HYDROGEOPHYSICAL APPRAISAL OF RISHA, PART OF AKWANGA SHEET 209NE, NORTH CENTRAL NIGERIA

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ABSTRACT
A geological traverse was undertaken in Risha, part of Akwanga Sheet 209NE North-Central Nigeria to appraise the rock types and their structural patterns that might enhance prospect for water. The geological traversing revealed basically three rock types which include schistose-gneiss, granite-gneiss and pegmatite (as veins and/or dykes) with their main structural pattern trending mostly NW-SE. Twenty three (23) Vertical Electrical Resistivity Soundings (VES) were carried out in the area using the **Campus Ohmega** digital resistivity meter. This is in order to study the subsurface geological layers with a view to determine the thickness, geoelectric layers, the depth to basement, aquiferous zones and groundwater potential. Field data obtained were interpreted quantitatively and qualitatively. The field curves were typical of H, KH, HK, A and K types. There are majorly five-Six geoelectric layers consisting of topsoil (sand/clay) with depth range of 0.3-2.4m and resistivity value of 66-2850Ωm. The second layer is lateritic clay with depth range of 0.4-5.7m and resistivity range of 222-3575Ωm. The third layer has a depth range of 1.2-8.6m with resistivity of 40-4591Ωm while the fourth layer, weathered rocks or regolith, has a depth range of 3-33m and resistivity range of 49-23668Ωm.Two locations gave six lithological layers/units being partially fractured/fresh basement with resistivity values of 1028-4574Ωm and depth range of 11.4-24m. The geoelectric section was produced and correlated with the existing geology of the study area and it was found to be in conformity with the existing geology. The water potential of the area may be classify as poor, moderate, good and very good and varied from location to location. The groundwater potential area varies with high potential around Risha, Tidde and Ridam compared to Ade-Katako, Ngazzu, Angwan Dorowa, Ngakide and Adande. Based on the textures, structural pattern and well measurement interpretations, the granite gneiss was observed to have more water prospectivity than the schistose gneiss.

Key words: Rocks, resistivity, groundwater, potential, Basement Complex

INTRODUCTION

Groundwater is one essential and necessary substitute to surface water in every society. It is no longer a hidden doubt that this replenishable resource varies in occurrence and distribution according to the local, as well as regional geology ,hydrogeological setting and to an extent the nature of human activities on the land. Groundwater occurrence in a Precambrian basement terrain is within zones of weathering and fracturing which often are not continuous in vertical and lateral extent (Jeff, 2006). There is a steady rise in the demand for groundwater in most hard rock areas most of which cannot boast of any constant surface source of water supply (Adanu, 1994). The study area is underlain by the rocks of the Nigerian Basement Complex such as the Migmatite-Gneiss Complex, the Schist Belt and the Older Granites.The aquifers of the Basement Complex rocks are the regolith and the fractures in the fresh bedrock which are known to be interconnected at depth (Mohammed, 1984; Alagbe, 1987; Uma and Kehinde, 1994).Geological mapping, structural analysis and geophysical investigation were done to ascertain the different rock types and to locate areas with thick weathered zone and fractures containing groundwater. The study area falls within Akwanga Sheet 209NE, latitude 08°16' to 08°19' and longitude 08°57' to

9°00' which is located in Akwanga L.G.A along Gudi-Andaha roadin Nasarawa State, covering an area of about 30km^2 in Risha area and its surroundings villages that fall within the coordinates, Risha and its surrounding villages can be accessed through the road that linked Abuja to Akwanga, on your way there is a small village by the road side called Mararaba-immediately after Gudi town, the minor tar road by the left-hand side leads to Risha and the surrounding villages.

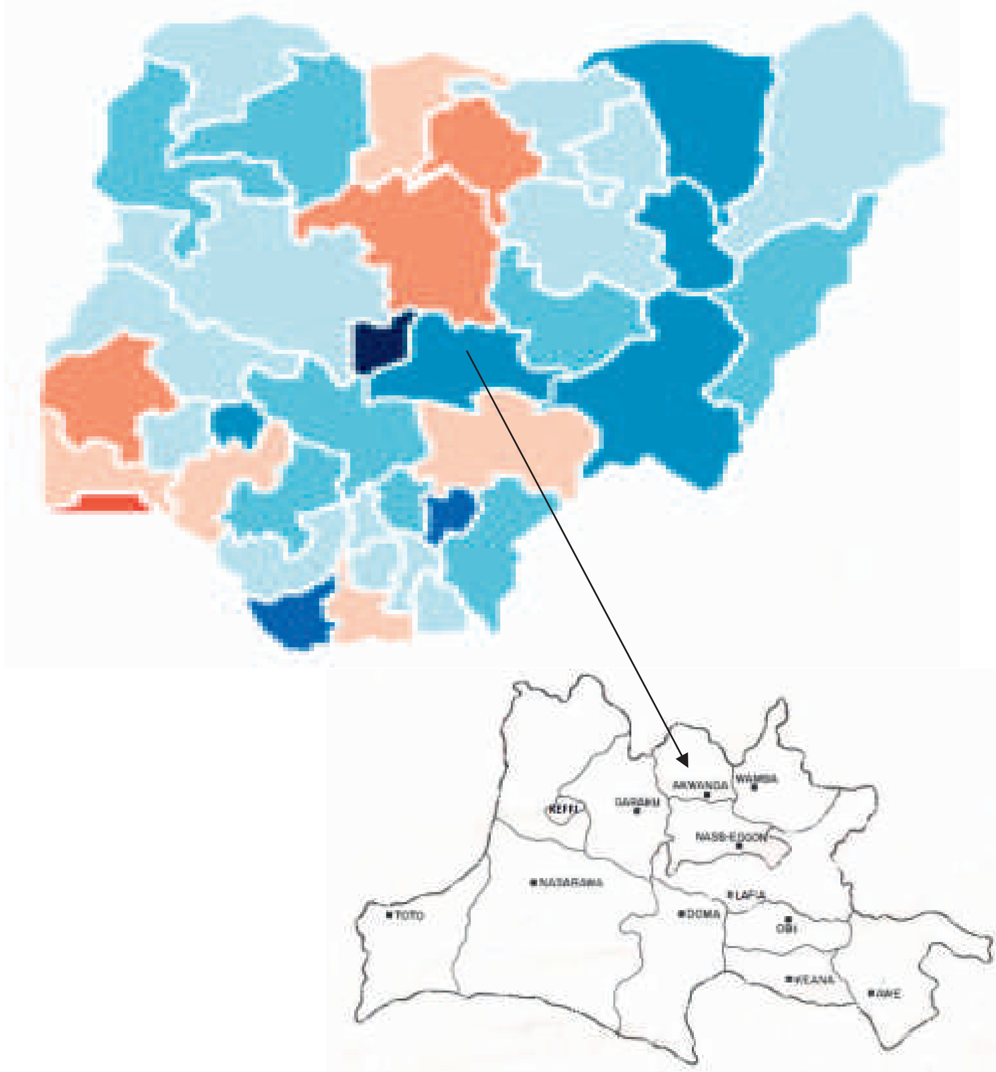


Figure 1.Location map of the Study Area (Risha and its environs). Adapted from Federal Survey Agency, 1976.

GEOLOGY OF RISHA AND ENVIRONS

Risha area forms part of Akwanga Sheet 209 NE, North Central Nigeria which falls within the Basement Complex of North Central Nigeria. The predominant rock in the area is the granite-gneiss covering about 70 % of the mapped area while schistose-gneiss covers about 29 % and the pegmatite is about 1 % (mostly occurring as vein and not mapable).

Pegmatite

The pegmatite is coarse grained, white to pinkish, composed of quartz, plagioclase feldspar, microcline and biotite which occur as late intrusive members (veins or dykes) in the rock exposures trending NW-SE and thickness range of 2cm to 1.5m.

Granite-gneiss

The type of granite-gneiss found in the locality is light gray with a fine to medium grained texture composed of plagioclase, quartz, microcline, muscovite and biotite. The rock exposures are mostly low lying, having a lot of joints and which resulted from both biological and physical weathering processes.

Schistose-gneiss

The schistose-gneiss has mineral alignment and foliations mostly striking NE-SW and dipping SE with beddings which breaks easily along planes of weakness. The schistose-gneiss is dark gray with very fine grained texture composing of quartz, plagioclase-feldspar biotite and some accessory minerals like silimanite and andalusite (Figure 2).

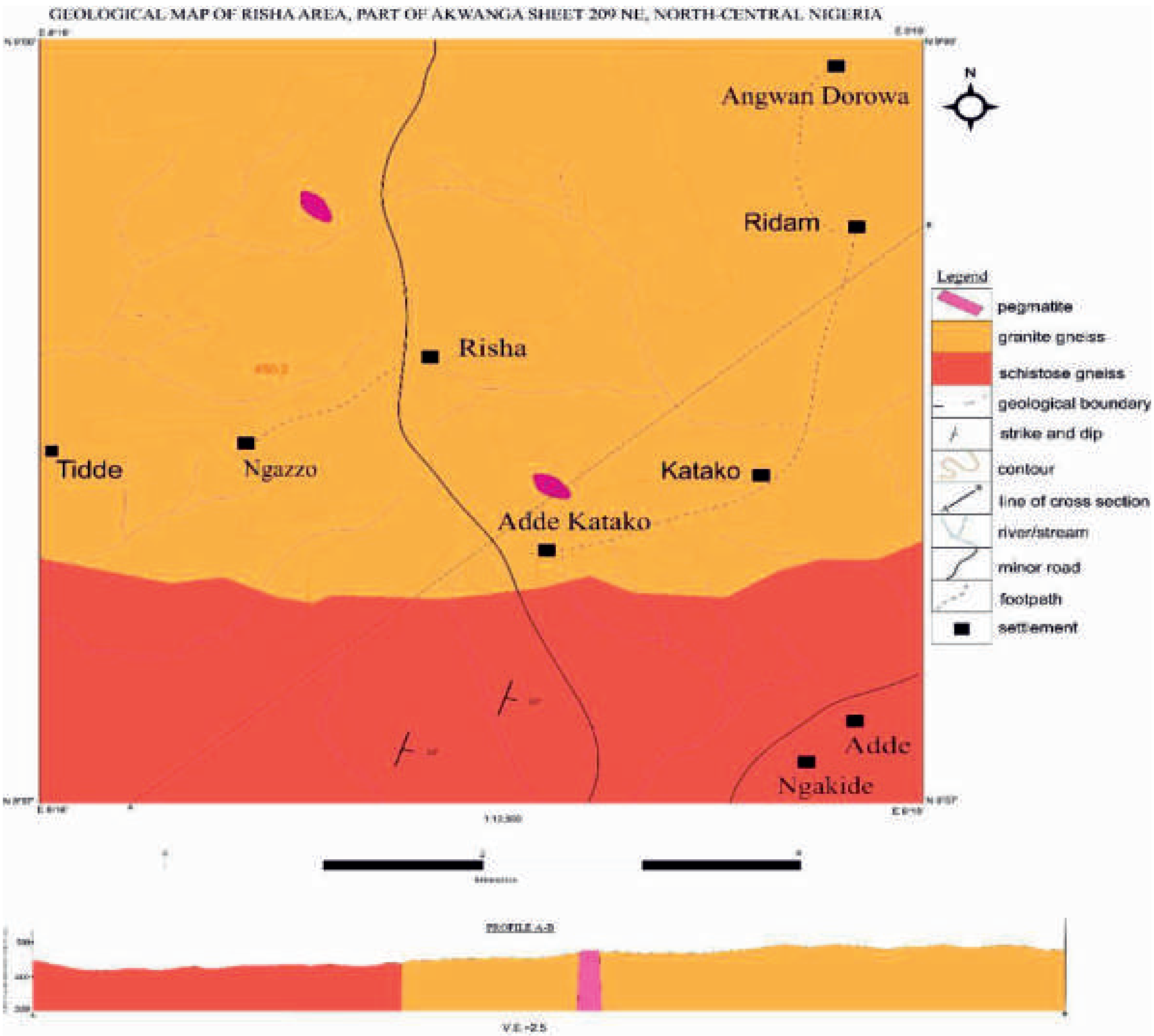


Figure 2.Geological Map of Risha and its Environs

Methodology

The study involved systematic geological mapping on a scale of 1:12,500 covering a total area of about 30km^{2}with the aim of identifying the various rock types found in the study area. The geological mapping was carried out along traverses and fresh samples of different rock types observed in the field were taken and analyzed petrographically, while Vertical Electric Sounding (VES) was carried in the area to appraise the various subsurface rock units and its groundwater potential. The electrical resistivity data were acquired from twenty three (23) VES stations using the **Campus Ohmega** digital resistivity meter. The VES utilized the Schlumberger electrode array with electrode separation (AB/2) ranging from 1m to 100m. The coordinates of each VES station were taken with the Germin handheld Global Positioning System (GPS) device to ensure accurate geo–referencing. Field data obtained were interpreted quantitatively using *IXID version 2.09* and qualitatively using *SURFER version*8.02 software.

Results and Discussion

A geologic map (Figure 2) was produced from the field work carried out and the result of the VES sounding was interpreted quantitatively using the *IX1D* version 2.09 (Table 1). The plotted graph of apparent resistivity (ohm-m) against the depth (m) gave the different types of curve (Figure 3 and Figure 4).The resistivity sounding curves obtained from the study area varied from the 4-layer (KH, K and H types), to 5-layer (H, A, and KH) types and 6-layer (HK) types.

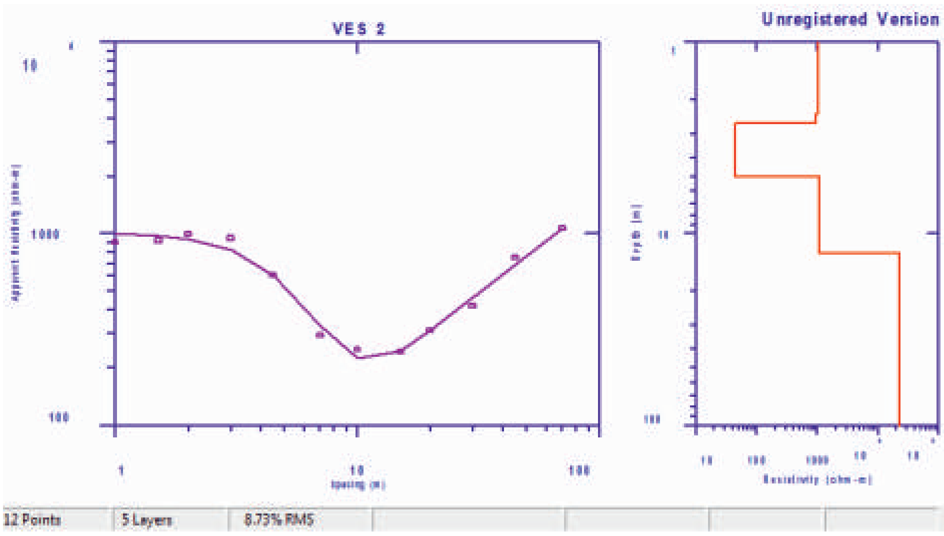


Figure 3: Curve type H

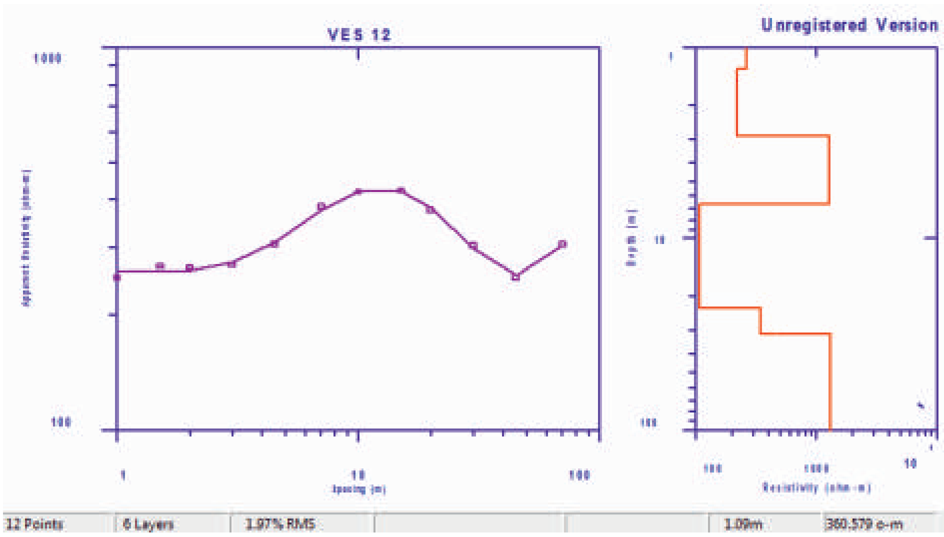


Figure 4: Curve type KH

Table 1: Interpreted model geoelectric parameters, curve and rock types of the study area

VES no	Layer thickness (m)						Layer resistivity (Ω-m)							No of layers	Curve type	Depth to basement (m)	Rock types
	T1	T2	T3	T4	T5	T6	LR1	LR2	LR3	LR 4	LR 5	LR 6	LR 7				
1	0.5	2.2	8.6	15.2	12.1	?	525	708	650	414	766	2082	-	5	H	38.6	Granite
2	2.2	0.4	2.7	6.4	-	?	1049	993	50	1174	17830	-	-	4	H	11.7	Granite
3	1.9	3.1	2.5	5	4.5	?	603	477	330	80	910	1345	-	5	H	16	Granite
4	1.8	2.1	6.3	19.5	-	?	1267	366	2401	510	17220	-	-	4	KH	39.7	Granite
5	1.6	0.6	4.3	12.6	7.4	?	1034	1446	69	93	170	2798	-	5	H	26.5	Granite
6	1.5	1.9	4.4	8.7	8.6	?	1245	357	155	65	412	749	-	5	H	25.1	-0
7	0.3	5.7	5.8	5.3	674	?	647	206	81	505	23668	-	-	4	H	17.1	Granite
8	0.4	2	4.8	15	30	?	169	1380	260	4591	303	171	-	5	A	52	Granite
9	2.0	2.3	3.5	9	-	?	271	200	1356	40	3946	-	-	4	K	16.8	Granite
10	1.0	1	10	12.2	7.8	?	237	642	175	96	221	3042	-	5	KH	32	Granite
11	1.5	1.1	2.8	10.9	6.3	?	322	196	60	253	425	1627	-	5	H	22.6	Granite
12	0.8	1.3	3.2	13.3	15.4	23.9	291	1293	322	1089	345	502	1028	6	HK	57.9	Granite

Table 1: Interpreted model geoelectric parameters, curve and rock types of the study area (continued)

VES no	Layer thickness (m)						Layer resistivity (Ω-m)							No of layers	Curve type	Depth to basement (m)	Rock types
	T1	T2	T3	T4	T5	T6	LR1	LR2	LR3	LR 4	LR 5	LR 6	LR 7				
13	1.2	1.7	3.7	16.8	8.7	**-**	260	222	1220	112	344	1172	-	5	KH	32.1	Granite
14	1.3	2.3	5.1	15.8	15	**-**	66	432	41	485	106	51	-	5	A	39.5	Granite
15	0.5	1.4	6.1	33.3	-	**-**	368	932	436	409	615	-	-	4	K	41.3	Granite
16	2.4	1.2	3.1	3	4	**-**	405	851	53	227	696	40407	-	5	H	13.7	Granite
17	0.3	2.1	2.6	2.3	3	**-**	699	1570	30	353	1229	88500	-	5	H	10.3	Granite
18	1.0	1.8	3.4	7.1	_	**-**	390	692	153	1385	2328	-	-	4	KH	13.3	Gneiss
19	0.5	3.5	4.3	6.7	4	**-**	502	344	178	131	521	54834	-	5	H	19	Gneiss
20	1.8	0.7	4.5	6.8	4.7	**-**	2850	1290	430	92	573	40189	-	5	H	18.5	Gneiss
21	0.3	0.6	1.2	3.6	10.5	**11.4**	315	3575	167	4107	49	464	4574	6	HK	27.6	Gneiss
22	1.0	1.3	4.7	7	6.3	**-**	666	1793	377	438	480	1200	-	5	KH	20.3	Gneiss
23	0.7	1.6	1.9	27.2	15.5	**-**	462	265	754	198	310	1386	-	5	HH	46.9	Gneiss

The quantitative result in Table 1 were used to deduce the qualitative result of the true aquifer resistivity, true aquifer thickness, Piezometric map, depth to basement, and geoelectric statistics and 3-D elevation maps.

Geoelectric Statistics and Parameters

The geoelectric statistics were deduced from the vertical electrical sounding results (Table 1). These layers consist of the top soil being sandy, clay, sand and laterites and hard pan with thickness range of 0.6-2.4m (Figure 5a) and resistivity values ranges from 66-2808Ωm (Figure 5g), as the first layer.

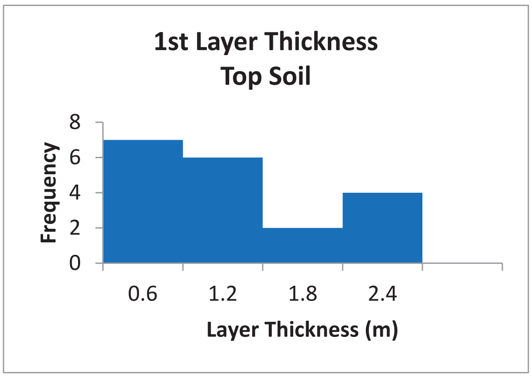
The second layer consist of laterites, clay, weathered layers with thickness range of 1.14-5.7m (Figure 5b) and resistivity value of 196-3575Ωm (Figure 5h).

The third layer consists of weathered rock units with a thickness value of 2.5-10m (Figure 5c) and a resistivity value of 30-2400Ωm (Figure 5i).

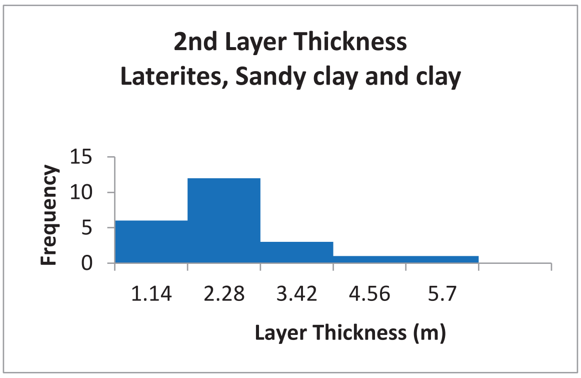
The fourth layer consists of saturated fractured rock units in the study area, showing a resistivity values of 40-3672Ωm (Figure 5j) with a thickness of 5.5-33m (Figure 5d).This fractured zones occur immediately below the weathered layer, however, this layer have the good characteristics to retain water beneath the surface, as such this rock units are the target for groundwater exploration.

The fifth layer consists of fractured/partial fractured fresh basement rock units, having the resistivity values of49-23668Ωm (Figure 5k) and thickness of 5-30m (Figure 5e). Although this layer form the fresh basement for other VES points with five layer cases.

The sixth layer consists of the Fresh basement rocks having the resistivity value of 51-88500Ωm (Figure 5l) and thickness of 11.4-23.9m (Figure 5f).



5a



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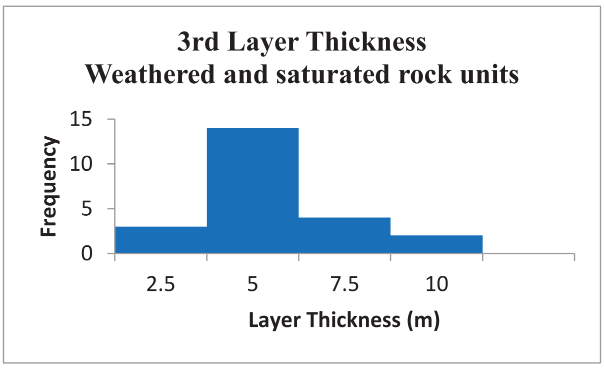

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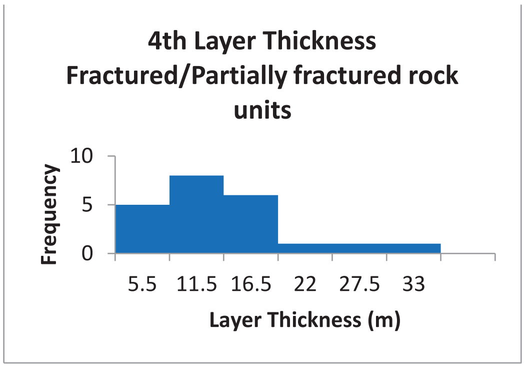

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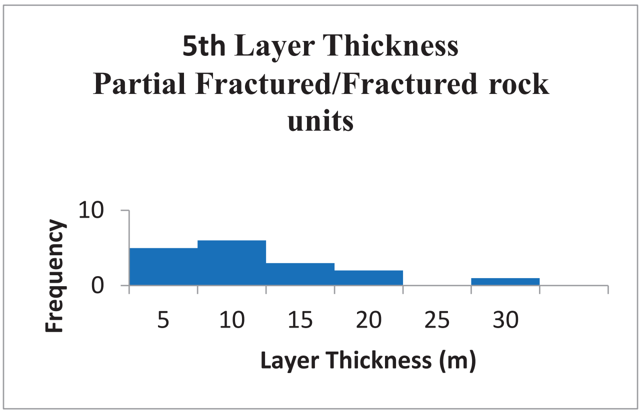
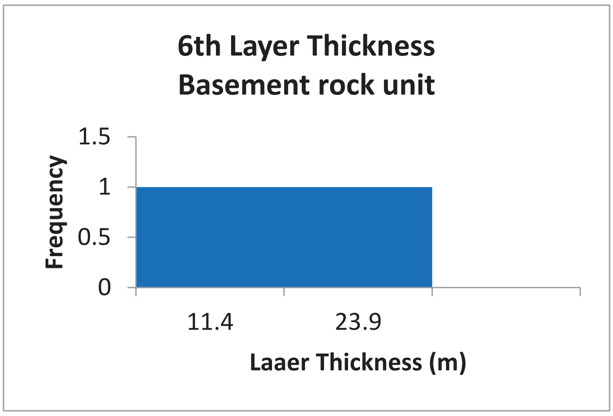
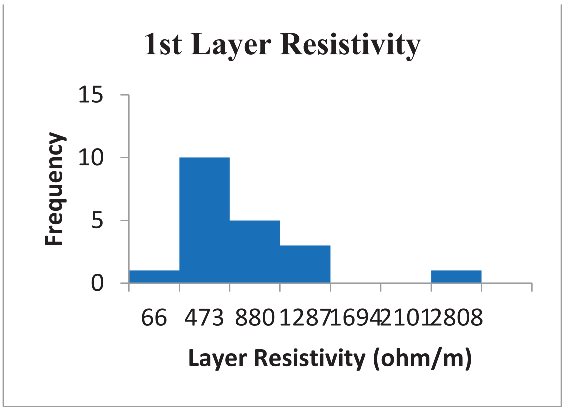


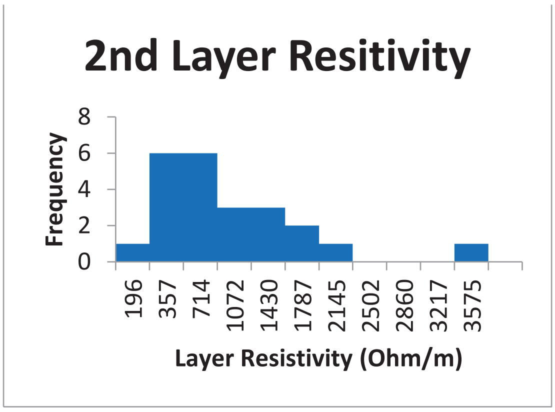
5e



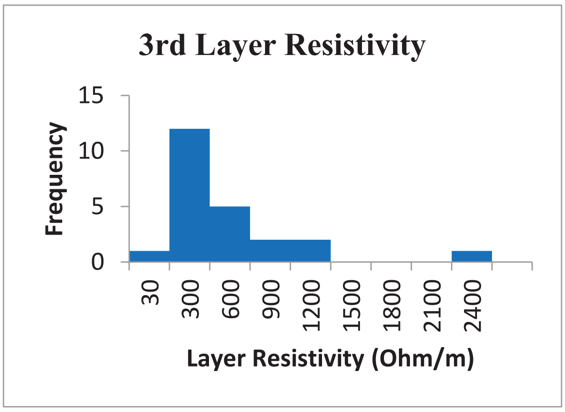
5f



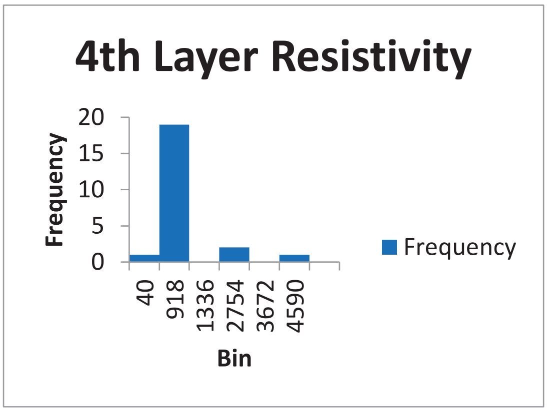
5g



5h



5i



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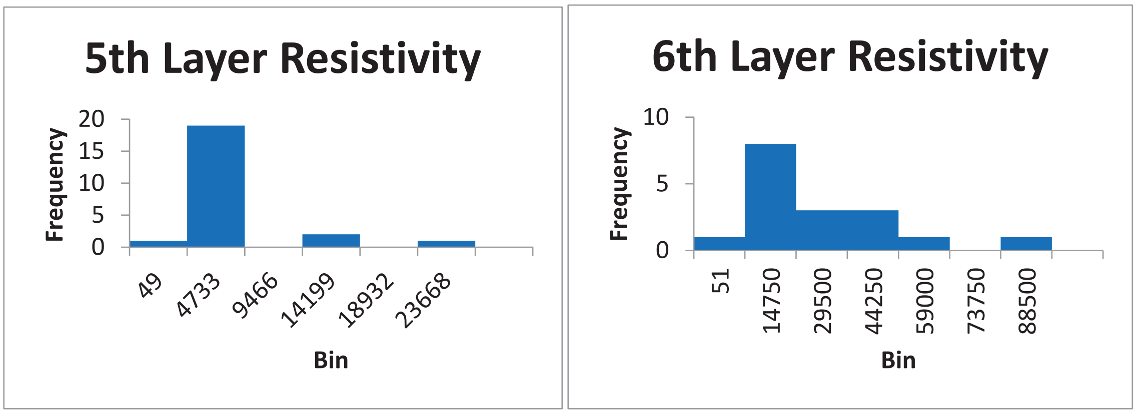

5k 5l

Figure 5(a-l) Layer thicknesses and resistivities histograms of Risha

Geoelectric/Lithologic Unit

The geoeletric section obtained from the quantitative interpreted results (Table. 1) is shown in Figure 6 and compared with lithologic log obtained near VES-12. The geoelectric layers correlate with the lithologic layers and this reveals five – six geolectric layers.

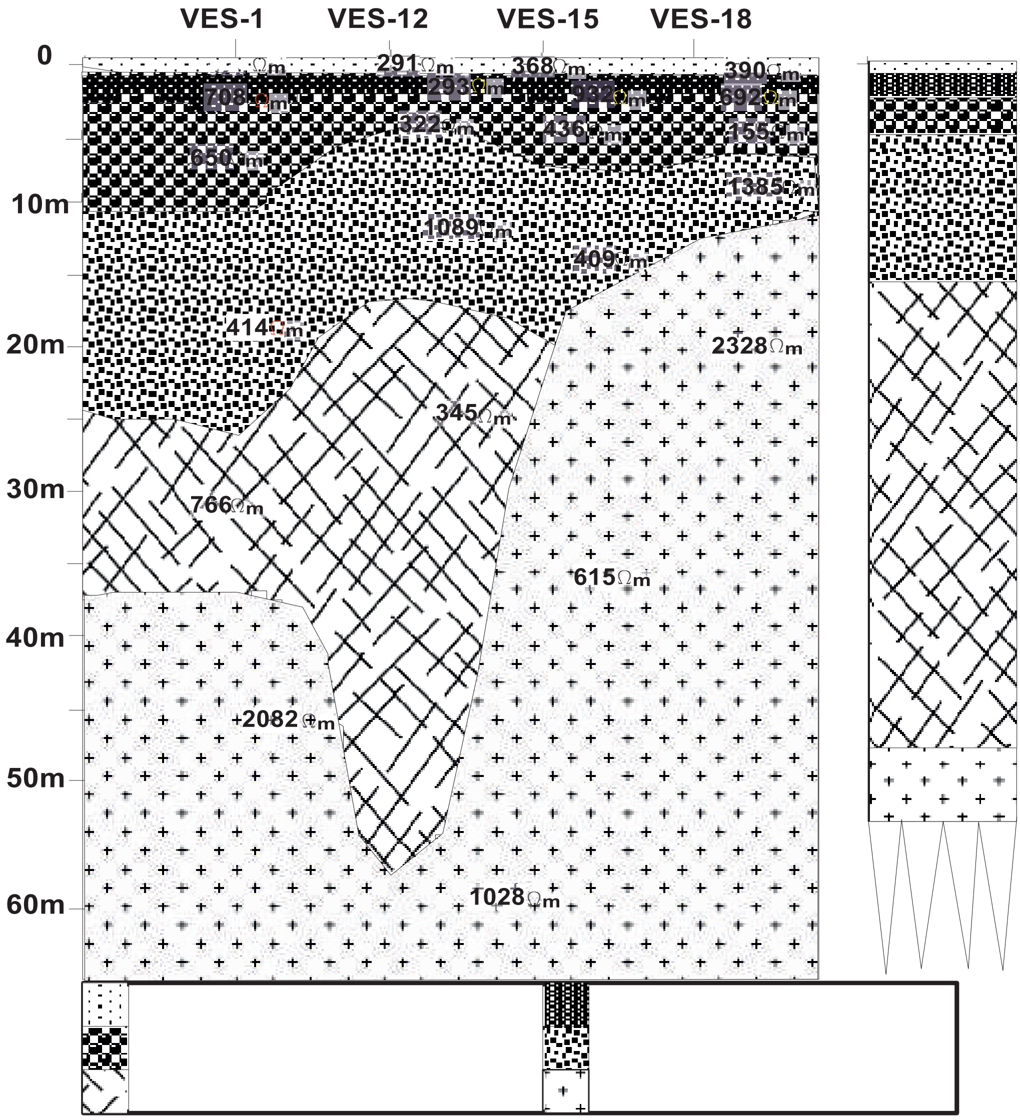

Figure 6: Geoelectric Section across of VES 1, 12, 15 and 18 and Lithologic log at VES12.

True Aquifer Resistivity

The true aquifer resistivity contour map (Figure 7) shows the variation in resistivity within the aquifer units of the study area. The resistivity value range is between 40 ohm-m and 510 ohm-m; with mean value 212 ohm-m. The classification of the groundwater potential of the aquifer units based on resistivity is premised on the findings of Wright (1992). Areas with resistivity less than 40 Ohm-m are clayey and possess limited aquifer potential. Zones whose resistivity are within the range of 40-80 ohm-m are zones with optimum weathering and good groundwater potential, while zones with resistivity values between 100 and 450 ohm-m possess medium aquifer conditions and potential.

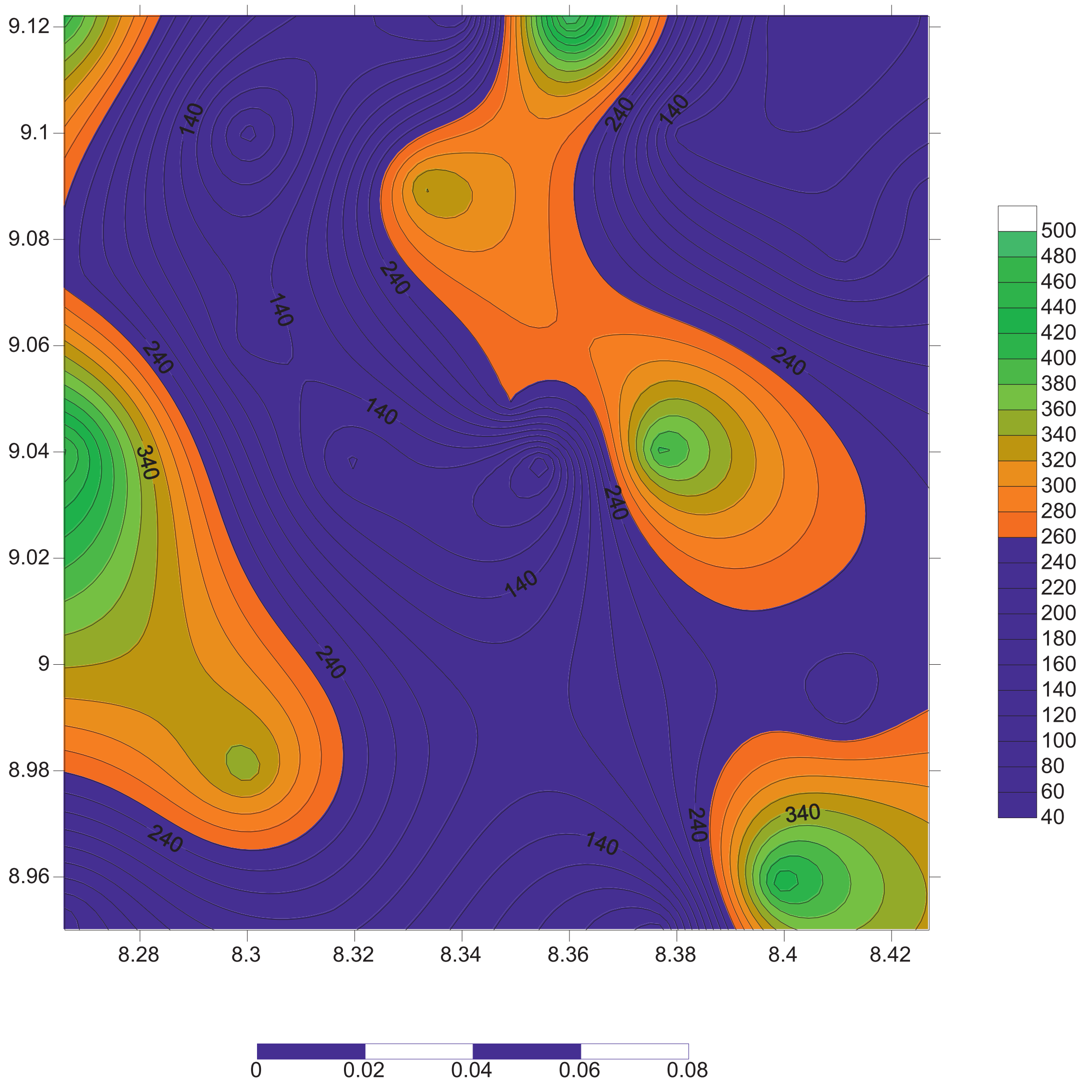

Figure 7: Groundwater Potential Map of Risha and its environs

True Aquifer Thickness

The thickness of the aquifer (weathered/fractured basement) varies between 2and 36m (Table 1, Figure 8). The aquifer units in the study area are mostly found in the weathered and fractured basement which has a mean thickness of 10 m, showing a relatively moderate appeal for groundwater development. However there are some areas whose aquifer units are relatively thicker varying between 12 m and 40 m. Such zones are considered in this study to have a good groundwater potential. More also, static water level and depth of ten (10) wells were measured in Risha village, revealing that the depth ranges mostly from 10 to14m while the static water level ranges from 8 to12m (which occurs mostly within the granite gneiss than in the schistose gneiss). This implies that the former has greater water potential than the latter.

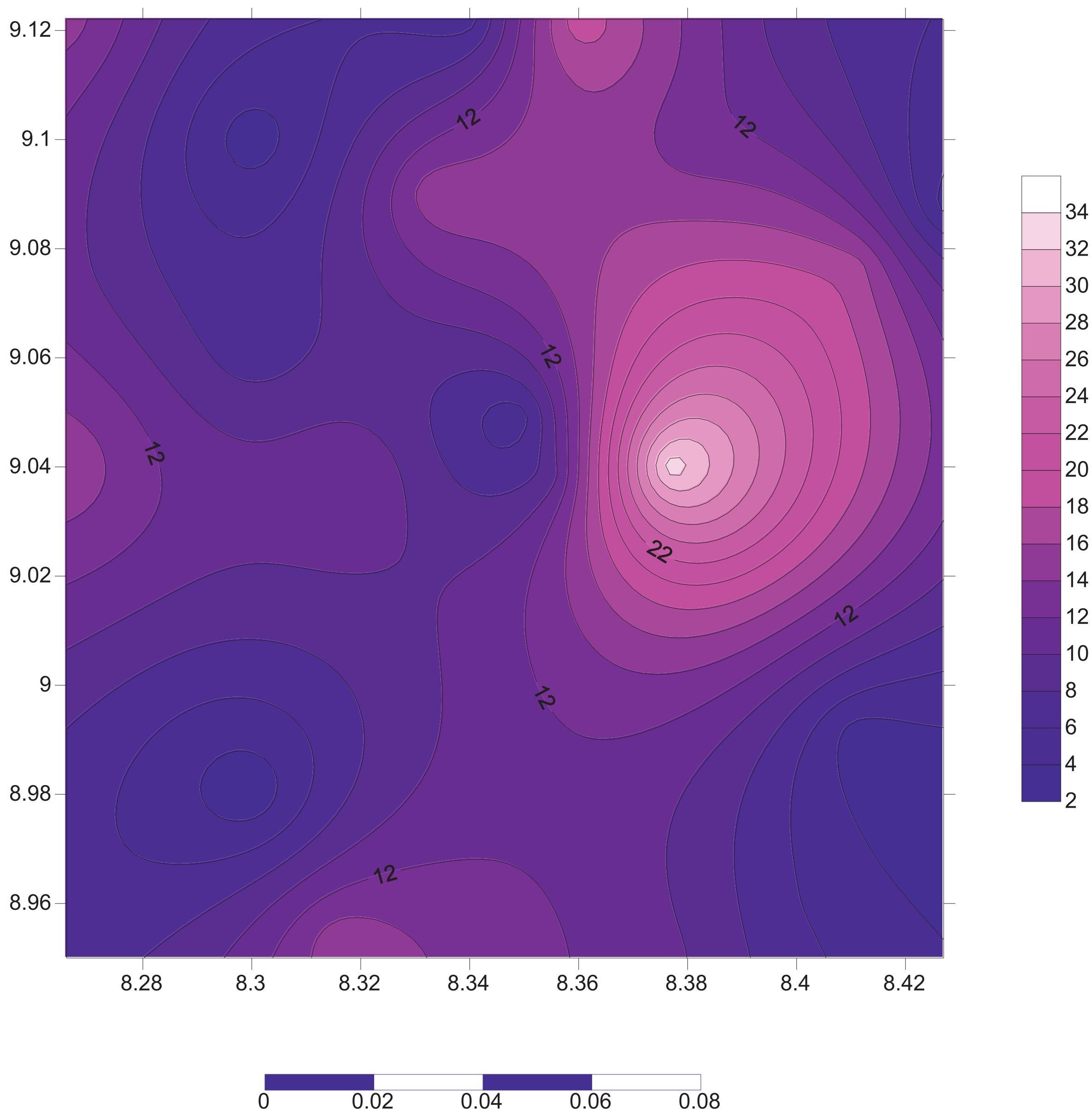

Figure 8: True aquifer thickness map of Risha and its environs

Top Layer Resistivity

The top layer resistivity map (Table 1, Figure 9) shows thatthe resistivity of the topsoil (sand/clay) with depth range of 0.3 to 2.4m and resistivity value of 66 to 2850Ωmvaries from one location to another. The thin overburden in the study area, the topsoil (clay/sand) permits more infiltration than runoff and most probable because of the elevation of the study area which shows a nearly flat terrain (Dearmannet *al*., 1978). The major source of the aquifer recharge is mainly precipitation.

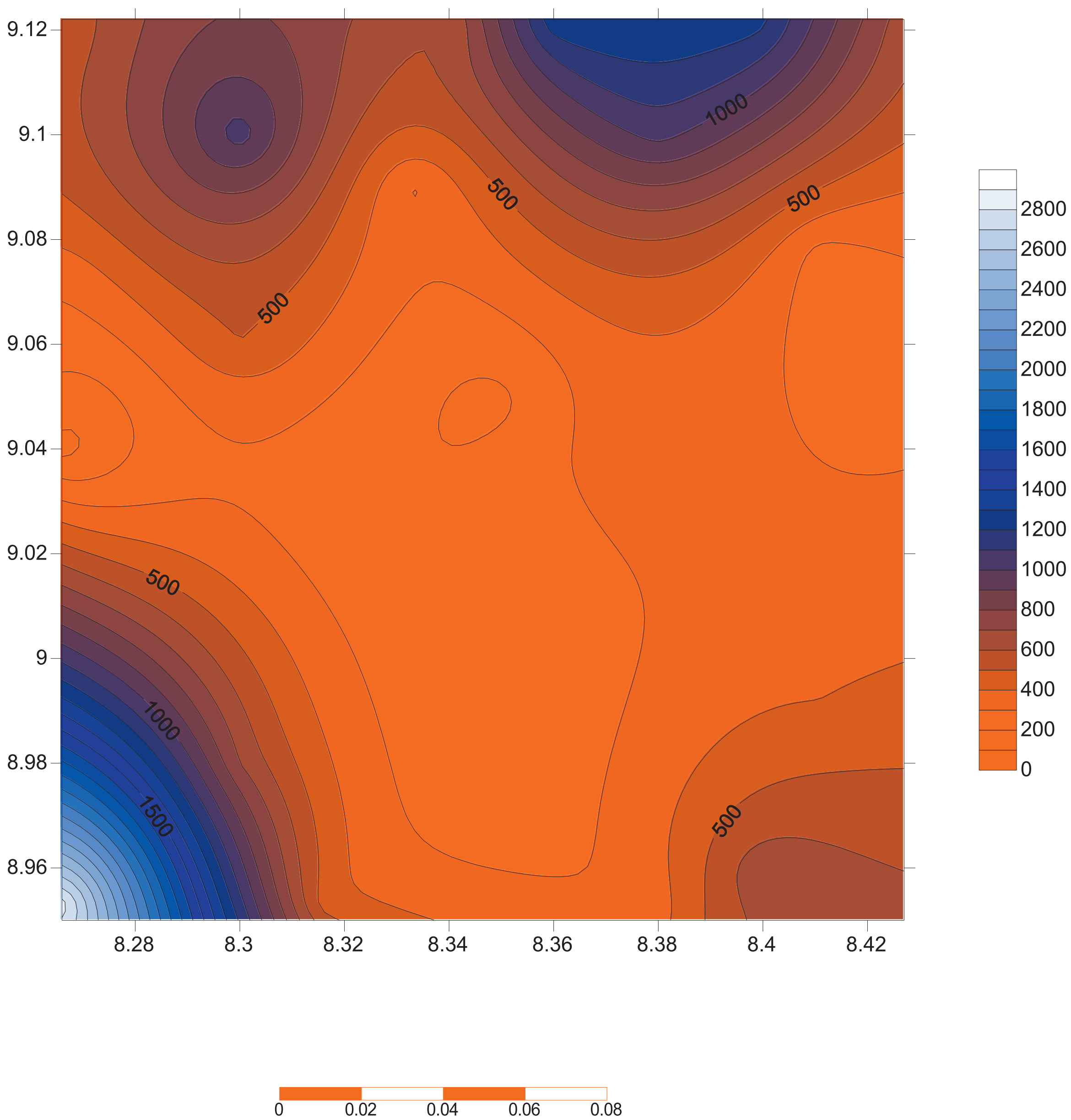

Figure 9: Top layer resistivity map of Risha and environs

Piezometric map

The piezometric map was produced by subtracting the surface elevation from the elevation of the bedrock. The piezometric water level shows the gradient flow of the aquifers which range from 415-483m as shown in (Figure 10). This implies that water will flow from region of higher elevation head to region lower elevation level. These differences in elevation head helps in the determination of the direction of flow of groundwater in the study area. From the piezometric map of study area it can be deduce that water flows from the North to West (above Tidde), North to East (AngwanDorowa/Ridam), West to South (below Tidde/Ngazzu) East to South (eastward from Risha) and South to West (around Adande/Ngakide).

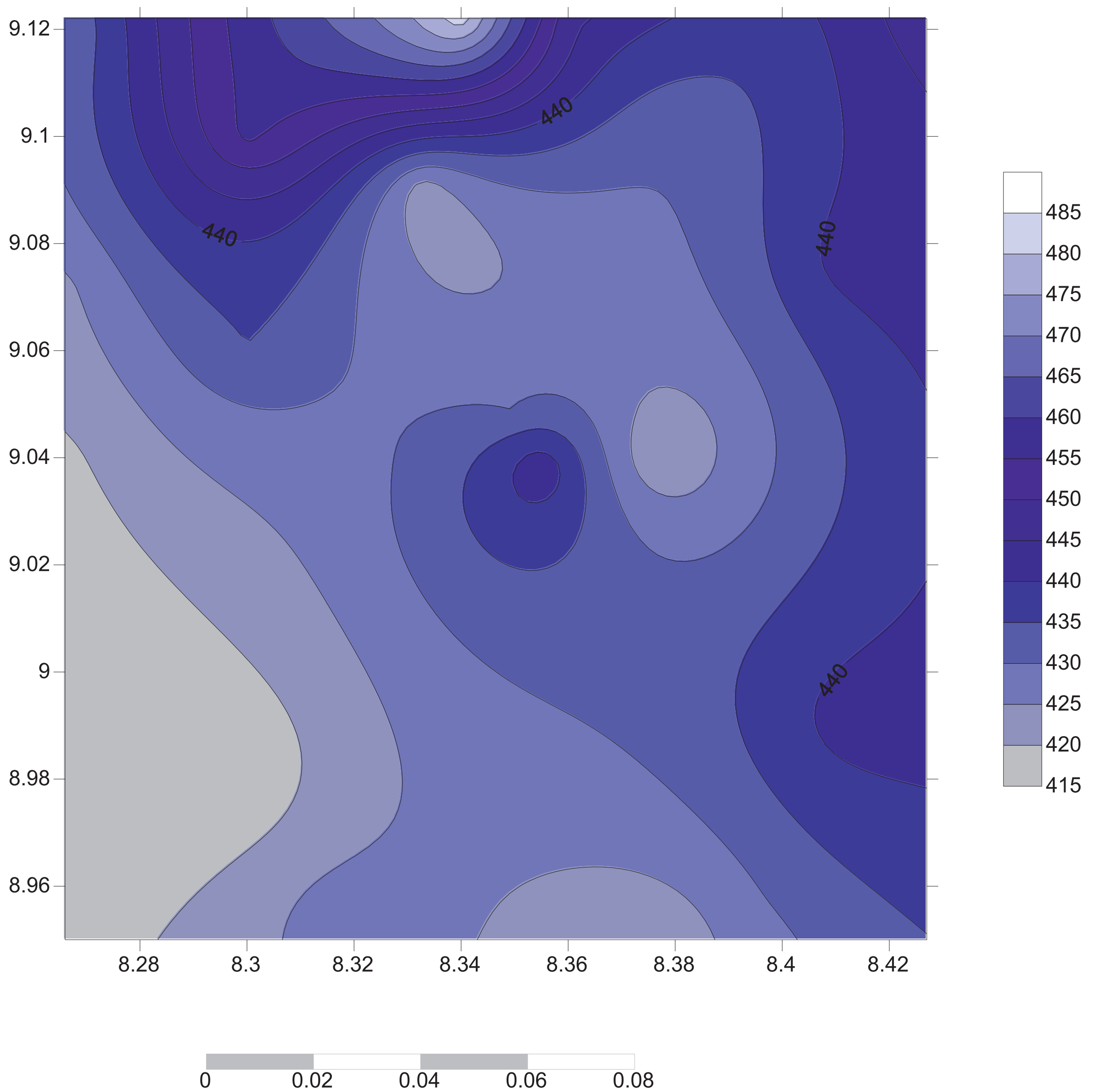

Figure 10: Piezometric map of Risha and its Environs

These results correlate favorably with the structural features (joints) of the study area (Plate 1 Figure 11).Joints are regular and irregular cracks with no relative movement. They were observed almost in all outcrop units. They are mostly product features of tectonic origin which resulted due to several deformational episodes that affect the Basement Complex. In the study area two types of joint were observed namely: the open joint and close joint. These structures observed are mostly interconnected (as seen at the surface) therefore can also be inferred for the structures underground, therefore the interconnectivity of the structures forms a good aquifer capable of retaining and transmitting substantial amount of water.

Plate1. Photograph showing (a) Open joint caused by plant root (b) Close joint (N08^0 59' 22.1'' E08^0 17' 50'')

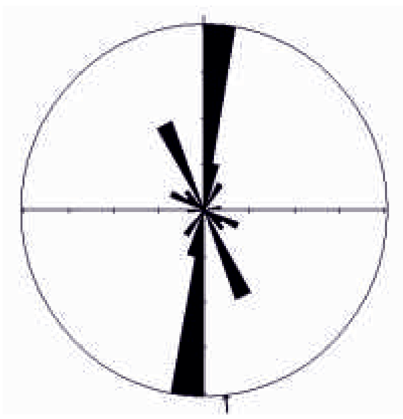

Figure 11: Rose plot for joints with the dominant direction in the NE-SW

Depth to basement

This is the depth to the basement rock (fresh bedrock) beneath the surface. The depth to fresh basement rocks beneath the sounding point was obtained from the quantitative interpretation (Table 1). The depth to basement rocks ranges from 10m to 58m and the layers encountered are inferred to be sand/clay, lateritic clay, weathered rocks or regolith, weathered fractured/fresh basement. The basement is deeper at the north-central (Risha), west

(Tidde and Ngazzu) and in the southern portion of the study area (Ngakide and Adande). Generally, the depth to the basement decreases northwest (AngwanDorowa and Ridam), northeast, southwest (Ngazzu area) and southeast (around Ngakide and Adande area) from the portion with high thickness. The zones with the high overburden thickness are groundwater receptacle and correspond to the basement depression areas. Furthermore with thick overburden, less percentage of clay and good degree of porosity and permeability could have relatively good groundwater yield (Jatau *et al*., 2013a).The result is in close agreement with the other research work carried out in the north-central Nigeria (Dan-Hassan and Olorunfemi 1999) that predicted 4.3m to 64m and Jatau *et al.,* (2013b)5m to 49m. Risha, Tidde, and Ridam villages fall within the area with thick overburden while Ngazzu, Ade-Katako, Adande, Ngakide and AngwanDorowa fall within the area of shallow overburden (Figure 12). Areas with thin overburden correspond to shallow depths of weathering while areas with thick overburden correspond to those with deeper depths of weathering.

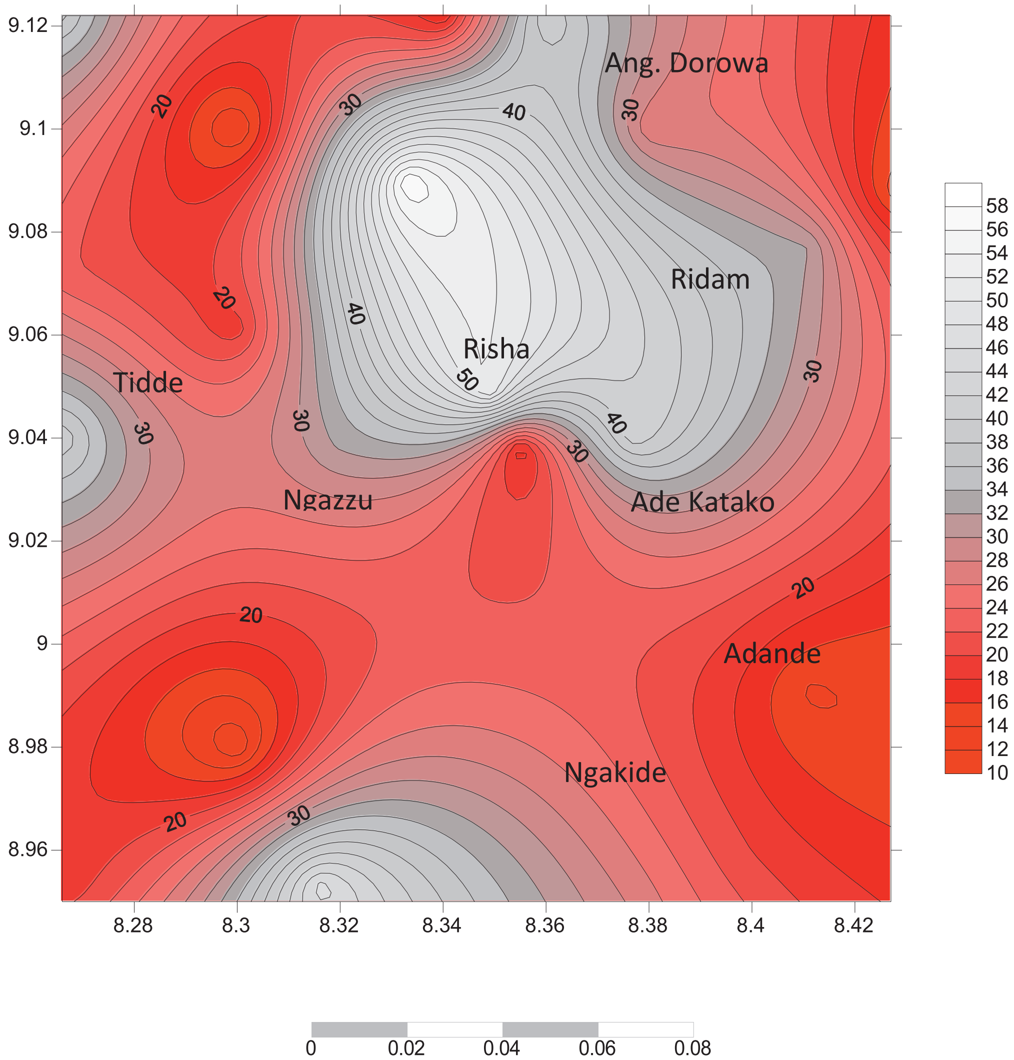

Figure12.Depth to Basement Map

3-dimensional Elevation plot

In the 3-Dimensional elevation plot (Figure 13) good groundwater potential zones coincide with areas characterized by depressions on the basement topography map. Also, the zones with poor groundwater potential correspond to areas associated with basement ridges.

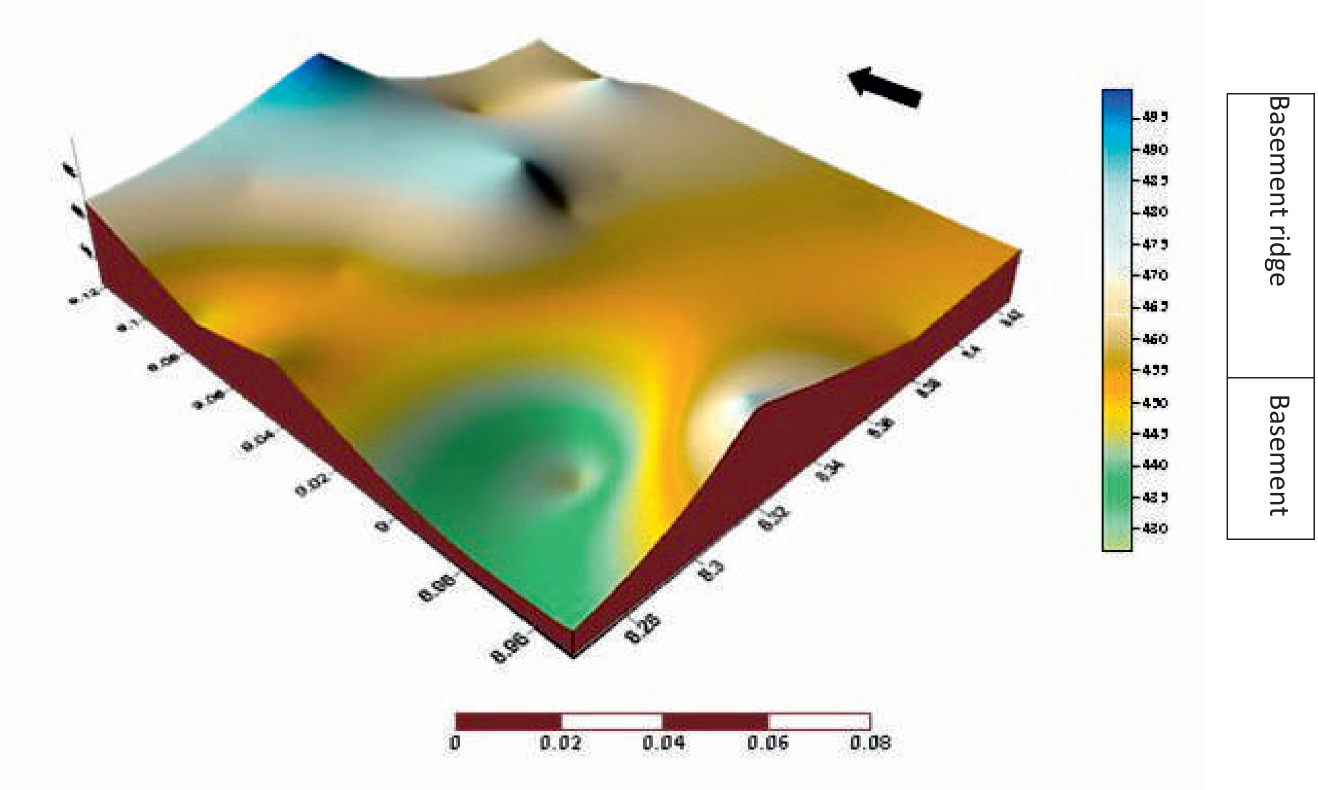

Figure 13: Three-dimensional elevation map of the area

CONCLUSION

They different kind of rock types found in the study area are schistose-gneiss, granite-gneiss and pegmatite. All these rock types are known to contain water in both weathered and fractured zones therefore the geophysical investigation revealed four to six (4-6) geoelectric layers in the geological units underlying this study area. The aquifer units (Figure 7) are mostly found within the weathered and fracture basement with depth ranging from 2 to 36m with resistivity range of 40 to 510Ωm. Areas with resistivity less than 40ohm-m are clayey and possess limited aquifer potential, zones whose resistivities are within the range of 40-260 Ωm are zones with optimum weathering and good groundwater potential (weathered zones) while zones with resistivity values between 260 and 510 Ωm possess medium aquifer conditions and potential (fractured zones).This is backed up the thickness of the aquifer (Figure 8) which shows that areas whose aquifer units are relatively thick, varying between 12m and 40m are considered in this study to have a good groundwater potential, while for depth less than 12m are considered to be poor. The depth to basement maps shows a depth range from 10m-58m and the layers are inferred to be sand/clay, lateritic clay, weathered rocks or regolith, weathered fractured/fresh The basement is deeper at the north-central (Risha), west (Tidde and Ngazzu) and in the southern portion of the study area (Ngakide and Adande), and the depth tends to decrease northwest (Angwan Dorowa and Ridam), northeast, southwest (below Ngazzu area) and southeast (around Ngakide and Adande area) from the portion with high thickness. The zones with the high overburden thickness are groundwater receptacle and correspond to the basement depression areas, furthermore with thick overburden, less percentage of clay and good degree of porosity and permeability which have relatively good groundwater yield.Furthermore, the thin overburden in the study area, the topsoil (clay/sand) permits more infiltration than runoff and most probable because of the elevation of the study area which shows a nearly flat terrain, therefore the major source of the aquifer recharge is precipitation.Finallythe 3-Dimensional elevation map (Figure 13) shows that good groundwater potential zones coincide with areas characterized by depressions on the basement topography map while zones with poor groundwater potential correspond to areas associated with basement ridges. From the interpretation of the aquifer resistivity map , aquifer thickness map, piezometric map and depth to basement map there exists a strong relationship between these maps and the groundwater potential map, as good groundwater potential zones coincide with areas characterized by depressions on the basement topography map. Also, the zones with poor groundwater potential correspond to areas associated with basement ridges. The groundwater potential around Risha, Tidde and Ridam is high compared to Ade-Katako, Ngazzu, Angwan-Dorowa, Ngakide and Adande.

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