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Geoelectrical investigation of aquifer problems in Gosa area of Abuja, North Central, Nigeria

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The study of aquifer problems in Gosa area of Abuja, North-central Nigeria, has been undertaken. Abuja, the capital city of Nigeria, is underlain by Precambrian basement rocks. Vertical electrical sounding (VES) was carried out at twelve locations within and around the Gosa area. The interpretation of the data obtained from the sounding revealed that six non-aquiferous geoelectrical layers overlie the unfractured basement. The first layer with average thickness of about 0.5 m and resistivity of 83 Ohm-m. The thickness of the second layer is about 0.7 m and resistivity of 438 Ohm-m. The third layer is about 3.4 m thick and resistivity of about 63 Ohm-m. The fourth layer with average thickness of about 16.0 m and resistivity, 236 Ohm-m. The fifth layer with average thickness of 42.7 m and resistivity of about 68 Ohm-m. The thickness of sixth layer varies from 42.7 m to infinity and resistivity of about 2067 Ohm-m. Eight boreholes of varying depths, 45 to 70 m were drilled. Other areas were drilled with good yield of static water level of about 3.7 m, whereas Gosa aquifers were found dried. It could be attributed to basaltic intrusion that shattered the aquifer bearing rocks thereby devoid water in the zone after pronouncing from geophysical investigation.

Key words: Geologic map, accessibility map, vertical electrical sounding (VES) profiles.

INTRODUCTION

Basement complex rocks do not inherently make good aquifers. The hydrogeologic characteristics of basement rocks are only enhanced when the rocks are fractured and/or when they are weathered. The conditions are better enhanced when the rocks are overlain by thick overburden. Groundwater potentials of a basement complex area are often determined by geophysical means, which determines the thickness of the overburden and the network of fractures that may exist in the area. Geophysical surveys are also important for groundwater investigation in basement areas in view of the discontinuous (localized) nature of basement aquifers (Satpatty and Kanugo, 1976). The use of the vertical electrical sounding (VES) method is popular for groundwater investigation in both soft rock (sedimentary) and hard rock (igneous and metamorphic) terrains (Barongo and Palacky, 1989; De Beer and Blume, 1985; Mbonu et al., 1991; Shemang, 1993). In the Basement Complex of Nigeria, extensive application of geoelectrical method for groundwater investigation has been reported (Pulawski and Kurth, 1977; Acworth, 1987; Olorunfemi and Okankune, 1992; Olorunfemi and Fasuyi, 1993;

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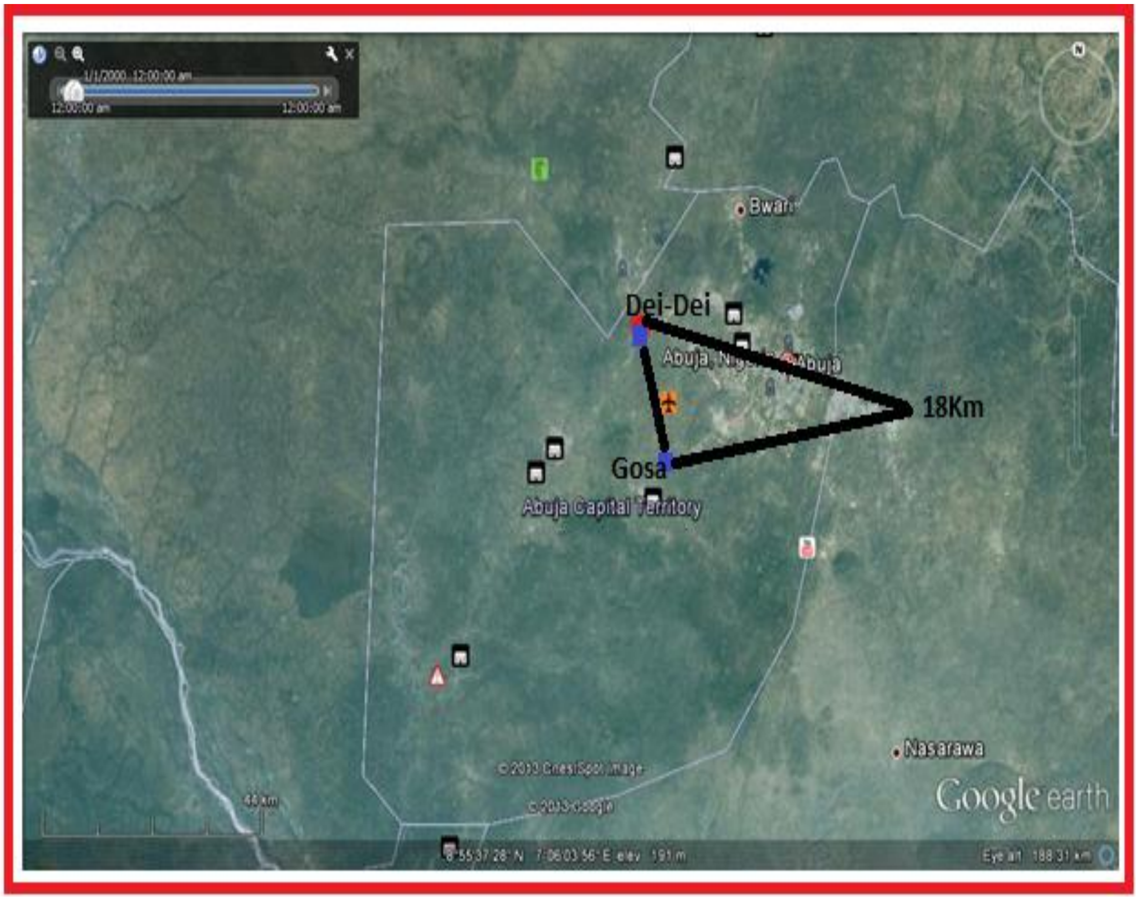

Figure 1. The Google earth map of the study area showing the study arean with blue dot.

Edet and Okereke 1997; Nur and Ayuni, 2004).

The area of study includes most parts of Abuja main city, and western surburbs. It includes areas around Maitama, Asokoro, Wuse, Garki, Gwarimpa, Kado, Jabi, Kubwa, Dei-Dei, Lugbe and Gosa. It is bounded by Latitudes 8° 53`N to 9° 13`N and longitudes 7° 00`E to 7° 30`E. Gosa has become important because of the increasing population of the suburbs of Abuja. Many residents of the area embark on the development of private boreholes to augment public water supplies which are inadequate. But most boreholes here are abortive, and so counter the intentions of the owners, in addition to loss of capital. This work is a first-hand study aimed at establishing the groundwater conditions in the Gosa area of Abuja, Nigeria, which will help in adequate planning and drilling of boreholes in the area.

Geology and hydrogeology of the area

The area of study forms part of the Basement Complex of north central Nigeria; with lithologic units falling under three main categories, which include (1) Undifferentiated migmatite complex of Proterozoic to Archean origin, (2) Metavolcano-Sedimentary rocks of late Proterozoic age and (3) older granite complex of late Precambrian - Lower Paleozoic age, also known as Pan-African granites. All these rocks have been affected and deformed by the Pan-African thermotectonic event. Detailed reports of the lithological description, age, history, structure and geochemistry of the Basement Complex of Nigeria are given in Oyawoye (1972); Black et al. (1979); Ajibade et al. (1987); Rahaman (1988); Caby (1989) and Dada (2008). Figure 1 shows the Google earth map of the location. Figure 2 is the geologic map of Nigeria showing the study area with red arrow.

In the study area, all the three major rock categories mentioned above are well represented (Figure 3). The rocks are generally weathered into reddish micaceous sandy clay to clay materials, capped by laterite. The hydrogeology of basement areas is simple since there is an inherent limitation to the occurrence of groundwater. However, where the regolith is thick, and there is a dense network of fractures, the potentials for the accumulation of groundwater in basement complex rocks may increase.

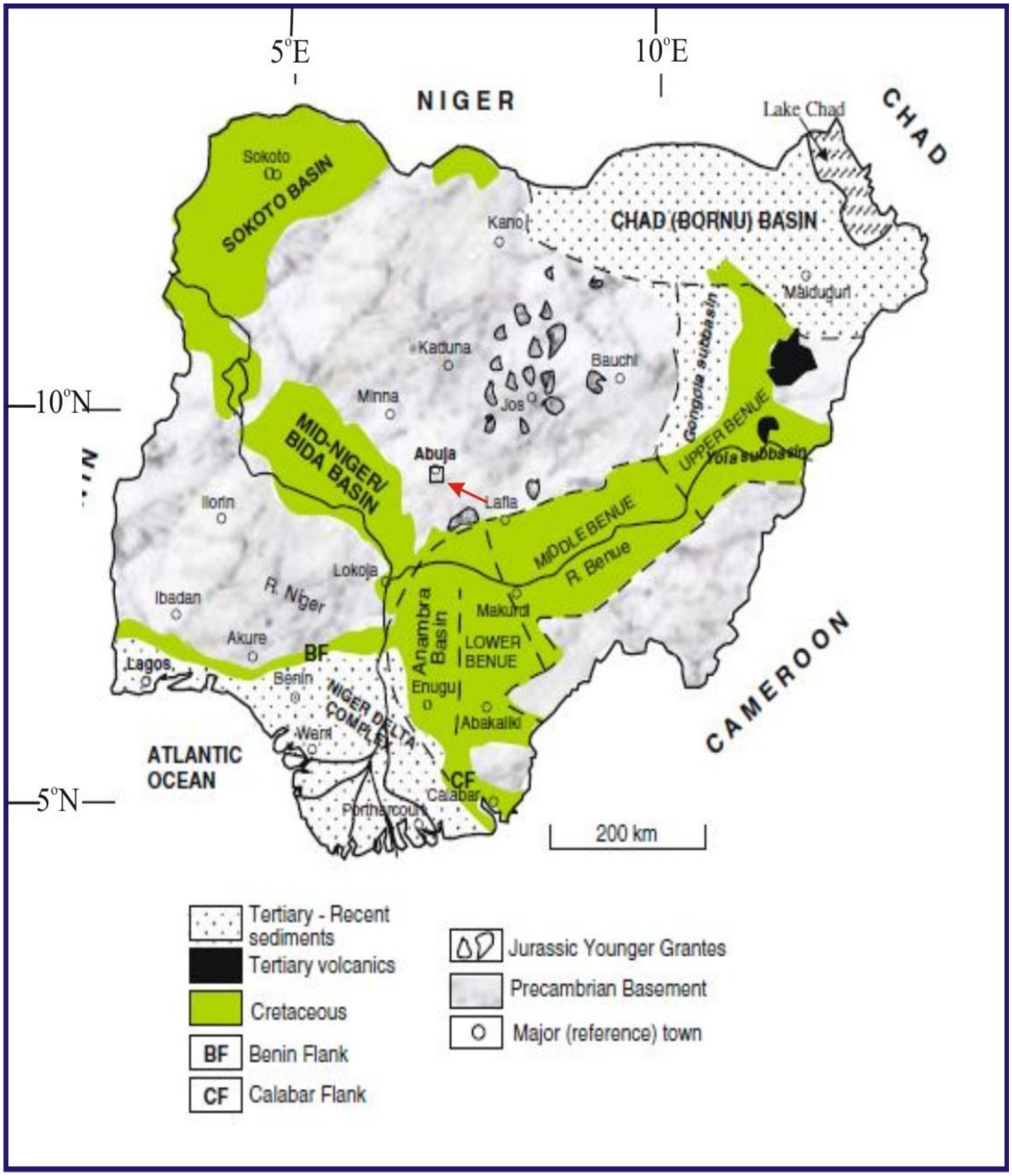

Figure 2. Geological Map of Nigeria, showing the position of Abuja (red arrow) in the Basement Complex of North central Nigeria (modified from Obaje, 2009).

MATERIALS AND METHODS

Geophysical investigation

The search for groundwater in Gosa and it's environ was carried out through the use of electrical methods of geophysical survey, (Figure 4). The Schlumberger configuration in VES was used to obtain field data. Vertical electrical sounding probes the vertical variation in resistivity of the subsurface, thereby indicating the presence of fluid and ionic concentration in the subsurface materials. It is also applied to determine the depth to bedrock, delineate the various units that constitute the overburden (regolith), determine the degree of fracturing of the bedrock; all of which would help in making the choice for a feasible site for constructing a successful borehole. VES data for this work were obtained using the Allied Omega C2 Terrameter. The field data obtained was presented as curve of apparent resistivity values against half of the current electrode separation (AB/2) in metres on a log-log scale.

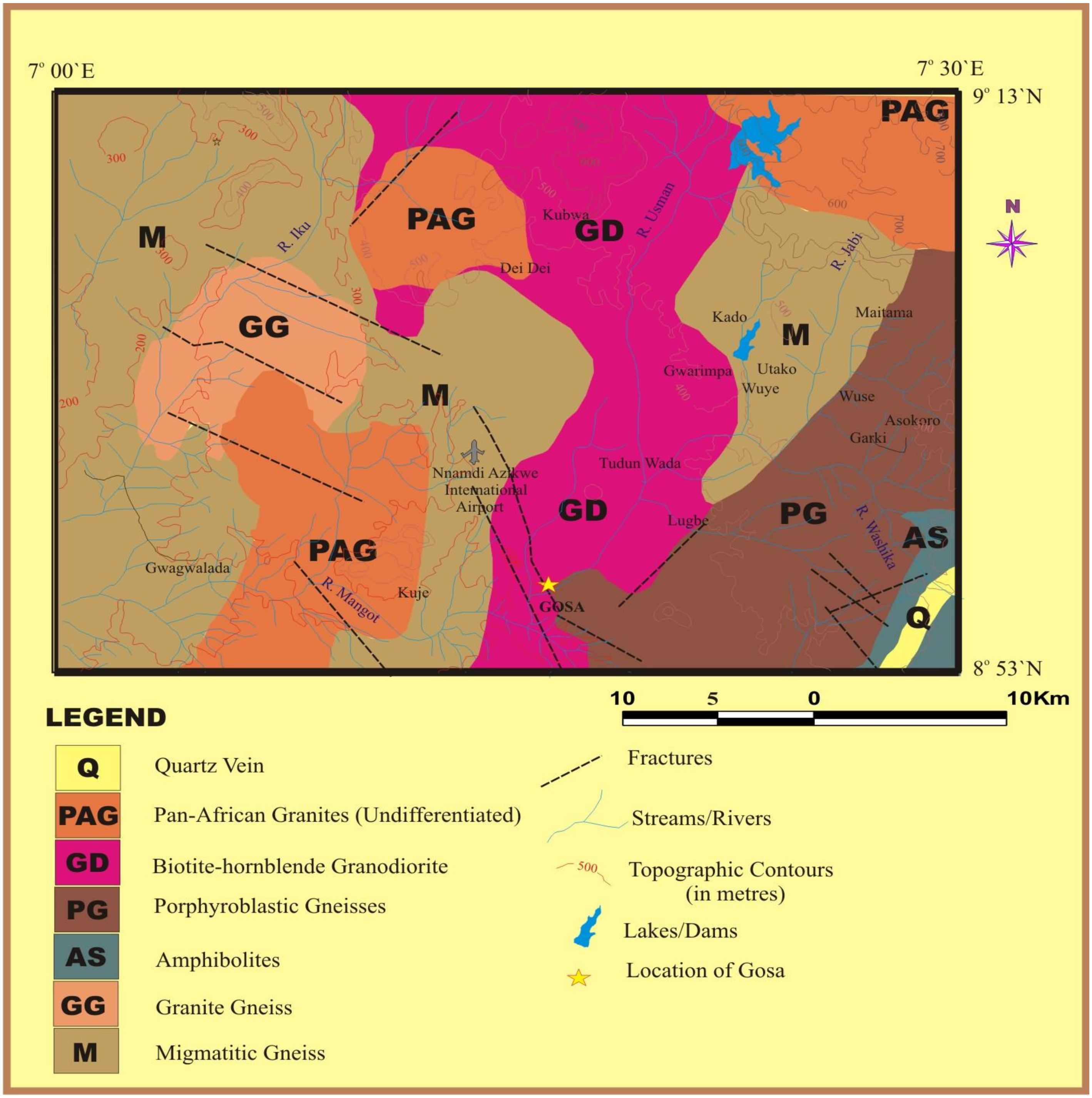

Figure 3. Geological map of the study area.

A 3-mode filter was employed to jettison associated noise due mostly to electrical signals and interference from adjacent power transmission lines. The VES data obtained were analyzed using the WINRESIST 2004 Version computer software to improve the quality of the interpretation by iteration and modelling to goodness of fit. The profiles plots of apparent resistivity against electrode spacing are shown in Figures 5, 6, 7, 8, 9 and 10.

Drilling of boreholes

Drilling boreholes

Among the drilled boreholes, two monitoring boreholes for this work were drilled at Dei-Dei and Gosa for proper investigation of

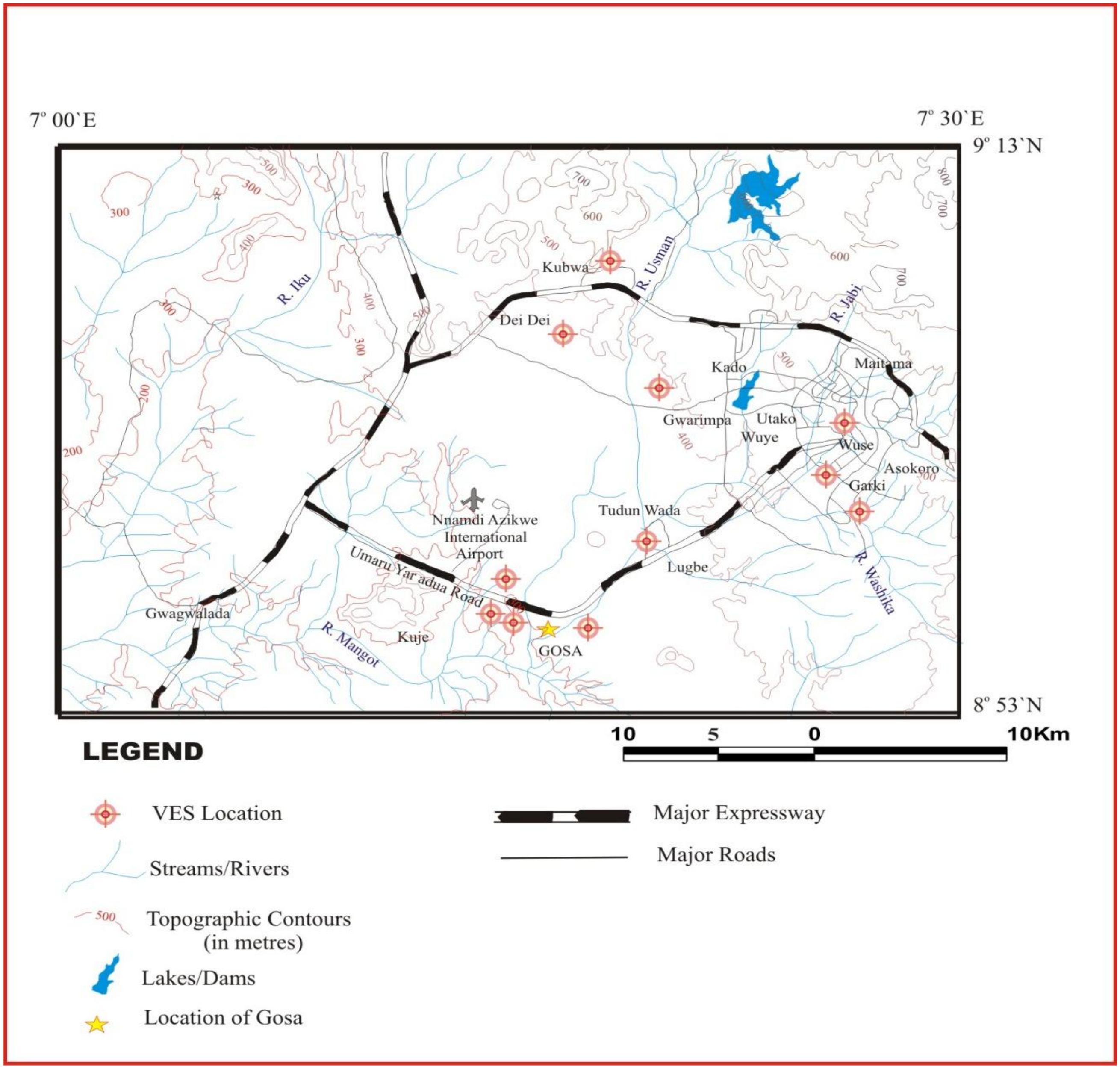

Figure 4. Accessibility map of the study area, showing positions of VES points.

subsurface step-by-step information with well log and GPS for the coordinates. The boreholes were drilled with the help of 30 ton capacity rig machine with compressor made of INGERSOL. The rocks were clay and sand, and the medium was heterogeneous as the thickness of the different layers differed in the boreholes.

Sample inventory

The identification of boundaries between layers with noticeably different particle sizes using visual manual logging method, record the thickness when the layer changes. Layer thickness change may range from less than one metre to tens of metres. After boundary of distinct layers have been clearly marked an indelible felt-tipped pen, using a single entry for each layer:

(a) Record the date the sample is logged and the initials of the logger,
(b) Record the designate geologically logged cut segment,
(c) Determine and record the depth interval for each layer,
(d) Photograph each layer using digital camera.

The two sites were Dei-Dei (about 60 m), and Gosa (49 to 50 m), Figure 3 shows the drilling points.

Site one borehole (S1): Details about the logging are given in Table 2.

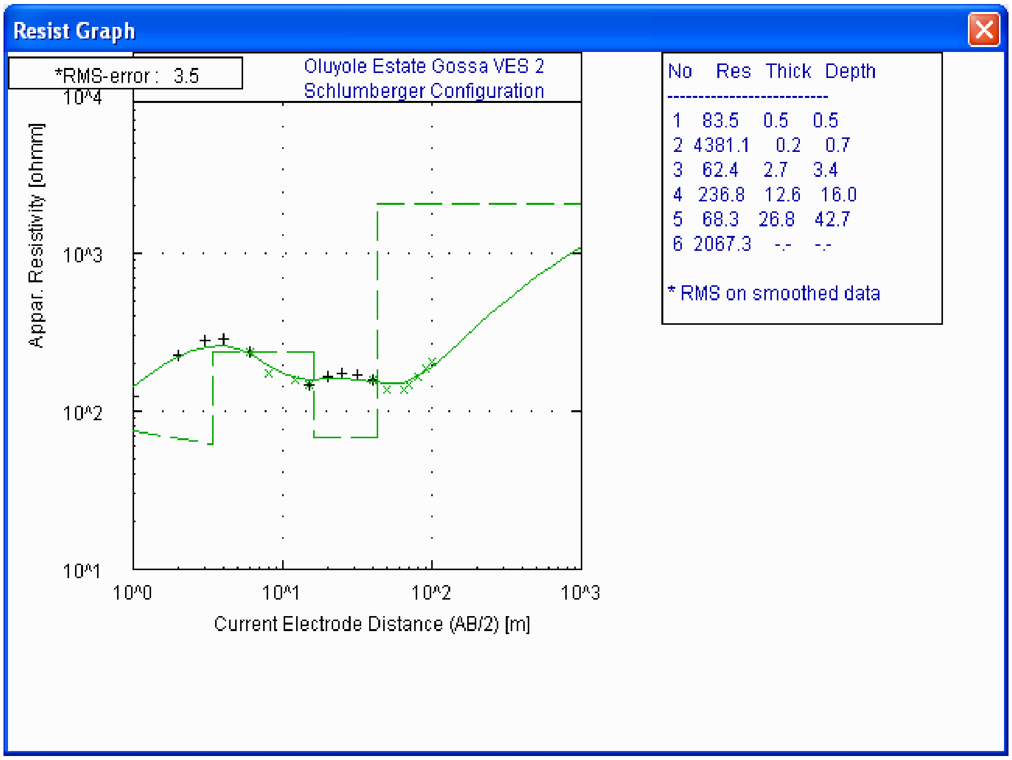

Figure 5. Gosa.

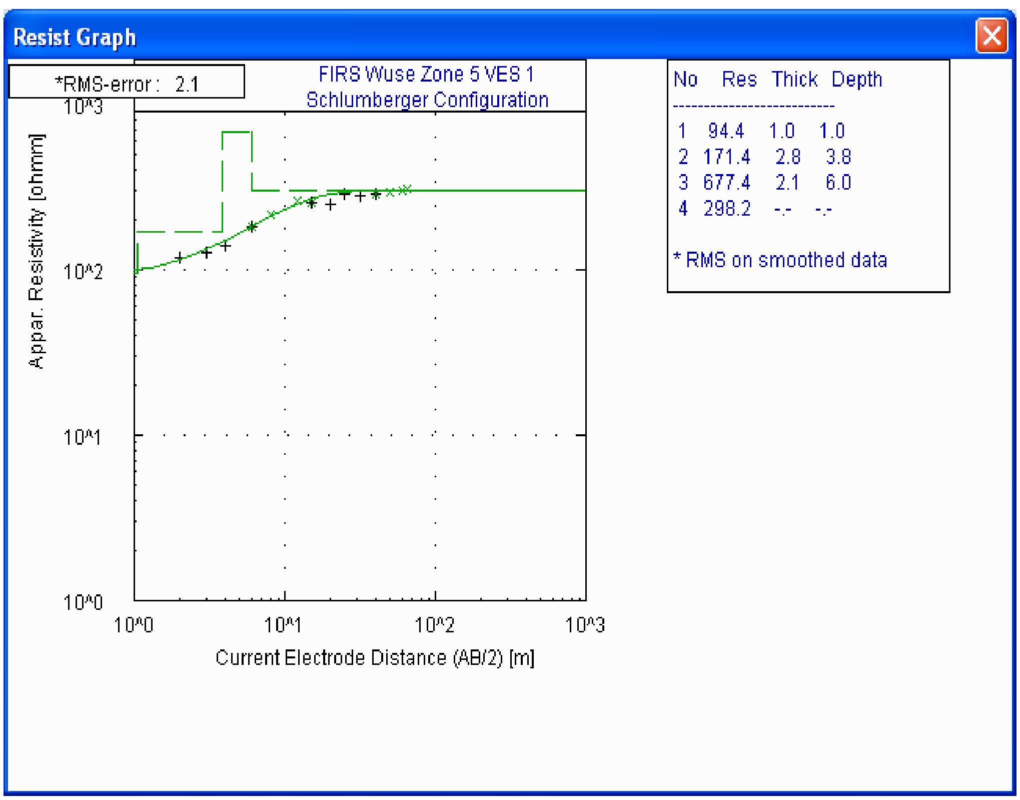

Figure 6. Wuse Zone 5.

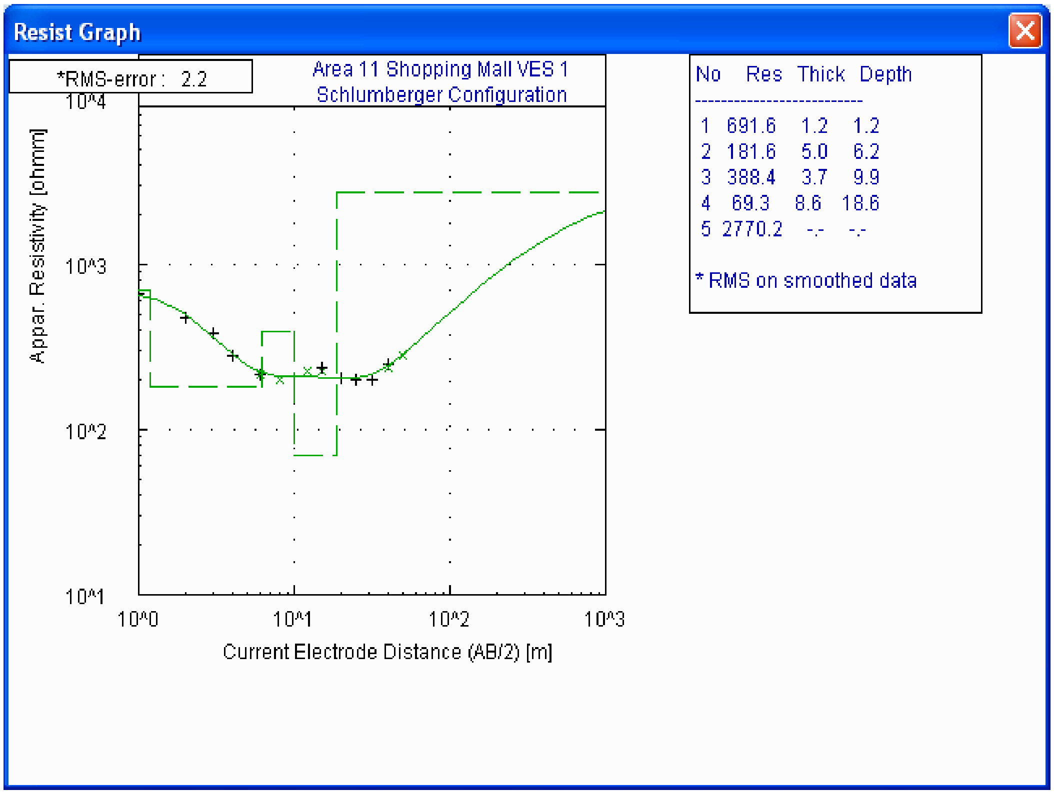

Figure 7. Area 11.

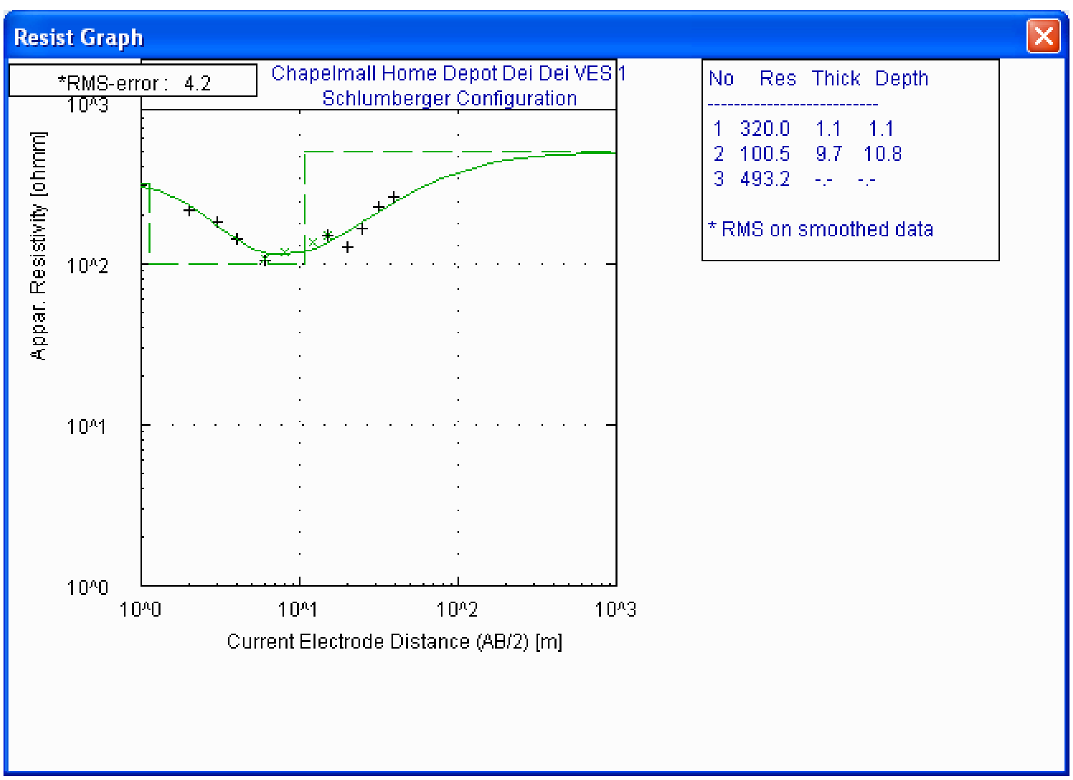

Figure 8. Dei-Dei.

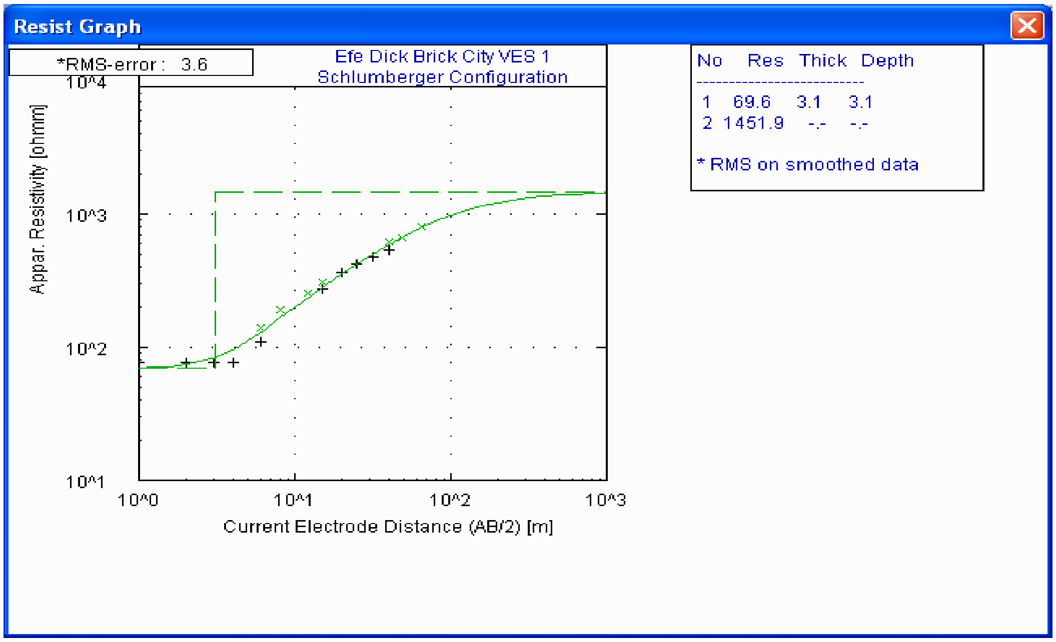

Figure 9. Brick City.

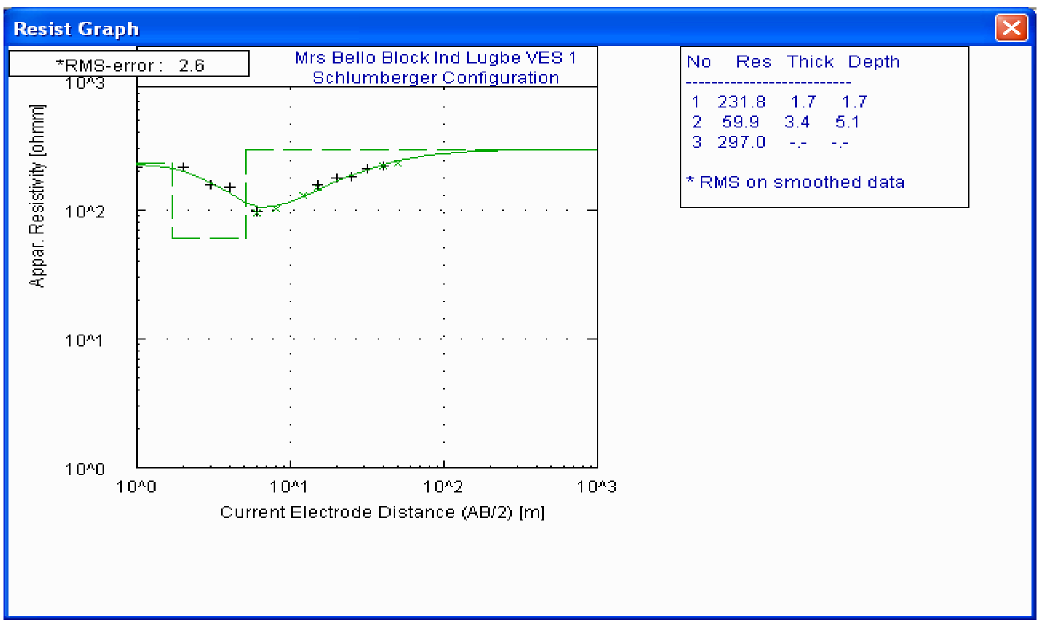

Figure 10. Lugbe.

Site two borehole (S2): Details about the logging are given in Table 3.

DATA INTERPRETATION AND RESULTS

VES data analysis and interpretation

Twelve VES points were studied in this work; five from areas around Gosa and seven from other parts of Abuja, (Figure 4). The five points in Gosa area were close to abortive borehole sites. Table 1 shows a summary of the results of the interpretations. The table shows that at the location of VES 1, there is a thick lateritic topsoil of up to 3.4 m, underlain by a thick micaceous sandy clay layer of weathered basement rock that cannot sustain boreholes. This is directly underlain by unweathered, unfractured

Table 1. Summary of results obtained from the computer output of the eight (12) VES in the area.

S/N	VES No.	Location	Resistivities(ohm-m) of geoelectric layers ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	Thickness (m) of geoelectric layers h1	h2	h3	h4	h5	h6	Lithology	Remarks
1.	VES 1	Gosa	83,	438,	62,	236,	68,	2067	3.4,	39.3,	∞				Lateritic topsoil, weathered basement, fresh basement	Dry
2.	VES 2	Gosa	410.6,	130.5,	47.72,	4869,	164.4		0.44,	1.22,	3.33,	4.88,	∞		Sandy clayey topsoil, fresh basement	Dry
3.	VES 3	Gosa	211.2,	82,	122,	54.29,	1140,	82043	0.6,	2.03,	2.86,	5.97,	12.48,	∞	Sandy topsoil, weathered basement, fresh basement	Dry
4.	VES 4	Gosa	1580,	332.8,	47.57,	19369,	72.7		0.49,	1.33,	4.44,	6.86,	∞		Sandy topsoil, clayey weathered zone, fresh basement	Dry
5.	VES 5	Gosa	184.3,	1104,	37.87,	1473			0.22,	2.46,	12.95				Sandy topsoil, weathered basement, fresh basement	Dry
6.	VES 6	Wuse zone 5	94,	171,	677,	298			1.0,	2.8,	2.2,	∞			Sandy topsoil, clayey sand, weathered basement	Wet
7.	VES 7	Lugbe	231,	59,	297				1.7,	3.4,	∞				Sandy clayey topsoil, weathered and fractured basement	Wet
8.	VES 8	Area 11	691,	181,	388,	69,	2770		1.2,	5.0,	3.7,	8.7,	∞		Lateritic topsoil, fractured basement	Wet
9.	VES 9	Dei-Dei	320,	100,	493				1.1,	9.7,	∞				Sandy clay topsoil, weathered basement	Wet
10.	VES 10	Phase 4	42,	1323,	217,	39,	444		0.9,	0.3,	4.6,	16.4,	∞		Lateritic clay topsoil, weathered and fractured basement	Wet
11.	VES 11	Kubwa	257,	1219,	530,	100000			0.8,	0.9,	13.9,	∞			Sandy clay topsoil, weathered basement	Wet
12.	VES 12	Brick City Estate	69,	1451					3.1,	∞					Sandy clay topsoil, fractured basement	Wet

Table 2. Depth and Lithologic Unit of Borehole at Dei-Dei. The drilling point coordinate, Lat. 9° 6'52"N and Long. 7° 15'39"E, using GPS, Model: Extrex high sensitivity 2000 to 2007 Garmin Ltd.

Sample ID	Depth (m)	Thickness (m)	Lithology description
S1L1	0-4	4	Sandstone, brownish and ferruginous, interbedded with quartz feldspar
S1L2	4-10	6	Coarse sand with clay, bright red.
S1L3	10-11.3	1.3	Slightly micaceous Sandy clay, brownish pebbly, fine to coarse feldspar.
S1L4	11.3-18.5	7.2	Fin to coarse sandy clayey and gravel
S1L5	18.5-24	5.5	Sand. Brown, clayey at the top, fine to coarse
S1L6	24-33	9	Light grey coarse sand, granite gravel
S1L7	33-45	12	Silty sand feldspar, blackish to grey
S1L8	45-49	4	Grey silty sand, low grade
S1L9	49-57	8	Greyish to Purple silty sand
S1L10	57-64.5	7.5	Sand, fine to coarse, pebbly blackish to grey

Table 3. Depth and Lithologic Unit of Gosa Site Borehole. Coordinate (Lat: 8° 56' 45.6" N and Long: 7° 13' 26.2" E, GPS- Model: Extrex high sensitivity 2000-2007 Garmin Ltd) was used for coordinate.

Sample ID	Depth (m)	Thickness (m)	Lithology description
S2L1	0-5.6	5.6	Sandy clay, reddish brown laterite top soil.
S2L2	5.6-15.6	8	Sandy clay, fine to medium, brownish to yellow.
S2L3	13.6-24.9	11.3	Clay sandy feldspar Yellowish brown pebbly
S2L4	24.9-32.3	7.4	Micaceous clayey, grey to black
S2L5	32.3-41.8	9.5	Sandy shinny greyish to black feldspar.
S2L6	41.8-50.8	9	Fine medium shinny, qartz interbed, greyish ash feldspar

basement. VES 2 shows an area with thicker lateritic topsoil underlying fresh basement at a very shallow depth. At the location for VES 3, the unweathered basement is encountered at a deeper depth; yet the area does not sustain a borehole. The location for VES 4 and 5, the fresh basement is encountered at shallow depth. We are of the opinion that part of the problem in the Gosa area is the occurrence of micaceous clayey sediment in addition to the existence of shallow unfractured basement rocks. The lithology around the other VES points is similar to that of Gosa area described above; however, all the wells are productive.

Borehole log interpretation

It is clear from the above log that in Dei-Dei, 7.2 m thickness of the basalt is buried about 4 m of clay capped by a top laterite bed. The basalt lie directly a thin gravely and sandy layer marked by deep brownish laterite surface. The gravely layers, though highly permeable produces good yield, deep brown in colour, the brown colour resulting from high iron concentration derived from the intensive ferruginisation associated with the ground surface before the volcanic eruption. The fractured bottom layer of the basalt provides less contaminated water.

In Gosa, the coarse granites weather into water bearing sandy residue, the syenitic rock types, with the predominance of unstable minerals eg. Feldspars, decompose into plastic or soft clay and other argillites which behave only as aquitards or aquicludes. Generally, only small amount of water can be obtained or dry well in the freshly unweathered bedrock below the weathered layers. Even when fractured and prevented water from being transmitted into the borehole.

Conclusion

Results from the VES surveys and well log carried out in the study area indicated the presence of lateritic or sandy topsoil, weathered basement and fractured basement. The similarity in the geoelectric sections suggests a homogenous aquiferous setting in the area. However, this is not the case as boreholes drilled in the Gosa area were dry, even when drilled to depths of over 120 m. Based on the findings stated above, the following conclusions can be made.

(1) In Gosa, the area is inextensive fracturing in younger granite, and not often coincide with the broad depression of valley within the formation. In nature, it situated in an elongated depression simulating one of such situation but

the hydrogeological information which are the deeply dissected by fractures within the rock formations are not interconnected.

(2) In Dei-Dei, the rock compositions are made up of coarse granitic material, gave relatively higher yields in the apparently fractured or faulted zones which could be the evidence of volcanic activity marked by the occurrence of flat toped lateritised basalt.

In this study, it suggests that most of the successful boreholes in the basement rocks should terminate at the depth of about 60 m in deeply weathered and fractured zones that are interconnected.

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