Electrical Resistivity Method for Ground Water Exploration Around Wuntin-Dada, Bauchi Sheet 149 NE

BY

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01/10723/2

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01/10723/2

A PROJECT SUBMITTED TO THE GEOLOGY PROGRAMME, SCHOOL OF SCIENCE, ABUBAKAR TAFAWA BALEWA UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF TECHNOLOGY (B.TECH) IN APPLIED GEOLOGY.

APRIL, 2009

DECLARATION

I hereby declare that this project was written by me and that it is the record of my own research work. It has not been presented anywhere before. All sources of information are duly acknowledged in the reference section.

______________________ 21/05/2009

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CERTIFICATION

I hereby certify that this project was an original work done by Abubakar, Abdussalam, A. under my supervision and has met the requirement for the award of bachelor of technology (applied geology) of Abubakar Tafawa-Balewa University Bauchi .

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Name ....

Signature .... Date ....

DEDICATION

I dedicate this project to my parents, late Dr Aminu A. Abubakar and Haj.Karimatu A.A for their love and concern.

ACKNOWLEDGMENT

I wish to express my profound gratitude to Almighty Allah, Most gracious most merciful, for bringing me to the successful completion this project.

My sincere appreciation goes to Mal Ahmadu Tukur (project supervisor) for his enormous assistance, encouragement, and professional guidance and also all my lecturers for their never- ending support and understanding.

I will like to thank my brother and sisters; Nafisatu, Hauwa, Abu-Ubaida, Hamdiyya, Hadiza, Maryam and my friends; Rabiu,Anas, Salisu, Kankarofi, Bashir-geology, Yalamuwa, Naziru, Abubakar, Mustapha , Jibril.

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Finally, I thank all those that help in providing me with conducive atmosphere and useful information used in the compilation of this project.

ABSTRACT

The study is aimed at determining lithologic units, establishing suitable drilling points in identified lithologic units and correlate aquifer potential of the rock units in the study area (Wuntin Dada). To achieve these two methods were used; Field Mapping, Geo-electrical resistivity Survey (Vertical Electrical Sounding).

The four rocks units (Migmatites, Gneiss, Bauchite and Migmatites-Gneiss) were identified, delineated and the area was mapped on a scale of 1:50000cm and covers an area of 40.25 KM^2. Total of Ten (10) VES points were surveyed on the different rock units in order to meet the aims of the project.

The field data was interpreted using a computer aided program (Offix). The result of the interpretation revealed three to four layers. The layers comprise of topsoil, weathered basement, fractured basement and fresh basement. The overall result of the resistivity shows that the Migmatite-Gneiss area has the higher aquifer potentials when compared to the areas covered by Gneiss, Migmatite and Bauchite,

Out of the ten VES soundings, the following points were recommended;

VES 01,04,05,06 and 10.

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CHAPTER ONE

1.0 INTRODUCTION

Ground water is a very important component of water resource. It is known to occur more widely than surface water .The last few decades have witness a tremendous increase in the application of geophysical techniques in locating ground water. This is more evident in areas underline by crystalline rocks, were scrupulous geological and geophysical investigations are needed to locate suitable groundwater (Dan-Hassan and adekile, 1991)

Sustained safe drinking water supply is essential to improve the living condition of the rural population. Wuntin Dada village is a small village located along Bauchi–Jos highway; it is a community with approximately 3000 population with approximate 250 houses. The populace mostly derived their source of water from hand-dug wells. Therefore, provision of more productive boreholes shall be of priority for the community's ever increasing population.

Consultation of topographic and geologic maps, borehole logs and other records gathered from previous works was first done in the area. This is followed by geologic field reconnaissance survey and evaluation of available hydrologic data on stream flow and springs, well yields, groundwater recharge, discharge, water levels and water quality.

The availability of groundwater in any area is primarily controlled by the geology of the area. Identifying the various rock and their properties will help in successfully location and retrieval of ground water. Important rock properties to look at include: porosity, permeability,

Ground water despite its relative abundance, ground water availability is limited by many factors as identified by Offodile (1992):

a) Rocks in the zone of saturation are permeable enough to transmit sufficient water to well, streams or springs.

b) When the zone of saturation is perennial or at least long enough to allow practical exploitation.

c) When the chemical composition is within tolerable limit.

Water available to support domestic and agriculture in the study area is largely exploited from the basement aquifer. This is because the area is underlain by crystalline rocks, which constitute part of the Nigerian basement complex. Aquifer in basement occurs in the weathered mantle or within the joints and fracture system in the unweathered rocks (Todd, 1980).

1.1 LOCATION AND ACCESSIBILITY

The area of study is covering Wuntin-Dada/Miri area at the outskirts of Bauchi town. The area is situated on longitudes 9°45'40"E and 9°48'38"E and latitude 10°17'55"N and 10°22'10"N. The area covers an area of about on the topographic map, sheet 149 NE.

The area is generally accessible with numerous interconnected footpaths, moterable tarred and untarred roads linking all parts of the study area.

1.2 CLIMATE AND VEGETATION

The study area falls within the tropical continental climate zone. It is characterized by two seasons: a rainy wet season, which starts in May and ends in October and the dry season, which normally spans between October and April. The rainy season is the period when tropical maritime air mass travels northwards over the study area from the Gulf of Guinea progressively dropping its moisture in form of precipitation. Consequently, rainfall diminishes from the south to north (Iloeje, 1982).

The mean annual rainfall is 1010 mm for Bauchi and environs (NIMET, 2007) where the study area is located. The dry season is characterized by an arid wind or tropical continental air mass originating from the Sahara desert. During the period, there is little cloud cover and temperature varying from 16-36°C (NIMET, 2007).

The study area is mainly classified as Sudan savannah, which is characterized by grasses, shrubs and trees with large trunks (e.g. baobab trees). The grasses dry and the trees shade off their leaves during dry season and flourish when wet season resumes. The vegetation of the area has been greatly modified by agriculture and other human activities.

1.3 RELIEF AND DRAINAGE

The study area is characterized by hilly topography, with elevation ranging from 533 to over 780 meters above sea level. The hills may be seen as inselbergs, with conical, elongated or irregular shapes. Others occur in a chain forming a ridge with serrated outline. The prominent among these hills include, Guru, wambai and Miri hills.

The drainage system of Bauchi and environs is mainly dendritic in nature, the two main streams in the area are: Shadawanka which flows in the north eastern part of the study area and Tambari which flows south – west part of the study area. These streams are perennial with their head courses and smaller tributaries drying up during the dry season.

1.4 SETTLEMENT AND LAND USE

The settlement pattern in the study area is the dispersed type. The linear pattern of settlement is found in the GRA. The settlements are mainly residential houses with some offices and schools (school of engineering). The main settlements include Wuntin-Dada, Miri, Guru, Rafin- Dinya, and Zamfara.

Farming is the major occupation of the residents of the study area. The crops mainly cultivated are: maize, millet, groundnut and sorghum.

1.5 OBJECTIVE THE STUDY

The objective of this project is to:

a) To determine various lithologic units in the study area

b) To establish suitable drilling points using VES in the identified lithologic units

c) To correlate aquifer potential of the rock units.

CHAPTER TWO

2.0 GENERAL GEOLOGY

The basement complex of Nigeria is a part of the pan African mobile belt of Africa; which lies east of the West African craton. It is the southern elongation of morocco and Algerian Hoggar and the air Of Niger republic. The Pan-African mobile belt of West Africa is considered to be continued into the south American continent to form the Boreman province of North east Brazil before the separation of African plate from the south American plate during the late Jurassic time.

The basement complex in Nigeria is made up of three (3) major groups.

a. Migmatite Gneiss complex

b. Younger Metasediments (schist belt)

c. Older granite

d. Volcanic rocks

a) MIGMATITE-GNEISS COMPLEX

This is the migmatite-gneiss complex (M.G.C.), it is the most widespread of the main Rock units in northern-western Nigeria. This Rocks under lies the entire northern Nigeria and intruded all the Rocks older than the late protozoic metasediments (younger metasediments).

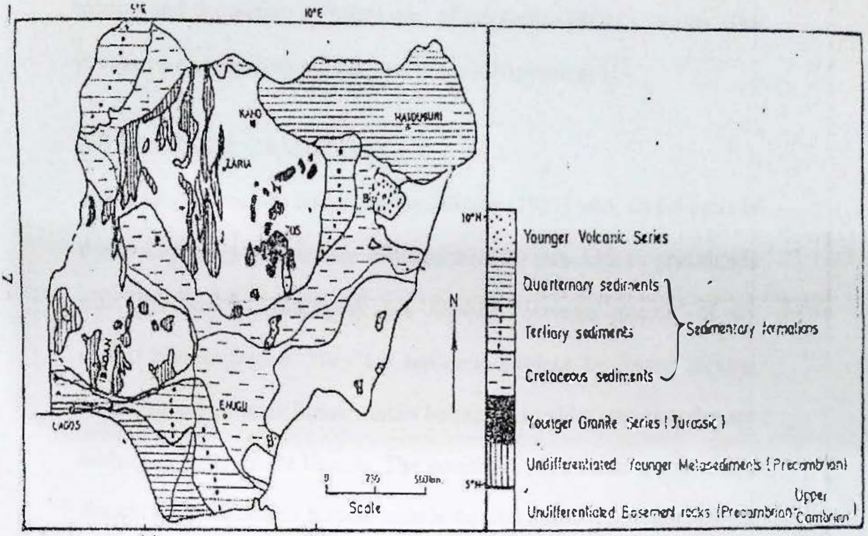

Figure 1: map of Nigeria showing basement complex (after G.S.N map, 1974)

b) THE YOUNGER METASEDIMENT

The younger metasediments are series of Rocks rich in mica, (wright et al, 1970) said the Nigerian schist but is commonly referred to as the younger Metasediments. It is normally but not exclusively in western part of the Nigerian basement. Oyawoye et al, (1972) and Rahaman, (1976); made it clear that the best preserved schist belt in Nigeria are those in the northern part of the country. The major Rock types include sedimentary amphibolites, schist, quartz-mica schist, quartzite, marble and cale-silicates etc. Many of the schist belt rocks are formed from weathering, erosion and deposition in paleobasin of migmatite-gneiss complex. The younger metasediments are the host of most Nigerian gold.

c) THE OLDER GRANITES

The older granites was introduced by falconer (1911) who, on the basis of their morphology and texture distinguished the pan-African granithoids from the Jurassic Anorogenic per Alkaline "younger granite" of the central Plateau region. They are acrogenic produce by partial melting continent-continent collision. Rocks belonging to older granite series are widespread in northern Nigeria. The granithoid which outcropped within Bauchi of north-eastern Nigeria include fayalite quartz monzonite, biotite hornblende granite and quartz hypersthenes diorite, but other school of thoughts are of the opinion that these rocks in many ways are typical of the other pan-African age intrusion of Nigeria but maintain characteristics of deep origin granulites fancies conditions.

Bauchi State is mainly underlained by crystalline rocks which belong to the Nigeria Basement Complex, thought to be mostly Pre-Cambrian in age (Oyawoye, 1970) and a minor occurrence of Tertiary sedimentary environments. The rocks of the basement complex are the migmatite-gneiss quartzite complex and granite gneiss. The older granites and the charnokitic rocks (Bauchites). The migmatites, migmatite-gneiss and granite gneiss complex form the oldest rock group of presumably late

Pre-Cambrian to early Paleozoic age. During pan African Orogeny, a suit of intrusive granites, older granites and the charnokite rocks were emplaced in a magnetic phase within the country rock migmatite-gneiss complex. The oldest granite suites are predominantly of porphyrite biotite granite or biotite-hornblende granites. They are usually foliated due to the mafic minerals present in them.

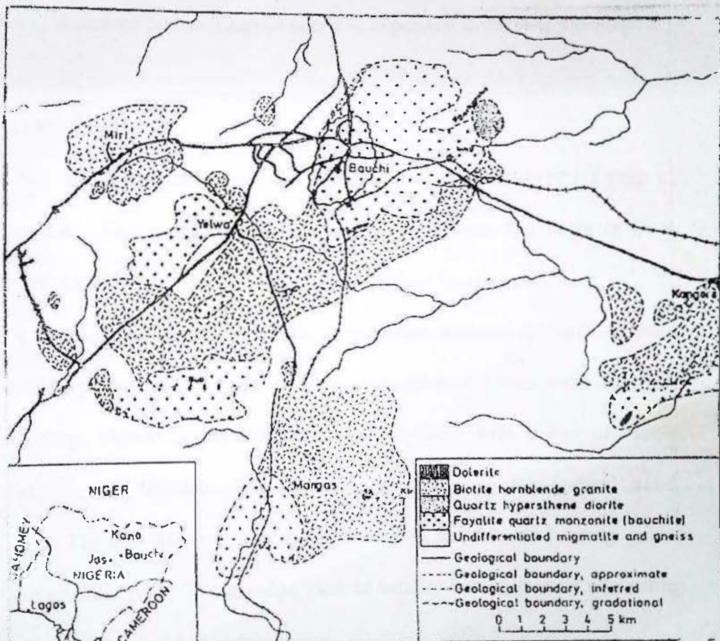

Fig. 1. Granitic and intermediate rocks of Bauchi area.

Figure 2: map showing Granite and Intermediate rocks of Bauchi (after Eborall,1978)

(a) Granite Gneiss

The granite gneiss occur at the southern zone of the state, comprising eastern and western parts of Bauchi local government, some part of Ganjuwa and Tafawa Balewa local governments. The granite-gneiss is fine to medium grained, biotite-rich granitic rocks. In general, they have uniform appearance and are relatively constant in composition. They are composed of white plagioclase and some microcline quartz and fairly abundant biotite. Hornblende is also present in varying amounts.

(b) Migmatites

The migmatites cover almost the entire part of the southern parts of the state. These areas are, Liman Katagum, Baraza and north of Dass town. Others include Tulai and Gumau in Toro local government.

Migmatites are variable in texture from medium to coarse-grained and they represent a high grade metamorphosed series with excellent banding. Generally, the migmatites are foliated with flakes of biotite defining the foliation. The foliation is parallel to the general trend.

The migmatite is a composite rock of hornblende bearing gneiss and granitic rock. The granitic rock is usually biotite granite alternating with the hornblende bearing gneiss.

(c) Fayalite Quartz Monzonite (Bauchite)

Fayalite bearing charnokitic rocks (Bauchite) are generally restricted to areas around Bauchi, Dandago, Gwaskarom and Kubi. They appear as oval to sub-circular scattered outcrops of various sizes.

Fayalite quartz monzonite (Bauchite) was first described as coarse grained augite syenite by Falconer (1911). But the distinctive features of the rock were first described by Oyawoye (1958, 1961) who named them Bauchite in 1965.

Clear occurrence of Bauchite was seen at Wambai hill, Guni and underlying Bauchi town. They occur as platy exposure with deep green colour when fresh and pinkish brown when weathered. The rocks are massive, homogenous and unfoliated. They have few joints, outcropping as smooth rounded boulders derived from massive unfoliated rocks by spherical weathering.

The mineral assemblage includes biotite, hornblende, fayalite and pyroxene. Accessory minerals found are apatite, zircon and iron oxides (fig 2)

(d) QUARTZ DIORITE

Quartz diorite occurs as veins and dykes within the migmatite and granites. The dykes vary in thickness from 10cm to as much as 100cm.

They generally cross cut the structure host rock having a sharp contract with host. The quartz diorite is a medium grained melanocratic rock.

(e) PEGMATITES

The pegmatites are found across the basement complex rocks mostly as veins. They can be divided into concordant and discordant. The concordant pegmatites are those found parallel to the pre-existing structure while discordant are those truncating the pre-existing structures in the rock.

The pegmatites are up to coarse quartz and feldspar, mostly potassium feldspar with little biotite and little or no muscovite.

(f) BIOTITE HORNBLEND GRANITE

Biotite hornblende granite occurs as prominent hill with rugged surfaces. The exposure show faint foliation defined by small streaks of biotite and hornblende alternating with feldspars and quartz.

They are characteristically porphyritic in texture. This is formed by phenocryst of perthite microcline in a ground mass of medium to coarse feldspar, quartz, biotite and hornblende.

YOUNG GRANITE SUITE

The younger granite of the Jurassic age occupy only a small portion of the state. The most prominent occurrences are the Zaranda ring complex along Bauchi –Jos road and the Ningi –Bura young granite ring complex. They are composed mainly of rhyolites, syenites, granites porphyritic and volcanic basalts.

2.1 VERTICAL ELECTRIC SOUNDING

The earliest geophysical investigation of ground water around the area of study was carried out by Edok-Eter-Mandilas Limited, under the supervision of Bauchi state water board. During the execution of the project in 1976, the following techniques were employed; aerial photographic interpretation, seismic refraction profiling and electrical resistivity sounding. At the end of the project they were able to study the hydrogeology of the state and delineate suitable points for ground water exploitation (borehole drilling), the project started in 1980 and completed in 1988, in two phases under supervision of Bauchi state Agricultural Development Programme (BSADP)/ Bauchi integrated Rural Development Authority (BASIRDA). At the conclusion stage of the project over 1500 boreholes were sited and drilled in various parts of the state. Boreholes in Bauchi town were drilled at an average depth of 30m and mainly through three (3) layers (top soil, weathered rocks and fresh crystalline basement)

Groundwater exploration was carried out in the Abubakar Tafawa Balewa University (ATBU) main campus at Gubi, by the hydrogeology research unit of the geology programme ATBU, Bauchi, under the leadership of Professor E. F. C. Dike in 1994 as a review of the earlier survey by Water Surveys Nigeria Limited in 1982.

During conduct of the project, the combined electromagnetic electrical resistivity techniques were employed. The exercise resulted in sighting three productive boreholes within the campus which is about 17 km from the study area.

Furthermore, a research work on the geophysical investigation for groundwater in areas around Bauchi town was carried out by Shemang and Umaru (1994),their aim was to determine the thickness, distribution and possible nature of fracturation (probable aquifer) a geophysical survey involving seismic refraction and electrical resistivity methods. A12-channel dresser RS4 seismograph and ABEM terrameter SAS 300B were respectively used.

In the recent pass a number of borehole projects have been executed for government, non governmental organizations and private individuals within and around Bauchi town. This projects are still in progress the only problem is that the information about such projects are not available.

The most important point to note here are almost all boreholes drilled recently and in the pass was sighted using electrical resistivity technique (vertical electrical sounding method).

2.2 GEOLOGY OF STUDY AREA

The study area, Wuntin-dada and environs are located on the basement complex of Nigeria made of crystalline rocks, consisting of Bauchite (fayalite quartz monzonite), migmatites, gneiss and migmatites-gneiss.

The oldest rocks of the area, the gneisses are believed to be Pennian age (Shamang and Umaru, 1994) are overlained by recent alluvium, resulting from the weathering and erosion of hills and decomposed rock materials. These materials cover large parts of the crystalline basement rocks. These alluvials are seems to be either sandy, gravely or cohesive alluvials at some places.

CHAPTER THREE

3.0 METHODOLOGY

This chapter discusses the processes involved in the conduct of the project work. Two methods were used, these are

a) Field Mapping

b) Geo-electrical Survey (Vertical Electrical Sounding)

The first step employed in the course of the conduct of this research was consultation of literatures on the study area and those of importance to the research. This was to acquire prior information about the geology and hydrogeology of the study area and the state at large. Geological reconnaissance survey was also conducted, to locate major outcrops, drainage patterns, study the lithology of the area.

3.1 Field Mapping

The area was mapped on a scale of 1:33000 and covers an area of 40.25 KM^2 (fig 3). Basic field work involved traversing the area to locate boundaries of the units. Mineralogical composition of the different rock units were studied macroscopically in the field. The aims of the project did not involve microscopic study. Instruments that were used in the field work include

I. Hammer

II. GPS

III. Compass

IV. Field book and pens

Base map (Bauchi N.E, Sheet 149) aided in the production of the production of a geologic map of the area.

PLATE 1: material used in mapping

3.2 GEO-ELECTRICAL RESISTIVITY (VES)

Vertical electrical sounding is the second component of the project. This was done using the schlumberger configuration standard (fig A) and ABEM SAS 300C Terrameter (fig). Ten (10) points were surveyed across the area. Offix software was employed in the interpretation of the result.

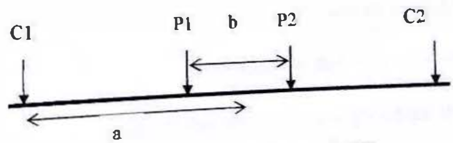

Figure A: Schlumberger Array

FIGURE 3: ABEM SAS 300C TERRAMETTER

3.2.1 Basic Principle of Electrical Resistivity Techniques

It was near the beginning of 20th Centaury that Cenrad Schlumberger first employed the technique of mapping subsurface geology. His pioneering studies led to an understanding of the significance of utilizing electrical resistivity methods, for exploring the subsurface.

Ohm's Law describes the electrical properties of any medium. Ohm's Law, $V = IR$, relates the voltage of a circuit to the product of the current and the resistance. This relationship holds for earth materials as well as simple circuits. Resistance, however, is not a material constant; instead, resistivity is an intrinsic property of the medium describing the resistance of the medium to the flow of electric current. Resistivity ($\rho = \delta A \delta R / \delta L$) is defined as a unit change in resistance scaled by the ratio of a unit cross-sectional area and a unit length of the material through which the current is passing. Resistivity is measured is measured in ohm-m or ohm-ft, and is the reciprocal of the conductivity of the material. Table 1 displays some typical resistivity. Earth resistivities can range over nine orders of magnitude, from 1-10^8 ohm-m.

Common Resistivities (ohm-m)

Material value	Resistivity range	Typical
Igneous &	10^2-10^8	10^4
Metamorphic rocks		10^3
Sedimentary rocks	10-10^8	10^3
Unconsolidated	10^{-1} – 10^4	10^3
Ground water	1-10^8	5
Pure water	10-10^8	10^3

The resistivity ranges of different earth materials overlap. Thus, resistivity measurements cannot be directly related to the type of soil or rock in the subsurface without direct sampling or some other geophysical; or Geotechnical information. Porosity is the major controlling factor for changing resistivity because electricity flows in the near surface by the passage of ions through pore space in the subsurface materials. The porosity (amount of pore space), the permeability (connectivity of pores), the water (or other fluid) content of the pores, and the presence of salts all become contributing factors to changing resistivity. Because most minerals are insulators and rock composition tends to increase resistivity, it is easier to measure conductive anomalies than resistive ones in the subsurface. However, air, with a theoretical infinite resistivity, will produce large resistive anomalies when filling subsurface voids. Electrical methods can be used to measure different quantities including current flow, electrical potential and electromagnetic fields. The electrical method to be discoursed will be direct current (DC) resistivity.

3.2.2 APPARENT RESISTIVITY

In an ideal situation of a perfect homogenous and isotropic conductive earth layer, the current flow lines seem like dipole pattern and the resistivity obtained with a four electrode array is the true resistivity of the layer. But in actual sense the earth is not uniform, heterogeneities in lithology and geological structures are always encountered which are controlling factors of the earth's resistivity values. This complexity is not considered when measuring resistivity with a four electrode method, based on the assumption that the ground sub-surface is uniform. The result obtained from such a measurement is called the apparent resistivity of an equivalent homogenous and isotropic earth layer and generally does not serve as representative of the true resistivity, therefore indicates changes in the subsurface condition. When interpreted, this can give quantitative information such as the thickness and true resistivity of the horizontally layered units.

CHAPTER FOUR

4.0 RESULT

The chapter presents result gotten from the field mapping exercise and geo-electric survey (VES)

4.1 FIELD MAPPING

The map covers an area of $40.25KM^2$ with a scale of 1:33000. The mapping exercise revealed four distinctive rock units. Also included in the map are VES points that show location were geo-electric surveys were conducted within the mapped area. The four (4) major rock types in the area are:

a) Gneiss

b) Migmatite

c) Fayalite Quartz Monzonite (Bauchite)

d) Migmatite-Gneiss

These rock units are conformity with rocks found in the area by Eborall (1978) fig 2.

4.1.1 GNEISS

Gneiss is a metamorphic rock form characterized by banding caused by segregation of different types of rock, typically light and dark silicates. Rather than an indication of specific mineral composition, the term is an indication of texture. The "gneissic texture" refers to the segregation of light and dark minerals. It is indicative of high-grade metamorphism where the temperature is high enough, say 600-700 °C, so that enough ion migration occurs to segregate the minerals. Within the banded structure are mostly elongated and granular structures rather than sheets or plates.

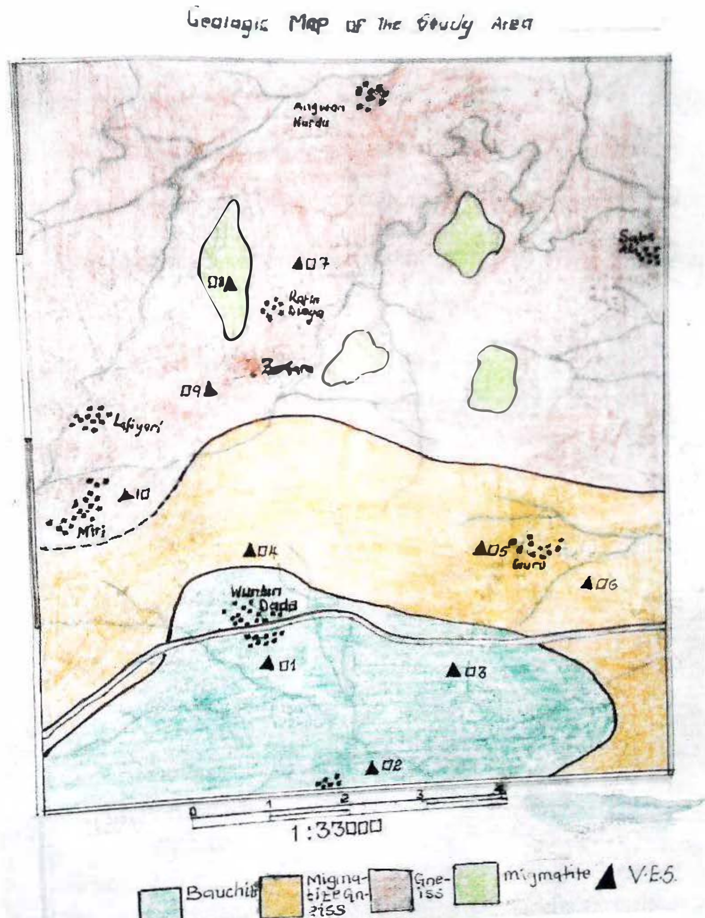

Figure 4: Map of the study Area

Some gneiss will split along the layers of materials, but most break in an irregular fashion.

Gneiss covers about 52% of the area mapped (fig 3), the gneisses of the area were seen to be mostly grey in colour with dark streaks and layers. Close observation showed that the gneisses in the area are Medium to coarse grained, Characterized by discontinuous altering of light and dark layers. Gneissose texture, banding on a large scale with layers and streaks of darker and lighter coloured minerals are the Structures visible. Granite and quartz veins are common.

In gneiss, Feldspar is abundant and together with quartz, forms the granular, lighter coloured layers. Muscovite, biotite and hornblende are commonly present, while any of the minerals characteristic of higher grades of regional metamorphism may occur

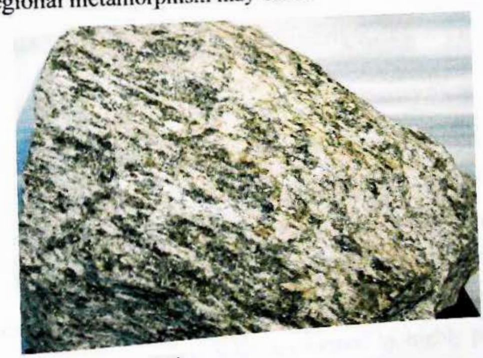

PLATE 2: GNIESS

At the highest grades of metamorphism rocks may approach melting temperature when they are able to recrystallize freely and so produce the textures characteristic of gneisses. Thus gneisses occur, in association with migmatites and granites.

4.1.2 MIGMATITE

A migmatite, or "mixed rock" in Greek, is a banded, heterogenous rock composed of intermingled metamorphic and igneous components. Migmatites generally occur in plate tectonic settings where regional belts of continental crust have been subjected to very high temperatures and pressures.

PLATE 3: Migmatite

Migmatite covers about 5 percent of the mapped area it occurs as patches within Gneiss dominated area. The migmatites were typically dark gray to nearly black in colour . Migmatite textures are the product of thermal softening of the metamorphic rocks. Schlieren textures are a particularly common example of granite formation in migmatites, and are often seen in restite xenoliths. Ptygmatic folds are formed by highly plastic ductile deformation of the gneissic banding, and thus have little to no relationship to a defined foliation unlike most regular folds. Dykes and joints are also common. Migmatites are macroscopically composite rocks, most of which consist of a dark colored amphibolite or biotite gneiss intimately mixed with a light colored rock of granitic or granodioritic composition. In most of these rocks, the light colored rock appears at one time in the rock's history to have been more mobile than the darker rock. Migmatites includes the minerals horneblende, plagioclase feldspar, and garnet

PLATE 4: Dyke in migmatite

4.1.3 FAYALITE QUARTZ MONZONITE (Bauchite)

Bauchite occupy the lower part of the study area, with large and extensive outcrops. They cover about 20 Percent of the area. Fresh specimen of Bauchites is typically dark green due to the green or brown colour of Olivine. Their texture ranges from medium to coarse grained, with a mineralogical composition of oligoclase, with eulite (or orthoferrosilite), ferrohastingsite, ferroaugite, and small amounts of quartz, fayalite, ilmenite and magnetite. Dykes are common especially quartz diorite dykes. Fractures and joints are very abundant. Some of the outcrops had outcrops had distinctive faults. Weathering has affected the surface of most of the outcrops.

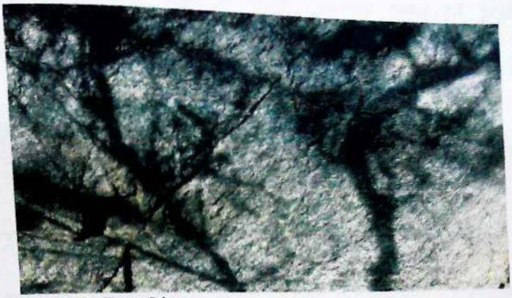

Plate 5: Bauchite

4.1.4 Migmatites –Gneiss.

These rocks form under extreme temperature condition during prograde metamorphism, where partial melting occurs in pre-existing rocks. Migmatites-Gneiss occupies the central part of the map covering from the edge of Lafiya village through to Guru and parts of GRA, covering about 23 Percent of the mapped area. These rocks showed typically dark gray to nearly black with dark streaks. There textures vary from medium to coarse grained.

PLATE 6: **Migmatite Gneiss**

In terms of mineralogy Migmatite Gneiss consist of a dark colored biotite gneiss intimately mixed with a light colored rock of granitic or granodioritic composition. Banding is very common and the rocks were weathered in to boulders in most of the places and fractured.

4.2.0 VERTICAL ELECTRIC SOUNDING FIELD DATA

Ten (10) vertical electric sounding (VES) points were measured in all (fig 3), Out of which three (3) were on bauchite, three (3) on Gneiss, one (1) on Migmatite and three (3) on Migmatite Gneiss.

The results are presented in Appendix 1, and the summary in table 1(below).

VES LOCATION	LAYER NUMBER	RESISTIVITY (Ω-M)	LAYER THICKNESS (M)	REMARKS
01	1 2 3	130.7 48.52 125.7	0.865 10.73 ∞	Top soil Decomposed basement rock Fresh basement
02	1 2 3 4	142.2 68.04 31.13 118.8	0.143 10.24 3.07 ∞	Top soil Decomposed basement rock Intensely weathered rock Fresh basement
03	1 2	58.72 52.66	1.43 7.52	Topsoil Decomposed

	3 4	117.0 149.7	6.32 ∞	basement rock Intensely weathered rock Fresh basement
04	1 2 3	111.5 36.12 121.5	1.90 10.25 ∞	Top soil Decomposed basement rock Fresh basement
05	1 2 3	69.87 29.47 70.51	1.29 20.02 ∞	Top soil Decomposed basement rock Fresh basement
06	1 2 3	157.1 85.13 194.8	1.01 7.03 ∞	Topsoil Decomposed basement rock Fresh basement
07	1 2 3	50.48 9.04 56.65	1.88 8.35 ∞	Top soil Decomposed basement rock Fresh basement
08	1 2 3 4	128.1 156.7 55.03 133.9	2.14 6.17 5.41 ∞	Top soil Decomposed basement rock Intensely weathered rock Fresh basement
09	1 2 3	138.9 21.55 385.6	0.770 4.99 ∞	Top soil Decomposed basement rock Fresh basement
10	1 2 3	104.5 38.06 67.53	1.88 17.40 ∞	Top soil Decomposed basement rock Fresh basement

TABLE 1: Table of VES readings

Various techniques are available for the interpretation of the acquired VES field data, but the most widely applied method is the curve matching method and the use of computer software programme. The acquired VES data were quantitatively interpreted using computer software OFFIX adopted for use on the infogold PC; OFFIX environment. The computer algorithm determine the model whose theoretical curve best fits the field data by a successive iterations dictated by the numerical programme in which estimate of input parameters is made for each geoelectric layer and the predicted curve of apparent resistivity against electrode spacing. The discrepancies between the observed and theoretical are then determined point by point. The computations repeated with new predicted curve compared with field data. The procedure is iterated further and further until the discrepancies become smaller than or equal to a predetermined value.

The interpreted field data were summarized in table 1 above . The results indicate various layers, their thickness in meters, resistivity in ohm-meter, and remarks on the interval lithology of each sounding points.

4.2.1 HYDROLOGICAL UNITS BASED ON RESISTIVITY

Based on the resistivity values of the subsurface geologic layers obtained from the interpreted VES curves, different profile separation can be established. The study area shows four geoelectrical units comprising the top soil, deeply decomposed crystalline rock, moderately weathered rock, fractured fresh basement rock and fresh impervious bedrock.

4.2.1.1 TOP SOIL

The top soil from the study area is made up of clay materials in some location and lateritic in some other areas. The resistivities of the top soil vary between 20 and 450 ohm-meter depending on the moisture content of the layer at a particular point. These have an average value of 188 ohm-meter. The static water as at the time of the data acquisition in November, 2008 ranges between 0.71m and 2.0m with an average of 1.01m. This layer in many location of unsaturated materials above the water table, hence relatively highly resistive, VES 05 for instance (table 1) is shallow. Hence, such layer relatively low resistivity.

4.2.1.2 DECOMPOSED CRYSTALLINE ROCKS

The layer is made up of deeply decomposed crystalline rock composed of appreciable amount of clay. Based on the low resistivity values, it is considered to be the highest ground water potential bearing zone. The resistivities of this layer vary between 9 and 120 ohm- meter with an average of 46.58 ohm-meter. It has a thickness range of between 1.5 meter to 25 meter with an average of 8.18meter, in a case where the resistivity values exceeded the stated range, VES 07 and 24 for instance, such layer may be considered as part of the fresh basement layer or the groundwater has high concentration of dissolved ions that are very conductive.

4.2.1.3 MODERATELY WEATHERED ROCK

The resistivity of the weathered mantle from 111.00 ohm-meter in VES 02 to about 200 ohm-mater with an average thickness of 41.46 meters. The layer serves as transitional zone between the deeply weathered regoliths and the fresh fracture basement rock layer. The relatively moderate resistivity values may be relevant to its attribute as aquiferous zone.

4.2.1.4 FRESH CRYSTALLINE BEDROCK

The bedrock has characteristic resistivity values that exceed 1,000 ohm-meter with an infinite thickness'. This is typical of fresh crystalline rock devoid of fissures/fracture zones.

CHAPTER FIVE

5.1 DISCUSSION OF RESULT

The abi ity for a basement rock to have a quantitative and qualitative aquifer depends on the level of fracturing and or weathering, while porosity and permeability play a greater role in sedimentary aquifer.

The result obtained from the resistivity survey indicated that the different rock types have different aquifer characteristics in terms of the thickness. This variation is also reflected in the top soil thickness.

The interpreted field data were summarized in table 1 above. The results indicate various layers, their thickness in meters, resistivity in ohm-meter, and remarks on the interval lithology of each sounding points. It was observed from the interpreted curves that the geo-electrical units obtained from the sounding points generally have shapes that are typical of basement complex areas, (i.e. H-type curves). These are characterized by a highly resistive overburden, low resistive intermediate layer and moderately to highly resistive deep laying crystalline rocks.

The basic three to four geoelectric layers normally encountered in basement terrain comprises the top soil, the intermediate conductive weathered zone and the highly resistive bedrock. In some areas, it may be possible to encounter a sufficiently thick transitional zone between the deeply weathered regolith at the top and fresh bedrock below.

Dan-Hassan (1991) pointed that, the intermediate layer in the H-type curve is commonly water saturated and is often characterized by low resistivity, high porosity and permeability. A semi confined aquifer condition may be created if the clay overlaying the aquifer may be very thick.

On the other hand, the main aquifer zone is often found at the bottom of the weathered profile where mineral decomposition is as a result of insitu chemical weathering producing gravel-like material of moderate to high permeability (Jones, 1985).

5.1.1 Gneiss

Resistivity interpretations of readings carried out on the Gneiss covered part of the map showed that all three (3) VES points (07, 09, and 10) have three layers. VES point 09 has greater aquifer potentials, with a weathered basement thickness of 10.25m (table 1, appendix 1, table 2 and figure--)

VES POINTS	TOP SOIL (m)	WEATHERED/ FRACTURED BASEMENT (m)	FRESH BASEMENT (m)
07	1.88	8.35	-
09	1.90	10.25	-
10	1.01	7.03	-

Table 2: RESISTIVITY INTERPRETATION IN GNEISS

5.1.2 Bauchite

Resistivity interpretations of three (3) VES points (01, 02, and 03) carried out on the bauchite produced two VES points (02 and 03) with four layers and one point (01) with three (3) layers. VES point 02 has the greater aquifer potential due to its thicknesses and the presence of both fractured and weathered basement (table 1, appendix 1, table 3)

VES POINTS	TOP SOIL	WEATHERED/ FRACTURED BASEMENT	FRESH BASEMENT
01	0.865	10.73	-
02	0.143	10.24 3.07	-
03	1.43	7.52 6.32	-

TABLE 3: RESISTIVITY INTERPRETATION IN BAUCHITE

5.1.3 MIGMATITE-GNEISS

Resistivity interpretations of three (3) VES points (04, 05, and 06) carried out on Migmatites-Gneiss produced three (3) layers for all the points (04, 05, and 06). VES point 05 has the highest thickness of second layer (20.06m.) and is considered to have greater aquifer potential. (Table 1, appendix 1, table 4)

VES POINTS	TOP SOIL	WEATHERED/ FRACTURED BASEMENT	FRESH BASEMENT
04	0.89	14.77	-
05	1.29	20.02	-
06	1.88	17.40	-

TABLE 4: RESISTIVITY INTERPRETAION IN MIGMATITE-GNEISS

5.1.4 MIGMATITE

One VES point (08) was measured in migmatite covered area because of the limited percentage coverage of the rock. The result shows the four layers, with varying thickness (Table 1, appendix 1, table 5).

VES POINTS	TOP SOIL	WEATHERED/ FRACTURED BASEMENT	FRESH BASEMENT
08	2.14	6.17 5.41	-

TABLE 5: RESISTIVITY IN MIGMATITE

The overall result of the resistivity shows that the Migamtite-Gneiss area has the higher aquifer potentials; this can be seen in the high thickness values of the weathered/fractured basement layers. The thickness of bauchite layers is significant enough to produce good aquifers.

The result of the geo-electric survey indicated that the resistivity values obtained (table 1, table2-5, appendix1) are in conformity with those obtained in areas around Bauchi (dike et al 1994).

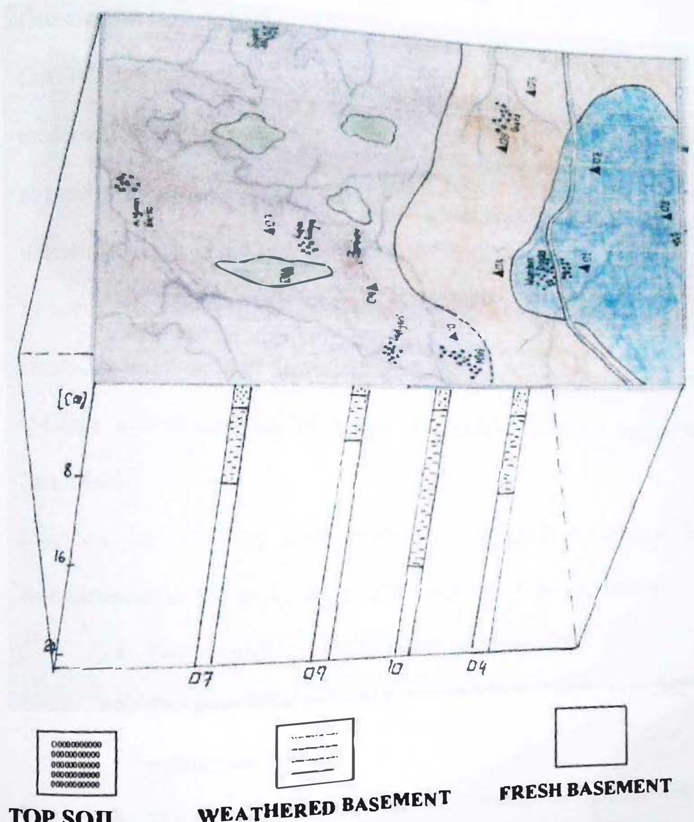

FIGURE 5: MODEL SHOWING SURFACE AND SUB-SURFACE RELATIONSHIP

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.0 CONCLUSION

Geo-electric survey in the study area distinguished three to four layers. Out of these recognizable hydrogeological units, only the low to moderate resistivity layers are found to have appreciable thickness (7 to 60) and a significant extent of weathering that qualifies it to be the most potential aquifer of the area.

In comparison with other ground water survey technique, the electrical resistivity method has proved to be extremely cost effective in the location and delineation of zones of weathering in the crystalline basement.

Base on the following some of the VES points were selected are recommended as the most viable points for ground water exploration.

1. Low resistivity of intermediate weathered layer.
2. The layer thickness and the depth of burial of the expected aquiferious layer.
3. Thick overburden with reasonable weathered regoliths and the presence of fractures with the underlying fresh bedrock.
4. Comparison with the preexisting information from borehole located in areas with similar geology as the study area, surrounding Bauchi town.

5. Less than ten percent (<10%) fitting error for the interpreted field data.

Out of the ten VES soundings, the following points were recommended; VES 01,04,05,06 and 10

6.2 RECOMMENDATION

It is recommended that detailed geophysical survey using electrical resistivity method should bee preceded by electromagnetic method, especially in more complex basement terrain. A combination of resistivity sounding and electromagnetic method will help in more accurate location of deep and narrow zones which are especially important for ground water development in the basement complex areas.

It is recommended that further water search efforts should concentrate outside the Miri residential area which is more viable for underground water development because of thick occurrence of the weathered Basement and relatively higher water saturation. This will go a long way in alleviating the untold hardship of water scarcity face by the Miri and Wuntin-Dada Community. It is also recommended that government agencies and other non-governmental organizations concerned should embark on more aggressive hydrogeological survey exercise so as to

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APPENDIX

DATA SET: VES 01

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: WUNTI DADA,BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: 10-01-2009
SOUNDING: 1
AZIMUTH: N-S
EQUIPMENT: SAS 300C

Schlumberger Configuration

FITTING ERROR: 8.088 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	130.7	0.865	0.0	0.00662	113.1
2	48.52	10.73	-0.865	0.221	520.9
3	125.9		-11.60		

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	105.0	100.4	4.35
2	2.50	73.00	73.95	-1.30
3	4.00	56.00	57.73	-3.09
4	6.00	52.00	52.59	-1.14
5	8.00	47.00	51.97	-10.57
6	10.00	45.00	52.72	-17.16
7	15.00	53.00	57.16	-7.85
8	20.00	60.00	63.12	-5.20
9	25.00	70.00	69.24	1.08
10	32.00	86.00	77.02	10.43
11	40.00	97.00	84.42	12.95
12	60.00	99.00	97.29	1.72
13	80.00	104.0	105.1	-1.11

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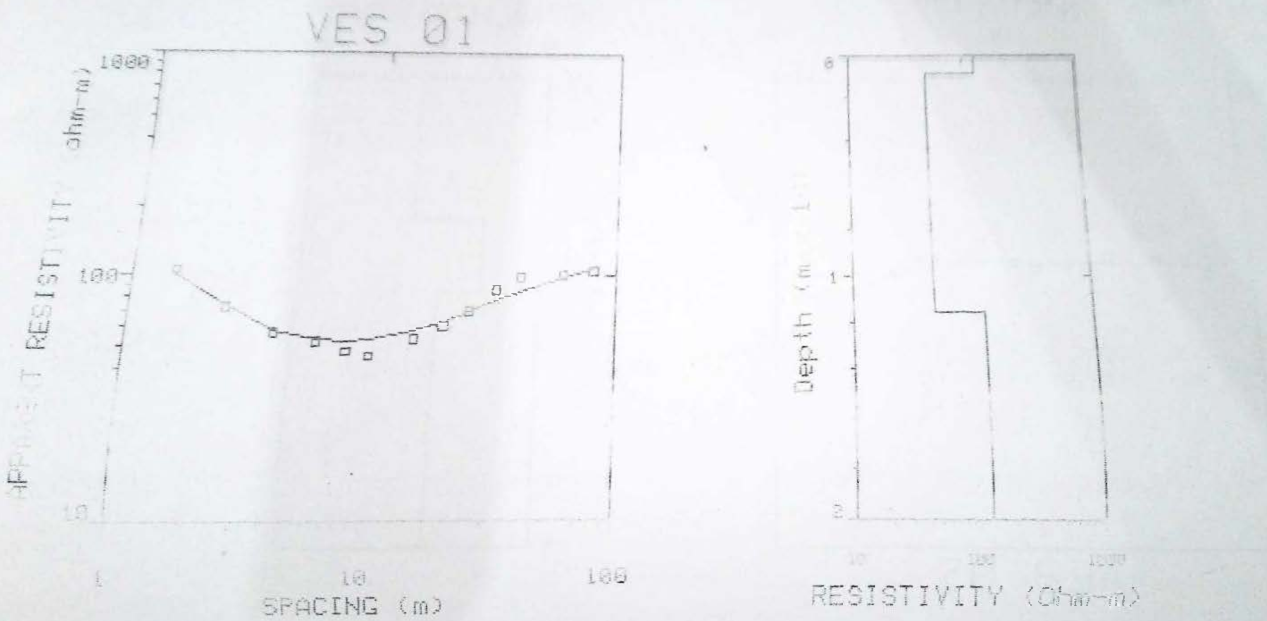
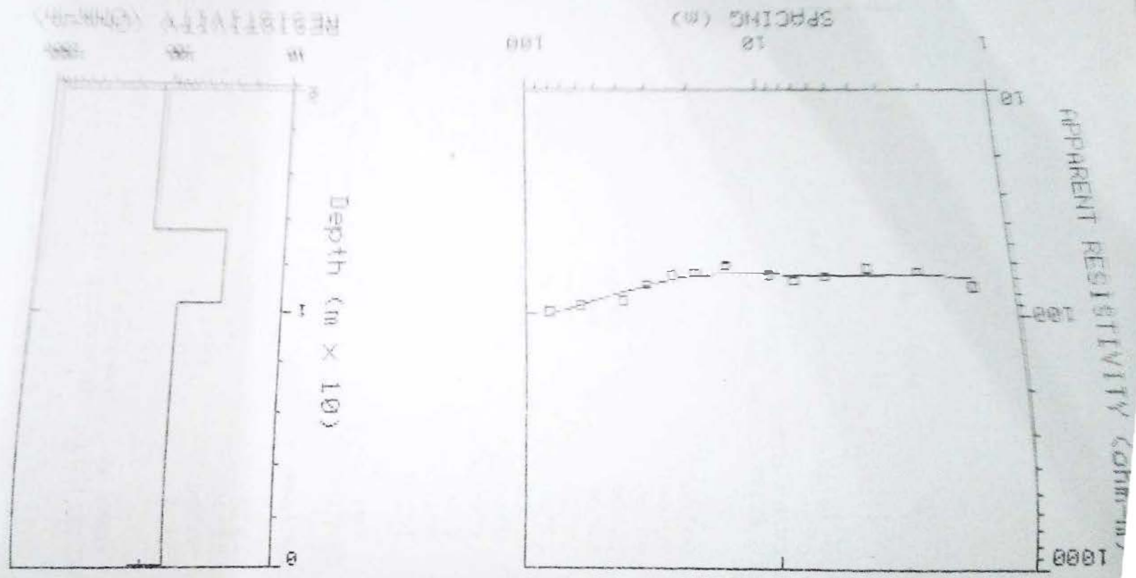
P 2 -0.02 0.97
P 3 0.00,-0.01 0.50



VES 01
1000
100
10
1
10
100
SPACING (m)
APPARENT RESISTIVITY (ohm-m)
0
1
2
Depth (m)
10
100
1000
RESISTIVITY (Ohm-m)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SPACING (m)
Depth (m x 10)
RESISTIVITY (Ohm-m)

VES 02

DATA SET: VES 02

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LOCATION: WUNTI DADA,BAUCHI L.G.A SOUNDING: 2
COUNTY: BAUCHI STATE AZIMUTH: N-S
PROJECT: GROUNDWATER EXPLORATION EQUIPMENT: SAS 300C
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Schlumberger Configuration

FITTING ERROR: 5.276 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	124.2	0.143	-0.143	0.00116	17.85
2	68.04	10.24	-10.39	0.150	697.4
3	31.13	3.07	-13.46	0.0987	95.74
4	118.8				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	76.00	69.43	8.63
2	2.50	66.00	68.49	-3.78
3	4.00	64.00	68.12	-6.44
4	6.00	69.00	67.83	1.68
5	8.00	72.00	67.53	6.19
6	10.00	68.00	67.25	1.10
7	15.00	62.00	67.06	-8.17
8	20.00	66.00	68.21	-3.35
9	25.00	68.00	70.64	-3.88
10	32.00	75.00	75.20	-0.267
11	40.00	88.00	80.67	8.32
12	60.00	91.00	91.73	-0.811
13	80.00	98.00	98.95	-0.977

PARAMETER RESOLUTION MATRIX:
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P 2 0.00 0.97

UNDR - Rusafaya Project

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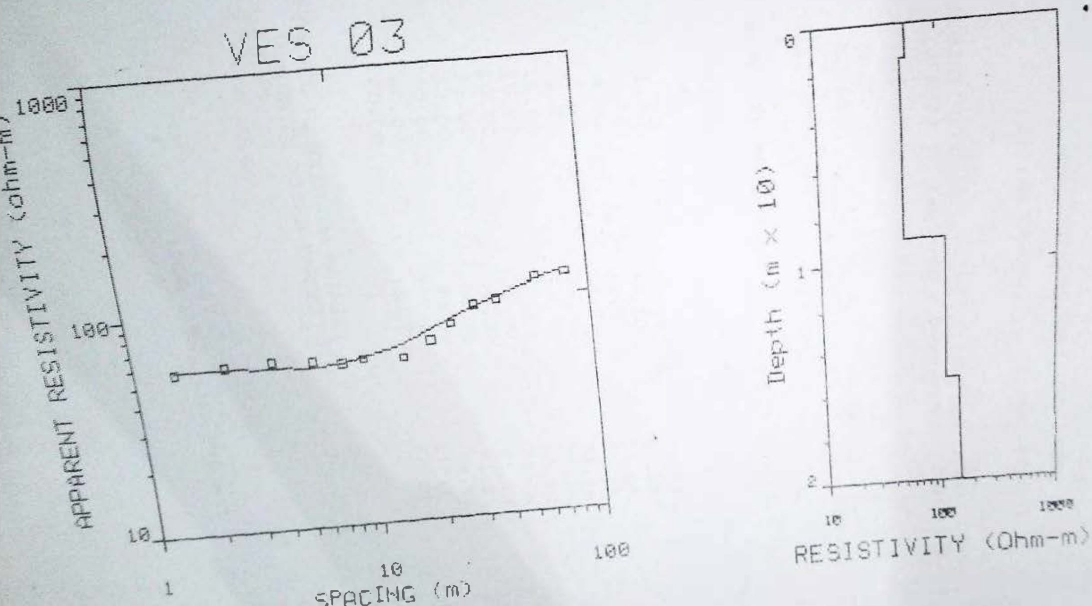
*

VES 03



APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
10
100
SPACING (m)
0
1
2
Depth (m x 10)
10
100
1000
RESISTIVITY (Ohm-m)

DATA SET: VES 03

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: WUNTI DADA, BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: 10-01-2009
SOUNDING: 3
AZIMUTH: N-S
EQUIPMENT: SAS 3000

Schlumberger Configuration

FITTING ERROR: 6.246 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	58.72	1.43	-1.43	0.0243	83.99
2	52.66	7.52	-8.95	0.142	396.3
3	117.0	6.32	-15.27	0.0540	739.8
4	149.7				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	56.00	58.10	-3.76
2	2.50	59.00	57.05	3.29
3	4.00	60.00	55.84	6.91
4	6.00	59.00	55.66	5.65
5	8.00	56.00	56.76	-1.36
6	10.00	58.00	58.76	-1.31
7	15.00	57.00	65.94	-15.68
8	20.00	67.00	74.06	-10.54
9	25.00	78.00	81.77	-4.83
10	32.00	94.00	91.15	3.02
11	40.00	98.00	99.91	-1.95
12	60.00	119.0	115.1	3.25
13	80.00	122.0	124.4	-2.04

PARAMETER RESOLUTION MATRIX:
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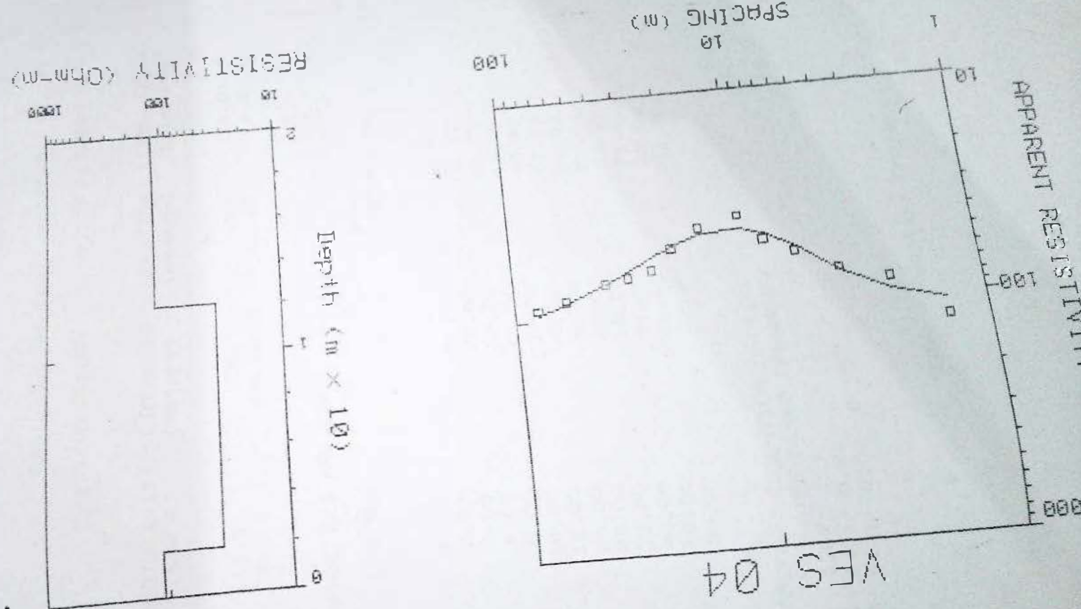
P 2 0.06 0.86

*

UNDR - Rusafaya Project

*



VES 04
APPARENT RESISTIVITY
SPACING (m)
1
10
100
1000
Depth (m x 10)
RESISTIVITY (Ohm-m)
0
1
2

DATA SET: VES 04

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI	DATE: 10-01-2009
LOCATION: WUNTI DADA,BAUCHI L.G.A	SOUNDING: 4
COUNTY: BAUCHI STATE	AZIMUTH: N-S
PROJECT: GROUNDWATER EXPLORATION	EQUIPMENT: SAS 300C

ELEVATION: 0.00

SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Schlumberger Configuration

FITTING ERROR: 9.227 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	111.5	1.90	-1.90	0.0170	212.0
2	36.12	10.25	-12.15	0.283	370.4
3	121.5				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	125.0	106.3	14.94
2	2.50	82.00	94.42	-15.15
3	4.00	72.00	73.79	-2.48
4	6.00	59.00	55.45	6.00
5	8.00	51.00	47.25	7.34
6	10.00	39.00	44.40	-13.84
7	15.00	43.00	45.75	-6.41
8	20.00	52.00	50.76	2.38
9	25.00	64.00	56.44	11.79
10	32.00	68.00	63.99	5.89
11	40.00	71.00	71.41	-0.585
12	60.00	82.00	85.00	-3.66
13	80.00	89.00	93.87	-5.47

PARAMETER RESOLUTION MATRIX:
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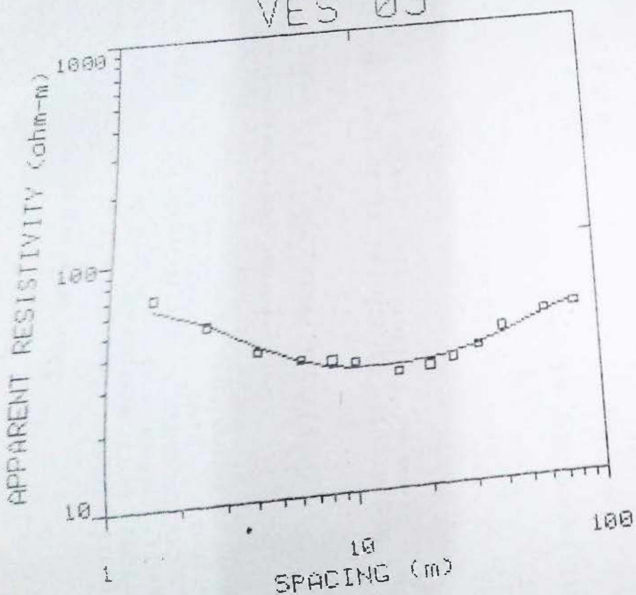
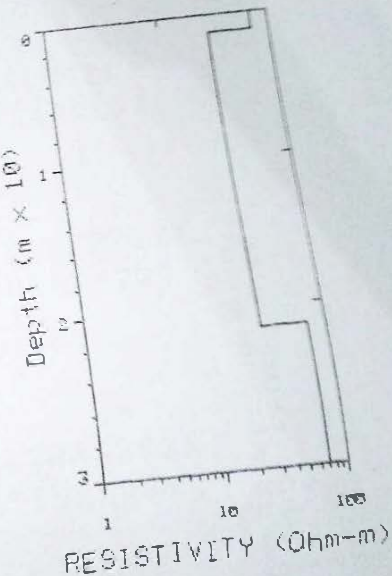
P 3 0.01 0.02 0.55

UNDR - Rumfaya Project

VES 05



APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
10
100
SPACING (m)



Depth (m x 10)
0
1
2
3
1
10
100
RESISTIVITY (Ohm-m)

DATA SET: VES 05

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: WUNTI DADA, BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: 19-01-2009
SOUNDING: 5
AZIMUTH: N-S
EQUIPMENT: SAS 300C

Schlumberger Configuration

FITTING ERROR: 5.416 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	69.87	1.29	-1.29	0.0185	90.74
2	29.47	20.02	-21.32	0.679	590.4
3	70.51				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	70.00	63.27	9.60
2	2.50	52.00	52.77	-1.48
3	4.00	39.60	41.08	-5.34
4	6.00	35.00	34.39	1.73
5	8.00	34.00	32.08	5.62
6	10.00	33.00	31.25	5.29
7	15.00	29.00	31.08	-7.17
8	20.00	30.00	31.92	-6.42
9	25.00	32.00	33.28	-4.00
10	32.00	35.00	35.64	-1.84
11	40.00	41.90	38.59	5.87
12	60.00	47.00	45.37	3.46
13	80.00	49.00	50.54	-3.15

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	1.00		
P 2	0.00	1.00	
P 3	0.00	0.00	1.00

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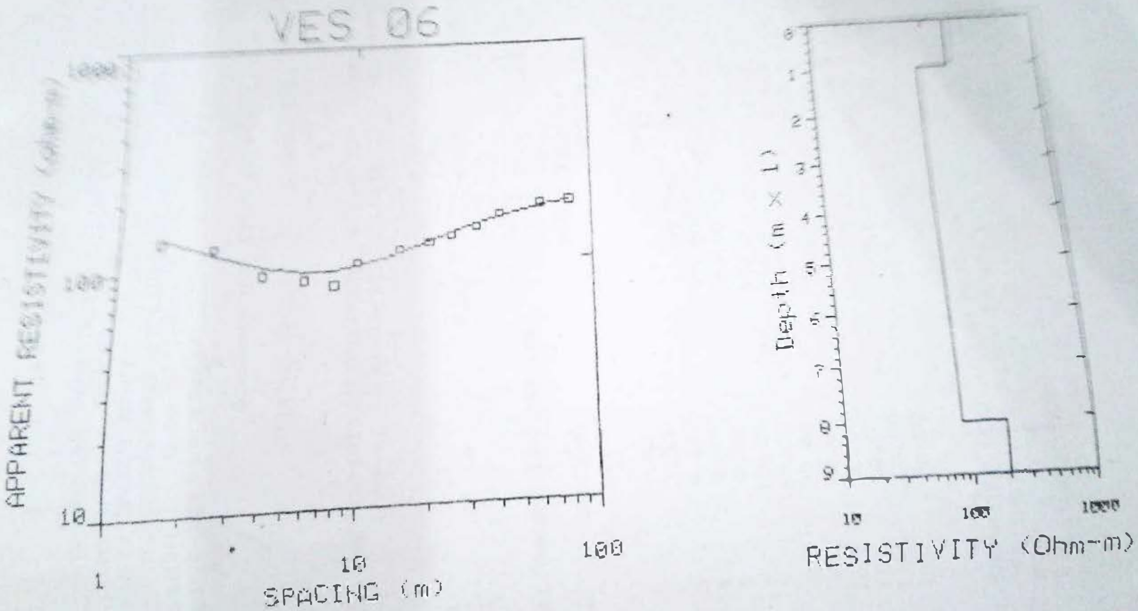

VES 06
APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
10
100
SPACING (m)
Depth (m x 1)
RESISTIVITY (Ohm-m)

DATA SET: VES 06

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: ZANFARA,BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: 10-01-2009
SOUNDING: 1
AZIMUTH: N-S
EQUIPMENT: SAS 300C

Schlumberger Configuration

FITTING ERROR: 6.095 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	157.1	1.01	-1.01	0.00645	159.4
2	85.13	7.03	-8.05	0.0826	598.9
3	194.8				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	134.0	138.8	-3.62
2	2.50	124.0	117.6	5.09
3	4.00	93.00	100.7	-8.30
4	6.00	88.00	94.64	-7.55
5	8.00	82.00	95.42	-16.36
6	10.00	103.0	98.89	4.02
7	15.00	114.0	111.3	2.32
8	20.00	122.0	124.0	-1.65
9	25.00	130.0	134.7	-3.67
10	32.00	141.0	146.5	-3.94
11	40.00	160.0	156.4	2.21
12	60.00	177.0	171.3	3.18
13	80.00	180.0	179.2	0.443

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.99		
P 2	0.00	0.99	
P 3	0.00	0.00	0.99

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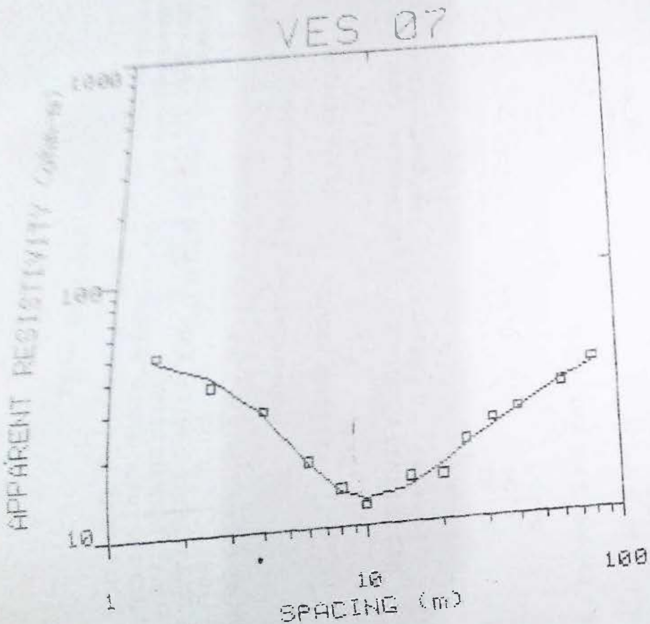
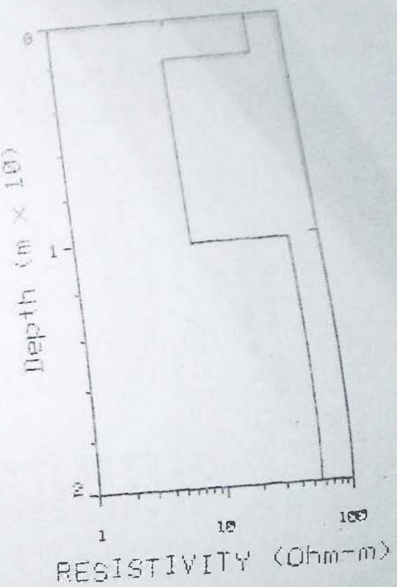

VES 07
APPARENT RESISTIVITY (Ohm-m)
1000
100
10
1
10
100
SPACING (m)


Depth (m x 10)
0
1
2
1
10
100
RESISTIVITY (Ohm-m)

DATA SET: VES 07

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: RIMIN DINYA, BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00

DATE: 11-01-2009
SOUNDING: 1
AZIMUTH: N-S
EQUIPMENT: SAS 300C

SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Schlumberger Configuration

FITTING ERROR: 5.576 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	50.48	1.88	-1.88	0.0373	95.10
2	9.04	8.35	-10.24	0.924	75.56
3	56.65				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	50.00	47.26	5.46
2	2.50	37.00	40.02	-8.17
3	4.00	29.00	27.83	4.02
4	6.00	18.00	17.67	1.82
5	8.00	14.00	13.64	2.53
6	10.00	12.00	12.56	-4.69
7	15.00	15.00	13.85	7.74
8	20.00	15.00	16.40	-9.36
9	25.00	20.00	19.04	4.77
10	32.00	24.00	22.43	6.50
11	40.00	26.00	25.81	0.709
12	60.00	32.00	32.38	-1.18
13	80.00	39.00	37.08	4.70

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1 1.00
P 2 0.00 1.00
P 3 0.00 0.00 1.00

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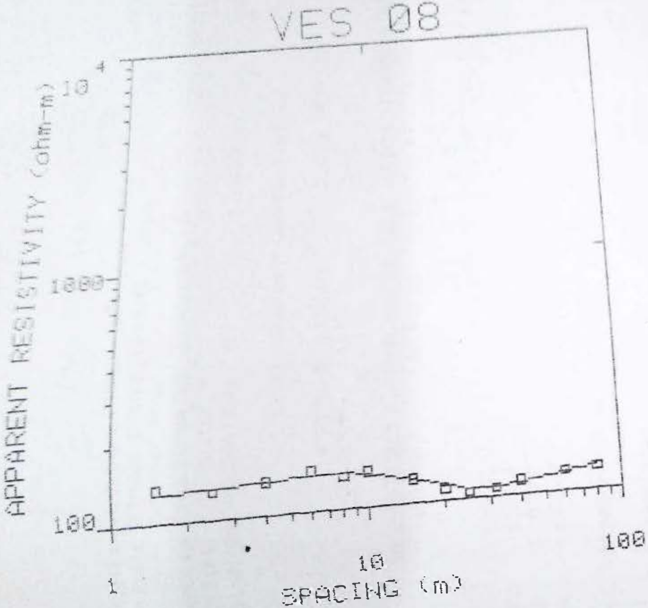
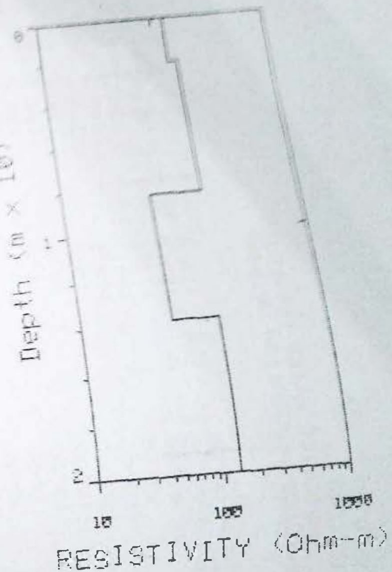

VES 08
APPARENT RESISTIVITY (ohm-m)
10^4
1000
100
1
10
100
SPACING (m)


Depth (m × 10)
0
1
2
10
100
1000
RESISTIVITY (Ohm-m)

DATA SET: VES 08

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: KIMIN DINYA,BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: 11-01-2009
SOUNDING: 2
AZIMUTH: N-S
EQUIPMENT: SAS 300C

Schlumberger Configuration

FITTING ERROR: 2.921 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	128.1	2.14	-2.14	0.0167	274.5
2	156.7	6.17	-8.31	0.0393	968.2
3	55.03	5.41	-13.73	0.0983	297.8
4	133.9				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	134.0	129.0	3.71
2	2.50	127.0	131.1	-3.24
3	4.00	135.0	135.0	-0.0550
4	6.00	144.0	138.2	3.97
5	8.00	133.0	138.0	-3.79
6	10.00	137.0	135.2	1.24
7	15.00	124.0	124.2	-0.230
8	20.00	110.0	114.9	-4.50
9	25.00	105.0	109.9	-4.70
10	32.00	108.0	108.3	-0.363
11	40.00	113.0	110.3	2.37
12	60.00	120.0	117.4	2.11
13	80.00	122.0	122.4	-0.373

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1 1.00
P 2 0.00 0.99

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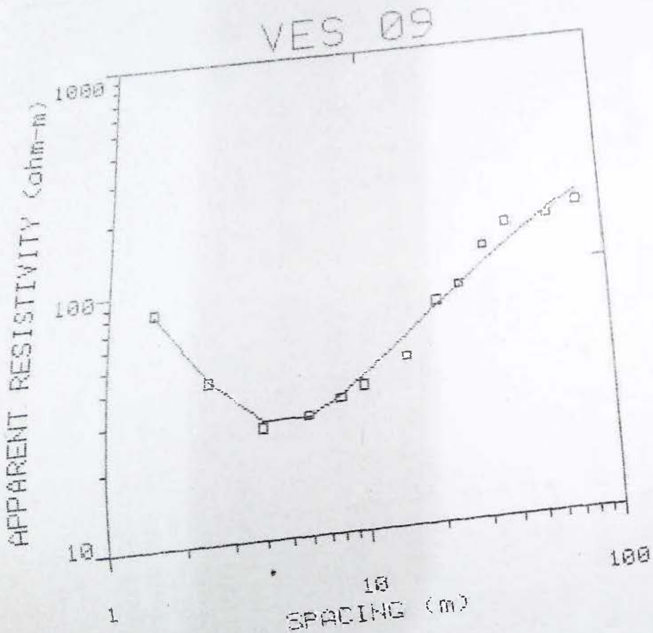
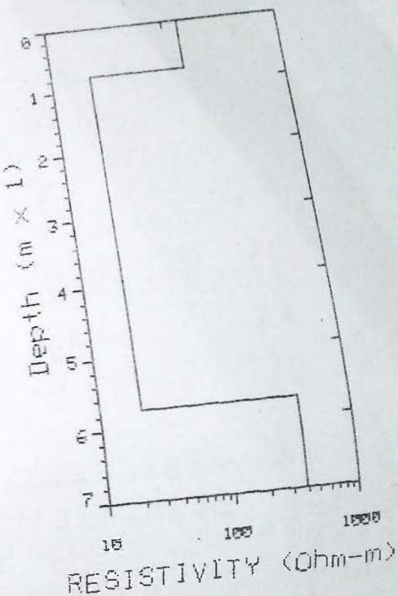

VES 09
APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
10
100
SPACING (m)


Depth (m X 1)
0
1
2
3
4
5
6
7
10
100
1000
RESISTIVITY (Ohm-m)

DATA SET: VES 09

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI
LOCATION: MIRI, BAUCHI L.G.A
COUNTY: BAUCHI STATE
PROJECT: GROUNDWATER EXPLORATION
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: 11-01-2009
SOUNDING: 1
AZIMUTH: N-S
EQUIPMENT: SAS 300C

Schlumberger Configuration

FITTING ERROR: 10.933 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	138.9	0.770	0.0	0.00554	107.0
2	21.55	4.99	-0.770	0.231	107.5
3	385.6		-5.76		

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	82.00	80.77	1.49
2	2.50	42.00	43.24	-2.95
3	4.00	27.00	28.48	-5.49
4	6.00	29.00	28.82	0.594
5	8.00	33.00	33.45	-1.38
6	10.00	36.00	39.34	-9.28
7	15.00	45.00	55.23	-22.66
8	20.00	74.00	70.44	4.79
9	25.00	85.00	84.64	0.412
10	32.00	122.0	102.8	15.66
11	40.00	149.0	121.6	18.33
12	60.00	153.0	161.0	-5.25
13	80.00	173.0	192.1	-11.07

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1 0.96
P 2 -0.05 0.88
P 3 -0.01 -0.02 0.97

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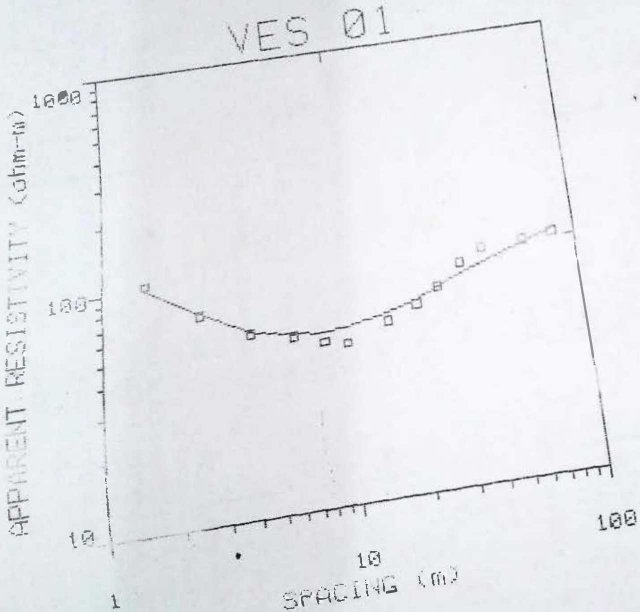
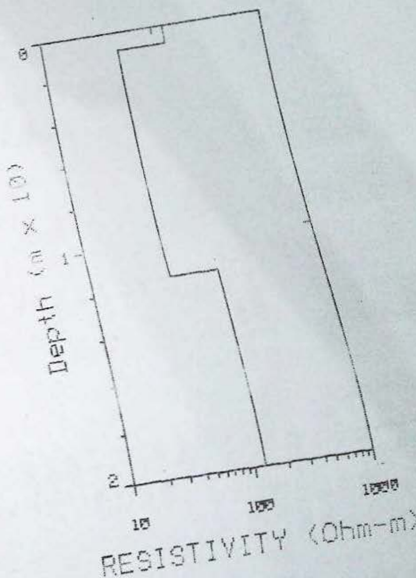

VES 01
APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
10
100
SPACING (m)


0
1
2
Depth (m x 10)
10
100
1000
RESISTIVITY (Ohm-m)

DATA SET: VES 10

CLIENT: GEOLOGY PROG. A.T.B.U BAUCHI DATE: 11-01-2009
LOCATION: MIRI,BAUCHI L.G.A SOUNDING: 2
COUNTY: BAUCHI STATE AZIMUTH: N-S
PROJECT: GROUNDWATER EXPLORATION EQUIPMENT: ABG 300C
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Schlumberger Configuration

FI TING ERROR: 3.499 PERCENT

L #	RESISTIVIT (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	104.5	1.88	-1.88	0.0180	197.1
2	38.06	17.40	-19.29	0.457	662.5
3	67.53				

ALL PARAMETERS A E FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	108.0	99.92	7.47
2	2.50	82.00	89.49	-9.14
3	4.00	69.00	71.39	-3.46
4	6.00	58.00	55.01	5.14
5	8.00	47.00	47.09	-0.209
6	10.00	42.00	43.52	-3.63
7	15.00	41.00	41.13	-0.339
8	20.00	39.00	41.49	-6.40
9	25.00	40.00	42.69	-6.74
10	32.00	41.00	44.90	-9.53
11	40.00	47.00	47.56	-1.19
12	60.00	52.00	53.11	-2.15
13	80.00	59.00	56.89	3.57

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.97		
P 2	-0.01	0.95	
P 3	0.00	-0.01	0.94

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