geoconvention
Calgary • Canada • May 12-14 2025

Quantitative analysis of geological structures and their potential impact on groundwater flow in the bedrock aquifers of Southwestern Nigeria

Adebiyi Samuel Adebayo[1], Ayodele Philip Olufemi[1,] & Damilola Doctor Awosika[2]
[1]Department of Physics – University of Medical Sciences, Nigeria
[2]Department of Physics – Adeyemi College of Education, Nigeria

Abstract
Heterogeneity introduced by geological structures along deformed strata has a significant impact on regional groundwater occurrences and water flow. Large-scale depictions of hydrogeological structures can be obtained through the integration of geophysical techniques with satellite remote sensing methods. In order to evaluate the geological structures and their potential for groundwater accumulation, this study used geophysical and satellite remote sensing techniques to map out a reliable structural discontinuity and illustrate the link between structural complexity and aquifer geometry. In order to achieve these objectives, scenes from Landsat-7 ETM+, the Aster Digital Elevation Map, and airborne magnetic data were collected and analyzed. The quality of the different remotely sensed data sets was improved for visualization and interpretation using a number of enhanced approaches. In the area under investigation, the preferred orientations of structural features are northwest-southeast, northeast-southwest, and north-northeast-south–southwest. The main geologic events in the region were defined by a northeast-southwest direction. The rocks were impacted by a significant concentration of lineament. The statistical analysis of the lineaments deduced from the satellite data indicates that the studied region features swarms of fractures in addition to highly weathered rocks. The findings indicated that 82.49% of the composite lineaments are tectonic in origin, while 27.51% of the composite lineaments are thought to be morphologically produced. Four zones of groundwater potential were identified for the research area: high, moderate, low, and extremely low. The areas showing high groundwater potential in the study area can be focused in better planning and management of groundwater resources. This study found that identifying regions with prospective groundwater occurrences may be accomplished using the integrated evaluation of high-resolution aeromagnetic data and satellite imagery.

Introduction
Traditional methods of mapping faults/structural lineaments require field investigations. However, fieldwork is usually time consuming, depending primarily on the accessibility of the area under consideration (Adebayo, 2024; Adebayo et al., 2021; Dasho et al., 2017). However, remote sensing has the advantage of providing synoptic overviews of a region; thus it may directly pinpoint the characteristics of structural geological features extending over large areas. In addition, the availability of objective image enhancement techniques used to generate image derivatives which are easier to interpret. It is also suitable for mapping of Lineaments in the area where accessibility is difficult.
A significant part of Southwestern Nigeria, which includes the study area, is underlain by Basement Complex rocks with rugged topography and poor accessibility. The area belongs to the tropical rain forest zone known for high rate and depth of weathering, which makes most

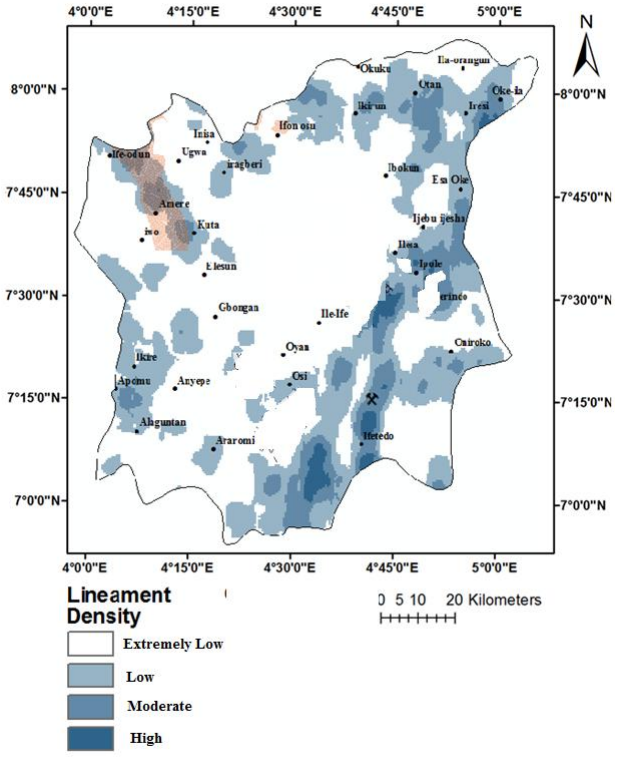

Figure 1: Lineament Density of the Study Area

lineaments to be covered by weathered material. Also, the dense vegetation cover sometimes does not permit direct geological observation. Hence, identification of subsurface structures within this region sometimes requires the use of regional geophysical surveys. Aircrafts and satellites are the common platforms for remote sensing data collection which has the advantage of providing synoptic overviews of a region. Therefore, remote sensing data serve as an advantage for mapping structures in the area. In addition, the use of geophysical data also serves as an advantage to locate the presence of hidden lineaments and their lateral extent. Aeromagnetic data allow fast coverage of large and inaccessible areas for subsurface mapping. The processing of these data can provide important evidence for regional-scale basement fault mapping in Southwestern, Nigeria. The objective of the present study was to delineate and map lineaments in parts of Southwestern, Nigeria from High Resolution Digital Aeromagnetic Data (HRDAD), ASTER DEM and Landsat Imageries. The extracted lineaments were evaluated for groundwater development.

Theory / Method / Workflow

High Resolution Aeromagnetic Data (HRAD), Landsat-7 ETM+ scenes and Aster Digital Elevation Map (ADEM) of the study area were acquired from the Nigeria Geological Survey Agency (NGSA), United States Geological Survey (USGS), and National Aeronautics and Space Administration (NASA) respectively. The Landsat-7 ETM+ scenes were mosaic into a seamless single image. Digital image processing (DIP) involving spectral, resolution, radiometric

and spatial enhancement, Hill shade and automatic line extraction was applied on the remotely sensed (Landsat-7 ETM+ and ADEM) images to generate lineament and drainage network maps. Statistical analysis involving azimuth-frequency diagrams, lineament frequency, lineament-length density and lineament intersection thematic maps of the lineament maps was applied from the extracted lineaments.

Results

Figure 1 displays the concentrations of the lineaments over the study area. The map discriminates the study area into regions of lower, intermediate, and higher density. Zones with relatively high lineament density are recognized as zones of high degree of rock fracturing, shearing, intensity of deformation, permeability, higher soil erodibility, higher groundwater yield (Dasho et al., 2017, Edet et al., 1998; Hung et al., 2005), slope failures, mineral occurrences associated with hydrothermal alteration zones. The lineament density map revealed medium-high lineament density around Ife Odan, Iragberi, and Kuta in the northwest; Ikirun, Otan, and Iresi in the northeast; Ikire in the west; Ilesa and Iperindo in the east, and Ifetedo and Oniroko in part of the southeast. The lineament density analysis indicated that the rocks were affected by high lineament concentration typical of Precambrian Basement Complex rocks. Lineament density of an area can indirectly reveal the groundwater potential of that area since the presence of lineaments may denote permeable zones. The clustered zones of lineaments (high lineament density) are potential zones for groundwater accumulation as well as the likely zones of mineralization within the study area. The lowest lineament density (0.000-0.099 km/km^2) and the highest lineament density (0.299-0.399 km/km^2) are spatially distributed and variable within the study area.

Conclusion

Geospatial datasets (airborne magnetic data, Landsat 7 ETM + and ASTER DEM) were used to map linear features in the study area and qualitatively determine the influence of these features on the occurrence of minerals in the study area. The main geologic events in the region were defined by a northeast-southwest direction. The rocks were impacted by a significant concentration of lineament. The statistical analysis of the lineaments deduced from the satellite data indicates that the studied region features swarms of fractures in addition to highly weathered rocks. The findings indicated that 82.49% of the composite lineaments are tectonic in origin, while 27.51% of the composite lineaments are thought to be morphologically produced. Four zones of groundwater potential were identified for the research area: high, moderate, low, and extremely low. The areas showing high groundwater potential in the study area can be focused in better planning and management of groundwater resources. This study found that identifying regions with prospective groundwater occurrences may be accomplished using the integrated evaluation of high-resolution aeromagnetic data and satellite imagery

References

Adebayo, A., 2024. Application of Remote-Sensing and Surface Geophysics for Groundwater Prospecting in a Hard Rock Terrain, Nigeria. WaterSciCon24.

Adebayo, A.S., Ariyibi, E.A., Dasho, O.A. and Olabode, A.O., 2021. Linear features in Osun State, Southwestern Nigeria: qualitative and quantitative study using magnetic and satellite data. Environmental Earth Sciences, 80: 1-12.

Dasho, O.A., Ariyibi, E.A., Akinluyi, F.O., Awoyemi, M.O. and Adebayo, A.S., 2017. Application of satellite remote sensing to groundwater potential modeling in Ejigbo area, Southwestern Nigeria. Modeling Earth Systems and Environment, 3: 615-633.

Edet, A., Okereke, C., Teme, S. and Esu, E., 1998. Application of remote-sensing data to groundwater exploration: a case study of the Cross River State, southeastern Nigeria. Hydrogeology journal, 6(3): 394-404.

Hung, L., Batelaan, O. and De Smedt, F., 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 V. International Society for Optics and Photonics, pp. 59830T

Hobbs, W.H., 1904. Lineaments of the Atlantic border region. Bulletin of the Geological Society of America, 15(1): 483-506.

O'leary, D., Friedman, J. and Pohn, H., 1976. Lineament, linear, lineation: some proposed new standards for old terms. Geological Society of America Bulletin, 87(10): 1463-1469.