Journal of Geology and Mining Research Vol. 4(5), pp. 105-117, August 2012
Available online at http://www.academicjournals.org/JGMR
DOI: 10.5897/JGMR12.001
ISSN 2006-9766 ©2012 Academic Journals

Full Length Research Paper

Combination of geological mapping and geophysical surveys for surface-subsurface structures imaging in Mini-Campus and Methodist Ago-Iwoye NE Areas, Southwestern Nigeria

Omosanya, K. O.[1,2]*, Mosuro, G. O.[1], and Azeez, L.[1]

[1]Department of Earth Sciences, Olabisi Onabanjo University, Ago-Iwoye, Nigeria.
[2]Cardiff University, School of Ocean, Earth and Planetary Science, United Kingdom.

Accepted 24 April, 2012

Electrical resistivity imaging and geological mapping were used to study the geology and delineate geologic structures at the Northeastern part of Ago Iwoye, Southwestern Nigeria. Two areas which include Mini-Campus Olabisi Onabanjo University (MCOOU) and Methodist Comprehensive High School (MCHS), Ago-Iwoye were studied. Electrical resistivity tomography (ERT) survey with Wenner configuration was done to reveal the horizontal and vertical variations in the subsurface geology; Azimuthal resistivity survey (ARS) was used to determine the orientation of the subsurface fractures. Both Wenner and Schlumberger array methods were employed. Measurement for each array were made about a fixed central point at an increment of 45° with respect to the reference axis using maximum electrode expansion of AB/2 at 130 m. Petrographic description and structural mapping were also carried out on three (3) outcrops nearest to the survey area in order to correlate the subsurface and surface geology and geologic structures. Petrographic study of rocks showed that the rock exposures are foliated biotite gneisses with mineralogical composition of quartz, plagioclase feldspar, biotite, and microcline. The orientation of joints (fractures) is dominantly ENE-WSW, E-W, and WNW-ESE. The electrical profiling revealed four geo-electric layers, clayey topsoil, clayey sand, sandy layer and weathered bedrock, the fresh bedrock/basement occurred at depth of 15.9 and 19.8 m subsurface at MCOOU and MCHS, respectively. The ARS showed that there is significant anisotropy between 30 and 65 m with fracture occurrence at 39 and 30 m at Methodist and Mini-campus; these fractures are oriented NW-SE, N-S and NE-SW, respectively. The coefficient of electrical anisotropy indicates that the intensity of fracturing at Methodist opens with depth at one part and later became constant with depth at other parts while that of Mini-campus is constant with depth. Fractures orientation suggests that surface structures are not deep seated and were produced by dissimilar tectonic event relative to subsurface fractures.

Key words: Geology, fractures, orientation, anisotropy, electrical resistivity tomography (ERT), Azimuthal resistivity survey (ARS).

INTRODUCTION

Fractures are breaks in rocks caused by tectonic stresses; on the basis of their dimension can be studied on mega scale (seismic section, satellite images, aeromagnetic data), macro scale (as joints, faults and veins in outcrop) and micro scale (in thin section). Fractures mapped on outcrops could be deep seated, consequently, it is possible to detect their orientations in the subsurface using certain geophysical techniques.

Azimuthal resistivity survey method has proved very successful in the delineation of subsurface geology and structures, especially for effective identification and

*Corresponding author. E-mail: kamaloomosanya@yahoo.com. Tel: +2348034454405.

delineation of strike (orientation) of fracture. The identification and characterization of fracture is important in rocks with low primary (or matrix) porosity because the porosity and permeability are determined mainly by intensity, orientation, connectivity, aperture and infill of fracture (Skynernaa and Jugerson, 1993). Azimuthal resistivity survey is a modified resistivity technique wherein the magnitude, intensity, and direction of electrical anisotropy are determined. An electrode array is rotated about its centre so that the apparent resistivity is observed for several directions (Taylor and Fleming, 1988).

The aims of this study include (i) identification of joints and other fractures in outcrops of the study area (ii) determination of their geometry, dimensions, and orientation (iii) mapping of the subsurface geology and structures using 2D profiling and Azimuthal resistivity survey (ARS), and (iv) correlation of fracture orientation on surface (outcrops) with subsurface.

Leonard and Mayer (1984), Taylor and Fleming (1988), Ritzi and Andoleck (1992), Skyernae and Jorgensen (1993), Hagrey (1994), and Boadu et al. (2005) employed Azimuthal resistivity survey technique to determine the principal direction of electrical anisotropy and any observed changes with azimuth was interpreted as invocative of anisotropy (general fracture anisotropy). Lane et al. (1995), Carlson et al. (1996a, b), Hansen and Lane (1996), and Chapman and Lane (1996) determined fracture geometry in crystalline rock and glacial using Azimuthal resistivity survey. Lane et al. (1996) also characterized the porosity and aperture of high angle fracture using the Azimuthal resistivity method.

MATERIALS AND METHODS

Location of study area

The study area is located within latitude 06° 57' 6.6''-06° 57' 14'' and longitude 003° 54' 27.8''-003° 54'46.1''. (Figure 1) It falls within the subequatorial tropical region of the world. The study areas include the Mini-Campus of the Olabisi Onabanjo University and Methodist comprehensive High School, Ago-Iwoye Nigeria. The landscape of the area is influenced by the geographic location, climatic condition, drainage pattern, vegetation and to a lesser extent, human activities. The study area is a low-lying basement terrain with a topographic elevation of ~41 to 51 m above sea level. The surface landscape has been modified by low-lying vegetation and shrubs. The area is characterized by high temperature, high humidity, and high precipitation with a gross influence of South-West winds during the wet season and North-East trade winds during the dry season. The temperature varies with season, ranging from about 23 to 25°C during the wet season and 23 to 30°C in the dry season (Akintola, 1986). The mean annual rainfall is measured to be ~1750 mm but could vary from ~1200 to 2300 mm.

Method

The study was divided into two parts, the surface geology and structures, and subsurface geology and structures. The surface geological study involved detailed mapping of three rock exposures closest to the area where geophysical survey was done; emphasis was placed on the fractures (joints), with the length, orientation and average perpendicular distance between joints measured. Rock samples were collected for petrographic analysis, basically for identification of the rock type. The orientation of the joints were plotted on rosette diagrams and histograms in order to understand the trend of the major tectonic force(s) in the region.

Geophysical survey includes ERT and ARS were carried out at both Mini-Campus and Methodist with a view to mapping the subsurface geology and fracture orientations. In the ARS study, both Wenner and Schlumberger were integrated to accomplish the essence of using these methods. The electrode configuration was rotated about a fixed point at an increment from 0, 45, 90, and 135° corresponding to the E-W, NE-SW, N-S, and NW-SE directions. The measured resistance R(Ω) from the configuration was later converted to apparent resistivity (Ωm) by multiplying with appropriate geometric factors.

ERT was done in order to reveal the horizontal and vertical variations in the subsurface geology using Wenner configuration. For this electrode configuration, a constant electrode spacing was maintained between the adjacent electrodes, and the whole spread is transverse along the survey line. In order to obtain a good 2D picture of the subsurface, the coverage of the measurement was done in 2D as well. The electrode spacing between the adjacent electrode was assigned "a". For a system with 20 electrodes, it has to be noted that there are (20-(1x3)), (20-(2x3), (20-(3x3), (20-(4x3) possible measurements for "1a", "2a", "3a", "4a" electrode spacing respectively and so on. This implies that, as the electrode spacing increases, the number of measurement decreases. The first procedure was to carry out all the possible measurements for the Wenner array with an electrodes spacing of "1a". For the first measurement, electrodes number 1, 2, 3, and 4 were used. Electrode 1 was used as the first current electrode (C_1), electrode 2 as the first potential electrode (P_1), electrode 3 as the second potential electrode (C_2) and electrode 4 as the second current electrode. For the second measurement, electrodes number 2, 3, 4, and 5 were used for C_1, P_1, P_2, and C_2 respectively. This was repeated down the line of electrodes until electrodes 17, 18, 19, 20 are used for the last measurement with "1a" spacing for Wenner array. After completing the sequence of measurement with "1a" spacing, the next sequence of measurement with "2a" was done. Firstly, the electrodes number 1, 3, 5, and 7 were used for the first measurement. The electrodes were chosen so that the spacing between the adjacent is "2a", while for the second measurement, electrodes 2, 4, 6, and 8 were used. This process was repeated down the last measurement with spacing "2a". The same process was done for measurements with "3a to 8a" spacing, with initial a-spacing being 5 m.

RES2DINV ver 3.55 software by Geotomo software was used to interprete the data colllected from the survey; before the data were uploaded onto the software, the resistance obtained on the field were multiplied with the equivalent geometric factor and the values were inverted on the software, both Smooth and Robust inversion were done, in order to compare the results. The inversion routine used by the program RES2DINV is based on the smoothness constrained least-squares method inversion algorithm (deGroot-Hedlin and Constable, 1990; Sasaki, 1992). The 2D model divides the subsurface into a number of rectangular blocks (Loke and Barker, 1996) and the resistivity of the blocks were adjusted in an iterative manner to minimize the difference between the measured and calculated apparent resistivity values. The latter are calculated by the finite difference method of Dey and Morrison (1979).

RESULTS

Petrography of rock

Three representative samples were collected from the

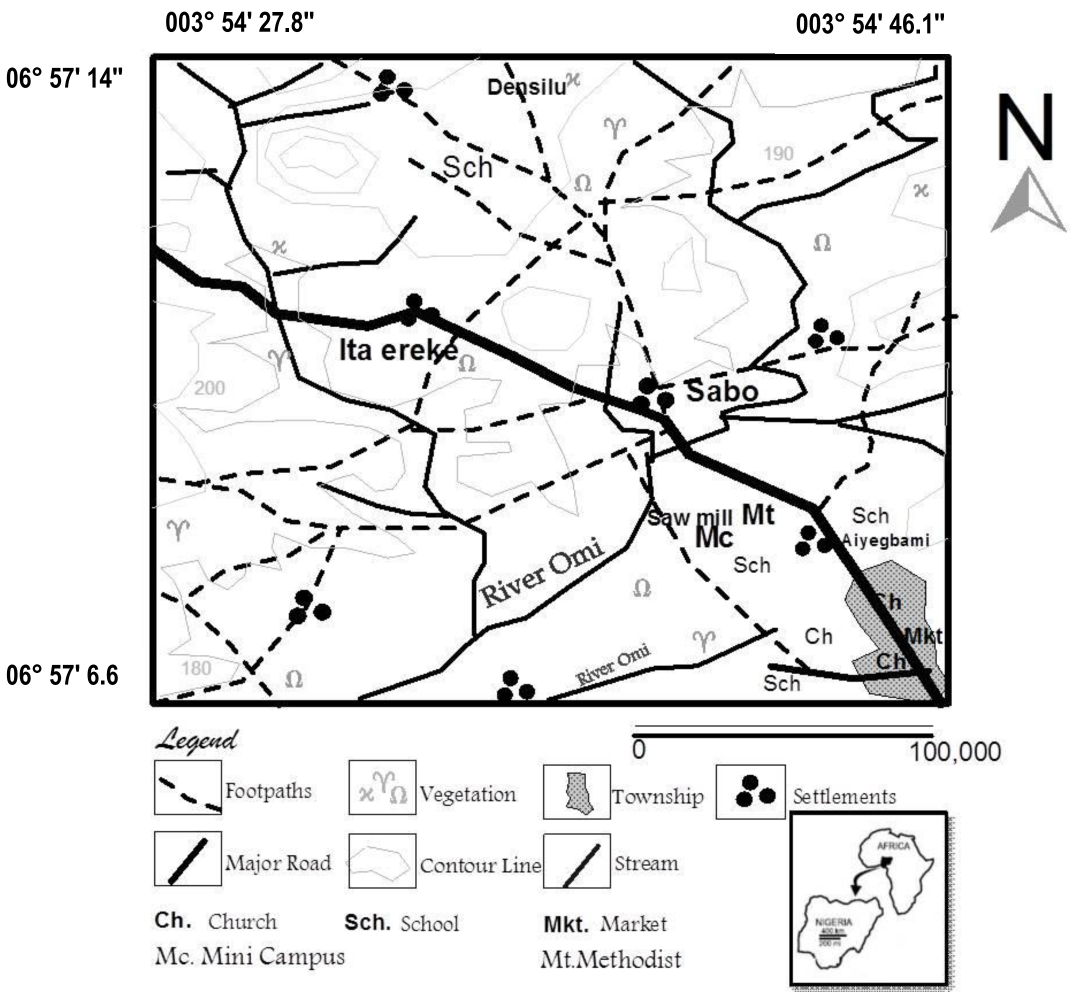

Figure 1. Index map of the study area. Mini-Campus- Mc, Methodist-Mt and the outcrop positions are Densilu, Saw Mill and Aiyegbami- Inset: Map of Nigeria and Africa.

three outcrops mapped. The samples were prepared into thin section and studied under the petrographic microscope. Minerals identified include quartz, biotite, plagioclase, microcline, and others beyond the resolution of the microscope. (Figure 2) The sample from Aiyegbami has quartz-45%, biotite-25%, plagioclase-10%, microcline-5%, and other minerals-10%. This sample showed evidence of foliation, with foliation estimated to strike approximately N35°W relative to the 0-calibration on the microscope. The outcrop at Sawmill has quartz-45%, biotite-35%, plagioclase-5%, microcline-3%, and other minerals-12% while that at Densilu is composed of quartz-35%, biotite-40%, plagioclase-10%, microcline-5% and other minerals-10%. Both rock show greater alignment of the platy minerals unlike the rock at Aiyegbami, the strike of the rocks are approximately N35°-40°W on the microscope.

On the basis of the mineralogy composition and textural make up of the rock, the samples are thought to have been derived from a granitic protolith, the foliation is evidence of metamorphism, and the rocks are named foliated biotite gneisses. They are greyish in appearance and are thought to belong to the rocks of the migmatite-gneiss complex of South-western Nigeria. The polycyclic migmatite-gneisses are highly foliated, deformed or metamorphosed rocks, most widely spread in South-west Nigeria, Oyawoye (1972). They include banded gneiss, migmatite gneiss, transition gneiss, augen gneiss and pegmatite. These group of rocks can be found in places like Ibadan, Iseyin, Ago-Iwoye and Iperindo, they are Archean in age (3.5 Ga) (Dada et al., 1993).

Previous classification of these rock types include: grey foliated biotite or biotite hornblende quartzo feldspathic gneiss of tonalite to granodioritic composition now referred to as grey gneiss by Rahaman (1981); Mafic to Ultra component which usually outcrop as discontinuous boudinaged lenses or concordant sheet of amphibolites with minor amount of biotite-rich ultramafite; and felsic component is varied group of rocks consisting essentially of pegmatite, granite gneiss, and porphyiritic granite.

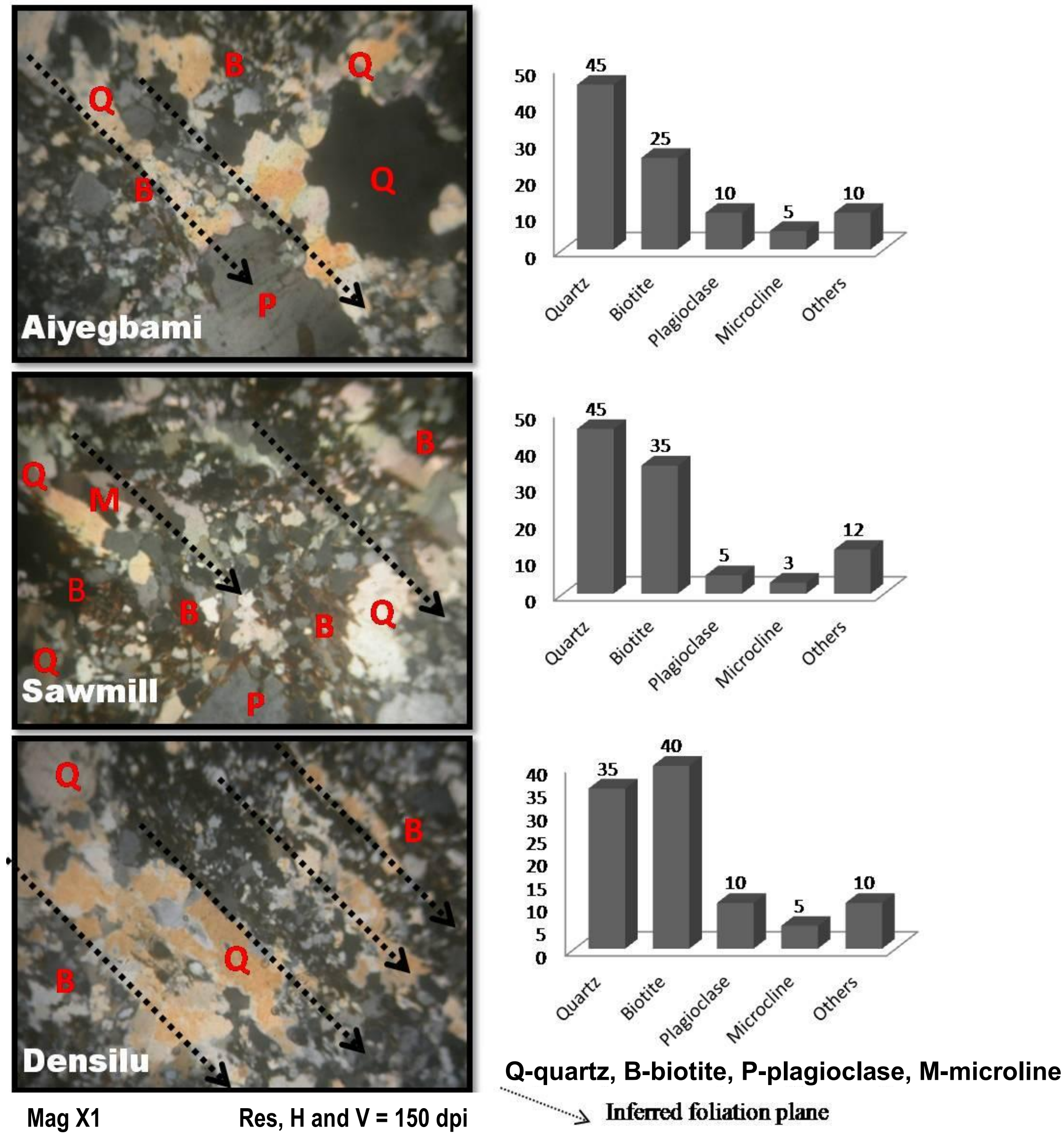

Figure 2. Photomicrograph of representative rock samples from the three outcrops nearest the survey area.

Surface joint mapping

At Aiyegbami, a total number of twenty six joints were mapped on the rock exposure; the longest joint measured was J8 (~395 cm) and the shortest was J16 with length of ~77cm (Figure 4, Table 1). Master joints identified in this outcrop were J7, J8, J4, J15, J19, and J26. When compared on the basis of the average perpendicular distance between the joints, the following joints were classified as systematic joints, J14 and J15; J23 and J24 with distance of approximately 15 cm between them. J9 and J10; J1 and J2; and J2 and J3 have average perpendicular distance of ~58 cm and are also categorised as systematic joints.

At Densilu, fifteen (15) joints were identified on the outcrop, the longest joints is J14 with length of ~412 cm while J2 with length (~43) was the shortest joint measured. J3, J1, J8, J11, J12, and J15 were identified as master joints with J1 and J2 and J9 and J10 categorised as systematic joints because of the average perpendicular distance of ~29 cm between them (Figure 5, Table 2). Other joints were non-systematic.

At the Sawmill, out of the twenty joints mapped, J4 and J5 and J11 and J12 were systematic joints with average perpendicular distance of ~ 12 cm. The longest joint measured in this exposure is J7 (~158 cm), while J15 was the shortest joint recorded with approximate length of 43 cm. Other joints were non-systematic, with J2, J3,

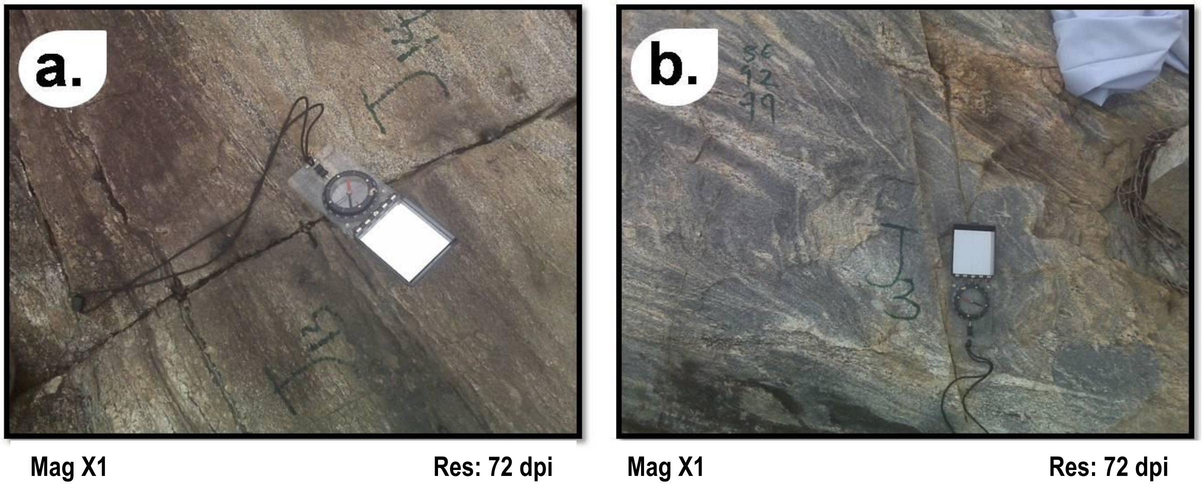

Figure 3. (a) J13 and J14 at Aiyegbami, the surfaces of these joints are nearly straight (b) Joint J3 at saw mill.

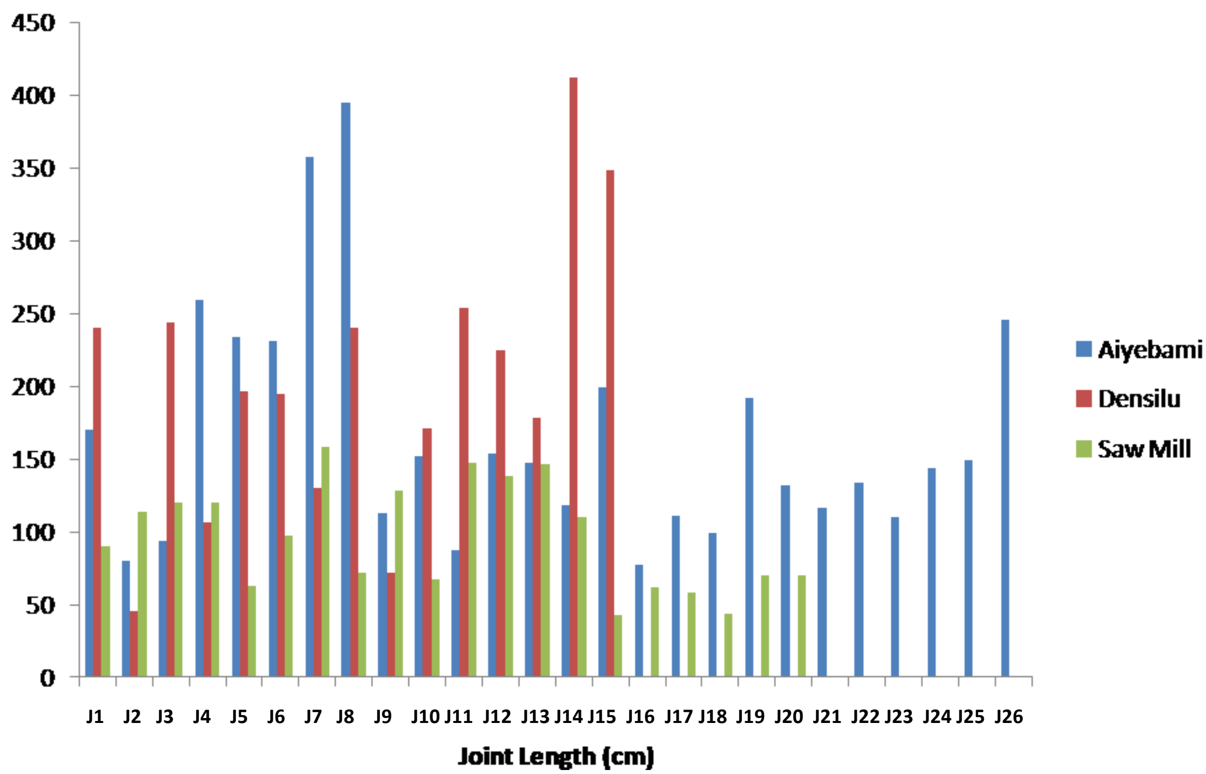

Figure 4. Plot of joint length for the three rock exposures closest to the study area.

J4, J9, J12, J13, and J14 identified as master joints. Surface geometry of most of the joints is straight and curved (Figure 3a and b).

When we plotted on orientation diagrams such as rosette diagram and stereonets (Figure 6a and b), the joints of the three exposures were dominantly oriented in the NEE-SWW direction with orientation of poles in the NW direction. Using the Bed-Egg-Cube model (Omosanya et al., 2011), the dip of the joints were determined; the joints are dominantly dipping in N, S, and SE directions with minor dips recorded in the NE, E and SW directions. This implies that the joints were produced by dominant NNW-SSE tectonic forces because the joints are thought to be extensional structures, since no

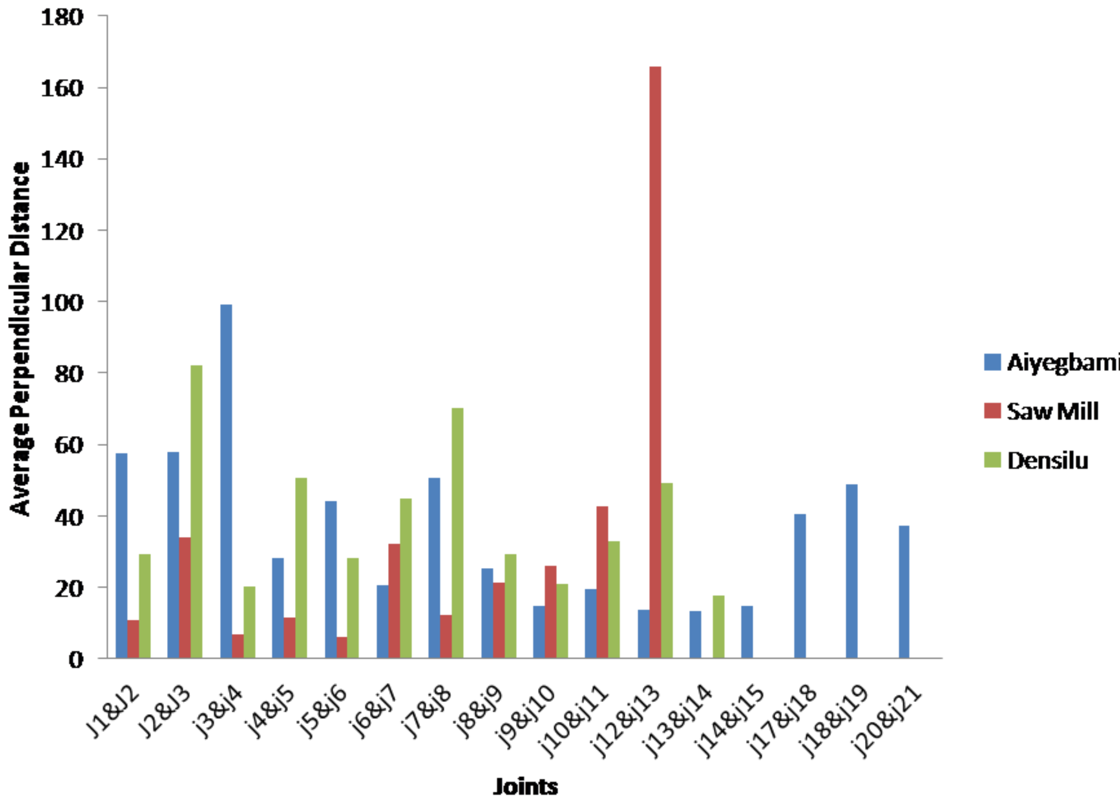

Figure 5. Plot of average perpendicular distance between joints mapped on the three rock exposures closest to the study area.

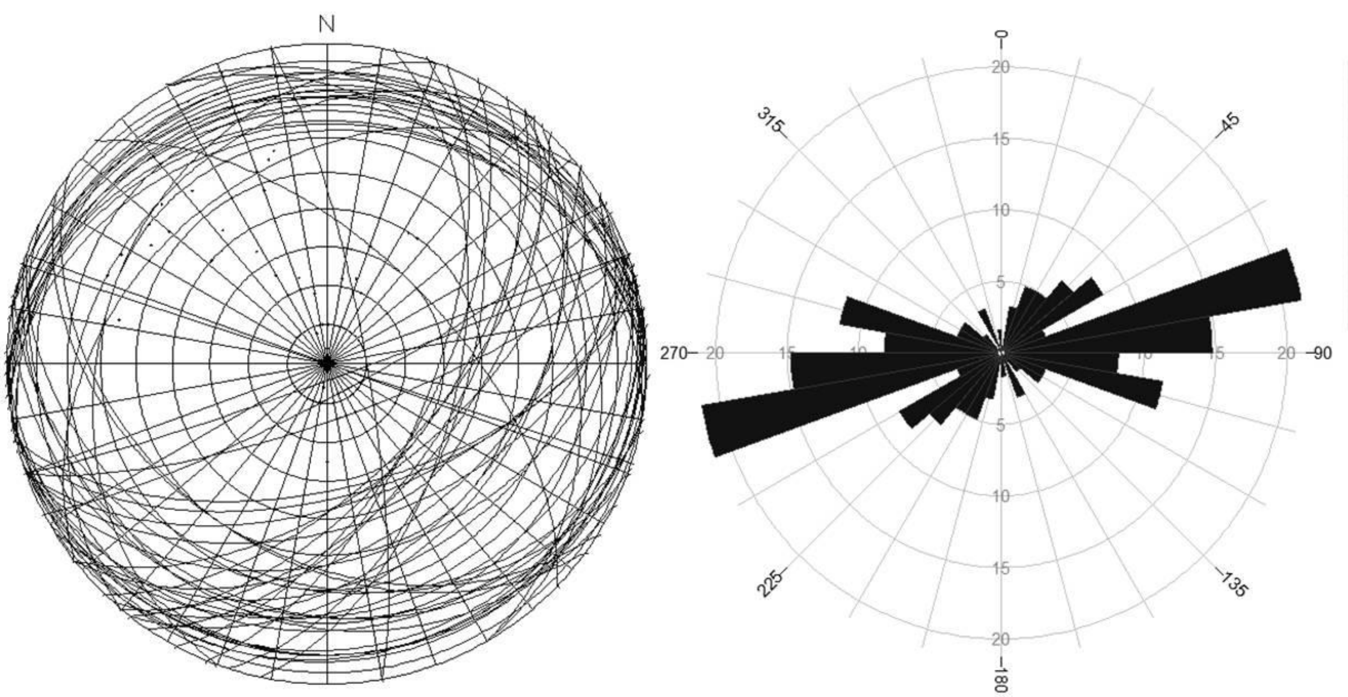

Figure 6. (a) Stereographic projections for all joints measured on the three outcrops, the dip of the joints were determined using the Bed-Egg-Cube model (Omosanya et al., 2011) (b) the joints are dominantly oriented in the NEE-SWW direction:-they are likely produced by NW-SE oriented extensional stresses.

conjugate joint was seen during the mapping exercise.

Geophysical survey

ERT

The results of 2D resistivity profiling were interpreted in two ways, the smooth inversion and the robust inversion in order to pick areas of sharp discontinuities from the robust inversion that may be related to geologic structures.

The Mini-Campus pseudosection

The apparent resistivities were inverted in order to obtain a true plot of apparent resistivity with depth rather than electrode spacing; both smooth and robust inversions were carried out. From the smooth inverted pseudosection, four layers were interpreted. These include the clayey topsoil, clayey sand, sandy layer and the bedrock with resistivity value ranging from 26.5 to 92.9, 174 to 326, 326 to 612, and 1146 to 2148 Ωm respectively. The first three layers have thickness of 8.36, 2.33, and 0.43; the bedrock's occur from depth ~13.0 m to infinity.

The four layers identified from the robust inverted pseudosection include the clayey Topsoil, sandy layer, weathered basement and the fresh bedrock. These layers have resistivity values of 28.9 to 67.9, 159 to 374, 878, and >2148 Ωm respectively. The upper layers have thickness of 9.75, 2.01 and 1.8 m respectively, with the basement or bedrock occurring from depth of ~13 m to infinity. No sharp discontinuity was found on the robust inverted pseudosection, this imply the absence of vertical inclined structures such as dykes, and faults along the profile covered by the ERT survey (Figure 7a and b).

The Methodist pseudosection

Two type of topsoil are interpreted from the smooth inverted pseudosection, they include sandy topsoil to the West that laterally grades into clayey topsoil that overlies most of the area. The sandy topsoil soil has a resistivity value of ~~260 to 500 Ωm and thickness of ~7 m into the subsurface while the clayey topsoil have a resistivity and thickness of ~66.4 to 132 Ωm and 12.2 m respectively. The topsoil was underlain by a sandy layer with resistivity value of ~260 to 516 Ωm and thickness of 1.46 m. The basement rock has resistivity value of ~1021 to 7926 Ωm and occurs from depth of -15 m to infinity.

To the west of the robust inverted pseudosection; the rock is overlain by sandy topsoil with resistivity value of ~260 to 500 Ωm, this layer grades into a clayey horizon (Clayey Topsoil) with a value between ~67.2 to 130 Ωm and thickness of ~12.25 m. The topmost layer was underlain by a sandy horizon with resistivity value that ranges from ~250 to 484 Ωm and thickness of ~1.90 m; this layer is preceded by a weathered basement with resistivity of ~934 Ωm and thickness of 1.57 m. The bedrock has resistivity of ~1803 to 6726 Ωm and occurs from depth of ~13 m to infinity (Figure 7c and d).

DISCUSSION

Integrating the result of the 2D profiling with surface geological mapping, the rocks mapped at the surface are Foliated biotite gneiss; it implies that the Basement rock at Mini-Campus and Methodist are subsurface expression of the foliated biotite gneiss. The nature of the basement rock cannot reliably be determined from a resistivity survey except when the rock is weathered or fractured. The basement rock at both location has resistivity value of >1000 Ωm. Since the area mapped belongs to the migmatised gneiss complex of South-western Nigeria, it is plausible to assume that the bedrock type at both point are outcropping as rock exposures seen closest to the area of the survey. The general surface and subsurface geology from Methodist to Mini-campus showed that the basement cover include a clayey to sandy topsoil, clayey sand, sandy layer, and weathered basement rock. All underlain by foliated Gneiss of the Migmatised gneiss complex of South-western Nigeria.

ARS

The result of the apparent resistivity obtained from the ARS is shown in Tables 3 and 4. The coefficient of anisotropy is calculated from the square root of the maximum to minimum apparent resistivity at any AB/2 spacing (Equation 1). For any formation which is anisotropic due to the presence of fractures, the apparent resistivity (ρt) measured normal to its strike direction was greater than apparent resistivity (ρs) measured along the strike direction, when Schlumberger or Wenner array was used (Lane et al., 1995).

$$\lambda = \sqrt{(\rho t \;/\; \rho s)} \qquad (1)$$

The anisotropy polygon (Figure 8) was plotted with increasing AB/2; this is done by joining lines of same resistivity value along different azimuths with different AB/2 separations. Anisotropy at values of AB/2 was (< 12 m) were neglected, surface irregularities associated with surveying may produce significant anisotropy at this depth (depth is considered AB/2 * 0.6). For an isotropic homogeneous formation, the resistivity anisotropy polygon will assume a circular shape. Any deviation from a circle to an ellipse is indicative of anisotropic nature of the formation (Mallik et al., 1983; Skerjenaa and Jorgensen,

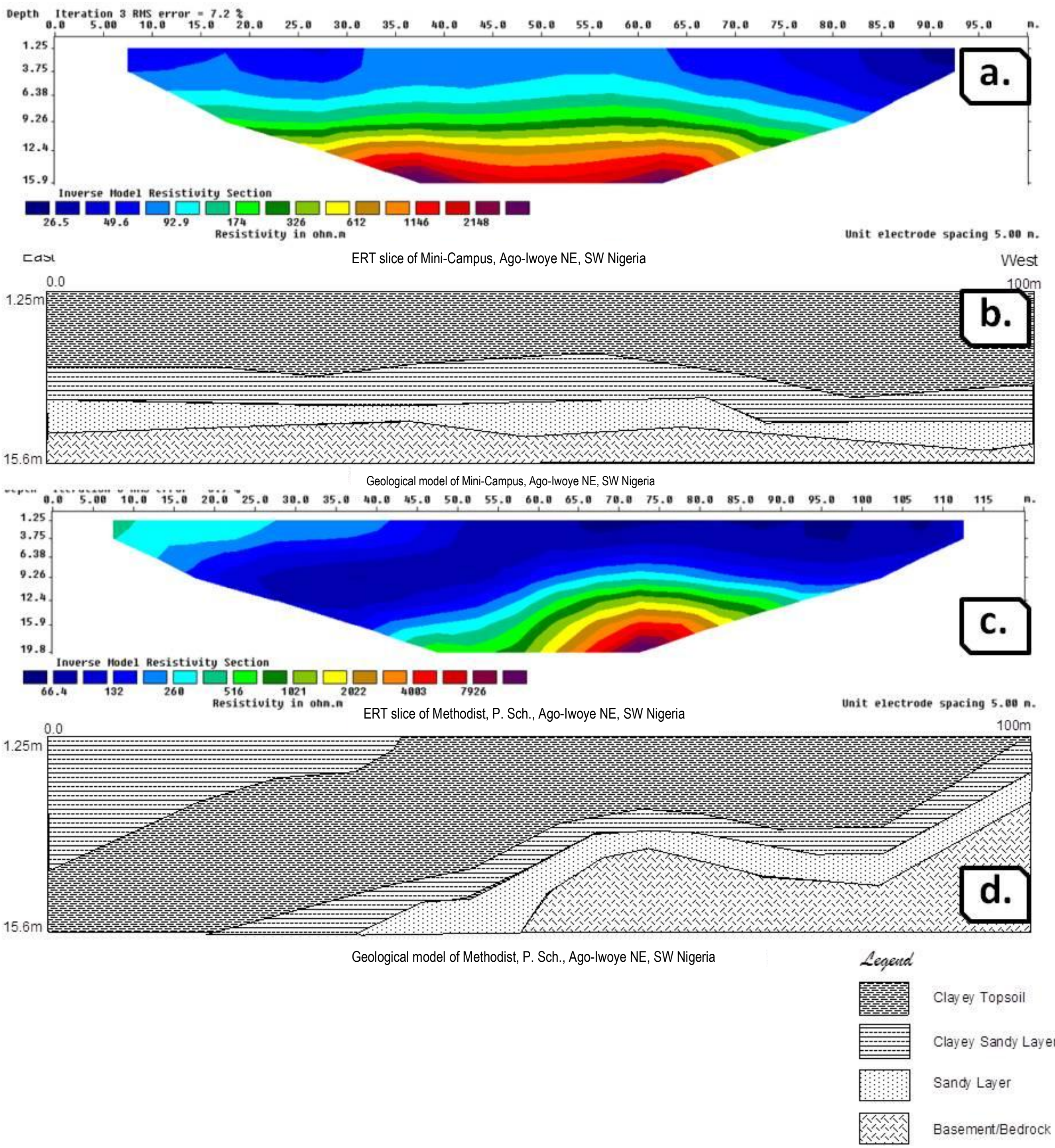

Figure 7. (a, b, c and d) Resistivity pseudosection and the inferred geological model for both Mini-Campus and Methodist, Ago-Iwoye, NE, SW, Nigeria. Location of pseudosection are shown as Mc and Mt in Figure 1.

1993). The direction of the longest axis of the polygon corresponds to the strike (orientation) of the fracture, and the ratio of the long to short axis is an indication of the presence of fractures (faults and joints system) in an area if high, and otherwise if low (Skjernaa and Jorgensen, 1993).

Ehirim and Essien (2009) showed that Wenner array has better sensitivity when it was used for the ARS, though their research was done in a sedimentary terrain, but there was need to validate such finding by carrying

Table 1. Parameters measured on the joints at Aiyegbami.

Aiyegbami	Joints	Orientation (°)	Length(cm)	Average distance
1	J1	22	170	J1 and J2=58
2	J2	28	80	
3	J3	68	94	J2 and J3=58
4	J4	80	259	J3 and J4=99
5	J5	83	234	J4 and J5=28
6	J6	109	231	J5 and J6=44
7	J7	76	357	J6 and J7=21
8	J8	72	395	J7 and J8=51
9	J9	40	113	J8 and J9=25
10	J10	34	152	J9 and J10=15
11	J11	38	87	J10 and J11=20
12	J12	350	154	
13	J13	314	147	J12 and J13=14
14	J14	270	118	J13 and J14=13
15	J15	42	199	J14 and J15=15
16	J16	12	77	J8 and J16=28
17	J17	52	111	
18	J18	44	99	J17 and J18=41
19	J19	58	192	J18 and J19=49
20	J20	60	132	
21	J21	52	116	J20 and J21=37
22	J22	126	134	
23	J23	102	110	
24	J24	102	144	J23 and J24=15
25	J25	108	149	J24 and J25=36
26	J26	122	246	J25 and J26=24

Table 2. Parameters measured on the joints at saw mill and Densilu.

Sawmill	Joints	Orientation (°)	Length(cm)	Average distance
1	J1	266	90	
2	J2	268	114	J1 and J2=11
3	J3	264	120	J2 and J3=34
4	J4	262	120	J3 and J4=7
5	J5	264	63	J4 and J5=12
6	J6	256	97	J5 and J6=6
7	J7	268	158	J6 and J7=32
8	J8	232	72	
9	J9	272	128	
10	J10a	220	67	
11	J10b	200	147	
12	J10c	38	138	
13	J10d	18	146	
14	J11	72	110	J10 and J11=166
15	J12	58	43	J11 and J12=12
16	J13	254	62	J12 and J13=21
17	J14	258	58	J13 and j14=26
18	J15	280	54	J14 and J15=43
19	J16	330	70	
20	J17	330	70	

Table 2. Contd.

Densilu				
1	J1	80	240	J1 and J2=29
2	J2	116	43	
3	J3	72	244	J2 and J3=82
4	J4	74	106	
5	J5	278	196	J4 and J5=20
6	J6	70	195	J5 and J6=51
7	J7	100	130	J6 and J7=28
8	J8	70	240	J7 and J8=45
9	J9	92	72	J8 and J9=70
10	J10	92	171	J9 and J10=29
11	J11	70	254	J10 and J11=21
12	J12	70	225	J11 and J12=33
13	J13	282	178	J12 and J13=49
14	J14	70	412	J13 and J14=17
15	J15	110	348	

Table 3. Apparent resistivity values derived for all the direction at Methodist Primary School.

Methodist	**Schlumberger**	**ARS**	**90°**	**135°**	**λ**
AB/2	**0°**	**45°**			
1	383.4979	398.3996	501.5924	507.6002	1.15
2	229.513	167.8856	206.2821	156.2826	1.21
3	103.7275	106.0301	97.4376	100.8634	1.04
4	74.3113	75.3128	84.82705	92.63875	1.12
6	77.84469	67.95965	66.05004	72.78984	1.09
9	89.56316	86.51852	75.35484	82.96644	1.09
12	103.8818	113.8183	93.04196	97.1069	1.11
15	118.6349	104.5117	103.8055	121.4595	1.08
20	153.5734	146.6782	141.6636	149.1855	1.04
25	191.1585	179.3949	174.4934	182.3358	1.05
32	250.7123	236.2481	221.7839	233.0339	1.06
40	319.0278	288.8835	273.8113	293.9075	1.08
50	387.0663	329.0847	354.1578	396.4687	1.10
65	459.9589	265.106	402.9611	498.3993	1.37
	Wenner				
1.5	351.2756	227.1666	46.36335	258.3352	2.75
3	122.9402	144.909	69.51361	97.86702	1.44
12	97.98013	86.01539	72.29114	92.34966	1.16
15	110.2842	97.96756	77.54456	99.35004	1.19
20	133.3884	128.1098	97.44389	133.3884	1.17
25	166.4213	164.3266	126.0989	169.8775	1.16
32	220.2584	211.6786	162.7472	217.175	1.16
40	283.8692	271.4688	200.0826	269.7931	1.19
50	350.4377	322.3692	226.4335	347.7147	1.24
65	433.5122	413.6338	241.8083	469.4567	1.39

Table 4. Apparent resistivity values derived for all the direction at Mini-Campus.

Mini-Campus AB/2	Schlumberger 0°	ARS 45°	90°	135°	λ
1	410.3563	345.9197	375.1341	412.7123	1.09
2	401.2828	338.1958	317.909	323.1044	1.12
3	320.9544	240.7018	230.9861	273.9485	1.18
4	227.8413	167.551	177.6661	201.3015	1.17
6	122.8515	90.78366	97.78439	105.011	1.16
9	99.20452	90.32432	75.86228	80.68296	1.14
12	119.6899	116.0766	90.332	98.01022	1.15
15	148.9998	140.5258	110.8671	118.6349	1.16
20	183.6612	173.6319	159.8417	171.7514	1.07
25	221.5478	219.5872	190.1782	198.0206	1.08
32	311.7832	308.569	223.3911	252.3194	1.18
40	406.9489	369.2684	256.2271	319.0278	1.26
50	360.4261	396.4687	319.6823	388.6334	1.11

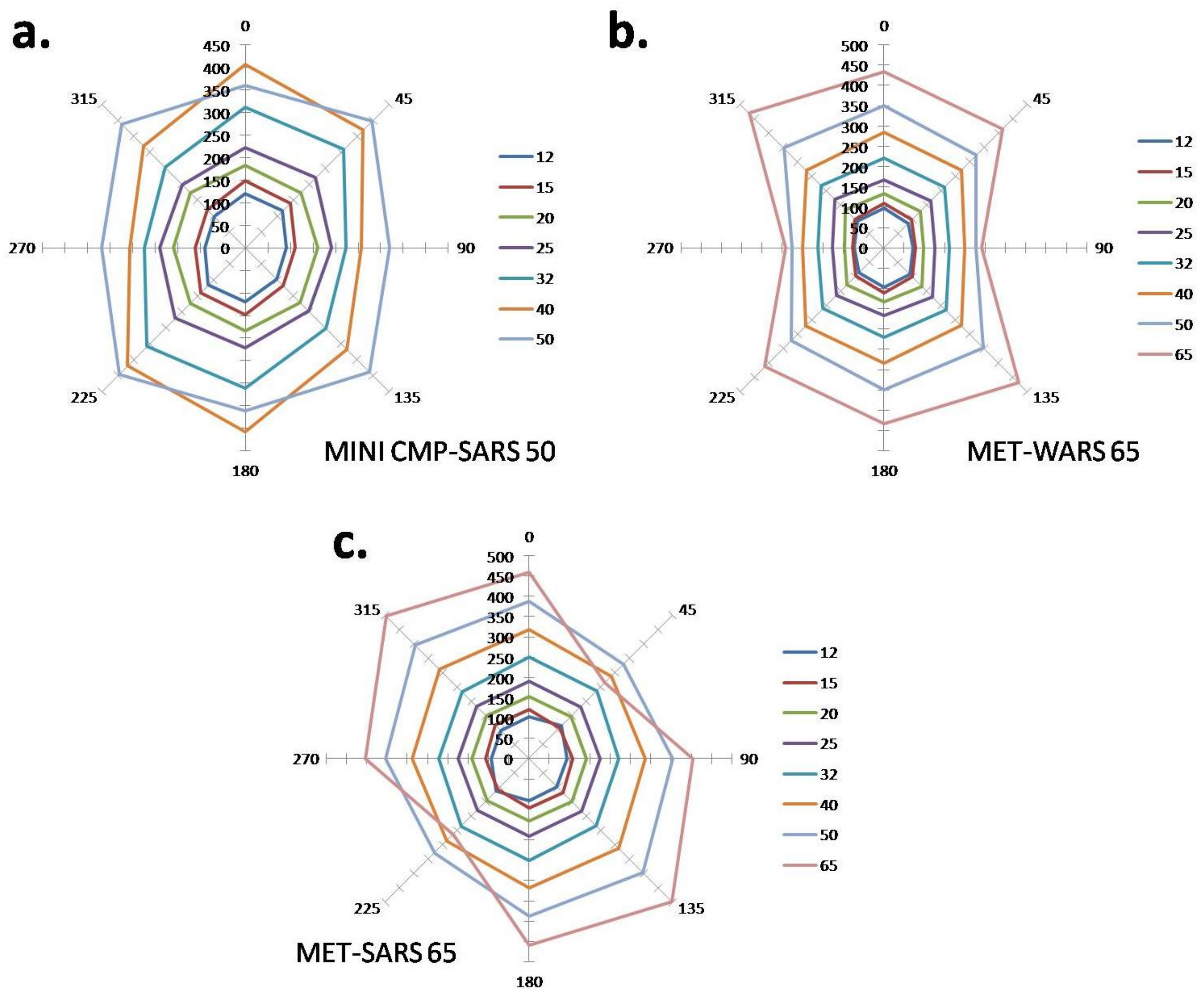

Figure 8. (a, b and c) Electrical resistivity anisotropy polygon for the two areas. At Methodist both Schlumberger and Wenner array configuration were used in order to check the sensitivity of each of the array layout to fracture in the subsurface.

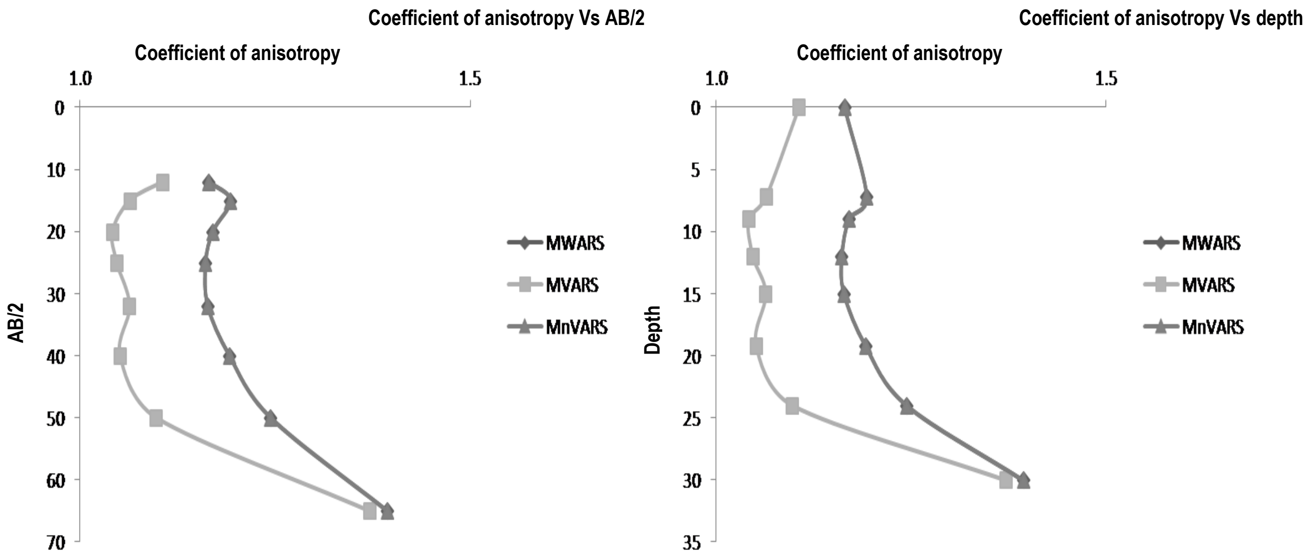

Figure 9. Plot of coefficients of anisotropy against AB/2 and depth for Mini-Campus and Methodist respectively.

similar technique in a basement complex environment.At Methodist, two different electrode configurations were used to compare results and test the sensitivity of the electrode configuration to the fracture detection using the Azimuthal technique, Wenner and Schlumberger electrode configurations. The anisotropy polygons for the two configurations are shown in Figure 8b and c.

The direction of electrical anisotropy is parallel to the direction of maximum apparent resistivity in the anisotropic figures (Habberjam, 1972). The strike direction of the fracture at Methodist were oriented NW-SE at depth of 39 m (AB/2=65 m) and N-S at 7.2 m (AB/2=12 m) while at Mini-campus the fracture was oriented NE-SW at depth of 30 m (AB/2=50 m). The result obtained for the two electrode configuration used at Methodist shows that the fracture occurs at the same depth, 39 and 7.2 m respectively.

The computed coefficient of anisotropy for the three investigation conducted varies between 1.04 to 1.37, 1.16 to 2.75, 1.07 to 1.26 for Methodist and Mini-campus respectively. From the plot of the coefficient of anisotropy with AB/2 (considered depth), (Figure 9) the degree of fracturing in Methodist opens with depth at one part and later became constant with depth at other part while that of Mini-campus is constant with depth.

Conclusion

Azimuthal apparent resistivity measurements are potentially powerful techniques for characterizing fractured rock since they measure parameters which cannot be obtained from traditional profile measurements. Azimuthal resistivity surveys and geologic field mapping conducted at Mini-campus of Olabisi Onabanjo University and Methodist Comprehensive High School, Ago-Iwoye was aimed at characterizing the subsurface geology and delineating the orientation of fractures in the study area. Fracture parameters obtained from field measurements include, fracture orientation, coefficient of anisotropy, and mean resistivity of rock layers. These parameters are useful in making preliminary inference on the degree of fracturing and permeability of the rock mass.

The following conclusions were deduced from this study:

(1) The surface rocks of the area belong to the migmatized gneiss complex of the basement complex of Nigeria.
(2) Fractures (joints) in the rock exposure are oriented dominantly ENE-WSW, E-W, and WNW-ESE.
(3) They are produced by NNW-SSE, N-S and NNE-SSW oriented tectonic forces. Some of these forces are been regionally identified from analysis of lineament and joints in the study area (Omosanya et al., 2012).
(4) The 2D resistivity revealed four (4) geo-electric layers with alternation between sand and clayey layer above the basement rock at both locations.
(5) The bedrock at both point are the subsurface expression of the foliated gneiss mapped at the surface.
(6) The Azimuthal resistivity survey revealed significant anisotropy between 30 to 65 m at subsurface depth with NW-SE, N-S and NE-SW oriented fracture at depths of 39 and 30 m at Methodist and Mini-Campus respectively.
(7) Coefficient of anisotropy shows that the degree of fracturing delineated at the study area investigated, were constant and opening with the depth at Methodist, and opening and closed, and constant at Mini-campus.
(8) Lack of overlap between fracture orientations at both surface and subsurface suggests that the surface

fractures were not deep seated, and that fractures at both scales were thought to be produced by different tectonic events.
(9) The fracture patterns recorded in the rocks have been previously observed in similar lithologies (Omosanya et al., 2012)

Characterizing the orientations of fracture is an important study needed in evaluating the permeability and porosity of rock mass at macroscopic and microscopic scale, as they are indicator of possible earthquake occurrence, migration of oil and gas, distribution of ore deposit for the miners, and important consideration for construction works close to quarries. The study of fractures is recommended for every geological study, this kind of study is relatively new in the study area and region, it has provided the impetus to investigate further subsurface structures and geology using ARS and ERT in the entire region, and also the need to acquire such knowledge for construction works. Furthermore, it supplements the work of Omosanya et al. (2012) which integrated the study of lineaments and fractures from outcrop and satellite imageries, elucidating that geologic structure can be studied on all scales, from subsurface, outcrop to regional satellite maps.

ACKNOWLEDGEMENTS

Department of Earth Sciences, Olabisi Onabanjo University, Loke M.H for writing the RES2INV software and making it available for academic use. Kamal' is grateful to the Department of Geophysics, University of Witwatersrand, South Africa for the training on acquiring and interpreting geophysical methods during the Africaaray Field School in 2011.. Muyideen Lawal, Sofade Aduragbemi, Ayodele Moyosore, Kuye Rasheedat, Bunmi Oremade, Bukky Oshiloye, Makinde Jamiu and Mrs H.O Omosanya for the proof read of the initial draft of the Manuscript.

REFERENCES

Akintola JO (1986). Rainfall Distribution in Nigeria 1982-1983, Impact Publishers Nigeria Limited, Ibadan, Nigeria, p. 371.
Boadu FK, Gyamfi J, Owusu E (2005). Determining subsurface fracture characteristics from azimuthal resistivity survey: A case study at Nsawam, Ghana. Geophysics, 70: 35-42.
Carlson DA, Taylor RW, Cherkauer DS (1996a). Azimuthal Resistivity as a Tool for Determination of the Orientation of Preferred Hydraulic Transmissivity for a Dolomite Aquifer in Southwestern Wisconsin: SAGEEP 1996 Conference, Environ. Eng. Geophys. Soc. Proc., pp. 1085-1094.
Carlson DA, Taylor RW, Cherkauer DS (1996b). Use of Azimuthal Electrical Resistivity Method Used for Determining Joint Orientations in Glacial Tills Around Milwaukee, Wisconsin: SAGEEP 1996 Conference, Environ. Eng. Geophys. Soc. Proc., pp. 51-59.
Chapman MJ, Lane JW (1996). Use of directional borehole radar and azimuthal square-array D.C. resistivity methods to characterize a crystalline-bedrock aquifer: SAGEEP 1996 Conference, Environ. Eng. Geophys. Soc. Proc., pp. 833-842.
Dada SS, Birck JL, Lancelot JR, Rahaman MA (1993). Archaean migmatite-gneiss complex of North Central Nigeria: Its geochemistry, petrogenesis and crustal evolution. Int. Colloguiom Afr. Geol., Mbabane Swaziland, 1: 97-102.
deGroot-Hedlin C, Constable S (1990). Occam's inversion to generate smooth, two-dimensional models from magnetotelluric data. Geophysics, 55: 1613–1624.
Dey A, Morrison H (1979). Resistivity modelling for arbitrarily shaped two-dimensional structures. Geophys. Prospecting, 27: 106–136.
Ehirim CN, Essien EE (2009). Comparative investigation of offset wenner, square and schlumberger arrays in electrical anisotropy studies, Sci. Afr., 8(2): 53-60.
Habberjam GM (1972). The effects of anisotropy on square array resistivity measurements. Geophysical prospecting., 20:249-266
Hagrey SA (1994). Electric study of fracture anisotropy at Falkenberg, Germany; Geophysics, 59: 881-888.
Hansen BP, Lane JW (1996). Orientation and Characteristics Of Fractures In Crystalline Bedrock Determined By Surface And Borehole Geophysical Surveys, Millville and Uxbridge, Massachusetts: SAGEEP 1996 Conference, Environ. Eng. Geophys. Soc. Proc., pp. 927-940.
Lane JW, Haeni FP, Soloyanis S, Placzek G, Williams JH, Johnson CD, Muursink ML, Joesten PK, Knutson KD (1996). Geophysical Characterization of a Fractured-Bedrock Aquifer and Blast-Fractured Contaminant-Recovery Trench: SAGEEP 1996 Conference, Environ. Eng. Geophys. Soc. Proc., pp. 429-441.
Lane JW Jr, Haeni FP, Waston WM (1995). Use of a Square-Array Direct-Current Resistivity Method to detect Fractures in Crystalline Bedrock in New Hampshire. Ground Water, 33(3): 476-485.
Leonard J, Mayer J (1984). A Surface resistivity method for measuring hydrologic characteristics of jointed formations, U.S. Bur. Mines Report of Investigations 8901.
Loke MH, Barker RD (1996). Practical techniques for 3D resistivity surveys and data inversion. Geophys. Prospect, 44: 499-523.
Mallik SB, Bhattacharya DC, Nag SK (1983). Behavior of Fractures in Hard Rocks-a Study by surface geology and radial VES method. Geoexploration, 21(3): 181-189.
Omosanya KO, Akimosin AA, Adio NA, Omosanya HO, Akinbodewa AE, Lawal MA (2011): A Simple 3D Visualisation Of Joints In A Migmatized Gneiss, Ago-Iwoye NE, SW Nigeria.- Int. J. Emerg. Sci., 1(3): 418-432.
Omosanya KO, Mosuro GO, Akinbodewa AE (2012). Integrated Mapping of Lineaments in Ago-Iwoye, SE, SW, Nigeria. United Kingdom. Int. J. Sci. Technol., 1(2): 68-79.
Oyawoye MO (1972). The Basement Complex of Nigeria. African Geology. Geology of Africa T.F.J Dessauvagie and A.J. Whiteman (Eds.). University Ibadan: Ibadan, Nigeria, pp. 67-99.
Rahaman MA (1981). Recent Advances in the Study of the Basement Complex of Nigeria. First Symposium on the Precambrian Geology of Nigeria, Summary.
Ritzi RW, Andolsek RH (1992). Relation between anisotropic transmissivity and azimuthal resistivity surveys in shallow fractured carbonate flow systems, Groundwater, 30: 774-780.
Sasaki Y (1992). Resolution of resistivity tomography inferred from numerical simulation. Geophy. Prospecting, 40: 453–464.
Skjernaa L, Jorgensen NO (1993). Evaluation of Local Fracture Systems by Azimuthal Resistivity Surveys. Examples from south Norway. Int. J. Appl. Hydrogeol., 2: 19-25.
Taylor RW, Flemming AH (1988). Characterizing Jointed Systems by Azimuthal Resistivity Survey. Ground water, 26: 464-474.