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Geophysical Investigation of the Precambrian Marble Occurrence in Itobe Area, Central Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MO designed the study, wrote the first draft of the manuscript and managed literature searches as well as data analysis using WINRESIST software and interpretation of the analysis result. Author AD wrote the final draft of the manuscript and managed additional literature searches as well as interpretation of the analysis results and writing of final manuscript. All authors read and approved the final manuscript.

Short Research Article

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ABSTRACT

Aim: The aim of the study is to delineate the outline of the Itobe marble using geophysical electrical survey method.
Study Design: Eight (8) vertical electrical sounding surveys were carried out along a profile parallel to the trend of the marble outcrop.
Place and Duration of Study: The study area is Itobe and its environs in Kogi state, central Nigeria. Field geophysical resistivity survey of the study area was carried out between January and April 2012.
Methodology: The field resistivity sounding surveys were carried out with an ABEM SAS (1000) Terrameter using the Schlumberger electrode array.
Interpretation of the resistivity sounding data was carried out first by curve matching technique and followed by computer iterative interpretation technique using the Winresist software (version 1.0).
Results: The results of the study revealed the occurrence of an additional marble unit (Mass III) at an elevation of 105m besides two marble units identified from outcrop studies. The thickness of the marble in mass I is 0.6m and that of mass II is 6m.
Conclusion: The outcrop geological survey revealed the occurrence of two marble units

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(described as mass I and mass II).The geophysical survey revealed an additional marble unit (described as mass III) in the study area.

Keywords: Marble; outcrop; apparent resistivity; mass survey; sounding.

1. INTRODUCTION

Marble, a major mineral raw material for industries, is a crystalline, non-foliated metamorphic rock formed from limestone or dolostone due to the action of heat and pressure.

The Itobe marble body is located about 1km from Itobe town along the Ajaokuta-Anyigba road, Kogi state, central Nigeria. The study area lies between longitudes $6^0 40'$ E and $6^0 48'$E and latitudes $7^0 22'$N and $7^0 30'$ N (Fig. 1).

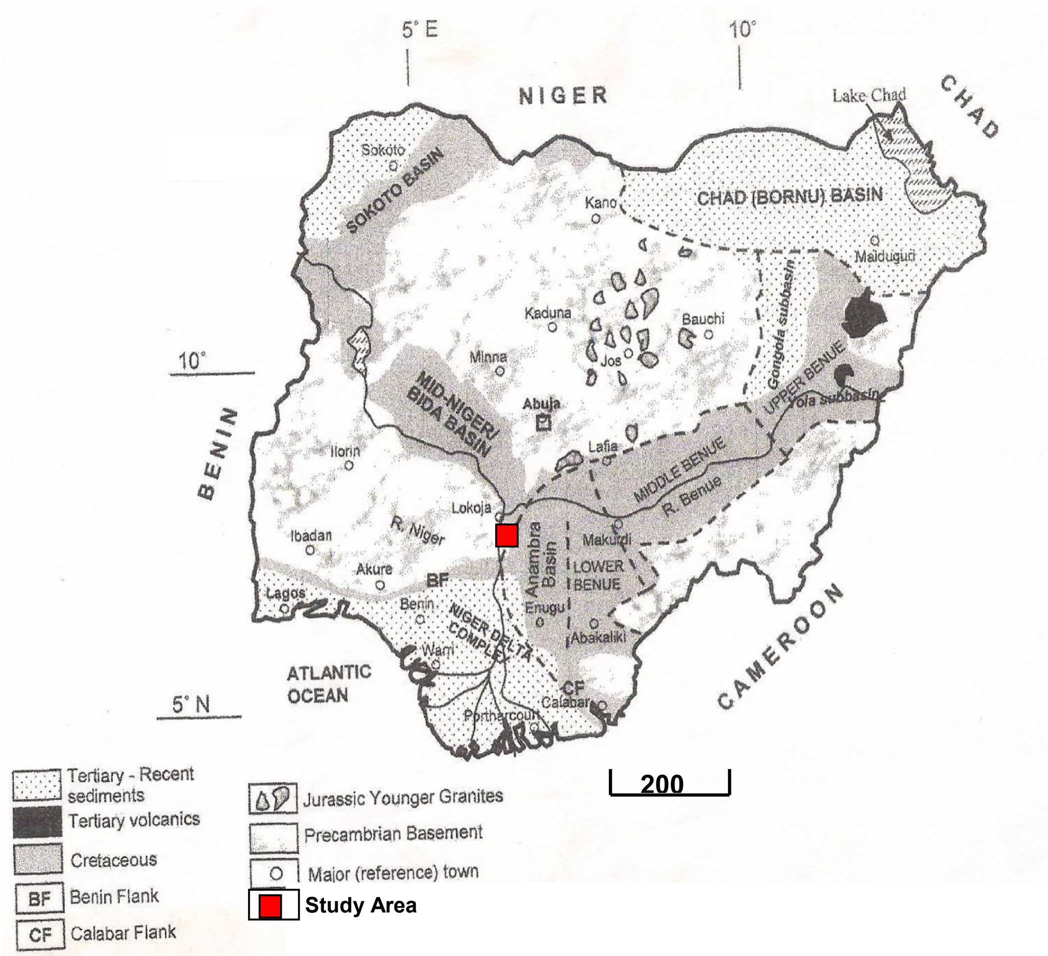

Fig. 1. Geological sketch map of Nigeria showing the location of the study area (After Obaje [1])

Geophysical investigation methods have been employed in the subsurface exploration of marble deposits to delineate the boundary and thickness of the deposits. The electrical resistivity method of geophysical prospecting in particular has been employed in the geophysical investigation of marble bodies. The choice of the resistivity method was informed by the local resistivity contrast characteristics of marble deposits (10^2 - 2.5×10^8 Ωm) compared to the immediate host rocks of schists (20 -10^4 Ωm) and quartzites (10 - 2×10^8 Ωm), Folami and Ojo, 1991, Ojo and Olorunfemi [2]; Aina and Olorunfemi [3] Odeyemi et al. [4], Jatau and Bajeh [5].

The properties that affect the resistivity of soil or rock include: porosity, water content, composition, salinity of water, and grain size distribution. Therefore, the electrical resistivity method provides information on ground water condition and lithology.

Ojo et al. [6] carried out a geophysical investigation involving electrical and magnetic surveying of the Burum-Takalafia marble deposit around Abuja, central Nigeria. The result of the investigation revealed a local resistivity variation in the range of 20-61 ohm-m within an immediate background of less than 10 ohm-m, and low magnetic effect of less than 800 gammas. The outline of the marble deposit based on the above characteristics has an approximately NE-SW trend with a lateral and width extent of about 400m and 40m, respectively and a plunge in the southwest direction.

Odeyemi et al. [4] employed the gravity, magnetic and geoelectrical methods to investigate the geophysical characteristics of the Ikpeshi marble deposit in Igarra area, southwestern Nigeria. The Geoelectrical (Resistivity) method was used to determine the initial overburden models for the gravity and magnetic models. Based on these investigations, a maximum overburden thickness of 40 meters was established for the marble deposit. Gravity survey data estimated a width of 360m and a thickness of 150m for the marble body while magnetic survey data indicated a width of 350m and a minimum thickness of 65m.

This study seeks to delineate the boundary of the Itobe marble deposit using the electrical resistivity method of geophysical prospecting.

2. FIELD GEOLOGIC OCCURRENCE

The Itobe marble body is associated with crystalline rocks of the Precambrian basement complex including biotite schist, mica (muscovite & biotite) schist, quartz- muscovite schist, quartzite, biotite- hornblende schist, quartz schist, gneissic granite and minor intrusive rocks including pegmatite, quartz and quartzo-feldspathic veins. The marble body occurs within a host rock of mica/ quartz schist and feldspathic quartzite (Fig. 2). Two outcrops (described as mass I and mass II) of the marble have been identified in the study area. Mass I with a dimension of 1.4m x 0.6m, trends NE - SW with a strike azimuth of 033°. It is poorly exposed at the road cut about 150 m to Alo I village along the Anyigba – Itobe road (Plate 1). It is light grey in colour and fine grained in texture. Mass II, which is about 800m from mass I on a NE-SW axis, is a much larger marble body and outcrops on the Ayanka hill as massive boulders. It is medium grained in texture, dark grey in color and rises from an elevation of 132m to 138m on the hill (Plate 2). It has a sharp contact with the quartz schist below and the feldspathic quartzite overlying it.

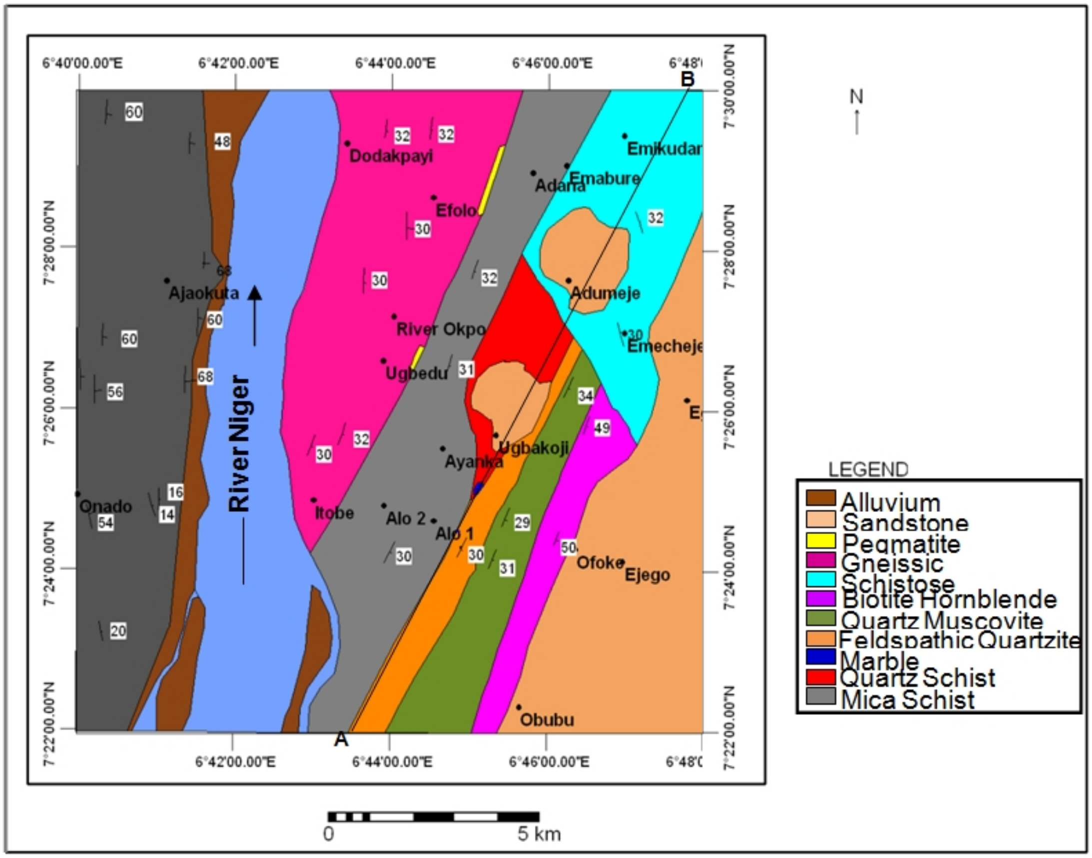

Fig. 2. Geologic Map of the Itobe Marble Area

Plate 1. Marble Outcrop (Mass I) at a Road Cut about 150m to Alo (GPS Location: N 07°24.627′, E 006° 45.163′)

Plate 2. Marble Outcrop (Mass II) on Ayanka Hill (GPS Location N 07°24.714′, E 006°44.848′)

3. METHOD OF STUDY

The geological survey of the study area was done by the traverse method which involves proceeding along pre-determined oriented compass routes, streams and bush paths, and locating rock outcrops, identifying the rocks on the field where possible and taking measurements of strike and dip (using the Bruton Compass-Clinometer) of rock outcrops and structures observed on them. Mapping was done using a 1: 25,000 topographic map prepared from the Idah topographic map sheet (sheet 267) on a scale of 1:100,000. Measurements/observations made on rock outcrops were plotted on the topographic map and the Geologic map was produced by drawing the contacts between the rock types. The ILWIS 3.1 academic software obtained from the National Remote Sensing Centre, Jos, Nigeria was used to produce the geologic map (Fig. 2).

The electrical resistivity method of geophysical prospecting employed in the survey of the marble deposit involves the measurement of the resistance of the earth using an ABEM SAS 1000 Terrameter.

The Vertical Electrical Sounding (VES) technique using the Schlumberger configuration was employed for the investigation. The apparent resistivity (ℓ_a) obtained for the Schlumberger configuration for the resistivity depth investigation along the marble deposit is given by:

$$\ell_a = \pi/4 \times \frac{((AB)^2 - (MN)^2)}{(MN)} \times R$$

Where AB is the current electrode separation, MN is the potential electrode separation, and R is the measured resistance in ohms.

Eight vertical electrical sounding surveys were carried out in the study area along profile AB on a NE- SW axis parallel to the trend of the outcropping marble in the area (Fig. 3). The geographic coordinates and elevations of the VES locations were obtained using the Etrex

Global Positioning System. The apparent resistivity values obtained from the VES survey were plotted against AB/2 on a bi-logarithmic paper to obtain the resistivity sounding curve. Preliminary interpretation of the VES data was done by curve matching. This was then followed by computer interpretation using the Winresist software (Version 1.0). The computer iterative interpretation of the sounding curves is based on the Digital Linear Filter method [7] for the fast computation of resistivity function for a given set of layer parameters. The technique involves seeking a solution to the inverse problem, namely the determination of the subsurface resistivity distribution from surface measurements. An important parameter in seeking a solution to the inverse problem is the Kernel function which is useful in interpreting apparent resistivity measurements in terms of lithological variations with depth.

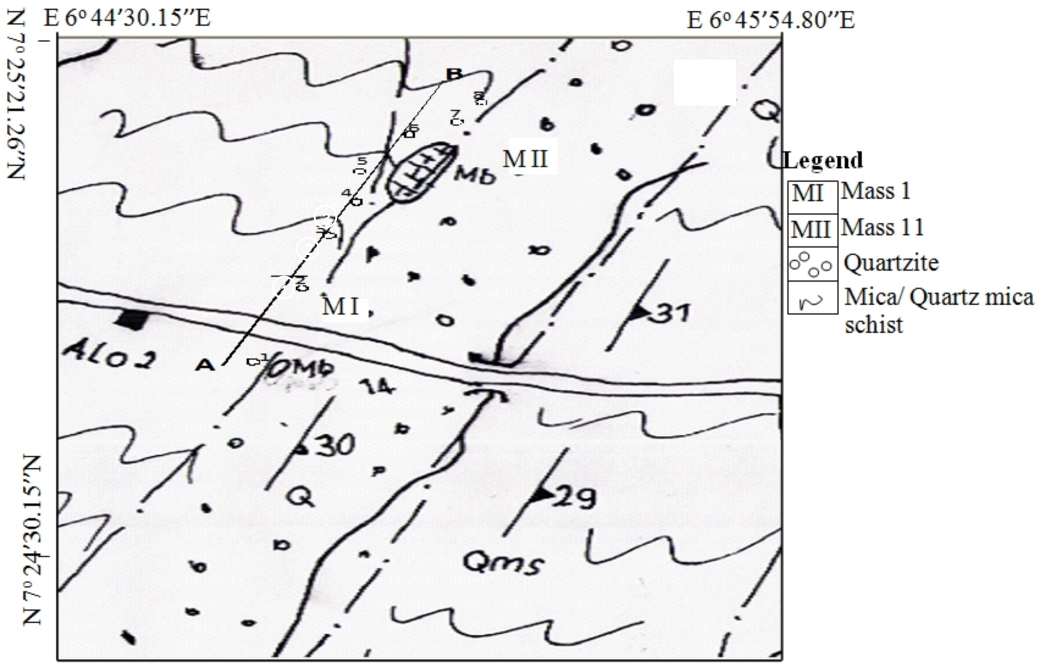

Fig. 3. Map of the study area showing the vertical electrical sounding locations

4. RESULTS AND DISCUSSION

The resistivity sounding data for the eight vertical electrical sounding surveys along the marble deposit are presented in Table 1, and the corresponding resistivity sounding curves are shown in Figs. 4 - 11. The interpretation of the VES surveys involves the determination of the geoelectric layer parameters (resistivity and thickness) of the marble and the surrounding rocks (Table 2).

An estimated value for marble resistivity in the locality based on the resistivity value obtained from the outcropping marble at VES 2 is taken to be between 500-600 Ωm depending on water content and porosity. The marble body in the study area is characterized by a local resistivity high in the range 500- 600 Ωm within a host rock of low resistivity (50 - 250 Ωm) characteristic of the mica schist/quartz schist and relatively high resistivity (1002 – 1967 Ωm) characteristic of the quartzite.

Table 1. Vertical electrical sounding data in the study area

AB/2 (m)	Apparent Resistivity (Ωm)					AB/2 (m)	Apparent Resistivity (Ωm)		
	VES 1 Elevation = 116m	VES 2 Elevation = 114m	VES 3 Elevation =113m	VES 4 El evation =112m	VES 5 Elevation =117m		VES 6 Elevation = 118m	VES 7 Elevation =114m	VES 8 Elevation = 112m
1.0	1185	380	340	1100	1776	1.1	61	110	105
1.3	1000	300	284	985	1544	1.6	69	95	93
1.8	642	160	147	778	1154	2.3	80	78	75
2.4	398	130	95	700	822	3.4	99	70	60
3.2	177	96	80	589	570	5.0	105	80	50
4.2	100	81	70	486	389	7.3	119	105	60
5.6	77	43	61	403	324	0.7	122	142	69
7.5	67	70	61	274	263	15.8	130	180	85
10.0	74	75	69	184	260	23.2	150	250	120
13.3	84	85	75	132	285	34.1	190	320	170
18.0	81		90	120	300	50.0	255	400	240
24.0	97		98	130	330	73.5	340	500	340
32.0	110			150	340				

The outcropping marble in VES 2 is suspected to extend to VES 3 as reflected by the resistivity values (552-523 Ωm) between the two VES stations. The resistivity sounding survey reveals the presence of a marble unit at a depth elevation of 105m below the outcropping marble between VES 5 and VES 6. This marble unit is characterized by a resistivity value in the range 538 - 600 Ωm, and is separated from the outcropping marble unit by a quartz schist layer (Fig. 13). Fig. 12 shows the profile of the possible geoelectric layers.

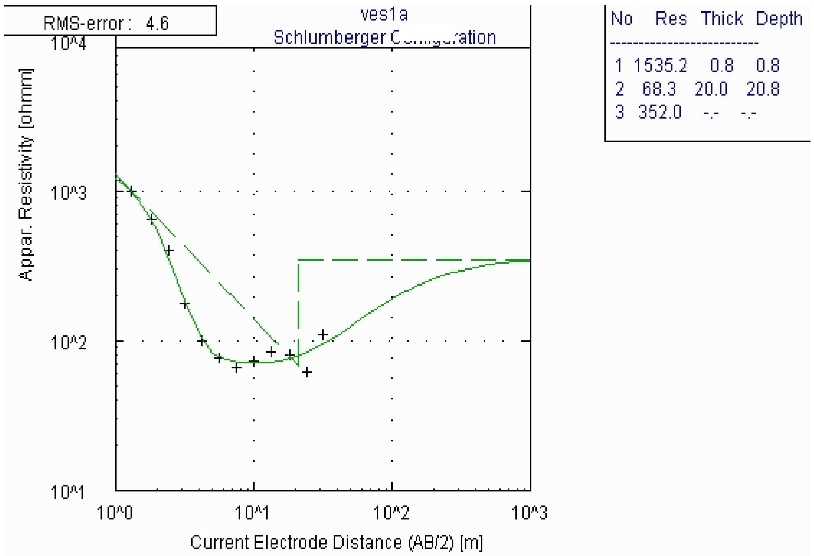

Fig. 4. Apparent Resistivity Sounding Curve for VES 1

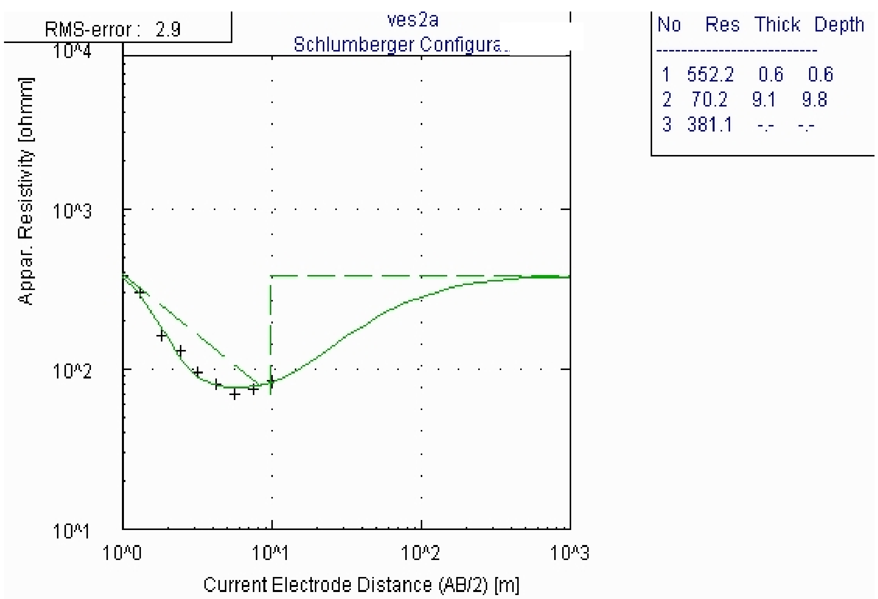

Fig. 5. Apparent Resistivity Sounding Curve for VES 2

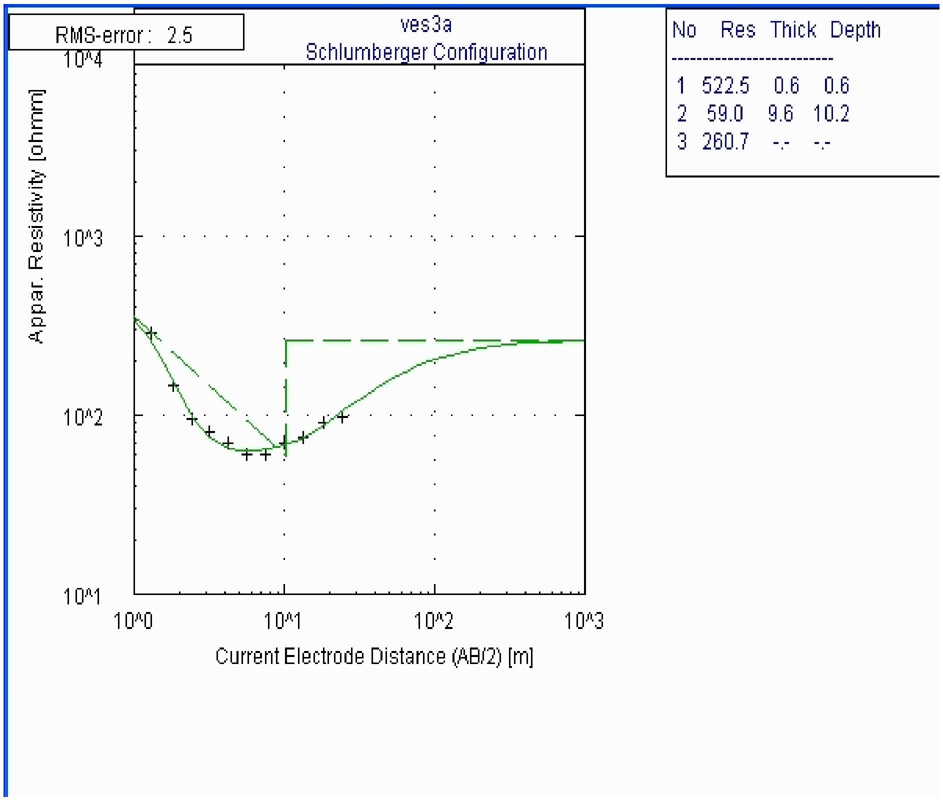

Fig. 6. Apparent Resistivity Sounding Curve for Ves 3

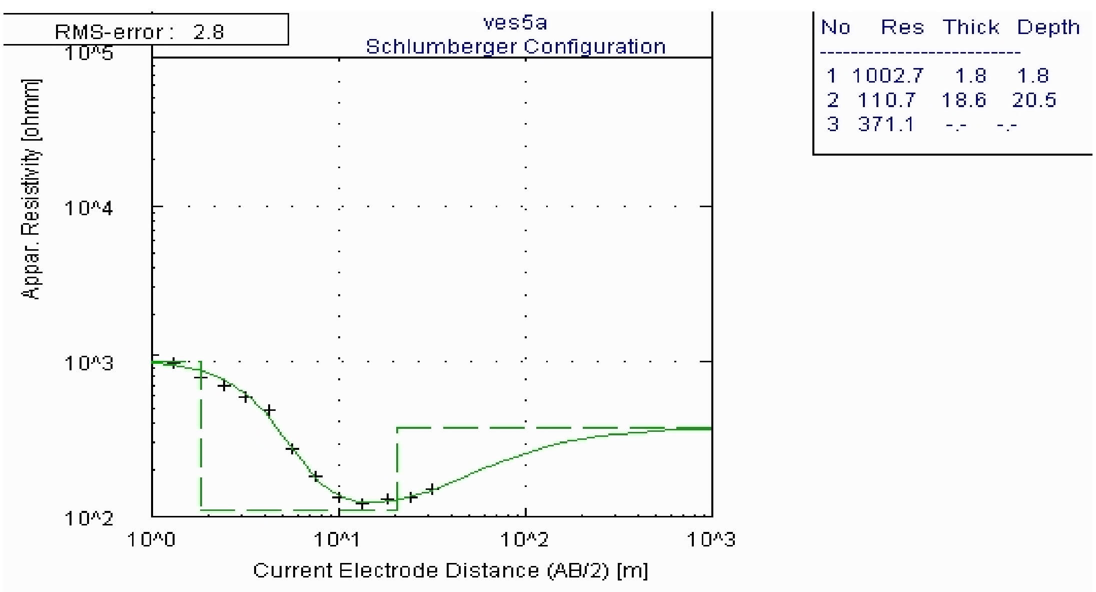

Fig. 7. Apparent Resistivity Sounding Curve for Ves 4

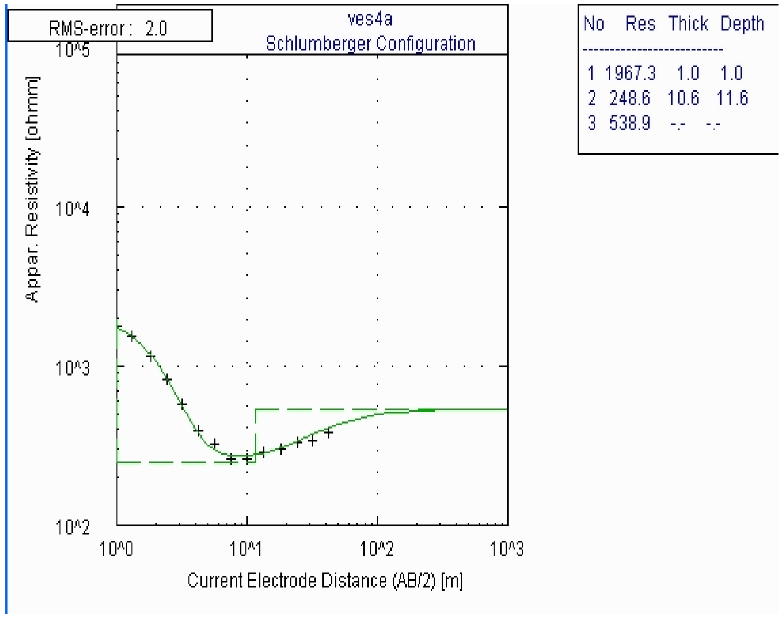

Fig. 8. Apparent Resistivity Sounding Curve for VES 5

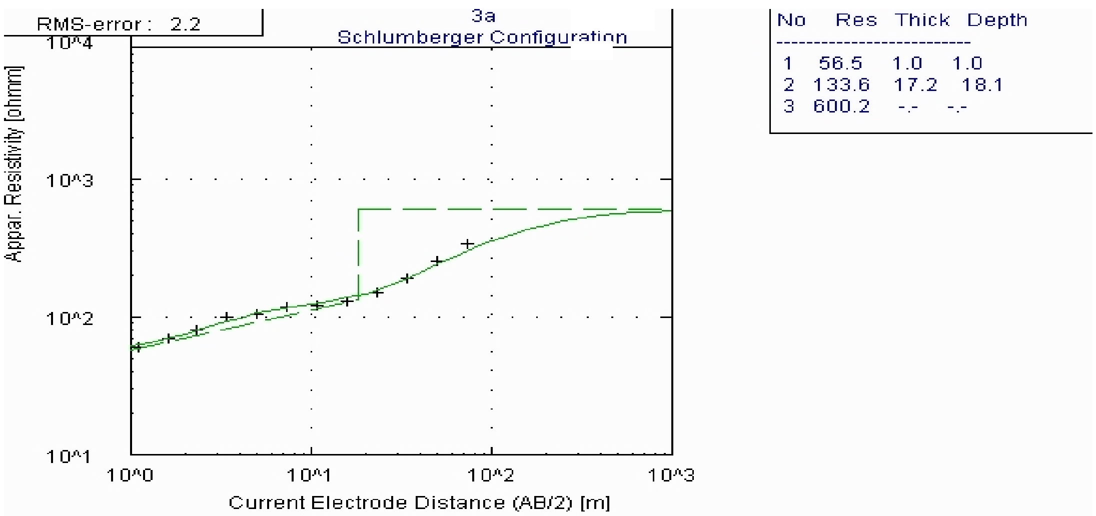

Fig. 9. Apparent Resistivity Sounding Curve for VES 6

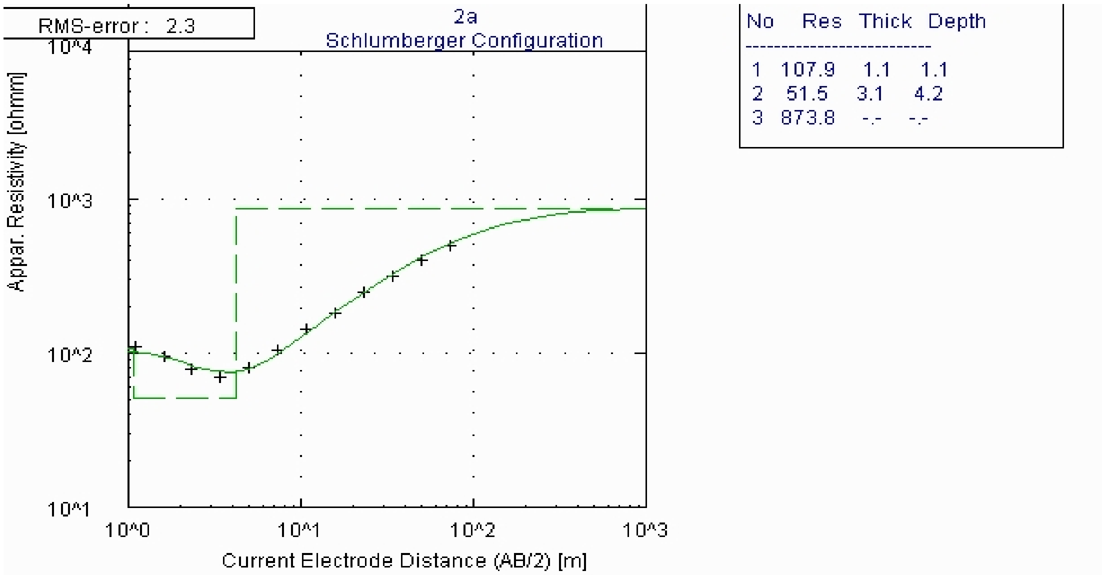

Fig. 10. Apparent Resistivity Sounding Curve for VES 7

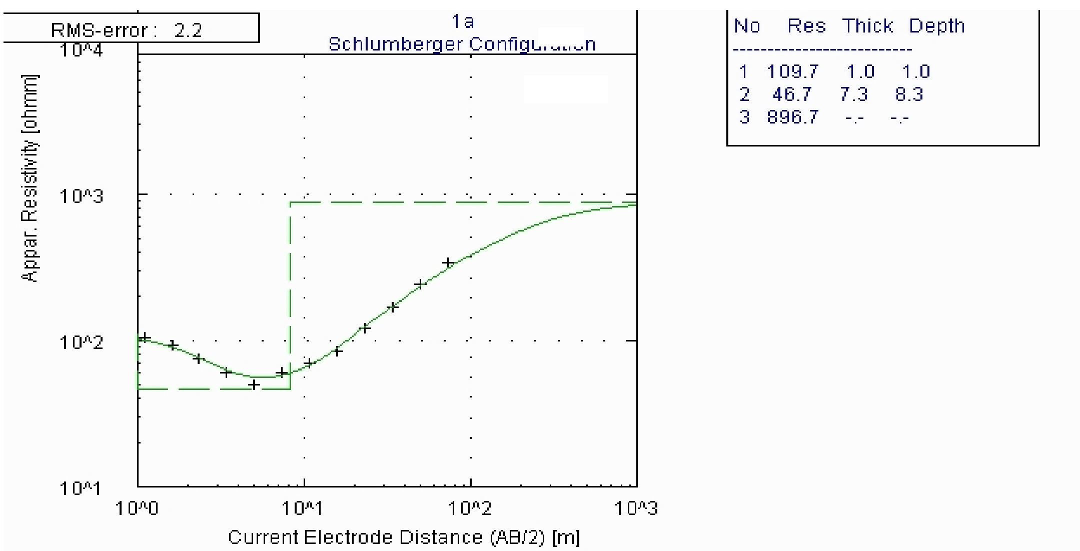

Fig. 11. Apparent Resistivity Sounding Curve for VES 8

Table 2. Geoelectric layer Parameters (Resistivities, Thicknesses and Depth) obtained in the VES location in the survey area

VES Location	RMS Errors	Layer Resistivity (Ωm)			Layer Thickness (m)			Depth to Layer (m)		
		1	2	3	1	2	3	1	2	3
VES 1	4.6	1535.2	68.3	352.0	0.8	20.0	-	0.8	20.8	-
VES 2	2.9	552.2	70.2	381.1	0.6	9.1	-	0.6	9.8	-
VES 3	2.5	522.5	59.0	260.7	0.6	9.6	-	0.6	10.2	-
VES 4	2.8	1002.7	110.7	371.1	1.8	18.6	-	1.8	20.5	-
VES 5	2.0	1967.3	248.6	538.9	1.0	10.6	-	1.0	11.6	-
VES 6	2.2	56.5	133.6	600	1.0	17.2	-	1.0	18.1	-
VES 7	2.3	107.9	51.5	873.8	1.1	3.1	-	1.1	4.2	-
VES 8	2.2	109.7	46.7	896.7	1.0	7.3	-	1.0	8.3	-

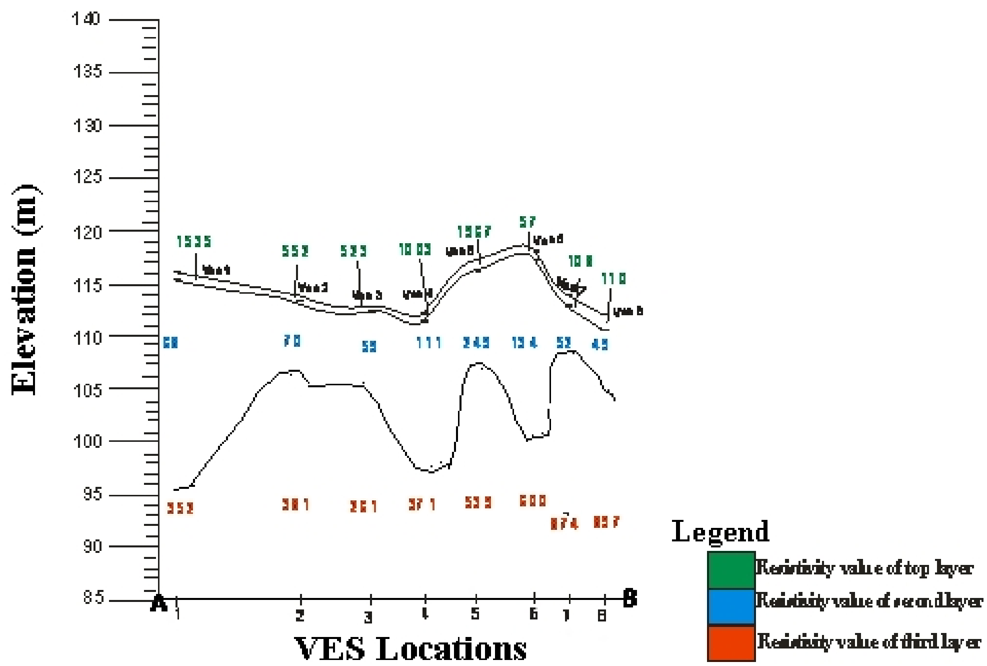

Fig. 12. Geoelectric section along profile AB.

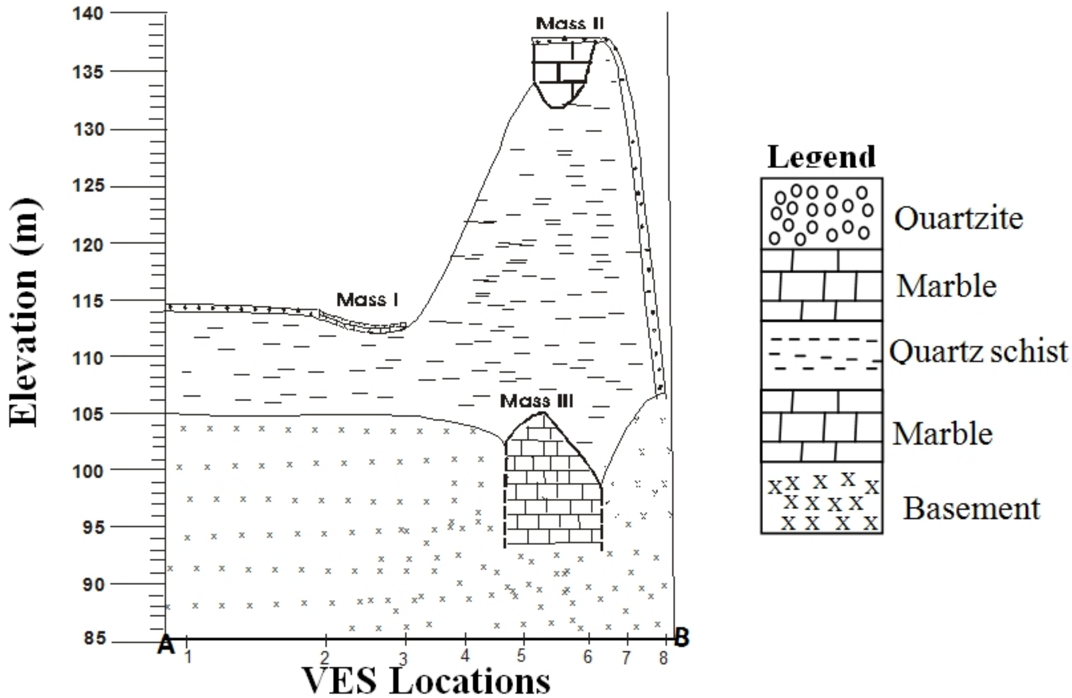

Fig. 13. Cross section along Profile AB delineating the boundary of the marble deposit from both geoelectric survey and outcrop survey.

5. CONCLUSION

Geophysical resistivity sounding survey in the Itobe marble area revealed an additional marble unit (described as mass III) besides the marble units (masses I and II) observed from outcrop geological studies. The probable thickness of the Itobe marble is not known as there are no lithologs from drilled holes in the study area; however a maximum thickness of 6m was established for the outcrops in masses I and II. The thickness of the marble in mass III could not be ascertained, but the elevation of the top of the marble has been delineated at 105m, below Mass II.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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