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Evaluation of Electrical Anisotropy within Ladoke Akintola University of Technology campus Ogbomoso, southwestern Nigeria

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Abstract

Radial Vertical Electrical Soundings (RVES) were carried out within Ladoke Akintola University of Technology campus, Ogbomoso, Southwestern Nigeria located on Ogbomoso Sheet 222, in order to evaluate the electrical anisotropy of the concealed basement complex rock(s) and its implication on the groundwater potential of the area. The study area is underlain by porphyritic gneiss. Sixteen RVES stations were occupied and four Vertical Electrical Soundings conducted at azimuths of 0^0, 45^0, 90^0 and 135^0 at each station using the Schlumberger electrode array with maximum current electrode spread of 100.0 m. The field data were interpreted by partial curve matching and computer iteration. Resistivity maps were constructed and coefficients of anisotropy were determined. The interpretation of the VES data revealed three main geoelectric units namely: the topsoil, regolith, weathered/fresh bedrock. The basement complex rocks beneath the study area are anisotropic. The anisotropy may have been caused by foliation. The inferred structural trends were along NE-SW, NW-SE, E-W and N-S. The coefficient of anisotropy varies from 1.05 to 1.45 with a mean value of 1.21. The low bedrock resistivity observed beneath RVES 14 indicates high groundwater potential. Radial vertical electrical sounding is effective for determining the strikes of foliation of concealed basement rocks in which foliation is predominant. The results of radial electrical sounding could aid geologic mapping in areas where the basement rocks are concealed.

Key words. Radial sounding, homogeneity, resistivity maps, coefficient of anisotropy, structural trends.

Introduction

Surface geologic mapping basically involves field examination of rock outcrops in their natural location in order to identify the rock types and structural features, and take measurements of strike and dip, among others, useful to establish geological boundaries, reconstruct the geologic history and evaluate the economic potential of the rocks in the area. Observations of rocks are, however, difficult or impossible in areas where the basement rocks are concealed. Subsurface investigation employing Radial Vertical Electrical Sounding (RVES) can thus be used to determine the structural trends or strikes of the predominant structural feature (e.g. foliation) of the concealed rocks. The technique is capable of evaluating electrical anisotropy in basement complex areas for geological mapping and groundwater development [12], [13], [11].

Electrical anisotropy in Basement Complex rocks is caused by in homogeneity in the subsurface resulting from variable degree of weathering and structural features such as faults, joints, foliation and bedding [1], most of which create secondary porosity in rocks and enhance the effective porosity essential for groundwater development. The occurrence of groundwater resources in crystalline basement terrain depends immensely on the development of secondary porosity as well as permeability arising from weathering and fracturing of parent rocks, and to a great extent on the fracture patterns [2].

The degree of homogeneity of a medium is expressed in terms of coefficient of anisotropy, λ which can be calculated from geoelectric parameters or deduced from the ratio of the length of the major axis to the length of the minor axis of a resistivity map constructed by plotting apparent resistivity as a function of direction [9], [19]. The resistivity map is circular for isotropic medium and elliptical for anisotropic medium. The azimuth of the major axis of the ellipse lies in the strike direction of the predominant structural feature causing the electrical anisotropy.

It is on this basis that geoelectrical surveys have been carried out within Ladoke Akintola University of Technology Campus, Ogbomoso, in order to evaluate the anisotropic properties and determine the structural trends of the concealed basement rocks from elliptical resistivity maps. The study area is located within latitude 8° 09´ 859´´-8° 10´ 363´´ and longitude 4°15´ 808´-4° 16´ 217´on Ogbomoso Sheet 222 (Fig. 1). It lies within the Precambrian basement complex of southwestern Nigeria and the dominant rock type is porphyroblastic gneiss [18].

Materials and Methods

Radial Vertical Electrical Soundings (RVES) were conducted at 16 stations along four azimuths: 0°, 45°, 90° and 135°using the Schlumberger electrode array. The maximum current electrode spacing (AB/2) was 75m. Fig. 2 shows the base map of the study area. A total of 64 sounding data sets, comprising four from each RVES station, were interpreted using partial curve matching and computer-aided iteration [17], [20]. The apparent resistivity data recorded along the four azimuths were plotted against electrode spacing (AB/2) and contoured to obtain apparent resistivity maps for the respective RVES stations. For an isotropic homogeneous formation, the resistivity map will assume a circular shape. Any deviation from a circle to an ellipse is indicative of anisotropic nature of the subsurface [7], [12], [8], [14]. The azimuths of the major axis of the elliptical resistivity maps correspond to the principal direction of the predominant structural feature(s) responsible for the anisotropy [9], [6], [12]. The coefficient of anisotropy (λ) at each RVES station was calculated from the ratio of the length of the major axis to the length of the minor axis of the anisotropy ellipse.

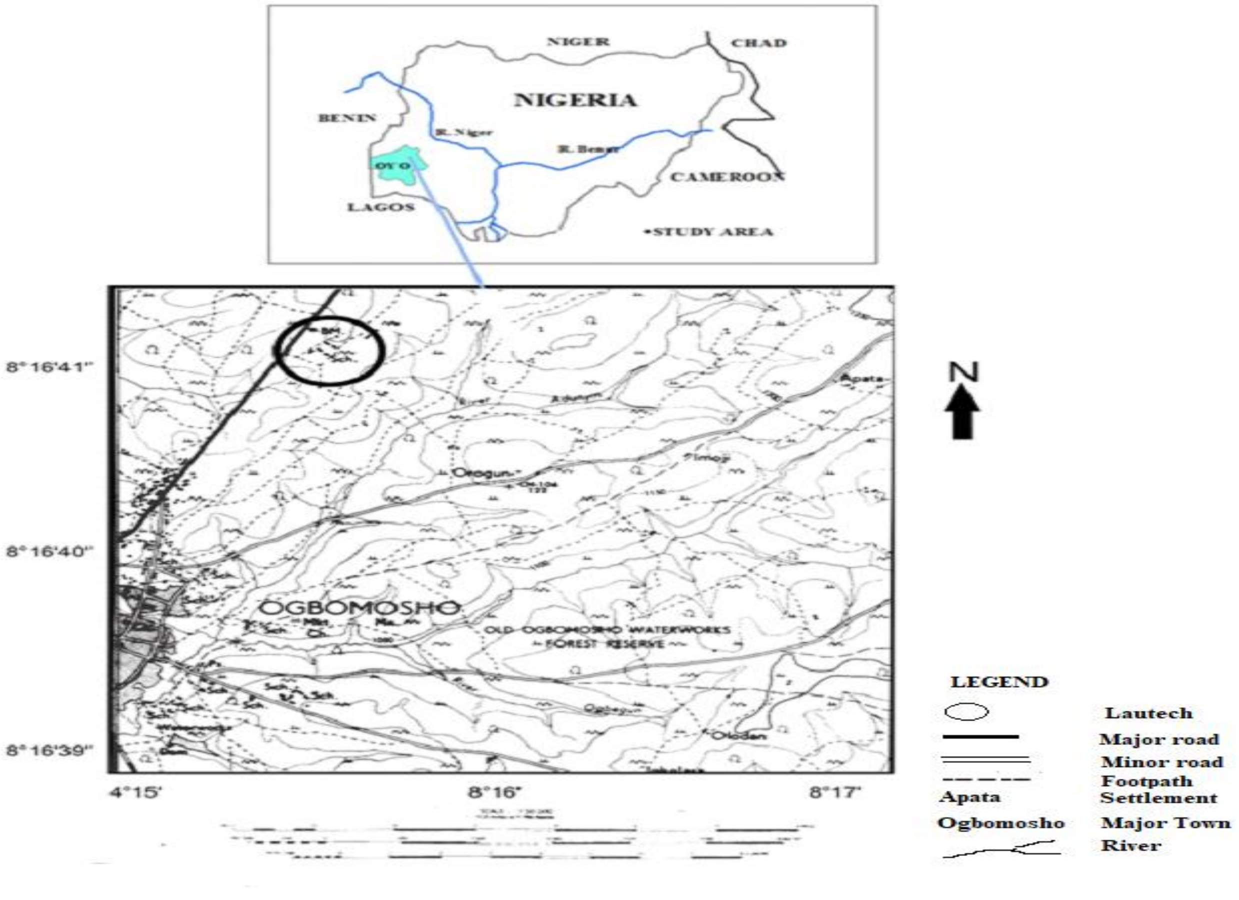


Figure 1. Location map of study area

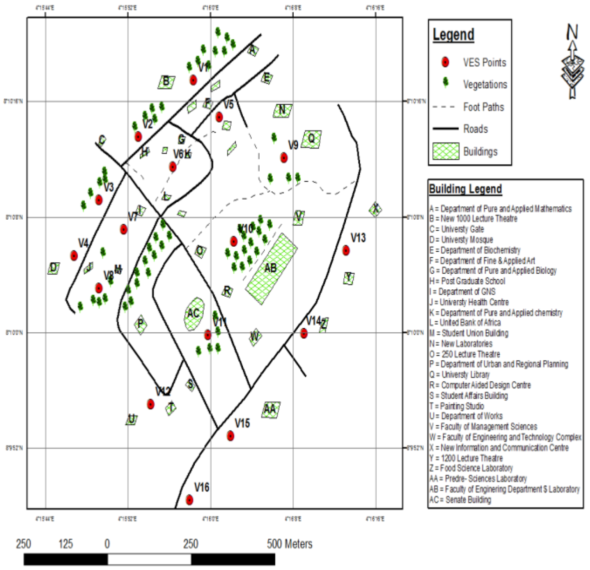
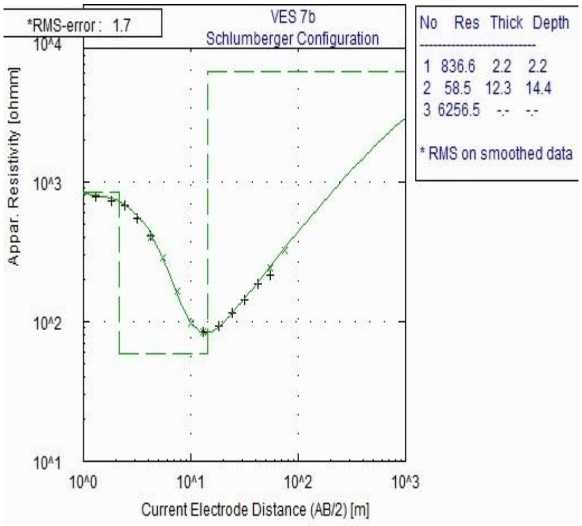


Figure 2. Base map of study area

Results and Discussion

Interpretation of the sounding data reveals three main layers beneath the study area defined as topsoil, weathered layer and fractured/fresh bedrock. A fourth layer in form of lateritic concretion underlies the topsoil at stations 5, 11 and 16. Eighty-one percent (81%) of the sounding curves are H-type ($\rho_1 > \rho_2 < \rho_3$) while about 16% are KH-type($\rho_1 < \rho_2 > \rho_3 < \rho_4$) and about 3% are QH type ($\rho_1 > \rho_2 > \rho_3 < \rho_4$) respectively. Typical sounding curves are shown in Fig. 3.

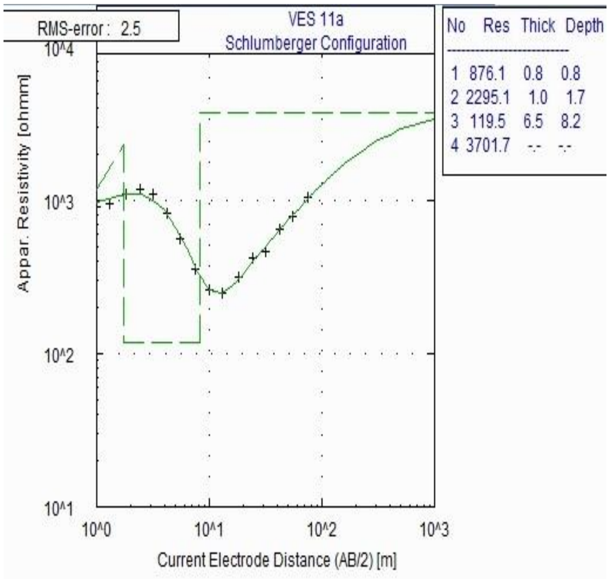
Since emphasis is on the degree of inhomogeneity and structural trends of concealed basement rocks with respect to groundwater potential, the data for the bedrock were considered. The depth to the bedrock and bedrock resistivity obtained along the different azimuths (0°, 45°, 90° and 135°) and their descriptive statistics are presented in Tables 1 and 2 respectively.



No	Res	Thick	Depth
1	836.6	2.2	2.2
2	58.5	12.3	14.4
3	6256.5	-.-	-.-

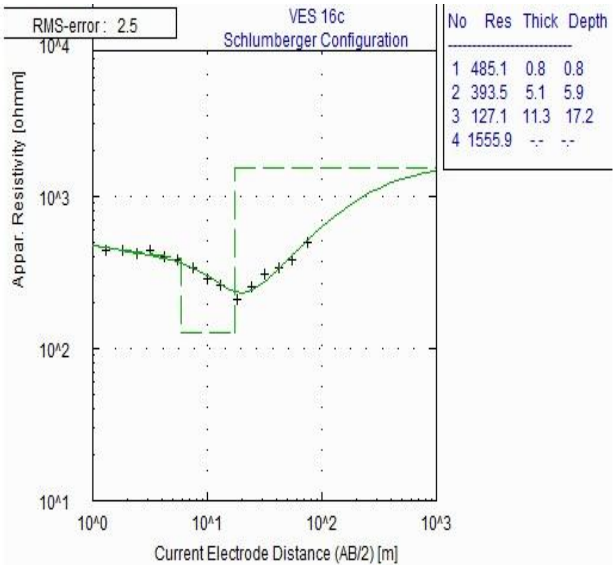
* RMS on smoothed data

(a)



No	Res	Thick	Depth
1	876.1	0.8	0.8
2	2295.1	1.0	1.7
3	119.5	6.5	8.2
4	3701.7	-.-	-.-

(b)



No	Res	Thick	Depth
1	485.1	0.8	0.8
2	393.5	5.1	5.9
3	127.1	11.3	17.2
4	1555.9	-.-	-.-

(c)

Figure 3(a, b, c). Typical H-type, KH-type and QH-type curves obtained from the study area.

The bedrock is generally shallow as the mean depth to the bedrock is less than 30 m at stations 1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 13, 14, 15 and 16 suggesting thin overburden and limited groundwater potential. The shallowest bedrock is beneath station 8 with a mean depth of 7.2±1.1m while the deepest is at station 9 with a mean depth of 39.0±13.6m. bedrock. The mean depth to the bedrock greater than 30m obtained at stations 6 and 9 is indicative of thick overburden which would support accumulation of groundwater, especially where a fracture system exists within the bedrock which serves as link with a neighbouring aquifer [16].

Table 1. Depth to the bedrock (m) along the different azimuths

VES	0°	45°	90°	135°	Mean	Standard Deviation	Coefficient of Variation (%)
1	19.7	17.9	25.3	19.9	20.7	3.2	15.4
2	22.1	24.8	23.2	20.9	22.8	1.7	7.3
3	14.6	15.1	20.6	18.5	17.2	2.8	16.6
4	19.4	20.0	19.3	19.0	19.4	0.4	2.2
5	9.4	6.9	13.5	12.6	10.6	3.0	28.6
6	35.0	24.7	41.2	28.3	32.3	7.3	22.6
7	19.3	14.4	21.4	27.2	20.6	5.3	25.8
8	7.5	5.6	7.5	8	7.2	1.1	14.8
9	28.7	28.2	42.3	56.9	39.0	13.6	34.8
10	11.9	10.0	11.2	9.9	10.8	1.0	9.0
11	8.2	5.0	9.2	11.3	8.4	2.6	31.1
12	8.9	9.2	11.1	15	11.1	2.8	25.4
13	17.7	14.2	14.6	14.6	15.2	1.6	10.7
14	7.8	8.1	14.8	7.2	9.5	3.6	37.7
15	26.8	33	29.9	27.4	29.3	2.8	9.6
16	11	18	17.2	15.5	15.4	3.1	20.3

Table 2. Bedrock resistivity from radial sounding

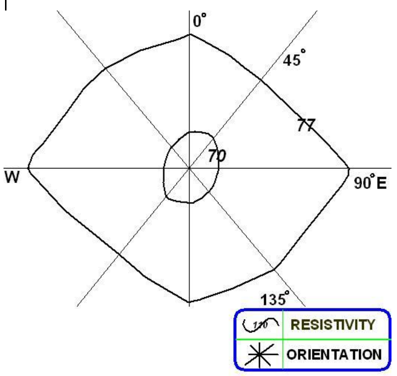
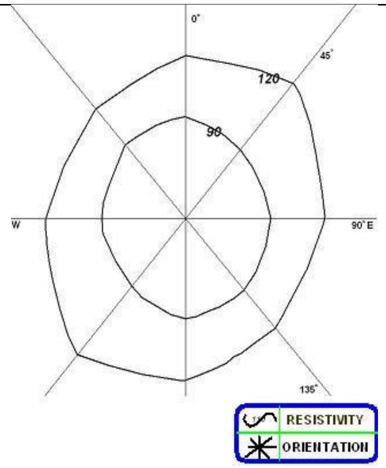
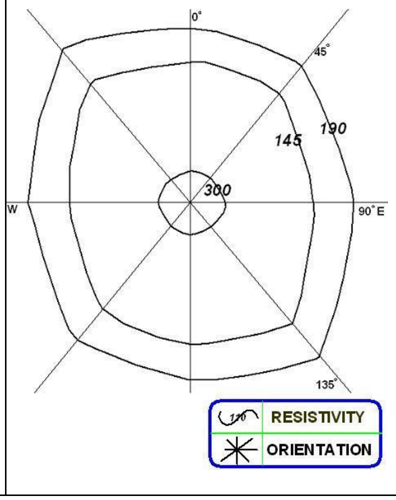
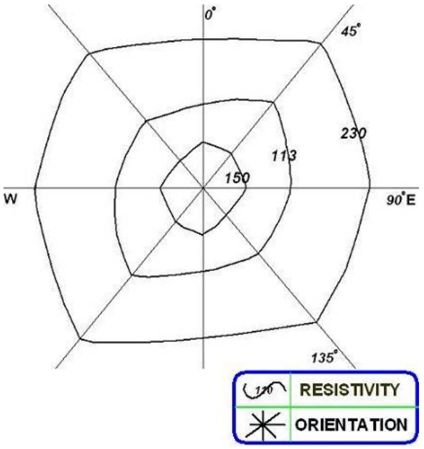
VES	0^0	45^0	90^0	135^0	Mean	Standard Deviation	Coefficient of Variation (%)
1	1642	1428	1671	1362	1526	154	10
2	2287	2940	2181	3111	2630	464	18
3	12442	13312	14451	16093	14075	1577	11
4	12976	19166	12428	8651	13305	4355	33
5	1364	525	3147	851	1472	1169	79
6	5776	10249	8102	9090	8305	1900	23
7	3871	6257	3900	8066	5523	2030	37
8	40214	26568	51827	53572	43050	12475	29
9	1317	1382	2065	3134	1975	844	43
10	1115	1033	1872	1357	1385	353	25
11	3702	4098	5626	36007	12358	15787	128
12	3805	3114	7104	1633	3914	2312	59
13	3007	1021	1054	2131	1803	954	53
14	636	629	1743	600	902	561	62
15	4134	5060	3459	3062	3928	874	22
16	1540	2240	1556	1960	1824	339	19

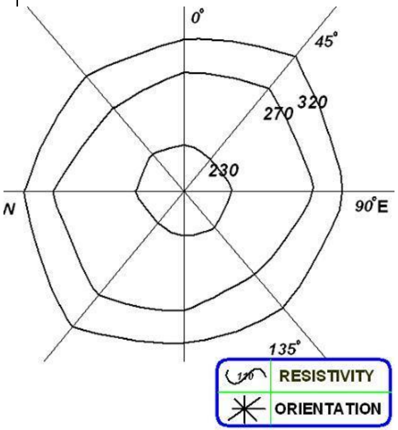
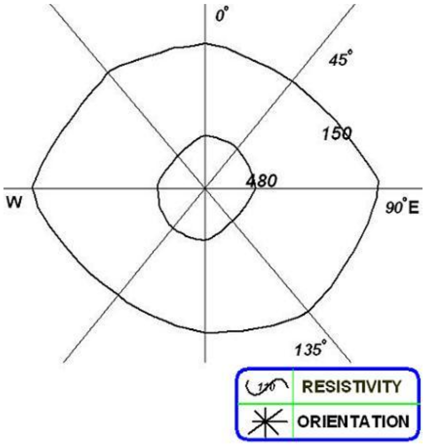
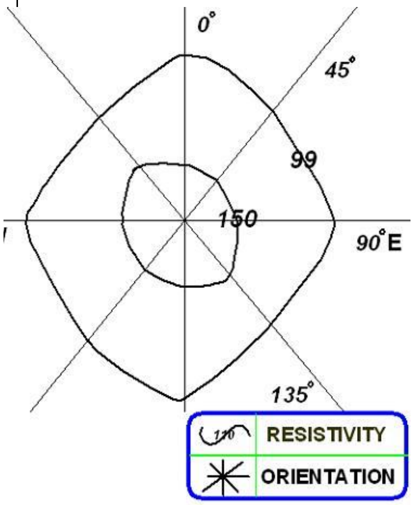
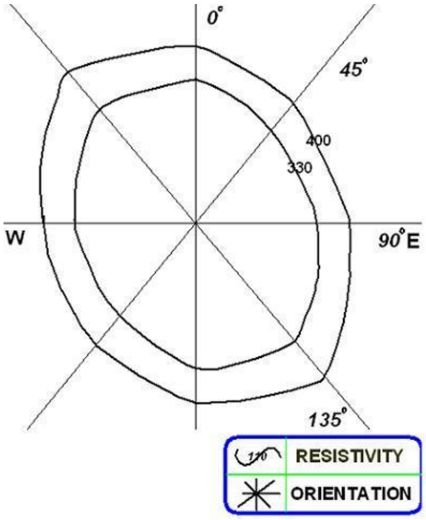
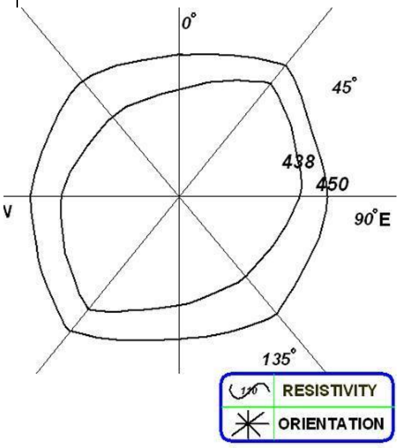
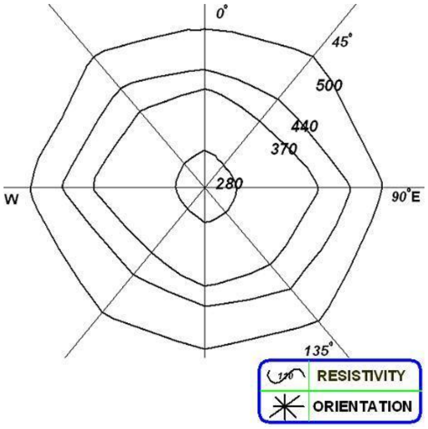
Depths to the bedrock and/or overburden thicknesses greater than 30 m are characteristic of high groundwater aquifer zones [15], [10], [5]. Water supply boreholes are often sited where the overburden is considerably thick with the hope that the location has optimum groundwater accumulation and occurrence of bedrock fissures [3], [4], [10]. However, groundwater potential rarely depends solely on overburden thickness, but a combination of geoelectric parameters such as depth to the bedrock, saprolite resistivity and fractured bedrock resistivity [10], [5]. The coefficient of variation in the depth to the bedrock ranges from 2.2% to 37.7%.

The lowest mean bedrock resistivity was recorded at station 14, with a mean of 901.75±560.8 Ωm while the maximum was obtained at station 8, with a mean of 43049.86 ±1900.1Ωm. Deviations in bedrock resistivity reflect inhomogeneity of the bedrock due to near-surface effects, variable degree of weathering [1]. The mean bedrock resistivity less than 1000 Ωm obtained at RVES stations 14 is classified as low and indicates high groundwater potential. Those between 1000 and 3000 Ωm recorded at stations 1, 2, 5, 9, 10, 13 and 16 are intermediate and indicative of reduced or fairly low effect of weathering and medium groundwater potential. Values greater than 3000 Ωm recorded at stations 3, 4, 6, 7, 8, 11, 12 and 15 are classified as very high and suggest limited occurrence or absence of fracture in the bedrock and negligible groundwater potential [11], [5]. The apparent resistivity maps are shown in Fig. 4 while the values of coefficient of anisotropy and the inferred structural trends are presented in Table 3. The elliptical shape of the resistivity maps is indicative of anisotropy and inhomogeneity. The coefficient of anisotropy estimated from the resistivity maps vary from 1.05 (at VES14) to 1.45 (at VES 1) with a mean of 1.21.

Table 3. The coefficient of anisotropy and inferred structural trend at the study area

VES	Coefficient of anisotropy, λ	Inferred structural trend
1	1.45	E-W
2	1.21	NE-SW
3	1.22	NW-SE
4	1.25	NE-SW
5	1.16	NE-SW
6	1.22	E-W
7	1.21	N-S
8	1.31	NW-SE
9	1.19	NE-SW
10	1.11	NW-SE
11	1.13	NW-SE
12	1.34	NE-SW
13	1.20	NE-SW
14	1.05	N-S
15	1.15	E-W
16	1.20	NE-SW

	Anisotropy Polygon		**Anisotropy Polygon**
1		2	
3		4	

5	0° 45° 320 270 230 N 90°E 135° RESISTIVITY ORIENTATION	6	0° 45° 150 480 W 90°E 135° RESISTIVITY ORIENTATION
7	0° 45° 99 150 90°E 135° RESISTIVITY ORIENTATION		0° 45° 400 330 W 90°E 135° RESISTIVITY ORIENTATION
9	0° 45° 438 450 90°E 135° RESISTIVITY ORIENTATION	0	0° 45° 500 440 370 280 W 90°E 135° RESISTIVITY ORIENTATION

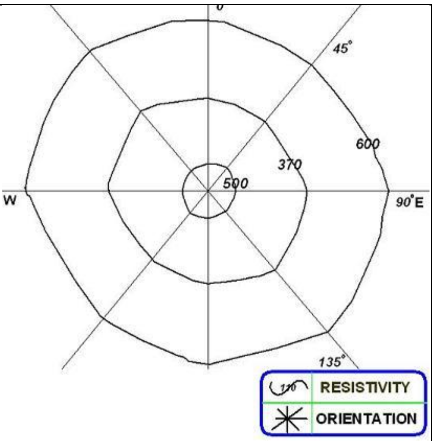
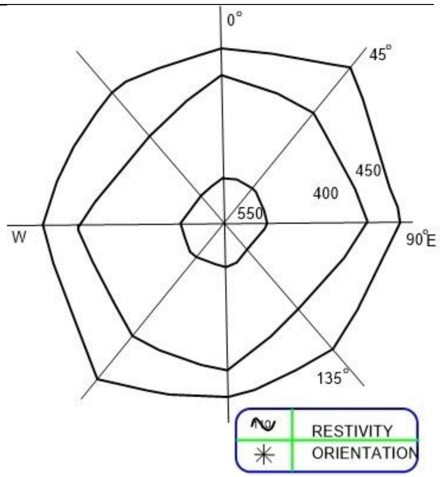
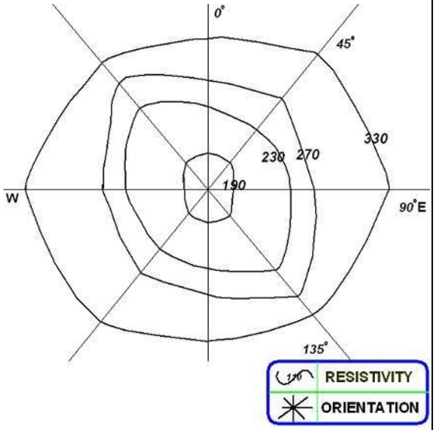
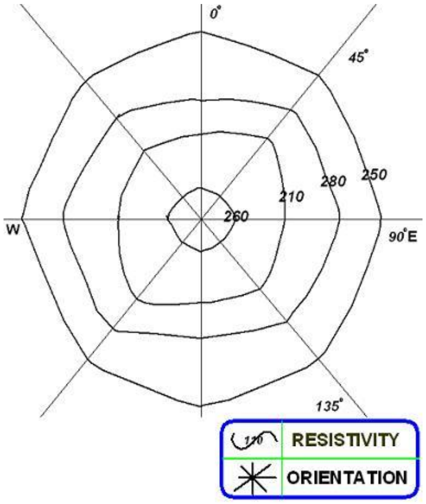
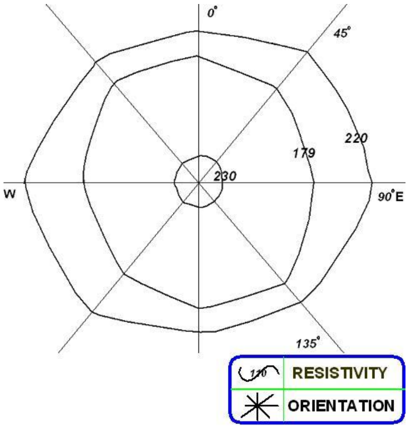
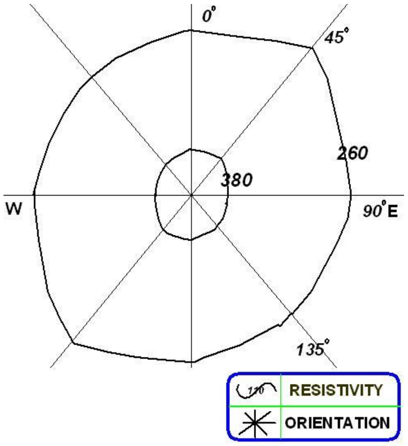
11		12	
13		14	
15		16	

Figure 4. Apparent resistivity maps constructed from the radial sounding

These values are within the range of coefficient of anisotropy, λ reported for basement complex rocks in literature [12], [13], [11]. There is no strong interrelationship between coefficient of anisotropy and depth to the bedrock (Fig. 5).

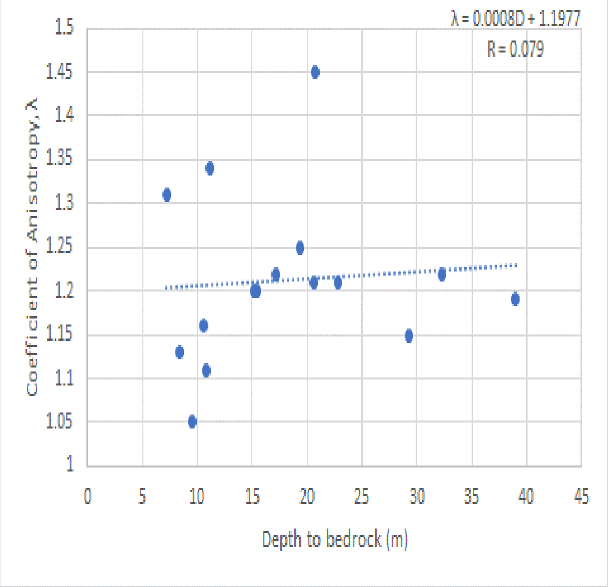


Figure 5. Interrelationship between coefficient of anisotropy and depth to bedrock

The bedrock beneath the study area cannot be said to be fractured since the reflection coefficient, R computed from resistivities of the bedrock and the weathered layer above it ranges from 0.545 to 0.997. R varies from 0.74 to 0.86 along the sounding azimuths even at station 14 beneath which the mean bedrock resistivity is apparently low. The electrical anisotropy may have thus been caused by foliation which is the predominant structural feature in the basement rocks. It is assumed that structural features in basement rocks remain intact even after weathering [12].

The azimuth of the major axis of each resistivity maps is the inferred trend of the foliation. The inferred structural trends are NE-SW for RVES 2, 4, 5, 9, 12 and 16; NW-SE for RVES 3, 8, 10, 11 and 13; E-W for RVES 1, 6, 15; and N-S for RVES 7 and 14. The inferred structural trends deduced from resistivity maps are expected to correlate remarkably with the strikes of the foliation [12], [11].

Table 4.Reflection coefficient, R computed from resistivities of the bedrock and the weathered layer

Station	ρ_1	ρ_2	$\rho_2 + \rho_1$	$\rho_2 - \rho_1$	R
1A	58	1642	1700	1584	0.931765
1B	59	1428	1487	1369	0.920646
1C	57	1671	1728	1614	0.934028
1D	54	1362	1416	1308	0.923729
2A	63	2287	2350	2224	0.946383
2B	78	2940	3018	2862	0.94831
2C	74	2181	2255	2107	0.934368
2D	68	3111	3179	3043	0.957219
3A	58	12442	12500	12384	0.99072
3B	74	13312	13386	13238	0.988944
3C	87	14451	14538	14364	0.988031
3D	73	16093	16166	16020	0.990969
4A	116	12976	13092	12860	0.982279
4B	92	19166	19258	19074	0.990446
4C	93	12428	12521	12335	0.985145
4D	93	8651	8744	8558	0.978728
5A	109	1364	1473	1255	0.852003
5B	134	525	659	391	0.593323
5C	143	3147	3290	3004	0.91307
5D	174	851	1025	677	0.660488
6A	262	5776	6038	5514	0.913216
6B	192	10249	10441	10057	0.963222
6C	254	8102	8356	7848	0.939205
6D	188	9090	9278	8902	0.959474
7A	64	3871	3935	3807	0.967471
7B	59	6257	6316	6198	0.981317
7C	80	3900	3980	3820	0.959799

7D	84	8066	8150	7982	0.979387
8A	71	40214	40285	40143	0.996475
8B	53	26568	26621	26515	0.996018
8C	77	51827	51904	51750	0.997033
8D	71	53572	53643	53501	0.997353
9A	388	1317	1705	929	0.544868
9B	386	1382	1768	996	0.563348
9C	458	2065	2523	1607	0.63694
9D	413	3134	3547	2721	0.767127
10A	211	1115	1326	904	0.68175
10B	177	1033	1210	856	0.707438
10C	176	1872	2048	1696	0.828125
10D	177	1357	1534	1180	0.769231
11A	120	3702	3822	3582	0.937206
11B	77	4098	4175	4021	0.963114
11C	129	5626	5755	5497	0.955169
11D	150	36007	36157	35857	0.991703
12A	305	3872	4177	3567	0.853962
12B	316	3203	3519	2887	0.820404
12C	375	7152	7527	6777	0.900359
12D	365	6507	6872	6142	0.893772
13A	166	3007	3173	2841	0.895367
13B	166	1021	1187	855	0.720303
13C	150	1054	1204	904	0.750831
13D	135	2131	2266	1996	0.880847
14A	93	636	729	543	0.744856
14B	81	629	710	548	0.771831
14C	135	1743	1878	1608	0.85623
14D	78	600	678	522	0.769912
15A	164	4134	4298	3970	0.923685
15B	169	5060	5229	4891	0.93536
15C	152	3459	3611	3307	0.915813
15D	136	3062	3198	2926	0.914947
16A	62	1540	1602	1478	0.922597
16B	96	2240	2336	2144	0.917808
16C	127	1556	1683	1429	0.849079
16D	99	1960	2059	1861	0.903837

Conclusions

The basement complex rocks underlying Ladoke Akintola University of Technology campus is anisotropic in nature. The structural feature responsible for the electrical anisotropy and inhomogeneity may be foliation in the bedrock which is composed of porphyroblastic gneiss. The inferred structural trends deduced from the resistivity maps are NW-SE, NE-SW, E-W and N-S. Radial electrical sounding can effectively be used to map subsurface geology in areas where the bedrock is concealed.

References

[1] Billings M. P., 1972. Structural Geology (3^{rd}edn.), 33-34. Prentice-Hall Englewood Cliffr. NJ.

[2] Carruthers R. M., 1984. Reviews of Geophysical Techniques for Groundwater Exploration in Crystalline Basement Terrain. British Geological Survey Report No. RGRGB5/3.

[3] Carruthers R. M. and Smith I. F., 1992. The use of ground electrical survey methods for siting water supply boreholes in shallow crystalline basement terrains, in Wright E. P. and Burgess W. G. (Ed). The hydrogeology of Crystalline Basement Aquifers in Africa, Geological Society Special Publication, No. 66.

[4] Chilton P. J. and Foster A. K, 1995. Characteristicsof Weathered Basement Aquifers in Malawi in relation to rural water supplies. Challenge in African Hydrology and Water Resources, JAHS, Publication No. 144, p. 57-72.

[5] Eduvie M. O. and Olabode O. T., 2001. Evaluation of Aquifer potential in the Crystalline Basement using Geoelectric sounding data from the southern part of Kaduna State, Nigeria. Water Resources–Journal of Nigerian Association of Hydrogeologists, Vol. 12, p. 56-61.

[6] Habberjam G.M, 1975. Apparent resistivity anisotropy and strike measurements.Geophys. Prospect., 23: 211-247.

[7] Malik S. B., Bhatacharya D. C. and Nag S. K. 1983. Behaviour of Fractures in Hard Rocks-A Study by Surface Geology and Radial VES method. Geoexploration, 21(3): 181-189.

[8] Mamah L. I. and Ekine A. S., 1989. Electrical Resistivity Anisotropy and Tectonism in Basal Nsukka Formation. Journal of Mining and Geology, vol. 25, Nos. 1 and 2, 121-129.

[9] Keller G. V. and Frischknecht F., 1966. Electricalmethods in Geophysical Prospecting. Pergamon Press, Oxford, 33-39.

[10] Olayinka A. I., Akpan E. J., Magbagbeola O. A., 1997. Geoelectrical sounding for estimating aquifer potential in the crystalline basement area of Shaki, southwest Nigeria. Water Resources, Vol. 8, No. 1 & 2, p. 71-80.

[11] Okurumeh O.K. and Olayinka A.I. 1998. Electrical anisotropy of Crystalline Basement rocks around Okeho, Southwestern Nigeria: Implications in Geological mapping and groundwater investigation. Water Resources. JNAH. 9: 41-50.

[12] Olorunfemi M. O. and OpadokunM. A., 1987. On the application of surface Geophysical measurements in Geological mapping. The Basement Complex of southwestern Nigeria as a Case study. Journal of African Earth Sciences, 6(3), 287-291.

[13] Olorunfemi M. O. and OpadokunM. A., 1989. Electrical Anisotropy in a Basement Complex area of southwestern Nigeria and its effect on depth sounding interpretation results. Journal of Mining and Geology, vol. 25, No. 1 &2, 87-95.

[14] Olorunfemi M. O., Olarewaju V. O., AladeO., 1991. On the electrical anisotropy and groundwater yield in a Basement Complex area of S. W. Nigeria.Journal of African Earth Sciences, 12(3), 467-472.

[15] Olorunfemi M. O. and Okhue E. T., 1992. Hydrogeologic and Geologic significance of a Geoelectric survey at Ile-Ife, Nigeria. Journal of Mining and Geology, vol. 28, No. 2, 1992.

[16] Omosuyi G. O., 2000. Investigation of geoelectric parameters, Dar Zarrouk parameters and aquifer characteristics of some parts of North-Central Nigeria. Journal of Science, Engineering and Tech., Vol. 7, No. 4, p. 2835-2848.

[17] Orellana E. and Mooney H. M., 1966. Master tables and curves for vertical electric sounding over layered structures. Interciencia, Madrid.

[18] Rahaman, M.A., 1988. Recent Advances in the study of the Basement Complex of Nigeria. In: Oluyide, P.O., Mbonu, W.C., Ogezi, A.E., Egbuniwe, I.G., Ajibade, A.C. and Umeji A.C. (eds.). Precambrian Geology of Nigeria, Geological Survey of Nigeria, p.11-41.

[19] Zohdy A. A. R., 1974. Application of surface geophysics to groundwater investigation. In: Techniques of water resources investigations of the United States Geological Survey, Book 2, Chapter D1, p. 26-30.

[20] Zohdy A. A. R., 1989. A new method for the automatic interpretation of Schlumberger and Wenner sounding curves. Geophysics, 54, 245-253.

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