatures, the geology of the area and the artisan activities on the ground, there is evidence that gold and iron mineralization are present in this schist belt. Areas of high presence of lineament population and high lineament intersection points are known to be harbour minerals since they are conduit path for mineral, they may be a very good starting points for any relevant mineral exploration survey. The artisan miners have dominated these areas and they have only started from exposed vein of gold mineralization. The results also show that the areas promising for mineral exploration are the North Eastern, the North Central and down to the South central (as indicated by the yellow and red colours in the lineament density map). With a rather fast and easier approach of obtaining such a map, this may be recommended as a preliminary information to plan for an exploration activity for solid mineral survey. It could be used as a start point for planning a geophysical or geological survey.

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