GEO-ELECTRIC SOUNDINGS FOR GROUNDWATER EXPLORATION IN PART OF PORT HARCOURT, RIVERS STATE, SOUTH-EASTERN NIGERIA.

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CERTIFICATION

I hereby certify that this project was carried out by Onayemi Ayomide Oluwatobi, Matric no: GPY/11/0297 in the department of geophysics, faculty of Science, Federal University, Oye, Oye-Ekiti, Ekiti State under my supervision.

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DEDICATION

This project is dedicated to the almighty God; the alpha and Omega, protector and provider, who has proved to me that He is indeed God and for being there for me throughout my stay in this university.

It is also dedicated to my mum; Mrs. Aderonke Onayemi and my grand uncle; Mr Kolawole for their financial support, moral words of encouragement and prayers throughout my stay in this university.

ACKNOWLEDGEMENT

I am very grateful to God for being my beginning and my end and for sustaining my life throughout the study of this course till the end. I am so grateful and I appreciate God, He is indeed the I am that I am.

Many thanks to my HOD and supervisor, Dr. J.O Fatoba for being a father and also a man of integrity. I am glad you supervised me sir, you are indeed an epitome of knowledge. Thank you sir for your perseverance and your listening ear, may your children be favoured wherever they get to in life.

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To my siblings, Babatunde, Oluwaseun, and my kid sis, Feyisayo Onayemi, I love you all. And my stubborn cousins, Timilehin and Desire Olukoga, I love you too.

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ABSTRACT

Groundwater is the water that exists in pore spaces and fractures in rocks and sediments beneath the water table. The need for groundwater has increased tremendously due to the unavailability and the contamination of surface water bodies by the intrusion of saline water and human activities.

The geo-electric soundings were carried out in Eleme Port Harcourt, capital of Rivers state in order to delineate the subsurface geo-electric layers and the depth to the aquifer unit for groundwater development.

Ten (10) vertical electrical sounding stations were occupied within the study area using the schlumberger electrode configuration. The Pasi Earth Resistivity Meter (16EL Model) was used. The sounding curves were classified into five (5) curve types: KH, HKH, QHK, HKQH and QQ curves. The quantitative interpretation of the geo-sounding curves by partial curve matching and computer iteration revealed 5 geo-electric layers based on characteristic resistivity ranges. The layers are; topsoil, lateritic sand, sand, coarse sand and clay. The major aquifer units in the area are the sand and the coarse sand formations.

Virtually all the VES points are good for groundwater development, because of the dominant sand and coarse sand formations, which is the major aquifer unit in the study area.

CHAPTER ONE

1.0 INTRODUCTION

1.1 GENERAL STATEMENT

Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the water table. It originates as rainfall or snow, and then moves through the soil and rock into the groundwater system, where it eventually makes its way back to the surface streams, lakes, or oceans. Groundwater makes up about 1% of the water on the Earth (most water is in oceans. Groundwater is found beneath the unsaturated zone where all the open spaces between sedimentary materials or in fractured rocks is filled with water and the water has a pressure greater than atmospheric pressure. To understand the ways in which groundwater occurs, it is needed to think about the groundwater bearing formation properties such as porosity and permeability. The water bearing formation is termed AQUIFER.

Porosity: this is the property of a rock possessing pores or voids.

Permeability: this is the ease with which water can flow through the rock.

Aquifer: which is a geologic formation sufficiently porous to store water and permeable enough to allow water to flow through them in economic quantities.

Storage coefficient:this is the volume of water that an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in the component of area normal to surface.

The occurrence of groundwater resources in a basement complex depends mainly on the secondary porosity (after deposition of sediments) and also permeability arising from weathering and fracturing of parent rocks and also the pattern of the fracture (Carruthers, 1984).

Fractures in rock are very important pathways for the flow of groundwater and the transportation of contaminants. In fractured rock systems, groundwater occupies voids that are formed by fractures, fissures, faults and joint planes which are constantly distributed inside the rock formation. Due to their nature, they exhibit unique problems in their investigation, evaluation and management largely because of their heterogeneous nature and the dependence of aquifer properties on fracture distribution and connectivity.

A relatively inexpensive way to prospect for groundwater, both on a small and large scale is by using electrical resistivity method of geophysical prospecting; this method is fast, repeatable, relatively cheap and non-intrusive, thus making it a practical alternative to traditional approaches (Skinner and Heinson, 2004). The electrical resistivity of rocks depend on several factors, some of which include; the presence of conductive minerals such as base metal sulphides or oxides and graphites in the rock. Most rocks without these minerals are usually poor conductors and their resistivity is determined primarily by their porosity, degree of fracturing and the degree of saturation of the pore spaces (Cook et al., 2001).

Electrical methods have been successfully employed to monitor groundwater occurrence and have also provided information on fluid electrical conductivity, fracture orientation and overall bulk porosity (Dailey et al., 1992, Slater et al., 1996, Skinner and Heinson 2004, Adepelumi et al., 2006, Batayneh 2006., Weiss et al., 2006).

AIM AND OBJECTIVES

The aim of the research is to use the electrical resistivity method to prospect for groundwater devolopment in the study area. The objectives of the study are;

- To determine the geo-electric parameters of the different geologic units.

- To delineate the geo-electric layers, their thicknesses and lateral extent.
- To determine the depth to the aquifer unit
- From the above objectives, to locate a borehole point.

1.4 PHYSIOGRAPHIC SETTING

1.4.1 LOCATION, ACCESSIBILITY AND DRAINAGE PATTERN

The study area lies within the sedimentary terrain of southern Nigeria between longitudes E: 007° 06.215ˈ to E: 007° 06.564ˈ and latitudes N: 04° 49.480ˈ to N: 04° 49ˈ793 in Port Harcourt, capital of Rivers state. The study area is accessible as a result of the availability of roads; the terrain is generally low-lying with elevation between 8 -17m above mean sea level and slopes unperceptively towards the Atlantic Ocean (International Journal of Science and Technology Volume 3 No. 2, February, 2014**)**. The drainage pattern is largely controlled by the Bonny River and its tributaries and creeks which together drain various outcrops of relatively higher land which are largely surrounded by mangrove swamps, (Bell-Gam 2002).

1.4.2 CLIMATE AND VEGETATION

Rainfall is high in Port Harcourt with annual mean of 240cm. the rainfall exhibits double maxima regime with peaks in July and September. The area falls within the humid tropics with humidity of 63- 79%, (Korean Report, 1980).The physiography conforms to the geomorphic features of the Niger Delta governed by several factors which influence transport and ultimate deposition of the sediment load, shape and growth of the delta. The Niger Delta comprises five geomorphic sub-environments(Osakumi and Abam 2004); the undulating lowlands of the coastal plain sands, the flood plain of the lower Niger with extensive sand deposits, the meander belts consisting of wooded freshwater swamps, the mangrove swamps and estuary complexes and the beach ridges. These sub-environments are zones where a vast amount of sediments are deposited by rivers in their search for lines of flow, (Osakumi and Abam 2004).

1.5 REVIEW OF PREVIOUS WORKS

The electrical resistivity method has been used by many researchers to detect bedrock fractures, overburden thicknesses, geoelectric layers, groundwater potential and so on.

Ozegin et al., (2008) used combined electromagnetics method and vertical electrical sounding to establish groundwater viability in Oke-Agbe high school field located in Akoko North-west local government area of Ondo state based on a clear-cut relationship between electromagnetics method and vertical electrical sounding. Both methods were jointly used for investigation to determine the overburden thickness, geo-electric parameters and groundwater potential.

Selemo et al (1995) worked on an appraisal of the usefulness of Vertical Electrical Sounding (VES) in groundwater exploration in Nigeria and concluded that the results of VES with the schlumberger array in many parts of Nigeria have being very useful in identifying viable locations for water boreholes.

Adiat et al., (2009) used integrated geophysical techniques involving the VLF-EM and the electrical resistivity sounding methods to map Oda town, Southwestern Nigeria to determine the groundwater potential of the town. The qualitative interpretation of the VLF-EM results identified areas of hydro-geologic importance and formed basis for vertical electrical sounding

(VES) investigation. On the basis of the geo-electric parameters, the area was zoned into good, intermediate and poor groundwater potential zones.

Olayanju G.M (2011) carried out a geophysical mapping involving VLF electromagnetic profiling along seven profiles, ten offset wenner and two azimuthal soundings in the study of perennial spring sites at Iloyin community in Akure metropolis, Southwest Nigeria.

Odoh and Onwuemesi (2009) use Azimuthal Resistivity Survey (ARS) to determine and characterize the anisotropic properties of fractures in Presco campus of Ebonyi state University Nigeria, for evaluation of groundwater development and flow within the area. The azimuthal resistivity survey results show that there is significant anisotropy between depth and fractures. Variation of the coefficient of anisotropy has been shown to have the same functional form as permeability anisotropy. Thus, a higher co-efficient of anisotropy implies higher permeability anisotropy. The results also indicate better permeability and porosity.

Isifile and Obasi (2012) used radial vertical electrical sounding (RVES) around Ifon, south western Nigeria, to determine electrical anisotropy and map trend of concealed structure. The results show that the concealed bedrock is anisotropic with causative features such as foliation, joints and fault which could favour groundwater storage.

Ajibade et al, (2012) used Azimuthal Resistivity Survey (ARS) to investigate the groundwater potentials and anisotropic properties of fractures for sustainable groundwater development within Ibadan metropolis. Result of groundwater head contouring showed that groundwater flow is dominantly in directions which are associated to fracture-controlled flow.

Olasehinde and Bayewu (2011) used evaluation of electrical resistivity anisotropy to report the potency of combination of anisotropy polygon and isoresistivity map in reducing ambiguity inherent in a single geophysical parameter in OdoAra, west central Nigeria.

Onabanjo (2001) carried out geophysical survey using resistivity method in Ago-iwoye southwestern Nigeria and discovered two types of subsurface zones which are associated with groundwater exploration namely the weathered basement and fractured basement in which both are separated by barriers of unaltered rocks tending to reduce the possibility of groundwater accumulation.

CHAPTER TWO

BASIC THEORY OF THE ELECTRICAL RESISTIVITY AND GEOLOGY OF THE STUDY AREA

2.1 BASIC THEORY OF THE ELECTRICAL RESISTIVITY METHOD

Electrical resistivity studies in geophysics may be understoodin the context of current flow through a subsurface medium consisting of layers of materials with different individual resistivity.For simplicity, all layers are assumed to be horizontal. The resistivity (ρ) of a material is a measureof how well the material retards the flow of electrical current.

Resistivity varies tremendously from one material to another. Due to this great variation, measuring the resistivity of an unknown material has the potential for being very useful in identifying that material, given little further information. In field studies, the resistivity of a material may be combined with reasoning along geologic lines to identifythe materials that constitute the various underground layers.

Resistivity is often first encountered in physics when discussing the resistance of an ideal cylinder of length *L* and cross-sectional area *A*of uniform composition. The resistivity appears as the material-specific constant of proportionality in the expression for the total resistance of the cylinder;

$R = \rho L/A$...1

The total resistance *R* may be obtained experimentally throughOhm's law;

$R = V/I$

Where*V* is the potential difference between the ends of the cylinder and *I* is the total current flowing through the cylinder. Edge effects are not considered. The resistivity of the material, an intrinsic property of the material, is then related to experimentally measure extrinsic parameters by;

$\rho = (V/I)\ (A/L) = R_{app}K$...2

In equation 2, the resistivity is given by the product of the ''apparent resistance'' $R_{app} = (V/I)$ and a ''geometric factor'' $K = A/L$, that carries information about the geometry of the cylinder. This type of product of an apparent resistance and a geometric factor will appear again when the resistivity of the ground is determined.

It is more difficult to arrive at an expression for the resistivity of material that is not as geometrically simple as a uniform cylinder. A good starting point is shown in Fig. 2.1,

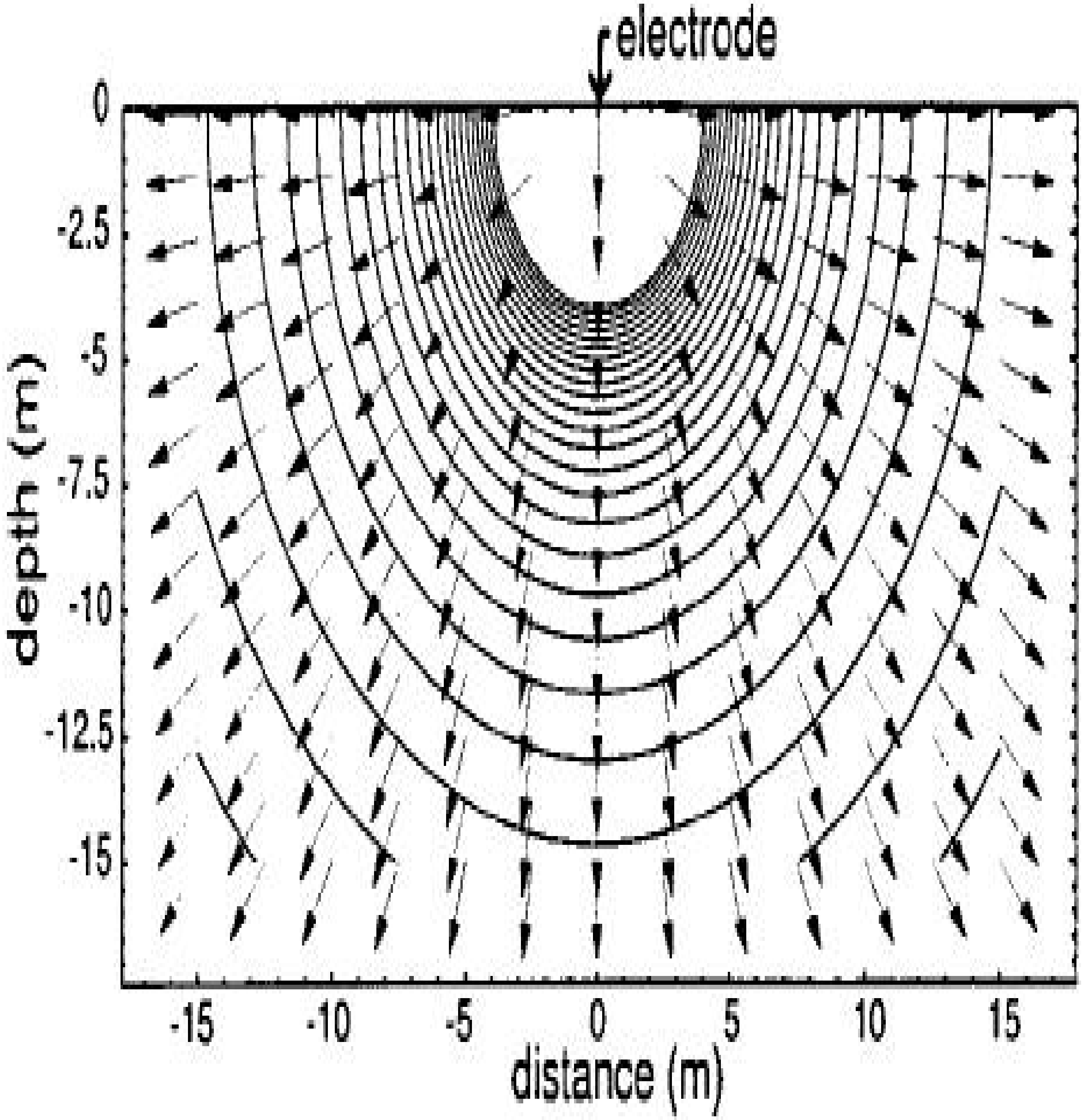


FIG 2.1 :Current flow and equipotential surfaces in a level field with homogeneoussubsurface structure. The unit vector field shows the directions of the current density **J** and thus the electric field **E**.

which depicts current flowing radially away from a single electrode at positive potential located on the surface of the ground. The subsurface is of uniform composition, and *V* = *0*infinitely far away from the electrode. Equipotential surfaces are indicated by solid lines, while the unit vector field shows the direction of **J** and thus **E**. The equipotential surfaces are perpendicular to the lines of current and may be understood as creating the local potential gradients or ‘‘voltage drops’’ that drive the current according to the simplescalar form of Ohm’s law given by;

I = V/R

The resistance of the air above the ground is assumed to be infinite so that the ground forms a Dirichlet-type boundary.

Amore realistic situation is depicted in Fig. 2.2. The two current electrodes are labeled *A* and *B* by convention. Figure 2.2 shows the current in one ac cycle flowing from *B* to *A*, with each line of current being driven from higher to lower potential throughout the medium. A plane of symmetry exists at the midpoint between the electrodes. It should be noted that alternating current is used in these studies to avoid macroscopic polarization of the subsurface material. Such macroscopic polarization would result from the bulk migration of charges in the subsurface in response to a constant applied field. This would create an artificial DC potential that would interfere with the resistivity measurements. An AC frequency in the range 1–100 Hz is sufficient to avoid this problem.

Figure 2.2 indicates that the spacing of the two current electrodes will determine the ‘‘effective depth’’ to which the current will penetrate. If the spacing between *A*and *B*is on the order of a meter, then the vast majority of the total current will flow no more than a few meters from the surface. If the spacing between *A*and *B*:is on the order of a kilometer, then most of the current will penetrate very deeply into the underlyingmaterial as it travels from *A* to *B*. Thus, the

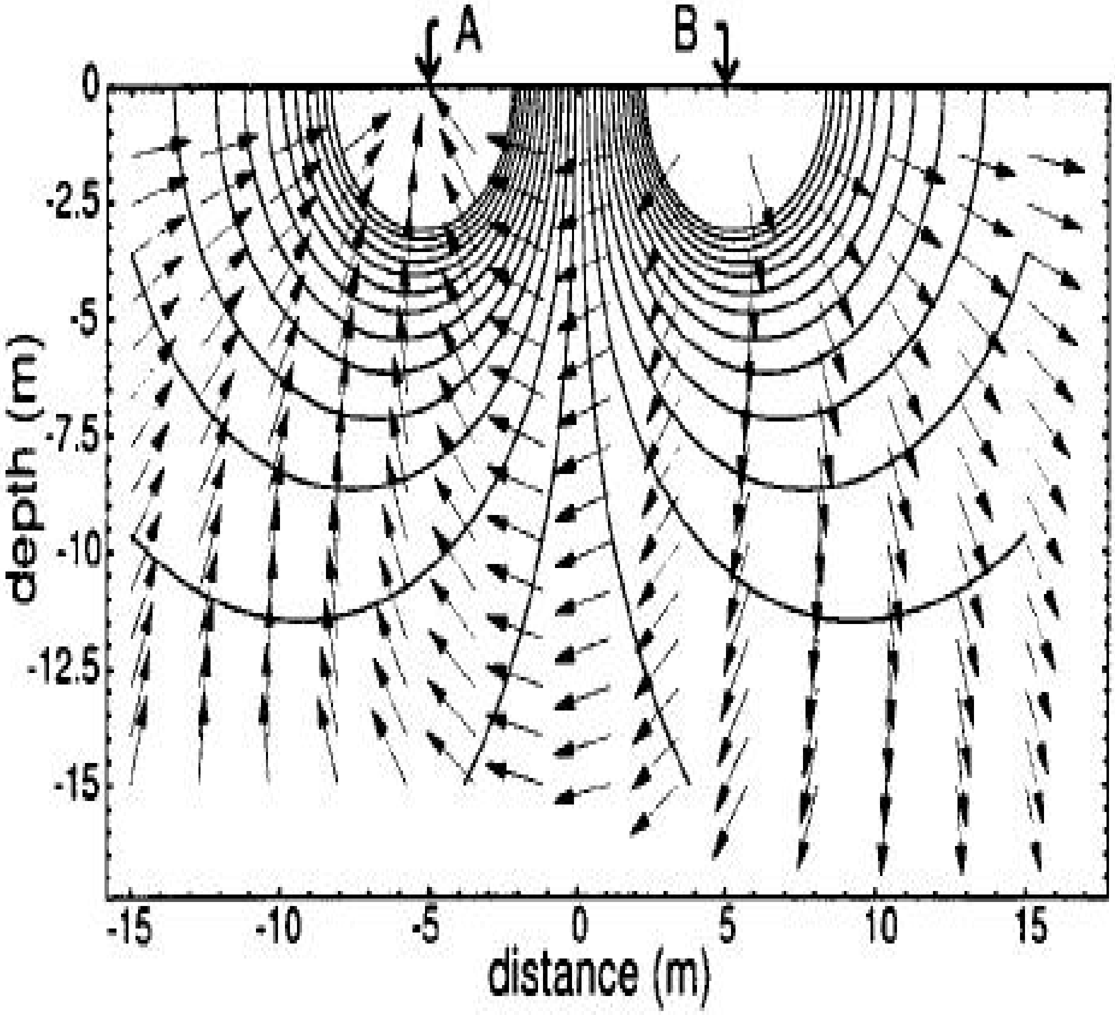


FIG 2.2: Current flow and equipotential surfaces between the two currentelectrodes *A*and B in a level field with homogeneous subsurface structure

resistancethat the current encounters between the electrodes is due primarily to the material that is at a depth that is less than several times the spacing of the current electrodes. For a uniform subsurface structure of Fig. 2.1, this is irrelevant since the entire subsurface would have the same resistivity. The effective depth does become relevant with the inhomogeneoussubsurface shown in Fig. 2.3.

Figure 2.3 illustrates the current flow when the subsurface material contains an upper region with higher resistivity than the resistivity of the region below. When the current encounters the region of lesser resistivity, the equipotential surfaces are further apart, and the current will alter its course through the lower material accordingly. If the distance between the current electrodes is the same, then the total resistance the current encounters in the situation in Fig.2.3 will be less than that depicted in Fig. 2.2. The total measured resistivity will be similarly lower, and the current will flow more easily between the electrodes. This alteration of the current flow between the electrodes is the basis for discerning both the presence of the boundary between the two layers as well as a value for the resistivity of the material in the lower layer.

Figure 2.3 indicates qualitatively how resistivity studies are able to discern the presence of the two layers. When the spacing between the current electrodes is much less than the depth of the boundary between the two layers, most of the current will not encounter the region of lower resistivity.This means that the total resistivity measured at the surface will be mostly due to the material that lies above the boundary. When the current electrodes are placed further apart, the current penetrates more and more into the region of lower resistivity, and the total resistivity begins to decrease from its initial value that it has when the electrodes are close together.

When the spacing between the current electrodes is much greaterthan the depth of the boundary, most of the currentwill spend most of its journey in the region of lower resistivity. The overall resistivity measured at the surface will be mostly due to the material in the lower layer.

It should be noted here that the total resistivity measured at the ground surface in field studies of multilayer systems is not the true resistivity of the underlying material. The measured resistivity is a weighted average of the resistivities of the various materials that the current encounters. When the current electrodes are placed very close together in the two layer system of Fig. 2.3, some small amount of the current still penetrates to the deep layer. Thus, the measured resistivity will not be exactly that of the upper material. Similarly, when the electrodes are spaced very far apart, some of the current still traverses the upper layer. The overall resistivity measured at the surface will then only asymptotically approach that of the lower material as the electrodes are moved toward infinite separation.

The behavior of the apparent resistivity of such an ideal two-layer _ system is shown in Fig.2.4, which plots the resistivity values [ρ1, ρ2......ρN] versus the effective depths

=>1 ,

?2 ,...,

@*N*ABversus the ‘‘effective depths’’

C*z*1 ,*z*2 ,...,*z*D*N*AEto _which the current is probing the subsurface.

The _ quantity *N*Fis the total number of data points collected.

In the next section, the effective depth*z*D

will be related to the

physical _ layout of the electrodes on the surface. Figure 4

shows the transition from the higher apparent resistivity of the _ upper layer to the lower apparent resistivity of the deeper

layer.

Just as the resistivity values obtained at the surface are

apparentresistivities and not the true resistivities of the underlying

material, so too are the effective depths

G

*z*DHnot the

exact depths of the locations of the boundaries between the

various layers. This is again due to the fact that the current is

so spread out and does not flow in a perfectly defined layer

of, for example, exactly 3 cm thickness as it travels between

2.1.1 FACTORS AFFECTING ELECTRICAL RESISTIVITY METHOD

There are various factors that influence the electrical resistivity method which include:

i. Mode of conduction of rocks and soils

ii. Rock texture

iii. Rock types

iv. Temperature

v. Degree of water saturation

vi. Permeability and porosity

Vii. Geological processes e.g. weathering, jointing, faulting etc.

2.1.2 APPLICATION OF ELECTRICAL RESISTIVITY METHOD

i. Groundwater Exploration

ii. Engineering Study

iii. Environmental Study

iv. Geological Mapping

v. Mineral Exploration

2.1.3 FACTORS FAVOURABLE TO THE USE OF ELECTRICAL RESISTIVITY METHOD FOR SITE INVESTIGATION

- Existence of simple geologic features.
- Existence of sufficient geophysical contrast between the bedrock and the overlying deposit.
- Existence of suitable contrast in the electrical property of the targeted feature.
- Absence of fill materials over the site, scattered metal and brick, buried Pipes and wire, fences, buried and overhead power lines and nearby Industries using electrical plant that adversely affect electrical sounding.

2.1.4 ELECTRICAL RESISTIVITY METHOD ARRAYS

The various electrical resistivity method arrays are;

i. Wenner array

ii. Schlumberger array

iii. Dipole-dipole array

iv. Pole-dipole array

v. Pole-pole array

vi. Gradient array

vii. Lee partition

Out of all the listed arrays, the most commonly used arrays are;

- Wenner Array
- Schlumberger Array
- Dipole-Dipole Array
- Pole-Dipole Array

In each configuration, the four electrodes are collinear but their geometric and spacing are different.

2.1.4.1 THE SCHLUMBERGER ARRAY

This array is the least cumbersome compared to the other three and it is not necessary to change the potential electrodes every time the current electrode spacing is altered. It is most commonly used to observe the variation of resistivity with depth. The mid-point is kept fixed while the distance between the current electrodes is progressively increased.

2.1.4.2 THE WENNER ARRAY

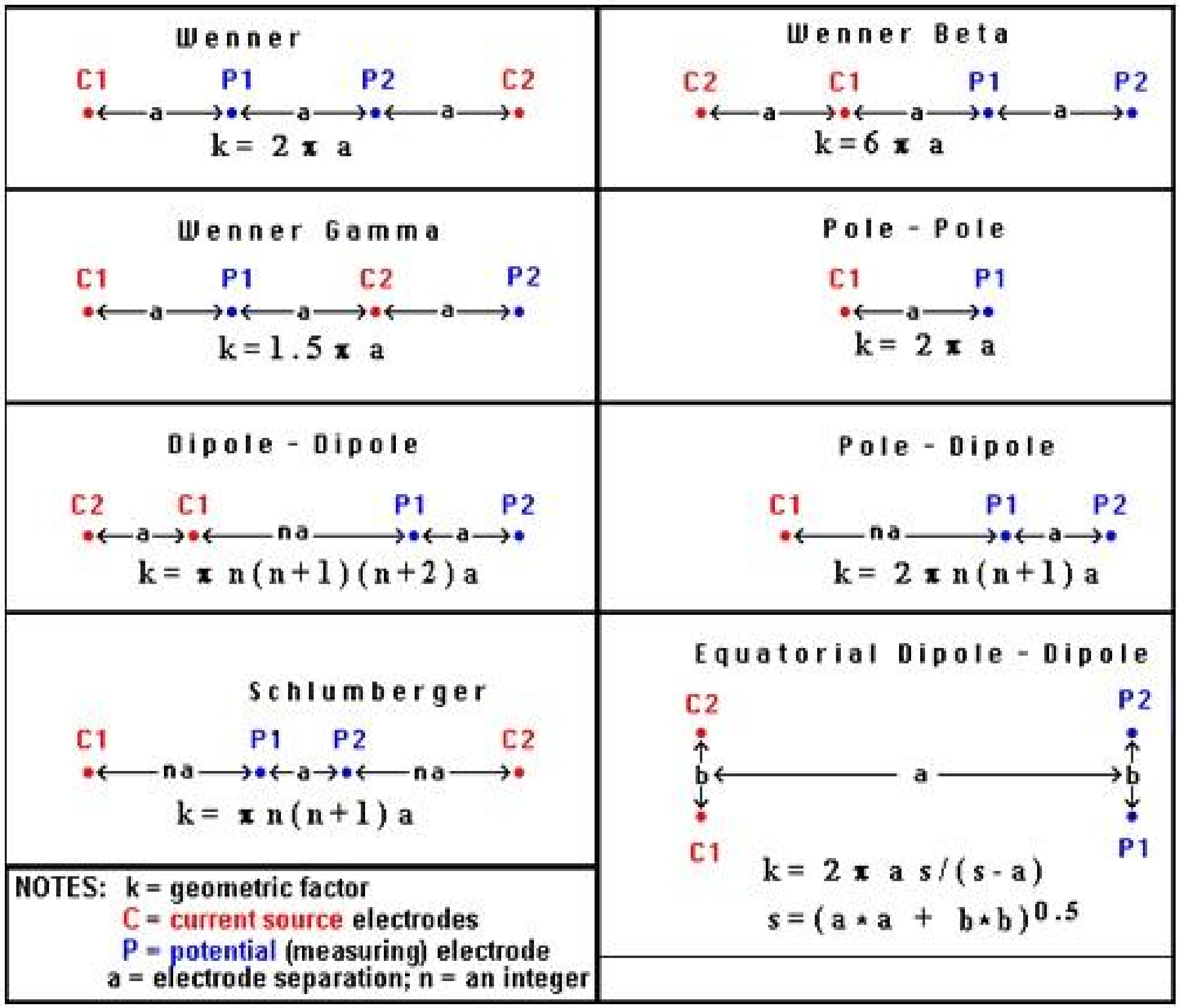
In this array, the current and potential electrodes are maintained at an equal spacing (a), the measurement of potential difference is done between two widely spaced electrodes.

2.1.4.3 THE DIPOLE-DIPOLE ARRAY

This involves measuring resistivity using a closed spaced current and potential electrode.

2.1.4.4 THE POLE-DIPOLE ARRAY

The potential electrodes are placed at the centre with one current electrode at the edge and the other current electrode at infinity.



THE VARIOUS ELECTRODE CONFIGURATIONS USED IN THE ELECTRICAL RESISTIVITY METHOD (LOKE, 1999).

2.2 GEOLOGIC SETTINGS

2.2.1 REGIONAL GEOLOGY

Nigeria is a country in West African continent with a surface area of 923,768km and lies within Latitudes 6° 48ˈN – 650N and longitudes 3° 58ˈE – 4° 00ˈE. The country is located in the Western portion of the African continent.

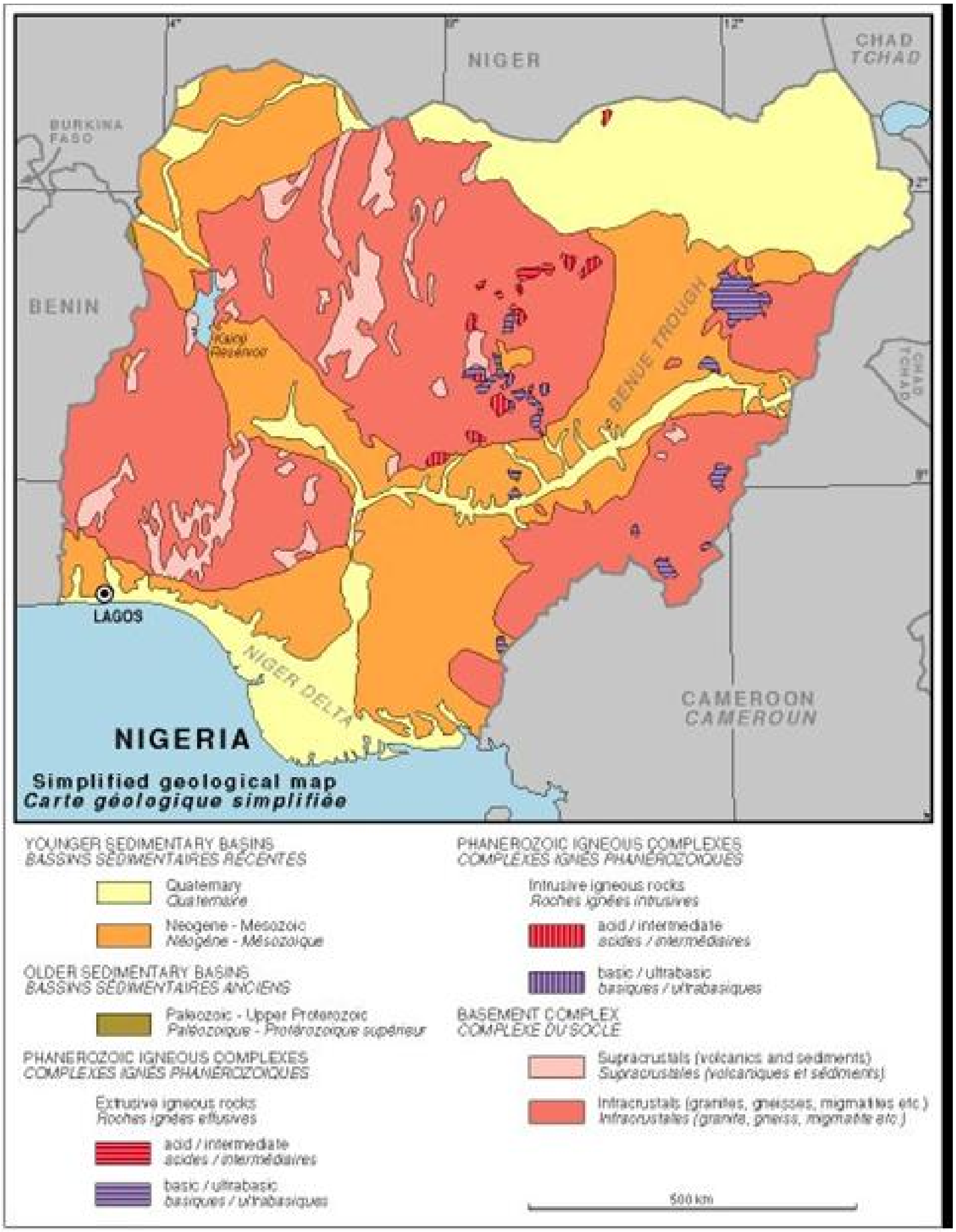
This continent is a product of the breakup of Gondwanaland. The country is bounded by the Atlantic Ocean at the Southern part, on the Northern part by the Republic of Chad, on the East by the Republic of Cameroun and the West by the Republic of Benin.

Nigeria is divided into two units geologically namely;

- The crystalline basement complex and
- The sedimentary terrain or basins

The Nigeria basement complex rocks consist of predominantly Archean polycyclic grey gneiss of granodioriticto tonalitic in composition. It is therefore said to be a polycyclic basement forming parts of West African and shows six evidences of orogenic events namely:

- Alpine Orogeny 100 to 900 Ma
- Hercynian Orogeny 350 to 300 Ma



SIMPLIFIED GEOLOGICAL MAP OF NIGERIA (OYAWOYE, 1972)

- Pan African Orogeny 600 to 150 Ma
- Eburnean Orogeny 2.2 to 2.0 Ga
- Late Archean 2.8 to 2.5 Ga
- Early to mid Archean >3.0 Ga

The pan African event is the result of the main thermo tectonic activity that took place 600 million years ago which created large masses of granite (older granites) as it can be seen everywhere in the basement rocks and are the main source of the sediments that fill the various sedimentary basins of Nigeria.

The rocks of the basement complex of Nigeria consist mainly of the following:

- The migmatite-Gneiss complex
- The metasediments which include the older and younger metasediments
- Charnockitic rocks
- Older granites

The sedimentary basins of Nigeria consist of sedimentary rocks of ages younger than the Jurassic. There is a long gap in the geologic history of Nigeria between the Precambrian and oldest sedimentary rocks, which are Cretaceous.

These sedimentary basins belong generally to the Hercynian basin of West Africa and can be grouped into two broad basinal classes using the kingston et al,1983 classification scheme.

- Marginal Sag Basins: they were formed in response to the generalized tensionsal regime which accompanied the opening of the central and south Atlantic in the middle Jurassic and the Equatorial Atlantic by Aptian/Albian times. The Niger Delta and Benin basin belongs to this group.

- Intra Continental Basins: they show complete cycle development, characterized by marine facies and continental sediments. Some basins show retreated cycles. The Bida basin, Benue trough and Chad basin belong to this group.

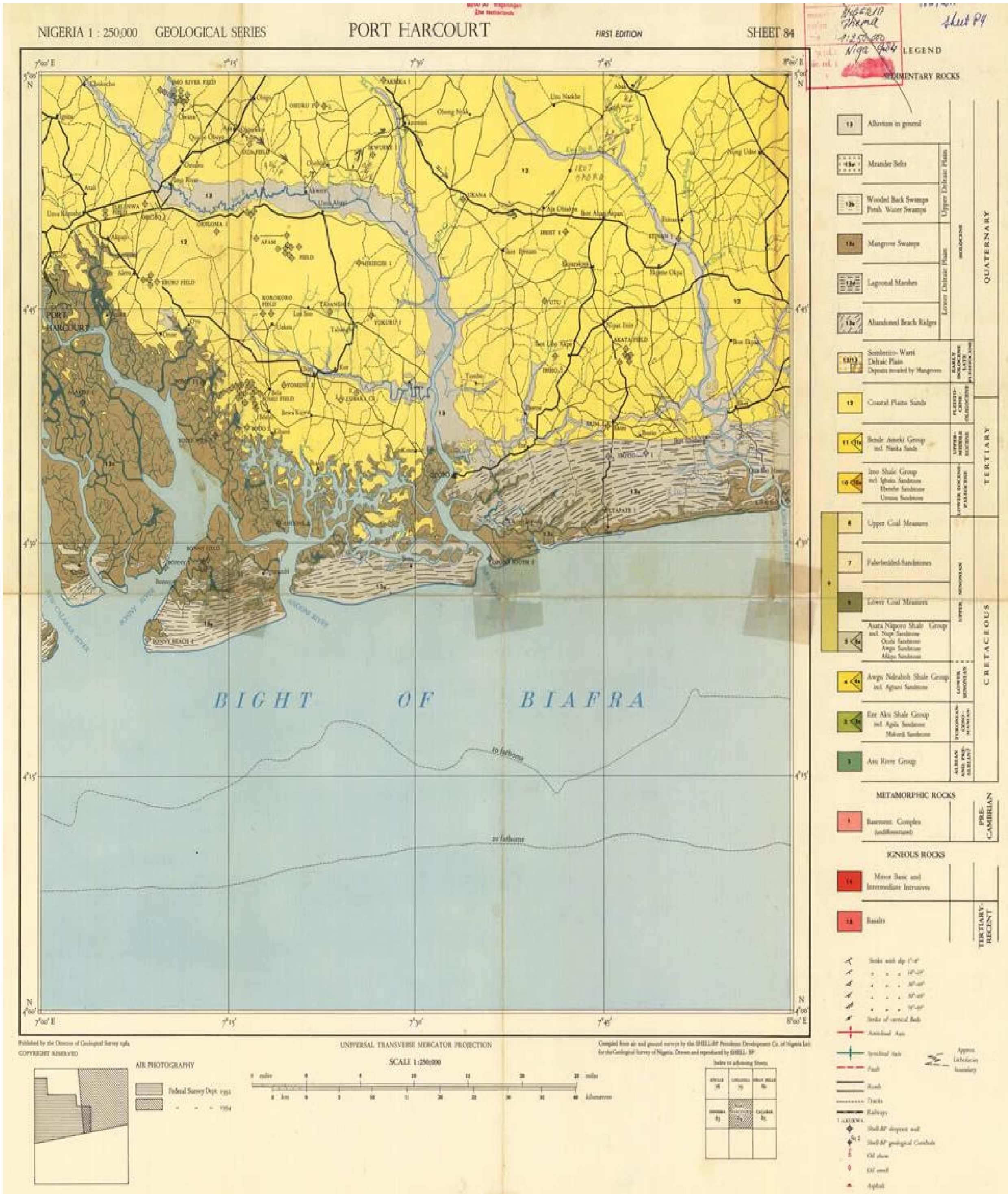
Sedimentary rocks are evenly distributed over eleven sedimentary basins but the major ones are:

- Chad or Borno basin
- Anambra basin
- Sokoto basin
- Dahomey/Benin embayment
- Bida/Nupe basin
- Niger Delta
- Benue Trough, which is made up of lower, middle and upper Benue Trough.

2.2.2 GEOLOGY OF THE STUDY AREA

The study area falls within the Niger Delta basin of the sedimentary part of the geology of Nigeria. The Niger Delta Basin is situated in the Gulf of Guinea in Guinea in equatorial West Africa, between latitudes 3° N and 6° N and longitudes 5° E and 8° E (Reijers et al, 1996).

The Niger Delta is framed on the northwest by a subsurface continuation of the West African Shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif (Murat, 1972). Well sections through the Niger Delta generally display three vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower pro-delta lithofacies (Reijers et al, 1996). These lithostratigraphic units correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent) of Short and Stauble (1967). The Akata Formation is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills. It is estimated that the formation is up to 7,000 metres thick (Doust and Omatsola, 1990). The Agbada Formation is the major petroleum-bearing unit in the Niger Delta. The formation consists mostly of shoreface and



THE GEOLOGICAL MAP OF PORT HARCOURT

channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 metres. The Benin Formation is about 280 metres thick, but may be up to 2,100 metres in the region of maximum subsidence (Whiteman, 1982), and consists of continental sands and gravels.

CHAPTER THREE

3.0METHODOLOGY AND INSTRUMENTATION

3.1METHOLOGY

For the purpose of this research, ten (10) Vertical Electrical Sounding stations were occupied within the study area. These stations were taken at different locations within the study area. The schlumberger array was employed. Current was passed into the ground through a pair of current electrode and the resultant resistance were obtained through pair of potential electrode and then recorded on the resistivity recording sheets. The study was carried out by usingPasi Earth Resistivity meter, measuring tapes, current and potential electrode, crocodile clips and hammers.

Basically, a station is chosen and an iron rod is driven into the ground, this marks the base station which is used as a mid-point from where MN/2 (potential electrode) spacing are measured in both directions using the marked mid-point and measuring tape.

The potential electrodes are driven in either side of the base stations at a specified distance. The current electrodes were driven in on either side and the spacing is given as AB/2, a straight line is maintained by the configuration of all the electrodes.

The measurement are repeated and recorded with MN fixed at its initial distance (current electrode) AB/2 is symmetrically increased where the resistance measured becomes too small MN/2 is increased symmetrically. The maximum spread of AB/2 is 300m, while the maximum spread os MN/2 is 10.0m.

The change in distance between the current electrodes increases the depth range at which current penetrates, the apparent resistivity is then plotted against the corresponding half electrode spacing (AB/2) on a bi-log paper. The curve types were interpreted qualitatively and quantitatively. The quantitative interpretation involved the partial curve matching and the computer iteration by using the Winresist software, while the quantitative interpretation involved the inspection of the curve types.

3.1.1 PARTIAL CURVE MATCHING

This technique is fairly accurate and dependable for interpretation. It involves the comparism of field curves with characteristics standard curves. The construction of series of standard curves is based in the hypothesis field curves of resistivity against depth.

Before interpretation is made with the master set of horizontal layer, it must be satisfied that the form of the sounding curve is sufficiently smooth and not distorted by sharp curves or discontinuities.

Two different set of curves are usually employed for this technique and they are:

- Theoretical 2-layer master curves.
- Auxiliary curves:
- ❖ Ascending type; where p2>p1.
- ❖ Descending type; where p1>p2

Also used in conjunction with the theoretical master curves are the four auxiliary curves designed for use in more than two layer interpretations.

3.1.2 COMPUTER ITERATION METHOD

This method involves the use of a geophysical software called Winresist. Field data are input and then modeled. Curve matching gets cumbersome where there are many layers, hence the computer iteration makes the interpretation of such problems easier.

A fast observation is allowed based on the iteration intense of the program. The layer parameters are altered until s good fit is achieved between the observed and the calculated values. The iteration process of a curve can go as far as 30 times of achieving an effect match, after which the computer displays the final result of the iteration and the layer parameters.

This method is the most effective method of all the interpretation method in terms of speed and accuracy.

3.2 INSTRUMENTATION

The instrumentations used for the vertical electrical sounding includes the Pasi Earth Resistivity Meterand its accessories like the connecting cables, four electrodes (steel rods), measuring tapes, hammers and the Global Positioning system (GPS).

TERRAMETER

It is a compact digital resistivity meter that contains a transmitter and receiver functions packed in one unit. It is designed to measure extremely weak electrical signal. The instrument can transmit up to 2900mA or less 200V, which is sufficient enough for ordinary resistivity surveying. It is highly sophisticated, compact lightweight equipment with inbuilt power source, signal receiver. It takes consecutive resistivity in several cycles and averaging the values obtained at each cycle to give the final resistivity.

ELECTRODES

The four electrodes used were made of steel and are driven into the surface of the earth to the subsurface (few cms) with the aid of a hammer for good contact. These electrodes are connected to their respective cables.

CABLES

There are four cables used on the field, two of which are about 500m in length used in connecting current electrodes (C1 and C2) while the other two cables of about 500m in length are used in connecting potential electrodes (P1 and P2)

MEASURING TAPE

The measuring tapes are of various lengths used to mark off the electrode spread.

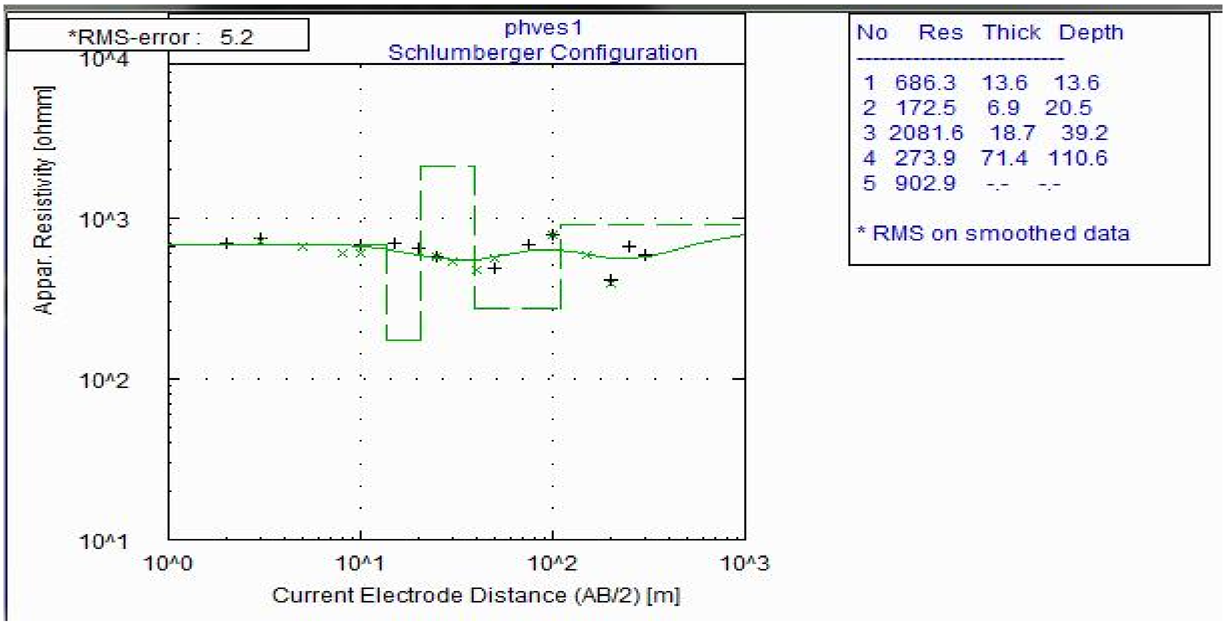
HAMMER

The hammer is used in driving in the electrode into the ground for proper electrical contact.

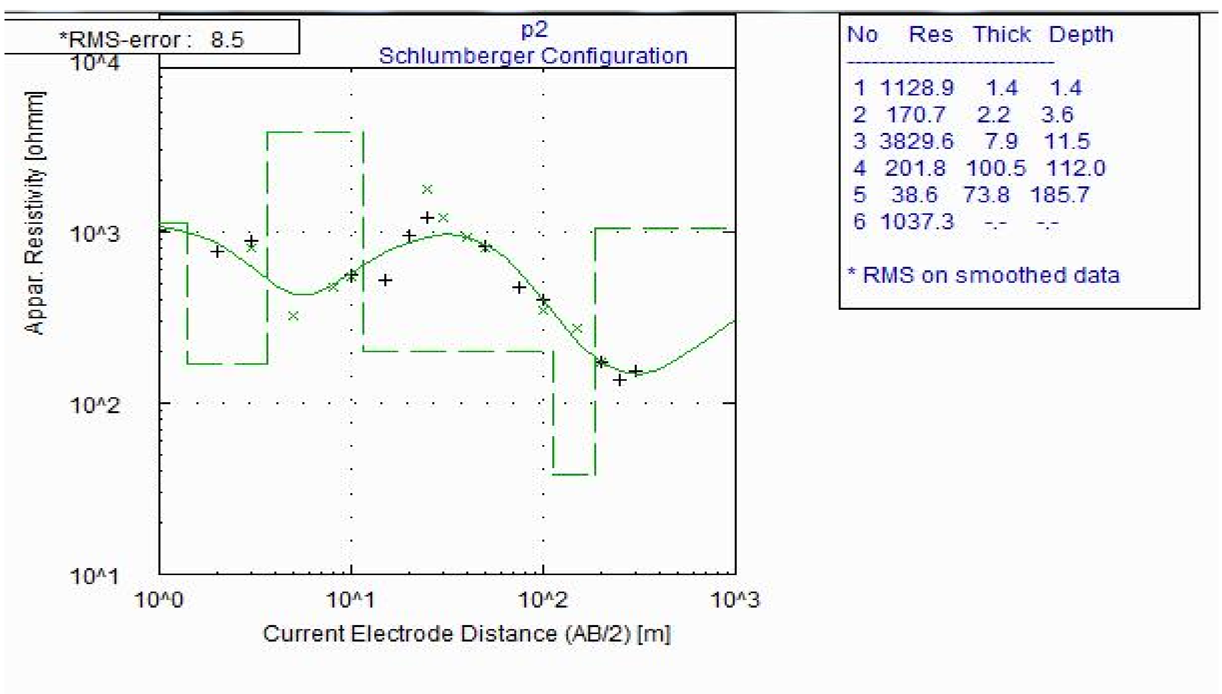
GLOBAL POSITIONING SYSYTEM

This is a very compulsory geologic instrument in any geophysical survey. It is used to mark the position of one's location on the globe which is the X,Y and Z, longitude, latitude and the elevation above the sea level which is also known as the altitude at that point.

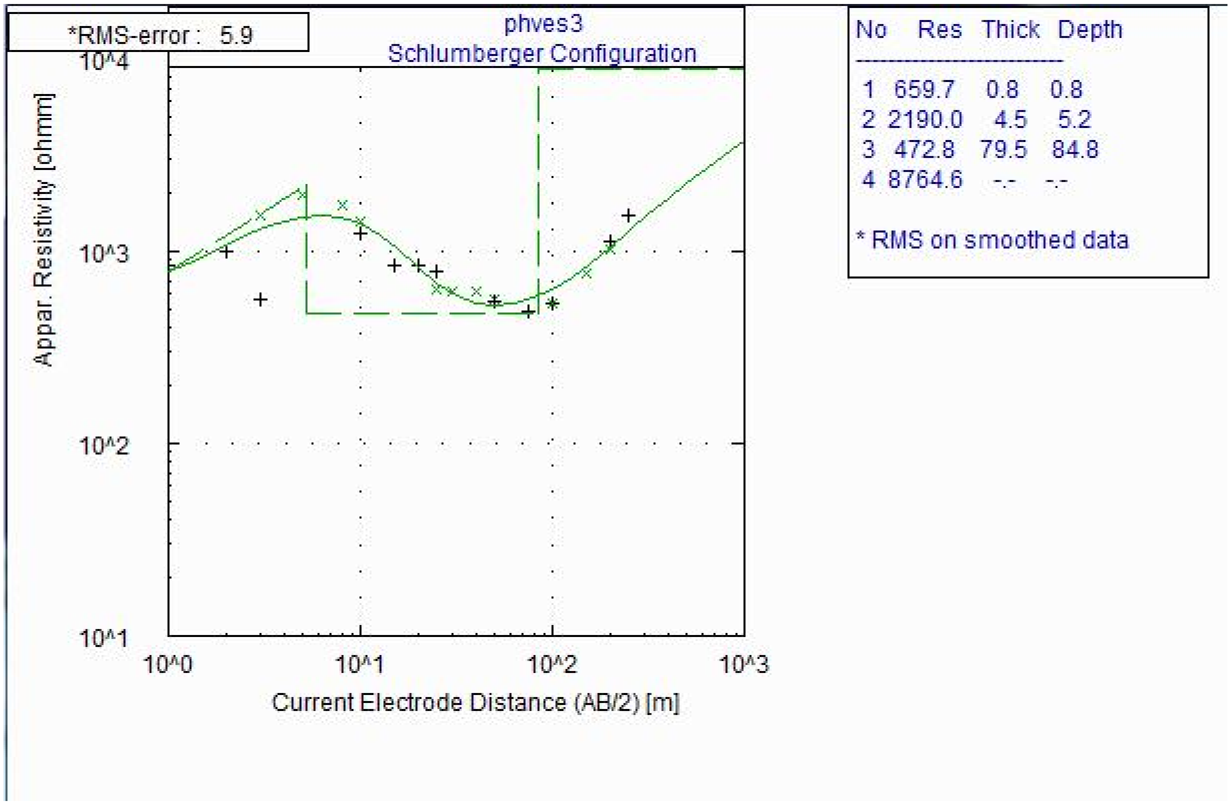
APPENDIX



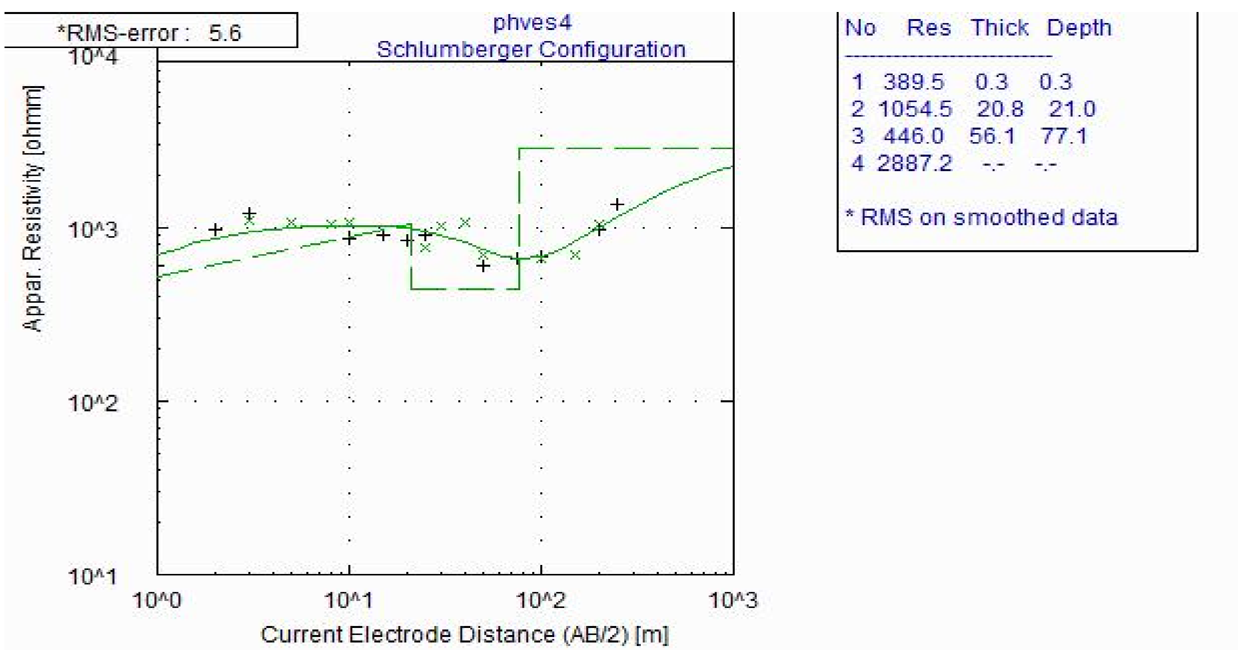
A TYPICAL HK CURVE (VES1)



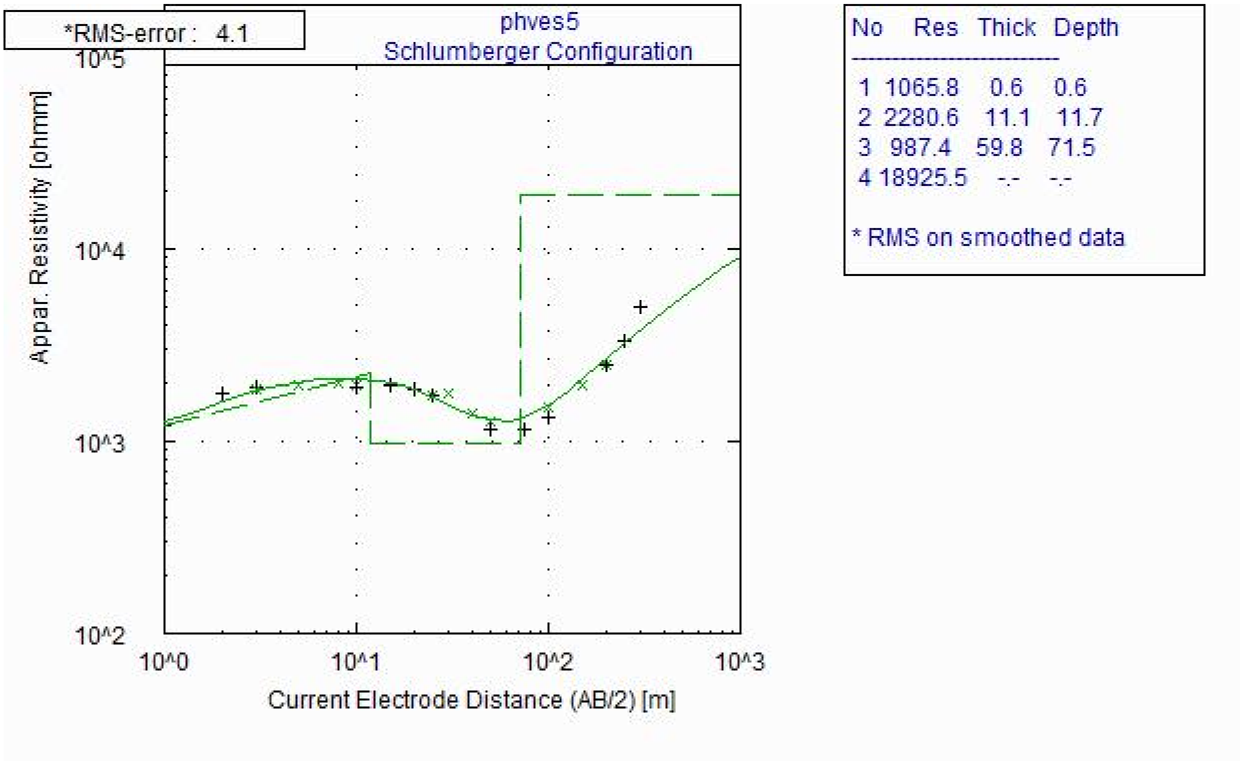
A TYPICAL HKQ CURVE (VES2)



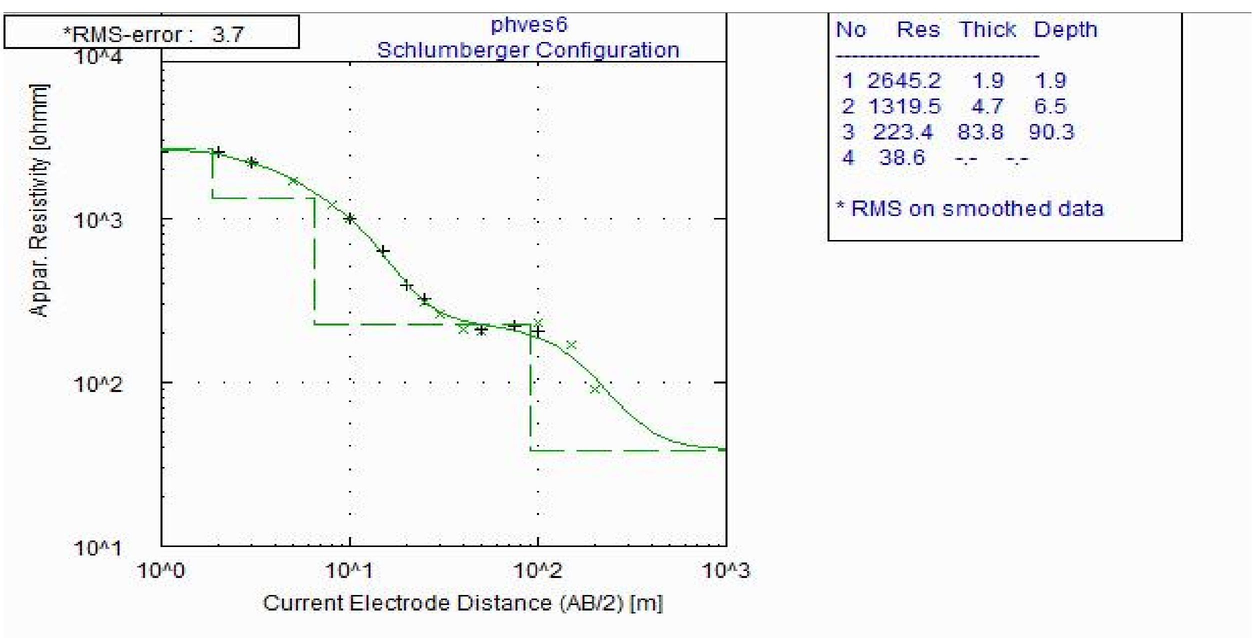
A TYPICAL KH CURVE (VES 3)



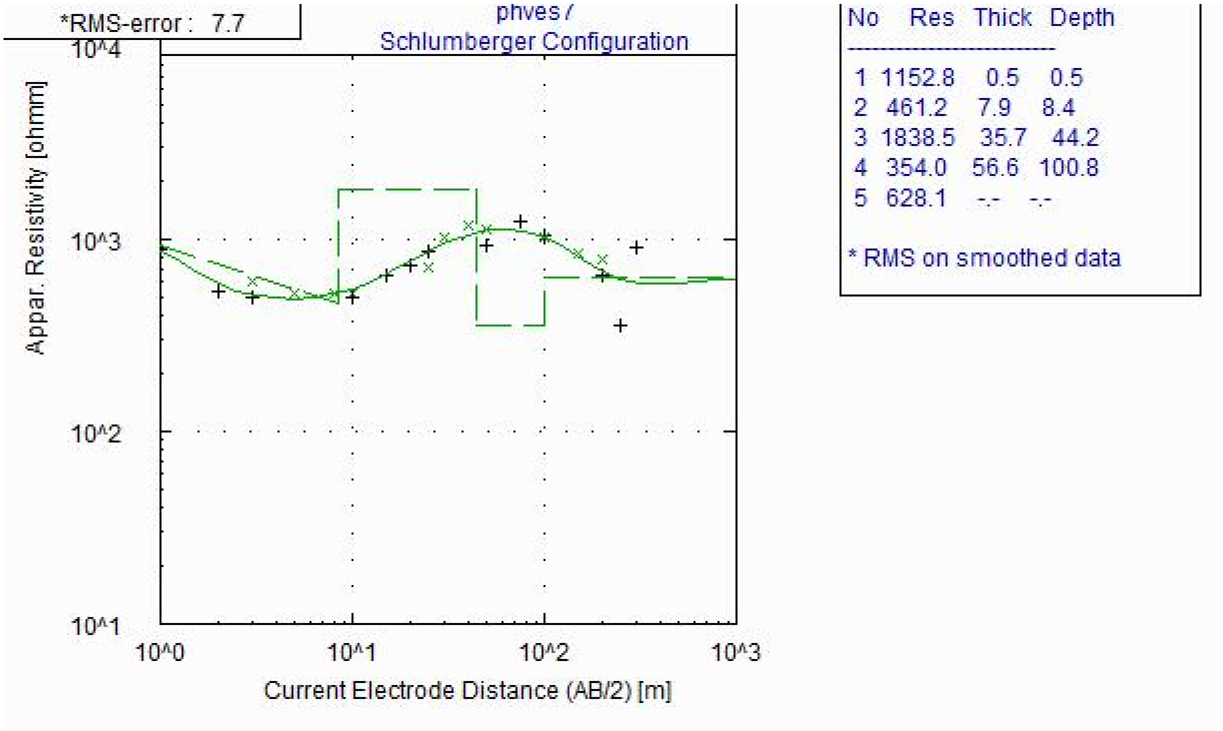
A TYPICAL KH CURVE (VES 4)



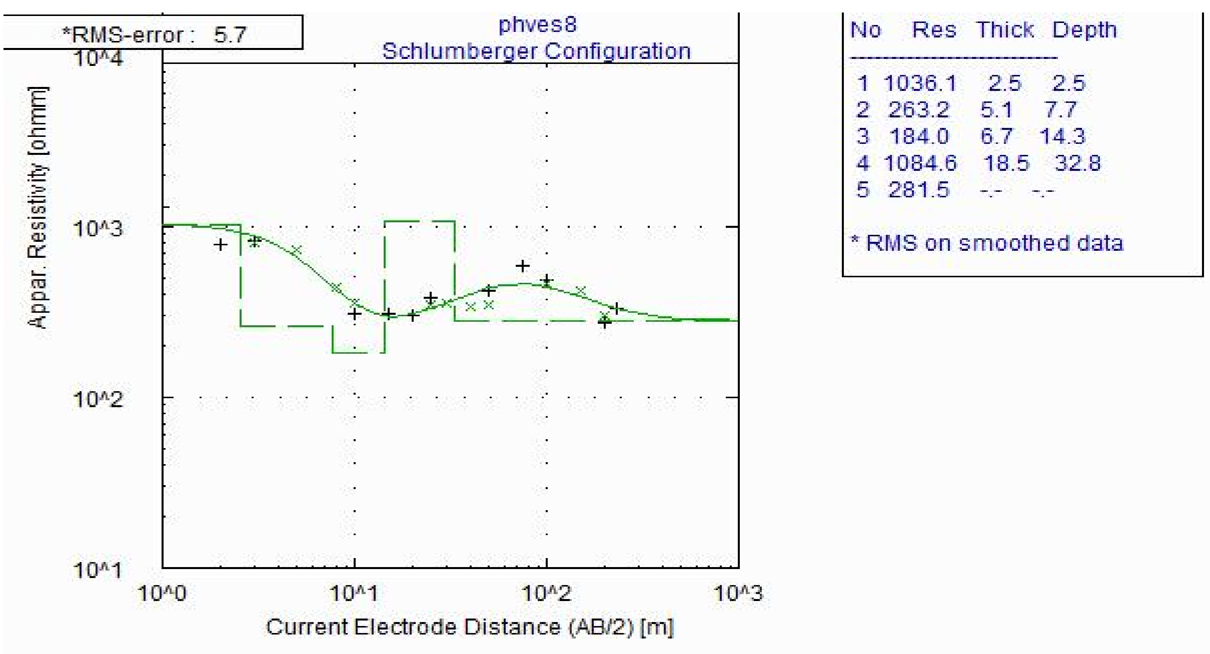
A TYPICAL KH CURVE (VES 5)



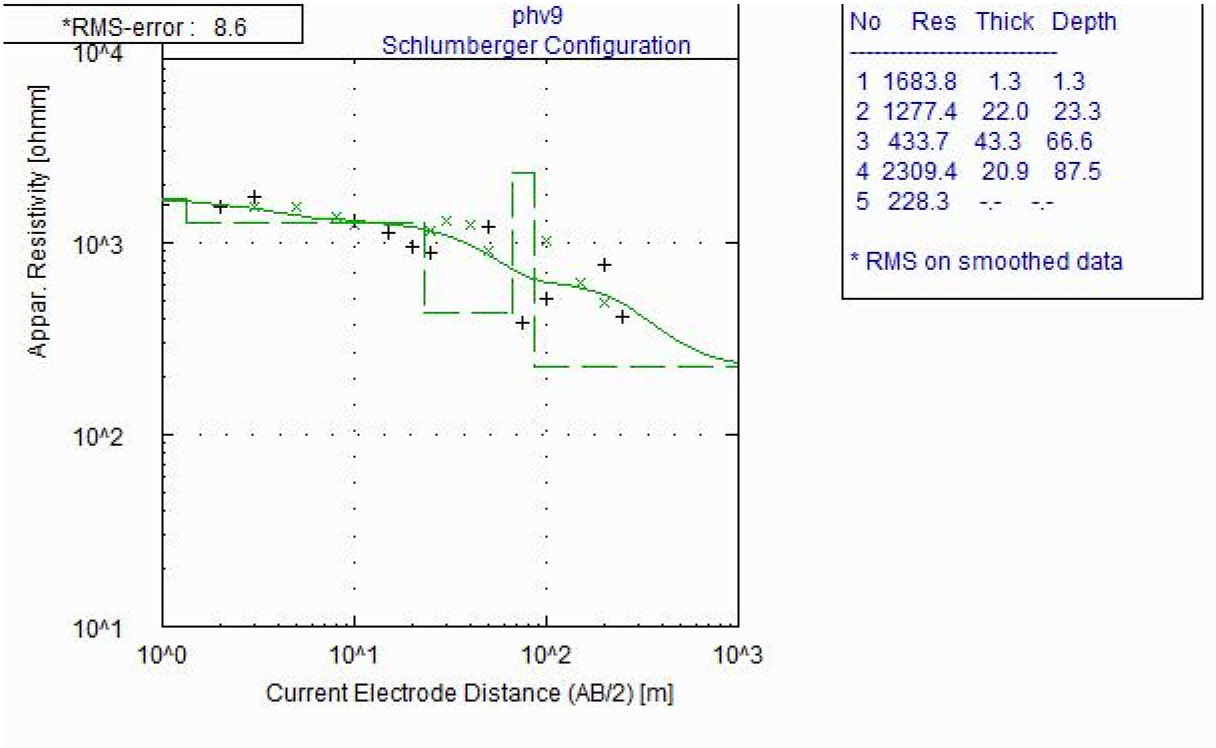
A TYPICAL QQ CURVE (VES 6)



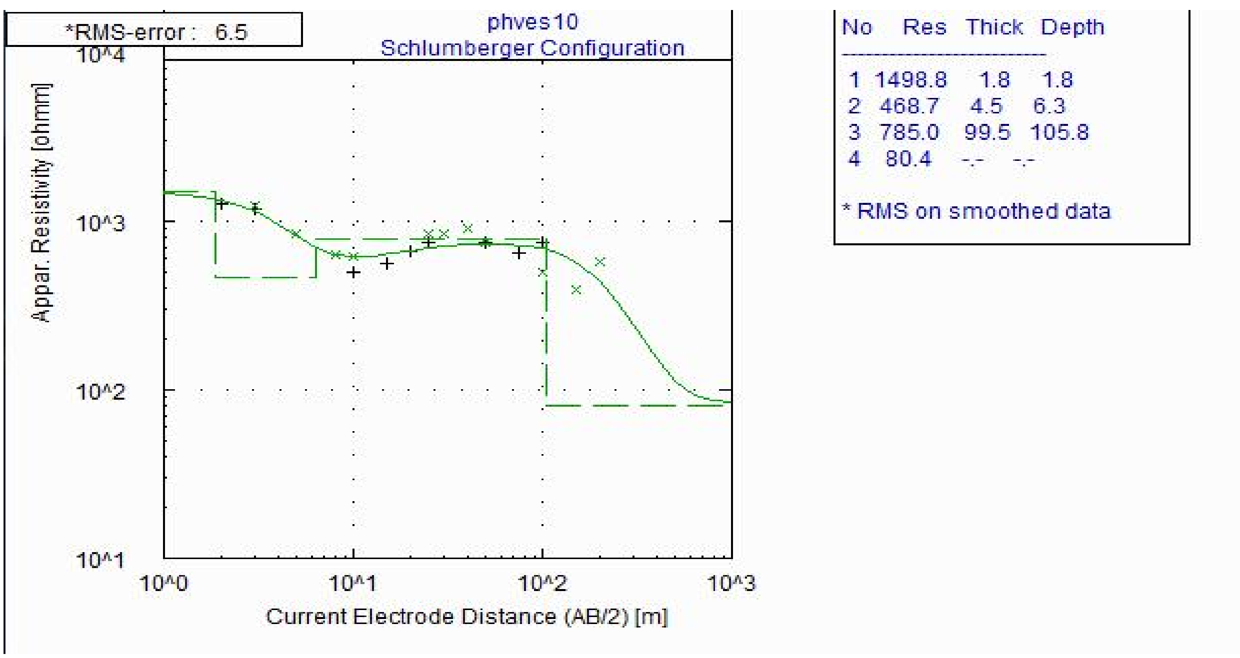
A TYPICAL HKH CURVE (VES 7)



A TYPICAL QHK CURVE (VES 8)



A TYPICAL QHK CURVE (VES 9)



A TYPICAL KH CURVE (VES 10)

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