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# Remote sensing signature of geological structures inferred on landsat imagery of Afikpo area Southeastern Nigeria

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**Satellite remote sensing has contributed immensely to the interpretation of linear features and other geological structures. In the study area, lineaments mapped were linear and planar features on satellite imageries that are expression of fractures, or faults within the subsurface. Image lines of different contrast may extend from a few centimetres to several of metres in length. The Landsat imagery used has a spatial resolution of 30 x 30 m, and eleven spectral bands covering the visible and thermal region of electromagnetic spectrum. Four spectral bands were selected and used for the purpose of structural mapping namely; thermal infra-red band (Band 11), 11.5 to 12.51 µm; Short-wave infrared (Band 6), 1.57 – 1.65 µm; near Infrared (Band 5) 0.85 to 0.88 µm and Red (Band 4) 0.64 – 0.67 µm. Lineaments extracted from the digital satellite scene are concentrated mostly on the sandstone belt in the North-East close to Amasiri area. A total of 116 lineaments were generated. Seven thematic maps were produced; digital elevation model (DEM) was used to create surface features maps, shaded relief and slope while the regional lineament map was digitized from the enhanced colour composites of Landsat ETM (bands 7, 5 and 2) image using ARCGIS 10.0 software for visual extraction and delineation of geological structures which were also ground-truth. The area indicates major NE – SW to minor E – W orientation of lineaments. The lineament density identified indicates regional lineaments are of great importance as indexes for groundwater exploration, mineralization targets, rocks quarrying and structural interpretation.**

**Key words:** Landsat imagery, geological structures, linear trends, ground-truth, Afikpo area Southeastern Nigeria.

## INTRODUCTION

The Precambrian Basement Complex rocks of Oban massif area southeastern Nigeria are the oldest rocks. They are overlain by the non-marine to marine deposits Asu River Group (Odigi, 2010). The Asu River Group represents deposits of the first transgressive – regressive marine depositional cycle in the area (Petters, 1982). The Eze Aku beds overlie the Asu River Group unconformably and consist of shales, limestones and sandstone ridges

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**Plate 1.** Field Photograph of Amasiri sandstone linear feature passes through Abakaliki road.

which strike on the average N040° E with dips ranging from 20° to 68°. The sandstone bodies appear in elongate parallel features (Plate 1). The Eze Aku beds represent the second transgressive depositional cycle that occurred during the Upper Cretaceous (Murat, 1972; Nwachukwu, 1972). The Lower Cretaceous sediments are in places rather strongly folded. A zone of fairly strong folding occurs in south of Abakaliki anticlinal axes traced for over fifty kilometres. The fold axes are oriented in a northeast-southwest direction and dips values of the anticlines range from 5° to 80°, the highest values obtained around Ameka, in the region of Lead-Zinc mineralization (Reyment, 1965).

Digital Elevation Model (DEM) as an ordered array of numbers (Meijerink et al*.,* 1994; Biswas et al., 2012, 2013; Jana et al., 2012). Elevation values were taken from the pixel values of processed Shuttle Radar Thematic Mapper (SRTM). The SRTM 90 m is the source data encoded into a referenced data and is advanced in providing high quality elevation values (Acharya et al., 2018). SRTM height values represent the average height of points within the cell. Geographic Information System (GIS) techniques were used in the analysis. GIS is designed to manipulate all types of spatial or geographical data. Location (point) of each pixel is the value of the elevation at the centroid. Here, locations (towns) within the study area are recorded as coordinates x = longitude, y = latitude, and z = elevation respectively. A usual approach for generating surface information is from contour lines extracted from topographical maps, which provide accurate terrain elevations. This research attempts to use satellite remote sensing imageries, geographical information systems and ground-truth to identify lineaments, their structural trends and interpret the geological features observed in the Afikpo area (Plate 1 and Figure 1).

## Geology of Afikpo area

Afikpo area has been one of the centre of deposition following the Santonian folding in Southeastern Nigeria (Figure 2). There are tectonic elements which characterize the onshore Nigeria, during this sedimentation. They are southern Benue Trough to the northeast, Abakaliki high an anticlinorium to the east, Onitsha high to the southwest, Ankpa Low in the northwest separated by Nsukka High, Calabar Flank of the Oban Massif and the Afikpo Low to the southeast. The thickness of the sediments in the area ranges from gravity measurements 3 to 4.5 km. According to Odigi (2007), in the Afikpo Syncline three main Cretaceous lithostratigraphic units were recognized, the Asu River Group, the Eze Aku Group and the post-Santonian proto-Niger Delta succession. The area consists of some parallel low and high anticlines and synclinal structures that show outcrops. The base of sediments of Asu River Group Late Albian to Early Cenomanian is about 3000 m. The Eze Aku Group overlies the Asu River Group unconformably with a thickness of about 2000m Late Cenomanian to Early Santonian sediments (Figure 2). The Eze Aku Group is unconformably overlain by post-Santonian sediments of pro-Niger Delta (Odigi and Amajor, 2009; Odigi, 2010).

## METHODOLOGY

Landsat 8 OL1 imagery of the area was downloaded from the

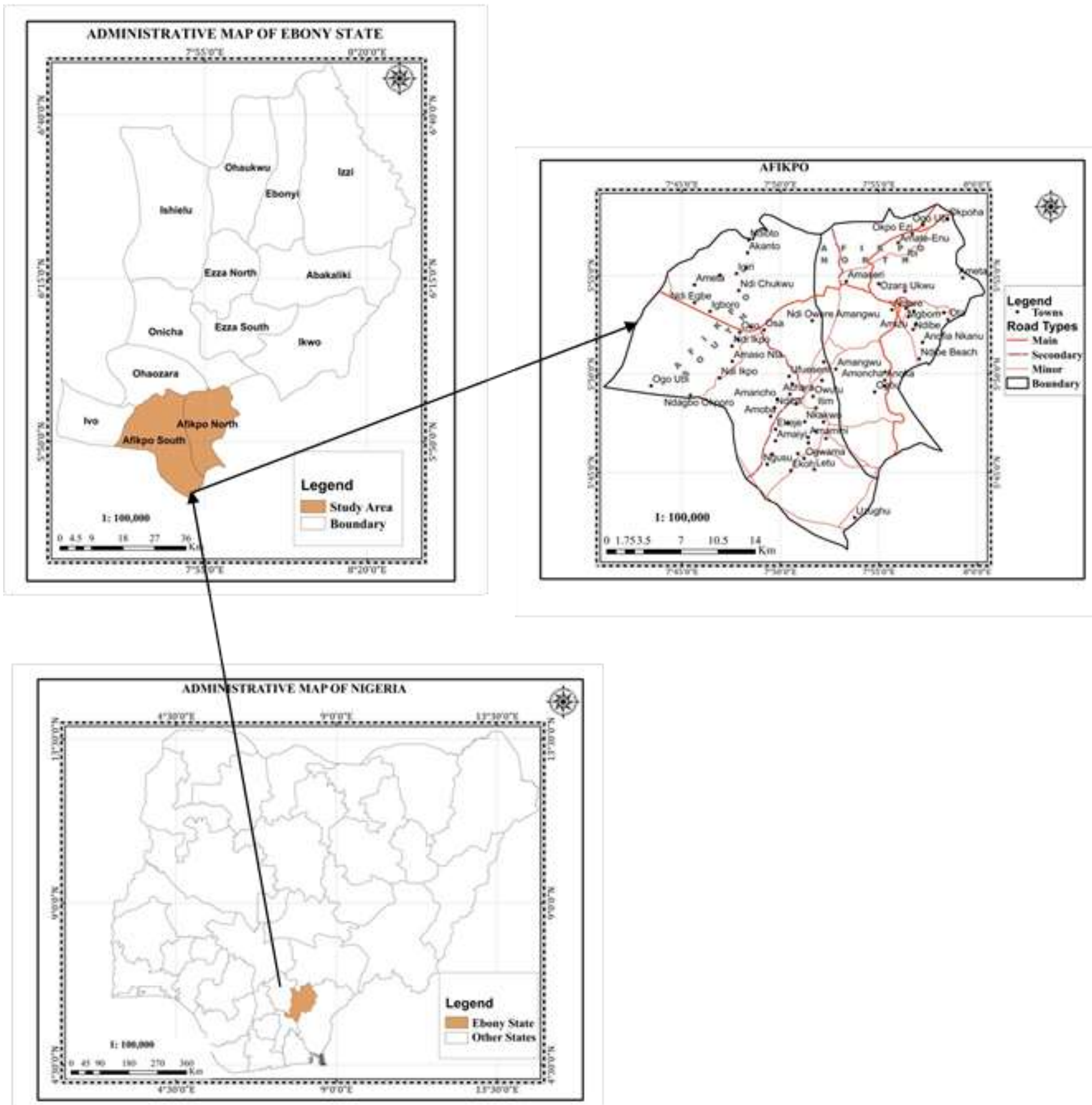



**Figure 1.** Nigerian Administrative map showing the Afikpo area (see the arrows).

United States Geological Survey USGS-GLOVIS online portal. The data was acquired on the 17th of January, 2015. The study area is covered by P188 r 056, that is part and row defining the image characteristics and consists of two administrative Local Government Areas LGAs namely Afikpo North and Afikpo South LGAs of Ebonyi State. The Landsat imagery has a spatial resolution of 30 x 30 m and 11 spectral bands covering the visible and thermal region of the electromagnetic spectrum . The four spectral bands selected and used for the purpose of structural mapping are; the thermal infra-red band (Band 11), 11.5 to 12.51 µm; this was useful for improved thermal mapping, identification and estimating of soil moisture content in top soil and rock outcrops; hort-wave infra-red (Band 6) 1.57 to 1.65 µm; this aided in the identification of moisture content of soil, vegetation and penetration of thin clouds; near infrared

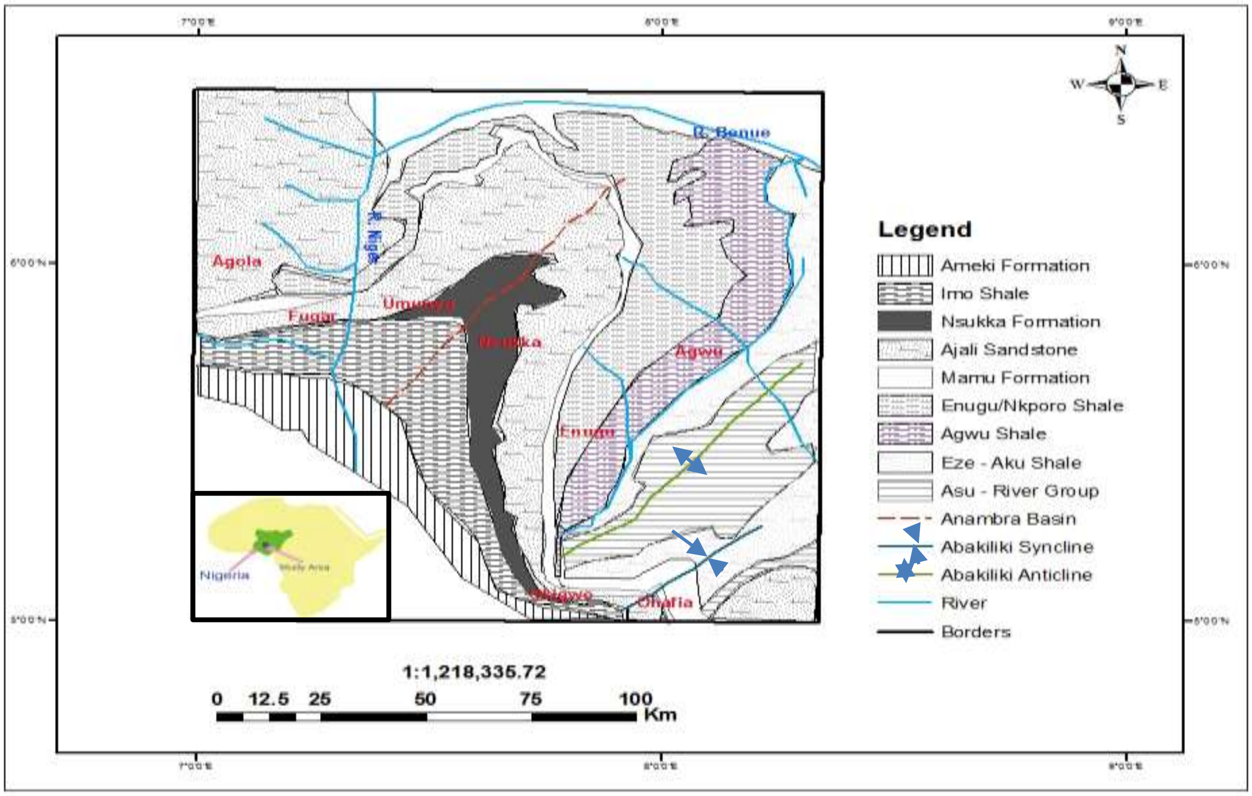



**Figure 2.** Geological map of parts of southeastern Nigeria showing the study area (Egesi, 2017).

(Band 5) 0.85 to 0.88 µm; useful in emphasizing rich vegetation, biomass content and shoreline ( Jana et al*.,* 2014; 2016 a, b; 2017); The Red (Band 4) 0.64 to 0.67 µm has the same use as Band 5. All data were geo-referenced to the Universal Tranverse Mercator (UTM) projection, WGS 84 datum and zone 32. Subsequently, the imagery was processed using ERDAS imagery software to improve its thematic and spectral qualities. The geological base map was imported into ARCGIS software environment for lithological extraction and visualization. The processed image was added in ARCGIS for visual extraction and delineation of geological structures, lineaments, anticlines, synclines, drainage channels and ground-truth for confirmation (Plates 1 and 2).

The topographic map and geologic map of Afikpo was extracted from Nigerian Geological Survey Agency NGSA map, were scanned and obtained as raster images and saved as TIFF format after which they were imported into ILWIS environment for further processing. This process is required to establish and assign real geographic coordinates to the scanned maps. A coordinate system was first created, then with file menu to create a geo-reference, specifying type and the raster image to be geo-referenced. The editor window appears and one enters the coordinate describing the tie point on the map. After repeating such for the minimum required number of four (4) tie points, save and exit editor. The image processing and interpretation have two principal application areas; to improve pictorial information and to process the screen data. Spatial enhancement images for the viewer and also image processing. A number of techniques can be applied to perform spatial enhancement, for this study linear filtering was used.

In this study, extraction was performed using manual lineament extraction method. The lineaments are extracted from satellite image using on-screen visual interpretation. The lineaments usually appear as straight lines or edges on the satellite images which is due to the colour differences in the surface material. The experience user is the key point in the identification of the lineaments particularly to connect broken segments into a longer one. Lineaments were digitized from the enhanced colour composites of Landsat ETM (bands 7, 5 and 2) and ASTER GDEM image using ARCGIS 10.0 software. This was carried out with the aim of discarding non geologic lineaments. However, features which help to identify the lineaments are listed as follows; topographic features such as straight valleys, scarps, straight rock boundaries, rivers offset, tonal variations and vegetation alignment. The features are digitized in form of layers; lineaments, rivers, roads and settlements. Plate 2 shows a field photograph of lineament in the area while Figure 3 shows ETM image data.

## RESULTS AND DISCUSSION

The results of several operations carried out followed the set objectives to identify lineaments for quarrying, mineral exploration and groundwater availability. Cartographic visualization as a mapping process has been applied to the lineaments extracted (Table 1). Results are presented in the form of maps, rose diagram, table and chart. Field photograph of linear structures at Ndibe area shows strike N000° to N054° in Plates 4a and b. Lineament analysis results from the Landsat imagery show a total of 116 lineaments as shown in Table 2a and b, trending in NE-SW, NW-SE, ENE-WSW and NNE-SSW with the

**Plate 2a.** Field Photograph showing Ndi Owerre Amangwu linear structure.

**Plate 2b.** Field Photograph showing linear planar beds showing top lap and onlap features at Ndi Owerre exposure.

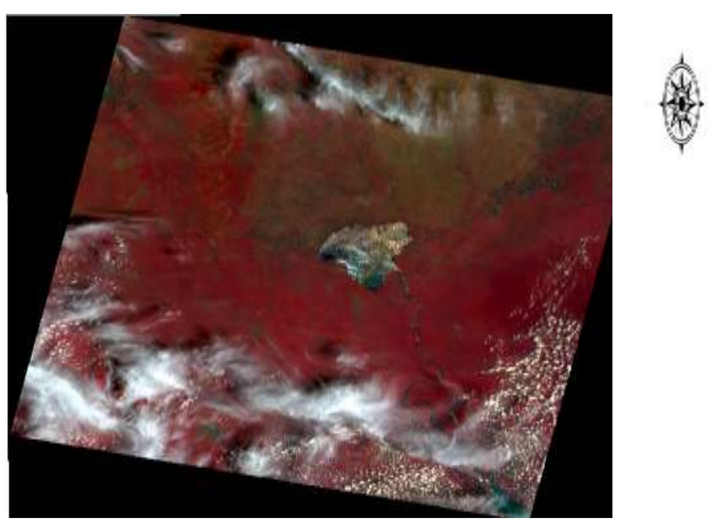


**Figure 3.** Landsat ETM image of the study area (Scale 30 x 30 m).

**Table 1.** Topographic elevation values.

| Towns | Elevation (m) |
|---|---|
| Ozara Ukwu | 31 – 70 |
| Ibii | 50 – 60 |
| Amasiri | 49 -65 |
| Ndibe | 64 -95 |
| Amizu | 76 – 88 |
| Mgbom | 89 – 111 |
| Afikpo | 46 – 123 |
| Ndibe Beach | 20 -26 |
| Ndi Owere Amangwu | 52 – 58 |
| Ndibe | 72 – 102 |

**Table 2a.** Number of extracted lineaments and their orientation.

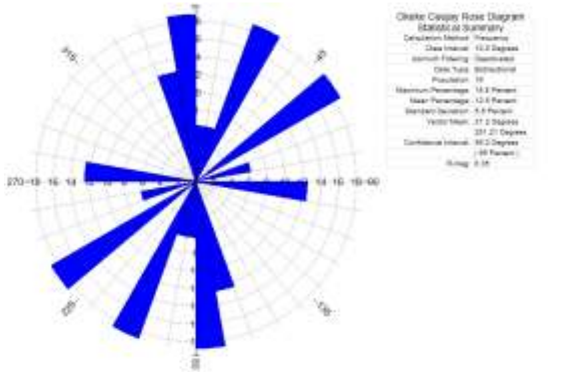
| Lineament orientattion in Afikpo north | | Lineament orientattion in Afikpo south | |
|---|---|---|---|
| **No** | **ORIENTATION** | **No** | **ORIENTATION** |
| 31 | NE-SW | 16 | NE-SW |
| 11 | NNE-SSW | 3 | NNE-SSW |
| 6 | NW-SE | 8 | NW-SE |
| 6 | NNW-SSE | 6 | ENE-WSW |
| 3 | E-W | | |
| Total | 57 | Total | 33 |

**Table 2b.** Statistical table of extracted lineaments within the Afikpo area.

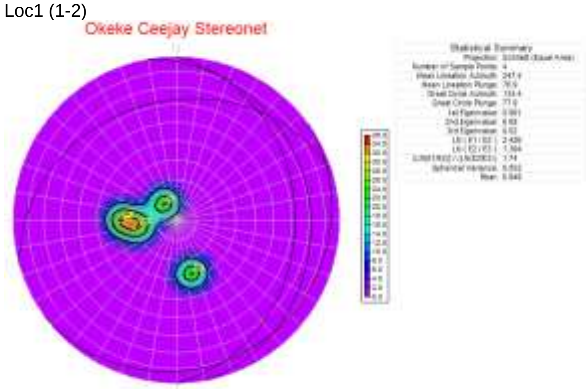
| S/N | Type | Length (km) | Number of Lineaments |
|---|---|---|---|
| 1 | Very Short | 0.38 - 1.42 | 32 |
| 2 | Short | 1.43 - 2.42 | 51 |
| 3 | Long | 2.43 - 3.54 | 28 |
| 4 | Very Long | 3.55 - 6.18 | 5 |
| **Total** | | | **116** |

major structural trends being in the NE-SW and minor E - W. The dominant lineament trend defined from this study is the NE-SW trend (52.2%) and the least E – W trend is (3.3%). This trend corresponds with the dominant Anambra structural trend as defined by Benkhelil (1989). According to Oden (2012), these features are definitely very strong directions of preferred orientation of mineral veins which incidentally; are the same as the trend in the Benue Trough. The typology of lineaments is based on length analysis using grouping method. The lineaments are grouped into four classes as follows; very long, long, short and very short, while the statistical representation is found in Figure 8; field measurements, regional linear map and lineament density map are found in Figures 4 to 9. Figure 4a, b and c show the rose diagram trend of the ground-truth in N-S to NE-SW, NE-SW to NW-SE and NE-SW and the corresponding stereonet (Figure 5).

Lineaments extracted were assessed using the lineament density and frequency parameters. Results were presented as lineament density map, rose diagram and pie chart. The purpose of the lineament density analysis is to calculate frequency of the lineaments per unit grid of cell (30 m). This produces a map showing concentrations of lineaments over the area. Lineament density map in Figure 6 reveals a high density fracture zones in the study area. The zones are thus interpreted because of high density of lineaments seen within the area. Lineaments seen have the same trend. This implies probably that there was intense tectonic activity within the area. The lineament density map shows lineament density variations. The denser the lineaments typified the higher the intensity of rock fracturing, which is a pre-

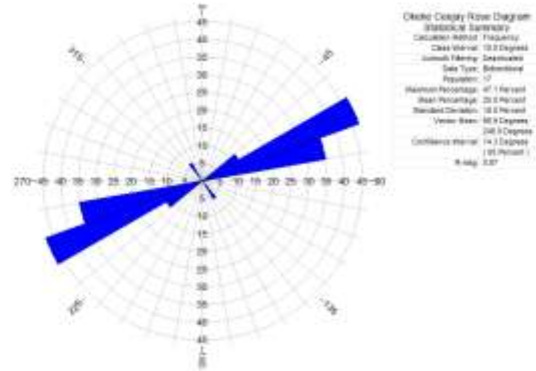


Loc1 (1-2)




Loc1Stereonet (1-2)

**Figure 4a.** Rose diagram and Stereonet of Ndibe beach area.



Loc 3 (14 – 18)

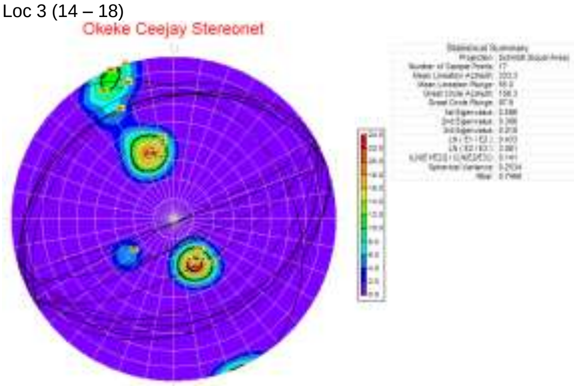
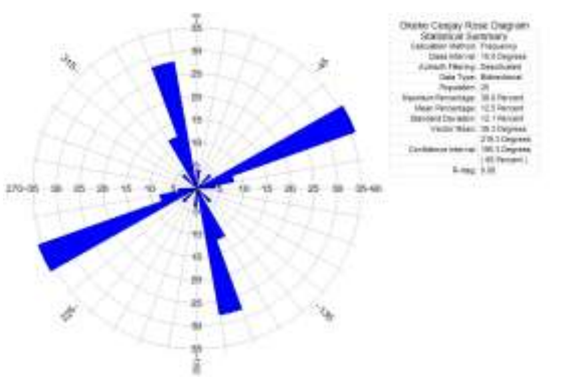



**Figure 4c.** Rose diagram and Stereonet of Amasiri area.



Loc 2(3-8)

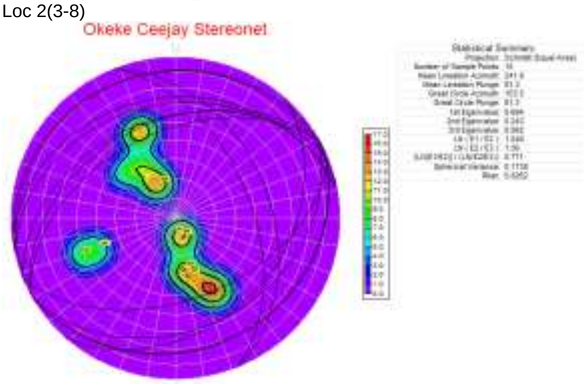



**Figure 4b.** Rose diagram and Stereonet of Ndi Owerre Amangwu

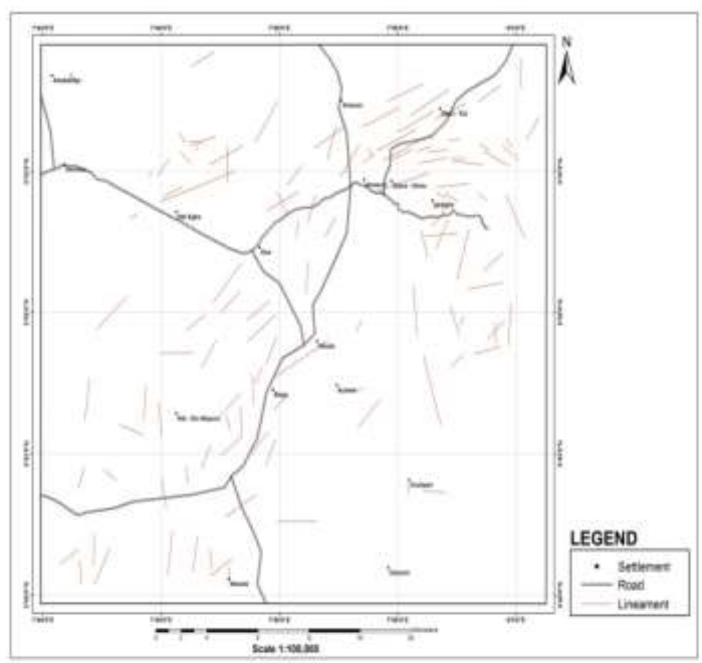



**Figure 5.** Regional Lineament Map of the Afikpo area

requisite for the development of hollow passages over an area (Figure 7).

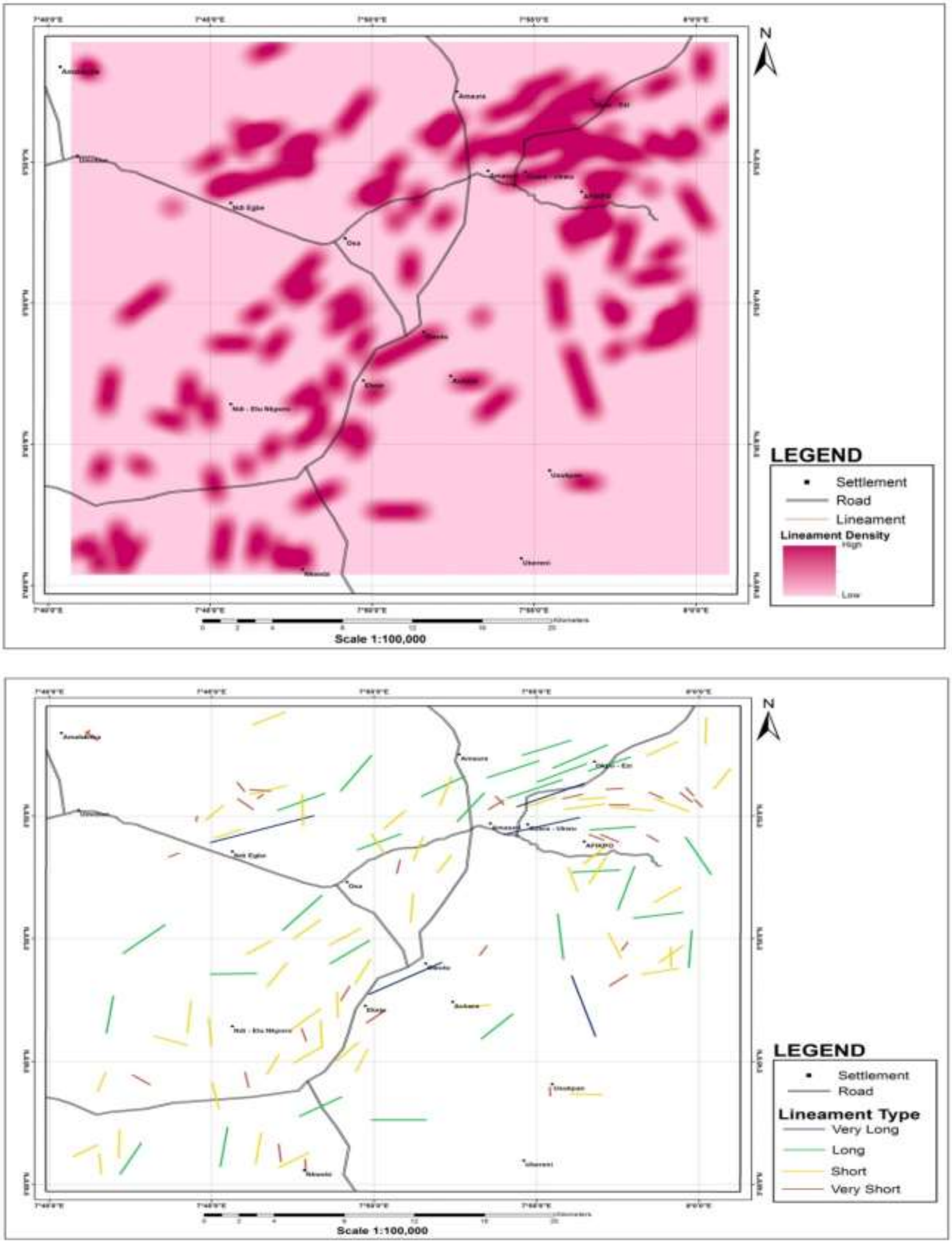



**Figure 6.** Lineament Density Map of Afikpo Area.


**Figure 7.** Typology map of the Afikpo Area.

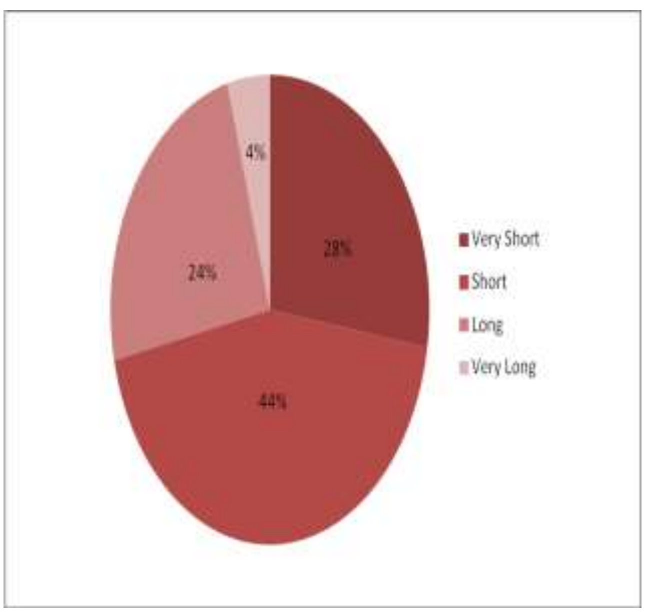



**Figure 8.** Percentage distribution of lineaments.

Digital Elevation Model (DEM) offers visual perspective capability of terrain features. It is used for structural, slope, lineament, drainage pattern, locating geologic boundaries and fault (Figure 8). Steeper slopes are shaded red, while the gentle slopes are shaded yellow. The DEM data derived from remote sensing data are used in determining characteristics of terrain, slope and aspect. Terrain analysis of DEM involves calculation of slope and aspect. Information can be extracted from DEM namely: (1) through visualization and (2) by quantitative analysis of terrain data. The green areas represent relatively flat areas. From the slope map, steep slope is seen at the Afikpo area and is interpreted as a sandstone ridge while the low lying and gentle slope is at Amasiri area (Figures 8 and 9). The slope of the ridge is identified as representing a sudden change in topography. The slope is characterized by numerous streams, gullies, and rivers. The high topographic relief area is indicated by sandstones and the low areas are characterized by mixture of shale, mudstones and sandstones. The dendritic pattern of drainage is evident in the areas mapped. The drainage pattern reflects a marked structural control of drainage by faults. The major drainage, the Cross River channel has many lineaments which run along the channel.

The DEM of the study area consists of six classes of surface elevation and shows the highest elevation value as red (76 to 281m) and the least elevation as blue (6 - 31m) as shown in the colour and slope map (Figures 10

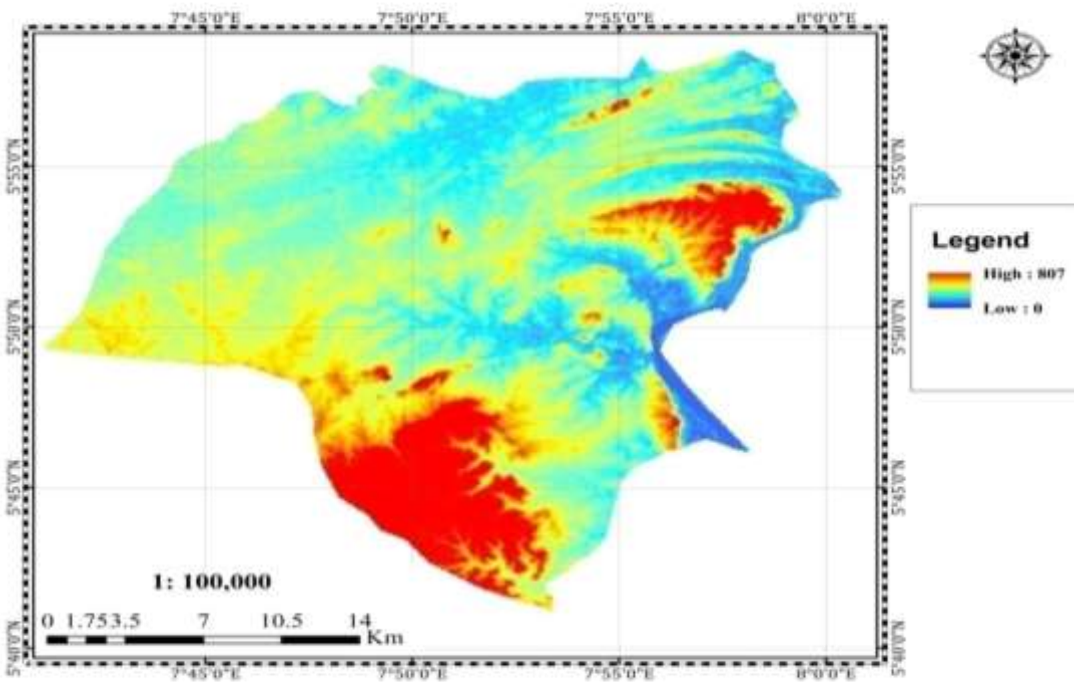



**Figure 9.** Digital Elevation Model of Afikpo Area.

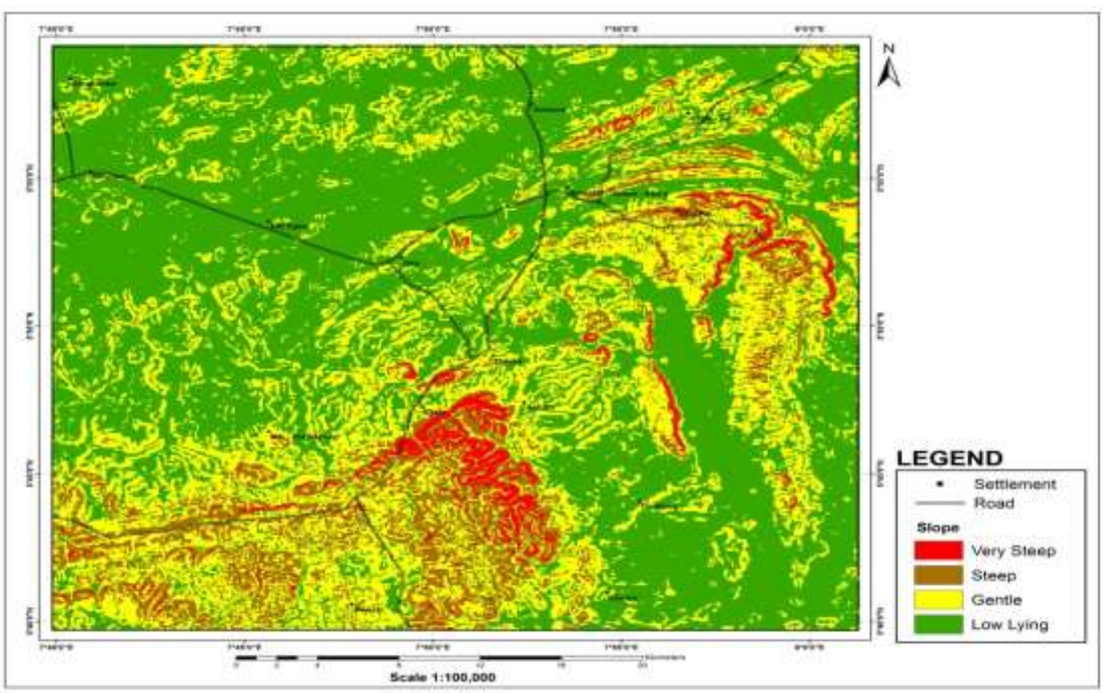



**Figure 10.** Slope map of Afikpo area.

and 11). The elevation in the north – east comprising Amuro, Mgbom, Afikpo, Ota and Amizu was discovered to have high elevations ranging from 78 to 180 m above sea level. The different elevation values are shown in Table 1. The DEMs are important for hydrological analysis, while slope and aspect were used to determine direction of surface runoff, and hence flow accumulation for the formation of streams, rivers and lakes.

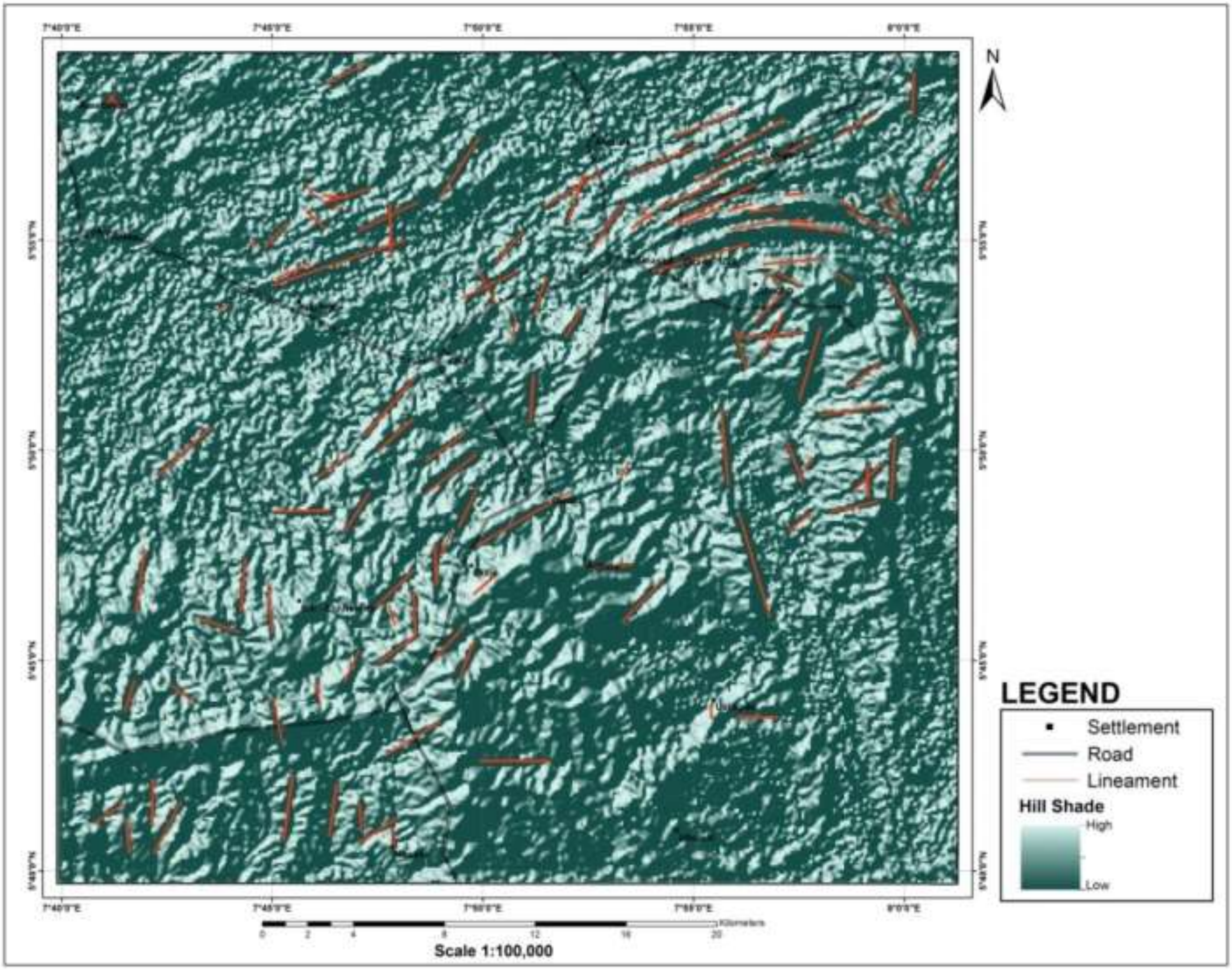



**Figure 11.** Hill Shaded Relief Image of Afikpo area.

The hill shaded relief image and drainage pattern were integrated to evaluate the structural implication of the extracted lineaments. The image was interpreted for geological interpretation using the seven (7) basic elements: tone, texture, pattern size, shape, shadow and association. The map in Figure 11 shows that the textural and pattern of certain areas were enhanced and this makes rock type and structural mapping easier.

The map of drainage pattern in Figure 12 was produced by digitizing the rivers and tributaries from the topographic map and the Landsat ETM image. The drainage pattern reflects the nature of the subsurface formations. The stream network flow directions always explore the conduit path of weak zones, joint and fracture portions of the subsurface formations. The dendritic pattern as expressed by the drainage map aided the extraction of lineament.

Orientation of lineaments is usually analyzed using rose diagrams. This diagram displays frequency of lineaments for particular interval. A summary of the lineament trend direction was done using rose diagram in Figure 4. In terms of length, the lineaments were categorized into four classes. Based on that classification, lineaments with lengths 0.38 to 1.42 and 1.43 to 2.42, constitute 28 and 44% respectively while 2.43 to 3.54 and 3.55 to 6.18 constitute 24 and 4%, respectively. The areas around northwestern, central and southeastern parts of the study area are covered by high density values and are also characterized by high lineament density intersection. According to Edet et al. (1994, 1998), zones of relatively high lineament density are identified as zones of high degree of rock fracturing which are prerequisite for

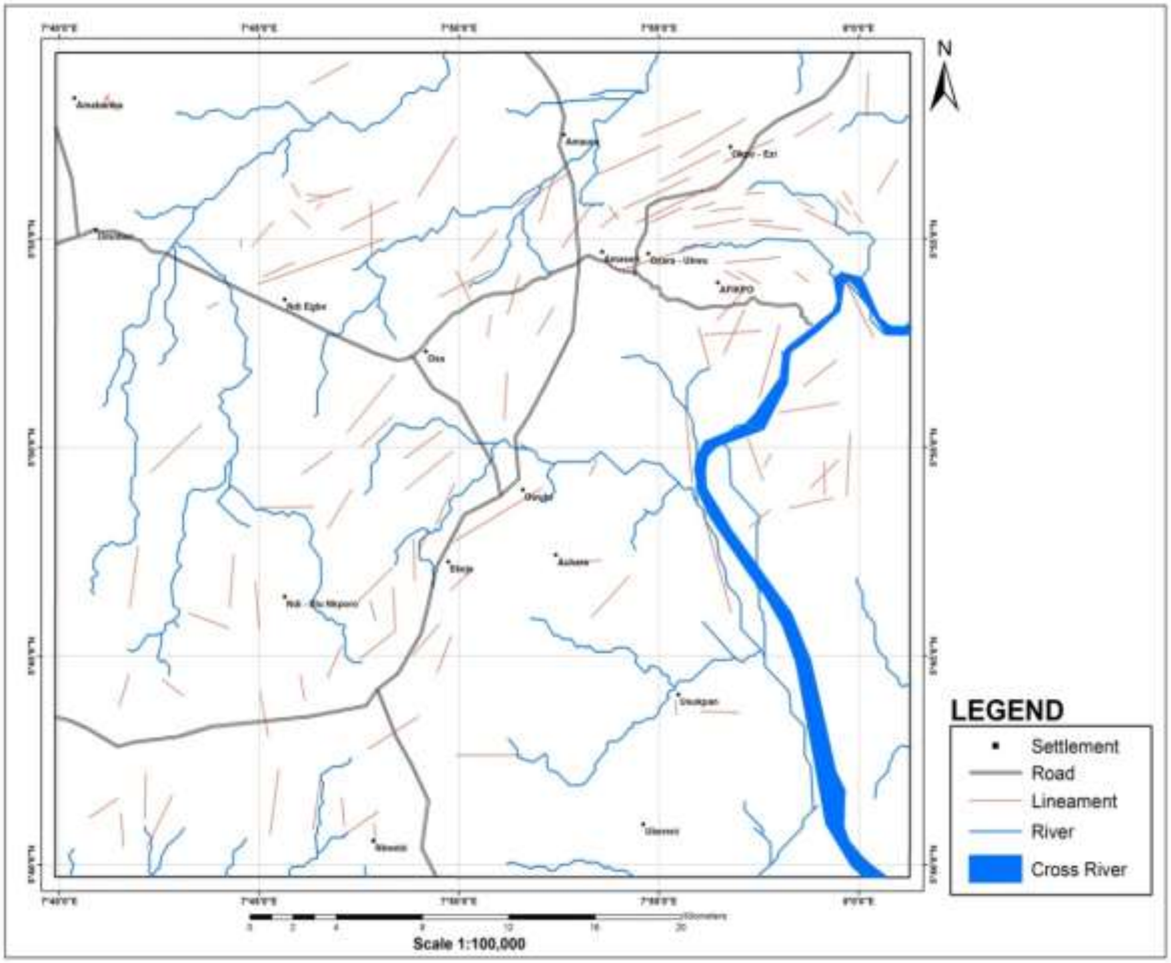



**Figure 12.** Drainage Pattern Map of Afikpo Area with lineaments.

groundwater conduit. Also, lineament density is high in areas of outcropping bedrock and thin overburden. Lineament density analysis has been the stock in trade in most geological applications of structural controls to mineralization such that points of intersections and trends are targets in explorations. Hence, zones where these lineaments intersect or cross rock boundaries constitute valuable target areas during mineral exploration (Ashano and Olasehinde, 2010). The trends observed within the study area are principal directions of regional structures. The presence of NE-SW, N-S and E-W trends has been reported in the area by Opara et al. (2014). These observations are in agreement with few earlier reports.

## Conclusion

The study was carried out to evaluate the regional lineaments within Afikpo Area, South-East of Nigeria using remote sensing and GIS techniques. SRTM and Landsat ETM images were acquired together with the topographical and geological maps of the study area used to prepare thematic maps, DTM, slope map, regional lineament map, typology map, hill shaded relief image map, drainage pattern map, regional structural lineaments, lineament density map and rose diagram for orientation of structures; they were tied together to obtain the signature of these features. The denser lineaments zones typified the intensity of rock fracturing which is a pre-requisite for the development of hollow passages over an area. It has proven to be a useful tool in lineament identification and mapping particularly difficult and dangerous cliffs in the area. Results have shown that the application of remote sensing and GIS in lineament mapping and structural analysis are beneficial in the area for quarrying, groundwater and mineral exploration targets. The synoptic view that remote sensing affords and the realization that geologic structures ranges from small scale to very large up to tens of kilometres makes this method suitable for a regional structural geological mapping. The relatively high density areas on the lineament density map are probably potential zones for groundwater and feasible zones for mineralization.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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