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SUBSURFACE GEOPHYSICAL MAPPING AND DRILLING OF ABA-ISU LIMESTONE DEPOSIT (SHEET 156E), SOUTH-EASTERN, NIGERIA.

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ABSTRACT: *Geoelectric mapping and drilling of Aba-Isu limestone deposit was carried out using a hybrid method, a combination of Wenner and Schlumberger resistivity techniques. The iso-resistivity maps indicated a roughly NW–SE trending of the limestone deposit. The resistivity values in the range of 40-260Ωm is inferred to be limestone with varying gradations, and relatively low resistivity values <40Ωm. Areas around the central line axis have resistivity values >100Ωm particularly for the "a" of 5m and 10m respectively and consistent and coincidental with the areas where the limestone massively outcropped. The study area indicated a 4-5 layer stratified alternating sequence of high and low resistivity horizons, the sequence start with high resistivity horizon with values >100 Ωm alternating with low-medium resistivity horizons with values in the range of 20-50Ωm. This sequence in 2 or 3 cycles and terminated by the highly conductive horizon with resistivity values of <20Ωms. The pseudo-sections, resistivity values greater 100Ωm are inferred as limestone, there is a consistency of these values on a trend coinciding with the central line axis. The same values are observed at various depths beneath the subsurface implying the occurrences of limestone which extend beyond 35m depth.*

KEYWORDS: Geophysical Mapping, Drilling, Aba-Isu, Limestone, Nigeria.

INTRODUCTION

The purpose of electrical survey is to determine the subsurface resistivity distribution by making measurements on the ground surface, from these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock (Acworth, 1999). Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations. More recently, it has been used for environmental surveys (Dahlin, 1996, Loke, 1997 and Loke, 1999). The resistivity measurements are normally made by injecting current into the ground through two current electrodes (C1 and C2), and measuring the resulting voltage difference at two potential electrodes (P1 and P2). From the current (I) and voltage (V) values, an apparent resistivity (*pa*) value is calculated.*pa* =kV/ I where k is the geometric factor which depends on the arrangement of the four electrodes (Griffiths and Turnbull, 1985). Resistivity meters normally give a resistance value, R = V/I, so in practice the apparent resistivity value is calculated by *pa* = k R. The calculated resistivity value is not the true resistivity of the subsurface, but an "apparent" value which is the resistivity of a homogeneous ground which will give the same resistance value for the same electrode arrangement. The relationship between

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the "apparent" resistivity and the "true" resistivity is a complex relationship (Griffiths and Turnbull, 1985). To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values using a computer program was carried out.A new hybrid between the Wenner and Schlumberger arrays arising out of relatively recent work with electrical imaging surveys (Pazdirek and Blaha 1996) was adopted for this study.

GEOLOGY OF THE STUDY AREA

The study area lies within the Cretaceous-Recent sediments of Southeastern Nigeria consisting of shale and limestone belonging to the ASU river group. The sediments consist of rather poorly bedded sandy shales known as the Abakaliki shales with embedded (Podiform) of limestone lenses. The limestone beds have thickness of 30m in some places. The area belong to beds of the south-eastern portion of the Calabar basin assigned to the Odukpani Formation dated as Conomanian to Turonian Age, the Ajali Formation (false-bedded sandstones) as well as Lower Coal Measures which (Reyment, 1965) called "Mamu" Formation. The coal-bearing part of the formations is predominantly mudstone and sandy clay (Simpson, 1955). The formation sediments were deposited during the late Tertiary-Early Cretaceous period. The false-bedded sandstones consist of thick, friable, poorly sorted sandstones typically white in colour, but sometimes iron-stained, often marked by repetitive banding of coarse and fine-grained layers. The sand grains especially the longer ones are sometimes sub-angular in shape. Due to these characteristics, the formation is highly porous (Igbozurike, 1986). The Lower Coal Measures comprises mainly of coarse-grained, alternating sediment of grey sand, dark, sandy shale and carbonaceous shale, containing thin brand of impure coal in place at various horizons with estimated thickness is 300 to 350m (Igbozurike, 1986). These formations give rise to the line of prominent hills along the eastern margins of the escarpment including those found on the old Okigwe-Enugu road through Ihube (Igbozurike, 1986).The localised geology consists of Limestone, sand and sandstone (Jatau and Lazarous 2013 (Figs.1and 2).

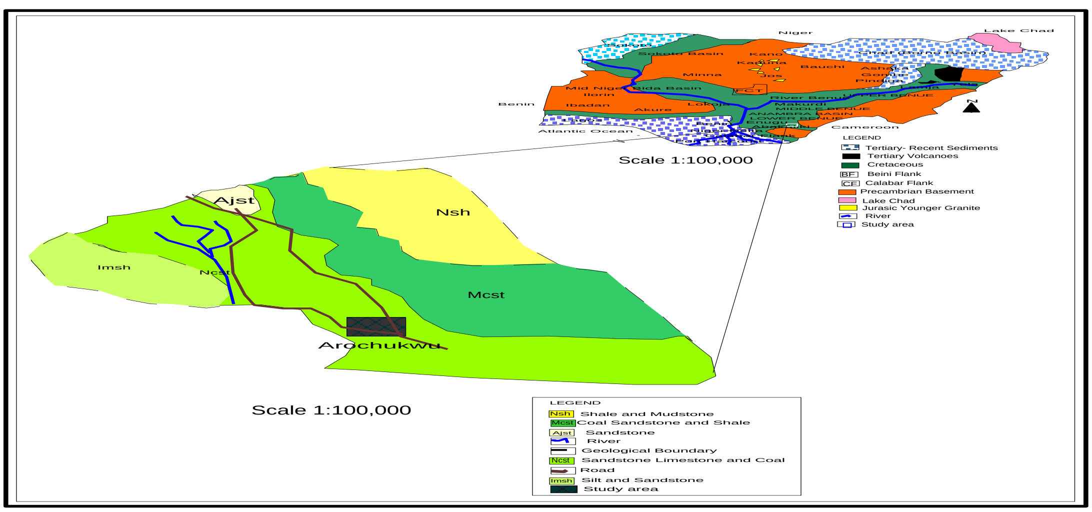

Fig.1. Geological Map of Abia State (Extracted from geological map Geological Survey Agency 2006)

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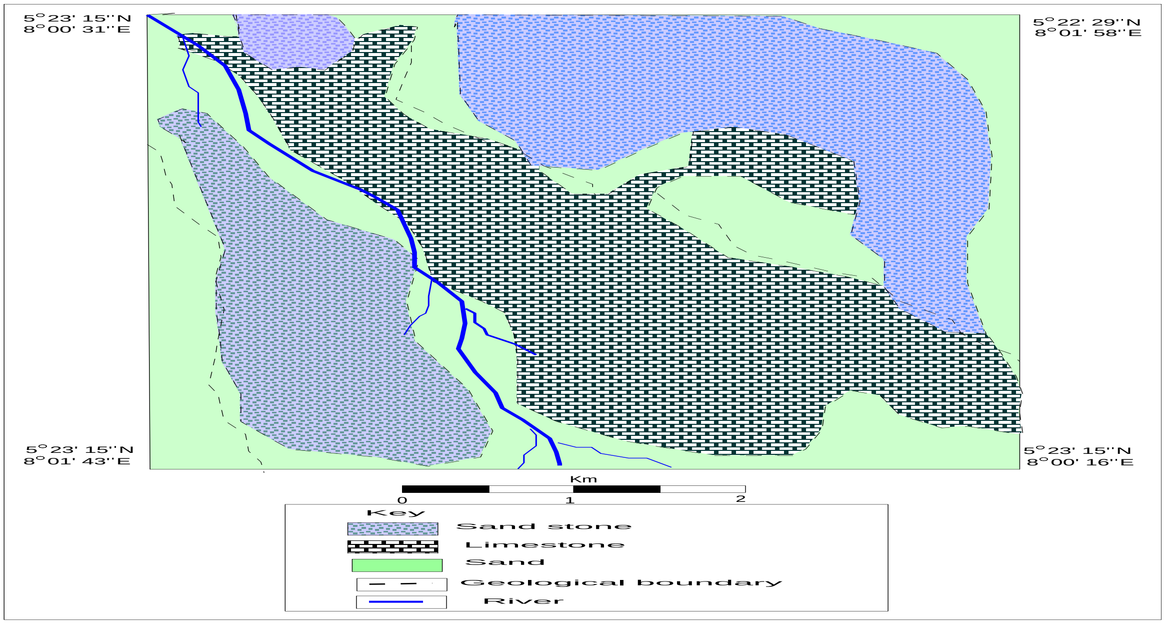
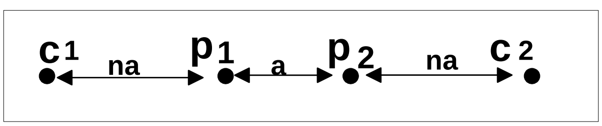


Fig.2 Geologic map of the study area.

METHODOLOGY

The method adopted for this study is Wenner- Schlumberger array. This method (Wenner-Schlumberger) configuration was chosen for this work due to the fact that it gives responses vertically and horizontally at the same time. Furthermore, it saves time and man power in that it requires less people and time. This is also known as a new hybrid between the Wenner and Schlumberger arrays arising out of relatively recent work with electrical imaging surveys (Pazdirek and Blaha 1996). Wenner Schlumberger array is shown below and is defined by K=(n+1)a where K is the geometric factor and "**n**" is the ratio of the distance between the C1-P1 (or P2-C2) electrodes to the spacing between the P1-P2 potential pair. The sensitivity pattern for the Schlumberger array is slightly different from the Wenner array with a slight vertical curvature below the centre of the array and slightly lower sensitivity values in the regions between the C1 and P1 (and also C2 and P2) electrodes. There is a slightly greater concentration of high sensitivity values below the P1-P2 electrodes. This means that this array is sensitive to both horizontal and vertical structures. In areas where both types of geological structures are expected, this array might be a good compromise between the Wenner and the dipole-dipole array (Pazdirek and Blaha 1996).



K=Πn(n+1)a

Fig.3 Wenner-schlumber array

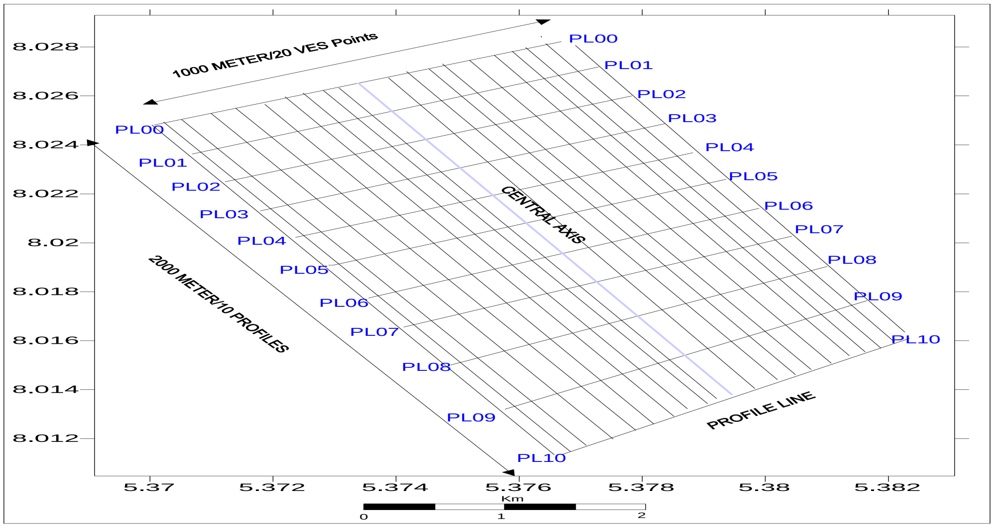


Fig.4 Schematic Map of the study area showing profiles and geophysical measurement points.

Table 1Field Data sheet used for the Geophysical survey.

S/N	AB/2(M)	MN/2(M)	K factor	Apparent Resistivity (M)
1	1.5	0.5	6.28	
2	2.0	1.0	4.71	
3	3.0	0.5	77.77	
4	5.0	1.0	37.71	
5	5.0	2.5	11.78	
6	7.5	1.0	86.79	
7	10	1.0	155.53	
	10	5.0	23.57	
8	15	1.5	233.29	
	15	7.5	35.35	
9	20	1.5	416.58	
	20	10	61.27	
10	30	5.0	274.93	
	30	15	70.69	
11	40	5.0	494.87	
	40	20	94.26	
12	45	5.0	628.4	
	45	1.0	3179.7	
13	60	5.0	1123.27	
	60	1.0	5654.03	
14	80	5.0	2003.03	
	80	40	188.52	
15	100	50	3133.94	
	100	50	235.56	
16	150	50	628.4	
	150	10	3519.04	

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RESULTS AND DISCUSSION

The response curves obtained for each of the measure VES points were subjected to data quality appraisal and initial/preliminary interpretation by visual/partial curve matching procedure in which the master curves in conjunction with auxiliary curves were progressively matched with each of the field curve examples are shown in (Figs.5-6).The initial layer parameters (that is layers resistivity values and their corresponding thicknesses); obtained from the above procedure were used to recalculate model apparent resistivity curves using IXID, IPIWIN, Surfer 7 packages to do inverse filter with appropriate computer-aided software. The results of the horizontal electrical profiling(HEP) also known as mapping using Werner Electrode configuration with six different cable spreads of "a" = 5m, 10m, 15m, 20m, 30m and 40m are presented in qualitative form (Figs.7-12). The six (6nos) iso-resistivity contour maps indicated a roughly NW – SE trending of the limestone deposit. The resistivity values in the range of 40-260Ώm is inferred to be limestone with varying gradations, and relatively low resistivity values <40Ώm with similar trend in the Northern part of Aba-Isu. Areas around the central line axis have resistivity values >100Ώm particularly for the "a" of 5m and 10m respectively and is consistent and coincidental with the areas where the limestone massively outcropped and this correlate favourably with the past work of (Keller and Frischknecht, 1966).

These observed consistencies in the low resistivity values in <20Ώm in this area could be inferred to indicate the occurrence of the highly conductive material (silty/clay) at relatively shallow depth in the sub-surface within the depth of penetration of the input current at the Wenner spreads of "a" = 5m and 10m respectively; overlying and grading progressively into the alternating layers of limestone and sandstone in this area at the depth of penetration of "a" = 10m and beyond. Three (3) major resistivity bands appear discernable from the iso-resistivity contour map closures, for "a" = 5m, to the south of the central line axis and the other at NW corner of the area investigated. The observed general trend is noted to persist for the depth of penetration of input current "a" = 5m, 10m, 15m, 20m, 30m, and 40m respectively. From the iso-resistivity maps which contain different colours representing different resistivity values as well as formations, these values represent different lithologies in the area. Resistivity values between 30-40Ώm indicates a sandy, alluvium to sandstone formation which may be water formation. Values from 40Ώm and above indicates a compacted/consolidated formation which is likely to be limestone material (Keller and Frischknecht 1966), therefore such areas suspected to be limestone are identified and most importantly these spots coincide with the outcrops on the field values, though some areas with similar resistivity values are not exposed but this fact shows that they are point of interest and exist beyond the surface at 5m, 10m, 15m, 20m, 30m and 40m, meaning that the deposit extent downward up to 40m depth. Therefore, further exploratory work such as core drilling would ascertain and establish the fact for proper correlation.

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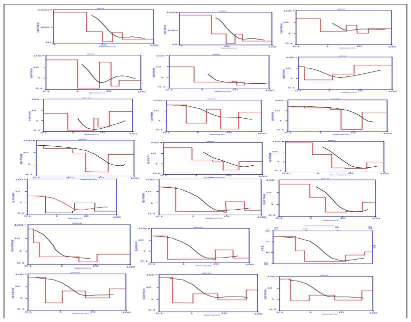


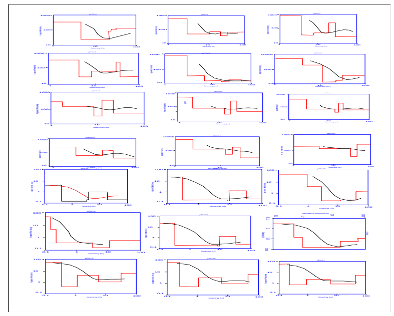
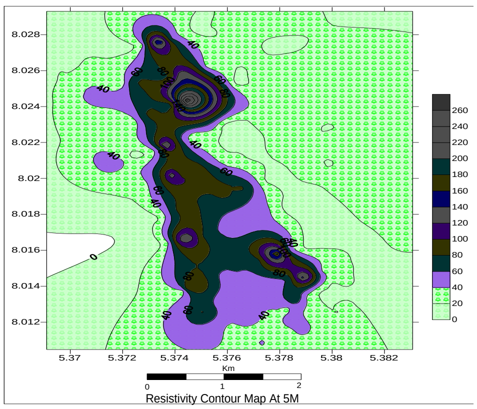


Fig. 5 Graphical curves for profile00 **Fig. 6 Graphical curves for profile 10**



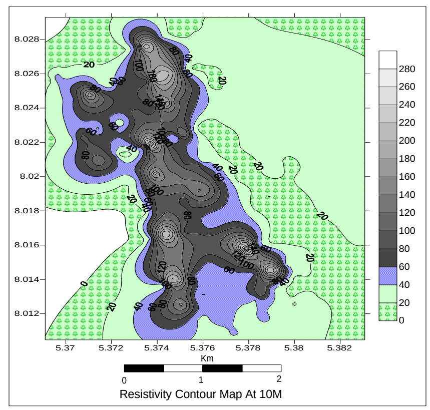
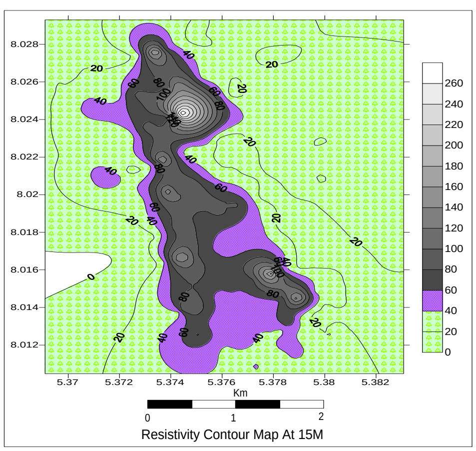


Fig. 7 Iso-resistivity map at 5m Fig. 8 Iso-resistivity Map at 10m



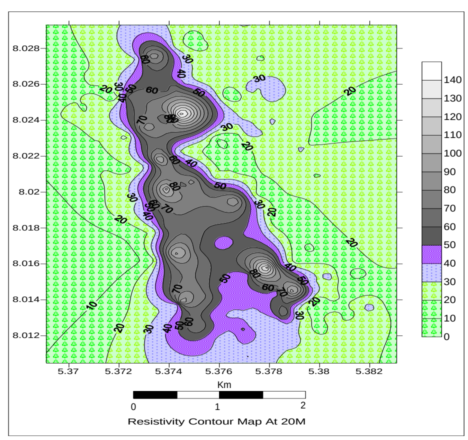


Fig. 9 Iso-resistivity Map at 15m Fig.10 Iso-resistivity Map at 20m

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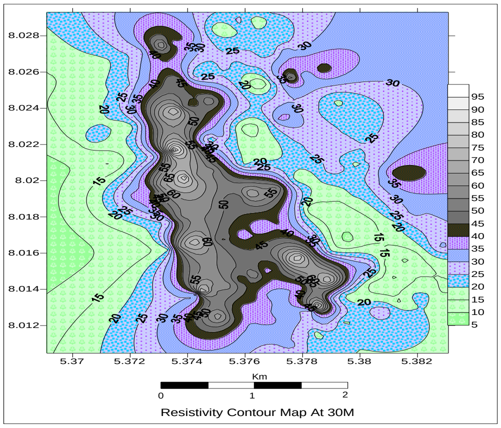

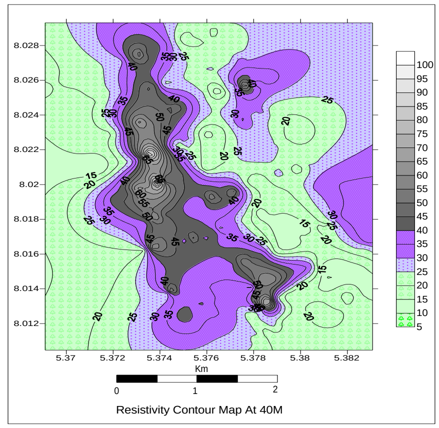

Fig. 11 Iso-resistivity map at 30m   Fig. 12 Iso-resistivity map at 40m

The Vertical electrical sounding (VES) also refers to as electrical drilling yield information related to individual points, while 2-D resistivity imaging yields more detailed geological information, such as thickness of overburden and lateral variation of resistivity. This technique provides true resistivity sections; Water-filled layers and structures that appear as conductive zones. This method has proven cost-effective in data gathering and interpretation and in providing increased understanding of sub-surface features. In order to have a view of the various lithologies over long distances, sections were drawn across VES points, at every sounding point, the various lithologies are drawn using the models obtained from curve matching (interpretation) that is, the number of lithologies, their thicknesses and apparent resistivity values. These sections show the characteristics of each lithology, the thickness of the lithology as well as the probable depth (Figs.13-17). One can easily deduce the position of the anomaly it extends as well as its depth. It is possible to also deduce shallow basins and deep basins as well as the groundwater flow in the area. The analysis shows a resistivity range of 8-850Ωm and a depth range between 12.5-83m, this implies that some areas are highly consolidated while other areas are moderate to lose formation. The depth change reveals the variation in the thickness of the lithologies at different locations. The response curve for most of the VES points indicated a 4-5 layer stratified alternating sequence of high and low resistivity horizons, at Aba Isu in the area South of the central line axis particularly where the limestone extensively outcropped, the sequence start with high resistivity horizon with values >100 Ωm alternating with low-medium resistivity horizons with values in the range of 20-50Ωm. This sequence in 2 or 3 cycles in most places in this area is terminated by the highly conductive horizon with resistivity values of <20Ωms particularly North of the study area. From the pseudo-sections, the resistivity values greater 100Ωm are indications of highly compacted formation which could be inferred as limestone, there is a consistency of these values on a trend coinciding with the central line axis, and this implies that the formation outcropped on all the profiles at the central line axis. The same values are observed at various depths beneath the subsurface implying the occurrences of same formation which extend beyond 35m depth. The variation in depth and location describes the undulating nature of the area. Moderate resistivity values between 25-30Ωm were also observed across the sections at various locations and depths, these values reflects pores of clay retaining water. Very low resistivity values less than 20Ωm were also observed mostly within a depth range of 2-15m and more at profile 04, in some areas this may be inferred to be top soil, silt or clayey formation that may constitute perch water in some cases.

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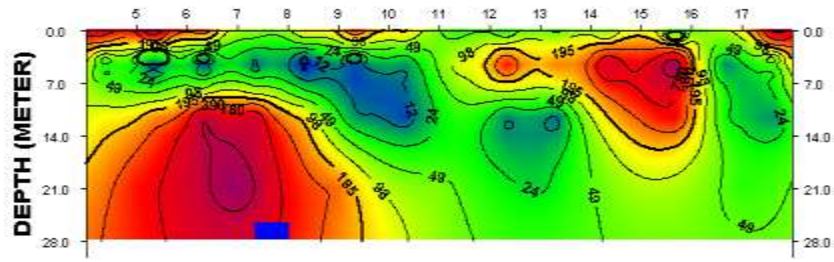


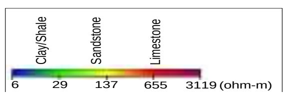
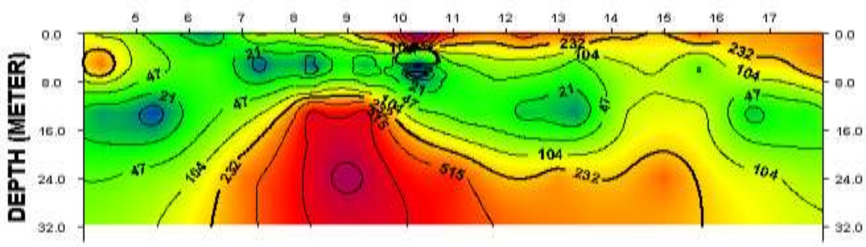


Fig. 13 Pseudo-section for profile 00



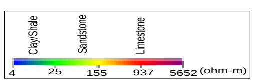
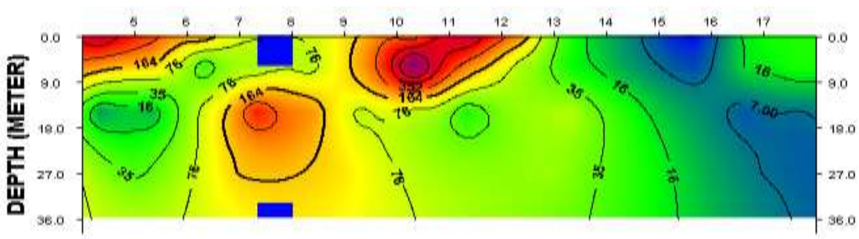


Fig. 14 Pseudo-section for profile 04



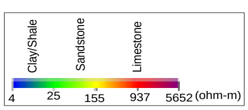


Fig. 15 Pseudo-section for profile 06

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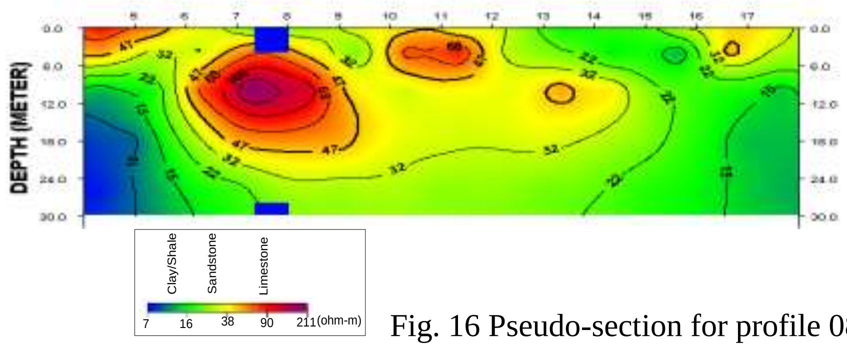

Fig. 16 Pseudo-section for profile 08

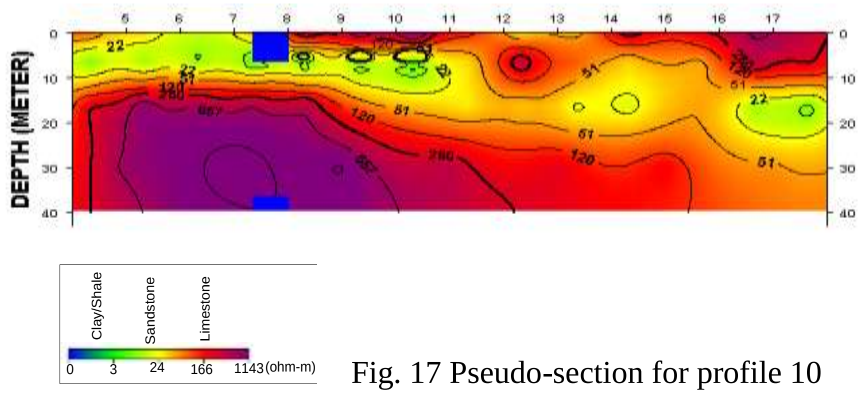

Fig. 17 Pseudo-section for profile 10

CONCLUSION

Geophysical results have provided the basis for the evaluation of the limestone deposit in terms of extent both lateral and vertical perspective of the limestone, this will go a long way to assist further exploration work (exploratory core drilling/ reserve estimation) and possible exploitation. However, only a detail drilling programme can provide information for decision making. Based on the results of interpretations and analysis of the field data, Itis therefore, recommended that 20 exploratory boreholes (an average of 5nos per (1km x 1km) for core drilling to depth range of about 25–40m each for possible reserve estimation and analysis to ascertain further the grade/quality of the limestone is essential. The exploratory holes will give an accurate correlation and broader perspective on the structural aspect of the limestone reserves, the general soil profile, stratigraphic sequence and the detail hydrogeological conditions can also be infer.

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