

GEOPHYSICAL STUDIES OF FRACTURES OF BASEMENT ROCKS AT UNIVERSITY OF ILORIN, SOUTHWESTERN NIGERIA; APPLICATION TO GROUND WATER EXPLORATION.

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ABSTRACT

In hard rock terrains, exploration for groundwater is essentially the detection of zones of intense jointing and fracturing / thick weathered residuum. These were the exploration criteria used in the study at the University of Ilorin. Results from the interpretations of thirteen (13) Radial Vertical Electrical Sounding data of the area has shown that the area is made up of three distinct geoelectrical layers except in the areas around foliated granodiorite where the layers are four. The first geoelectric layer is the brownish loose sandy-clay soil containing some lateritic particles which has thicknesses in the range of 0.6m to 2.0m and resistivity values of 202.1m to 1205.1m. The second geoelectric layer corresponds to the weathered basement whose thicknesses and resistivities range from 2.5m to 9.6m and 27.2m to 589.2m respectively. The third geoelectric layer corresponds to the basement rock. The resistivity values of this layer range from 1293m to 20192m. The area is intensely fractured and the fracture directions found are NW-SE, N-S and NE-SW. The fractures expectedly diminish with depth, and it also controls the river flow in the area. The weathered layer is not thick enough to produce an economic water aquifer as generally found here except in areas around location 1 and 9 where the thicknesses are 9.6m and 9.9m respectively. However, the presence of intense fracture zones in the basement rocks provided secondary porosity for the migration and accumulation of groundwater.

INTRODUCTION

Occurrence of ground water in hard rock is different from that in granular media, being highly irregular due to variable subsurface geology and hydrogeology (Malik et al, 1983). Experience shows that in hard rock terrains, bore-wells made even at short distances behave in entirely different ways from the point of view of ground water development. The accumulation and movement of water in such areas are governed not by primary porosity but by secondary ones, due to weathering, jointing and fracturing. It is also found that the potential water may reside preferentially in those regions where either weathering attains considerable thickness or where fracturing/jointing is intense, (Malik et al., 1983, Olaseinde, 1999). Also it is common to observe that when water occurs in joints and fractures, it is of very high quality and the well yield is usually high.

In any given area, rock with fractures may or may not be exposed. If they are exposed, the behaviours of their fractures at the surface can be understood, but at depth, they cannot be predicted with certainty. However, radial vertical electrical sounding (RVES) has been used to monitor the behaviour of rock at depth and throw some light on this problem (Malik et al, 1983 and Olaseinde, 1983). Resistivity soundings can also provide information on the depth to the basement, and the thickness and resistivity of probable aquifer. This work present the geoelectrical characteristics of regolith materials developed upon the Basement Complex rocks around University of Ilorin Permanent Site, southwestern

Nigeria, based on the results of resistivity survey carried out as part of exploration for ground water in the area. It has been observed that on a local scale, differences in rock mineralogy and structure may produce significant variation in the physical and chemical characteristics of the aquifer (Chilton and Smith-Carlington, 1984) and consequently produce geoelectric anomalies leading to structural identification.

LOCATION OF THE STUDY AREA

The study area is the University of Ilorin Permanent campus. The campus is bounded by longitude 4°39'E - 4°42'E and latitude 8°27'N - 8°29'N [fig. 1]. The main campus of the University is situated at about 15 kilometers east of Ilorin township and occupies about 15,000 hectares of land.

The topography of the Unilorin permanent site is relatively high and rugged. The highest point is in the eastern part measuring about 375 metre (around Budo-Ogi village). Rock exposures are prominent along the river course due to erosion of the top soil. The topographic slope is steep in the eastern part and dip gently towards the western part of the campus [Olaseinde, 1983].

The area mapped is well drained. The most prominent drainage system is formed by the Oyun River. The Oyun river traverses Unilorin permanent campus from the south to the north, flowing down the hill. There are many small streams adjoining river Oyun to form a trellis to sub-dendritic drainage pattern. The size of the drainage changes with season, reaching its peak in the raining season. Rocks in the drained area are highly fractured both at the surface

and at depth thus making the drainage to be fracture-controlled.

GEOLOGY OF THE AREA

The area under study is part of the Basement Complex of Nigeria considered by various workers to be Precambrian to lower Paleozoic in age (Oyawoye, 1970; Grant, 1978 and Rahman, 1976). The basement rocks consist of a variety of both migmatized to unmigmatized gneisses, schists, amphibolite and quartzites intruded by 600-150 Ma granitic to dioritic rocks (Oyawoye, 1970; Rahman, 1976).

Crystalline rocks of the Basement Complex outcrops over large area in Nigeria, in three broad regions separated by Mesozoic and Cenozoic sedimentary basins [fig. 1]. The crystalline basement rocks occupy about half of Nigeria while the Cretaceous to Recent sediments cover the remaining part.

The geological map of the area is produced as shown in Fig. 1. Rocks Identified in the area are mainly metamorphic and igneous rocks, and are classified below:

- The Gneiss Complex: Augen Gneiss, Banded Gneiss and Granite Gneiss.
- Granite Suite: Foliated granodiorite and foliated microgranite.
- The veins: Pegmatites and Quartz veins

FIELD PROCEDURE AND DATA COLLECTION

Radial Vertical Electrical soundings using Schlumberger electrode system was adopted, using ABEM 300B SAS Terrameter. The electrode arrangement was first positioned along N-S direction and later rotated twice at an angle 60° each time to give NE-SW and NW-SE directions respectively. Thirteen current electrode spacings were probed along each orientation [see fig. 2]. These measurements were repeated at thirteen different stations (fig 1). The resistivity values were plotted against current electrode separation for each orientation as shown in Table 1. Apparently, three VES curves are plotted on the same graph paper using the same axis. This method gives room for direct comparison of curves and their subsequent interpretations. These curves are presented in fig. 3 for location 1. Resistivity values measured in thirteen locations are plotted against half-electrode separation (AB/2 m). Isoresistivity lines are drawn using the methods of Malik et al; 1983 and Olaseinde; 1983. RVES method was adopted in order to understand the fracture behaviour at depth along difference directions, to discern the degree of variation of ρ_a at different orientation and the presence of resistivity anisotropy. This method also affords the opportunity of check and control for qualitative results. The resulting elliptical polygon anisotropy polygon is presented in fig. 4 for location of 13.

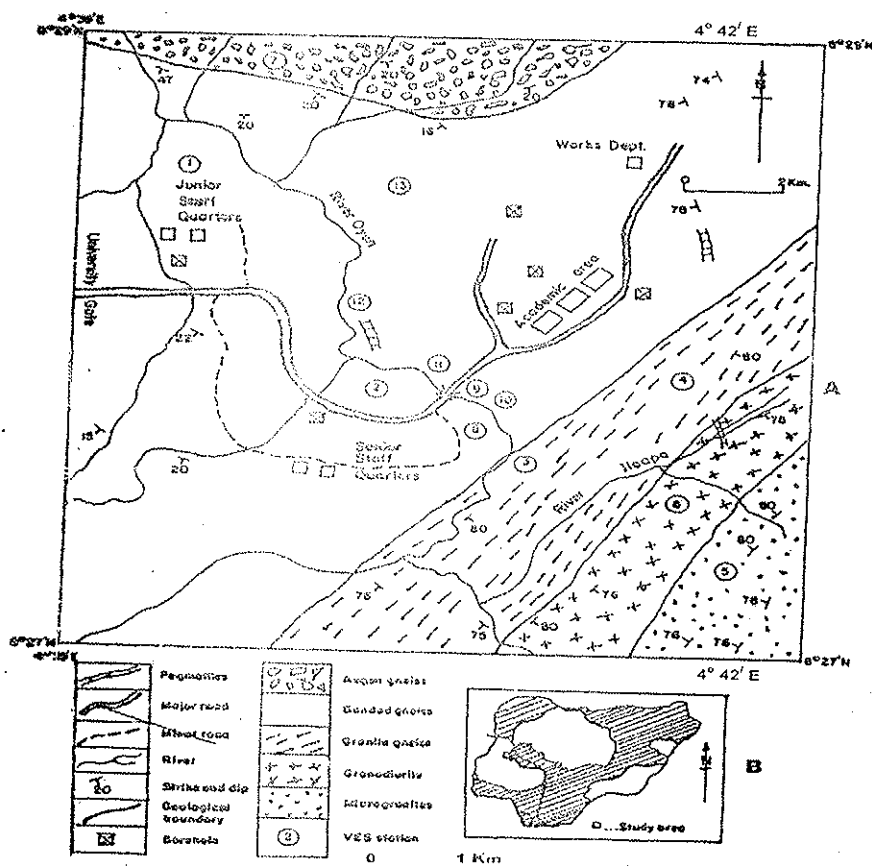


Fig. 1A: Geological map of Unilorin and the RVES stations.

Fig. 1B: Geological Map of Nigeria showing position of Ilorin.

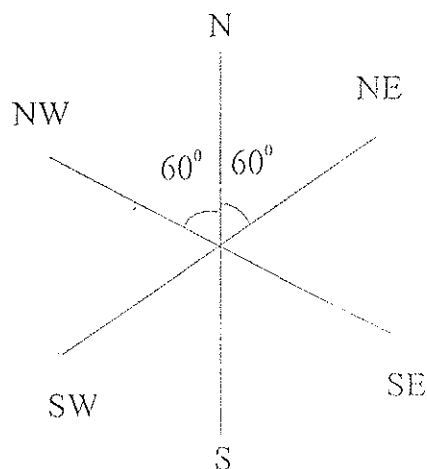


Fig. 2 schematic diagram of Radial Vertical Electrical Sounding directions

TABLE 1: DATA SHEET LOCATION 1 of 13

LOCATION:..... ONE (1) UNIVERSITY OF ILORIN
DISTRICT:..... SCHLUMBERGER RADIAL
TYPE OF ARRAY:.....
AZIMUTH:.....

S/No	AB/2(m)	MN/2(m)	G	0°	60°	120°
				$\rho(\Omega m)$	$\rho(\Omega m)$	$\rho(\Omega m)$
1.	1	0.2	7.543	933.07	722.77	349.39
2.	2	0.2	31.114	450.84	419.10	451.77
3.	3	0.2	70.4	332.64	392.27	338.41
4.	3	0.6	22.628	409.57	414.09	337.84
5.	5	0.6	64.53	238.16	252.18	349.75
6.	7	0.6	127.39	176.82	210.57	256.56
7.	10	0.6	260.96	266.18	205.06	620.16
8.	10	2.0	75.428	255.55	223.95	273.05
9.	15	2.0	173.64	366.73	151.69	468.65
10.	20	2.0	311.142	225.45	295.62	579.04
11.	20	4.0	150.86	238.51	301.72	499.80
12.	30	2.0	704.0	449.01	480.62	393.82
13.	30	4.0	347.286	474.74	503.22	284.84

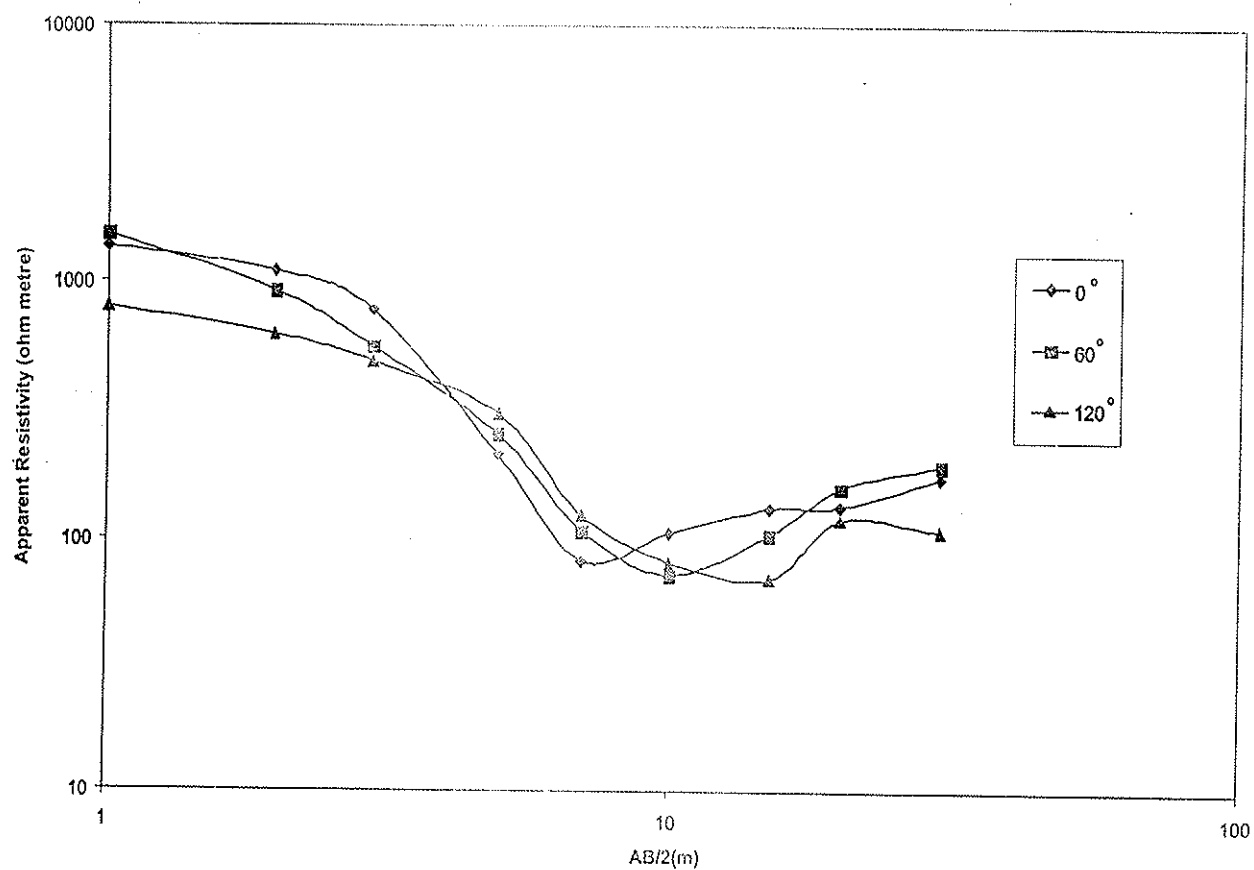


Fig 3: VES curves for location 1 of 13 in three directions

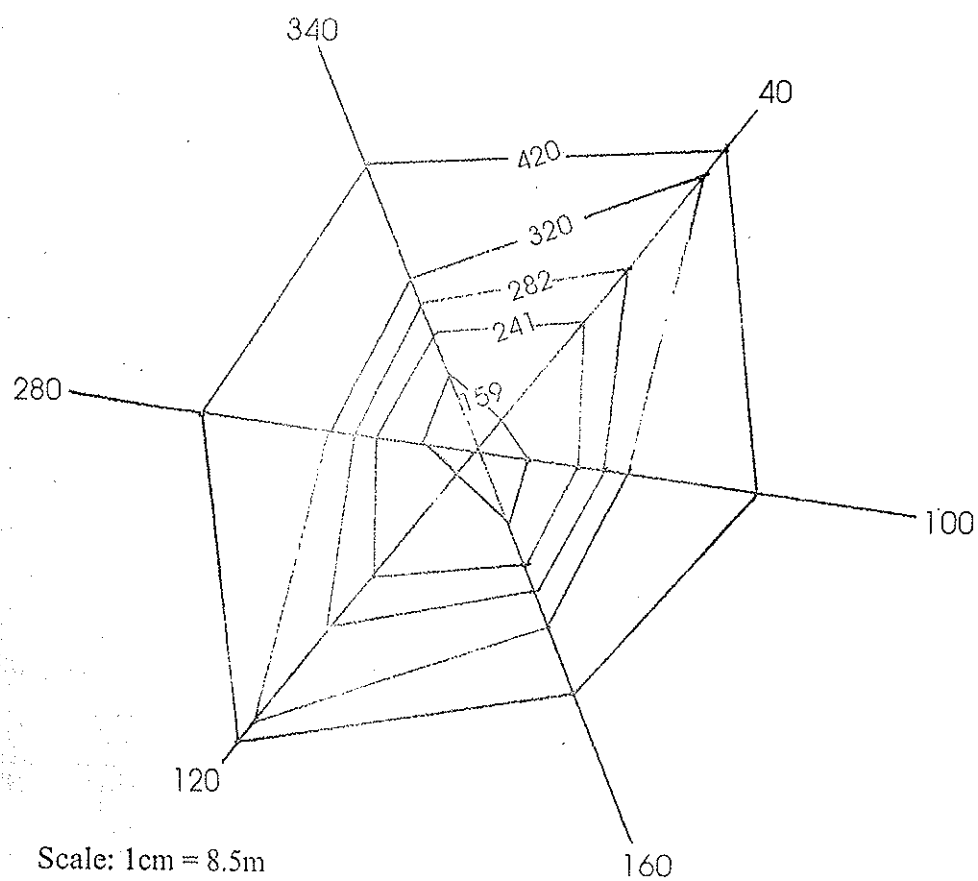
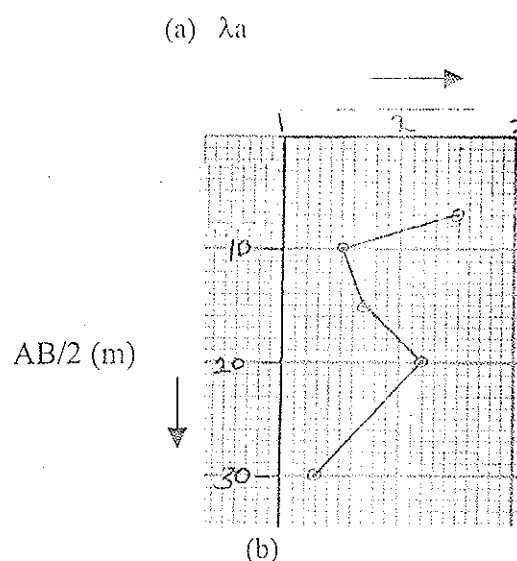


Fig. 4: (a) Anisotropy polygons of location 3 using Schlumberger array.



4b Variation of degree of fracturing λa fracturing a with depth $AB/2$

INTERPRETATION AND DISCUSSION

In areas underlain by sedimentary formations, where the aquifer materials and water quality are often fairly homogeneous, Niwas and Singhal (1981), Onuoha and Mbazi (1988) and Mbonu et al (1991) have shown that the Dar Zarrouk Parameters of longitudinal conductance and transverse resistance determined from resistivity data can be used to predict hydrogeological parameters such as transmissivity and hydraulic conductivity. However, in basement areas, there is a composite aquifer of the weathered zone and fractured basement neither of which is really homogeneous. Hence the prediction of aquifer parameters in this geological terrain is often difficult. With the combination of conventional interpretations of VES and radial VES

in this study, the predictions of aquifers have been enhanced.

The VES data were interpreted using both computer iteration and partial curve matching (Zohdy et al, 1974; Olayinka and Mbachi, 1987). The resistivity and thickness of each geoelectric layer from computer iteration are presented in Table 2.

All the VES curves from the area showed characteristic H-type interpreted into three distinct geo-electric layers. The first geo-electric layer corresponds to the top soil. This consist of brownish loose sandy clay soil containing some pebbles and lateritic particles. The thickness of this layer varies from 0.6m to 2.0m and its resistivity ranges from 214m to 1250m. The porosity of this top soil aid percolation of rain water into the substratum. The second geoelectric

Table 2: Average Resistivities and Thicknesses of Geoelectric layers of Locations 1to13 Using Computer Iterations method.

Location	1	2	3	4	5	6	7	S_1	S_2	S_3	N_1	N_2	N_3
$\rho_1(\Omega m)$	772	1250	869.3	214.5	231.7	231.7	638.0	677.9	970.6	248.3	202.1	1130.5	473.1
h_1	0.9	1.4	0.6	1.3	1.8	1.8	1.4	1.2	0.9	1.2	2.0	0.9	0.7
ρ_2	419.2	181.4	99.5	58	99.6	589.2	62.6	79.5	90.8	27.2	72.3	87.5	58.9
h_2	9.6	9.1	3.3	4.3	2.8	1.1	5.5	5.6	9.9	2.6	5.0	4.7	4.2
ρ_3	5797	2002	3525	1963	1297	152.5	2337	3114.4	4514.8	1533.3	7349.3	20192	10678
h_3	α	α	α	α	α	3.5	α	α	α	α	α	α	α
ρ_4						11448.8							
h_4						α							

Layer corresponds to the weathered basement (regolith). This is common to every location except location 6 (within the foliated granodiorite) where a thin lateritic layer of 1.1m thick and resistivity 589.2m succeeded the top soil. This weathered basement has resistivity ranging from 27.2m to 419.2m and thickness ranges from 2.6m to 9.9m. Very low resistivity values in this layer is attributed to the presence of in situ weathered clay. This layer is commonly water-saturated and is often characterized by low resistivity, high porosity, low specific yield and low permeability (Jones, 1985). A semi-confined aquifer condition may be created if the clay content is very thick. On the other hand, the main aquifer zone may be found at the base of the weathered profile where mineral decomposition resulting from in-situ chemical weathering has produced a gravel like material of moderate to high permeability (Jones, 1985; Acworth, 1987). The last geoelectric layer corresponds to the geoelectric basement rock. This

layer is infinitely thick and its resistivity ranges from 1128.7m to 10, 310m. The basement rocks, most especially in the banded gneiss areas have been intensely fractured as can be seen from table 3. A geoelectric cross section is shown in fig 5.

The resistivity anisotropy polygons show characteristic elliptical shape. The direction of the long axis of the ellipse is taken to be the strike direction of the fracture (Malik et al 1983; Olasehinde, 1983). The resistivity anisotropy polygons suggest two fracture directions except in location 4, 5, 7, 11, 12 and 13 (see Table 3) where the fracture direction is the same at both shallow and greater depths. The fractures diminishes with depth and their direction are along NW-SE, N-S and NE-SW respectively. In places where the fracture zone is more than one, the first fracture zone is found at depth less than 10 metres, while the second zone is found at greater depths.

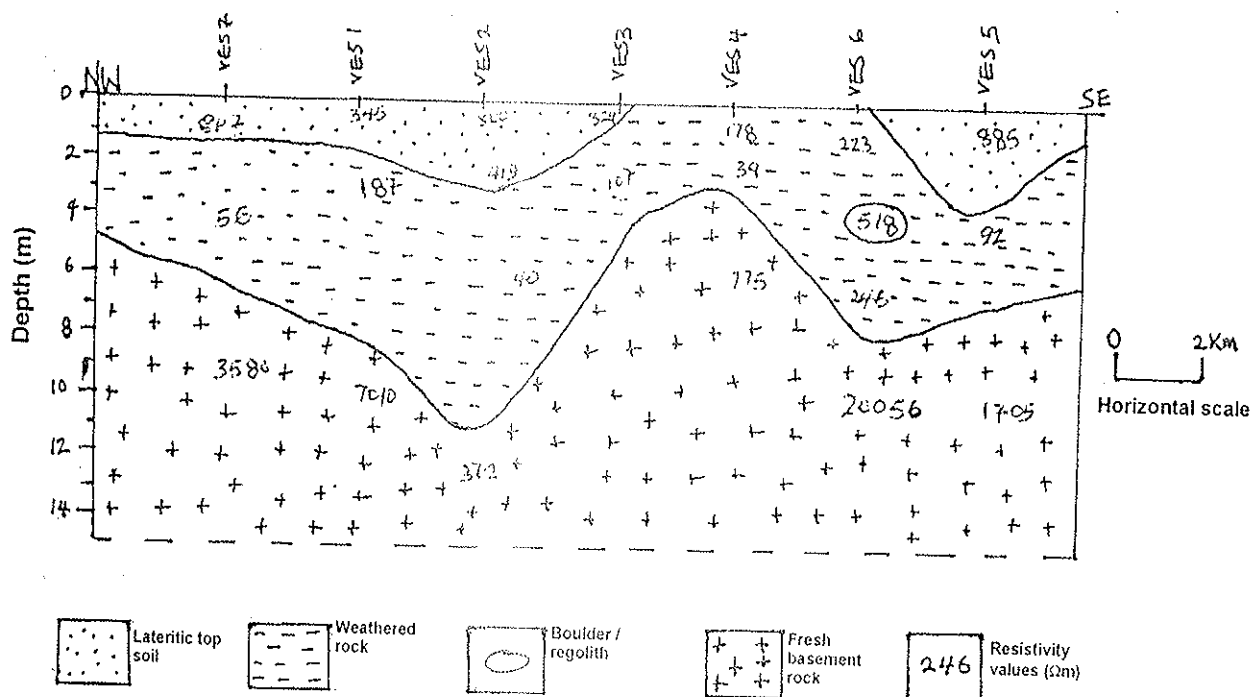


Fig. 5: Geoelectric cross-section for locations 1 - 7.

The presence of fractures in the area is important in the migration and accumulation of ground water. This explains why boreholes drilled on the fractured basement in the areas are very productive. At shallow depth of about 25m, at

borehole (east of the study area), the yield and transmissivity have been found to be 9.8m³/hour and 2.41m³/day respectively (Olasehinde, 1999). Most boreholes drilled in the area are successful having been located on fractured basement.

Table 3: Showing locations and rock types, fracture directions and coefficient of anisotropy.

Location	Rock type	Fracture directions		Coefficient of anisotropy λ
		First regime	Second regime	
1.	Banded gneiss	NW-SE	WE-SW	1.23
2.	Banded gneiss	N-S	NW-SE	1.28
3.	Granite gneiss	NE-SW	-	1.18
4.	Granite gneiss	N-S		1.21
5.	Micro granite	NW-SE		1.23
6.	Granodiorite	NE-SW	N-S	1.30
7.	Augen gneiss	NE-SW		1.10
8.	Banded gneiss	NW-SE		1.10
9.	Banded gneiss	NW-SE		1.22
10	Banded gneiss	NE-SW		1.04
11.	Banded gneiss	N-S	NW-SE	1.10
12.	Banded gneiss	NE-SW	NW-SE	1.04
13.	Banded gneiss	NW-SE	NE-SW	1.10

$$\lambda = \sqrt{\frac{\rho_t}{\rho_L}}$$

CONCLUSION

The University of Ilorin Permanent Site form part of the basement complex of south-western Nigeria. The lithologies present include banded gneiss, granite gneiss, augen gneiss, granodiorite and microgranite. All the lithologies are intruded in places by pegmatites in both concordant and discordant manner.

The area is intensely fractured and the fractures diminish with depth. The strike of the fracture is in the NE-SW, N-S and NW-SE directions. Two fracture zones are identified except in areas around locations 3, 4, 5, 7, 8, 9, 10 (see Table 3) where there is a single fracture zone. Depths to the

geoelectric basement were estimated to range from 3.6m to 10.8m.

The weathered layer (regolith profile) has been estimated. Its thickness varies from one location to the other, ranging from 2.6m to 9.9m. In most places the thickness of this layer is not sufficient to form an aquifer except in areas around locations 1 and 9 where thicknesses are 9.6m, and 9.9m respectively. The detection of fracture zones in the area is very important as they serve as secondary porosity and aid the migration and accumulation of ground water. Location of fractures in this area is therefore important in the exploration for ground water.

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