KAOLIN QUANTIFICATION IN UKWU-NZU AND UBULU-UKU USING ELECTRICAL RESISTIVITY METHOD

J.C. Egbai
Department of Physics, Delta State University, Abraka, Nigeria
E-mail: jamesegbai@yahoo.com

ABSTRACT

Vertical electrical sounding (VES) using Schlumberger electrode configuration was carried out at Ukwu-Nzu and Ubulu-Uku both at Aniocha North Local Government Area of Delta, Nigeria. The survey was aimed at investigating kaolin deposit within the two communities. A total of 12 VES stations, six from each community uniformly distributed within the surveyed areas were carried out. The data from the field was interpreted using the conventional curve matching and computer iteration techniques where the geoelectric model parameters and curves were obtained. The results reveal four to eight distinct geoelectric layers namely topsoil laterite, kaolin, sandy clay, medium grained sand, clay, gravel and coarse gravel, with their various resistivities and thicknesses.

The investigated areas were divided into four rectangular and four square blocks for Ukwu-Nzu and Ubulu-Uku respectively. The analysis shows that reserve of kaolin deposit was established as 401,235.84 tonnes and 69535.44 tonnes. The volume of the overburden to be excavated was estimated as 33720.00m^3 and 21,384.00m^3 for Ukwu-Nzu and Ubulu-Uku respectively. The quantity of kaolin deposits in these two communities may not be enough for commercial purpose but could be mined locally for local advantage.

Keywords: *kaolin deposits, resistivity soundings, geoelectric, clay, Ubulu-Uku, Ukwu-Nzu, lithology.*

1. INTRODUCTION

Kaolin is a clay mineral made up of aluminum, silicon and water. It is a hydrated silical of aluminum with a composition of silica of aluminum with an approximately 46% sio_2, 40% $Al_2 0_3$ and 14% H_20. There are two types of kaolin in sedimentary rock based on their geological origin. These are the primary and secondary kaolin.

The primary kaolin is found and originated from parent rock and have not been transferred by the force of nature. This class of kaolin is purer in nature.

The secondary kaolin are kaolin that have been removed or eroded, transported and deposited as sediment from the site of their parent rock by the force of nature such as water, wind, or glacial action. As transportation and deposition was going on, they become contaminated with material of different origin.

Kaolin formation results as a result of the alteration of the feldspar of granites. This alteration may be caused by the process of ordinary weathering of feldspar first, into clay mineral to kaolin with less water. It is also formed by the action of gases on the feldspar deposit formed as a result of intrusion of granite associated with some special set of mineral such as cassiterites and other minerals of pnevmatolytic origin.

Kaolin as a mineral is described technically as a white alumina-silicate. It does not react with other materials and is insoluble in water. It is used in the manufacture of paint, paper, soap, ink, textile, pharmaceutical, ceramic, and tyre manufacturing industries Egbai [1]. In the Agricultural sector, it is used to help control damage to fruits and vegetables from insects, termites, fungi. In homes, it is used to manufacture ceiling boards used to protect sunburn and heat stress. In the paint manufacturing industry for instance, kaolin is used to create the effect of whiteness as well as hold every other ingredients together. The degree of whiteness of any paint, therefore, depends on the quality or grade of kaolin being used in its manufacture Oruobu [2].

The search for kaolin starts with geophysical survey, exploring areas where the deposits are suspected Egbai [1]. This study is aimed at determining the existence and quantity of kaolin in Ukwu-Nzu and Ubulu-Uku areas of Aniocha-North of Delta State. The survey was carried out using the electrical resistivity method.

The electrical resistivity method is commonly used in engineering site investigation. It is useful in depth to bedrock determination, structural mapping, determination of nature of superficial deposits etc. Afolabi et al [3], Bisdorf [4], Lucius and Bisdorf [5], Bisdorf [6] and Egbai [1]. It is very useful in groundwater study in terms of quality study. Egbai [1], [7]. The method is very useful for mineral exploration e.g. Afolabi et al [3] used the method to investigate the reserve of kaolin deposit as well as the excavable overburden of the mineral. Egbai [1] used the vertical electrical sounding (VES) method to study kaolin deposit in Ozanogogo area in Ika South Area of Delta State.

The study was carried out in the determination of the reserve of kaolin deposits in Ubulu-Uku and Ukwu-Nzu respectively. The excavable volume of the overburden over the deposit will be determined to ascertain if the mining operation will be profitable or not.

Further work on kaolin qualification and electrical resistivity method could be seen from research carried out by eminent Geophysicists such as Afolabi et al [3]; Olowolafe [8], Swart and Stewart [9]; Fretwell and Stewart [10]; Singh and Gilkes [11] and Casmir [12].

GEOLOGY OF THE AREA

The geology of these two areas could be seen from the work of Egbai, [1] and Egbai [7].

LOCATION

Ukwu-Nzu and Ubulu-Uku are both located in Aniocha North Local Government Area of Delta State. Ukwu-Nzu is located between latitude 06^0 23^1 and 06^0 25^1N and longitude 06^0 20^1 and 06^0 24^1E. It is located about 15km north of Issele-Uku, the headquarters of the local Government Area. Ubulu-Uku on the other hand is located between latitude 05^0 30^1 and 05^0 34^1N and longitude 06^0 30^1 and 06^0 35^1E. It is located about 20km South of Issele-Uku, the headquarters of the local Government Area. The sketch map of the studied area is as shown in Figure 1.

The vegetation of the study areas is that of rain forest having two seasons- the rainy and dry seasons. The rainy season starts from April to September while the dry season starts from October and ends in March. The inhabitants of these areas are peasants' farmers who practice subsistence farming.

Ubulu-Uku has no source of water like streams or rivers. The Government borehole is not functioning since the subsurface ground water is extremely low. The inhabitants of Ubulu-Uku only depend on rain water collected in tanks or wells. Ukwu-Nzu on the other hand suffers the same scarcity of water. The town has a spring which is very far (about 5km) from the town. The spring is about 40.0m deep below sea level and flows northwards.

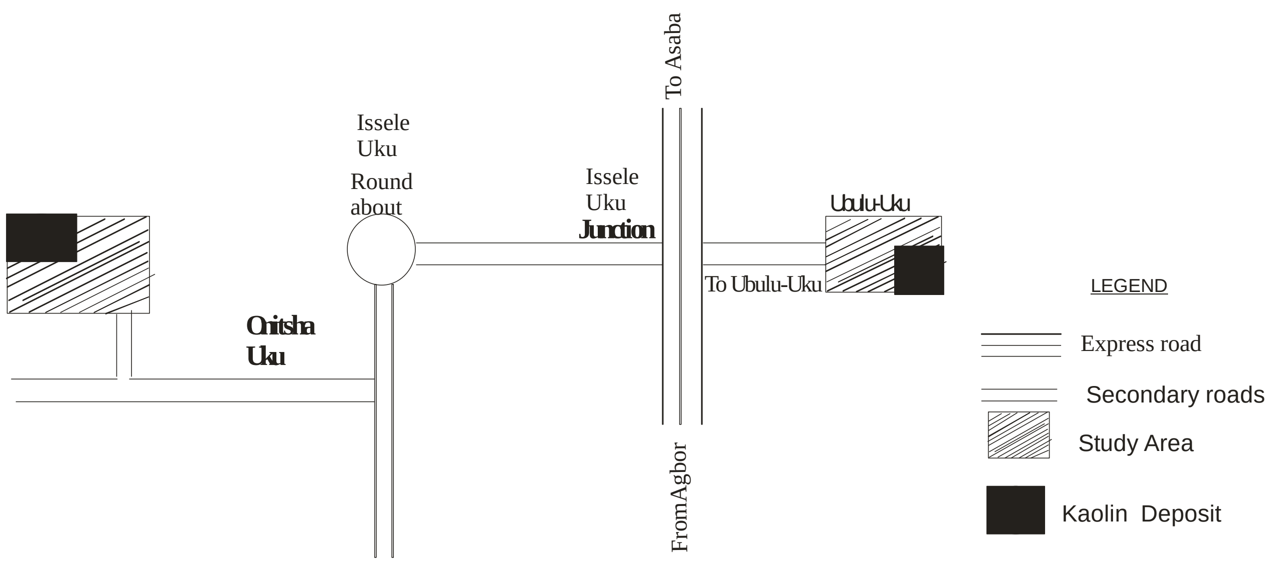


Figure 1: sketch map of the studied area

METHODOLOGY

The geophysical survey was carried out in the two communities of Ubulu-Uku and Ukwu-Nzu both in Aniocha North Local Government of Delta State, Nigeria to determine kaolin reserve deposit, and the volume of excavable overburden.

The Schlumberger electrode configuration was carried out for data collection. The Abem Terrameter SAS 1000B with an inbuilt booster for greater current injection into the subsurface was used for exploration in the field. A total of 12 sounding stations were carried out, six from each community. A pit dug for local mining was used as test pit which provided information about the subsurface lithology of the two communities- Ukwu-Nzu and Ubulu-Uku. The Block diagrams for the two communities are shown in figure 2.

The data got from the field were presented as VES curves which were interpreted quantitatively by applying the curve matching procedure after smoothening before computer base iterative technique using Resist software. The computer modeling results give, the layer resistivities and thicknesses of the subsurface. The curves are presented in Figure 3-6 for Ukwu-Nzu and 7-8 for Ubulu-Uku.

The areas covered in the two communities were divided into square blocks and rectangular blocks for Ubulu-Uku and Ukwu-Nzu respectively. The average kaolin thickness as well as the overburden thickness were determined from the model parameters of the iterated values. The square and rectangular blocks surface area and the thickness within each block were used to calculate the volume of kaolin and overburden Egbai [1]. Standard density bottle was used in the determination of density of kaolin by displacement method. This was done three times and the average determined. The density of kaolin from displacement method was 2.469g/cm^3 and 2.47g/cm^3 for Ukwu-Nzu and Ubulu-Uku respectively. The product of the volume and density gave the reserve of the kaolin deposit.

(A)

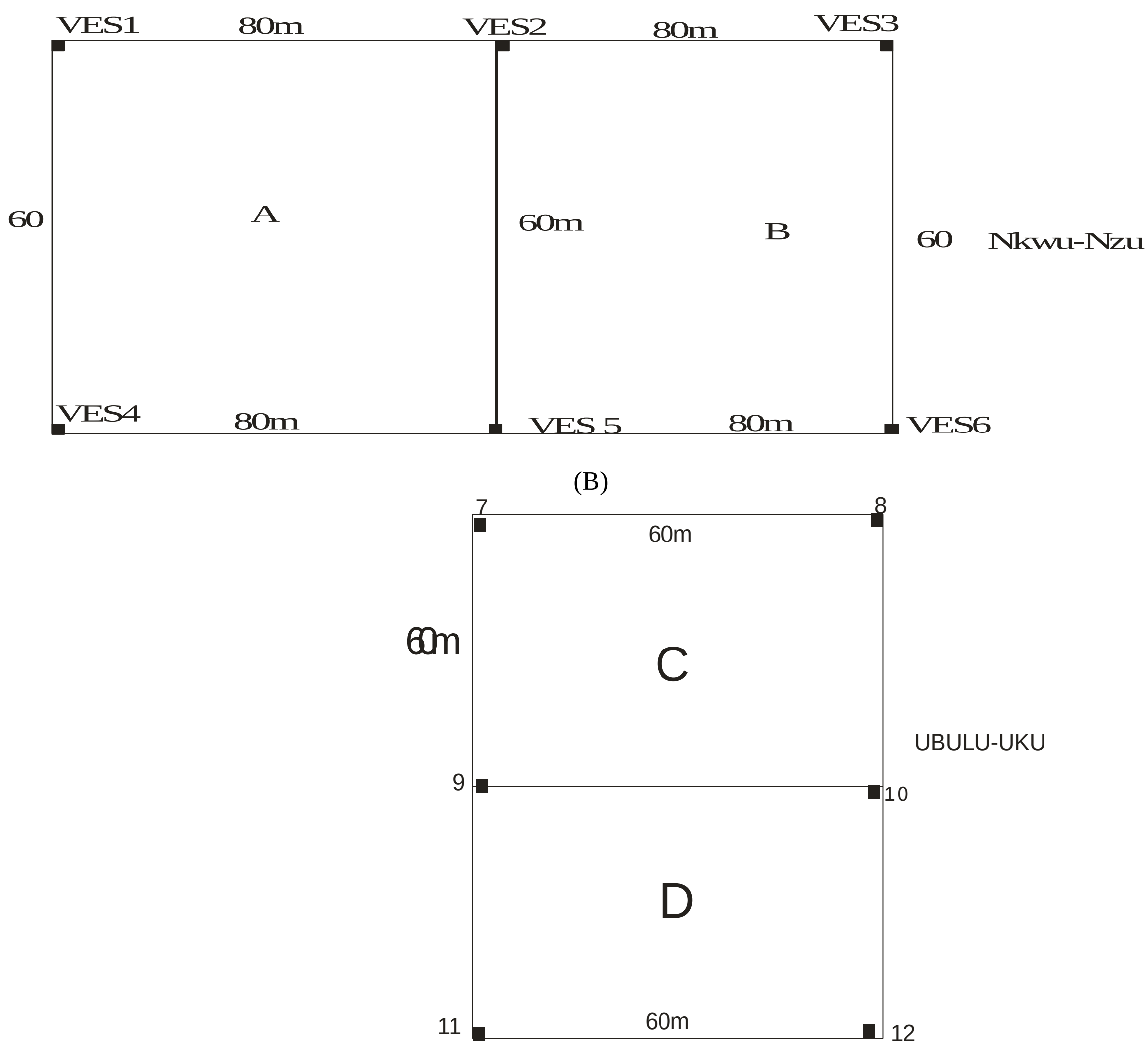
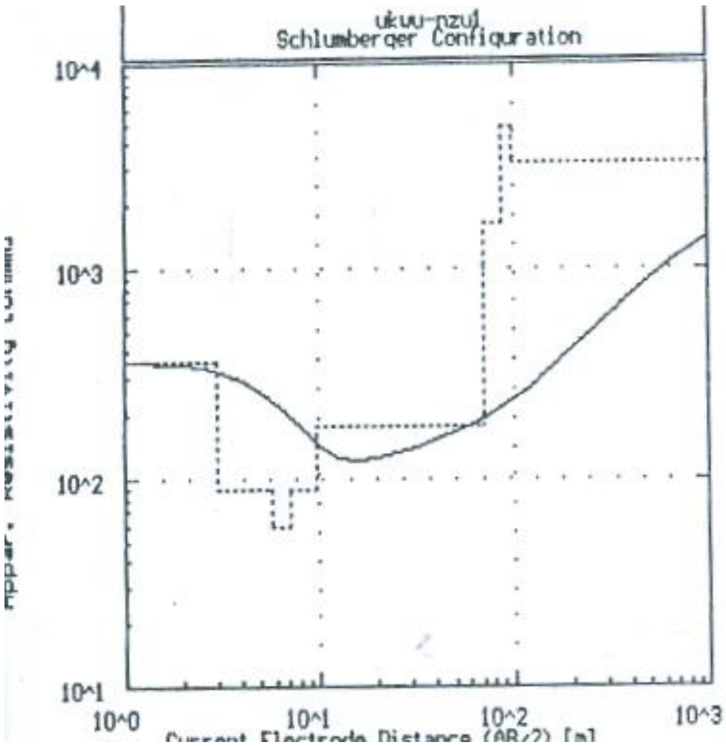


Figure 2: Block diagrams for VES in the (A) Ukwu-Nzu and (B) Ubulu-Uku.

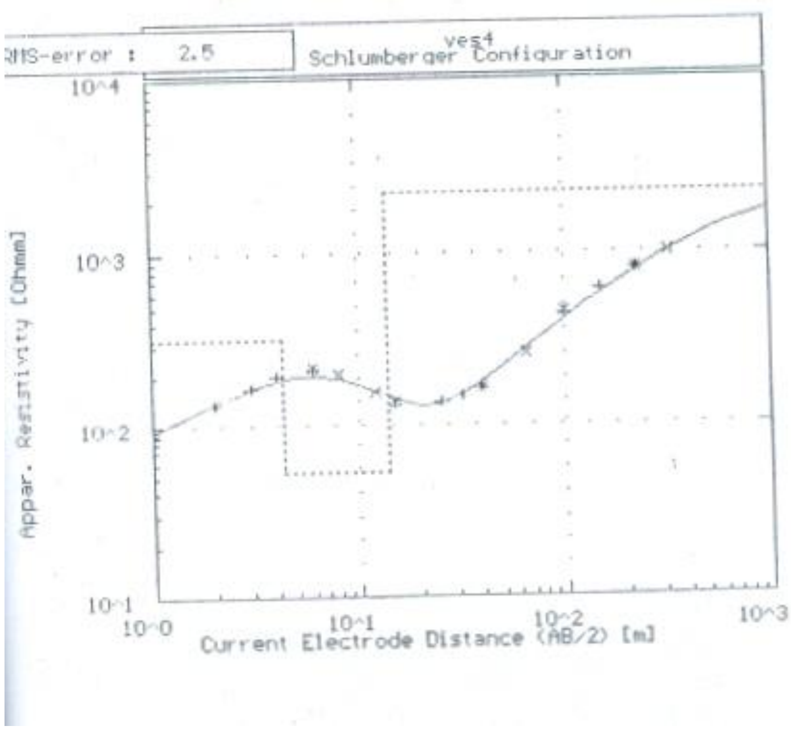
Table 1: **MODEL PARAMETER FOR AND LITHOLOGY FOR UKWU-NZU**

VES STATION	LAYER NUMBER	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology	Curve Type
1	1	716.2	0.5	0.5	Top soil	
	2	210.1	0.6	1.1	Clay laterite	
	3	447.6	19.0	20.1	Kaolin	
	4	553.8	12.8	32.9	Sandy clay	
	5	14980.0	28.8	61.7	Gravel sand	
	6	2302.0			Coarse gravel	
2	1	360.0	3.0	3.0	Topsoil	
	2	90.0	2.7	5.7	Clay	
	3	60.0	1.4	7.1	Kaolin	
	4	90.0	2.6	9.7	Clay	
	5	180.0	60.7	70.4	Clay sand	
	6	1620.0	16.7	87.1	Smooth	
	7	4860.0	10.0	97.1	Smooth gravel	
	8	3240.0			Coarse gravel	
3	1	166.7	0.9	0.9	Top soil	
	2	3555.5	0.1	1.0	Gravel	
	3	153.5	3.6	4.6	Clay	
	4	340.6	34.5	39.1	Kaolin	
	5	5402.2	171.7	210.8	Gravel	
	6	8174.2			coarse	
4	1	68.3	0.6	0.6	Top soil	
	2	329.9	3.6	4.2	Laterite	KA
	3	52.8	9.5	13.7	kaolin	
	4	2273.9	-	-		
5	1	384.7	0.7	0.7	Topsoil	
	2	1252.9	2.1	2.8	Laterite	KA
	3	418.5	33.7	36.5	Kaolin	
	4	6259.8	∞	∞		
6	1	225.5	0.4	0.4	Top soil	
	2	1538.3	0.8	1.2	Coarse sand	KHA
	3	104.9	2.7	3.9	Kaolin	$\rho_1 < \rho^2 > \rho_3 < \rho_4 < \rho_5$
	4	723.6	181.0	184.9	sand	
	5	17754.2	∞	∞		



No	Res	Thick	Depth
1	360.0	3.0	3.0
2	90.0	2.7	5.7
3	60.0	1.4	7.1
4	90.0	2.6	9.7
5	180.0	60.7	70.4
6	1620.0	16.7	87.1
7	4860.0	10.0	97.1
8	3240.0	-.-	-.-

Fig 3: Ukwu-Nzu (VES 2)



No	Res	Thick	Depth
1	68.3	0.6	0.6
2	329.9	3.6	4.3
3	82.8	9.5	13.7
4	2273.9	-.-	-.-

* RMS on smoothed data

Fig 4: Ukwu-Nzu (VES 4)

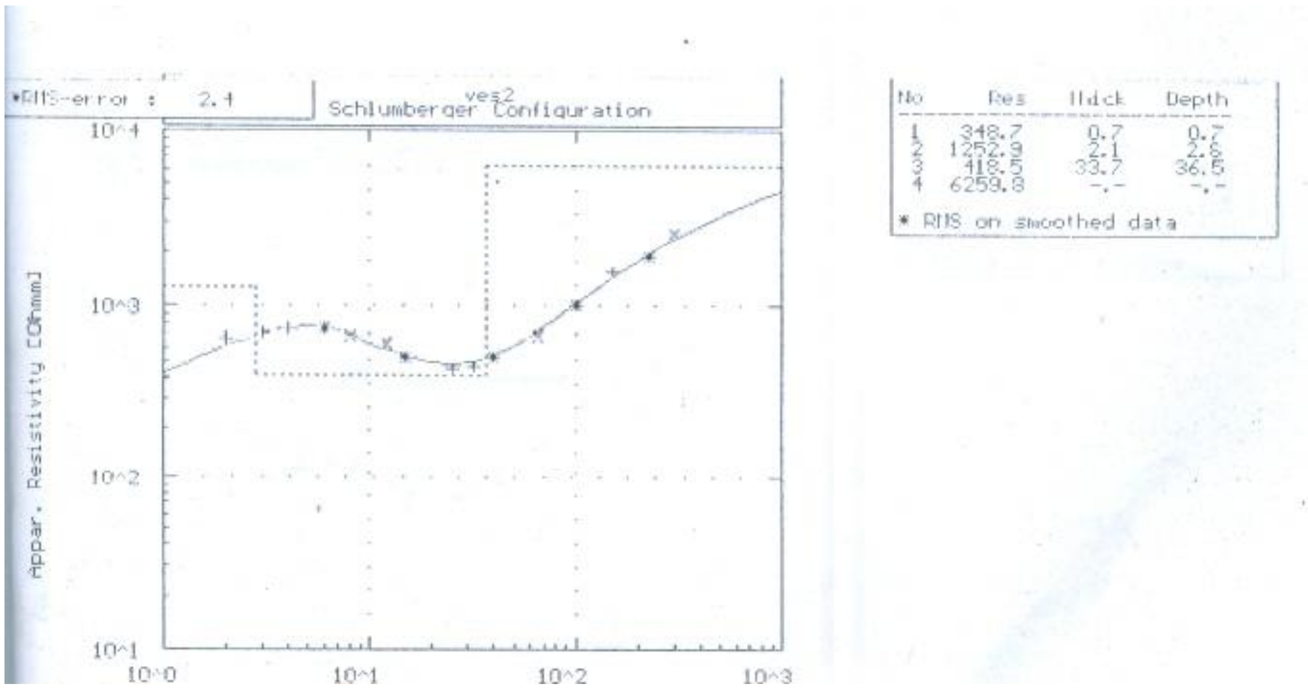


Fig 5: Ukwu-Nzu (VES 5)

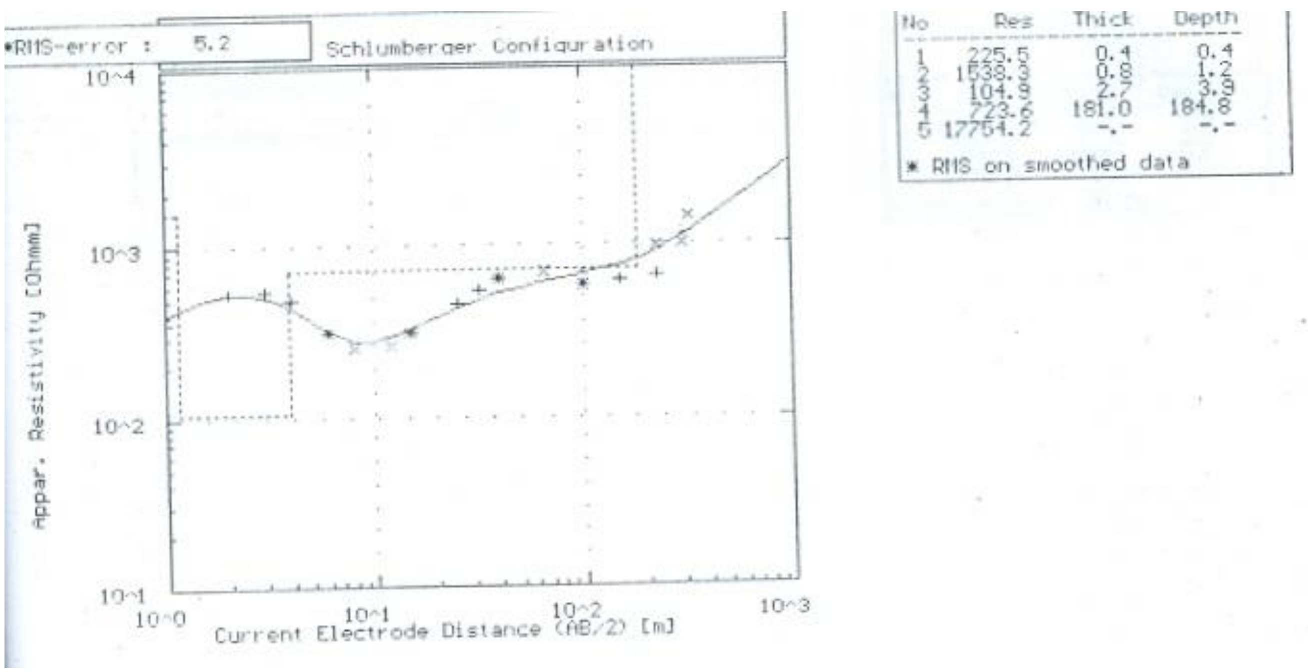


Fig 6: Ukwu-Nzu (VES 6)

Table 2: MODEL PARAMETER AND LITHOLOGY FOR UBULU-UKU

7	1	1212.6	1.7	1.7	Top soil	
	2	3872.9	0.1	1.8	Coarse gravel	
	3	3477.5	14.8	16.6	Gravel sand	
	4	331.1	46.0	62.6	Kaolin	
	5	3929.9	∞	∞	Coarse gravel	
8	1	33.0	0.4	0.4	Kaolin	
	2	1626.4	0.4	0.8	Medium grained sand	
	3	7013.0	4.3	5.1	Coarse gravel	
	4	610.3	56.2	1.3	Clayey sand	
	5	532.2	∞	∞	Coarse sand	
9	1	49.6	0.5	0.5	Top soil	
	2	1278.2	0.6	1.1	Medium grained sand	
	3	317.5	5.2	6.3	Kaolin	
	4	665.6	19.6	25.9	Sandy clay	
	5	1362.5	34.6	60.5	Gravel	
	6	3702.5	20.0	80.5	Coarse gravel	
	7	1133.9	∞	∞		
10	1	2910.2	0.8	0.8	Gravel sand	
	2	403.0	2.5	3.3	Kaolin	HA
	3	3981.9	44.3	47.6	Gravel	$\rho_1 > \rho_2 < \rho_3 < \rho_4$
	4	6093.1	∞	∞	Coarse gravel	
11	1	161.7	0.7	0.7	Top soil	
	2	111.3	1.0	1.7	Kaolin	HAK
	3	793.1	8.4	10.1	Sand	$\rho_1 > \rho_2 < \rho_3 < \rho_4 > \rho_5$
	4	6285.7	27.3	37.4	Coarse gravel	
	5	68.8	∞	∞	Clay	
12	1	63.4	0.6	0.6	Top soil	
	2	260.0	2.06	2.66	Clayey soil	
	3	112.0	9.04	11.70	Kaolin	$\rho_1 < \rho_2 > \rho_3 < \rho_4 > \rho_5 > \rho_6$
	4	1178.0	12.80	24.50	Sand	
	5	77.8	84.7	109.2	Clay	
	6	8129.0	∞	∞	Coarse gravel	

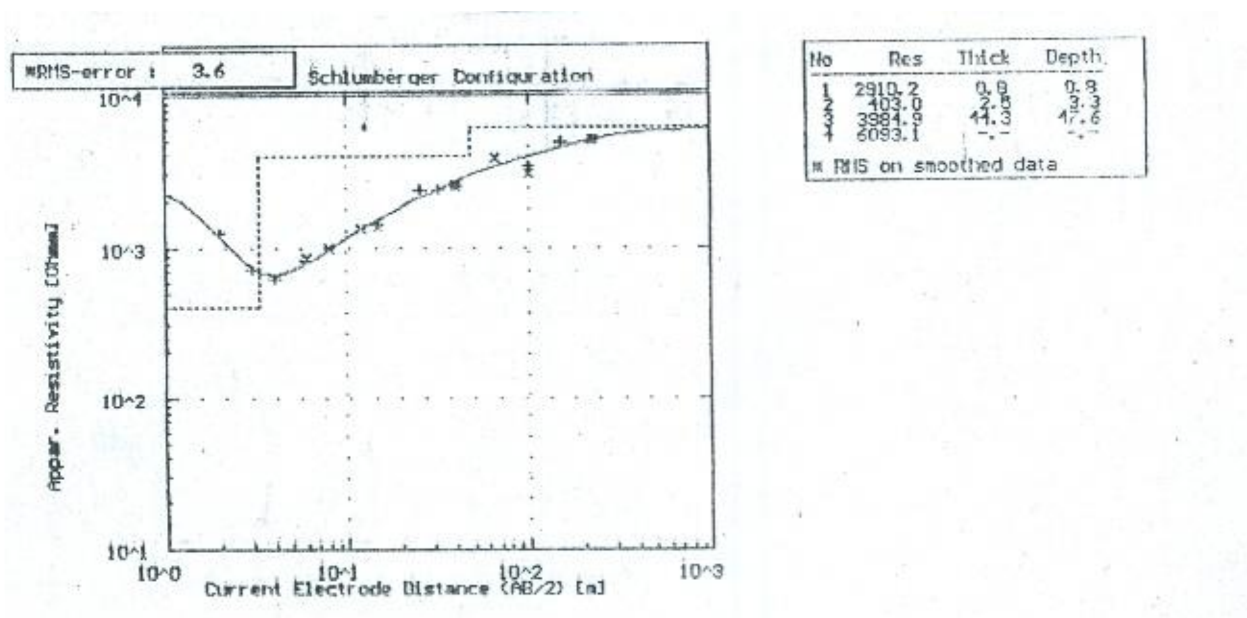


Fig 7: Ubulu-Uku (VES 10)

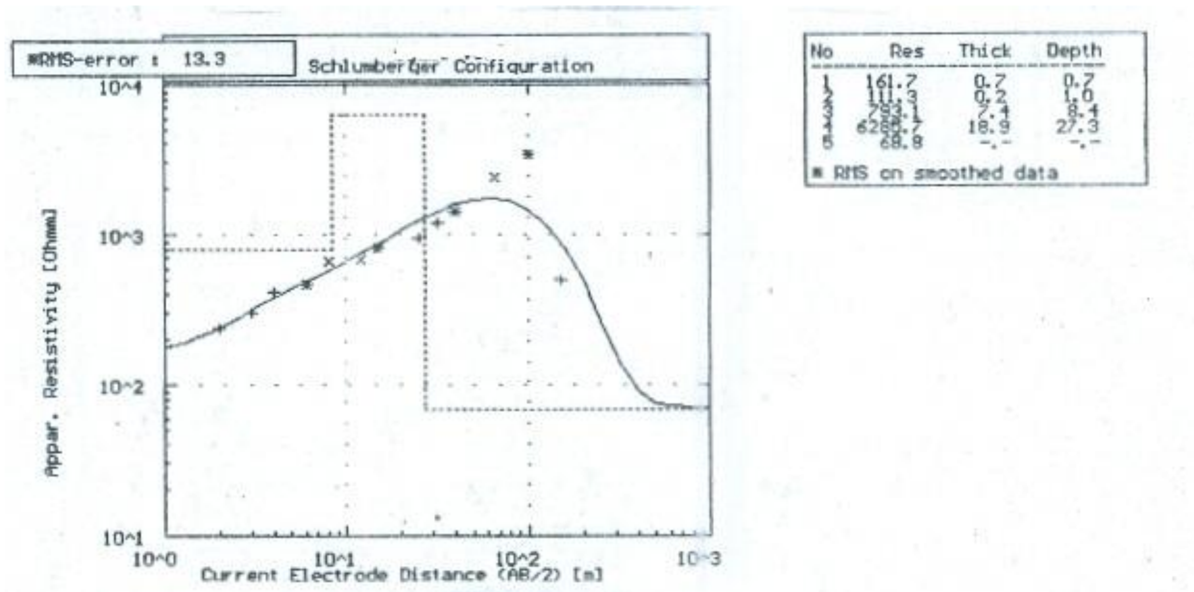


Fig 8: Ubulu-Uku (VES 11)

Table 3: Estimation of Volume of Kaolin from VES survey.

Block	Point of Sounding	Thickness from Model parameter (m)	Mean Thickness (m)	Area of Block m^2	Volume of Kaolin m^3
A	1	19.0			
	2	1.4	15.90	4800.00	76320.00
	4	9.5			
	5	33.7			
B	2	1.4			
	3	34.5	18.08	4800.00	86784.00
	5	33.7			
	6	2.7			
Total					163,104.00
C	7	46.0			
	8	0.4	3.38	3600.00	1268.00
	9	5.2			
	10	2.5			
D	9	5.2			
	10	2.5	4.44	3600.00	15984.00
	11	1.0			
	12	9.04			
Total					28152

=Density × Volume

Volume = 163104 m^3

Total volume of Kaolin at Ukwu-Nzu

$=163104 \times 2.46 \times 10^3$kg

$=401235.84 \times 10^3$kg

=401,235.84 tonnes.

UBULU-UKU

Mass = Volume × Density

$28152 \times 2.47 \times 10^3$kg

$=69535.44 \times 10^3$

$= 69.535 \times 10^3$

=69535 tonnes.

Table 4: VOLUME ESTIMATION OFOVERBURDEN FROM VES VALUES FOR UKWU-NZU AND UBULU-UKU.

BLOCK	Point of sounding	Thickness from model parameter (m)	Mean Thickness (m)	Area of Block (m^2)	Vol of Overburden (m^3)
A	1 2 4 5	1.1 5.7 4.2 2.8	3.45	4800	16560.00
B	2 3 5 6	5.7 4.6 2.8 1.2	3.58	4800	17160.00
Total					33720.00
C	7 8 9 10	16.6 - 1.1 0.8	4.63	3600	16650.00
D	9 10 11 12	1.1 0.8 0.7 2.66	1.32	3600	4734.00
Total					21384.00

Volume of overburden for Ukwu-Nzu (A and B)
= Area × mean thickness
= $33720.00m^3$

Volume of overburden for Ubulu-Uku (C and D)
= $21384.00m^3$

RESULTS AND DISCUSSION

The geoelectric sections show four to eight distinct layers. Location (VES) 4, 5 and 10 are four layers, 6, 7, 8 and 11 are of five layers, while 1, 3, 12 are made of six layers. Others are VES 9 made of seven layers and VES 2 is of eight layers. VES 1 to 6 are of Ukwu-Nzu locations while VES 7 to 12 are equally of Ubulu-Uku locations.

The geoelectric for Ubulu-UKu for VES 1 at Ukwu-Nzu shows six distinct varying from topsoil, clay, kaolin, sandy clay, gravel sand and coarse gravel. The topsoil has thickness varying from about 0.0m to 0.5m with resistivity of 716.2 Ωm. The second layer is lateritic clay with resistivity values ranging from 210.0 Ωm to 716.2 Ωm and thickness varying from 0.5m to 0.6m. The third layer is made of kaolin having resistivity values ranging from 210.1 Ωm to 447.6 Ωm and thickness ranging from 1.1m to 19.0m. The fourth layer is made of sandy clay having resistivity values ranging from 447.6 Ωm to 553.8 Ωm and thickness 20.1 to 39.9m. The fifth layer is of gravel sand having resistivity values ranging from 553.8 Ωm to 14980.0 Ωm and thickness varying from 32.9m to 61.7m. The sixth layer is made up of coarse gravel with resistivity values ranging from 2302.0 Ωm to infinity.

The geoelectric sections for VES 2 to 6 are shown in table 1 model parameters and lithology for Ukwu-Nzu. Blocks A and B are rectangular for Ukwu-Nzu. The resistivity for Block A ranges from 52.8 Ωm to 14980.0 Ωm with average thickness of 15.9m while the resistivity for Block B ranges from 60.0 Ωm to 17754.2 Ωm with average thickness of 18.08m.

The geoelectric section of VES 7 at Ubulu-Uku is five layers varying from topsoil, coarse gravel, gravel sand, kaolin and coarse gravel. The resistivity for the topsoil is about 1212.6 Ωm with thickness of about 1.7m. The second layer is made of coarse gravel has resistivity values ranging from 1212.6 Ωm to 3872.9 Ωm with thickness ranging from about 1.7m to 1.8m. The third layer is gravel sand with resistivity ranging from 3477.5 Ωm to 3872.9 Ωm and thickness ranging from about 1.8m to 16.6m. The fourth layer is kaolin deposit with resistivity of about 331.1 Ωm and thickness of about 46.0m. The fifth layer is of coarse gravel with resistivity values of 3929.9 Ωm and above. The geoelectric section for VES 8 to 12 are shown in the table for model parameters and lithology for Ubulu-Uku.

Block C and D for Ubulu-Uku are square blocks. The resistivity for Block C ranges from 33.0 Ωm to 7013.0 Ωm with average thickness of about 3.38 Ωm while the resistivity for block D ranges from 49.6 Ωm to 8129.0 Ωm and average thickness of about 4.44m.

RESERVE QUANTIFICATION OF KAOLIN FROM MODEL PARAMETER

The site investigated in Ukwu-Nzu is of rectangular shaped with two square blocks. The thickness of Block A and B were calculated from the model parameter and the mean thickness calculated. The mean thickness was calculated as

15.90m and 18.08m for Blocks A and B respectively. These values were used to calculate the volume of kaolin deposits in Ukwu-Nzu. This was equally done in the case of kaolin deposits at Ubulu-Uku.

The estimated kaolin thickness, area and volume for each block and the total volume of kaolin for both communities were calculated as shown in Table 3.

The total volume of kaolin within the two communities investigated are 163,104.00m^3 and 28,152.00m^3 for Ukwu-Nzu and Ubulu-Uku respectively.

The average density of kaolin from displacement method was 2.46g/cm^3 and 2.47g/cm^3 for Ukwu-Nzu and Ubulu-Uku respectively. The product of the density and volume gave the reserve deposits of kaolin as 401,235.85 tonnes for Ukwu-Nzu and 69,535.44 tonnes for Ubulu-Uku.

VOLUME ESTIMATION OF OVERBURDEN FROM MODEL PARAMETERS

The volume of the excavable overburden was calculated in a similar way as that of kaolin from model parameter of figure 3. The product of average thickness and area of each block gave the volume of the overburden.

Table 4 shows the estimated overburden volume as 33720.00m^3 and 21,384.00m^3 for Ukwu-Nzu and Ubulu-Uku respectively.

CONCLUSION

This paper describes the electrical resistivity survey method in the determination of kaolin deposits in Ukwu-Uku and Ubulu-Uku communities in Aniocha North Local Government Area of Delta State. A total of 12 Schlumberger vertical Electrical soundings six each from each community were uniformly distributed within the survived areas. The data obtained from the field were presented as VES curves.

The result obtained was very reliable when compared with the driller's log obtained from the community. There was high correlation between VES survey and the driller's log of the locations making the method very reliable.

The reserve of kaolin deposit within the area under study is estimated to be approximately 401,235.84 tonnes for Ukwu-Nzu and 69,535.44 tonnes for Ubulu-Uku. The escavable volume of overburden is estimated to be 33720.00 m^3 and 21,384.00m^3 for Ukwu-Nzu and Ubulu-Uku respectively.

The deposits may not be mined economically for industrial purpose because of low quantity. It could be mined locally for the production of ceramic, paint, etc. The overburden thickness ranges from 0.4m to about 14.8m hence surface mining could be carried out locally. Results show that there may be kaolin deposits beyond the area studied. Further investigation is herby recommended to study kaolin deposit beyond the studied areas.

ACKNOWLEDGEMENT

I wish to express my profound thanks to my final year students of 2010/2011 academic session for the field work carried out where the data were collected for this research. My wife, Lady Egbai, F.O is highly acknowledged for her contribution, morally and financially.

REFERENCES

[1]. Egbai, J.C 2011, Vertical Electrical Sounding for the investigation of kaolin deposits in Ozanogogo Area of Ika South Local Government Area of Delta State, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2(1): 147-151

[2]. Oruobu, D (2004) Kaolin as bedrock of manufacturing industry. Business Times, Monday, June 22 p.12

[3]. Afolabi, O; Olunfemi, M.O; Olagunju, A.O; and Afolayan J.F, 2004, Resource Quantification of kaolin deposit using the Electrical Resistivity method – Case study from Ikere Ekiti, South west Nigeria. Ife Journal of Science vol. 6 no:1 pp35-40.

[4]. Bisdorf R.J. 1985: Electrical techniques for engineering applications. Bulletins of the Association of Engineering Geologists Vol. XXII, No.4 pp 421-433. U.S Geological survey open-file report pp. 96-668.

[5]. Lucius, J.E and Bisdorf, R.J., 1995. Sult of geophysical investigations near the Norman, Oklahoma, Municipal land fill. U.S. Geological survey open file report 93-524

[6]. Bisdorf, R.J. 1996 Schlumberger soundings at the Norman landfill, Norma Oklahoma. U.S geological survey Open-file Report pp. 96-668.

[7]. Egbai 2012: Geological Evaluation of Groundwater potential in the sedimentary Region of Abavo Delta State and Urhonigbe, Edo State. Int. Journal of Research and Reviews in applied Science (IJRRAS) 10 (3) 491-498

[8]. Olowolafe, O.M; 1991. Electrical resistivity survey of a kaolin deposit at Ubulu-Uku area of Delta. Unpublished B.Sc Project, Department of Geology , OAU, Ile-Ife, Nigeria 122pp.

[9]. Swart, J.H and Stewart, M., 1981. Resistivity survey of a coastal karst terrain: Groundwater, 19, 219-223.

[10]. Fretwell, J.D and Stewart, M., 1981. Resistivity study of a coastal karst terrain, Groundwater, 19, 19-223.

[11]. Singh,B. and Gilkes, 1991.alteration of Cr-muscovite to kaolinite in a weathered quartzite.Clays and clay minerals 39, 571-579.

[12]. Casmir Akaolisa 2006, Aquifer transmissivity and Basement structure determination using Resistivity sounding at Jos, Plateau state, Nigeria. Environment Monitoring and Assessment, 114: 27-34.