OPEN ACCESS Journal of Environmental Science and Technology

ISSN 1994-7887
DOI: 10.3923/jest.2019.

Research Article
Mineralogy of Clay Components of *Aquic arenic paleudults* Soils of Akamkpa, Southeastern Nigeria

[1]John Kingsley, [2]O. Ayito Esther, [2]Ackley U. Akpan-Idiok, [3]Olusola Bodede and [3]Roshila Moodley

[1]Department of Soil Science and Soil Protection, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences, Prague
[2]Department of Soil Science, University of Calabar, PMB 1115, Cross River State, Nigeria
[3]School of Chemistry and Physics, University of KwaZulu-Natal, Westville, Durban, South Africa

Abstract

Background and Objective: Aquic arenic paleudults soils are developed at valley bottom of a basement complex parent material of the sub-humid tropical rainforest. The aim of the study was to determine the mineralogy of clay components of *Aquic arenic paleudults* soils of Akamkpa, southeastern Nigeria. **Materials and Methods:** The study mineralogy of clay components of *Aquic arenic paleudults* soils of Akamkpa, southeastern Nigeria was carried out on 50 ha land. Two soils were collected from each pedogenic horizon of a representative pedon dug at valley bottom from the depth: Ap = 0-12 cm and Bt_1 = 12-25 cm. The clay fraction of the soil was separated and the fine and coarse-clay fractions analyzed for its mineralogical content with the aid of an X-ray diffractometry. **Results:** The XRD analysis showed the abundance of the available clay mineral in this order: Illite>Chlorite>Quartz> Kaolinite and Quartz>Kaolinite>Illite>montmorillonite> Chlorite for surface and subsurface soils, respectively. While the overall abundance of clay mineral component in the soil system were in this order: Illite>Quartz>Chlorite>kaolinite>montmorillonite. Illite proved to be the dominant clay mineral at both surface and subsurface. This relative amount of clay minerals may be attributed to weathering conditions probably due to internal drainage and inter stratification. **Conclusion:** The study revealed that 2:1 expanding clay (illite) were predominant at the valley bottom of the landscape but often transformed through inter stratification processes and thus should be utilize in crop production since they can retain input materials such as fertilizers and herbicides.

Key words: *Aquic arenic paleudults*, clay mineralogy, x-ray diffractogram, basement complex, clay minerals, valley bottom

Citation: John Kingsley, O. Ayito Esther O, Ackley U. Akpan-Idiok, Olusola Bodede and Roshila Moodley, 2019. Mineralogy of clay components of aquic arenic paleudults soils of Akamkpa, southeastern Nigeria. J. Environ. Sci. Technol., CC: CC-CC.

Corresponding Author: John Kingsley, Department of Soil Science and Soil Protection, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences, Prague Tel: +2349056420148

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Aquic arenic paleudults are soils developed at the toe-slope or valley bottom of a landscape. They are referred to as inland valley bottom soils which belong to the group of wetland soils under the category of headwater valley[1]. The landscape where which this soils are formed generally flat-floored and relatively shallow and they have become less prominent due to their narrowing resulting from deeper incision into the pediplains[2]. These soils are characterized with poor drainage either because of the flooding or high groundwater table including ponding, to the point that it influences their development and properties[1]. Furthermore, they are characterized by coarse, loamy and fine sand texture throughout the sub-layer extending from the mineral soil surface to the top of the argillic horizon. The clay content greater than 35% with rock fragment inclusive, mixed mineralogy of quartz, kaolinite and montmorillonite.

Clay mineralogical properties are easily influenced by the soil forming processes. Clay illuviation is the major pedogenic processes in the soils of the study area. The location of study is all covered with argillic horizons and this has lead studies of clay mineralogy by several researchers in paleogeographical and environmental[3-5]. Furthermore, the increase in clay material with depth may be due to the internal weathering of feldspar, mica or some other minerals[6]. Illite typical breaks down to vermiculite through the release of potassium from the interlayer, the intercalation of Al-hydroxyl-polymers often occurs, giving rise to hydroxyl interlayered vermiculites (HIV) and to the pedogenic chlorites as the end product of the transformation[6]. Also, the transformation of detrital chlorite by weathering processing to vermiculite or smectite and also the formation of mixed clay minerals is common. Similarly, kaolinite has been reported to occur in all primary minerals but most typically in oxisols and ultisols suggesting origin from the parent material[6].

The clay mineralogical components of these soils are still generally little studied in the southeastern part of Nigeria. The frequent users of these soils are small-scale farmer who produces 3-6 times as much as the upper landscape. Despite their agricultural potentials as reported by IITA[7] soils developed on this part of the landscape are consciously neglected by agricultural researchers and some other land users as well as by farmers in favour of the more often cultivated upper slope. Knowledge of soils developed at the toe-slope of a landscape is important for maximum use of the soils for food production and sustainability through their release of nutrient elements. This study aimed to report the mineralogy of clay components of *Aquic arenic paleudults* soils of Akamkpa, southeastern Nigeria.

MATERIALS AND METHOD

Research duration: The study was conducted within 2 years, between May, 2015-December, 2017.

Study area: The study area was located in Ekprilbami near Calabar River with 42 km distance from the north part of Akamkpa then emptying itself into Cross River. The area lies between the latitude 05°18'53"N and longitude 08°13'25"E at an elevation 82 m a.s.l. of southeastern Nigeria as shown in Fig. 1. The area was characterized by sub-humid tropical climate with distinct wet and dry seasons. Rainfall range between 1500 and 3500 mm per annum, relative humidity was between 80 and 90% and mean annual temperature between[8] 25.4 and 27.5°C. However, the topo sequence was covered with secondary forest re-growth. The topography of this land is strongly undulating. The land was used for the cultivation of the following crops; *Zea mays*, *Manihot* spp., *Oryza sativa*, *Musa* spp., *Dioscorea* spp. and perennial crops such as *Carica papaya*, *Elaeis guineensis*, *Hevea brasiliensis* and *Irvingia gabonensis*. Dominant trees, climbers and shrubs such as *Daniella oliveri*, *Ficus* spp., *Khaya senegalensis*, *Laxifora* spp., *Combretum* spp., *Alcohornea* spp., *Andropogon* spp. and *Digitaria* spp., were scattered almost evenly while African bamboo trees grew wildly near the streams and lowland areas.

Geological formation: The basement complex rocks occupied about 10,000 km^2 in southeast Nigeria: out of which about 40% was found in Cross River state which makes up the Oban-Obudu massif and a continuation of the African-pan Basement Complex of the Cameroun highlands[9]. The characteristics of the material reflected the processes that formed the underlying and the influence of the environment where which they occurred.

Soil sampling: Two soil samples were collected from each identified and described pedogenic horizons of depth intervals of Ap = 0-12 cm and Bt_1 = 12-25 cm of the profile pit dug at the valley bottom of the landscape of Akamkpa and transported to the laboratory for clay mineralogical determination.

Mineralogical analysis: Chemical cementing agents were removed and clay fractions separated according to Mehra and Jackson[11], Kittrick and Hope[12] and Jackson[13]. Iron-free samples were centrifuged at 750 rpm for 5.4 min to separate total clay (<2 µm) and at 2700 rpm for 42 min to separate fine clay (<0.2 µm). The fine and coarse-clay fractions were analyzed mineralogically by X-ray diffractometry. The same

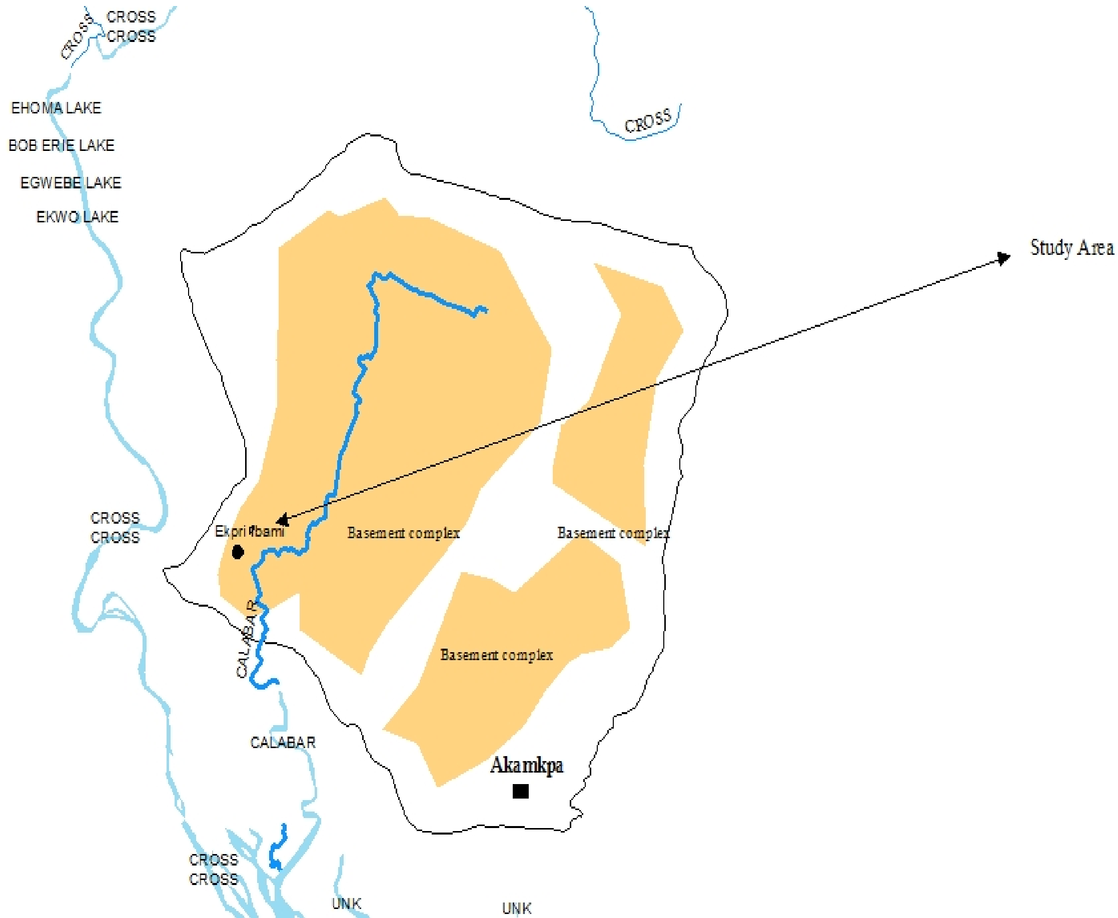

Fig. 1: Map of Akamkpa, southeastern Nigeria showing study area
Source: Pedoenviron[10]

concentration of clay suspensions was used for all samples to give reliable comparisons between relative peak intensities. Two drops of the prepared suspension were used on each glass slide. The (001) reflections were obtained following Mg saturation, ethylene glycol solvation and K saturation. The K-saturated samples were studied both after drying and after being heated at 550°C for 4 h.

RESULTS AND DISCUSSION

The mineralogical results from the XRD were presented in Fig. 2 and 3 while Table 1 showed the interpretation of the diffractogram that was the percentage of minerals in each pedogenic horizon.

The XRD analyses (Fig. 2, 3, Table 1) revealed that at Ap horizon (0-12 cm), the occurring minerals were Illite (72.5% at the highest peak of 2θ) followed by Chlorite (18.3%) then by Quartz (7.4%) then Kaolinite (1.7%) and finally montmorillonite (0.0%). While the approximate minerals content in clay fraction of the Bt_1 horizon (12-25 cm) were 63.7% Quartz (highest) followed by 11.8% kaolinite, 10.2% illite, 8.4% montmorillonite and 5.8% chlorite. Averaging, the XRD showed that the dominant clay was illite (41.4%) followed by Quartz (35.4%), chlorite (12.0%), kaolinite (6.8%) and montmorillonite (4.2%). All occurred in *Aquic arenic paleudults* soils of Akamkpa, southeastern Nigeria.

Illite: It is 2:1 type of non-expanding (mica type) mineral occurring in pedogenic and sedimentary environment and is believed to be inherited largely from parent rocks and constitute on an average of 41.4% of the minerals (Table 1). The result obtained in this study was in contrast with the report by Hajirasouli *et al.*[6] that mineral components increased with increasing depth also that of Essien and Edet[5], who stated that the Illite was the second dominant mineral in basement complex soil of Akamkpa.

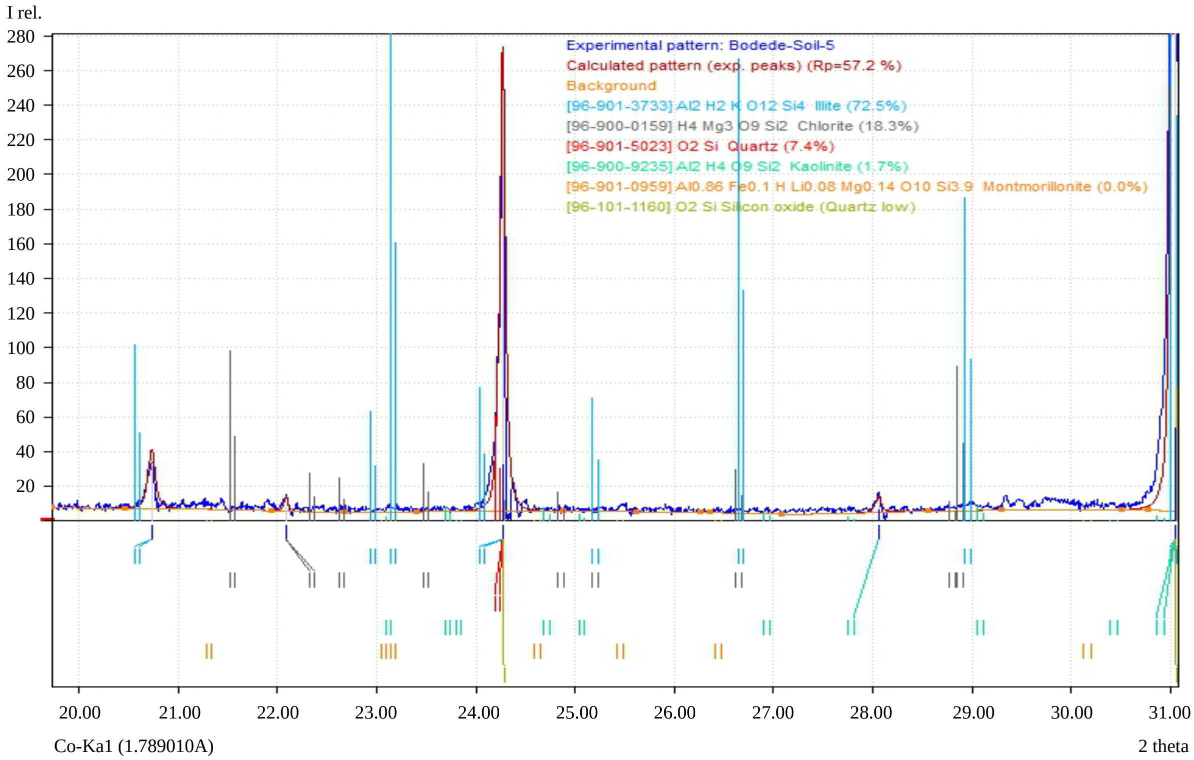

Fig. 2: X-ray diffractogram of clay mineral components for Ap (0-12 cm)

Table 1: Approximate minerals content in clay fraction of *Aquic arenic paleudults* soils of Akamkpa, southeastern Nigeria

Study Area	Sample depths (cm)	Illite	Quartz	Chlorite (%)	Kaolinite	Montmorillonite
Ekprilbami	Ap = 0-12	72.5	7.4	18.3	1.7	-
	Bt1 = 12-25	10.2	63.7	5.8	11.8	8.4
Average minerals in *Aquic arenic paleudults* soils		41.4	35.4	12.0	6.8	4.2

Quartz: The result obtained was in line with the report of Ogbaji and Akpan-Idiok[14], who reported high occurrence of quartz in fluvic deposits. The abundance of inert mineral like quartz in clay fraction as obtained revealed that the soils were in their advanced stage of weathering as confirmed from the absence of weatherable minerals such as biotite which was a constituent of micas[15] (Fig. 2, 3). Chemically, quartz mineral rarely contributed to soil nutrient status or plant nutrient uptake but its reaction with other soil elements influences structural development, water permeability, biomass productivity, resistance to erosion and aeration[15].

Chlorite: The structure of chlorite was a mixed layer, composed of regularly stacked, negatively charged 2:1 layers with a single layer of positively charged interlayer octahedra connected by H-bonds. Chlorites are usually trioctahedral, with Mg^{2+}, Al^{3+}, Fe^{3+} and Fe^{2+} on octahedral sites, tetrahedral cations are mainly Si^{4+} and Al. The implication was that chlorite clay minerals ensures the availability of Mg^{2+}, Al^{3+}, Fe^{3+} and Fe^{2+} in the soil environment[15].

Kaolinite: It had a low shrink-swell properties and a low cation-exchange capacity (1-15 cmol kg^{-1}). The X-ray diffraction data showed that kaolinite constituted about 6.8% in the soils formed on granite-mica gneiss of basement complex and happens to be the end-point materials formed through series of weathering of granite-mica gneiss parent material. The implication of the identified minerals, kaolinite showed that the high degree of weathering has yielded production of low charged surface area, low activity clay, low cation reserve and low fertility status of the soil[15].

Montmorillonite: They are expandable layer silicates with shrinking and swelling capacity; large cation exchange capacity value of 60-150 cmol kg^{-1} in soil[16]. The implication of the identified minerals is that due to their large surface area they absorb natural organic compounds as well as herbicides and pesticides. Their expansive nature and negative charge of montmorillonite cause them to be extremely reactive in soil ecology.

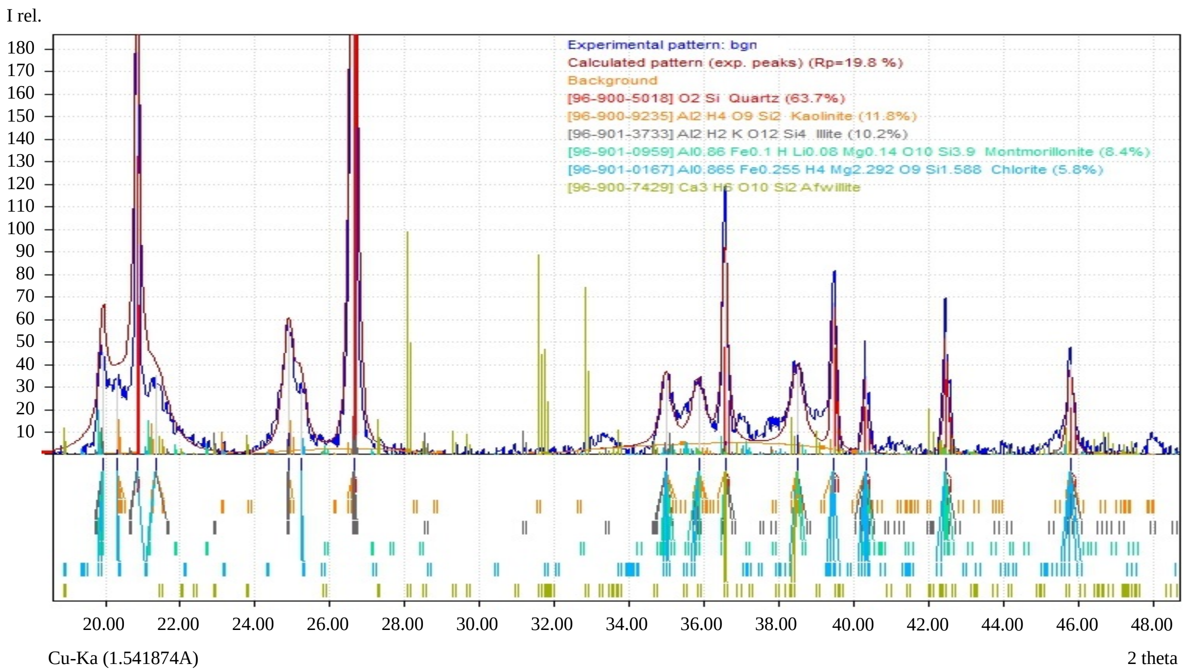

Fig. 3: X-ray diffractogram of clay mineral components for Ap (12-25 cm)

CONCLUSION

The clay mineralogical of the soil under study showed difference in the quantity of clay minerals down the profile depths and this relative amount of clay minerals may be attributed to weathering conditions probably due to internal drainage and also interstratification. The drainage condition is caused by the topography which is vital in the alteration and distribution of clay minerals in the valley bottom. Due to poor drainage, there is mottling and a characteristic pale grey colour.

SIGNIFICANCE STATEMENT

This study discovered the abundance of illite clay mineral at the valley bottom that can be beneficial in crop production in that they are characterized by large surface area thus they retain organic compounds, fertilizers and this study will help the farmers of the study area to uncover the critical areas of nutrient management that many farmers of valley bottom were not able to explore. Thus a new theory on expandable clay mineral may be arrived at.

REFERENCES

1. Ogban, P.I. and O. Babalola, 2009. Characteristics, classification and management of inland valley bottom soils for crop production in subhumid southwestern Nigeria. J. Trop. Agric. Food Environ. Ext., 8: 1-13.
2. Mackel, R., 1974. Dambos: A study in morphodynamic activity on the plateau regions of Zambia. Catena, 1: 327-365.
3. Etu-Efeotor, N.O., 1984. Mineralogy and evaluation of recent clays from eastern Niger Delta. Niger. J. Mineral Geol., 21: 49-54.
4. Adeleye, D.R., 1978. Tertiary provenance changes and clay mineralogy of part of the Western Niger Delta. Niger. J. Mineral Geol., 15: 91-103.
5. Essien, N. and A. Edet, 2001. Mineralogy of the clay components of the famosing limestone, Se Nigeria. Global J. Pure Applied Sci., 7: 683-687.
6. Hajirasouli, M., S. Mahmoodi and H. Torabi, 2010. Distribution of clay minerals along a soil toposequence. J. Food Agric. Environ., 8: 1162-1167.
7. IITA., 1990. Inland valley farming systems. Annual Report, International Institute of Tropical Agriculture, Ibadan, Nigeria, pp: 20-21.
8. NIMET., 2015. Nigeria meteological agency. Calabar Station.
9. Ekwueme, B.N., 2003. The Precambrian Geology and Evolution of the Southeastern Nigerian Basement Complex. University of Calabar Press, Calabar, Nigeria, ISBN: 9870070109, Pages: 135.
10. Pedoenviron, 2018. Geospatial and mapping company. Calabar, Cross River State.
11. Mehra, O.P. and M.L. Jackson, 1960. Iron oxide removal from soils and clays by a dithionite-citrate system buffered with sodium bicarbonate. Clays Clay Mineral, 7: 317-327.
12. Kittrick, J.A. and E.W. Hope, 1963. A procedure for the particle size separation of soils for X-ray diffraction analysis. Soil Sci., 96: 319-325.

13. Jackson, M.L., 1975. Soil Chemical Analysis-Advanced Course. University of Wisconsin, College of Agriculture, Madison, WI.
14. Ogbaji, P.O. and A.U. Akpan-Idiok, 2013. Mineralogical and textural characteristics of Onwu floodplain soils, Yala Cross River State, Nigeria. Int. J. Agric. Crop Sci., 6: 539-544.
15. Akpan-Idiok, A.U. and E.E. Ukwang, 2012. Characterization and classification of coastal plain soils in Calabar, Nigeria. J. Agric. Biotechnol. Econ., 5: 19-33.
16. Esu, I.E., 2010. Soil Characterization, Classification and Survey. African Books Collective, Nigeria, ISBN-13: 9789780813734, Pages: 232.