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PRELIMINARY INVESTIGATION OF KAOLIN MINERALIZATION ZONES WITHIN THE OLIGOCENE-MIOCENE SEDIMENTS OF THE NIGER DELTA BASIN USING ELECTRICAL RESISTIVITY

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ABSTRACT

This paper presents preliminary findings from electric resistivity study on Oligocene-Miocene sediments of the Niger Delta with emphasis on identification of mineralization zones of kaolin. Fifteen (15) vertical electrical soundings (VES) data were obtained using Schlumberger configuration with maximum electrode spacing of 600 m. The results of the VES correlated with borehole data shows five (5) to six (6) geoelectric layers: top soil, sand/clay, kaolin/sand, sand/clay/kaolin, sand/clay and sand. The area is characterized by lateral lithologic heterogeneity resulting from gradational lithologic contacts, thus lithologic units are quite impersistent over a small area. Kaolin mineralization occur mainly in the third geoelectric layer, with resistivity values varying between 108 – 675 Ωm; thickness of kaolin increases from about 0.5 m around outcrops to 7.1 m in the study area. Depth to kaolin varied from 1.3 m at Ukwu-nzu to 19.1 m at Ubulu-uku; depth to mineralization generally increase with elevation in the area.

Keywords: kaolin, resistivity, thickness, lithofacie, geoelectric layer

INTRODUCTION

Sedimentary kaolinitic clays occurs at Ubulu-uku and Ukwu-nzu in the Niger Delta Basin. They occur as secondary clays associated with sedimentary deposits within the basin and drainage systems. They form as clayey materials eroded from primary sources and were deposited with other sediments. Kaolin as part of our natural world has multiple and diversified uses; its whiteness and plasticity makes it extremely suitable for use as filler, paper coating, ceramics, pigments, ceramics, paints, refractories, cosmetics and pharmaceuticals. According to MCIC (2001) large quantity of kaolin were found out cropping along river banks in the study area, (Ubulu-uku and Ukwu-nzu). This suggests that, an intimate relationship exists between the existence of these rivers and depositional history of the kaolin. Since present river course are likely to be significantly different from their ancient course, kaolin is bound to occur beyond the banks of existing rivers. Ancient fluvial depositional environment and adjacent territories are possible targets for search of kaolin and other minerals deposit (Ananaba *et al*., 1993).

Accurate characterization of kaolin deposits is crucial for maximizing extraction, processing and utilization of the resources. Several geologic exploration methods such as drilling and sampling are expensive, time consuming and not environmentally friendly. Direct current

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(DC) has become a worthwhile non-invasive geophysical method for investigating several mineral resources. This method measures the electrical resistance of the subsurface and capable of providing insights into the distribution of lithologic units and their thickness (Loke, 2011). Ohwoghere-Asuma *et al*. (2019) successfully characterized subsurface lithological units using resistivity data while the findings of Aweto (2019) shows a strong positive correlation (r^2 = 0.77) between lithofacies deduced from resistivity data and those from borehole data. Several studies (Hussain *et al*., 2016; Yahaya *et al*., 2018; Akinsumade *et al*., 2019; Osueje *et al*., 2021; Yellapu *et al*., 2021) have successfully used resistivity method in search of kaolin. Hence, resistivity method is capable of identifying the vertical and lateral extent of kaolinised layer in the subsurface.

This work is a preliminary investigation with the aim of characterizing kaolin mineralization at Ubulu-uku and Ukwu-nzu area of Western Niger Delta using electrical resistivity method. The result of this study may provide a comprehensive understanding of subsurface geology of the study area, and to serve as a guide for efficient exploration and exploitation strategies.

MATERIALS AND METHODS

Study Area and Geology

The study area Ubulu-uku and Ukwu-nzu lies between latitude $6^0$00'N and $6^0$20'N and longitude $6^0$20'E and $6^0$40'E. It is located within areas where the lithofacies of the Tertiary Niger Delta Basin grade gradually into the lithofacies of the Cretaceous Anambra Basin. The area is characterized by series of transgressive regressive cycles that produced a stacked succession of sedimentary sequences each representing different phases of relative changes in sea level and sedimentation (Reijers, 2011). The lithostatigraphic units include the basal Imo Shale, Ameki, and Ogwashi-Asaba Formations. Subsurface lithostratigraphic include: Akata Formation (transgressive marine shales), Agbada Formation (paralic sequence of sand and shale) and the continental Benin Formation.

Methodology

The ABEM SAS 1000 Terrameter was used to acquire resistivity data, the vertical electrical sounding (VES) techniques adopting the Schlumberger array was used. A total of seven sounding stations were occupied at Ubulu-uku and Ukwu-nzu. The current electrodes separation ranged from 1 to 600 m depending on accessibility. The apparent resistivity (ρ_a) values measured on the field were plotted on the vertical axis against the half current electrode spacing, (AB/2) on the horizontal axis of the bi-logarithm paper. Line of best fit were drawn from the plotted points to form a curve. The sounding curves were interpreted by sectional curve matching using the relevant master curves with their correspondent auxiliary curves (Koefoed, 1979; Orellana and Mooney, 1966) and followed by computer iterative modeling using winResist software (Vander Valpen, 2004)

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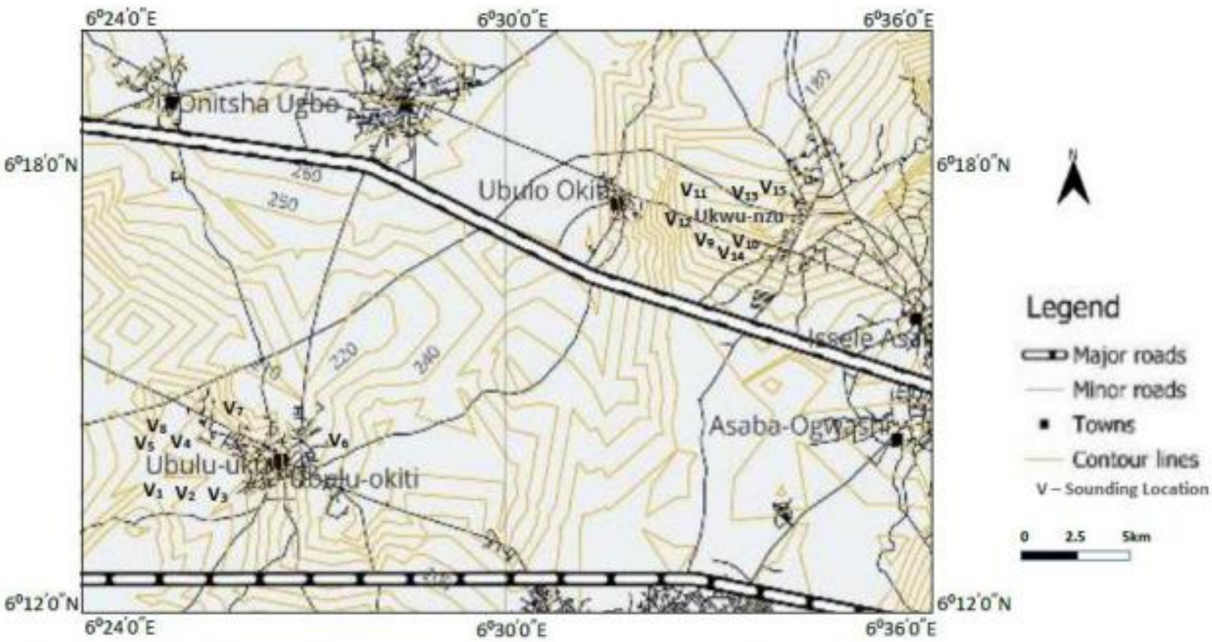
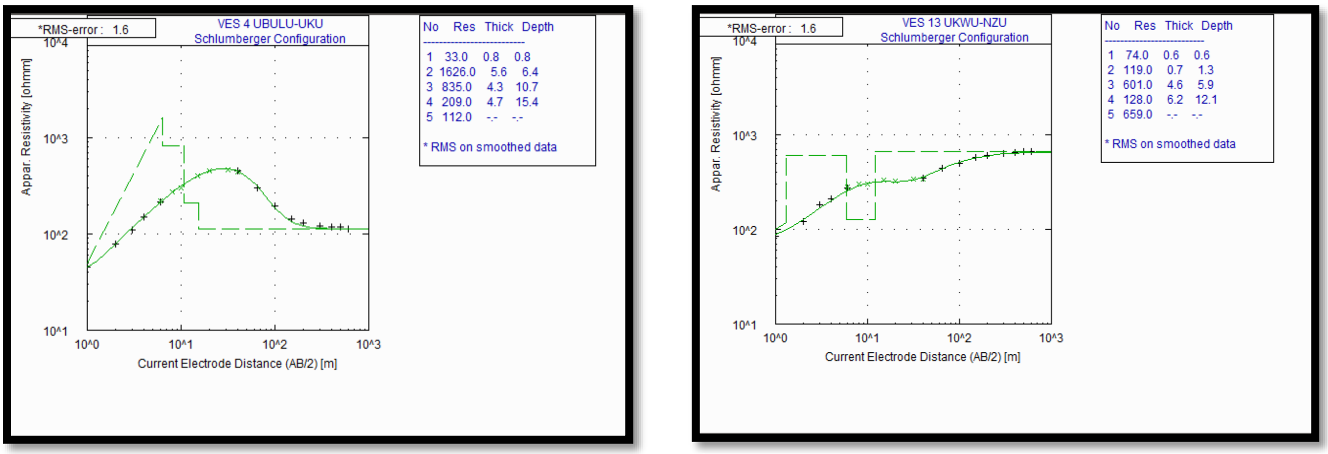


Fig. 1: Map of study area

RESULTS AND DISCUSSION

The results of the resistivity investigation are presented as table, sounding curves and geoelectric sections and sand. The geoelectric parameters and lithological delineation of the study area are shown in Table 1. The resistivity sounding curves (fig. 2) show five to six geoelectric layers. The geoelectric sections (figs. 3 and 4) show five (5) to six (6) geoelectric layers: top soil, sand/clay, kaolin/sand, sand/clay/kaolin, sand/clay and sand.



(a) (b)

Fig. 1: Typical sounding curves from study area

The first layer is the top soil with resistivity values ranging from 33 – 1278 Ωm and thickness of between 0.5 – 1.5 m. The second layer is composed of mostly sand (lateritic) and in some places clayey sand; the resistivity of this layer is between 49 – 2972 Ωm with thickness ranging from 1.7 – 18.6 m. The third layer with resistivity values ranging from 108 – 835 Ωm and thickness of 3.3 – 10.4 m, this is diagnostic of kaolin mineralization. The depth to the kaolin varies between 1.3 and 19.1 m; depth to kaolin is generally greater where elevation is high. The fourth layer have resistivity values ranging from 78 – 1583 Ωm and have thickness of between 1.6 – 37.9 m; this layer is comprises of mostly equal proportions of sand and clay with occurrence of kaolin at VES 3 and 4. The fifth layer is characterized by resistivity values varying between 85 – 2404 Ωm. This layer is made up of more sand and lesser amount of clay; the thickness of this layer could not be ascertained because current electrode terminated within this layer. Inference from VES 6 and 8 indicate that this layer could be over 16 m thick. The last layer is characterized by resistivity ranging between 197 – 3701 Ωm, this is mostly sand whose thickness could not be ascertained.

Kaolin mineralization occur mainly in the third geoelectric layer, with resistivity varying between 108 – 675 Ωm. Similar resistivity values have been reported by Afolabi *et al*. (2004); Adamu, *et al*. (2019); Yusuf *et al*. (2022). The variation in resistivity values may be due to factors such as moisture content, compaction density and purity. The thickness of kaolin increases from 0.5m (around Omi-Oke spring and several road cuts) to 7.1 m in the study area. Depth to kaolin varied between 3.1 – 19.1 m at Ubulu-uku and 1.3 – 11.5 m at Ukwu-nzu. The geoelectric sections of the study area (figs. 4 and 5) indicates lateral lithologic heterogeneity resulting from gradational lithologic contacts. According to Avbovbo (1979) and Freeborn (2006), lithologic units are quite impersistent over a small area; and lithologic variation is quite common in the study area. This makes lithologic correlation between sounding locations difficult over a wide area. This is anticipated because at the proximal part of a coastal sedimentary basin where the study area lie, depositional conditions are rarely persistent over a wide surface area and a long duration of time. Thus, there is a close association of several sub-environments such as estuary, lagoon, lake delta/delta lo, tidal flats, channel fill over bank/food plain and alluvial plain; most of which are influenced by marine processes including changes in relative sea level. Each of these sub-environments has its characteristic lithofacies consequently. There is a complex lithofacies association in response to changing depositional condition.

Table 1: Geoelectric parameters deduced from computer iteration and lithological delineation

VES Station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred lithology
VES 1	1	734	1.5	1.5	Top soil
Ubulu-uku	2	1633	7.4	8.9	Sand
	3	501	5.9	14.8	Kaolin
	4	128	3.1	17.9	Sandy clay

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	5	596			Sand
VES 2 Ubulu-uku	1	1213	1.3	1.3	Top soil
	2	2972	15.6	16.9	Sand
	3	347	3.4	20.3	Kaolin
	4	78	6.8	27.1	Clay
	5	929	-	-	Sand
VES 3 Ubulu-uku	1	33	0.8	0.8	Top soil
	2	1626	5.6	6.4	Sand
	3	835	4.3	10.7	Sand
	4	209	4.7	15.4	Kaolin
	5	112	-	-	Silty clay
VES 4 Ubulu-uku	1	219	0.8	0.8	Top soil
	2	633	4.8	5.6	Sand
	3	174	10.4	16.0	Clayey sand
	4	410	5.6	21.6	Kaolin
	5	85	-	-	Clay
VES 5 Ubulu-uku	1	296	1.7	1.7	Top soil
	2	432	15.4	17.1	Sand
	3	675	2.3	19.4	Kaolin
	4	110	4.5	23.9	Clay
	5	142	-	-	Silty clay
VES 6 Ubulu-uku	1	49	0.5	0.5	Top soil
	2	1218	18.6	19.1	Sand
	3	117	5.2	24.3	Kaolin
	4	225	3.5	27.8	Sand

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	5	1362	6.8	34.8	Sand
	6	3701			Sand
VES 7	1	734	0.6	0.6	Top soil
Ubulu-uku	2	1633	8.8	9.4	Sand
	3	501	6.1	15.5	Kaolin
	4	128	6.2	21.7	Sandy clay
	5	596			Sand
VES 8	1	1278	0.5	0.5	Top soil
Ubulu-uku	2	49	2.6	3.1	Clay
	3	227	3.9	7.0	Kaolin
	4	125	9.5	16.5	Silty sand
	5	762	16.9	33.4	Sand
	6	1224			Sand
VES 9	1	716	0.9	0.9	Top soil
Ukwu-nzu	2	210	10.6	11.5	Sand
	3	108	1.5	13.0	Kaolin
	4	114	11.8	24.8	Sandy clay
	5	1981			Sand
VES 10	1	1278	1.5	1.5	Top soil
Ukwu-nzu	2	65	2.3	3.8	Clay
	3	219	5.9	9.7	Kaolin
	4	138	9.5	19.2	Silty sand
	5	962	24.8	44.0	Sand
	6	1391			Sand
VES 11	1	167	0.9	0.9	Top soil

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Ukwu-nzu	2	856	8.1	9.0	Sand
	3	153	3.6	12.6	Kaolin
	4	341	14.5	27.1	Sand
	5	2402			Sand
VES 12	1	74	0.6	0.6	Top soil
Ukwu-nzu	2	119	0.7	1.3	Sandy clay
	3	601	4.6	5.9	Kaolin
	4	128	6.2	12.1	Sandy clay
	5	659			Sand
VES 13	1	561	1.1	1.1	Top soil
Ukwu-nzu	2	172	11.9	13.0	Clayey sand
	3	298	1.7	14.7	Kaolin
	4	110	10.1	24.8	Sandy clay
	5	976			Sand
VES 14	1	354	1.2	1.2	Top soil
Ukwu-nzu	2	732	6.1	7.2	Sand
	3	204	4.4	11.6	Kaolin
	4	121	1.6	13.2	Sandy clay
	5	53	2.6	15.8	Clay
	6	197			Silty sand
VES 15	1	214	1.0	1.0	Top soil
Ukwu-nzu	2	155	4.4	5.4	Clayey sand
	3	309	3.8	9.2	Kaolin
	4	1583	37.9	47.1	Sand
	5	2381	-	-	Sand

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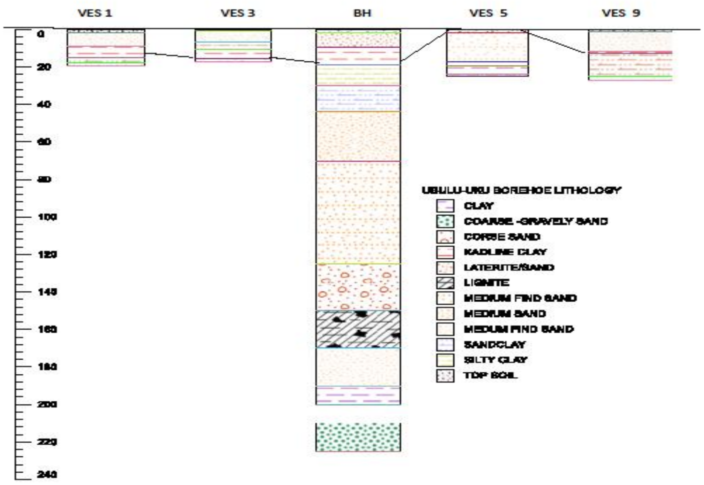

Fig. 3: The geoelectric section for Ubulu-uku

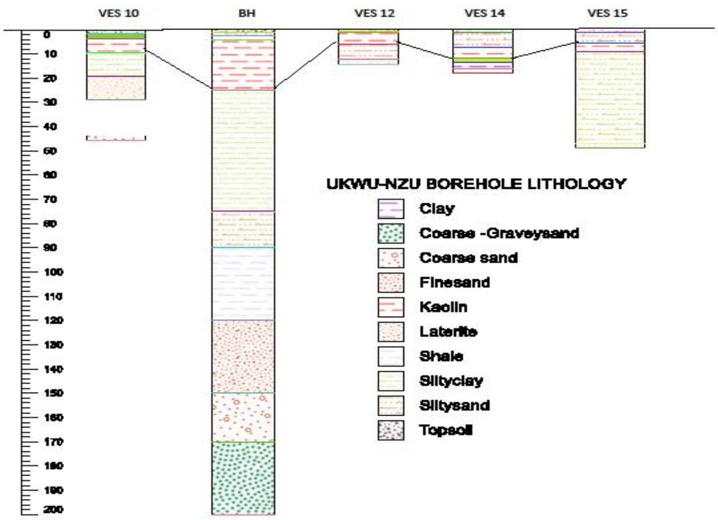

Fig. 4: The geoelectric section for Ukwu-nzu

CONCLUSION

This study has demonstrated the effectiveness of the use of DC electrical resistivity method as a cost-effective and non-invasive method in delineating kaolin mineralization in areas of limited outcrops. The result of 15 Schlumberger sounding data acquired with an ABEM SAS 1000 Terrameter indicates the presence of kaolin mineralization within the Oligocene-Miocene sediments at Ubulu-uku and Ukwu-nzu. This study revealed that Kaolin of between 0.5 – 7.1 m thick occur mainly in the third geoelectric layer at depths ranging between 1.3 – 19.1 m. The depth to kaolin is generally greater in areas at higher elevations.

Conflict of Interest

The authors declare that they have no conflict of interest

REFERENCES

Adamu, A., Fahad, A., Ologe, O., Sagagi, Y.M. and Shamsudeen, A. (2019) Electrical Resistivity Investigation of Kaolinitic and Laterite Deposits within Birnin and Environs, NW Nigeria. *Savanna Journal of Basic and Applied Sciences*, 1(2): 160-168

Afolabi, O., Olorunfemi, M. O., Olagunju, A. O. and Afolayan, J. F. (2004). Resource quantification of a kaolin deposit using the electrical resistivity method – case study from Ikere-Ekiti, southwest, Nigeria. *Ife Journal of Science*, 6(1): 35 – 40

Akinsunmade, A., Tomecka-Suchoń, S. and Paweł Pysz, P. (2019). Assessment of kaolin resources using electrical resisitivity method in part of Ekiti State Southwest Nigeria. *Proceedings of 5th International Scientific Conference on Civil Engineering-Infrastructure-Mining*, 1 – 8.

https://doi.org/10.1051/e3sconf/201910601009

Ananaba, S.E. (1983). Evaluation of remote sensing application to geophysical studies in Nigeria. Unpublished Ph. D. Thesis, Ahmadu Bello University, Zaria, Nigeria.

Avbovbo, A. A. (1978). Tertiary lithostratigraphy of Niger Delta: Geologic Notes. *AAPG Bulletin*, 62:295 – 300

Aweto, K. E. (2019). The efficiency of resistivity method in delineating lithologic units of the Quatenary deposits of the Niger Delta. *FUW Trends in Science & Technology Journal*, 4 (2): 446 – 451

Freeborn, O. E. (2006). Geoelectrical investigation for groundwater in Aniocha South Local Government Area, Delta State. *Global Journal of Geological Sciences*. 4(2): 209 – 219

Hussaini, A., Sule, P.O., Osumeje, J.O., Daniel, E., Zainab, M. (2016). Two-dimensional electrical resistivity imaging applied to the delineation of kaolin deposit at Dajin Gwamna, Katsina State, Northwestern Nigeria, *Nigerian Journal of Scientific Research*, 15(2): 234 – 244.

Koefoed, O. (1979). Geosounding principles 1. Resistivity sounding measurements. *Elsevier Scientific Publishing Company*, Amsterdam, 275 pp.

Loke, M. H. (2011) Electrical resistivity surveys and data interpretation. In Gupta, H. (ed.). Solid Earth Geophysics Encyclopaedia (2nd Edition), *Electrical and Electromagnetic*. Springer-Verlag, pp. 276 – 283

MCIC (2001). Report on solid mineral deposits in Delta State, Ministry of Commerce, Industry and Cooperative, Asaba.

Ohwoghere-Asuma, O., Aweto, K. E. and Ugbe, F. C. (2019). Lithofacies identification and multivariate analysis of groundwater chemistry in coastal aquifers in Koko area of the Western Niger Delta. *Hydrology*, 6, 31; doi: 10.3390

Orellana, E. and Mooney, H. M. (1966). Master tables and curves for vertical electrical sounding over layered structures. *Intersciencia*, Madrid. 34 pp.

Osumeje, J. O., Eshimiakhe, D. and Lawal, K. M. (2021). Application of geophysical method to delineate kaolin deposit at Kankara, Northwestern Nigeria Dutse *Journal of Pure and Applied Sciences*, 7 (4b): 39 – 49. https://dx.doi.org/10.4314/dujopas.v7i4b.5

Reijers, T. J. A. (2011). Stratigraphy and sedimentology of the Niger Delta. *Geologos*, 17: 133 – 162.

Vander VBPA (2004). WinResist version 1.0. M.Sc. Research Project ITC, Deft, Netherland

Yahaya, B., Ojoina, O. A. and Ojonugwa, U. A. (2018). Geochemical and

https://doi.org/10.61448/njse231254

Geophysical Investigations of Kaolin Deposits of the Maastrichtian Mamu Formation, Northern Anambra Basin, Nigeria. *International Journal of Geophysics and Geochemistry*, 5(2):45 – 52

Yellapu, S. A. and Bekkam, V. R. (2021). Delineation of kaolinised and aquifer formations using electrical resistivity tomography (ERT) and induced polarization (IP) techniques. *Environmental Earth, 81(484)*, doi: 10. 1007/s12665-022-10616-1

Yusuf, T. U., Obaje, N. G., Aweda, A. K., Yabagi, A. J. and Ishaq, Y. (2022). Discovering the rabba potential for kaolin deposit worth of optimal return on investment: a geophysical perspective. *International Journal of Science Academic Research*, 3 (11): 4616 – 4620