Ife Journal of Science vol. 7, no. 2 (2005)

INFLUENCE OF LITHOLOGY AND GEOLOGICAL STRUCTURES ON DRAINAGE PATTERNS IN PART OF THE BASEMENT COMPLEX TERRAIN OF SOUTHWESTERN NIGERIA

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(*Submitted*: 23 August 2005; *Accepted*: 10 November 2005)

Abstract

Structural and Drainage lineament were extracted from enhanced SPOT-XS imagery and topographic maps of Ilesa area Southwestern Nigeria. The drainage and structural lineament were statistically analysed and compared to establish the degree of influence of geological structures and lithology on drainage pattern of the area. The prominent azimuth sets N-S, NE-SW, NW-SE and E-W that were conspicuous in the drainage lineament histogram were also present in the structural lineament histogram. A positive above average cross correlation coefficient (0.68) was obtained between the drainage and the structural lineament. This was due partly to the influence of Ifewara fault system that runs across the area and the effect of Efon-Psamite ridges located to the eastern half of the area. However, the abrupt changes in the drainage density of the western half compared to eastern half are an indication of lithologic differences.

1. Introduction

In the course of drainage development, several factors determine the ultimate type, density, and other characteristics of the drainage patterns of an area. The more significant of the factors are rock type, climate, and vegetation. For instance, resistant rocks, such as sandstones, quartzite, and conglomerates prevent the development of many small tributary streams. Areas underlain by such rock units are usually drained by a relatively few widely spaced, large tributary streams. Soluble rocks, such as limestone and dolomites accommodate within themselves a large portion of the precipitation and permit less surface runoff in the form of stream. Areas underlain by such rocks are, therefore, frequently characterized by low drainage density and large tributaries.

Drainage patterns may therefore refer to the planimetric arrangement of several streams and their tributaries which are usually adjusted to certain topographic, structural, or lithologic controls within a given drainage basin. Such patterns can be classified as dendritic, trellised, rectangular, annular, radial, parallel and deranged. Trellised drainage patterns consist of stream channels which are aligned to structures in the bedrock with minor tributaries appearing at right angles, while areas with tectonic fault or bedrock joints can cause streams to take on a grid-like or rectangular pattern. The parallel drainage patterns are often found in areas with steep relief or where flow occurs over non-cohesive materials. Patterns described here are in no way exhaustive.

These patterns are formed due to factors such as: geological structure, lithology and, at the early stage of development, topography (Onyedim, 1996). Moreover, various combinations of the aspect of drainage like genetic classification of streams, drainage patterns, anomalous drainage within a given pattern or stage of development of streams may be used in lithologic identification or link the pattern to tectonic history of an area. Therefore, in the context of this paper, geological structure refer to faults, joints, linear valleys, alignment of crest of ridges or the boundaries of elevated areas and fold-axial planes. Although, attempt were not made to categorise or distinguish geological structures in the study area, but their influence on drainage patterns of the area were analysed.

On remote sensing imagery, the aforementioned structures appear as lineament or slightly curvilinear. In this work such structural lineament were mapped from SPOT-XS imagery. Thus, it was presumed that the structural lineament network or lithology of an area has association with the development of a particular drainage pattern.

Onyedim (1996) investigated structural controls of drainage patterns in the southwest of Ilesa covering latitudes 7° 30'N to 7° 45' and longitudes 4° 30'E to 4° 45'E. The result revealed a local influence of structures and lithology on drainage patterns of the area. However, the major objective of the present study is to extend the study area to cover the entire sheet 243 and to quantitatively analyse the influence of geological structures and lithology on drainage

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patterns of the area. The regional consideration was necessary because of the contrasting drainage patterns of the eastern part compared to the western part of the area as shown in Fig.2. This study is pertinent because of its environmental planning implication, mineral exploration and agricultural development application.

2. Geological structures in the study area

The study area is located around Ilesa in southwestern Nigeria and is covered by the four-component maps that make up sheet 243 (NE, NW, SE, and SW) of the 1:50,000 topographic map series published by the Federal Survey of Nigeria. It is bounded by latitudes 7°30'N and 8°00'N and longitudes 4°30'E and 5°00'E respectively. The area lies within the tropical rainforest zone, characterized by two seasons: a rainy season (April-October) and a dry season (November-March).

The area forms part of the Nigeria Basement Complex situated within the Pan-African mobile belt located to the east of the West African craton (Fig. 1). Recent geochronological data revealed that the Nigerian basement complex has been involved in at least two orogenic episodes: Eburnean and Pan-African Orogeny (Rahaman, 1988). The Pan-African Orogeny was characterised by deformation, which either obliterated pre-existing structures or re-orientated them. Boesse and Ocan (1988) recognized two major phases of deformation categorized as D_1 and D_2, which produced folds of different styles. The D_1 deformation is responsible for the geometric form of the Effon ridges and the double-ridge system South of Ipetu and is also responsible for the shallow dips of foliation west of Iwaraja. The D_2 deformation produced open folds, refolding the D_1 folds and big fault zones, which create new isoclinical folds or reorientating pre-existing structures. The large, open folds are significant in the metasedimentary series with thick bands of quartzite.

A major NNE-SSW trending Ifewara fault zone has been recognized east of the study area (Hubbard, 1975; Elueze, 1977). Boesse and Ocan (1988) observed that the Ifewara fault zone modified the structures in the southeastern quadrant. Ridges of quartzite and quartzo-feldspathic gneisses dominate the eastern part of the study area.

3. Materials and method

The materials used in this study were SPOT XS multi spectral data that have the following characteristics: three spectral bands (0.50-0.59 μm, 0.61-0.68 μm and 0.79-0.89 μm), 4.13° field of view, 3000 pixels per line with a ground resolution of 20 m; four-component sheets 243 (Ilesa NE, NW, SE & SW) of the 1:50,000 topographic maps of the area, with contours drawn at 50ft (15m) interval and a geological map of the area (modified after Odeyemi, 1993).

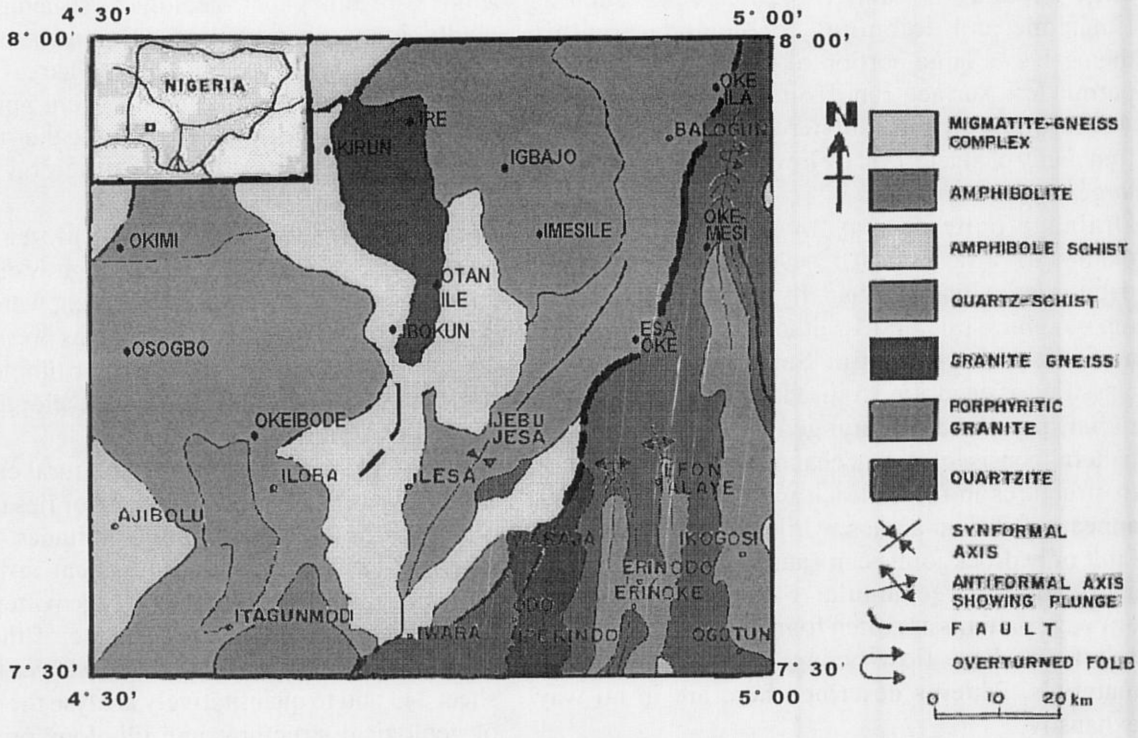


Figure 1: Geological Map of Ilesa area (Modified after Odeyemi, 1993)

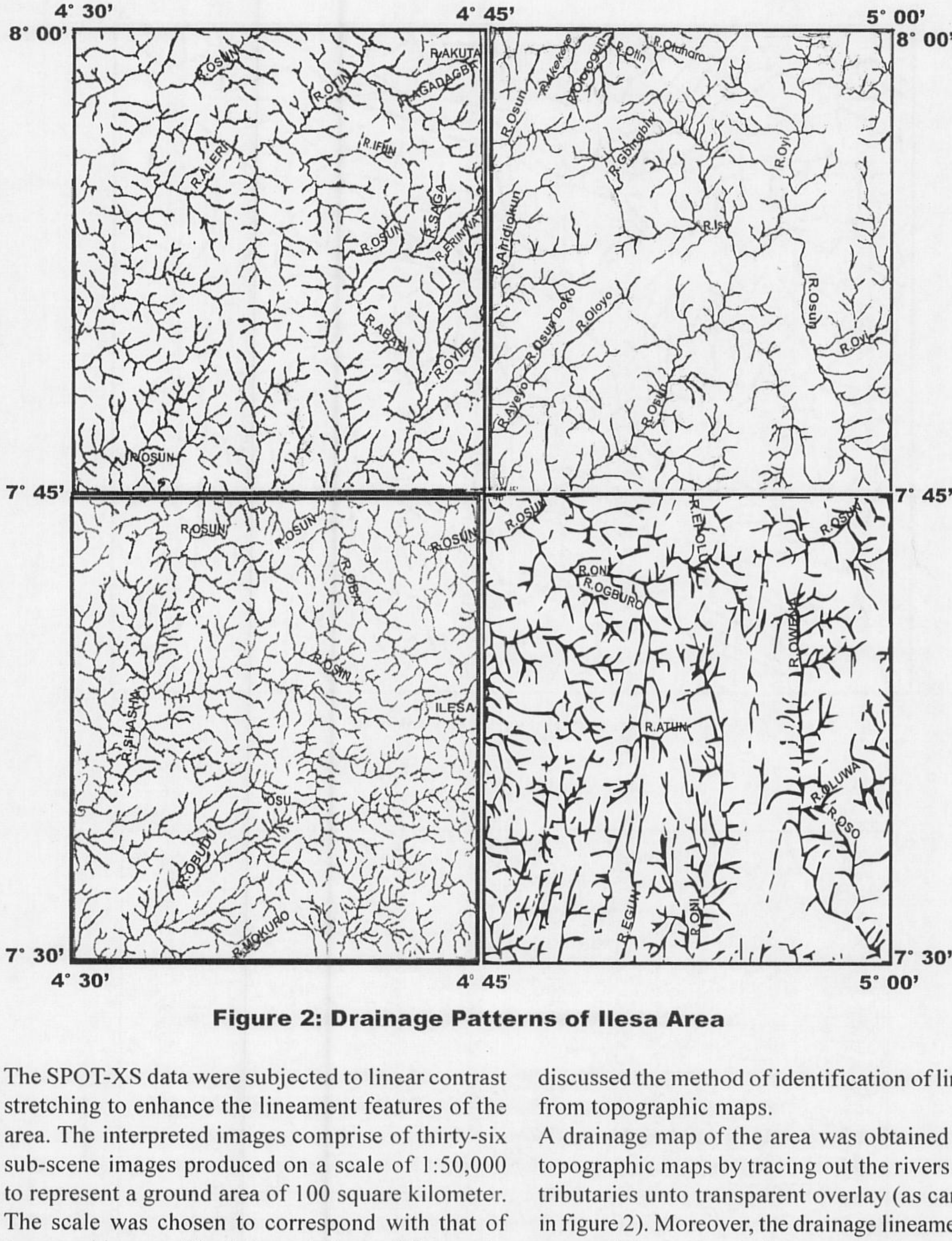


Figure 2: Drainage Patterns of Ilesa Area

The SPOT-XS data were subjected to linear contrast stretching to enhance the lineament features of the area. The interpreted images comprise of thirty-six sub-scene images produced on a scale of 1:50,000 to represent a ground area of 100 square kilometer. The scale was chosen to correspond with that of topographic map. The interpretations of these sub-scenes were done by three independent interpreters to avoid bias. During interpretation, the interpreters sought for and traced out the alignment of topographic highs and linear valleys; depressions along the fault trace, and abrupt changes in vegetation texture as displayed on the images. The interpreted lineaments from the thirty-six sub-scene were assembled into a mosaic.

Several authors have discussed details of the techniques of extraction of lineament from remote sensing images, such are Lattman (1958), Lillesand and Kiefer (1987). In addition, Ojo (1992), Awoyemi (2000) and Onyedim and Ogunkoya (2002) have discussed the method of identification of lineaments from topographic maps.

A drainage map of the area was obtained from the topographic maps by tracing out the rivers and their tributaries unto transparent overlay (as can be seen in figure 2). Moreover, the drainage lineaments were mapped from the drainage maps by tracing out segments of second, third and higher order streams that are rectilinear in form unto another transparent overlay. First order streams were not included because they are likely to be controlled by topography rather than structures. The final lineament maps from the two sources are presented in Figs. 3 and 4.

4. Analysis of structural and drainage linear

The maps of both drainage and structural lineaments shown in Figs. 3 and 4 were digitized and compiled (as shown in Table 1) in azimuth classes of 10°. A

Figure 3. Drainage Lineament map

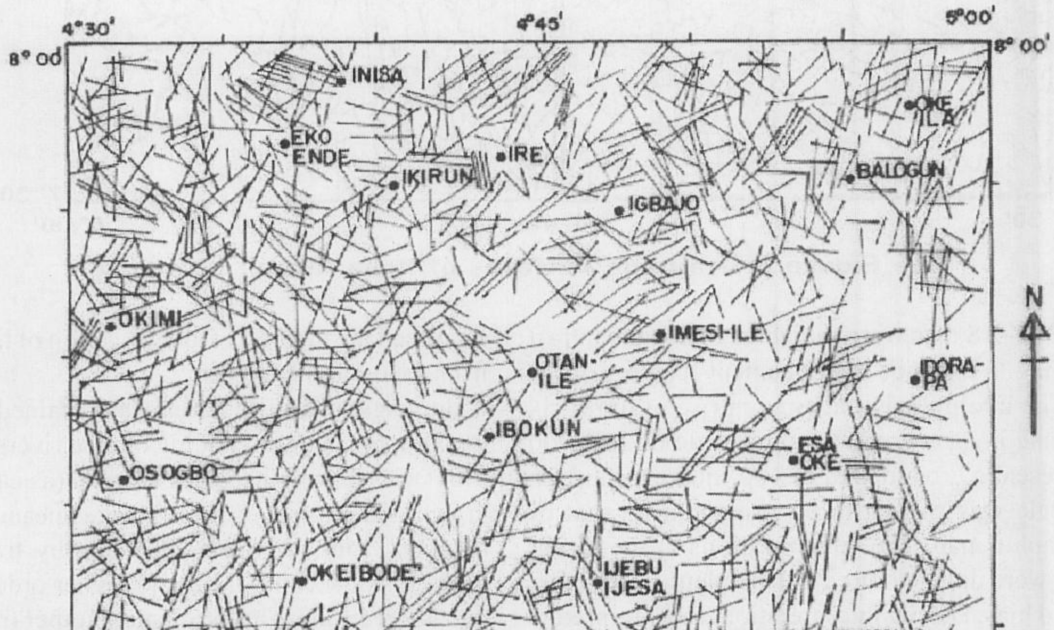


Figure 4: Sructural Lineament Map of Ilesa Area.

total of 1,233 structural lineaments were used in the construction of the Azimuth-Frequency histogram (A-F histogram), showing the frequency percentage of the structural lineament in each 10° azimuth class. Similar A-F histograms were drawn using 549 drainage lineaments (Fig. 5). Moreover, statistical correlation of the two linear data sets was computed.

5. Result and Discussion

A characteristic feature of the structure of the Nigerian Basement Complex is the wide spread occurrence of lineaments as defined by joints, shear zones mylonites, faults, strike ridges and straight channeled streams. Although, the nature and origin of an individual lineament as observed on the satellites images may be difficult to establish, hence, emphasis was placed on the spatial and directional attributes of the lineament sets as appeared on A-F histogram. In this study, summations of lineaments that form a significant peak in the A-F histogram were taken to represent surface expression of fractures which include: Joints, faults, axes of folds, strike ridges or shear zones.

The principal fracture directions prominent in the study area were seven (N-S, NNE-SSW, NE-SW, E-W, NNW-SSE, NW-SE and WSW-ENE). Some of these trends are regionally prominent while some are localized. For instance, the significant development of N-S, NNE-SSW, NE-SW and E-W were conspicuous. However, the pair of histograms of the structural and drainage lineament of Fig. 5 shows that the azimuth classes identified is being present in both cases. Thus, a positive above average correlation (0.68) was obtained between structural and drainage lineament sets. This above average correlation obtain may indicate possible structural control of drainage in the area.

Table 1: Frequency in percentage of both structural and drainage lineaments

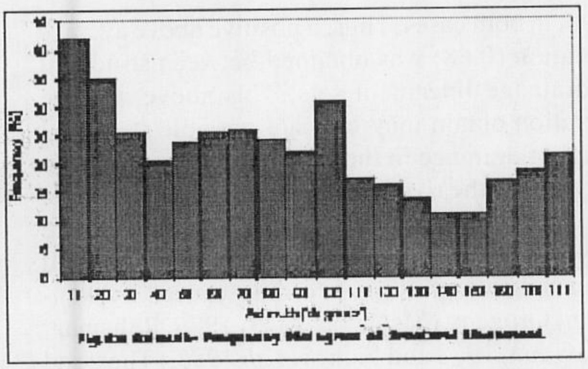
Azimuth (Degrees)	Freq.(%) of S.L	Freq.(%) of D.L
010	42.14	39.53
020	34.94	39.97
030	25.22	17.9
040	20.59	18.97
050	23.79	22.03
060	25.33	21.69
070	26.12	21.56
080	24.11	23.13
090	22.15	19.79
100	30.83	15.74
110	17.16	25.69
120	15.96	21.85
130	13.58	16.09
140	10.82	12.67
150	10.65	23.47
160	16.77	18.3
170	18.36	20.32
180	21.52	21.29

S.L (Structural Lineaments) D.L (Drainage Lineaments)

Analytically, the rivers that flow in the approximate directions of N-S and E-W in the eastern half are likely to be controlled by the structures formed during the two phases of folding caused by Pan-African Orogeny (McCurry, 1973; 1976, Rahaman, 1976, Grant, 1978 and Fiches *et al.* 1985.) The trend could also have appeared on the drainage linear as a result of the control imposed by two phases of deformation that produced the D_1 and D_2 (Boesse and Ocan, 1988). The D_1 deformation is manifested in the geometric form of the Effon-ridges and the double ridge system south of Ipetu, which structurally control the flow of rivers Owena, Osun and Oyi. Moreover, the NNE-SSW and NE-SW trending rivers like Obudu and Mokuro are possibly influenced by the disposition of the Ifewara fault zone that runs across the study area. Also, the drainage lineament sets trending NNW-SSE and NE-SW are possibly controlled by the strike of pegmatite veins and joints in the area. de Swardt (1953) and Odeyemi *et al.* (1985) confirmed the existence of these structures.

Generally, the texture of the drainage patterns of the study area is fine at the western half and coarse at the eastern half. The coarseness may results from the long quartzite ridges that dominate the eastern area, while the fine texture to the west may be interpreted as due to one common element homogeneity. About sixty-six percent of the drainage networks from west to east in the area are dendritic in nature. Although, conspicuous parallelism exists between the trunks of some rivers at the eastern half of the study area, examples are rivers Owena, Oni and Egun, they run approximately in a N-S or NNE-SSW direction. There is an abrupt change in density between western half and eastern half which may be as a result of difference in lithology. Also noticeable at the western half, is the contorted appearance of River Osun with a completely reversed direction, this could be that it encountered resistant rock or granular barrier. Furthermore, the disposition of the drainage pattern at the eastern half are generally curvilinear, this is often associated with folds, craters, domes or basins Onyedim and Ogunkoya (2002). These characteristic features may be interpreted as structural influence on the drainage.

The drainage network arrangement at the western half of the area is majorly dendritic, this arrangement may due to uniformity in the rock resistance of the area. This pattern dominates despite the fact that the study area had undergone stages of folding, refolding and faulting. Moreover, it may be that the fracture present in western half may have been sealed to a



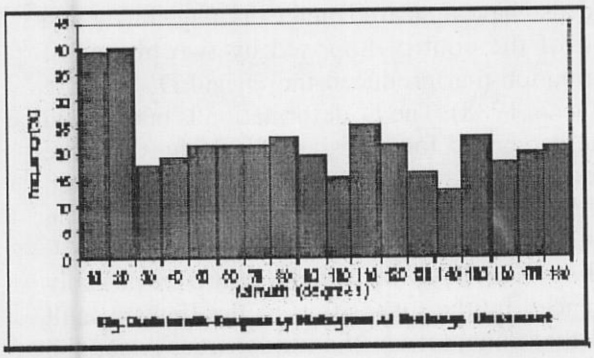


Figure 5: Azimuth-Frequency Histogram of Drainage and Structural Lineaments drawn from Table 1

degree, that they neither constitute significant lines of less resistance nor have a resistance exceeding that of the surrounding rock. However, it was deduced that lithology of the exposed rock at the western half may be the major factor that influences the drainage network.

6. Conclusions

Both quantitative and qualitative approaches have been adopted in the analysis of the structural and drainage linear. A positive above average correlation coefficient obtained between structural and drainage linear indicated that there is a significant control of drainage in the area by geological structures. More so, abrupt changes in the drainage density observed in the western half compared to eastern half was taken to be due to difference in lithology of the areas. The trends obtained confirm the various results of geological structural trends mapped in the Nigerian Basement Complex. This method of structural and drainage lineament analysis is pertinent to delineate structurally controlled anomaly. It could also be used to determine changes in the width of a belt having certain drainage characteristics. Also, it may be possible to locate a fault by noting the juxtaposition of two drainage textures which elsewhere are separated by a constant horizontal distance or interval.

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