SSRG International Journal of Geo-informatics and Geological Science
ISSN: 2393 – 9206 /doi:10.14445/23939206/IJGGS-V9I1P101

Volume 9 Issue 1, 1-12, Jan-April, 2022
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Original Article

Geology and Aquifer Potential of Some Cretaceous Deposits Around Kwadon Village, Upper Benue through N-E Nigeria

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Received Date: 01 January 2022
Revised Date: 01 February 2022
Accepted Date: 10 February 2022

Abstract - *In the last few decades, there have been increased demands for water and the largest available source of freshwater lies underground. In the area studied, the main source of water supply is the Dadin Kowa Dam. Complementing this, people resort to the use of hand-dug wells, which are shallow and exposed to various forms of contaminations causing typhoid fever, cholera, and other water-related diseases. Thus, the use of vertical electrical sounding (VES) becomes imperative in locating viable aquifers in the area. In the course of this study, rock samples from the field were collected from the field were thin-sectioned, and the result of the study showed that quartz dominated the samples that were examined, with Gombe Sandstone having the highest percentage (90%) of quartz. The raw data obtained from the field using vertical electrical sounding (VES) was interpreted using the WinResist software. The interpreted results from the VES showed that most of the layers have low - moderate resistivity values, with sandstone localities having the least resistivities. All the information obtained points to the fact that Gombe Sandstone is the most porous and permeable (aquiferous) in the area.*

Keywords - *Vertical Electrical Sounding (VES), Aquifer, Quartz, Gombe Sandstone, Resistivity.*

I. INTRODUCTION

Water is an essential commodity to mankind, and the largest available source of freshwater lies underground. In our day to day life, water plays an important role in serving our daily needs. As compared to past days, there is a great depletion of surface as well as groundwater (Ramaraju et al., 2017). Increased demands for water have stimulated the development of underground water supplies. Inevitably, when progress magnifies and adds new problems, efforts are increased to solve these problems (Todd 1980). The last few decades have witnessed a tremendous increase in the application of geophysical techniques in locating aquifers (Dan Hassan and Adekile (1991). However, for a geophysical survey to be effective, a thorough mapping of the area of study is needed so as to know the hydrological features of the area, which gives an insight into the porosity and permeability of the soil and, by and large, helps to detect the aquifer potential of an area. A small percentage of Gombe town and its surrounding villages rely on water supply from hand pump boreholes, and a larger percentage rely on water supply from dadinkowa dam and hand-dug wells, which are very shallow and as such exposed to various forms of contaminations. Thus, the use of vertical electrical sounding (VES), commonly known as Schlumberger array, becomes imperative in locating viable aquifers in the area because of its high resolution in respect of the particular problems encountered in prospecting for groundwater. Groundwater quality is crucial to the determination of water suitability for drinking, domestic, agricultural and industrial purposes (Oyewumi et al. 2019).

This report describes the results of hydrogeological site investigation for Kwadon village and environs, Gombe State, Nigeria. The aim of the investigations was to locate a suitable borehole/Shallow well-drilling site within the Kwadon area. To accomplish this, detailed hydrogeological and geophysical investigations have been executed.

II. LITERATURE REVIEW

The area is Kwadon and its surrounding villages. It lies within the Gongola Basin of the Upper Benue Trough, North-East Nigeria. The entire Benue Trough is filled with sediments that range from late Aptian to Paleocene (Allix *et al.*, 1981). The environment of deposition also varied over time, such that the sediment varies from continental lacustrine/fluviatile sediments at the bottom (through various marine transgression and regression) to immature reddish continental sands at the top.

The Benue Trough is divided into Lower, Middle, and Upper (Fig.1) by Zaborski (1998), while Nwajide (2013) subdivided it into Southern, Central and Northern (this subdivision was used in this study). The Northern Benue Trough is made up of two major sub-basins: the N-S trending Gongola Sub-basin and E-W trending Yola sub-basin (Nwajide, 2013). The Geology and stratigraphy of Northern Benue Trough were described in detail by Carter et al. (1963), Offodile (1976), Benkhelil (1989), Zaborski et al. (1997), Abubakar (2006) and Tukur et al. (2015).

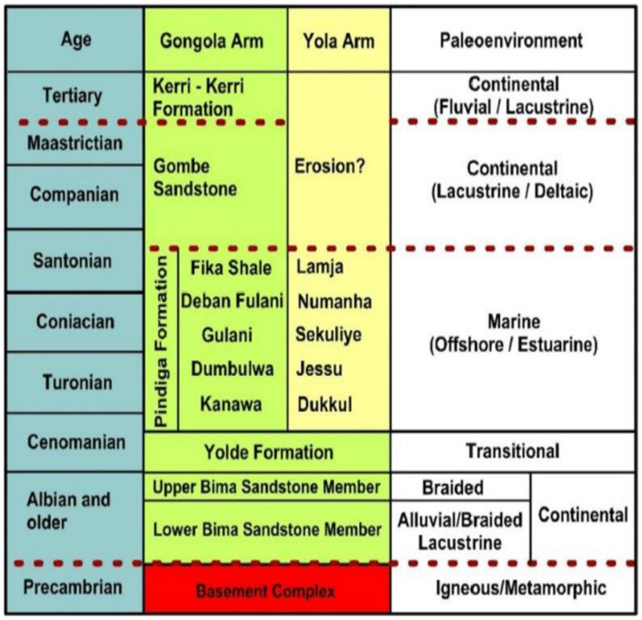

Fig. 1 Stratigraphic successions of upper benue trough (Tukur et al., 2015)

The trough is up to 6000m thick with Cretaceous-Tertiary sediments of which those predating the mid-Santonian were compressional deformed, faulted and uplifted in several places. The trough is believed to have provided the major link between the Tethys Ocean and the Gulf of Guinea through the Chad Basin during the Upper Cretaceous times (Obaje 2009). The Gongola Basin consist of 5 formations. The Bima Formation is the oldest sediment that directly overlies the crystalline basement rocks, although its type section is Bima Hill (Falconer 1911, Carter *et al.* 1963), it comprises pale grey, trough cross-bedded, coarse-grained conglomeratic arkoses with subsidiary interbedded moulded purple – grey clays. This is a braided river lower Bima sandstone facies (Guiraud, 1990, 1991) the Yolde Formation, which is a transitional deposit from the dominantly continental Early Cretaceous to the dominantly marine Late Cretaceous formations. It reaches a maximum thickness of about 200m but shows considerable lateral facies variation. Rather imprecisely dated, it has age limits between Late Albian and Late Cenomanian (Lawal and Moullade1986). The Yolde Formation represents a transition from fluvial to littoral to shallow sublittoral environments. Its upper parts mark the onset of the major Late Cenomanian transgression that affected the entire Benue Trough and large parts of the Saharan region (Reyment,1980). The Pindiga Formation, the Gombe Formation and the Kerri-Kerri Formation. The thickest sedimentary successions occur in the western part of Gongola Basin, to which Campano – Maastrichtian and Cenozoic deposits are restricted. Over 5km of sediment occur in the Dukku, Akko and Bashar sub-basin; thinner successions occur in the Lau and Numan sub-basin of the Yola arm (Benkhelil, 1988, 1989). The study area was restricted to the Gombe and Pindiga Formations. One borehole in the northern part of Gombe town showed the Pindiga Formation there to be some 155m thick (Thompson, 1958), but in the southwestern part of the inlier between Wuro Birji and Dabala, it thins to barely 30m in places. At Kumo, it is about 800m thick(Lawal 1982), and over 400m in the Fika Member alone occurs just a few km west of Gombe (Allix, 1983)

III. MATERIALS AND METHODS

Description of the study area with maps and Locations: The study area lies within latitude 10^0 15’ 00’’ and 10^0 18’ 00’’ N and longitude 11^0 16’ 00’’ and 11^0 19’ 00’’. The climate is classified as a sub-Sudan savannah with two distinct seasons: the wet season, which starts from about the end of March until October, and the dry season, which starts from November and continues till March. The temperature is constantly high but lowest during the harmatan period and highest just before the rains in March/April. The vegetation of the study area is savannah, and the trees are variable in height ranging from 10-15 feet with scattered shrubs and sparse grasses.

A. Geology

The field mapping was carried out, taking significant exposures into consideration. Dips, strikes and GPS coordinates were taken, and fresh samples were collected. A concise geological map of the area was produced.

B. Petrography

The collected samples were cut into considerably small chips of various sizes and each glued to a slide, using Araldite solution. The glass slides were then mounted on a hot plate to be baked, i.e. for the samples to firmly stick to the glass slide. The procedure lasted for 5 – 10 minutes. After baking, each sample was then taken to the frinding machine for further grinding so that it would be much thinner. The slide is then further polished by robbing it using a process referred to as abrasion.

The slides were viewed as a thin section under plane-polarized and cross-polarized light under a microscope. The stage is rotated to view a different section of the rock’s morphological features. Percentages of the various minerals were taken at different points, and the average was calculated to get the actual percentage of the various minerals in each slide.

C. Geophysical Fieldwork

The Resistivity method was used for the present investigations. Geophysical measurements were used to determine the thickness of the underlying layers, their potential as aquifers, and the expected quality of groundwater in these formations. Ten Vertical Electrical Soundings (VES) was executed at different selected points. An ohmega resistivity terrameter was used during the data acquisition to determine the thickness of each layer and the probable water-bearing zones.

IV. RESULTS

A. Field and Laboratory Results

The area mapped is made up of two formations, namely the Turonian-Santonian Pindiga Formation and the Campanian-Maastrichtian Gombe Sandstone. The Pindiga Formation occurs in the North-Eastern part of the area(fig.1), consisting of marine mudstone and limestone and covers about 10% of the area. The mudstone is grey in colour, while the limestone is light brown in colour with an abundance of ammonite. The thickness of the units ranged from 0.3m-0.7m, and it is laterally extensive.

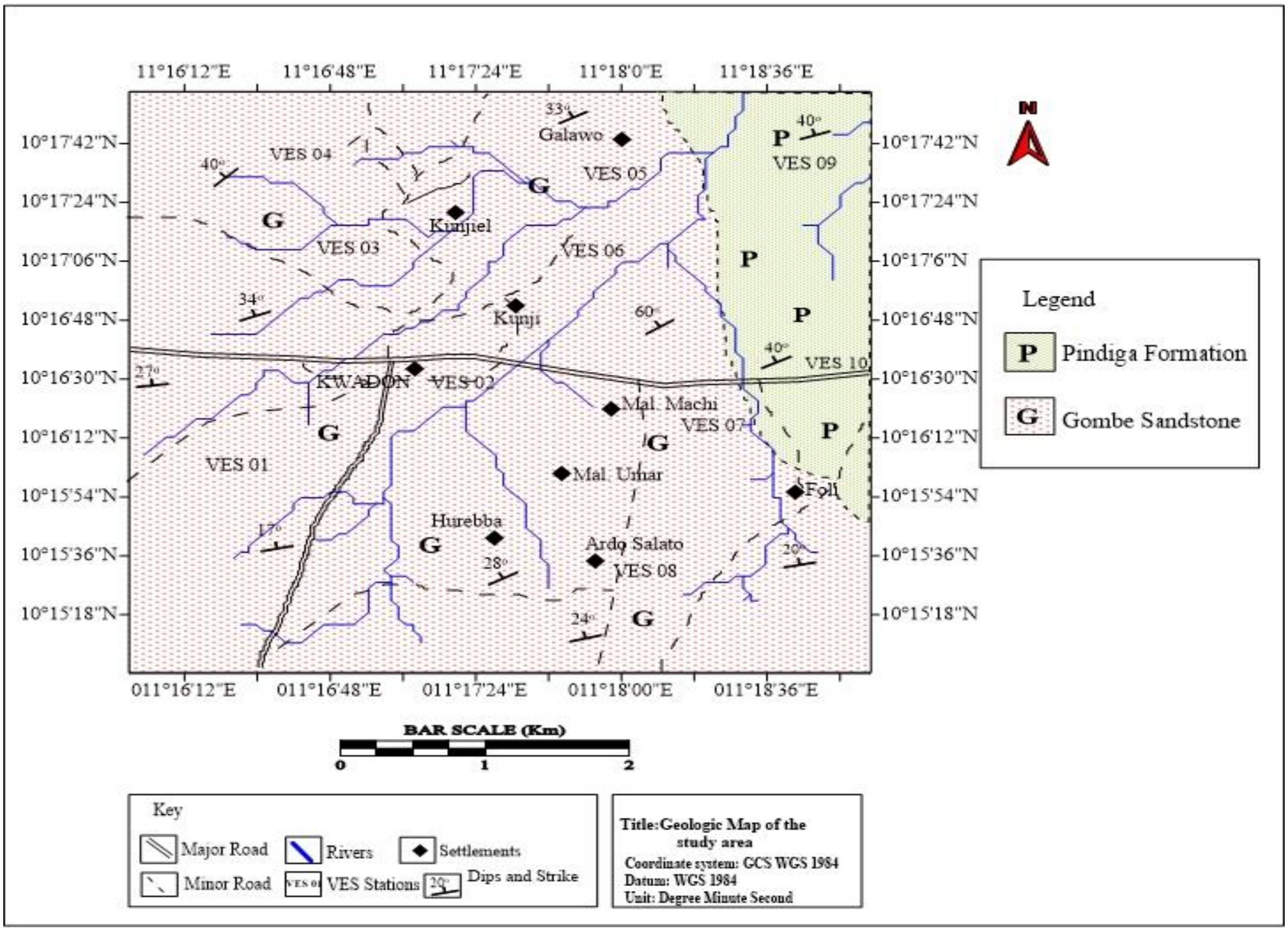

Fig. 2 Geologic map of the study area showing the VES points

The Gome Sandstone occur at the NN-SS part of the area(fig.1) and consist of continental sands, shales and mudstone, which covers about 90% of the area. The sandstone is medium to coarse in texture dark brown to light brown in colour. It is characterized by large scale trough cross-bedding and also characterized by sandstone noodles. The contact between the sandstone beds is sharp. Bed thickness ranged from 30cm-200cm and is traceable for a distance of 50m. The sandstone occurs interbedded with siltstone at an exposed section (fig.2). The shales and mudstones, as introduced, covers a surface area of about 50%(fig.2) and form the entire mass of section 2. The bed thickness of this unit ranged from 0.1m-2.4m and was also laterally extensive.

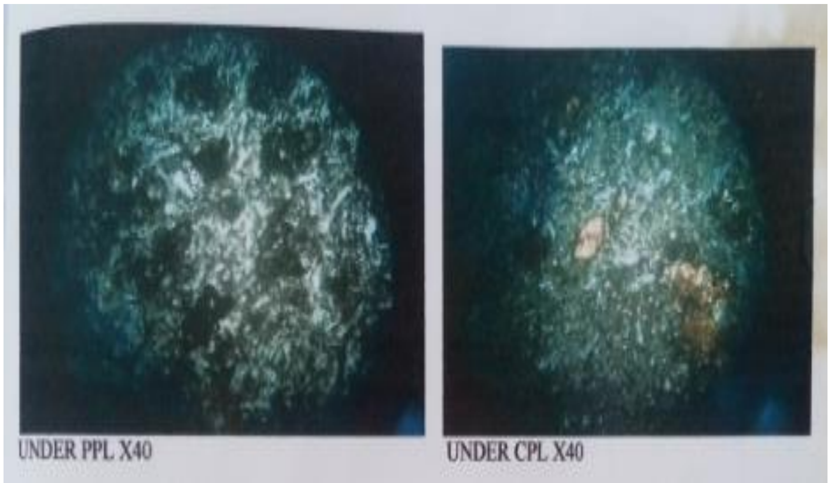

Plate 1 Shale of the pindiga formation

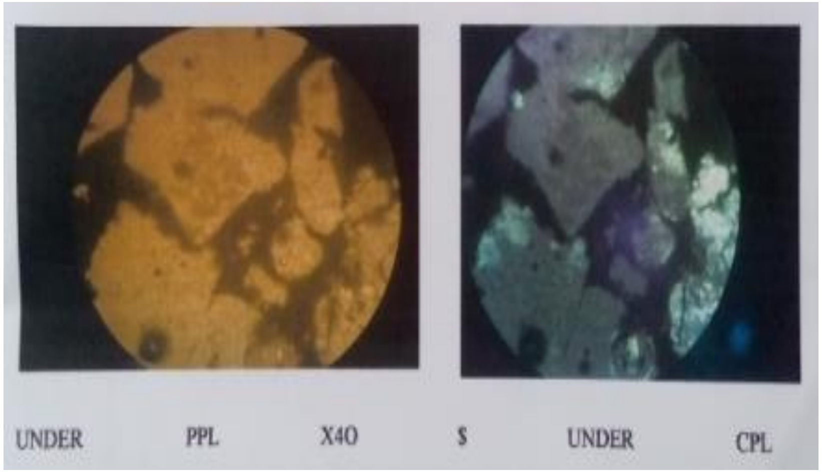

Plate 2 Sandstone of the gombe formation

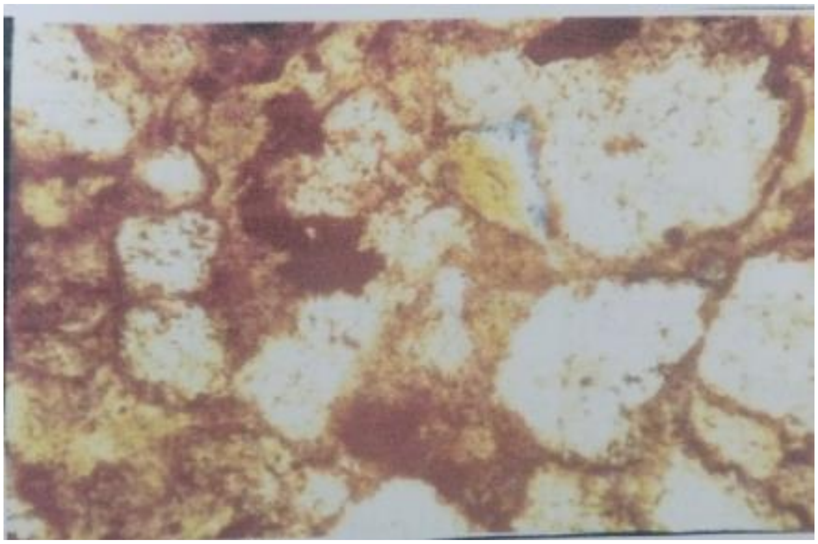

Plate 3: Limestone (under CPL X40) of the Pindiga Formation

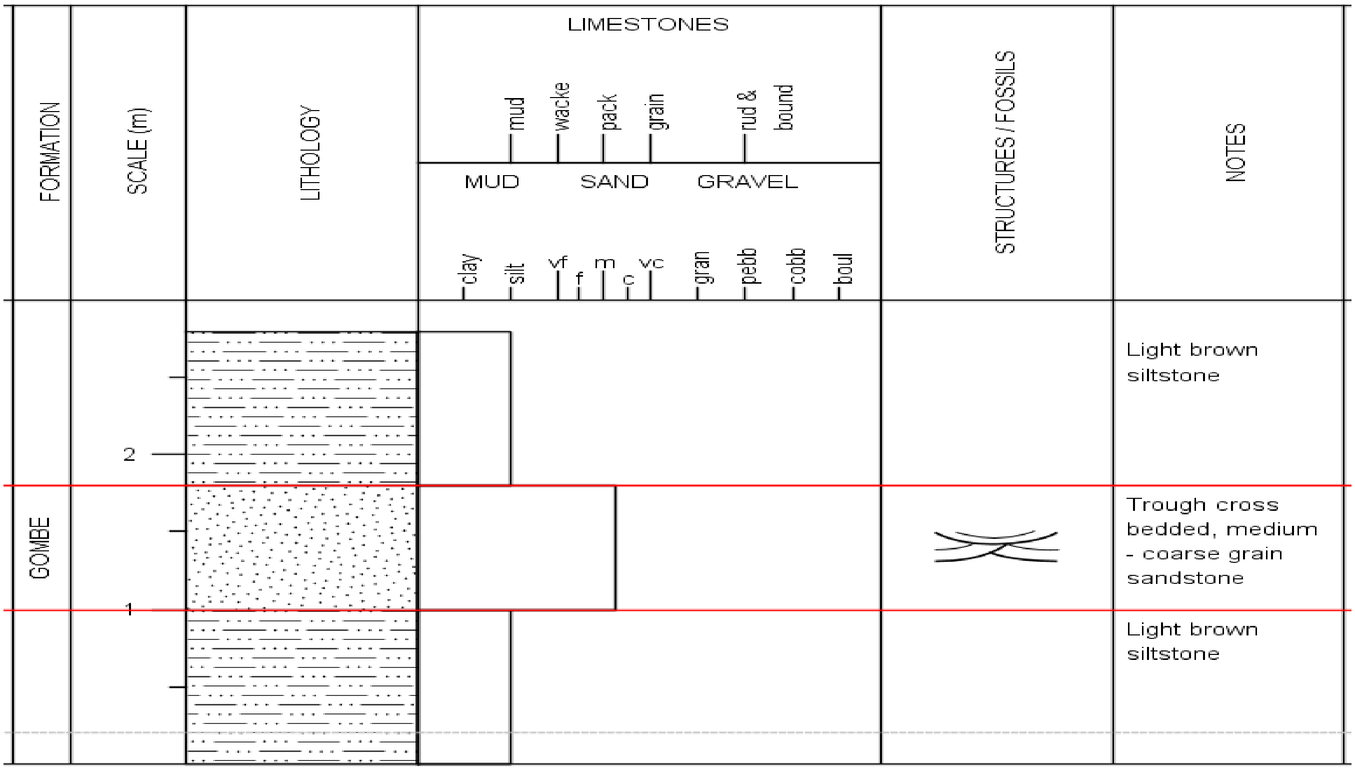

Fig. 3 Section 1(Lithostratigraphic Section of Gombe Sandstone at Location 1

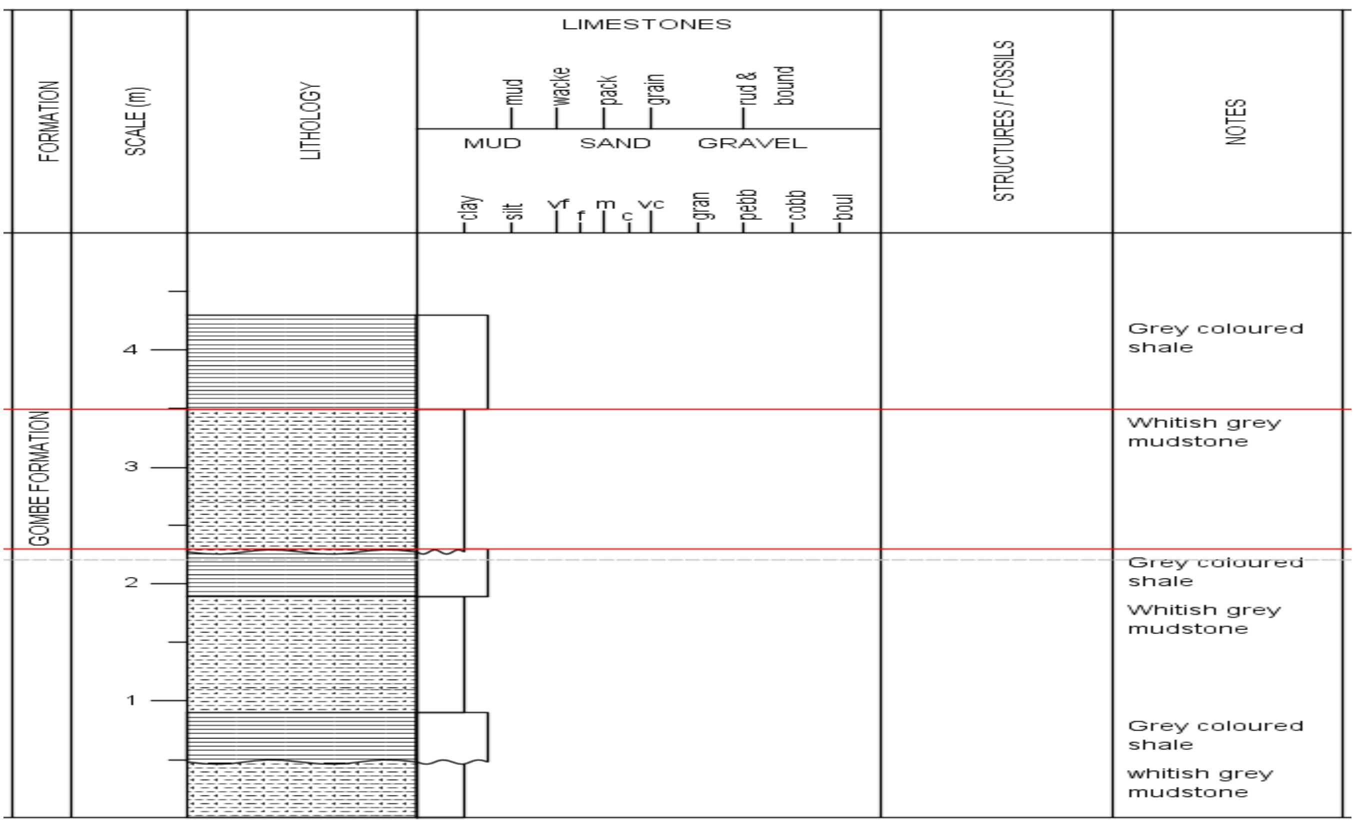

Fig. 4 Lithostratigraphic Section of Shale and Mudstone at Location 2

B. Results of the VES Data

A total of 10 VES points were cited, with about 8 of them in the Gombe Sandstone because it covers a major part of the study area, while 2 of them were cited in the Pindiga Formation. The results of the VES shows that the number of layers at each point ranged from 3-to 4 and most of the layers have moderate to low resistivities.

Table 1. Showing results of ves

VES NUM-BER	LAYER NUMBER	THICK-NESS (M)	RESISTI-VITY(ohm-m)	INFERRED LITHOLOGIES	AQUIFE-ROUS LAYER	AQUIFER POTENTIAL
01	1 2 3 4	0.6 1.8 6.1 -	48.4 374.1 4.4 1124.1	Topsoil(clayey) Silty sand Clay Indurated sandstone	4	Aquiferous
02	1 2 3	1.6 1.4	65.6 298.4 16.3	Top soil Sandstone Clay/Mudstone	2	Non-aquiferous
03	1 2 3	0.4 5.0 17.6 -	87.5 13.7 90.9 27.3	Clayey top soil Clay/mudstone Silty sand Mudstone/ Clay	3	Aquiferous
04	1 2 3	1.5 2.8 -	155.2 5.1 328.3	Silty top soil Clay/mud Sandstone	3	Aquiferous
05	1 2 3	4.0 4.6 -	33.4 5.7 129.5	Clayey/muddy topsoil Clay Clayey sand	-	Non-aquiferous
06	1 2 3 4	2.3 4.9 85.1 -	174.0 9.9 986.1 1316.8	Topsoil (silty sand) Clay Coarse/fine quartz sand Indurated sandstone	3	Aquiferous
07	1 2 3 4	2.5 3.7 0.6 -	77.3 6.5 15.7 853.7	Clayey/muddy top soil Clay Clay Sandstone	4	Aquiferous

08	1	1.0	86.7	Muddy topsoil	4	aquiferous
	2	3.8	9.1	Clay		
	3	5.4	6.6	Clay		
		-	1053.5	Indurated sandstone		
09	1	1.3	9.6	Clayey topsoil	3	Aquiferous
	2	20.8	46.6	Mudstone		
	3	12.7	113.5	Silty sandstone		
		-	1060.6	Indurated sandstone		
10	1	29.4	60.2	Mudstone/clay	2	Aquiferous
	2	66.2	960.1	Sandstone		
	3	-	238.7	Silty sandstone		

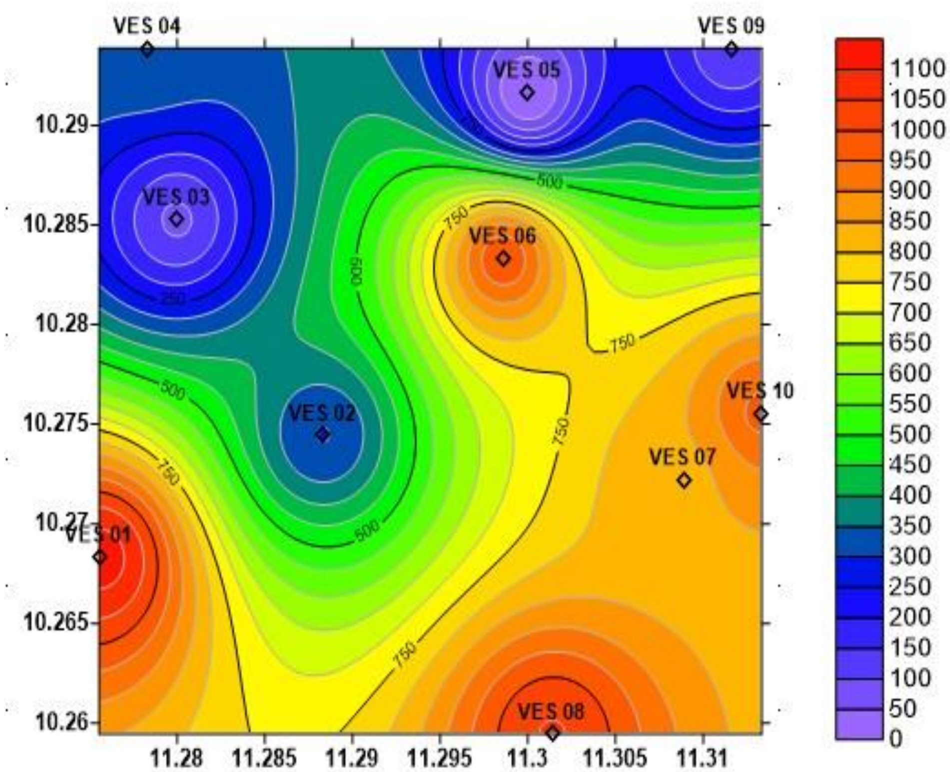

Fig. 5 Aquifer resistivity map

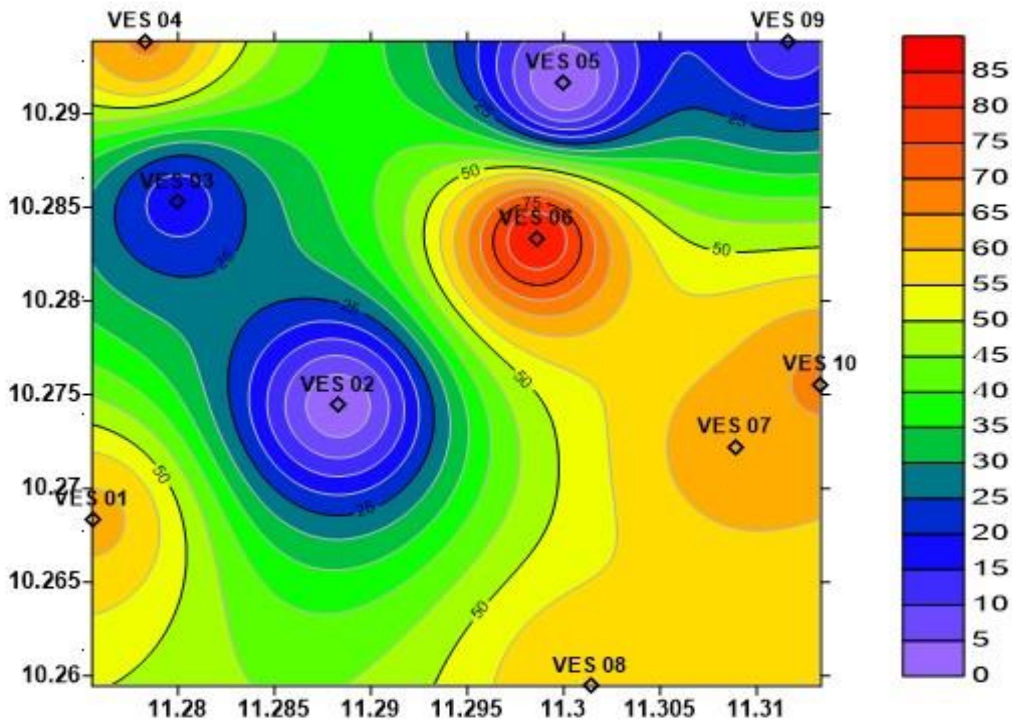

Fig. 6 Aquifer Thickness Map

V. DISCUSSION OF RESULTS

As presented, the area comprises mudstone, limestone, sandstone, and shale. The sands occur in the Gombe Sandstone, and previous workers (Carter et al. 1963, Zarboski 1998) have interpreted Gombe Sandstone as deposits of deltaic to lacustrine. Deltaic sand deposits are normally well-sorted sand due to the action of waves and tidal currents (Dike 1995). The present data shows that the sandstone has about 90% quartz content (plate 2), and most grains of the sands are angular to sub-angular. Sandstones with 90-95% quartz content is regarded as sub-arkosic (Dott 1964). This sand is highly homogeneous compositionally, with little or no possibility of generating secondary clay minerals that can block porosity and permeability. The resistivity values obtained from the Gombe Sandstone show that they have some aquiferous zones, indicated by their low resistivities, which could be the sandstone as the interbedded shales are aquicludes (Carter et al. 1963).

The mudstones and limestone occur in the Pindiga Formation. The Pindiga Formation have been interpreted by several workers (Zarboski 1998, Carter et al. 1963 e.t.c.) as a sequence of marine mudstones and shales which may include a number of limestone towards the base. The present data shows that the limestone has about 54% quartz content (plate 3), and the others are feldspar and rock fragment. Also, the limestone is poorly sorted and contains a lot of matrices which is capable of blocking pore spaces and portends low porosity and permeability. Because limestone is an aquitard, it has very few aquiferous zones, which may be as a result of the presence of fractures on the limestone. The interbedded mudstone is also an aquitard but is unlikely to be fractured since it is not fissible, which makes it to be totally impermeable. The VES results from table 1 above indicates the aquiferous layers, their thickness in meters, depth, resistivity in ohm-m, inferred lithologies, aquiferous layers and remarks on the aquifer potential of each point. Out of the 10 VES sounding points. The following points were regarded as aquiferous VES 01, 03, 04, 06, 07, 08, 09 and 10, while VES 02 and 05 were regarded as non-aquiferous.

Comparing the aquifer resistivity and aquifer thickness map, the result shows that areas with higher resistivities have higher thickness. The sandstone dominated areas have the highest aquifer potential due to the high thickness and resistivity, which corresponds with the geology of the area.

VI. CONCLUSION

From the interpretations above, it can be deduced that the sandstone and limestone are more aquiferous than mudstone, and this is in tandem with Carter et al., which stated that the sandstone, siltstone and shale of Gombe sandstone form efficient aquifers and adequate yield could be obtained from them while the limestone and mudstone of Pindiga Formation are virtually impermeable and wells produce small yield unless a thick weathered zone is penetrated. This goes to a large extent to show that the electrical resistivity method has proved extremely cost-effective in the delineation zones of high porosity and permeability in the area.

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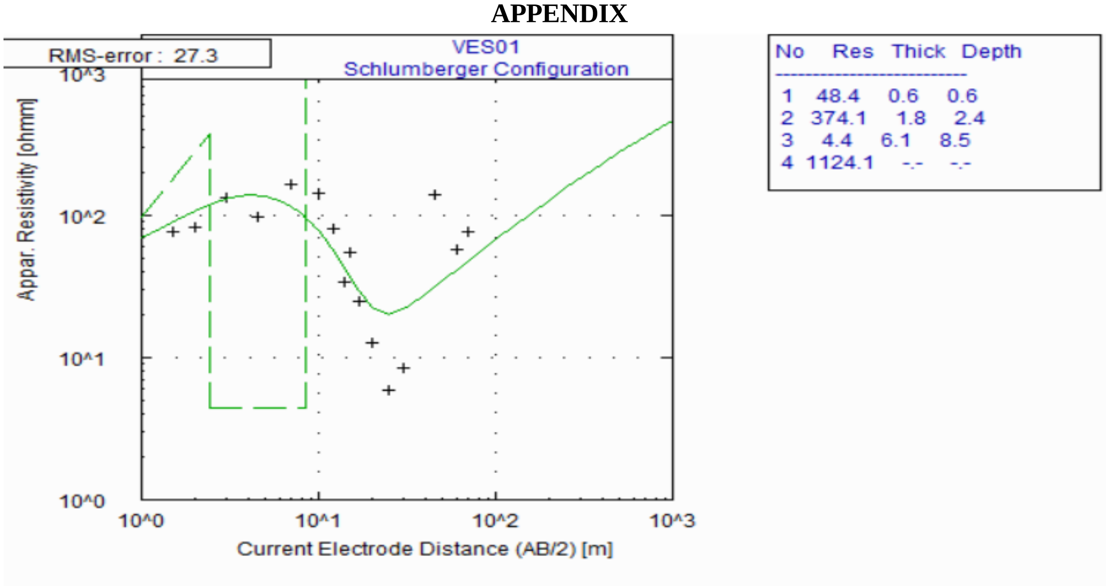
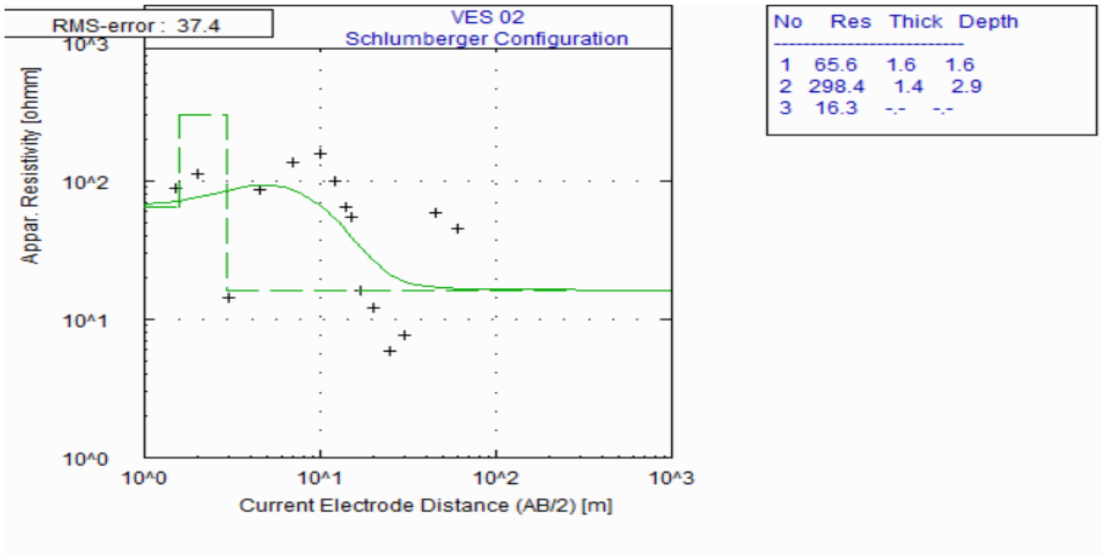
APPENDIX

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VES 02
Schlumberger Configuration
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10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
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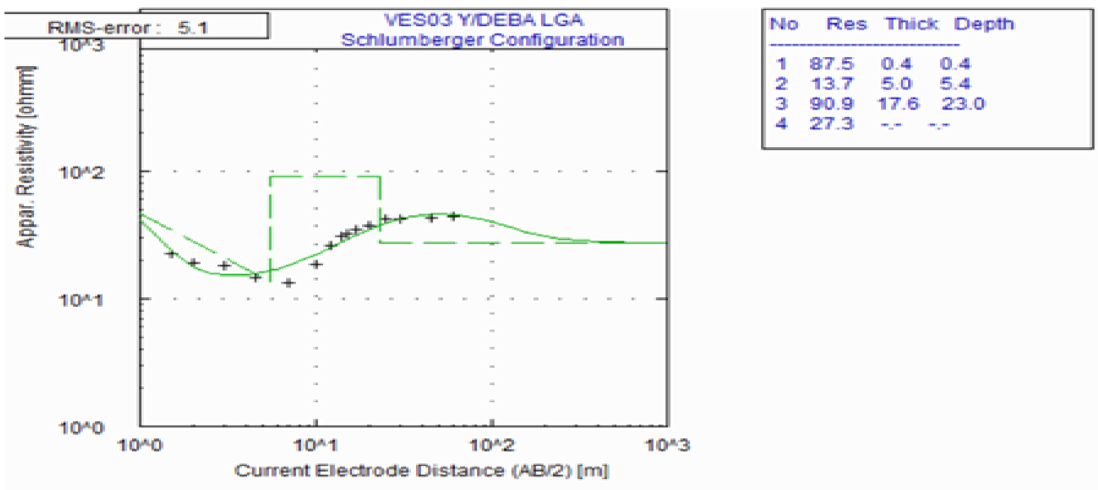
2 298.4 1.4 2.9
3 16.3 -.- -.-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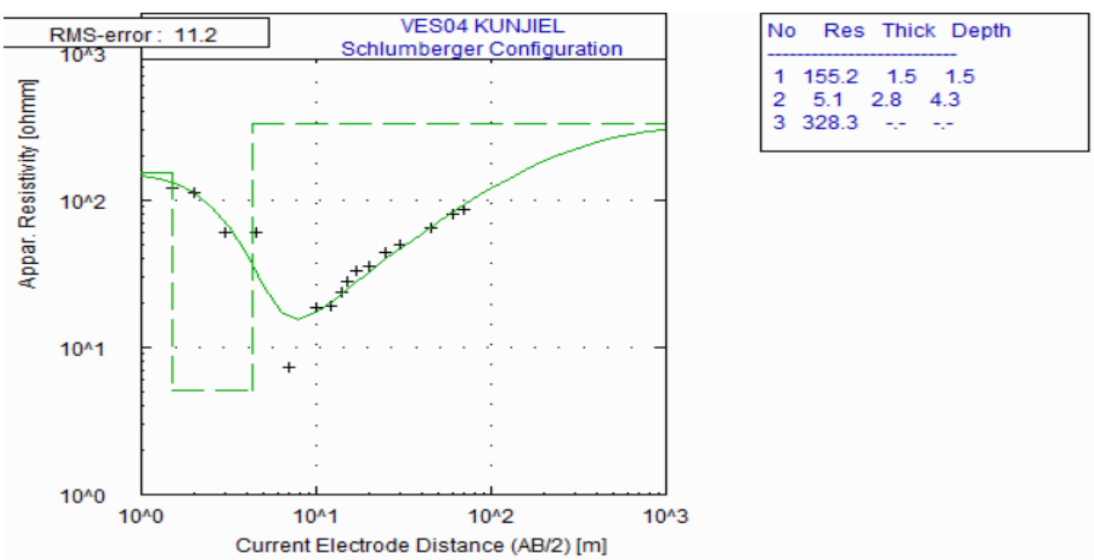
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 87.5 0.4 0.4
2 13.7 5.0 5.4
3 90.9 17.6 23.0
4 27.3 -.- -.-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Schlumberger Configuration
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10^0
10^1
10^2
10^3
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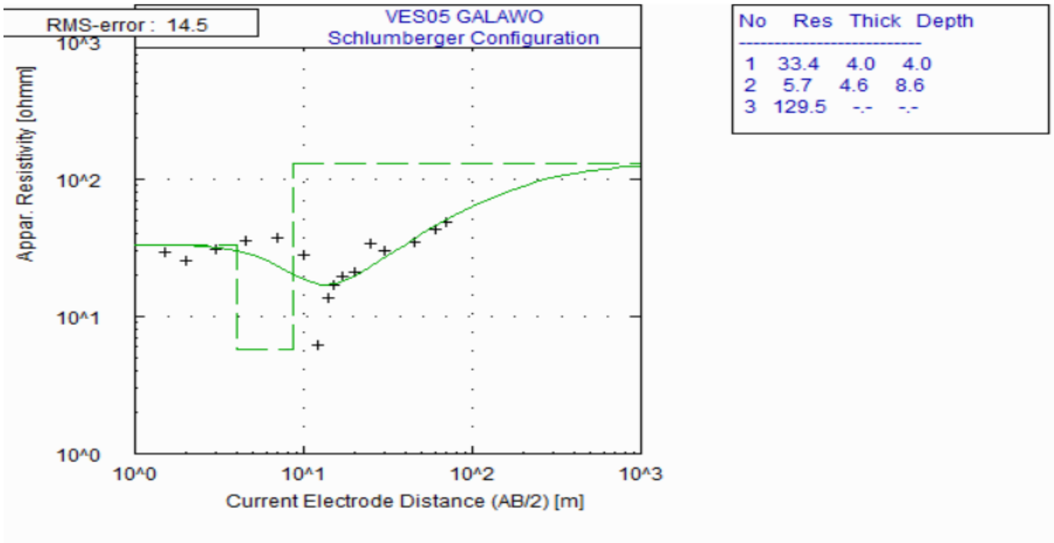
2 5.1 2.8 4.3
3 328.3 -.- -.-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10^2
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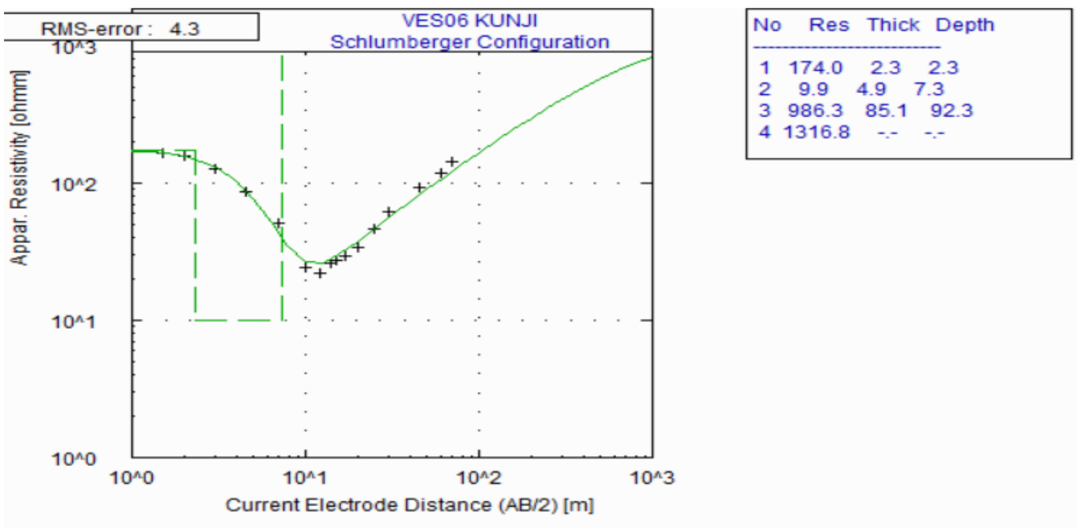
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10^0
10^1
10^2
10^3
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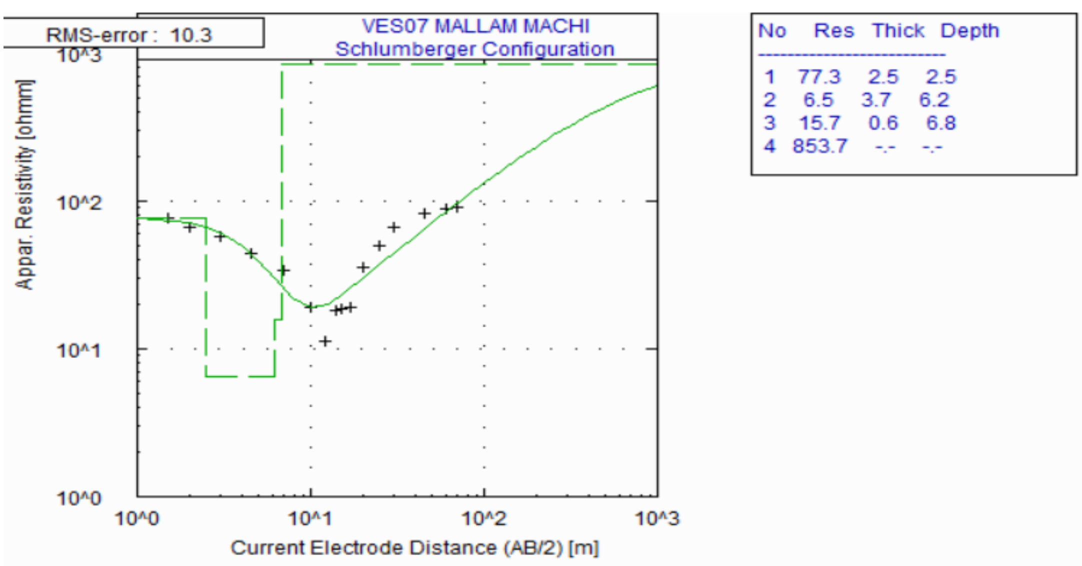
4 1316.8 -.- -.-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10^1
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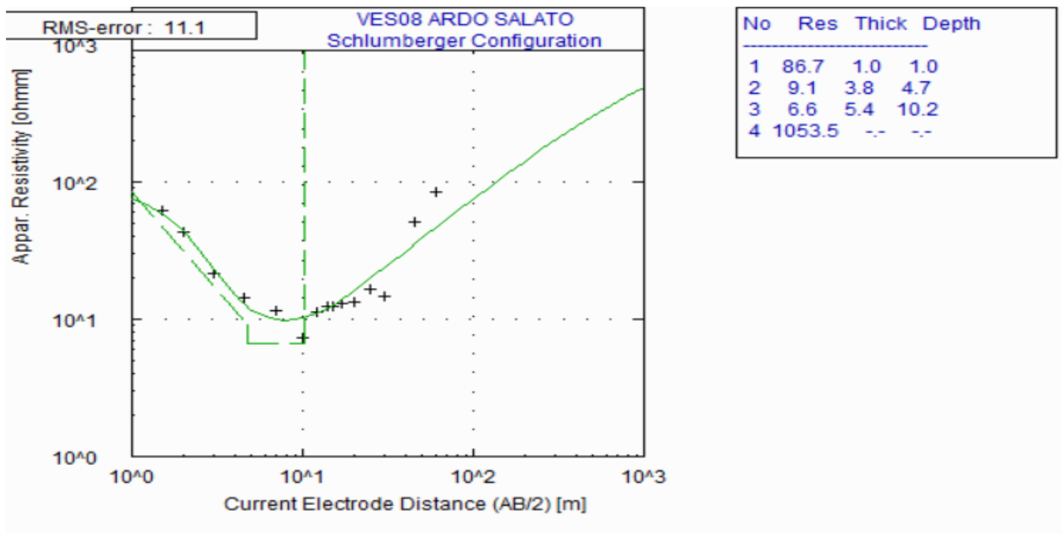
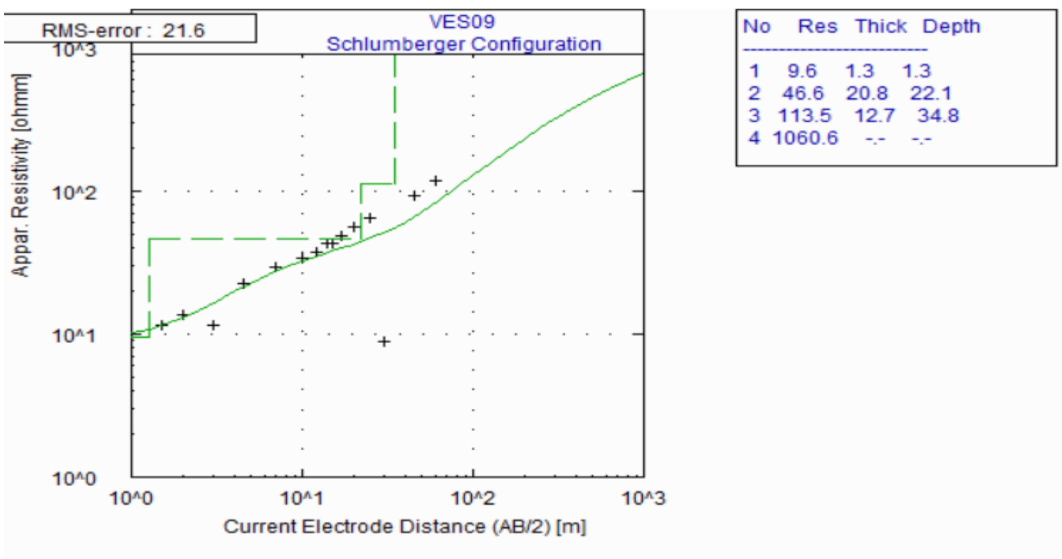
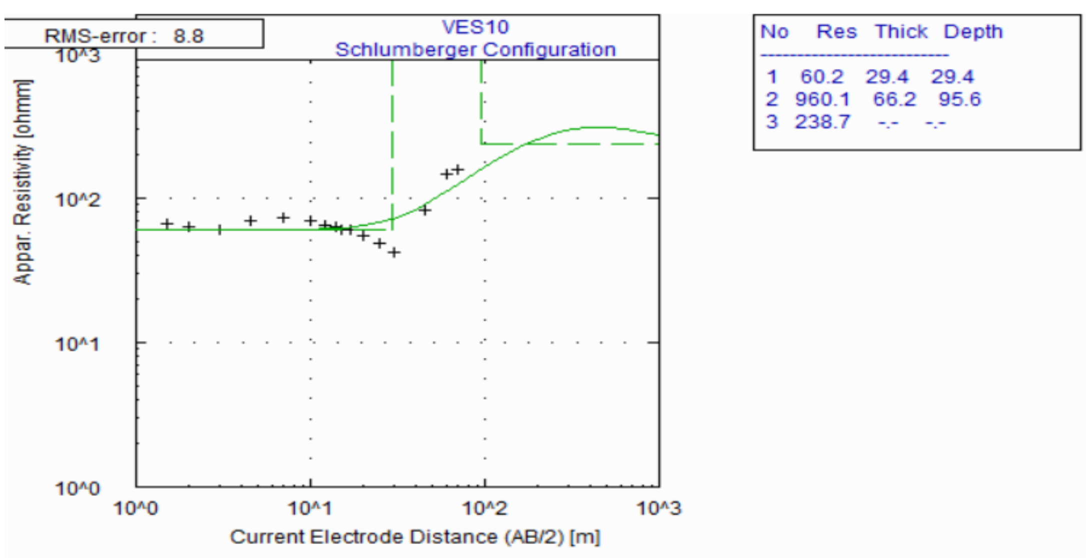
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 77.3 2.5 2.5
2 6.5 3.7 6.2
3 15.7 0.6 6.8
4 853.7 -.- -.-


RMS-error : 11.1
VES08 ARDO SALATO
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 86.7 1.0 1.0
2 9.1 3.8 4.7
3 6.6 5.4 10.2
4 1053.5 -.- -.-


RMS-error : 21.6
VES09
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 9.6 1.3 1.3
2 46.6 20.8 22.1
3 113.5 12.7 34.8
4 1060.6 -.- -.-


RMS-error : 8.8
VES10
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 60.2 29.4 29.4
2 960.1 66.2 95.6
3 238.7 -.- -.-