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# LITHOLOGY AND CHANNEL NETWORK INITIATION AND ORIENTATION: A CASE STUDY OF UPPER OGUN RIVER BASIN, SOUTHWESTERN NIGERIA

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*Abstract*— **Several geomorphologists have highlighted the importance of structure on landform evolution. However, studies concerned with the impact of underlying structure on channel initiation and evolution are still growing. In this study, six-third order basins were selected systematically from Upper Ogun River Basin, Southwestern Nigeria for lithology and channel network initiation and orientation evaluation. Rose diagrams were used to present the influence of underlying lithological units on river network orientation and initiation. The approach here is to identify lineaments and river networks for each basin and compare the presented patterns. The study area is underlain by granites, migmatites, schists, pegmatites, quartzite, etc. with migmatite being the most obvious in terms of spread. Lineament and channel network pattern and orientation were extracted for each of the basins from Shuttle Radar Topography Mission (SRTM) at 30m resolution using Rockworks 15 and ArcGIS 10.2. The Rose diagram for the lineament trends suggests four major trends; E-W, N-S, SSE-SSW and NE-SW. Across these four major trends, the N-S and E-W were particularly dominant showing a bimodal distribution that has corresponding peaks on the length-orientation axis of the Rose diagram of the river channels. Since the general trend of tectonic grains within the Nigerian Basement Complex is relatively N-S, the main channels draining the selected basins in Upper Ogun appear to have been controlled along pre-existing weak zones in the country rocks.**

## Introduction

Until recently, information about streams in humid tropics was limited to their description in relation to geological structure; there remain a large gap to fill as regards mechanics of how river channels and networks evolve, lithological units and channel network pattern, etc. Most studies especially in temperate regions or river channels with(out) glacial history have been studied and underlying interactions between process-form dynamics presented in the literature. The inherent characteristics observed in humid tropical regions as a result of differential weathering suggest that most valley settings and fluvial processes are unique in this area. However, narratives concerning humid tropical basins without glacial history are still growing. The problem, however, is that information on basins within a humid tropical region is too limited for any reasonable and definitive inferences and deductions to be made [1, 2]. Hence, the need to take advantage of big data available in Digital Elevation Models (DEMs) and emerging geo-computational tools cannot be overemphasized.

This study seeks to contribute to geomorphic understanding by using Digital Elevation Models (DEMs) to provide interactions between process and form within a typical drainage basin in Southwestern Nigeria. This will ensure the co-production of knowledge for locations with limited geomorphological understandings.

This study aims to understand the influence of lithology on river channel orientation. The use of Rose diagrams presents an avenue to highlight the influence of underlying lithological units on river network orientation and initiation.

## I. METHODS

### Basin determination and procedure

Seventeen (17) third-order basins were identified across the Upper Ogun River Basin using topographical maps and Geographic Information Systems. This involves the use of Shuttle Radar Topography Mission, SRTM, a Digital Elevation Model, DEM, at 30m resolution. The output from the DEM was cross-validated with topographical maps of 1:50 000 covering the entire basin. The 30meter DEM was projected in the Universal Traverse Mercator Zone 31N based on Nigerian Grid Datum. The directions of surface water flow, flow accumulation area and stream network coverage were obtained from a filled DEM based on the methods of [3], while a variety of methods were used to determine an appropriate flow accumulation area for a stream [4, 5].

### Geoprocessing

The steps used in extracting the channel networks from Upper Ogun River Basin involves the clipping and processing of the DEM. Processing the DEM from the clipped DEM involves filling of depressions in the DEM, assignment of flow directions on the filled DEM and the calculation of flow accumulation on the flow direction using hydrological tools of the ArcToolbox (ArcGIS 10.x). After these processes, the channel network was then extracted using the con Tool and ordered using the Strahler

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method. The ordered stream network raster was then converted into vector.

After ordering, seventeen third-order basins were identified across the Upper Ogun Basin. The seventeen third-order basins which form the population of the study were then cross-validated with the topographical maps. After which the raster form of the channel networks was converted into vector form.

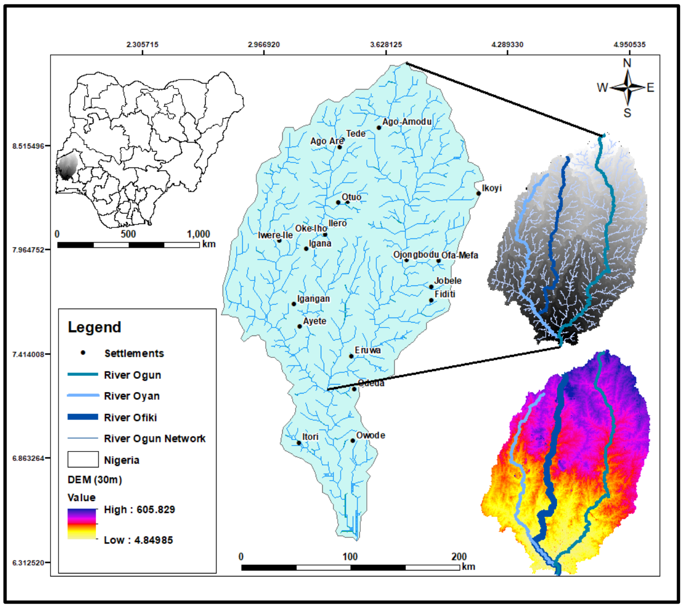


**Figure 1.** The extent of the Ogun River Basin showing a section of the Upper Ogun River Basin and the DEM

## Sampling

To identify the basins to be studied, a systematic and random sampling technique was employed. The first step was to identify basins that were heterogeneous based on lithological variations. For a basin to be heterogeneous, it must have more than two lithological units within the basin, none of which must be more than seventy percent in terms of areal coverage across the basin. The benchmark of seventy percent was set for the study because the area is a basement complex and largely underlain by migmatites [6]. Applying this yardstick, six basins (Table 1) were selected from the population (Figure 2).

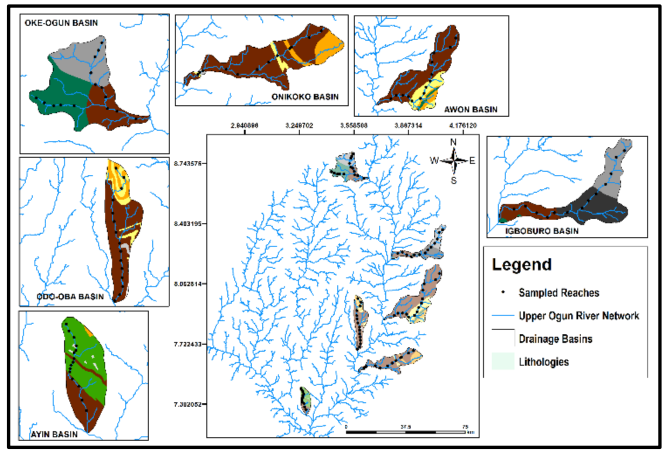


**Figure 2.** Selected third-order basins

## Data Analyses

Topographic properties were extracted using System for Automated Geoscientific Analysis (SAGA) version 4.0.0, a GIS software. Rockware software was used in creating Rose diagrams for lineament patterns and channel networks

**Table 1.** Selected third-order basins

| Basin ID | BASIN NAME | GEOLOGY |
|---|---|---|
| 1 | OKE-OGUN | OGe -Medium to coarse-grained hornblende; OGp – Coarse porphyritic and biotite hornblende granite; and M - Migmatite |
| 2 | IGBOBURO | OGp – Coarse porphyritic and biotite hornblende granite; M – Migmatite; and OPg – Prophyroblastic gneiss |
| 3 | AWON | Su – Undifferentiated Schists; Qs – Quartzite Schist; and P - Pegmatite |
| 4 | ONIKOKO | OGe – Medium to coarse-grained hornblende; M – Migmatite; and OGp – Coarse porphyritic and biotite hornblende granite |
| 5 | ODO-OBA | OGb – Coarse porphyritic biotite and biotite muscovite granite; OGh – Coarse porphyritic hornblende granite; and M - Migmatite |
| 6 | AYIN | OGu – Undifferentiated Older Granite; Su – Undifferentiated Schists; OGp – Coarse porphyritic and biotite hornblende granite |

## II. Results and conclusions

Environmental factors such as climate, lithology, vegetation, etc exercise control through their direct and indirect impact on fluvial process and dynamics. Within a homogenous climatic zone, lithology stands to be one of the most important environmental factors to influence river channel morphology. Rose diagrams (Figure 3) present the influence of underlying lithological units on river network orientation and initiation. The approach here is to identify lineaments and river networks and compare the pattern. It has been established that known methods of relating lineament patterns to morpho-tectonic subsets are Rose diagrams [7, 8]. In recent times, other attributes can be generated from lineament properties especially since the advent of computer-aided programs. It is important to state here that the area is a Basement Complex with the occurrence of Inselbergs and domes across the entire landscape of the Upper Ogun River Basin (UORB) (Figure 1). The area is underlain by granites, migmatites, schists, pegmatites, quartzite, etc. with migmatite being the most obvious in terms of spread (Table 2).

The frequency and length of lineaments (fractures) in the Rose diagram for the study area (Figure 3) shows a bi-modal distribution in most cases along the EW-NS (East West – North South) and N-S (North-South) directions. The distributions (EW-NS and N-S) have corresponding peaks on the length-orientation axis of the Rose diagram of the river channels (Figure 3). Specifically, within the Oke-Ogun basin (Figure 3a), the lineament pattern showed a more N-S direction as the main lineament axis with other minor sub-trends show more of the E-W direction. The river network presents for its main channel an E-W trend with its tributaries showing largely ENE-WSW trends. By implication, the main channel of the basin is largely controlled by minor sub-trends of the lineaments. For the Igboburo basin (Figure 3b), the lineament trend shows E-W, N-S, SSW-NNE and ENE-WSW, while the channel network for the main channel showed E-W trend and its tributaries showing N-S and SSE-SSW trends. This implies that the main channel draining Igboburo basin is being controlled by the main structural trend. Awon basin (Figure 3c), showed a trend of N-S, E-W and SSE-SSW, while the river network presents a N-S trend. The implication here is that the main channel draining Awon basin is being controlled by the main structural trend in the N-S direction. Onikoko basin (Figure 3d) showed for its lineament trend E-W and SSE-SSW as its major trends, while the river network within the basin presents SSE-SSW as the trend direction for its main channel. In essence, the main channel draining the Onikoko basin is being controlled by the main structural trend along the SSE-SSW direction. Odo-Oba basin (Figure 3e), presents a dominant trend direction for its lineament along N-S, NE-SW, NNE-SSW and NWN-SES, while the main channel network as presented in the Rose diagram is along NNE-SSW and NWN-SES. For the Ayin basin (Figure 3), the main lineament trend is along N-W, while the minor sub-trends are along NE-SW direction. The main channel network presented a NW-SE direction. By extension, the main channel network within the Ayin basin is controlled by minor sub-trends of the lineament pattern.

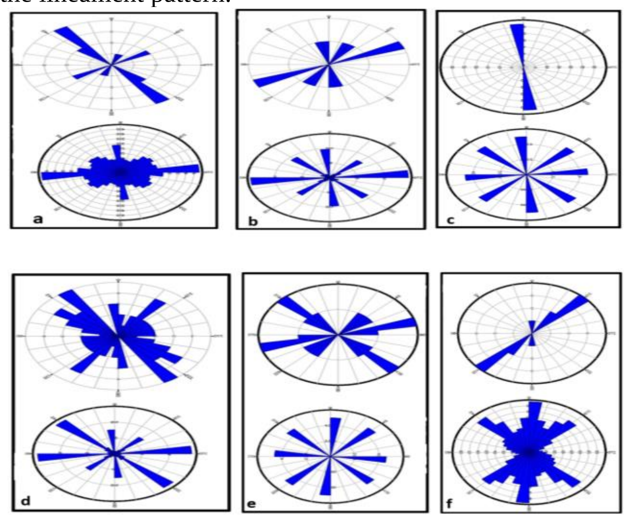


**Figure 3.** Rose diagram illustrating trends of lineament (upper Rose diagram) and channel network (lower Rose diagram) (a) Oke-Ogun Basin (b)Igboburo Basin (c) Awon Basin (d) Onikoko Basin (e) Odo-Oba Basin (f) Ayin Basin

In conclusion, the Rose diagram for the lineament trends suggests four major trends; the E-W, N-S, SSE-SSW and NE-SW. Across these four major trends, the N-S and E-W were particularly dominant. The general trend of tectonic grains within the Nigerian Basement is relatively in the N-S trend [9], the main channels draining the selected basins in Upper Ogun appear to have been controlled along pre-existing weak zones in the country. Hydro-geomorphologically, the E-W and N-S lineament trend as observed in this study can be tied to tectonic events that have affected the evolution of the Upper Ogun Basin [10]. Furthermore, it is established that groundwater flow in the Basement complex is likely to follow the path of porosity in fractures as well as weathered overburden [11]. It can, therefore, be implied that these two lineament orientation sets (N-S, E-W) could define the preferred orientation of groundwater occurrence within the Upper Ogun River Basin (UORB). Another far-reaching implication is the observation that the occurrence of the N-S and E-W trending lineaments in the area might suggest that they serve as active conduits connecting most springs in the area to the main channel.

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