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The Aquifer System Within the Crystalline Rocks of the Jos - Plateau and Environs.

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ABSTRACT

An investigation into the aquifer system of the crystalline rocks within Jos and environments was carried out. The area covered some selected sites from the northern senatorial zone down to southern senatorial zone of the state. The geology of each site was study to establish the grain size, texture and geological structures associated with each of the rock type. The rock types in the area are: migmatites, gneisess, granites, and basalts. Vertical electrical sounding (VES) using the Schlumberger full electrode spread was adopted for the geophysical investigation. The spread ranged from 95m-215m. the software IX1D Package developed by Interpex Limited was used for plotting data and iteration of the curves. Thereafter drilling of favourable sites were carried out as the clients could afford at that time using PAT DRILL 301, 401, and Indian Motor Rigs. The VES curves showed that the basement rocks are characterized by A, KHA and KHK curves types. Most of the VES points have four geoelectric layers whose apparent resistivities range from 19Ω -344Ω. The younger granites are characterized by H and HA curves of which the H curves dominate. Here, the geoelectric layer and the apparent reistitvies range from 4-5 and 21 Ω -834Ω respectively. Within the basement complex, drilling revealed that the aquifers are located mainly within the basement rocks, while within the younger granites, they are located at the contact between the regolith and the crystalline rocks and also within the crystalline rocks as fractures. In terms of drillabiblity, the aquifers within the crystalline rocks have low drillability than the unfractured or fresh rocks. Whereas within the regolith, the aquifers have high drillability than the non aquiferious clay. Drilling also showed that coarse grain rocks are more aquiferious than fine grain rocks when weathered. From the investigations, the chances of getting groundwater is higher within the basement complex than the younger granites as the basement complex are more deformed and altered.

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INTRODUCTION

Apart from rain water, groundwater is another good source of portable water. Groundwater is good not only for domestic use but also for industrial and agricultural purposes. Groundwater like mineral deposits is not readily available everywhere hence the need to precede the development of groundwater by geological and geophysical surveys in order to locate the position and nature of the aquifer.

Various geophysical methods such as gravity, seismic and electrical resistivity can be used to search for groundwater. The methods employed for this research work are geological, hydrogeological and electrical resistivity using the Schlumberger electrode configuration. Afterwards, favourable sites were drilled which also served as test for the geophysical data that had been generated.

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The aim of this work is to be achieved through the following objectives:

i. Geological field study visits
ii. Vertical electrical sounding
iii. Drilling and lithologging of water boreholes

Location and physiography

The boreholes were sited in Jos North, Basa, Jos South, Barkin Ladi, Pankshin, Quan-Pan and Shendam Local Government Areas of plateau state.

With the exception of Quan-Pan and Shendam LGAs which are undulating lowlands, the rest are highlands that composed of rugged hills as a result of the evolution of the younger granites. The area being a plateau also serve as watershed for the surrounding lands as occasioned by the dendritic drainage system from which some major rivers originated. Figure 1shows the locations of the boreholes.

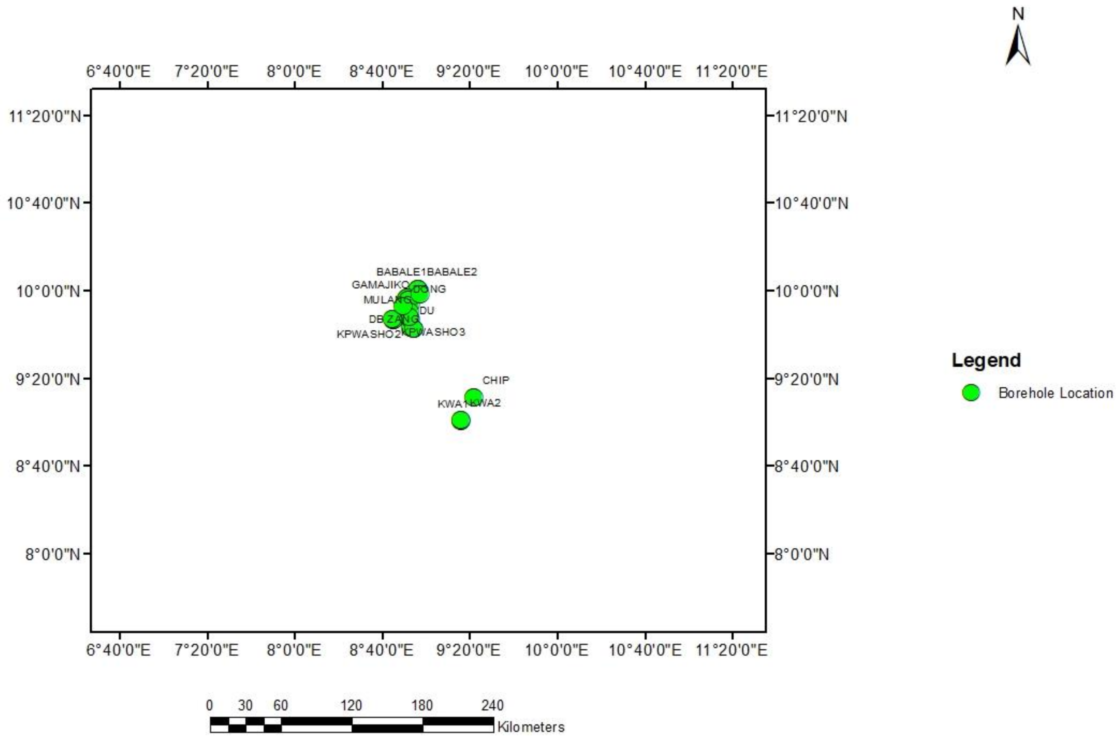

Figure 1. Location map of the boreholes within the study area

Geology and Hydrogeology

Macleod et'al 1971 outlined the succession of the geology of the Jos Plateau as crystalline basement, younger granite, older basalt, alluvium and newer basalt, whereas Mallo 2007, established the rock succession of the Jos plateau as the basement complex (migmatite, gneisses and older granites), the younger granites (granites, porphyries and rhyolites), older basalt (lava flows now largely decomposed and the newer basalt (lava flows and volcanic cones). Obaje 2009, identified the geology of Nigeria as made up of the basement complex, the younger granites and the sedimentary basins.

Field study revealed that the basement complex rocks include: gneisses, older granites and pegmatites with dolerite and basalt occurring as mafic dykes. Within the younger granite province, the rocks include granites of differing colours viz: pink, white and gray and rhyolites. Also from field study the granites range in grain size from medium to coarse grained. In terms of deformation, the basement rocks are more fractured (with the exception of rhyolite) and are more weathered than the younger granites and rhyolite.

The drainage system is dendritic, which is typical of crystalline environments. Sources of water in the areas are streams, rivers, wells and boreholes. D.C.Ozoko (2014), pointed out that aquifers in the crystalline basement rocks are constituted in the weathered and fractured portion of the rocks. Dibal et'al (2016), classified groundwater aquifers into alluvium, weathered overburden and fractured crystalline aquifer. He further stated that the depth ranges for which groundwater exist in these aquifers are 4-5m, 10-15m and 30-35m. Raghunath 2007, stated that factors that should be considered in groundwater exploration are: topography, geology, existing wells and streams within the vicinity, climate, rock alteration and deformation. Fetter 2007, mentioned that groundwater exploration consists of examination of air photos, topographic and geologic maps, logs and reports of existing wells, a walking survey followed by geophysical surveys and test wells. Fetter 2007, classified geologic aquifers as unconsolidated materials, lithified sediments and crystalline rocks. TEN and COMEG (2017) unpublished training manual for groundwater development for staff of NIMG stated that for accurate assessment of the potential for groundwater, the following should be considered: geological maps, geology, sources of contamination, accessibility to users, topography, vegetation, surface water, subsurface condition, subsurface soil and geophysics. The geology of the areas is as shown in figure 2.

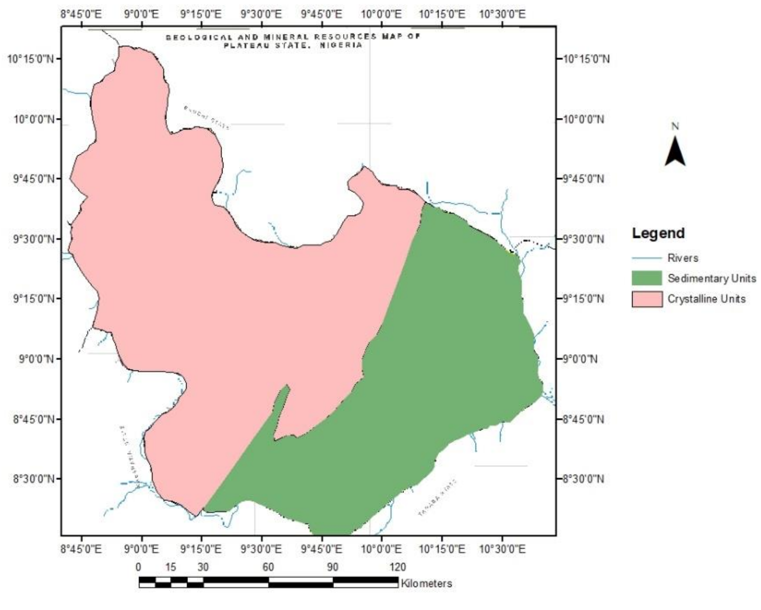

Figure 2. A simplified geologic map of the Jos Plateau and environs (After NGSA 2006)

Materials and Methods

Materials

The materials employed for the research are: global positioning system, clinometer compass, hammers, Abem and Omegah tetrameters/accessories, field note book, pen, ARCGIS, water borehole drilling rigs, casings, sharp sand, cement, and bags

Method

Before the commencement of the geophysical survey at each site, a geological investigation of the rocks with respect to their lithologies, geological structures, composition, grain size, texture, degree of weathering, jointing, faulting and foliation were carried out. In addition to these, wells and streams/rivers were also investigated to determine whether they are perennial or not.

The geophysical investigation involved the vertical electrical sounding technique for which the Schlumberger electrode configuration was adopted. The current electrode spacing AB/2 mostly ranged from 1.5 to 125m and a maximum spread of 215. At each VES point, the array was oriented as much as possible perpendicular to the local structures in the areas. Abem terrameter SAS300 and Omega terrameters were used for the generation of VES data. The field data were then reduced to apparent resistivities after which the computer software IX1D was used for plotting and iteration. The VES curves are as shown in figure 3 and 4.

Drilling of VES points that were favourable was carried out using PATDRILL301, 401, with Atlas Copco compressor and Indian Motor Rigs. The cuttings were also logged as this can be used to confirm the VES curves and also helped to confirm the location of aquifers. Figure 4 shows the lithologs of the drilled sites within the study area.

RESULT AND DISCUSSION

Subsurface layers and their geoelectric characteristics.

Within the basement environment, the curve types obtained are A, KHA and KHK. Most of the VES points have four geoelectric layers whose apparent resistivities range from 19 Ωm. -344 Ωm. At Babale the predominant curve type is the type A curve. Figure 3a-3f.

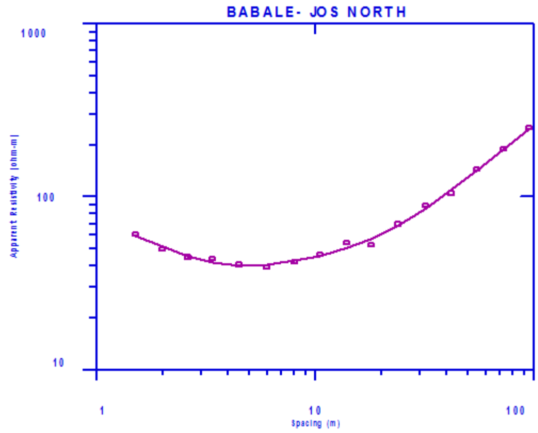

Figure 3a: VES curve for Babale, Jos North LGA

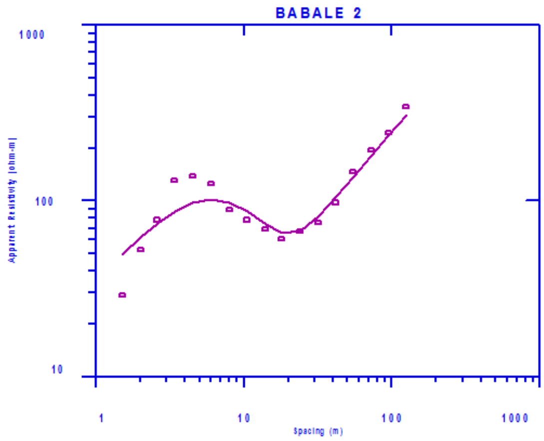

Figure 3b: VES curve for Babale 2, Jos North LGA

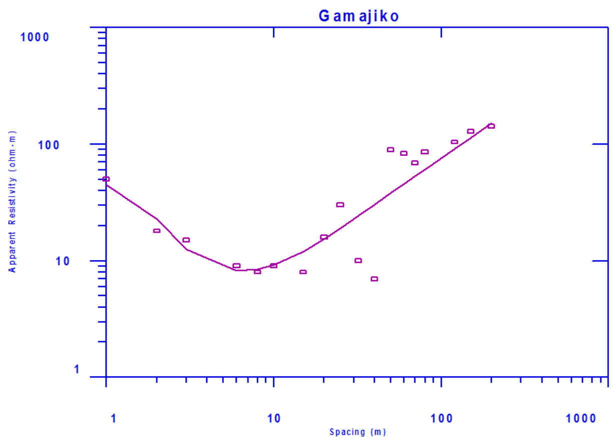

Figure 3c: VES curve for Gamajiko, Jos North LGA

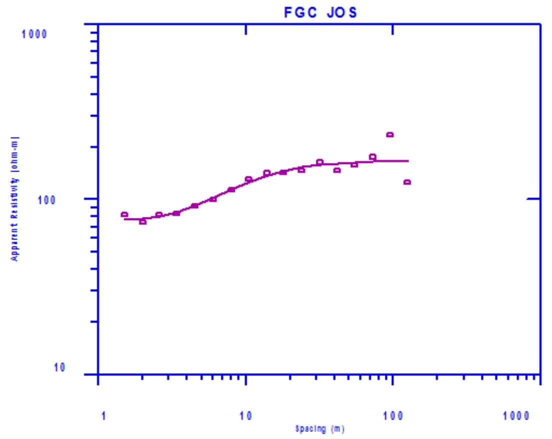

Figure 3d: VES curve for FGC, Jos North LGA

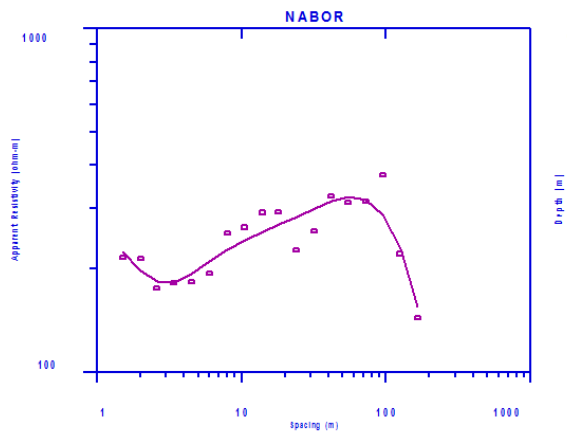

Figure 3e: VES curve for Nabor, Jos North LGA

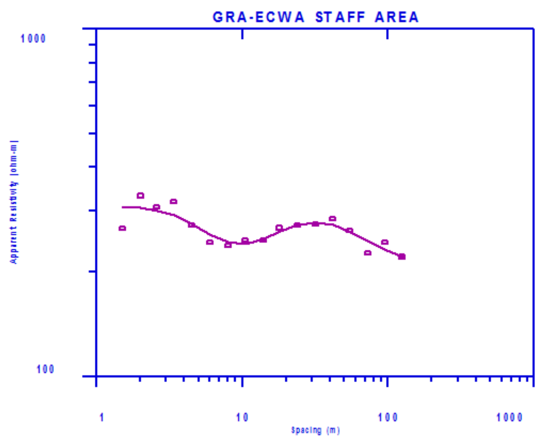

Figure 3f: VES curve for GRA, ECWA Staff Area, Jos North LGA

Within the younger granite environment, the curve types obtained are: H and HA of which the H type curves are dominant. In this environment the geoelectric layers ranged from 4-5, whose apparent resistivties also ranged from 21 Ωm -834 Ωm. Figure 4a-4h.

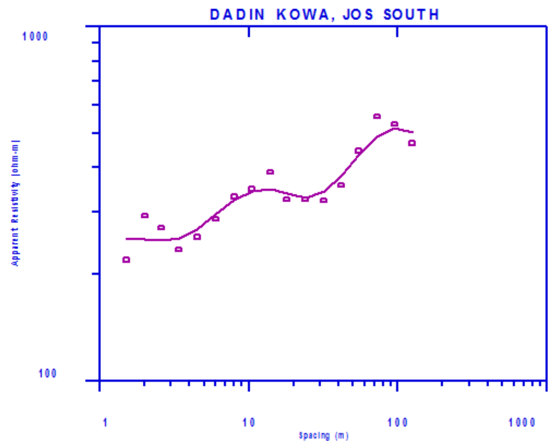

Figure 4a: VES curve for Dadin Kowa, Jos South LGA

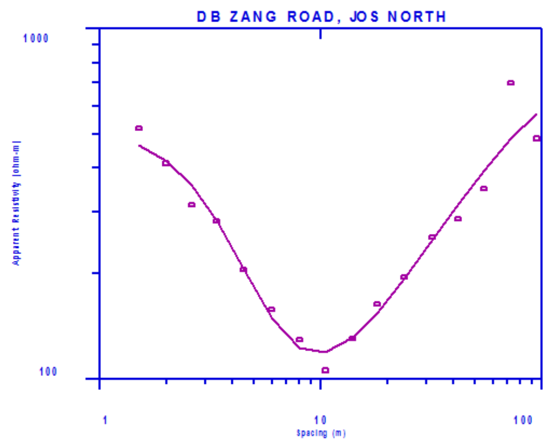

Figure 4b: VES curve for DB Zang Road, Jos North LGA

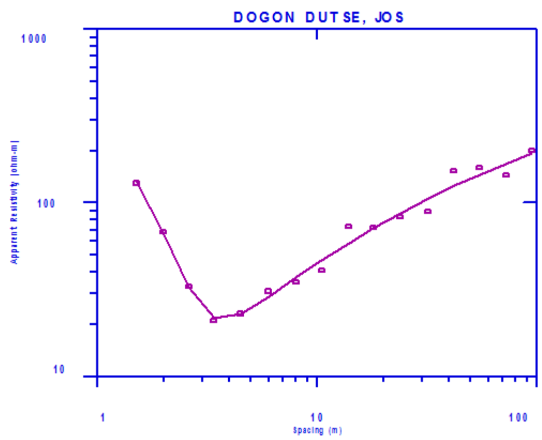

Figure 4c: VES curve for Dogon Dutse, Jos North LGA

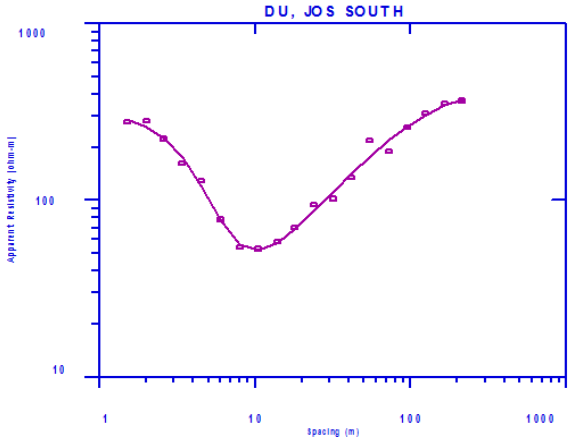

Figure 4d VES curve for DU, Jos South LGA

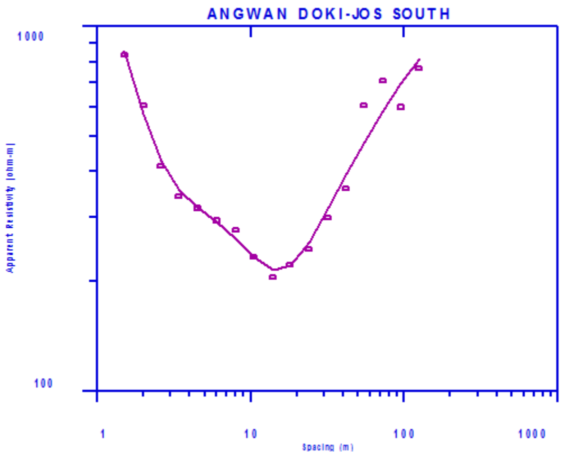

Figure 4e: VES curve for Angwan Doki, Jos South LGA

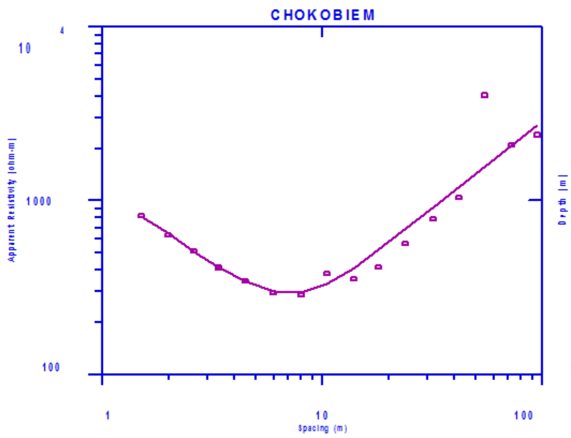

Figure 4f: VES curve for Chokobiem, Jos South LGA

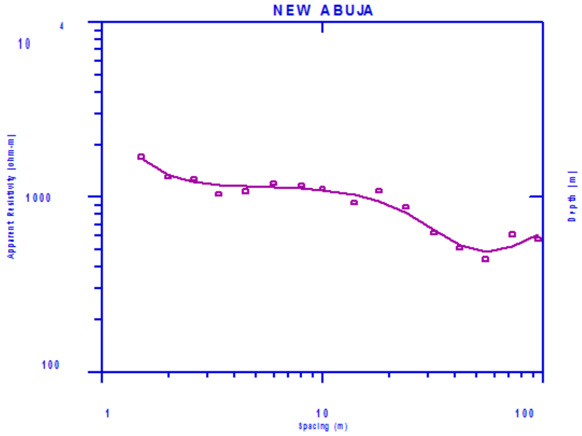

Figure 4g: VES curve for New Abuja, Jos South LGA

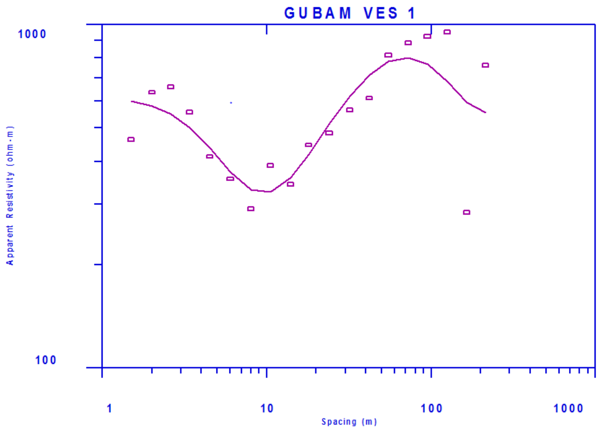

Figure 4h: VES curve for Dong, Jos South LGA

Within the volcanic (basaltic) environment, the resistivities ranged from 45.1 Ωm. to 1474.5 Ωm. the curve types are QA, QH, KH and H, figure 5a-5c. The contacts between the overburdens and the crystalline rocks are not aquiferious as it is expected due to the vesicular nature of the basalts, the water cannot accumulate between the contact but percolate through the vesicles. Obviously, the aquifers are located within the crystalline rocks as vesicles and fractures.

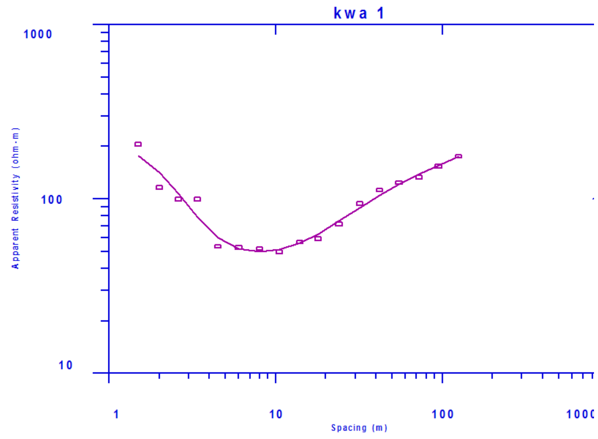

Figure 5a: VES curve for Kwa 1, Quan-Pan LGA

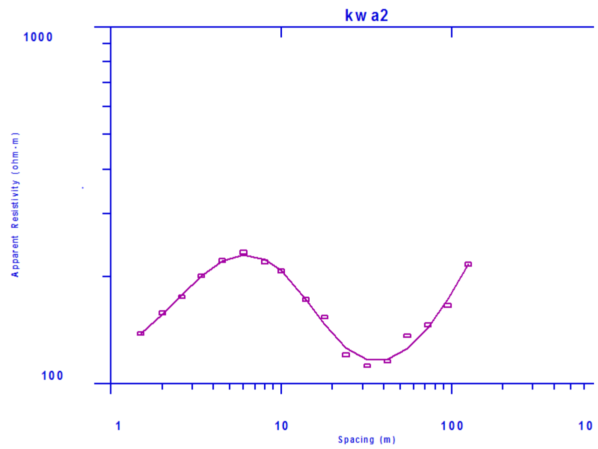

Figure 5b: VES curve for Kwa 2, Quan-Pan LGA

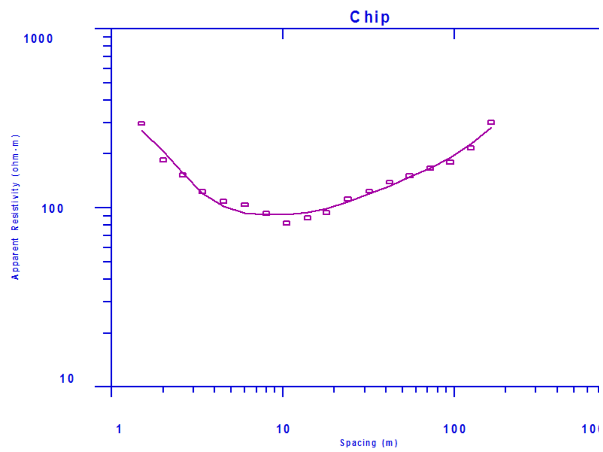

Figure 5c: VES curve for Chip, Pankshin LGA

Drilling

Five water boreholes were drilled within the basement complex. Two at Babable, two at Farin Gada and one at Gamajiko. At Babale 1, the basement is so weathered such that there is no difference in the drillability between the overburden and the weathered basement. From the cuttings logged, the basement rock is gneiss. At VES 2 in Babale, the overburden overlies the same basement rock too. At this site, the borehole intercepted a basaltic dyke. The basalt is highly fractured as indicated by the low drillability. The yield of these boreholes are high.

At ECWA Staff Area, around the Cocin Church, the overburden is underlain by applo-pegmatite as indicated by the cuttings. The copious water that was pumped out during drilling and well completion signified that the basement rock is highly fractured and aquiferious.

At down base, near ECWA Staff Area, the overburden is underlain by Older Granite. This rock is poorly fractured as indicated by the variable drillabilities and the amount of water that was pumped out during drilling and well completion. At Gamajiko, the overburden is underlain by applo-pegmatite which is highly fractured as viewed on the wall of a well within the vicinity and also from the cuttings. The borehole intercepted a mafic dyke. The drillabilities varies due to the presence of aquiferous fractures. The yield is excellent as judged from the drilling and flushing of the well.

Within the basement complex, the aquifers are mostly found within the fractured portions of the rocks.

Within the younger granite, a total of 16 boreholes were drilled. The overburdens are underlain by the granitic rocks mostly biotite granites. The aquifers mostly occur at the base of the overburden. i.e. at the contacts between the overburden and the crystalline rock where the concentration of quartz particles increases towards the overburden-younger granite contact as is the case at Rahol Kaneng, Bisichi, kpasho, Lamingo Junction and Dadin Kowa. The young granites are weakly aquiferous. Examples are: Rock Haven, Sabon Barki, and DB Zang Road. The younger granites are less fractured compare to the basement complex.

Within the basaltic rock, especially at chip and kwa, where four boreholes were drilled, the fractures occur within the crystalline rocks due to the vesicular and fractured nature of the basalt, their overburdens hold no water. All the four boreholes are of very good yield.

Identification of aquifers can also be done through drilling. Drilling has revealed that while drilling the overburden, the drillability of non aquiferious layers are lower than the drillability of aquiferious layers except for hardpan. This is due to the concentration of quartz particles within the aquiferious zones which makes it difficult to penetrate. The reverse is the case for the fractured aquiferious crystalline rocks, where the drillability is lower for the aquiferius fractures and higher for the unfractured /fresh crystalline rocks. For the reason that water flowing through the fractures has weathered the rocks in contact with the water. Lithologs of the borehole's concord with the VES data /curves. Table 1 shows the location and the characteristics of some selected boreholes drilled within the study area.

From the lithologs a generalized profile was established as follows: top soil, laterite, clay, weathered rock, fractured/fresh rock. In some cases, the laterite can be missing due to erosion e.g. at Babale, Figure 6a-6i.

Table 1. characteristics features of boreholes within the study area.

S/N	LOCATION OF BOREHOLE	COORDINATE	DEPTH (M)	AQUIFER	TERRANE	REMARK
1	Babale 1	N10° 01' 12", E8° 56' 19"	26	Weathered basement	Basement (Gneiss)	Very good yield
2	Babale2	N10° 01' 25", E8° 56' 19"	30	Fractured mafic dyke/joints	Basement (Gneiss)	Very good yield
3	ECWA Staff	9° 57' 02"N, 8° 50' 53"E	27	Overburden/fracture	Basement (Aplite)	Very good yield
4	Downbase	9° 57' 17"N, 8° 51' 11"E	90	Fractured	Basement (older granite)	Good
5	Federal low cost	N9° 52' 41" E8° 50' 40"	28	Overburden	Younger granite	Good
6	Db zang road Jos	9° 54' 14"N, 8° 52' 58"E	38	Weathered overburden	Younger granite	Good
7	Du	9° 01' 18"N, 8° 52' 44"E	70	Fracture	Younger granite	Very good
8	Angwan Doki	N9° 47' 27",8° 52 41.6"	33	Overburden	Younger granite	Good
9	Nyango Gyel	9° 49' 44"N,8° 51' 25"E	76	Fracture	Younger granite	Poor
10	Dadin kowa	N9° 51' 22" E8° 51' 18"	23	Overburden	Younger granite	Good

S/N	LOCATION OF BOREHOLE	COORDINATE	DEPTH (M)	AQUIFER	TERRANE	REMARK
11	Rock Haven	N9 º 56' 29" E8 º 51' 39"	66	Fracture	Younger granite	Poor
12	Lamingo	N9 º 51' 22", E º 8 51' 18"	27	Overburden	Younger granite	Average
13	Zarmaganda	N9 º 50' 48.6", E08 º 52' 23.8"	40	Fracture	Younger granite	Good
14	Bisichi1	9º 42' 58"N,8º 54' 22"E	30	Overburden	Younger granite	Good
15	Bisichi2	9º 43' 01"N, 8º 54' 21"E	38	Overburden	Younger granite	Good
16	Dadin Kowa2	N9º 51' 19.83", E8 º 51' 11.78"	21	Overburden	Younger granite	Good
17	Mulang	N9 º 48' 38.7",E8 º 52' 17.7"	28	Overburden/fracture	Younger granite	Good
18	kpwasho1 near Kwall	9º 47' 12"N, 8º 44' 56"E	36	Overburden	Younger granite	Good
19	Kpwasho 2 near Kwall	9º 47' 11"N, 8º 44' 48"E	28	Overburden	Granite	Good
20	Kpwasho 3 near Kwall	9º 47' 35"N, 8º 44' 15"E	22	Overburden	Younger granite	Good
21	Kwa1	9º 00' 45"N, 9º 15' 39"E	31	Fracture/porosity	Vesicular basalt	Good
22	Kwa2	9º 01' 18"N, 9º 15' 59"E	26	Fracture/porosity	Vesicular basalt	Very good
23	Dong	9 º 53' 11"N, 8 º 49' 87"E	100	Fracture	Younger granite	Poor
24	Chip	9º 11' 30"N, 9º 21' 37"E	52	Fracture/porosity	Vesicular basalt	Good
25	Gamajiko	N9 º 58' 41'', E8 º 51' 24''	70	Dyke/ fractures	Applo-pegmatite	Very good

Conclusion

From the geological investigations, the geophysical survey and the drilling information, the following conclusion were drawn:

The basement rocks are more weathered and more fractured than the younger granite.

Vertical electrical sounding has revealed that within the overburden, weathered layers that are rich in quartz have high resistivities than clayey layers.

For the regolith, the drillability of aquiferious zones is higher than that of the non aquiferious zones. On the other hand, for the crystalline environment, the drillability of aquiferious fractures are lower than that of the fresh and unfractured rocks.

Drilling also showed that coarse grain rocks are more aquiferious than fine grain rocks when weathered.

within the basement environment, the aquifers are mostly fractures within the crystalline rocks, while in the younger granite environment, the aquifers are found at the base of the regoliths and within crystalline rocks as fractures. Within the basaltic rock, the aquifers occur within the crystalline rocks due to the vesicular nature and fractures of the basalt.

From the investigations, the chances of getting groundwater is higher within the basement complex than the younger granites as the basement complex are more deformed and more weathered.

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Appendix i

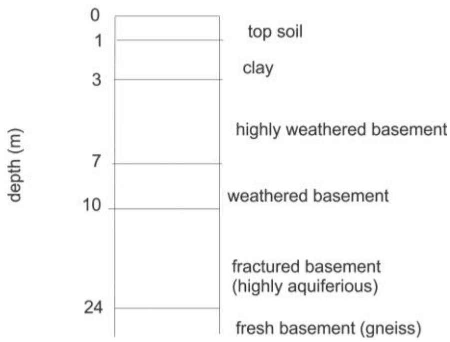

Figure 6a: Litholog of Babale

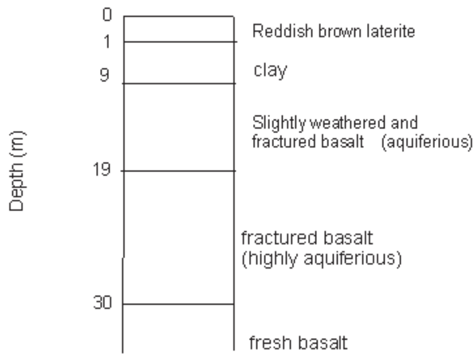

Figure 6b: Litholog of Babale 2

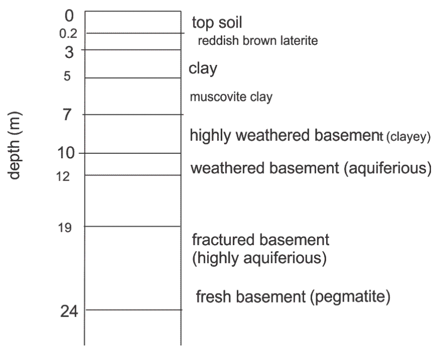

Figure 6c: Litholog of New GRA

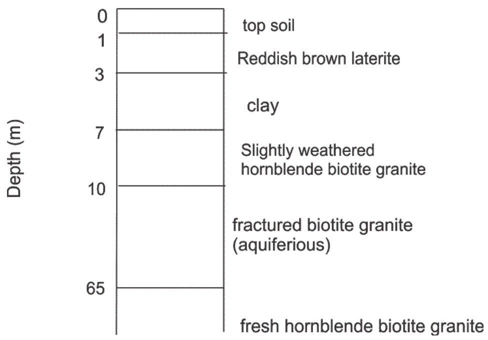

Figure 6d: Litholog of Du

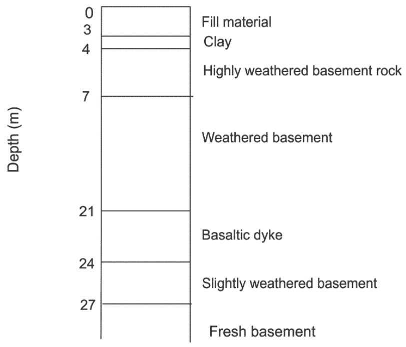

Figure 6g: Litholog of DB Zang Road

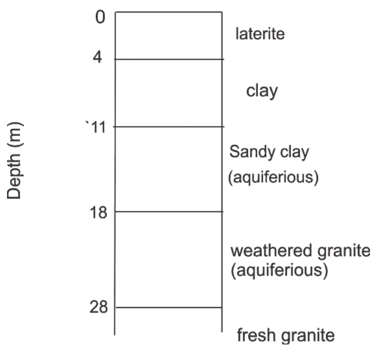

Figure 6e: Litholog of Kpasho, 1

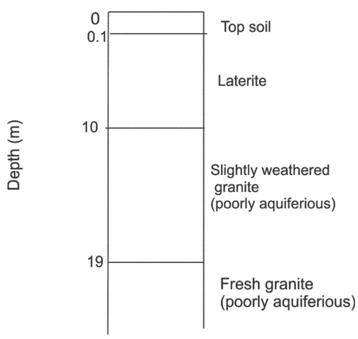

Figure 6h: Litholog of Rock Haven

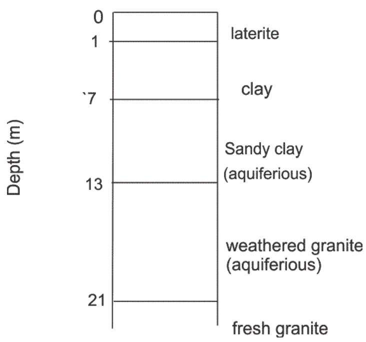

Figure 6f: Litholog of Kpasho 2

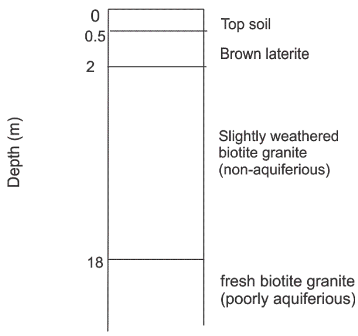

Figure 6i: Litholog of Sabon Barki

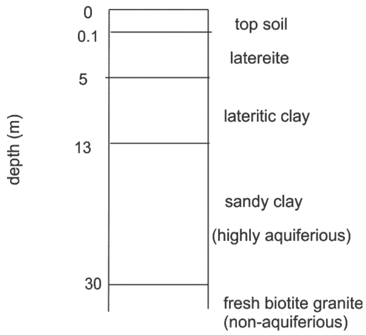

Figure 6j: Litholog of Rahol Kaneng

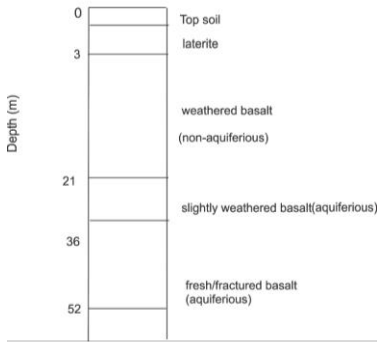

Figure 6k: Litholog of Chip

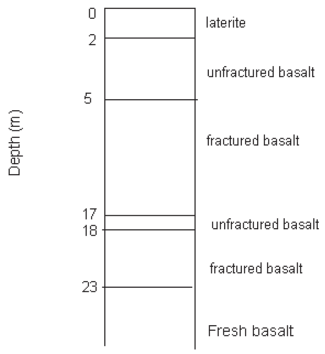

Figure 6l: Litholog of Kaduara, Kwa