EMPIRICAL CHARACTERIZATION OF ECONOMIC MINERAL (KAOLIN) DEPOSITS FROM VERTICAL ELECTRICAL SOUNDING INVESTIGATIONS IN UBULU-UKU, DELTA STATE NIGERIA

Emmanuel Chukwuemeka Okolie
Department of Physics, Delta State University Abraka, Nigeria
okoliepeace@yahoo.com

ABSTRACT

Ubulu-Uku is specifically characterized with heavy lateritic deposits to far depth. However, with its sloppy terrain which tends to terminate at springs and streams there are evidences of thick clay deposits at near surface in the slopes. The properties of this clay deposits seem to change rapidly and drastically into kaolinite. Kaolin is a solid mineral of traditional, medicinal and economic importance since numerous industries now use kaolin as raw material. It is therefore necessary to carry out empirical investigation in Ubulu-Uku, Delta State so as to determine Kaolin occurrence. Thus, five vertical electrical soundings with Schlumberger array were made across the town in selected sites using ABEM SAS 1000 terrameter. The obtained field data were analyzed by computer iteration from which the subsurface structures were obtained. The results show that the formations in Ubulu-Uku are of A, HA, KH and AH - curve types. They also show that Ubulu-Uku contains large quantity of kaolin with high concentration within Aniomah in Isho and around the **Iyi-Agor** valleys at depths of about 20 m to 70 m. In some parts it outcrops with high regenerative capacity as in Aniomah Isho.

Keywords: *Empirical Investigation, Kaolin occurrence, Schlumberger array, Terrameter, Ubulu-Uku, Industries*

1. 1NTRODUCTION

Ubulu-Uku is a town situated in the high altitude zone of Delta state. It is characterized with heavy lateritic deposits to far depths and slopes continuously terminating in valleys which harbour springs and streams. Although, the town seems to possess thick lateritic formations, traces towards the valleys are indicative of existence of a mix of thick clay and clayey formations and sometimes evidence of patches of kaolin [1]. Kaolin is a solid mineral of both traditional and economic importance as numerous industries require kaolin as raw material. Kaolin, also called China clay is an important and widely used mineral which is refined from kaolinite. It is a naturally occurring mineral of the clay family. In its natural form it may contain a number of impurities such as quartz, feldspar, tourmaline, etc derived from parent rocks. It is a whitish weathering product of silicate rocks with plastic touch but its colour may vary depending on the neighbouring rock formation [2]. Its chemical formula is $Al_2Si_2O_5(OH)_4$ or $Al_2SiO.H_2O$ and may vary slightly depending on its water and impurity contents. This characteristic chemical composition of kaolin usually encourages its numerous industrial utilization and applications. Hence empirical investigation of kaolin occurrence in Ubulu-Uku Delta State was necessitated and made to determine its mean subsurface depth and thickness and ascertain sites of economic viability. Five Vertical Electrical Sounding sites were studied using a sensitive ABEM 1000 Signal Averaging System (SAS) 1000 terrameter and applying Schlumberger configuration. The obtained field data were analyzed qualitatively by curve matching for credibility and quantitatively by computer iteration with the aid of "Win RESIST version 1.0" based on Vander Velpen models [3] from which the subsurface structure of Ubulu-Uku was obtained and the occurrence of kaolin ascertained and quantified.

2. LOCATION AND GEOLOGY OF STUDY AREA

Ubulu-Uku is a town in Aniocha South LGA of Delta state of Nigeria. It is situated about 30 km West of the River Niger and within Latitude N06 ^{o} 14.44 and N06^{o} 10 and Longitude E006 ^{o} 25.18 and E006^{o} 27 approximately with an elevation range of about 220m -165 m. It is bounded on th North by Issele-uku on the East by Ogwashi-Uku on the west by neighbouring Obior and Umunede towns. It is a relatively busy traffic town as it links the State capital, Asaba to several other towns and cities within and beyond the state. It is geologically within the three major depositional stratigraphic structures typical of most deltaic environments – the Benin, Agbada and Akata formations which consist of a mix of marine and continental deposits [4]. Although, it has appreciable rainfall for up to six months in the year its sloppy terrain and topography exposes it to high erosion effect leaving only thick lateritic top soil. The slope which cuts through the town terminates in valleys of springs and streams of interesting geology.

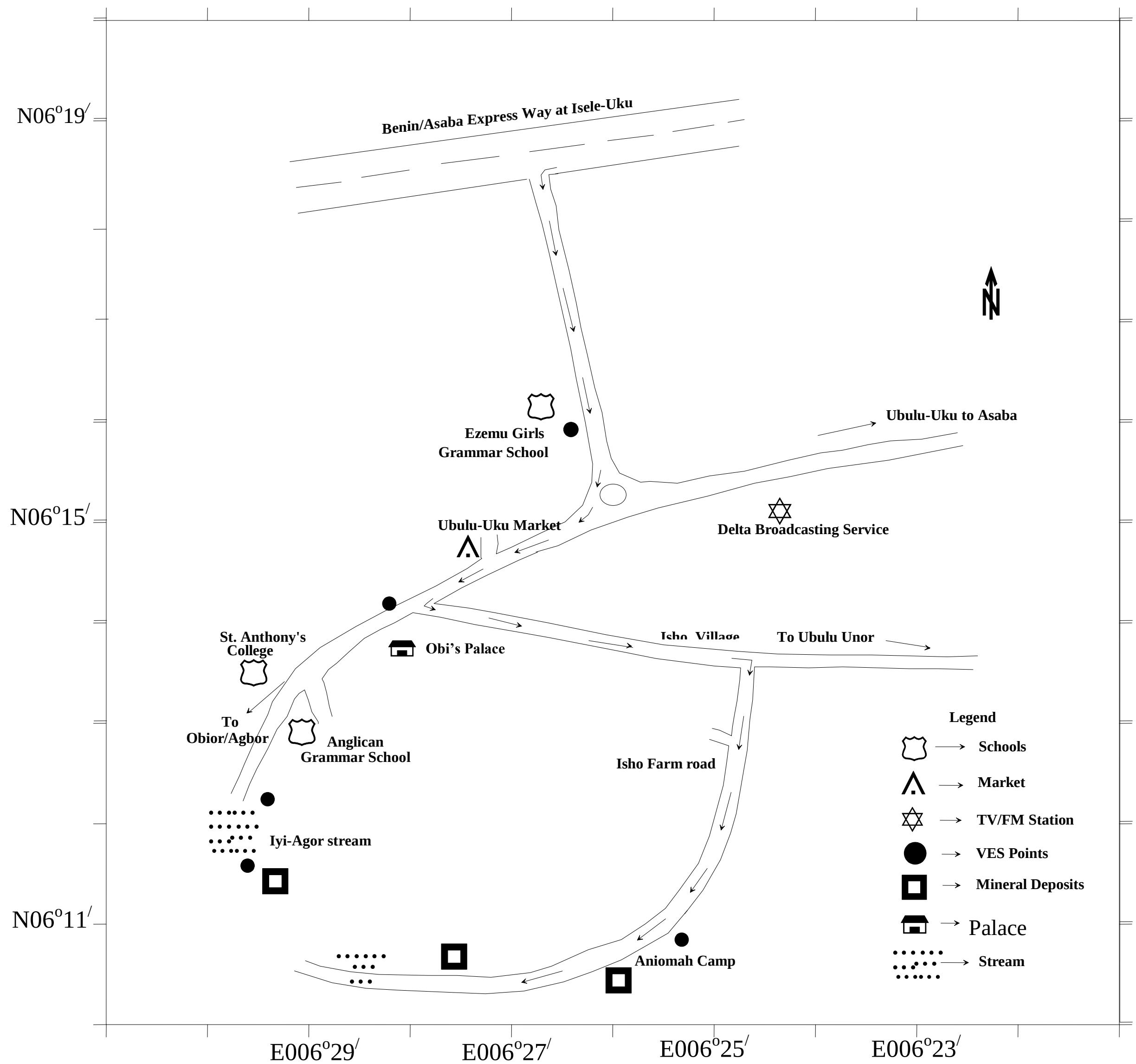

Fig 1: Base Map of Ubulu-Uku showing VES sites and some essentials – A sketch

3. MATERIALS AND METHOD

Electrical resistivity is a fundamental electrical property of rock materials closely related to their lithology. The determination of the subsurface distribution of resistivity from measurements on the subsurface can yield useful information on the lithology or composition of buried formations [5]. This study was therefore done using a highly sensitive ABEM made Signal Averaging System (SAS) 1000 terameter [6] which is capable of determining and digitally displaying the resistivity values of the subsurface formations. The Vertical Electrical Soundings (VES) were made using Schlumberger array in five selected sites in Ubulu-Uku with a view of having good coverage. In each site four steel electrodes are collinearly arranged and pinned into the earth with the current electrodes spacing much greater than the potential electrodes spacing and ensuring that $^{AB}/_{2} \geq {}^{5MN}/_{2}$ where "AB" is current electrodes separation and "MN" is potential electrodes separation (Fig. 2 & 3). The two outer electrodes were plugged to current terminals of the terrameter while the two inner electrodes were plugged to the potential terminals [7]. The Schlumberger array for which current electrode separation is much greater than the potential separation is a choice because of its reduced man power needs, generally smoother and step free curves as well as greater probing depths and resolving power [8]. Over thirteen subsurface data were obtained in each site with maximum electrode separation of about 632 m depending on accessibility and availability of assess road (Table 1).

3.1 Theoretical Background

From first principle, the potential difference ($V_c - V_D$) between the two inner electrodes measured by the terrameter in Fig 2 is

$$\nabla V = (V_c - V_D) = \frac{\rho I}{2\pi}\left\{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left\{\frac{1}{R_1}-\frac{1}{R_2}\right\}\right\}. \quad (1)$$

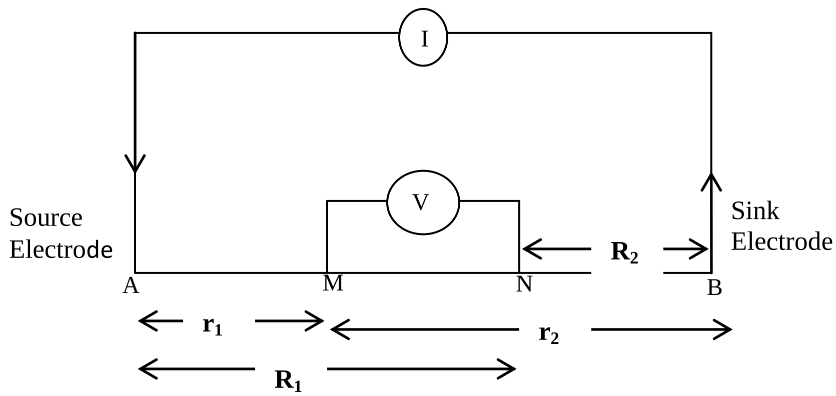

Fig 2: General four-electrode configuration for resistivity survey

Hence by definition

$$\rho = 2\pi\frac{\Delta V}{I}\left\{\frac{1}{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}\right\} \quad (2)$$

$$\Rightarrow \rho = 2\pi r\left\{\frac{1}{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}\right\} \quad (3)$$

Applying equations 1 – 3 to Schlumberger array (Fig 3), the potential difference "dV" between the two potential electrodes by [8] becomes

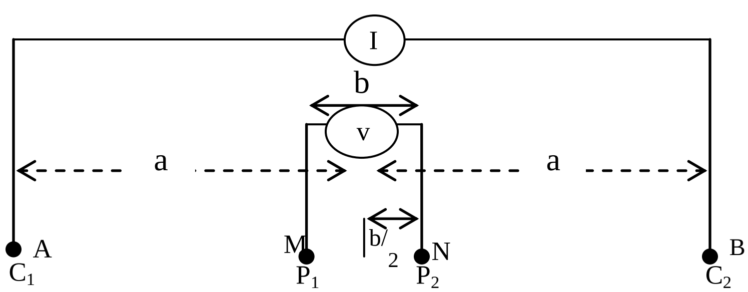

Fig 3: Schlumberger Field Electrode Array

Where "a" is the distance between the current electrode and station midpoint, "b" is the distance between potential electrodes and "2a" is the current electrode separation with a>>b as in Schlumberger array

$$dV = V_{P1} - V_{P2} = \frac{\rho I}{2\pi}\left\{\frac{1}{a - b/2} - \frac{2}{a + b/2} + \frac{1}{a - \frac{b}{2}}\right\} \quad (4)$$

$$= \frac{\rho I}{2\pi}\left\{\frac{2}{a - \frac{b}{2}} - \frac{2}{a + \frac{b}{2}}\right\} \quad (5)$$

$$= \frac{\rho I}{2\pi}\left(\frac{8b}{4a^2 - b^2}\right) \quad (6)$$

Furthermore,

$$dV = \frac{\rho I}{2\pi}\left(\frac{8b}{4a^2 - b^2}\right) \text{ becomes}$$

$$= \frac{\rho Ib}{\pi a^2}$$

$$\text{and } \rho_{as} = \frac{\pi a^2}{b}\frac{dV}{I} = \frac{\pi a^2}{b}R \quad (7)$$

where ρ_{as} apparent resistivity for Schlumberger array and

Schlumberger array Geometric factor $K_s = \frac{2\pi}{8}\left(4a^2 - b\right)$

Hence, $$K_S = \frac{\pi a^2}{b} \quad (8)$$

The apparent resistivity value is the product of the geometric factor and the subsurface resistance (eqn 7). To maintain the Schlumberger array requirement that ($C_1C_2 \geq 5P_1P_2$), the values of $^{AB}/_2$ are increased to $a\sqrt{2}$ after each sounding (Table 1) while the potential electrodes separations are guided accordingly [9].

Also, the Schlumberger potential difference of the n[th] layer with reflection coefficient *k* and thickness *z* becomes

$$\Delta V_s = \frac{\rho_1 2b}{\pi a^2}\left[1 + 2\sum_{n=1}^{\infty}\frac{k^n}{\sqrt{1 + \left(\frac{2nz}{a}\right)^2}}\right]$$

$$= \frac{\rho_1 I 2b}{\pi L^2}\left[1 + 2D_s\right] \quad (9) \text{ and } (10)$$

and its apparent resistivity by [10] is

$$\rho_{as} = \rho_1 \left[1 + 2\sum_{n-1}^{n} \frac{k^n}{\left(1 + \frac{2nz}{a}\right)^{3/2}} \right]$$

$$= \rho_1 \left[1 + 2 D_s^1 \right]$$

where

$$D_s^I = \sum_{n-1}^{n} \frac{k^n}{\left(1 + \frac{2nz}{a}\right)^{3/2}} \quad (11)$$

When the electrodes spacings are very small (r << z, and r $\rightarrow$ 0), the series term for all arrays tend to zero, the resistivity measured becomes that of the upper formation called surface resistivity ℓ_1 which is the true resistivity at the surface. Thus,

$$\frac{\rho_a}{\rho_1} = 1 and\ {a}/{z} = 1 \quad (12)$$

When the current electrode spacing is very large compared to the depth or thickness of bed, the series equation becomes

$$\rho_a = \rho_1 \left(1 + 2\sum_{n=1}^{\infty} k^n \right)$$

where

$$\sum_{n=1}^{\infty} K^n = \frac{1}{(1-k) - 1.} \quad (13)$$

Since k < 1for all spread types.

Table 1 Field Data obtained in Ubulu Uku

Current Electrode Separation AB/2 (m)	Potential Electrode Separation MN/2 (m)	Geometric factor (K) $K = \frac{\pi a^2}{b}$	Apparent Resistivity (Ω m) VES 1	Apparent resistivity (Ω m) VES 2	Apparent resistivity (Ω m) VES 3	Apparent Resistivity (Ω m) VES 4	Apparent Resistivity (Ω m) VES 5
1.00	0.2	6.28	29289	32948	128.78	59	90
1.47		25.13	24546	42802	101.98	128	175
2.15		56.55	26284	49538	129.6	203	243
3.16		100.53	339.9	59325	199.94	281	274
4.64	0.2/1.0	226.19	820.07/3291	79943/863	29.0 /150	456/436	251/254
6.81		113.10	827.50	92196	231.7	477	327
10.00	1.0/3.0	201.06	886.5/34063	107730/92532	311/318	719/725	359/348
14.70		452.39	912.16	89744	449.4 /271	1076	367
21.50		706.86	1536.80	98690	498.5	1339	378
31.60	3.0/8.0	353.43	949.81/1526	1056/88357	310.9 /243.6	1318/1405	387/394
46.40		981.75	2461.2	1911.1	954.3 /352.8	1686	482
68.10	16	1608.50	2157.3	1906.6	898.1	1458	569
100.00	16.0/30.0	2513.31	2146.1/2203	1538/2889	1541.4	1296	601
147.00	30.0/50	1005.31	2039.6/2387	1219/1091	2096.6/ 3627.1	1335/1386	572/590
215.00		2654.65	44702	1647.8	2373.5 / 4513.6		722/754
316.00		6283.19	2135		3058.9		112

Position Guide:

VES 1 (Ubulu Uku)
By Ezemu Gram School
N06° 14.733′ E 006° 27.134′
Elevation: 202±12 m

VES 2 (Ubulu Uku)
Aniomah camp in Isho Village
N06°11.026/ E006° 25.111′
Elevation: 167±17 m

4. DATA ANALYSIS

The data analysis was done in two parts, qualitative and quantitative sections. The qualitative data analysis was done to deduce the curve types on the log-log graph [11] and [12]. Thereafter, partial curve matching technique in which field curves were matched segment by segment with the relevant two layer master curves and the corresponding auxiliary curves using the appropriate procedures to obtain the various reflection coefficients and depth indices was applied (DI) [13]. The apparent resistivities and thicknesses of the various layers were then deduced from

$$\rho_{a=k_{(n+1)}} \times \rho_{(n-1)r} \qquad (14)$$

Where n is an integer greater than one, while the real depth is obtained from

$$h_n = h_{(n-1)} \times \Delta I \qquad (15)$$

Although, the thickness and apparent resistivity for the first medium are real, the resistivity replacements and depth indices were used to obtain the thicknesses and apparent resistivities of the subsequent layers by computer iteration with software called ‘Win RESIST’ [3].

The computer iteration involves entering the current electrode separation AB/2 and apparent resistivity values obtained from field in the columns given by the software for the Schlumberger array and modelling the total number of layers, resistivity and corresponding thickness of each layer from the qualitative interpretation and curve matching into the computer programme for the software to automatically iterate the result to its lowest root mean square percentage error. The curve types and smoothened results of the computer iterations are shown in the figures 4 to 8.

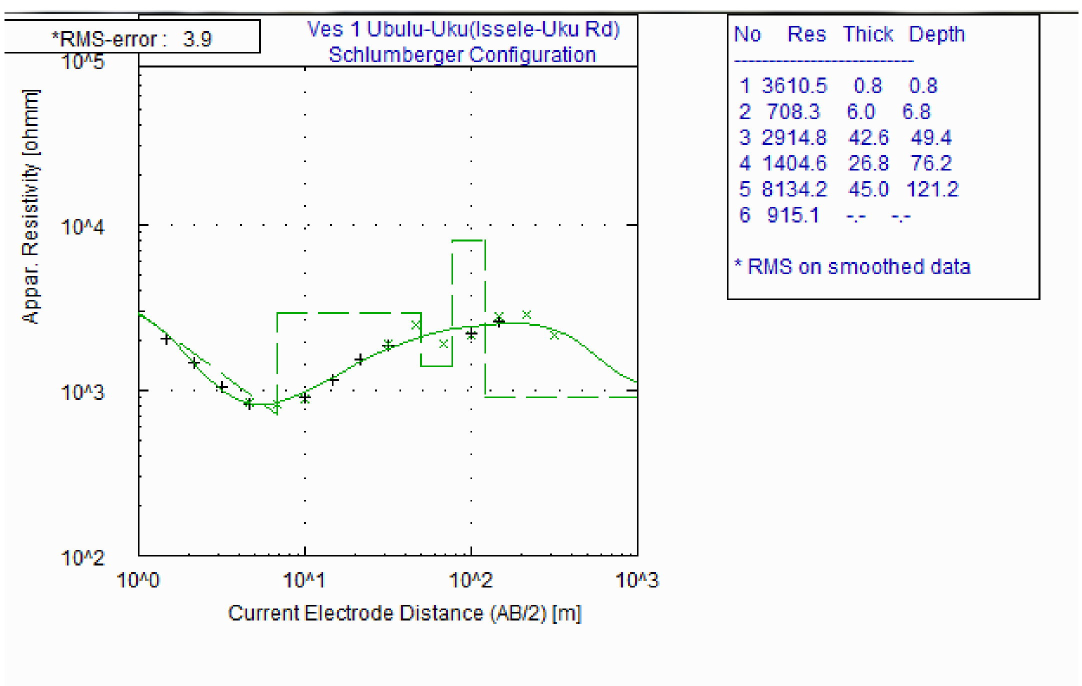

Fig 4: Iterated plot of VES 1 in Ubulu-Uku ---- HA – Curve type

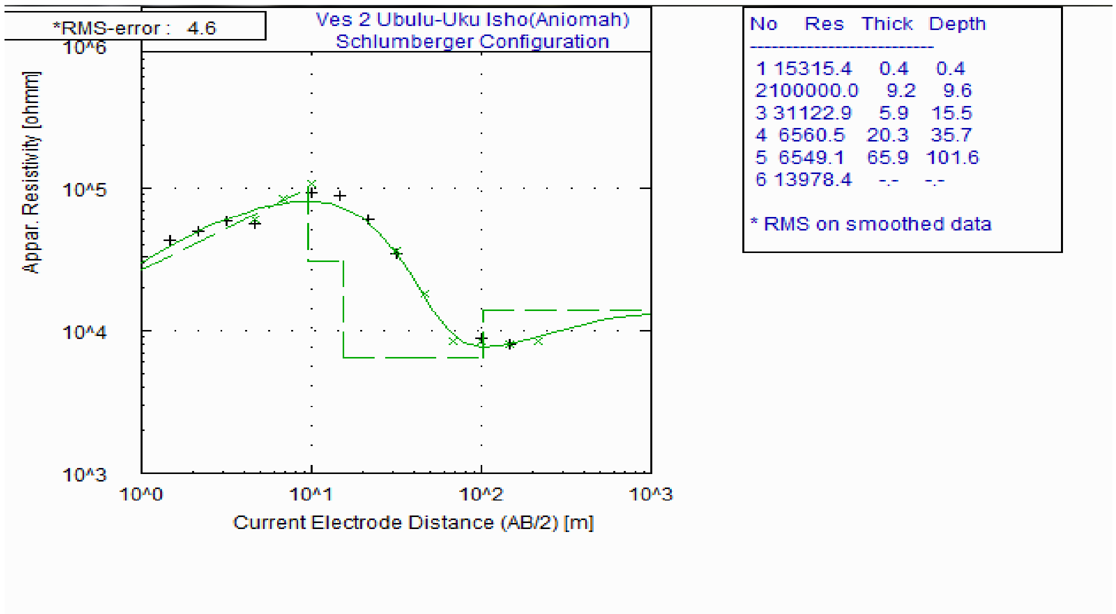

Fig 5: Iterated plot of VES 2 in Ubulu-Uku ---- KH – Curve type

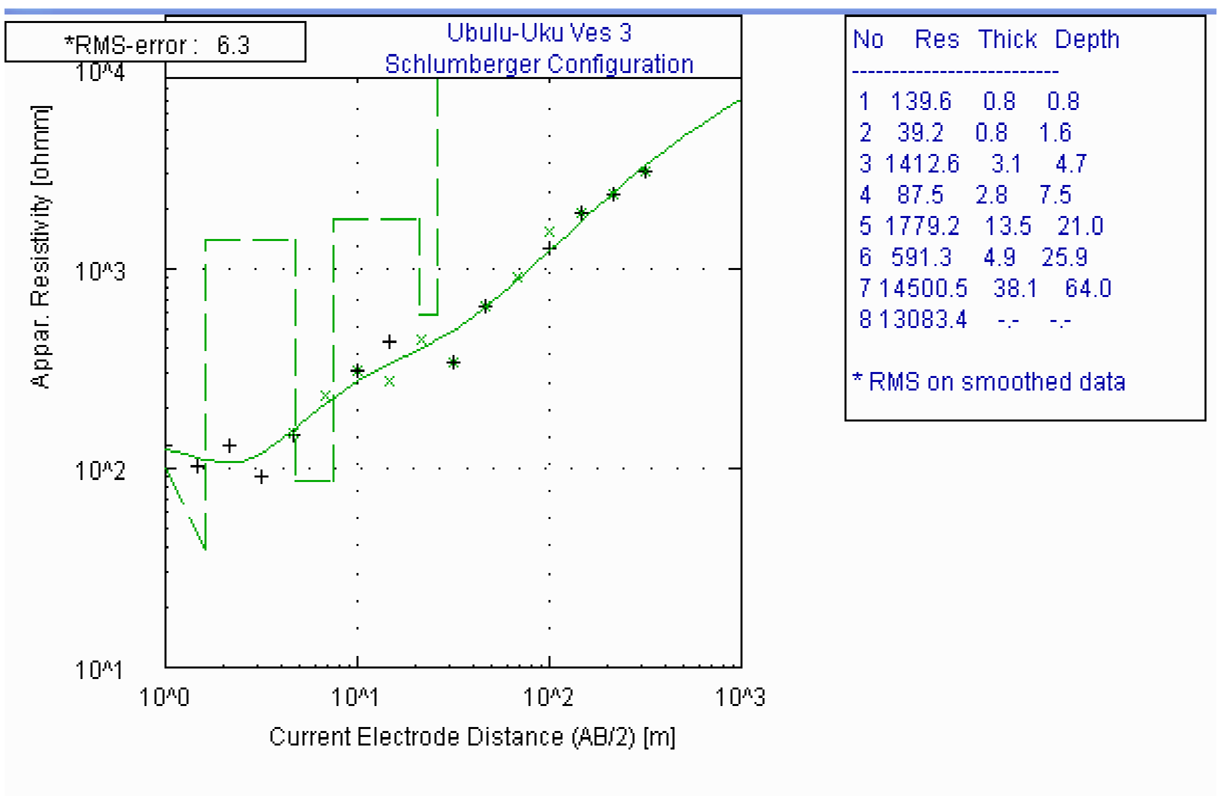

Fig 6: Iterated plot of VES 3 in Ubulu-Uku ---- A – Curve type

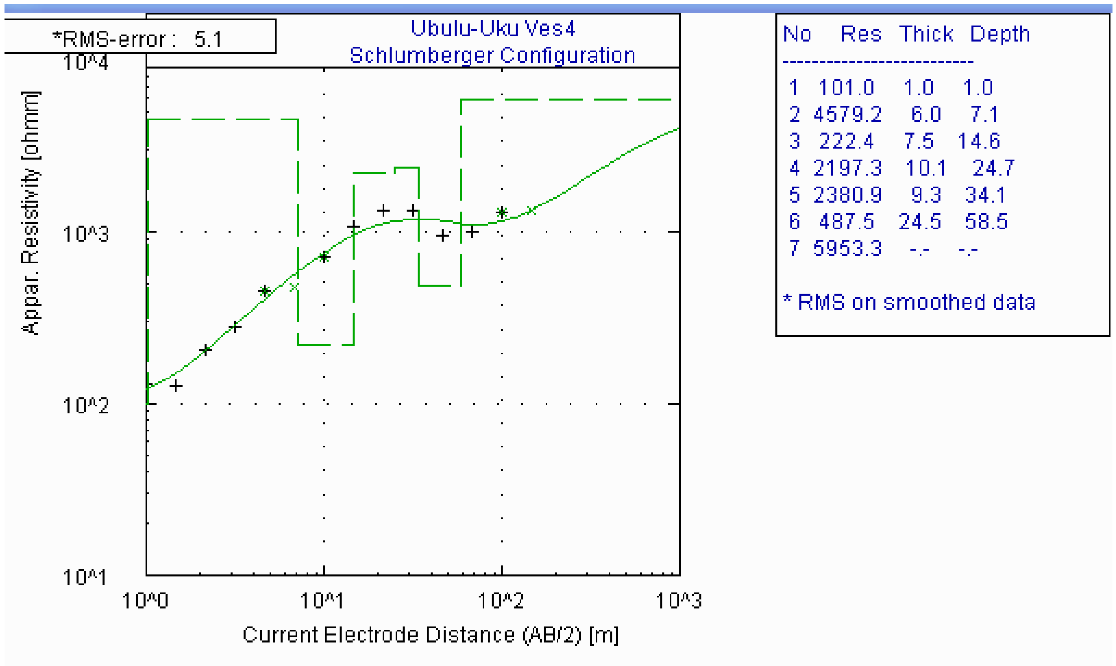

Fig 7: Iterated plot of VES 4 in Ubulu-Uku ---- AH – Curve type

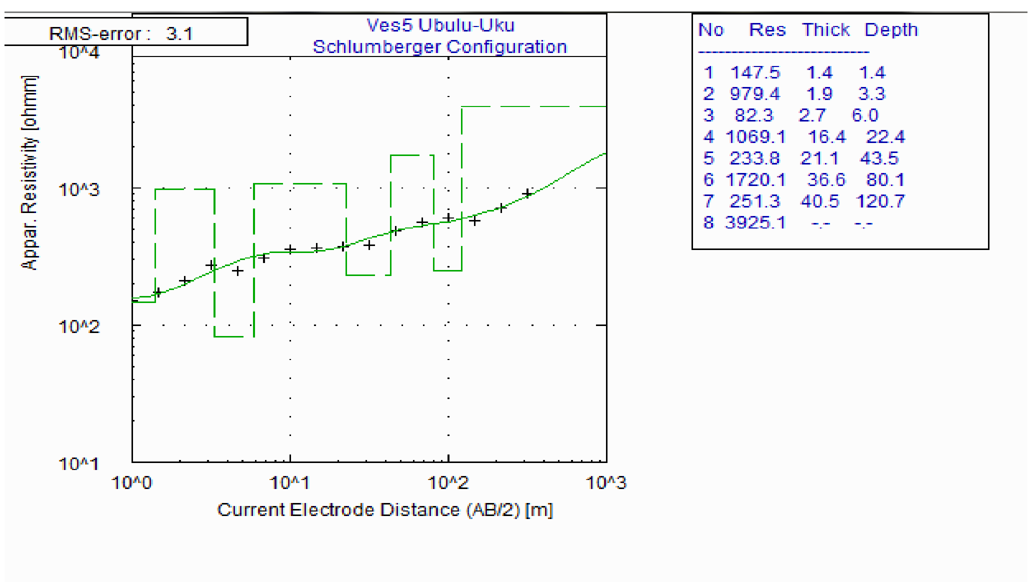

Fig 8: Iterated plot of VES 5 in Ubulu-Uku ---- A – Curve type

5. DISCUSSION

The results show that the subsurface formations in Ubulu-Uku have basically A, HA, KH and AH - curve types (Figs 4 – 8) [14]. At site 2, Kaolin formation is within 20 m to far depth of over 70 m. The depth of 20 m corresponds to the point of outcrop at the slope near the stream at Aniomah Isho where there are hugh kaolin deposits. At Aniomah Isho there is a mix of kaolin and thick laterite resulting to hard lignite-like formations which is responsible for the high resistivity responses to far depth in Isho. The high resistivity responses detected at Ezemu primary School along Issele Uku road are due to the peculiar thick lateritic formations to very far depth in the hill top zone in Ubulu Uku. As one moves down the slope along the major road and beyond the secondary schools to Iyi-Agor stream very low resistive formations are encountered. These resistivity values of VES 3 – 5 are generally very low because the formation strata consist of pure Kaolin (fine white clay). At depths of about 15 m and beyond, these formations are specifically rich in clay and from 20 m to 65 m kaolin is obtained in large quantity. In these sites, the clay formations are enormous and caking in layers which are evident of kaolin deposits. The kaolin in this section is very different from that in Aniomah Isho because this is whitish and laterite free. It therefore has a sedimentary origin. Moreover the kaolin here can be obtained by mining under scanty flowing waters. On the other hand, kaolin outcrops to the surface in Aniomah Isho (Plate 1). The kaolin at Aniomah Isho is large, reddish-white and has high regenerative capacity which suggests that it is associated with granitic rocks and extends to very far depth beneath the subsurface. Thus, it has the capacity to replace mined or excavated kaolin and produce more. Indeed, Kaolin occurrence in Ubulu-Uku is of high commercial value (Plate 1). This makes Ubulu-Uku a viable seat for companies, industries and Governments interested in mining or harnessing this very essential solid mineral particularly now that Delta State Government is working towards a Delta State with less emphasis on oil revenue. Interactions with the people of Ubulu-Uku in the process of this work show that they are naturally hospitable, peaceful and ready to welcome investors in this area for the benefit of all.

Plate 1: A section of Kaolin deposits in Aniomah - Isho, Ubulu Uku, Delta State Nigeria

6. CONCLUSION

Ubulu-Uku contains large quantity of kaolin with high concentration within Aniomah in Isho, and in Iyi-Agor stream valleys along Obior road. The volume of the deposits is massive as it continuously regenerates from within the subsurface. In some parts it outcrops with high regenerative capacity which implies that it has the capacity to replace mined or excavated kaolin and generate more. It is therefore, naturally occurring and almost inexhaustible. Kaolin is chemically inert over a wide pH range with controlled electrical conductivity. It is suitable for moulding mixtures in cast iron and steel foundry and insulator refractory. It is also useful in traditional and orthodox medicine and in tile production. Since, Kaolin has these numerous industrial applications and new applications are still being discovered, Governments and viable investors are advised to take advantage of the existence, accessibility and regenerative capability this raw material in this very peaceful and hospitable environment to establish viable industries and companies within and around Ubulu-Uku in Delta State.

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