ISSN 2229-5518

MAPPING AND ANALYSIS OF TECTO-LINEAMENTS OVER PARTS OF NORTH EASTERN NIGERIA, WEST AFRICA

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Abstract— Lineaments are essential for understanding the structural geology as well as for mineral prospecting. A manual digitization technique was used to extract lineaments from Landsat images. Lineaments properties such as lineaments number, orientation, length, relative abundance as well as statistical relationship between lineament length and orientation were studied. The NE-SW lineaments dominate the study area. Such lineaments can be attributed to the opening of the Benue Trough. Statistically, the NW-SE lineaments and E-W lineaments are more correlating in terms of lineaments. These lineament pair is more correlating in terms to the N-S lineaments than the NE-SW lineaments.

Index Terms— Basement Complex, Benue Trough, Landsat, Lineaments, Northeastern Nigeria, Structures, Tectonics,

1 Introduction

The Precambrian crust of West Africa appears to have been subjected to a series of essentially small cycle of events throughout most of its history [1]. Such events were associated with the production of brittle structures such as lineaments that characterized each event. It is worth noting that lineaments of each event have a particular characteristics relating to certain period of deformation. The term lineaments have been define by several authors [2], [3], [4], [5]. Though lineaments may refer to any linear feature, geologically lineaments are natural crustal structures that may represent a zone of structural weakness [6]. Tectono-lineaments refer to those groups of lineaments whose origin can be traced to a particular geological event. The Nigerian Basement complexes have responded differently to many episodes of folding, faulting and granitic emplacement along the linear shear zone [7]. Linear structures such as fracture and shear zones characterized the basement complex [7].

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The structural and tectonic framework of Nigerian Basement has been reported as comprising NE-SW and NW-SE lineaments superimposed over a dominant N-S trend [8] and NW-SE and NE-SW pair super imposed on a N-S joint set. Fracturing is more intense on the Cameroon flank of the country than anywhere else. Here fractures emanating from the Basement Complex, traverse the Benue valley rocks with surface traces across the younger granite in Jos Plateau onto the sediments of the Sokoto basin [9] Also, many drainages in the area followed these fracture direction [9].

2 Geology

The study area is underlain by the undifferentiated Basement Complex rocks which consit mainly of the migmatite, gneisses and the older granite, Tertiary to recent Basalts also occur in the study area. A close examination of the undifferentiated Basement complex particularly the migmatite generally vary from coarsely mixed gneisses to diffused texture rocks of variable grain size and are frequently porphyroblastic [10]. According to [11], these rock units constitute chiefly the undifferentiated igneous and metamorphic rocks of Precambrian age. The Pan African granites which either occur as basic or intermediate intrusive are equally widespread in the area [12]. On the older granites, texturally fine to medium to coarse grains can be noticed [13]. Doleritic and Pegmatitic rocks mostly occur as intrusive dykes and vein in both the undifferentiated Basement complex rocks and the Older granites [14], [13]. The Tertiary basalts are restricted to the Mabila Plateau mostly formed by Trachytic Lavas and extensive basalts occurring aroung Nguroje [15]

3 MATERIALS AND METHODS

Landsat ETM Satellite images were downloaded from global land cover facility website of the University of Maryland. Geometric and radiometric corrections were then carried out. A false color composite images of band 7, 3, 1 was carried using Envi 4.5 software in order to enhanced lineaments within the study area Figure (1). Manual digitization was performed using Global mapper software 16 software. Digitized lineaments were then exported to Arc GIS software where lineaments properties such as lineaments length, lineaments orientation, Lineaments density and lineament intersection, lineament length density as well as other statistical properties of these lineaments

4 RESULTS

4.1. Lineament Length

A total of 769 lineaments were manually extracted from Landsat imagery Figure (1). These lineaments had a total length of 3625170 meters. The lineaments had a mean length of 4720m, a standard deviation of 5030, with a minimum length of 585m and a maximum of 54080m. Histogram for lineament length is positively skewed and has positive kurtosis Figure (2). Orientation analysis for lineaments reveals a dominant NE-SW direction accompanied by a less dominant NNE-SSW and NW-SE direction. According to [7], the NE-SW and NW-SE conjugates set lineaments are probably strike slip faults. Also [16], noted that many numerous fractured control phenomena in Nigeria basement for example mineralization are also NE-SW oriented. A simple stress configuration produced by [17], Figure (3), revealed the NE-SW and NW-SE lineaments as being simple shear 1 and 2 respectively.

A

B

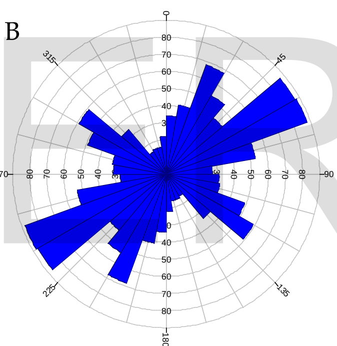

Fig. 1. A= Lineaments from study area, B= Rose diagram

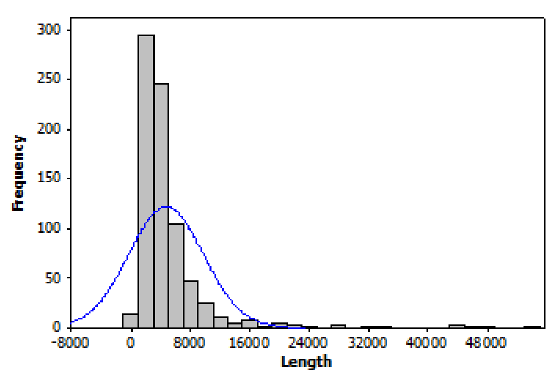

Fig. 2. Histogram Plot for Lineaments

ISSN 2229-5518

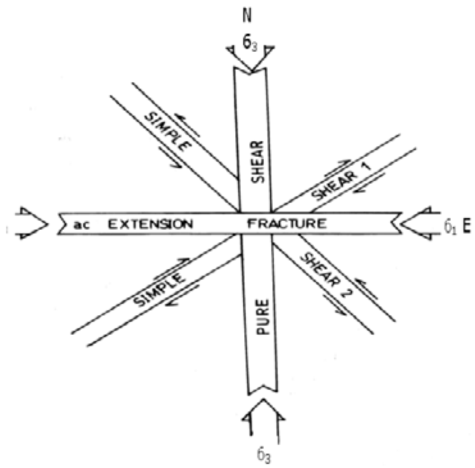

Fig. 3. Main tectonic axis of the Basement complex [17]

4.2. Lineament Density

Lineament density defined as the number of lineaments per unit area was classified into five classes. Areas of high to extremely high lineament density was observed in central, south west, south, south east and northern part of the study area. Very low lineament density areas were observed in the north western part of the study area Figure (4).

Fig. 4. Lineament Density for the study area

Lineament density ranged from 0 to 1.527 numbers of lineaments per unit area. Areas of very low lineament density accounts for 35714 m^2 accounting for 53.49%, areas of low lineament density accounts for 18932m^2 and accounts for 28.36%. Areas of moderate lineament density occupied an area of 10022m^2 and accounts for 15.01 %, Areas of highly dense lineaments occupy an area of 1932m^2 which represents 2.89%. Extremely dense lineament areas have a total area of 166m^2 and account for 0.2% of the study area.

4.3. Mean Length

Analyzing the mean length for lineaments, it is observed that the minimum mean length is 292.38 m, maximum is 27040 m. Using the mean length, the mean frequency map was produced Figure (5). The mean length frequency map was classified into five classes consisting of very short, short, long, very long and extensive mean lineament length frequency. A close observation of the mean length frequency map reveals the short to very short mean lineament lengths are located mostly on the south east and northwestern part of the study area. The long to very long mean lineament and extensive mean length are located on the central, north and north eastern part of the study area. The very short mean lineament length frequency occupies an area of 40573m^2 and accounts for 42.5%. Areas with short mean lineament frequency length occupies a total area of 42557m^2 and account for 44.6%. Areas of long lineament frequency length occupy a total area of 10304m^2 accounting for 10.8% of the study area. Very long lineament frequency length areas occupied a total area of 1651 m^2 accounting for 1.73%. Areas of extensive lineaments length accounts for 0.33% of the study area, representing 315m^2 of the study area.

4.4. Lineament Intersection Density

Analysis of lineament intersection density was carried out by plotting the intersection of two or more lineaments as a point and contouring these points. This gives zones of different degree of fracturing within the study area. Lineament intersection density for the study area had a minimum of 0, maximum of 1.020, a mean of 0.04 and a standard deviation of 0.090. Lineament intersection was classified into five classes; very low, low, moderate, high and very high Figure (6).

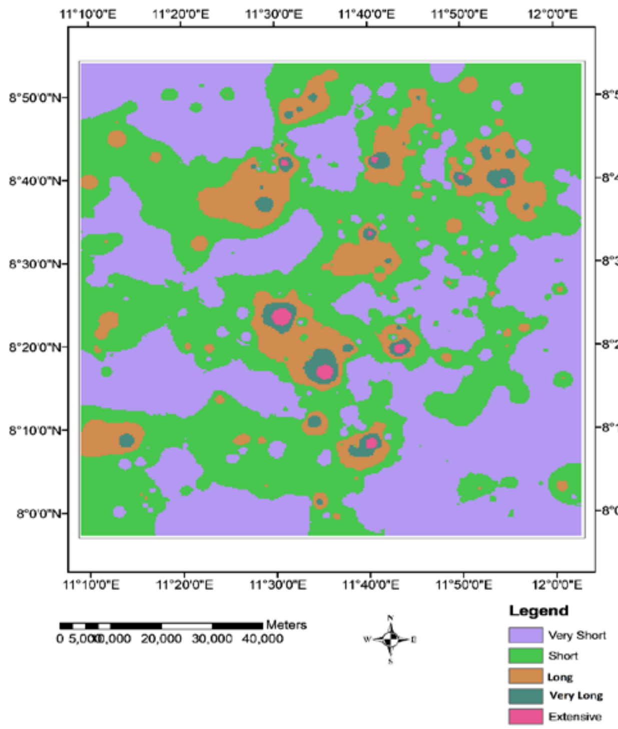

Fig. 5. Mean length frequency for study area.

Fig. 6. Lineament intersection density for study area

Observing the lineament intersection density map we realized that very low and low lineament intersection areas are located mostly in the northwestern part of the study area. Areas of high and very high lineament intersection are located in parts of the north, south, south west and central part of the study area. Areas of moderate lineament intersection dominate the central to north eastern part of the study area. Areas of very low lineament intersection density occupy a total area of 43521m² and a percentage of 67.99%. Areas of low lineament intersection density cover an area of 12694 accounting for 19.83% of the study area. Areas of moderate lineament intersection density cover an area of 5455m² and account for 8.52% of the study area. Areas of high lineament intersection density have an area extent of 1988m² and account for 3.11% of the study area. Areas of very high lineament intersection density have an area extent of 347m² and account for 0.54% of the study area.

4.5. Relative Abundance

Abundances of different lineament orientation proportion was displayed using the relative abundance map. Lineament relative abundance was studied for N-S, NE-SW, E-W and NW-SE lineaments.

4.5.1. North-South Lineaments Relative Abundance

Analysis of N-S relative abundance for lineaments revealed a minimum of 0, maximum of 0.26, a mean of 0.01 and a standard deviation of 0.03. Classification of lineaments into five classes revealed high relative abundance predominates in the North to Central and Southern part of the study area. Low relative lineament abundance predominates in the Western part of the study area Figure (7).

Fig. 7: Relative Lineament abundance for N-S Lineaments

ISSN 2229-5518

4.5.2. North East- South West Lineament Relative Abundance

Relative abundance for these lineaments has a minimum of 0, a maximum of 0.48, a mean of 0.02, and a standard deviation of 0.04. Classification of these lineament abundances into five classes reveals very high lineament abundances predominates in the North to eastern, western to south west and south eastern part of the study area Figure(8).

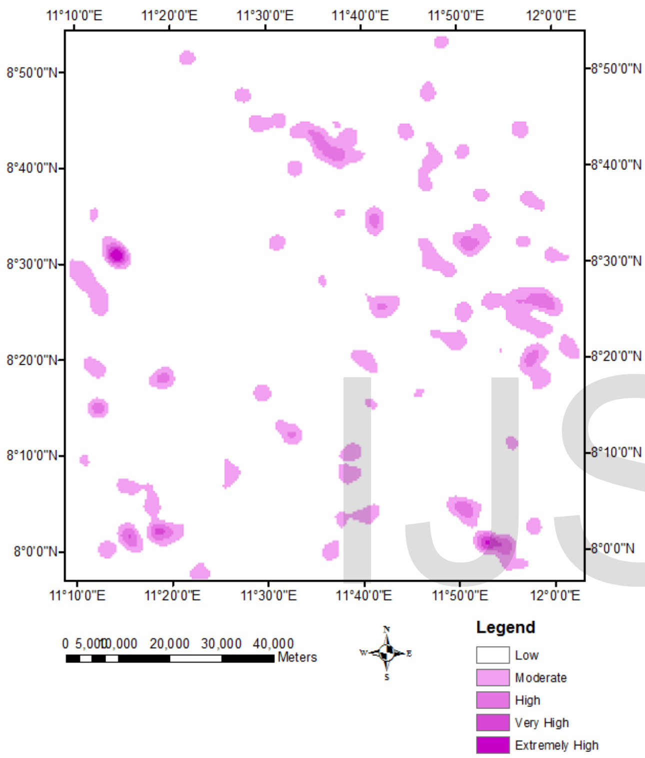

Fig. 8. Relative Lineament abundance for NE-SW lineaments

4.5.3. East to West Lineament Relative Abundance

Relative lineament abundances for East-West lineaments have a minimum of 0, a maximum of 0.27, mean of 0.01 and a standard deviation of 0.03. Classification of these abundances into five classes reveals high relative lineaments predominates in the east, south eastern, western and central part of the study area Figure (9).

Fig. 9. Relative Lineament abundance for E-W lineaments

4.5.4. North West to South East Lineament Relative Abundance

These lineaments relative abundance has a minimum of 0, maximum of 0.26, a mean of 0.01 and a standard deviation of 0.03. Classification of relative abundance reveals high relative abundance predominates in Northwest, west and south west, south, central to eastern part of the study area Figure (10).

4.6. Statistical Relationship

Statistical relationship was used to compare different parameters for different lineament orientations.

4.6.1. Mean Length and Azimuth

Relationship between mean lineament length and orientation was compared using tables and diagram. Mean lineament length for different N-S, NW-SE, E-W and NE-SW was sub divided into five classes Table (1).

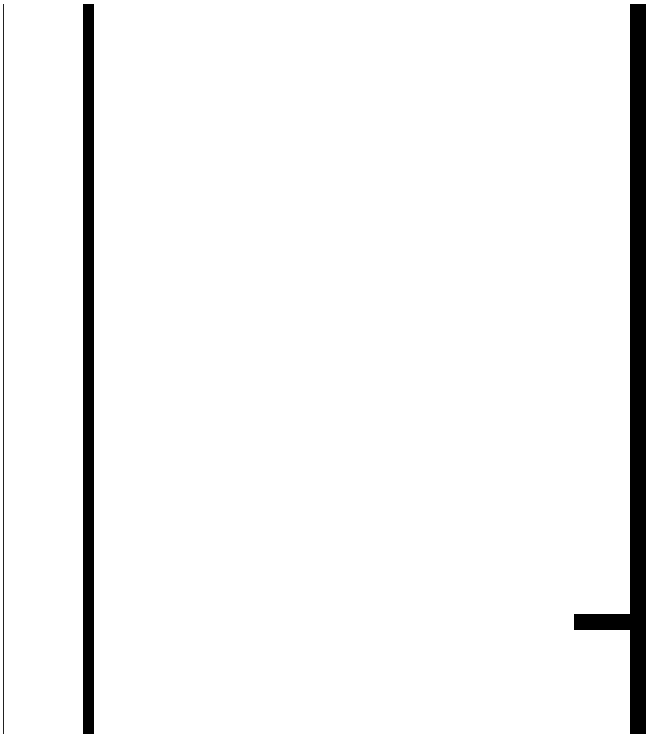

Fig. 10. Relative Lineament abundance for NW-SE lineaments

TABLE 1.
RELATIONSHIP BETWEEN LINEAMENTS AND ORIENTATION

	N-S	NW-SE	E-W	NE-SW	Sum	Percentage
Very Short	16	22	21	69	128	16.8%
Short	94	96	105	195	490	64.5%
Long	19	34	32	32	117	15.4%
Very Long	5	10	3	3	21	2.7%
Extensive	1	5	3	3	12	1.5%
Sum	135	158	164	302	759	
Percentage (%)	17.7%	20.8%	21.6%	39.7%		
Mean	27	33.4	32.8	60.4		
Standard Deviation	38.19	36.75	42.21	79.98		

Highest Lineament Population for each

Lowest Lineament population for each

Results show that the short lineament is the most abundant lineament population making up 64.5% of the study area. While the extensive lineaments are the least consisting of 1.5 %. Within the very short and short class the most dominant lineament type are those having the NE-SW orientation, while the least dominant are those having the N-S orientation. For the long class, N-S lineament is least dominant while the NW-SE lineaments are the most dominant. For the very long class, the NW-SE lineament is the most dominant while the E-W and NE-SW Lineaments were the least dominant. For the extensive class, the N-S Lineament populations were the least dominant while the NW-SE lineaments were the most dominant.

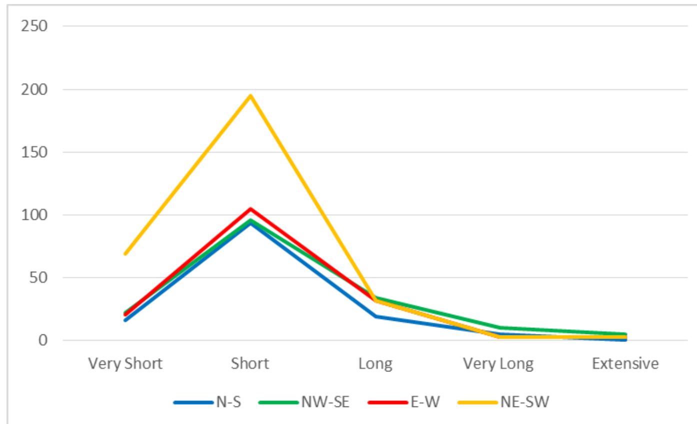

Fig. 11. Relationship between Lineament orientation and Mean Length

Using dendrogram and correlation plot to compare mean lineament length population among the different orientations (Figure 13), it is observed that the mean length lineament populations of NW-SE and E-W are similar. Also a close similarity exists between mean length lineament population of N-S and NW-SE, E-W. A less similar correlation exist between mean length lineament population of NE-SW and N-S, NW-SE, E-W Figure (11, 12).

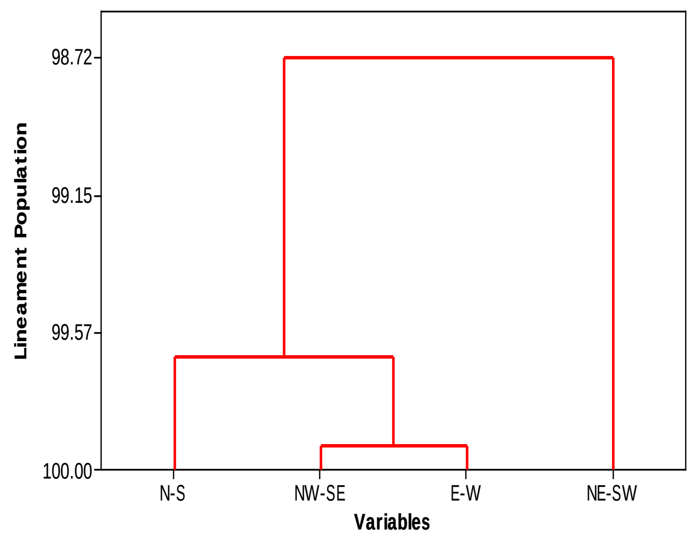

Fig. 12. Correlation between of mean length population for different Orienttion

5. DISCUSSION

Technically lineaments are a depiction of the regional structural geology of any area. An understanding of lineament properties gives a clue to the regional tectonic history of an environment. Lineaments were extracted using manual digitization technique. Manual digitzation was used because of its huge advantage in avoiding lineaments of non-geological origin. A total of 769 lineaments were extracted having a length ranging from 585m-54080m, the total length for these lineaments was 3625170m. A positively skewed histogram was observed from the lineament lengths suggesting dominance of less extensive lineament population. Orientation analyses for these lineaments suggest a dominant NE-SW accompanied by less dominant NNE-SSW and NW-SE direction. Lineament density for the study area ranges from 0-1.527. Areas of low lineament density are observed in the North western through Central and part of South Western, North Eastern and South Eastern sections of the study area. High lineament densities areas suggest prolong action of tectonism on these areas. Mean length analysis suggest areas with short mean length dominates the North western and South Eastern part of the study area. Also occurrences of short mean length are observed in the southern and western part of the study area. Lineament intersection density for the study area ranges from 0.04-1.020 with a mean of 0.09. Low lineament intersection densities are dominant in the north western part of the study area. Other small occurrences of low lineament density intersection are observed in the north western, south western and south eastern part of the study area. Areas of high lineament intersection density occurs as patches and are spread through the south, western, central and northern part of the study area. Lineament intersection density gives us an idea on the degree of fracturing within the study area. The occurrence of different lineament specie was studied using lineament relative abundance. The relative abundance for N-S lineaments ranges from 0-0.26. Areas of high relative abundance are observed for N-S lineaments are scattered as patches throughout the study area but dominants the south to central and northern part of the study area. Low occurrences were observed in the northern part of the study area. The NE-SW lineaments relative abundance ranges from 0-0.48 with a mean of 0.02 and a standard deviation of 0.04. High abundances for these lineaments are commonly observed in the south eastern, south western, east, west and central part of the study area. No occurrences were observed in the North Western part of the study area. The east west lineament had a relative abundance ranging from 0-0.27, a mean of 0.01 and a standard deviation of 0.03. High relative abundance for these lineaments are observed in the south eastern, eastern, western and central part of the study area. The NW-SE lineaments had a relative abundance ranging from 0-0.26, a mean of 0.01 and a standard deviation of 0.03 areas of high relative abundance are scattered in the North West, west, south west, and south, central and eastern part of the study area. According to[18], the NE-SW lineaments are deep seated Basement faults genetically related to the Benue trough, while the NW-SE are Basement faults with deep origin. [7], described the NE-SW and NW-SE conjugate as probable strike slip fault with the North eastern ones being characterized by dextral sense movement. It is significant that many fracture controlled phenomena in Nigerian Basement (mineralization) are NE-SW oriented [16] of great interest is the very prominent NE-SW lineament trend parallel to the Nigerian Cameroon boarder. This coincide with parts of the of the lead-zinc mineralized zones in Nigeria. Statistical analysis on the relationship between length and orientation suggest the NW-SE lineaments populations are most extensive, while the NE-SW lineaments are the least extensive. Correlating length for different lineament populations, it is observed that the NW-SE and E-W lineaments are the most correlating pair in terms of length. These pair is more correlating to the N-S lineaments than the NE-SW lineaments.

6. CONCLUSION

Lineaments analyses are essential tools in understanding the structural evolution of an area as well as prospecting for mineral deposits. Analysis of lineaments within North eastern Nigeria reveals a dominant NE-SW direction accompanied by a less dominant NNE-SSW and NW-SE direction. Origin of the NE-SW and NNE-SSW direction can be attributed to the opening of the Benue trough. It is worth noting that several streams within the study area is structurally controlled by lineaments. Lineament density map for the study area reveals the central eastern part of the study area as having the highest lineament density. Regarding lineament length, the central part of the study area has the most extensive length. Highest lineament intersection density occurs in the south west, south central and northern part of the study area. Based on relative abundances, the N-S lineaments predominate in the North to central and southern part of the study area. The NE-SW predominates in the North to eastern, western and central part of the study area. The E-W lineaments predominate in the east, south eastern, western and central part of the study area. The NW-SE predominates in the North West, west, south west, and south central to eastern part of the study area. Statistically, the NE-SW lineaments are the least extensive in terms of length. The NW-SE is the most extensive in terms of length. Interns of length the NW-SE and E-W lineaments are the most correlating. This pair is more correlating to the N-S than the NE-SW lineaments.

ACKNOWLEDGEMENT

We would like to thank Global land cover facility for free provision of satellite imagery.

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