GEOPHYSICAL SURVEY FOR GROUNDWATER DEVELOPMENT IN GBAMZE AND ENVIRONS, PARTS OF AKWANGA SHEET 209 SW, NORTH CENTRAL NIGERIA

BY

BULUS ESLA SYLVESTER

NSU/NAS/PGD/GEO/333/12/13

JANUARY, 2021

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A PROJECT SUBMITTED TO THE DEPARTMENT OF GEOLOGY AND MINING, NASARAWA STATE UNIVERSITY, KEFFI, NIGERIA.
IN PARTIAL FULFILLMENT FOR THE AWARD OF POST GRADUATE DIPLOMA (PGD) IN GEOLOGY AND MINING

FEBRUARY, 2021

DECLARATION

I hereby declare that this project is actually the products of my personal research efforts. Undertaken under the supervision of Dr. B.S Jatau, also it has been clearly proved that this work has not been presented somewhere for the award of degree or any certificate. All the sources in this project have been duly distinguished and appropriately acknowledged.

12/02/2021.

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CERTIFICATION

This is certify that this project was undertaken by BULUS ESLA SYLVESTER and was read, examined and approved for the award of Post Graduate Diploma (PGD) in Geology and Mining, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, Nasarawa State.

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DEDICATION

This project is dedicated to God Almighty, who kept me for this purpose. Unto him alone is all my praise, honour, glory and adoration now and forever. I also dedicate this project to my father Mr. Bulus Agu (the Aren Gbamze), my mother Alice Bulus, my step mother Alisa Bulus, sons and daughters of Bulus family.

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I express my profound gratitude to God Almighty, for his sufficient love, grace, mercies and favour towards me.

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I wish to express gratitude to my father Bulus Agu and mother Alice Bulus. You are indeed a parent with a difference. I thank God for giving you to me; you have devoted time, resources and energy to see me advance educationally. Thanks a lot Daddy and Mummy.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

ABSTRACT

Vertical Electrical Sounding (VES) method was used in carrying out geophysical investigation for groundwater in Gbamze and environs with a view of determining the apparent resistivity and thickness of various layers of the geological formations, the depth to the bedrock, and references of lithologic units. Vertical Electrical Sounding (VES) using Schlumberger array was done at twenty four (24) VES stations using GPS Garmin XP to establish sounding points. The L and R terrameter was used for the data acquisition. The field data obtained were analysed using computer software IpIwin and IxId inversion. Results got from the interpretation suggest six layers in virtually all parts of the study area. The topsoil layer resistivity varies from 25.04Ωm to 413.50Ωm having thickness that ranges from 0.24m to 8.71m. The second layer contains clay, laterite and sand. Its thickness and resistivity values are 0.76m to 4.08m and 27.55Ωm-7547.6Ωm respectively. The third layer also consists of sandy clay, laterite and clayey sand. Its thickness ranges from 2.07m to 10.29m and the resistivity varies from 19.27Ωm to12.65.60Ωm. The fourth layer has thickness and resistivity values of 2.85m to 18.80m and 22.35Ωm to 605.30Ωm respectively. This is mainly of highly fractured/weathered basement rock units. The fifth layer is a partially weathered/fractured basement rock unit. Its thickness and resistivity ranges from 3.82m to15.99m and 64.26Ωm to 1224Ωm respectively. The last layer, being fresh basement rock unit has resistivity values ranging from 221.80Ωm to 19863.40Ωm. The general depth to basement and the groundwater potential varies from location to location but can be inferred as very good, moderate and poor areas.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Insufficient supply of pipe-borne water in urban centres and likewise the complete absence of the supply of water in rural areas are peculiar problems facing most parts of Nigeria as well as other developing countries, especially in Africa. The natural surface and groundwater are always seen as the only source of water. Groundwater is the water found in consolidated or unconsolidated rocks that are permeable enough to permit economic quantities of water to move into wells. It is the water that lies beneath the ground surface completely filling the pore spaces between grains of sediments, sedimentary rocks, cracks and crevices in all types of rocks. Locating groundwater however means determining where the water occurs under conditions that permit exploitation and development.

The study of earth using physical measurements at the surface is termed geophysics. It involves the study of the parts of the earth hidden from direct view by measuring their physical properties with appropriate instruments, usually on the surface. It also includes interpretation of the measurements to obtain useful information on the structures and composition of the concealed zones (Dobrin, 1981).

In other words, geophysical survey is carried out to locate subsurface geological structures or bodies and to measure their dimensions and relevant physical properties and interpretations to make inferences. There are several methods of geophysical exploration, however, the method adopted or applied for this research work is the vertical electrical sounding otherwise known as Schlumberger method.

As population is growing rapidly, especially in Gbamze and its environs, the demand for water will increase. It is therefore important to provide necessary information on the sites for groundwater development in the area. That necessitated this research work.

1.2 Location, Extent and Accessibility

The study area (Gbamze and environs), forms parts of the Akwanga Sheet 209 SW and lies within latitudes N8°34'50" and N8°37'47" and longitudes E8°16'47" and E8°20'00". The area extent surveyed covers 30km^2 expanse of land. The study area is highly accessible as it is traversed by some secondary roads and networks of tracks and footpaths. Some of the roads include the Nasarawa Eggon - Mada Station road serving as the secondary road and the road from Mada Station which passes through Gbamze and (Fig. 1.1).

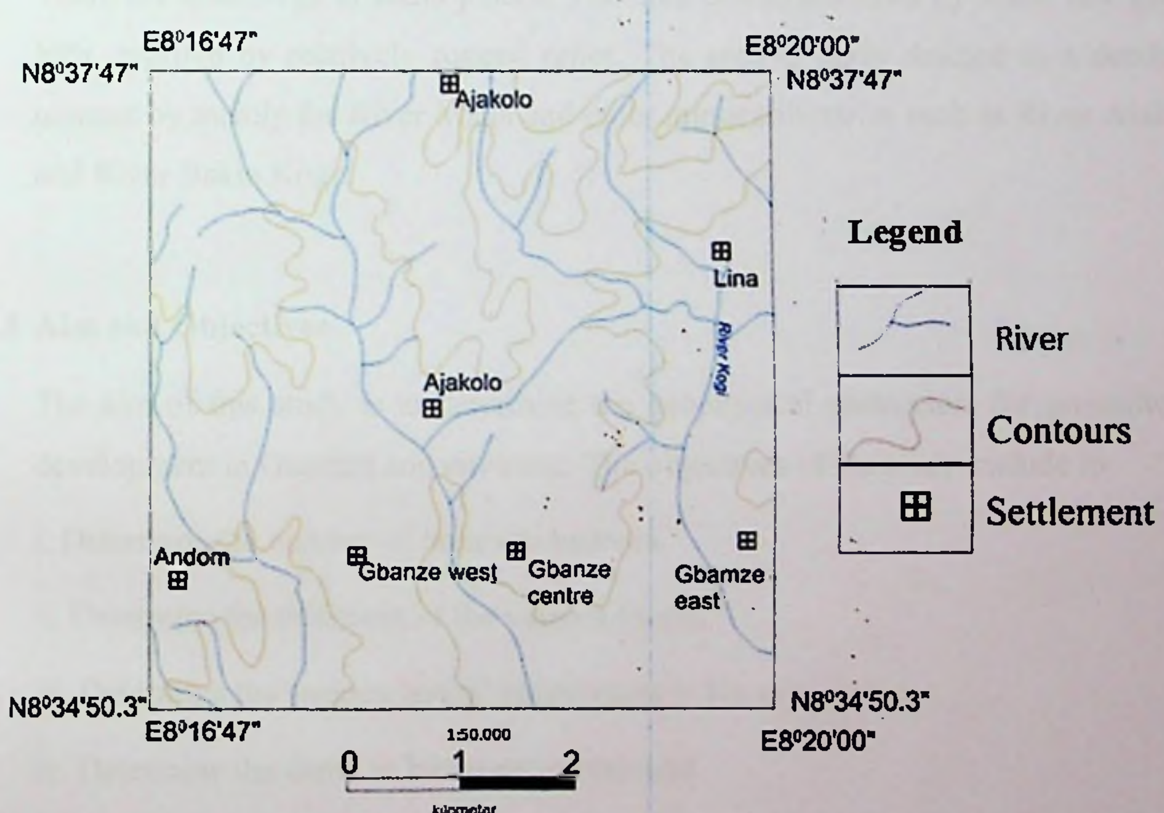

Fig 1.1 Location, Relief and Drainage map of Gbamze and enivirons

1.3 Climate, Vegetation and People of Gbamze and Environs

The climate of the study area is typical of the Savanna region with a mean annual rainfall of about 1335mm. The month of September has the highest mean monthly rainfall (Town Planning and Ministry of Environment, 1984).

The indigenous people of the study area are known as the Eggons. Other inhabitant tribes are mada, tiv, gwandara, nugu and igbo. The people of the study area engaged mainly in farming, fishing, and mining.

1.4 Relief and Drainage

The land is generally a low-lying terrain having elevation value ranges of 80m to 215m with gently undulating plains containing patches of some knolls to the south. There are inselbergs in some places. The area is characterized by some few gentle hills, typified by relatively rugged relief. The area is fairly drained in a dendritic manner by mainly the River Mada and other minor tributaries such as River Ajakolo and River Bakin Kogi.

1.5 Aim and Objectives

The aim of this study is to determine the geophysical parameters for groundwater development in Gbamze and environs. The objectives of the study include to:

i. Determine the number of layers to bedrock

ii. Determine the thickness of the various layers

iii. Determine the various layers' resistivities in the area

iv. Determine the depth to basement of the area

v. Deduce the groundwater potential of the area

1.6 Justification

The need for water and current trends in the long-term sustainable development of groundwater aquifers resources require studies that combine geological, hydrogeological and geophysical information. The static water level measurements and geo-electrical sounding could be effectively used to determine depth to watertable, which in turn could be used to determine groundwater potential of an area. This approach enhances the development of conceptual hydrogeological framework for the area under investigation.

The electric resistivity method (Vertical Electrical Sounding) technique has been successfully and extensively used for groundwater exploration in most of the basement terrains, because it can define the significant contrast in the geo-eletrical parameters of the topsoil and in-situ weathered material, fractured zone and the fresh basement rock. Using the Schlumberger arrangement in the geoelectric sounding has proved useful especially for delineation of weathered and fractured zones which may constitute the aquifers in the basement rocks.

The data obtained from the geo-electrical sounding enable the preparation of a potentiometric surface map for the area under investigation. Also, the geoelectric depth soundings allowed for the delineation of the vadoze and phreatic zones and enabled characterization of their lateral and spatial variations across the area. In the vadoze and phreatic zones the major difference between them is that the former is mostly filled with air while the later is filled with groundwater. This difference in water content frequently enables subsurface geoelectric stratification through geoelectric depth sounding.

This study is also expected to be useful in the development of conceptual model of the hydrogeologic system in the study area (Gbamze).

1.7 Significance

The study is envisaged to upgrade knowledge of the geophysical survey for groundwater development in the area and enhance water development in the area. In addition, the study will serve as a useful guide to an elaborate groundwater development programme proposed for the area. The government may find the study useful in designing a water development scheme for Gbamze and environs. In time to come further researchers in the field of geology may find this piece a useful literature for further work in the area and also water boards, agencies and water management establishments.

1.8 Scope

This study involves the application of VES (Schlumberger array) technique for groundwater investigation and development strategy, achieved by intensive field observations and measurements, analysis of previously derived and collated datasets in comparison with present results obtained for the area. This formed the basis in which field measurement data were correlated with existing borehole logs in the area. A total number of 24 vertical electrical sounding (VES) points were sounded in addition to some existing obtained VES reading.

1.9 Limitations

The limitations of the study include the following:

i. Spreading of electrodes was a problem because there are no straight path, no levelled ground, and obstruction by some large trees.

ii. Interference of instruments from electrical cables and buried pipes.

iii. Difficulties in carrying the instruments due to poor road networks

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Geology of Nigeria

Geology, the study of rocks, minerals and the physical make-up of the solid earth, determines the environment and natural resources and thence, also the industrial potential and wealth of a nation (Petters, 2000).The vast ocean margin that borders Nigeria to south; the intricate drainage systems that sculpture the physical landscape; the mountainous eastern frontier and the windswept northern hinterland; with the great plains on the Sahara fringe, are all parts of the surface geological features that bestow upon Nigeria it unique physical attributes. Inspite of political differences, the landscape is a continuum in a seamless physical web that unites the physical entity termed Nigeria. For instance, the Niger-Benue drainage system, which has long geological period of 55 million years (Petters, 2000) supplied sediments from Nigeria hinterland for construction of the Nigeria Petroleum rich Niger Delta on the coast, has demonstrated the, long term impact of unifying geological processes in the nation with divergent human interest. Economic self sufficiency is also feasible in Nigeria, where diversity of rocks and mineral wealth, combined with cheap sources of renewable and non-renewable energy, create an enormous industrial potentials.

The three major rocks types-igneous, metamorphic, and sedimentary abound in Nigeria. Igneous and metamorphic rocks constitute the Precambrian basement complex which is the oldest, crystalline, solid foundation of the country. Basement complex rocks are sub-divided into migmatite-gneiss complexes, the older metasediments, the younger metasediments, the older granite and the younger granite alkaline ring complexes and volcanic rocks (Petters, 2000). These underlain the study area.

Sedimentary rocks fill up the basins which are vast depressions between basement landmasses (Fig.2.1). Nigeria is underlain by seven major sedimentary basins, the Calabar Flank, the Benue Trough, the Borno (Chad) Basin NE, lullemmenden (Sokoto) Basin, the Dahomey (Bida) Basin and the Niger Delta Basin (Fig. 2.1) (Petters, 2000). Sedimentary successions in these basins are of middle Mesozoic to recent age. Older sedimentary deposits were not preserved, probably because during the Paleozoic-mesozoic, what is now Nigeria was broad basement uplift, with no major basin subsidence for sedimentary accumulation, (Petters, 2000).

Nigeria sedimentary basins are broadly divided into coaster Calabar Flank, Niger Delta, Dahomeh Basin, and interior basin (Benue Trough) (Upper Benue, middle Benue and Lower Benue), Anambra basin, Borno Basin, Bida (middle Niger) Basin and Sokoto basin However, the sedimentary successions in these basins are broadly divided into:

i. Basal continental sandstones, siltstones and mudstone

ii. Middle marine shale and limestone interbedded with sandstones and siltstones.

iii. Upper sandstones sequence that is continental.

Although the three parts subdivision is also applicable to the Niger Delta, this sequence has been growing seaward with lower marine shale, grading through thick ancient coastal sandstones and shale into upper continental sequence. The middle ancient coastal sediments are oil and gas bearing (Petters 2000).

The sedimentary basins and the basement complex are equally dispersed in Nigeria; the basement is most extensive in northern Nigeria; less in the south-western part of Nigeria; and least along the eastern margin The sedimentary basins occupy the central X-shape in Nigeria; they underlie all of the southern Nigeria; and are also found in the north-west in Sokoto and North-eastBorno state, and occupied the entire Lake Chad in the north-east (Petters, 2000).Jos Plateau, is occupied largely by igneous and volcanic rocks, which are sources of mineral deposits such as tin, columbite, tantalite wolframite, monazite and gemstones, Gold, molybdenite and non-metallic minerals such as marble, feldspars and talc are among the minerals in the basement complex.

Apart from oil and natural gas, ground water and host of industrial minerals such as barite, limestones and clay the older sedimentary rocks are mineralized with lead and zinc. The southern and middle Benue trough is occupied extensively with coal and lignite where lignite belt extended into Delta State. Bitumen or tar occurs in Cretaceous sediment extending from Ogun to Ondo States. Laterites superficial are ubiquitous in Nigeria (Petters, 2000).

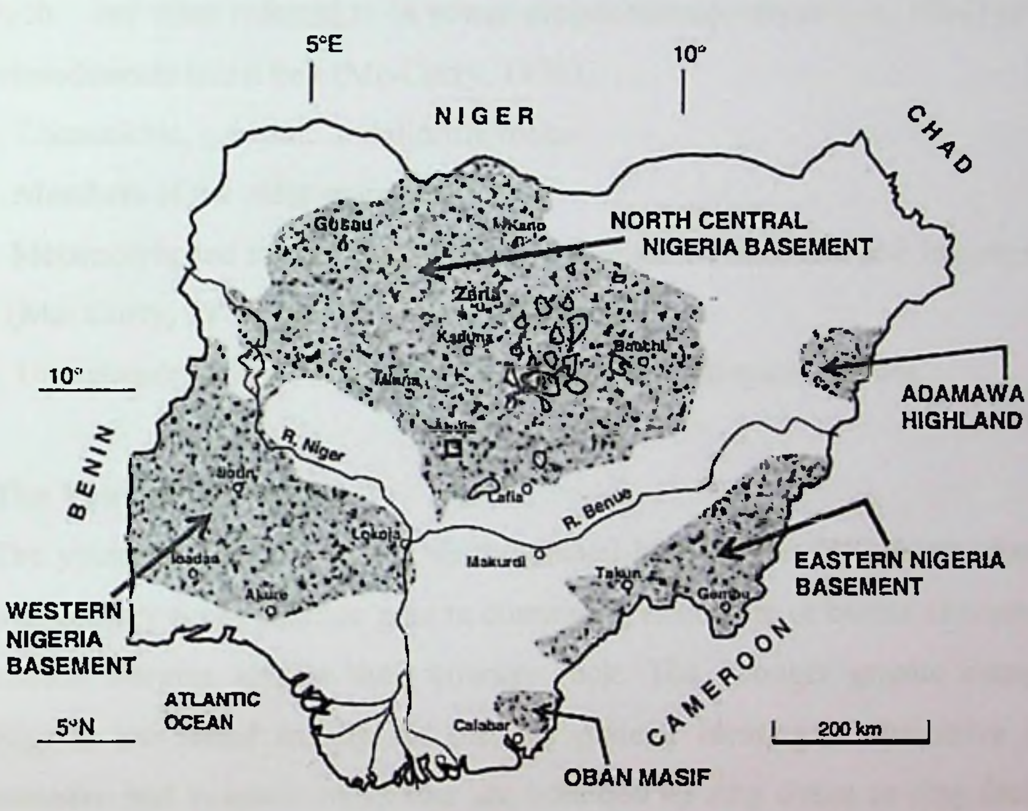

Figure 2.1 Basement Geology of Nigeria (After Obaje, 2009)

2.2 Geology of the Basement Complex of Nigeria

The Nigeria Basement Complex occupies nearly half of Nigeria and extends in the west into the Benin Republic and in the east into Cameroon. While the remaining half is the Nigeria cretaceous and younger sediment. The Nigeria basement complex is believed to be mostly Precambrian in age. However, it probably contains a number of intrusions of Paleozoic age (Oyawoye, 1964). The earliest study of the Basement complex was mapped by (Falconer, 1911) who recognized the age distinction between the Precambrian older granite and Jurassic younger granites of Jos Plateau. The pronounce terrain represents a level at considerable depth in the earth which has now been exposed through erosion over several million years. The rocks have multiple folding, fracturing and igneous activities. The Nigeria Basement Complex consists of six major rock groups namely:

i. Migmatite-Gness-quartzite complex

ii. Slightly migmatized to non-migmatized metasedimentary and meta-igneous rocks which are often referred to as newer metasediments (Oyawoye, 1964) or younger metasediments schist belt (Mc-Curry, 1976).

iii. Chanockitic, gabbroic and dioritic rocks

iv. Members of the older granite suite

v. Metamorphosed to unmetamorphosed cal-alkaline volcanic and hypabysal rocks (Mc- Curry, 1976; Mc-Curry and Wright, 1977).

vi. Unmetamorphosed dolerite dykes, basic dykes and syenite dykes.

2.2.1 The Younger Granites

The younger granite was first distinguished by Falconer (1911), as cross cutting (the country rock) alkaline granite containing riebeckite or biotite characterized by chilled margins against their country rock. The younger granite complexes in Nigeria are found mainly on the Jos plateau forming a distinctive group of intrusive and volcanic rocks that are bounded by ring dykes or ring faults. Other occurrences approximate a north-south belt towards the middle Benue in the south where the ages are younger and towards Niger Republic in north enormous variety in granite composition of these rocks, (Petters, 2000).

2.2.2 The Older Granites

The term "older granite" was introduced by Falconer (1911) to distinguish the deep – seated often concordant and or semi-concordant granites of the basement complex from the high level, highly discordant tin-bearing granite of north – central Nigeria. The older granite which occurs within the gneise complex and the schist belts has been described from all parts of the basement. They include a wide spectrum of rock types from the tonalities through granite to syenite and charnockitic rocks (Mc Curry, 1976. Rahaman, 1976. Ajibade and Fitches, 1988; Obaje et al; 2006). They have Rb/Sr ages ranging between 750-450 Ma, which are considered to reflect the ages of emplacement (Ogezi, 1977). The older granite seems to belong unequivocally to the Pan-African event sensustrict older granite therefore occurred in most places where rocks of the migmatite-gneiss complex occurred, but are particularly noteworthy in and around Wusasa (Zaria), Abuja, Bauchi, Akwanga, Ibadan, and Obudu area. In Bauchi area and parts of south western Nigeria, most of the older granite occur as dark, green grey granites with significant quantities of olivine (Fayalite) and pyroxene occurring with quartz feldspars and micas. For this unusual composition, the older granites in these areas are termed Bauchites (in Bauchi area) and Oyewoyite (after Professor Oyewoye) who first mapped them in western Nigeria. For the uniformity of terminology, both the bauchites, and the oyawoyites constitute the charnokitec rocks (charnokitis) of the basement complex (Obaje et al; 2006). The mode of emplacement of the older granite has been a subject of controversy. Oyawoye (1972) for example, suggested that they originated from potash, Metaso-matism of the original gneiss. Jones and Hockey (1964), believed that the older granite are both magmatitic intrusion and partly metasomatic in origin and that they are Cambrian to proterozoic and affected by Pan-African orogeny.

2.2.3 The Migmatite-Gneiss Complex

These are described as the oldest rocks and also as the polycyclic crystalline complex of migmatites and gneisses, are the most widespread group of rocks in the basement complex of Nigeria which account for 30% of the total surface area of Nigeria (Rahaman, 1988). They form the crystalline platform over which other basement rocks have been laid or into which they have intruded. The migmatite-gneiss complex is composed of a series of rock types including migmatites, gneisses of various origins and a series of metamorphosed basic and ultra-basic rocks represented by amphibolites and take schist (Jones and Hockey, 1964). Definite meta-sedimentary rocks are represented by quartzites, marble and mica schist (Jones and Hockey, 1964) according to Ajibade and Fitches (1988), the meta-sedimentary rocks have been referred to as the older meta-sediments by Oyawoye (1972) and Mc Curry (1976) and that the rocks have been metamorphosed in to middle to upper amphibolites facies.

Age determinations from various parts of Nigeria indicate that the gneissic complex has gone through four major tectonic Cycles of deformation, metamorphism and remobilization in the Liberian (2700Ma); Eburnean (200Ma); the kibaran (1100Ma); and Pan-African (600Ma) (Ajibade and Fitches, 1988) Rocks of the Migmatite-Gneiss Complex occupied most of the area around Kano, Zaria Funtua, Bauchi, Akwanga, Abuja, Keffi in the North; Ilorin, Ibadan, Ile-ife in the west and around Obudu, the oban massifs and the manfe region in the south east (Obaje *et al*; 2016).

2.2.4 Volcanic and Hypabyssal Rocks

Volcanic and hypabyssal rocks of possibly late Pan-African age occur in several localities within a 200km by 30km linear zone associated with the Anka meta sedimentary belt in northwest Nigeria. The rocks are frequently associated with faults which controlled their emplacement. The maradum volcanic (Mc-Curry, 1976) consist of unmetamorphosed volcanic aggregates tuffs, rhyolites and ryhodacites in a 6km by 2km zone. They are intrusive into the mail chi granodiorite and are in turn cut by very late pegmatites. Around Kesemi 90km southwest of Maradum, partly deformed porphyritic and non porphyritic dacites occur. They contain inclusions of fine grained materials and cut by amphibolites, microgranites, pegmatite and epidote rich veins.

2.2.5 Charnockitic Gabroic and Dioritic Rocks

Charnockitic rocks can be identify on the basis of structure and petrographic characteristics, banded and or gneisses charnockites; coarse often homogeneous sometimes porphyritic, foliated charnockites and bauchites, fine-medium grained foliated basic charnockite; dioritic rocks of charnockitic affinity often associated with more acid coaster grained charnockites or granites. The contact relationship between coarse charnockites and their association texturally similar granites have often been described as gradational and marked by a colour change. This among other reasons was used to argue in favour of a metamorphic origin for these rocks (Oyewoye, 1965). Indeed it is often not possible to decide on fresh outcrop which is older (Breemen *et al*; 1977). Wright *et al*; (1971) Hurbard (1968, 1975), have used the evidence available in the field to suggest that the dioritic charnokites are older than the older granites with which they are associated. The evidence consists of hybrid rocks and granite veins cross-cutting the diorite in the marginal area.

2.3 Geology of the Study Area

Gbamze and environs is entirely underlain by Basement Complex rocks of the north central Nigeria. The two different rock groups that constitute the area are as follows:

i. Granite-gneisses

ii. Migmatite-gneisses

2.3.1 Granite – Gneiss

Granite gneiss is a common rock type in the Nigeria basement Complex. It consists of light and dark mineral layers or lenses. The minerals found in this rock have been separated into layers due to high temperatures and pressures. Platy or elongate minerals (such as mica or amphibolites), in dark layers alternate with layers of light-coloured minerals of no particular shape-usually, coarse feldspar and within the light-colored layer the predominant minerals are quartz. The compositions of gneiss resemble that of granite or diorite, but it is distinguishable from those plutonic rocks by its foliation.

Based on grain size, the different types of Granite - Gniess found in the study area includes: porphyritic to coarse grained granite gneiss, medium to fine grained granite gneiss, porphyroblastic gneiss.

2.3.2 Migmatite – Gneiss

Migmatite-Gneiss is also found rock type in places within the study area. It comprises two main types – the biotite gneiss and the banded gneiss. Very wide spread, the biotite gneisses are normally fine-grained with strong foliation caused by parallel arrangement of alternating dark and light minerals. The banded gneisses show alternating light coloured and dark bands. The migmatite gneiss complex is the oldest basement rock and is believed to be of sedimentary origin but was later profoundly altered into metamorphic and granitic conditions, (Peters, 2000).

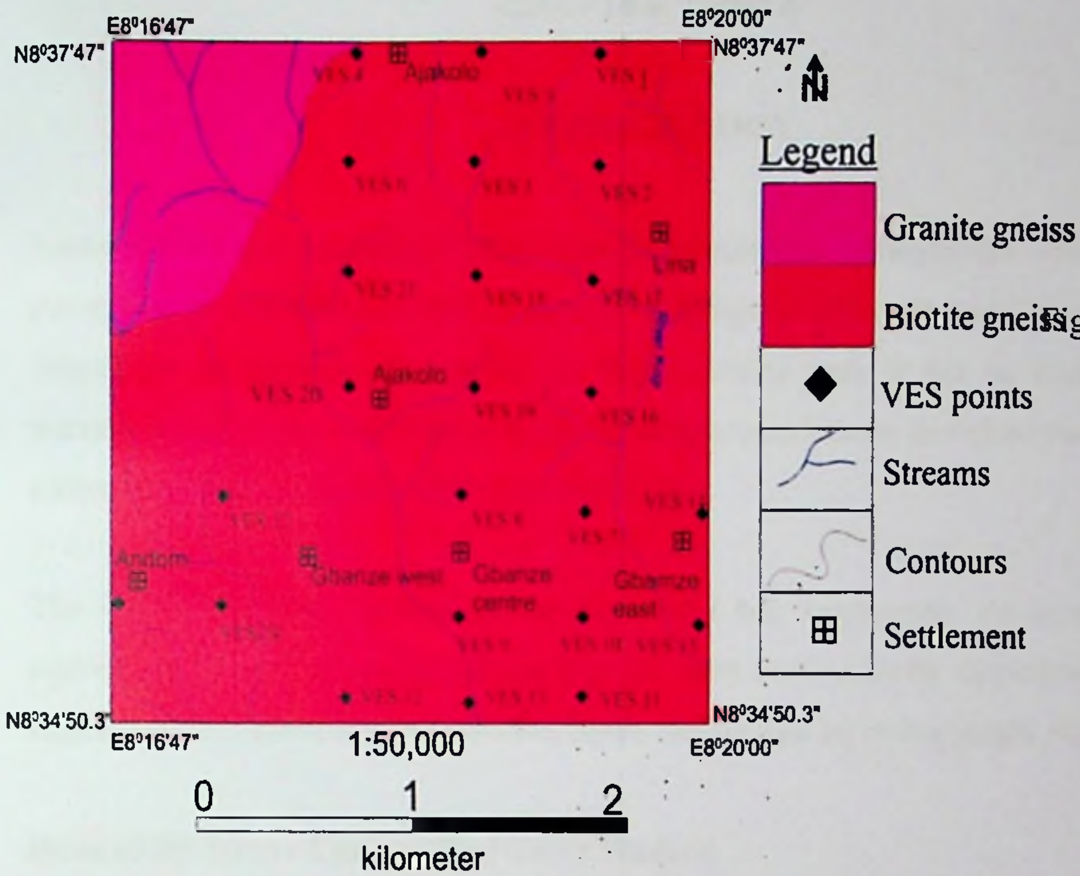

Figure 2.2: Geological Map of Gbamze and Environs

CHAPTER THREE

3.0 METHODOLOGY

Vertical Electrical Sounding (VES) using schlumberger arrangement was carried out at twenty four (24) stations. A normal direction of N-S was maintained in the orientation of profiles. Overburden in the basement area is not as thick as to warrant large current electrode spacing for deeper penetration therefore the largest current electrodes spacing AB/2 used was 100m.

The instrument used for this survey was the L&R Terrameter. At every VES station, the resistance readings in each point were automatically displayed on the digital readout screen and then written down and plotted on bi-log graph paper.

3.1 Basis of the Direct Current Resistivity Method

There are several methods in geophysical survey for groundwater. Some make use of fields within the earth while others require the introduction of artificially generated currents into the ground. The resistivity method is used in the study of horizontal and vertical continuities in the electrical properties of the ground and also in the detection of 3-dimensional bodies of anomalous electrical conductivity. It is routinely applied in engineering and hydrogeological investigations for shallow sub-surface geology. The electrical resistivity method generally uses direct current (DC) or low frequency alternating current (AC) to investigate the electrical properties of subsurface (Kearey *et al*, 2002). The resistivity of rocks is strongly influenced by the presence of groundwater which acts as an electrolyte. The resistivity (inverse of conductivity) of a particular rock unit is influenced by the porosity and permeability of the rock and also by the concentration and types of dissolved minerals and salt it contains.

3.2 Vertical Electrical Sounding for Groundwater

This method is used mainly in the study of depth of probe (vertical plane) due to current that flows at depth that varies with the current electrode separation, the field procedure use a fixed centre with an expanding spread and the whole spread is progressively expanded about a fixed point. This cause the current lines penetrate to ever greater depth depending on vertical distribution of conductivity. The goal is to observe the variation of resistivity with depth. This technique is best adapted to determine depth and resistivity of flat layered rock structure such as sedimentary rocks or the depth of watertable. It is also used in geotechnical surveys to determine over burden thickness and also in hydrogeology to defined horizontal zones of porous strata. The Schlumberger configuration is most commonly used (Kearey *et al*; 2002, Telford *et al*; 1990 and Lowrie, 1997).

3.4 Instrumentation

The equipment used for this survey is the L and R terrameter. The terrameter displays the computed values of the successive resistance (R = V/I) of each of the sounding point or profile. Resistance values obtained for each VES point is recorded on the standard resistivity data sheet which shows the electrode spacing with the corresponding geometric factor K. To obtain the apparent resistivity for each of the sounding point, the value of R is multiplied by K for each vertical distance AB/2.

This calculations work on the well known cross-coil ohm- Meter principle, in which the ratio of the voltage at the input terminals to the current at the output terminals is read directly as a resistance. The great advantage of such direct reading instrument is their great speed of operation but the potentiometer apparatus is more flexible in areas of consistently high electrode resistance (Telford et al; 1990). By multiplying the coefficient value by a geometric factor that depends on the electrodes configuration the apparent resistivity (ρa) is obtained. The apparent resistivity is the weighted average of the resistivity of all the formation through which current is been passed.

Five steel rods, (two as current electrodes, two as potential electrodes and one used for reference point of sounding) were coupled to the terrameter. Four reels of calibrated (marked) cables that connect to the terrameter to the current and potential electrodes were also used for transmission of currents. Other field accessories include; the hammer used to peg marks and electrodes into the ground; survey tapes, used to measure and mark the current and potential electrode separation and the VES station point. The L and R is robust and versatile equipment which can be used for resistivity survey, induced polarization (IP) and self potential (SP) surveys. Each task is accomplished by choosing the appropriate mode on the display menu bar of the terrameter.

3.5 Fieldwork Precautions

The following precautions were taken in the course of the survey;

i. Measures were taken to avoid twitting and sagging of electric cables by straightening them frequently.
ii. Appropriate numbers (5) of electrode for VES were used.
iii. Site umbrella was used to protect the terrameter from direct heat from the sun.
iv. The electrodes were driven to about 10-20cm into the ground to ensure satisfactory electrical contact.
v. Resistivity readings were allowed to be averaged for sometimes before recording, as selected during this work to avoid recording wrong values of the area.
vi. High and/Low tension electric cables and buried metallic pipes were avoided in the course of survey to avoid interference with the reading of the terrameter.
vii. Appropriate electrode spacing as specified by standard record sheet was

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Presentation of Result (Quantitative)

The field curves were typical of K, Q, A and H types. The K-curve type rises to a maximum then decreases, which shows that the intermediate layer has higher resistivity than the top and bottom layers. The Q curve type decreases continuously along with a progressive decrease of resistivity with depth. A-curve type shows a continuous and uniform increase resistivity with increasing electrode separation, indicating that the true resistivities increase with the depth from layer to layer. The H type curve, falls to a minimum then increases again due to an intermediate layer that is a better conductor than the top and bottom layers (Lowrie, 1997). In a case whereby the bedrock is not fractured a borehole can be located at a point having a relatively higher resistivity greater than 150ΩM but less than 600Ωm (Danttaussen and Olorunfemi, 2009). The quantitative summary result is presented in Table 1.

4.2. Interpretation of Result (Quantitative)

4.2.1 True Resistivity Map of Weathered/Fractured Layer

True resistivity map for the weathered/fractured layer in the study area was plotted as shown in Fig. 4.1 using the processed data in table 1. The map (Fig 4.1) reveals that river Kogin and its tributaries flow within the basins of the basement depression. Structural patterns and topography shows a good correlation (Jatau and Ajodo, 2005).

The structural trend confirms direction of flow of the river and structural control pattern of the drainage system in the area along river Kogin and other rivers in NNW, NNE, SSE, SW, NS and NW respectively. This tends to agree with (Olugboye, 1974 and Oluyide, 1988).

Table 1: Interpreted Vertical Electrical Sounding Field Resistivity Data

			LAYERS THICKNESS (M)					LAYER'S Resistivity (ΩM)							
VES Points	No of Layers	Curve type	1	2	3	4	5	1	2	3	4	5	6	Elev.(m)	Total depth
VES 1	6	A	1.72	2.78	5.29	11.47	9.30	125.8	24.03	156.1	23.92	70.19	100.0	167	30.56
VES 2	6	B	0.830	4.46	4.46	6.97	6.53	1219.2	296.7	215.0	416.5	755.3	1598.0	189	25.03
VES 3	6	Q	0.744	1.78	4.14	6.83	5.15	996.4	453.0	280.0	38.97	307.1	30468.5	187	18.644
VES 4	6	H	1.19	1.36	3.27	6.43	4.97	278.8	800.2	84.81	183.4	655.0	71148.9	205	17.22
VES 5	6	Q	0.492	1.89	1.81	1.47	1.92	631.4	87.31	14.43	243.5	702.9	88621.0	206	7.582
VES 6	6	H	4.21	0.921	0.837	2.65	1.69	26.83	20.69	161.3	2649.4	2630.8	59283.3	199	10.308
VES 7	6	Q	0.948	1.29	2.55	1.80	2.33	788.3	153.8	20.94	329.2	1088.1	94446.9	146	8.918
VES 8	6	H	0.410	0.900	2.35	6.65	4.79	989.5	77.71	438.0	68.97	420.6	42223.8	159	15.1
VES 9	6	H	0.218	1.99	4.48	5.54	4.45	5969.2	409.9	118.9	183.5	508.4	43499.8	144	16.678
VES 10	6	H	0.500	2.92	5.26	17.19	7.55	2620.1	257.2	174.6	311.8	410.3	2610.4	153	33.42
VES 11	6	H	0.41	1.84	2.48	2.27	2.26	775.31	151.0	19.39	568.78	1438.1	131206.9	152	9.269
VES	6	H	0.18	1.73	5.03	2.44	2.9	5691.	107.	56.1	125.9	631.5	75800.2	104	12.35

12			6				7	0	8	7					6
VES 13	6	H	0.984	2.03	2.80	2.59	3.55	205.7	229.6	27.20	67.59	489.8	21752.7	121	11.954
VES 14	6	Q	1.34	2.08	6.18	9.84	8.61	448.6	232.5	56.79	203.1	303.8	984.9	115	28.05
VES 15	6	Q	0.688	1.24	2.26	1.60	2.35	641.4	339.5	12.60	213.2	853.7	148142.2	137	8.138
VES 16	6	H	0.547	0.735	2.10	2.40	2.41	80.24	393.3	7.27	379.0	934.5	30241.3	162	8.192
VES 17	6	Q	1.12	1.75	3.61	3.64	3.42	456.9	169.1	32.68	308.2	733.8	15556.1	173	13.54
VES 18	6	Q	0.858	1.27	1.49	7.79	5.50	643.0	64.95	50.90	596.6	533.1	34190.0	167	16.908
VES 19	6	Q	0.857	1.70	2.10	2.92	3.40	383.8	57.58	34.48	109.1	452.2	15401.4	151	10.977
VES 20	6	Q	0.616	2.74	2.56	3.03	3.29	478.3	335.5	41.18	67.47	433.2	31262.1	149	10.236
VES 21	6	Q	0.714	1.40	2.53	2.27	2.26	605.7	300.8	18.98	411.3	1693.5	143811.5	163	9.174
VES 22	6	Q	0.406	0.944	1.35	1.60	1.89	181.7	48.99	28.27	435.2	1837.5	205031.2	155	6.19
VES 23	6	Q	0.701	1.75	1.79	1.73	1.88	312.0	177.5	43.32	404.8	1791.8	205480.8	139	7.851
VES 24	6	Q	0.415	1.68	2.29	1.26	3.17	1660.0	339.0	27.85	470.4	2776.3	56931.2	126	8.815

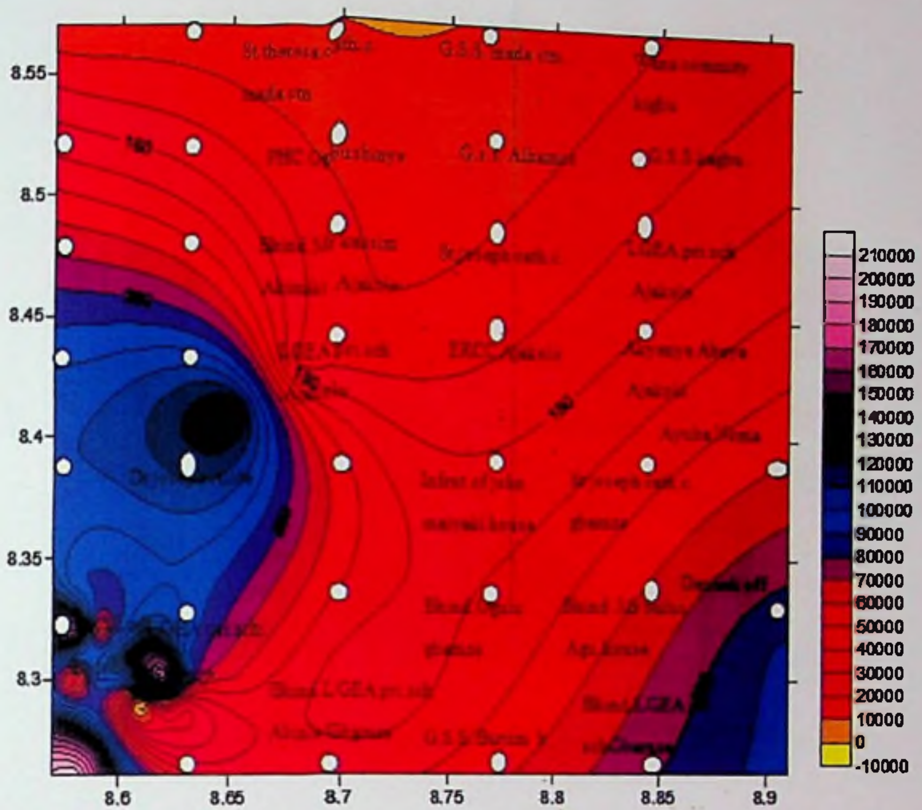

Fig 4.1: True Aquifer Resistivity Map for Weathered/Fractured Layer

4.2.2 Top Layer Resistivity Map of the Study Area

The highest spots are found in the western part of the study area and grading NE to SW direction while the lowest spots were observed South East of the study area. This therefore can enhance run off in the N-S and NNE, SSE directions respectively (Fig.4.2)

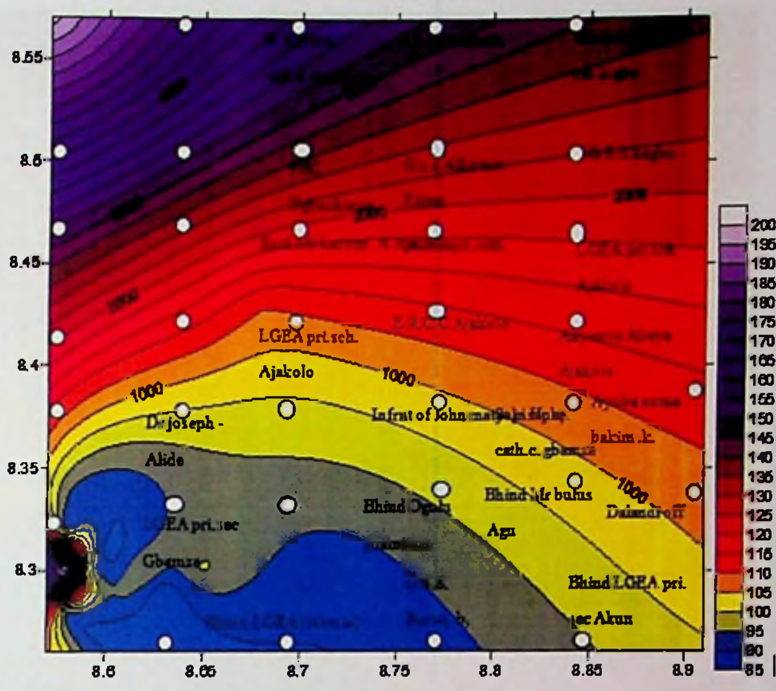

Fig 4.2 Top Layer Resistivity Map of the Study Area

4.2.3 Basement Resistivity Map of the Study Area

The areas with high resistivity are mostly areas of moderate to high hills. Those areas are mostly of lateritic clay and less fractured while those with low to moderate resistivity are good for groundwater such as zones of weathered/fractures rocks. Areas with high resistivity include: GSS Kagbu, LGEA Primary School Ajakolo, ERCC Ajakolo. St. Joseph Catholic Church Ajakolo and St. Joseph Church Gbamze while moderate resistivity areas to the northern part of the study area include; Wana Community Secondary School, Kagbu. St Theresa Catholic Church Mada Station and GSS Alhamis Ezzen, western part of PHC Ogbushinyi behind LGEA Primary School Gbamze Centre. Low resistivity areas include: places in Gbamze Centre, GSS Burumburum and GSS Ladi Endeh.

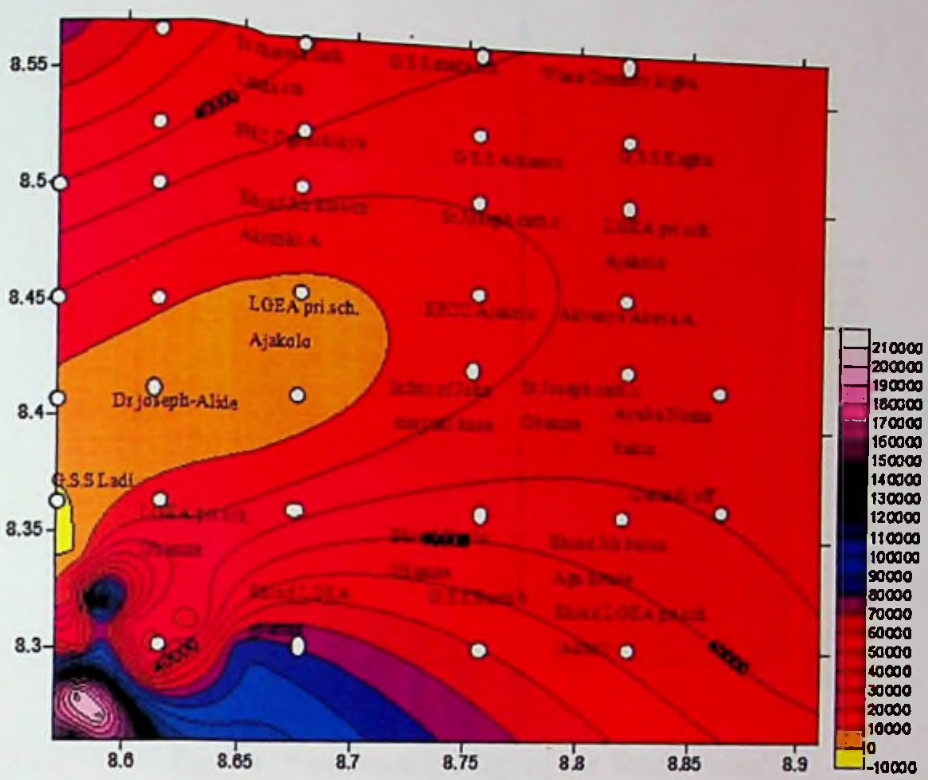

Fig 4.3: Basement Resistivity Map of the Study Area

4.2.4 Piezometric Map of the Study Area

This is obtained by subtracting depth to basement from the elevation to observe the groundwater flow due to gradient difference (piezometer). The piezometric map reveals four depressions and three ridges. The depression trends approximately (N-S, NW-SW, NE-SE; with depression being at GSS Ladi Endeh, LGEA Primary School, Ajakolo, and PHC Ogbushinyi. Ridges trend towards SSW, NNE and NS directions with ridges at GSS Ladi Endeh. This reveals that rivers and tributaries flow within the basement depression and are also controlled structurally as shown in true aquifer resistivity map (Fig 4.1).

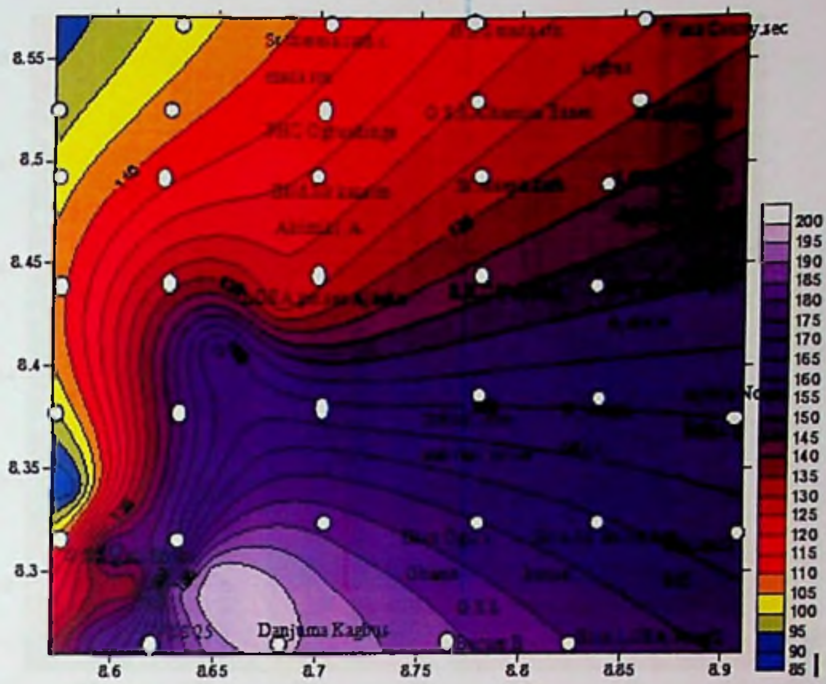

Fig 4:4: Piezometric Map of the Study Area

4.2.5 Depth to Basement Resistivity Map of the Study Area

The depth to basement map was obtained from the quantitative result (Table 1) and contoured as shown in Fig. 4.5. The highest depth to basement, observed at 26m-36m were located in the centre of the study area (ERCC Ajakolo, LGEA Pri Sch. Ajakolo, and St. Joseph Catholic Church Ajakolo. To the northern parts, GSS Mada Station, GSS Alhamis Ezzen and PHC Ogbushinyi while medium depth to basement was observed at 16m which is located at the southern part GSS Burumburum, GSS Ladi Endeh and LGEA Pri. Sch. Gbamze.

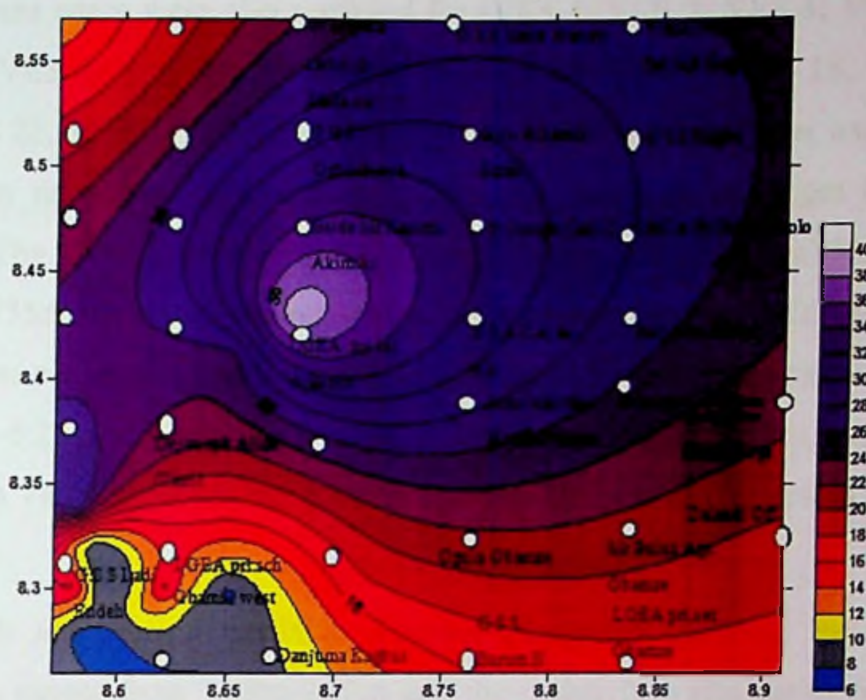

Fig 4.5: Depth to Basement Resistivity Map of the Study Area

4.3 Results Discussion

The Interpreted Vertical Electrical Sounding Field Resistivity Data (Table 1) revealed five layers case for VES 11, VES 12, VES 17, VES 18, VES 19 and VES 20, with topsoil being sandy clay with thickness of the first layer ranging from 0.186m-0.98m second layer composed of lateritic clay has thickness varies from 1.27m-274m and resistivity values varies from 57.58Ωm-335.5Ωm. The third layer is lateritic clay and sandy clay. The thickness varies from 1.49m-5.03m and resistivity values vary from 17.39Ωm-5.6.7Ωm.

The fourth layer, being weathered basement rock units, has resistivity and thickness ranging from 67.47Ωm-596.6Ωm and 2.27m-7.79m respectively. The fifth layer which is the last layer has thickness values range from 2.26m-5.50m and resistivity values of 43.4Ωm-1438.1Ωm. The thickness of the fresh basement is assumed to be infinite.

Five layers cases were also recorded for (VES 1, VES 2, VES 3, VES 4, VES 5, VES 6, VES 7, VES 8, VES 9, VES 10, VES 14, VES 15, VES 16, VES 17, VES 21, VES 22, VES 23, VES 24). The topmost layers are sandy, clay and laterite. The resistivity ranges are 26.83Ωm-5969.2Ωm and the thickness ranges from 0,218m-4.21m. The second layer consists of laterite, sand and clay. The thickness ranges from 0.735m-446m and the resistivity value ranges from 20.69Ωm-800.2Ωm. The third layer consists of laterite, sand clay and clayed sand. The thickness ranges from 0.837m -6.24m and resistivity value ranges from 7. 27m-438.0m. the fourth layer thickness varies from 1.26m-17.19m and resistivity value ranges from 23.92-m - 2649.8m.

The fifth layer being partially weathered/fractured basement rock units. The thickness ranges from 1.68m-9.30m and the resistivity value varies from 70.19m-2776.3m. The last layer being fresh basement rock unit with resistivity values ranges from 100.0m-205. 480.8 m.

The low resistivity value (< 100Ωm is diagnostic of lateritic clay, sand or with lateritic clayed sand, while the high resistivity values (>100m) is typical compacted sand clay and clayed sand, (Odusanya and Amadi 1990).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Vertical Electrical Sounding (VES) results revealed the curves types A, Q and H and a five - six (5 - 6) layers geo - eletrical sequence. The geological sequence beneath the surface composes of topsoil, weathered resolution layer, partly weathered/fractured basement and fresh basement. The depth to bed rock thickness and resistants of the geo-electric layers and weathered basement were determined. The main aquifer is the weathered/fractured basement. The major river and its tributaries in the study area flow within the basement depression, and are controlled structurally. The depth to basement varies from 8m - 36m. The topsoil is composed of sandy-clay, clay and laterite. The resistivity ranges from 205.7 Ωm - 5691.0Ωm and thickness ranges from 0.186m-0.984m thinnest at VES 5 and thickest at VES 6. It is however, observed that VES 1, 4, 6, 8, 9, 10, 11, 12, 13 and 16 are characterized with low resistivity values suggesting a lateritic and clayey nature of the topsoil in the area, with possibly a high moisture content. The second layer resistivity varying from 20.69 Ωm-800.2 Ωm and the thickness varies from 0.735m -2.92m. The third layer resistivity value varying from 7.27Ωm-438.0Ωm and the thickness ranges from 0.837m-5,29m. Fourth layer resistivity ranges from 23.92Ωm-2649.8Ωm and the thickness varies from 2.27m-17.19m. The fifth layer being weathered/fracture basement rock units. Resistivity and thickness varies from 70.19Ωm-2630.8Ωm and 1.69m-9.30m. The last layer being fresh basement rock unit with resistivity value varies from 100.0Ωm-131206.9Ωm, with an infinite depth.

5.2 Recommendations

The delineation of aquiferious potential units in the study area has been attempted. Detail geophysical survey may be useful in the future to obtain high success rate in locating boreholes for the communities thereof.

Boreholes drilling within the recommendation depth at VES 1 to 9 and 10 to 13 with exception of VES 2, 3, 5, and 7 can yield productive boreholes. Detail Geochemical study of the water system in the Area may be necessary to ascertain the geochemical characteristics of the study area after the drilling exercise.

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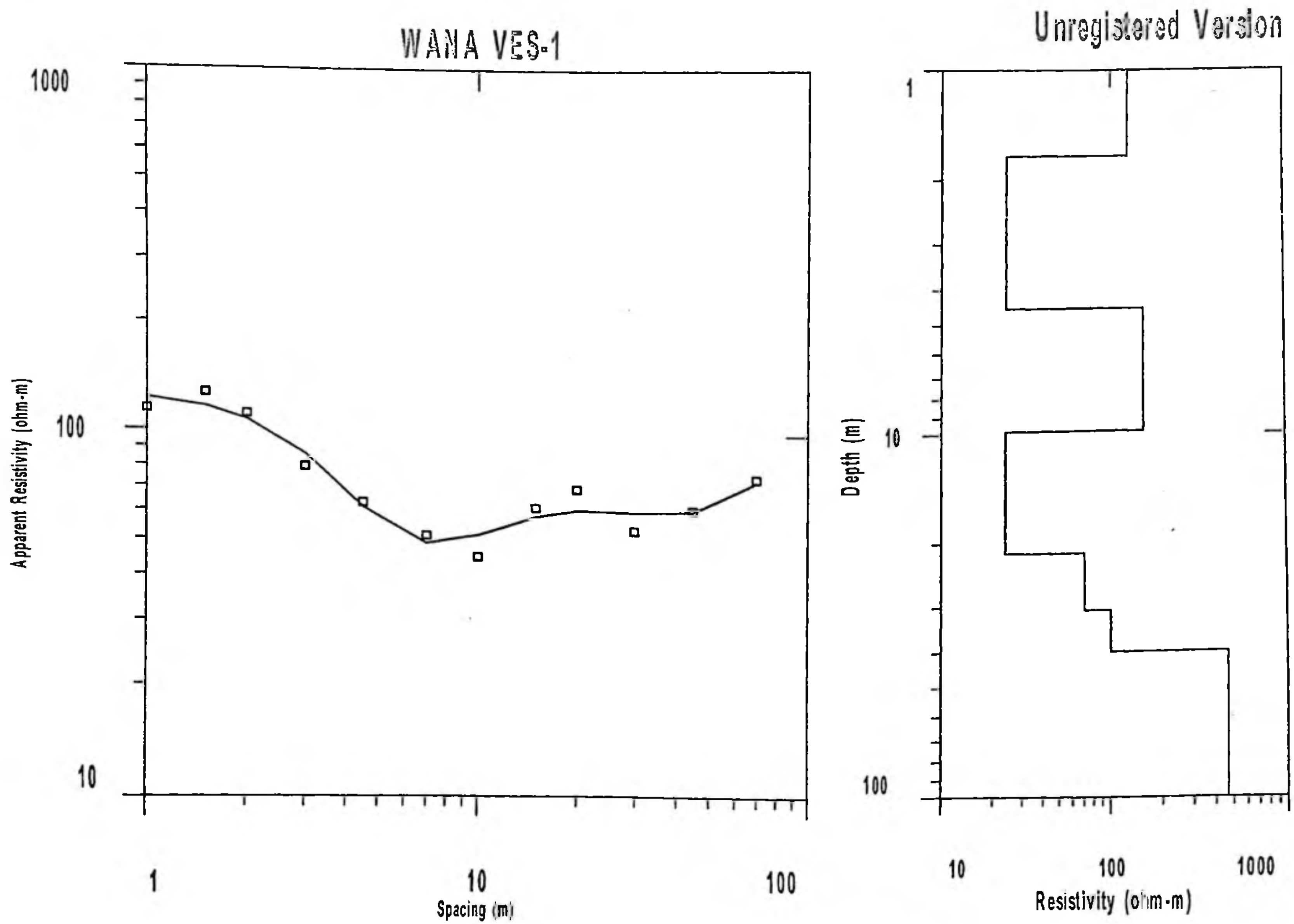
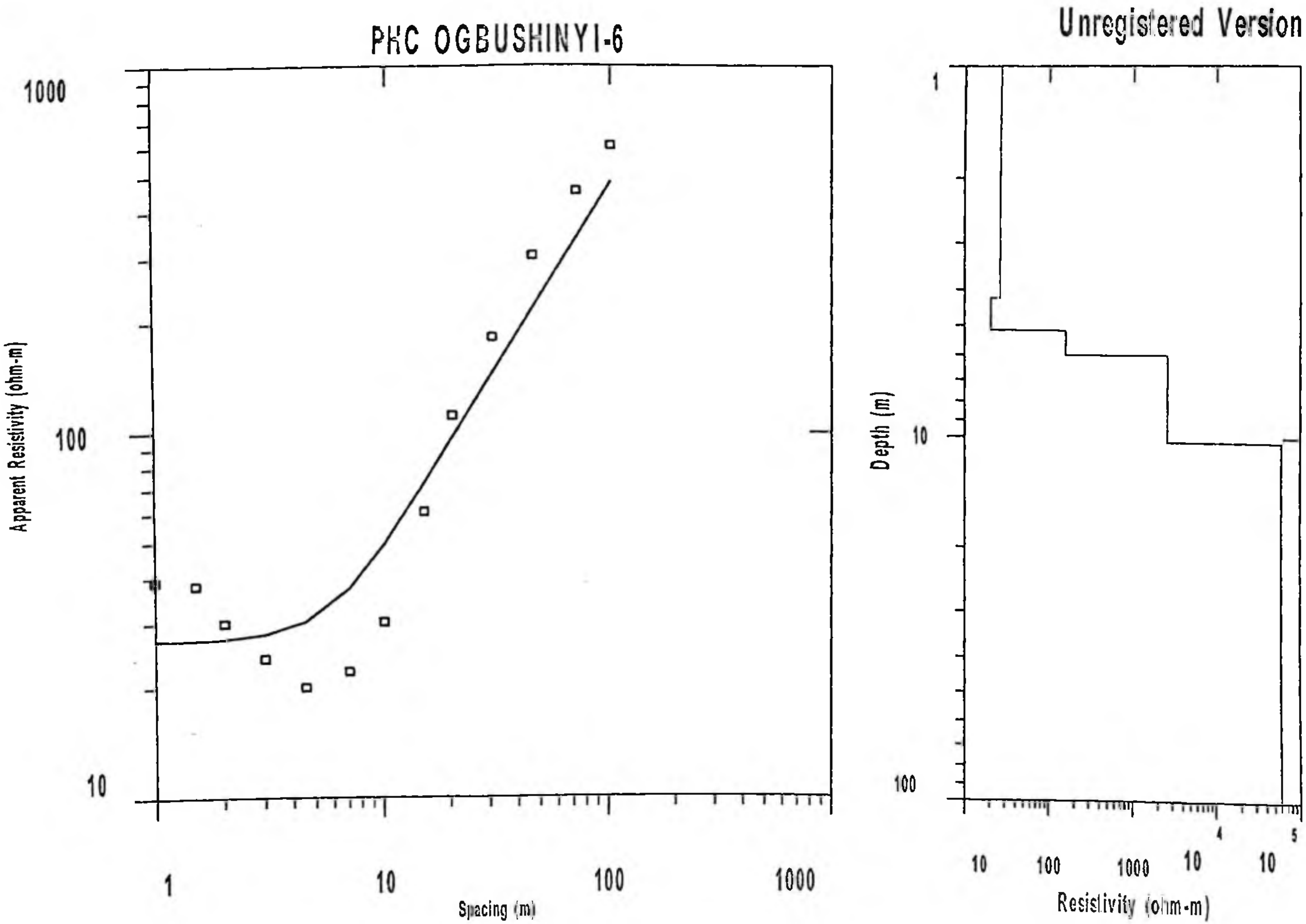
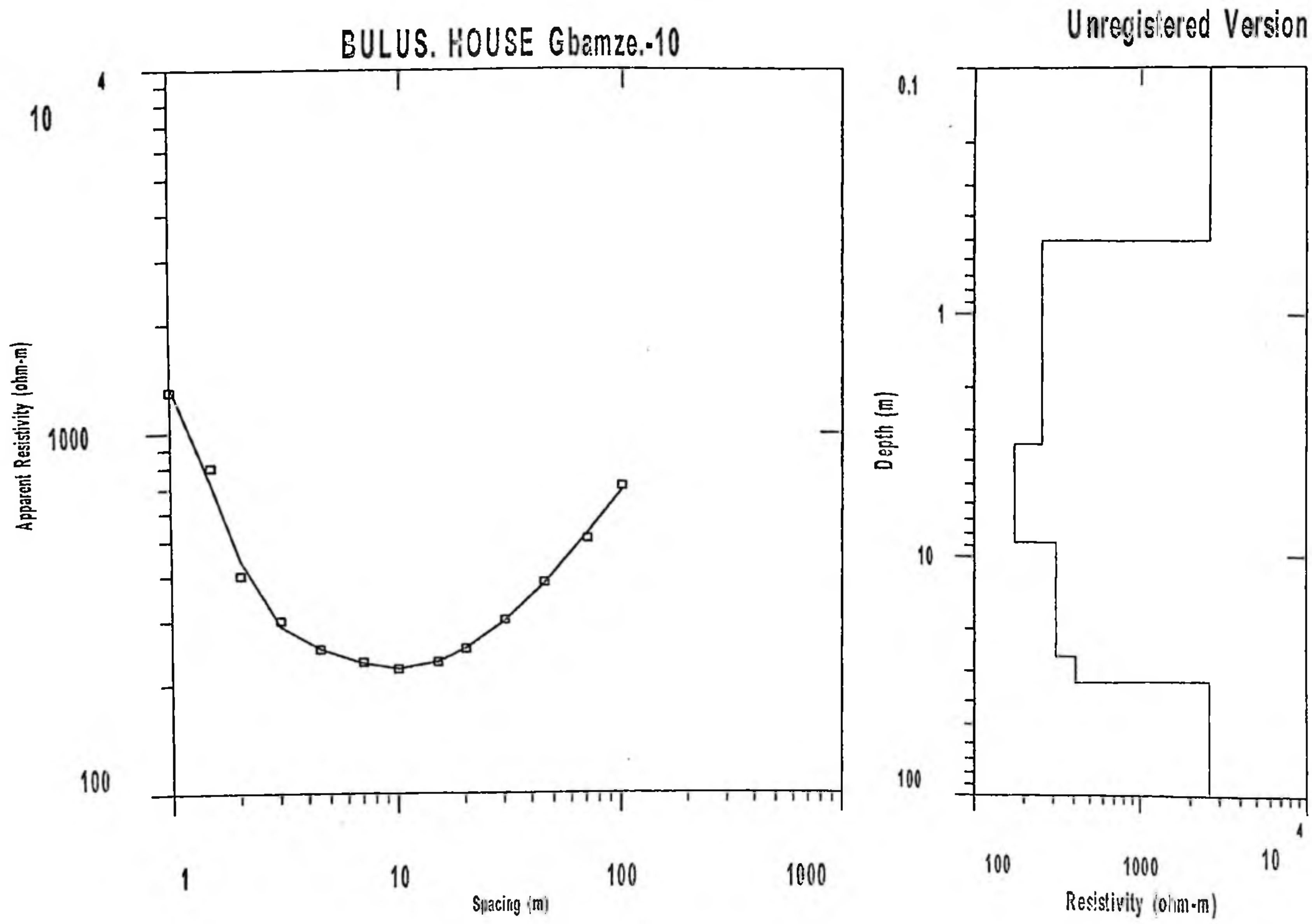
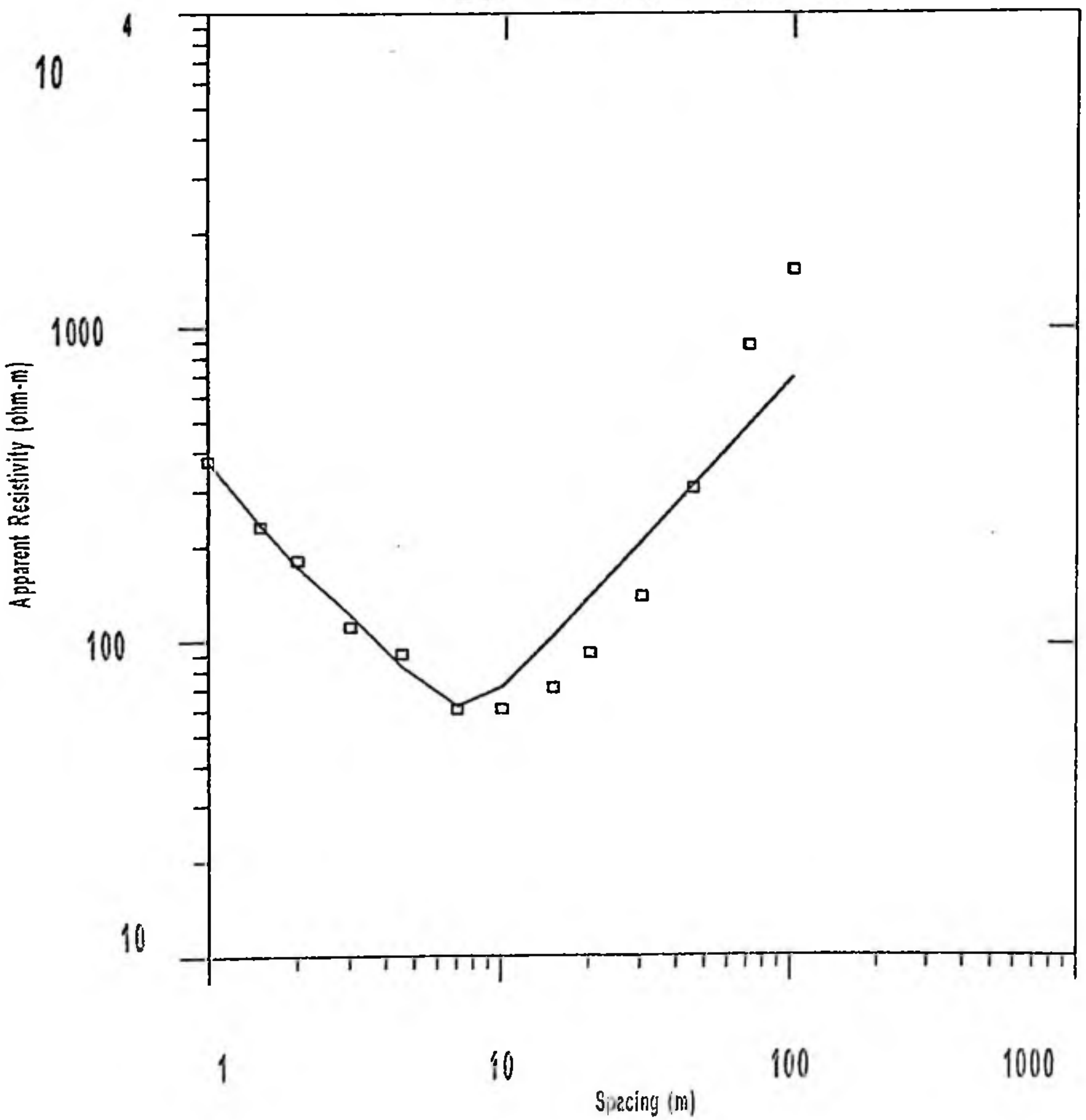


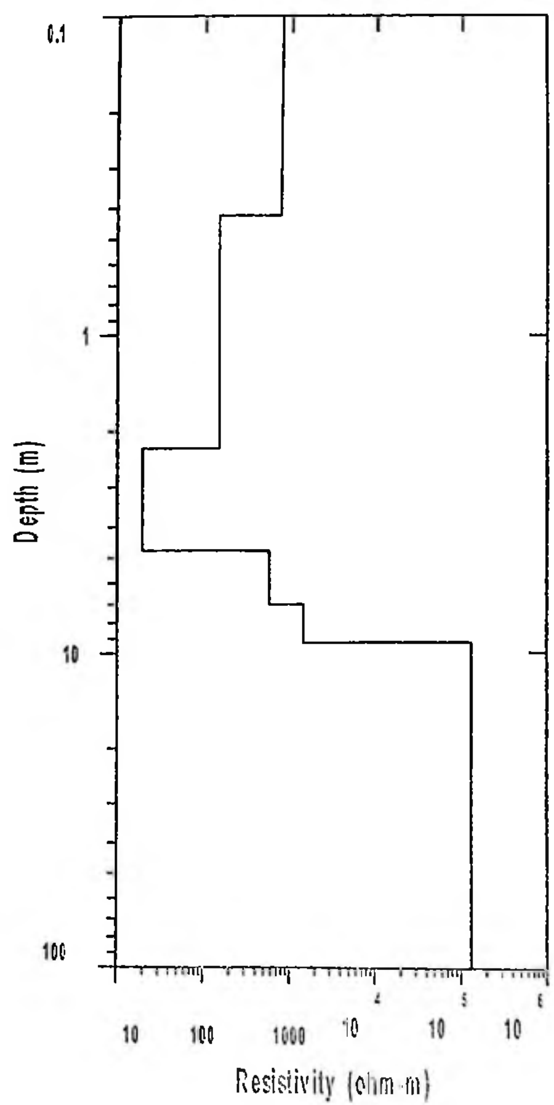
WANA VES-1
Unregistered Version
1000
100
10
Apparent Resistivity (ohm-m)
1
10
100
Spacing (m)
Depth (m)
Resistivity (ohm-m)
1000

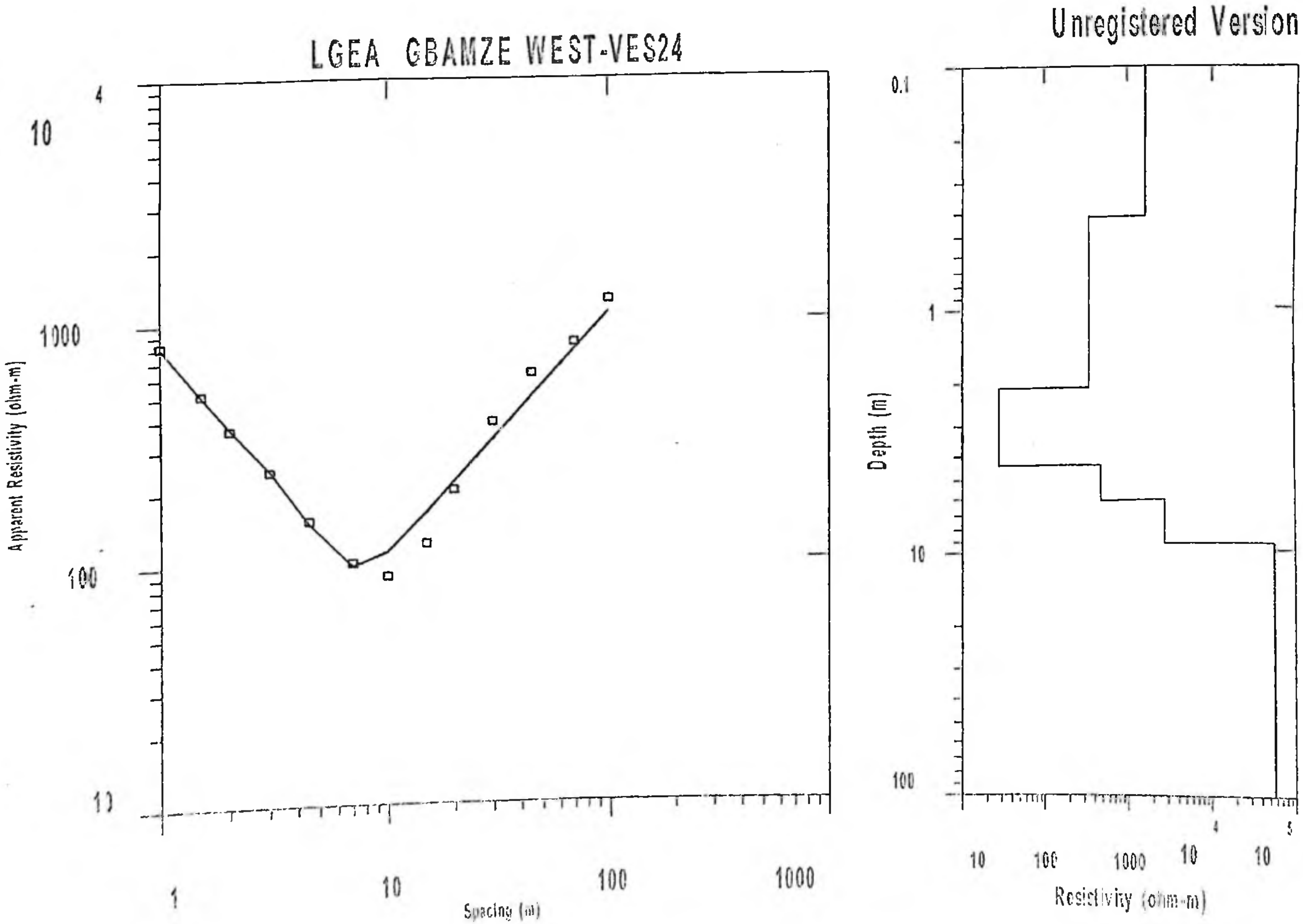

PKC OGBUSHINYI-6
Unregistered Version
Apparent Resistivity (ohm-m)
1000
100
10
1
10
100
1000
Spacing (m)
Depth (m)
1
10
100
10
100
1000
10^4
10^5
Resistivity (ohm-m)


BULUS. HOUSE Gbamze.-10
Unregistered Version
Apparent Resistivity (ohm-m)
10
4
1000
100
1
10
100
1000
Spacing (m)
Depth (m)
0.1
1
10
100
100
1000
10
4
Resistivity (ohm-m)

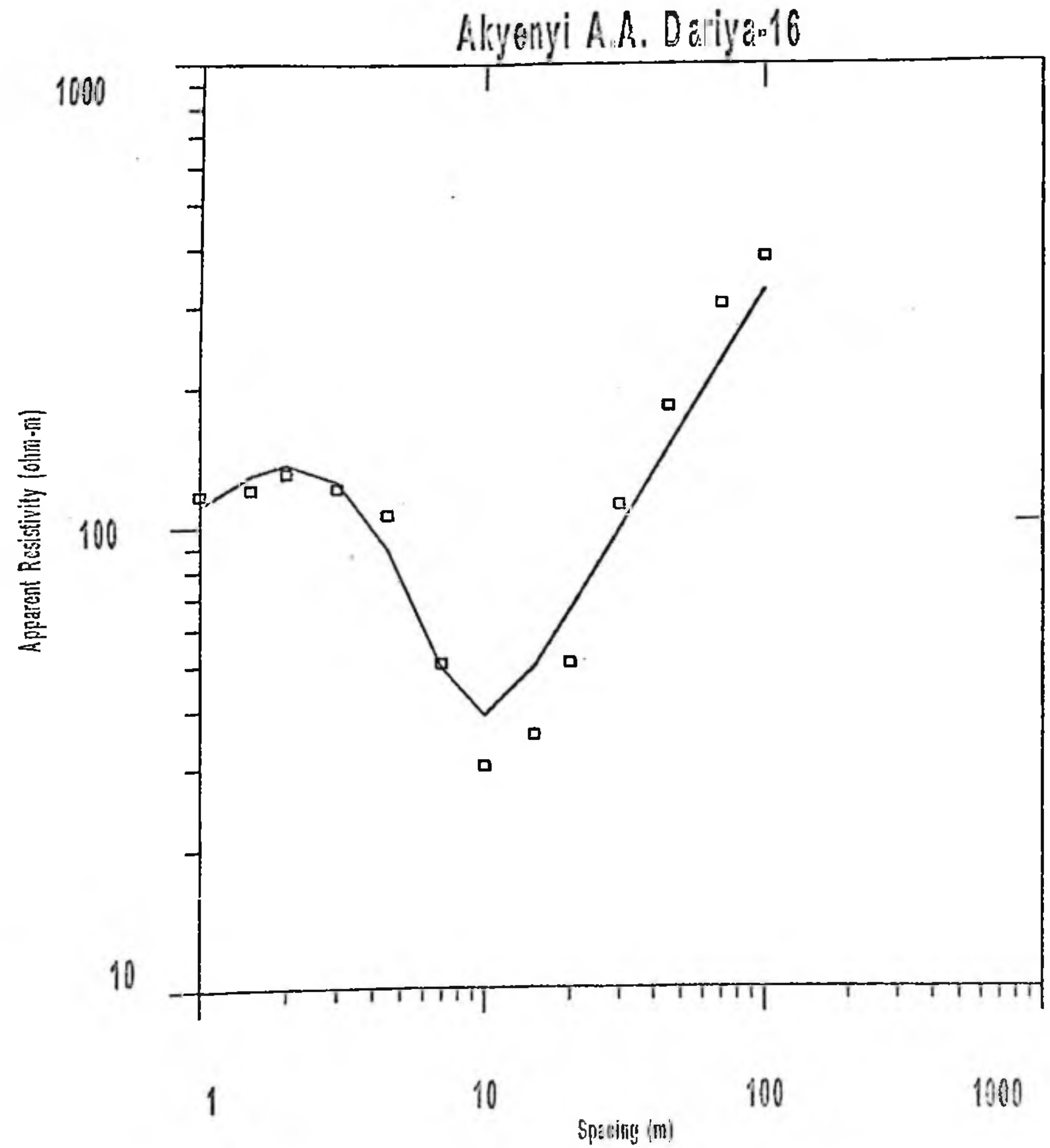
LGEA AKUN ABINLE-11

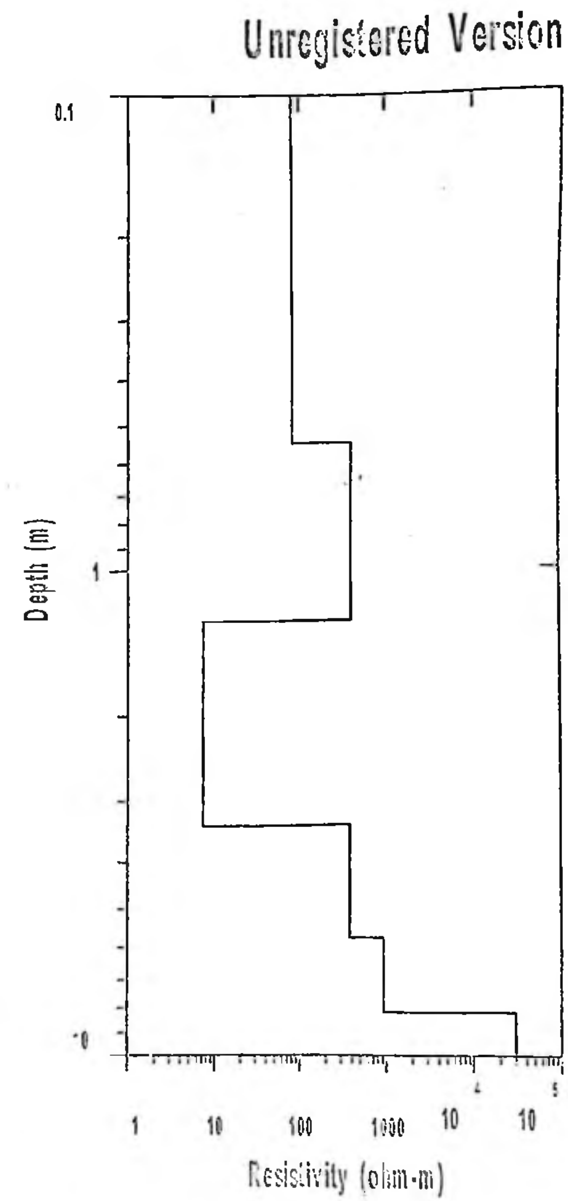






LGEA GBAMZE WEST-VES24
Unregistered Version
Apparent Resistivity (ohm-m)
Spacing (m)
Depth (m)
Resistivity (ohm-m)


Akyenyi A.A. Dariya-16
1000
100
10
Apparent Resistivity (ohm-m)
1
10
100
1000
Spacing (m)


Unregistered Version
0.1
1
Depth (m)
1
10
100
1000
Resistivity (ohm-m)