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GEOELECTRIC CHARACTERIZATION OF AQUIFER TYPES IN THE BASEMENT COMPLEX TERRAIN OF PARTS OF OSUN STATE, NIGERIA

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ABSTRACT

Vertical electrical sounding data have been analyzed and used to delineate and characterize the aquifers of the basement complex terrain around Irewole and Isokan Local Government Areas of Osun State, Southwest Nigeria.

A maximum of four subsurface geological units were delineated in the study area. The first is the topsoil with resistivity value varying from 19 – 1400 Ohm-m and thickness range of 0.4 to 3 m. The second layer is the weathered layer. The resistivity value varies from 10 – 700 Ohm-m and thickness of between 0.8 and 29.4 m. The third layer is the weathered/fractured basement with resistivity value ranging from 85 – 400 Ohm-m and thickness of between 1.6 and 23.2 m. The last layer is the fresh basement rock with resistivity value ranging from 2400 – infinity Ohm-m.

The fractured basement rock and the overlying weathered layer constitute the two main aquifer units in the study area. Three of the five-aquifer types delineated by Olorunfemi and Fasuyi, 1993 in the Nigerian basement terrains were also delineated from the area. Borehole logs observed from the study area of study show that the fracture thickness varies from 3 – 23 m. The Pegmatite is more fractured than the other rocks, followed by the Fine-grained granite.

KEYWORDS: Geoelectric Characterization, Aquifer Types, Basement Terrain.

INTRODUCTION

The basement complex area is mainly characterized by two major aquifer types, namely weathered and fractured basement aquifers. The weathered layer aquifer may occur alone or in combination with the fractured aquifer in the same locality. Aniya and Schoeneick (1992) and Olorunfemi and Fasuyi (1993) identified the aquifer types in the basement complex area of Nigeria. These include the weathered layer aquifer, the weathered/fractured (unconfined) aquifer, the weathered/fractured (confined) aquifer, the weathered/fractured (unconfined)/fractured (confined) aquifer and the fractured (confined) aquifer.

Field observations show that the aquifers in the basement rocks are highly localized and are mainly controlled by the weathered regolith and secondary porosities derived from joints, faults, shears and fractures. The capacity of the basement rocks to store, transmit and yield reasonable quantity of groundwater depends on the extent, thickness and continuity of the fractures and on the degree to which the fractures are hydraulically connected (Bayode, 2000).

The geoelectric survey method is the most widely used geophysical method for groundwater exploration in the basement complex area. This is due to the fact that the method is capable of defining the significant contrast in the geoelectric parameters of the superficial deposit/topsoil and the in-situ weathered material, fractured zone and the fresh basement rock.

The present study intends to define and identify from borehole logs and VES interpretation results, the aquifer types and the possible aquifer combinations that characterize the basement complex area of Irewole and Isokan Local Government areas of Osun State Nigeria.

GEOMOPHOLOGY, GEOLOGY AND HYDROGEOLOGY

The study area lies within latitudes 7° N and 7°3 N and longitudes 4°15 E and 4°23 E. It covers an areal extent of about 900km^2 (Fig. 1). The topography is gently undulating with low-lying outcrops. Recent alluvial deposits, resulting from the weathering and erosion of basement complex rocks, cover a greater part of the area.

The area is underlain by the Precambrian Basement Complex rocks of South-western Nigeria, which form part of the Basement Complex of Nigeria. The major lithological units include fine-grained granite, porphyritic granite, gneiss and migmatite undifferentiated, pegmatite and charnockite (Fig. 2). The basement rocks are mostly concealed in the study area.

In the basement complex area, groundwater is contained in the weathered, partly weathered/fractured zones, fault breccias and joints. In weathered rocks, both intergranular and fracture porosities exist. In hard rock areas, the weathered and fractured aquifers are capable of yielding sufficient quantities of water to meet the need of a small community or a village (Verma, et al, 1980). In the study area, the groundwater is primarily recharged by rainfall and small contributions from lateral groundwater flow and from river channels where possible.

THE GEOELECTRIC SURVEY

The electrical resistivity survey of the study area involved vertical electrical sounding (VES) with the Shlumberger array. The electrode spacing (AB/2) was varied from 1m to a maximum of 150m. Forty nine (49) vertical electrical sounding (VES) stations were occupied in ten (10) communities and villages in the study area (Fig. 2). The VES curves were quantitatively interpreted by partial curve matching and computer iteration technique. The RESIST version 1.0 software was used for the computer iteration.

The resultant geoelectric parameters and borehole logs were used for the delineation and characterization of the aquifer units. The fractured thickness and depth of occurrence were determined from the resulting geoelectric logs and the borehole logs where possible.

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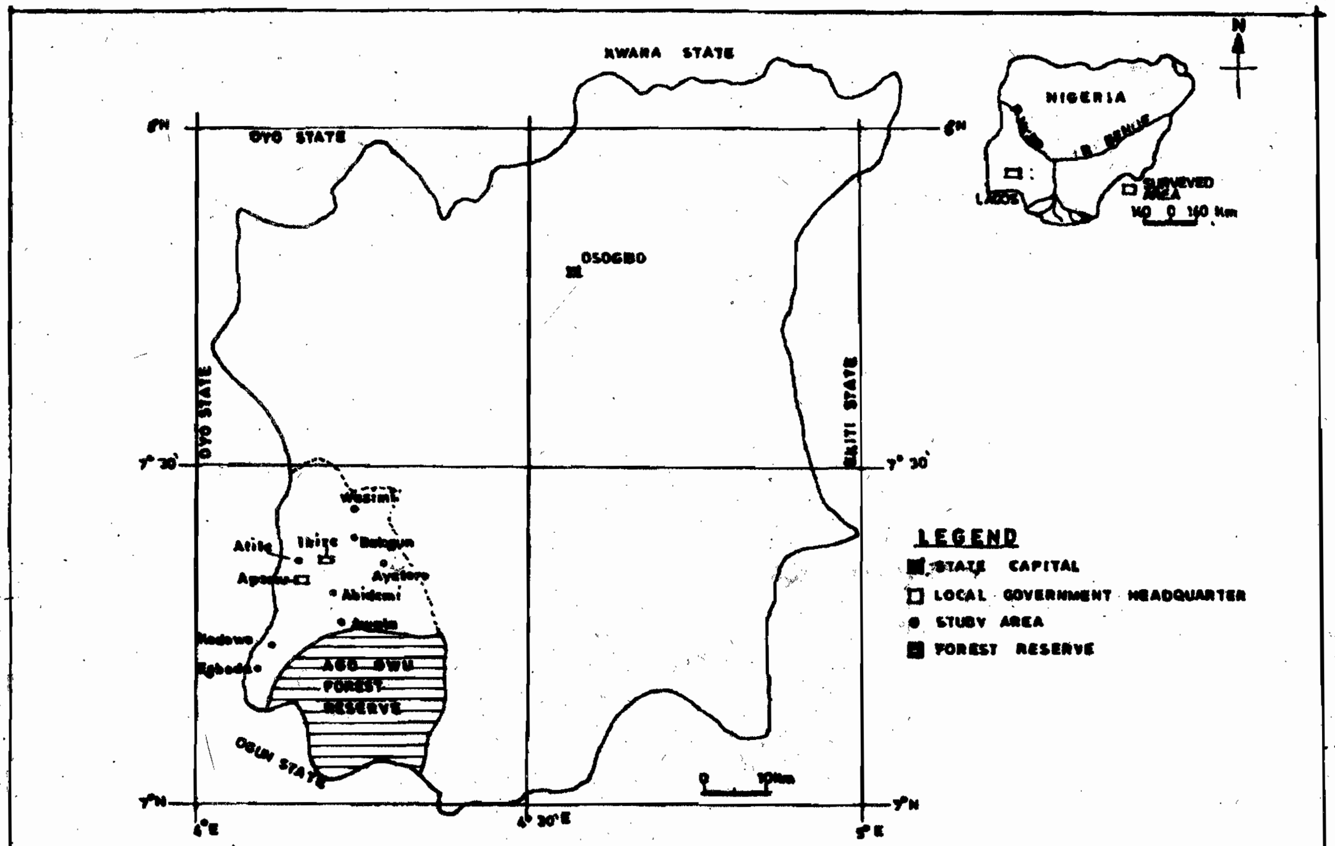


Fig. 1: Map of Osun State Showing Location of the Study Area.

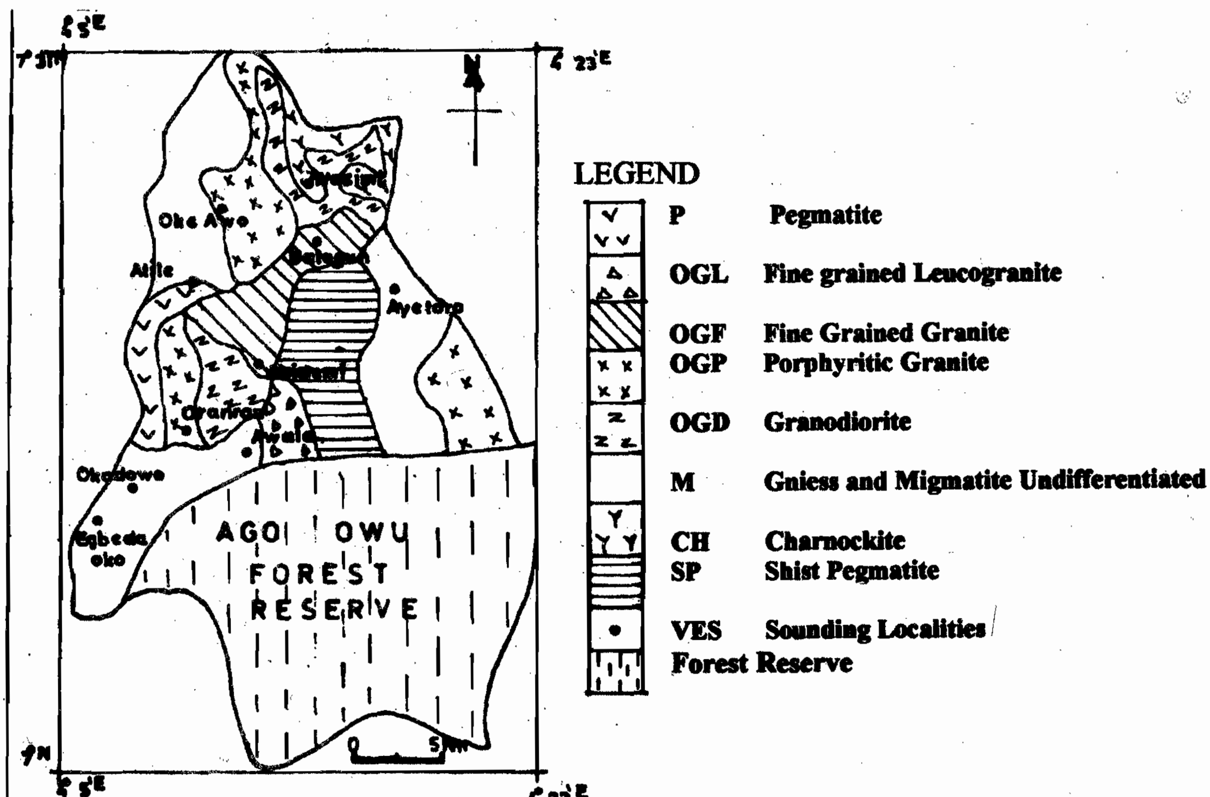


Fig. 2: Regional Geological Map of the Study Area (Adapted from Iwo Sheet 60: Compiled by the Geological Survey of Nigeria).

RESULT AND DISCUSSION

Two major aquifer units were identified in the study area. These include the weathered and the fractured aquifers. The weathered layer resistivity varies between 10 and 700 Ohm-m. The lower range of 10-100 Ohm-m is typical of clay, while the 100-250 Ohm-m range typifies sandy clay. The 251-700 Ohm-m range is characteristic of clayey sand and sand. The weathered layer thickness generally ranges from 0.8-29.4 m (Fig. 3 -7).

The fractured basement resistivity varies from 41-1000 Ohm-m. The lower resistivity and (<750 Ohm-m) is characteristic of zones with high fracture frequency and or thick fractured column that are possibly groundwater saturated.

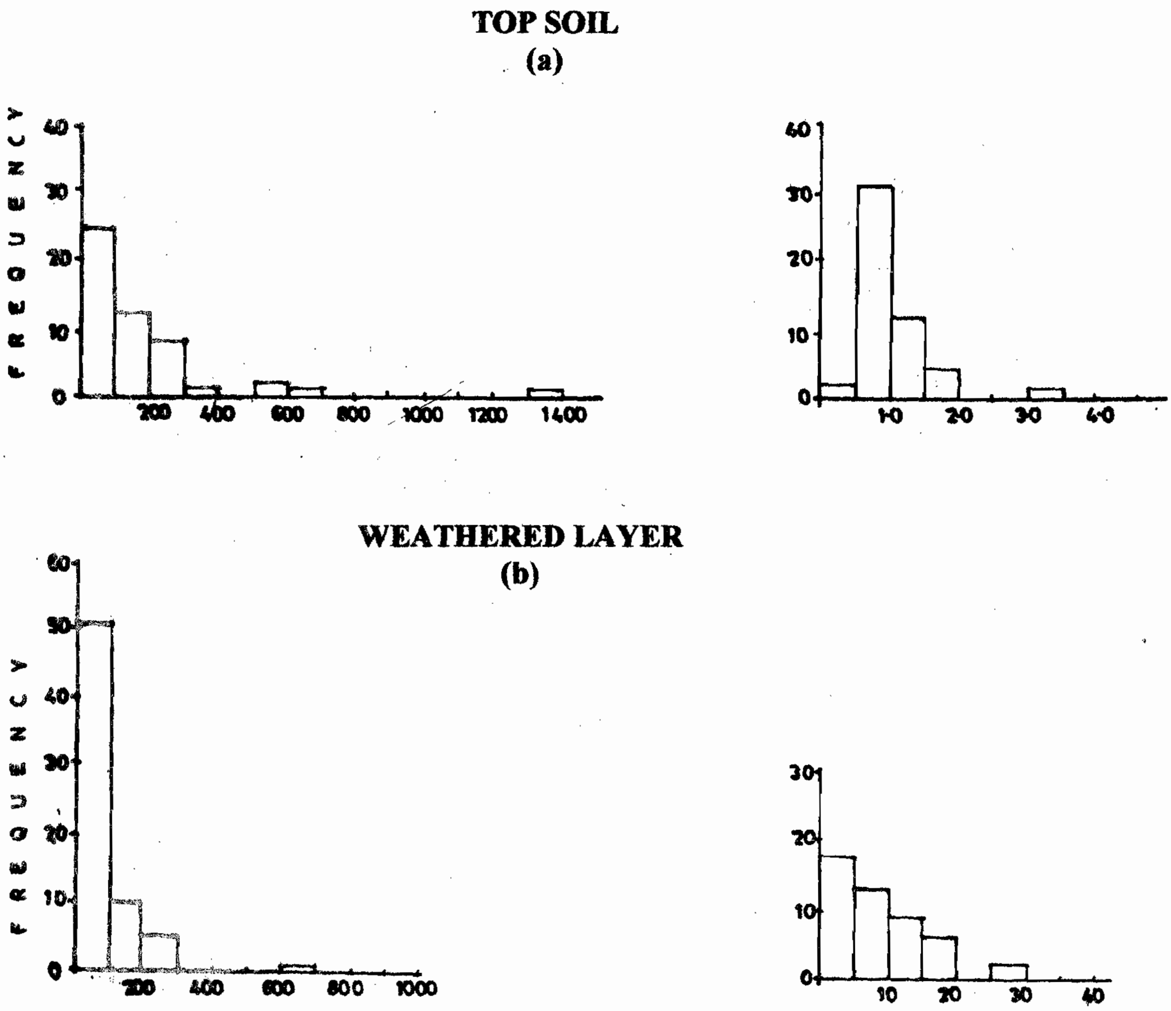


Fig. 3: Histograms of (a) Top Soil (b) Weathered Layer Resistivity and their Corresponding Thicknesses.

AQUIFER TYPES AND THEIR GEOELECTRIC/HYDROGEOLOGIC CHARACTERISTICS

Three of the five aquifer types earlier identified by Olorunfemi and Fasuyi (1993) were delineated within the study area. They are:

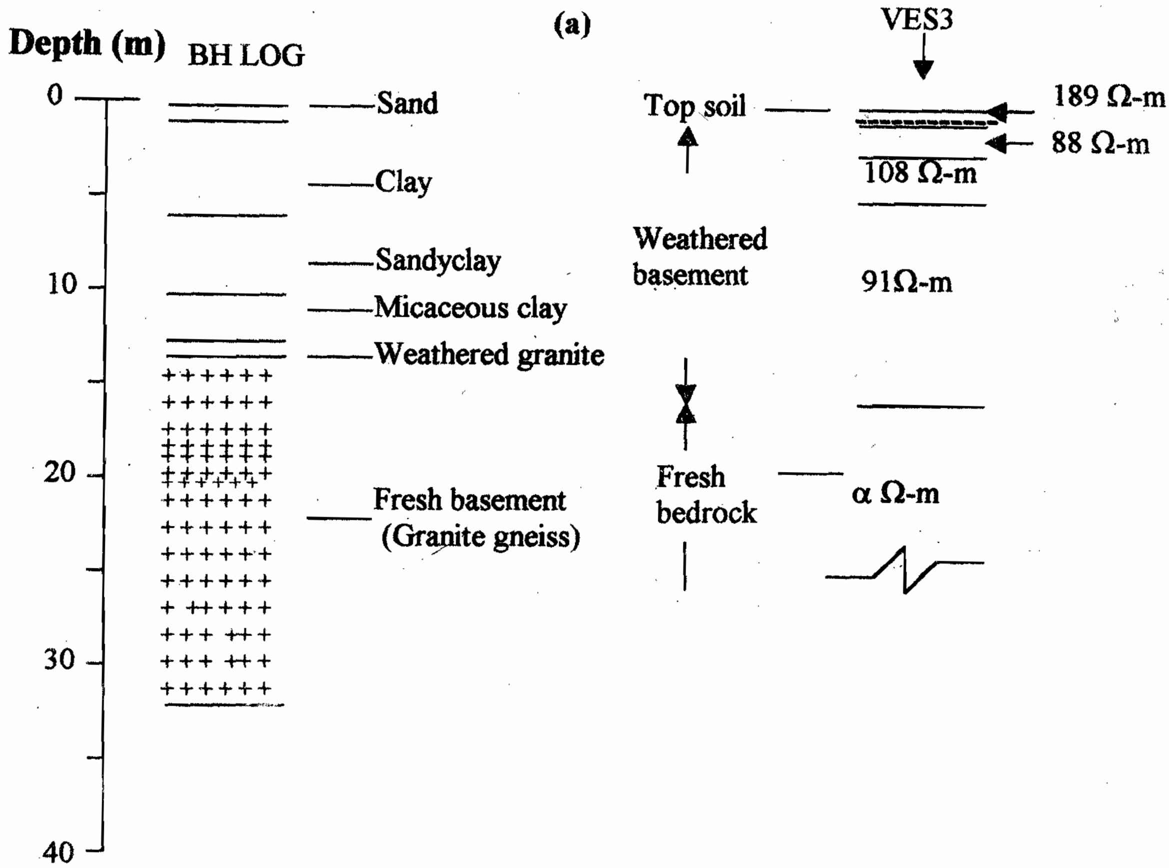
Type I: Weathered layer aquifer (w)
Type II: Weathered/fractured (unconfined) aquifer {W/F (u)
Type III: Weathered/fractured (confined) aquifer {W/F (c)}

Type I weathered layer aquifer – The mode of occurrence of this aquifer type as earlier discussed by Olorunfemi and Fasuyi (1993) were also detected in the area of study. This aquifer type is characterized by a sharp transition between the weathered layer and the fresh bedrock (e.g. Fig. 4a). The resistivity depth sounding curve types include A, H, KH and HKH (e.g. Fig 4b). The weathered layer is exhibited in some of the geoelectric curves as a three-layer bow shaped (H – type) curve where the topsoil, the weathered layer and the bedrock are represented. In some cases it is exhibited as a four-layer bell and bow (KH) type curve where a resistive layer provides an ascent at the leftmost segment of the curve (David and Ofrey 1989). The borehole report show that the borehole drilled at VES 3 at Oranran (Fig. 4a) yield is >1.0 L/S.

The weathered layer aquifer has the highest cumulative frequency of occurrence in the study area. It accounts for 71.43% of the total aquifers in the study area (Table 1). Out of the five lithological units investigated in the area, the gneiss and migmatite undifferentiated have the highest thickness of weathered layer, varying from 0.8-29.4 m

LOCALITY ORANRAN

(a)



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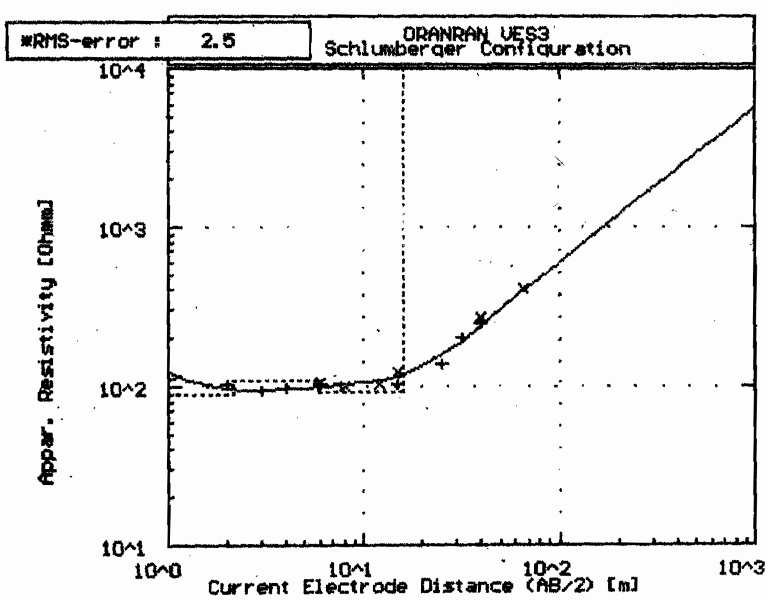


No	Res	Thick	Depth
1	172.8	0.4	0.4
2	87.9	1.8	2.2
3	107.8	3.7	5.9
4	90.9	10.0	15.9
5100000.0		-.-	-.-

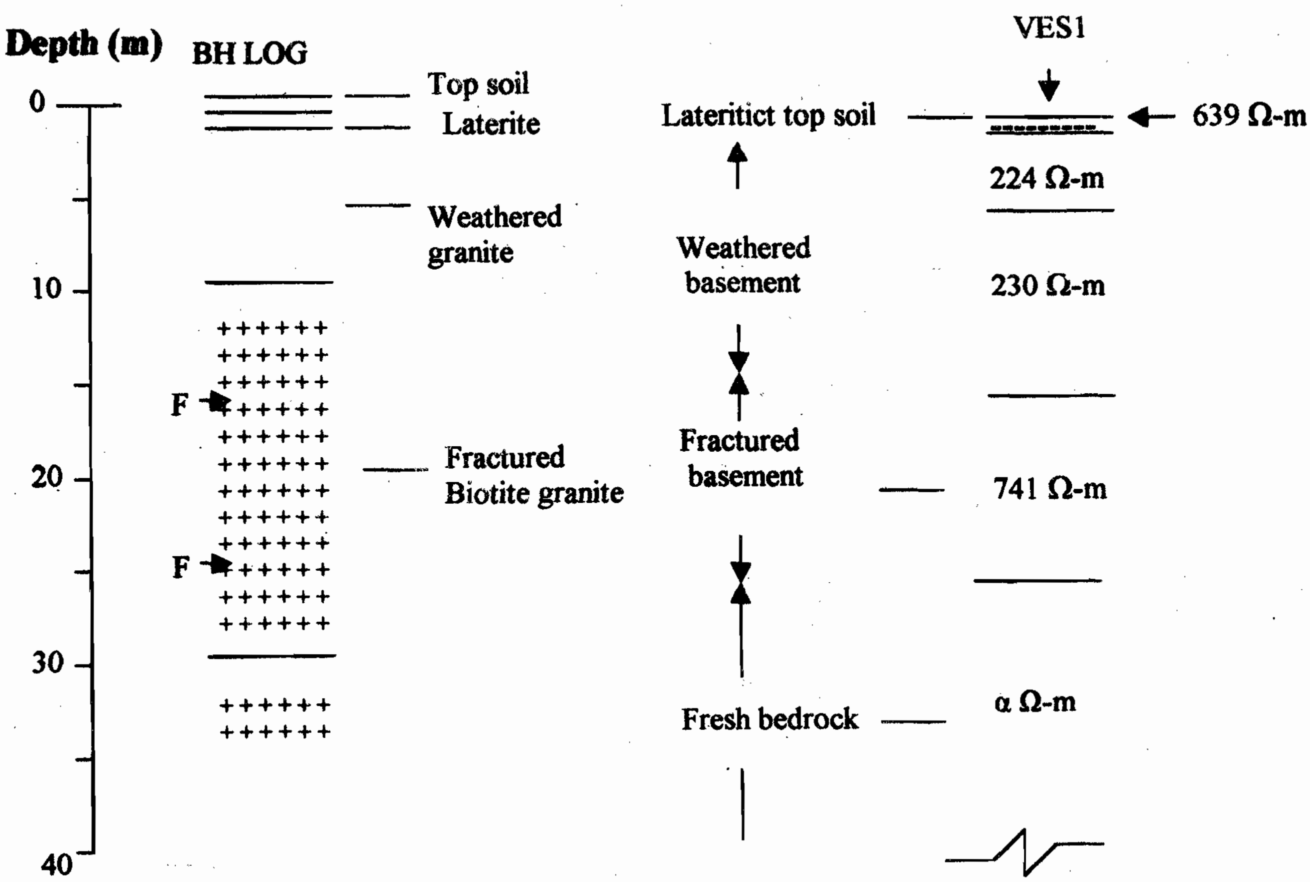
* RMS on smoothed data

Fig. 4: (a) Weathered layer Aquifer type (Locality Oranran)

(b) Corresponding depth sounding curve (VES 3 HKH type).

LOCALITY EGBEDAOKO

(a)



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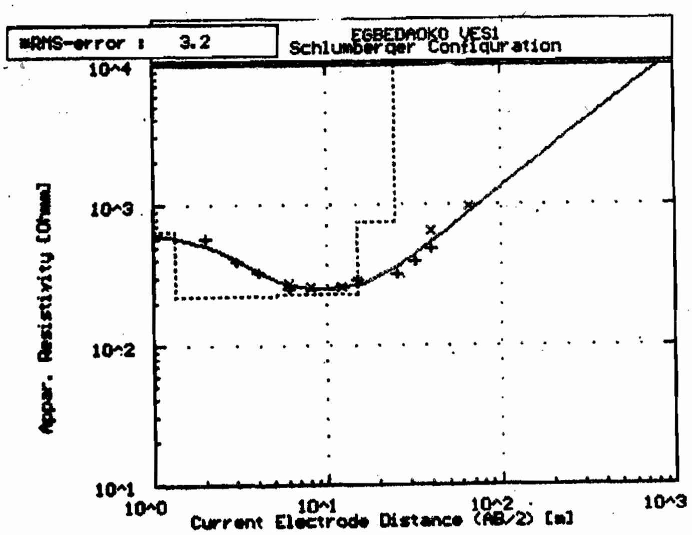


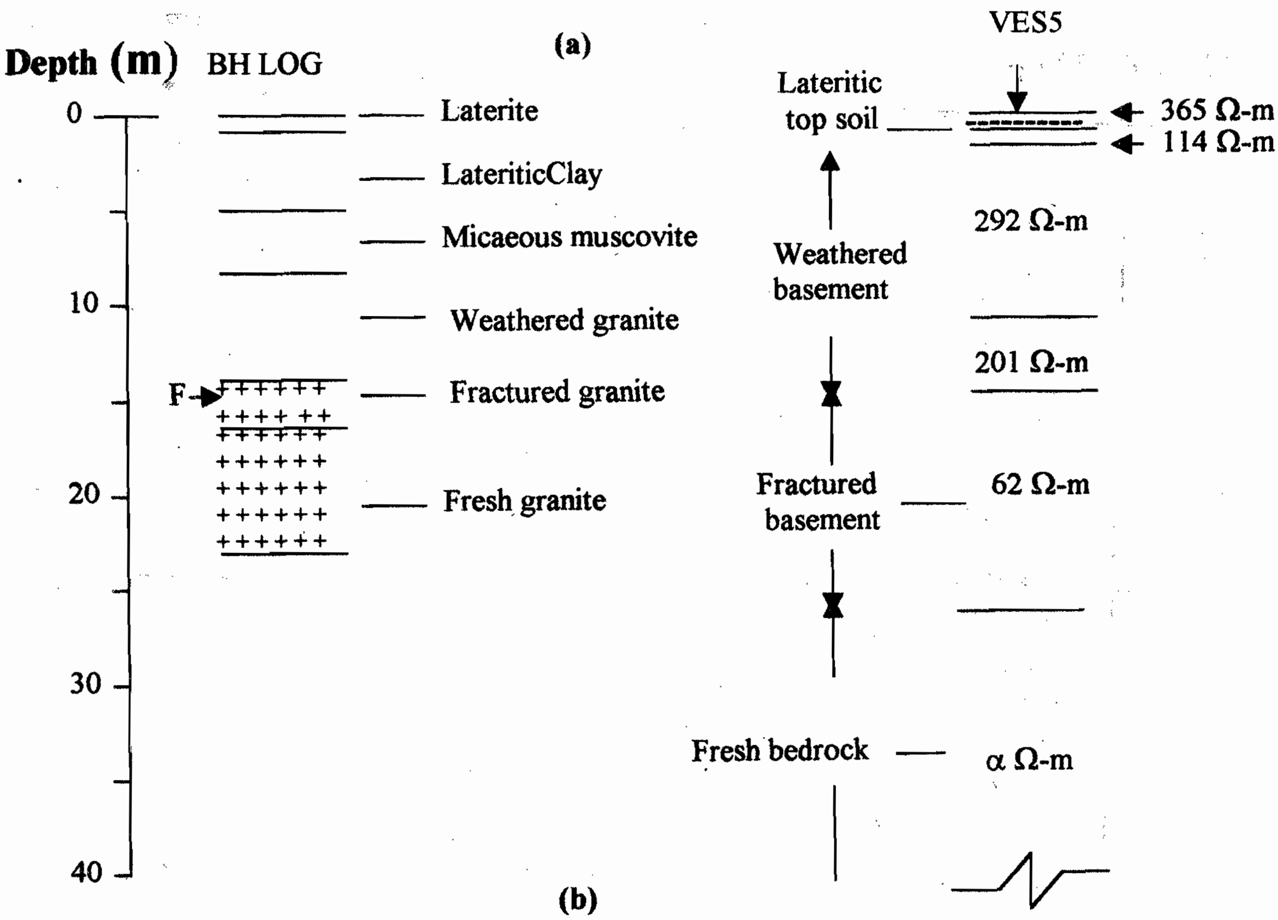
No	Res	Thick	Depth
1	639.0	1.3	1.3
2	224.4	3.7	5.0
3	229.6	9.7	14.7
4	741.1	10.0	24.7
5	100000.0	-.-	-.-

* RMS on smoothed data

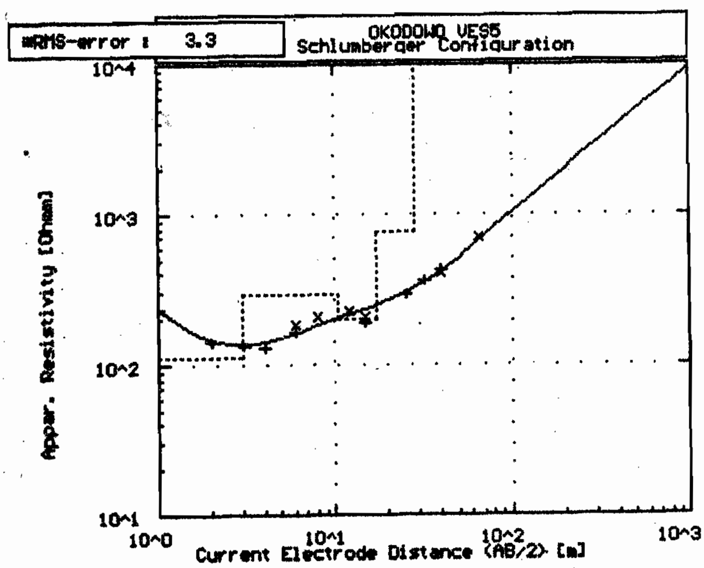
Fig. 5: (a) Weathered/Fractured (unconfined) Aquifer Type Locality Egbeda-Oko (b) Corresponding depth Sounding Curve (VES 1 HA type)

LOCALITY OKODOWO

(a)



(b)



No	Res	Thick	Depth
1	364.5	0.5	0.5
2	113.9	2.5	3.0
3	292.0	7.5	10.5
4	201.5	6.9	17.3
5	762.4	10.8	28.2
6	100000.0	-.-	-.-

* RMS on smoothed data

Fig. 6: (a) Weathered/Fractured (unconfined) Aquifer Type Locality Okodowo

(b) Corresponding depth Sounding Curve (VES 5 HKHA type).

LOCALITY AWALA

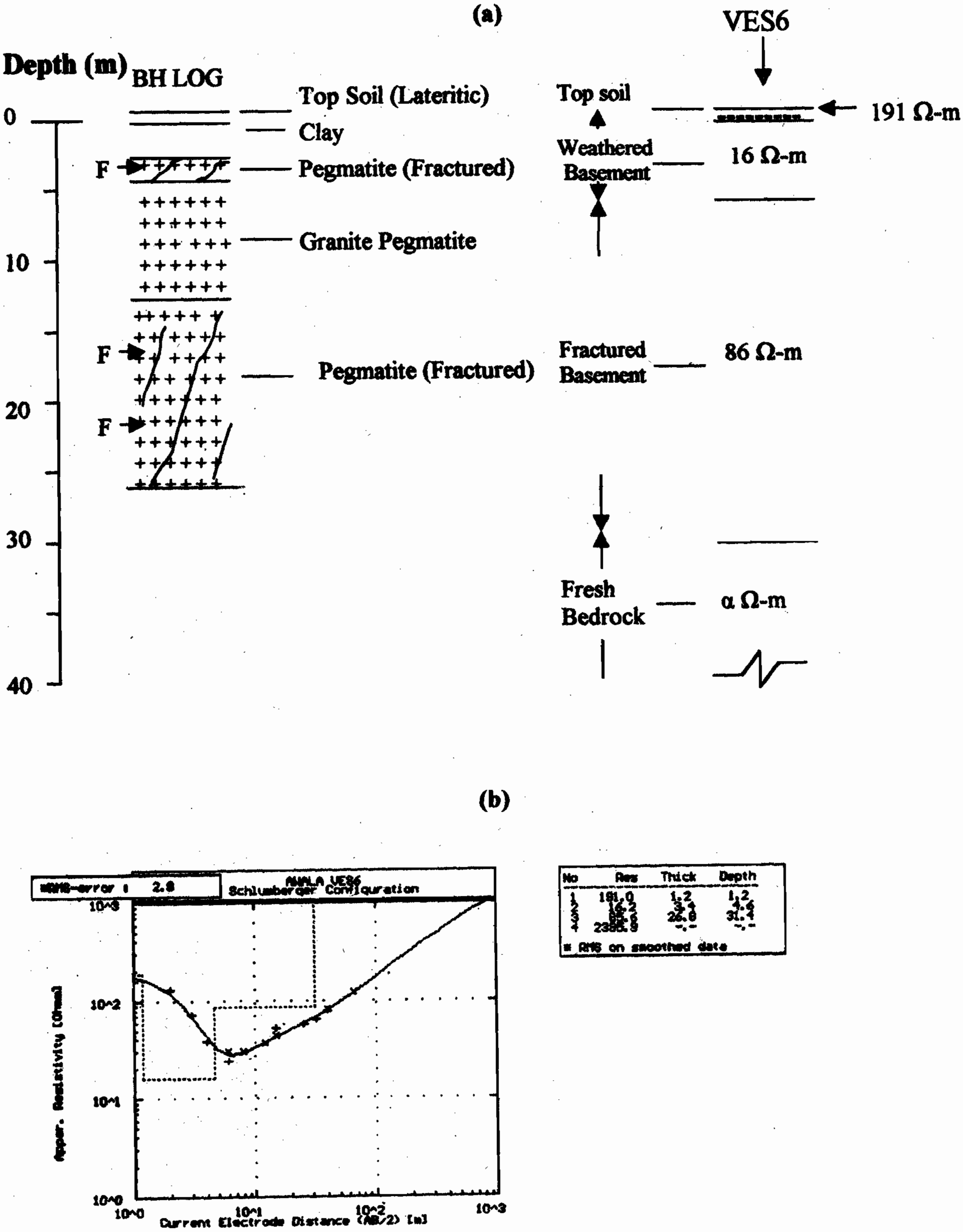


Fig. 7: (a) Weathered/Fractured (confined) Aquifer Type Locality Awala (b) Corresponding depth Sounding Curve (VES 6 HA type).

Table 1: Percentage occurrence of aquifer type for different geologic units in the study area.

SS	Pegmatite	Fine grained granite	Porphyritic granite	Gneiss and migmatite undiff.	Charnockite
Range of weathered Thickness	5.8 - 27.1	3.1 – 13.3	2.2 - 19	0.8 – 29.4	3.0 – 10.3
Mean value	15.72	6.53	9.31	7.91	6.7

Table 2: Value for weathered layer thickness in the study area.

Aquifer Type	VES NO	Cumulative Occurrence of Aquifer Type	Pegmatite	Fine grained granite	Porphyritic granite	Gneiss and migmatite undiff.	Charnockite
W	35	71.43	33.33	44.44	70.00	89.47	100.00
W/F (u)	11	22.45	66.67	33.33	30.00	5.26	0
W/F(c)	3	6.12	0	22.22	0	5.26	0
Σ	49	100%	100%	100%	100%	100%	100%
Total % of Fractured Aquifers	14	28.57	66.67	55.55	30.00	10.52	0

with a mean value of 7.9 m, followed by the pegmatite with thickness varying from 5.8-27.1 m with a mean of 15.72 m. The porphyritic granite weathered layer thickness ranges between 2.2-19 m with a mean value of 9.31 m; Charnokite has a thickness range of 3.0 – 10.3 m with a mean value of 6.7. The F-grained granite weathered layer thickness ranges from 3.1 – 13.3 m with a mean of 6.53 m (Table 2).

Type II Weathered/fractured (unconfined) aquifer - According to Olorunfemi and Fasuyi (1993), this aquifer type is characterized by a detectable transition zone otherwise referred to as partially weathered and or fractured zone between the weathered layer and the presumably fresh bedrock (e.g. Fig.5a – 6a). The resistivity value of the aquifer varies from 110 – 1000 Ohm-m and the thickness ranges from 1.6 to 23.2 m. The resistivity curve types include the HA, KH, HKH and HKHA (e.g. Fig. 5b – 6b). The groundwater yield of this aquifer type is about the highest if the fracture zone is significantly thick with high fracture frequency. Borehole drilled within this aquifer type should be able to take advantage of both the weathered and the fractured zone. The weathered/fractured (unconfined) aquifer has a cumulative percentage occurrence of 22.45% (Table 1). From borehole record, the Pegmatite has the highest percentage occurrence of fractures with a value of 66.67%, followed by the Fine-grained granite with 55.55%. Porphyritic granite has a value of 30%, Gneiss and Migmatite undifferentiated has 10.52%, while the charnockite indicated no fracture (table 1).

The two bore holes displaying this aquifer type (Fig. 5a and 6a) in the study area show that the groundwater yield varies from 1.2 – 2.0 L/S. The yield is expected to increase with increase in fracture thickness and density.

Type III Weathered/fractured (confined) aquifer - This aquifer type is a combination of an upper weathered layer and an enclosed aquifer within the fresh basement fractured zone. The borehole from which the aquifer type was identified is characterized by very thin weathered layer as shown in (Fig. 7a). The VES curve types include HA and HKH type (Fig. 7b). Borehole report show that the borehole drilled at VES 6 Awala (Fig. 7a) yield is >2 L/S.

The groundwater yield varies depending on the thickness of the weathered layer, the thickness and frequency of the fractured zone. The aquifer yield is high for a thick weathered layer with resistivity range from 150 – 250 Ohm-m and fractured zone with high fracture frequency. Boreholes penetrating this aquifer should take advantage of both the weathered and fractured zone with the borehole terminating within the fractured zone. The percentage occurrence of this aquifer type in the study area is 6.12% (Table 1).

HYDROGEOLOGICAL SIGNIFICANCE OF FRACTURES IN GROUNDWATER DEVELOPMENT

The results above show that weathered layer aquifers combined with fractured bearing basement aquifers are relatively more productive than the weathered layer aquifers.

This is as a result of high permeability of such fractured zones especially when it has a direct link with the recharge source. The yield of the overburden layer is often reduced by its clay content due to low permeability.

Out of the five lithological units investigated in the study area, the charnockite displayed no fracture. Gneiss and migmatite undifferentiated, porphyritic granite, F-grained granite and pegmatite were fractured. The VES interpretation results and the borehole log showed that the fractures occurred mainly between 4 – 28 m depths.

In most cases, factures, joints and fissures tend to close at depth greater than 70 m (Verma, Rao and Rao, 1980). Discontinuous basement aquifers, with variable porosity and permeability resulting in widely variable yields do exist in the basement complex areas to supply adequate quantity of groundwater for both domestic and industrial use. Groundwater storage mainly depends upon the total thickness of both weathered and fractured zones and the fracture frequency.

CONCLUSIONS

The delineation and characterization of aquifer types in the basement complex rocks of the study area have been carried out. Three aquifer types were identified, namely weathered layer aquifer, weathered/fractured (unconfined) aquifer and the weathered /fractured (confined) aquifer. The weathered layer aquifer constitutes the principal water-bearing unit in the area.

Basement fractures increase in density with depth from 4 m to a maximum at about 28 m and then decreases to almost zero at a depth greater than this. The pegmatite have been found to be the most highly susceptible to fracturing, followed by Fine – grained granite, the porphyritic granite and lastly by gneiss and migmatite (undifferentiated). The charnockite is not fractured at all. Its aquifer is predominantly the weathered layer type. Therefore, boreholes located within the pegmatite, Fine-grained granite, the gneiss and migmatite undifferentiated are expected to be more productive than those located within the charnockitic rocks, in the area of study.

As a result of the complex nature of basement aquifer types, there is need for careful selection of borehole site to take advantage of both the weathered and the fractured basement for optimum groundwater yield.

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