MAPPING OF GEOLOGICAL LINEAMENTS FROM DIFFERENT SUN ELEVATION ANGLES USING DIGITAL ELEVATION MODEL (DEM): A CASE STUDY OF NIGERIA GEOLOGY MAP SERIES SHEET 135 (DUHU SHEET)

ABSTRACT

The study focuses on the mapping of geological lineaments from the following different sun elevation angles: 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° of the Digital Elevation Model (DEM). Four of the images with azimuth; 0°, 45°, 90° and 135° were combined to producea single image with multi-illumination directions. The images with azimuth; 180°, 225°, 270°, and 315°were equally combined to produce another single shaded relief image with multi-illumination directions. The two multi-illumination direction images were used for the automatic lineament extraction using PCI Geomatica software.The extracted lineaments were overlaid and duplicate lineaments were eliminated. The final lineaments of the study area were screened using high-resolutionGoogle images for non-geological features. The dominant trending pattern in the final lineaments of the study area is NE-SW direction. The Lineament density for the studyarea ranges from 0 to 1.36 km/sqkm with about 69.1% of the study area being mapped as poor and low density while the high and very high densities area account for just about 30.9% of the study area.

Keywords: Lineament, DEM, Hill shade, Azimuth, Mapping.

INTRODUCTION

Lineaments have been defined as linear topographical or tonal features on the terrain representing zones of structural weakness. They are usually manifestedas; shear zones/faultsrift valleys truncation of outcrops, fold axial traces; joint and fracture traces, straight valleys, continuous scraps, straight streams segmentsand rock boundaries, a systematic offset of streams, sudden tonalvariations and alignment of vegetation topographic, (Raj et.al., 2017; Gupta, 1991).According to Abdullah et al. (2010), shaded relief images generated from Digital Elevation Model (DEM) are helpful in identifying lineaments in different distinct relief and topography because this approach can enhance lineaments at specific orientations by simulating topographic illumination under various light directions. They further classified lineaments as positive and negative lineaments based on tonal variation. Positive lineaments, interpreted as linear ridges, scarps, ridges, troughs and craters are represented as light-toned lineaments while negative lineaments, representing joints, faults, and shear zones are seen as dark-toned lineaments.

Many researchers have extracted lineament from remotely sensed images for various applications in the field of geosciences such as; water resource exploration and abstraction, hydrogeomorphology, ore and mineral exploration, and geological mapping for several purposes (Das et al. 2018; Das and Pardeshi 2018; Hubbard et al. 2012;Aluko and Igwe, 2018; Kamil and Setiawan, 2022)

DEM data are digital elevation data sets recording the topographic surface expression ofany area. Topographic attributes from DEM data can be extracted by applying special computer algorithms which include slope, aspect and shaded relief algorithms. (Abdullah et. al., 2010). DEM, unlike

Landsat images, represents true real projections with no distortion; tonal variations are entirely identified with relief, the sun position can be placed anywhere above the terrain surface, and in most cases, DEM has better resolution than satellite images (Schowengerdt and Glass, 1983).DEMs shaded relief images and terrain derivative maps (slope, aspect and curvatures) have largely demonstrated their usefulness for lineaments and fault extraction. Sarat et. al., (2007) first demonstrated the role of light in observing an object. They found that when an object is illuminated with light from a few angles it causes what is known as the False Topographic Perception Phenomenon (FTPP). The perception of valleys as ridges and vice versa is the result of FTPP having a strong influence on the identification of lineaments from different azimuth angles. Some azimuth angles are very good to provide a higher number of lineaments with great accuracy where FTTP is not detected or corrected.

This study aims at applying GIS technology to automatically extract, map and analyze lineaments from multi-directional light sources (different sun azimuth angles) shaded relief images derived from DEM data set of the Nigeria geological map series Sheet 135 known as Duhu sheet.

STUDY AREA

The study area lies between northings 10^{o}30'N to 11^{o}00'N and eastings 13^{o}00'E to 13^{o}30'E in the North-eastern part of Nigeria. The area is characterized by hills to the southeastern and eastern parts, with other areas having low undulating topography. According to Nigerian Geological Survey Agency, NGSA (2006), the area is part of Mandara Mountains which together with the adjacentHawal and Adamawa Massifs form the northeastern basement complex of Nigeria, which is underlain mainly by granite and pegmatite with minor quartzite. Outcrops are restricted to the eastern part of the study area, as the western side is characterized by pond and flood plains. Granites are most dominant rock in the study area. They grade from fine to medium to coarse and even porphyritic grains.Drainage pattern is of the dendritic type, typical of a basement area.

MATERIALS AND METHOD

The material used in this work are the DEM image of the study area retrieved from the Shuttle Radar Transmission Mission (SRTM) and google earth. While the respective software are ERDAS Imagine 2015, PCI Geomatica 2015, ArcGIS 10.5 and Rockworks 2016. The method employed consists of the following sequences.

The first step is the generation of eight shaded relief maps from the following sun illumination direction (azimuth); 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° using ERDAS Imagine software. A solar elevation angle of 30° and an ambient light setting of 0.20 was chosen to ensure good contrast (Abdullah et al., 2010).

After the generation of the eight shadedrelief images, four of the images with azimuth; 0°, 45°, 90° and 135° were combined to producea single image with multi-illumination directions. Equally, the images with azimuth; 180°, 225°, 270°, and 315°were combined to produce another single shaded relief image with multi-illumination directions.

The production of the two multi-illumination direction images of the shaded relief images was followed by automatic lineament extraction.

The "Lineament Extraction" (LINE) algorithm of PCI Geomatica software was used to automatically extract lineaments in this work. The algorithm consists of edge detection,thresholding and curve extraction steps (PCI Geomatica, 2001).Thesesteps were carried out on the two multi-illumination direction images with the six defaultparameters (RADI, GTHR, LTHR, FTHR, ATHRand DTHR)ofthe algorithm. The input of these parameters are

Comment [ma1]: There is no projection that represents the earth in its true form. Each projection contains a distortion. The distortion may be in distances, angles or area

Comment [ma2]: Satellite image is raster data also DEM .Each pixel in DEM represent Z Value and each pixel in satellite image have reflectivity of photographed targets.I don't think there is any comparison between Dem and Satellite Image .

usually pixel or threshold values that control the process of the lineament's extraction. They are briefly explained according to Hubbard et. al., 2012 as;

RADI (Filter radius)specifies the pixel distance of edge detection filtering such that smaller values can be used to detect more detail, but larger values can be used to minimize the detection of noise.

GTHR (Gradient threshold)specifies the minimum threshold change in brightness, which defines an edge pixel.

LTHR (Length threshold) specifies the minimum threshold of curvature (in pixel distance) used for mapping curved features as valid lineaments.

FTHR (Line fitting error threshold)specifies the maximum error (in pixel distance) allowed in fitting a vector GIS arc or polyline to pixels defining a curved feature, such that lower values yield better fits using a number of shorter line and arc segments, while higher values yield coarser fits using longer lines and arcs with fewer segments.

ATHR (Angular difference threshold)specifies the maximum angle (in degrees) between two neighboring polyline or arc segments, below which they can be linked into a single vector polyline or arc.

DTHR (Linking distance threshold)specifies the minimum distance (in pixels) between the end points of two polyline or arcs for them to be linked.

The extraction process is manipulated by changing the values of the sixparameters in order to obtain the most suitable pixel and threshold values. General properties such as the size of the study area and data resolution were taken intoconsideration (Kusak and Krbcova, 2017; Hubbard et. al., 2012). The parameters values used in this work are presented in Table 1.

Table 1: Parameters and values of automatic extraction process.

Parameters	Description	Values
RADI	Filter radius (pixels)	50
GTHR	Edge gradient threshold	10
LTHR	Curve length threshold (pixels)	30
FTHR	Line-fitting error threshold	3
ATHR	Angular difference threshold (degree)	15
DTHR	Linking distance threshold (pixels)	10

The LINE module extracts all linear featuresfrom animage and records the polylines in a vector layer (Manjare and Pophare, 2019).The extracted lineaments were compared with a topographical map, high-resolutionGoogle images and drainage map of thestudy area to screen and eliminatenon-geological lineaments such as roads, drainage, footpaths,field boundaries etc.

After thiselimination process, the remaining geological lineaments fromthe two multi-illumination direction images are stored in separate GIS shape files and analysed for the number and length of lineaments. This was followed by combining the two GIS shape files into a single shape file to eliminate any duplicates. From this output, the total lineamentmap of the study area was generated. In the final stage, the orientation of lineaments of the study area was alsoanalysed and a rose diagram generated usingRockworks software.

RESULTS AND DISCUSSION

The result of the generated eight hill-shaded relief maps from the sun illumination direction (azimuth) of; 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° using ERDAS Imagine software is presented in figure 1(a – h). The combined hill-shade image ofazimuth 0°, 45°, 90°and 135° and that of azimuth180°, 225°, 270°, and 315° are respectively present in figure 2a and b) with their automatic extracted lineaments.

a)

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b)

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c)

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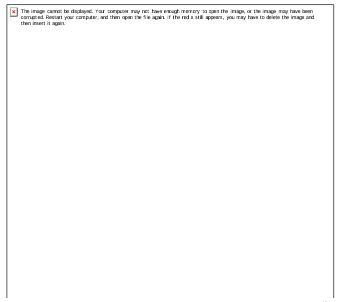
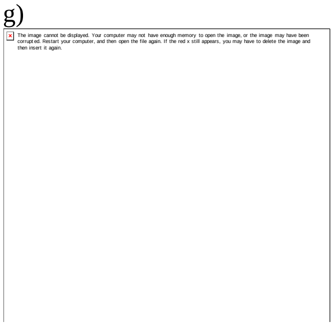
e)

f)



g)



h)

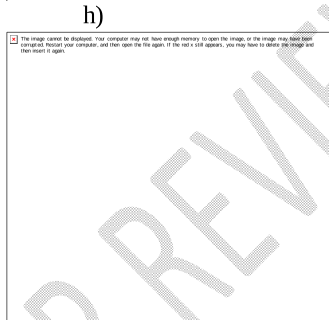


Fig 1a-h). Hill shaded image of azimuths 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° respectively.

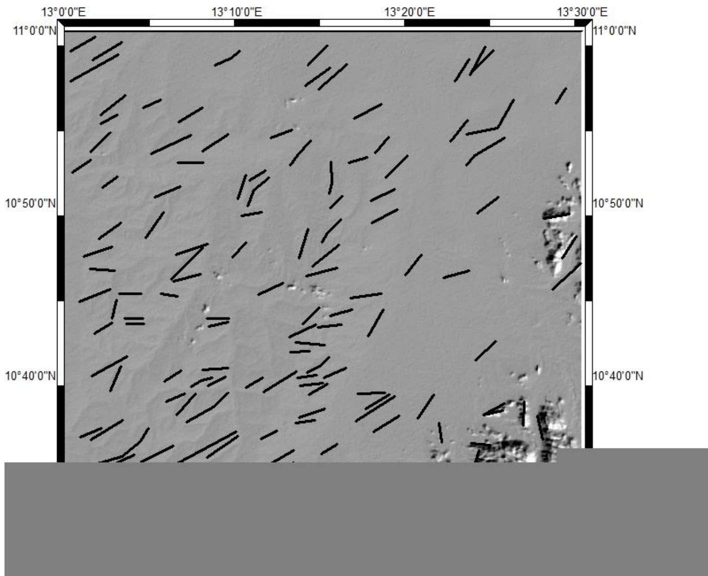


Fig. 2a) Combined hill-shade image ofazimuth 0°, 45°, 90°and 135° with the automatically extracted lineaments

Fig. 2b) Combined hill-shade image ofazimuth180°, 225°, 270°, and 315° with the automatically extracted lineaments

The combined extracted lineaments from the two multi-illumination direction images of the shaded relief images were overlayed and mapped out to give an overall total lineament map of the study area as presented in figure 3 with the statistical analysis in Table 2.

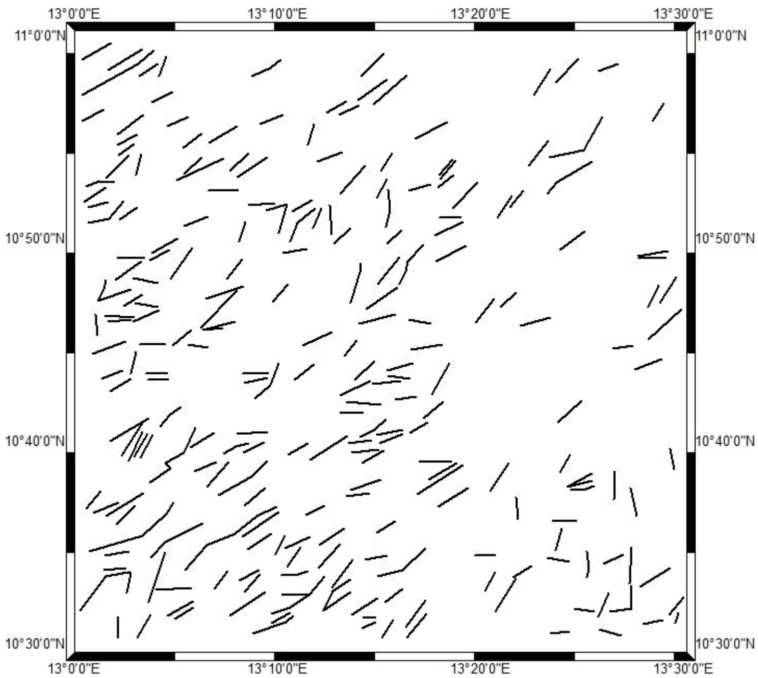


Fig. 3: Total lineament map of the study area.

Table 2: Basic statistics of the automatic lineaments' maps.

	Lineaments of the combined hill-shade image of azimuth 0°, 45°, 90° and 135°	Lineaments of the combined hill-shade image of azimuth 180°, 225°, 270°, and 315°	Overlay lineaments of the study area
Number of Lineaments	151	191	237
Min. length (km)	1.16	1.83	1.16
Max. length (km)	10.12	10.13	1.83
Mean length (km)	3.01	1.11	2.43
Total length (km)	453.97	494.37	647.77

A total of 151 lineaments have been extracted from the combined hill-shadedimages of azimuth 0°, 45°, 90°and 135° while191 lineaments from the combined hill-shadedimages of azimuth 180°, 225°, 270° and 315°(Table 2). The combined western azimuths (180°, 225°, 270° and

315°) is observed to have a greater number of extracted lineaments than the combined eastern azimuth (0°, 45°, 90°and 135°). This is in agreement with the work of Oguchi et. al., (2003) where they observed that certain illumination angles are easier to identify a fault which some angles failed to reveal the fault.

The total length of combined hill-shaded images ofmulti-directional with azimuth 0°, 45°, 90° and 135° is 452.97Km with a minimum length of 1.16Km, maximum length of 10.12Km and a mean length of 3.01Km. The combined hill-shaded image with azimuth 180°, 225°,270° and 315° has a total length of494.37Km, minimum length of 1.83Km, maximum length of 10.13Km and mean length of 2.59Km.

The total number of lineaments in the study area that were mapped out from the overlay of the extracted lineaments from the two multi-directional sun angle hill-shaded images are 237, with a total length of 649.77Km and a mean length of 1.19Km. From the Histogram plot of the total lineament length of the study area(Figure 4), the lineaments show a positive skewness, which is an indication that mostlineaments in the study area are not extensive (Ishaku and Abubakar, 2016).

The orientation of the lineaments represented by the rosediagrams in figure 5 shows the trend in terms of the length anddirectional frequency which are an indication of the dominantdirections of the lineaments. The dominant trending pattern in the lineaments is NE-SW direction.

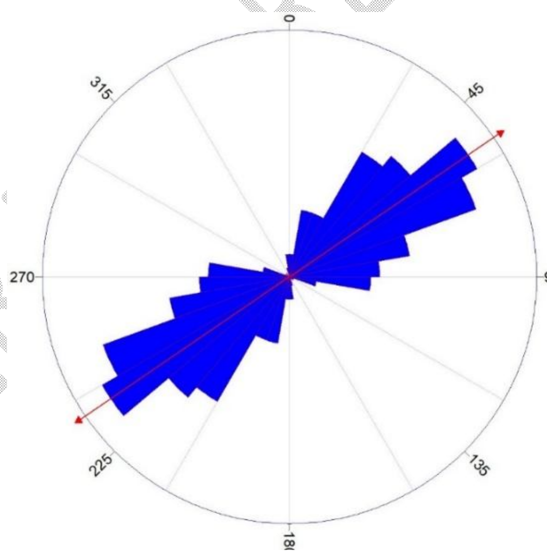


Fig. 4: Rose diagram of the lineament map

Lineament density

The lineament density calculates the magnitude of lineaments per unit area(Fig. 5). It aids in expressing the spatial variation in the geologic or geomorphologic processes taking place on the subsurface, surface or terrain of the area under investigation. Lineament density for the studyarea ranges from 0 to 1.36 km/sqkm(Fig. 5).

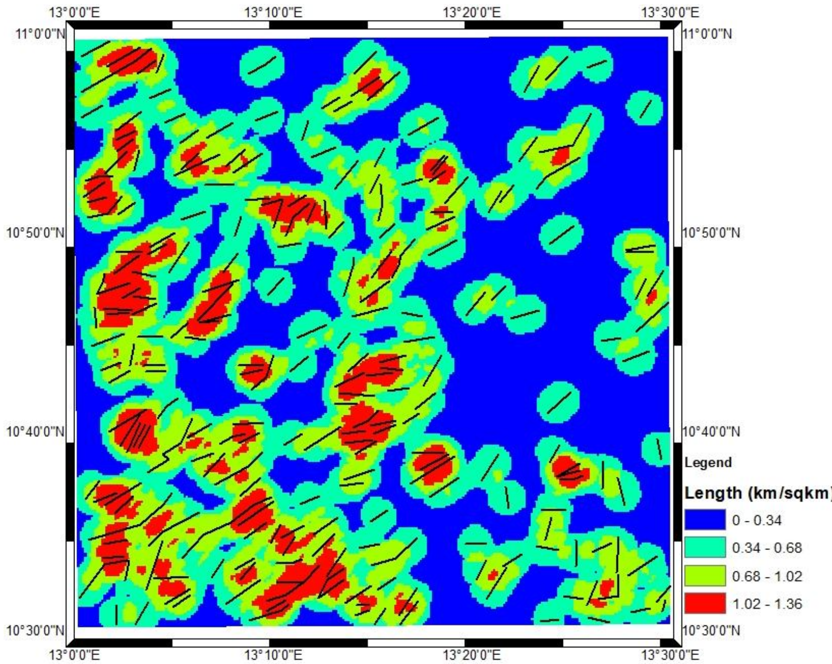


Fig. 5; Lineament density map of the study area

Table 3. Statistical description of lineament density map of the study area

S/N	Lineament density (km/sqkm)	Area (sqkm)	Description
1	0 – 0.34	522.20 (38.2%)	Poor
2	0.34 – 0.68	422.23 (30.9%)	Low
3	0.68 – 1.02	296.97 (21.7%)	High
4	1.02 – 1.36	126.57 (9.2%)	Very high

The statistical description of the lineament density map presented in Table 3 shows that areas of poor and low densities make up the greater part of the study area, with a total area of about 522.20sqkm and 422.23sqkm respectively. This land mass accounts for about 69.1% of the study area. The high and very high densities area account for just about 30.9% of the study area with an area of about 296.97sqkm and 126.57sqkm respectively.

CONCLUSION

The study demonstrates the use of DEM with 30m spatialresolution for lineamentextraction. Hill-shaded relief images withvariations of azimuth were employed for the automatic extraction. Lineament extracted from the multi-directional Sun angle(180°, 225°, 270°, 315°) gives a greater number of both lineaments and total lineaments length than that of the multi-directional Sun angle (0°, 45°, 90°, 135°). It is therefore clearly understood that the most common method to extract lineaments from a single azimuth angle cannot provide detailed information of available lineaments of an area. However, more accurate information can be extracted by tracing the lineaments from different azimuth angles, to give the true picture of the number and length of lineaments (Jawahar et al.2017).

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