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PHYSICAL AND MECHANICAL PROPERTIES OF ROCKS FROM THE ARCHEAN-PROTEROZOIC TERRAIN OF ADO-EKITI, SW NIGERIA: IMPLICATIONS ON ITS GROUNDWATER POTENTIAL

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Abstract

Overburden thickness and volume of water in existing wells of a basement terrain are critical to its groundwater occurrence. This study examined the physical and mechanical properties of basement rocks at Ado-Ekiti vis-a-vis the volume of water in existing wells and depth to the basement to infer groundwater potential based on rock units. Field operations involved measurement of wells diameters using tape rule while wells water levels and depths were taken using dip-meter. Volume of water in each well was estimated employing $V = \Pi r^2 h$, where V = volume of water in a well (m^3), $\Pi = 3.14$, r = radius of a well (m). In addition, five fresh rock samples were obtained per each lithology. The samples were subjected to laboratory analysis involving the determination of porosity, specific gravity and uniaxial compressive strength (UCS) employing standard methods. Subsequently, vertical electrical soundings (occupying minimum of five locations per lithology) employing Schlumberger array were sounded using Ohmega Ω Resistivity Meter. The results of the soundings were interpreted using Ipi2win resistivity software. Average overburden thickness was computed. The overburden thickness and estimated volume of water in existing wells of the area were correlated with the physical /mechanical properties of the rocks. Field operations revealed five litho logic units including; migmatite-gneiss (M); quartzite (Q); porphyritic granite (PG); fine-medium grained granite (FG) and charnockite (C). Results of physical-mechanical properties of the rocks showed water absorption capacity (W_{ac}) average percentage variations as Q(1.12)> M(0.92)> PG (0.89)> FG(0.82)> C(0.79) while the order of average specific gravity values is C (2.70)> FG(2.69)> PG(2.68)> M(2.68)> Q(2.67).The porosity average values in percentage showed that Q(0.81)> C(0.79)> M(0.76)> PG(0.65)> FG(0.60) while that of the uniaxial compressive strength (UCS) average values (MPa) is Q(165.21)>FG(156.11)>C(153.49)> M(151.48)> PG(148.64).Average values of overburden thickness in meter indicated FG(29.76)>PG(23.83)>Q(17.93)>C(9.32)>M(6.19). The average values of volume of water in wells of the area (m^3) showed order of increase; Q(4.71)>M(2.97)>PG(2.64)>FG(1.73)>C(1.72). Quartzite stands out as hills in some locations in Ado-Ekiti reflecting its resistance to weathering. Despite the competency of quartzite, it has high porousity (av. 0.80%) and W_{ac} (av.1.12%) compared with other rocks and is considered most favorable rocks for groundwater occurrence while charnockite (av. volume of water in wells, 1.72m^3) was least favorable. However, low to negative correlative values (-0.4 to 0.17) of the physical-mechanical parameters with the volume of water in existing wells and overburden thickness are indicative of erratic occurrence of groundwater in basement terrains and this research could only serves as a guide that is not absolute.

Keywords: Overburden thickness, Schlumberger array fresh rock, groundwater potential, litho logic unit,

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I. INTRODUCTION

Rocks from the Archean-Proterozoic terrain of Ado-Ekiti, south-western Nigeria comprise mainly of migmatite, granite-gneiss, quartzite, granite (porpyritic and fine-medium grained) and charnockite. These lithologies with differences in their structure offer varying resistances to various geomorphic processes and as such would have different physical and mechanical properties. The anisotropic nature of these rocks is believed to be caused by variations in their petrography (mineralogy, texture and micro-structures) and physical properties. These variations have been discovered to occur even in locations which are only a few centimeters apart on an outcrop. As a result of this, similar rock types in the same locality may not yield the same engineering properties and therefore may not be suitable for the same use. This explains why rock mechanical properties confirmatory tests require lots of test samples and are therefore very expensive, time consuming and tedious [1]. By implications, the rocks would have different weathering rates and groundwater occurrence. Weathering processes are responsible for breaking down the rocks into smaller fragments and preparing the way for formation of not only regolith and soils, but also erosion and mass movements. The physical and mechanical properties of a rock reflect indirectly the susceptibility to weathering and development of regolith overburden. Thus, the occurrence of groundwater in each of the rock unit conversely, depends on the degree of weathering, extent of fracturing and mineralogical composition of the rock. In Ado-Ekiti, consolidated rocks are dominant and the porousity and permeability are attributable to processes of rock fracturing and weathering controlled by topography, lithology, structure and climate [2]. The depth of fracturing and weathering as well as the nature of weathered product together determine the availability of groundwater and its supply to wells. Humans depend on the rocks for their sustenance and have been using them extensively and intensively. So, it is essential to understand their nature in order to use them effectively without disturbing their balance and diminishing their potential for the future.

[3] researched into the geoelectric properties and aquifer characteristics in parts of the Basement Complex, Southwestern Nigeria using Vertical Electrical Sounding (VES) techniques. The study reported that clayey soil and weathered bed rock which may be fractured constitute the aquiferous zone of the area. Also, [4] carried out a systematic geophysical investigation for groundwater in parts of Southwestern Nigeria covering the coastal aquifers and the crystalline basement areas of parts of Lagos and Ogun states. He used the seismic refraction and electrical resistivity methods in the basement areas whilst only the resistivity method was used in the sedimentary area. Results of this research revealed that subsurface fractures are good targets for groundwater in the basement terrains. This study aimed at assessing the groundwater potential of Ado-Ekiti based on rock units using overburden thickness, volume of water in exisisting wells and the physical and mechanical properties of the lithologies.

II. LOCATION AND GEOLOGY/HYDROGEOLGY

Ado-Ekiti is the state capital of Ekiti State, located within the North Western part of the Benin-Owena River Basin development Area. Precisely, Ado-Ekiti lies within Latitude7°34′ and 7°44′North of the Equator and Longitude 5°11′ and 5°18′ east of the Greenwich Meridian. The city is bounded to the North by Iworoko town, to the east by Are and Afao, to the West are Iyin and Igede while to the South is Ikere-Ekiti. Ado-Ekiti is a nodal town with roads leading to other parts of the state converging in the city. This study extends into the periphery of Ado-Ekiti where most outcrops have been exposed by erosion, hence, were easily assessable. Geologically, Ado-Ekiti constitutes a miniature of the geology of south western Nigeria. Most of the rocks in south western Nigeria with the exception of the schistose rocks are found in Ado-Ekiti. Migmatite-quartzite complex are the oldest rocks into which other rocks (older granite, charnockite, aplite and quartz veins) got intruded. The charnockites and the older granites intruded into these hoist rocks during the Pan-African orogeny. Migmatite - gneiss covers over 60% of the study area (Fig.1) into which the other successions of rocks have intruded. Migmatite rock exposures occur as highly denuded hills of essentially fine textures. The rocks composed of a mafic portion made up of biotite, hornblende and opaque minerals while the felsic portion is quartzo-feldspartic. The rocks display compositional variations indicated by closely spaced alternating bands of leucocratic minerals (quartz and feldspars) and melanocratic minerals indicated by the preponderance of biotite minerals.

The quartzite in the study area exhibits white to gray colour due to varied iron oxide in the rock. A few good massive quartzite outcrops rising upto 100 metres above the surrounding terrain occur around the south western part of the study area. Quartzite is very resistant to chemical weathering and often forms ridges and resistant hilltops.

The charnockitic rocks outcropped as oval or semi-circular hills of between five and ten meters (10m) high with a lot of boulders at some outcrops. They are generally massive, dark-greenish in colour with medium to coarse grained texture. The general trend of the intrusions is N-S. The dominant trend of the joints that occur on the rock is N-S. The charnockites in Ado-Ekiti fall within those that occurr along the margins of Older Granites bodies especially the porphyritic granites. The other mode of occurrence comprising of charnockites that aligned in a NW-SE direction hardly outcropped in Ado-Ekiti but are found at Itapa, Ijelu, Oye and Ikole areas of Ekiti State. Megascopic examination with the aid of hand lens revealed the presence of quartz, alkali feldspar, plagioclase and biotite as major mineral in the charnockitic rocks of the study area. The Older Granites comprise of felsic and mafic minerals. The felsic minerals include quartz, orthoclase, plagioclase feldspar and muscovite while the mafic group comprise of the black coloured biotite and the dark green to black hornblende of the amphibole group. The granites are distinguishably unique in that it lacked foliation but with visible mineral components. In addition, the granites have porphyritic and fine-medium grained texture with compact interlocking crystals. Some of the outcrops occur as well-rounded boulders devoid of any preferred orientation of component minerals. Generally, the porphyritic granite is light coloured and fairly weathered compared to the fine-medium grained variety.

Generally, the hydrogeology of an area depends on geology, structure and climate of the area. The geological formation underlying the area and the structures determine the types of aquifer and the means of recharging them while the climate determines the amount and rate of recharge of the aquifer [5]; [6]. The major rivers in the study area include, Ureje, Ero and Oni. There are other small streams joining the rivers. The volume of water in the streams depends on the response to wet and dry seasons. During the rainy season, there is a great increase in water flow volume in the major rivers while there is hardly water in some of the streams during the dry season. Rainfall is the dominant factor that determines the occurrence of groundwater and this factor greatly influences the groundwater in the study area. During the rainy season, the area enjoys a high amount of rainfall. Rainfall data for the last 40 years show that the highest rainfall occurs in August while the lowest is recorded in November [7]. In the study area like any typical Basement Complex terrain, groundwater occurs in either the weathered mantle or in the joints and fractured systems in the unweathered rocks and buried stream channels [8] and [9]. The basement rocks are mechanically competent and respond differently to impose strains by brittle fracture with granite more competent than the gneisses. Surface water percolates down through the fractures and the process of chemical weathering proceeds to form the regolith overlay which constitute the aquiferous layers.

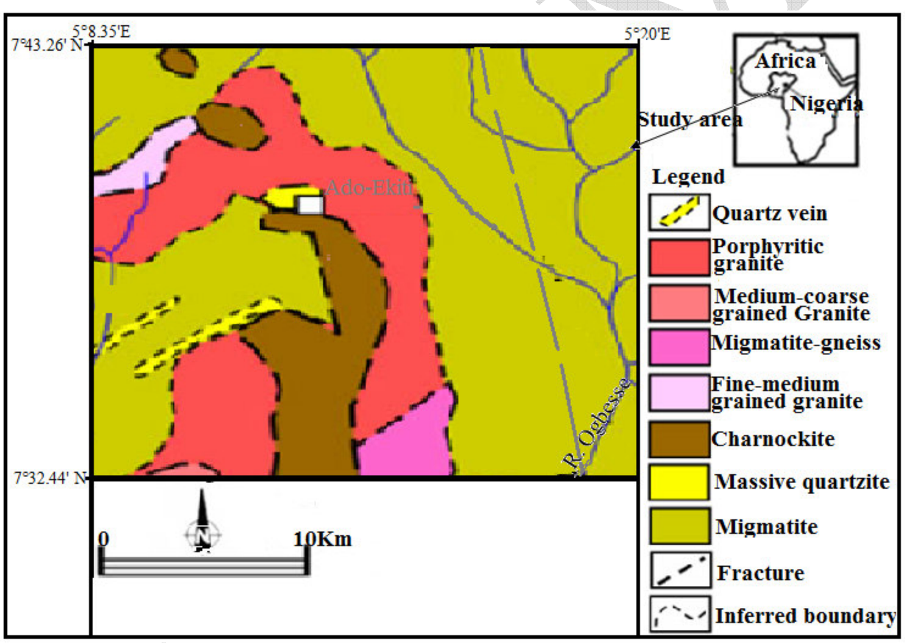

Fig. 1. Location and Geologic map of the study area

III. METHODOLOGY

The method employed in this study was designed to measure porosity, specific gravity, water absorption capacity and unconfined compressive strength (UCS) of the major lithologies (migmatite-gneiss, granites, charnockite and quartzite) and carry out resistivity

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survey as well as measure few in-situ parameters (water level, well depth and well diameter) on each lithology. As part of the methodological approach, field investigation and detailed laboratory analysis were undertaken. Field investigation entailed a reconnaissance survey of the area during which wells water level, depth and diameter were taken using dip-meter and tape rule. Water column was calculated (well depth-water level) and volume of water in each well using the formula; $V = \Pi r^2 h$. V = volume of water in a well (m^3), $\Pi = 3.14$, r = radius of a well (m).

Plans with respect to rocks sampling operation and vertical electrical sounding positions were earmarked during this survey. Five fresh rock samples were obtained per each lithologic unit. At each sampling point, geographic locations were taken and recorded using etrex 12 channel Garmin GPS. The samples vary from one location to another in terms of lithology, texture and mineralogy. Laboratory analysis involving the determination of porosity, specific gravity, water absorption capacity and UCS were carried out in accordance with [10] and [11] specification. Subsequently, vertical electrical soundings employing Schlumberger array, occupying minimum of five locations per lithology were sounded using Ohmega Ω Resistivity Meter. The results of the soundings were interpreted using Ipi2win resistivity software. Average overburden thickness were computed and correlated with the physical /mechanical properties of the rocks.

The porosity, water absorption capacity, specific gravity and unconfined compressive strength of the various rocks directly or indirectly reflect weathering intensity of the various lithologies in the study area. Development of overburden thicknesses as well as volumetric quantity of well water is also reflection of weathering intensity. Therefore these various parameters are considered to reflect the groundwater potential of the study based on lithology.

IV. RESULTS AND DISCUSSION

The various samples collected based on rock units in the study area is presented in Table 1 Five majour lithologic units including; migmatite-gneiss; quartzite; porphyritic granite; fine-medium grained granite and charnockite were found in the study area. Results of the vertical electrical soundings are presented in Table 2 while the sounding curves are in Fig. 2. The simple H curves representing 40% of the sounding curves was dominant while HA curves representing 20% were predominant in the fine-medium grained granite. Other curve types include K (16%), QH(16%) and KH (8%). The relevant data to this study (overburden thickness) were extracted and incorporated with other results as shown in Table 3. Detailed results of Physical/Mechanical Properties and well data of Basement rocks of the study area are presented in Table 4. The summary of the physical/mechanical properties of the rock units, volume of water in exisisting wells and overburden thickness (Table 3) generally revealed water absorption capacity (W_{ac}) average percentage variations as Q(1.12)>M(0.92)>PG (0.89)>FG(0.82)>C(0.79) while the order of average specific gravity values is C(2.70)>FG(2.69)>PG(2.68)>M(2.68)>Q(2.67). The porosity average values in percentage showed that Q(0.81)>C(0.79)>M(0.76)>PG(0.65)>FG(0.60) while that of the uniaxial compressive strength(UCS) average values in (MPa) is Q(165.21)>FG(156.11)>C(153.49)>M(151.48)>PG(148.64). Average values of overburden thickness in meter indicated FG(29.76)>PG(23.83)>Q(17.93)>C(9.32)>M(6.19). The average values of volume of water in wells of the area (m^3) showed order of increase; Q(4.71)>M(2.97)>PG(2.64)>FG(1.73)>C(1.72). The fine-medium grained granite with average specific gravity (2.69), porosity(0.60%), water absorption capacity(0.82%) and UCS (156.11MPa) is the most competent rock unit in the study area. Conversely, the fine-medium grained granite would have low weathering intensity and low overburden thickness. Except when fractured, the occurrence of groundwater in this rock may be low. However, little variability exists to this generalization i.e average water absorption capacity of charnockite (0.79%) compared with fine-medium grain granite (0.82%) portraits the former rock as more competent. The average volume of water in wells in fine – medium grained granite (1.73m^3) was slightly higher than that of charnockite (1.72m^3), a reflection of the higher water absorption capacity of the former and fracture rocks as revealed in the sounding curves of the rock. In similar vein, quartzite with UCS (165.21) (MPa) also appeared to be more competent compared to the fine-medium grained granite with UCS (156.11MPa). This situation arose from textural and mineralogical arrangement of the rocks. Quartzite is made up majourly of quartz and this explains why its UCS value was higher than that of the fine-medium grained granite. Quartzite stands out as hills in some locations in Ado-Ekiti reflecting its resistance to weathering. Despite the competency of quartzite, it has high porousity (av. 0.80%) and W_{ac} (av.1.12%) compared with other rocks and is considered most favourable rocks for groundwater occurrence while charnockite (av. volume of water in wells, 1.72m^3) was least favourable. However, low to negative correlative values (i.e. r = -0.4 to 0.17) for the few cross plots of the measured groundwater potential indices (Fig. 2) are indicative of erratic occurrence of groundwater in basement terrains and any research on groundwater potential assessment in basement terrains could provide a guide that is not absolute.

A. WATER ABSORPTION (W_{AC})

The result of W_{ac} analysis is presented in Table 4 while the summary is in Table 3. The result showed that W_{ac} ranged from 0.65 to 1.17 %, with mean value of 0.88 %. The minimum value was recorded on fine-medium grained granite while the highest value was on quartzite. [12] observed that the strength of an aggregate is a reflection of the amount of water it can absorb. From their study, they concluded that strong aggregates will have a very low Wac value, usually below 1.0 %. According to [11], Wac of construction aggregate should be<2.5 %. The general low Wac (all below 2.5 %) is an indication of the freshness or very low degree of weathering of the mineral contents in the rock units of the study area. However, in this study the order of variation of Wac based on average values is quartzite >migmatite-gneiss> porphyritic granite> fine-medium grained granite>charnockite. Similarly, it is expected that groundwater potential in the rock units should follow the same order. However, average depth to basement (m) revealed an order that FG(29.76)>PG(23.83)>Q(17.93)>C(9.32)>M(6.19). This order was at variance with that of W_{ac} an indication that there were other salient factors (mineralogy, fracture system, climate etc) responsible for groundwater occurrence apart from overburden thickness.

TABLE 1. SAMPLES LOCATIONS AND BRIEF DESCRIPTION

Code	Sample location	Rock name	Description
PG1	Opposite school of nursing, Ado-Ekiti.	Porphyritic alkali granite	Coarse grained in-equigranular light coloured.
PG2	Yinka quarry, Iyin road. , Ado-Ekiti.	Porphyritic granite	Coarse grained in-equigranular with abundant plagioclase.
FG1	Owode quarters, Ado-Ekiti.	Fine-medium grained granite	Biotite is predominant after quartz.
FG2	Okeyimi, Okuta gbokutaleri, Ado-Ekiti.	Fine-medium grained granite	The outcrops are boulders of fin-medium granite.
MG1	Owode quarters, Ado-Ekiti.	Biotite gneiss	Gneissic texture with distinct banding of leucocratic and malanocratic minerals.
MG2	Off Old garage, Ado-Ekiti	Migmatite-gneiss	Coarse-medium grained leucocratic migmatite-gneiss.
Q1	NTA road, Ado-Ekiti.	Quartzite	Massive non-foliated. Quartz mineral was predominant.
Q2	GRA, Ado-Ekiti	Quartzite	Massive non-foliated. Quartz mineral was predominant.
Q3	Oke Ayaba, Ado-Ekiti	Quartzite	Massive non-foliated. Quartz mineral was predominant.
C1	St. Jude Catholic church Ado-Ekiti	Charnockites	The charnockites occur concurrently with granite
C2	Odo-Ado, Ado-Ekiti	Charnockites	The charnockites occur as boulders.
C3	Idemo, Ado-Ekiti.	Charnockite	Dark greyish colour, f-m grained charnockite
C4	Textile road, Ado-Ekiti.	charnockite	Grey/bluish colour/coarse grain charnockite

B. SPECIFIC GRAVITY (SG)

Generally, the specific gravity of rocks in this study ranged between 2.65 and 2.71 with minimum value from quartzite and maximum value from fine-medium grained granite. [13] stated that if a rock is dominated by plagioclase, calcite, or chlorite, its specific gravity should range between 2.62 and 2.90. The specific gravity values in this study are within this range an indication of dominancy of plagioclase and chlorite in the mineral constituents of the rocks. [14] also reported that SG is a reflection of the amount of heavy elements (especially Fe and Mg) present in a rock. In most cases, SG can serve as an indirect means of determining the amount of stable and potentially durable minerals in aggregates. The significant values of specific gravity in this study are a reflection of presence of pyroxene and iron minerals in the rock units of the area. Nonetheless, the order of increase of specific gravity values based on

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average value of each rock unit is charnockite>fine-medium grained granite>porphritic granite>migmatite-gneiss>quartzite. Rocks with high value of SG are least susceptible to weathering and as such least in terms of groundwater occurrence. This observation is reflected in the volume of water in exisisting wells of the area with charnockite having the least value of $1.72m^3$. Similarly, this was reflected in the value of overburden thickness (9.32m).

C. UNIAXIAL COMPRESSIVE STRENGTH (UCS)

The UCS values of the tested samples ranged from138.98 – 167.52 MPa, with an average value of 153.30 MPa (Table 3). The least value was recorded on charnockites while the highest was on quartzite. The order of increase of UCS in the rocks employing their average values is quartzite>fine-medium grained granite>migmatite-gneiss>charnockite>porphyritic granite. This observation portrays quartzite as the most competent rock and as such the least susceptible to weathering as the dominant mineral quartz controls the strength characteristics of the quartzite. This explains why quartzite stands out as ridges in the study area. However, since quartzite occurs in rubbles, it is highly porous (av. 0.80%) (Table 4), so it is considered most favourable for groundwater occurrence. In other words, the difference in the values of UCS, specific gravity, and water absorption of the investigated samples can only be ascribed to differences in their modal mineralogy and texture.

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VES No	Rock Type	No of Layers	Curve Type	Resistivity of Layers (Ω-m)					Thickness of Layers (m)				Depth to Bedrock (m)
				P_1	P_2	P_3	P_4	P_5	T_1	T_2	T_3	T_4	
VES-Q1	Quartzite	5	QH	446	25	151	15.9	5020	0.5	0.19	14	8.07	22.76
VESQ-2	Quartzite	5	QH	118	7.06	778	22.2	5730	0.5	0.4	1.36	38.9	41.1
VESQ-3	Quartzite	3	H	88.4	16.4	4507	-	-	0.72	11.3	-	-	12
VESQ-4	Quartzite	3	H	61.6	17.2	4992	-	-	1.01	6.2	-	-	7.2
VESQ-5	Quartzite	3	H	61	16.3	22036	-	-	1.04	5.56	-	-	6.6
VES-PG1	Porphy. granite	5	QH	503	64.8	4750	209	5730	1.6	0.71	0.97	127	130
VES-PG2	Porphy. granite	4	HA	385	171	19.9	346	-	0.6	2.76	3.55	-	6.91
VES-PG3	Porphy. granite	3	K	102	1185	3.91	-	-	14.9	23.7	-	-	38.6
VES-PG4	Porphy. granite	3	K	362	1634	12.4	-	-	14.5	15.2	-	-	29.7
VES-PG5	Porphy. granite	4	HA	286	134	1626	29.4	-	5.02	3.65	11.4	-	20.1
VES-FG1	F-M grained granite	4	HA	143	4.54	42.3	11313	-	1.47	0.57	22.9	-	25
VES-FG2	F-M grained granite	4	HA	192	30.1	48.8	134	-	0.5	3.88	14.8	-	18.7
VES-FG3	F-M grained granite	4	HA	450	22.5	549	25313	-	0.5	0.21	64.1	-	65.6
VES-FG4	F-M grained granite	4	QH	1845	506	119	1829	-	1.43	4.1	7.81	-	13.3
VES-FG5	F-M grained granite	5	KH	1287	11301	909	171	71706	0.5	0.69	17.6	17.4	26.2
VES-C1	Charnockite	3	K	23	19050	23.3	-	-	1.78	5.85	-	-	7.63
VES-C2	Charnockite	3	K	20.3	21172	20.6	-	-	1.82	5.12	-	-	6.93
VES-C3	Charnockite	3	H	91.3	37.5	32021	-	-	1.64	7.72	-	-	9.36
VES-C4	Charnockite	4	H	140	21.9	73.3	5603	-	0.50	0.73	13	-	14.20
VES-C5	Charnockite	4	KH	70.4	149	63.4	702	-	0.83	3.05	4.6	-	8.5
VES-M1	Migmatite	3	H	283	41.4	24781	-	-	1.15	2.67	-	-	3.82,
VES-M2	Migmatite	3	H	968	35.4	16827	-	-	1.14	3.06	-	-	4.2
VES-M3	Migmatite	3	H	1143	29	16185	-	-	0.7	2.57	-	-	3.27
VES-M4	Migmatite	3	H	278	88.7	93090	-	-	0.67	8.83	-	-	9.5
VES-M5	Migmatite	3	H	437	90	26486	-	-	0.6	7.19	-	-	7.79

TABLE 2. CORRELATION TABLE (VES DATA).

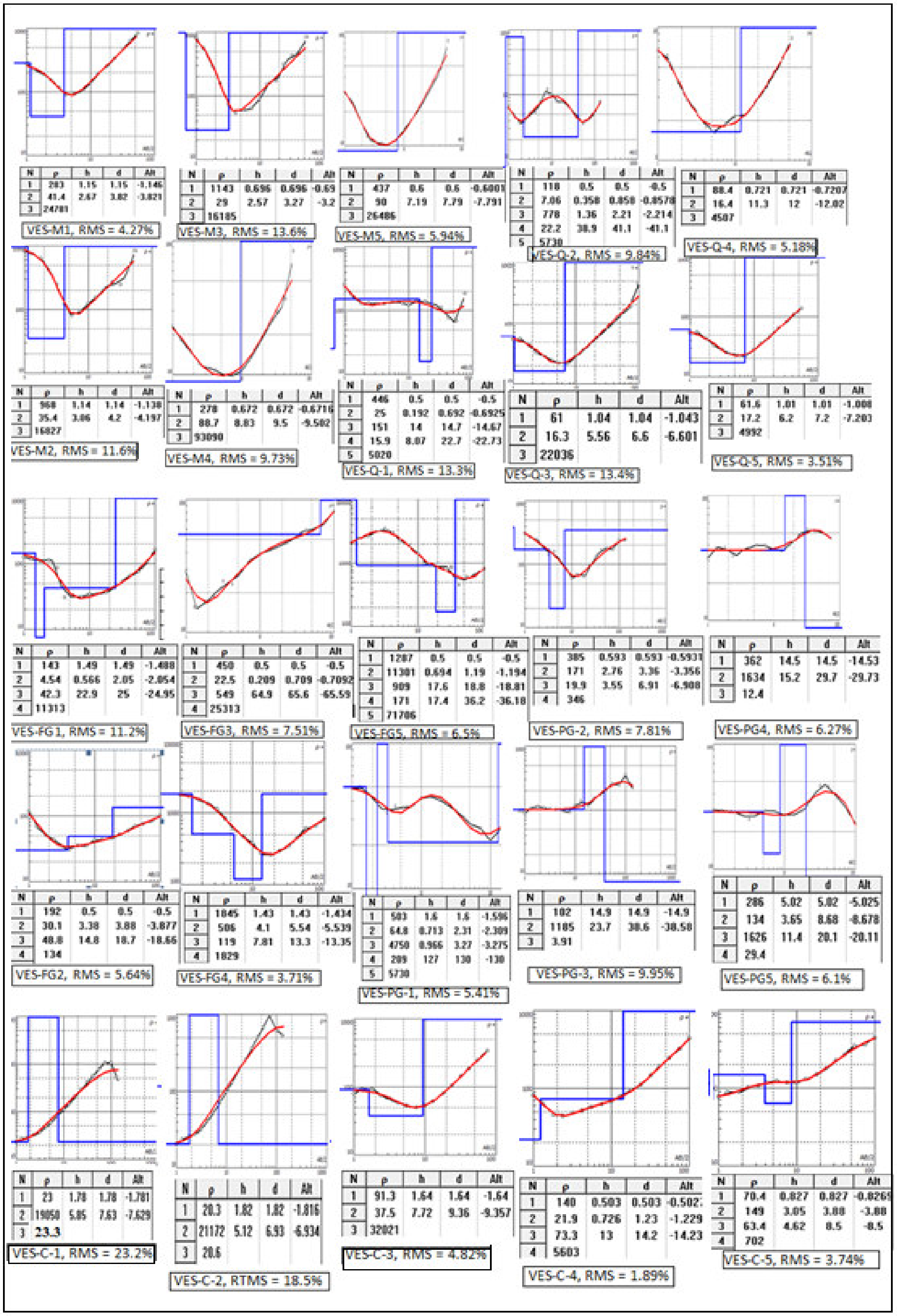

Fig. 2. VES curves from the study area

TABLE 3. SUMMARY OF PHYSICAL/MECHANICAL PROPERTIES OF ROCKS AND WELL DATA IN THE STUDY AREA

Rock	Para meters	**Specific gravity**	**Porosity (%)**	**W_{AC} (%)**	**UCS (MPa)**	Depth to Basement (m)	Water Level (m)	Well Depth (m)	Water column (m)	Well diameter (m)	Volume of water (m^3)
Migmatite	Min	2.66	0.71	0.83	147.53	3.27	1.50	4.10	0.10	1.30	0.13
	Max	2.69	0.82	1.00	156.44	9.50	9.70	11.50	4.80	1.60	9.65
	Mean	2.68	0.76	0.92	151.48	6.19	5.34	7.09	1.75	1.42	2.97
	Stdev	0.01	0.05	0.06	2.56	2.94	2.74	2.50	1.56	0.11	2.91
Quartzite	Min	2.65	0.79	1.06	162.84	6.60	1.20	4.40	2.40	1.30	3.18
	Max	2.68	0.82	1.17	167.52	41.10	7.10	10.40	3.30	1.60	6.43
	Mean	2.67	0.81	1.12	165.21	17.93	3.28	6.12	2.83	1.45	4.71
	Stdev	0.01	0.01	0.05	2.09	14.48	2.14	2.20	0.44	0.10	1.08
Porphyritic Granite	Min	2.66	0.61	0.84	144.36	6.91	1.50	4.30	0.30	1.30	0.60
	Max	2.70	0.69	0.93	152.71	38.60	6.20	9.20	7.70	1.60	10.22
	Mean	2.68	0.65	0.89	148.64	23.83	4.73	6.31	1.84	1.40	2.64
	Stdev	0.01	0.03	0.03	2.74	13.57	1.57	1.45	2.11	0.09	2.73
Fine-medium grained granite	Min	2.67	0.57	0.65	152.84	13.30	0.20	1.60	0.60	1.30	0.80
	Max	2.71	0.63	0.98	159.78	65.60	10.30	11.30	1.70	1.60	3.22
	Mean	2.69	0.60	0.82	156.11	29.76	5.69	6.77	1.08	1.42	1.73
	Stdev	0.01	0.02	0.14	2.10	20.69	3.40	3.34	0.40	0.09	0.75
Charnockite	Min	2.69	0.72	0.74	139.89	6.93	1.80	3.00	0.50	1.30	0.77
	Max	2.71	0.84	0.83	163.54	14.20	11.00	11.50	2.00	1.40	3.08
	Mean	2.70	0.79	0.79	153.49	9.32	5.10	6.51	1.21	1.35	1.72
	Stdev	0.01	0.05	0.03	10.78	2.87	2.85	2.67	0.44	0.05	0.64

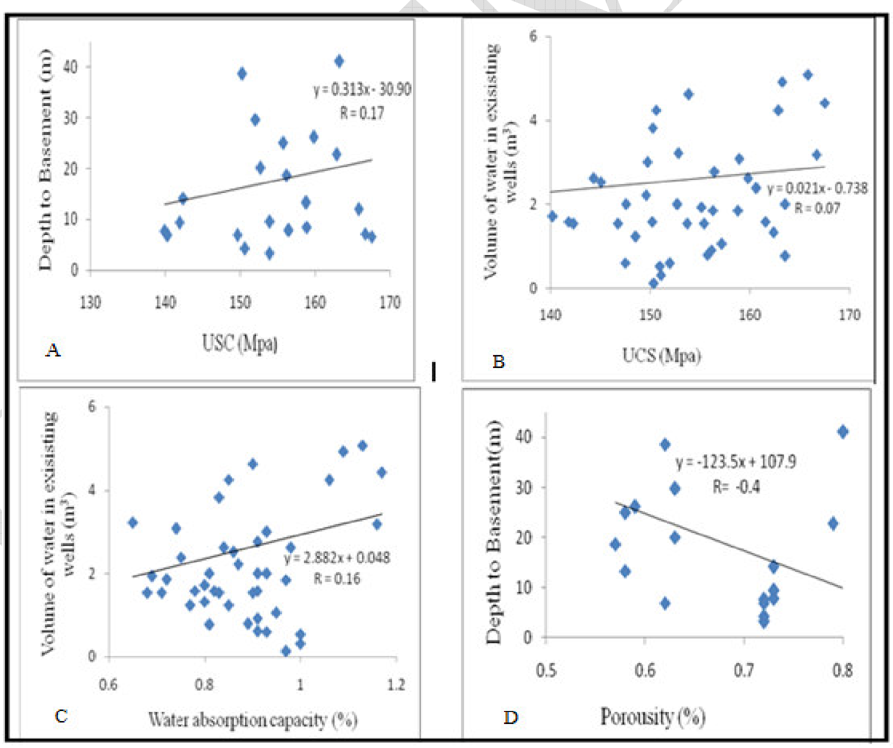

Fig. 3. Cross Plots of some groundwater potential parameters in the study area

Table 4 physical/mechanical properties of rocks and well data of Basement rocks of the study area.

Rock type	**Code**	**Specific**	**Porosity**	**W_{ac}**	**UCS**	Water	Well	Water	Well	Volume of

		gravity	**(%)**	**(%)**	**(MPa)**	Level(m)	Depth (m)	column (m)	diameter (m)	water (m^3)
	M1	2.66	0.71	0.83	150.27	3.90	5.80	1.90	1.60	3.82
	M2	2.67	0.72	0.85	150.60	7.10	10.30	3.20	1.30	4.25
	M3	2.67	0.72	0.89	153.88	1.80	6.60	4.80	1.60	9.65
	M4	2.68	0.73	0.90	153.89	1.50	4.50	3.00	1.40	4.62
Migmatite-Gneiss	M5	2.68	0.73	0.91	156.44	9.70	11.50	1.80	1.40	2.77
	M6	2.67	0.79	0.91	147.53	4.70	5.10	0.40	1.40	0.61
	M7	2.68	0.80	0.93	149.73	5.60	7.30	1.70	1.50	3.00
	M8	2.68	0.81	0.97	150.35	4.0	4.10	0.10	1.30	0.13
	M9	2.69	0.81	1.00	150.98	6.10	6.50	0.40	1.30	0.53
	M10	2.69	0.82	1.00	151.08	9.0	9.20	0.20	1.40	0.31
	Q1	2.65	0.79	1.06	162.84	3.60	6.00	2.40	1.50	4.24
	Q2	2.66	0.80	1.09	163.21	1.20	4.40	3.20	1.40	4.92
	Q3	2.67	0.81	1.13	165.80	7.10	10.40	3.30	1.40	5.08
Quartzite	Q4	2.67	0.81	1.16	166.66	3.40	5.80	2.40	1.30	3.18
	Q5	2.68	0.82	1.17	167.52	3.10	5.60	2.50	1.50	4.42
	Q6	2.68	0.71	0.76	138.98	1.30	4.50	3.20	1.60	6.43
	PG1	2.66	0.61	0.85	148.53	5.80	6.60	0.80	1.40	1.23
	PG2	2.67	0.62	0.87	149.59	3.10	4.30	1.20	1.50	2.22
	PG3	2.67	0.62	0.91	150.25	6.20	7.40	1.20	1.30	1.59
	PG4	2.68	0.63	0.93	151.98	5.90	6.20	0.30	1.60	0.60
Porphyritic granite	PG5	2.68	0.63	0.93	152.71	3.70	5.00	1.30	1.40	2.00
	PG6	2.68	0.67	0.84	144.36	4.70	6.40	1.70	1.40	2.62
	PG7	2.69	0.68	0.86	145.07	4.40	6.30	1.90	1.30	2.52
	PG8	2.69	0.68	0.90	146.80	6.10	7.10	1.00	1.40	1.54
	PG9	2.70	0.69	0.91	147.58	5.90	4.60	1.30	1.40	2.00
	PG10	2.70	0.69	0.92	149.55	1.50	9.20	7.70	1.30	10.22
	FG1	2.67	0.58	0.89	155.75	5.20	5.80	0.60	1.30	0.80
	FG2	2.68	0.57	0.91	156.16	5.40	6.00	0.60	1.40	0.92
	FG3	2.68	0.57	0.95	157.16	5.20	5.80	0.60	1.50	1.06
	FG4	2.69	0.58	0.97	158.79	4.30	5.50	1.20	1.40	1.85
Fine-medium grained granite	FG5	2.69	0.59	0.98	159.78	1.00	2.70	1.70	1.40	2.62
	FG6	2.69	0.61	0.65	152.84	9.70	11.30	1.60	1.60	3.22
	FG7	2.69	0.62	0.68	153.71	6.60	7.60	1.00	1.40	1.54
	FG8	2.70	0.62	0.69	155.15	9.00	10.10	1.10	1.50	1.94
	FG9	2.70	0.63	0.71	155.44	10.30	11.30	1.00	1.40	1.54
	FG10	2.71	0.63	0.72	156.3	0.20	1.60	1.40	1.30	1.86
	C1	2.69	0.72	0.77	139.89	4.80	5.60	0.80	1.40	1.23
	C2	2.69	0.72	0.80	140.26	4.80	7.10	1.30	1.30	1.72
	C3	2.70	0.73	0.82	141.85	1.90	3.10	1.20	1.30	1.59
	C4	2.70	0.73	0.83	142.35	4.90	5.90	1.00	1.40	1.54
Charnockite	C5	2.69	0.81	0.74	158.89	2.50	4.50	2.00	1.40	3.08
	C6	2.70	0.82	0.75	160.62	6.40	8.20	1.80	1.30	2.39
	C7	2.70	0.82	0.78	161.58	1.80	3.00	1.20	1.30	1.59
	C8	2.71	0.83	0.80	162.34	8.00	9.00	1.00	1.30	1.33
	C9	2.71	0.84	0.81	163.54	11.00	11.50	0.50	1.40	0.77
	C10	2.71	0.84	0.81	163.54	4.90	7.20	1.30	1.40	2.00
Min		2.65	0.57	0.65	138.98	0.20	1.60	0.10	1.30	0.13
Max		2.71	0.84	1.17	167.52	11.00	11.50	7.70	1.60	10.22
Mean		2.68	0.71	0.88	153.52	4.96	6.60	1.65	1.40	2.59
Stdev		0.01	0.09	0.12	7.41	2.64	2.44	1.33	0.09	2.11

WAC = water absorption capacity porosity and UCS = uniaxial compressive strength

D. POROSITY

Basement aquifers are distinctive in that their occurrence and characteristics are largely a consequence of the interaction of weathering processes related to recharge and groundwater through flow [15]. Geology controls the rate of groundwater movement. The size of the cracks in rocks, the size of the pores between soil and rock particles and whether the pores are connected determine the rate at which water moves into, through and out of an aquifer. Porosity to some extent can serve as a guide to groundwater occurrence in basement complex rocks. The porosity values in this study ranged between 0.57% and 0.84% with fine-medium grained granite having the minimum value and quartzite the highest. The average values per rock unit show the order of porosity increase as quartzite>charnockite>migmatite>porphyritic granite>fine-medium grained granite. Groundwater occurrence in basement terrain is erractic but to a fairly accurate prediction, quartzite appears to be the most prolific aquifer in this study. However, when other rocks are fractured, there could be a reverse of this statement.

V. CONCLUSION

This study attempted to give a synoptic picture of groundwater occurrence based on rock units in Ado-Ekiti. Five majour rock units dominate the area including migmatite-gneiss; quartzite; porphyritic granite; fine-medium grained granite and charnockite. The depth to basement was thickest in fine-medium grained granite (29.76m) and least in migmatite (6.19m). Volume of water in exisisting wells was found to be more than all other rock units in quartzite (4.71m^3) while the least value was recorded in charnockites (1.72m^3). The physical/mechanical properties followed no definite patterns in the rocks. However, the UCS values of the rocks indicated quartzite (165.21 MPa) as the most competent rock unit while porosity value (1.12%) revealed same rock as most porous. These peculiar characteristics of quartzite arose from its mineralogical and textural characteristics with the rock considered the best in terms of groundwater occurrence. The low to negative correlation (i.e. r = -0.4 to 0.17) for the few cross plots of the measured groundwater potential indices are indicative of erratic occurrence of groundwater in Ado-Ekiti basement terrain and this research at best provides a guide that is not absolute.

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