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RESEARCH ARTICLE

LINEAMENT INTERSECTIONS MAPPING AND ANALYSIS OF KAGORO YOUNGER GRANITES AND ENVIRONS, NORTH CENTRAL NIGERIA

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ABSTRACT

Histograms of lineament intersection lengths in the study area are positively skewed Variations in frequencies within their respective class intervals suggest that the stress intensity which gave birth to the lineaments are unequal. This is also true by the absence of lineaments within some class intervals. Directional lineaments' intersection of the rose diagrams are mainly found in conjugate NE – SW and NW – SE orientations. Only small parts of the Kagoro hill area and associate rocks are covered by lineament intersections of high densities by drainage and satellite maps which suggest that they were produced mainly from shallow structural features associated with joints, stream and rivers. Magnetic and gravity maps present ideal images of lineament intersections, as high lineament intersections are located on the Kagoro Younger Granite outcrop and other rock exposures, which clearly indicate that they are derivatives of deep seated structures which could be linked to fractures and faults. A combined map of the four lineament sources expresses clearly the locations and trends of the Kagoro Younger Granite complex and its associate rocks. On this map, densely populated lineament intersections are located over outcropped rock units and trend in the same directions. Generally the two dimensional maps indicate the main structural features to be trending along the N – S, NE – SW, E – W and NW – SE directions, which is consistent with structural trends in the region and regional tectonic stress regimes and fractures in Nigeria.

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INTRODUCTION

(Sabins, 2000) defined lineaments as extended linear or curvilinear fractures of a surface whose parts align in straight or nearly straight lines that may be the expression of folds, fractures or faults in the subsurface. In Nigeria these structures are the results of ductile and brittle deformational events (Onugba and Eduvie, 2003). Their main orientations are in the N – S, NE – SW, NW – SE and sometimes E – W directions (Wright, 1976; Oluyide, 1988; Udoh, 1988; Olasehinde and Awojobi, 2004). Some of these features formed deep valleys. Lineamentsare often mapped at various scales; ranging from local to regional. The local lineaments are mostly joints that resulted from the effects of tensional stresses. They often criss crossed each other and because they are commonly sealed up by the weight of the overlying rocks and/or siliceous materials they tend to decrease in width and size with depth. Linear features are good exploratory targets as they aid migration of fluids and host accumulation of economic minerals, especially at points of intersections. The study area shown in Fig. 1 is situated between latitudes 9^{o}08’41.2” – 9^{o}56’22.5” N and between longitudes 8^{o}06’30.0” – 8^{o}42’51.2” E. This covers an approximate area of about 5827 km^2. This work intends to use the results of lineament intersection data derived from four sources and their overlays to gain some information on the lineament intersections’ spatial distribution and structural orientation.

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Geology of the Younger Granite

Structural trends in the central part of the Basement Complex of Nigeria are dominantly in ENE – WSW direction with significant NW – SE and N – S trends (Oluyide, 1988). These regional trends are lineation that were active zones or spots of magmatism, ring fracturing and cauldron subsidence during the Mesozoic times when granite intrusion that formed ring complexes were emplaced. A culmination of the geologic events along these lineaments were essentially responsible for the opening of South Atlantic in part during early Cretaceous along ENE – WSW active fracture zones by the Rift, Rift, Rift (RRR) triple junction situated below the Niger Delta miogeosyncline.

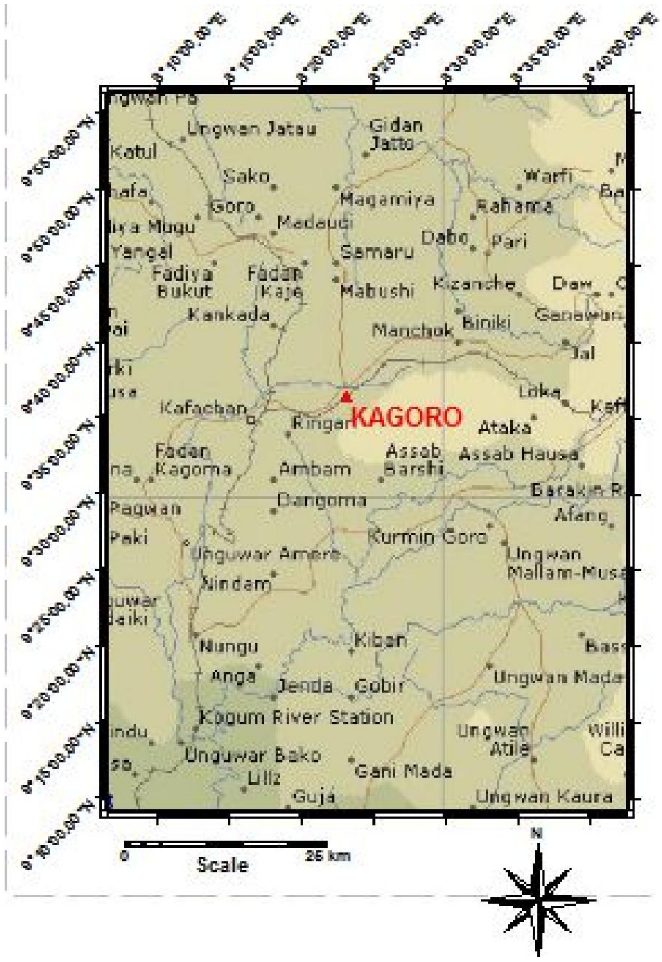


Fig. 1. Location Map of the Study Area (Microsoft Encarta, 2007)

The Cretaceous separation was accompanied by the development of the Benue Valley (south of the study area) which evolved as a deep rifting trough. Cretaceous sediments were deposited along the middle Niger Basin and Benue Trough. Emplacement of the Younger Granites is associated with epeirogenic uplift (Turner, 1989). The age of the Younger Granites is Jurassic; around 160 to 170 million years. The Older Granites and accompanying metamorphism of the basement are about 500 to 600 million years, which represent the Pan African age (van Breeman and Bowden, 1973). Ring faulting and cauldron subsidence are the major tectonic controls that governed the emplacement of the Younger Granites. (MacLeod *et al.,* 1965) stated that the pattern of the initial volcanism was mainly by ring fractures which extended to the surface. These fractures were responsible for the alignment and distribution of the vents and major surface cauldron. Continuation of the same mechanism at greater depth beneath the lava accumulations localized the peripheral ring dykes and the granite plutons. Many of the granite plutons were covered by volcanic hoods. Segmentation of the basement and differential subsidence of extensive blocks are seen clearly around some complexes because erosion has partly removed the upper sub-horizontal sections of the granite intrusions and exposed the network of polygonal feeder ring dykes. Where greater volumes of magma were involved, the intricate patterns of emplacement of the granite plutons are unraveled. In most of the complexes, volcanic rocks have either been obliterated by later granite intrusions or eroded to an extent that their original pattern of distribution is conjectural. Well preserved lavas are invariably confined within major peripheral ring faults (MacLeod *et al.,* 1965). The fractures extended to the surface and provided zones of weakness that facilitated the upward passage of the magma. These same ring-fractures frequently served as the loci of intrusion of the large ring-dykes.

Mapping and Analysis Methodology

Identification and analysis of lineaments' data from drainage, satellite, magnetic, gravity and their combination were performed by visual and manual inspections. Lineaments were digitized on computer screen using the (ILWIS, 2005) software. The same software was used togeo referenced the maps produced. Single lineaments were analyzed for direction trends in the (ILWIS, 2005) submenu. Rose diagrams of the lineament intersection values were presented within directional trends of 10^o in (Grapher, 2004) environment. The lineament intersection values were also statistically analyzed and plotted on frequency distributions of lineaments length intersection per lineament length intersection class in a (Grapher, 2004) environment. The four sources of lineation were superimposed into a single map. Lineament intersection was calculated for each section of cell of the data using the total lineaments length intersections contained within each section. The nodes were assigned to the central points of each of the sections in (ILWIS, 2005) so as to extract their geographic coordinates and manage the corresponding lineament intersection data file. Lineament maps derived from the four sources of data and their resulting overlays are given in Fig. 2.The X, Y, Z data file was imported into (Surfer, 2009) environment for intersection mapping and contouring using simple kriging interpolation algorithm. The interpolated intersection contour maps were then imported into (ILWIS, 2005) for coordinate projection. Structural features were positioned on the maps by georeferencing using the Universal Transverse Mercator (UTM) system available in (ILWIS, 2005) environment. UTM system divides the Earth into sixty discrete zones, each representing a vertical slice of the globe spanning six degrees of longitude. Distance measurements on the maps used the scale factor of 0.9996. Clarke (1880) given in (ILWIS, 2005) ellipsoid was adopted. Coordinate projection parameters used in this study is shown in Table 1.

Data Analysis

Statistical distributions of lineaments obtained from the various sources are given in Table 2. In the table, the cumulative lineament lengths that constitute the streams and rivers in the area is 947.44 km and their average number per kilometer is 5.26. The total length of lineaments derived from the satellite image is 1486.21 km, which gives an average of 8.25 lineaments per kilometer. Magnetic lineaments' data have cumulative length of 1055.76 km and average of 5.87 lineaments per kilometer.

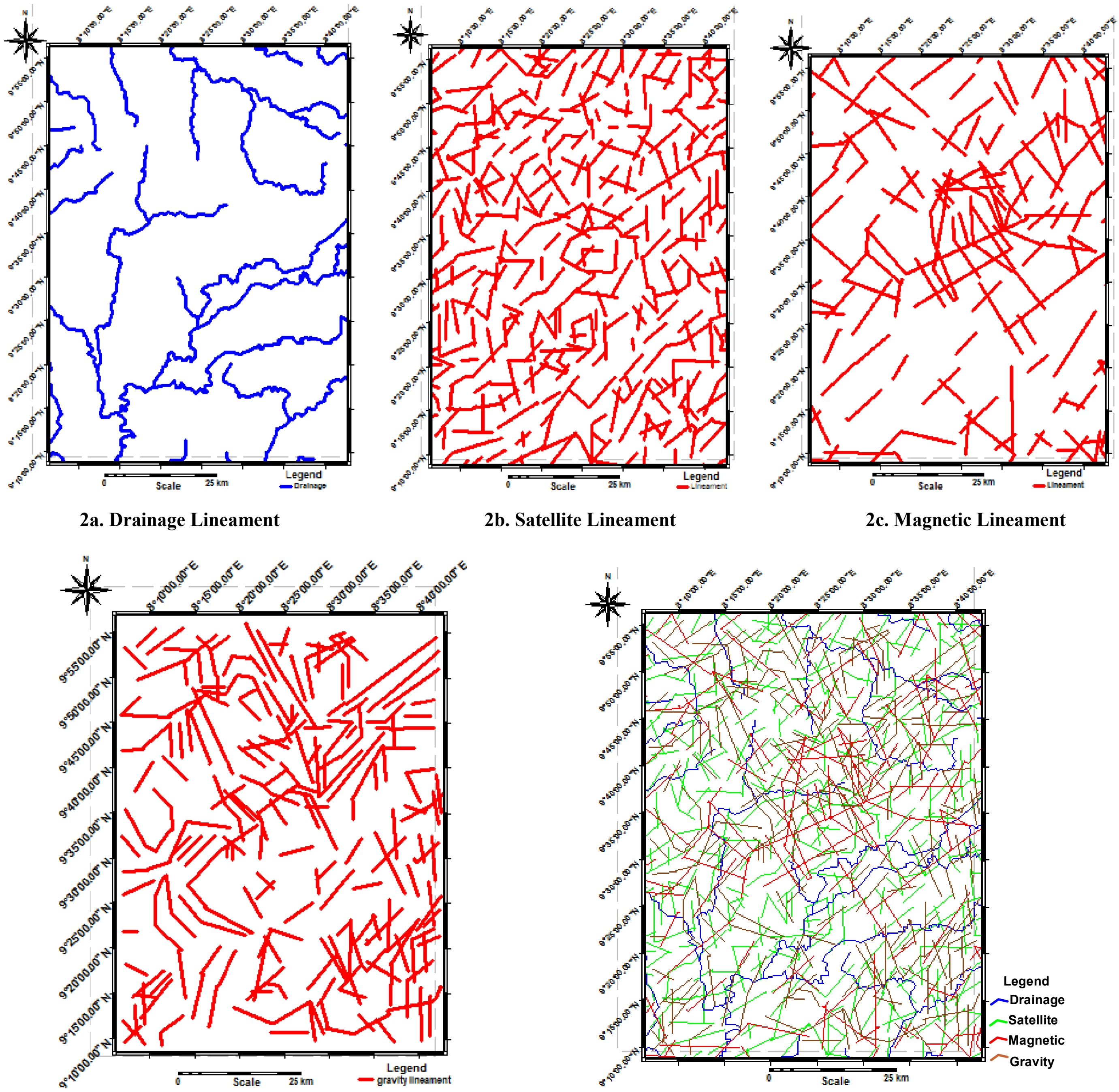
The cumulative length of the lineaments given by the gravity data is 1565.29. This yields a mean of 8.70 lineaments per kilometer. Combined lineaments intersection source produces lineaments length of 2636.90 kilometres and average of 14.65 lineaments per kilometer.

Table 1. Coordinate System Projection Parameters (ILWIS, 2005)

Projection	Datum Area	Datum	Ellipsoid Parameters		Ellipsoid	Hemisphere	Zone
UTM	Nigeria	Minna	a	6378249	Clarke, 1880	Northern	32
			1/f	293.465			

Table 2. Statistical Distribution of the Lineaments

Lineament Source	Lineament Length Characteristics (km)					
	Sum	Minimum	Maximum	Mean	Standard Deviation	Skewness
Drainage	947.44	0.21	33.73	5.26	4.99	1.53
Satellite	1486.21	0.96	31.14	8.25	4.67	0.95
Magnetic	1055.76	0.76	26.49	5.87	5.24	1.20
Gravity	1565.29	1.18	38.13	8.70	6.39	1.33
Merged	2636.90	1.01	56.85	14.65	9.62	1.24



2a. Drainage Lineament

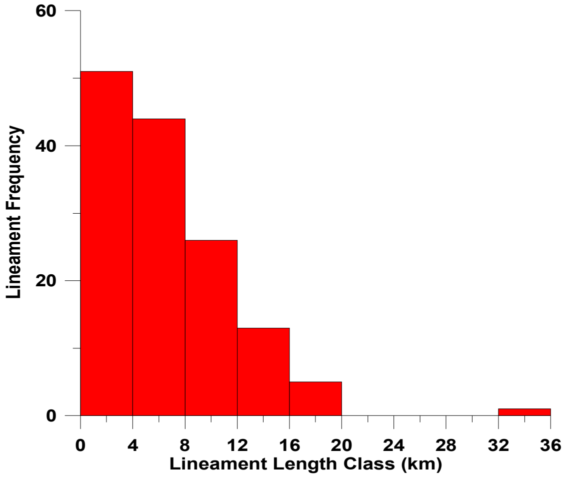
2b. Satellite Lineament

2c. Magnetic Lineament

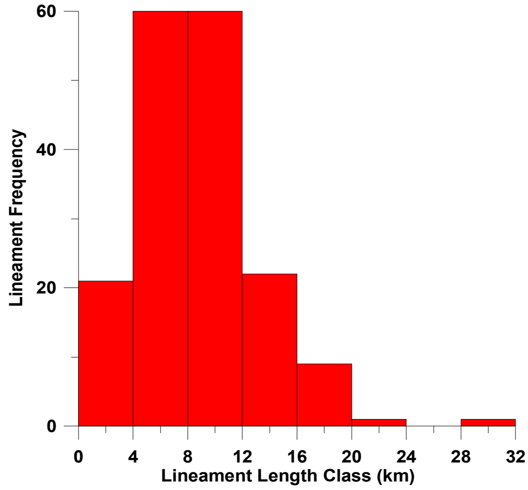
2d. of Gravity Lineament

2e. Combined Lineaments

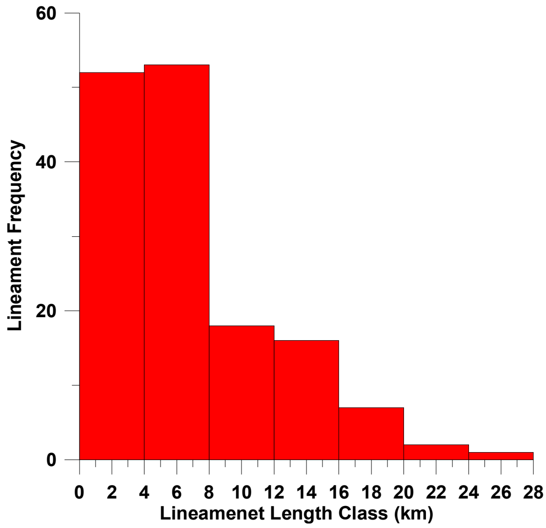
Fig. 2. Lineaments' Data Sources



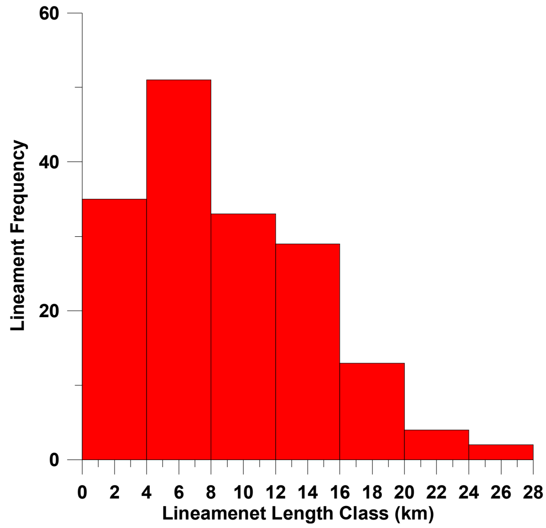
(a). Drainage Lineament Histogram



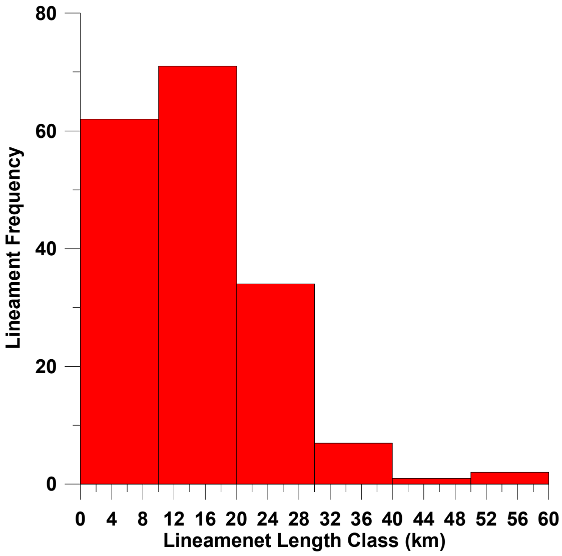
(b). Satellite Lineament Histogram



(c). Magnetic Lineament Histogram



(d). Gravity Lineament Histogram



(e). Combined Lineament Histogram

Fig. 3. Lineament Intersection Histograms

Lineament Intersection Histograms

Histograms have played significant roles of graphical data presentations. The ordinate of the plot was obtained by dividing the number of the data within the particular interval by the total number of the data. The frequency of the lineaments is plotted against the lineament length class. Lineament intersection lengths of the histograms in Figs. 3a - d were grouped into class intervals of four and that of Fig. 3e into class intervals of ten. Fig. 3a shows the histogram of the drainage lineament intersection. The histogram is positively skewed with the highest lineament frequency value of52occurring within the class interval of 0 - 4. Next is the classintervalof4 - 8 with frequency value of45. Lineament frequency value of one only occurs within class interval of 32–36.None of the class intervals 20 – 24, 24 – 28 and 28 – 32 has a record of linear feature intersection value. Satellite lineament intersection histogram produces equal frequency maxima of magnitude 60 within the intervals of 4 – 8 and 8 - 12 (Fig. 3b). A minimum frequency value of one was recorded in the class interval of 20 – 24, and the 24 – 28 class interval has no lineament intersection value. Graphical presentation of magnetic lineament intersection values is presented in Fig. 3c. This histogram is positively skewed. Lineament intersection value in the class interval of 4 – 8 has frequency value of 53. The class interval within the 0 – 4 group has frequency value of 52, and the 24 – 28 class interval contains numerical frequency value of one only. Lineament intersection values within the range of 4 – 8 of gravity data histogram in Fig. 3d produces maximum frequency value of 57. Next in the hierarchy is the lineament intersection class interval of 0 – 4which contains35. The class intervals within 28 – 32, 32 – 36 and 36 – 40have lineament intersection frequency of 2 each. The overlaid lineament intersection histogram in Fig. 3e produces the highest lineament frequency value of 72 within lineament intersection class interval of 10 – 20. Ranking next to this is the 0 – 10class interval with lineament frequency value of 62. The minimum lineament frequency value of 2 occurs within the class interval of 40 – 50.

Lineament Intersections' Trends

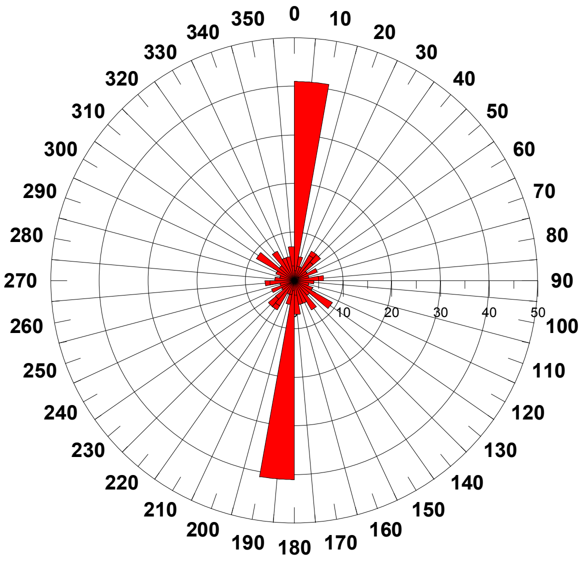
Lineament intersection orientations of the fracture data are summarized on Table 3 and presented graphically by the rose diagrams in Fig. 4.The trend and/or strike data of the rose diagrams were organized into class intervals of 10^o, where each class represents the number of the data that fall within the angular region specified. A family of circles provides scaled control for the number of fracture-orientations that occupy each class interval. The number of points from the data column control the bar length of each class. Two directional plotting of the data is achieved by selecting bi-direction from the software window submenu. Drainage lineament intersection rose diagram exhibits two major directional trends (Fig. 4a).A primary 1^o trend of N 5^o E along with a conjugate 2^o trend of N 55^o W were identified. Four directional trends were observed within the lineaments intersection rose diagram of satellite imagery given in Fig. 4b. A 2^otrend of N 85^o E along with a conjugate tertiary3^o trend of N 25^oE are significant characteristics of the satellite rose diagram. The magnetic lineaments intersection rose diagram in Fig. 3c produces only one structural trend which is the primary 1^o trend of N 5^o E. Lineament intersection rose diagram of gravity data exhibits five directional trends (Fig. 4d.). A 3^o trend of N 45^o E along with a conjugate 3^o trend of N 15^o W was observed, in addition to another 3^o trend of N 35^o W together with another conjugate 3^o trend of N 5^o W. The combined lineament intersection rose diagram exhibits four main orientations (Fig. 4e). A secondary 2^o trend of N 45^o W along with a conjugate tertiary 3^o trend of N 15^o W was obtained. Also a tertiary3^o trend of N 35^o E with another tertiary3^oorthogonal trend of N 55^o Wis a significant directional trend observed from the diagram.

Table 3. Lineament Intersection Trends

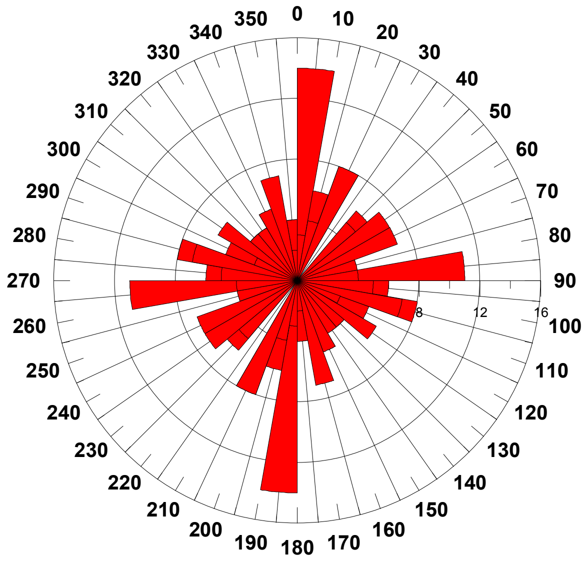
Data Type	Number of Trends	Orientation Description		
		1°	2°	3°
Drainage	2	N 5° E	N 55° W	-
Satellite	4	N 5° E	N 85° E	(a) N 25° E (b) N 75° W
Magnetic	1	N 5° E	-	-
Gravity	5	N 5° E	(a) N 45° E (b) N35°W (c) N15°W (d)N5°W	-
Combined	5	N 35° W	N 45° W	(a) N 35° E (b) N55°W (c) N15°W

Lineament Intersection Maps

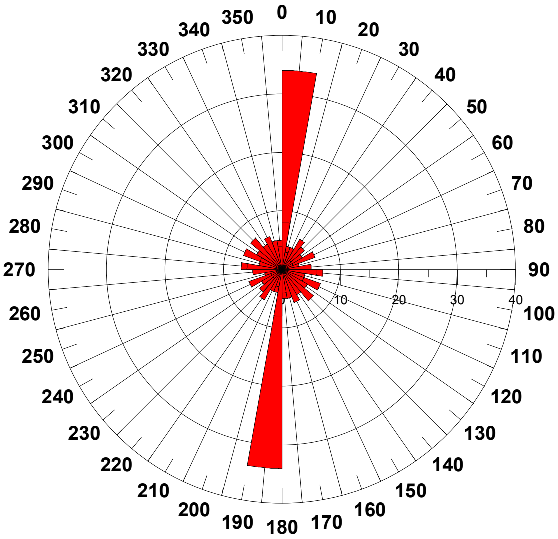
Distribution of the lineament intersections is display in two-dimensional contour maps. The area was divided into equal domains. The numerical values of lineament intersections in each domain counted were assigned to the centre of such domain and then contoured. Interpolated contour pseudo representations of the lineament intersection maps for the five sources of data are presented in Figs. 5.Map of the drainage lineament intersection in Fig. 5a yields low intersection structural values along a NW – SE direction at the northeastern part and a NE – SW trend from the northeast to the southwest of the area. Structural features of low intersection values are observed also at the extreme edge of the southeast. The numerical values of these features range from 1.0 – 1.8. Intermediate lineament intersection values are found along three major areas which include the south, the northwest and the extreme northeast. Along these areas they sandwich high values lineament intersection structures. Estimated values of the intermediate linear features lie within 1.8 – 3.0. High values lineament intersection structures occupy the same region occupied by lineament intersection structures of intermediate values on a smaller scale. At the southwest its alignment is oriented along the NW – SE direction, at the southeast the orientations are along the N – S, NE – SW and NW – SE directions. Pockets of low values satellite lineament intersection (2.1 – 3.4) in Fig. 5b are observed along the extreme northwest and western parts of the central area. The eastern part of the central region and the south western part host slightly higher values lineament intersection areas. Structural orientations of these features which are all enclosed by lineament intersection of intermediate values are align along the N – S and the NE – SW directions respectively. Lineament intersection structures of intermediate values around 3.4 – 5.2 occupy more than sixty percent of the entire area. These lineaments sandwich the low and high values lineament intersection structures throughout the entire map.



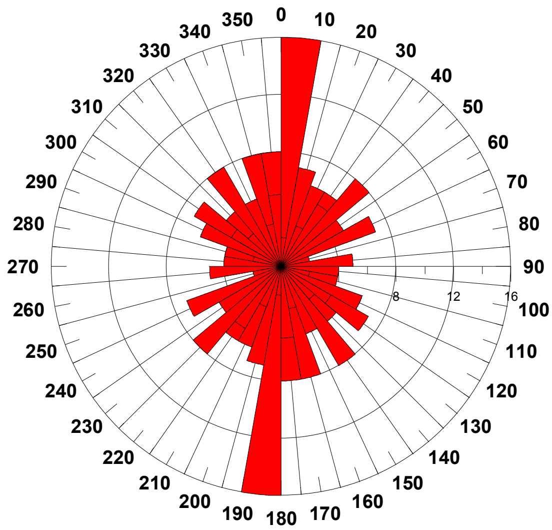
4(a). Drainage Lineament Rose Diagram



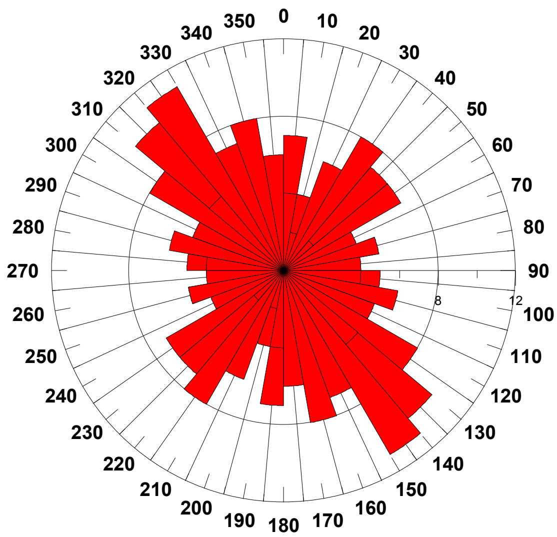
4(b). Satellite Lineament Rose Diagram



4(c). Magnetic Lineament Rose Diagram



4(d). Gravity Lineament Rose Diagram



4(e). Combined Lineament Rose Diagram

Fig. 4. Lineament Intersection Rose Diagram

High values lineament intersection structural features of 5.2 – 8.4 occur at the southeast along the NE – SW direction, east and northeast edge along the N – S direction, central and southwest along the NE – SW and NW – SW respectively. The northwest structure is in alignment with the central structure along the NW – SE direction. Magnetic lineament intersection map displays majority of its low values lineament intersection structures within the range of 1.0 – 2.2 (Fig. 5c). These structures sandwich structures of intermediate and high values at the central and extreme southeast edge of the entire figure. Structures of intermediate values (approximately 2.2 – 4.3) also envelope lineament intersections of high values (4.3 – 6.8) at the central and southeast edge of the map. These are aligning along the NE – SW direction. In Fig. 5d low values lineament intersection structures envelope intermediate and high values lineament intersection structures throughout the area. The values of the lineaments range from 1.0 – 2.3. Lineament intersection of intermediate and high values structures occur separately in three main areas which comprise the extreme north, the north central and the southeast. In all cases, structures of intermediate values envelope those of high values. Approximate values ranges of these structures are from 2.3 – 4.2 and from 4.2 – 7.4 respectively. Coincidentally they both align along the NE – SW directions. The combined lineament intersection map in Fig. 5e presents a slightly different result from the single source maps. Here low values lineament intersection structural areas occur in patches and trend along the NE – SW and partly along the E – W directions. Their values range from 11.4 – 14.0. Structures of intermediate values are found almost along the same geographic location as structures of low values. Their values fall within the interval of 14.0 – 17.2 and are aligning along the NE – SW and E – W directions. The approximate values of the high values structures are from 17.2 – 23.0. These are oriented along the azimuths of N – S, NE – SW and NNE - SSW. They occur almost within the entire area; however their concentration is greatly enhanced around the north central.

DISCUSSION

Differences in the frequency values within the various class intervals may be explained by the intensity of the stress that produced the lineaments which did not act equally in the area. A further prove is the absence of lineament intersections among some class intervals. The N – S, NE – SW, E – W and NW – SE structural trends of the lineament intersections agreed reasonably well with those given by (Wright, 1976; Oluyide, 1988; Udoh, 1988; Olasehinde and Awojobi, 2004; Alkali and Yusuf, 2010)in the region and regional tectonic stress regimes and fractures in Nigeria. Absence of high values lineament intersections in the drainage map over the Kagoro hill area is explained by the fact that these structural features are mainly joints, streams and rivers. On the satellite map only a small portion of the Kagoro hill area and associate rock units were covered by high values lineament intersection, which is attributed to shallow penetrating characteristics associated with satellite imageries. Lineament intersection map from the magnetic data present an ideal image as high values lineament intersections are centred over the Kagoro Younger Granite complex and other rock outcrops. The gravity map also shows the exposed parts of the granites and other rocks units to constituting high values lineament intersections. Thus images of lineament intersection given by the magnetic and gravity maps were derived basically from deep seated structures which may be linked to fracturing and faulting in the region. Combined map of the four lineament sources expresses clearly the locations and trends of the Kagoro Younger Granite complex and its associate rocks. On this map, densely populated lineament intersections are located over the granite exposures and trend along the same directions.

Conclusion

The orientations of the fractures and their frequencies have great influence on their patterns. Densely populated lineaments appear to be located over the Kagoro hill area where great volume of magma was involved during emplacement of the granite. Low lineament intersection values are characteristics of smaller rock outcrops as small volume of magma was probably involved.

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