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Subsurface Structural Studies of Bayero University, Kano Permanent Site Using Electrical Methods

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Abstract

This paper centers on the investigation of the subsurface condition of Bayero University Kano Permanent site with the aim of understanding the lithology and also to map out the groundwater patterns within the area. To achieve this, Resistivity, Time Domain Induced Polarization (IP) and Self-Potential (SP) methods were adopted using Vertical Electrical Sounding (VES) technique. ABEM Terrameter SAS 1000 was used for the sounding with Schlumberger electrode array configuration and a total of 49 stations were sounded. Some software's were used to analyze and interprete the measured data. The result of the analysis shows that the area is underlain by two to five subsurface layers. The aquiferous zone of the study area occurs in the weathered and fractured basement rocks. SP values were plotted against depths of investigation. The peak SP values were used in identifying areas with greater depth of flow in the study area. From the analysis of the overburden thickness, aquifer thickness and SP values, the most favorable regions for groundwater exploitation were VES 11(11.9734^{0}N, 8.4371^{0}E), 13(11.9771^{0}N, 8.4342^{0}E) 19(11.9723^{0}N, 8.4311^{0}E) and 44(11.9645^{0}N, 8.4282^{0}E). The suitability of the groundwater in the area for drinking was assessed and it was found that it is safe for drinking and other domestic usages. The investigation also provides information about the subsurface condition with regards to engineering construction and safe place for refuse dumping in order to avoid groundwater contamination.

Keywords: Contamination, Polarization, Potential, Resistivity, and Structural

1.0 Introduction

Access to clean water is a human right and a basic requirement for economic development [1]. As groundwater becomes more important and a source of uncontaminated water, methods for locating good aquifers must become more efficient [2].

Understanding the subsurface structure is very crucial to construction engineers. This information about the subsurface distribution of rock types proved essential to engineers in three perspectives namely (i) gaining understanding of the competence of the host environment of engineering works (ii) establishing the amount of earthwork needed when generating bill of quantity by Quantity Surveyors and (iii) strategizing the positioning of lay out to ensure a more environmental friendly disposition of structures.

Electrical prospecting involves the detection of surface effects produced by electric current flow in the ground. Using electrical methods, one may measure potentials, current and electromagnetic fields that occur naturally – or are introduced artificially into the earth. Basically it is the enormous variation in electrical conductivity found in different rocks and minerals that makes this technique possible. This method which include resistivity method, spontaneous potential (SP) and induced polarization (IP) have been used over the years to study the subsurface structure as well as in ground water prospecting.

2.0 Aim and Objectives

The aim of this work is to evaluate the subsurface condition of Bayero University, Kano permanent site using electrical methods,

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The objectives of the study are:

a- To locate the ground water patterns within the Bayero University Kano permanent site.

b- To produce the aquifer thickness map of the study area

c- To locate safe place for refuse dumping to avoid groundwater contamination.

2.1 Location, Geology and Hydrogeology of the Study Area

Bayero University, Kano New Campus is located along the Gwarzo road in Ungoggo Local Government and it lies between latitude 11.9615^0N to 11.9922N and longitudes 8.4257^0E to 8.4399^0E. It is located at the outskirt of the ancient city of Kano state. The campus covers an area of $15.04km^2$.

The geology of the study area is the same as that of Kano state in general(Figure 1). The rock types in the area are older granites, sediments and older basement. The older basement is composed of migmatite, biotite gneiss, and blended gneiss. Migmatite is composite gneiss produced by injection of molten magma into schist host. Gneiss is metamorphosed granite and is grantic in composition, while biotite gneiss is a foliated crystalline rock with high biotite content. Banded gneiss has dark and light bands with a light fraction of quartz while the dark bands consist of biotite plagiodase and minerals [3].

Mohammed (1984) as quoted by Abubakar and Auwal [4] indicated that aquifer of the Basement Complex ofKano state is the weathered and fracture rocks in which ground water exists under water table condition. Water table lays at a depth generally less than 20m, and the maximum of boreholes rarely exceed 60m. Annual rainfall ranges from over 1000mm in the extreme south to a little less than 800mm in the extreme north. The rain last 3 to 5 months [5]

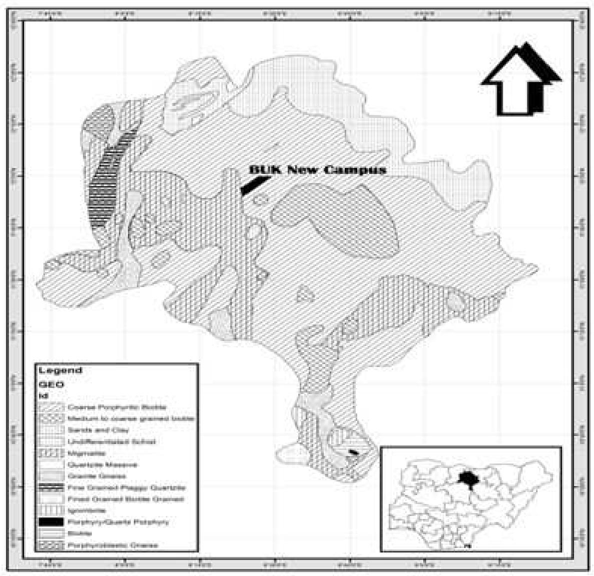


Figure 1: Geologic Map of Kano State Showing Ungoggo, The Study Area*[6]*

3.0 Theory

The fundamental physical law used in resistivity surveys is Ohm's law that governs the flow of current in the ground. The equation for ohms law in vector form for current flow in a continuous medium is given by [7]

$$\boldsymbol{J} = \sigma \boldsymbol{E} \qquad (1)$$

Where σ is the conductivity of the medium, **J** is the current density and $\boldsymbol{E}$ is the electric field intensity. In practice, what we measured is the electric field potential which is related to the field intensity as

$$\boldsymbol{E} = -\boldsymbol{\nabla}\Phi \qquad (2)$$

Combining equations 1 and 2, we get

$$J = -\sigma \nabla \Phi \qquad (3)$$

We consider a case of homogeneous subsurface and a single point current source on the ground surface. In this case, the current flows radially away from the source, and the potential varies inversely with distance from the current source. The equipotential surface has a hemisphere shape, and the current flow is perpendicular to the equipotential surface. The potential in this case is given by [7]

$$\emptyset = \frac{\rho I}{2\pi r} \qquad (4)$$

Where r is the distance of a point in the medium (including the ground surface) from the electrode.

In practically all surveys the potential difference between two points (normally on the ground surface) is measured. The potential difference is then given by

$$\Delta\emptyset = \frac{\rho I}{2\pi}\left\{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{r_3}-\frac{1}{r_4}\right)\right\} \qquad (5)$$

Equation (5) gives the potential that would be measured over a homogeneous half space with a 4 electrodes array. Resistivity measuring instruments normally give a resistance value $R = \Delta\emptyset/I$, so in practice the apparent resistivity value is calculated by

$$\rho_{a=KR} \qquad (6)$$

Where $K = \frac{2\pi}{\left\{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{r_3}-\frac{1}{r_4}\right)\right\}}$ is called the geometric factor which depends on the arrangement of the four electrodes.

The study of the decaying potential difference as a function of time is known as the study of induced polarization in the time domain. In this method the geophysicist looks for the portion of the earth where current flow is maintained for a short time after the applied current is terminated [8]. The most commonly used quantity in time domain IP measurement is the Chargeability η defined by

$$\eta = \frac{1}{V_C}\int_{t_1}^{t_2} V(t)dt \qquad (7)$$

Where V(t) is the residual voltage and V_c is the steady voltage. When V(t) and $V_c$have the same units, the chargeability $\eta$is in milliseconds.

Self-Potential can also be referred to as spontaneous potential. It occurs when no current is injected and yet there are potential measurable on the potential electrode. It can be due to manmade disturbances of the environment such as buried electrical cables drainage pipes or waste disposal sites [9].

Self-Potential can also be due to natural effects. One of these natural effects is one caused by electrikinetic potential which is observed when a solution of electrical resistivity ρ and viscosity η is forced through capillary of porous medium. The resultant potential difference between the ends of the passage is

$$E_k = -\frac{\xi \Delta P K_p}{4\pi\eta} \qquad (8)$$

Where ξ is the adsorption potential, ΔP is the pressure difference and k is the solution dielectric constant.

4.0 Methodology

A total of 49 VES were conducted using Schlumberger array (Figure 2). The four electrodes were placed symmetrically along the same line about the investigation point with the potential electrodes closed to the point. The outer current electrodes were shifted from AB/2 = 1.5m to 200m symmetrically along the array line where as MN/2 was changed from 0.5m to 10.0m (Table 1)

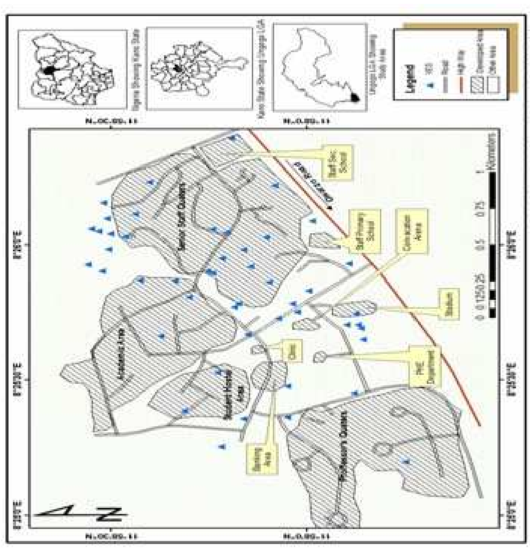


Figure 2: Map of the Study Area Showing VES Points [10]

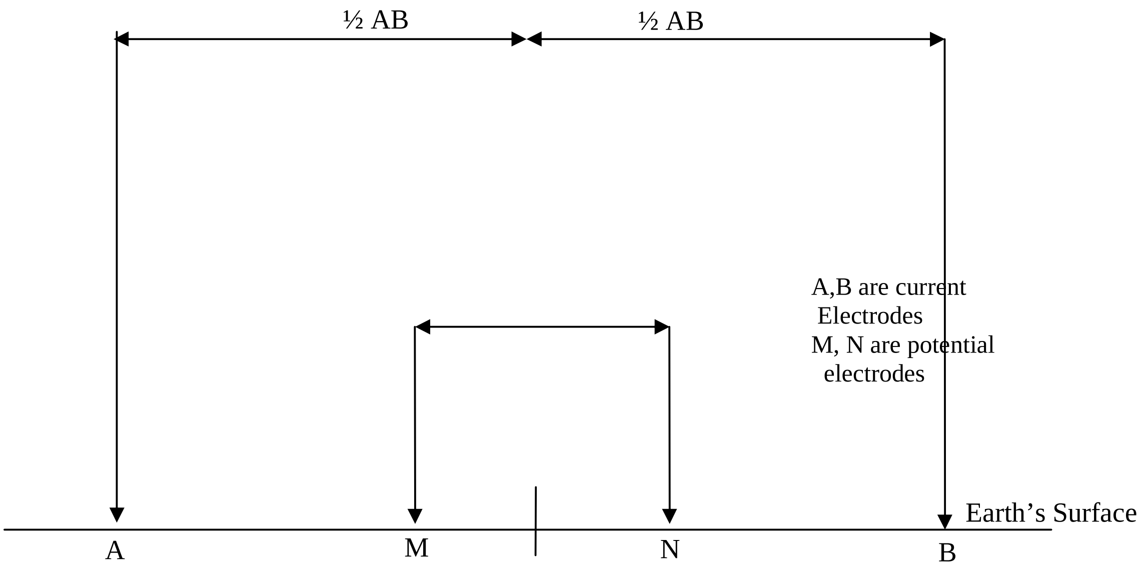


Figure 3: Array Line

Table 1: Typical field Data for Station 1

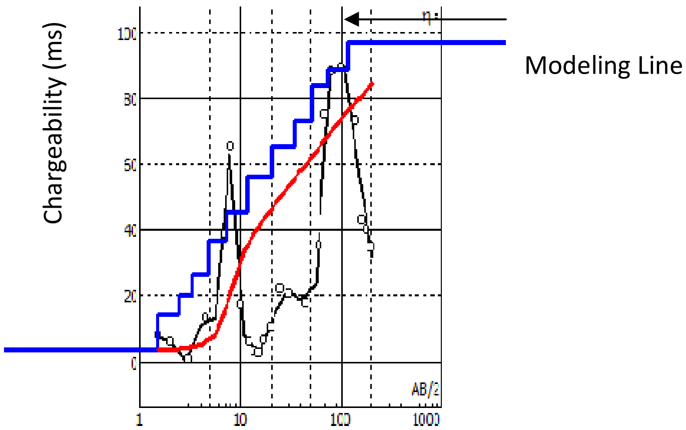
AB/2 (m)	MN/2 (m)	ɳ (ms)	SP (mV)	ρ (Ωm)
1.5	0.5	7.92	12.57	394.99
2	0.5	6.33	17.7	417
3	0.5	0.93	24.916	334.19
4.5	0.5	13.4	6.1462	193.09
7	0.5	38.9	13.93	106.67
8	0.5	65.3	8.8156	88.277
10	0.5	29.5	4.5711	64.253
10	2	5.1	46.574	138.52
12	2	6.3	11.737	104.87
14	2	3.08	8.2695	92.015
15	2	2.57	7.2186	74.381
17	2	6.5	5.7788	89.43
20	2	10.5	3.4634	139.07
25	2	22.4	0.1822	156.36
30	2	20.8	0.4132	121.53
45	2	14.7	3.1146	117.66
45	5	21.1	1.4609	94.891
60	5	35.2	4.0032	299.4
70	5	75.1	1.429	331.12
80	5	88.2	1.53	500.78
100	5	89	0.923	802.9
140	5	79.23	0.3216	722.12
140	10	66.9	7.481	1024
160	10	43.1	5.53	884.42
180	10	40.2	7.48	214.3
200.00	10.00	34.9	8.89	972.4

The field values collected for array disposition were chargeability, self potential and apparent resistivity (Table 1).
The PH and conductivity of some groundwater samples in the area were measured using a digital dialysete meter in order to assess the suitability of the groundwater for drinking.

5.0 Data analysis

A software was used to plot the measured chargeability and resistivity values against the half electrode spacing i.e. AB/2. The resulting IP and resistivity curves were modeled with the same software to obtain the equivalent n-layer model from the chargeability and resistivity curve of each sounding. Figure 4 and 5 shows a representative sample of IP and resistivity curves and their corresponding model parameters Tables respectively. Furthermore, the SP values were plotted against depths of investigation in each VES station. This is to delineate the peak SP values and their corresponding depths. These depths were then used to produce the map of the ground water flow pattern. Figure 6 shows a sample of the SP graph.

The subsurface structure was analyzed based on the borehole information of areas around the study area obtained from the department of water and technical services of Kano state ministry of works.The interpretation of the IP and resistivity data was done by comparing the chargeability values as well as the resistivity values on the model parameters Table to the typical values adopted for this research as presented in Table 2.



N	ρ	η	h	d
1	3166	3.73	1.5	1.5
2	38.9	14.4	0.93	2.43
3	38.9	20.2	0.867	3.3
4	38.9	26.5	1.56	4.86
5	38.9	36.7	2.31	7.17
6	38.9	45.5	4.32	11.5
7	38.9	56.2	8.52	20
8	38.9	65.4	13.9	33.9
9	38.9	73.1	17.5	51.4
10	38.9	83.8	22.3	73.7
11	38.9	88.7	44.4	118
12	38.9	96.9		

N- Serial Number

P- Resistivity (Ωm)

η- Chargeability (ms)

h- Thickness (m)

d- Depth (m) to bottom of overlying layer

Figure 4: IP Curve and corresponding model parameters Table for VES 1

N	ρ	h	d	Alt
1	26.8	4.62	4.62	-4.624
2	106	2.32	6.94	-6.942
3	144	3.94	10.9	-10.88
4	191	8.74	19.6	-19.62
5	344	16.8	36.4	-36.39
6	539	13.2	49.6	-49.56
7	945	17.9	67.5	-67.5
8	1855	27	94.5	-94.54
9	3345	41.7	136	-136.2
10	5703	49.3	185	-185.5
11	7988			

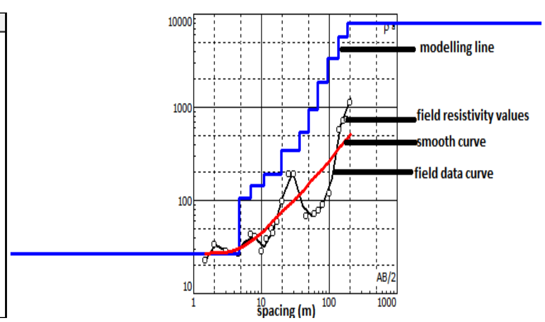


Figure 5: Resistivity Curve and corresponding model Parameters Table for VES 1

Table 2:*Adopted Chargeability and Resistivity values [9 and 11]*

VES	SP (mV)	Depth (m)
1	46.574	4
11	86.777	40
13	36.794	56
19	95.787	72
44	36.89	40

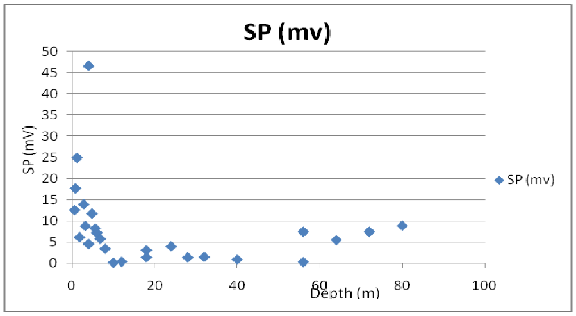


Figure 6: Graph of SP against Depth for VES 1

6.0 Result and Discussion

The study revealed that the area is underlain by two to five subsurface layers which include topsoil, laterite, weathered basement complex rocks, fractured basement complex rocks and fresh basement complex rocks. The result of the interpreted layer parameters for VES 1 is presented in Table 3. The thickness map of the aquifer layer was then produced Cross – correlation of IP, resistivity and SP resultant data analysis showed good agreement in terms of identifying fluid flow pattern, thus they provide complementary information that could be used for structural studies.

Table 3: Interpreted Layer Parameters of VES 1

VES	Layer	Thickness (m)	Depth (m)	Rock Type
1	1	1.236	1.236	Laterite
	2	1.224	2.46	Weathered basement
	3	1.54	4.00	Fractured basement
	4			Fresh basement

Table 4: Depths with peak SP Values of some VES stations

Rock type	Chargeability (ms)	Resistivity (Ωm)
Topsoil	0-5	0-50
Laterite	6-25	51-200
Weathered Basement Complex Rocks	26-54	201-500
Fractured Basement Complex Rocks	55-70	501-800
Fresh Basement Complex Rocks	71 and above	>800

6.1 Aquifer thickness map

The weathered and fractured basement has been identified as the aquifer limits which characterize the study area [4].

The map is produced using the thickness of the weathered and fractured basement obtained at each VES station. The aquifer thickness ranges from 1.44 to 70.15m. It is shallowest around VES 29.

A comparison between aquifer thickness and overburden thickness reveals that areas of low aquifer thickness corresponds to shallow basement and area with large aquifer thickness corresponds to larger basement depth.

Areas of large aquifer thickness are more likely to retain good quality of ground water. Figure 4 shows the aquifer thickness map.

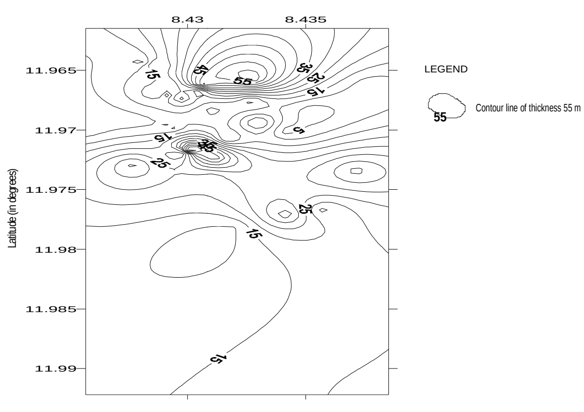


Figure 7: Aquifer Thickness Map contoured at 5m interval

6.2 SP Analysis

The analysis of SP revealed that ground water in the study area flow to areas around VES 11, 13, 19 and 44 as shown in Table 4. This is because at these stations, peak SP values were recorded at greater depths. Figure 5 shows the contour map indicating the locations of peak SP values giving flow topography.

According to Telford et al [11], one of the mechanisms producing Self-Potential is electrokinetic potential which is observed when a fluid is forced through a capillary or porous medium. This effect is shown in equation (8). It is evident from this equation that the potential E_k is dependent on the pressure gradient ΔP. Hence points with high SP values with great depths indicate points with higher flow.

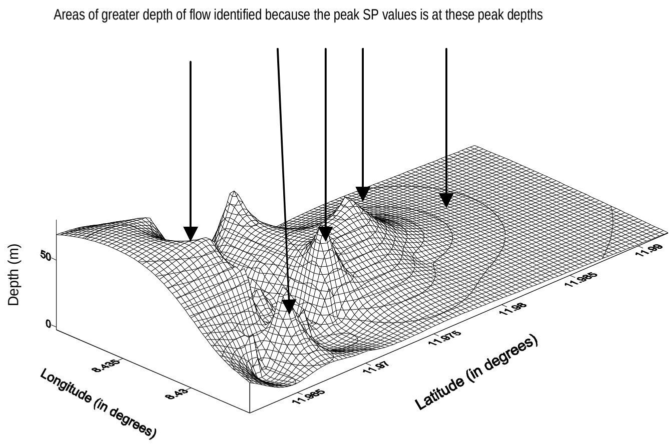


Figure 8: Location of Peak SP values giving flow topography

6.3 Water Quality

In order to assess the suitability of the groundwater in the area for drinking, the PH and conductivity of the water samples collected were compared with the standard obtained in the Nigerian standard for drinking water quality as published by the Nigerian industrial standard and approved by the standard organization of Nigeria. The comparism shows that sample 1,2,3,4,16,18,19,20,22,27,28 and 30 have pH within the range recommended by the standard organization of Nigeria, where as in the remaining samples, the pH is beyond the standard. It can also be seen from the comparism that the conductivity of all the 30 water samples is within the Nigerian standard for drinking water quality with a mean value of 262.67µs/cm.

The pH of water recommended for drinking by the Nigerian standard for drinking water quality is between 6.5 to 8.5 and the maximum conductivity permitted is 1000µs/cm.

Table 5: Parameters and Maximum Allowable Limits [12]

Parameter	Unit	Maximum permitted
Conductivity	µs/cm	1000
PH	-	6.5-8.5

Implication of the work for engineering constructions

It is necessary that detail investigation about the characteristics of the subsurface lithology and ground conditions be carried out prior to the commencement of construction works in an area. The result of this geophysical investigation carried out showed that the study area is strong enough to accommodate low to high engineering structures. But area around VES 27 can only accommodate low engineering structure because of clay materials that predominates the area, however, in areas around VES 6, 11, 13, 14, 15, 16, 17, 19, 21, 29, 31, 32, 43, 45, there is the need of clearing away the topsoil for a depth of about 1 to 5m before the commencement of engineering structure.

Location of safe place for refuse dumping

Gajanan et al [13] have established that groundwater can be contaminated due to waste disposal. Hence marking out areas for refuse dumping becomes important. The result of this study shows that VES 27 can be earmarked for refuse disposal as the area is dominated by clay up to a depth of 44m and because of the absence of aquifer in the area.

7.0 Conclusion

This study was carried out to investigate the subsurface structures of Bayero University Kano permanent site using geoelectric method. The following conclusions were drawn from the study:

- The study area is underlain by 2 to 5 subsurface layers of different lithologies namely- topsoil, laterite, weathered basement complex rocks, fractured basement complex rocks and the fresh basement complex rocks.
- The topsoil in the study area is generally thin.
- The aquifer thickness ranges from 1.44m to 70.157m while the overburden thickness is between 1.6m and 72.104m
- The best location for ground water exploitation are around VES 11, 13,19 and 44.
- To avoid groundwater contamination, areas around VES 27 is found to be safe for refuse dumping site.
- The survey showed that the underground water in the area is safe for drinking and other domestic usages.
- Although most of the VES stations can support both low and high buildings, only low buildings are advised around VES 27.

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