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Reserve estimation of limestone deposit in Obiaja area, Southern Benue Trough, Nigeria using integrated approach

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Abstract

A combination of electrical resistivity survey and borehole data has been employed in reserve estimation of limestone within Obiaja area of southern Benue Trough. The area is bounded by Latitudes 427500mE – 431500mE and Longitudes 567000mN - 571000mN with an area extent of 0.32km^2. Vertical electrical sounding (VES) technique was used to delineate the thickness and depth to the top of the limestone, while geochemical analysis was used to estimate the grade of limestone deposit within the study area. Grid pattern was used within the area of the limestone mineralization for obtaining the data. Interpretation of the VES data was done using conventional manual curve matching and computer iteration techniques using IPI2win program. The result of vertical electrical soundings (VES) was correlated with borehole data within the study area. The result of VES shows four-five geoelectric layers consisting of clays with sands, shale, limestone, shaley sandstone and sandstone. Electrical resistivity of the limestone horizon ranges between 35 and 253 Ωm suggesting a highly porous formation. The depth to the top of limestone and the thickness of limestone ranges from 1.00m to 16.20m and 6.94m to 17.40m respectively. The geochemical analysis gave the average specific gravity of limestone to be 2.62 with very high percentage concentration of CaO ranging from 44.07% to 55.02%, indicating a good quality limestone deposit. The dimensions of the deposit suggest conservative limestone tonnage of 5,664,440 metric tonnes; whereas the volume of overburden is estimated to be approximately 1,570,000 cubic meters with stripping ratio of 0.73:1.

Keywords: Reserve Estimation, Limestone, Resistivity Survey, Integrated Approach, Benue Trough.

Introduction

Limestone is a major raw material for cement manufacturing. It can also be used to produce asphalt filler, ceramics, flux in glass making, fertilizer filler, explosives to mention just a few[1]. Although Nigeria is endowed with large deposits of limestone, the limestone at Mfamosing, near Calabar, is the largest and the purest deposit in Nigeria[2]. It is about 50 metres thick at outcrop (type section) and 450 meters thick in the subsurface on the Ituk High[2]. Limestone and marble, the principal raw materials for cement manufacture, are very essential for a rapidly growing nation like Nigeria. Presently, there are positive efforts by the Federal Government of Nigeria to de-emphasize the country's total dependence on oil by encouraging the rapid development of the non-oil sectors especially agriculture and solid minerals[3].

However, the limestone deposits of the Calabar Flank are widespread and occur in different locations like the Mfamosing, Etankpini, New Netim-Odukpani, Obotme, Njagachang, Okoyong, Mbot Okpai and Ikot Okpora[4-6]. These limestone deposits are currently being quarried for cement production in Mfamosing by UNICEM that operates a Portland cement plant in the area while little (or no) attention is given to the other limestone deposits including the area of study (Obiaja). Some of these mineral deposits have never been given any serious attention and consequently, the amount of limestone in place is not quantified and little geological knowledge is known about their reserve; whereas the deposits at Mfamosing and Obotme have received proper geophysical attention[4-8]. However, geophysical and laboratory investigations of the study area can give better information that can convince investors more than just using geological data alone.

In addition, the recent growth in populations in Calabar and its environs has imposed significant stress on the existing inadequate building materials for construction. Consequently, it became very expedient to expand the existing quary sites in the area as a result of the daily increase in the demand of cement for building construction. This has caused the need for the exploration for more competent rocks (limestone) to serve as quarry sites so as to meet this ever increasing demand.

It is against this background that this study utilizes an integrated approach, involving electrical resistivity surveying, field mapping and ground-truth in the form of geological information obtained from core drilling, to investigate the prospect of Obiaja limestone deposit. The choice of electrical resistivity is based on its cost effectiveness and capability of providing 2D or 3D models of the subsurface[9-11]. However, this approach abridged sensitivity with depth and this reason necessitated the use of borehole data to improve its accuracy[12].

The findings of the study will be beneficial to prospective investors, the host community, construction companies and even the nation as well. Investors will specifically benefit from the findings of this study because they will have good knowledge of limestone reserve of the area. This information will help them in decision making process before any investment is made. The host community will benefit from the result of this study because when the reserve is known, it will attract investors, who in turn site companies for exploration and exploitation of limestone. It will create job opportunities for many unemployed people especially from the host community as well as having multiplying effects on other industries like building and construction companies. The nation will also benefit from the result of this study because through maximum exploration and exploitation of the limestone deposits, it can earn more foreign exchange to compliment her earnings and making positive contribution to the national economy.

Geologic setting of the study area: Obiaja is located in the Calabar Flank sedimentary basin of Southern Benue Trough, southeastern Nigeria. It is situated within latitudes 05°06’E and 05°11’E and longitudes 008°20’N and 008°25’N (Figure-1). The main access road that connects the area is the Calabar-Ikom road.

The stratigraphic succession of the area shows that the flank is mostly of Cretaceous age[13]. Sedimentation begun in the Calabar Flank as a result of deposition of fluvio-deltaic clastics on the Oban Massif (Basement Complex). These sediments are associated with the Awi Formation[7]. The initial marine transgression into the Calabar Flank is the deposition of platform carbonate of the Mfamosing Limestone. The carbonate platform within the area signifies the thickest carbonate body in Nigeria[4]. The Mfamosing Limestone (which is distinguished by small intercalation of marls, calcareous mudstone and oyster beds) is overlain by the Ekenkpon Formation (which is a thick sequence of black to gray shale unit)[14]. The Ekenkpon Shales are overlain by the New Netim Marl (a thick marl unit). This formation is usually interbedded with thin layer of shales in up-section as well as nodular and shaley at the base. The New Netim Marl is unconformably overlain by the Nkporo Formation which is carbonaceous dark gray shale[15]. The Cretaceous sequence in the Calabar Flank ended with the Nkporo Shale. Finally, the established Cretaceous sedimentary succession in the Calabar Flank is capped by the Benin Formation (mainly continental sands and gravels of Late Tertiary to Recent age)[16].

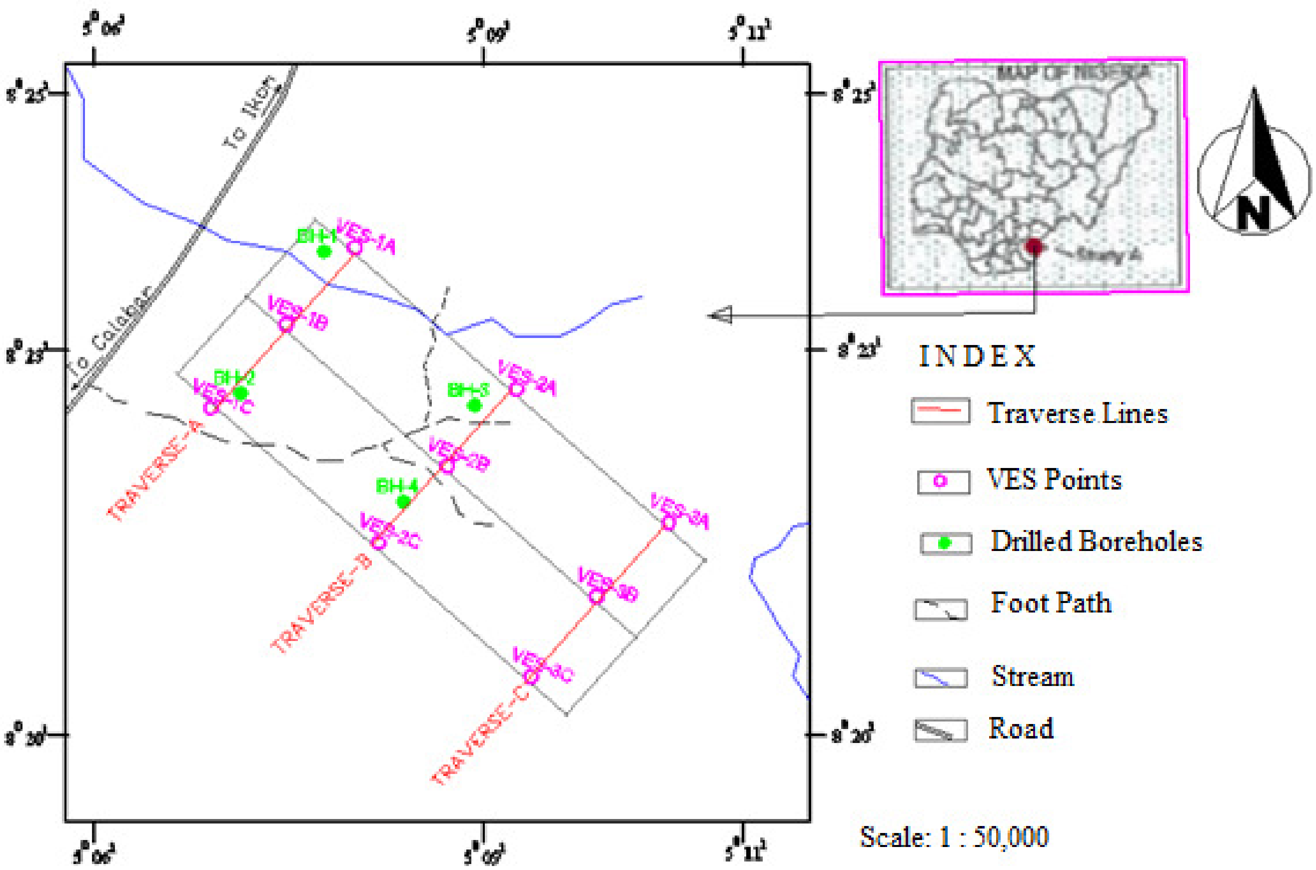


Figure-1: Map showing VES traverses and borehole points within the study area.

Methodology

Electrical resistivity surveying was carried out employing vertical electrical sounding (VES) technique using Schlumberger electrode configuration along three parallel traverses (Figure-1) in northeast-southwest azimuth in the study area. Each traverse was about 400 m in length and separated by a distance of 400 m such that the total area surveyed was $3.2x10^5 m^2$. Three VES points were established along each traverse with minimum current electrodes separation of 2.0 m and maximum current electrodes separation of 300m. The potential electrodes were made to remain fixed while the current electrodes spacing was extended symmetrically about the centre of the spread. For large values of current electrodes spacing the separation of the potential electrodes were also increased in order to maintain measurable potential at all times. The ground resistance R measured at each current electrode sampling point was recorded and inserted into equation below to obtain corresponding apparent resistivity (ρa) value.

$$\rho a = KR \qquad (1)$$

Where: K= Geometric factor.

The density of the sampled limestone from displacement method was 2620 kg/m^3. Based on the grade and quality (depth wise) of the limestone for cement manufacturing, the area covered with the deposit was divided into two blocks (A and B) and both the limestone thicknesses as well as the overburden thickness (Table-1) were gotten from the model parameter generated. The surface area, thickness and specific gravity of the blocks were used to calculate the quantity of the limestone in metric tonnes. The total volume of the limestone deposit were gotten summing up the volumes of the two blocks obtained.

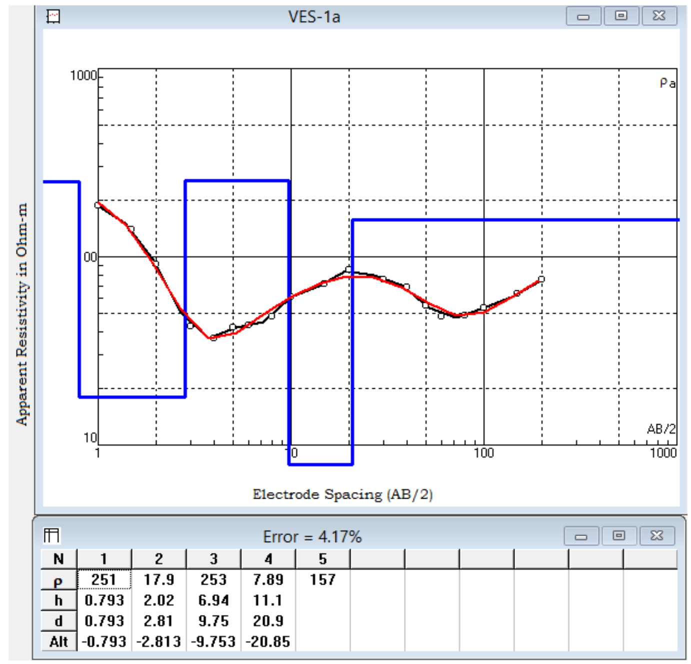
The apparent resistivity data computed were plotted against the current electrodes spacing (AB/2) on a bi-logarithmic graph. The generated curve will be interpreted using manual technique (which involves partial curve matching technique) to obtain initial layering models (number of layers and their trends) and parameters (resistivity and thickness of each layer). The initial layering parameters were further subjected to iterative computer interpretation using IPI2WIN software.

Geoelectric sections tied to borehole logs were also constructed along each traverse to obtain stratigraphic models.

Results and discussion

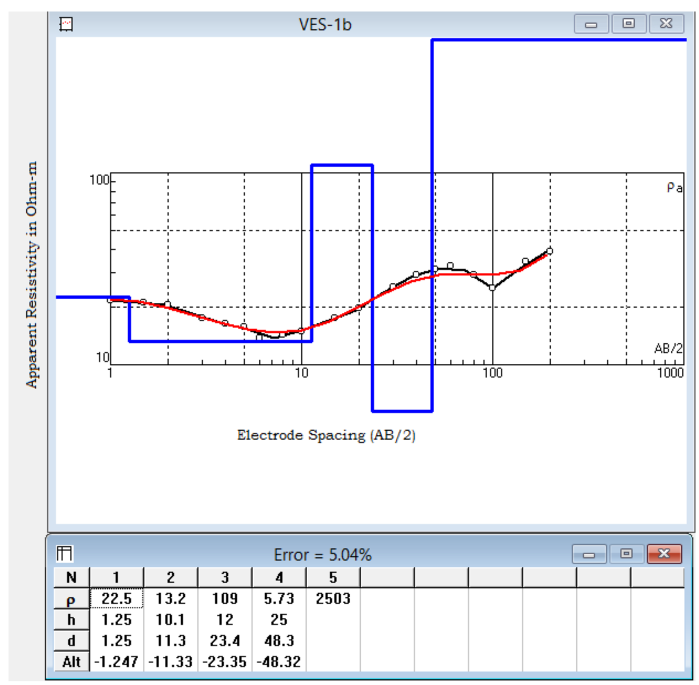
The sample apparent resistivity curve types were obtained from the interpretation of the apparent resistivity data set (Figure-2, a, b, c, d). The geoelectric sections constructed using the layering parameters obtained along each traverse and borehole logs as control are shown in Figures-3, 4 and 5 revealing three to five layers beneath each VES station. Actually, five established geologic sequences found within the study area are top soil, shale with marl concretions, limestone, shaley sandstone and sandstone.

Geoelectric Sections and Stratigraphic Models: The underground stratigraphy for all the three transects (traverse-A, traverse-B and traverse-C) are shown in Figures-3, 4 and 5 respectively. Various stratigraphic layers were marked in each transect with respect to the various range of resistivity values that were identified after data calibration.



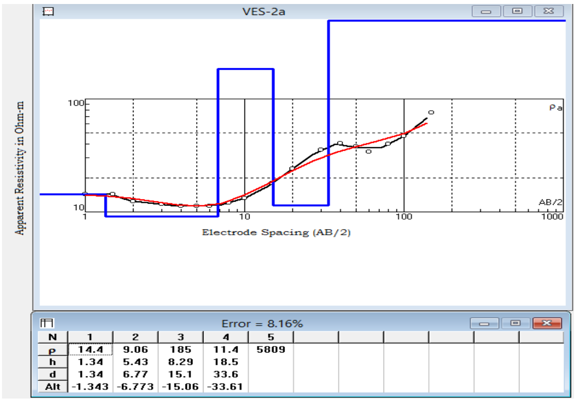
N	1	2	3	4	5
ρ	251	17.9	253	7.89	157
h	0.793	2.02	6.94	11.1	
d	0.793	2.81	9.75	20.9	
Alt	-0.793	-2.813	-9.753	-20.85	

Figure-2a: VES-1a curve along Traverse-A.



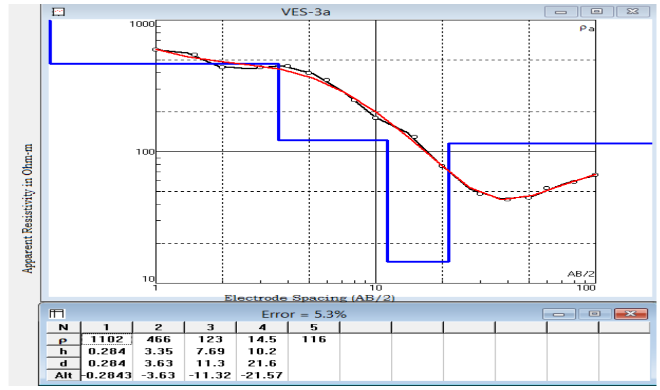
N	1	2	3	4	5
ρ	22.5	13.2	109	5.73	2503
h	1.25	10.1	12	25	
d	1.25	11.3	23.4	48.3	
Alt	-1.247	-11.33	-23.35	-48.32	

Figure-2b: VES-1b curve along Traverse-A.



N	1	2	3	4	5
ρ	14.4	9.06	185	11.4	5809
h	1.34	5.43	8.29	18.5	
d	1.34	6.77	15.1	33.6	
Alt	-1.343	-6.773	-15.06	-33.61	

Figure-2c: VES-2a curve along Traverse-B.



N	1	2	3	4	5
ρ	1102	466	123	14.5	116
h	0.284	3.35	7.69	10.2	
d	0.284	3.63	11.3	21.6	
Alt	-0.2843	-3.63	-11.32	-21.57	

Figure-2d: VES-3a curve along Traverse-C.

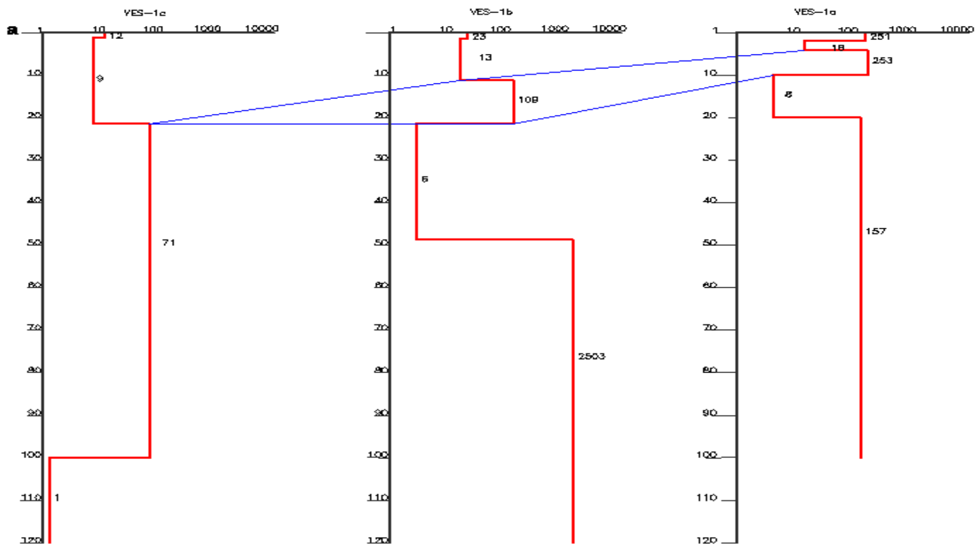


Figure-3a: Resistivity sounding data for 3 sites along Traverse-A.

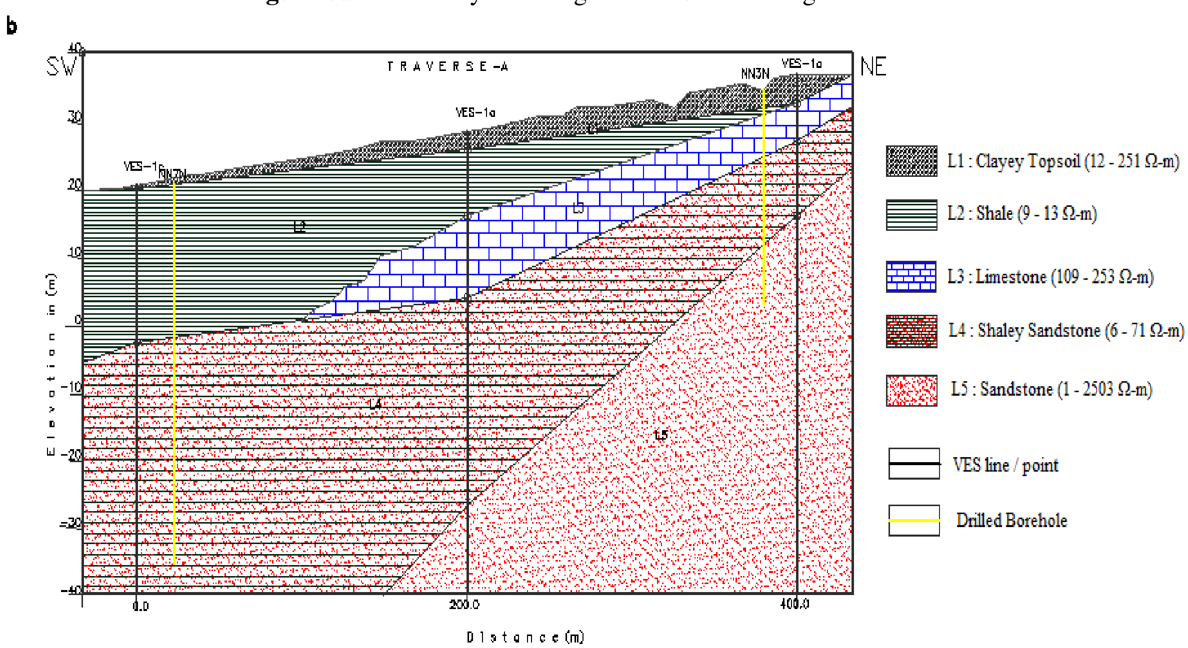


Figure-3b: Stratigraphic model based on Resistivity for transect along Traverse-A.

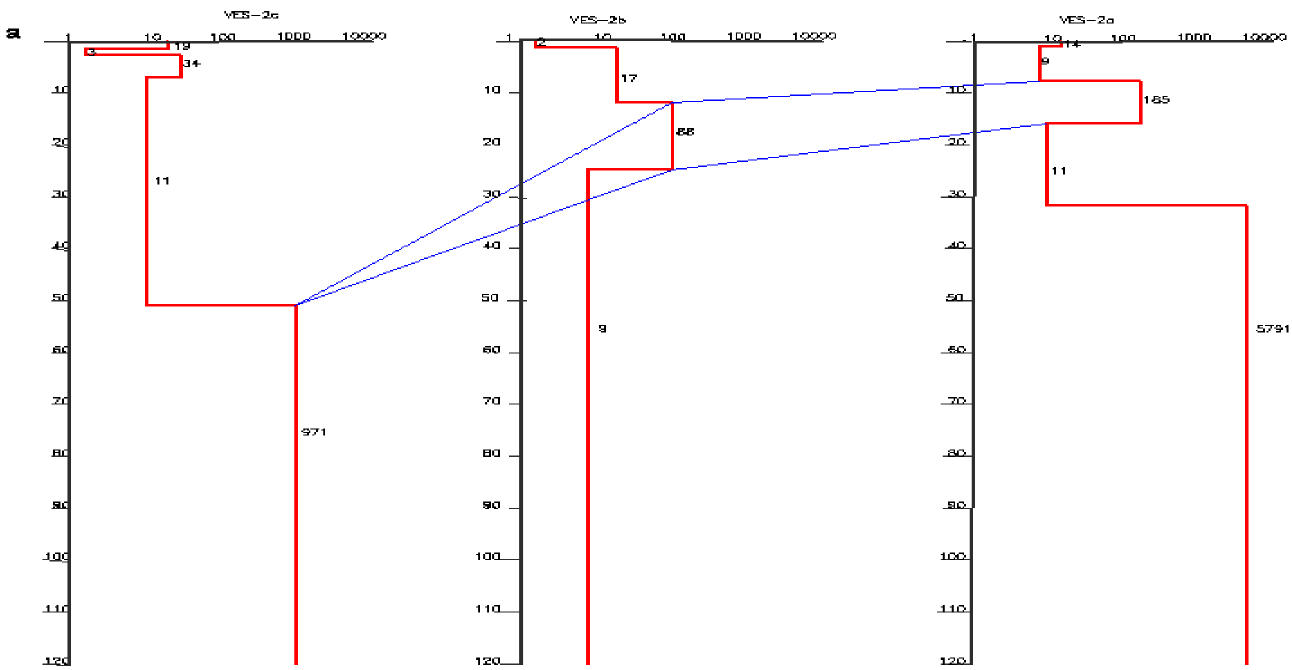


Figure-4a: Resistivity sounding data for 3 sites along Traverse-B.

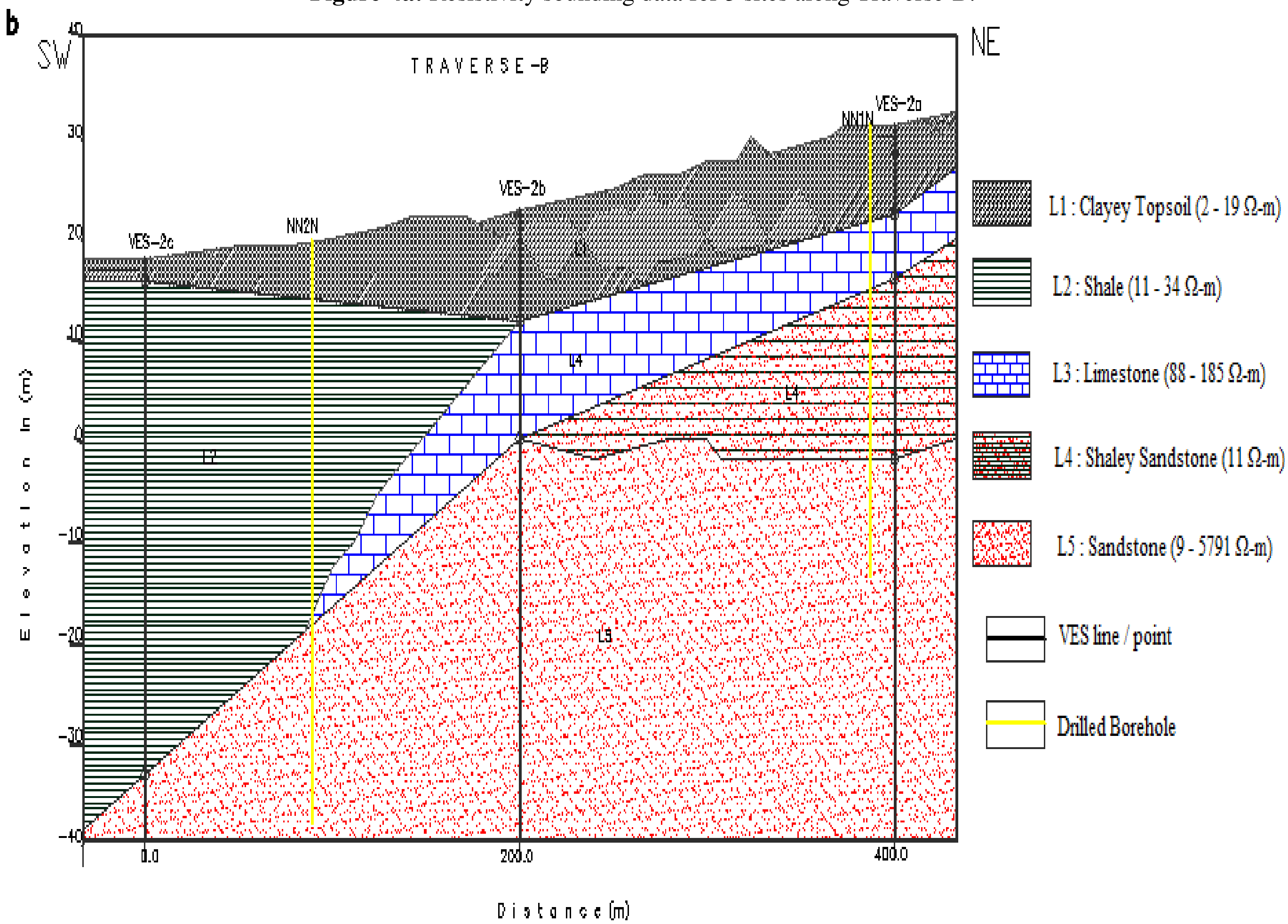


Figure-4b: Stratigraphic model based on Resistivity for transect along Traverse-B showing 5 layers.

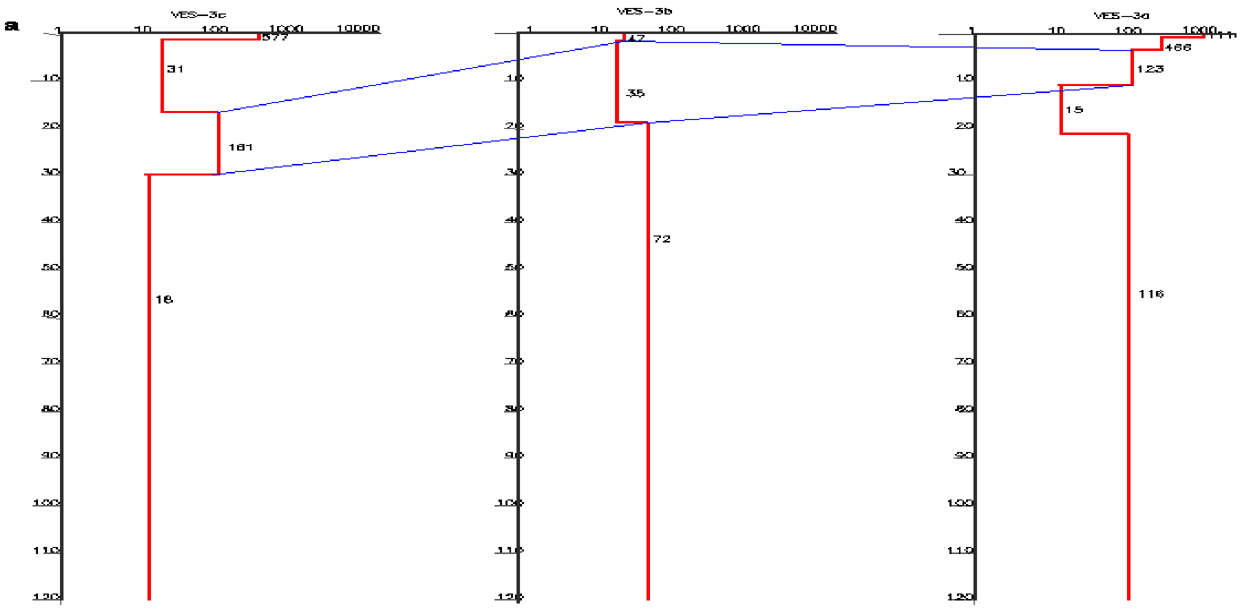


Figure-5a: Resistivity sounding data for 3 sites along Traverse C.

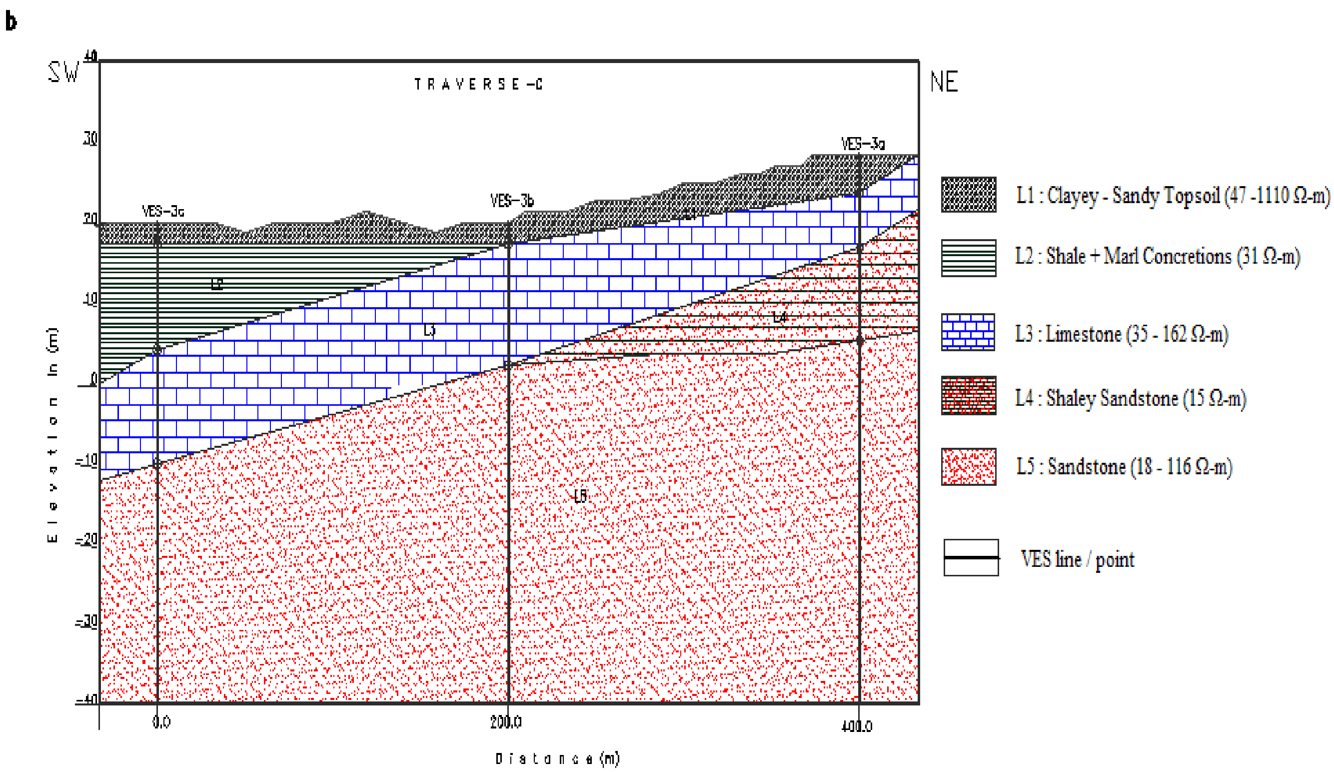


Figure-5b: Stratigraphic model based on Resistivity for transect along Traverse-C.

Reserve Quantification of the Limestone Deposits: The buried limestone deposit of the site investigated has a rectangular shape (Block-A) and trapezium shape (Block-B) with the three (3) transects as shown in Figure-6. The average thickness of the blocks was calculated as well as the volume of each limestone block (Table-1). The total area of the limestone in the area surveyed is 200,000 m^2. The specific gravity of the limestone was 2.62. The product of the specific gravity and volume gave the reserve deposit of limestone in the area investigated. The result from the Table-1 and model (Figure-6) gave the deposit reserve as 5,664,440 metric tonnes.

Table-1: Estimation of Thickness of Limestone and Overburden from VES Survey.

Traverse	Ves No.	Limestone Thickness from Model (m)	Mean Limestone Thickness (m)	Overburden Thickness (m)	Mean Overburden Thickness (m)
A	1a 1b 1c	6.94 12.00 -----	9.47	2.81 11.40 ----	7.11
B	2a 2b 2c	8.29 12.00 ----	10.15	6.77 12.00 ---	9.39
C	3a 3b 3c	7.69 17.40 13.30	12.80	3.63 1.32 16.20	7.05

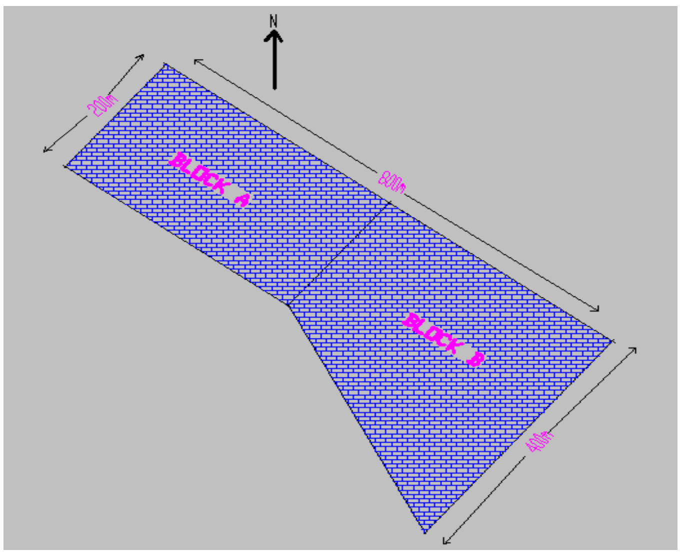


Figure-6: Established model of the limestone deposit from VES data.

Table-2: Calculation of Limestone Reserve and Value.

Mean thickness of limestone (Block A and Block B)	10.81m
Area of limestone (Block A)	80,000m^2
Area of limestone (Block B)	120,000m^2
Total Area of limestone (Block-A + Block-B)	200,000m^2
Volume of limestone	(10.81x200,000)m^3 = 2,162,000m^3
Conservative average specific gravity of limestone	2.62
Conservative Tonnage of limestone	(2,162,000 X 2.62) =5,664,440 metric tonnes
% CaO content	(44.07 – 55.02)% Grade
Minimum limestone tones	5,664,440 X 0.4407 = 1.5 million tones
Maximum limestone tones	5,664,440 X 0.5502 3.1 million tonnes

Estimation of the Volume of Overburden from VES Values: Estimation of the volume of overburden was calculated using the same principle for calculating limestone reserve. Hence, the multiplication of average thickness and area of each block gave the volume of overburden of 1,570,000m^3. The overlying shaley materials could serve as raw material for cement manufacturing.

Conclusion

The limestone body mapped by resistivity data has a defined geometry. The limestone appears to outcrop with the sandstone contact updip and overlain by shale and marl layers contact downdip. Overburden thickness varies from ~1.00-2.00m updip to ~16.20m downdip of a 400m width of the deposit. The dimensions of the deposit suggest conservative limestone tonnage of 5,664,440 metric tonnes; although the estimation of the volume of overburden is approximately 1,570,000 cubic meters. The percentage concentration of CaO (44.07% - 55.02%) in the limestones are very high ranging from 2.5 – 3.1 million tonnes and these values suggest that the limestone deposit here is of a good quality which worth investing in. The low values of resistivity obtained within the area are assumed to be caused by ground water level and also to the high porosity of limestone within the study area. Due to low overburden in this area, surface mining system could be adopted.

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