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APPLICATION OF GEOPHYSICAL TECHNIQUE IN DELINEATION OF MARBLE DEPOSIT IN IKPESHI, EDO, NIGERIA

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ABSTRACT: *The increasing demand for mineral substances and the need to maintain the current consumption pattern require constant research for new deposits or studies to expand exploration reserves. A geophysical technique was employed in the delineation of this mineral deposit. The results obtained in each VES have three geo-electric layers, which comprise clay/clayey-sand (81.8 – 155.7 Ωm), Sand (101.8 – 380.4 Ωm) and marble (1019 – 4419 Ωm) horizon units. The geologic section was deduced from borehole log data acquired within the study area. All the surveyed locations show traces of the existence of marble deposits in the area. The study revealed occurrences of marble deposits in the study area, which will be of economic importance if exploited. The reserve tonnage was calculated to be about 1.69 x 10^6 tons. This estimate signifies that there is a fair reserve of marble within the study portion of the location.*

KEYWORDS: Marble, Resistivity, Vertical Electrical Sounding (VES), Reserve Toonage, and reserve volume.

INTRODUCTION

The increasing demand for mineral substances and the need to maintain the current consumption pattern require constant research for new deposits or studies to expand exploration reserves. The procedures traditionally used in the discovery and characterisation of new mineral occurrence include the sampling of soil, rock, and chemical analysis and direct tools like surveys, besides indirect tools, such as the geophysical methods (Moon et al., 2006). When a prospect is defined, the exploration work progresses through a series of detailed incremental steps, where success leads to the beginning of a new phase. On the other hand, negative results can lead to discarding the prospect or sale, implicating waiting for new technologies. Generally, techniques for prospecting obey a sequence of working phases essential for developing the prospectus, such as the generation of targets, targets for drilling, assessment of drilling resources and feasibility studies (Marjoribanks, 2010).

Marble is a metamorphic rock that forms when limestone is subjected to the heat and pressure of metamorphism. It is composed primarily of the mineral calcite ($CaCO_3$) and usually contains other minerals, such as clay minerals, micas, quartz, pyrite, iron oxides, and graphite. Under the conditions of metamorphism, the calcite in the limestone re-crystallises to form a rock that is a mass of interlocking calcite crystals. A related rock, dolomitic marble, is produced when dolostone is subjected to heat and pressure.

The transformation of limestone into marble usually occurs at convergent plate boundaries where large areas of the earth’s crust are exposed to the heat and pressure of regional metamorphism. Some marble also forms by contact metamorphism when a hot magma body heats adjacent limestone or dolostone. This process also occurs at convergent plate boundaries. Before metamorphism, the calcite in the limestone is often in the form of lithified fossil material and biological debris. During metamorphism, this calcite re-crystallises and the texture of the rock changes.

The study area lies within latitudes $7^0$13’94” N to $7^0$14’02” N and longitudes $6^0$19’26” E to $6^0$19’42” E of Ikpeshi in the northern part of Edo State, Nigeria. Geologically, it falls within the Basement Complex of south-southern Nigeria.

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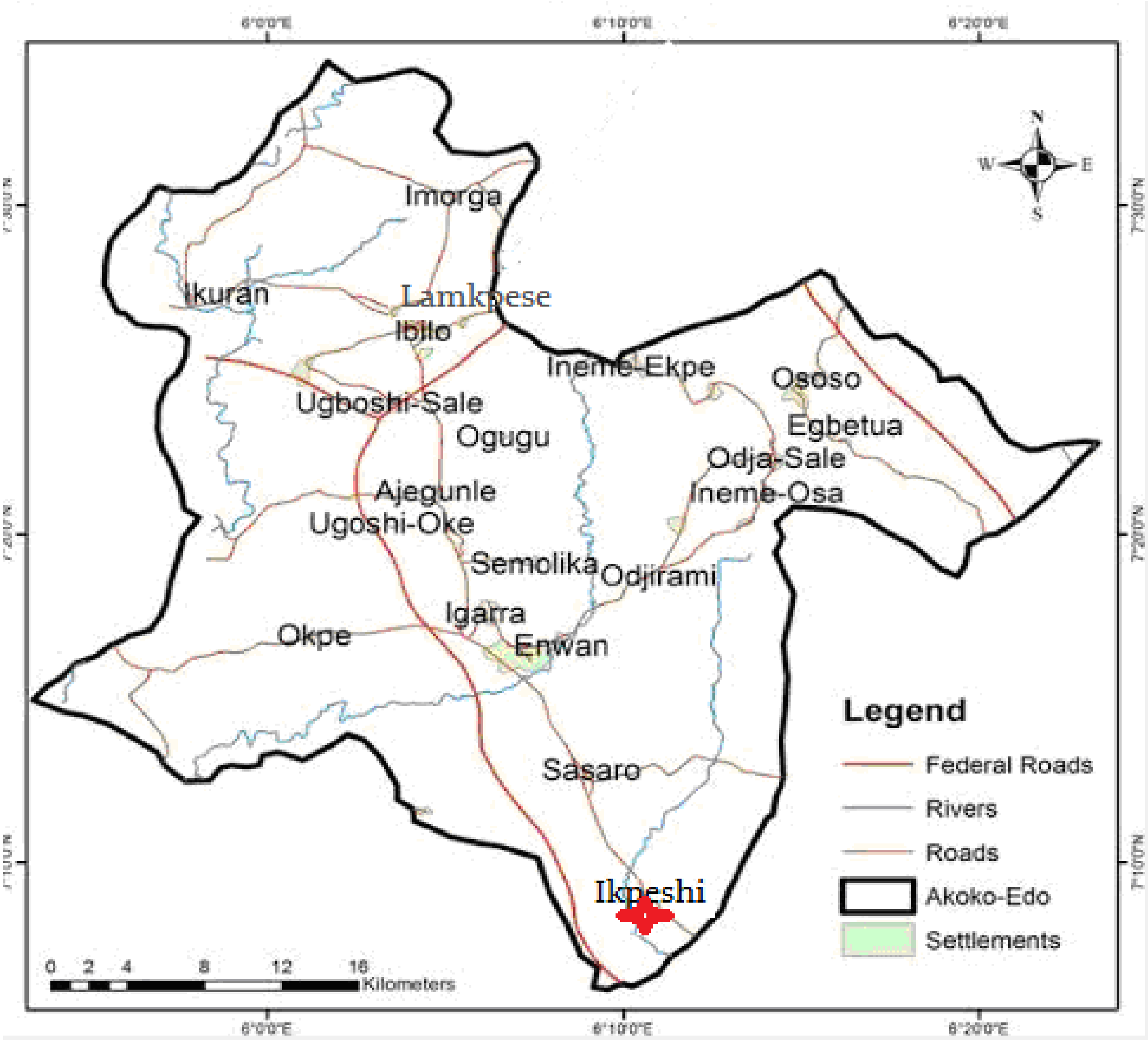

Figure 1: Map of Akoko-Edo, showing the location of Ikpeshi

Geology of the Study Area

Ikpeshi is underlain by the rock of the Precambrian Basement Complex; its marble strikes regionally at about 140^0- 145^0. The outcrop surface shows an assemblage of thin dykes, especially along the river channel.

The deposit occurs as a north-south trending unit of marble, exposed along a river, 3km north-east of Ikpeshi. Marble found is fine to medium-grained and has dark grey, grey, sugary white, and blue in colour, with a complete absence of calc-gneiss or other impurities, Odeyemi (1997). Ikpeshi marble is said to be the most beautiful because it's typically bluish in colour. The finer-grained varieties show a conspicuously strong foliation, which runs at 140^0. The deposit is disposed of within a generally flat terrain. It is flanked on the east by quartz-biotite schist and on the west by pink feldspar granite.

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The petrology of Ikpeshi marble consists dominantly of equigranular granoblasts of calcite, which show mutually interlocking gain boundaries. The crystals are typically rhombohedral and show distinctive polysynthetic twinning. Where foliation is strong, the long axes of the calcite grains exhibit mutual parallelism. No cal-silicate minerals are observable.

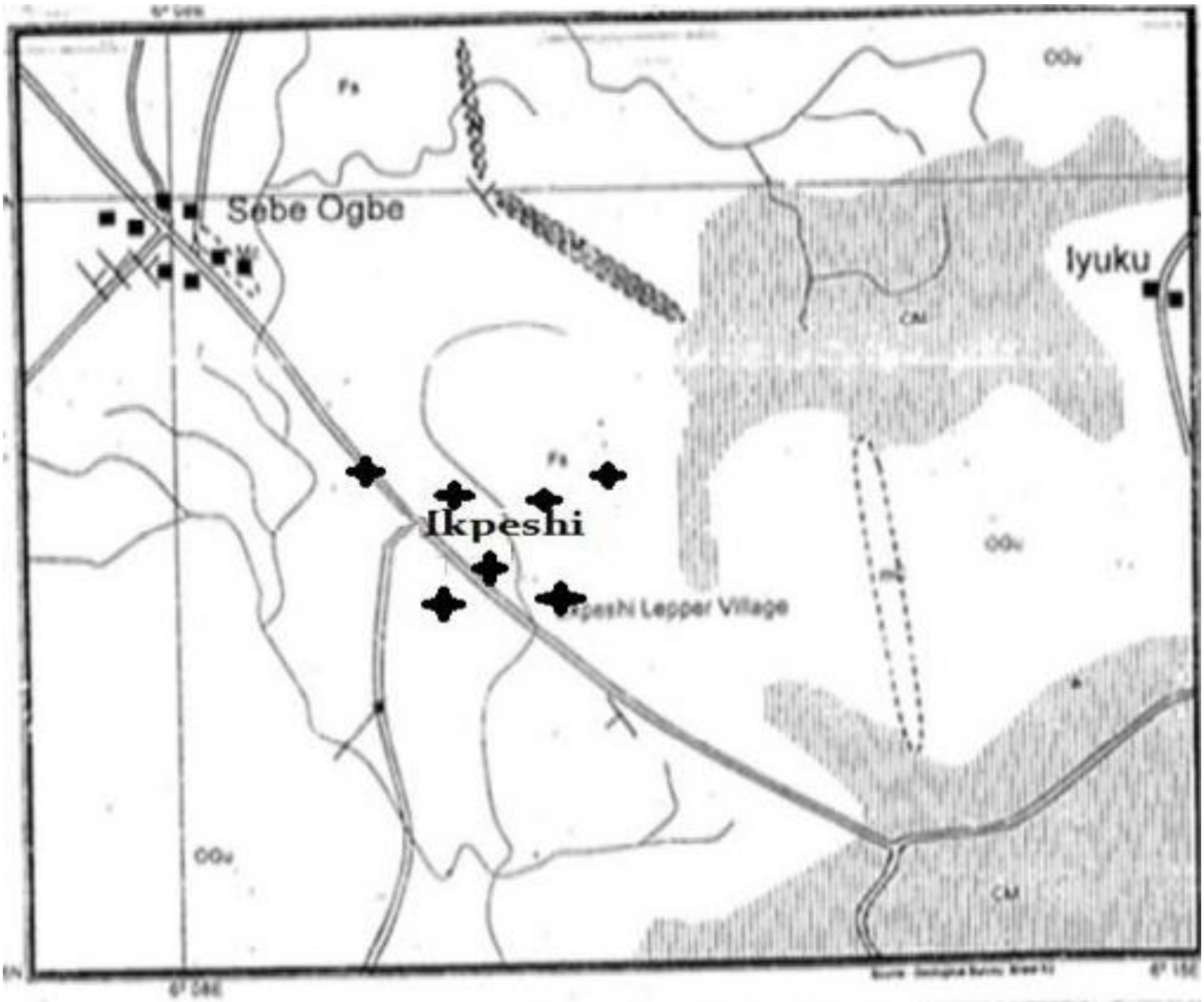

Figure 2: Map of Ikpeshi, showing the sampling VES points. Modified after Ajibade & Olaleye, (2012)

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MATERIAL AND METHOD

An electrical resistivity technique was employed using Schlumberger array configuration. The instruments used are a Herojat terrameter, accessories, compass clinometer, hand lens, and Global Positioning System (GPS) to delineate the extent of marble deposit and trending direction. This is an active technique in the electrical method where current is injected into the subsurface. A third-party software package, WinResist (1-Dimension processing software), was used for the resistivity data processing.

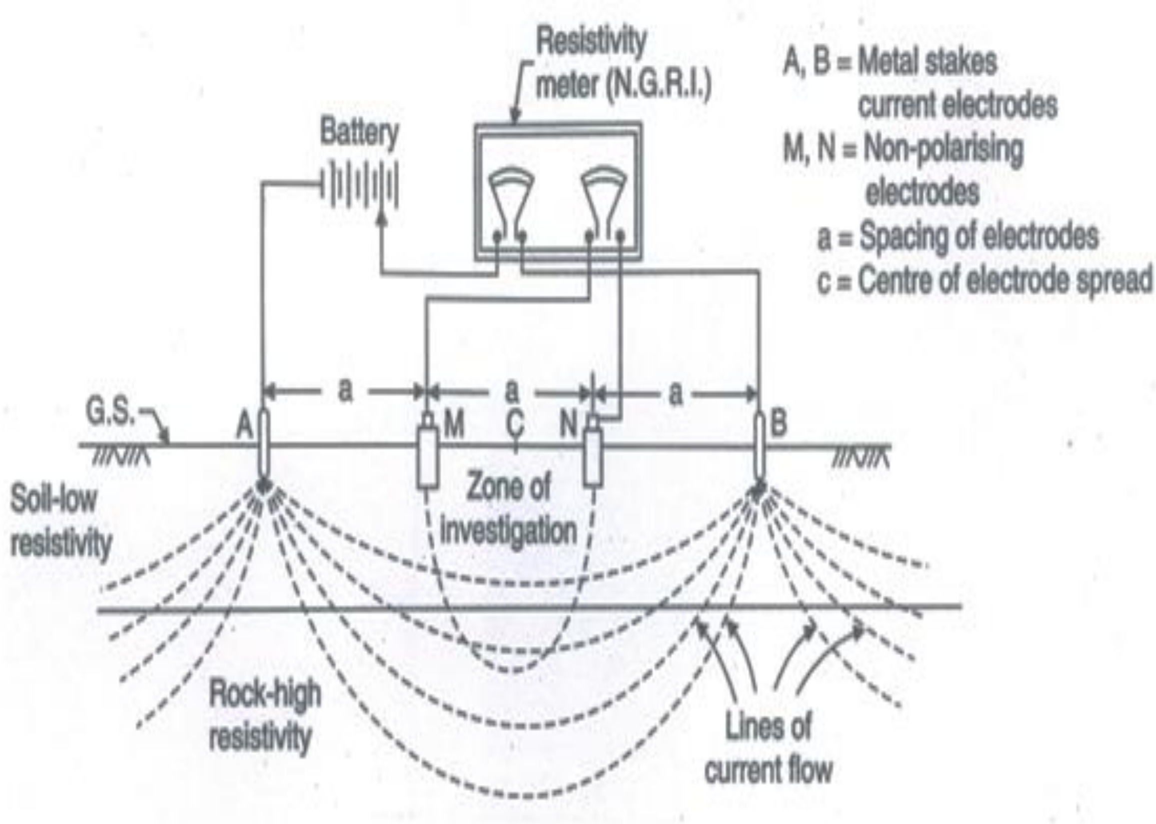

Figure 3: Schematic view of the Wenner electrode arrangement. (Source: Raghunath, 2007)

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RESULTS AND DISCUSSION

Table 1 shows the geo-electric layers of the seven geophysical surveys carried out in the study area

Table 1: Showing Resistivity, Thickness, Depth of VES

VES STATION	LAYER	RESISTIVITY (Ωm)	LAYER THICKNESS	DEPTH	INFERED LITHOLOGY
VES 1	ρ_1 ρ_2 ρ_3	380.4 62.4 4418.5	1.0 3.8 ∞	1.0 4.9 -	SAND CLAYEY-SAND MARBLE
VES 2	ρ_1 ρ_2 ρ_3	282.7 37.3 1275.2	1.1 4.2 ∞	1.1 5.2 -	SAND CLAYEY- SAND MARBLE
VES 3	ρ_1 ρ_2 ρ_3	101.8 70.6 956.1	1.6 3.2 ∞	1.6 4.9 -	SAND CLAYEY-SAND MARBLE
VES 4	ρ_1 ρ_2 ρ_3	341.0 155.7 1019.8	1.1 7.1 ∞	1.1 8.2 -	SAND SAND MARBLE
VES 5	ρ_1 ρ_2 ρ_3	380.2 247.1 1640.8	1.2 20.2 ∞	1.2 21.4 -	SAND SAND MARBLE
VES 6	ρ_1 ρ_2 ρ_3	228.4 73.3 790.5	1.1 5.2 ∞	1.1 6.3 -	SAND CLAYEY-SAND MARBLE
VES 7	ρ_1 ρ_2 ρ_3	228.1 81.8 1863.1	1.1 5.3 ∞	1.1 6.4 -	SAND CLAYEY-SAND MARBLE

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The field data were then processed to obtain geo-electric parameters and interpreted quantitatively and qualitatively. The curves at each VES point are shown below;

Location 01: (N07^{0}8’23”, E006^{0}11’38”. ELV. 142.4 m)

Distance	Resistivity	No
1.00	533.0000	1
2.00	188.0000	2
3.00	134.0000	3
5.00	116.0000	4
6.00	106.0000	5
8.00	64.0000	6
10.00	134.0000	7
15.00	206.0000	8
20.00	258.0000	9
30.00	394.0000	10
40.00	625.0000	11
50.00	895.0000	12
60.00	982.0000	13
70.00	1126.0000	14
80.00	1185.0000	15
100.00	1302.0000	16

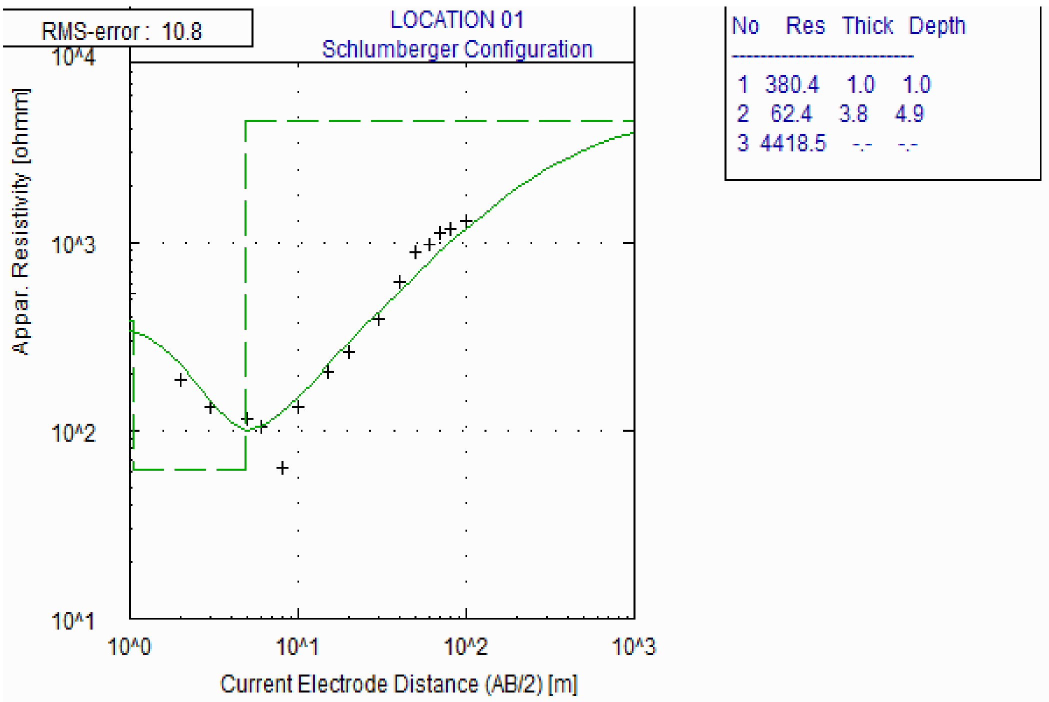

Figure 4: Resistivity values and matching curve for sounding point 1.

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Location 02: (N07⁰8'26", E006⁰11'41". ELV. 147.8 m)

Distance	Resistivity	No
1.00	422.0000	1
2.00	169.0000	2
3.00	82.0000	3
5.00	64.0000	4
6.00	59.0000	5
8.00	57.0000	6
10.00	72.0000	7
15.00	109.0000	8
20.00	150.0000	9
30.00	246.0000	10
40.00	313.0000	11
50.00	329.0000	12
60.00	408.0000	13
70.00	477.0000	14
80.00	529.0000	15
100.00	620.0000	16

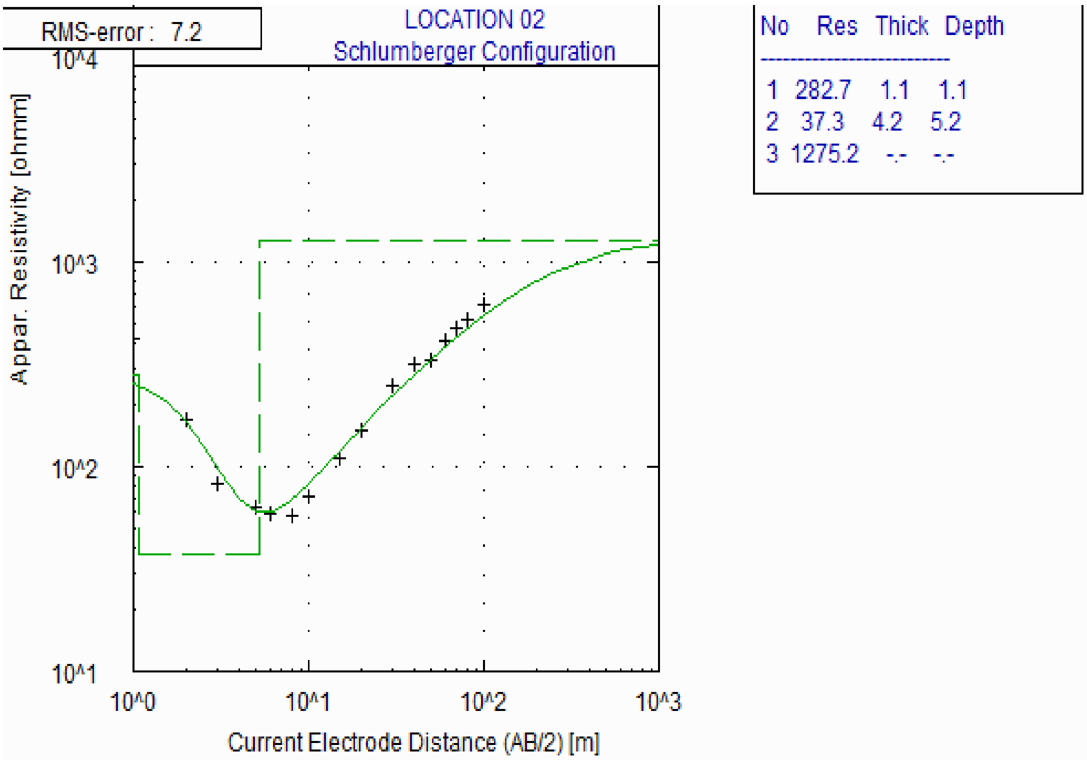

Figure 5: Resistivity values and matching curve for sounding point 2.

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Location 03: (N07^{0}8’23”, E006^{0}11’35”. ELV. 156.4 m)

Distance	Resistivity	No
1.00	93.0000	1
2.00	115.0000	2
3.00	88.0000	3
5.00	97.0000	4
6.00	102.0000	5
8.00	132.0000	6
10.00	135.0000	7
15.00	176.0000	8
20.00	268.0000	9
30.00	370.0000	10
40.00	463.0000	11
50.00	465.0000	12
60.00	489.0000	13
70.00	558.0000	14
80.00	601.0000	15
100.00	641.0000	16

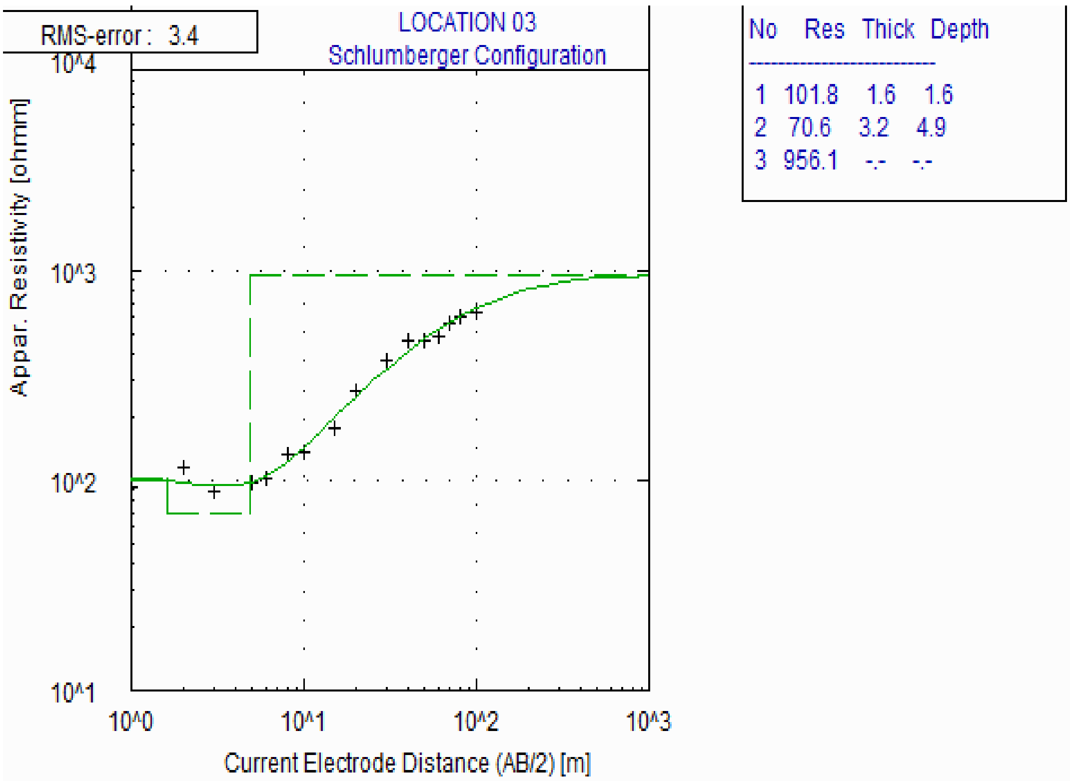

Figure 6: Resistivity values and matching curve for sounding point 3.

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Location 04: (N07^{0}8'24", E006^{0}11'37". ELV. 147.2 m)

Distance	Resistivity	No
1.00	430.0000	1
2.00	238.0000	2
3.00	171.0000	3
5.00	199.0000	4
6.00	201.0000	5
8.00	205.0000	6
10.00	217.0000	7
15.00	277.0000	8
20.00	304.0000	9
30.00	371.0000	10
40.00	433.0000	11
50.00	513.0000	12
60.00	588.0000	13
70.00	712.0000	14
80.00	727.0000	15
100.00	795.0000	16

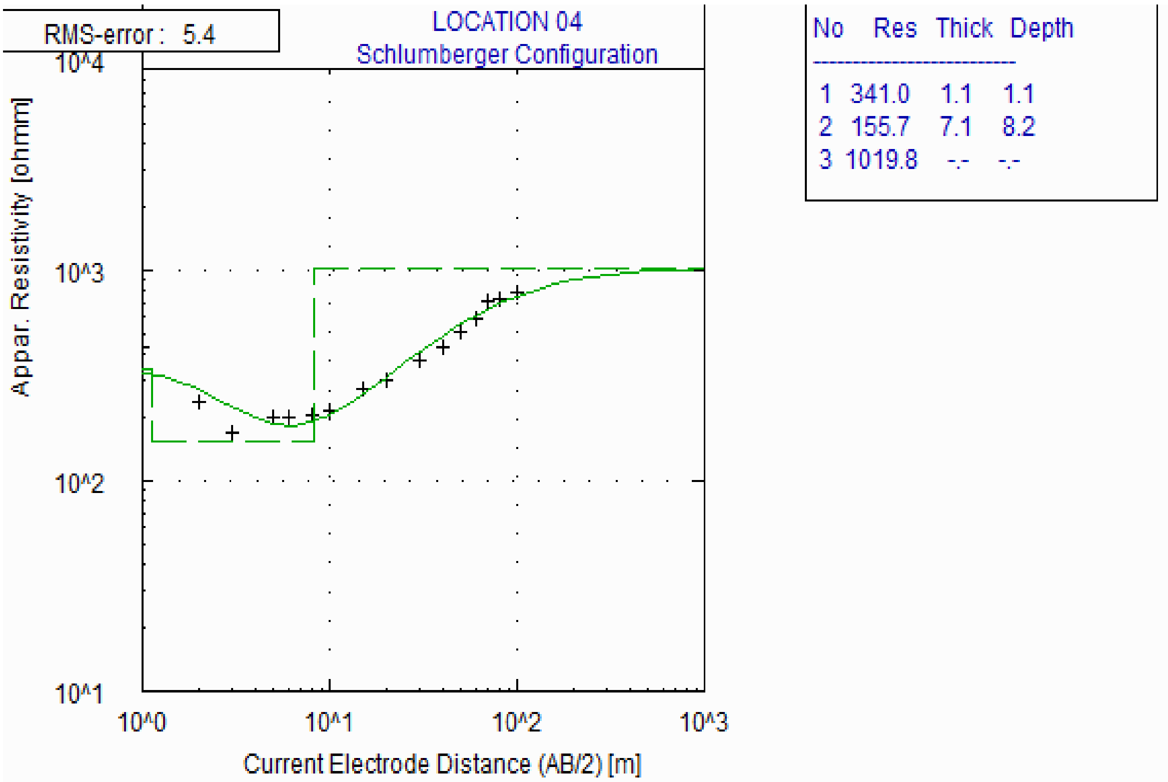

Figure 7: Resistivity values and matching curve for sounding point 4.

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Location 05: (N07^{0}8'25", E006^{0}11'39". ELV. 143.4 m)

Distance	Resistivity	No
1.00	936.0000	1
2.00	214.0000	2
3.00	166.0000	3
5.00	241.0000	4
6.00	245.0000	5
8.00	266.0000	6
10.00	274.0000	7
15.00	429.0000	8
20.00	295.0000	9
30.00	307.0000	10
40.00	377.0000	11
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60.00	507.0000	13
70.00	577.0000	14
80.00	665.0000	15
100.00	760.0000	16

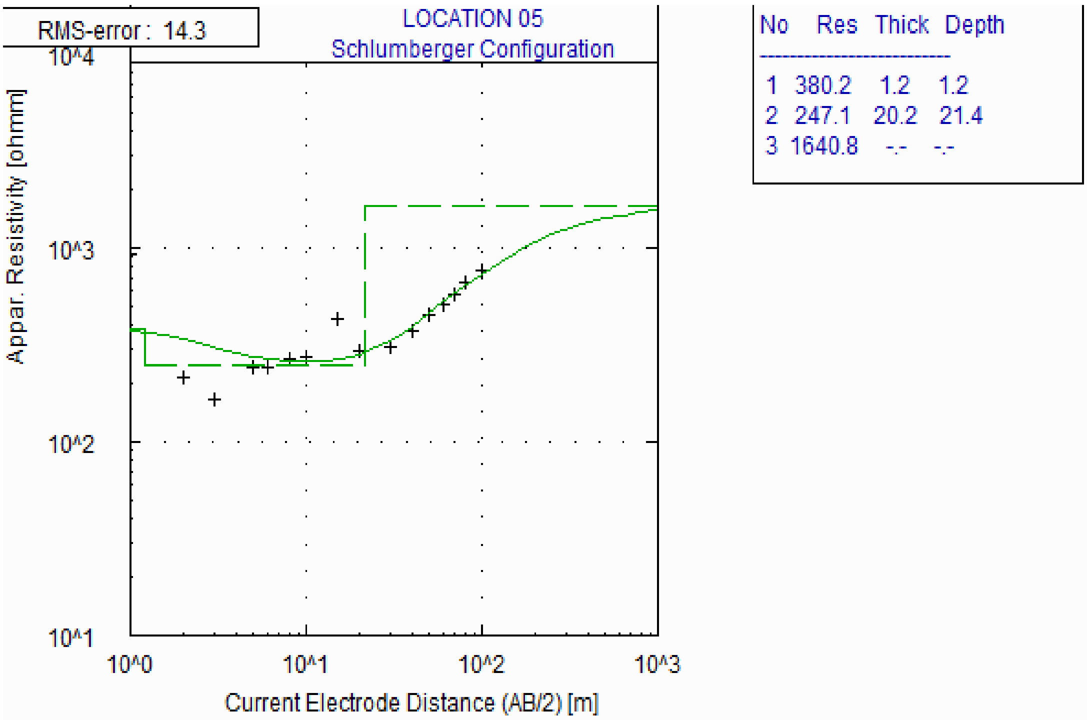

Figure 8: Resistivity values and matching curve for sounding point 5.

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Location 06: (N07^{0}8'24", E006^{0}11'33". ELV. 142.6 m)

Distance	Resistivity	No
1.00	360.0000	1
2.00	135.0000	2
3.00	86.0000	3
5.00	104.0000	4
6.00	102.0000	5
8.00	121.0000	6
10.00	126.0000	7
15.00	140.0000	8
20.00	206.0000	9
30.00	321.0000	10
40.00	382.0000	11
50.00	390.0000	12
60.00	390.0000	13
70.00	405.0000	14
80.00	455.0000	15
100.00	571.0000	16

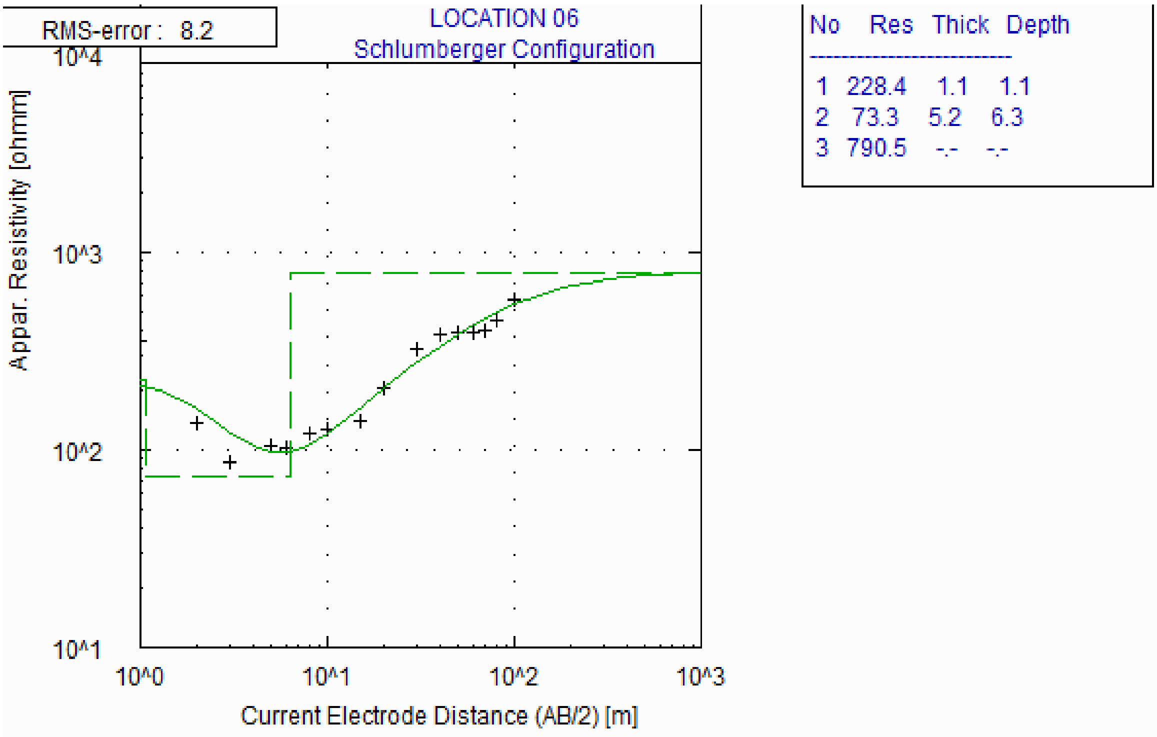

Figure 9: Resistivity values and matching curve for sounding point 6.

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Location 07: (N07^{0}8’25”, E006^{0}11’34”. ELV. 146.5 m)

Distance	Resistivity	No
1.00	312.0000	1
2.00	123.0000	2
3.00	118.0000	3
5.00	129.0000	4
6.00	114.0000	5
8.00	120.0000	6
10.00	134.0000	7
15.00	185.0000	8
20.00	249.0000	9
30.00	380.0000	10
40.00	435.0000	11
50.00	524.0000	12
60.00	649.0000	13
70.00	706.0000	14
80.00	779.0000	15
100.00	902.0000	16

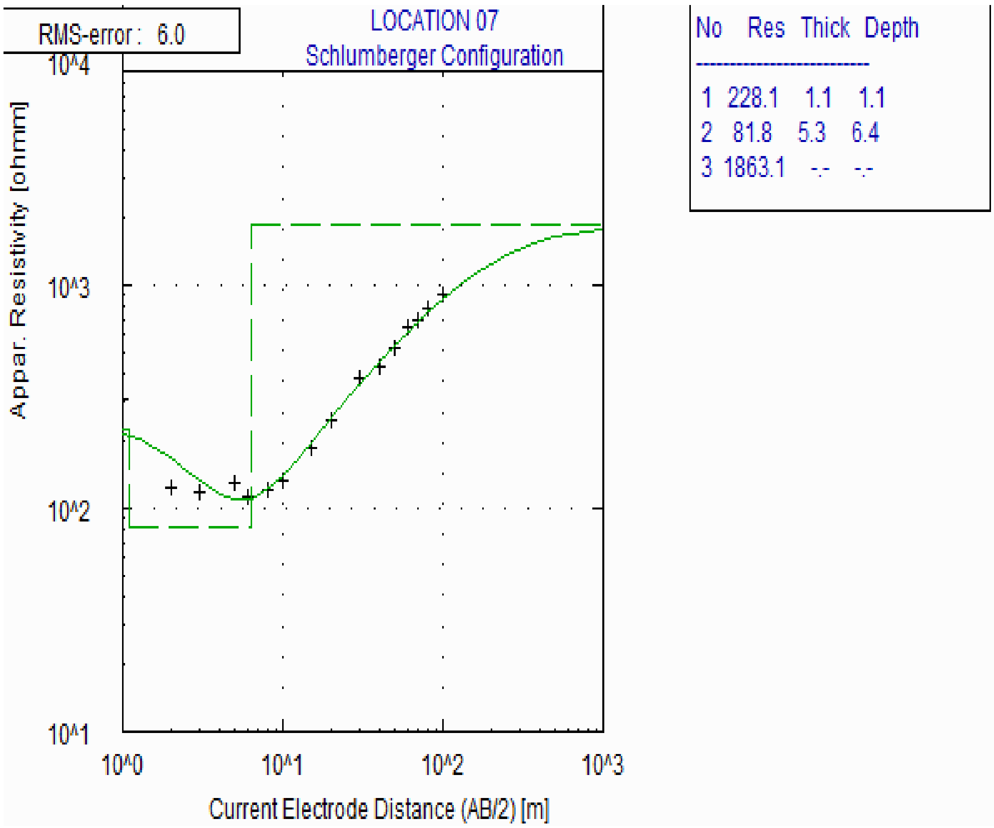

Figure 10: Resistivity values and matching curve for sounding point 7.

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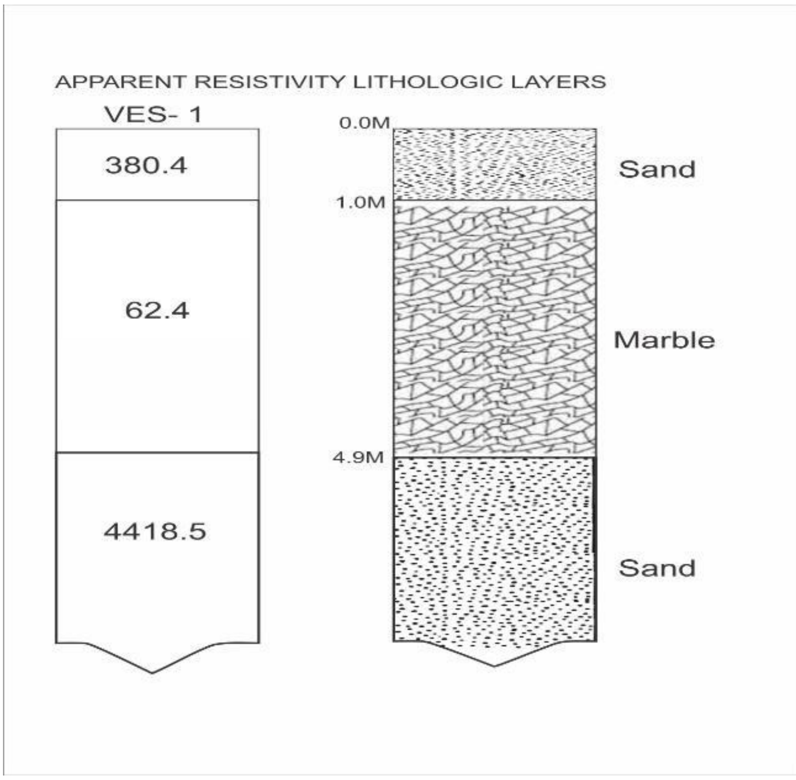

Figure 11: Showing the geo-electric layers and the Lithologic profile of location 01.

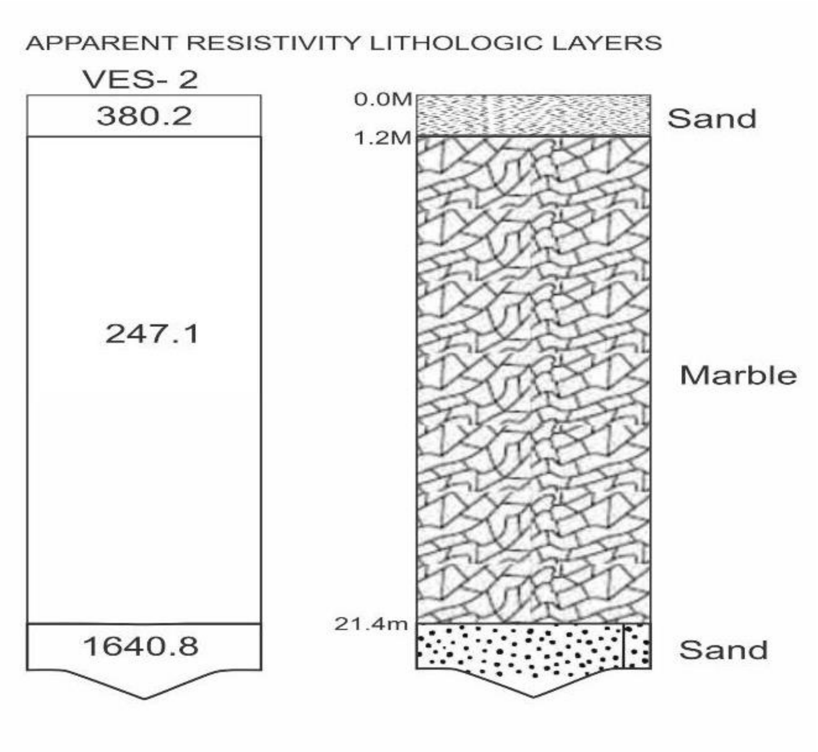

Figure 12: Showing the geo-electric layers and the Lithologic profile of location 02.

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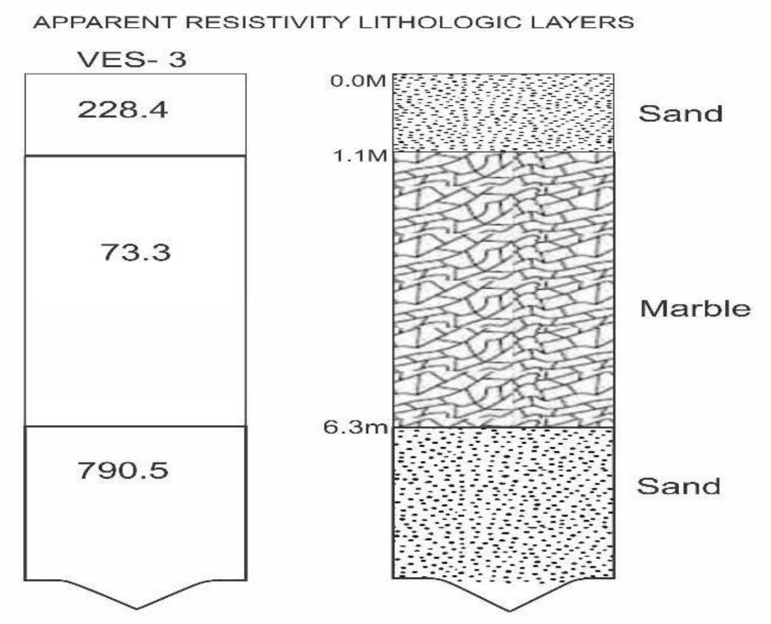

Figure 12: Showing the geo-electric layers and the Lithologic profile of location 03.

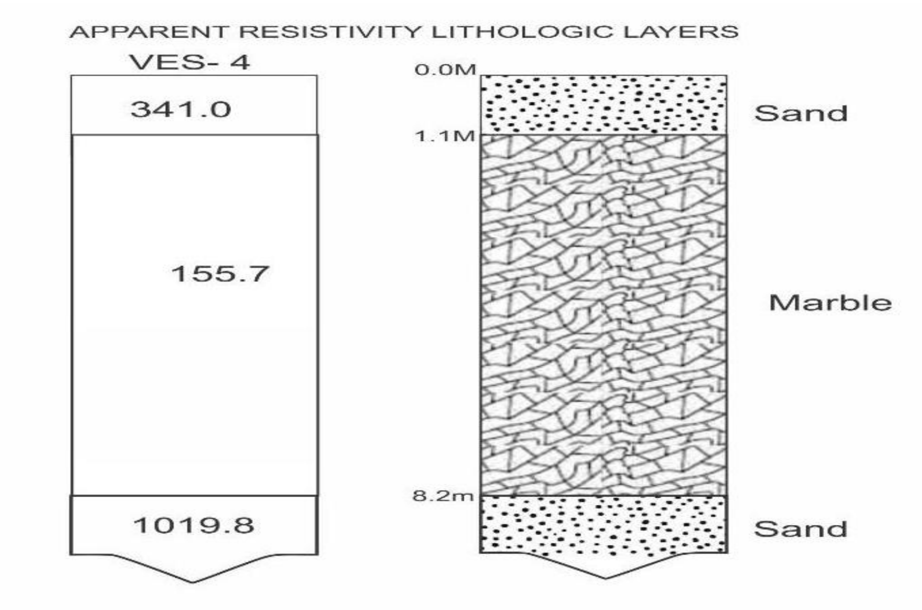

Figure 13: Showing the geo-electric layers and the Lithologic profile of location 04.

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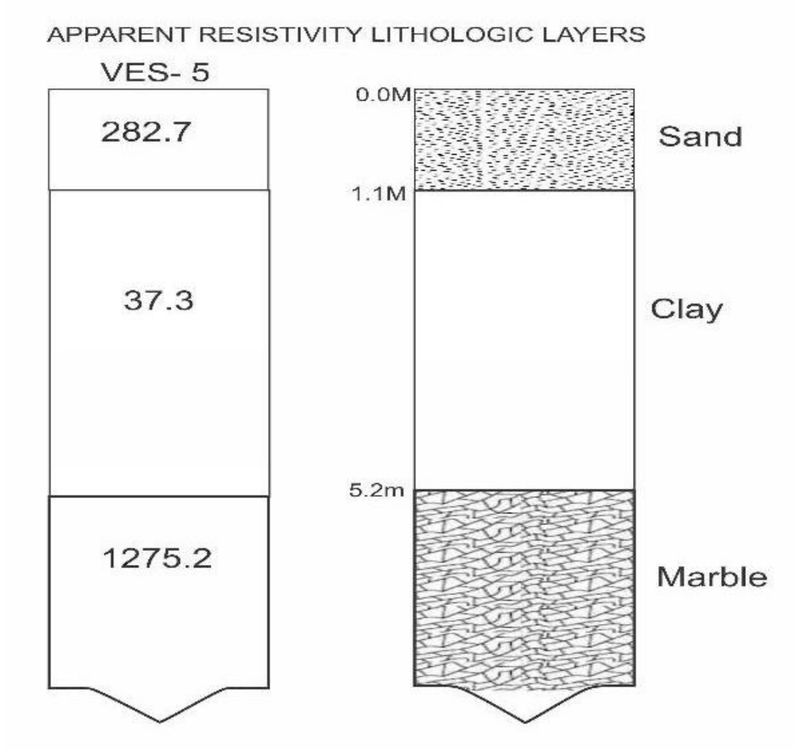

Figure 14: Showing the geo-electric layers and the Lithologic profile of location 05.

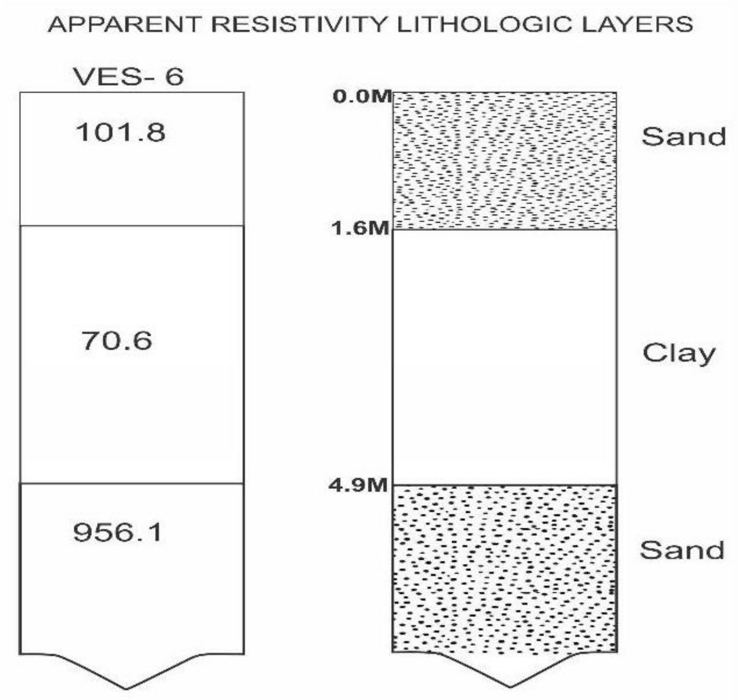

Figure 15: Showing the geo-electric layers and the Lithologic profile of location 06.

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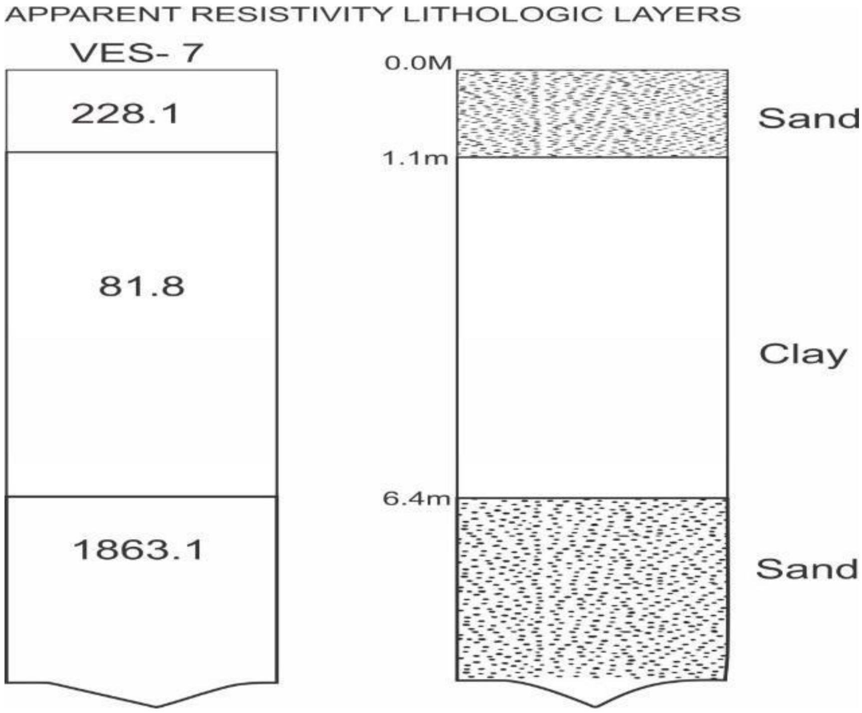

Figure 16: Showing the geo-electric layers and the Lithologic profile of location 07.

Resistivity measurements at the surface of the earth are associated with varying depths relative to the geometry of the current and potential electrodes in the survey. A vertical electrical sounding technique using the Schlumberger array configuration was carried out at seven locations in the study area. The results obtained from soundings delineated three geo-electric layers which compress clay/clayey-sand (81.8 – 155.7 Ωm), Sand (101.8 – 380.4 Ωm) and marble (1019 – 4419 Ωm) horizon units.

There are many factors that affect the resistivity of earth materials. It is affected by natural geology, hydrogeology, mineralogical composition, porosity, temperature, pressure, water saturation, dissolved electrolytes, etc., depending on whether the anticipated deposit is dry or contains a resistivity alteration agent, it ranges from 100 Ωm – 2.5 x10^8 Ωm. The high resistive part of it is witnessed at the northern and north, which is a clear indication that the undisturbed or free from impurities (i.e., factors affecting resistivity of earth materials like fracture, fissures, fault, etc. are very less or have no effect in that area).

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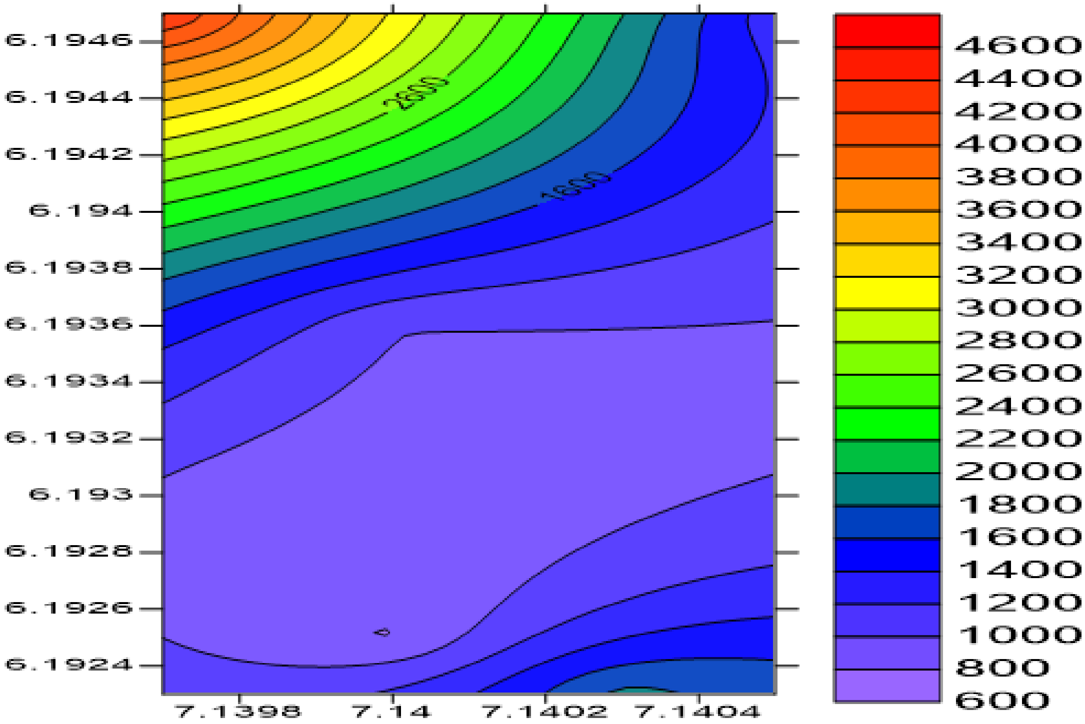

Figure 16: Iso resistivity of the third layer

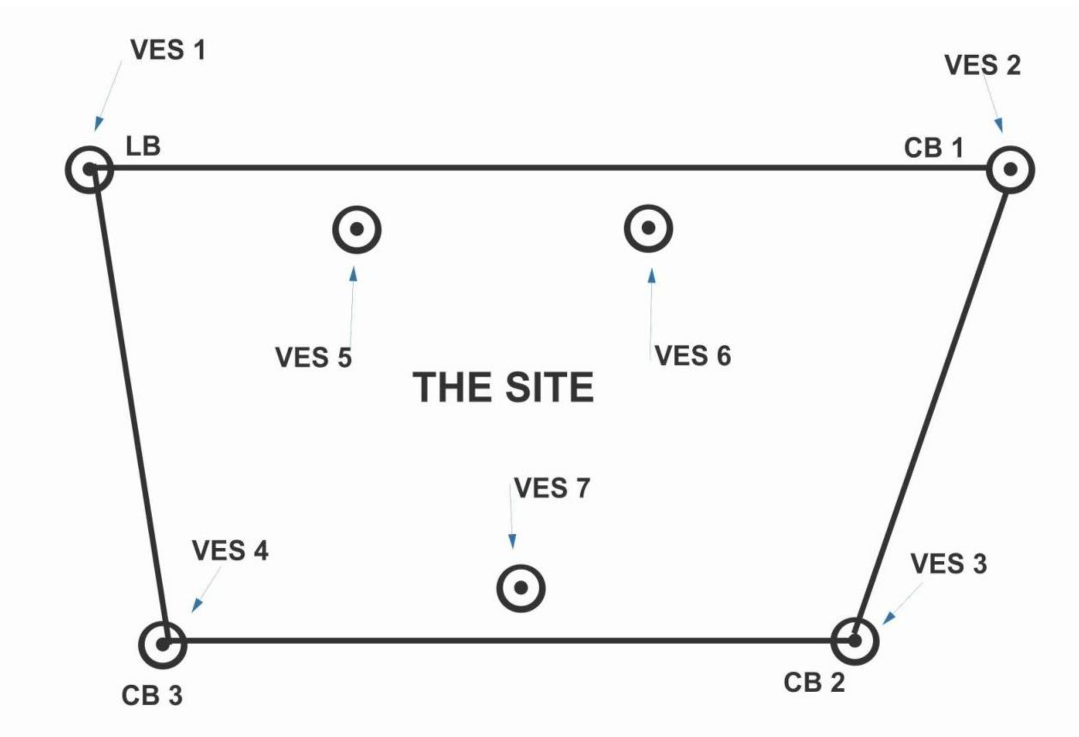

Figure 16: Schematic diagram showing the seven sounding points carried out at Ikpeshi.

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The geologic section was deduced from borehole log data acquired within the study area. Each sounding location is presented in Table (1). Acquired field data is presented in 1D geo-electrical sounding curves. The results show variable composition of subsurface geologic formations. The characteristic curve type obtained in the study area is an H-curve in all the VES points. All the surveyed locations show traces of the existence of marble deposits in the area.

- **Reserve Estimation**

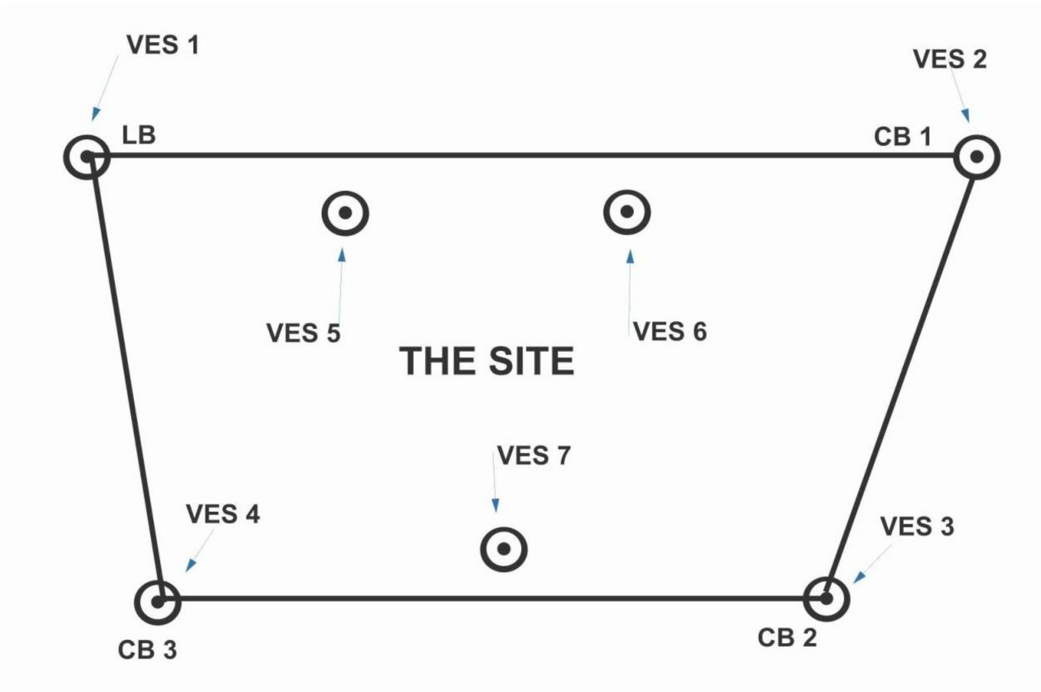

Figure 17: Schematic diagram of the vertical electric sounding points used for the reserve estimation.

The estimation of the tonnage is derived from elevation and the overburden thickness of the area. The shape of the study area is equal to the shape of a trapezoid. The Area of a trapezoid is given as $(a + b/2)h$

- **Reserve Volume**

Reserve volume = Area of the site (m^2) x Average thickness of the bedrock.

From Figure 16,

The surveyed area represents a trapezoid, given as; $(a + b/2)h$.

Therefore;

$$\frac{(100 + 75)\ 80}{2}$$

$= 7000\ m^2$

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Reserve volume = Area of the site (m^2) x Average thickness of the bedrock.

Reserve volume = 7000 m^2 x 94.9 m = 664,300 m^3

- **Reserve Tonnage**

This is the product of the reserve volume and the specific gravity of the bedrock. The specific gravity of marble at the site is estimated to be 2.55. Therefore, the reserve tonnage is given as:

Reserve tonnage = Reserve volume x Specific gravity

= 664,300 m^3 x 2.55

= 1,693.965 Tons

- **Overburden volume**

The overburden volume is the product of the average overburden thickness of the site and the trapezoidal area given as; Area of the site is 7000 m^2 by the average overburden thickness, which is estimated as 5.1 m

Overburden volume = 7000m^2 x 5.1 m = 35,700 m^3

Therefore, rock mass reserve to overburden volume ratio = 949:51.

CONCLUSION

The study revealed occurrences of marble deposits in the study area, which will be of economic importance if exploited. The results further show a lithologic profile that was deduced from existing well log data comprising clay and clayey sand as the topsoil and sand as the second layer, while the third layer comprises the marble deposit, which extends deeper. The reserve tonnage was calculated to be about 1.69 x 10^6 tons. This estimate signifies that there is a fair reserve of marble within the studied portion of the location. Also, the estimated overburden volume suggests that there is a low overburden volume within the studied area, with a rock mass reserve to overburden volume ratio of 949:51.

RECOMMENDATION

The study shows that the project area had the occurrence of marble deposits. However, detailed investigations over a wide area and choice of electrode configuration (e.g., Dipole-dipole), as well as expansion of the survey depth, is recommended to discover more marble deposits. Also, a geochemical analysis of the marble will be needed to establish its mineralogy qualitatively. Lastly, a geotechnical assessment that will include a coring will have to be done within the project area so as to establish the actual tonnage of the marble deposit within the study area.

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