Groundwater Potential Evaluation in the University of Ilorin Main Campus, Southwestern Nigeria, Using Multisensory Data Techniques

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Abstract

This study, has adopted multi-data sets results, first on a regional scale to depict the structural fabric of Ilorin sheet 223 and then at chosen locations within the University of Ilorin Main Campus which is made up of the Basement Complex rocks. From the remote sensing map; Ilorin sheet 223 structural trend has been divided into two: the NE-SW and the NW-SE structural trends. The aeromagnetic anomalies divide the rocks in Ilorin into metamorphic (low to medium magnetic intensity) and igneous (high magnetic intensity) rocks. The resistivity data interpretation reveals the weathered basement in Ilorin to range from 5 to 20m and the first fracture regime ranging from 20m to 45m. The radial sounding results reveal the structural trend to be NW-SE and NE-SW with interconnection of joints. The radial sounding shows the rock types to be quartzitic, clayey and igneous as judged from the near hexagonal and elongated shapes of the polygons. The results indicated a good agreement between the trends of fractures derived from the radial VES and that from the lineament maps. Areas with low bedrock resistivity, thick overburden, presence of two or more interconnected fractures and high co-efficient of anisotropy indicate intense fracturing, thus, indicate areas of high groundwater potentiality.

Keywords: Remote sensing. Aeromagnetic, VES, structural trend, groundwater direction, anisotropy polygon and coefficient of anisotropy.

INTRODUCTION

University of Ilorin has attracted increased-student patronage for admissions due to stable academic calendar in the last 20years. Consequently, demand for potable water to meet demands of the students and staff is consistently on the increase due to increased population and climatic changes. This is a common phenomenon in developing areas with characteristic population increase, industrial expansion and urbanization (Ige *et al.,* 2017). Thus, this has generated interest in academic research into assessing factors that enhance adequate detection and supply of water, such as geological attributes (Olasehinde and Raji, 2007) and evaluation of quality of groundwater (Ige *et al.,* 2013) within the university main campus. Consequently, potential for availability of this natural commodity within the university has not been harnessed. The dam water source is not reliable for adequate and sufficient supplies due to its seasonal and pollution potential by climatic changes and run-off activities during raining season respectively (Olasehinde, 2010). Most boreholes are either abortive or abandoned due to deficiency in exploratory techniques and /or drilling/development procedure (Eduvie and Olabode, 2001). The consequences of abortive boreholes range from loss of money, resources, energy, morphological disorder of landmass, build-up pressure within the earth crust and environmental pollution. Therefore, reliability of data and assurance of success in borehole drilling within the University community will largely depend on the accuracy of exploration techniques, among other factors. Direct current resistivity method is a popular tool for groundwater exploration is areas of complex geology with contrasting electrical properties (Abied, 2008). The Vertical Electrical Sounding (VES) is a low-cost technique and veritable tool is groundwater exploration that has been used to solve a wide range of groundwater related problems (Alabi and Makinde, 2016). Delineation of zones of contamination and exploration of geothermal reservoirs has been successfully carried out using VES techniques with Schlumberger array (Busby, 2000). Integrated approach to resolve groundwater exploration using combinations of methods has gained tremendous acceptance in the last decade (Abied, 2008; Amadi and Olashiende, 2010 and Bayewu, 2014). Therefore, a combination of VES and radial sounding (RS), which promises to give better result, was use in this study to unravel groundwater potential within the community of UNILORIN main campus.

Study Area Description

The study area is located in Southwestern part of Nigeria in the southern part of Ilorin area, Kwara State as shown in Figure 1. It lies within longitudes 4 30’ 00’’E and latitudes 08°25”00’ to 08° 35”00’ N. The area of study covered about 2865.10 square kilometers, underlain mainly by metamorphic rocks and few granitic rocks (Figure 2). The prevailing high features are in the Northeastern and southwestern parts of the study area, where the elevation reaches up to 355m while the central part are a valley. River Ileapa joins river Oyun at the eastern part of the area forming a u-shape and in which river Oyun joins river Asa towards the north, whereas the drainage system slopes eastwards and southwards; the rivers and the many tributaries are suspected to be fracture controlled.

Geological Setting of University of Ilorin

The area mapped lies within the Basement Complex terrain of Nigeria consisting of high grade metamorphic rocks in form of gneisses and migmatite, and granitic suites (Figure 2).

The major rock types identified includes: Migmatite, Migmatite Gneiss, Biotite Granite, Granite Gneiss, and Granite.

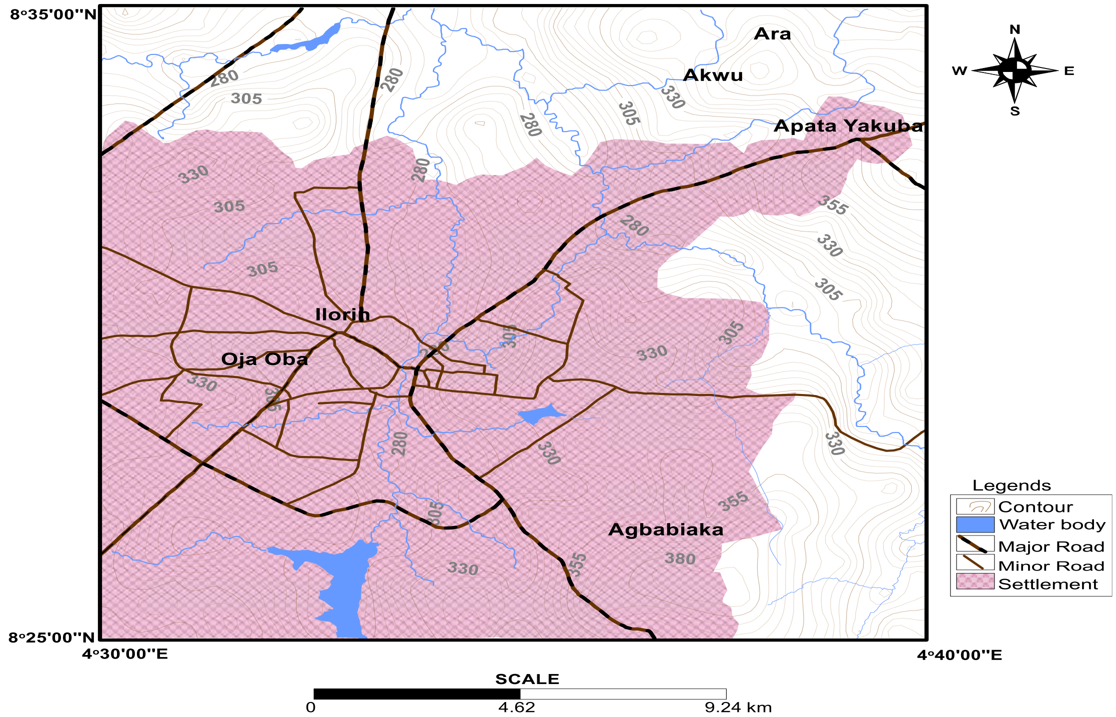

Figure 1: Location Map of Ilorin Area (Olasehinde *et al.*,2007)

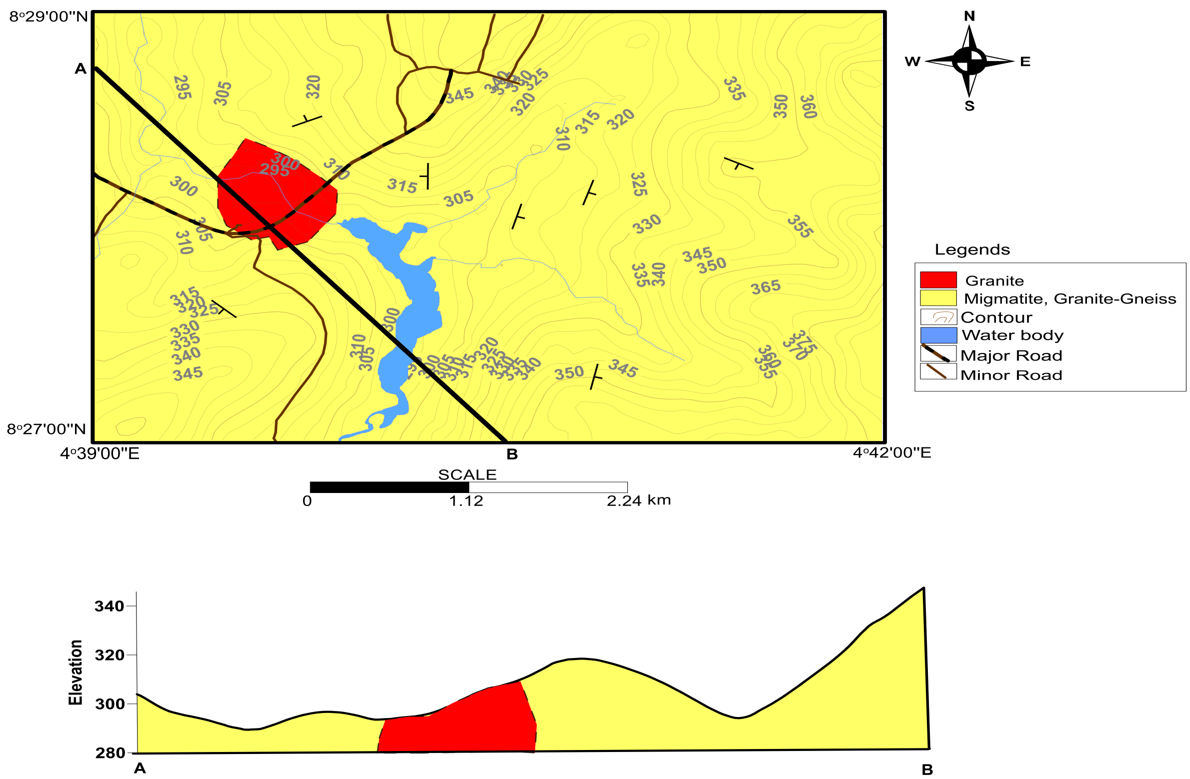

Figure 2. Geological map of the University of Ilorin

MATERIALS AND METHOD

Geological mapping was carried out in the study, to determine the rock types and structures. Vertical electrical resistivity sounding (VES) was done in pre-selected areas using schlumberger and radial electrical array (RVES), the VES were interpreted for electrical variations with depth to determine the lithology variation of the area, and RVES was used to determine the fracture directions in the pre-selected areas and areas of interconnected joints.
The remote sensing imagery and topographic lineaments from aeromagnetic data were obtained to determine the fracture direction in area.

RESULTS

Remote Sensing Interpretation

The Enhanced Thematic Mapper Plus (ETM+) instrument is a fixed “whisk-broom”, eight-band, multispectral scanning radiometer installed in Landsat 7 capable of providing high-resolution imaging information of the Earth’s surface. It detects spectrally-filtered radiation in the visible and near-infrared (VNIR)– (portion of the electromagnetic spectrum, which has wavelengths between approximately 400 and 1400 nanometers (nm), Short-wavelength infrared (SWIR), Long-wavelength infrared (LWIR) and panchromatic bands from the sun-lit Earth in a 183 km wide swath when orbiting at an altitude of 705 km.

Band 7 (Figure 3) reflects the short-wave infrared light within wavelength band 2.09 – 2.35; this band map helped in bringing out the lineaments of Ilorin sheet 223; the map shows the dam areas in Ilorin sheet 223SW.

The lineaments trends majorly NNW, NW direction of the map, NW and SSE lineaments are found about 3km to the north and 4.5km to the east of Agba dam which trends 5km and 5.1km distances respectively, at 4.7km of Asa dam there are SSW lineaments trending at 2.7km distance while at the University of Ilorin four lineaments which trends at 10km distance in the SE direction in which these lineaments are found close the University Dam. These lineaments found close to the dam suggest the possibility of seepage.

Aeromagnetic Interpretation

Magnetic anomalies are a local variation in the earth’s magnetic field resulting from variations in the chemistry or magnetism of the rocks. Mapping of variation over an area is valuable in detecting structures obscured by overlying material. The residual anomaly map, analytical signal map, tilt-angle derivative and vertical derivatives (first and second) map were used complementarily in conjunction with the geology of the area to delineate the structural trend in the study area

Total Magnetic Intensity Map (TMI)

Magnetic intensity of the local (residual) field ranges between –22.344nT to 27.7705nT corresponding to the blue colored shade on the Total Magnetic map below (Figure. 4); intermediate color shades; namely green, yellow and red, in that increasing order of magnitude, also characterize the area. Color green and blue depicts low magnetic intensity area, ‘yellow’ indicates magnetic quiet area while red and violet represent areas of high magnetic intensity

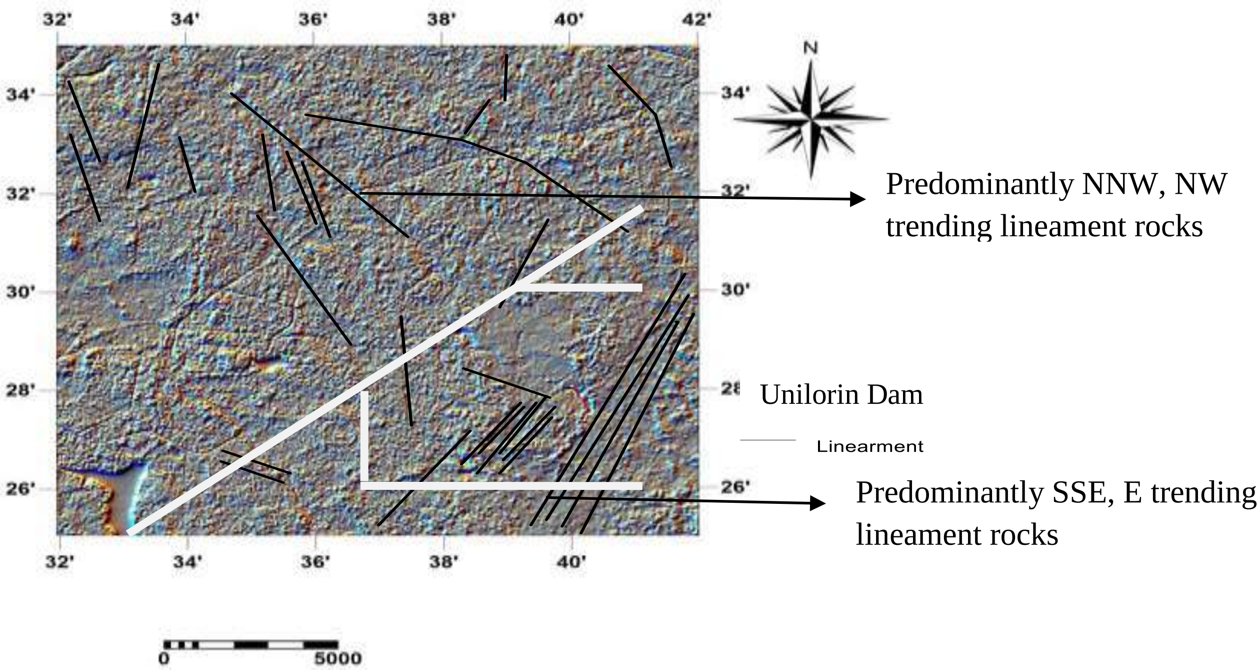

Figure 3: Lineament map of Ilorin Sheet 223 and Part of Share 204 with the dams

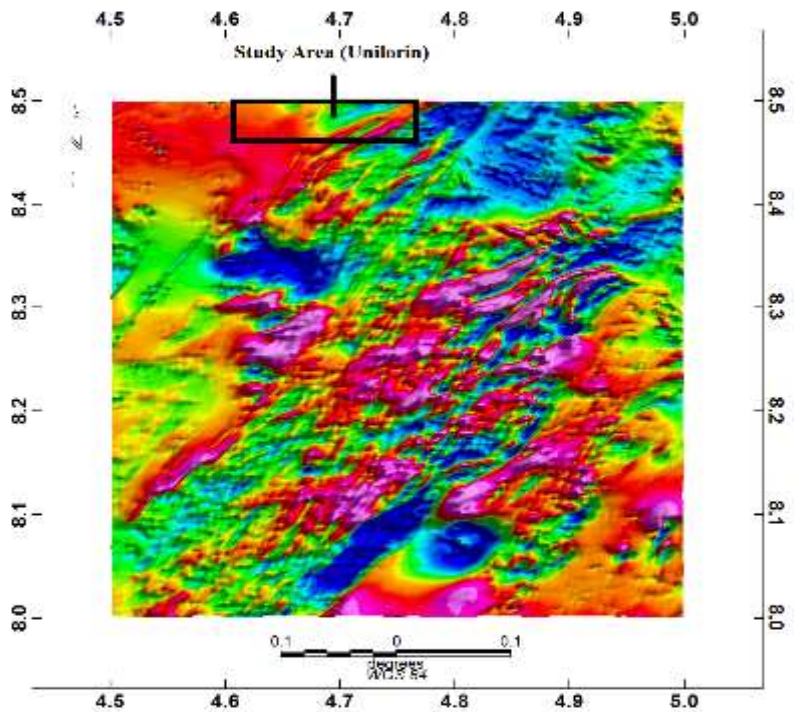

Figure 4: Total magnetic Intensity of Ilorin Sheet 223 (University of Ilorin on the top central portion)

First Vertical Derivative

This First Vertical Derivatives map is a very good shallow body detector, which aids in the separation of shallow bodies from deep ones (Figure 5). Enhancement and identification of shallow geologic sources are better resolved using the first vertical derivative; which ranges between –0.0570nT/Km to 0.0951nT/Km. The blue color indicate areas of deep seated bodies, the violet sand pink colors indicate shallow bodies. A prominent feature revealed by the first vertical derivative below is the NE-SW lineament trend on the eastern half of the University of Ilorin. Other short distance lineaments are also structurally aligned in the aforementioned direction.

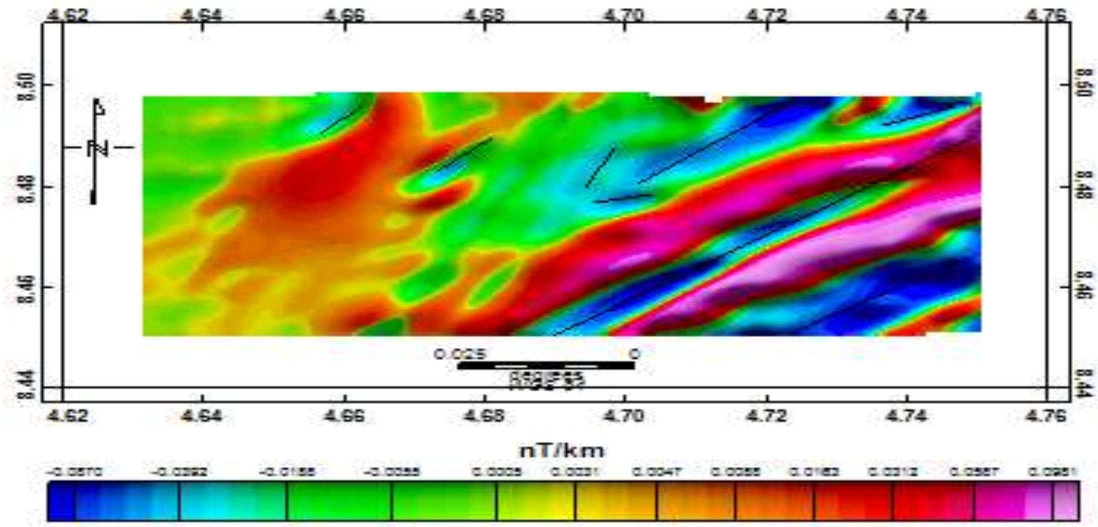

Figure 5: First Vertical Derivative map of University of Ilorin showing the lineament.

Electrical Resistivity Interpretation

Interpretation of VES data involves the determination of the thickness and resistivity of different horizons and the inference of the lithologies based on their resistivity. The typical iterated curves generated from the field measurements in the area are shown in Figure 6a-c.

The iso-resistivity map in Figure 7 shows the variation in the resistivity in which the VES locations are grouped into three profiles, profile 1 (VES 1-3) are areas of low resistivity value which signifies areas of loose geologic material, profile 2 (VES 4-7) are also areas of low resistivity, profile 3 (VES 8-10) are areas of high resistivity values which means that the geologic materials in these areas are well compacted. The contour lines in VES 1-7 are well spaced which means they are lowland areas, the contour lines in VES 8-10 are closely spaced which signifies area of highland, groundwater recharge in areas of highland and discharge in areas of lowland.

The isopach map of the area in Figure 8 reveals that high thickness covers major part of the study area. The Northeastern part of the study area has high overburden thickness which range from 25-30m; Northwestern part ranges from 24-30m;

Southwestern ranges from 25-30m; Southeastern part ranges between 15-25m. The resistivity revealed that the area is dominated with weathered layer basement. Most of the VES locations have the overburden thickness between 25-30m which signifies area of high groundwater potential with weighting of 7.5 except for location 8 which has the overburden thickness of 15m which is an area of moderate groundwater potential with weighting of 5.

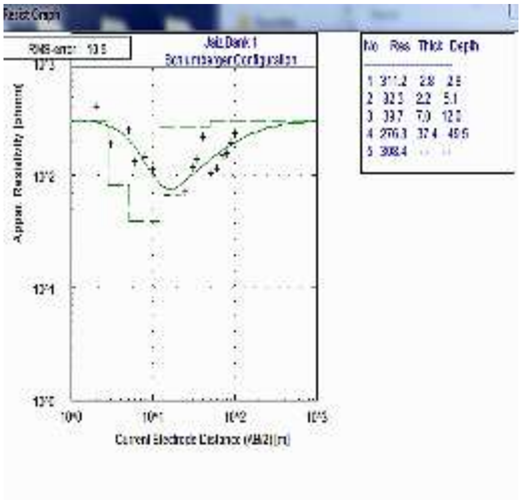

Figure 6a: Five layer KH type curve

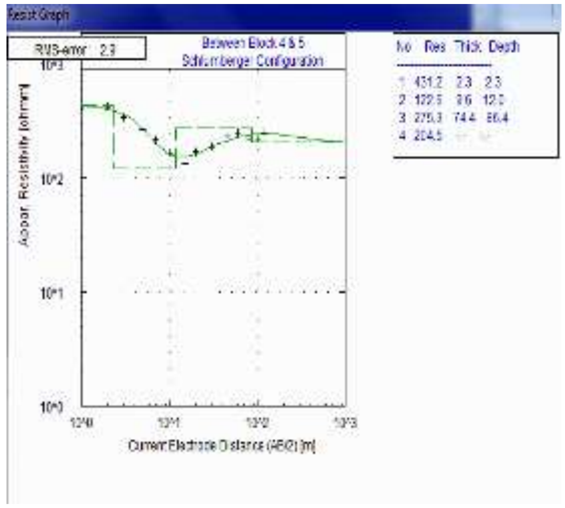

Figure 6b: Four layer HA type curve

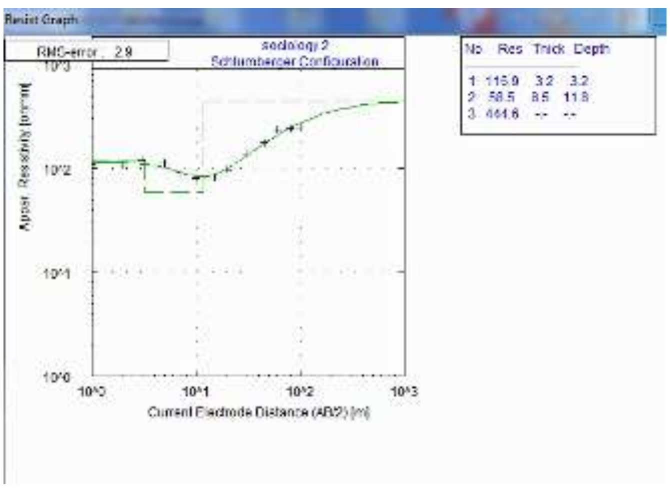

Figure 6c: Three layer A- type curve.

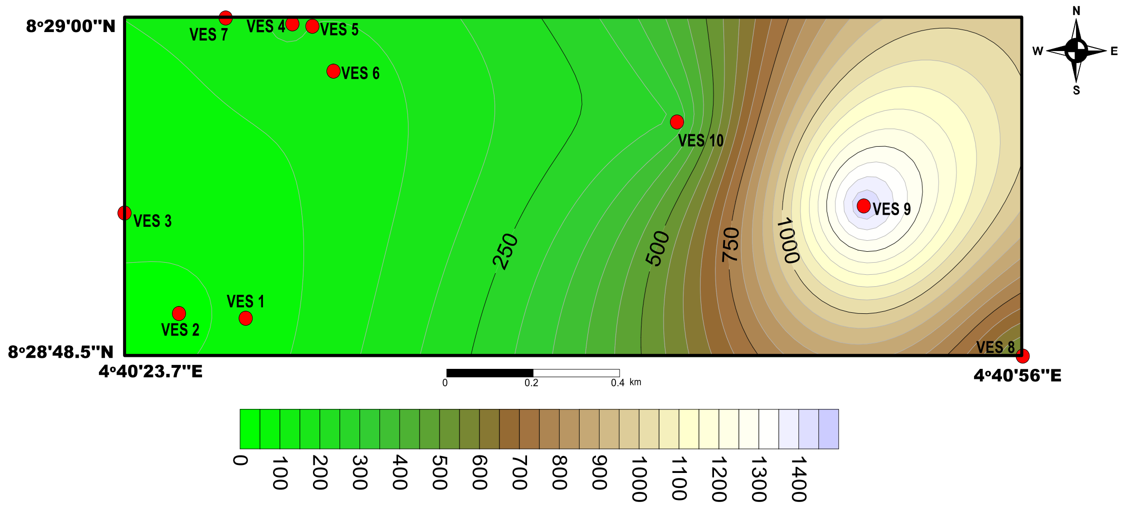

Figure 7: Iso-resistivity maps of the VES locations.

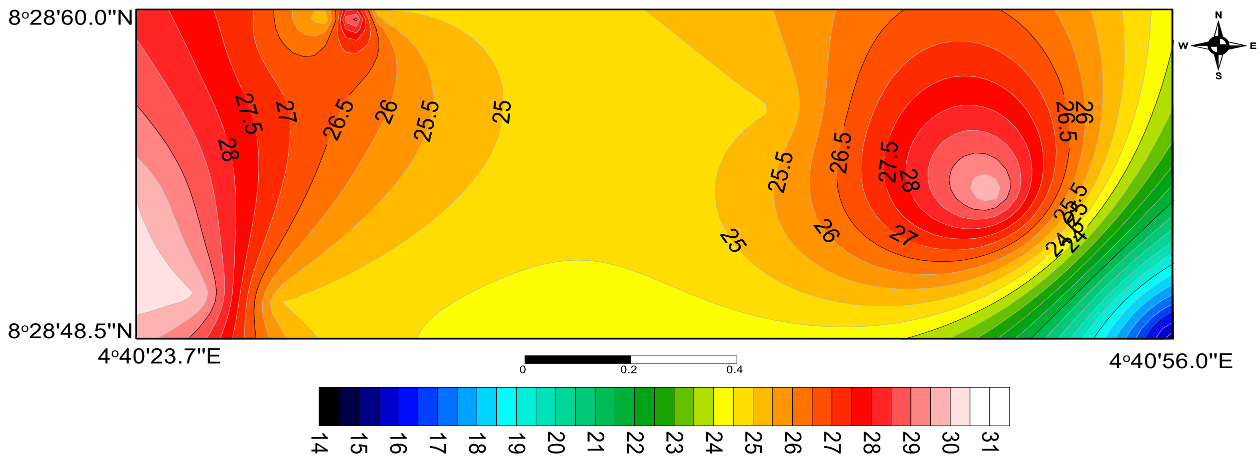

Figure 8: Isopach map of the VES locations.

The Pseudo-section maps in Figures 9a-c shows how the resistivity values varies vertically and horizontally with depth in each VES location the information obtain is useful for both engineering and hydrogeology in term with the competency of the geologic material.

Profile 1 (Figure 9a) shows the resistivity value of VES 1 increases with depth which makes of advantage for engineering purpose both not for hydro-geological purpose; VES 2 and 3 has high resistivity value at 30-48m vertically and decrease at 50m the depth of lower resistivity for VES 2 is at 70m and for VES 3 is at 50m. At horizontal depth, the resistivity value is between 220-290Ωm.

Profile 2 in Figure 9b reveals the change in resistivity value with depths, vertically VES 4-6 the resistivity value increases with depth with highest value of 280Ωm for VES 4 but increase value in VES 5, 6 which makes it fairly suitable for engineering purpose and moderate yield for groundwater potential; VES 7 the resistivity value is low but becomes high at greater depth the area is suitable for hydro-geological purpose. At horizontal depth the resistivity value increases from VES 4-7.

In profile 3 (Figure 9c), VES 8 shows increase in resistivity values with depth; VES 9 shows increase in resisitivity with depth with 1400Ωm as the lowest resistivity value; in VES 10 the resistivity values are all through low. Horizontally the resistivity value increases from VES 8 to 9 but decreases at 150m depth to VES 10.

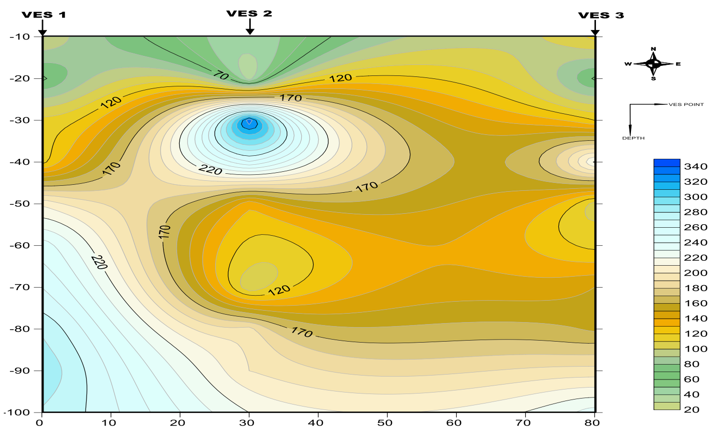

Figure 9a: Pseudo-section of profile 1

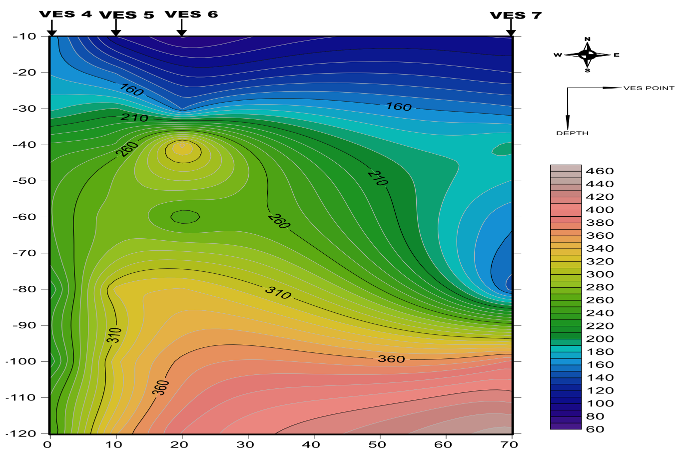

Figure 9b: Pseudo-section for profile 2

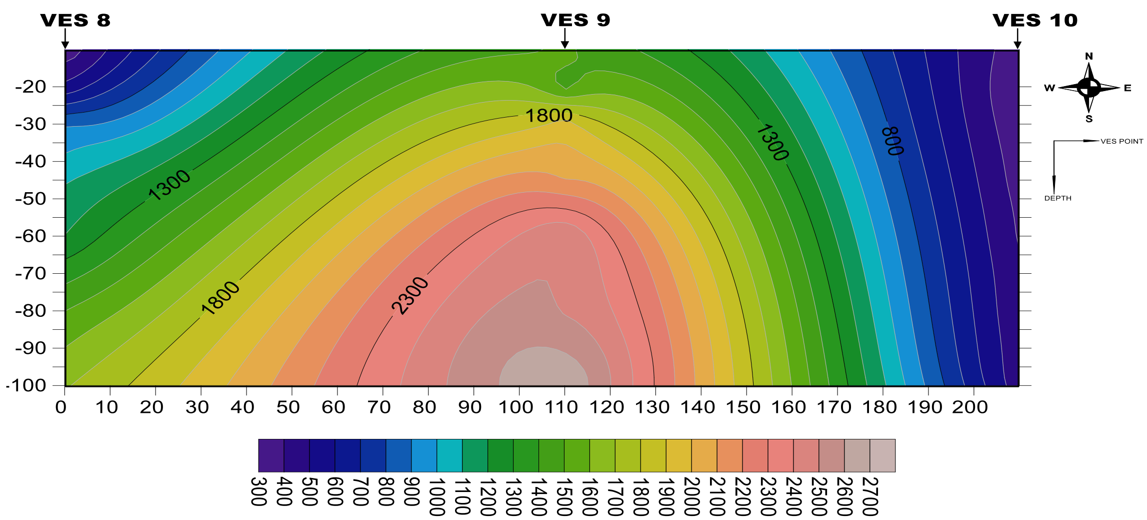

Figure 9c: Pseudo-section Map of Profile 3

Radial Resistivity Interpretation

The results of the radial geo-electric sounding carried out in some locations in the study area were used in determining the fracture patterns. The concept of the radial geo-electric sounding is that, lowest resistivity values are obtained along directions where fractures and weathering have taken place. It should be noted that the earth is anisotropic and non-homogenous. This implies that when VES are done in three different coordinates, the lowest resistivity values are obtained along the direction where fractures and weathering have taken place. This implies that the polygon drawn from the radial geo-electric soundings will have a short axis along the fracture directions. The anistropy polygon of the area is shown in Figures 10a-e.

At location 3 the anisotropy polygon reveals that at shallow depth the direction of fracturing is more elongated than at deeper depth and no change in the direction of fracturing, from the shape of the polygon at deeper it suggest the area to be quartzitic terrain. At location 7, dual structural trends was revealed at shallow depth, the direction of fracturing is NW/SE while at deeper depth the direction of fracturing is NE/SW; this can be attributed to intersection of either joints or a joint and foliation plane, the shape of the polygon suggest a clayey terrain. At location 8, dual structural trend also occur with the direction of fracturing at shallow depth to be NE/SW and at deeper depth NW/SE, the shape of the polygon suggest a hard rock terrain. At location 9, the direction of fracturing is at NE/SW and the shape of the polygon suggest a hard rock terrain. At location 10, trio structural trend was observed; the shape of the polygon at deeper depth suggest a quartzitic terrain while at shallow depth a clayey terrain.

The coefficient of anisotropy ranges from 0-1 with 1 as the highest and 0 as the lowest and the greater the value of coefficient of anisotropy the higher the intensity of fracturing. Fracture either closes up with depth or open with depth; when fracture closes with depth the location is suitable for engineering construction; this indicate compacted geologic material at depth while when fracture opens with depth it is suitable for hydro-geological purpose; this indicates loose geologic material at depth which gives room for the passage and accumulation of fluid. Table 3 shows the variation in anisotropy coefficient with depth and their geological suitability applications; Figures 11a-e shows the scatter diagram representation of the variation of coefficient of anisotropy values with depth; from the scatter diagram it can be deduce that the degree of fracturing increases with depth in the locations and is lowest at depth 10-30m which suggest areas of fresh basement and fracturing occurring within the basement has shown in the geo-electric section.

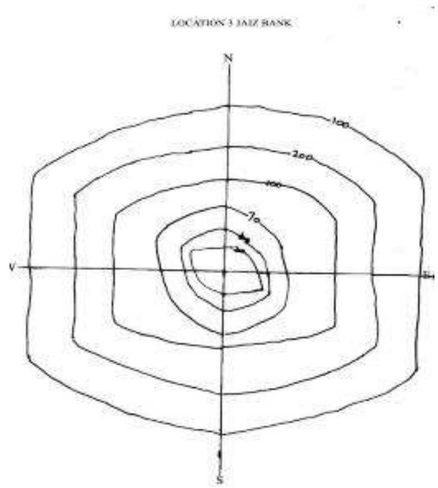

Figure 10a: Location 3 (Jaiz bank)

Figure 10b: Location 7 (beside block10)

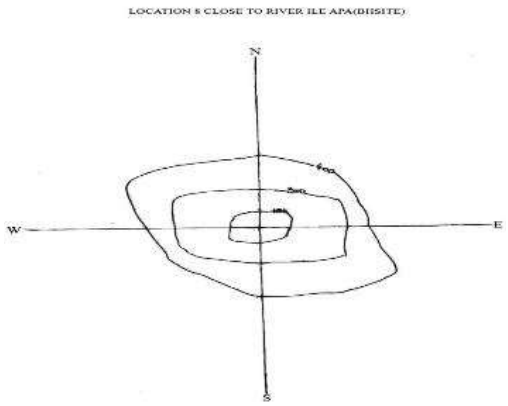

Figure 10c: Location 8 (Close to River Ileapa)

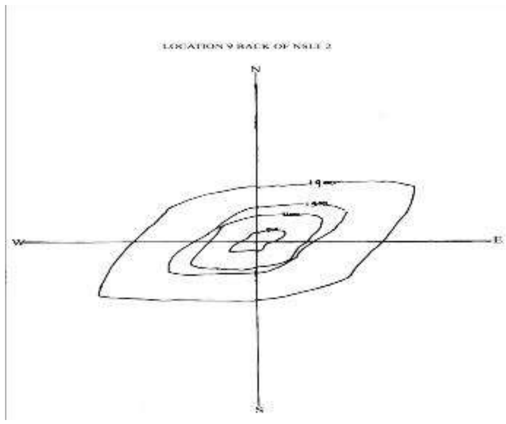

Figure 10d: Location 9 (Back of NSLT2)

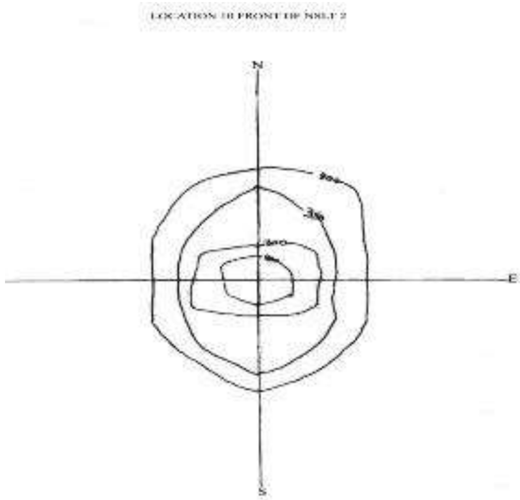

Figure 10e: Location 10 (Front of NSLT2)

Table 3Interpretation of Anisotropy Coefficient values

Locations	Intensity of Fracture with Electrode Spacing	Geological Application
1.	Intensity of Fracture increases with increase in electrode spacing. The intensity of fracture is high from AB/2= 30-50m	Suitable for hydrogeological purpose
2.	Intensity of Fracture highest at 15m.	Suitable for hydrogeological purpose but caution must be taken from 30m
3.	Intensity of fracture is highest at 30m.	Suitable for hydrogeological purpose but fracture closes up with depth.
4.	Intensity of fracture is highest at AB/2= 15m.	Suitable for hydrogeological purpose but fracture closes up with depth.
5.	Intensity of fracture highest at 5m, fracture closes with at depth but increase at 45m.	Suitable for hydrogeological purpose but caution must be taken.

DISCUSSION

An in-depth analysis of the various results obtained from the techniques applied in delineating rock boundaries and structural pattern for groundwater potential of the study has yielded very important findings. The geological mapping reveals the predominant rock type in the study area to be Migmatite, Granite- gneiss with the structures trending NNE, NE, and NW.

From the remote sensing map of Ilorin sheet 223NW the lineament trends NW/SE and NE/SW at the SSE part at several distance, comparing the remote sensing map with the drainage map of Ilorin suggests that the drainage patterns are structurally controlled and aligned parallel.

The difference in the Total Magnetic Intensity values of Ilorin sheet 223NW suggests that the rocks in the area can be divided into three;

i. Low magnetic rock type (metamorphic rocks/ loose particles) which is predominant in the North, NE, central and southern part of the map
ii. Intermediate magnetic rock type (Metamorphic rocks) which scattered all through the map
iii. High magnetic rock type (Igneous rocks) which is the predominant rock type

This result suggests that the predominant rock type at Ilorin sheet 223 NW varies from metamorphic to igneous rock type.

The total magnetic intensity map of University of Ilorin suggests that the predominant rock type in the area is metamorphic rocks. From the first vertical derivatives map the metamorphic rocks are deep seated rocks and are areas of lineaments; the lineament map shows the lineament is predominantly in the NE/SW direction in which the lineament aligned with the drainage in the area which suggest the drainage to be structurally controlled. From the Vertical Electrical Sounding; the weathered basement ranges from 5m to 20m and the fracture basement ranges from 20m to 45m within the basement. Comparing the Isopach, Iso – resistivityand Pseudosection maps reveals that the degree of weathering in the area is moderately to highly weathered.

From the RVES results suggest that the fracture direction in the area is predominantly NW-SE and NE-SW which changes with depth and interconnection of joints or foliation planes at location 7, 8 and 10 with degree of fracturing increasing with depth in all locations. The RVES result divides the rocks in the area into three: the clayey rock, the quartzitic rock and the hard rock; the coefficient anisotropy ranges from 0.72 to 2.63. The radial sounding coefficient of anisotropy and the VES lithology interpretation of weathered and fractured basement agree.

Summary of Findings

The boundary between the granite-gneiss/migmatite and the granite has been inferred from the geological map. From the remote sensing map; Ilorin sheet 223 structural trend has been divided into two: the NE-SW and the NW-SE structural trends. The aeromagnetic anomalies divide the rocks in Ilorin sheet 223 into metamorphic (low to medium magnetic intensity) and igneous (high magnetic intensity) rocks. The resistivity data interpretation reveals the weathered basement at the University of Ilorin to range from 5 to 20m and the fractured basement range from 20m to 45m. The radial sounding reveals the structural trend to be NW-SE and NE-SW and interconnection of joints at Vertical Electrical Sounding locations 7, 8 and 10 at the University of Ilorin with the fracture intensity ranging from 0.72 to 2.63. The remote sensing lineament compared with an existing radial anisotropy in the area confirms the presence of fault in the south-south axis of the campus. The radial sounding shows the rock type in University of Ilorin to be quartzitic, clayey and igneous as judged from the near hexagonal and elongated shapes of the polygons. The results reveal a good agreement between the trends of fractures derived from the radial VES and that from the lineament maps. Areas with low bedrock resistivity, thick overburden, presence of two or more interconnected fractures and high co-efficient of anisotropy indicate intense fracturing, thus, a potential site for the drilling of water borehole and good water quality.

CONCLUSION

This study, using Multi Criteria Decision Analysis, Geological mapping, Aeromagnetic, Remote Sensing and Electrical Resistivity method has been able to demonstrate the effectiveness of integration of multiple data sets, with various indications of groundwater availability, which can decrease uncertainties and lead to safer and more reliable decisions in choosing sites for the development of groundwater resources. The study revealed two major fracture patterns within the area which runs in a NW-SE and NE-SW direction and the drainage pattern to be structurally controlled. Ore mineral and groundwater exploration in the area should be concentrated along NW-SE and NE-SW direction since their presence is fracture driven and these directions should be avoided for engineering construction. The rock type in the area is divided into metamorphic and igneous rocks. The use of more than a single method in carefully delineating the fracture patterns in the area has shown to be more effective than singular method and has reduced errors arising from a single method.

The pie chart in Figure 11 quantifies the methods of approach in this research work based on accuracy of the results in delineating the structural trends and rock boundaries in the area both regionally and locally for groundwater potential.

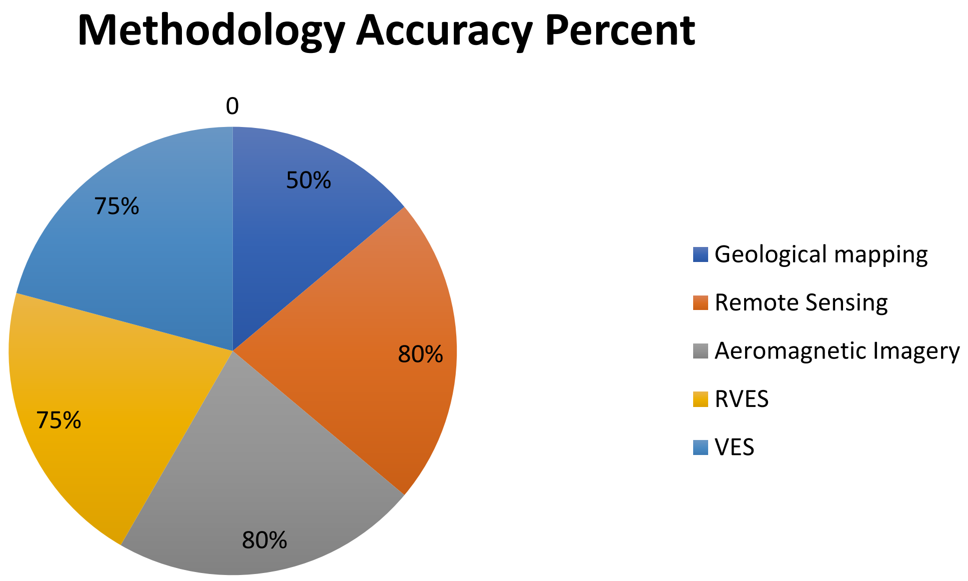

Figure 11: Pie chart of Methodology Accuracy.

The caveat is that this approach is suitable for regional groundwater exploration studies and delineation of rock boundaries.

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