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# Remote Sensing Technique as Exploration Tool for Ground water in Parts of the Upper Benue Trough, Nigeria

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**ABSTRACT**
*The study area lies within latitudes 8°00' – 9°00'N and longitudes 11°30' – 12°30'E. Analysis of remote sensing imageries of part of the Upper Benue Trough of Nigeria was carried out on a scale of 1:100,000. The aim of this study includes the structural interpretation of the remote sensing data and the identification of the lineament and drainage patterns associated with the area to infer the influence of such structures on the economic potential of the basin. Results of the structural analysis revealed numerous lineaments. Trend analysis of the lineaments plotted on a rose diagram using the strikes and lengths of the entire lineaments revealed structural trends predominating in the NE-SW direction. The absence of visible lineaments in parts of the area may not indicate absence of geological structures. Some of these lineaments were found on some drainages showing that the drainages in those areas are structurally and tectonically controlled. The areas where the lineaments cross each other are indicative of groundwater availability and there correspond to regions of mean topographic height of about 900m.*

***KEYWORDS**: Lineaments, Drainage, Groundwater, Rose Diagram, Upper Benue Trough*

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## I. Introduction

The objective of the study is to give a regional analysis of part of the Upper Benue trough. Remote sensing (satellite and aerial imageries) provides a continuous source data for mapping lineaments, which frequently reflect surfaces of discontinuity in the rocks (Mostafa and Bishta, 2005). Lineament analysis provide methods for detecting past tectonic trends, minerals, oil and groundwater explorations, geomorphologic studies and geologic mapping, structural studies, glaciology, geodesy, weather studies, etc (Sondergger, 1970; Bagheri and Keifer, 1986; Mostafa and Bishta, 2005). Ananaba et al (1987) confirmed that Nigeria which is characterised by conjugate strike- slip fault system consisting of NE- SW dextral and NW- SE sinstral trends of faults has been attributed to a horizontal maximum stress axis oriented E-W, by identifying the NE- SW and NW- SE lineament trends located and interpreted on landsat imagery from the schist belt. A regional analyses of landsat data of Nigeria suggested a complex nature of fractures or lineaments with directions that are dominant in NE-SW, NW-SE and N- S directions (( Chukwu-Ike (1977), Ananaba et al (1987) and Udoh (1988)). Investigation on the morphology of the basement beneath the pile of the sediment in the parts of the middle Benue trough, Nigeria resulted in the delineation of the twelve major fault segments which divide the basement rocks into discrete blocks (Onyedim et al (2006)).

The linear features are classified according to their length and photographic expression and may be referred to as fracture traces, analytical linear features, or lineation, when their length is between one and ten or 20km according to the scale of the images employed. Those much longer, measured in tens and sometime in hundreds of kilometres, are termed lineaments. Lineation are considered to be the expression of tectonic deformation affecting a relatively small thickness of rocks, thus reflecting the detail of the local structures, although concentrations and belts may help to delineate regional features. Lineaments, because of the length, are generally the expression of regional structures. Faults, fractures and dislocations occurring in the brittle basement rocks are caused by tectonism (Krishnamurty et al, 1980; Danielska et al, 1986; Defu et al, 1986). These weak crustal tectonic zones are observed as lineaments on remote sensing data. Such linear zones are easily prone to crustal movement.

Changes in lithology are often marked by lineaments. Escarpments with less resistant rocks at lower topographic levels often mark a decrease in resistance to weathering. The lineament pattern often yields information concerning the host lithology. The relationship between lineaments and groundwater was proved by

Mabee et al (1994), Magowe and Carr (1999) and Krishnamurty et al (1980) who in their separate studies agreed that high density of lineaments indicate in general, the presence of groundwater. In basement rocks, the amount of groundwater available is highly dependent on the storage and rate of infiltration into faults and fractures. This in turn depends on whether the fractures are open or closed. Larsson (1977) and Fernandez and Rudolph (2001) concluded that tectonic activities which result in brittle deformation, generate shear fractures which is orthogonal or inclined to the direction of tectonic stress (that is, it is compressed and tight) and therefore not transmissive; and extension fractures which are parallel to the direction of tectonic stress or orthogonal to the direction of crustal extension and is associated with wider aperture. Therefore, tight/ closed fractures (that is, shear fractures) contain little or no water, while open fractures (extension fractures) may produce considerable amount of water.

The course of rivers has been found to lie in the same orientation as structures caused by tectonism and zones of weaknesses (Russ, 1957).Fracture traces and lineaments also reflect secondary permeability and porosity in carbonate rocks. These fractures become zones of weathering and therefore are permeable and porous. The fracture zone forms an interlaced network of high transmissivity and serves as local groundwater conduits for massive rocks in inter –fractured areas. Therefore, the occurrence of a well defined lineament network proves very useful for groundwater exploration.

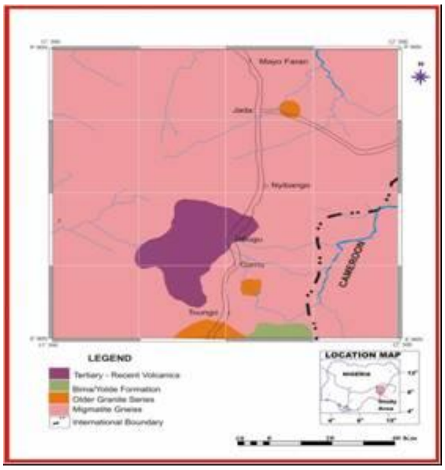



**Figure 1: Geological Map of the Study Area**

## II. Geology Of The Upper Benue Trough

In the Upper Benue Trough, the lithostratigraphic pile includes a lower continental unit formed by the Bima sandstone series deposited in a Lacustrine- Deltaic environment. Above a marine sequence of shales with interbedded carbonates, represent the Turonian and the Santonian stages. The Cretaceous sequence is capped by the regressive formation of the Gombe sandstone of Maastrichtian age. The Tertiary, represented by continental deposits of the Kerri- Kerri Formation, is restricted to the western part of the Upper Benue Trough. The Upper Benue Trough is formed by several sub-basins of which evolution and distribution were closely controlled by a fracture system where the N55°E trend dominate. From the upper Aptian to lower Albian times, the Kaltunge fault, an inherited Pan- African mylonite, has played as a sinistral wrenching responsible with other faults of the formation of pull-apart basins. A comprehensive phase of late Maastrichtian age is responsible for the fracturing and folding of the Cretaceous cover. The style and directions of folds are greatly influenced by the basement structures. The fracture system is mainly formed by strike- slip faults resulting from a N155°E trending horizontal compression. A post- Cretaceous tectonics is marked along the western edge of the Kerri- Kerri plateau by normal faults (Benkhelil, 1982). Evidence of tensional movements are also known in the Yola branch where N-S trending faults are found to result from the tensional regime related to the emplacement of the Cameroun volcanic line. The Yola arm has the oldest sediment as the Bima sandstone and Yolde Formation which outcrops in the major parts of the area. The Bima sandstone and Yolde Formation are of variable sequence of sandstone and shale, which marks the transition from continental to marine sedimentation. The upper part of the Bima sandstone and Yolde Formation contain blue- black shales. It can be observed from the map of the area, that the basement complex outcrops on the surface. The basement comprising of older granite series, migmatite, gneiss/ schist complex covers most of the area with tertiary to recent volcanic centralised. Significant features of sandbars running from Toungo in the south to north- east of Jada is evidenced from the area map. Fractures can also be inferred in the south western part to the North – Central intersecting Belwa River.

## III. Methodology And Materials

The materials used for the analysis include the geological map of the study area and the satellite image data. A subset of the satellite data covering the study area was created using Erdas image processing software. A high speed large memory digital electronic PC with a coloured printer and plotters for map printing as well as a colour monitor for visualization of image are needed. A table scanner is also needed which is used to scan all the relevant maps used for this study. Integrated Land and Water Information System (ILWIS) was used for creating several themes or layers from the satellite image. This software has the capabilities for various image enhancement techniques such as linear (edges) enhancement, statistical analysis, principal component analysis and normalized difference vegetation index.

## IV. Discussion Of Results

Simple digital image processing techniques, which involves image classification, linear/edge enhancement, etc were applied on the image to enhance edges of linear features, followed by computer aided visual interpretation of geological structures and lithological units. The processing led to the production of drainage and fracture/lineament patterns as well as geological map. Further mapping of the area was carried out by producing composite images. The drainage system analysis of the basin revealed the radial drainage pattern. The radial drainage pattern is associated with circular network of approximately parallel channels flowing away from a central high point, and this pattern is usually indicative of resistant materials with regard to the local environmental conditions. This pattern is mostly evident in volcanoes, isolated hills and dome-like structure.

Lineament (fracture) analysis was done to delineate zones of fracture concentration, so that information on the structural deformation occurring in the area can be exposed or revealed. The structural interpretation of the remote sensing image revealed a number of lineaments and mega lineaments predominating in the NE-SW and NW- SE portions. In the upper part of the Benue Trough of Nigeria, several major NE–SW lineaments are essential components in the structure of both the Pan-African basement and the Cretaceous sediments. The lineament analysis is an effective method of mapping sub – surface deformation (shear and extensional features). The lineament map of the study area is shown in Figure 3 below.

The result of the remote sensing imagery study carried out in the Yola arm of the Upper Benue Trough, presented two-dimensional interpretation of several profiles across the area of study showing that although the anomalies over the Upper Benue Trough can be independently accounted for in terms of either a basement of variable topography or intrusive bodies, they were best interpreted in terms of the combined effects of intrusive bodies and a crystalline basement of variable topography. The upliftment of the topography is as a result of tectonic activities that took place in the study area as shown in the topographic map.

The Digital Elevation Model (DEM) is employed for structural geologic and tectonic interpretations such as locating faults, drainage pattern, plate positions, slope, lineaments and the boundary between geologic units. Colour and colour tone are the brightness levels in digital images. Reflection of colour tones of different materials on the earth helps in distinguishing surface materials and their boundaries. The colours on the DEM include blue, pink, red, orange, yellow and green in ascending order.

Earth materials that can be distinguished on the DEM include vegetation, soil, rocks, water, cloud, fire and smoke. The reflectance from soil and rocks is influenced by colour, mineral contents (chemical composition or crystalline structure), structure, etc. Figure 4 above shows topographic roughness and geomorphologic structures.

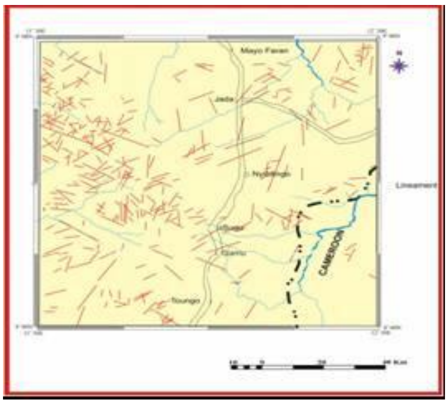



**Figure 3: The Lineament Map (with drainage superimposed) of the Study Area**

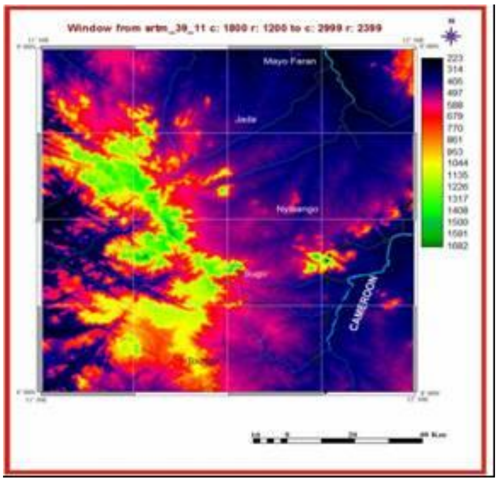


**Figure 5: The Digital Elevation Model (DEM) of the Study Area**

The output of NDVI (Figure 6) is a measure of vegetation richness of an area. Values of NDVI can range from -1.0 to +1.0, but values less than zero typically do not have any ecological meaning, so the range of the index is truncated to from 0.0 to +1.0. Higher values signify a larger difference between the red and near infrared radiation recorded by the sensor - a condition associated with highly photosynthetically-active vegetation. Low NDVI values mean there is little difference between the red and NIR signals. This happens when there is little photosynthetic activity, or when there is just very little NIR light reflectance (i.e., water reflects very little NIR light).

This was generated to delineate zones of vegetation and bare rocks. From Figure 6 below, dark brown areas correspond to bare rock zones, light brown areas correspond to soil and very little vegetation, yellow corresponds to sparsely vegetated areas and green to thick vegetation. With this image, traverse for field work can be better planned.

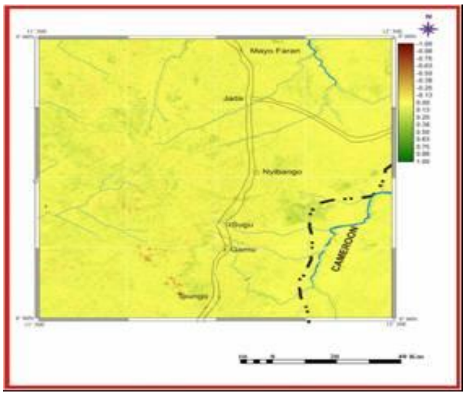


**Figure 6: The Normalized Differential Vegetation Index (NDVI) of the Study Area**

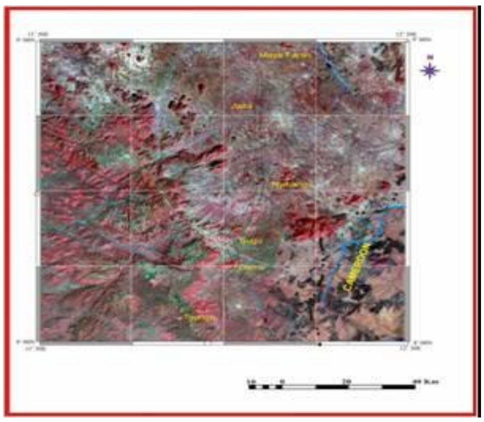


**Figure 7: RGB 432**

In this study there are three false colour composite images with RGB (R = Red, G = Green, B = Blue) bands of landsat 5 TM multi spectral image respectively. The mid infrared portion of the spectrum is sensitive to active vegetation, water bodies and soil moisture.
The composite image provides a naturalistic and earth view of the landscape of the study area. The green areas represent the vegetation (trees), the red areas represent bare rocks or ground surface and the blue areas represent water.

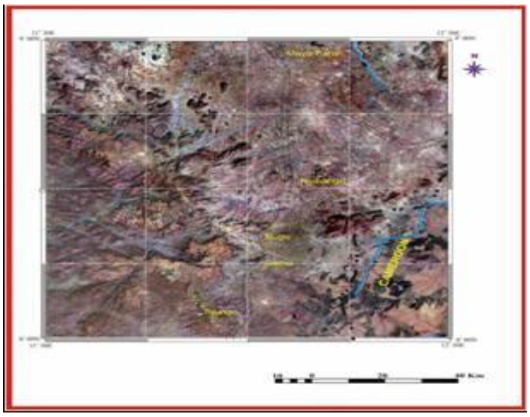


**Figure 8: RGB 532**

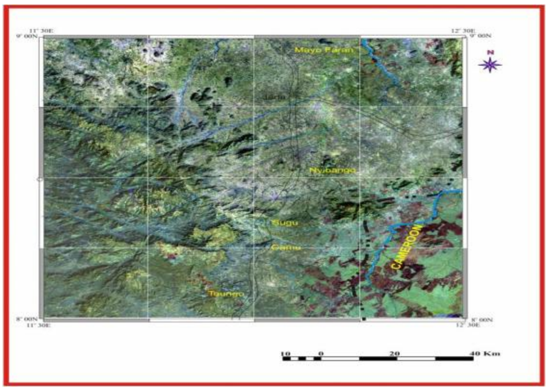
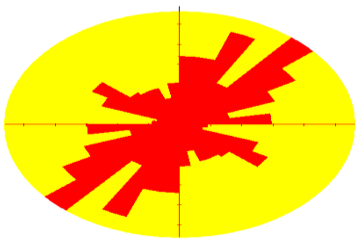


**Figure 9: RGB 752**

Rose diagrams are used to easily identify the orientation and frequency of distribution of lineaments over the study area. The rose diagram plotted from the lineament map that was extracted from the remote sensing image of the area (Figure 7), shows the dominant trend of lineaments and drainage to be of the NE-SW inclination.



Number of data plotted = 338; Sector Interval Angle = 10°; Scale spacing = 2% [7 data];
Maximum = 11.2% [38 data]; Mean Resultant direction = 036; Circular Mean Dev. = 48°
**Figure 10: Rose Diagram**

## V. Conclusion

The general conclusion that can be drawn from this study is that remote sensing techniques (Landsat thematic imagery) is applicable in lineament identification and drainage characterization, with high and desirable levels of accuracy depending on the spatial, spectral and temporal resolution of the imagery. Significant relationships exist between vegetation types, topography and rock/ soil characteristics (physical and chemical).

Remote Sensing, which is not a solution in itself but only a means to an end, has become a powerful tool in both survey and evaluation of land resources, monitoring changes in the atmosphere and in the environment. The predominant structural trend is the NE-SW direction. The occurrence of a well defined lineament pattern proves very useful for groundwater exploration. The areas where the lineaments cross each other are indicative of groundwater availability. These correspond to regions of mean topographic heights of about 900m.

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