Continental J. Earth Sciences 5 (1): 56 - 63, 2010 ISSN: 2141 - 4076
 http://www.wiloludjournal.com

GROUNDWATER EXPLORATION IN A BASEMENT COMPLEX TERRAIN USING ELECTRICAL RESISTIVITY SOUNDING (VES): A CASE STUDY OF RIMIN GADO TOWN AND ENVIRONS, KANO STATE NORTH CENTRAL NIGERIA.

[1]E.Y. Mbiimbe, [2] N.K. Samaila and [2]D. K. Akanni
[1]Department of Geology, Gombe State University, PMB 127 Gombe, Nigeria, [2]Geology Programme Abubakar Tafewa Balewa University, Bauchi, Nigeria.

ABSTRACT
Groundwater occurrence and distribution in Basement Complex is localized and confined to weathered /fractured zones. Hence exploration for groundwater in such terrains posses a great challenge to groundwater development agencies as in most cases the risk of failure of such projects is very high. This study was carried out with the aim of demonstrating the application of vertical electrical sounding method of investigation in the exploration for groundwater in Rimin Gado town and environs. A total of 16 VES points were probed located in 4 settlements spread at a distance of 200-300m apart. ABEM SAS 300C terameter was used to generate field data applying the Schlumberger Array with an AB/2 of 1.5-100m. The field data were simulated using Zhody and OFFIX software. The results show that there are 2-4 Geo-electric layers: topsoil (sandy/lateritic), highly weathered Basement (clay and sandy clay), slightly weathered/ fractured Basement (Clay,sand/clayey sand) and Fresh bed rock. Three basic resistivity zones were identified: low resistivity zone (49-95 ohm-m) corresponding to highly weathered Basement material, the high resistivity zone (294-1543 ohm-m) representing fresh bed rock and intermediate resistivity zone (114-219 ohm-m) corresponding to slightly weathered/ fractured Basement. ButuButu and Dan Isa with a weathered Basement thickness of 25-34m and resistivity of 66-140 ohm-m therefore have high potentials for good Borehole yields. It is suggested that groundwater exploration in Basement Complex terrain should include geophysical investigation especially VES along with geological methods as an integral part of the program.

KEYWORDS: Groundwater Exploration, VES, Rimin Gado, Kano State, Nigeria.

INTRODUCTION

Groundwater is one essential but necessary substitute to surface water in every society. It's no doubt a hidden, replenish able resource whose occurrence and distribution greatly varies according to the local as well as regional geology, hydrogeologic setting and to an extent the nature of human activities on the land. Groundwater occurrence in a Precambrian Basement terrain is hosted within zones of weathering and fracturing which often are not continuous in vertical and lateral extent (Jeff, 2006). There is a steady rise in the demand for groundwater in most hard rock areas most of which can not boast of any constant surface source of water supply (Adanu, 1994). The failure rate in most groundwater project recorded in Basement Complex aquifers has informed the general acceptance of a geophysical survey as a compulsory prerequisite to any successful water well drilling project (Dan Hassan, 1999). The electrical resistivity method involving the vertical electrical sounding (VES) technique is extensively gaining application in environmental, groundwater and engineering geophysical investigations (Zohdy *et al* 1980, Aina *et al* 1996, Olorufemi *et al* 1993 and 2004 and Afolabi and Olorufemi 2004). This paper is a report of the findings of an investigation carried out to establish the role and significance of vertical electrical resistivity method in groundwater exploration in Rimin Gado town and environs. The main objectives of the investigation were:

To establish that groundwater development in Basement complex is facilitated by proper geophysical investigation prior to drilling.

To show the role of Vertical Electrical Sounding in groundwater exploration in hard rock areas.

To define the nature and distribution of groundwater in typical Basement Complex aquifers.

Study Area

Rimin Gado town is located within latitudes N 11^{0}56’ and N 12^{0}00’ and longitudes E 08^{0}12’ and E 08^0 18’. The town is situated along the Kano- Sokoto high way and is the head quarter of the Rimin Gado local Government area of Kano state. It has a growing population of about 76,855 inhabitants (1999 Estimate) mostly involved in agricultural activities as a means of livelihood. The area is part of the tropical climate zone of North central Nigeria with a mean annual rainfall of about 635mm (Wardrop Engineering, 1990). There are two seasons the raining season which begins in May and ends in October and the dry season which runs from November to April. The Sudan savannah vegetation characterized by sparse shrubs generally less than 6m high defines the vegetation pattern of the area. The area is gently low lying with Dutsen Dan Isa as the only prominent outcrop. River Gata which runs in the NW-SE direction constitutes the main drainage system with other seasonal streams as its tributaries giving a dendritic pattern of drainage.

Geology

The geology of the area is part of the Precambrian Basement Complex of North Central Nigeria. The mineralogy of the rocks are described in the works of Falconer 1911, Raeburn and Jones ,1934, , Barber and Jones 1960, McCurry 1973, Schroeter, 1974,Van Breemen *etal* 1977,Wright *et al* 1985,Macdonald and Partners, 1986 and Kogbe 1989. The major rock types in the area include older granites, gneiss, migmatites and metasediments mainly to the North and North West of the study area. These metasediments are mostly undifferentiated schist and quartzite. In some parts the older granites have been intruded by felsic dykes and are also associated with anatectic migmatites and a host of syn-tectonic and post tectonic granites with a common genetic origin. The unweathered bedrock is characterized by rapid grain size variations from micro to pegmatitic regions but normal sizes are dominant (Uma and Kehinde, 1994). The Basement is generally fractured with North-South and Northeast- Southwest lineaments very prominent and easily picked from aerial photographs. The summary of the geology of the study area and location of probe points is presented in figure 1.

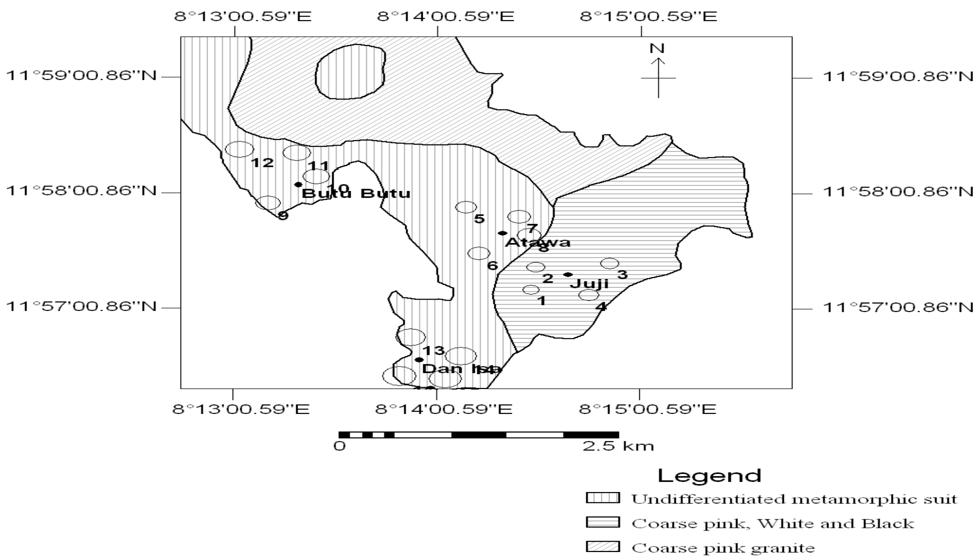


FIG 1. GEOLOGIC MAP/LOCATION OF VES POINTS OF THE STUDY AREA

Groundwater occurrence

The hydrogeologic setting of the study area is typical of any Basement Complex terrain and groundwater in such terrains is usually found in three situations (Bannerman and Ayibotele1984):

Fractured poorly decomposed or fresh rock overlain by a relatively deep zone of well decomposed rock.

The fractured rock

Fractured veins (quartz and Aplite) occurring in an otherwise non water bearing weathered mantle.

Groundwater is known to be more promising within granular alterite and the transition zone immediately overlying the fresh bedrock (Chilton and Smith-Carrington 1984).In the study area groundwater was identified to occur within the weathered mantle developed on the crystalline rocks mainly pinkish granite and granite gneiss and within fractured pegmatite and quartz veins in the moderate – highly decomposed granite –gneiss. The zone of weathering is extremely irregular as confirmed by the variations in the depth to bedrock which varies from 6.78m at ButuButu to 85.66m at Atawa. The granitic suite mainly the older granites have experienced prolonged weathering and tectonism which has given rise to thick weathered mantle of 30-40m and a sequence of fractures whose borehole yields have been consistently good (50lpm).

Data source and method of study

Introduction

This research was carried out with the primary goal of generating data from field measurement which is required to identify potentials of groundwater occurrence in the study area. Using ABEM SAS 300 terameter a total of 16 points were investigated spreading across four different settlements. The probe points were selected at a lateral distance of 200-300 m apart and the depth of investigation falls between 1.5- 100m (electrode separation). The settlements used for the study are Juji,Atawa,ButuButu and Dan Isa.

Basic principle of the Method

Groundwater through the various dissolved salts it contains is ionically conductive and enables electric current to flow into the ground. Consequently measuring the ground resistivity gives the possibility of identifying locations with high potentials of water bearing based on the following properties:

A hard rock without pores or fractures and a dry sand without water or clay are very resistive (several tens of thousands ohm-m)

A porous or fractured rock bearing fresh water has a resistivity which depends on the resistivity of the water and the porosity (several tens to several thousands ohm-m)

An impermeable clay layer which has bound water has low resistivity (several units to several tens ohm-m)

Mineral ore bodies (iron, sulphide etc) have very low resistivity due to their electronic conduction usually lower or much lower than 10 ohm-m

The value of any geophysical method of survey is measured by the amount of geological information that can be deduced from the interpretation of the data obtained (Ariyo and Adeyemi 2009)

Method of study

In the study, the electrical resistivity method with schlumberger array using ABEM SAS 300 C terameter was employed for the acquisition of VES data in the field. A total of sixteen (16) VES points at a lateral distance of 200-300m apart were investigated four from each of the four settlements that make up the study area. The depth range of investigation falls within 1.5-100m. The acquired field data was first plotted on a log log paper to produce a field curve which was subsequently correlated with a standard curve using the curve matching method. The data generated was interpreted using Zhody and OFFIX computer soft wares to give information on the geo-electric layers, the thickness of the layers, the resistivity of the layers and depth to bed rock.

RESULTS AND DISCUSSIONS

The results of the 16 VES points are presented in table 1. The simulated results of the 16 VES points reveal the presence of 2-4 geoelectric layers. These layers are grouped as: topsoil (clayey, sandy or lateritic), weathered Basement (clays/sandy clays), slightly weathered/ fractured Basement (clayey sand) and fresh bedrock. The resistivity of the topsoil varies from 49-885 ohm-m while the thickness varies from 0.9- 4.9 m. the resistivity and the thickness of the weathered Basement range between 55 and 1543 ohm-m and 1.2- 34.2m respectively. The resistivivity of the fresh bed rock is in the range of 294 ohm-m and above. The results further differentiate three basic resistivity zones: very low resistivity zone (49-95 ohm-m), very high resistivity zone (294-1543 ohm-m) and the zone of intermediate resistivity (114-219 ohm-m). The three zones correspond to; highly weathered Basement, fresh bed rock and slightly weathered Basement/fractured Basement respectively. The aquifer in the study area is therefore defined by the highly weathered zone and the slightly weathered/fractured zones which are in agreement with Ariyo, 2007 and Olayinka, 1999 observation that common aquifers in typical Nigerian Basement Complex are composed of weathered and fractured Basement. The variation recorded in the resistivity and thickness of the aquiferous materials is due to the different rates at which different rocks respond to weathering from one location to another.

Table 1: Simulated results of resistivity data from the study Area.

Location	VES POINTS	Layers	Thickness (m)	Resistivity (Ohm-m)	Inferred Litho-strata	Remarks
JUJI	01	1	4.9	885	Lateritic Topsoil	
		2	28.3	66	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
	02	1	4.9	885	Lateritic Topsoil	
		2	28.3	66	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
	03	1	1.1	49	Clayey Topsoil	
		2	32.1	77	Weathered/Fractured Basement	Possibly Aquiferous
	04	1	1.1	393	Sandy Topsoil	
		2	32.1	109	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
Atawa	05	1	0.94	79	Sandy Topsoil	
		2	3.5	291	Laterite	
		3	15.9	80	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
		4	9.5	123	Slightly Weathered Basement	Possibly Aquiferous
	06	1	3.4	175	Lateritic Topsoil	
		2	19.8	96	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
	07	1	2.3	197	Lateritic Topsoil	
		2	20.3	98	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
		3	10.6	105	Slightly Weathered Basement	Possibly Aquiferous
	08	1	3.3	150	Lateritic Topsoil	
		2	12.1	95	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
		3	17.7	132	Slightly Weathered Basement	Possibly Aquiferous
ButuButu	09	1	10.5	68	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous

		2	22.6	1543	Slightly Weathered to Fresh Basement	
	10	1	1.1	124	Sandy Topsoil	
		2	1.2	79	Weathered Basement (sands/ sandy Clays)	
		3	30.9	262	Slightly Weathered to Fractured Basement	Possibly Aquiferous
	11	1	2.5	70	Weathered Basement (sands/ sandy Clays)	
		2	34.3	151	Slightly Weathered to Fractured Basement	Possibly Aquiferous
	12	1	13.8	91	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
		2	16	193	Slightly Weathered to Fresh Basement	
Dan Isa	13	1	3.3	99	Sandy Topsoil	
		2	29.8	78	Weathered &fractured Basement	Possibly Aquiferous
	14	1	2.9	280	Lateritic Topsoil	
		2	17.4	113	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
		3	9.5	140	Slightly Weathered Basement	
	15	1	0.9	216	Lateritic Topsoil	
		2	3.5	55	Weathered Basement (sands/ sandy Clays)	Possibly Aquiferous
		3	25.4	144	Slightly Weathered Basement with minor Fractures	Possibly Aquiferous
	16	1	0.9	527	Lateritic Topsoil	
		2	28.9	225	Slightly Weathered to Fresh Basement	Possibly Aquiferous

CONCLUSION

The method of investigation adopted by this study has helped in the identification of the aquiferous units and has provided an understanding of aquifer dimensions especially the thickness of the weathered mantle, the depth to bed rock and fractured zones which are required for locating points with high potentials for groundwater occurrence. The study has also revealed that ButuButu and Dan Isa have very high potentials for good borehole yields while Atawa and Juji can provide moderate yields. It is therefore suggested that groundwater development through borehole construction in the study area as well as other Basement Complex should be preceded by geophysical investigation (VES). This will minimize the problems associated with the occurrence and distribution of groundwater in Basement Complex terrains.

ACKNOWLEDGEMENT

The authors are grateful to some members of Staff of ATBU Bauchi and the Computer analyst in Jos whose contributions made this research a success.

REFERENCES

Adanu E.A. (1994) “Groundwater Development and Management in the Basement Complex Terrain in Zaria, Kaduna Area “Water *Resources* 4(1&2): 64-68.

Afolabi,O. and Olorunfemi M.O. (2004), “ Laboratory Modelling of Geoelectric Response of a leakin Underground Petroleum Storage tank in Sand Formation” *Global Journal of Geological Sciences*. 2 (2): 207-220.

Aina A. Olorunfemi M.O. and Ojo J .S. (1996), “An integration of Aeromagnetic and Electrical Resistivity Methods in Dam Site Investigation “Geophysics 61 (2): 349-356.

Ariyo S.O., (2007) “Hydro-Geophysical Investigation for Groundwater at Atan/Odosenbora Area, Southwestern Nigeria” *Ife journal of Science*. 9 (1): 87-92

Ariyo S.O. and Adeyemi G.O. (2009) “Role of Electrical Resistivity Method for Groundwater Exploration in Hard Rock Areas: A case study from Fidiwo/Ajebo Areas of Southwestern Nigeria” *Pacific Journal of Science and Technology* 10 (1): 483-486

Bannerman R.R. and Ayibotele N.B. (1984) “Some Critical Issues with Monitoring Crystalline Rock Aquifers for Groundwater Management in Rural Areas.” *Challenges in African Hydrology and Water Resources*, IAHS publ. (144): 47-56.

Barber W. and Jones D.G. (1960) “The Geology and Hydrogeology of Maiduguri, Borno Province” *Rec. Geol. Surv. Nig.*

Chilton J.P. and Smithcarrigton A.K. (1984) “Characteristics of Weathered Basement Aquifer in Malawi in Relation to Rural Water Supplies, “*Challenges in African Hydrology and Water Resources*, IAHS publ. (144) 57-72.

Dan Hassan M.A. and Adekile (1991)” Geophysical Exploration for Groundwater in Crystalline Basement Terrain: A case study of Zabenawan Dansudu, Kano State, Nigeria” *Journal of mining and Geology* 27 (2): 71-75.

Dan Hassan M.A. and Olurunfemi, M.O.(1999) “Hydrogeophysical investigation of a Basement Terrain in the North Central part of Kaduna State Nigeria” *journal of mining and Geology* 35 (2) pp 189-206

Falconer J.D. (1911), “The Geology and Geography of Northern Nigeria.” McMillan, London pp295.

Jeff D. (2006) “Forum for groundwater” *htt://www.waternet.co.za/groundwater/*(3) December 2006.

Kogbe C.A. (1989) “Geology of Nigeria Edited “2nd revised edition Paris , Rock View International pp538
Macdonald and Partners (1986) “Final Report on Rural Water Supplies for Kano State” vol. 2 Unpublished Report.

McCurry P., (1973) “Geology of Degree Sheet 21 (Zaria)” *Overseas Geol.Min Res*. 45 London.

Oluronfemi M.O. and Fasuyi s.A . (1993) “Aquifer types and Geoelectrical/ hydrogeologic Characteristics of Central Basement Terrain of Nigeria “*Journal of African Earth Science* (16): 309-317.

Olorunfemi M.O., Afolayan J. F. and Afolabi, O. (2004)“Geoelectric/Electromagnetic VLF Survey for groundwater in a Basement Terrain: A case Study,” *Ife journal of Science* 6 (1): 74-78.

Olayinka A.I (1999) “ Electromagnetic Profiling and Resistivity soundings in Groundwater Investigations near

Egbeda- Kabba Kwara State, Nigeria “ *Journal of mining and Geology*, 27 (2): 243-250.

Raeburn C. and Jones B.(1934), “The Chad Basin Geology and Water Supply” *Bull. Geol. Surv. Nig*. (15).

Schroeter P.Y. (1974) “The Hydrogeology of Bauchi Town Northern Nigeria” *Rec. Geol. Surv. Nig*. (8): 17-23.

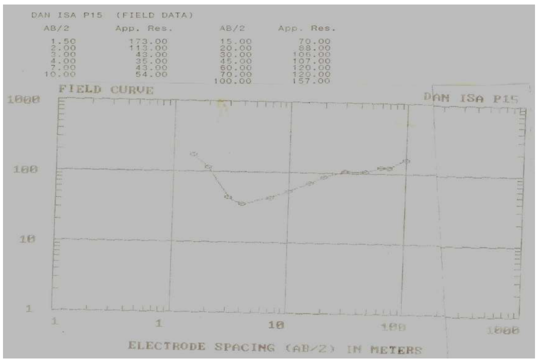
Uma K.O. and Kehinde M.O. (1994)“Potentials of regolith Aquifers in relation to Water Supplies to rural Communities: A case study from parts of Northern Nigeria” *journal of Mining and Geology* 30 (1): 97-109

Van Breeman O. R.T., Pidgeon and Bowden P. (1977) " Age and Isotope Studies of Some Pan African Granites from North Central Nigeria " *Precambrian Res*., (4): 307-309.

Wardrop Engineering Inc (1990) "Final Report on Rural Water Supply Project for Kano "

Wright E.P and Herbert R. (1985) "Collector Wells in Basement Aquifer" *Waterlines* (2): 8-11.

Zohdy A.A.R., Eaton G.P. and Mabey D.R. (1980) "Application of surface Geophysics to Groundwater Investigations:" *Techniques of Water Resources Investigations of the United States Geological Survey* 1-3



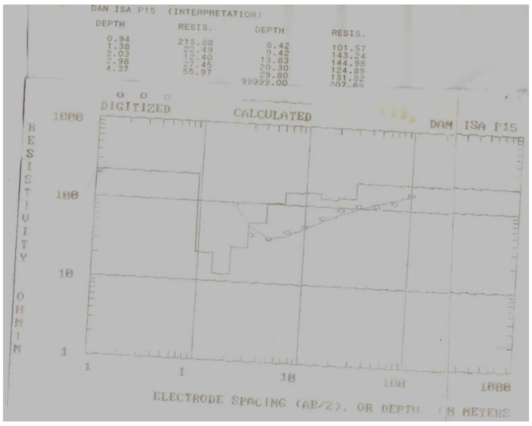
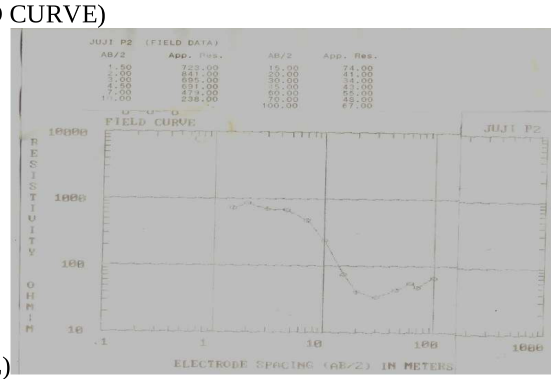


FIG.2a. A TYPICAL 3- LAYERED VES CURVE. (FIELD CURVE)

FIG.2b. A TYPICAL 3- LAYERED VES CURVE. (SIMULATED

CURVE)



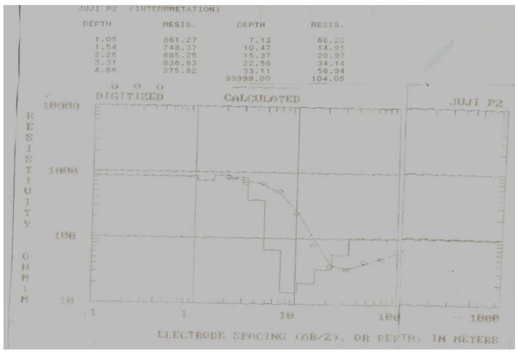


FIG.3a. A TYPICAL 2 - LAYERED VES CURVE. (FIELD CURVE)

FIG.3b. A TYPICAL 2 - LAYERED VES CURVE. (SIMULATED)

FIG.4a. A TYPICAL 4 - LAYERED VES CURVE.

(FIELD CURVE)

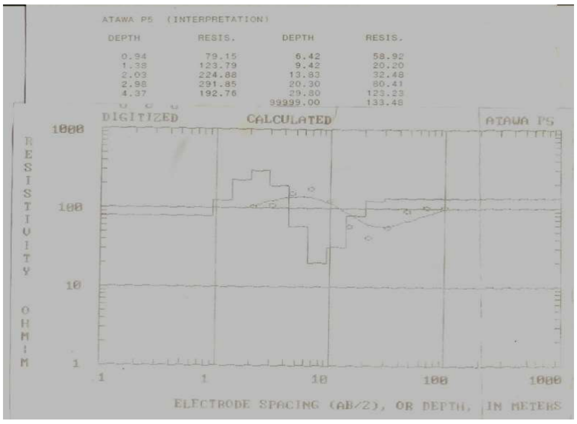


FIG.4b. A TYPICAL 4- LAYERED VES CURVE.

(SIMULATED)

Received for Publication: 05/06/10
Accepted for Publication: 20/07/10

Corresponding Author
E. Y. Mbiimbe, Department of Geology , Gombe State university, PMB 127, Gombe , Nigeria.