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Determination of Reserve Estimate of Quartzite Deposit using Geoelectric Sounding and Laboratory Measurement - A Case Study of Ipinsa area, near Akure, Southwestern Nigeria

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Abstract

A total of 36 Vertical Electrical Sounding data and laboratory analysis was carried out at southern part of Ipinsa, near Akure, Southwestern Nigeria with the aim of determining the reserve estimate of a portion of the quartzite deposit in the area. The Vertical Electrical Sounding (VES) method adopted Schlumberger configuration with half current electrode spacing varying from minimum of 1 to maximum of 40 to 150 m. The VES results delineated three to six geoelectric layers which correspond to the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh basement. At the top soil, the resistivity varies from 38 to 878 ohm-m, while the thickness value ranges from 0.1 to 6.8 m. At the weathered layer, resistivity varies from 17 to 9749 ohm-m, while the thickness value ranges from 0.1 m to infinity. The weathered basement resistivity ranges from 24 to 18088 ohm-m, while the thickness values range from 0.6 m to infinity. The partially fractured basement resistivity varies from 62 to 1331ohm-m and its thickness range from 4.0 to 5.1 m. The quartzite layer resistivity value in the study area is generally greater than 150 ohm-m, with average thickness of 8.86 m. From the 14 quartzite samples collected across the study area, the average density value was determined to be 2.51 g/cm^3 (2510 kg/m^2). The area extent of the quartzite deposit was calculated to be 1,024,729 m^2, while the volume of the quartzite deposit is 9,079,098 m^3. The mass of the quartzite deposit was estimated to be 22,788,538 tonnes.

Keywords: Vertical electrical sounding, laboratory measurement, density, thickness, area, volume and tonnage.

1. Introduction

Quartzite is a metamorphic rock consisting primarily of quartz grains, formed by the recrystallization of sandstone by thermal or regional metamorphism (MacDonald et. al., 2006). Quartz is a compound consisting of one molecule of silicon and two molecules of oxygen, silicon dioxide (SiO_2). Quartz is a trigonal mineral and crystalline polymorph of silica, SiO_2. It commonly occurs as six-sided crystals with pointed terminations. It is colourless and transparent. However some varieties of quartz are coloured because of presence of impurities (MacDonald et. al., 2006).

Quartzite is utilized in the construction industry, especially in making of reinforced concrete and general concrete works. The use of quartzite as decorative material in construction is becoming increasingly popular. When quartzite is cut into slabs, it is good for decorating floors, stair steps, walls, roofing tiles and in making kitchen table tops among many other decorative uses. Due to its hard surface and angular shape, quartzite is used as a stone for stabilization (ballast) along the railroad tracks. When quartzite is packed in between the rails and tiles, it facilitates drainage and prevents the growing of vegetation. Quartzite has not been used extensively, as other softer stones; however, it is expected that its utilization will increase in the near future.

This study is aimed at determining the quantity of part of quartzite deposits at Ipinsa, Ifedore Local Government area of Ondo State. The survey was carried out using the electrical resistivity method. The electrical resistivity method is commonly used in engineering site investigations. It is useful in structural mapping, determination of depth to bedrock, nature of superficial deposits and mineral exploration deposits (Zhody et. al. 1974). Afolabi et. al.

(2013) used the method to investigate the reserve estimate of kaolin deposit and the excavable overburden of the deposits. Egbai (2011) used the vertical electrical sounding (VES) method to study kaolin deposit in Ozanogogo area, Ika South Local Government area, Delta State. Akintorinwa et. al. (2012) used vertical electrical sounding technique of electrical resistivity method to determine the geoelectric reserve estimate of laterite deposits along Oshogbo-Iwo highway, southwest Nigeria, a basement complex environment.

2. The study area

The study area is located at Ipinsa off Ilesha-Akure expressway, Ondo State, Nigeria. The major road in the area runs from Ilesha through Akure to Owo. While the minor roads runs within Ipinsa town. The minor roads were used as access paths for the data acquisition exercise.

The area lies within 808000 - 809400 m (Northing) and 735100 - 736800 m (Easting) in the Universal Traverse Mercator (UTM) Minna Zone 31 coordinates.

The topography of the study area is moderate to rugged consisting of hilly and flat terrains, while the surface elevation varies between 372 and 420 m. The quartzite generally occurs as ridge in the study area. The study area falls into a tropical climate and belongs to the equatorial rain forest belts. There are several attractive varieties of vegetation in the area.

The study area falls within the basement complex of Southwestern Nigeria (Jones and Hockey, 1964, Rahaman and Ocan, 1978 and Rahaman, 1988). The identified rock units in the area are older granites, charnockites, granite-gneiss and quartzite rocks.

3. Methodology

This study comprises geoelectric sounding and laboratory measurement. The geoelectric sounding data were acquired using Schlumberger array technique and a total of 36 VES stations were occupied across the study area. The current electrode spread (AB/2) range from minimum of 1m to maximum of 40 to 150 m. The PASI 16 GL earth resistivity meter was used for this survey; the equipment has the capacity to automatically determine the resistance R, such that the three values (Current, I; Potential difference, ΔV and Resistance, R) are displayed after each measurement. The acquired VES data were plotted on a transparent log-log graph as a plot of apparent resistivity values (ρ_a) against the electrode spacing (AB/2). The curves were interpreted both qualitatively and quantitatively. The quantitative interpretation was done using partial curve matching technique and the resultant geoelectric parameters were further refined using computer iteration algorithm (RESIST Version 1.0). The Vertical Electrical Soundings results were presented as sounding curves, geoelectric sections and maps. Fourteen (14) fresh quartzite samples were taken at different location across the study area in order to determine the density of the samples using Archimedes' principle. The mass of each sample was determined using Citizen Electronic Balance. 100ml measuring cylinder was used to measure the volume. The volume of water inside the measuring cylinder was known before suspending the sample inside cylinder. The final volume was measured and their difference was calculated as the volume of the sample.

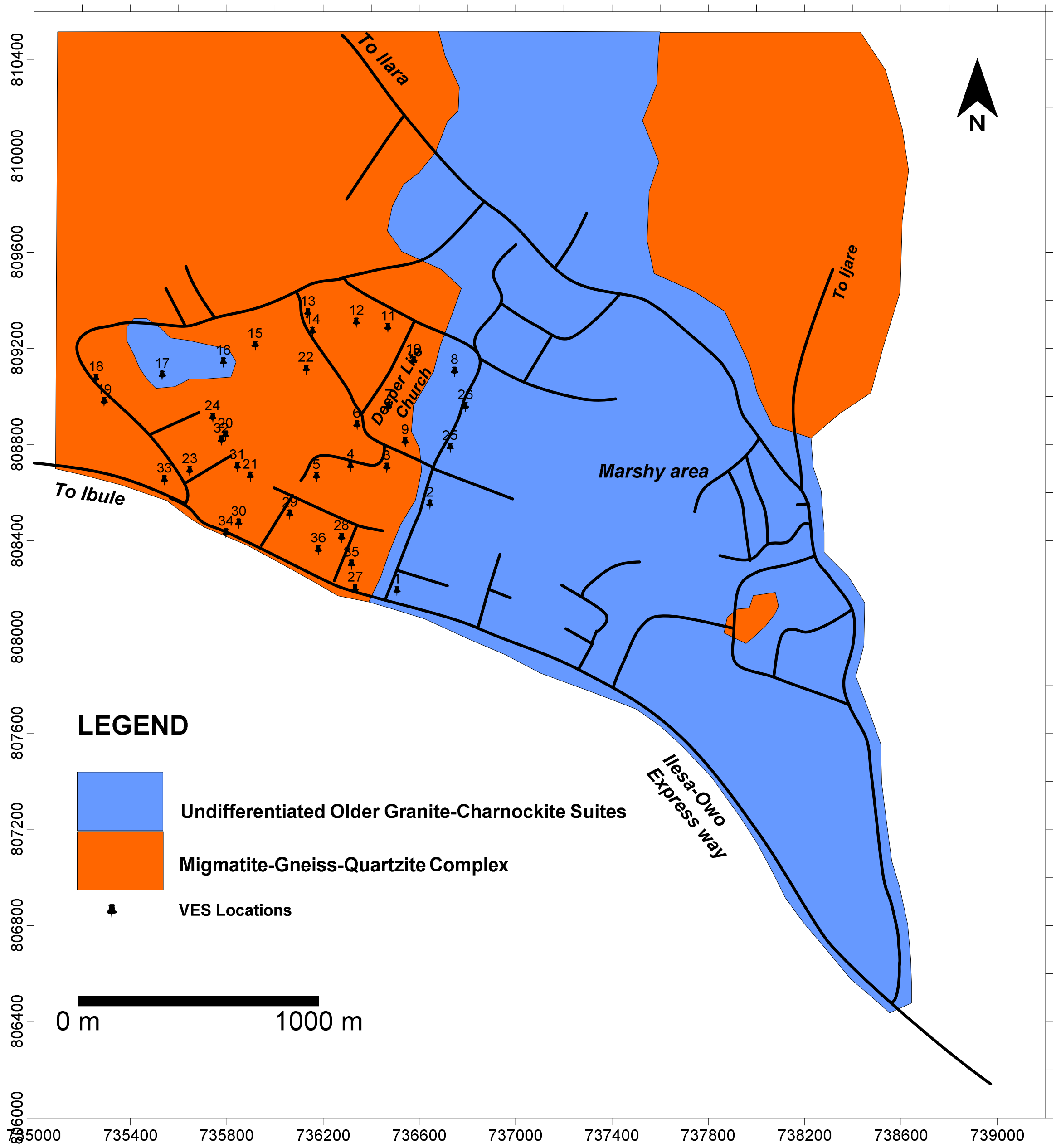


Figure 1: Simplified geological map of Ipinsa showing the VES locations

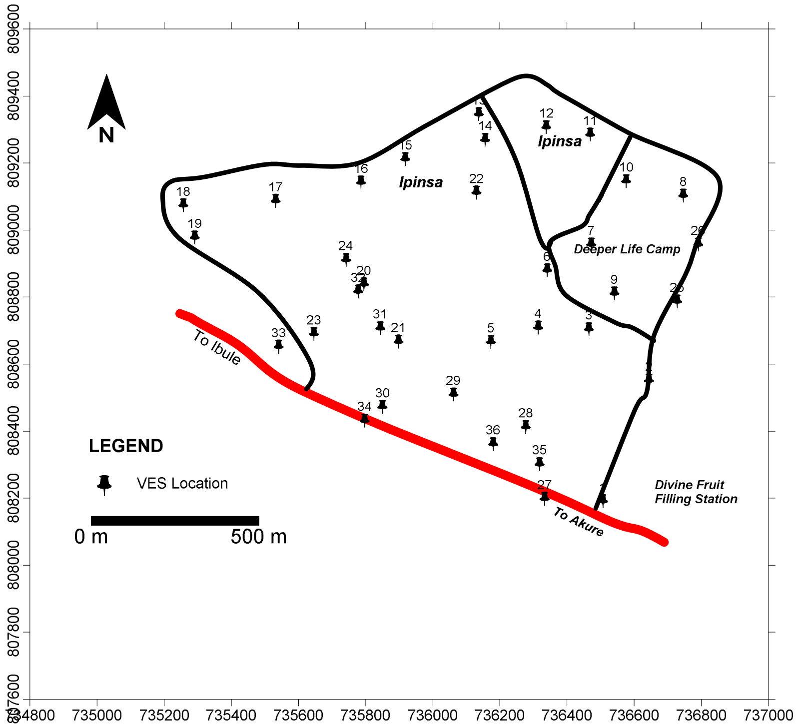


Figure 2: Basemap of the study area showing the VES locations.

4. Discussion of Results

The density of each sample is calculated using the following relationship;

Density = Mass/Volume 1

The average density was determined as 2.51 g/cm^3 or 2510 kg/m^3 (Table 1).

The interpretation models and the geo-electric parameters generated from the VES data are as contained in Table 2. The subsurface sequence at the investigated sites is generally composed of the topsoil (which is quartzite in place), weathered layer and the basement bedrock (host rock). The VES curves identified in the study area includes KH, H QH, and HKH and HK type (Figure 3). The predominating KH curve type constitutes 75% of the total followed by the H curve type which constitutes 11.11% of the total. Consequently, HKH constitutes 8.3% while QH and HK each accounts for 2.8%. The predominance of the KH type curve is not surprising in quartzitic environment with a well-developed fracture system which makes quartzite a favourable source of groundwater in a basement complex. The geoelectric sounding results delineated three (3) to six (6) layers across the study area which corresponds to top soil, weathered layer, weathered basement, fractured basement and the presumed fresh basement. Six geoelectric layers were delineated beneath VES 4. Five were delineated beneath VES point 3, 6, 11, 12 and 27 while the remaining VES points have three (3) or four (4) layers. The layer resistivity values vary respectively across the study area from 38 to 878 ohm-m in the topsoil with thickness ranging from 0.1 to 6.8 m. The resistivity value in the weathered layer ranges from 17 to 9749 ohm-m with thickness ranging from 0.1 to 23.4 m to infinity. In the weathered basement, resistivity value ranges from 24 to 18088 ohm-m while the thickness ranges from 0.6 to infinity and in the fractured basement/presumed fresh basement, resistivity value ranges from 62 to 1331 ohm-m with thickness ranging from 4.0 to 5.1 m.

Table 1: Density Determination Results

SAMPLE	MASS (g)	VOLUME (cm^3)	DENSITY(g/cm3)
1	18.16	7.00	2.59
2	17.45	6.50	2.68
3	13.17	6.00	2.20
4	17.75	7.00	2.54
5	13.00	5.00	2.60
6	10.73	4.00	2.68
7	22.02	9.50	2.32
8	19.06	7.00	2.72
9	14.79	6.00	2.47
10	12.12	5.00	2.42
11	16.59	7.00	2.37
12	12.34	5.00	2.47
13	13.61	5.00	2.72
14	17.54	7.50	2.34

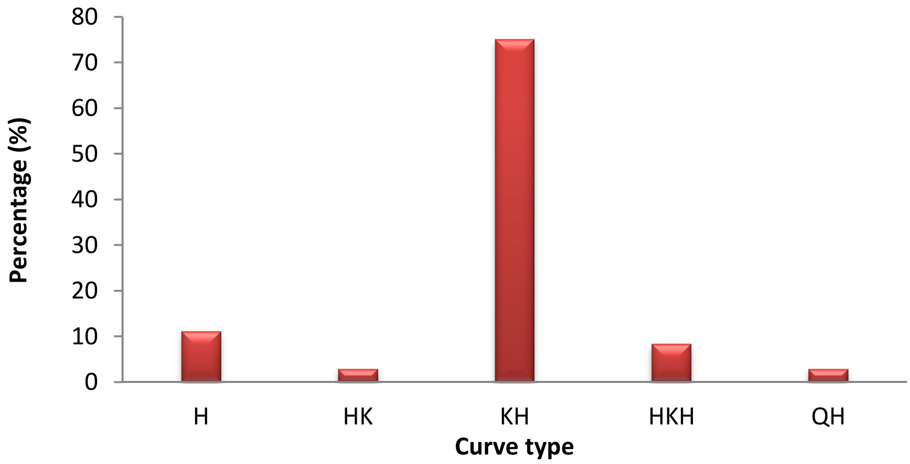


Figure 3: Curve types obtained in the study area

Table 2: Summary of Vertical Electrical Sounding Results

VES NO	LAYER RESISTIVITY (Ohm-m) $\ell_1/\ell_2/\ell_3 \ldots \ell_{n-1}/\ell_n$	LAYER THICKNESS (m) $h_1/h_2/h_3 \ldots h_{n-1}/h_n$	CURVE TYPE
1	249/64/390	2.2/6.6	H
2	243/850/161/2766	0.4/2.3/6.1	KH
3	349/254/754/145/1331	0.4/0.1/2.5/4.0	KH
4	79/591/105/380/62/664	0.1/0.4/2.0/3.8/5.1	HKH
5	426/713/51/433	0.3/5.1/8.0	KH
6	619/126/1767/107/1185	0.4/1.3/3.9/25.8	HKH
7	706/67/639	0.3/11.4/10.1	KH
8	706/67/639	0.7/3.7	H
9	507/187/1602	0.6/6.5	H
10	124/480/282/1655	0.4/1.5/12.8	KH
11	147/272/1090/230/1863	0.6/3.0/13.2/20.0	KH
12	460/127/736/340/382	0.9/0.4/3.7/0.6	HK
13	39/239/44/257	0.5/3.4/6.9	KH
14	80/698/73/665	0.2/3.4/47.9	KH
15	110/931/29/977	0.7/3.2/15.7	KH
16	229/734/17/375	0.6/7.5/23.0	KH
17	97/646/104/2958	0.5/4.3/22.9	KH
18	61/247/138/924	0.7/4.5/26.7	KH
19	404/609/86/342	0.6/1.8/15.4	KH
20	103/146/97/3827	0.5/3.3/16.7	KH
21	619/410/78/13756	0.4/9.3/114.3	KH
22	220/863/315/616	0.2/5.8/39.3	KH
23	196/706/136/169	1.0/4.2/1.0	KH
24	93/375/167/607	0.5/1.9/64.6	KH
25	479/176/9749	0.3/4.6	H
26	289/523/356/5765	0.3/0.9/6.7	KH
27	132/33/353/24/790	0.4/0.7/6.0/6.7	HKH
28	149/757/183/900	0.7/11.6/23.0	KH
29	270/79/139/1584	6.8/23.4/28.1	KH
30	149/415/81/544	0.6/2.7/22.0	KH
31	2107/582/68/336	0.6/7.6/28.2	QH
32	78/346/136/1564	0.7/5.8/26.4	KH
33	164/571/89/18088	0.6/9.0/58.6	KH
34	42/286/71/653	1.0/4.9/24.0	KH
35	878/653/137/929	0.4/3.0/16.7	KH
36	681/1419/541/597	0.6/3.2/21.1	KH

4.1 Geoelectric sections

4.1.1 Geoelectric sections along east-west direction

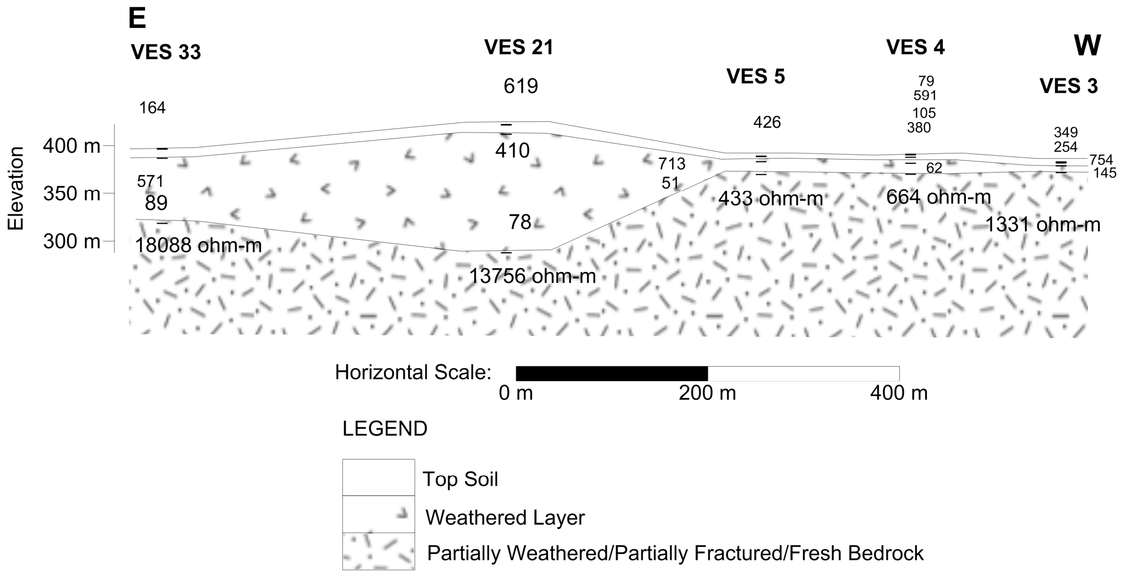
This geo-electric section connects VES 33, 21, 5, 4 and 3 along the E-W direction (Figure 4a). Four to six geoelectric layers were delineated across this section which corresponds to three geologic layers namely, the top soil, weathered layer, fractured basement/presumed fresh basement. The layer resistivity varies respectively as 79 - 619 ohm-m, 254 - 713 ohm-m, 51 - 754 ohm-m, 62 - 380 ohm-m and 433 - 18088 ohm-m, while the layer thickness vary respectively as 0.1 - 0.6 m, 0.1 - 9.3 m, 2.0 - 114.3 m, 3.8 - 4.0 m and 5.1 m - infinity.

4.1.2 Geoelectric sections along northwest-northeast direction

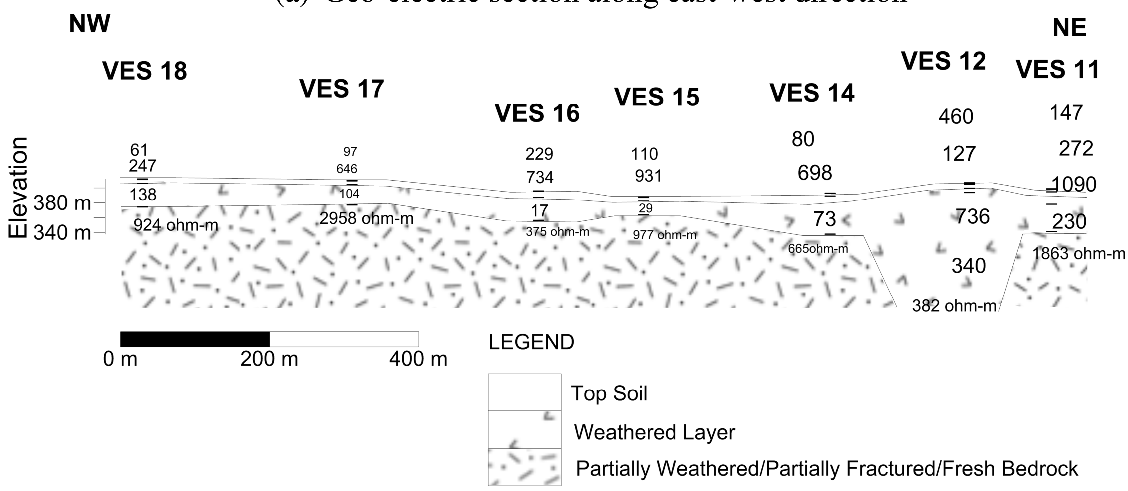
In this geoelectric section; VES 18, 17, 16, 15, 14, 12 and 11 were connected along east-west direction (Figure 4b). Four to five geoelectric layers were delineated across this section which possibly corresponds to three geologic layers namely, the top soil, weathered layer, fractured basement/presumed fresh basement. The layer resistivity varies respectively as 61 - 460 ohm-m, 127 - 931 ohm-m, 17 - 1090 ohm-m, 230 - 340 ohm-m and 375 - 2958 ohm-m, while the layer thickness vary respectively as 0.2 - 0.9 m, 0.4 -7.5 m, 3.7 - 47.9 m and 0.6 - 20.0 m.

4.1.3 Geoelectric sections along north-south direction

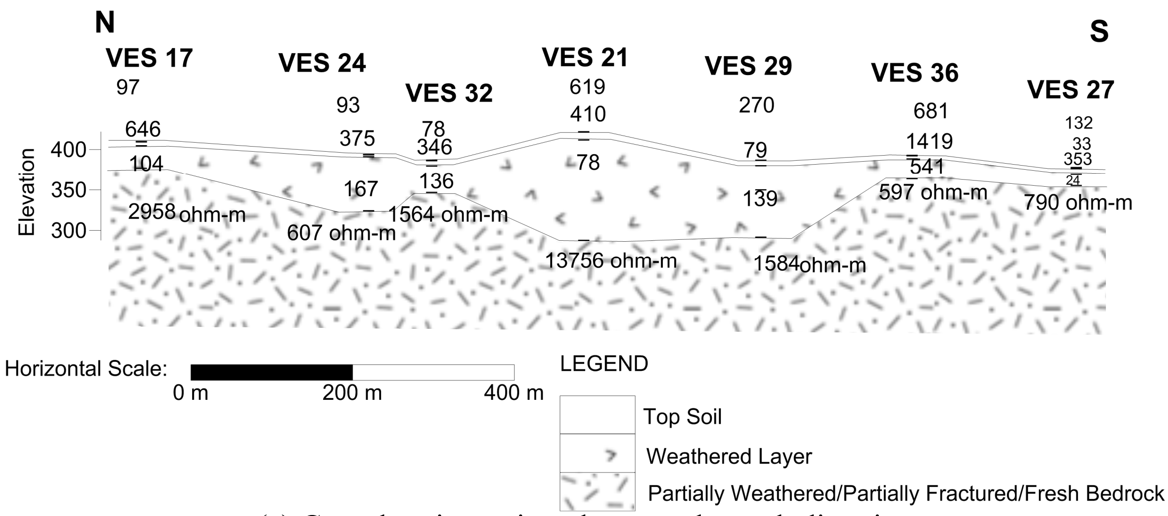
This geoelectric section connects VES points 17, 24, 32, 21, 29, 36 and 27 along the N-S direction (Figure 4c). Four to Five geoelectric layers were delineated across this section which corresponds to three geologic layers namely, the top soil, weathered layer, fractured basement/presumed fresh basement. The layer resistivity varies respectively as 78 - 681 ohm-m, 33 -1419 ohm-m, 78 - 541 ohm-m, and 597 -13756 ohm-m, while the layer thickness vary respectively as 0.2 - 1.3, 3.0 - 12.2, 12.3 - 23.7 and 23.6 - 30.1 m.



(a) Geo-electric section along east-west direction



(b) Geo-electric section along northwest-northeast direction



(c) Geo-electric section along north-south direction

Figure 4_{a-c}: Geo-electrric sections across the study area

4.2 Quartzite reserve estimate calculation

The average traverse resistivity was calculated using this Darzarrouk relationship (Zhody et. al. (1074);

$$\ell_t = T/H = \sum_{i=0}^{n} h_i \ell_i \Big/ \sum_{i=o}^{n} h_i \qquad 2$$

ℓ and h is the layer resistivity and thickness respectively. The average traverse resistivity map (Figure 5) of the study area was generated to ascertain the degree of weathering or freshness of the quartzite deposits. This would give us an insight into the quality of the quartzite deposit. The map (Figure 5) shows that the quartzite deposits has higher average transverse resistivity value at the western and central parts compared to the flanks, this suggest that the deposits is fresher at the central compare to the other flanks.

The quartzite thickness map (Figure 6) was generated from the thickness of the quartzite layer. The thickness of the quartzite deposit varies from 5 to 80 m. This value is a necessary input for the calculation of deposits volume and mass. The quartzite thickness map (Figure 5) shows that the deposit is thicker at the western and central parts, this agrees with the average traverse resistivity map (Figure 5), because the deposit is expected to be thicker where it is less weathered. The average thickness was calculated by adding the thicknesses of the quartzite deposits and divided by number VES points at which quartzite were delineated. The average thickness was estimated to be 8.86 m. The area extent of the quartzite deposit was calculated to be 1,024,729 m^2 using Surfer^{TM} 11 area calculation facility and corroborated with Trapezoidal rule. The volume of the quartzite deposit was calculated by multiplying the average thickness of the quartzite by the area extent. The estimated volume of the quartzite deposit is 9,079,098.9 m^3. Finally the total mass of the quartzite deposit was derived to be 22,788,538 tonnes (Table 3) from the product of the average density (2510 kg/m^3) and the estimated volume of the deposit.

Table 3: Estimated volume and tonnage of the Quartzite deposits

Average thickness (m)	Area (m^2)	Volume (m^3)	Mass (kg)	Mass (tonnes)
8.86	1,024,729	9,079,098.9	22,788,538,000	22,788,538

5. Conclusion and Recommendation

A geophysical investigation was carried out at Ipinsa, near Akure, Ondo State. The study was aimed at estimating the quantity of part of the quartzite deposit in the study area. The survey employed 36 vertical electrical sounding technique using Schlumberger configuration and laboratory measurements of 14 samples of quartzite picked at different locations across the study area in order to determine the average density of the deposits.

The KH curve type constitutes 75% of the total VES curves. The predominance of the KH type curve is not surprising in quartzitic environment with a well-developed fracture system which makes quartzite a favourable source of groundwater in a basement complex environment. The subsurface sequence beneath the study area is generally made up of the quartzite, weathered layer and the host basement bedrock; since quartzite usually occur as vein within the Migmatite-Gneiss-Quartzite environment. The average thickness of quartzite deposit is 8.86 m, while the average resistivity value of the deposit is 150 ohm-m. The area extent of the study area is 1,024,729 m^2, while the estimated volume of the quartzite deposit within the study area is 9,079,098.9 m^3.The estimated tonnage of the study area is 22,788,538 tonnes. Since this research work is a pilot scheme that covers only a portion of Ipinsa quartzite deposits. A total and comprehensive investigation of the whole Ipinsa which must include coring analysis should be carried out in order to determine the total quantity of the quartzite deposits in Ipinsa area.

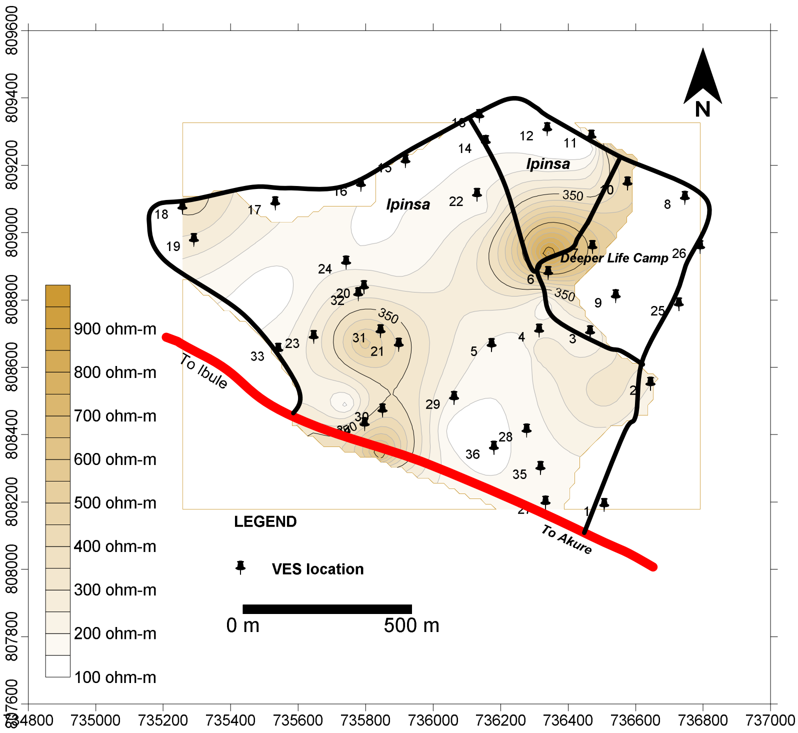


Figure 5: Average transverse resistivity map of the quartzite deposit

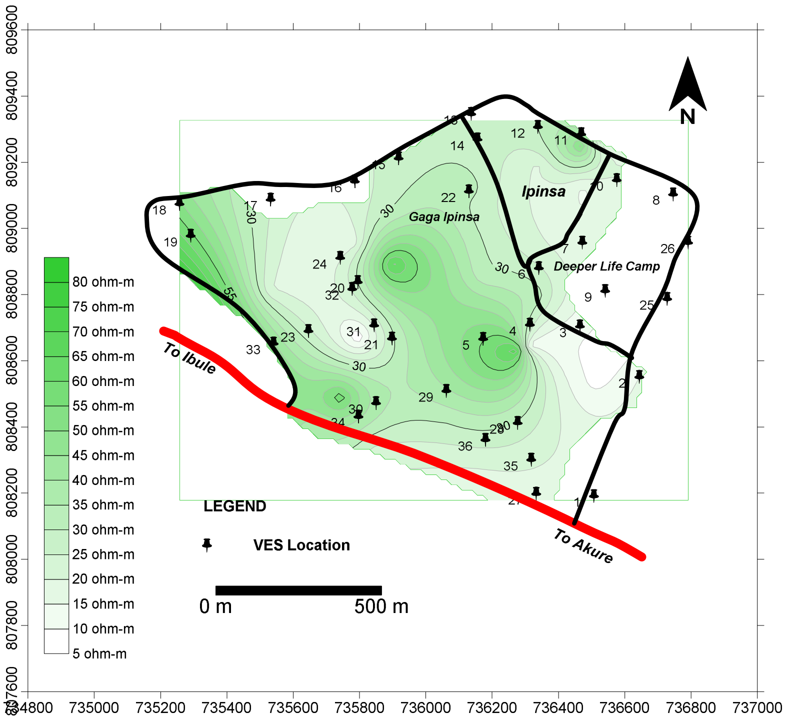


Figure 6: Thickness map of the quartzite deposit

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