J. Geophys. Eng. **2** (2005) 118–125 doi:10.1088/1742-2132/2/2/006

Current variation in electrical resistivity probing using Wenner and Schlumberger arrays in a basement terrain

B S Badmus[1], E A Ayolabi[2], J A Olowofela[3], S A Adisa[1] and T O Oyekunle[1]

[1] Department of Physics, University of Agriculture, Abeokuta, Nigeria
[2] Department of Physics, University of Lagos, Akoka, Lagos, Nigeria
[3] Department of Physics, University of Ibadan, Ibadan, Nigeria

Received 13 August 2004
Accepted for publication 15 April 2005
Published 17 May 2005
Online at stacks.iop.org/JGE/2/118

Abstract
Schlumberger and Wenner vertical electrical soundings (VES) were carried out at five locations each within the campus of University of Agriculture, Abeokuta, Nigeria, with the aim of imaging the subsurface using different current values varying from 0.2 A to 20.0 A at each location as it appears on an ABEM SAS300B terrameter. The results of the interpretation for both electrode arrangements revealed six geo-electric layers: topsoil, sandy clay, clayey sand, sandstone, shale/clay and fresh basement. The work revealed that a current range of 0.2–1.0 A is ideal for both Schlumberger and Wenner arrays in a basement terrain.

Keywords: Geo-electrical resistivity, current variation, geo-electric layers, Schlumberger and Wenner arrays and curve types

Introduction

Geo-electrical resistivity methods, amongst various other geophysical techniques, are commonly used in groundwater prospecting and groundwater contamination as well as in most environmental studies. The electrical resistivity of the subsurface, thickness of overburden, characteristics of the aquiferous units as well as the depth to basement can be reasonably determined at minimal cost. The success of employing geo-electrical resistivity methods for groundwater exploration has been found to depend on the available electrode arrays and reasonable interpretation of the data obtained with good correlation with known geology of the study area (Beck 1981). In the recent past, many geologists and geophysicists went to the field with ABEM SAS300B equipment without an idea of what magnitude of current should be sent into the ground. However, an arbitrary current value is used by varying the current in the following order: 0.2 A, 0.5 A, 1.0 A, 2.0 A, 5.0 A, 10.0 A and 20.0 A.

This idea of current variation between 0.2 A and 20.0 A results in many ambiguities in the interpretation of the acquired data and does not depict the true nature of the subsurface; it constitutes a waste of data acquisition and interpretation time. These ambiguities prompted this research work which attempts to ascertain the ideal current range for subsurface probing in basement terrain. Extensive studies have shown that amongst the available electrode arrangements, the Schlumberger and Wenner arrays are the most widely used electrical methods of geophysical prospecting (Sharma 1976, Olayinka 1990). Wenner and Schlumberger arrays are used to delineate different depths of penetration, with the Schlumberger array revealing greater depth of penetration than the Wenner (Apparao 1997, Ojelabi *et al* 2002). The depth of investigation of an electrode array is defined as the depth at which a thin horizontal (parallel to the ground surface) layer of ground contributes the maximum amount to the total measured signal at the ground surface (Roy and Apparao 1971).

Location of the study area

The study area is located within the University of Agriculture, Abeokuta campus, in the basement complex of southwest Nigeria. It is between longitude 3°15′E and 3°25′E, and latitude 7°20′N and 7°25′, as shown in figure 1. The study area covers an area of about 2.0 km^2 of the entire campus

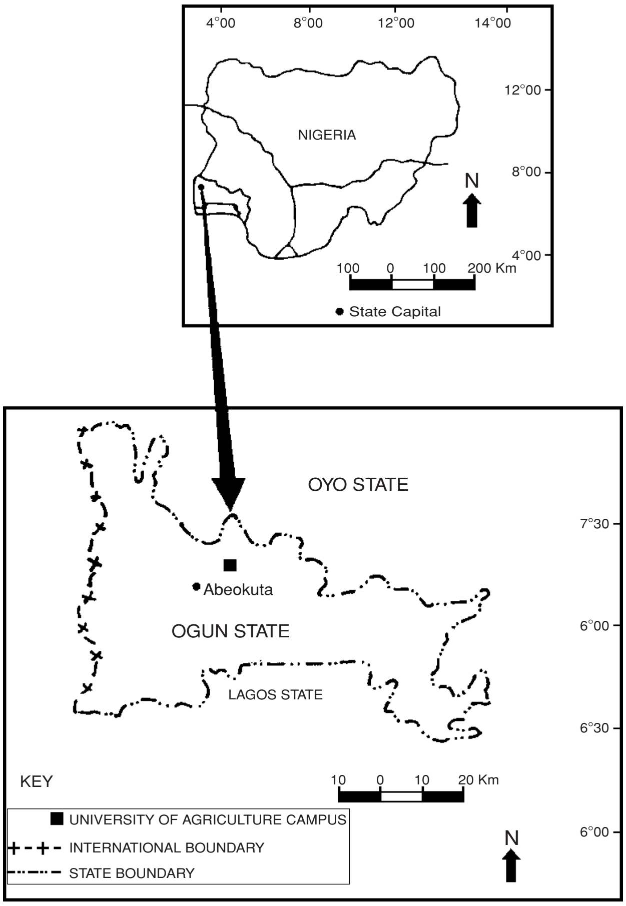

Figure 1. Map showing the location of study area.

(figure 2). The campus has an approximate total area of 100 km^2 with the first two geo-electric layers consisting of lateritic clay of various compositions, colours and porosities.

Field procedure

In this paper, current variation in the electrical resistivity method using Wenner and Schlumberger arrays was investigated within a complex basement terrain in the southwestern part of Nigeria, with the goal of establishing ideal current values between ranges of current available on the ABEM SAS300B terrameter. Five vertical electrical soundings were each carried out using Wenner and Schlumberger electrode arrangements. For the Wenner array, the current electrode spacing varied from 6.0 m to 162.0 m and the potential electrode spacing varied from 2.0 m to 54.0 m. For the Schlumberger array, the current electrode spacing ranged from 2.0 m to 200.0 m, and the potential electrode spacing ranged between 0.5 m and 10.0 m.

The same locations were used for both arrays and the separation between each VES station was 20.0 m. At each station, the current was varied in the order 0.2 A, 0.5 A, 1.0 A, 2.0 A, 5.0 A, 10.0 A and 20.0 A at every current electrode and potential electrode separation along each line. This means that at every VES station, a total of seven sets of data should have been acquired, making a total of thirty-five sets of data for the five Wenner array and a similar number for the Schlumberger array. However, some of the data with current variation above 10.0 A were not interpreted because of the error due to the high current. In all, a total of 26 data sets were possible in the case of the Wenner array and a total of 27 data sets were possible in the case of the Schlumberger array.

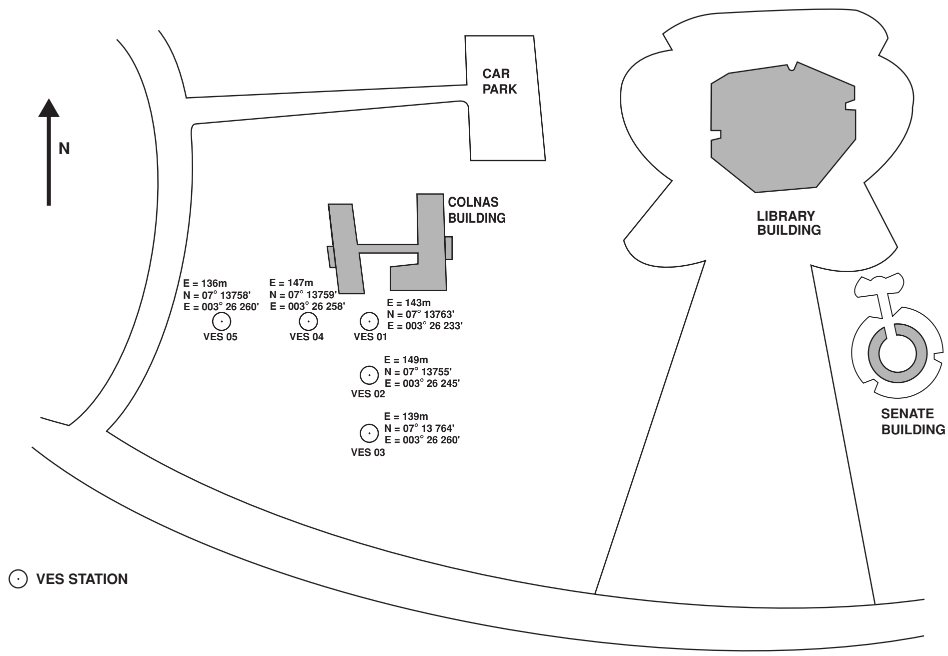

Figure 2. Data acquisition map.

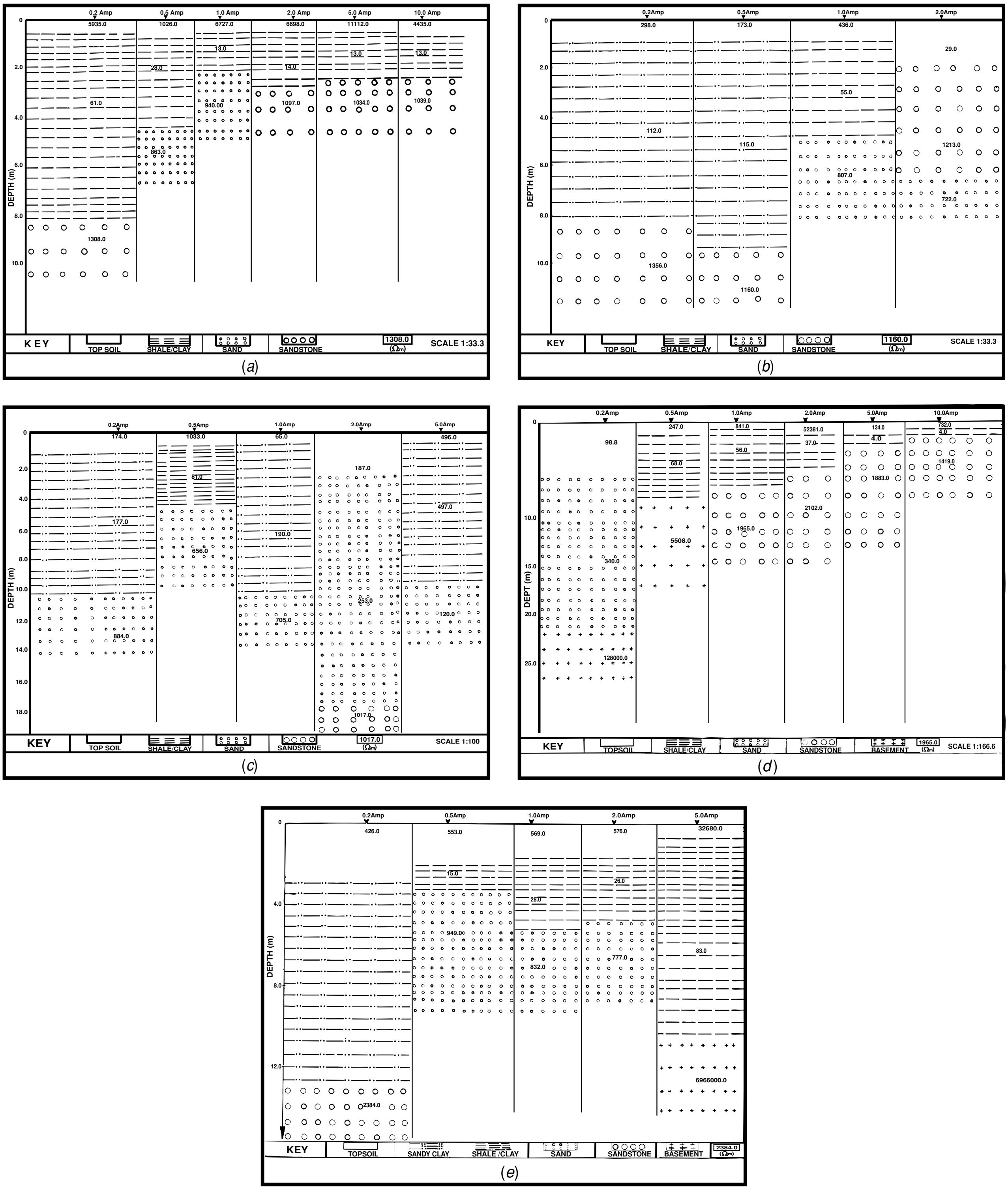

Figure 3. Geo-electric sections using Wenner array: (*a*) beneath VES01 (0.2–10.0 A), (*b*) beneath VES02 (0.2–2.0 A), (*c*) beneath VES03 (0.2–5.0 A), (*d*) beneath VES04 (0.2–10.0 A), and (*e*) beneath VES05 (0.2–5.0 A).

Results and discussion

Results

The field data acquired for both electrode arrays were first interpreted quantitatively using the usual partial curve-matching method and corresponding auxiliary curves (Bhattacharya and Patra 1968, Zohdy *et al* 1974, Zohdy 1989). The results obtained from this method were then used as initial parameters (resistivities and thicknesses of each subsurface layer) for the computer iterative interpretation

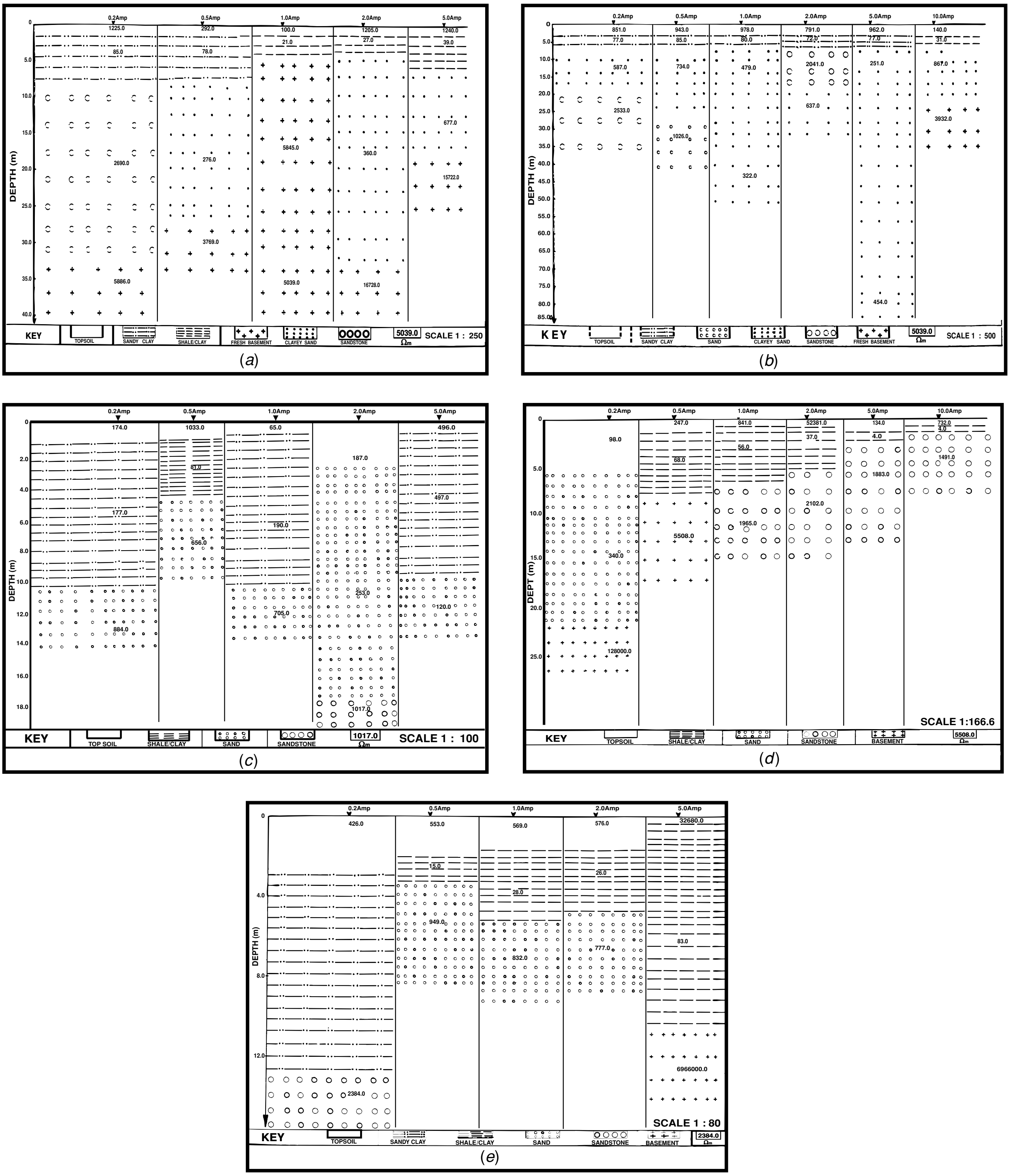

Figure 4. Geo-electric sections using Schlumberger array: (*a*) beneath VES01 (0.2–5.0 A), (*b*) beneath VES02 (0.2–10.0 A), (*c*) beneath VES03 (0.2–5.0 A), (*d*) beneath VES04 (0.2–10.0 A), (*e*) beneath VES05 (0.2–5.0 A).

technique using the software 'Resist' for the Schlumberger and 'Offix' for the Wenner array respectively, to obtain a final quantitative interpretation. The results obtained from the computer modelling are presented in the form of geo-electric sections in figures 3 and 4; a summary of VES curve type, layer thickness, resistivity and lithology is presented in tables 1 and 2 for the Wenner and Schlumberger arrays respectively, using the criteria for lithological interpretation given in the appendix.

A similar boreholed terrain was investigated using current variation between 1.0 A and 2.0 A and though little time was spent in acquiring the data, the interpreted results conformed

Table 1. Summary of VES curve type, layer resistivity and lithology using the Wenner array.

Array type, VES no and curve type		Layer 1 Res. (Ω m)	Layer 1 Thick. (m)	Layer 2 Res. (Ω m)	Layer 2 Thick. (m)	Layer 3 Res. (Ω m)	Layer 3 Thick. (m)	Depth of penetration (m)
Wenner, VES01	At current 0.2 A, H-curve	9535.1 Topsoil	0.5	60.68 Shale/clay	7.63	1307.8 Sandstone	–	8.10
	At current 0.5 A, H-curve	1025.6 Topsoil	1.03	27.78 Shale/clay	3.15	863.3 Sand	–	4.20
	At current 1.0 A, H-curve	6727.20 Topsoil	0.604	12.92 Shale/clay	1.47	940.20 Sand	–	2.00
	At current 2.0 A, H-curve	6698.2 Topsoil	0.605	14.26 Shale/clay	1.68	1097.2 Sandstone	–	2.30
	At current 5.0 A, H-curve	11112.3 Topsoil	0.547	12.98 Shale/clay	1.56	1034.2 Sandstone	–	2.10
	At current 10. A, H-curve	4435.0 Topsoil	0.666	12.90 Shale/clay	1.55	1039.0 Sandstone	–	2.20
Wenner, VES02	At current 0.2 A, H-curve	297.7 Topsoil	0.835	112.4 Sandy clay	7.23	1356.4 Sandstone	–	8.10
	At current 0.5 A, H-curve	172.9 Topsoil	0.816	114.9 Sandy clay	8.33	1160.4 Sandstone	–	9.20
	At current 1.0 A, H-curve	435.9 Topsoil	0.854	55.12 Shale/clay	3.50	806.8 Sand	–	4.40
	At current 2.0 A, K-curve	28.73 Topsoil	1.93	1212.6 Sandstone	4.23	722.2 Sand	–	6.20
Wenner, VES03	At current 0.2 A, A-curve	173.7 Topsoil	1.0	176.7 Shale/clay	9.34	884.1 Sands	–	10.30
	At current 0.5 A, H-curve	1032.5 Topsoil	0.698	80.82 Shale/clay	3.75	655.8 Sand	–	4.40
	At current 1.0 A, A-curve	64.73 Topsoil	0.210	190.0 Sandy clay	10.30	705.4 Sand	–	10.50
	At current 2.0 A, A-curve	187.1 Topsoil	3.75	253.4 Sand	13.84	1016.5 Sandstone	–	17.60
	At current 5.0 A, H-curve	495.6 Topsoil	0.04	174.1 Sandy clay	10.08	719.08 Sand	–	10.10
Wenner, VES04	At current 0.2 A, A-curve	98.12 Topsoil	5.79	340.1 Sand	16.31	128 000.0 Fresh basement	–	22.10
	At current 0.5 A, H-curve	247.1 Topsoil	0.713	67.62 Shale/clay	7.05	5508.8 Fresh basement	–	7.80
	At current 1.0 A, H-curve	840.6 Topsoil	0.02	56.21 Shale/clay	5.88	1965.2 Sandstone	–	5.90
	At current 2.0 A, H-curve	52 381.3 Topsoil	0.09	37.16 Shale/clay	4.05	2101.8 Sandstone	–	4.10
	At current 5.0 A, H-curve	134.0 Topsoil	1.76	3.72 Shale/clay	0.36	1882.8 Sandstone	–	2.10
	At current 10. A, H-curve	731.5 Topsoil	0.01	3.80 Shale	0.40	1491.1 Sandstone	–	0.40
Wenner, VES05	At current 0.2 A, H-curve	426.2 Topsoil	2.52	125.7 Sandy clay	9.90	2383.7 Sandstone	–	12.40
	At current 0.5 A, H-curve	552.8 Topsoil	1.89	15.20 Shale/clay	1.43	949.4 Sand	–	3.30
	At current 1.0 A, H-curve	568.5 Topsoil	1.81	28.05 Shale/clay	2.69	832.1 Sand	–	4.50
	At current 2.0 A, H-curve	576.3 Topsoil	1.78	25.57 Shale/clay	2.44	776.9 Sand	–	4.20
	At current 5.0 A, H-curve	32 680.1 Topsoil	0.46	83.08 Shale/clay	9.72	696 600.0 Fresh basement	–	10.20

to the borehole lithological data and the borehole depth of recommendation.

Discussion

Wenner. At VES01, only six sets of data were acquired with current variations between 0.2 A and 10.0 A. The interpretation is of three geo-electric layers all characterized by the H curve type ($\rho_1 > \rho_2 < \rho_3$) (table 1). The first geo-electric layer at this station comprises lateritic topsoil, with a resistivity value ranging between 1025.6 Ω m and 11 112.3 Ω m, and thickness between 0.5 m and 1.03 m. The second geo-electric layer consists of shale/clay with a resistivity value between 12.90 Ω m and 60.68 Ω m, and thickness between 1.47 m and 7.63 m. These layers are

Table 2. Summary of VES curve type, layer resistivity and lithology using the Schlumberger array.

Array type, VES no and curve type		Layer 1 Res. (Ω m)	Layer 1 Thick. (m)	Layer 2 Res. (Ω m)	Layer 2 Thick. (m)	Layer 3 Res. (Ω m)	Layer 3 Thick. (m)	Layer 4 Res. (Ω m)	Layer 4 Thick. (m)	Depth of penetration (m)
Schlumberger, VES01	At current 0.2 A, HA-curve	1225.0 Topsoil	0.90	84.90 Sandy clay	7.30	2690.40 Sandstone	24.1	5885.6 Fresh basement	–	32.30
	At current 0.5 A, HA-curve	1292.4 Topsoil	0.80	77.90 Sandy clay	4.40	275.6 Clayey sand	20.5	3769.2 Fresh basement	–	25.70
	At current 1.0 A, HA-curve	1100.30 Topsoil	1.00	20.70 Shale/clay	2.10	5846.80 Fresh basement	28.1	6039.0 Fresh basement	–	31.20
	At current 2.0 A, HA-curve	1204.80 Topsoil	0.90	27.40 Shale/clay	1.60	359.50 Clayey sand	30.1	16728.10 Fresh basement	–	32.60
	At current 5.0 A, HA-curve	1240.40 Topsoil	0.90	38.70 Shale/clay	4.10	677.30 Clayey sand	10.0	15721.80 Fresh basement	–	15.00
Schlumberger, VES02	At current 0.2 A, HA-curve	850.90 Topsoil	0.60	76.90 Sandy clay	4.90	586.70 Clayey sand	10.30	2531.70 Sandstone	–	15.8
	At current 0.5 A, HA-curve	943.10 Topsoil	0.60	84.60 Sandy clay	5.10	734.40 Clayey sand	20.60	1025.80 Sand	–	26.30
	At current 1.0 A, HA-curve	978.60 Topsoil	0.60	79.70 Shale/clay	3.90	479.00 Clayey sand	30.50	321.60 Clayey sand	–	35.00
	At current 2.0 A, HK-curve	790.80 Topsoil	0.70	71.70 Sandy clay	4.70	2041.30 Sandstone	8.90	637.20 Clayey sand	–	14.30
	At current 5.0 A, HA-curve	692.00 Topsoil	0.60	76.10 Sandy clay	2.90	351.10 Clayey sand	77.50	453.80 Clayey sand	–	81.00
	At current 10.0 A, HA-curve	169.70 Topsoil	2.30	30.80 Shale/clay	3.60	866.50 Clayey sand	11.60	3932.10 Fresh basement	–	17.50
Schlumberger, VES03	At current 0.2 A, HK-curve	1362.10 Topsoil	0.70	46.00 Sandy clay	1.60	2684.00 Sandstone	10.90	1006.80 Sand	–	13.20
	At current 0.5 A, HA-curve	1393.70 Topsoil	0.70	47.50 Sandy clay	1.80	1536.80 Sand	29.60	2737.90 Sandstone	–	32.10
	At current 1.0 A, HK-curve	1500.90 Topsoil	0.60	104.00 Sandy clay	6.00	2789.40 Sandstone	8.90	1378.0 Sand	–	15.50
	At current 2.0 A, HK-curve	1335.90 Topsoil	0.70	78.90 Sandy clay	4.20	7554.80 Fresh basement	11.30	2023.20 Sandstone	–	16.20
	At current 5.0 A, HA-curve	240.20 Topsoil	1.80	84.80 Sandy clay	2.20	674.20 Clayey sand	34.50	4114.90 Fresh basement	–	38.50
Schlumberger, VES04	At current 0.2 A, HA-curve	352.30 Topsoil	0.60	38.20 Sandy clay	1.60	652.30 Clayey sand	69.10	4887.10 Fresh basement	–	71.30
	At current 0.5 A, HA-curve	305.90 Topsoil	0.60	62.10 Sandy clay	3.80	923.00 Clayey sand	33.50	1592.70 Sand	–	37.90
	At current 1.0 A, HK-curve	269.90 Topsoil	0.80	30.90 Shale/clay	2.70	1676.20 Sand	16.20	871.80 Clayey sand	–	11.20
	At current 2.0 A, HA-curve	277.50 Topsoil	0.70	40.90 Sandy clay	2.70	1676.20 Sandstone	16.20	871.80 Clayey sand	–	19.60
	At current 5.0 A, HA-curve	351.40 Topsoil	0.60	50.20 Sandy clay	3.10	892.60 Clayey sand	44.40	1555.10 Clayey sand	–	48.10
	At current 10.0 A, HA-curve	92.30 Topsoil	1.40	42.70 Shale/clay	2.30	1133.20 Sand	43.90	1984.80 Sandstone	–	47.60
Schlumberger, VES05	At current 0.2 A, HK-curve	1028.10 Topsoil	0.80	85.70 Sandy clay	4.30	1353.30 Sandstone	10.10	665.80 Sand	–	16.10
	At current 0.5 A, HA-curve	1042.60 Topsoil	0.70	91.00 Sandy clay	4.40	523.60 Sand	50.80	4158.10 Sandstone	–	55.90
	At current 1.0 A, HA-curve	1225.50 Topsoil	0.60	114.90 Sandy clay	5.80	211.80 Sandstone	4.70	982.70 Sand	–	11.10
	At current 2.0 A, HA-curve	1335.90 Topsoil	0.70	78.90 Sandy clay	4.20	7554.80 Fresh basement	11.30	2023.20 Sandstone	–	63.90

Table 2. (Continued.)

Array type, VES no and curve type	Layer 1 Res. (Ω m)	Layer 1 Thick. (m)	Layer 2 Res. (Ω m)	Layer 2 Thick. (m)	Layer 3 Res. (Ω m)	Layer 3 Thick. (m)	Layer 4 Res. (Ω m)	Layer 4 Thick. (m)	Depth of penetration (m)
At current 5.0 A, HA-curve	240.20 Topsoil	1.80	84.80 Sandy clay	2.20	674.20 Clayey sand	34.50	4114.90 Fresh basement	–	68.6

underlain by a third geo-electric layer of sandstone (at 0.2 A, 2.0 A, 5.0 A and 10.0 A) and sand (at 0.5 A and 1.0 A). This is shown in figure 3(*a*).

At VES02, only four sets of data were obtained with current variation ranging from 0.2 A to 2.0 A. The lithological interpretation at this station is of a three-layer model, all characterized by an H curve type except at 2.0 A where the curve type is K ($\rho_1 < \rho_2 > \rho_3$) (table 1). The geo-electric section (figure 3(*b*)) revealed topsoil with resistivity values ranging from 28.73 Ω m to 435.9 Ω m and thicknesses ranging from 0.816 m to 1.93 m. The second geo-electric layer at this station is composed of sandy clay, shale/clay and sandstone with resistivity values of 112.4 Ω m, 55.12 Ω m and 1212.6 Ω m, respectively. The third geo-electric layer is composed of sandstone (at 0.2 A and 0.5 A) and sand (at 1.0 A and 2.0 A).

For VES03, five sets of data were acquired and interpreted with current variation ranging from 0.2 A to 5.0 A. They are characterized by H ($\rho_1 > \rho_2 < \rho_3$) and A ($\rho_1 < \rho_2 < \rho_3$) curve types. The result of the interpretation at this station also revealed a three-layered model with the topsoil having resistivity values ranging from 64.73 Ω m to 1032.5 Ω m and thicknesses from 0.04 m to 1.0 m. This layer is underlain by sandy clay, shale/clay and sand, and the current penetration terminated at the third layer, a sand unit, in all locations except at current 2.0 A where the current penetration terminated in sandstone (figure 3(*c*)).

At VES04, a total of six sets of data were acquired with current range between 0.2 A and 10.0 A. The lithological interpretation is of a three-layered model with the topsoil having resistivity values ranging from 98.12 Ω m and 52 381.3 Ω m. The second geo-electric layer composes of shale/clay and sand. This is underlain by fresh basement with resistivity of 12 800.0 Ω m and 5508.8 Ω m at current values of 0.2 A and 0.5 A while at other current values, it is underlain by a sandstone unit with resistivity values ranging between 1491.1 Ω m and 2101.8 Ω m, as shown in figure 3(*d*). Curve types A ($\rho_1 < \rho_2 < \rho_3$) and H ($\rho_1 > \rho_2 < \rho_3$) describe the graph at this station.

At VES05, a maximum of five sets of data were acquired over current variation of 0.2–5.0 A. This station is characterized by the H curve type. The interpretation of the geo-electric section is of a three-layered model with topsoil having resistivity values ranging between 426.2 Ω m and 32 680.1 Ω m and thicknesses between 0.46 m and 2.52 m while sandy clay was delineated at a 0.2 A current with resistivity value of 125.7 Ω m and thickness of 9.90 m. The current penetration terminated in the third geo-electric layer in sandstone, sand and fresh basement zones as shown in figure 3(*e*).

Schlumberger. For the Schlumberger electrode array, five vertical electrical soundings (VES) were carried out in the same manner as the Wenner array. At VES01, five sets of data were acquired with current variation between 0.2 A and 5.0 A, and the lithological interpretation is of a topsoil of resistivity ranging from 1100.30 Ω m to 1192.4 Ω m, and thickness from 0.8 m to 1.0 m. The second geo-electric layer at this station is composed of sandy clay and shale/clay. The third geo-electric layer is composed of sandstone, clayey sand and fresh basement. However, the fourth geo-electric layer at this station is composed of fresh basement with resistivity between 3769.2 Ω m and 16 728.1 Ω m. The curve type HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$) characterizes this station (figure 4(*a*)).

For VES02, six sets of data were obtained with current variation between 0.2 A and 10.0 A. They are characterized by HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$) and HK ($\rho_1 > \rho_2 < \rho_3 > \rho_4$) curve types. The geo-electric section at this station revealed topsoil with resistivity between 169.7 Ω m and 978.0 Ω m, and thickness between 0.6 m and 2.3 m. The second geo-electric layer is composed of sandy clay at all current variations at this station except at 10.0 A where shale/clay is delineated. This layer is underlain at all currents by the third geo-electric layer of clayey sand with resistivity ranging between 351.1 Ω m and 866.5 Ω m, and thickness between 10.3 m and 77.5 m except at current 2.0 A where sandstone was delineated. The fourth geo-electric layer consists of sandstone, sand, clayey sand and fresh basement (figure 4(*b*)).

For VES03 five sets of data were obtained with current variation between 0.2 A and 5.0 A and the result of the interpretation is described by HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$) and HK ($\rho_1 > \rho_2 < \rho_3 > \rho_4$) curve types. The lithology is of a topsoil of resistivity between 240.2 Ω m and 1500.9 Ω m, and thickness between 0.7 m and 1.8 m. A second geo-electric layer of sandy clay was delineated with resistivity between 46.0 Ω m and 104.0 Ω m, and thickness range from 1.6 m to 6.0 m. This layer is underlain by a third geo-electric layer of sandstone, sand, clayey sand and fresh basement. Fresh basement is, however, delineated only at current 5.0 A while a fourth layer of sand and sandstone was delineated, as shown in the geo-electric section (figure 4(*c*)).

VES04 has a maximum of six sets of data with current varying from 0.2 A to 10.0 A. The lithological interpretation of the geo-electric section is of a topsoil layer with resistivity ranging from 92.3 Ω m to 352.3 Ω m and thickness ranging from 0.6 m to 1.4 m. The second geo-electric layer is composed of shale/clay at currents 0.2 A and 1.0 A while at current variations of 0.5 A, 2.0 A, 5.0 A and 10.0 A, sandy clay was delineated with resistivity ranging from 40.9 Ω m to 62.1 Ω m and thickness ranging from 2.3 m to 3.8 m. This layer is underlain by a third geo-electric layer of clayey sand, sand and sandstone. Fresh basement was delineated in a fourth layer only at 0.2 A with a resistivity value of 4887.1 Ω m while at other current variations, sand, clayey sand and sandstone were delineated (figure 4(*d*)). Curve types HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$) and HK ($\rho_1 > \rho_2 < \rho_3 > \rho_4$) are attributed to this line.

At VES05, five sets of data were acquired and interpreted with current variation from 0.2 A to 5.0 A. They are characterized by HK ($\rho_1 > \rho_2 < \rho_3 > \rho_4$) and HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$) curve types. The geo-electric section revealed topsoil with resistivity from 379.0 Ω m to 1225.5 Ω m and thickness ranging from 0.6 m to 1.3 m. The second geo-electric layer is composed of sandy clay with resistivity from 58.7 Ω m to 114.9 Ω m and thickness ranging from 3.8 m to 5.8 m. The third geo-electric layer at this station is composed of clayey sand and sand; this is underlain by fresh basement at current variations of 0.5 A, 2.0 A and 5.0 A where the current penetration terminated, while at current variations of 2.0 A and 1.0 A, current penetration terminated at clayey sand, as shown in figure 4(*e*).

Conclusion

The geophysical investigation carried out at this location using Wenner and Schlumberger electrode arrangements revealed clearly the implication of varying arbitrarily the current being introduced into the ground for subsurface imaging. From the discussion and analysis of results thus far, using these electrode arrays in basement complex terrain for geophysical investigation, using the ABEM SAS300B terrameter and the like, the current should be varied between 0.2 A and 1.0 A, as this range of current depicts the true nature of the subsurface. However, any current variation above this range may not depict the true ‘depth to basement’ lithology and thus results in a misleading interpretation. But if in the process of probing, a hard formation is encountered, the current may be increased between 2.0 A and 5.0 A. The results of this research work also confirmed that the Schlumberger array probes deeper than the Wenner array as reported in literature (tables 1 and 2). From the interpretation criteria (appendix), deviations from horizontal layering and lateral changes in surface materials may contribute to some differences in the interpreted geo-electric models.

Appendix

Criteria for lithological interpretation

Every first geo-electric layer of a section is referred to as topsoil and usually consists of organic matter, animal burrows and broken rock material of various resistivity ranges. McNeill (1980), Telford *et al* (1990), Schemang *et al* (1994) and Philip *et al* (2002) have provided resistivity values, as given below, as a guide for lithological interpretation within complex basement.

Lithologies	Resistivity range (Ω m)
Fadama loam	3.0×10^1–7.0×10^1
Sand and silt	7.1×10^1–2.0×10^2
Sand and gravel (wet)	1.0×10^2–1.8×10^2
Sandstone	1.0×10^3–3.25×10^3
Clay	2.0×10^1–1.5×10^2
Alluvium	5.0×10^1–1.5×10^2
Consolidated shale	2.0×10^1–2.0×10^3
Lateritic soil	1.2×10^2–7.5×10^2
Sandy clay	5.0×10^1–2.15×10^2
Clayey sand	2.5×10^2–8.0×10^2
Mudstone	2.0×10^1–6.0×10^1
Chalk	5.0×10^1–1.5×10^2
Fresh basement	3.0×10^3–1.0×10^9
Marble	3.0×10^2–1.0×10^6
Sand (sand)	5.0×10^2–1.25×10^3

References

Apparao A 1997 *Development of Geo-Electrical Methods* (Rotterdam: Balkama) p 293

Beck A E 1981 *Physical Principles of Exploration Methods* (New York: Macmillan) p 20

Bhattacharya P K and Patra H P 1968 *Direct Current Geo-electric Sounding: Principles and Interpretation* (Amsterdam: Elservier) p 135

McNeill J D 1980 Electromagnetic terrain conductivity measurement at low induction numbers *Technical Note TN-6* Geonics Limited, Ontario 15 pp

Ojelab E A, Badmus B S and Salau A A 2002 Comparative analysis of Wenner and Schlumberger methods of geo-electric sounding in subsurface delineation and groundwater exploration: a case study *J. Geol. Soc. India* **60** 623–8

Olayinka A I 1990 Case history of multi-electrode resistivity profiling array for groundwater in basement complex areas of Kwara State, Nigeria *J. Mining Geol.* **26** 27–34

Philip K, Micheal B and Ian H 2002 *An Introduction to Geophysical Exploration* (Oxford: Blackwell) p 262

Roy A and Apparao A 1971 Depth of investigation in direct current method *Geophysics* **36** 943–59

Sharma P V 1976 *Geophysical Methods in Geology* 2nd edn (New York: Elservier) pp 276–8

Shemang E M and Umaru A F M 1994 Geophysical investigations for groundwater in the area around Bauchi town. *J. Miner. Geol.* **30** 81–6

Telford W M, Geldart L P and Sheriff R E 1990 *Applied Geophysics* 2nd edn (Cambridge: Cambridge University Press) p 70

Zohdy A A R, Eaton G P and Maybey D R 1974 Application of surface geophysics to groundwater investigation *US Geological Survey* BK2, chapter D1 pp 47–55

Zohdy A A R 1989 A new method for interpretation of Schlumberger and Wenner sounding curves *Geophysics* **54** 245–53