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Lineaments Analysis and Interpretation for Assessment of Groundwater Potential of Lafia and Environs, North Central Nigeria

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Abstract: *This work was carried out to investigate the groundwater potentials of Lafia and environs using lineaments analysis. It studied the relationship between the characteristics and occurrence of groundwater in aquifers ranging from 50m-150m depth in the varying sedimentary rocks of the area by examining the possibility of groundwater occurrence in the different sedimentary rocks, despite the general understanding that shales are less porous and permeable. It shows the use of LANDSAT ETM+ imagery and geological map to investigate areas favourable for groundwater development. This was achieved by plotting the lineament trends, and lineament density to know the groundwater potentials. Rose (azimuth-frequency) diagram of the lineaments delineated on the imagery shows the trends in the directions N-S, NE-SW and NW-SE. The two dominant trends are N-S and NW-SE. The analyses have shown that the study area has numerous fractures whose major trends are mainly in north-south and northwest-southeast directions. Lineament density maps shows the cross-cutting lineaments are relatively high in the areas around the north-eastern south-western parts of the study area but low in the other areas. The zones of high lineament intersection density are feasible zones for groundwater prospecting.*

Keywords: *Lineaments, groundwater, aquifer, fractures, porous, permeable.*

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I. Introduction

The application of remote sensing technology may cover many fields of studies, especially in structure geology, mineral exploration, even groundwater exploration, where the remote sensing is useful for lineaments and structure features extractions. Lineaments are linear features which provide information about the underlying geological structure [1]. Thus, accurate geological features mapping is a critical task for oil exploration, groundwater storage and understanding the mechanisms of environmental disasters [2].

Studies of linear geologic features (lineaments) of both local and regional significance, have been progressing rapidly [3, 4]. Accurate geological and lineament mapping is a critical task for structural analysis and tectonic interpretation in stable platform domain, the recognition of geological linear structures such as bedrock fault and shear zones, thrust faults, lithological contacts and fold structures is essential when exploring for mineralization [5].

The detection of lineament can be done using satellite imagery. There are a number of techniques including; applying sobel and gradient. There are two general methods of extracting lineaments from satellite imagery; the first involves manual digitizing of visually identified lineaments after image processing and the second is automated lineament extraction where the satellite image is subjected to automated processing by specifying different parameters such as curve length, linking distance, kernel size [6,1]. The most popular automated processing tool used over the past few years has been LINE from PCI Geomatica [7, 1].

II. Research Methods

Study Area

The study area is located within the Middle Benue Trough, North Central Nigeria on the Lafia sheet 231 NW. It is bounded by latitude 8^0 15' to 8^0 30'N and longitude 8^0 30' to 8^0 45'E. The area is accessible through Lafia – Makurdi and Lafia – Awe trunk 'A' roads, and many rural roads and foot paths linkage. It covers an area of about 770 km^2 (Fig. 1). Rivers and annual streams form the drainage networks of the area of study. The area has a tropical climate, characterised by dry and rainy seasons. The rainy season is from April to October, and dry season is from November to March. The mean annual rainfall varies from 1,290mm to

1,595.7mm. The annual mean temperature ranges from 22.2^{0}C to 23.5^{0}C, The highest temperatures are recorded between March and April. The relative humidity ranges from 88% during the raining season to 30% during the dry season. However, the later could be lower during the dry harmattan period. The area is a generally undulating lowland. The highest point is 244m (above sea level) and the lowest point is 132m (above sea level). The area is well drained by major rivers like Ashara which flows to the NW of Lafia town. Others are Agbaide, Atabula, Duduguru and Agyaragun Tofa, which all eventually drained into River Benue (Figure 2).

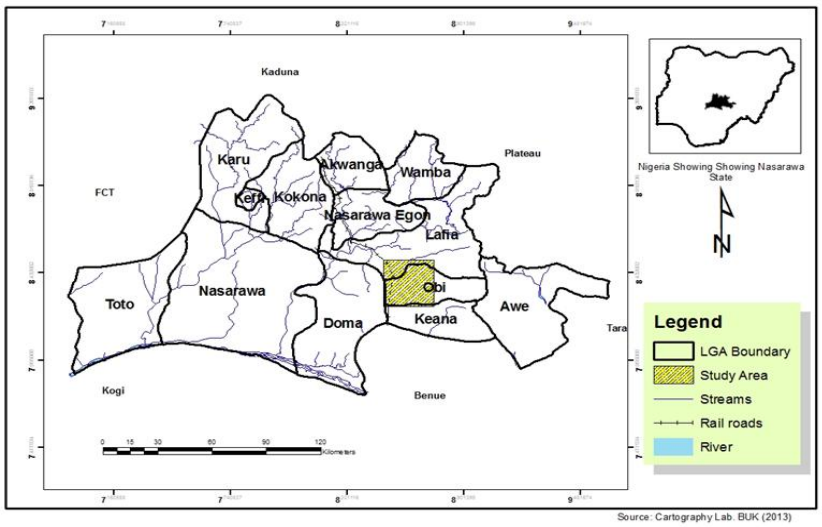

Figure 1: Location Map of the Study Area

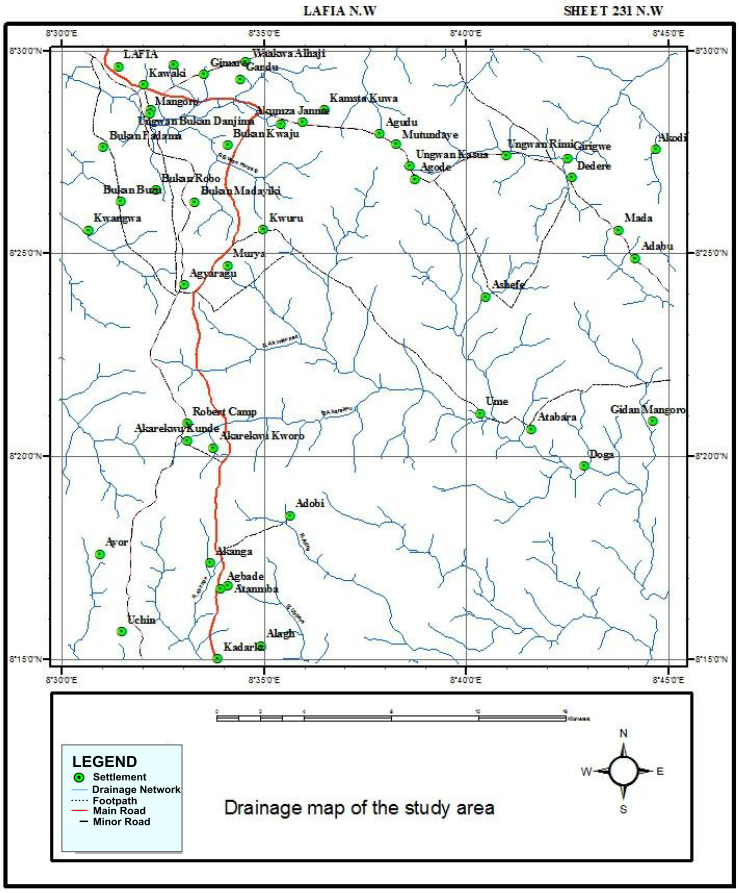

Figure 2: Drainage Map of the Study Area

Detection of structures is an essential element in structural geology. remote sensing with other image processing techniques also accounts for the method of detection of geologic structures that could serve as potential aquifer zones.

According to [8], structural trends such as discontinuity can be detected in many forms, such as faults, joints, bedding planes or foliation, and may be detected in the form of a lineament using remote sensing data such as conventional aerial photographs and satellite imagery.

The commonest method used to calculate lineament density is based on the number of lineaments per unit area (number/km^2), or the total length of lineaments per unit area (km/km^2) or combining both [9]. Areas with higher number of lineaments are considered to be good for groundwater development.

Boreholes are drilled into the sedimentary rocks for the purpose of community and rural water supplies. Though the existing shaley formations yield less water, this prompted boreholes drilling along their jointed/fracture zones in other to tap groundwater at various depths ranging from 50m – 150m.

Geology and Hydrogeology of the Study Area

Lafia and environs is underlain by rocks of the Middle Benue Trough comprising the Asu, Awgu and Lafia Formations (fig. 3). The predominant rock type is the Lafia Formation.

The Asu Formation comprises mainly shales and mudstones. Others include limestones, shales, calcareous, micaceous siltstones and clay.

The Awgu Formation is mainly made up of shales and limestones. Other constituents are bluish-gray to dark black carbonaceous shales, calcareous shale, shally limestones, limestones, sandstones, siltstones and coal seams.

The Lafia Formation is the youngest, consisting of essentially ferruginized sandstones and red loose sands. Others are flaggy mudstones, clays and claystones. The type locality is in and around the town of Lafia [10]. The Lafia formation has also been described as coarse grained sandstone outcropping in the Lafia district with black coal occurring a few miles south of the town [11].

The area of study lies mostly within the Lafia and Awgu formations. Groundwater availability in the sedimentary rocks greatly depends on the degree of joints, fractures, porosity and permeability of the rocks [12]. Higher yields of groundwater are found in the areas underlain by the Lafia formation.

The aquifers found within the sedimentary rocks of the study area are:

Aquifer of the Awgu Formation

The Aquifer of Lafia Formation

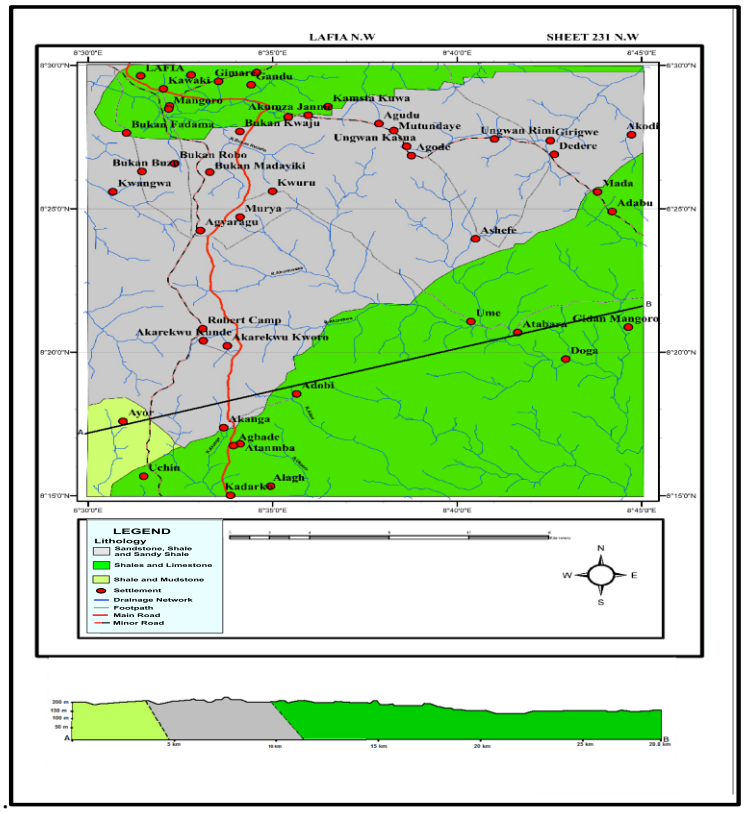

Figure 3: Geological and Cross-Sectional View of the Study Area

III. Methodology

LANDSAT ETM$^+$ imagery of the area was downloaded from global land cover facility site. Lineaments were generated from SRTM DEM by producing shaded relief images. Eight solar relief images were created from the following solar angles, 0^0, 45^0, 90^0, 135^0, 180^0, 225^0, 270^0 and 315^0. Production of shaded relief images was followed by combination of shade relief images to produce two combined shaded relief images. Production of the first and second combined shaded relief images was followed by automatic generation of lineaments with the aid of the Line module of the PCI Geomatica software. After generation of lineaments; buffering was carried out on both automatically generated lineament images and followed by combinations of buffered images. A combined buffered image was reclassified into two classes and manual digitization was done to produce final lineament map (fig. 4). The calculation of lineament related values with script files was done using Arc GIS 9.3 software. A lineament density map was produced (fig. 4). Then rose diagram was generated using Rockworks 15 software to determine lineaments trends.

IV. Results and Discussion

The N-S and NW-SE directions are the dominant trends of lineaments in the area as can be observed from the Rose diagram (fig. 5). This is in agreement with the geology of the study area being predominantly occupied by sandstone and shales. The areas of high lineaments density (fig. 4) cover the north-eastern and south-western parts and are the most probable feasible zones for groundwater prospecting in the study area.

In respect of the geologic formations and lineaments of the area, the geological map was superimposed on the lineament map (fig. 6). The observation made was that, most intersected lineaments are common on the sandstone and shale. Apparent studies and field observations have that highly porous and permeable sandstone(s) contain groundwater in economic quantity in contrast to the shales.

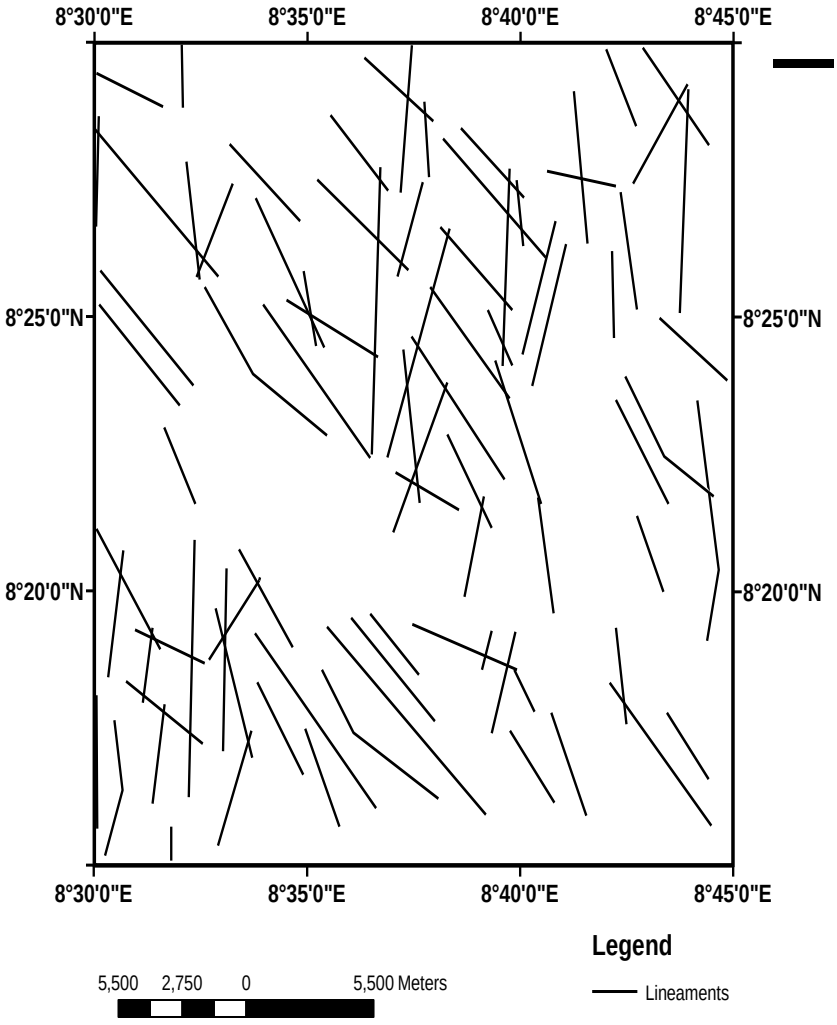

Fig. 4: Lineament Map of the Study Area

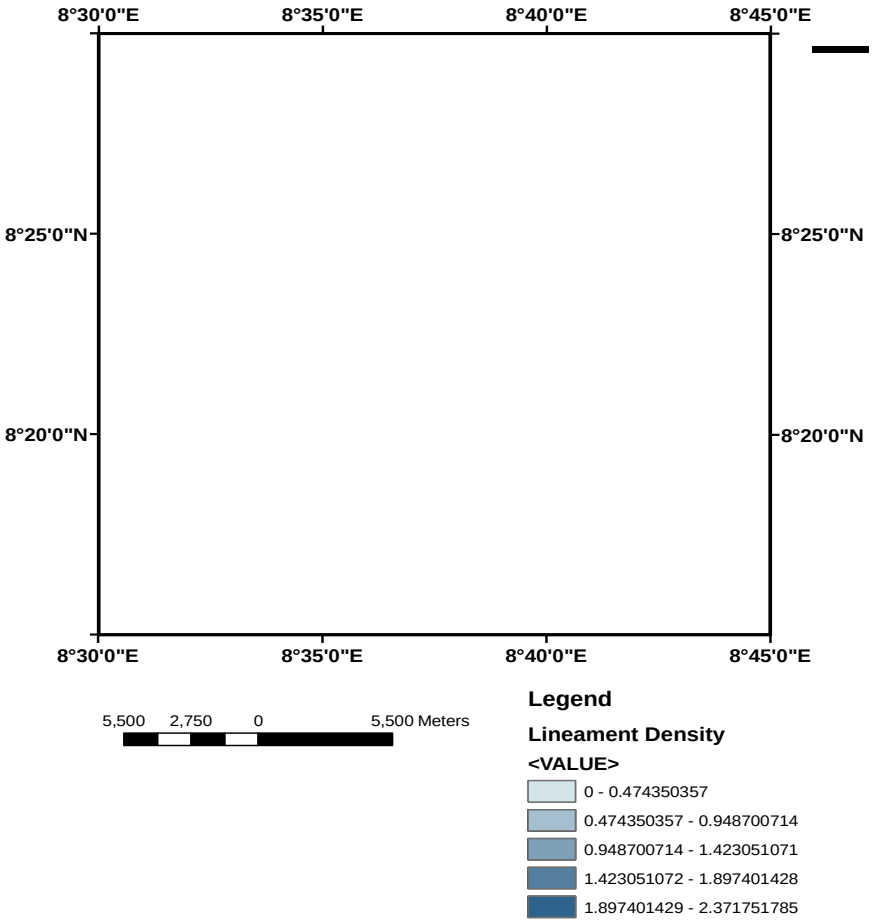

Fig. 5: Lineament density map of the study area.

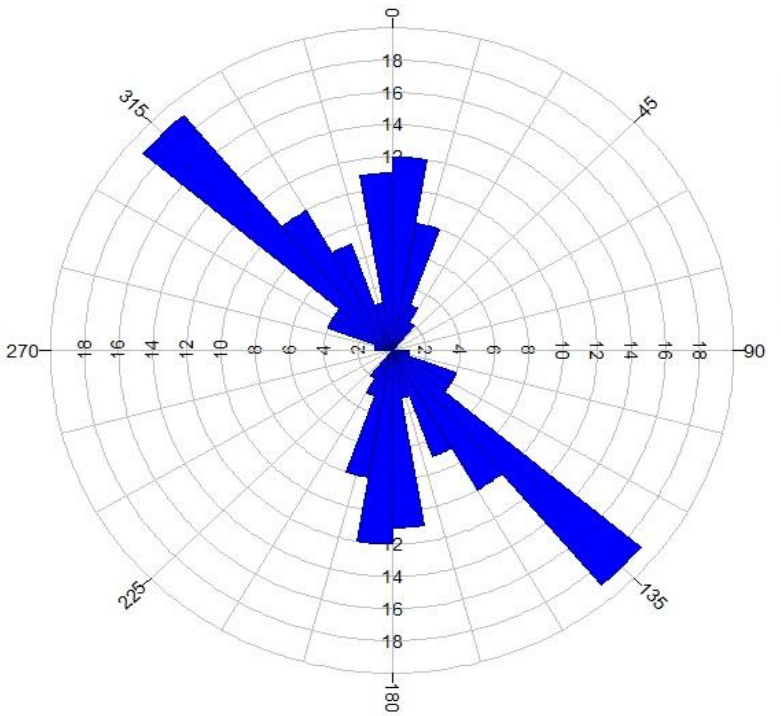

Fig. 6: Rose (Azimuth-Frequency) Diagram of Lineaments Orientations.

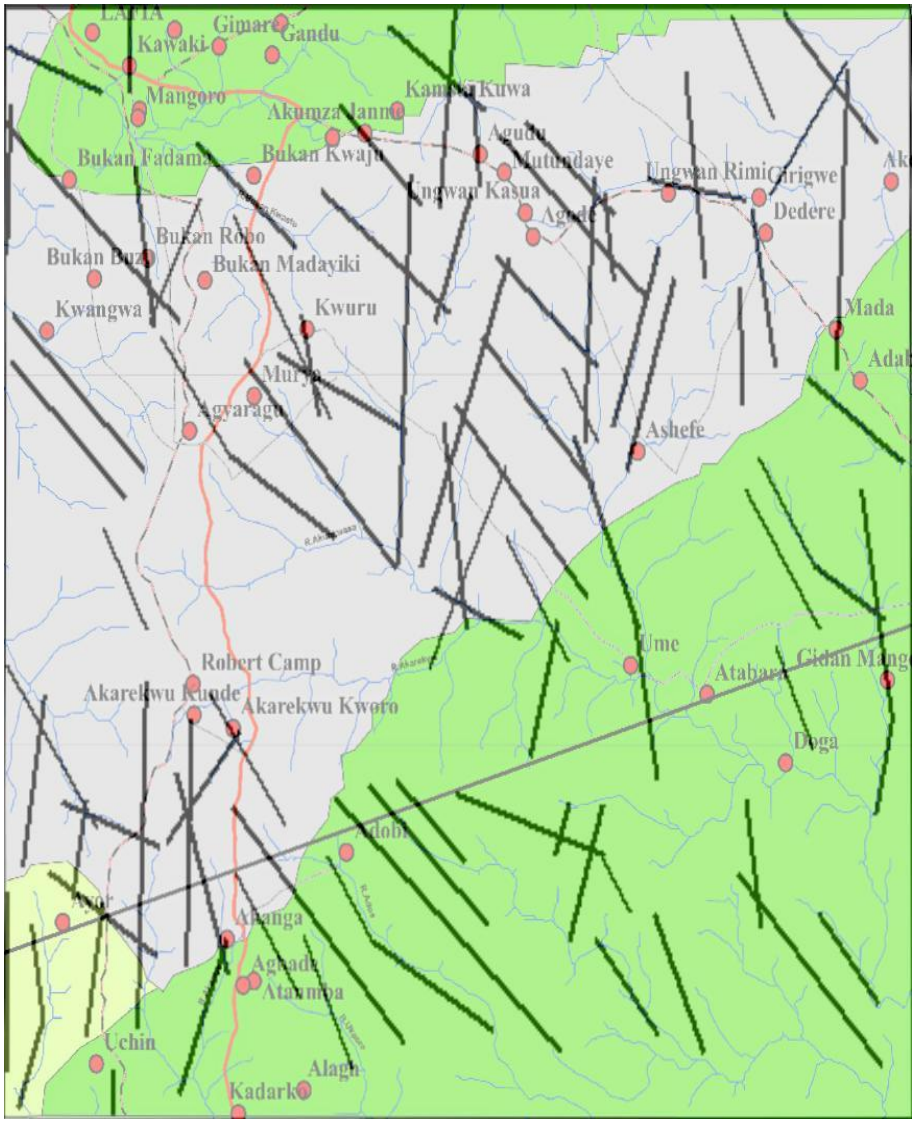

Fig. 7: Lineament Map Superimposed on Geological Map of Lafia and Environs

V. Conclusion

Lineament analysis for groundwater exploration in Lafia and environs shows that the study area is underlain by the Awgu (shale) and Lafia (sandstone) Formations. Plots of the lineaments observed on the imagery show dominant trends in NW-SE directions. The lineament density of the area was calculated using the number of lineaments per unit area (number/km^2) of grid. Two forms of lineaments density maps were produced; they are lineament map and lineament density map of the area. These maps show that lineament density is high in areas underlain by Agwu and Lafia Formation covering places like Lafia, Agyaragun Tofa, Agyaragu Station, Gwadanye, Mararaba Akunza etc in the north and Akanga, Akaleku and Adevi in the south. Result from the lineament analysis shows that groundwater potential is high in the areas with lineament density. Surface and ground water exploitation structures should be constructed taking cognisance of the high lineament density areas and the general lineament strike orientation directions in the area.

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