

# ASSESSMENT OF THE EFFICIENCY OF GEOELECTRIC SOUNDING RESULTS IN PREDICTING LITHOLOGICAL SEQUENCES IN A TYPICAL BASEMENT COMPLEX OF IJESA-ISU, SOUTHWESTERN NIGERIA

A. O. OYINLOYE and L. O. ADEMILUA

(Received 4 November, 2004; Revision Accepted 3 January, 2005)

## ABSTRACT

A study of the efficiency of geoelectric sounding using Schlumberger array electrode configuration in predicting lithological sequences and depth to bedrock in a typical basement complex area (Ijesa-Isu) has been carried out. The predicted geoelectric layers from the topsoil to the last unit obtained from the VES interpretation results were compared with the actual lithological log, and the level of agreement between the predicted and the actual sequences were scored on a scale of 2. The agreement level between the predicted sequence and the actual lithological layers expressed in percentages vary from 70% to 90% giving an overall average predictive efficiency of 81%. This high level of predictive efficiency shows a strong predictive correlation between geoelectrically delineated layer sequence and actual lithological sequence. However, the fact that the overall average agreement is not 100% means that the geoelectric layers sequences and depth to bedrock are not always exactly the same as lithological ones.

**KEYWORDS:** bedrock, sequence, predict, lithologic )

## INTRODUCTION

The need for the use of pre-drilling geophysical survey has been taken for granted in many parts of the country, Nigeria. Many clients believe that it is just one exercise whose costs, in terms of time, materials and money should be saved or avoided. This has resulted into the attendant and rampant borehole failures often recorded from the many wild-cat drilling exercises. However, the need for pre-drilling survey is gradually gaining acceptability. Although the electrical resistivity data acquisition either in the form of vertical electrical sounding (VES) or electric mapping has been in vogue in Nigeria for long, yet the efficiency with which such surveys have produced the desired results have been understudied.

Though the electrical resistivity method has contributed immensely to the study of the hidden subsurface structures (mainly joints and fractures) and rock types (O'asehinde, 1989; Ojo et al, 1990; Olayinka 1996; Ako and Olorunfemi, 1989), and much has been done in the areas of analytical comparison of the interpreted results with the drilling log in order to determine efficiency levels, yet this work is necessary as a complementary effort in the direction. The geoelectric layer is that layer of the earth which is represented by formations which differ much more by their electrical parameters like resistivity, dielectric and polarization etc, than by their lithological contents.

However, there exists a unique relationship between the geoelectric layers of the earth and the lithologic layers which can possibly be delineated from the interpretation of resistivity sounding data. Since the immediate aim of electrical resistivity prospecting is the prediction of lithologic layering and depth to fresh bedrock, it is necessary to investigate how efficiently this is done by comparing geoelectrically delineated layers with the actual lithologic layers from the driller's log, as a means of entrenching further confidence in pre-drilling geophysical survey.

The Schlumberger electrode configuration is the most widely used of all other arrays in the depth sounding techniques for pre-drilling geophysical survey because of its high depth probing capabilities in ground water investigation (Olorunfemi and Opadokun 1987, Ako 1996). The present study therefore is aimed at correlating the Schlumberger array geoelectric sections obtained from VES data interpretation results with carefully supervised borehole lithologic logs from six wells located in the study area, in order to determine the efficiency and level of agreement between the two, in a typical basement complex area of southwestern Nigeria.

## GEOLOGICAL SETTING

The study area, Ijesa Isu Ekiti, is located in Ikole Local Government area of Ekiti State, southwest Nigeria (Fig. 1). It is bounded by longitudes 5°25'E and 5°26'E and latitudes 7°45'N and 7°46'N. The area falls within the tropics and there is high annual rainfall of about 1500mm. The area lies within the Precambrian basement complex terrain of southwestern Nigeria. The major lithologic units according to Rahaman and Ocan (1978) include among others, the migmatite-gneiss complex, which is the most widespread rock type in Ekiti State. The migmatite gneisses are made up of three main components, (i) the early gneiss, (ii) the amphibolites, biotite gneiss, and (iii) the granitic or felsic components, which is the main rock type in the study area.

Noticeable geologic structure include faults, folds and joints. These structures control the flow of ground water and determine the amount of recharge and discharge. The overall drainage pattern is trellis in outlook. Rahaman (1976) recognized that the migmatite gneiss complex might have resulted from a complex association of deformative, shearing and folding, granitisation and migmatitisation processes.

The hydrogeology of an area is controlled by such factors as geology, structures and climate of the area. The climate determines the amount and rate of recharge of the aquifer (Mailu 1989, Shemang 1990). The major surface waters in the study area are Rivers Opeitan and Abusoro and their tributaries and other adjoining streams. During the rainy season, there is a great increase in flow volume in the major rivers while there is hardly water in some of the streams during the dry season. The highest rainfall usually occurs in August while the lowest is recorded in November.

## MATERIALS AND METHODS OF STUDY

In the present study, the electrical resistivity sounding using Schlumberger array was employed. This array is preferred to Wenner because the small spacing between potential electrodes renders it less sensitive to shallow inhomogeneities. The current electrode separation was varied between 1.50 and 75 meters throughout the survey. The instrument used for the study is the SAS300B ABEM Terrameter, which energises the ground with a current supply of very low frequency. The data were collected in six locations where boreholes were sited within the study area ( Fig 1.).

The borehole lithologic logs were obtained from six carefully supervised drilled borehole in the study area. The

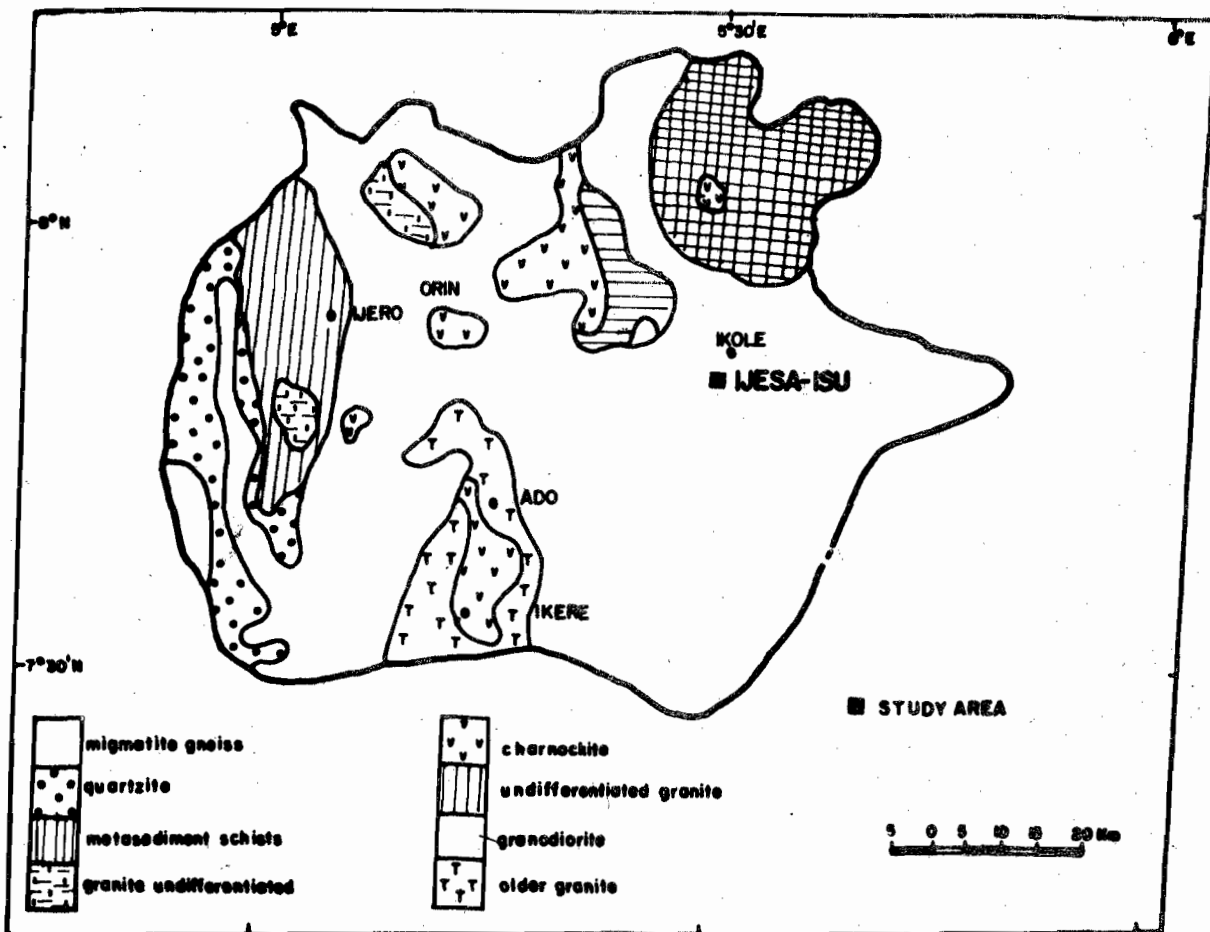


FIG. 1. Geological Map of Ekiti State (Adapted from Rahman, 1978)

log interval of 3.3 metres was used. The lithology and drill time (in minutes) for each interval were also recorded. This therefore enabled the production of the lithologic sections.

The VES curves were interpreted using partial curve matching and computer iteration methods. The results from the manual curve matching were used as initial model parameters for an iterative computer program RESIST 1.0 by Vander Velpen (1988).

The resulting curve and their final model parameters after iterations are as presented in Figures 2-4. The final model parameters (layer resistivities and thicknesses) were used for the preparation of the geoelectric sections. ( Figures 5-10)

**COMPARISON OF GEOELECTRICAL LAYERS WITH LITHOLOGIC LAYERS**

The geoelectric layers from the topsoil to the fresh bedrock unit obtained from VES interpretation results were compared with the actual lithology as revealed by the driller's

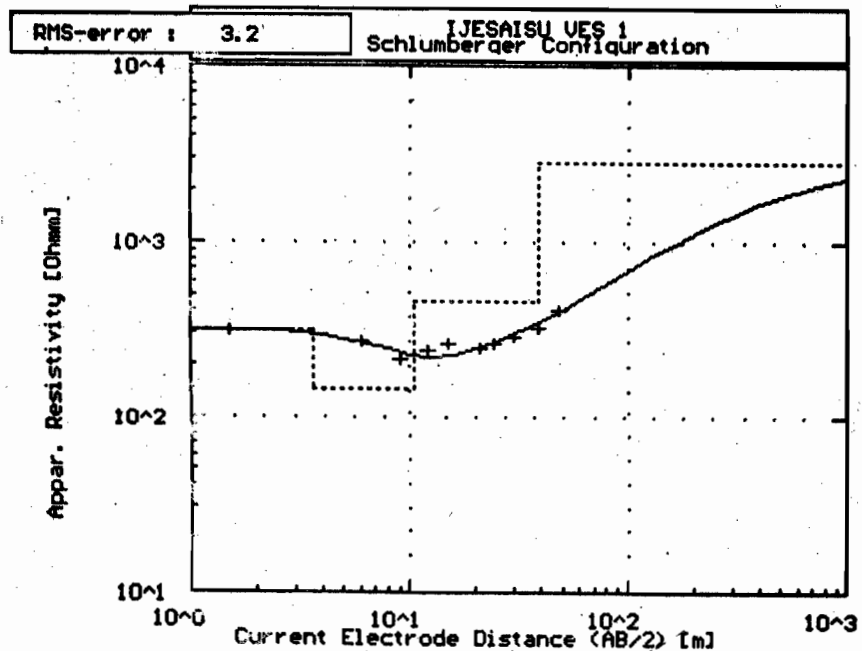
log and the levels of agreement between the predicted and the actual sequences were scored on a maximum scale of 2, where a score of 2 is allocated to cases of complete agreement between the predicted and actual lithologies.

The scores for partial agreement and non-agreement are 1 and zero respectively. The analytical tool used in the overall assessment of the level of comparison is the percentage agreement (PA). Following equation 1.

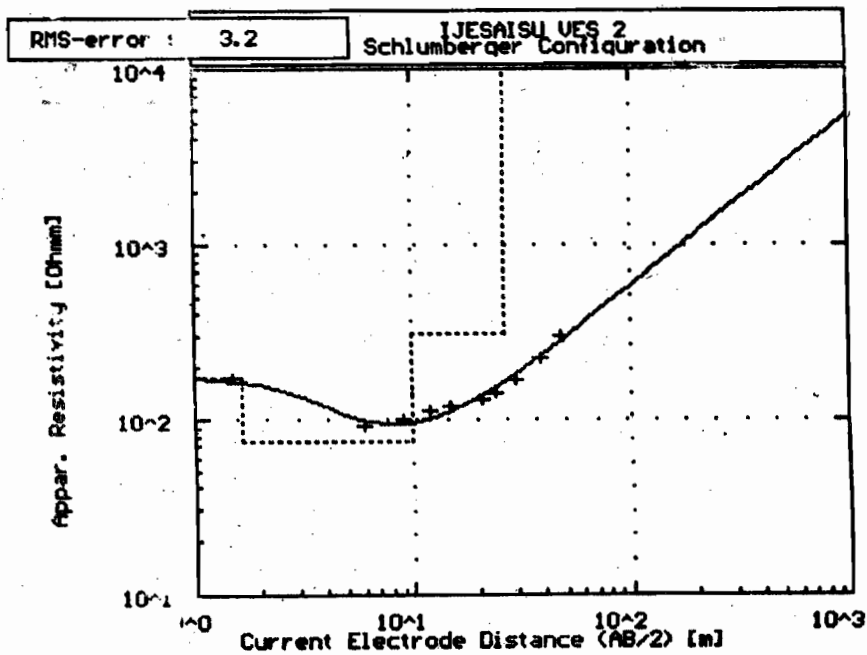
$$PA = \frac{\sum SP}{\sum MSP} \times 100\% \dots\dots\dots (1)$$

where PA = Percentage agreement  
 SP = Score of Prediction  
 MSP = Maximum Score of Prediction

The values obtained from the layer to layer comparison are as presented in table 1 below:

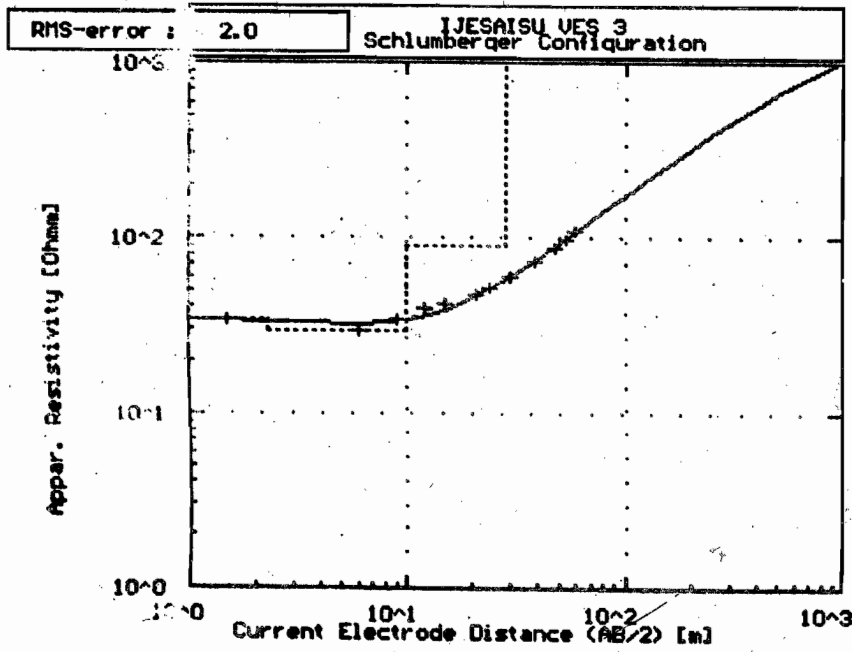


No	Res	Thick	Depth
1	315.5	3.7	3.7
2	147.9	6.7	10.3
3	449.3	28.6	39.0
4	2838.1	-	-

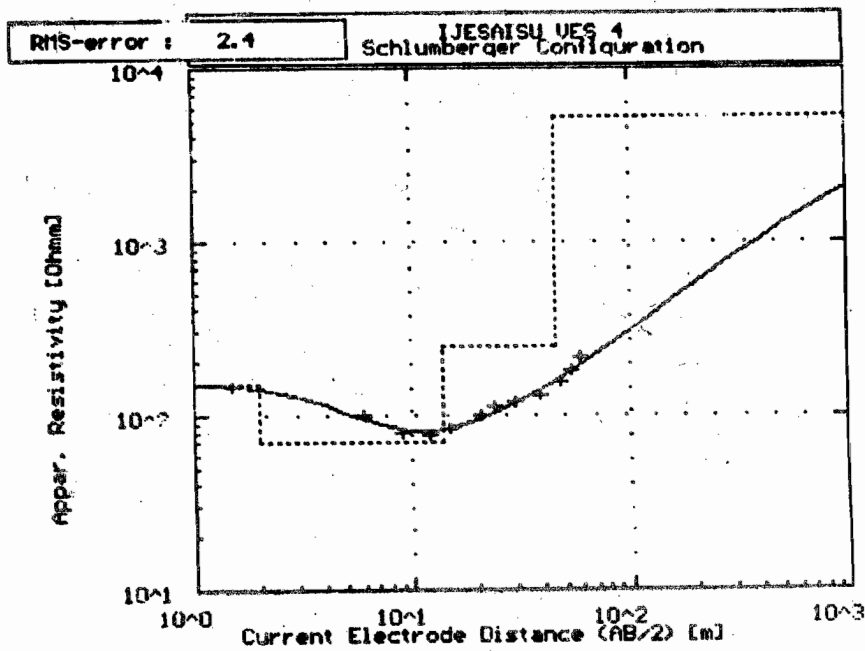


No	Res	Thick	Depth
1	175.3	1.6	1.6
2	75.7	8.3	9.9
3	313.5	16.3	26.2
4	9992.8	-	-

Fig. 2 SOUNDING CURVES OBTAINED FROM VES STATIONS 1 AND 2

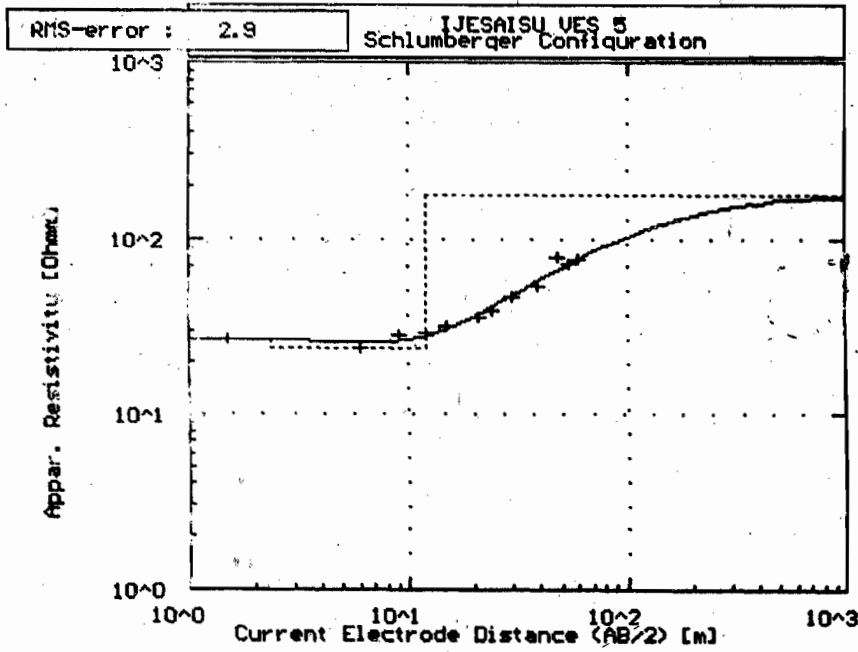


No	Res	Thick	Depth
1	33.8	2.3	2.3
2	29.4	7.7	10.0
4	1947.3	-	-

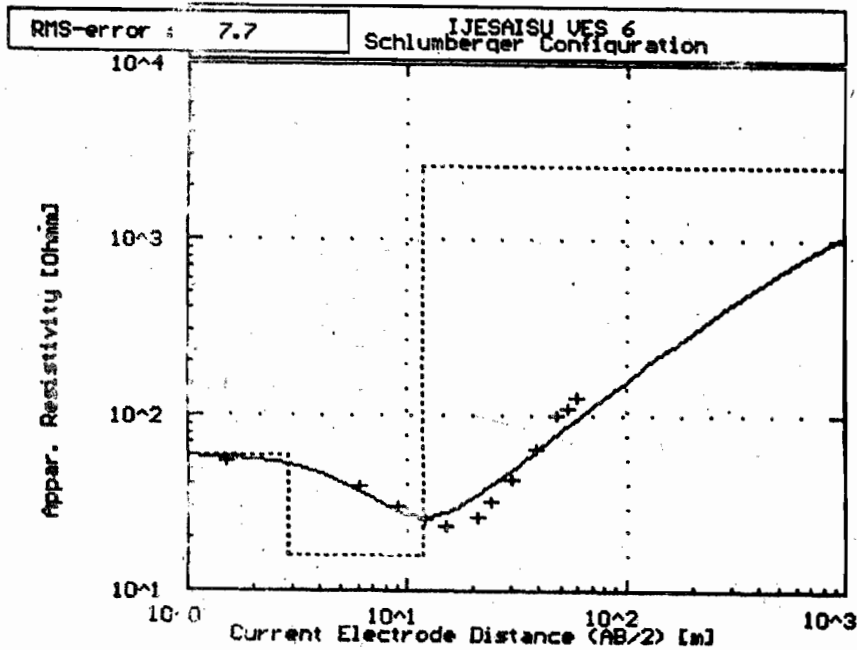


No	Res	Thick	Depth
1	161.6	2.0	2.0
2	69.8	12.0	14.0
4	5272.1	-	-

Fig. 3 SOUNDING CURVES OBTAINED FROM VES STATIONS 3 AND 4



No	Res	Thick	Depth
1	27.2	2.4	2.4
2	23.9	-	12.0
3	178.7	-	-



No	Res	Thick	Depth
1	59.7	2.8	2.8
2	16.1	8.9	11.7
3	2632.4	-	-

Fig. 4 SOUNDING CURVES OBTAINED FROM VES STATIONS 5 AND 6

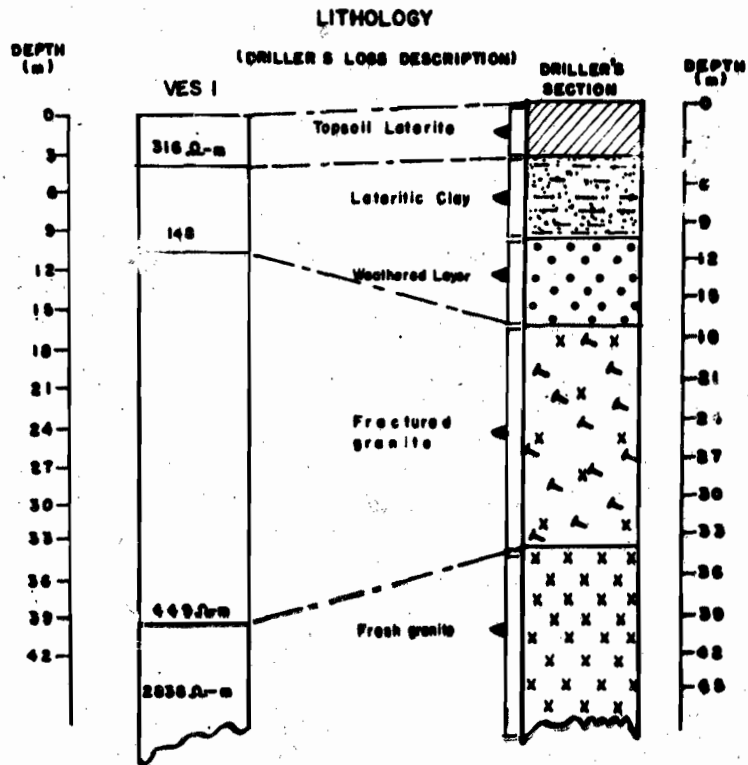


Fig. 5: Correlation of VES 1 Interpretation Result With Corresponding Driller's Log.

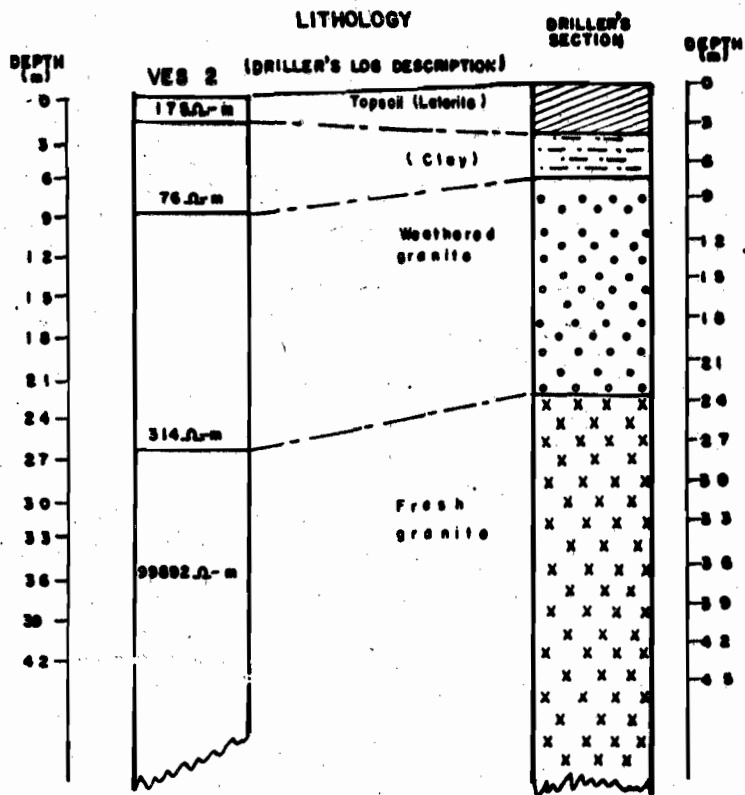


Fig. 6: Correlation of VES 2 Interpretation Result With the Corresponding Driller's Log.

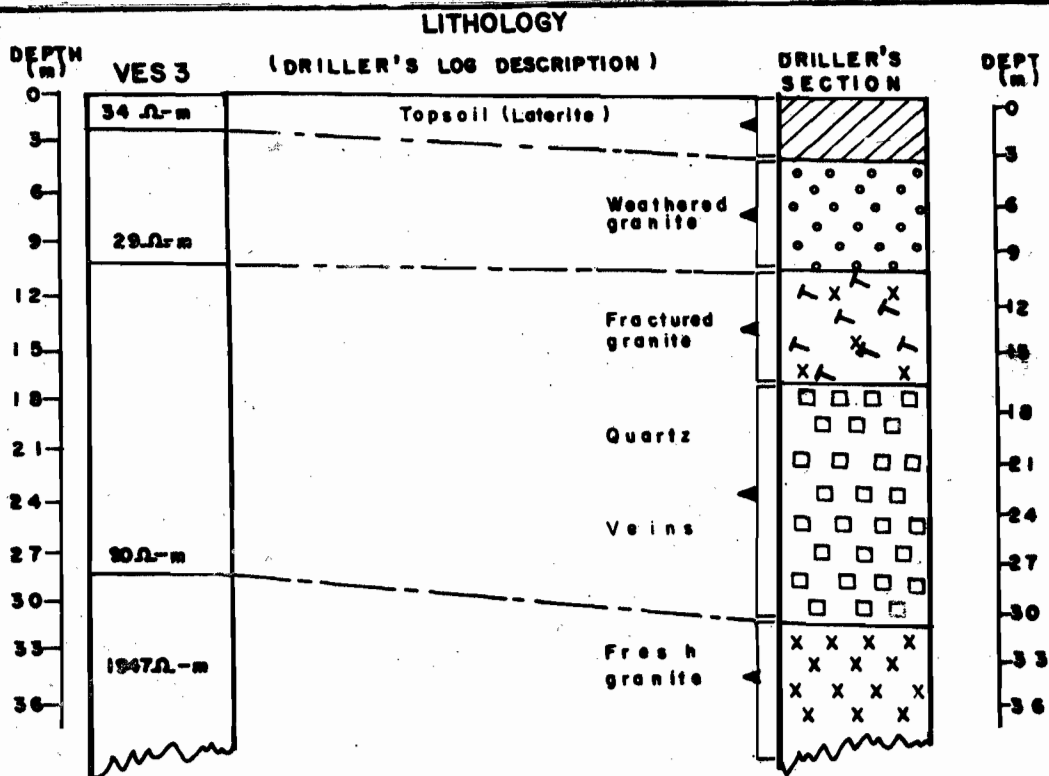


Fig.7: Correlation of VES 3 Interpretation Result With the Corresponding Driller's Log .

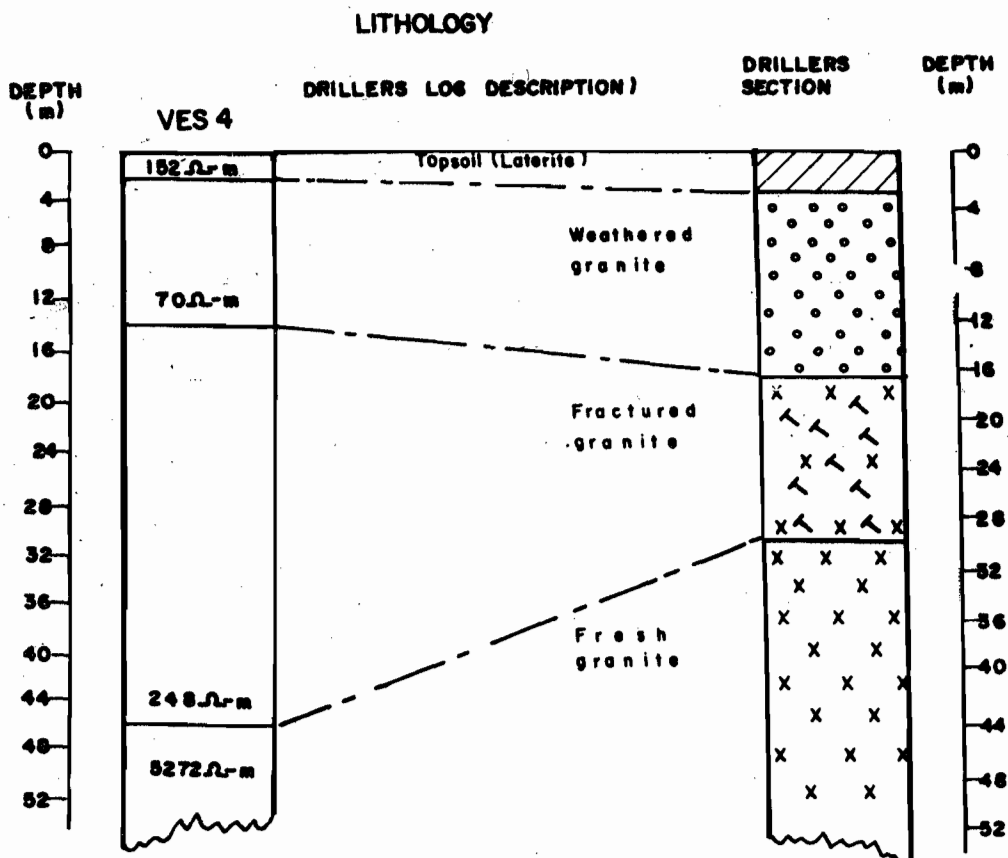


Fig.8 : Correlation of VES 4 Interpretation Result With the Corresponding Drillers Log

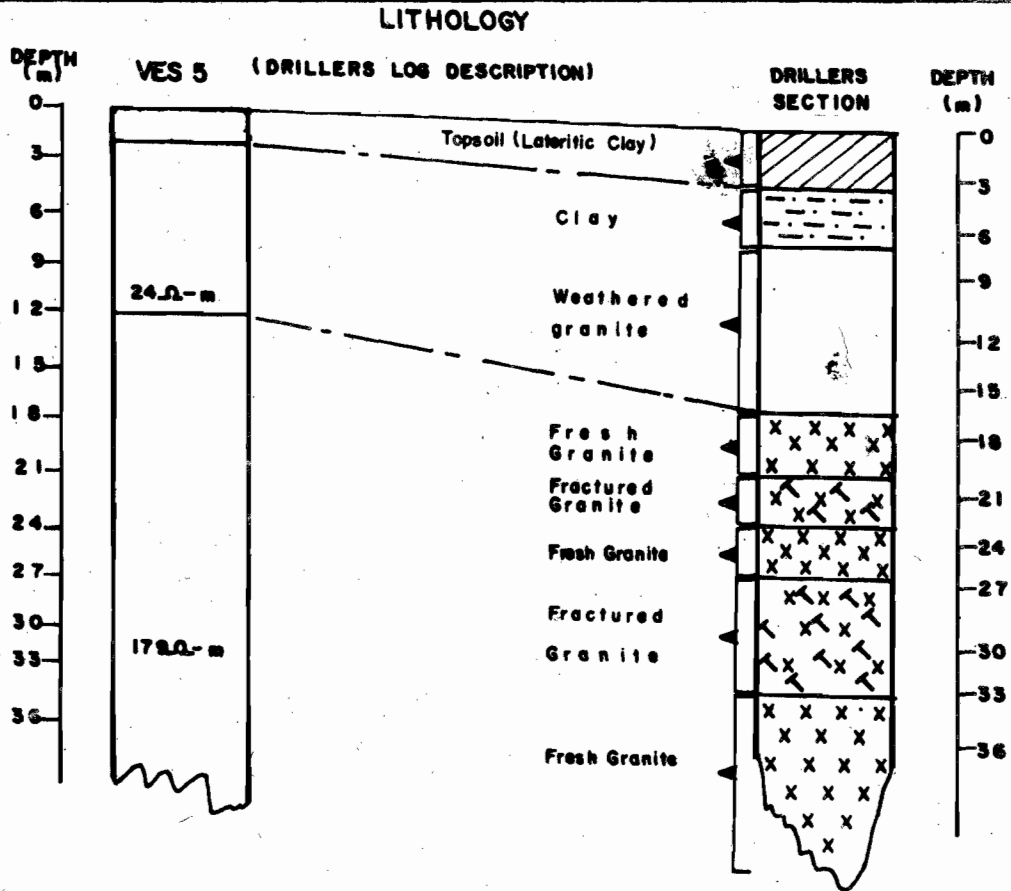


Fig.9: Correlation of VES 5 Interpretation With the Corresponding Drillers Log .

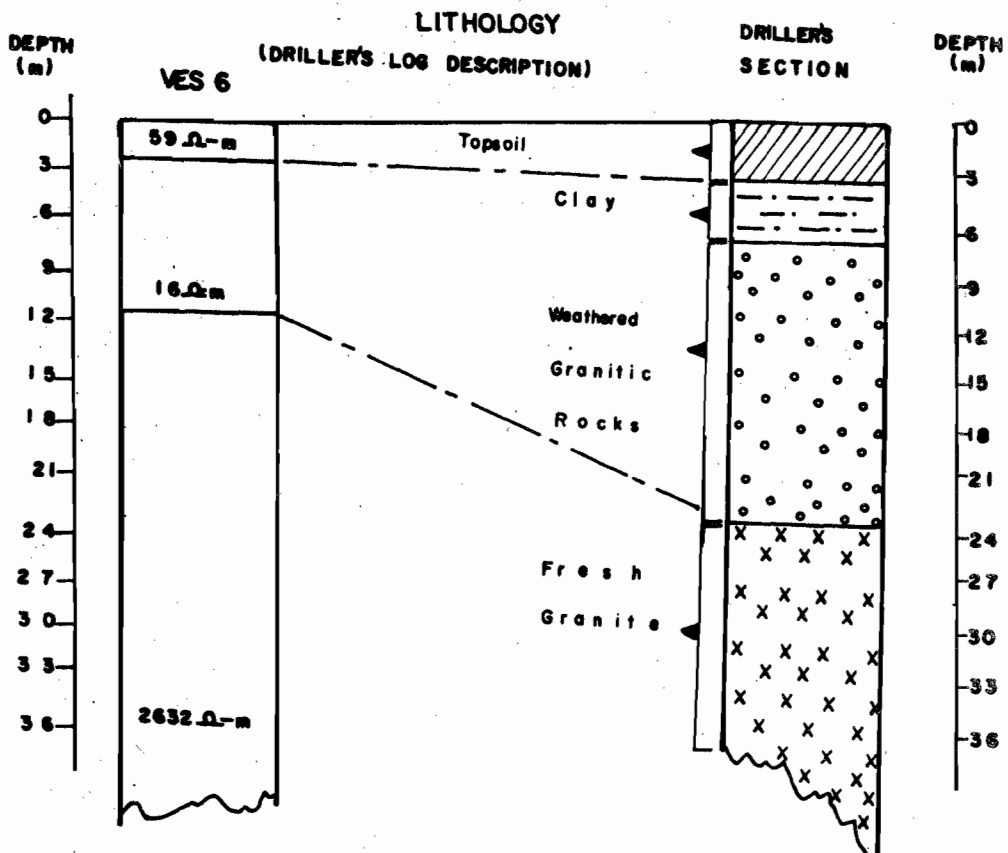


Fig. 10 : Correlation of VES 6 Interpretation Result With the Corresponding Driller's Log.



TABLE 1: Assessment Parameters for estimating Predictive Efficiency of VES Section

VES No	Driller's section (Lithologic Log)	Assessment parameters of predictive efficiency of VES section					% score of prediction	Rem
		P	PP	NP	MSP	SP		
1	i. Topsoil				2	2	90%	
	ii. Weathered layer	√	-	-	2	2		
	iii. Fractured layer	√	-	-	2	2		
	iv. Fresh Basement	√	-	-	2	2		
	v. Depth to Bedrock	√	√	-	2	1		
	Sub Total				10	09		
2.	i. Topsoil	√	-	-	2	2	90%	
	ii. Clay	√	-	-	2	2		
	iii. Weathered Layer	√	-	-	2	2		
	iv. Fresh Basement	√	-	-	2	2		
	v. Depth to Bedrock	-	√	-	2	1		
	Sub Total				10	09		
3	i. Topsoil	√	-	-	2	2	83%	
	ii. Weathered Layer	√	-	-	2	2		
	iii. Fractured Basement	√	-	-	2	2		
	iv. Quartz vein	√	-	-	2	2		
	v. Fresh Basement	-	√	-	2	1		
	vi. Depth to Bedrock				12	10		
	Sub Total							
4	i. Topsoil	√	-	-	2	2	80%	
	ii. Weathered Layer	√	-	-	2	2		
	iii. Fractured Basement	√	-	-	2	2		
	iv. Fresh Basement	-	√	-	2	1		
	v. Depth to Bedrock	-	√	-	2	1		
	Sub/Total				10	08		
5	i. Topsoil	√	-	-	2	2	78%	
	ii. Laterite / Clay	-	√	-	2	1		
	iii. Weathered Rock	√	-	-	2	2		
	iv. Fresh Bedrock	√	-	-	2	2		
	v. Fractured granite	-	√	-	2	1		
	vi. Fresh granite	√	-	-	2	2		
	vii. Fractured granite	-	√	-	2	1		
	viii. Fresh granite	√	-	-	2	2		
	ix. Depth to Bedrock	-	√	-	2	1		
	Sub Total				18	14		
6	i. Laterite / Topsoil	√	-	-	2	2	70%	
	ii. Clay	-	-	√	2	0		
	iii. Weathered Basement	√	-	-	2	2		
	iv. Fresh granite	√	-	-	2	2		
	v. Fresh granite	-	√	-	2	1		
	v. Depth to Bedrock				10	07		
<b>GRAND TOTAL.</b>					70	57	81%	

P - Predicted  
 PP - Partially Predicted  
 NP - Not Predicted  
 MSP - Maximum score of prediction  
 SP - Score of Prediction

## DISCUSSION OF RESULTS

From the assessment of the predictive level in station 1, (Table 1), the percentage agreement of the predicted with the actual lithologic sequences in VES station 1 is 90%, the predicted geoelectric layers are in sequential agreement with the actual lithologic layers. Also, the depth to bedrock predicted by VES section (39m) was just higher than the actual depth (33.3) as in Figure 5.

For station 2, this agreement level is 80% (Table 1); the depth to bedrock (24m) is actually very close to the predicted value (26.2m), so also are the lithologic layers in complete sequential agreement with the geoelectrically predicted layers. In station 3, (Figure.7), the agreement level is 83%, the layers were correctly predicted in sequence while there is only insignificant difference between the predicted depth to bedrock (28.6m) and the actual depth (31m). Stations 5 and 6 have agreement levels of 78% and 70% respectively. There are good agreements in the sequences while the depth to bedrock prediction are actually smaller than the real situation. The error of equivalence was responsible for the differences encountered between the predicted and actual situations, and consequently on the prediction efficiencies.

On the overall predictive performance for the six (6) station studied, the agreement level is encouraging, (81%) which is a high percentage and a mark of high level performance. The predictive level of geoelectrically delineated layers and depth to bedrock to the actual situation could therefore be said to be very high.

## CONCLUSIONS AND RECOMMENDATION

The results obtained in this study show high level percentage of sequential agreement between the geoelectrically predicted layers and depth to bedrock and the actual lithologies and depths encountered.

This high level agreement indicates a strong relationship between predicted layer (sequence from VES study) and the lithologic layers. It should be noted that the fact that the overall average agreement level is not 100% signifies that the geoelectric layers sequence are not always entirely the same as the lithologic sequence and that the depth to fresh bedrock could also vary significantly.

Notwithstanding this, the study gives encouraging high level agreement and results. Therefore arising from this study, the use of electrical resistivity method in unravelling and predicting the subsurface geologic sequence and depth to bedrock, given proper data processing and interpretation cannot be overemphasized. The Schlumberger array resistivity sounding technique has been further entrenched as one, if not the best method, of predicting lithologic layering and depth to bedrock and therefore effective in borehole siting endeavours.

## ACKNOWLEDGEMENT

The authors gratefully acknowledge the technical and field assistance rendered by Mr. L. A. Fasooto of the Department of Geology, University of Ado Ekiti and Engr. R. Obasi of the Department of Mineral Resources Engineering, Federal Polytechnic, Ado-Ekiti.

## REFERENCES

Ako, B.D., 1996. Applied Geophysics. The subsurface and the treasures. An inaugural Lecture delivered at the Obafemi Awolowo University, Ile-Ife. Inaugural lecture series 113, Obafemi Awolowo University Press Ltd., Ile-Ife 42p.

Ako, B.D. and Olorunfemi M.O., 1989. Geoelectric survey for groundwater in the Newer Basalts of Vom, Plateau State. *Nig. Journal of Mining and Geology*. Vol. 25, 1 and 2, 247-251.

Mailu, G.M., 1987. Hydrogeology of the metamorphic region of Athi drainage area, Kenya. *Proceedings of the Basement aquifer workshops*; Zimbabwe. Commonwealth Science Council, CSC (89) WMR - 13. TP. 273.

Murali S., 1975. A synopsis of topics covered in Exploration Geophysics. In Pal, P.C and Bhimasankaram, V.L.S.(eds), *Exploration Geophysics* Osmania University, Hyderabad, 36-39.

Ojo, J.S., Ayangbesan, T.A. and Olorunfemi M.O., 1990. Geophysical survey of a dam site a case study. *Journal of Mining and Geology*. 26, (2): 201 - 206.

Olasehinde P.I., 1989. Elucidating fracture pattern of the Nigerian basement complex using electrical resistivity method. *Zangew. Geowiss, Left*, S. 109 - 120.

Olayinka A.I., 1996. Non-uniqueness in the interpretation of bedrock resistivity from sounding curves and its hydrogeological implications. *Journal of Nigerian Association of Hydrogeologists*. 7 (1 and 2): 49-55.

Olorunfemi M.O. and Opadokun M.A., 1987. On the application of surface geophysical measurements in geological mapping of the Basement Complex of Southwestern Nigeria as a case study. *Journal of African Earth Sciences*. 6(3): 287 - 291

Rahaman, M.A., 1976. Review of the basement geology of Southwestern Nigeria. In *Geology of Nigeria*, Elizabethan Publishing company, Nigeria 41-58

Rahaman, M.A. and Ocan O., 1978. On relationships in the Precambrian migmatic gneiss in Nigeria. *Journal of Mining and Geol. Nigeria* 15: 23-33.

Sherang, E.M., 1990. Electrical depth soundings at selected well sites within the Kabami river basin, Zaria, Nigeria. Unpubl. M.Sc Thesis, Ahmadu Bello University, Zaria. 108 p.

Taiwo, K.A. 2000. An Interpretation of the Vertical Electrical Sounding data and its correlation with depth to the basement in the Nigerian basement complex. (Unpublished M.Sc Thesis. University of Ilorin, Nigeria.)

Vander Velpen B.P.A., 1988. RESIST version 1.0, M.Sc Research Project, ITC, Netherlands