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Lineaments Characterization of Gound-Water Potential of the Ningi-Burra Complex, North Eastern Nigeria Using Remote Sensing Techniques

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ABSTRACT

A Landsat Enhanced Thematic Mapper plus (ETM+) data was georeferenced using the coordinates of the Nigeria Topographic Map Sheets of Part of Birnin-Kudu sheet 105 SE, Gwaram sheet 106 SW, Kalatu sheet 127 NE and Kaffin Madaki sheet 128 NW, lies between Latitudes 10° 55' N to 11° 10' N and Longitudes 9°20' E to 9° 35' E, ERDAS imagine software (Version 8.6) was used for image processing, enhancement and filtering as well as interpretation and digitization using ILWIS 3.3, the lineaments of the Ningi-Burra was extracted from the satellite, digital elevation and surface lineaments to express the ground water potential zones in the area, the extracted lineament structures were interpreted as fractures, joints and drainage lines for the accessibility of the ground water potential of the area. The satellite lineaments are oriented in a NE – SW direction with major N-S and minor NW – SE. The lineaments from digital elevation model (DEM) were divided into several groups; N-S, E-W, NE-SW, NW-SE, NNE-SSW, ENE-WSW, WNW-ESE, and NNW-SSE. The statistical results have the sum of 898,584.40 km with minimum value of 0.00 and a maximum value of 39,101.40 km. The intensity of groundwater potential decreases with increasing distance from the lineaments. Satellite lineament bar chart has the highest lineament frequency of 5 within the class interval of 9 km and the lowest lineament frequency of 0 occurring within the class interval of 12, 13, 1617, 19 km which represents the drainage lineaments of the stream channels The satellite lineament density map has highest value of 10 - 19 and lowest values of 1.0 and 3.0 densities.

Keywords: Ground water potential zone, Satellite imagery, Digital elevation model and surface lineaments

INTRODUCTION

Backround

Remote sensing can be used as a reconnaissance and feature identification technique for identifying surface and subsurface water potential zones. The study and analysis of the lineaments features of the Ningi-Burra complex using remote sensing methods for integrating maps and data is to have a Spatial distribution and lineament density that will provide a useful database in hydrogeology, ground-water potential, water borehole drilling, road and dam location and alignments, environmental planning as well as potential Hazard Monitoring and Control (Odeyemi *et al.*, 1999)

Groundwater is a critical resource for human activities and ecosystems, particularly in regions where surface water resources are limited or unreliable. Mapping groundwater potential zones is essential for identifying areas with high potential for sustainable groundwater development and management (Kumar, 2024)

The study employs the use of remote sensing techniques that will reveal the geological lineaments structures which will help to establish the ground water potential zones in the area (Dunning *et al.*, 1998; Jefferies *et al.*, 2000; Ashano and Olasehinde, 2010).

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Location of the Area

The area is located within Birnin-Kudu Sheet 105 SE, Gwaram Sheet 106 SW, Kalatu Sheet 127 NE and Kaffin Madaki 128 NW, is bounded between Latitudes 10° 55' N to 11° 10' N and Longitudes 9°20' E to 9° 35' E (Figure 1). The area is in Ningi local Government, Bauchi State, Nigeria. Topographically, the Ningi-Burra Complex forms a range of hills with NE-SW trend over a distance of about 70 km and a width of about 20 km. The range of hills rise about 100 - 300 m above the surrounding basement plains. Volcanic rocks occupy areas of high topography.

The drainage pattern is mainly dendritic. The main river and its tributaries take their source from surrounding hills. The area is drained by Rivers Tsangaya, Dagwalo, Tabula and Tebbi to the south and Rivers Dengir, Jigawa and Lumbu to the north, which empties their water to river Dilimi and subsequently to Lake Chad (Fig. 1). The streams and rivers in the area are seasonal with the water having their highest flow in the rainy season around August and lowest flow during the dry season around March.

The climate of the area is marked by three distinct seasons: -

i Late November – February: Harmattan (NE trade wind from the Sahara that blows toward the south western coast of Africa).

ii. March - May: Dry season, usually very hot with few isolated rain falls. The wind blows from northeast to southwest and temperature may rise more than 35^0 C.

iii. May - September: Wet or rainy season, wind blows to the south-westerly direction with occasional sunshine and temperature reaches more than 35^0 C. September-Late November is characterized by wind from south-west to north east.

Rainfall is usually very heavy in August and finally fading in early November. The mean annual rainfall is about 100 cm. while the mean relative humidity at 0600 hours and 1200 hours is 50 percent and 58 percent respectively (Schroeder, 1974).

The vegetation in the area corresponds to the Sudan-Savannah type, which is characterized by a sparsely distributed shrubs and grasses. The grasses can be as tall as 1m above ground surface during the raining season. Common trees include; *Acacia albida*, *Adansonia digitata*, *Meliaindica*, *Delamixregia*, *Pamae Adenium obtusum* due to their ability to survive dry season.

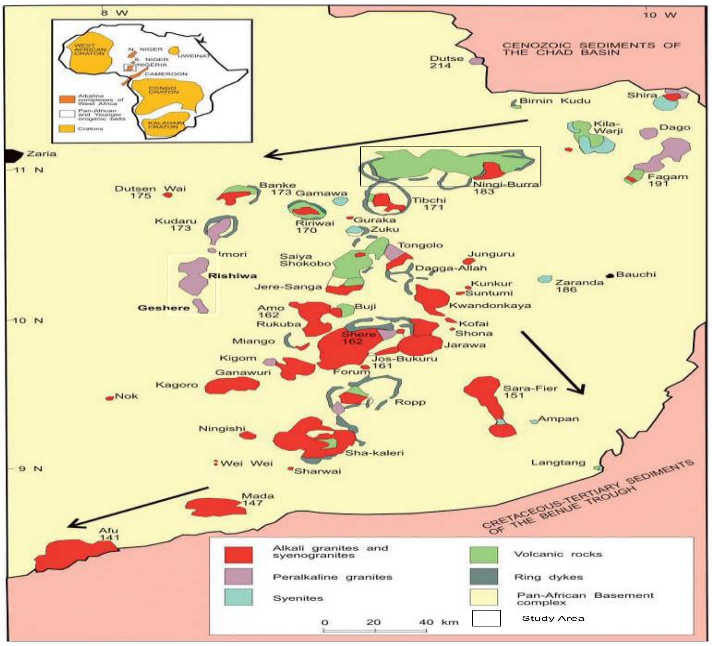

Figure 1: Simplified geological map of the Nigerian Younger Granite (NYG) complexes (after Kinnaird, 1985) rectangle showing the location of the Ningi-Burra Complex.

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Aim and Objectives

The aim of the study is to interpret the satellite lineaments structures for Ground water potential of the Ningi-Burra complex.

The objectives are to:

i) Produce lineament maps of the area.

ii) Compile and interpret the satellite imageries of the area and interpret the structural features for Ground Water potential

METHODOLOGY

The satellite data used in this research is acquired from LANDSAT-TM which covered an area located between latitudes 10°55'N-11°10'N and longitudes 8°55'-9°55'E. Bands 7 is selected according to Marghany *et al*., (2009) which can provide accurate geological information, the Digital Elevation Model (DEM) data with a resolution of 30m covering the area was obtained from the United State Geological Survey Website (USGS). The ASTER-DEM was imported into ArcMap software where the extended elevation range was classified using the classification algorithm of spatial analysis tool of ArcMap. A hill shade value of 2 was assigned in order to reveal the third dimension of hills. The final image was embellished and exported. The data was georeferenced using the coordinates of the Nigeria Topographic Map within the Sheets of Birnin-kudu 105, Gwaram 106, Kalatu 127 and Kaffin-Madaki 128. The georeferenced projection in Universal Transverse Mercator (UTM), Minna Datum.

ERDAS imaging software (Version 8.6) was used for image processing, image enhancement and filtering as well as interpretation and digitization were carried out using ILWIS 3.3.

For this study, the Landsat 7 ETM+ image data was used, the application of the Landsat spectral bands is presented in Table 1. Band 7 of this image data according to this table is useful for the discrimination of minerals, rocks, lineament and structural types (Lilles and Kieffer, 1994). Satellite images acquired in this band have high information content that means there is large variation in the spectral response of materials in the environment. Band 7 is the least affected by atmospheric attenuation compared with the reflected infrared bands. Landsat 7 also carries a panchromatic band (visible through near infrared), with 15 meters’ resolution for “sharpening” of multispectral images.

This procedure of lineament extraction has been used to extract lineaments pattern from LANDSAT TM satellite images. Following (Maged and Mazlan, 2008) image enhancement contrast, as demonstrated in figure 2, stretching and linear enhancement are applied to acquire an excellent visualization.

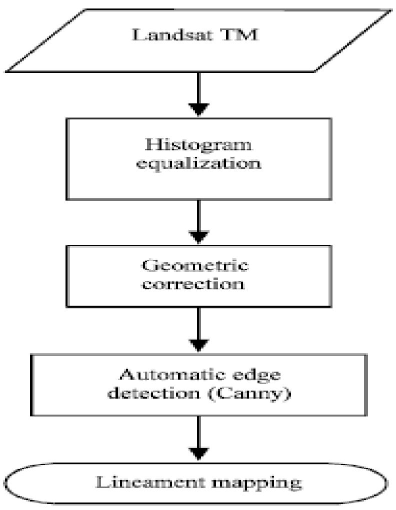

Figure 2: Flow chart of lineament mapping from LANDSAT-TM satellite data

RESULTS AND INTERPRETATION

Satellite Lineaments are linear features in a landscape that generally give an expression of an underlying geological structure in an area such as a fault, fracture, or joint. They are generally extracted from the satellite imagery during remote sensing analysis of fractures.

Lineaments are extracted based on arrangement of vegetation, river course straightness and plane of weakness, the extracted lineaments were classified based on their lengths. There are three types of satellite lineaments patterns that are oriented in a NE – SW direction (expression of the sub-surface structures) and N-S (are the flowing streams) and a NW - SE directions (Fig. 3).

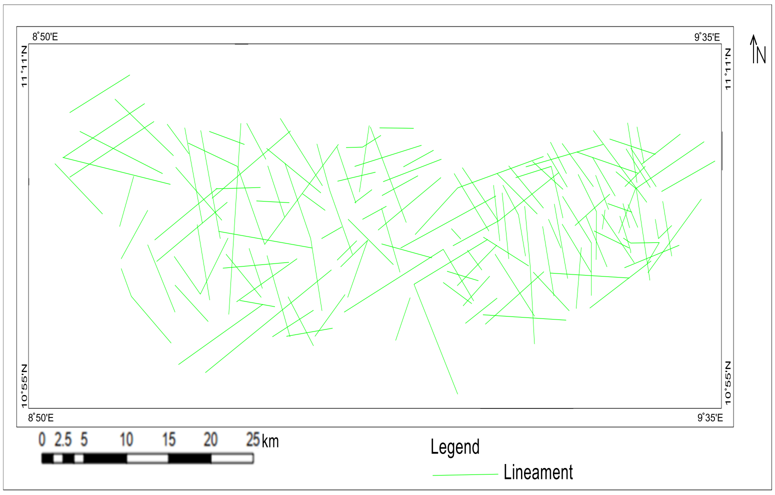

Figure 3: Lineaments extracted from Satellite Images of the Ningi-Burra

Surface Lineaments

Surface lineaments show geomorphological features such as aligned ridges and valleys, displacement of ridge lines, scarp faces and river passages, straight drainage channel segments, pronounced breaks in crystalline rock masses and aligned surface depression in the area as represented in figure 4.

Generally, the fractures in the Nigerian Basement complexes and associated areas are oriented in four principal directions: E-W, N-S, NE-SW and NW-SE. The E–W fractures are discernible locally, having been overprinted by latter events. The N-S fractures determined the causes of the major N-S flowing streams in the area.

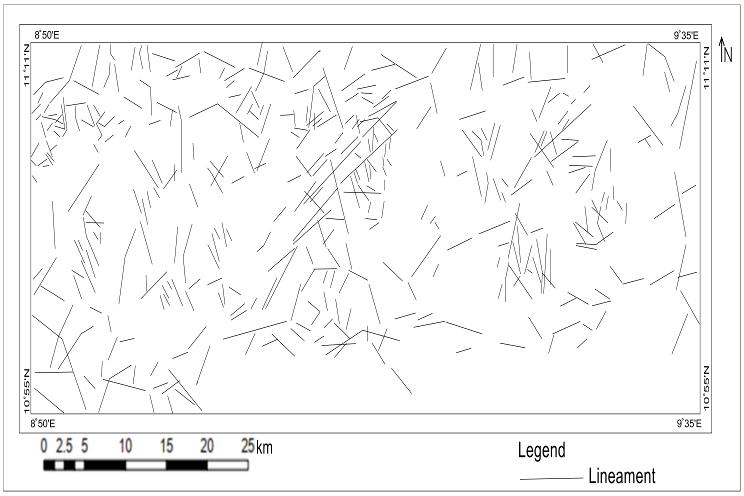

Figure 4: Surface Lineament of the study area

The lineaments intersection map represents the lineaments that are crosscutting each other in the area, the area

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of high intersections of lineaments expressed areas of higher fracture zones which means the area is highly porous as represented in figure 5.

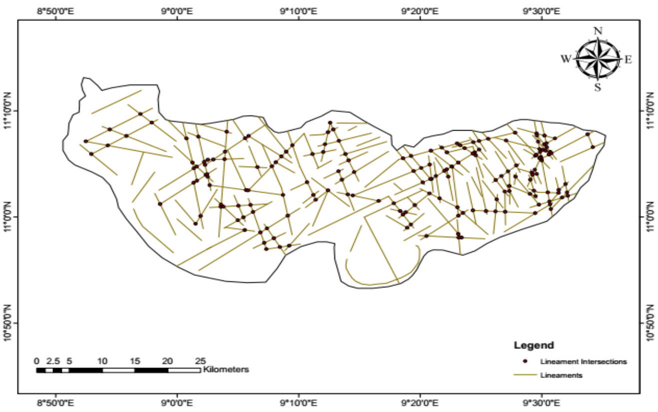

Figure 5: Lineaments Intersection of the Ningi-Burra

The lineament intersection Density as shown in figure 6, represents areas of higher lineament density which is depicted by red colour (1.25223.), areas with low lineaments density is represented with blue colour (0.00249048).

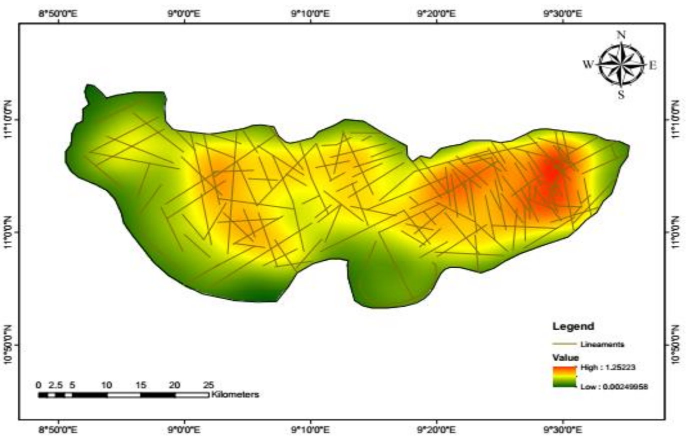

Figure 6: Lineament intersection Density of the Ningi-Burra Complex

Digital Elevation Model (Dem) Lineament Map

Topography of an area plays important roles in recharge rates of ground water prospect of an area. The distribution of a low topography or slope values in an area is typical of crystalline basement terrain, thus, a reason why groundwater potential varies significantly in basement complex terrains. In areas of low slope values, surface runoff is low, allowing more time for infiltration of rainwater, higher slopes produce smaller recharge because the water received from precipitation flows rapidly down a steep slope during rainfall, therefore, it does not have sufficient residence time to infiltrate and recharge the saturated zone. The area with highest elevation is characterized by a rugged topography; these areas form a dendritic drainage pattern which signify various rivulets, gullies and drains that flow towards the lowest part of the areas.

The Digital Elevation Model (DEM) map of the area shows elevation values ranges between 448m and 1,167m above sea level. The topography of the study area was divided into three segments namely; high, low and intermediate elevation represented by pink, blue and yellow colors as represented in figure 7.

The highest elevation is depicted by pink color ranges from 854 – 1,167m above sea level around Kurmi and Kaluki, areas with the lowest elevation is represented by blue and green colors ranges from 448 -642m above sea level, it is observed that topographically high areas are characterized by higher elevation of the area (Kurmi, koluki and Old Ningi settlements) and the low areas has lower elevation representing the Basement

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complex rock of the area (Ningi, Lumbu, Jigawa, Burra).

The intermediate elevation is denoted by yellow and orange colors ranges from 642 -864m above sea level includes areas around Kafin Fulani, Tamba, Jimmi and Tabula settlements

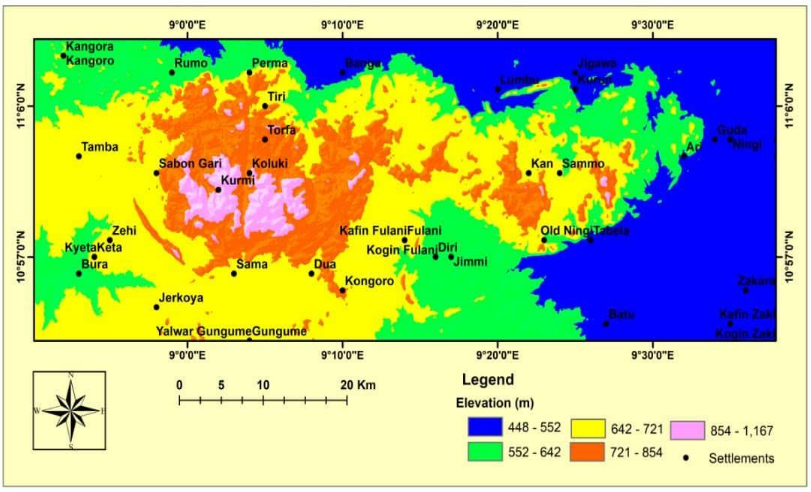

Figure 7: Digital Elevation (DEM) map of the Ningi-Burra

The digital elevation model lineaments extracted from the area is complex and actual representation of the landform based on elevation of the area.

The lineaments are trending in the N-S, NW – SE, and NE – SW directions (Fig. 8).

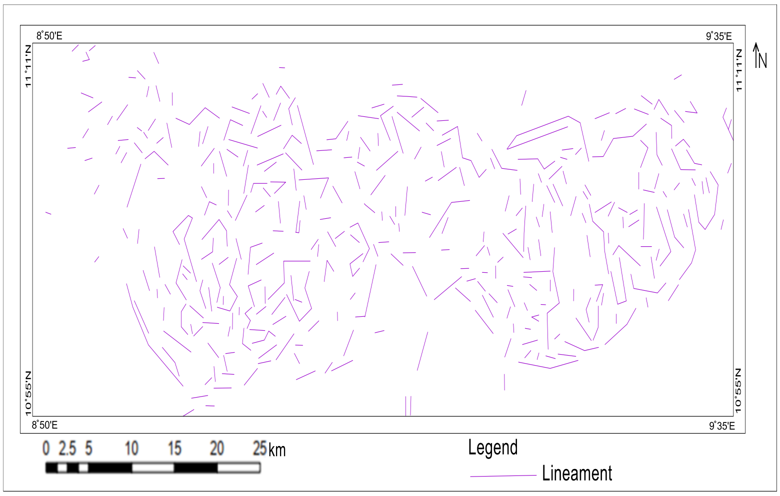

Figure 8: Digital Elevation (DEM) Lineament of the Ningi-Burra

Lineament Density Maps

This concept refers to the area of the unit circle needed to calculate the lineament density factors distributed within the circle; length counts and cross-points counts. The circle is a unit circle where one calculates the sum of the lineament length, lineament counts and the number of cross-points within it. Lineament density maps display the distributions of the lineaments in two-dimensional maps. The area was divided into equal area grids; the number of lineaments in each grid were counted and recorded, lineament that extended into another domain boundary was counted within the grid area that extended into, the numbers were assigned to the center of each grid area and then contoured at appropriate intervals.

To produce the Lineament density map, the area was divided into equal area grids of 60 blocks (6 columns and 10 rows). The number of lineaments in each grid were counted and recorded. A lineament that extended into another domain boundary was counted within the grid area extended into it. The numbers were assigned to the

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center of each grid area and then contoured at appropriate intervals. The maps are shown as Interpolated contour pseudo representations of the lineament density maps. The ranks are given for lineament density based on proximity of lineaments with increasing distance from the lineaments It is revealed that the intensity of groundwater potential decreases with increasing distance from the lineaments. Areas having high lineament densities are inferred to be fracture zones having high porosity and permeability which has greater chance of accumulating groundwater potential.

The satellite lineament density map represented in figure 9, produces low density linear structures (Yellow color) with values ranging between 1.0 and 3.0 and trending along the trend of the younger granite complex direction as observed at the peripheral side of the complex. Intermediate value lineament density structures (Pink color & Blue) range from 3.0 to 10 and follows the trend of the complex in the S-E direction and sandwich both the low and high lineament density structures within the entire map with the exception of the center of the complex which are sandwiched by low density linear structures (yellow color). High values lineament density features are displayed in orange color ranges from 10 - 19 and was displayed in red colors.

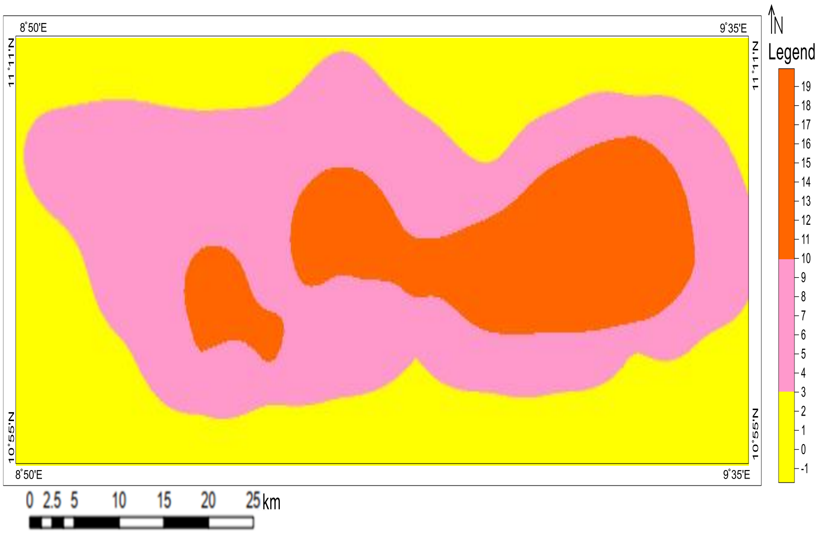

Figure 9: Satellite Lineament Density Map the Ningi-Burra Complex

The surface lineament density shown in figure 10, shows structural value at the eastern and southern part of the study area as represented with yellow color with value ranging from 1-5, while the intermediate values ranges from 5-13 as depicted with pink color which occupied the highest portion of the complex, the pink color sandwich the orange color zones. The high surface structural frequency value represented by orange color portion of the study area has the highest density frequency value ranging from 13-25

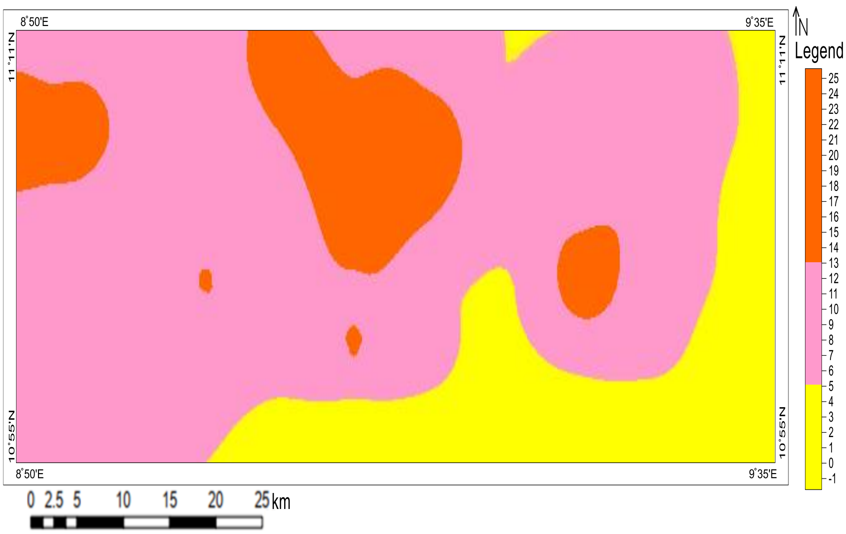

Figure 10: Surface Lineament Density Map of the Ningi-Burra complex

The lineament density map extracted from DEM in figure 11, produces low density linear structures (yellow color) with values ranging between 1- 4 and trending in a W – E.

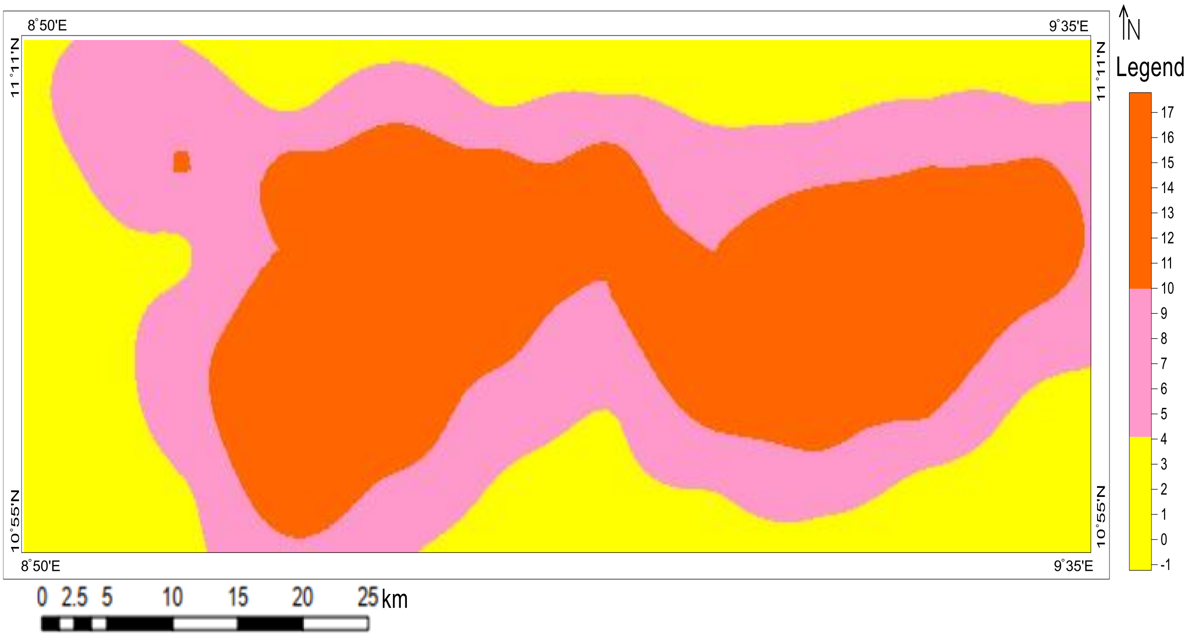

Figure 11: DEM Lineament Density Map the Ningi-Burra Complex

Lineament Statistical Analysis

PREAMBLE

Descriptive statistical analysis results gave the cumulative distances of satellite, surface and DEM are; 898,584.40 km, 944,834.20 km and 684,512.00 km respectively and its average at 4,992.10, 5,249.10 and 3,802.80 lineaments per kilometer respectively, Table 2 represent the statistical distribution of the lineament source and distance in kilometres (Km).

Table 2: Statistical distribution of the Lineaments

Lineament Source		**Lineament Length Characteristics (km)**				
	Sum	**Minimum**	**Maximum**	**Average**	**Standard Deviation**	**Skewness**
Satellite	898,584.40	0.00	39,101.40	4,992.10	6,854.70	1.89
Surface	944,834.20	0.00	20,944.60	5,249.10	3,530.20	0.80
DEM	684,512.00	0.00	15,886.90	3,802.80	3,069.00	1.19

Lineament Histogram

The most common method of graphical data presentation is the histogram or Bar chat, which is a plot of the proportional frequency of observed values lying within given numerical values. The ordinate of the plot is obtained by dividing the number of values within the particular interval by the total number of values. For the purpose of this work, the frequency of the lineaments was plotted against the lineament length class (km).

The satellite lineament Bar chat in figure 12, is positively skewed with the highest lineament frequency of 5 occurring within class interval of 9km and the lowest lineament frequency of 0 occurring within the class interval of 12 – 13, 16-17, 19 kilometers.

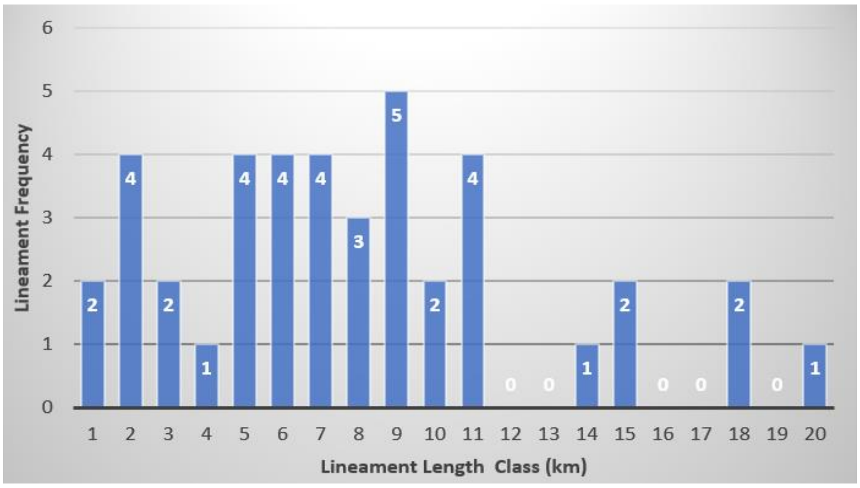

Figure 12: Satellite Lineament Bar chart

The surface lineament Bar chat (Fig. 13), has the highest lineament frequency of 9 within the class interval of 5 and 7 kilometers and the lowest lineament frequency of 0 within the class of 15, 17-18, 21-23 and 25 kilometers.

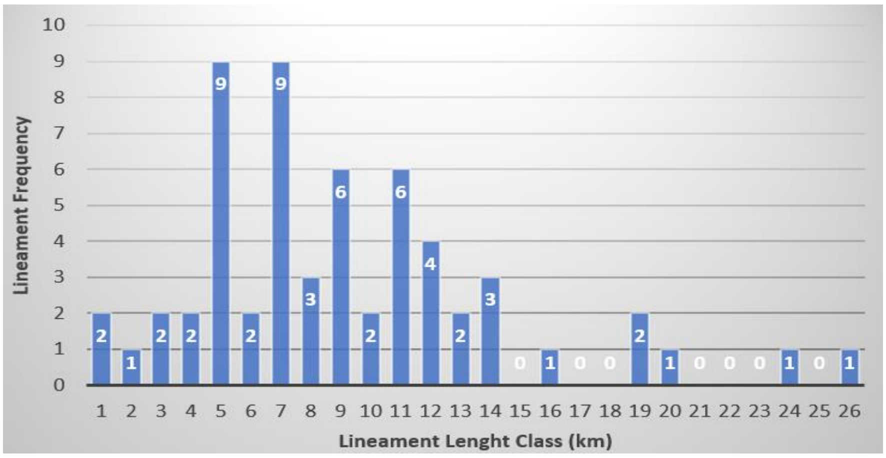

Figure 13: Surface Lineament Bar chart

The lineament density Bar chat (Fig. 14), extracted from Digital Elevation Model (DEM) produces highest lineament frequency value within the class of 3 km and 10 km with minimum frequency value of 1 within 4,9,16 and 17 kilometers.

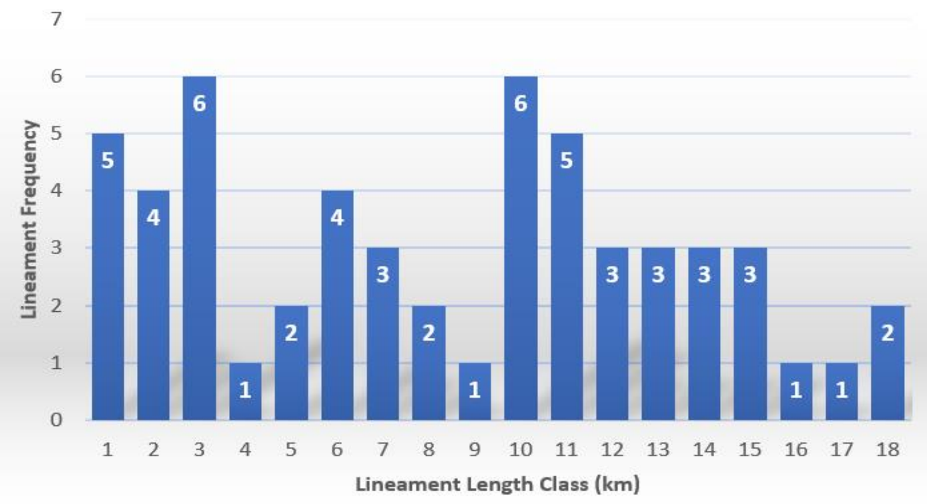

Figure 14: DEM Lineament Bar chart

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Lineaments Trend

Preamble

These lineament directions correlate well with joint directions mapped on the surface; the lineaments correspond with alignment of stream segments which signifies a form of structural control of the drainage system. The lineaments trends presented in rose diagrams reveals several trends in NE-SW, NW-SE, N-S and E-W directions; with the dominant structural trends in NE-SW and NW-SE directions.

Lineaments Orientation Trends on Rose Diagrams

Directional data extracted during analysis of the fractures as summarized on Table 3 and presented in a rose diagram in figures 15, 16 and 17, the trend and / or strike data are organized into bin sizes (class intervals) of 10^0, where each bin represents the number of values that fall within the specific angular region. A family of concentric circles provides scaled control for the number of fracture orientation values that occupy each bin size

Table 3: Lineament Orientation Trend

Data Type	Number of Trends	Orientation Description				
		1^0	2^0	3^0	4^0	5^0
Satellite	6	N320^0 W	N55^0 E	N340^0 W	(1) N65^0E (2) N355^0 W	N315^0 W
Surface	6	N60^0E	N335^0W	(1) N45^0E (2) N315^0 W	N25^0E	N290^0 W
DEM	6	N355^0W	N55^0E	(1) N90^0E (2) N325^0 W	N35^0E	N310^0 W

Satellite lineament density rose diagram represented in figure 15, produces six (6) numbers of trends which is one primary (1^0) trend of N320^0 W with one secondary (2^0) trends of N55^0 E with one tertiary (3^0) trends of N350^0 W and two quaternary (4^0) N65^0 E, N335^0 W and one pentagonal (5^0) trends of N315^0 W.

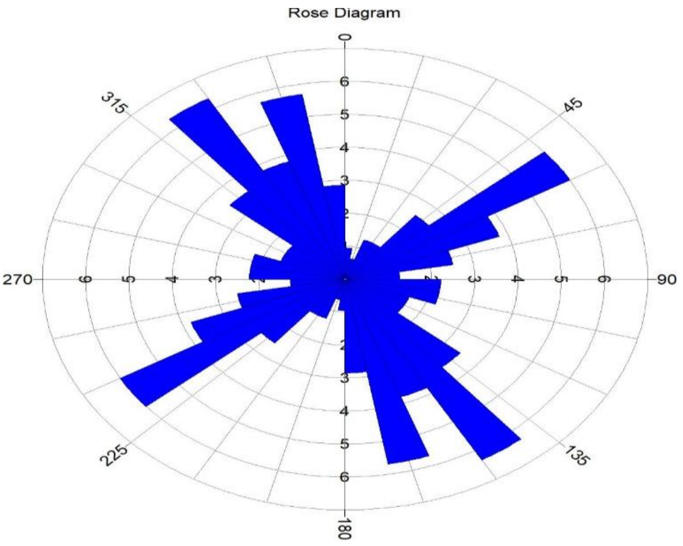

Figure 15: Satellite Lineament Rose Diagram

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Surface lineament density rose diagram represented in figure 16, produces six (6) numbers of trends, one primary (1^0) trend of N60^{0}E with one secondary (2^0) trends of N335^0 E, with two tertiary (3^0) trends of N45E and N315^{0}W with one quaternary (4^0) trends of N25^0 E and one pentagonal (5^0) trends of N290^0 W.

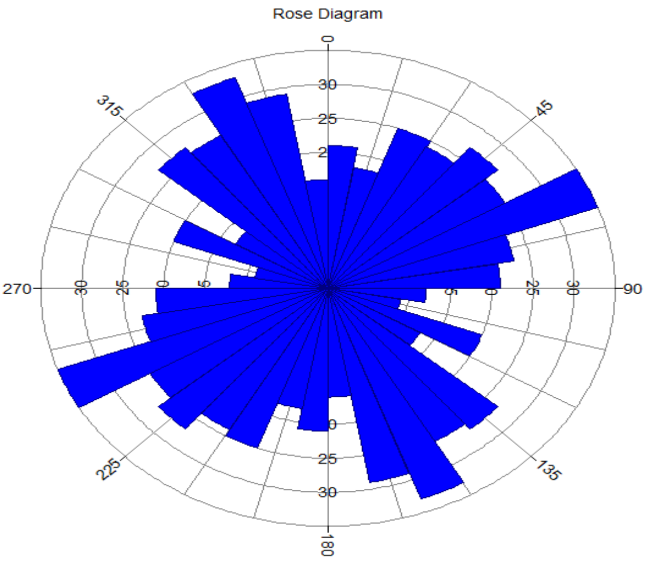

Figure 16: Surface Lineament Rose Diagram

DEM lineament density rose diagram represented in figure 17, produces six (6) numbers of trends which are one primary (1^0) trend of N355W with one secondary (2^0) trend of N55^{0}E, two tertiary (3^0) trend of E90W and N325^{0}W with one Quaternary (4^0) trends of N35^{0}E one pentagonal (5^0) trends of N310^{0}W.

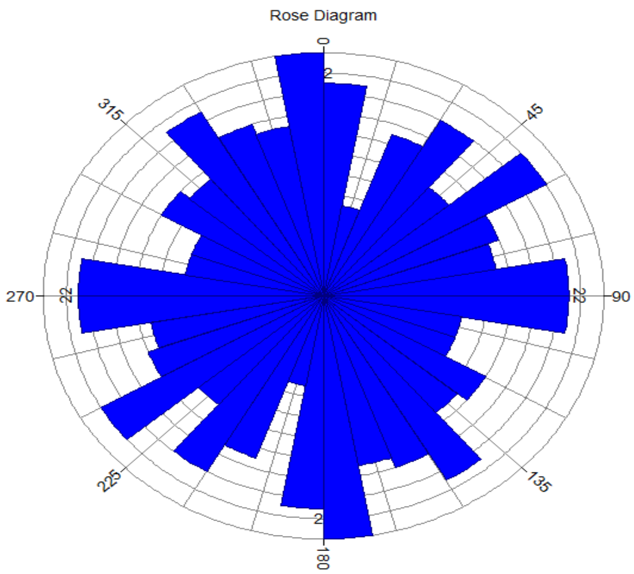

Figure. 17: DEM Lineament Rose Diagram

CONCLUSION

Based on the results obtained it is very possible that Ground water is more than the surface water found in the area, as the area is very porous due to high lineaments density. The use of remote sensing data has helped in obtaining detailed surface situation which is a representation of the subsurface situation in the study area.

Based on the results obtained, lineament characterization will enable a better understanding of the role of structural features, such as joints and faults, in groundwater infiltration and accumulation.

Remote sensing techniques can be used for mapping groundwater potential zones which has important applications in various sectors, such as agriculture, industry, and urban water supply.

The map of the lineament density produced from Landsat imagery and DEM tend to show the area of high lineament density, which could be the target area for exploration.

The result obtained is of advantage in modern exploration geosciences in that they offer quick glance at the spatial distribution of the density of lineament and hence provide database in hydro geology, mineral exploration, hazard assement and engineering construction.

RECOMMENDATIONS

i) Based on the results obtained, remote sensing should be used for geological mapping as a data acquisition method complementary to field observation. About one-fourth of the Earth's total surface area is exposed land where information is ready to be extracted from detailed earth observation via remote sensing to be used in the study of modeling of subsurface flow and natural recharge, pollution control and hydro geologic process monitoring.

ii) Geological mapping methods have been undergoing continuous change along with technological and scientific advances in other relevant fields. Remote sensing techniques are now being increasingly used to prepare geological maps and obtain the basic geological information on which further detailed work is based.

iii) Based on the results obtained from this research work, it is recommended that more detailed geophysical investigation should be carried out to study the sub-surface ground water potential

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