Resistivity Modeling of Confined Fractured Basement Column for Varying Thicknesses and Depth of Burial.

Adebayo O. Ojo, M.Sc.[*] **and Martins O. Olorunfemi, Ph.D.**

Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria.

E-mail: ojo.adebayo.oluwaseun@gmail.com[*]
mlorunfe@yahoo.co.uk

ABSTRACT

This research involved theoretical modeling of a basement profile containing a confined fractured basement column with varying resistivity and thicknesses at different depths of burial. This was with a view to investigating the range of thicknesses and resistivity values for which the suppression prone confined fractured basement column is identifiable on the Vertical Electrical Sounding (VES) curve at different depth of burial.

Theoretical Schlumberger VES curves for typical basement complex profiles containing the confined fractured basement column while varying its thicknesses, resistivities and depth of burial were generated. Several five-layer HKH-type VES curves were generated by variously keeping the resistivity of the topsoil, the weathered layer and the fresh basements constant at 500, 200, 2500 and 10,000 ohm-m respectively while varying the resistivity of the confined fractured basement column from 100 to 1000 ohm-m at an increment of 100 ohm-m. The thickness of the topsoil and weathered layer was fixed at 1 and 20 m, respectively, while that of the fresh basement was varied from 10 to 180 m at an increment of 10 m as a means of increasing the depth of burial of the confined fractured basement column whose thickness was varied from 5 to 50 m at an increment of 5 m.

The results showed that the confined fractured basement columns were only detectable on the VES curve for thicknesses ranging from 10 m to 50 m and depths of burial ranging from 31 m to 201 m for resistivity reflection coefficient (k) values ranging from -0.92 to -0.56. The thickness ratio between the confined fractured basement column and the overburden for which the inflection characterizing the presence of the confined fractured basement column began to emerge on the VES curve ranging from shallow depth (31 m) to deep depth (201 m) were obtained for different resistivity reflection coefficient values. These were 0.81 - 0.05 for k = -0.92; 1.45 - 0.07 for k = -0.85; 1.22 - 0.10 for k = -0.79; 0.88 - 0.10 for k = -0.72; 0.82 - 0.12 for k = -0.67; 0.70 - 0.15 for k = -0.61 and 0.38 - 0.20 for k = -0.56. None of the range of thickness ratios obtained for different thicknesses of the confined fractured basement column and depth of burial allowed for detectability on the VES curve for resistivity reflection coefficient values of -0.52, -0.47 and -0.43.

The study concluded that confined fractured basement columns were only detectable on the VES curve within certain limits of thicknesses and resistivity ratios.

(Keywords: resistivity modeling, confined fractured basement column, detectability)

INTRODUCTION

Resistivity modeling refers to the process of calculating, usually by some numerical techniques, the theoretical electric response of the earth for a given situation (resistivity model) and particular electrode configuration. It is an indispensable aid in resistivity data interpretation, and an essential part of resistivity inversion where one attempts to obtain the resistivity distribution by fitting the observed data to a suitable theoretical model which involves iterative model adjustment and forward computations until the misfit is reduced to some acceptable error tolerance, subject to certain regularization procedure, often involving smoothing, damping and constraints. In general, computer modeling helps to understand questions of detection and resolution (i.e., whether certain targets can be delineated and what the likely anomaly effect is).
It is also an integral part of sensitivity analysis

which is important in any geophysical inversion. The interpretation and modeling of vertical electrical resistivity sounding field data are commonly done by assuming that the subsurface consists of a system of uniform and homogeneous parallel layers (Irshad, 1976). However, ambiguities exits in the interpretation of VES curve as several geologic models can be said to give similar sounding curve. An important source of such ambiguity for multi-layered earth strata is called suppression which in practical terms means that the presence of a particular layer may not be observable on the VES curve if its resistivity is intermediate between that of the enclosing layers without appreciable thickness or if the thickness of the layer is very small compared to its depth when its resistivity is neither zero nor infinity (Parasnis, 1994).

A typical geologic situation in which suppression is encountered in areas underlain by crystalline basement complex rocks is in the identification of a confined fractured column sandwich between two fresh basement rocks (Figure1). This generally leads to misinterpretation of the VES curve as the suppressed layer is missing out of interpretation consideration. As shown in Figure 1, confined fractured basement column is that zone of relatively much lower resistivity than the overlying and underlying fresh bedrock. While a somewhat undefined infinite resistivity value may be assigned to the supposedly fresh massive, compact and unfractured basement rock, the value for fractured basement column is often less than 1000 (Ohm-m) (Beeson and Jones, 1988; Olayinka, 1990; Olorunfemi et al., 1991; Hazel et al., 1988; Ademilua, 2007). A list of generalized geoelectric parameters (layer resistivity and thicknesses) of the subsurface layers in a typical basement complex area given by Olorunfemi (2008) in addition to the work of Acworth (1987); Buckley and Zeil (1987); White et al. (1988); Olayinka and Oladipo (1994) informed and served as basis for the model parameters adopted.

The confined fractured basement column is an hydrogeologically important aquifer unit in a typical basement complex environment.

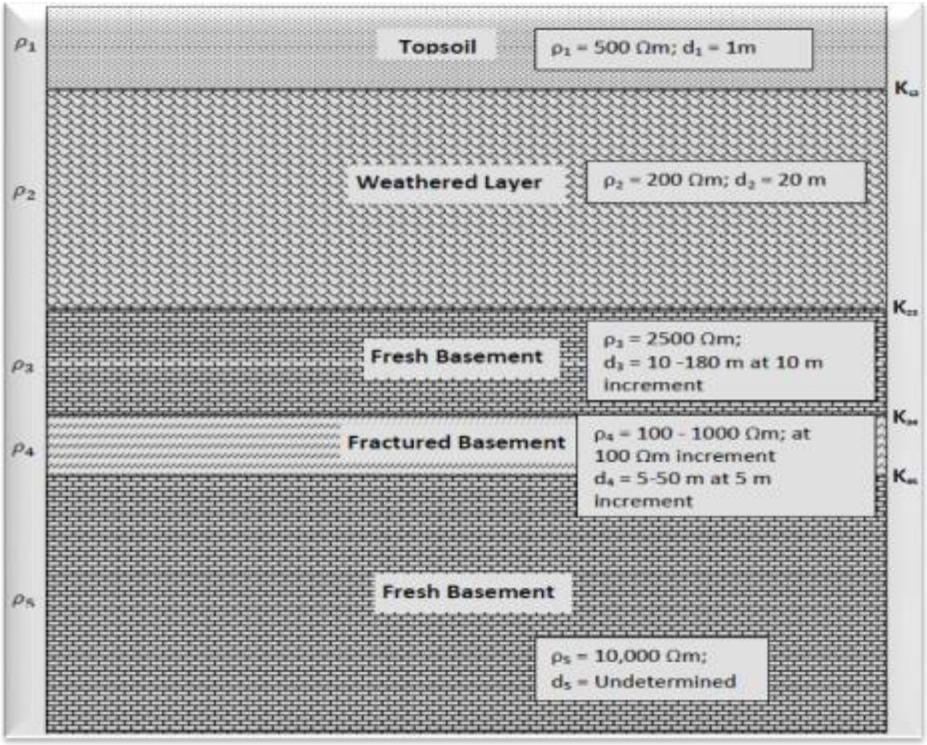


Figure 1: Model of a Typical 5-layer Earth in the Basement Complex Area Containing a Confined Fractured Basement Column.

RESEARCH METHODOLOGY

Resistivity Modeling

As shown in Figure 1, confined fractured basement column as earlier mentioned is that zone of relatively much lower resistivity than the overlying and underlying fresh bedrock. The typical Schlumberger Vertical Electrical Sounding (VES) curve depicting the detection of this zone and the overlying layers (topsoil, weathered layer and fresh basement) and underlying layer (fresh basement) is the five-layer HKH-type curve with the resistivity combination $\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$. This curve is usually characterized by an inflection between the rising (basement) segments of the VES curve (Olorunfemi and Fasuyi, 1993). When detectable, a typical resistivity depth sounding HKH-type curve becomes segmented and displaced (Figure 2). In this case, the whole curve is correctly interpreted as a five-layer HKH-type curve. However, when the inflection is not detectable, the VES curve is erroneously interpreted as a four-layer HA type curve or even a three-layer H-type curve as the case may be. This becomes a problem that cannot be ignored as further action based on the interpretation would be based on this wrong premise.

To successfully assess the detectability of the confined fractured basement column on the VES curve, a forward modeling software (Synthetic VES) developed by the authors were used for the purpose of generating theoretical VES curves resulting from several five-layer basement profile containing a confined fractured basement column with varying thicknesses, resistivities and depth of burial.

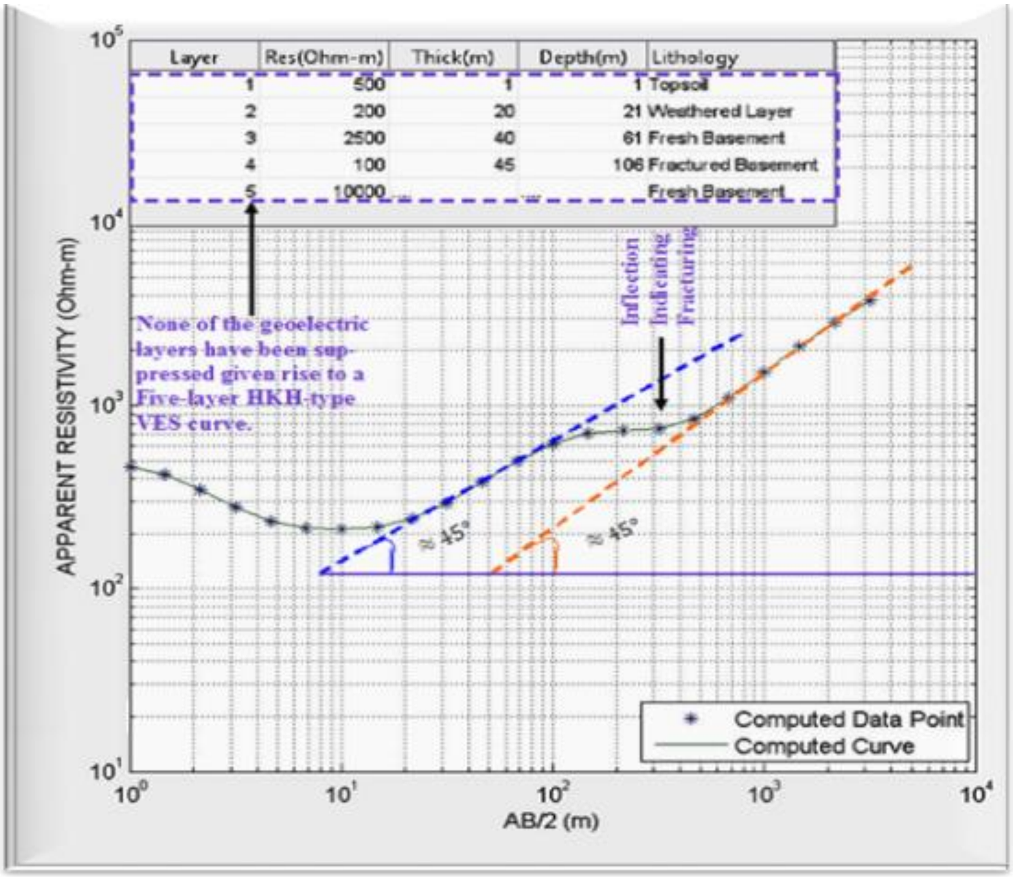


Figure 2: Geoelectric Signature of a Typical Basement Profile Containing a Confined Fractured Basement Column.

The first layer is the topsoil and the resistivity is fixed at 500 ohm-m while the thickness is fixed at 1.0 m. The second layer is the weathered layer with resistivity value fixed at 200 ohm-m and thickness of 20 m. The third layer is a fresh basement column with resistivity of 2500 ohm-m and varying thicknesses with values from 10 m to 180 m at an increasing interval of 10 m. This variation is aimed at varying the depth of burial of the confined fractured basement which is the layer of interest. The fourth layer is the layer of interest which is the confined fractured basement column with a typical resistivity value varying from 100 ohm-m to 1000 ohm-m at an increasing interval of 100 ohm-m while the thickness is also varied from 5 m to 50 m at an increasing interval of 5 m. The fifth layer is another fresh basement column with a fixed resistivity value of 10,000 ohm-m and an undetermined layer thickness, as usually the case.

While the first and second layer resistivities and thicknesses and the third and fifth layer resistivities are fixed, ten (10) different geologic models result from varying the thickness of layer four from 5 – 50 m at an increment of 5 m. This is done for 18 different overburden thicknesses obtained by varying the thickness of the third layer from 10 – 180 m at an increment of 10m. This in turn, results into a total of 180 unique geologic models for a given resistivity value of layer four. However, we have 10 different resistivity values for the fourth layer which results from varying its resistivity from 100 to 1000 ohm-m at an increment of 100 ohm-m. This results in a total of 1, 800 unique geologic models which were used in the resistivity modeling analysis.

A descriptive summary of the geologic models used and their geoelectric parameters are as presented in Table 1.

Model Analysis

For each of the resulting parameter set from the variations presented in Table 1, a theoretical VES curve was generated using the developed software (SyntheticVES). The generated theoretical VES curves from the different geologic models and their respective geoelectric parameters were subjected to visual inspection aided by fitting parallel ≈ 45° lines to the rising basement segments of the VES curves and check if an inflection indicating the detectability of the confined fractured basement columns was identifiable between the two fitted parallel lines on the VES curve as illustrated in Figure 1.

Table 1: Geologic Models and Geoelectric Parameters for Resistivity Modeling.

Layer	Resistivity (Ohm-m)	Thickness (m)	Lithology
1	500	1	Topsoil
2	200	20	Weathered Layer
3	2500	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180.	Fresh Basement
4	100, 200, 300, 400, 500, 600, 700, 800, 900, 1000.	5, 10, 15, 20, 25, 30, 35, 40, 45, 50.	Fractured Basement (Confined)
5	10, 000	Not Determined	Fresh Basement

RESULTS AND DISCUSSION

The results obtained from the analysis of the 1,800 theoretical VES curves used for this study are presented in form of a table. These include a summary of the results obtained from the visual inspection method of analysis as well as computed results for all the resultant theoretical VES curves generated from the different geologic models and their respective geoelectric parameters (i.e. layer resistivities and thicknesses). The results presented in the tables include the individual model name and respective geoelectric parameters, the resultant VES type curve, a comment on the detectability (D means detectable while ND implies non-detectable), and the thickness ratio (thickness of the confined fractured basement thickness divided by the overburden thickness). Although all the resultant VES type curves are generated from a five-layer geologic model, the resultant VES curves generally ranged from three-layer H-type VES curve when the rising basement segments of the VES curve is neither segmented nor displaced to four-layer HA-type VES curve when the rising basement segments of the VES curve is segmented but not displaced when the confined fractured basement column is suppressed on the VES curve and five-layer HKH-type curve when the rising basement segments of the VES curve is both segmented and displaced indicating the detectability of the confined fractured basement column signature on the VES curve. A sample result for the first twenty geologic models is presented in Table 2.

To facilitate a focused discussion and understanding of the results obtained from the model analysis and in line with the aim of this study; the results will be discussed by providing answers to the following research questions.

(i) Can geo-electric sounding utilizing the Schlumberger Vertical Electrical Sounding (VES) technique image confined fractured basement column at depth of burial of up to 250 m?

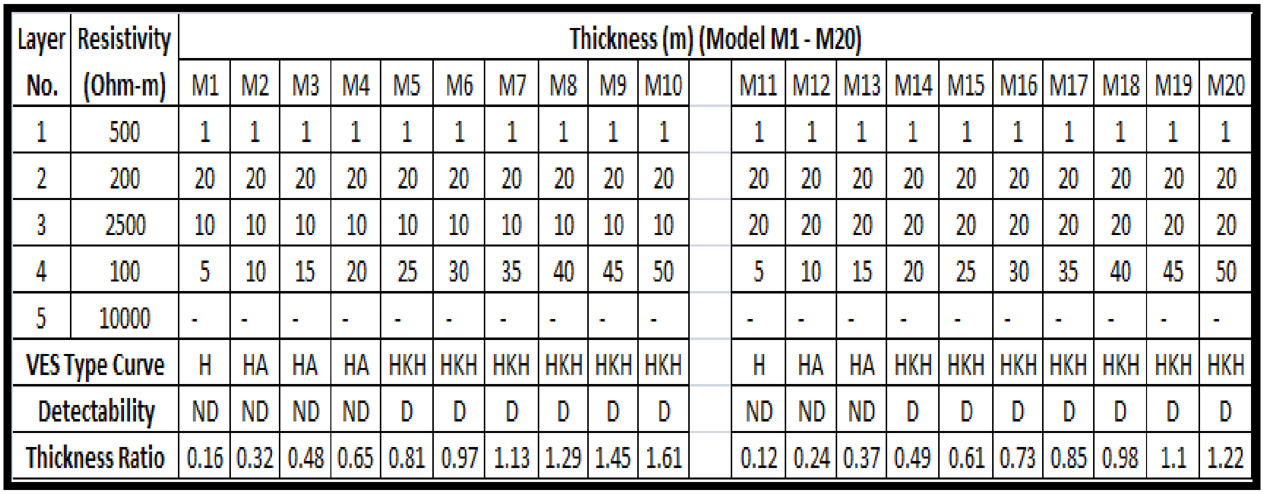
(ii) At what resistivity values expressed in terms of the resistivity reflection coefficients or resistivity ratios do the confined fractured basement columns become detectable on the Vertical Electrical Sounding (VES) curves?

(iii) What is the range of minimum thickness or thickness ratio for which the confined fractured basement columns become detectable on the Vertical Electrical Sounding (VES) curves at different depth of burial?

In providing answers to the above stated research questions, the minimum thicknesses of the confined fractured basement columns modeled (5 - 50 m) from which the inflection characterizing the presence of the confined fractured basement columns began to emerge on the Vertical Electrical Sounding (VES) curves at different overburden thicknesses and resistivity reflection coefficient (k) values were extracted from the entire result of the model analysis and presented in Table 3.

It can be observed from these results that even at deep depth of burial of up to 201 m, confined fractured basement column thicknesses ranging from 10 to 50 m allow for detectability on the VES curve.

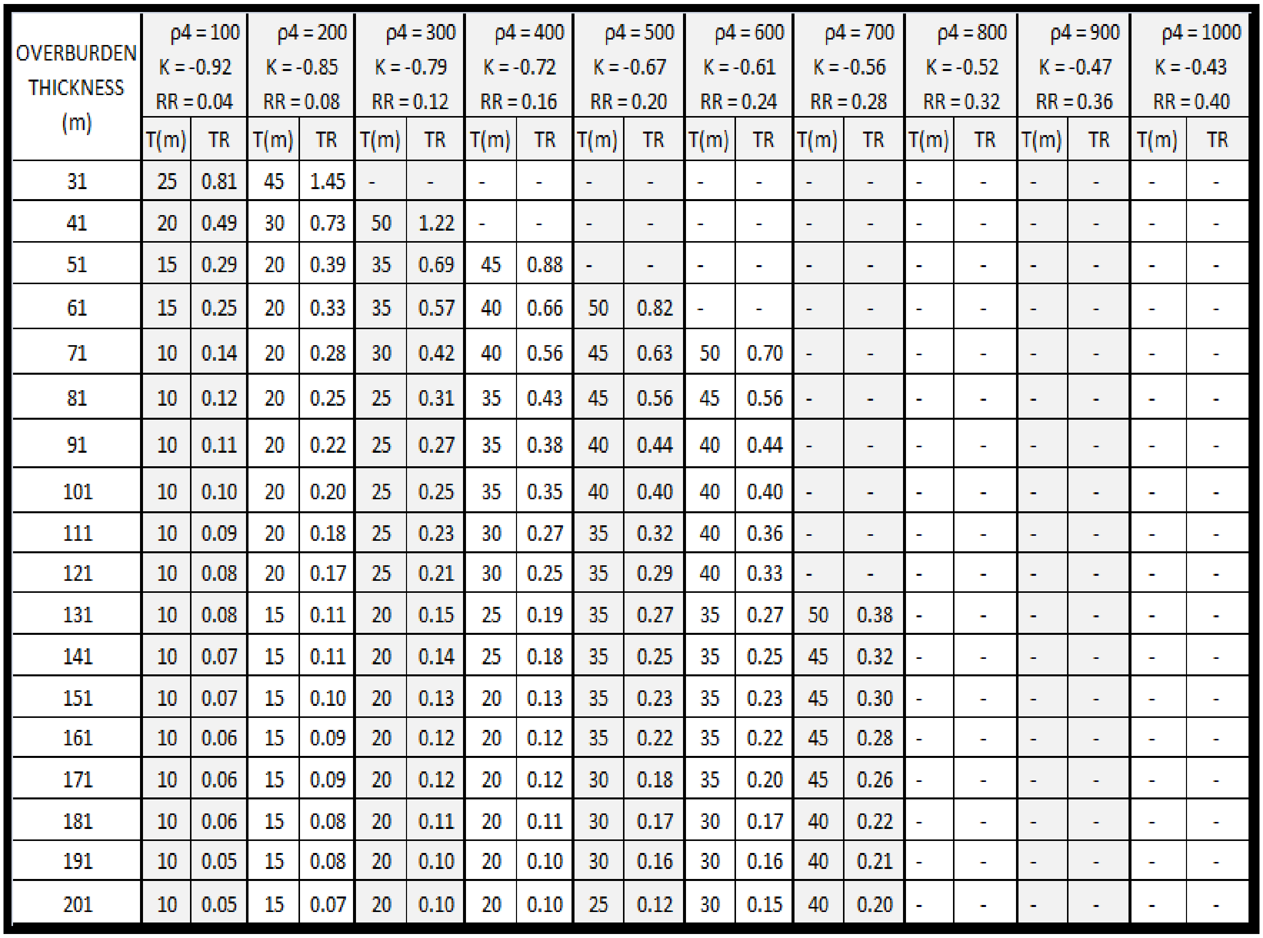
Table 2: Sample Model Analysis Result.



Layer No.	Resistivity (Ohm-m)	Thickness (m) (Model M1 - M20)																			
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
1	500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	200	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
3	2500	10	10	10	10	10	10	10	10	10	10	20	20	20	20	20	20	20	20	20	20
4	100	5	10	15	20	25	30	35	40	45	50	5	10	15	20	25	30	35	40	45	50
5	10000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VES Type Curve		H	HA	HA	HA	HKH	HKH	HKH	HKH	HKH	HKH	H	HA	HA	HKH	HKH	HKH	HKH	HKH	HKH	HKH
Detectability		ND	ND	ND	ND	D	D	D	D	D	D	ND	ND	ND	D	D	D	D	D	D	D
Thickness Ratio		0.16	0.32	0.48	0.65	0.81	0.97	1.13	1.29	1.45	1.61	0.12	0.24	0.37	0.49	0.61	0.73	0.85	0.98	1.1	1.22

Note: ND means Non-Detectable; D means Detectable.

Table 3: Minimum Thickness Ratio Allowing for Detectability of the Confined Fractured Basement Column.

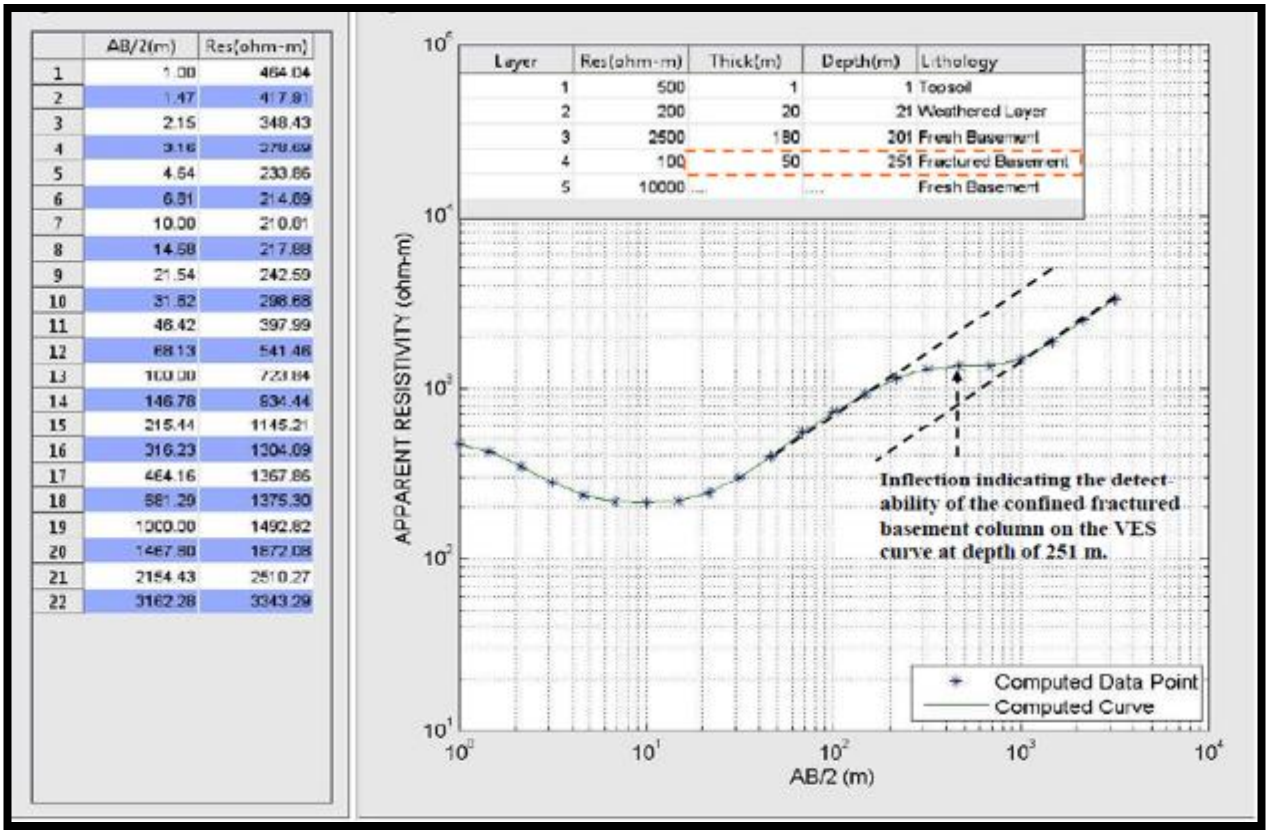


OVERBURDEN THICKNESS (m)	ρ4 = 100 K = -0.92 RR = 0.04		ρ4 = 200 K = -0.85 RR = 0.08		ρ4 = 300 K = -0.79 RR = 0.12		ρ4 = 400 K = -0.72 RR = 0.16		ρ4 = 500 K = -0.67 RR = 0.20		ρ4 = 600 K = -0.61 RR = 0.24		ρ4 = 700 K = -0.56 RR = 0.28		ρ4 = 800 K = -0.52 RR = 0.32		ρ4 = 900 K = -0.47 RR = 0.36		ρ4 = 1000 K = -0.43 RR = 0.40	
	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR	T(m)	TR
31	25	0.81	45	1.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	20	0.49	30	0.73	50	1.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	15	0.29	20	0.39	35	0.69	45	0.88	-	-	-	-	-	-	-	-	-	-	-	-
61	15	0.25	20	0.33	35	0.57	40	0.66	50	0.82	-	-	-	-	-	-	-	-	-	-
71	10	0.14	20	0.28	30	0.42	40	0.56	45	0.63	50	0.70	-	-	-	-	-	-	-	-
81	10	0.12	20	0.25	25	0.31	35	0.43	45	0.56	45	0.56	-	-	-	-	-	-	-	-
91	10	0.11	20	0.22	25	0.27	35	0.38	40	0.44	40	0.44	-	-	-	-	-	-	-	-
101	10	0.10	20	0.20	25	0.25	35	0.35	40	0.40	40	0.40	-	-	-	-	-	-	-	-
111	10	0.09	20	0.18	25	0.23	30	0.27	35	0.32	40	0.36	-	-	-	-	-	-	-	-
121	10	0.08	20	0.17	25	0.21	30	0.25	35	0.29	40	0.33	-	-	-	-	-	-	-	-
131	10	0.08	15	0.11	20	0.15	25	0.19	35	0.27	35	0.27	50	0.38	-	-	-	-	-	-
141	10	0.07	15	0.11	20	0.14	25	0.18	35	0.25	35	0.25	45	0.32	-	-	-	-	-	-
151	10	0.07	15	0.10	20	0.13	20	0.13	35	0.23	35	0.23	45	0.30	-	-	-	-	-	-
161	10	0.06	15	0.09	20	0.12	20	0.12	35	0.22	35	0.22	45	0.28	-	-	-	-	-	-
171	10	0.06	15	0.09	20	0.12	20	0.12	30	0.18	35	0.20	45	0.26	-	-	-	-	-	-
181	10	0.06	15	0.08	20	0.11	20	0.11	30	0.17	30	0.17	40	0.22	-	-	-	-	-	-
191	10	0.05	15	0.08	20	0.10	20	0.10	30	0.16	30	0.16	40	0.21	-	-	-	-	-	-
201	10	0.05	15	0.07	20	0.10	20	0.10	25	0.12	30	0.15	40	0.20	-	-	-	-	-	-

Notation: **ρ_4:** Resistivity of the Confined Fractured Basement Column;
K: Resistivity Reflection Coefficient between the Confined Fractured Basement Column and the Overlying Bedrock
RR: Resistivity Ratio Coefficient between the Confined Fractured Basement Column and the Overlying Bedrock
T: Thickness of the Confined Fractured Basement Column
TR: The thickness of the Confined Fractured Basement Column Divided by the Cumulative Thickness of the Overlying layers
– : Implies that none of the modeled thicknesses of the Confined Fractured Basement Column allow for Detectability on the VES Curve.

It can therefore be said from the result obtained from the present study that geoelectric sounding utilizing the Schlumberger Vertical Electrical Sounding (VES) technique has the required resolution capacity to image deep confined fractured basement columns within some detectability criteria provided in Table 3. An example of this observation is shown on the VES curve in Figure 3 for a 50 m thick confined fractured basement column at a depth of 251 m.

To provide answer to the second research question, It can be noted from the results presented in Table 3 that for resistivity reflection coefficient values of -0.92, -0.85, -0.79, -0.72, -0.67, -0.61 and -0.56, some of the confined fractured basement column thicknesses modeled (i.e. 10, 15, 20, 25, 30, 35, 40, 45 and 50 m) at different depth of burial ranging from 31 to 201 m allow for detectability on the VES curve whereas for resistivity reflection coefficient



	AB/2(m)	Res(ohm-m)
1	1.00	464.04
2	1.47	417.81
3	2.15	348.43
4	3.16	278.69
5	4.64	233.86
6	6.81	214.09
7	10.00	210.01
8	14.68	217.88
9	21.54	242.59
10	31.62	298.68
11	46.42	397.99
12	68.13	541.46
13	100.00	723.84
14	146.78	934.44
15	215.44	1145.21
16	316.23	1304.09
17	464.16	1367.86
18	681.29	1375.30
19	1000.00	1492.82
20	1467.80	1672.08
21	2154.43	2510.27
22	3162.28	3343.29

Layer	Res(ohm-m)	Thick(m)	Depth(m)	Lithology
1	500	1	1	Topsoil
2	200	20	21	Weathered Layer
3	2500	180	201	Fresh Basement
4	100	50	251	Fractured Basement
5	10000	....	....	Fresh Basement

Figure 3: Vertical Electrical Sounding (VES) Curve showing the detectability of a Confined Fractured Basement Column buried at 201 m.

values of -0.52, -0.47 and -0.43, none of the confined fractured basement column thicknesses modeled from 5 to 50 m allow for detectability on the VES curve. Hence it can be stated that for the present study that when the resistivity reflection coefficient value between the confined fractured basement column and the overlying bedrock is greater than -0.56 or when the resistivity ratio between the confined fractured basement column and the overlying bedrock is greater than 0.28, confined fractured basement columns thickness ranging from 5 to 50 m cannot be imaged (detected) on the Vertical Electrical Sounding (VES) curve. The trend of observation at different overburden thicknesses suggests that geoelectric suppression is dominant at higher resistivity reflection coefficient values and resistivity ratios values where the resistivity contrast between the confined fractured basement column and the overlying bedrock is low. Hence, the resolution capacity of the geoelectric sounding technique to image the confined fractured basement column is consequently reduced. Likewise, as we decrease the resistivity contrast between the confined fractured basement column and the overlying bedrock i.e. at greater resistivity reflection coefficient (k) values, larger thicknesses of the confined fractured basement column are required for detectability at different overburden thicknesses. This generally implies that there is higher probability of misinterpretation at higher resistivity reflection coefficient values because the inflection characterizing the presence of the confined fractured basement column generally becomes less defined and discernible on the VES curve. A graphical example of this observation is illustrated in Figure 4 where VES curves for the same confined fractured basement column thickness and overburden thickness are superimposed for different resistivity reflection coefficient values.

In answering the third research question stated above, Table 3 which presents a concise result for the present study will be relevant. It can be noted from this table that the range of minimum

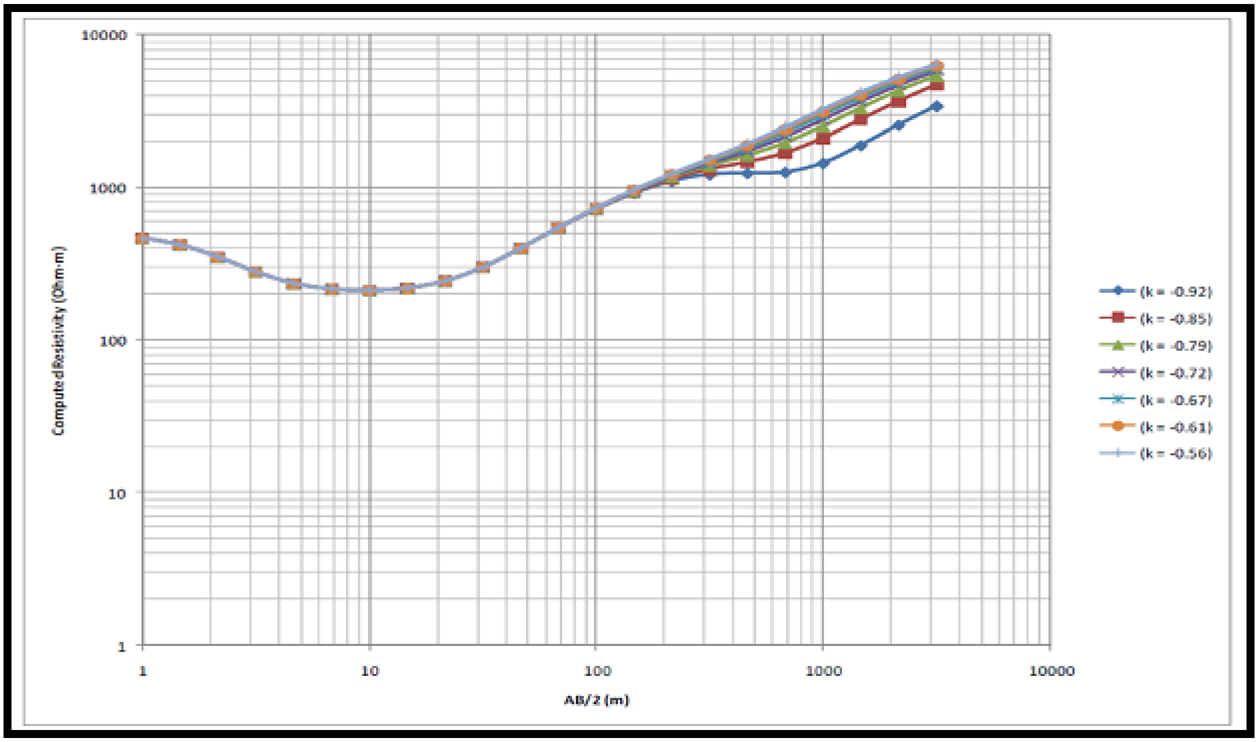


Figure 4: Superimposed VES Curves for Confined Fractured Basement Column Thickness of 50 m at a Depth of 151 m for Different Resistivity Reflection Coefficient (k) Values.

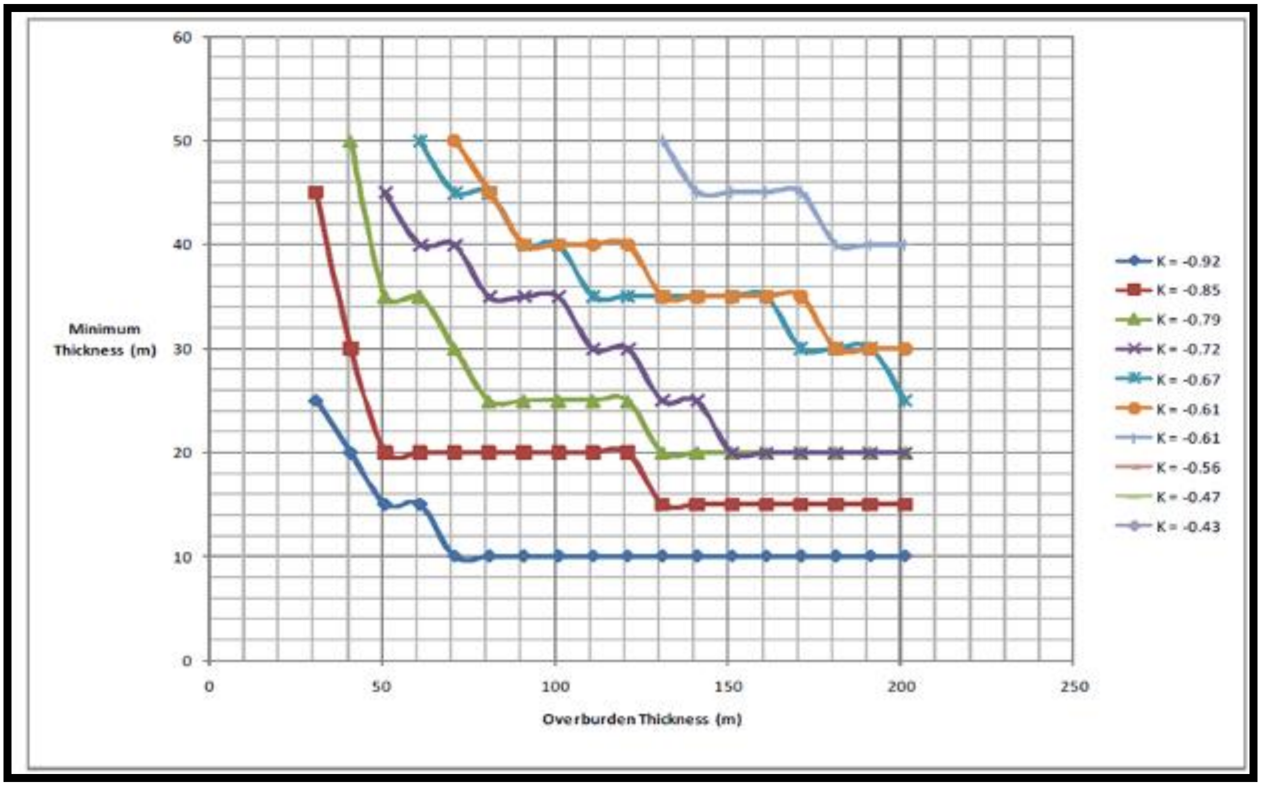


Figure 5: Plot of Minimum Thickness of the Confined Fractured Basement Column Allowing for Detectability against Overburden Thickness for Different Resistivity Reflection Coefficient (k) Values.

thickness ratio (i.e., the thickness of the confined fractured basement column divided by the cumulative thicknesses of the overlying layers) from which the inflection characterizing the presence of the confined fractured basement column began to emerge on the VES curve at different resistivity reflection coefficient values for which the confined fractured basement column becomes detectable on the VES curve ranging from shallow depth (31 m) to deep depth (201 m) of burial were 0.81 - 0.05 for k = -0.92; 1.45 - 0.07 for k = -0.85; 1.22 - 0.10 for k = -0.79; 0.88 - 0.10 for k = -0.72; 0.82 - 0.12 for k = -0.67; 0.70 - 0.15 for k = -0.61 and 0.38 - 0.20 for k = -0.56. It can also be noted that none of the range of thickness ratios modeled allowed for detectability on the VES curve for resistivity reflection coefficient values of -0.52, -0.47 and -0.43.

Other Observations

For further clarification, a plot of the minimum thickness of the confined fractured basement column from which the inflection characterizing the presence of the confined fractured basement column began to emerge on the VES curve against their respective overburden thickness for different resistivity reflection coefficient values from Table 3 is presented in Figure 5. It can be observed from this plot that for each resistivity reflection coefficient (k) value, the minimum thickness of the confined fractured basement column for which the inflection characterizing the presence of the confined fractured basement column began to emerge on the VES curve decreases with increasing overburden thickness. This implies that at smaller overburden thicknesses i.e. at shallow depth of burial, larger thickness of the confined fractured basement column are required for detectability on the VES curve than at greater overburden thicknesses where smaller thickness of the confined fractured basement column began to allow for detectability on the VES curve. This suggests that some thickness of the confined fractured basement column which did not allow for detectability at smaller overburden thickness allowed for detectability at greater overburden thickness for different resistivity reflection coefficient (k) values. A graphical illustration of this observation is shown in Figure 6 where VES curves for a 15 m thick confined fractured basement column buried at 31 and 201 m are superimposed for resistivity reflection coefficient (k) value of -0.92.

It can be observed from this plot that a four-layer HA-type VES curve resulted from the modeling of a five–layer geologic model containing a 15 m thick confined fractured basement column buried at 31 m. Analyzing the resultant VES curve by the visual inspection method earlier discussed, it was noted that the inflection characterizing the presence of the confined fractured basement column did not emerge on the VES curve whereas when another five–layer geologic model containing a 15 m thick confined fractured basement column buried at 201 m was modeled, the resultant VES curve was a five-layer HKH-type curve indicating the detectability of the confined fractured basement column on the VES curve by an inflection along the rising (basement) segments of the VES curve.

Likewise, it was also observed that the width of the inflection characterizing the presence of the confined fractured basement column on the VES curve for the same thickness of the confined fractured basement column at smaller overburden thickness is smaller than that at greater overburden thickness for the same resistivity reflection coefficient (k) value. This simply imply that the mathematical behavior of the Vertical Electrical Sounding (VES) curve allow for improved imaging of the confined fractured basement columns at deep depth than at shallow depth of burial. This observation is illustrated graphically in Figure 7 where VES curves resulting from the modeling of a five-layer geologic model containing a 30 m thick confined fractured basement column buried at 31 and 201 m (shallow and deep) allowing for detectability are superimposed for reflection coefficient (k) value of -0.92. It can be observed from this plot that the width of the inflection characterizing the presence of the 30 m thick confined fractured basement column at 201 m is greater than that at 31 m depth of burial.

Lastly, whenever the confined fractured basement column thickness is increasingly varied beyond the minimum thickness for which the inflection characterizing the presence of the confined fractured basement column began to emerge on the VES curve for specific overburden thickness and resistivity reflection coefficient value, the width of the inflection along the rising basements segment of the VES curve denoting the presence of the confined fractured basement column becomes more obvious and discernible as the thickness of the confined fractured basement column increases.

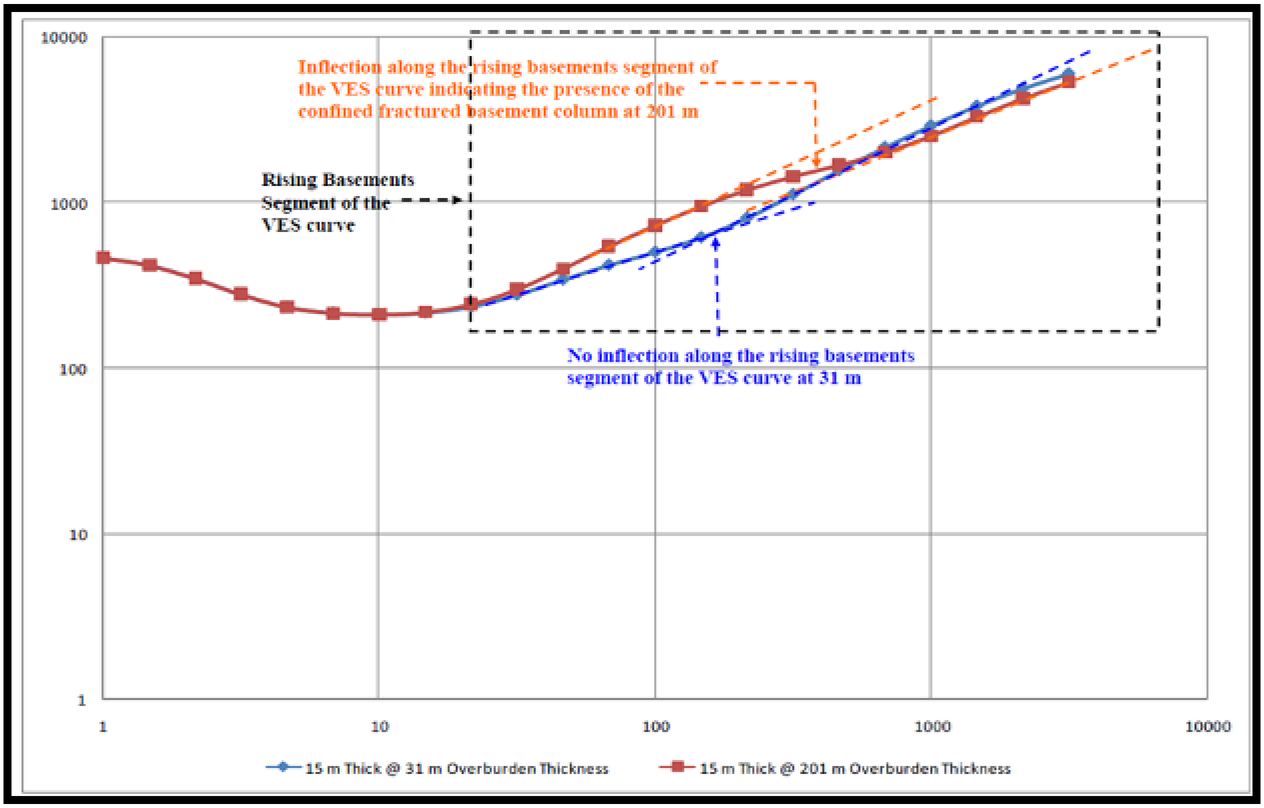


Figure 6: Superimposed VES Curve for 15 m Thick Confined Fractured Basement Column at Depths of 31 and 201 m for Resistivity Reflection Coefficient (k) Value of -0.92.

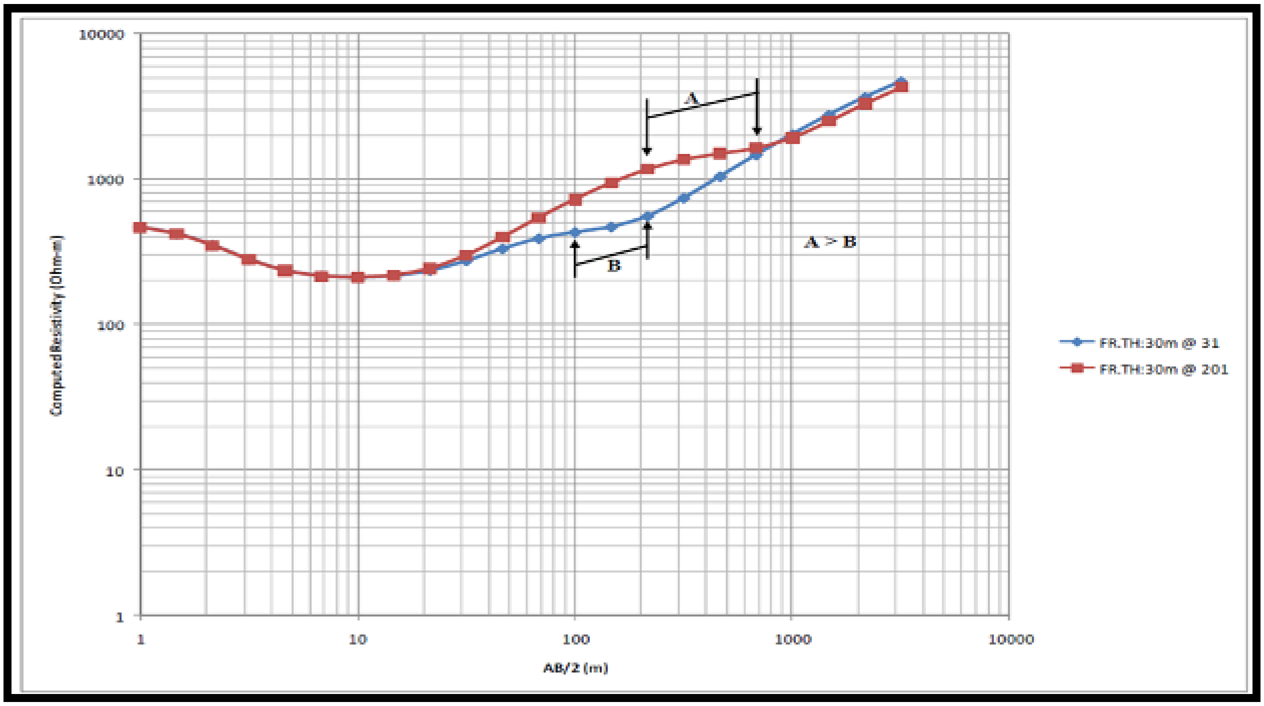


Figure 7: Superimposed VES Curve for 30 m Thick Confined Fractured Basement Column at Depths of 31 and 201 m for Resistivity Reflection Coefficient (k) Value of -0.92.

An example of this observation is illustrated in Figure 8 where VES curves resulting from a five-layer geologic model containing a confined fractured basement column with different thicknesses (10, 20, 30, 40 and 50 m) buried at the same depth of 31 m for resistivity reflection coefficient (k) value of -0.92 are superimposed. From this plot, as the thickness of the confined fractured basement column increases, the width of the inflection characterizing its presence on the VES curve also increases.

CONCLUSION

It can be concluded from the results of this study that geoelectric sounding using the Schlumberger Vertical Electrical Sounding (VES) technique can resolve confined fractured basement column at depths of up to 250 m under some detectability criteria as presented in Table 3 and discussed above. However, It is worthy of note that these results are in agreement with Olayinka and Oladipo (1994) who posited that for a layer to be detectable, its thickness does not necessary have to be larger than its depth of burial, rather it could just be a fraction of the depth of burial and Zhody et al. (1974) who observed that the minimum relative thickness permitting for detectability can vary from less than 0.5 to well over 1.0. However, the present study indicates that the detectability of the confined fractured basement column on the VES curve is dependent on three parameters namely: the resistivity reflection coefficient (k) value between the confined fractured basement column and the overlying bedrock; the thickness of the confined fractured basement column; and the depth of burial.

The results obtained from this study are applicable to all other possible geologic models with the same thickness ratios and resistivity reflection coefficients (k) values or resistivity ratios obtained from varying the geoelectric parameters as justified by the principle of geoelectric equivalence.

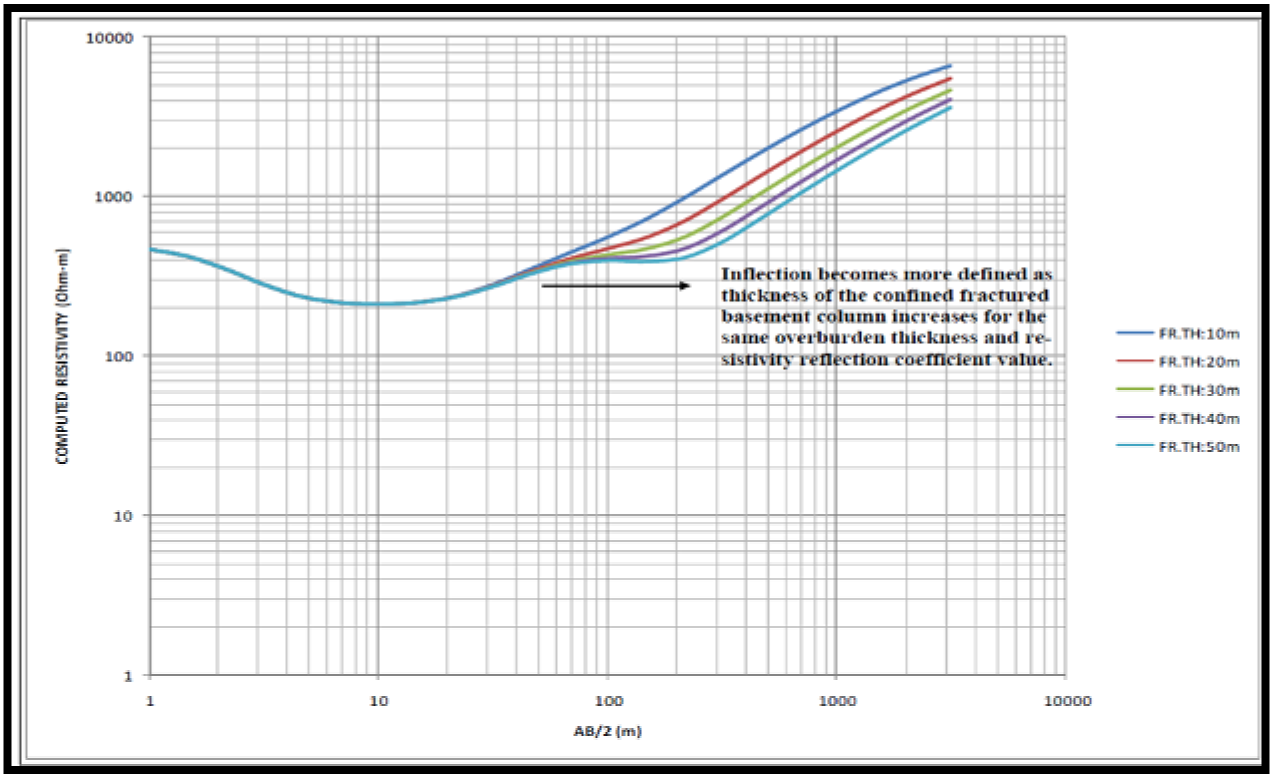


Figure 8: Superimposed VES Curve for Overburden thickness of 31 m and Confined Fractured Basement Column Thick of 10, 20, 30, 40 and 50 m for Resistivity Reflection Coefficient (k) Value of -0.92.

REFERENCES

1. Ademilua, O. L. 2007. “Computer Modelling and Detectability Assessment of the Transition Zone in the Basement Complex Terrain of Southwest Nigeria”. Unpublished Ph.D. Thesis. Dept. of Geology, Obafemi Awolowo University: Ile-Ife, Nigeria. 438.

2. Acworth, R.I. 1987. “The Development of Crystalline Basement Aquifers in Tropical Environment”. *Quarterly Journal of Engineering Geology*. 20:265-272.

3. Beeson, S. and C.R.C. Jones. 1988. “The Combined EMT/VES Geophysical Method for Siting Boreholes”. *Groundwater*. 26(1):54-63.

4. Buckley, D.K. and P. Zeil. 1984. “The Character of Fractured Rock Aquifer in Eastern Botswana”. IAHS publication. No 144:25-36.

5. Hazel, J.R.T., C.H. Cratchley, and A.M. Preston. 1988. “The Location of Aquifers in Crystalline Rocks and Alluvium in Northern Nigeria with Resistivity Techniques”. *Quarterly Journal of Engineering Geology*. 21:159-175.

6. Irshad, R.M. 1976. “Finite-Difference Resistivity Modelling for Arbitrarily Shaped Two-Dimensional Structures”. *Geophysics*. 41(1):62-78.

7. Olayinka, A.I. 1990. “Electromagnetic Profiling and Resistivity Soundings in Groundwater Investigation near Egbeda-Kabba, Kwara State”. *Journal of Min. and Geol*. 26: 243-250.

8. Olayinka, A.I. and A.O. Oladipo. 1994. “A Quantitative Assessment of Geoelectrical Suppression in Four-Layer HA-type Earth Model”. *Journal of Min. and Geology*. 30(2):251-258.

9. Olorunfemi, M.O. 2008. “Voyage on the Skin of the Earth: A Geophysical Experience”. Inaugural Lecture Series 211, Obafemi Awolowo University: Ile-Ife, Nigeria. March 11, 2008.

10. Olorunfemi, M.O., V.O. Olarewaju, and O. Alade. 1991. “On the Electrical Anisotropy and Groundwater Yield in a Basement Complex Area of S.W. Nigeria”. *Journal of African Earth Sciences*. 12(3):467–472.

11. Olorunfemi, M.O. and A.S. Fasuyi. 1993. “Aquifer Types and the Geoelectric/Hydrogeologic Characteristics of the Basement Terrain of Niger State, Nigeria”. J*ournal of African Earth Sciences.* 16(3):309-317.

12. Parasnis, D.S. 1994. *Principles of Applied Geophysics.* J. W. Arrowsmith Ltd.: Bristol, UK. 102-169.

13. White, C.C., J.F.T. Houston, and R.D. Barker. 1988. “The Victoria Province Drought Relief Project I. Geophysical Siting of Borehole”. *Groundwater*. 26:309-316..

14. Zohdy, A.A.R., G.P. Easton, and D.R. Mabey. 1974. “Application of Surface Geophysics to Groundwater Investigations”. U.S. Geological Survey Techniques of Water Resources Investigations. Book 2, Chapter D1.

ABOUT THE AUTHORS

Adebayo Oluwaseun Ojo, received his B.Sc. degree in Engineering Physics and M.Sc. degree in Applied Geophysics, from the Obafemi Awolowo University, Ile-Ife, Nigeria. He is currently preparing for a Ph.D. degree program in Applied Geophysics.

Olorunfemi Martins Olusola is a Professor of Applied Geophysics in the Department of Geology, Obafemi Awolowo University, Ile-Ife. He received his B.Sc., from the University of Ife, Ile-Ife, Nigeria with first class honors, after which he proceeded to the University of Birmingham, U.K., for his M.Sc. and Ph.D., both in Applied Geophysics. He has edited several journals at the local, national, and international levels. He researches in groundwater, environmental, mineral, and engineering geophysics.

SUGGESTED CITATION

Ojo, A.O. and M.O. Olorunfemi. 2013. “Resistivity Modeling of confined Fractured Basement Column for varying Thicknesses and Depth of Burial”. *Pacific Journal of Science and Technology*. 14(1):464-475.

Pacific Journal of Science and Technology