JSRD Journal of Scientific Research & Development

UNIVERSITY OF LAGOS IN DEED AND IN TRUTH

A bi-annual journal published by the Faculty of Science, University of Lagos, Nigeria

http://jsrd.unilag.edu.ng/index.php/jsrd

Groundwater Potential Zone Identification by Lineament Mapping using Shaded Relief Images Derived from Digital Elevation Model (DEM)

Kuforiji Hakeem Iyiola[1], Ganiyu Saheed Adekunle[2], Olurin Oluwaseun Tolutope[2], Bello Rasaq[3], and Musa Hayatudeen[3]

[1]Department of Physical Sciences, Al-Hikmah University, Ilorin, Kwara State, Nigeria
[2]Department of Physics, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria
[3]Department of Physics, Federal University of Kashere, Gombe State, Nigeria

Corresponding author: hakeemkuforiji@gmail.com

(Received 01 February 2025/ Revised 23 April 2025/ Accepted 28 April 2025)

-Abstract

The study area, Obafemi-owode, is an important area of Ogun state due to its proximity to Lagos State, a major industrial hub of Nigeria. Being a developing country, most parts of Nigeria do not have access to quality water, both for domestic and industrial uses. The study area is not an exception, as the residents rely mainly on groundwater for various purposes. Lineament identification using the Digital Elevation Model (DEMs) can provide useful information about the underlying geological structure, which can be very helpful in fault and aquifer identification. It involves the creation of shaded relief images of the study area from the DEM. In the present work, four shaded relief images were produced with sun azimuth angles and elevations of 315˚ and 45˚, 200˚ and 60˚, 100˚ and 60˚ and lastly 60˚ and 80˚. The various azimuth angles and elevation combinations enhanced distinct relief and topography for better lineament extraction. Lineaments (linear and curvilinear) were extracted from the four generated relief images, and the lineament density map was plotted. The result showed that the lineaments trend dominantly in the NNE-SSW direction, which could be considered to be an effect of the Mesoproterozoic Benin-Nigeria block of the West Africa orogeny. The area of lineament density is underlain by the Abeokuta formation, and the zone with high lineament intersection within this area is identified as the region of high groundwater potential.

Keywords: Digital Elevation Model, Groundwater Potential, Lineament, Shaded relief image

---

Introduction

Mineral and groundwater explorations are often the focus of most geophysical prospecting. As the human population increases, the need for water and important minerals such as oil and hydrocarbons increases. The remote sensing technique, which is known to be very useful in many fields of study, including structural geology, has gained the attention of scientists working in areas of geophysical prospecting. Lineament study is a remote sensing method that has been widely used in several geological and geophysical studies all over the world (Juhari and Ibrahim, 1977; Magowe and Carr, 1999; Fernandes and Rudolph, 2001; Solomon and Ghebreab, 2006). Geophysical investigations involving lineament studies for groundwater potential, stratigraphy, and subsurface structure analysis have been carried out in various research works, yielding very important results (Alhirmizy, 2015; Abdullah *et al*., 2010; Maged and Mazlan, 2010). This is possible because some very useful information about the underlying geological structure is obtainable from the linear and curvilinear features present in the topography map of an area. Accurate mapping of geological features, if ensured, can provide information about possible regional and local environmental disasters (Andi *et al*., 2017). Lineament study has been helpful in thrust faults, bedrock faults, shear zones and lithological contact identification (Rochidi *et al*., 2012). It is an extensive linear or curvilinear feature on a planet, which presumably is capable of reflecting some sub-surface phenomenon (O'Leary *et al*., 1976). The term was first used to describe the landscape of basement rock with a significant line by Hobbs (1904). Also, it was described as a mappable linear feature of a surface with its parts aligning in a linear or curvilinear manner with a clear distinction from the surrounding features (O'Leary *et al*., 1976). In a geophysical data processing tool like the popular ArcGIS, a shaded relief image can be produced by applying a z-factor to the hill shade effect of a digital elevation model (DEM). In this manner, the topography of the area is well represented naturally on the map. After the production of the shaded relief image, lineaments can be generated either manually or automatically using PCI Geomatica Focus, ENVI etc (Abdullah *et al*., 2010; Hung *et al*., 2005; PCI Geomatica 2001). Obafemi-owode, like many other local governments in Nigeria, depend largely on the groundwater for various uses. However, the geology and terrain of the area do not favour blind borehole drilling and hand-dug wells, which is very affordable to the people. Thus, the present work is undertaken with aim of identifying groundwater potential zones in the Obafemi-owode Local Government Area of Ogun State using the method of lineament mapping.

Study Area

The location of this study is the Obafemi-owode Local Government Area in Ogun State, southwestern Nigeria. The study area is bounded in the north partly by Odeda Local

Government of Ogun state and Oyo state, by Ifo Local Government Area and Lagos state in the south. To the east, it shares boundaries with Ikenne and Shagamu Local Government Areas of Ogun State (Figure 1). The ever-busy Lagos–Ibadan expressway passes through the corridor of the study area. This makes the study area one of the most populous Local Governments not only in Ogun state but also throughout the southwestern region of the country. Obafemi-owode, which forms part of Abeokuta, the Ogun state capital, is located between latitude 6˚41'26" and 7˚9"40" and longitude 3˚16'11" and 3˚46'41". It is accessible through many major federal roads and the new standard rail recently completed by the federal government of Nigeria. Its population as of the 2006 census is 228, 851 and covers an area of 1,410 square kilometres. No major river in Ogun State passes through the study area, but it has good drainage networks for erosion and annual streams.

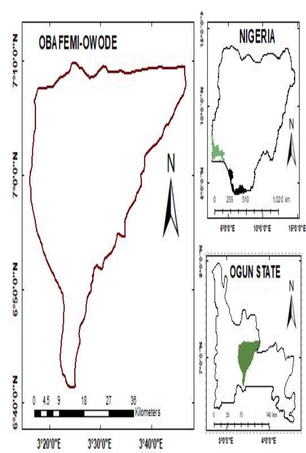


Fig. 1 Location map of the study area

Geology of the study area

Geologically, Obafemi-owode comprises four of the Ogun main geological units. Namely: Abeokuta formation, Ewekoro formation, the basement complex, and the recent alluvium. In the basement dominated area of Ogun state, gneiss, granodiorite, monzogranite, etc, of Archean age form the northern part of the study area (Badmus and Olatinsu, 2009). Ewekoro and Abeokuta formations span through Ogun state from the state boundary with the Benin Republic to southern Nigeria, of the study area. Thus, Obafemi-owode is an important part of the popular Dahomey basin in Nigeria (Figure 2). Generally, Ogun state is known for the tropical pattern of the wet season that runs between March and November and the dry season, which comes up between December and February (Gabriel *et al*., 2020). The mean annual rainfall is about 120 cm, and the maximum monthly temperature of about 32 ˚C (occurs in February). The topsoil in the study area is mostly sandy loam and thus very good for various agricultural purposes.

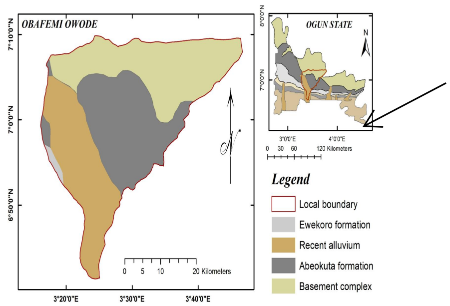


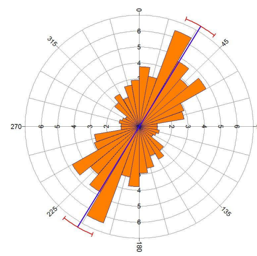
Fig. 2 Geology of Obafemi-owode Local Government, Ogun State Nigeria forming parts of the sedimentary rock

Materials and Methods

A digital elevation model (DEM) was obtained from SRTM (90 × 90m global DEM) and was analysed using ArcGIS 10.5. The SRTM DEM is freely available on the global land cover facility sites. For this work, the DEM was downloaded from the website of the United States Geological Survey (USGS). Two data sheets covering the study area were acquired and merged before being clipped to the study area, Obafemi-owode Local Government Area of Ogun State southwestern, Nigeria. Good lineaments can be produced by creating shaded relief images (of the study area) from the digital elevation models. Four shaded relief images were produced with sun azimuth angles and elevations of 315˚ and 45˚, 200˚ and 50˚, 100˚ and 60˚ and lastly 60˚ and 90˚ (Figure 3). The various azimuth angles and elevation combinations enhanced distinct relief and topography for better lineament extraction. In addition, all the shaded relief images were produced with a z factor of one. Lineaments (linear and curvilinear) were extracted (over the study area) from the four generated relief images and were followed by the production of the lineament density map. Paths, roads and other man-made features can be captured in the lineament mapping of the area. Since these are non-geological features, there is a need to eliminate them. To do this, methods of geographical mapping and field checking were adopted (Pothiraj and Baskaran, 2013; Yassaghi, 2006).

Results

The extracted lineament map of the study was analysed, and the lineament density map was plotted (Figure 4). The lineament trend direction was also studied, and its analysis shows the trends of the lineaments along NE-SW, N-S and NW-SE. The Rose diagram, which was roduced with the aid of Rockworks17 software, gave the orientation of the lineaments in the study area (Figure 5). The major (and the average) trend direction (the blue line on the Figure).



Statistical Summary	
Calculation Method:	Frequency
Class Interval:	10.0 Degrees
Min.Length Filtering:	Activated
Minimum Length:	0.0
Max.Length Filtering:	Deactivated
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	358
Total Length of All Lineations:	598,834.59
Maximum Bin Population:	46.0
Mean Bin Population:	19.89
Standard Deviation of Bin Population:	10.68
Maximum Bin Population (%):	6.42
Mean Bin Population (%):	2.78
Standard Deviation of Bin Population (%):	1.49
Maximum Bin Length:	37,766.48
Mean Bin Length:	16,634.29
Standard Deviation of Bin Lengths:	10,082.6
Maximum Bin Length (%):	6.31
Mean Bin Length (%):	2.78
Standard Deviation of Bin Lengths (%):	1.68
Vector Mean:	30.9 Degrees
	210.9 Degrees
Confidence Interval:	7.9 Degrees
	(80 Percent)
R-mag:	0.34

Fig. 5 Rose Diagram showing the Trend of Lineaments in the Study Area

Discussion

The major lineament trends in the study area were observed to be along the NE-SW direction, which is in the Pan African age. In structural geology, rose diagrams are very useful in the analysis of the orientation of dips and strikes of bedding. It can be obtained by plotting the frequency of occurrence of the directional (azimuthal) data to give the rose petals that appear like a circular histogram.

In the present work, the major trend of the lineament was given by the Rose diagram as NNE-SSW. This result is evidence of orogeny in Africa (Keita et al., 2016)). Nigeria is a West African country that was once part of the ancient supercontinent Gondwana. It has been established that the Pan-African thermo-tectonic event (650 ±150) notably occurred in Nigeria just as it occurred in other areas of the West Africa (Burke and Dewey 1972).

It was observed that distinct areas of high lineament density coverage were found in the north, down to the centre of the area and in the eastern part of the area. The result further showed that areas of lineament density are underlain by Abeokuta formation and the zones with high lineament intersection within this area are identified as the zones of high groundwater potential..

The western and southern parts of the study area were observed with low values of lineament density. This result, however disagrees with Gabriel et al., (2020), where the composite images of seven different bands of LANDSAT 8 images were used for the lineament extraction, which produced a high value of the lineament density in the eastern and southern part of the study area (Gabriel et al., 2020).

The Benin-Nigerian block of the West Africa orogeny runs from northern Nigeria down the west and continues into the Benin Republic via Oyo and Ogun states, southwestern Nigeria. The Sahara metacraton, which entered into north-east Nigeria from the East Sahara and the Oubangides belt that occupies the south, are orogens of Neoproterozoic. Thus, the north-east and southern Nigeria are within the orogenic events of the major Neoproterozoic in Nigeria. This is the Pan-African Orogeny within which the study area, Obafemi Owode Local Government Area, did not fall.

The Benin-Nigeria block is Mesoproterozoic in which the northern part of Ogun state falls, with other parts (including the study area) lying completely in the Archean rocks of the Gondwana. Then, the lineament observed in this study is an indication of the effect of the orogenic event of the Mesoproterozoic in the northern part of Ogun State. More importantly, the result showed that the direction of the trends of the lineaments extracted in the study area followed the trending of the Mesoproterozoic Benin-Nigeria block of the West Africa orogeny.

Conclusion

The extracted lineament map of the study area has been analyzed, and it can be concluded from the result that the trends of the lineaments are along NE-SW, N-S and NW-SE, with NNE-SSW as the major trend. Since the Benin-Nigeria block of the West Africa orogeny trends in this direction and close to the study area, it can be concluded that the dominant trend of lineament (in the study area) is an effect of the Mesoproterozoic orogeny. Areas of high lineament density coverage were found in the north, down to the centre of the area and in the eastern part of the study area. The areas of lineament density are underlain mainly by the Abeokuta formation, while the zones with high lineament intersection within this area are identified as the regions of high groundwater potential. The western and southern regions of the study area are characterised by low values of the lineament density.

Conflict of Interest

The authors admit that there exist no conflict of interest whatsoever as regards the writing and publication of this article.

References

Abdullah, A., Akhir, J. M. and Abdullah, I. (2010). Automatic Mapping of Lineaments Using Shaded Relief Images Derived from

Digital Elevation Model (DEMs) in the Maran - Sungi Lembing Area, Malaysia, *The Electronic Journal of Geotechnical Engineering*, 15: 949-957.

Abdullah, A., Akhir, J. M. and Abdullah, I. (2010). The Extraction of Lineaments Using Slope Image Derived from Digital Elevation Model: Case Study: Sungai Lembing-Maran area, *Malaysia. Journal of Applied Sciences Research,* 6 (11): 1745-1751.

Alhirmizy, S. M. (2015). Automatic Mapping of Lineaments Using Shaded Relief Images Derived From Digital Elevation Model (DEM) in Kirkuk northeast Iraq, *International Journal of Science and Research*, 4(5): 2227 – 2233.

Andi, A. N., Gumilar, U. N. and Pulung, A. P. (2017). Interpretation of Groundwater Potential Zones Based on Lineament Pattern Data Analysis in Ambon Island, Moluccas Province, Indonesia, *International Journal of Applied Engineering Research,* 12 (17): 6941-6945.

Badmus, B. S. and Olatinsu, O. B. (2009). Geophysical evaluation and chemical analysis of kaolin clay deposit of Lakiri village, southwestern Nigeria. *Int J. Phys Sci,* 4(10):592–606

Burke, K. C. and Dewey, F. (1972). Orogeny in Africa in Aft. Geol. Ibadan. Eds. Dessauvagie and Whiteman, Ibadan Univ. Press. pp. 588--608,

Gabriel, E. O., Ilesanmi, M. O., Adebowale, E. A., Rotimi, P. A., Akinpelumi, A. A., Kayode, L. O. and Oluseun, A. S. (2020). Integration of remote sensing, GIS and 2D resistivity methods in groundwater development. *Applied Water Science,* 10:129 https://doi.org/10.1007/s13201-020-01219-x

Hobbs, W. H. (1904). Lineaments of the Atlantic border region. *Geological Society of America Bulletin*, 15, 483-506.

Hung, Q. L., Batelaan, O. and Smedt, F. D., (2005). Lineament extraction and analysis, comparison of LANDSAT ETM and ASTER imagery. Case study: Suoimuoi tropical karst catchment, Vietnam," Remote Sensing for Environmental Monitoring, GIS Applications, and Geology.

Ibrahim, U. and Mutua, F. (2012). Lineament Extraction using Landsat 8 (OLI) in Gedo, Somalia. *International Journal of Science and Research* (IJSR), 3, 291-296.

Juhari, M. A., and Ibrahim, A. (1997). Geological Applications of Landsat Thematic Mapper Imagery: Mapping and Analysis of Lineaments in NW Peninsula Malaysia. ACRS. Available online at: www.gisdevelopment.

Keita, I., Tsuyoshi, I., Qing, C., Jun-Ichi, K. and Shigenori, M. (2016). U–Pb chronology and geochemistry of detrital monazites from major African rivers: Constraints on the timing and nature of the Pan-African Orogeny, Precambrian Research 282 139 – 156. https://doi.org/10.1016/j.precamres.2016.07.008

Ma'aji, U. M. and Sarki, M. U. (2019). Lineaments Analysis and Interpretation for Assessment of Groundwater Potential of Lafia and Environs, North Central Nigeria IOSR Journal of *Applied Geology and Geophysics* (IOSR-JAGG), 7.1: 22-28 DOI: 10.9790/0990-0701012228

Maged, M. and Mazlan, H. (2010). Lineament Mapping Using Multispectral Remote Sensing Satellite Data, *International Journal of the Physical Sciences,* 5(10): 1501-1507, Magowe, M. and Carr, J. R. (1999). Relationship between lineaments and ground water occurrence in western Botswana. *Ground Water,* 37 (2), 282-286.

O'Leary, D. W., Friedman, J. D. and Phn, H. A. (1976). Lineament, Linear, Lineation: Some proposed new standard for old terms. *Geol. Soc. Amer. Bull.*, 87, 1463-1469.

PCI Geomatica, (2001). "PCI Geomatica user's guide version 9.1", Ontario. Canada: Richmond Hill.

Pothiraj, P. and Baskaran, R. (2013). Mapping of Lineaments for Groundwater Targeting and Sustainable Water Resource Management in Hard Rock Hydrogeological Environment Using RS-GIS. 10.5772/55702.

Rochidi, C., Samir, B., Herwig, P. and Janauschek, W. (2012). Lineament Analysis of South Jenein Area (Southern Tunisia) Using Remote Sensing Data and Geographic Information System

Solomon, S. and Ghebreab, W. (2006). Lineament characterization and their tectonic significance using Landsat TM data and field studies in the central highlands of Eritrea. *Journal of African Earth Sciences,* 46, 371-378.