FUOYE Journal of Pure and Applied Sciences

Available online at www.fuoye.edu.ng

AN APPRAISAL OF THE GEOLOGIC SETTING IN THE BASEMENT COMPLEX TERRAIN AROUND MALETE, SOUTHWESTERN NIGERIA: IMPLICATIONS ON GROUNDWATER OCCURRENCE

Ajadi Jimoh, Adeyemi Sultan Faruq, Olasunkanmi K. Nurudeen, Babalola Olufemi
Department of Chemical, Geological and Physical Sciences
Kwara State University, Malete. PMB 1530, Ilorin Nigeria

ARTICLE INFO

Received: 01 April, 2018
Accepted: 03 December, 2018

Keywords:
lithologic geometry, geoelectric sequence, tectonic imprints, overburden, groundwater

Corresponding author:
jimoh.ajadi@kwasu.edu.ng

Abstract

In an attempt to update the geologic setting and investigate groundwater resources of Malete in Moro Local Government area of Kwara State, reconnaissance geological mapping and electrical resistivity geophysical field mapping were carried out. The lateral lithologic geometry and geologic features were established on the outcrops while the vertical extents were interpreted from resistivity sounding that involved Schlumberger electrode configuration. The lithologic units formally reported by Nigeria Geological Survey Agency as comprising migmatitic gneiss and porphyritic granite, were updated as including massive and foliated quartzites, porphyroblastic gneiss, biotite granite and other minor intrusives viz; pegmatites, aplites, and vein quartz. The granitic rocks discordantly intrude the migmatites and quartzites and mostly appear to have been caught up by tectonism at the waning stage of the Pan African orogeny as evident from the observed tectonic imprints not uncommon with the Nigerian older granite suites. Occurrences of intermittent pelitic bands observed to be alternating with large blocks of massive quartzitic layers suggest a sedimentary precursor for the quartzite bodies in the area. The resistivity variation ranged between 13.6 and 7740.4 Ωm and four-layer earth models which comprised sand/lateritic topsoil, clayey sand, weathered basement and fresh/fractured basement were identified. The models revealed KH, HK, HA and AK types apparent resistivity curves with overburden thickness range between 0.2 and 9.6 m. The HK-type with geoelectric sequence of resistive–conductive–resistive–conductive, within quartzitic layer and thick overburden exhibit good aquifer characteristic and depict probable point for groundwater in the area.

1.0 Introduction

Soils are result of natural intense weathering of rocks. Soils can be systematic mixture of several grain sizes of minerals (sand, silt, clay) and organic matter ranging in thickness and compactness. They also serve as conduit for groundwater and load of overlying structures which influences groundwater exploration and construction of man-made structures. Malete can be regarded as sub-urban area of Nigeria, where dwellers lack access to pipe-borne water supply as a result of failure on the part of government to provide reliable water supply from the surface water scheme. The inhabitants therefore rely on shallow hand-dug wells within variably low yield and susceptibility to pollution. With influx of students and staffs of Kwara State University (KWASU),the population has significantly increased and deeper source of water is strongly anticipated, preferably through drilled wells or boreholes. Hence the need to investigate the occurrence, facies and hydrogeologic systems of the aquifer units of groundwater in the area becomes essential [1].The area is underlain by crystalline rock (figure 1) which possesses little or no primary intergranular

porosity and permeability and thus the occurrence of groundwater is due largely to the development of secondary porosity and permeability by weathering and/or fracturing of the parent rocks [2] [3] [4] [5] [6].Available published work on Malete area is relatively scanty. The earliest available record was the geology of Ilorin area, sheet 50 [7]. The study area is underlain by rocks that are typical of the basement complex of Nigeria, some of which show tectonic imprints that are indicative of the various degree of deformation they have suffered. The lithological characteristics of Malete area is succinctly described in this work (figure 3) while a comprehensive study of rocks and associated structural imprints of Alagbede area, including the present study area around Malete can be found in previous work by the author [8]. In an attempt to establish geoelectric sequence of Malete, available records on previous works were consulted. While some of the reports are on engineering foundation studies, few are targeted at groundwater investigation. An integrated geological and geophysical investigation using Electrical Resistivity and insitu and laboratory soil stability analysis was carried out to determine the lithologic settings, competency and bearing capacity of the rocks beneath selected engineering structure sites within Kwara State University, Malete [9]. This was complemented with a comprehensive survey on the entire Institution [10]. An integrated of evaluation of the groundwater potential zones using electrical resistivity method and GIS modelling tool, over about forty (40) villages (including Malete) within four Local Government Areas of Kwara State was also carried out [11] [12]. The study area is bounded by latitudes $8^{o}40'$N to $8^{o}45'$N and longitudes $4^{o}25'$E to $4^{o}30'$E, covering an area of about 10 square kilometers. The area is characterized by flat to rolling peneplains dotted by isolated low to undulating ridges and hills which correspond to areas of granitic and quartzitic outcrops, interspersed by the guinea savannah-type vegetation. In this study, geologic and geophysical survey involving field mapping and electrical resistivity method has been employed to delineate lithologic units, weathering, fissure and/or fractures within the bedrock of selected part of Malete.

2.0 Methodology

2.1 Geological Mapping

The geologic mapping involved physical/visual rock identification and laboratory analysis of rock samples. The outcrops in the area were accessed through footpaths and minor roads while traverses were established through bushes with the aid of compass clinometers and Garmin etrex 10 Global Positioning System (GPS). The lithologic description, coordinates, trend, strike and dip of planar surfaces were recorded (Table 1) while fresh samples were taken for further petrographic analysis. Thin sections of the samples were prepared and were examined under petrological microscope in terms of the minerals' optical properties such as lustre, relief, colour, cleavage, micro fracturesetc., to identify mineral composition and assemblages under a plane polarized light (PPL) and crossed polarised light (XPL). The results from the petrographic studies were used for the determination of modal composition to characterise the underlying rocks in the study area in terms of the lithological types, metamorphism and imprints of the thermotectonic deformation the rocks have suffered since emplacement.

2.2 Geophysical Mapping

Earth resistivity meter was used to measure the apparent resistivity of the subsurface soil at four selected points in the study area, on a pre-determined grid system. It involves the Schlumberger four electrode probe system, where the electrodes were driven into the ground (at AB spacing) and used as medium to transfer current (I) into the subsurface while the resulting potential differences

(V) were measured through the potential electrodes at MN spacing range of 1 – 350 m. The apparent resistivity (ρ_a) values were obtained by multiplying the resistance with equivalent geometric factors G_s (Equation 1) which is converted to apparent resistivity for different rock units vertically.

$$\rho_a = G_s \cdot \frac{\Delta V}{I} \qquad (1)$$

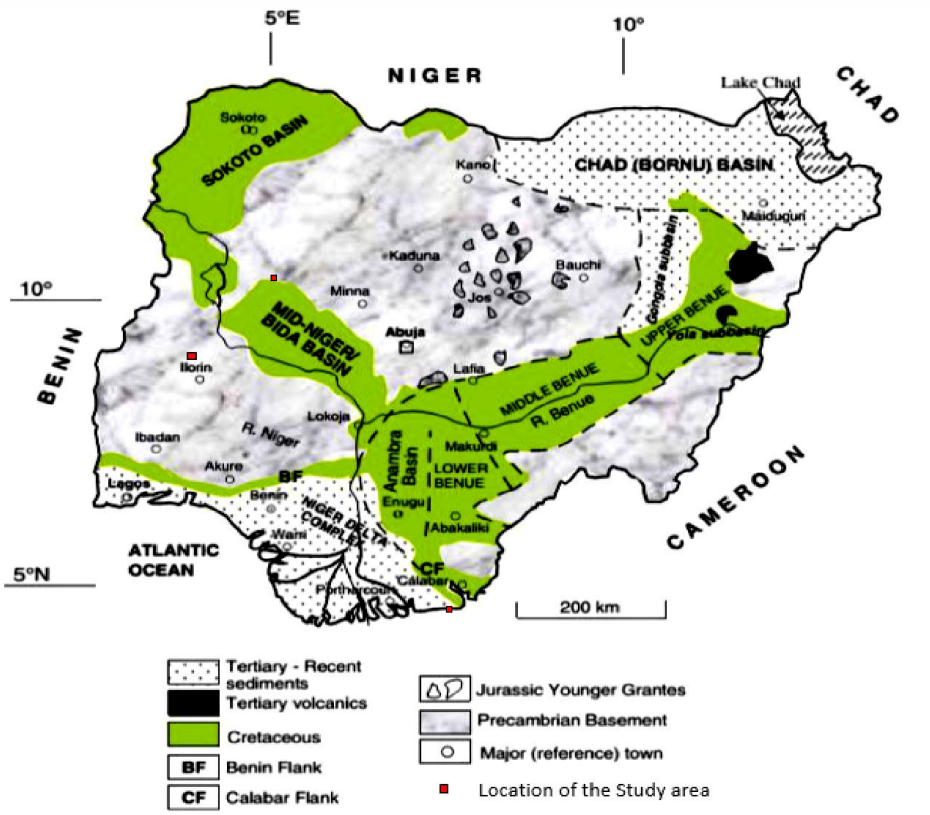


Figure 1: Geological map of Nigeria showing the study area (Adapted from [13]).

Sounding curve for each point was obtained by plotting the apparent resistivity on the ordinate against half current-electrode spacing (AB/2) on a bi-logarithmic transparent paper. Parameters such as apparent resistivity and thickness obtained from manual curve matching were used as input data for computer iterative modelling using the IPI2win software.

Table.1: Locations of rock outcrops

SN	Rock Type	Location Coordinates
1	Migmatite	N08^{0}43$^{'}$06.1'' E004^{O}29$^{'}$10.5''
2	Migmatite	N08^{0}43$^{'}$03.4$^{''}$, E004^{0}29$^{'}$11.7$^{''}$
3	Migmatite	N08^{0}43$^{'}$04.4$^{''}$, E004^{0}29$^{'}$07.2$^{''}$
4	Migmatite	N08^{0}43$^{'}$06.2$^{''}$, E004^{0}29$^{'}$16.2$^{''}$
5	Migmatite	N08^{0}42$^{'}$53.8$^{''}$, E004^{0}29$^{'}$49.3$^{''}$
6	Migmatite	N08^{0}42$^{'}$53.3$^{''}$, E004^{0}30$^{'}$18.9$^{''}$
7	Migmatite	N08^{0}42$^{'}$01.9$^{''}$, E004^{0}29$^{'}$55.3$^{''}$
8	Quartzite	N08^{0}41$^{'}$44.8$^{''}$, E004^{0}29$^{'}$42.2$^{''}$
9	Quartzite	N08^{0}42$^{'}$02.7$^{''}$, E004^{0}29$^{'}$13.3$^{''}$
10	Granite	N08^{0}42$^{'}$08.6$^{''}$, E004^{0}29$^{'}$15.3$^{''}$
11	Quartzite	N08^{0}40$^{'}$00.8$^{''}$, E004^{0}29$^{'}$22.9$^{''}$
12	Quartzite	N08^{0}42$^{'}$38.9$^{''}$, E004^{0}27$^{'}$24.7$^{''}$
13	Biotite Granite	N08^{0}43$^{'}$13.2$^{''}$, E004^{0}27$^{'}$39.1$^{''}$
14	Quartzite	N08^{0}43$^{'}$42.1$^{''}$, E004^{0}28$^{'}$28.9$^{''}$

3.0 Results and discussion

3.1 Lithological Description

Rocks of the study area bears the imprints of the major geologic events corresponding to the Liberian, Eburnean and Pan African of round 2500 Ma, 2000 Ma, and 500 Ma respectively which are associated with the formation of the migmatites, quartzite and Pan African granites (figure 3). Migmatites, which forms the country rock in the study area constitutes the oldest rock on which the ancient sediments were unconformably overlain and subsequently metamorphosed to form quartzite in the early- to mid-Proterozoic [14] [15]. Most quartzitic outcrops had been weathered due to high susceptibility to weathering and are mostly mapped as in-situ quartzite rubbles and boulders exposed generally along N-S rending narrow bands.

Migmatite – The field inter-relationship between the neosome in the migmatite, usually leucosomes and the pre-existing paleosome gave rise to a number of migmatite bearing the imprints of the various thermotectonic events suffered by the rocks during which the leucosomes are usually melted and remobilized into weak zones or perhaps existing foliation or faults within the paleosome (protolith) (figure 4). The deformation fabrics in the migmatite show a general NE-SW trends and constitute the background rock within which other younger rocks were unconformably emplaced. Some of the lithological components mapped within the migmatitic outcrops include porphyroblastic diorite, porphyritic granite, granite gneiss, biotite granite, pegmatitic and quartz-feldspathic veins as well as cognate bodies mostly composed of residues of refractory minerals left behind after partial melting and fractional crystallization.

Quartzite – The metasedimentary rock, consisting of bands of psammitic strata alternating with relatively thinner pelitic bands, conspicuously shows the imprints of the tectonic compression it had suffered during thermotectonic orogeny the study area had been subjected to, as manifested in form of ductile shears and folds as well as brittle fractures. Most quartzitic outcrops in the study area were mapped as boulders (figure 5) and rubbles, exhibiting

various shades of yellowish to reddish brown due to varying amounts of iron oxide (Fe_2O_3). The individual quartz grains observed in the quartzite recrystallized along with the former cementing material to form an interlocking mosaic of quartz crystals in which virtually all of the original sedimentary textures and structures of the source material have been obliterated by the metamorphism and recrystallization. In some places, minor amounts of the initial cementing materials such as iron oxide, silica, carbonate and clay are often remobilized during recrystallization and metamorphism, forming streaks and lenses within the quartzite with a north-south trending foliation planes ranging from 020^o to 030^o and dips ranging from 35^o to 72^o either easterly or westerly.

Biotite Granite – The medium grained biotite granite outcrops mostly as low lying hills and hills characterized by sub rounded in situ boulders of up to 1.2m in sizes. In terms of mineralogical composition, the rock predominantly possesses large grains of quartz, microcline, biotite, muscovite and plagioclase feldspars, giving it a general leucocratic appearance.

Porphyritic Alkali Granite – The porphyritic granite is rich in alkali feldspar and composed of large platy phenocrysts of feldspar embedded within a matrix of quartz, feldspar, biotite and hornblende. The rock shows slight deformation with fractures healed with quartz and biotite and mostly underlain the western part of the study area. The hydrological yield from a hand-dug well shows that the rock serves as a good aquifer, but the ground water is contaminated with clay minerals and ions derived from chemical weathering of feldspar in the parent surrounding rock. The preponderance of the feldspar phenocrysts gave the rock its leucocratic colour.

Fine-grained Alkali Granite – Alkali granite was mapped as small fracture-filling intrusions within the porphyritic granite and also as a dug-out from a 9m deep hand-dug well. The well is about 9 meters beneath the ground surface. The hand specimen from the dug-out display some fabrics which suggest that the might be occupying a narrow band of shear zone associated with high deformation with joints healed with quartz and biotite.

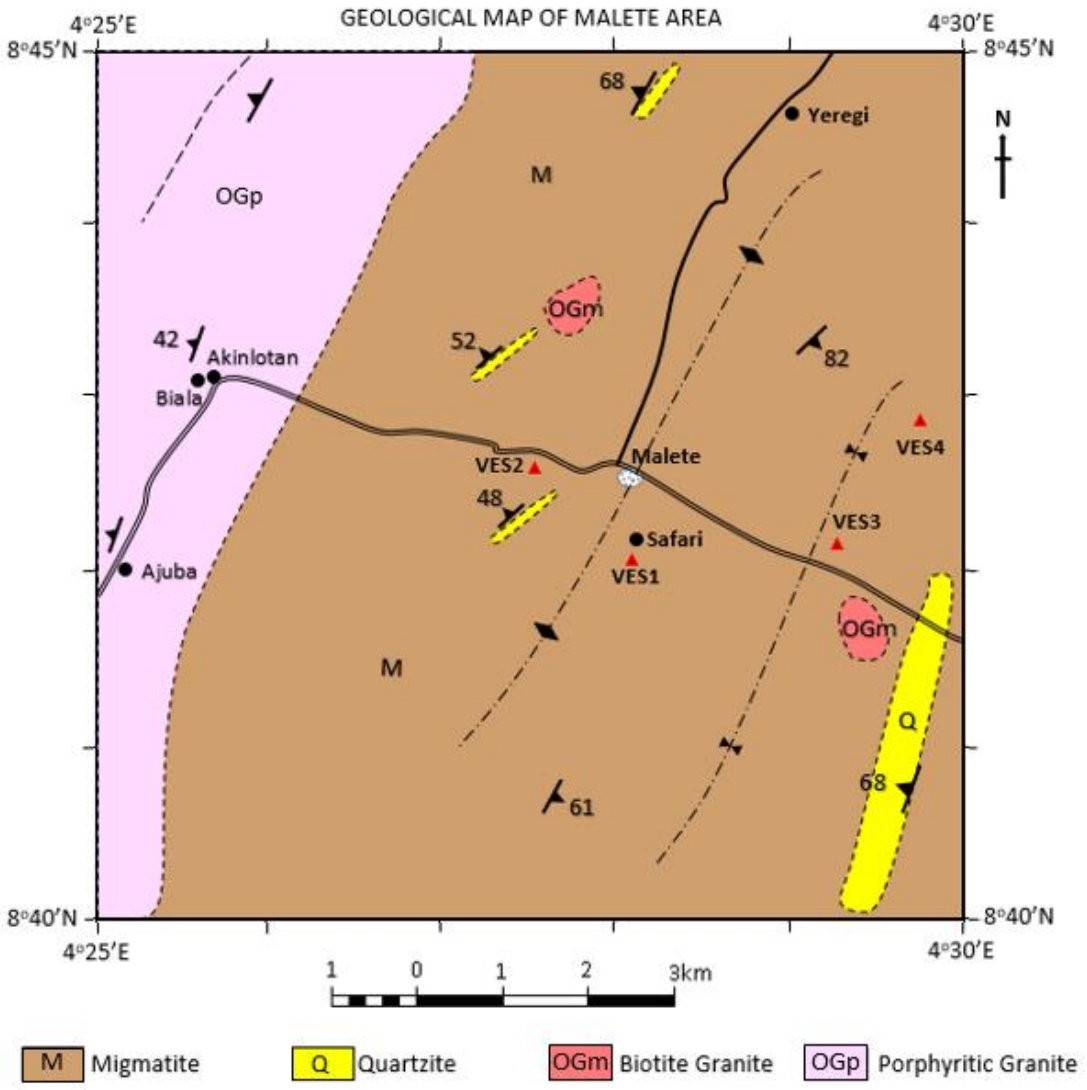


Figure 3: Geological map of the study area showing lithological distributions

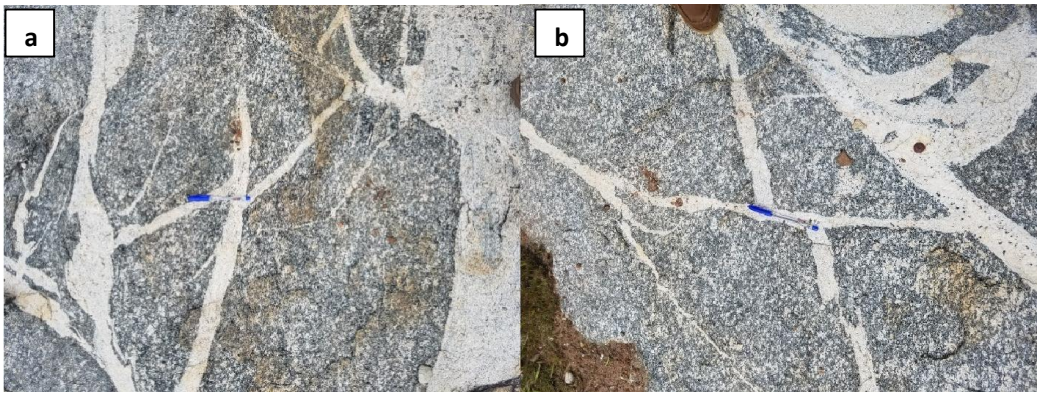


Figure 4: Outcrop of migmatite showing the neosome (leucocratic minerals) in healed faults with (a) dextral displacement of 6 cm (b) sinistral displacement of 9cm.



Figure 5: Bouldery outcrop of quartzite showing parallel joint sets.

3.2 Geoelectric Characteristics

Hydrogeologic significance of each resistivity and depth range of probable lithologic layers are depicted in Tables 2, 3, 4 and 5. Resistivity variations for different lithologic settings at depths are presented with apparent resistivity curves in Figures 6, 7, 8 and 9. The curves majorly revealed four-layer earth models namely; KH, HK, HA and AK types. The KH-type (VES 1) is characterised by conductive-resistive-conductive–resistive geoelectrical signature with resistivity range from 20.7 to 1069 Ωm. Overburden at this point consist of topsoil, lateritic clay/sand and weathered layer with estimated thickness of 1.3, 1.2 and 7.1 m respectively. The weathered layer could make an aquifer with very low potential. The HK-type (VES 2) is characterised by *resistive-conductive–resistive-conductive* geoelectrical signature with resistivity range from 13.6 to 1988.4 Ωm. The fractured basement (quartzite) is overlain by topsoil and saturated clayey sand at this VES point and its overburden thickness is estimated as 8.72 m. The fractured basement is significant to development of secondary porosity and permeability that transforms to good aquifer. The HA-type (VES 3) is characterised by *resistive-conductive–resistive-resistive* geoelectrical signature with resistivity range within 61.3 to 1143 Ωm. The AK-type (VES 4) also have resistivity variation within 462.05 and 40847.6 Ωm. This is a typical hard rock terrain curve, showing fresh basement at shallow depth and fracture bedrock at deeper depth; which is favourable for good groundwater exploration.

Table 2: Resistivity and depth distribution range, probable lithologies settings and hydrogeology characteristics of KH-earth model resistivity curve over Quartzite terrain at Malete.

Layer	Resistivity Range (Ωm)	Thickness range (m)	Probable lithology	Hydrogeologic Significance
1	381	1.3	topsoil	-
2	1069	1.2	lateritic clay/sand	Poor aquifer
3	20.7	7.06	Weathered layer	Very low potential
4	794	--	Fresh bedrock	Poor Aquifer

Table 3: Resistivity and depth distribution range, probable lithologies settings and hydrogeology characteristics of HK-earth model resistivity curve over Quartzite terrain at Malete.

Layer	Resistivity Range (Ωm)	Thickness range (m)	Probable lithology	Hydrogeologic Significance
1	465.5	3.94	Topsoil	-
2	13.6	4.70	weathered layer	Very low potential
3	1988.4	26.54	fresh basement	poor aquifer
4	160.8	--	Fractured basement	Good aquifer

Table 4: Resistivity and depth distribution range, probable lithologies settings and hydrogeology characteristics of HA-earth model resistivity curve over Granitic terrain at Malete.

Layer	Resistivity Range (Ωm)	Thickness range (m)	Probable lithology	Hydrogeologic Significance
1	1143	1.38	Topsoil	-
2	61.3	3.61	sandy clay	Poor aquifer
3	334.6	28.72	weathered basement	Fairly good
4	759.5	-	fresh basement	Poor aquifer

Table 5: Resistivity and depth distribution range, probable lithologies settings and hydrogeology characteristics of AK-earth model resistivity curve over Migmatitic terrain at Malete.

Layer	Resistivity Range (Ωm)	Thickness range (m)	Probable lithology	Hydrogeologic Significance
1	462.05	0.18	Lateritic hard pan	-
2	5870.7	28.70	Fresh basement	Poor aquifer
3	40847.6	24.95	Fresh basement	poor aquifer
4	7740	-	Fractured bedrock	Good aquifer

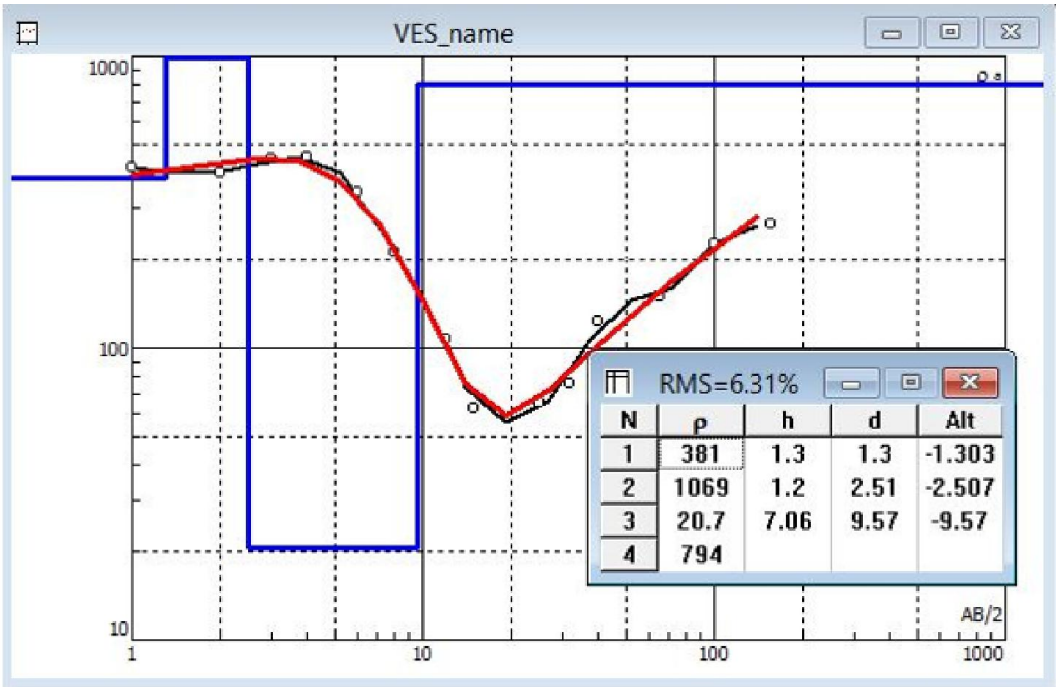


Figure 6: Apparent resistivity curve of KH-type for VES 1

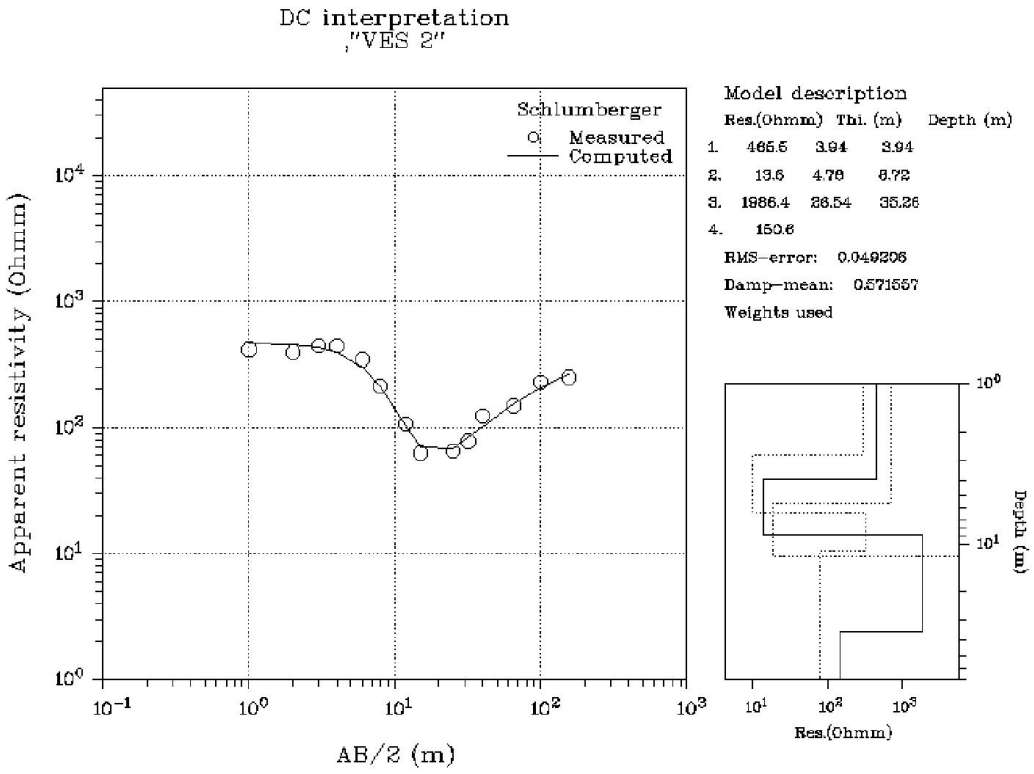


Figure 7: Apparent resistivity curve of HK-type for VES 2

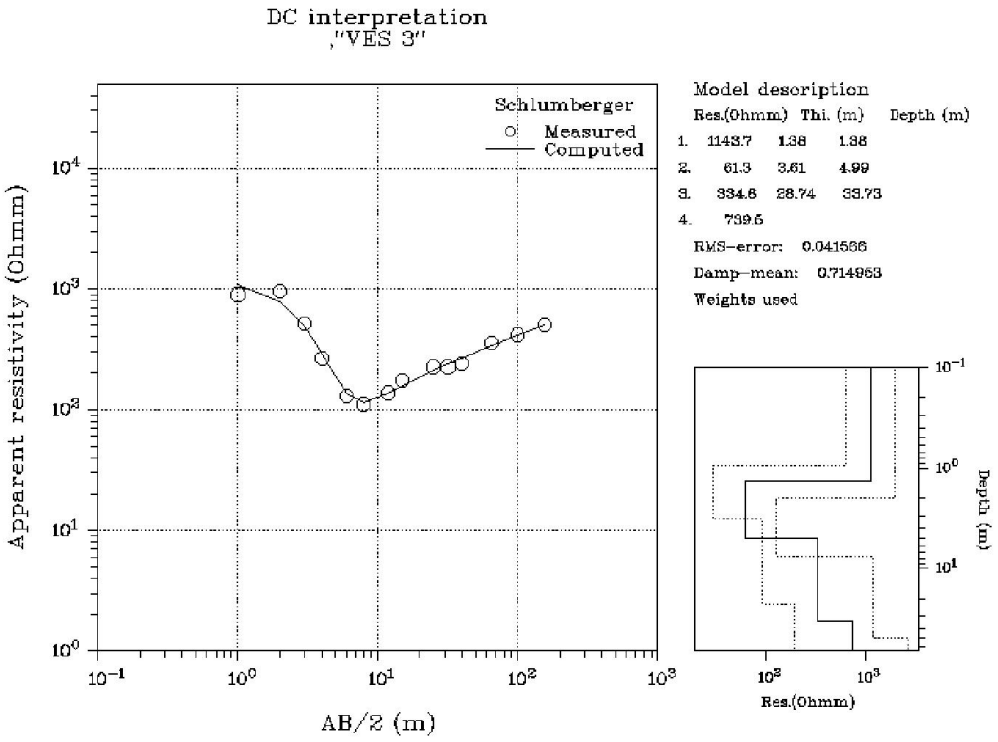


Figure 8: Apparent resistivity curve of HA-type for VES 3

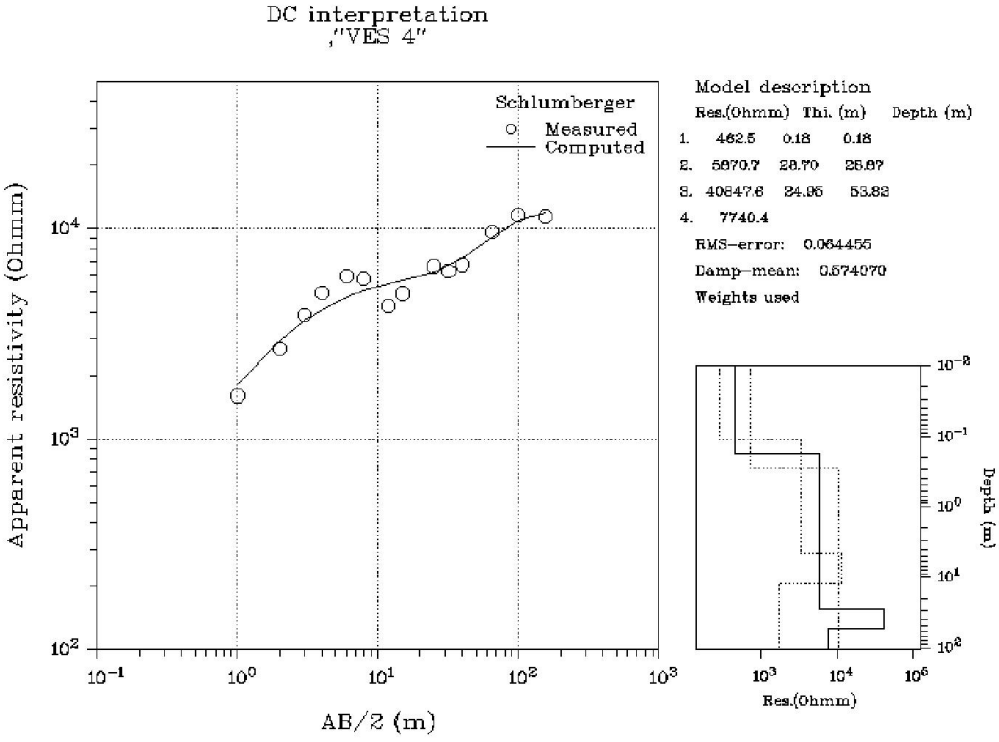


Figure 9: Apparent resistivity curve of AK-type for VES 4

Field evidence shows that Malete area is underlain by migmatite, quartzite, biotite granite, alkali granite, porphyritic granite and quartzo-feldspatic as well as quartzitic intrusions. Both the paleosome in the migmatite and the quartzite appeared to have suffered more intensive regional metamorphism and deformation as depicted in the severity of their thermotectonic fabrics. The quartzite consist of bands of psammitic strata alternating with relatively thinner pelitic bands, suggesting that the quartzitic rock possibly evolved from sedimentary source of quartz feldspathic arenite precursor. Vertical electrical sounding revealed that the quartzite terrain possesses more overburden and constitute a good hydrological province. However, areas underlain by Pan African granitic plutons makes a poor hydrological section despite the fact they hold much of the groundwater occurrence in fractures. Three dimensional gravimetric survey can be used to map out the position of the granitic plutons to avoid exploiting groundwater from a point vulnerable to this negative factor. The regional water table tends to vary with seasons. Apparently the water table is within the range of 6 to 8 meters during wet season and increases drastically during the dry season to a remarkable extent of dry relatively shallow wells. The resistivity data from the migmatite terrain showed that the probability of encountering water within the terrain is relatively low. However, the probability might increase with increasing depth within the lithosphere because the possibility of encountering interconnected fractures or fault which may host water increases.

4.0 Conclusion

The reconnaissance geological mapping led to the production of a detailed geological map of Malete area which shows that the study area is underlain by migmatitic gneiss, quartzite, biotite granite, porphyritic granite and alkali granite. Geological and geophysical evidence suggest a correlation between the lithologies and their hydrogeological potentials. Geophysical investigation showed that the quartzite is more susceptible to weathering. Occurrence of intensely weathered horizon is therefore thicker on the quartzitic terrain and least on the porphyritic granite. Areas overlying the quartzite are therefore excellent for exploitation of sand while regions straddled with weathered or fractured bedrock are prospect for groundwater exploration.

Acknowledgement

The success of this research wouldn't have been possible without the undergraduate research grant courtesy the Centre for Undergraduate Research of the Kwara State University, Malete, Nigeria for which the authors are most grateful.

References

[1] Silas Dada and Jimoh Ajadi (2018). Exploiting Kwara State Mineral Resources for Economic Sustainability. In Kwara @ 50: Achievements and Aspirations by Fifty-Fifty Institute Ltd. pp 123-137.

[2] Acworth R. I (1987). The development of cry stalline basement aquifers in a tropical environment. EngGeol 20: pp 265-272.

[3] Adabanija, M. A., Afolabi, A. O., Olatunbosun, A. T. and Kolawole L. L. (2015). Integrated approach to investigation of occurrence and quality of groundwater in Ogbomoso North, Southwestern Nigeria. Environ Earth Sci. 73: pp 139-162.

[4] Olayinka A. I, Akpan E. J, Magbagbeola O. A. (1997). Geoelectric sounding for estimating aquifer potential in the crystalline basement area around Saki, southwestern Nigeria. Water Resour J 8(1 & 2): pp 71-81.

[5] Olorunfemi M. O, Fasuyi S. A. (1993). Aquifer types and the geoelectrical/hydrogeologic characteristics of part of the central basement terrain of Nigeria. J Afr Earth Sci 16: pp 309-317.

[6] Palacky, G.J., (1989). Resistivity Characteristics of Geologic Targets. In: Babighion, M.N. (Ed.), Electromagnetic methods in Applied Geophysics, Vol. 1 (Theory) IG, No.3 (Society of Exploration Geophysicist), pp 53-129.

[7] Oluyide, P.O., Nwajide, C.S. and Oni, A.O. (1998). The Geology of Ilorin Area: Explanation of the 1:250,000 series, sheet 50 (Ilorin). Geological Survey of Nigeria bulletin 42, pp 1-84.

[8] Ajadi, J., Dada, S. S., Nnabo, P. N. and Owoeye, B. A. (2018). Lithostructural description and metallogeny of Alagbede gold deposit, West Central Nigeria. Journal of Environment and Earth Science, Vol. 8, (5), pp 115-132.

[9] Awojobi, M. O., Owoyemi O. (2015). Report of engineering foundation investigation at selected locations within Kwara State University (KWASU), Malete. Submitted to TETFund, through Institutional Based Research.

[10] Olasunkanmi, N. K., Lawal S. K., Awojobi, M. O., Aina A., Suleman K. O and Owolabi D.T (2018). Integrated geophysical approach to building foundation studies within Kwara State University, Southwestern, Nigeria. In Press, Nigeria Journal of Physics.

[11] Bawallah M.A, Adebayo A, Ilugbo S.O., Olufemi B., Alagbe O.A., Olasunkanmi K.N, (2018a). Evaluation of Groundwater Prospect in a Clay Dominated Environment of Central Kwara State, Southwestern Nigeria. *International Journal of Advanced Engineering Research and Science (IJAERS) Vol-5, Issue-6,* https://dx.doi.org/10.22161/ijaers.5.6.8

[12] Bawallah M.A., Aina A.O., Ilugbo S.O., Olufemi B. , Olasunkanmi K.N., Olaogun S.O, Ajayi-Gidi I.O. (2018b). Modeling of groundwater potential using GIS and multi-criteria decision analysis around Kwara State, Southwestern Nigeria. *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) Vol. 6, Issue 3, pp* 58-67. DOI: 10.9790/0990-0603025867.

[13] Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria, Lecture Notes in Earth Sciences 120, (DOI 10.1007/978-3-540-92685-61), C. Springer-Verlag Berlin Heidelberg.

[14] PaulinausNnabo and Jimoh Ajadi (2017). Surface water contamination by heavy metals from Enyigba Pb-Zn mine district, southeastern Nigeria using metal enrichment and pollution indices. Science & Technology, 3 (11), pp 146-157.

[15] Ajadi, J. and Yakubu, S. (2017). Preliminary Studies of the Litho-Structural Evolution of areas around Obudu Northeast, Sheet 291, Southeastern Nigeria. International Journal of Research in Engineering and Science. Vol. 5 (6), pp 15-31.

www.fuoye.edu.ng