Geological and Structural Control of Groundwater Occurrence in parts of Abuja, North-Central Nigeria.

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Abstract
The study of geological and structural control of groundwater occurrence in parts of Abuja, North-central Nigeria was investigated with the aim of providing a model for groundwater occurrence in the area. The study area of lies between latitude 9°07'30"N to 9°15'00"N and longitude 7°19'5"E to 7°27'20"E covering Kubwa, Tunga Alhaji, Dutsen Alhaji and Tunga Magaranta area of Abuja. The geological mapping revealed three rock types in the area: migmatites, schist and granites which were differentiated in two based on texture. Structural analyses of the area indicate NW-SE as the principal joint direction in the area which corresponds to the area underlain by the granites. The vertical electrical sounding method was used to delineate the fracture density and aquifer characteristics of the area. The results of the VES investigation also confirm the NW-SE direction as the major fracture axis and also conform to the regional fracture pattern of the area. Thick weathering layer of about 25m to 40m was discovered along the NW-SE direction and the groundwater flows majorly in the same direction which implies that it is structurally controlled and the same with the river flow in the area. The geoelectric layers were found in the order of: top layer, weathered layer/fractured zone and fresh basement rock typical of a basement aquifer. The isoresistivity maps taken at various depths further ascertain the dominance of fractures in the NW-SE direction. For good yield in boreholes and wells, it is recommended that groundwater abstraction in the area should concentrate more on the northwestern and southeastern portions of the area.

Keywords: Geological mapping, Fracture analysis, Groundwater Occurrence, Abuja, North-Central Nigeria

Introduction

Groundwater models are computer models of groundwater flow systems and are used by hydrogeologists to simulate and predict aquifer conditions. Groundwater is found in geologic structures such as fractures and joint in basement rock, while in sedimentary rock, it is found in aquifers, and obtained through boreholes and hand dug wells. However the study of Geological control for groundwater occurrence in pats of Abuja, North Central Nigeria has been carried out to create a model for groundwater exploration in the area. The geology and structural configuration of an area determines the occurrence and movement of groundwater (Amadi *et al.*, 2015). Studies has revealed that drainage system and rivers flow in an area give clues to the structural signatures which control the groundwater flow (Olasehinde, *et al.*, 2016).

Due to inadequate supply of public water within Abuja municipality, the inhabitants are resort to construction of boreholes and hand-dug wells for their daily water needs. The success of these boreholes and hand-dug wells hinges on geological structures, textures and hydraulic properties of the aquifers, hence the need for the present study. It was designed to integrate geological mapping, electric resistivity sounding and remote sensing data to establish the geological structures and textural attributes of the aquifer that drive groundwater migration (Okoye and Amadi, 2010; Goki *et al.*, 2011; Momoh *et al.*, 2012; Amadi *et al.*, 2013; Alao *et al.*, 2013; Omanayin *et al.*, 2013).

Methodology

Description of the Study Area

The study area lies between latitude 9°0'00"N to latitude 9°15'00"N and longitude 7°15'00"E to 7°30'00"E and part of sheet 186, Abuja SE, covering a total area of about 752.60 km^2 (Fig. 1).

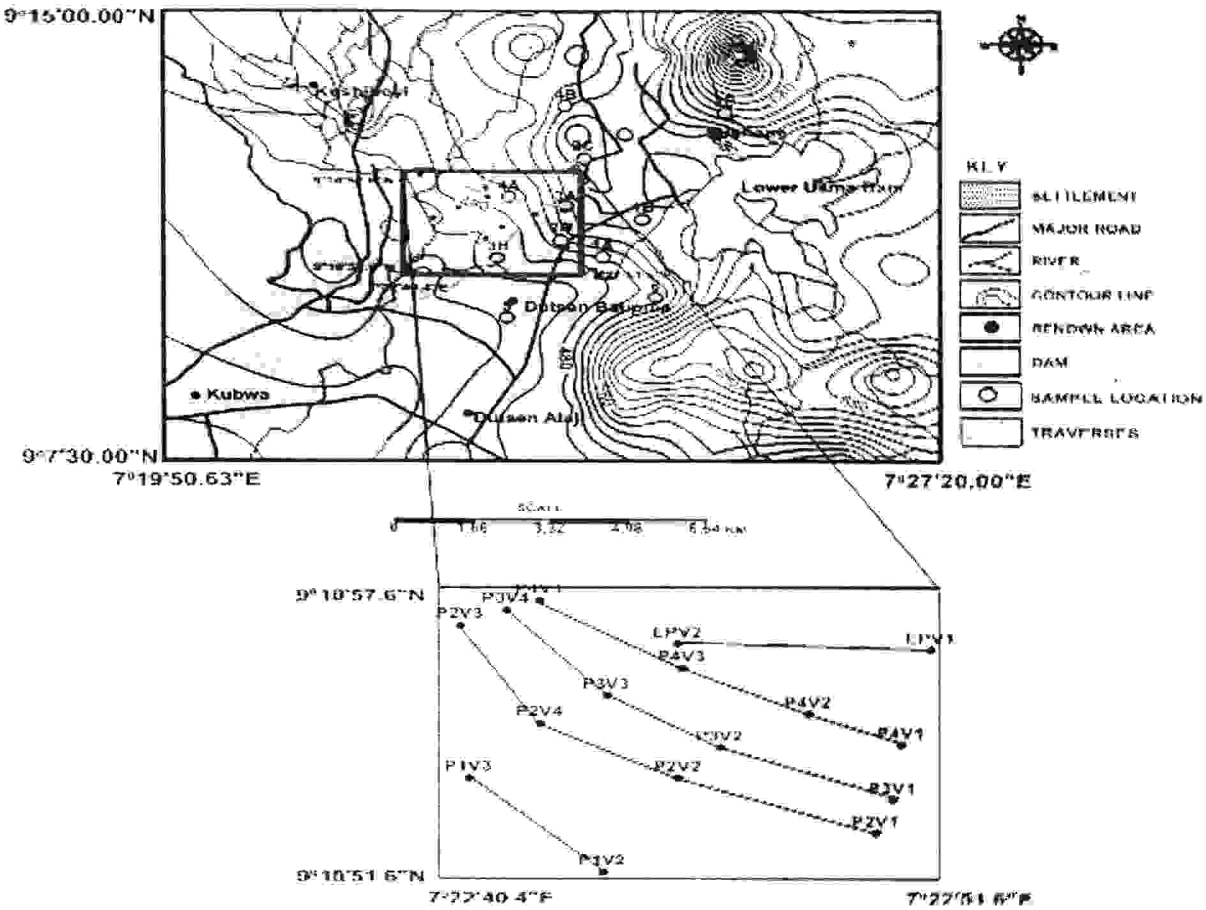

Fig. 1: Topo map of the Study Area showing the profiles and VES points

The climate of the area is made up of the rainy season (April-October) and dry season (November-March). Abuja falls within the Guinea savanna, which consists of tall grasses and trees. The area is characterized by high relief and rugged topography. The relief bears the signature of remobilized rocks during the Pan-African Orogeny as most of the surface structures are well pronounced and can be studied regionally (Ajibade and Woakes, 1976; Offodile, 1983).

Theory and Principle of Electrical Resistivity Sounding

Electrical resistivity techniques are based on the response of the earth to the flow of electric current. With an electrical current passed into the ground and two potential electrodes to record the resultant potential difference between them, we can obtain a direct measure of electrical impedance of the subsurface material (Olasehinde *et al.*, 1998). The resistivity of the subsurface material observed is a function of the magnitude of the current, the recorded potential difference and the geometry of the electrode array used. Measurement of resistivity is, in general, a measure of water saturation and pore space connectivity. Resistivity measurements are associated with varying depths relative to the distance between the current electrodes (AB) and potential electrodes (MN) in the survey (Fig. 2), and can be interpreted qualitatively and quantitatively in terms of a lithologic or geohydrologic model of the subsurface (Amadi *et al.*, 2015). Electrical resistivity method involves the supply of direct current or low-frequency alternating current into the ground through a pair of current electrodes and the measurement of the resulting potential through another pair of electrode called potential electrodes. Rock resistivity depends on a number of factors such as the amount of water present in fractures and features, porosity and the degree of saturation.

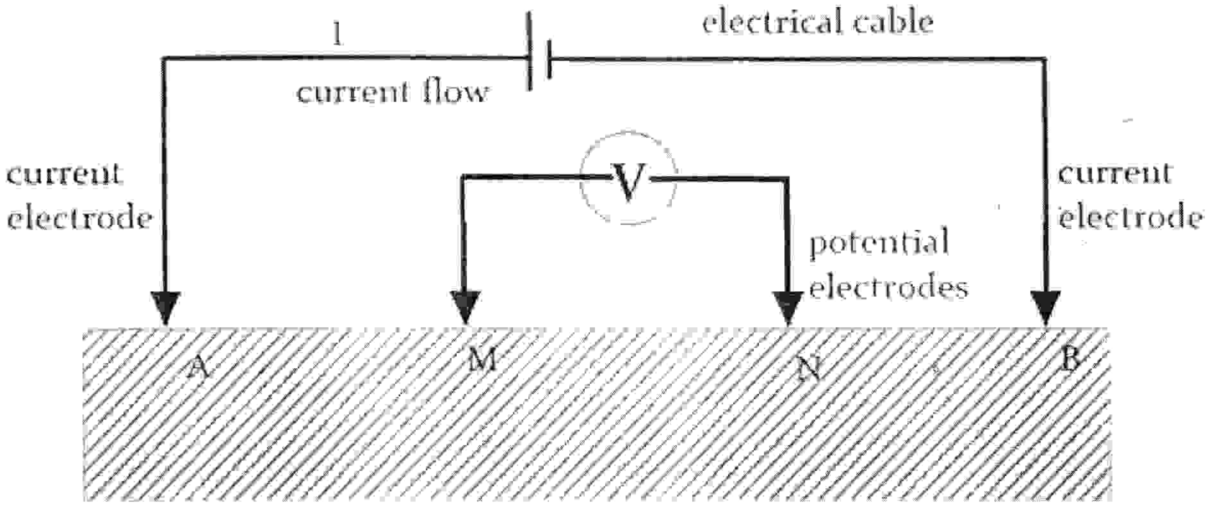

Fig. 2: Schlumberger Array for Electrical Resistivity Sounding

Results

The geological map obtained from the geological mapping exercise is shown in Fig. 3 while the rosset diagram generated through the joint values collected in the field during mapping is revealed in Fig. 4.

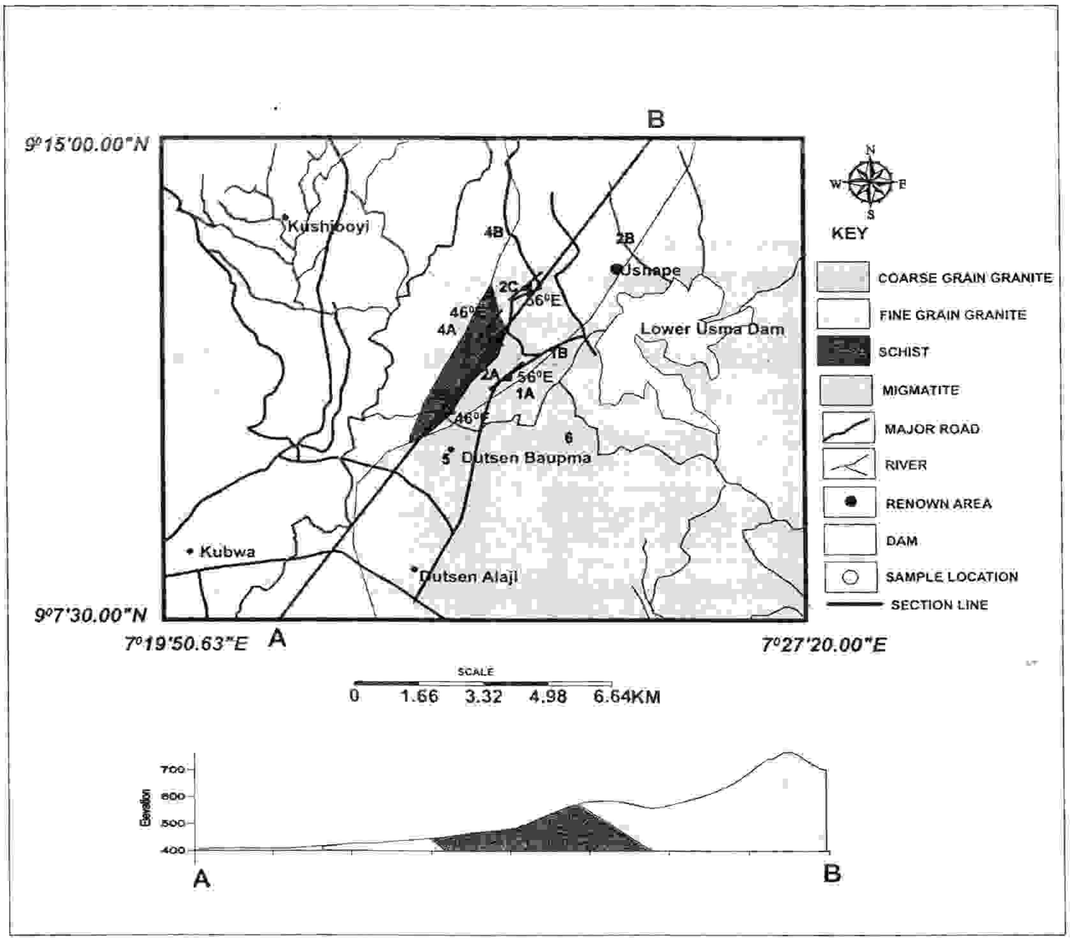

Fig. 3: Geological map of the Study Area

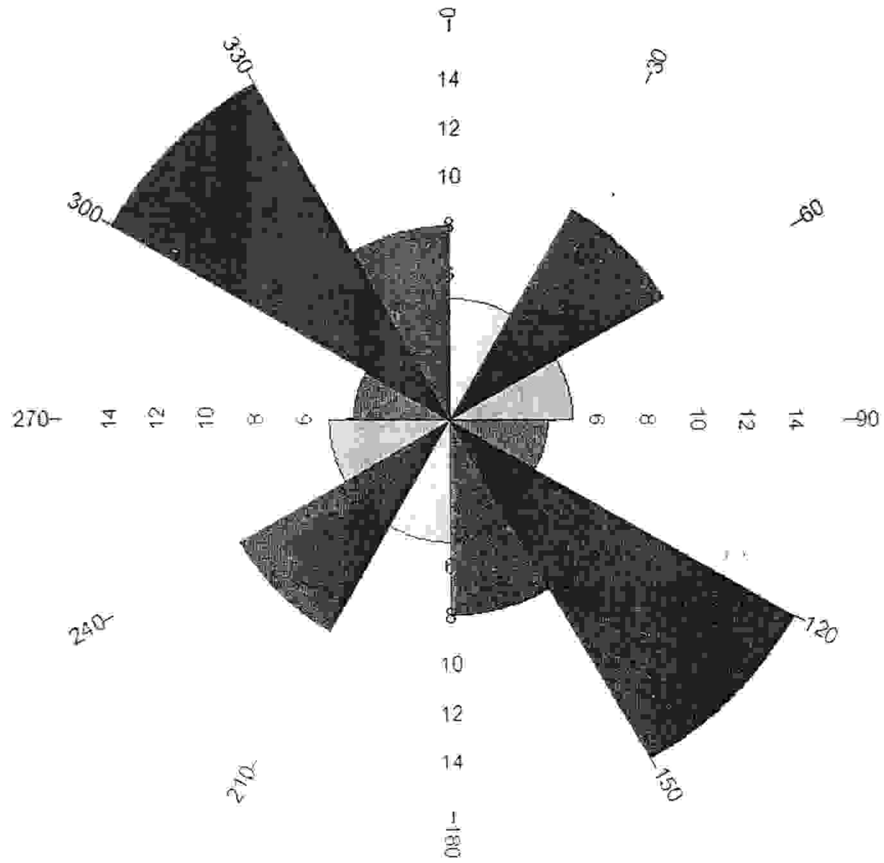

Fig. 4: Rosset diagram showing the principal joint directions in the study area (NW-SE)

The vertical electrical sounding (VES) data using the Scglumberger Array was used to generate geo-electric sections of the area. Fig. 5a shows a 3 layer section while Fig. 5b indicates a 4 layer system. A representative computer modeled VES curve is illustrated in Fig. 6. The VES data obtained in the field is summarized in Table 1. The computer modeled curves were elucidated using curve matching techniques. Furthermore, the VES field data were used to generate subsurface Iso-resistivity maps at 10 m (Fig. 7) and 30 m (Fig. 8) below the ground level respectively.

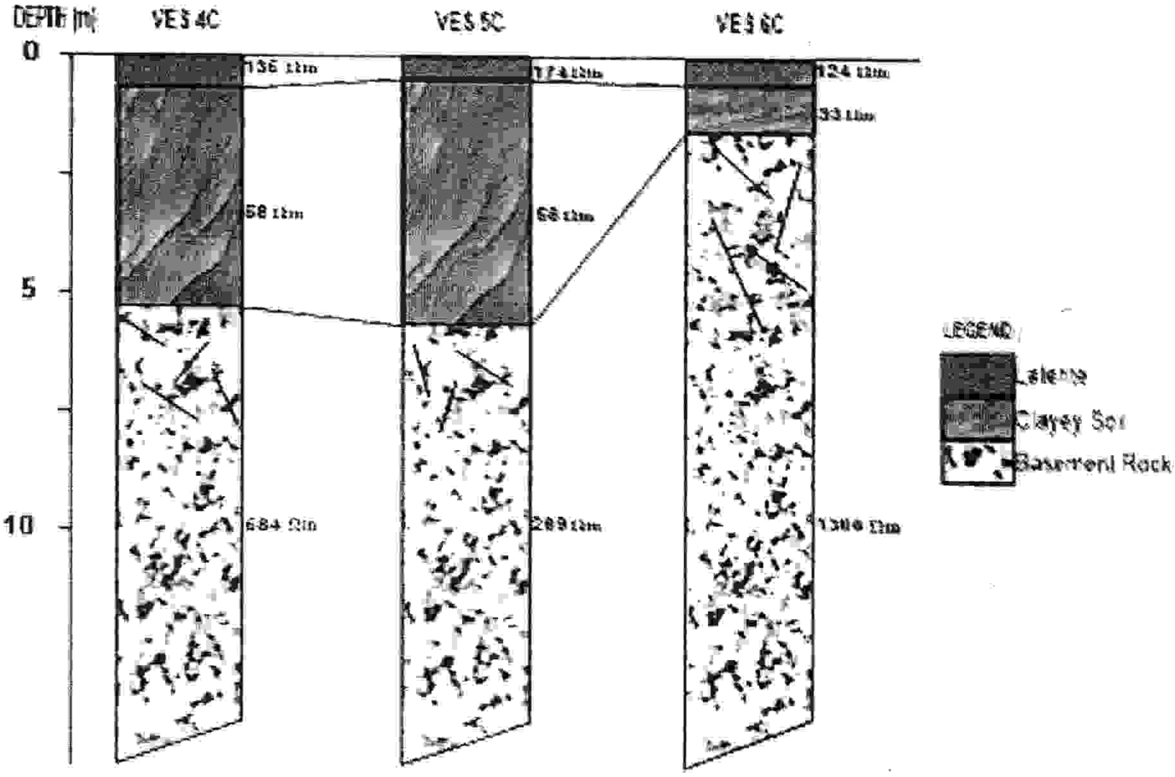

Fig. 5a: Geo-electric Section of a 3 layer system for the Study Area

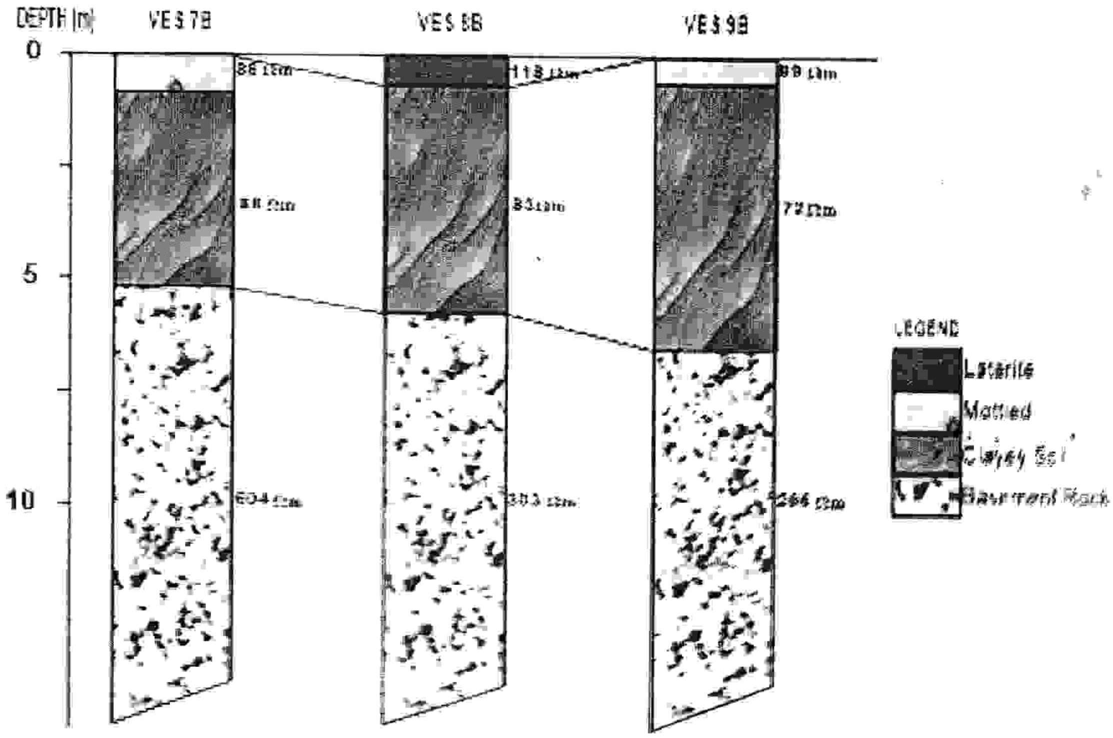

Fig. 5b: Geo-electric Section of a 4 layer system for the Study Area

Table 1: The VES locations and their respective computed apparent resistivity values

AB/2	1	2	3	5	6	8	10	15	20	25	30
P1V2	80	168	191	314	339	464	414	441	539	560	556
P1V3	183	259	356	475	548	665	781	970	902	848	826
P2V1	151	167	196	210	213	75	229	190	180	183	186
P2V2	225	192	161	96	118	108	103	119	136	183	174
P2V3	30	111	90	75	78	76	73	86	96	132	129
P2V4	227	10	170	134	115	94	94	96	111	148	214
P3V1	203	274	316	303	325	344	318	318	304	284	337
P3V2	294	257	249	261	257	230	56	210	269	1622	287
P3V3	73	109	129	176	159	161	140	126	128	121	242
P3V4	41	82	58	62	80	83	120	132	128	144	169
P4V1	262	395	361	306	275	284	285	285	319	350	405
P4V2	167	214	227	210	200	212	207	237	282	346	399
P4V3	298	281	314	1824	344	404	432	554	593	650	658
P4V4	155	172	192	202	216	243	183	289	343	416	461
EPV1	492	698	494	498	249	345	620	528	54	1272	753
EPV2	233	297	683	1128	1310	1399	1724	1939	2203	2447	2754

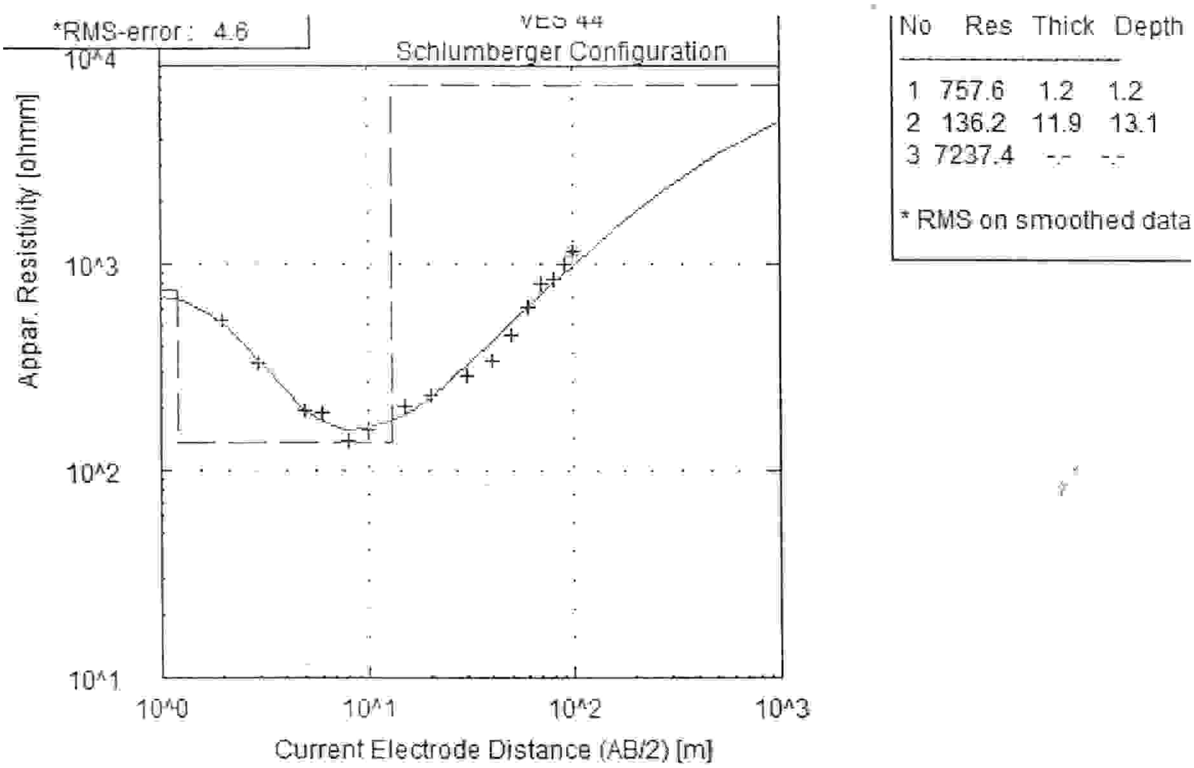

Fig. 6: Typical computer modeled curve for the area

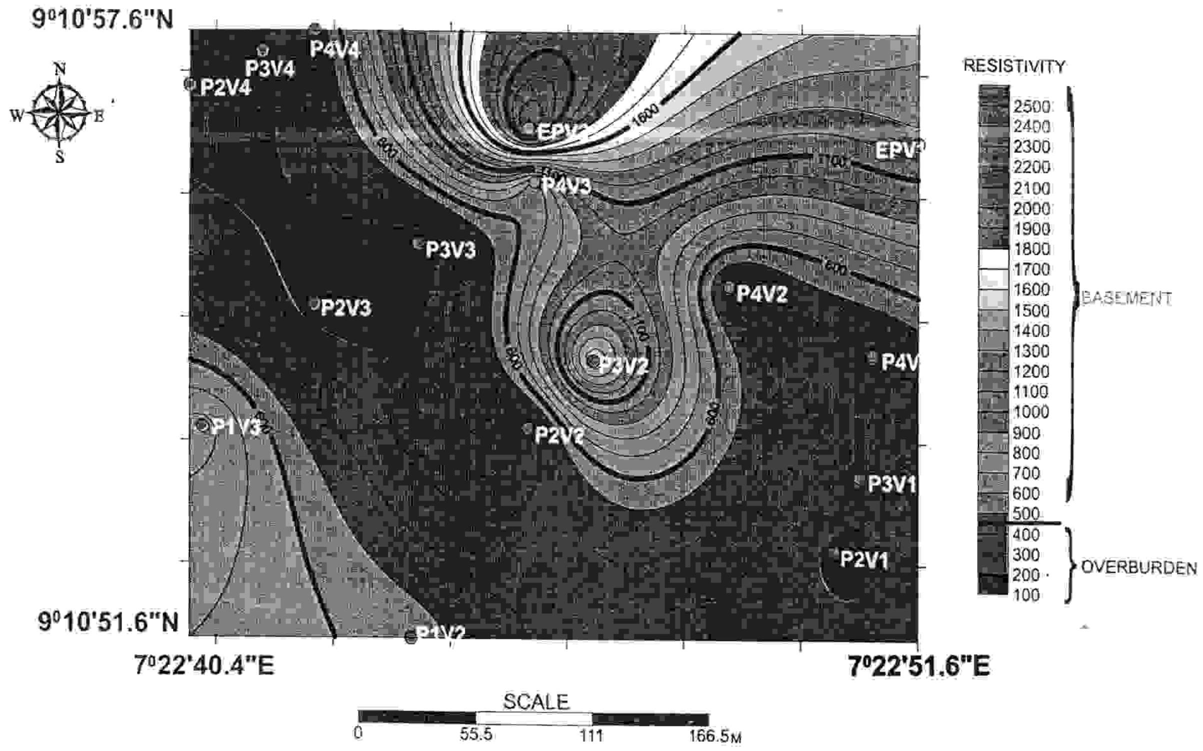

Fig. 7: Isoresistivity map at 10m below ground surface

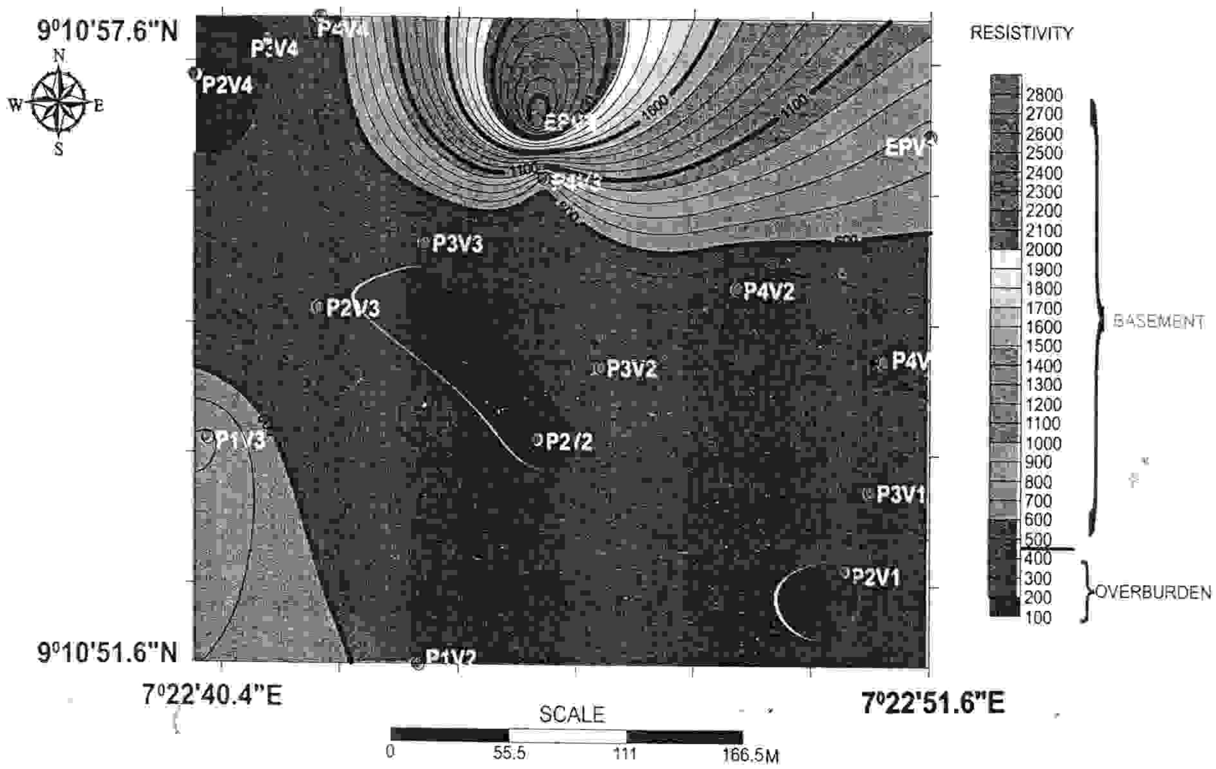

Fig. 8: Isoresistivity map at 30m below ground surface

Discussion

Geological and Structural Mapping of the Study Area

Detailed geological mapping of the study area revealed the following rock types: Migmatite, Schist, coarse grain Muscovite Granite and fine to medium grain Biotite Granite (Fig. 3). The joint values collected during the fieldwork were used to construct the rosset diagram for the study area. The determination of the principal joint direction (NW-SE), implies the dominant fracture density in the area (Fig. 4). They are potential sites for mineralization and groundwater accumulation, while geotechnical, fractures are disadvantageous as the lead to structural failure over-time. They drainage pattern in the area is trellis in nature and the flow of major rivers in the area is structurally controlled in line with the major joint direction (Amadi *et al.*, 2016).

Geophysical Investigation

In order to elucidate the orientation, frequency and depth to bedrock, geophysical investigation employing horizontal profiling (HP) and vertical electrical sounding (VES) was employed to further correlate the geological and structural signatures. The depth of overburden, depth to fractured zone and depth to fresh basement were determined using the isoresistivity map at 10 m and 30 m below the ground surface. This result of the VES data (Table 1) showed the dominance of fractures along the NW-SE direction of the study area in line with the rosset diagram (Fig. 4). The low resistivity values imply high conductivity values which are good characteristics of saturated aquiferous zone. Non-fractured crystalline rocks have high resistivity due to the absence of water. Fractures are conduits through which water infiltrates into such rocks and their presence are confirmed by low resistivity or high conductivity (Amadi *et al.*, 2014). The dominance of low resistivity values long the NW-SE axis as shown in the isoresistivity maps at depths of 10m (Fig. 7) and 30m (Fig. 8) confirm the findings of both geological and structural mapping of the area. The computer modeled curve and geo-electric section testify to the fact that the northwestern and southeastern portions of the study area has good groundwater potentials.

Conclusion

The structural and textural characteristics of rocks in an area influence the occurrence, distribution and availability of groundwater. The orientation of the structural elements in a rock in enhances groundwater accumulation in an area. The geological mapping of the area indicates the presences of three litho-facies: migmatites, schist and granites of varying grain sizes. The structural mapping revealed the principal joint direction in the area as NW-SE. The geophysical investigation as reflected in the isoresistivity maps at various depths further ascertain the dominance of fractures along the NW-SE direction. The study revealed that the groundwater movements as well as the flow of rivers in the area are structurally controlled. The recommended minimum drill depth for the area is 45m.

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