Asian Journal of Geological Research

1(1): 36-51, 2018; Article no.AJOGER.42078

Significances of Deep Seated Lineament in Groundwater Studies around Ilesha, Southwestern Nigeria

S. O. Ilugbo[1*] and K. O. Ozegin[2]

[1]Department of Applied Geophysics, Federal University of Technology, Akure, Ondo State, Nigeria.
[2]Department of Physics, Ambrose Ali University Ekpoma, Edo State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author SOI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author KOO managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOGER/2018/42078
Editor(s):
(1) Mohamed M. El Nady, Department of Exploration, Egyptian Petroleum Research Institute, Egypt.
Reviewers:
(1) Théophile Lasm, University Felix Houphouët-Boigny, Cote d'Ivoire.
(2) Maurice Odondi K'orowe, Jmo Kenyatta University of Agriculture and Technology, Kenya.
(3) Azubuike Ekwere, University of Calabar, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/25644

Original Research Article

Received 29th March 2018
Accepted 8th June 2018
Published 23rd July 2018

ABSTRACT

This research show the significance of deep seated lineament in groundwater investigation around Ilesha, Osun State in a basement complex terrain using satellite imagery remotely sensed and aeromagnetic dataset. This hydrogeological investigation involved the extraction of lineaments from Landsat Thematic Mapper (TM) satellite imagery and aeromagnetic lineament of the area. The processed image revealled lineaments trending in approximately NE-SW direction; also, Landsat and aeromagnetic lineament trends tend to agree in the study area, suggesting real continuous fractures at depth. Lineament density maps were produced from the generalized lineament trends in the area. The lineament analysis has been effectively done in a GIS environment and the results justified that deep seated lineament (aeromagnetic lineament) is more significances in term of groundwater studies. Moreover, if surface (landsat) lineament is the only available information, it should be superimposed on topographical map for proper clarification and justification and also

*Corresponding author: E-mail: bussytex4peace44@gmail.com;

follow up by ground truthing. The lineament density maps of the study area were generally classified into very low, low, moderated, high and very high in term of their groundwater significances. The results from boreholes drilled across the entire study area, were used to validate the accuracy of the lineament density maps.

Keywords: Landsat Lineament; aeromagnetic lineament; topographical map; GIS.

1. INTRODUCTION

Groundwater is one of the most valuable natural resources on the earth surface and serves as main sources of drinking water. Basement complex have problem of potable groundwater supply due to the crystalline nature of the underlying rock which lack primary porosity [1,2,3]. Groundwater storage capacity in those areas depends on the depth of weathering and the intensity of fracturing of the underlying rock. For basement rocks to become good aquifers, they must be highly fractured and highly weathered. Thickness of the weathered overburden and fractured zone determined the nature and intensity of hydrodynamic activities within the usually discrete bodies of aquifer in the terrain [4,5,2,3]. Groundwater in crystalline rocks has no intergranular porosity moves in a connected fracture network. But far from all fractures are permeable, and fracture permeability varies considerably [6,3]. It is generally recognized that, in the prospect area of faults and fracture lineaments, the fault core and central zone have low permeability while the outer damage zone has enhanced permeability compared with the surroundings [7,8,9,3]. Lineament mapping was used long before this work in other geological applications and the first usage of the term lineament in geology is probably from a paper by [10,11] cited in [3] who defined lineaments as significant lines of landscape caused by joints and faults, revealing the architecture of the rock basement**.** This was later used by [12] as a basis for developed definitions. Lineaments have been defined as extended mappable linear or curvilinear features of a surface whose parts align in straight or nearly straight relationships that may be the expression of folds, fractures or faults in the subsurface. These feature mappable at various scales, from local to continental, and can be utilised in mineral, oil and gas, and groundwater exploration studies. Linear features on the Earth's surface have attracted the attention of geologists and geophysicists for many years. This interest has grown most rapidly in geological studies since the introduction of aerial photographs and satellite images [3]. At the beginning, to the middle of the twentieth century, several geologists and geophysicsts recognised the existence and significance of linear geomorphic features that were the surface expression of zones of weakness or structural displacement in the crust of the Earth [3]. Generally lineaments are underlain by zones of localised weathering and increased permeability and porosity. In the last four decades remote sensing and GIS have been widely used for preparation of different types of thematic layers and their integration for different purposes [13,3]. Therefore, this research focus on significances of deep seated lineament in groundwater studies using landsat imagery and aeromagnetic dataset.

2. STUDY LOCATION AND GEOLOGY

Ilesha located on the crystalline basement complex. It falls within latitude 7°32′20″ to 7°38′20″ North and longitude 4°36′20″ to 4°44′20″ East (Fig. 1). This area falls within the 1:50,000 topographic map of Ilesha sheet 234 SW. Major and minor road linkages characterize the study area linking both towns and villages together. In general, the location can be said to be fairly assessible with footpaths in areas where there are neither major nor minor roads. Regionally, the study area belong to the Southwestern Nigeria basement complex comprising migmatite-gneiss complex, metaigneous rock such as pelitic schist, quartzite, amphibolites, charnokitic rocks, older granite and unmetamorphorsed dolerite dykes. The rock sequence consists of basically weathered quartzite of older granite. The basement complex rocks of Nigeria are made up of heterogeneous assemblages [15]. The geology of Ibodi and its environs is mainly Precambrian Basement rock (Fig. 2). This is because of the tectonics and metamorphic changes that has occurred in the area [17]. Schist and amphibolites, magnetite - gneiss undifferentiated and amphibolites stands out in the Basement rock of the investigated area.

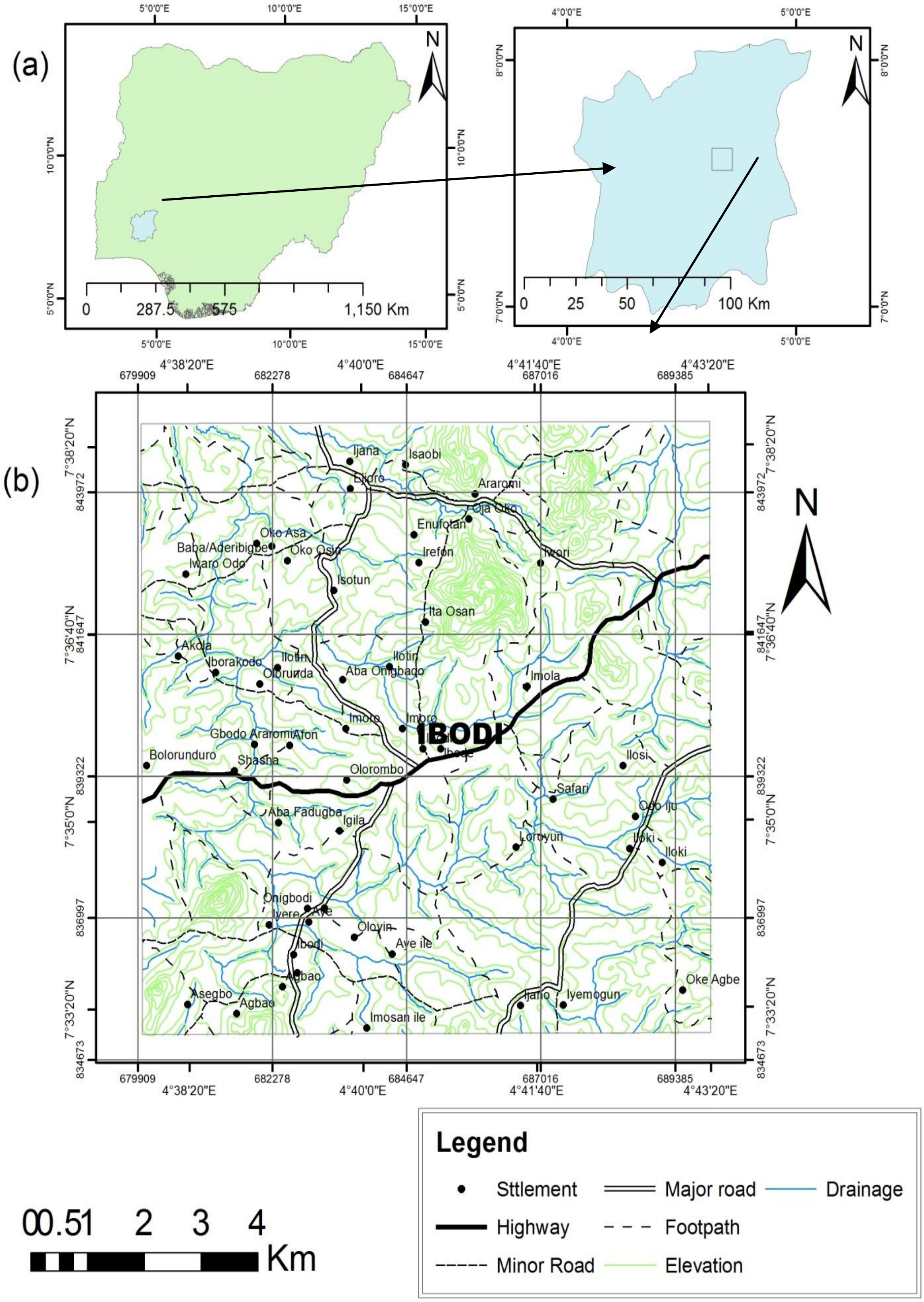

Fig. 1. (a) Map of Nigeria and Osun state showing the study area, (b) location map of the study area [14]

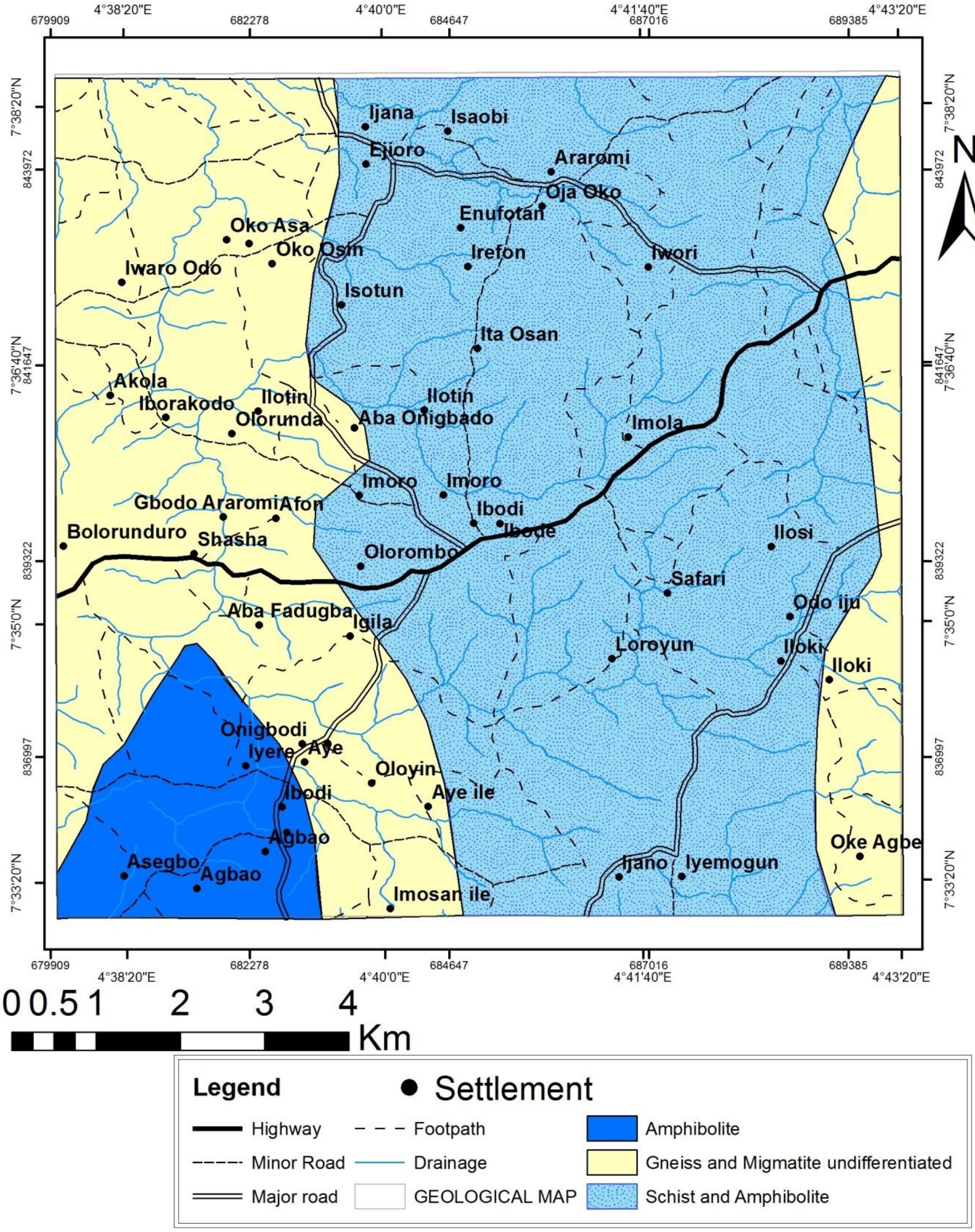

Fig. 2. Geological map of the study area [16]

3. METHODOLOGY

The work utilised “remote sensing” and aeromagnetic data around Ilesha, Osun State. The remote sensing data (Landsat imagery) were acquired from the Global Land Cover Facility homepage. The automatic lineament extraction process was carried out using “ENVI” 4.5, which was used for digital image processing to enhance sharpness of the satellite image for better visual clarification and to aid structural interpretation. Similarly, “Geomatical’’ pcl and “ArcGIS’’ 10.2 software was used to extract the lineaments and drainage network that covers the study area. The Aeromagnetic data was acquired from Nigerian Geological Survey Agency. The data set was gridded using minimum curvature gridding method with 50 m cell size to produce total magnetic intensity map. Data enhancement techniques involving Butterworth filter, Reduction to Equator and Derivative filters were applied to the magnetic intensity map using Oasis Montaj 6.4.2 software package. 3D Euler deconvolution data assisted in determining the locations and depths of the geologic sources. Structural index of 1.0 was found appropriate for delineation of structures that are favourable for groundwater accumulation. Aeromagnetic lineaments were generated by georeferencing and digitizing 3D Euler deconvolution results. Aeromagnetic and landsat lineaments were superimposed on topographical map and rose diagram was generated using “Georient”. The results from boreholes drilled across the entire study area, were used to validate the accuracy of the lineament density maps.

4. RESULTS AND DISCUSSION

4.1 Remote Sensing Data

4.1.1 Lineament analysis from landsat imagery

The results obtained from the satellite image interpretation (Fig. 3) are discussed to demonstrate the usefulness of remote sensing in lineament mapping and analysis i.e. to delineate zones that are prone to groundwater development in the study area. A total of 69 lineaments were extracted from the satellite image having a total length of 312.01 km. The map shows that the northeastern characterized by very high concentration of lineaments. The central parts of the study area were characterised by moderate concentration of lineaments while the northwestern and the southeastern parts have low to very low concentration of lineaments. The rose (azimuth-frequency) diagram of the lineaments (Fig. 4) prepared from the extracted lineaments on the imagery showed three predominant sets which are closely related to “tectonic activities” such as fractures, faults and joints in the study area. The lineaments trends in NE-SW, ENE-WSW and NW-SE directions.

4.1.2 Landsat lineament on topographical map

Fig. 5, landsat lineament is display on topographical maps. It shows that the northeastern parts, majority of the lineaments fall within the high hill with elevation ranged from 380 m to 420 m and at the southwestern part. Areas with high lineament density excluding (the residual hill environment) are good for groundwater development. These exhibit that in groundwater studies landsat lineaments should be strictly considered, because some of the landsat lineament is not hydrogeological significances. landsat imagery pick some man-madefeatures as lineament such as road, aliment of vegetation and houses, power line which were not hydrogeological significances. So landsat lineament is not sufficient enough for groundwater studies. Furthermore, it should be superimposed on topographical map in order to delineate lineaments that are hydrogeological significances and eliminate those that are not hydrogeological significances.

4.1.3 Landsat lineament density map

The lineament density was computed base on the number of lineaments per unit area (km/km^2) of grid, for quick graphical assessment of the lineament density values of the area. Areas with high lineament density excluding (the residual hill environment) are good for groundwater development. Fig. 6 shows five different hydrogeological potential zones distributed as patches in the study area. The zones are summarized in Table 1. The lineament density map shows that the lineament density is high around area like Ibodi, Iloki, Iwori, Ijano, Ilotin, Aye, Igila, Agbao, Araromi and Oja Oko when compare to other areas in the study area.

Table 1. Groundwater prospecting of the study area based on Landsat Lineament density

Lineament density colour code	Lineaments density range (Km/Km^2)	Groundwater prospecting
Lemon	0 – 0.87	Very low
Yellow	0.87 – 1.73	Low
Red	1.73 – 2.60	Moderate
Pink	2.60 – 3.46	High
Blue	3.46 – 4.33	Very high

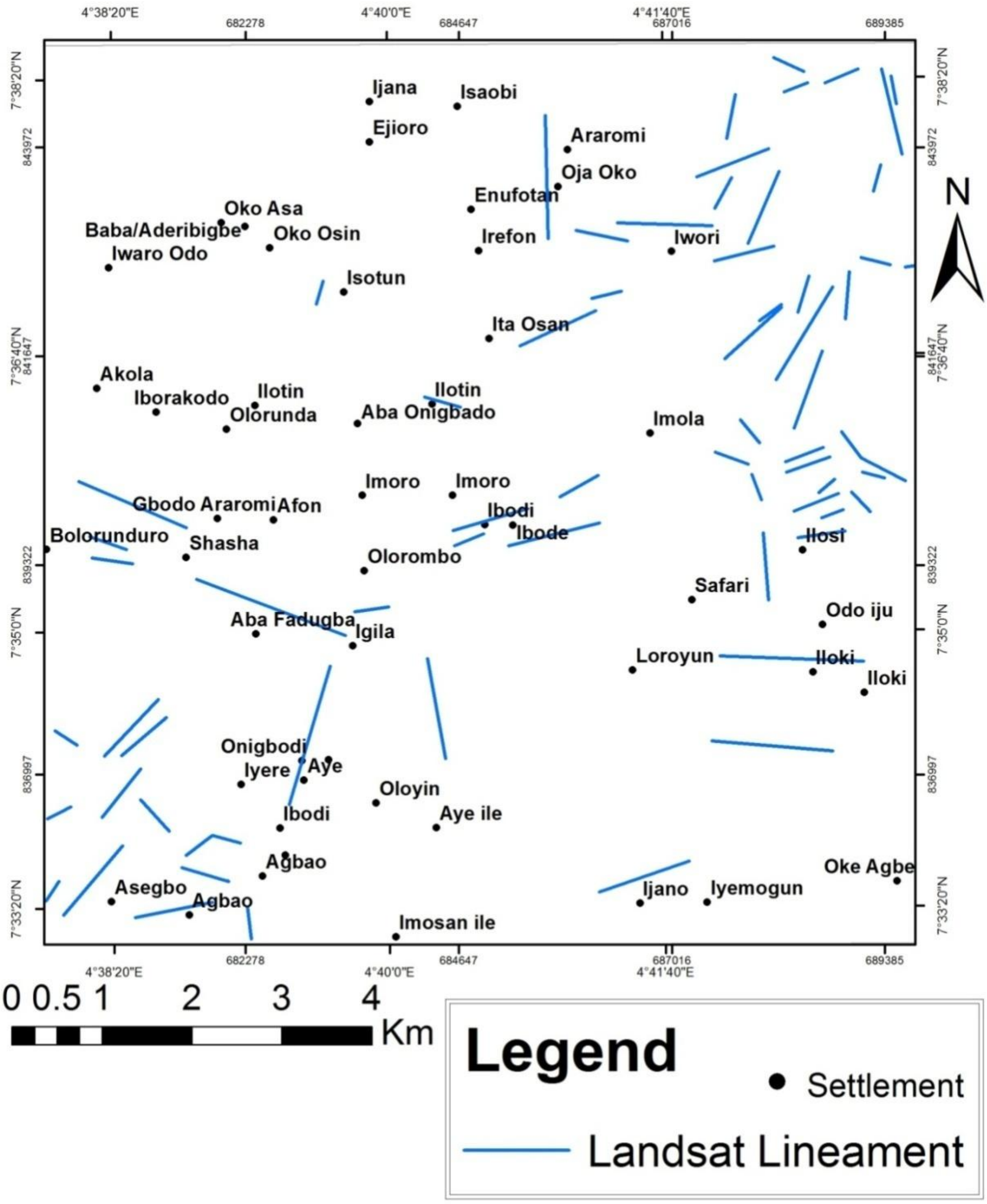

Fig. 3. Landsat Lineaments map of the study area

4.2 Validation of Landsat Lineament Density Map

4.2.1 Borehole yields and their depth in the study area

The bar chart plot of borehole yields of drilled groundwater holes and their respective depth carried out in some locality within the studied area are presented in Fig. 7. It shows that the depth and yield of these boreholes vary within the area considered; hence the same can be cited for other areas within the studied area. Their values ranged from 27.7 m to 40m for the depth and 11 – 50 (Litres/minutes) for yield. The Ilosi area have the higher yield and depth which implies that the area have high groundwater potential compared to other areas in the study area. Landsat Lineament density map (Fig. 8) shows that the borehole yield doesn't correlates very well with the lineament density.

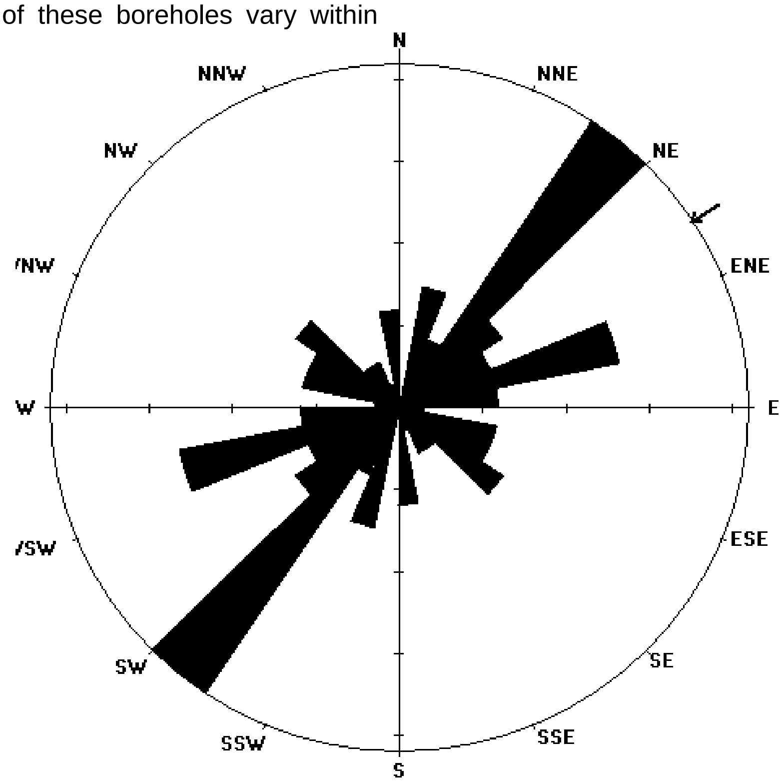

Fig. 4. Rose (azimith-frequency) diagram of Landsat Lineaments orientations

4.3 Aeromagnetic Data

4.3.1 Lineament analysis using 3D euler deconvolution

3D Euler solution using Structural Index (S.I = 1) was applied to the aeromagnetic data for lineament analysis (Fig. 9). The delineated solutions were extracted and digitized to produce the lineaments from magnetic data (Fig. 10). A total of 118 lineaments were extracted from the aeromagnetic data having a total length of 484.01 km. The map shows that the northeastern and northwestern parts have high concentration of lineaments. The central parts of the study area were characterized by moderately concentrated lineaments while the southeastern and southwestern parts have low to very low concentration of lineaments. The rose (azimuth-frequency) diagram of the lineaments (Fig. 11) prepared from the extracted lineaments on the aeromagnetic structures shows two predominant directions of lineament which is closely related to "tectonic activities" such as fractures, faults and joints in the study area. The lineaments trends NE-SW and ENE-WSW directions. Here it indicates more fracturing towards the NE direction and thus suggests comparatively more potential groundwater zone and hence better prospect for groundwater availability.

4.3.2 Aeromagnetic lineaments on topographical map

Fig. 12 displays aeromagnetic lineament on topographical map. It reveals that the majority of

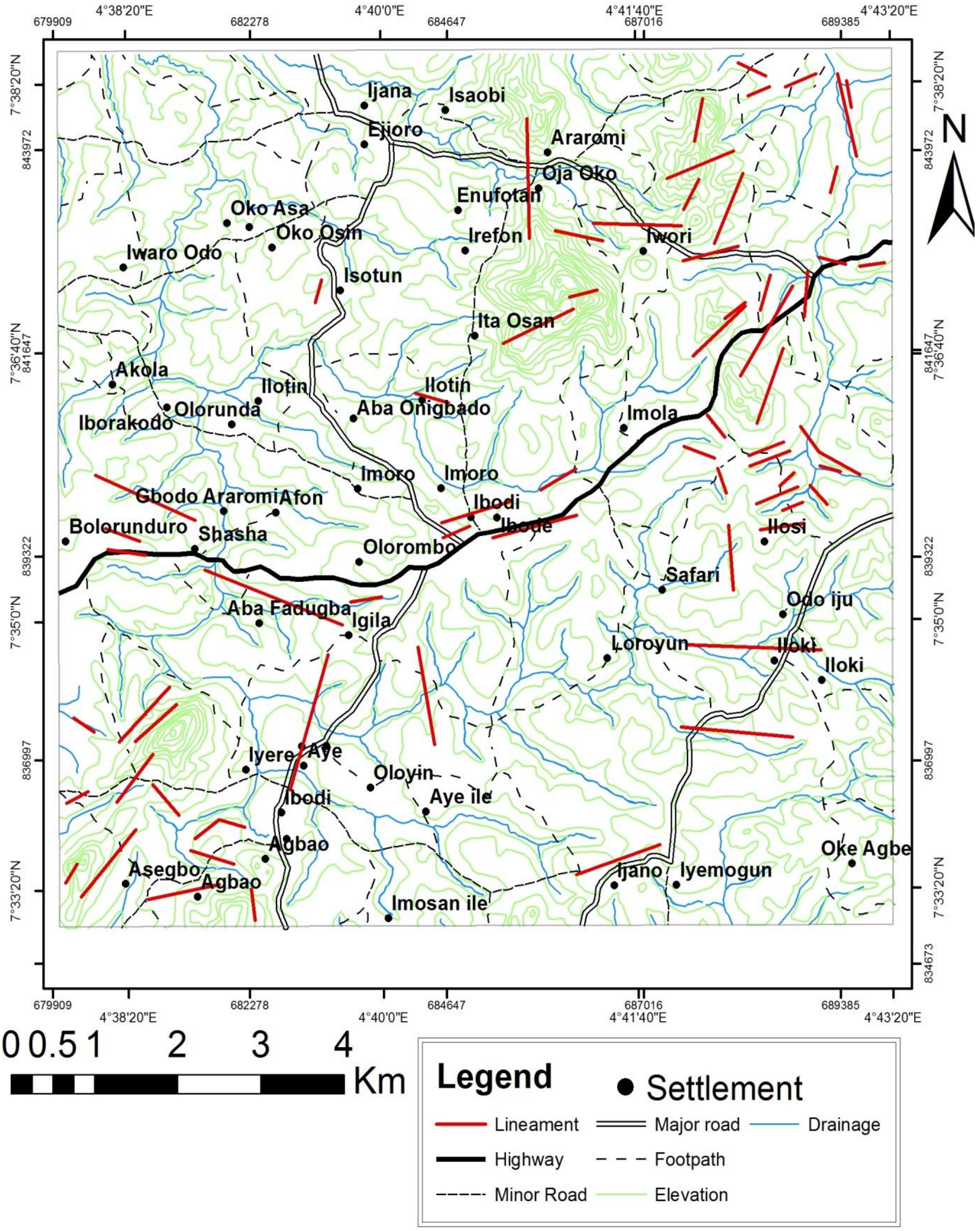

Fig. 5. Landsat Lineaments on topographical map of the study area

the lineaments fall within the plain land unlike surface lineaments (Landsat Lineament) which fall within the high hill. This implies that we cannot base our presumption on surface lineament without ascertaining it with subsurface lineaments in order to have clearer pictures of the groundwater prospect within the study area. It also illustrate that we cannot base our justification on surface lineament without superimposing it on topographical map, in order to delineate those that are hydrogeological significance and eliminate those that are not

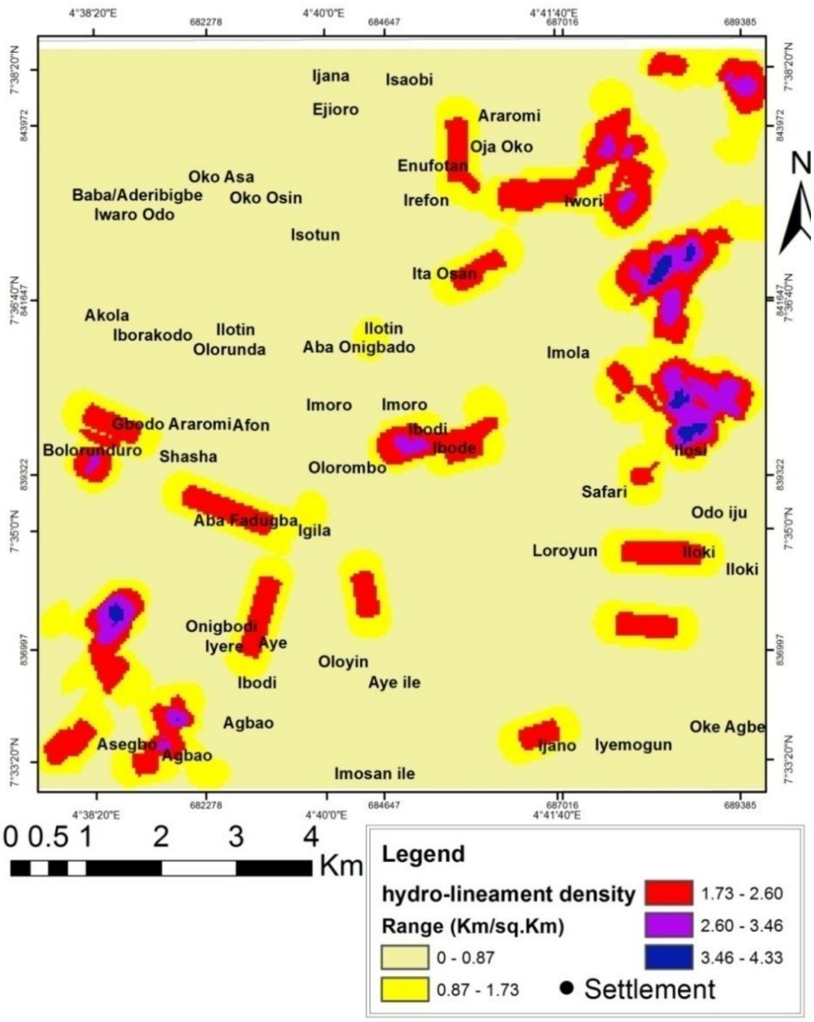

Fig. 6. Landsat Lineament density map of the study area

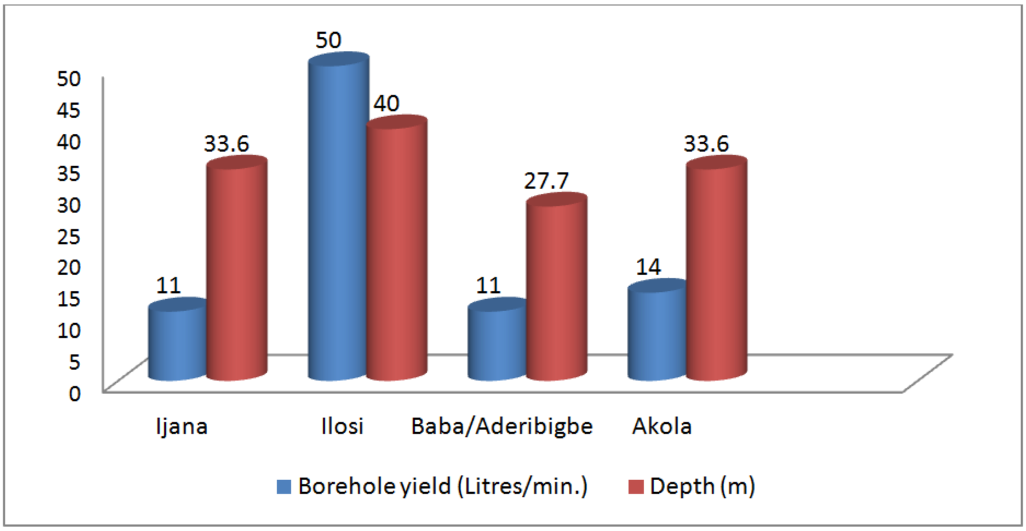

Fig. 7. Bar chart plot of borehole yield and depth within the study area. (after FADB RWSS in Osun State)

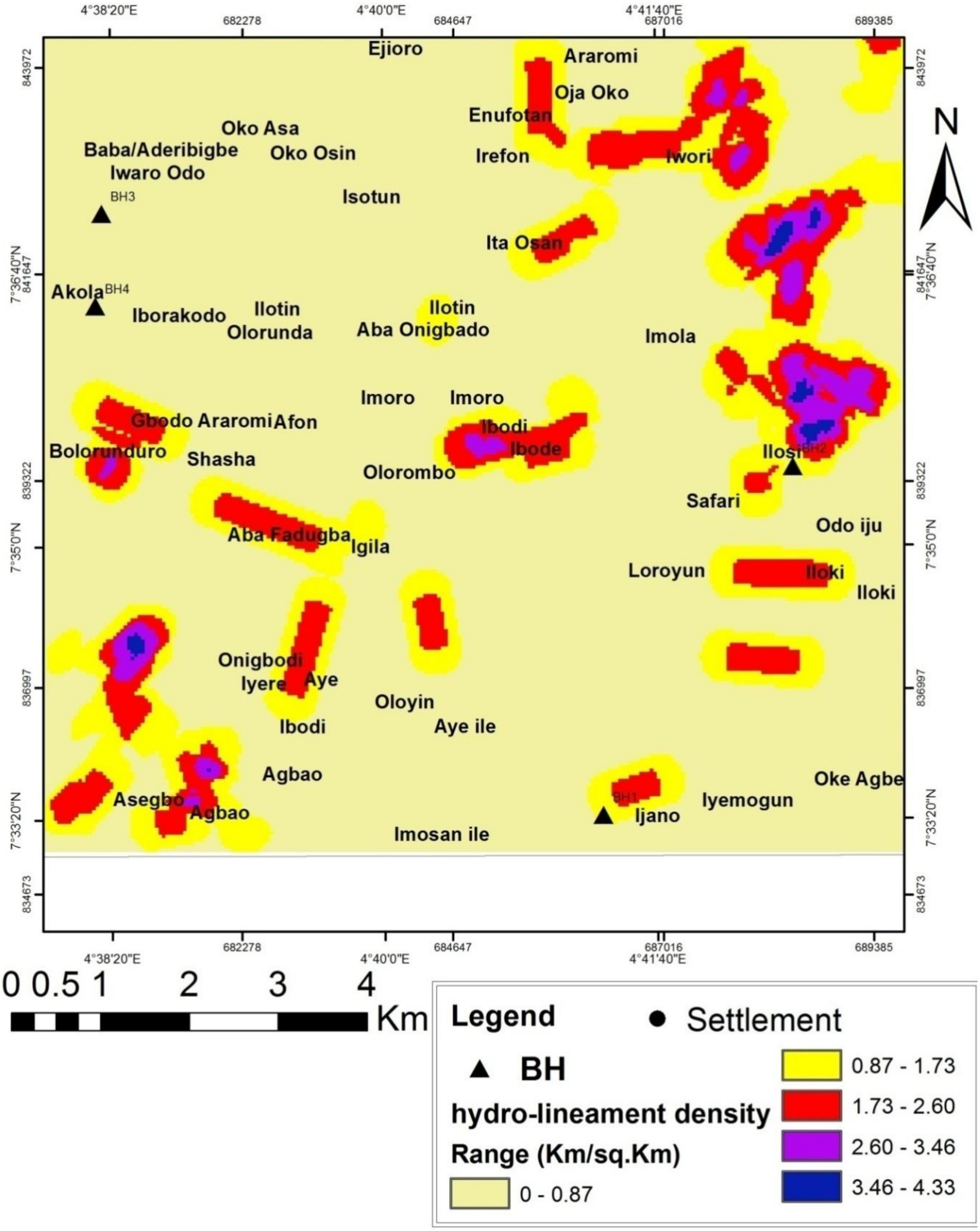

Fig. 8. Validation map of the study area

hydrogeological significance (man-made lineaments). From these we are able to justified that deep seated lineament (aeromagnetic lineament) is more significance in term of groundwater studies. This is because, ajority of the deep seated lineament fall within the low land and there are not man-made features. For future groundwater studies, deep seated lineament should be more considered. Moreover, if surface lineament is the only available information, it should be superimposed on topographical map for proper clarification and justification and also follow up by near surface investigation.

4.3.3 Aeromagnetic lineament density map

Lineament density map is one of the important maps prepared from the lineaments, which are critically used in groundwater studies related to hard rock terrain [3]. Fig. 13 displays the aeromagnetic lineament density map of the study area. The map reveals five different hydrogeological potential zones distributed as patches in the study area. The zones are summarized in Table 2. The lineament density map reflects high density around Ibodi, Iworo Odo and Sefari, when compare to other areas. The area with high lineament density suggests that the lineament must have extended in all the directions with different degrees of fracturing, which had greater water – holding capacity from different directions of the lineament(s) within the rock. At the same time, unidirectional lineament may not produce good yield of water and such areas show low concentration of lineaments. Regarding groundwater exploration, these aforementioned areas may have high groundwater potentials due to their high concentration of lineaments i.e. since groundwater occurs within faults and fractures in the basement rocks. It is seen that the aeromagnetic density map corroborates very well with the borehole yield.

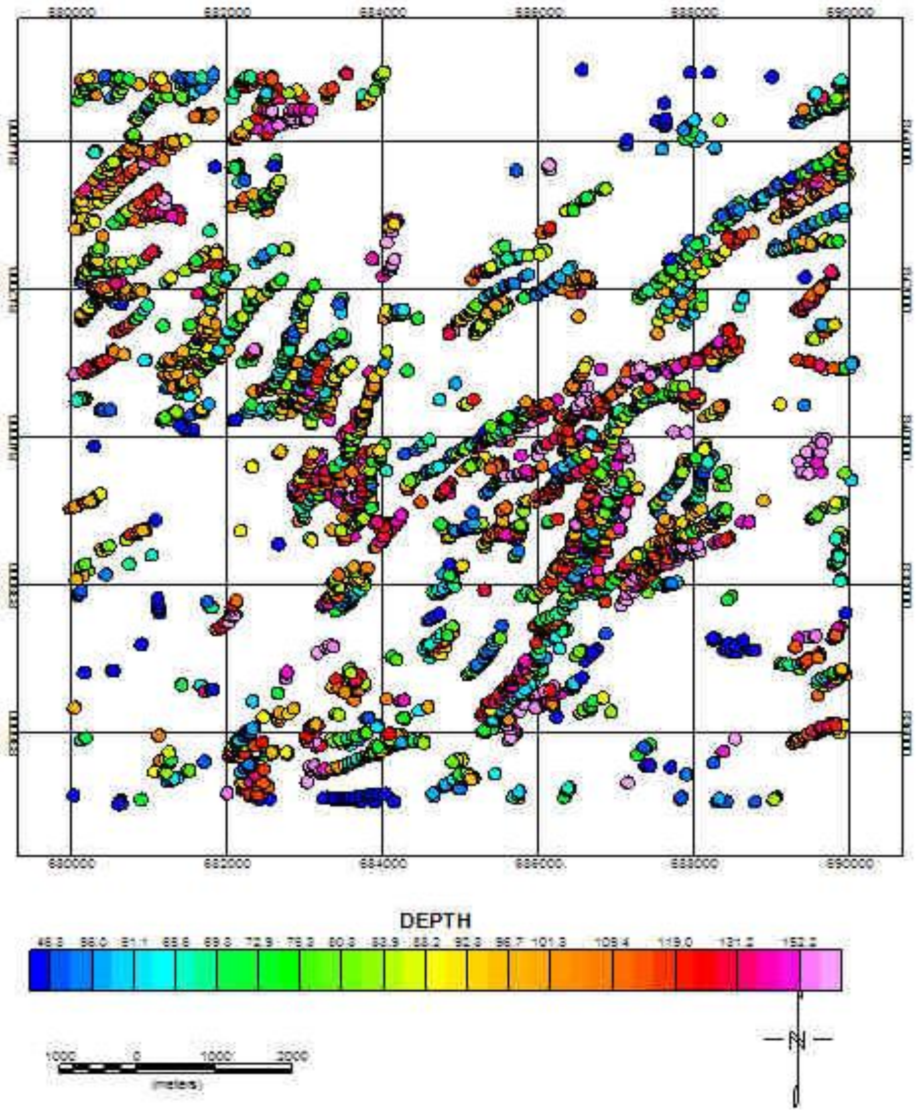

Fig. 9. 3D Euler solution from the analysis the aeromagnetic data over the study area with structural index (S.I = 1)

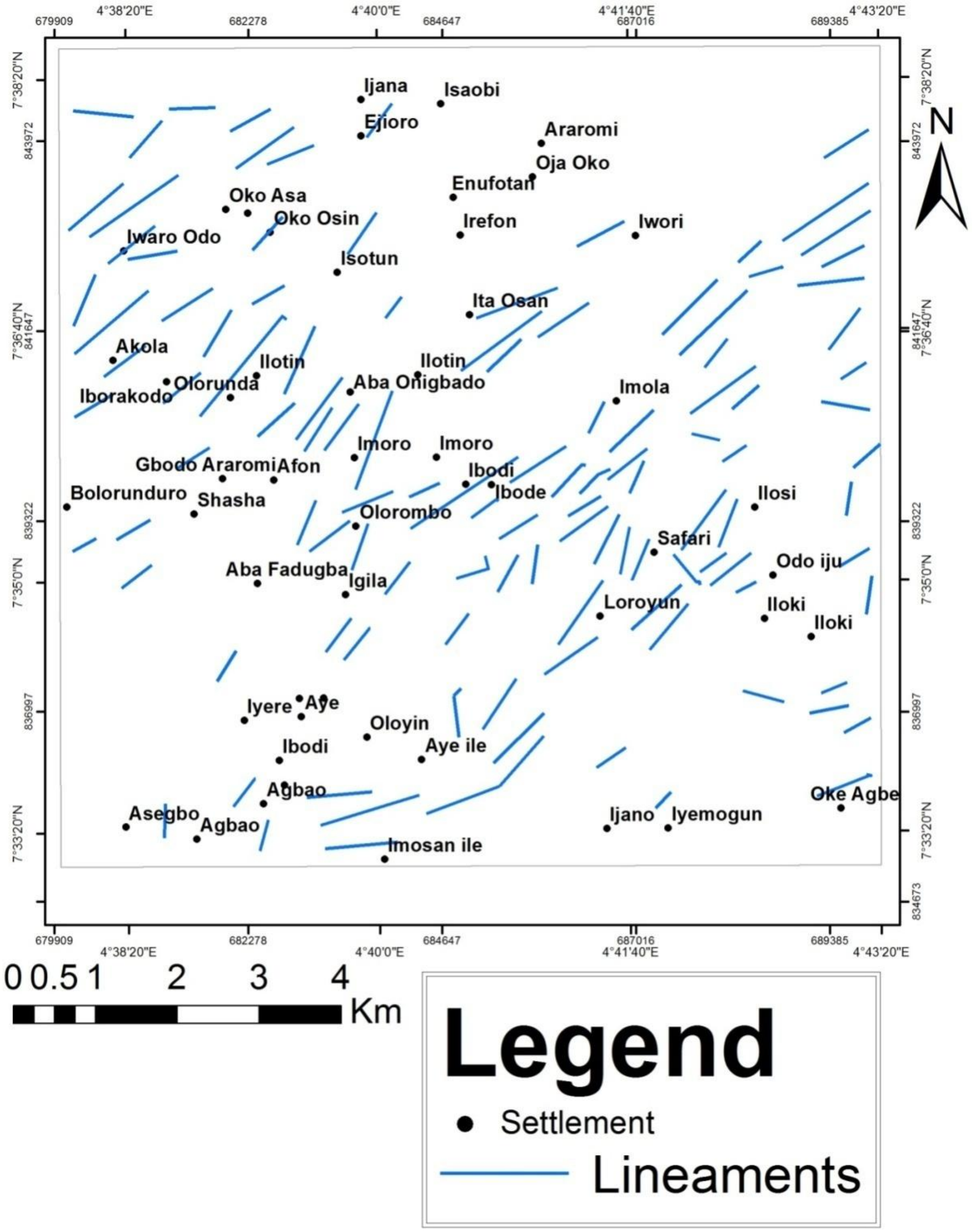

Fig. 10. Aeromagnetic Lineaments of the study area

Table 2. Groundwater prospecting of the study area based on aeromagnetic Lineament density

Lineaments density colour code	Lineaments density range (km/km^2)	Groundwater prospect
Lemon	0 – 1.06	Very Low
Yellow	1.06 – 2.11	Low
Red	2.11 – 3.17	Moderate
Pink	3.17 – 4.23	High
Blue	4.23 – 5.28	Very High

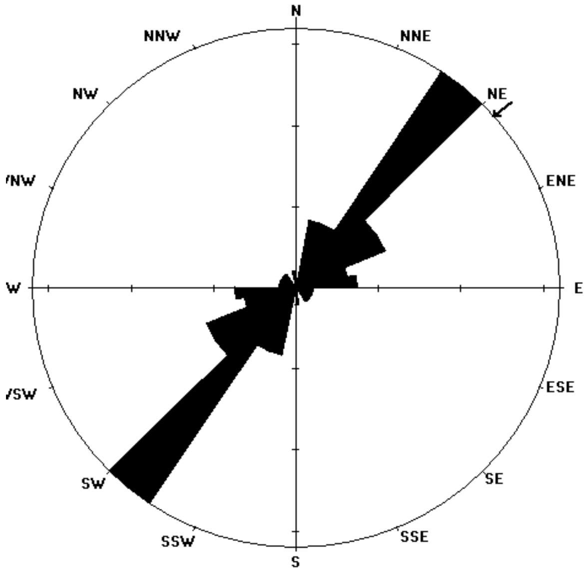

Fig. 11. Rose (azimuth-Frequency) diagram of aeromagnetic Lineaments orientations

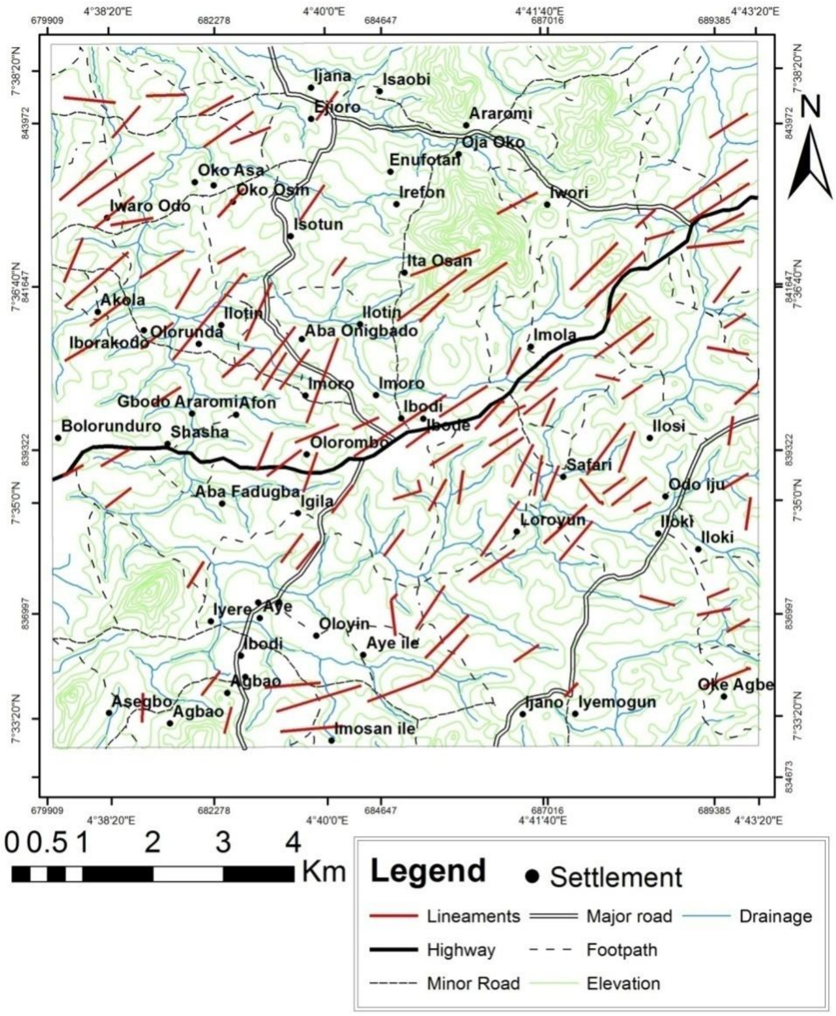

Fig. 12. Aeromagnetic Lineament on topographical map of the study area

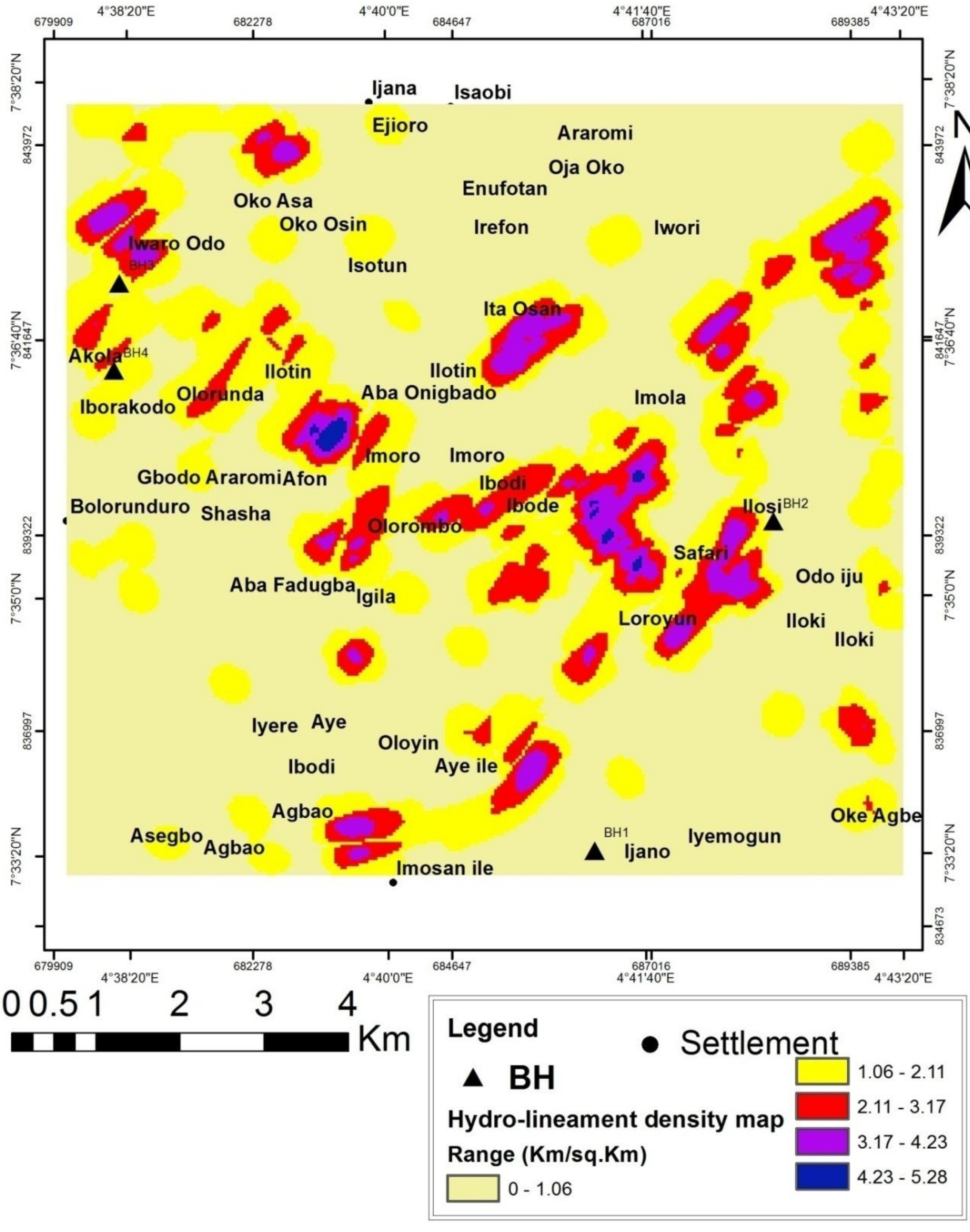

Fig. 13. Aeromagnetic Lineament density map of the study area

5. CONCLUSION

This research show the significance of deep seated lineament in groundwater studies around Ilesha, Osun State in a basement complex terrain using satellite imagery remotely sensed, aeromagnetic dataset and borehole data. The hydrogeological investigation involved the extraction of lineaments from Landsat Thematic Mapper (TM) satellite imagery and aeromagnetic lineament from the investigated area. The processed image displays the lineaments trending NE-SW directions. Landsat and aeromagnetic lineament trends tend to agree in the study area, thereby implying that these lineaments reflect real continuous fractures at depth. Lineament density maps were produced from the generalized lineament trends in the area in term of hydrogeological significances. The study has led to the delineation of areas where groundwater occurrences are most promising for sustainable supply, suggesting that an area where will have high concentrations of lineament density has a high tendency for groundwater prospecting. The lineament analysis has been effectively done in a GIS environment and the results was able to justified that deep seated lineament (aeromagnetic lineament) is more significances in term of groundwater studies. Moreover, if surface (landsat) lineament is the only available information, it should be superimposed on topographical map for proper clarification and justification and also follow up by ground truthing. The lineament density maps of the study area were generally classified into very low, low, moderated, high and very high in term of their groundwater significances. The results from boreholes drilled across the entire study area, were used to validate the accuracy of the lineament density maps.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Olorunfemi MO, Fasuyi SA. Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central basement terrain of Nigeria (Niger State). J. African Earth Sciences.1993;16:309-317.
2. Ilugbo SO, Adebo BA, Olomo KO, Adebiyi AD. Application of GIS and multi criteria decision analysis to geoelectric parameters for modeling of groundwater potential around Ilesha, Southwestern Nigeria. European Journal of Academic Essays. 2018;5(5):105-123.
3. Ilugbo SO, Adebiyi AD. Intersection of Lineaments for groundwater prospect analysis using satellite remotely sensed and aeromagnetic dataset around Ibodi, Southwestern Nigeria. Int. J. of Phys Sci. 2017;12(23):329-353.
4. Amudu GK, Onwuemesi AG, Ajaegwu NE, Onuba LN, Omali AO. Electrical resistivity investigation for groundwater in the Basement Complex terrain: A case study of Idi- Ayunre and its environs, Oyo State, Southwestern Nigeria. Natural and Applied Sciences Journal. 2008;9(2):1-12.
5. Amadi AN, Olasehinde PI. Application of remote sensing techniques in hydrogeological mapping of parts of Bosso Area, Minna, North-Central Nigeria. Int. J. Physical Sciences. 2010;5:1465-1474.
6. Banks D, Odling NE, Skarphagen H, Rohr-Torp E. Permeability and stress incrystalline rocks. Terra Nova.1996;8: 223-235.
7. Caine JS, Evans JP, Forster CB. Fault zone architecture and permeability structure. Geology.1996;24:1025-1028.
8. Evans JP, Forster CB, Goddard JV. Permeability of fault-related rocks andimplications for hydraulic structure of fault zones. J. Structural Geology. 1997; 19:1393-1404.
9. Henriksen H, Braathen A. Effects of fracture-lineaments and in situ rock stresses on groundwater flow inhard rock. A case study from Sunnfjord, Western Norway. Hydrogeology J. 2000; 14:444-461.
10. Hobbs WH. Lineaments of the Atlantic border region. Geological Society of America Bulletin. 1904;15:483-506.
11. Hobbs WH. Earth features and their meaning: An Introduction to Geology for the Student and General Reader. Macmillan Co. New York.1912;347.
12. Leary O, Freidman DW, Pohn JD. Lineaments, linear, lineation-some proposed new standards for old terms. Geological Society of America Bulletin. 1976;87:1463-1469.
13. Rahaman MA. Review of the basement of SW. NigeriaInc. Kogbe (ed) Geology of Nigeria. Elizabethan Press, Lagos. 1976; 41–58.
14. Osun State ministry of lands and physical planning. Geological Map of Ilesha Iwo Sheet. 1980;60.
15. Pothiraj Prabu, Baskaran Rajagopalan. Mapping of lineaments for groundwater targeting and sustainable water resource management in hard rock hydrogeological environment using RS- GIS. Climate Change and Regional/Local Responses; 2013.
Available:http://dx.doi.org/10.5772/55702

16. Osun State ministry of lands and physical planning. Topographical Map of Ilesha southwestern Sheet. 1965;234.
17. Olade MA. General features of a Precambrian iron deposit and its environment at Itakpe Ridge Okene, Nigeria. Trans. Inst. Min. Metallurgy, Sect. 1978;B87:81-89.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/25644