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PRELIMINARY MINERALOGICAL AND GEOTECHNICAL CHARACTERIZATION OF KAOLIN FROM ABEOKUTA AREA, SOUTHWESTERN NIGERIA

Olisa, O.G. [1], Ajibade, O.M[1], Ogunjinrin, O.A [1], Ayodele M. [2] and Bamgboye D. O.[1]
[1]Department of Earth Sciences, Olabisi Onabanjo University, Ago-Iwoye
[2]Department of Geological Services, Ogun State Ministry of Commerce and Industry, Abeokuta
Corresponding author: olusegun.olisa@oouagoiwoye.edu.ng

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ABSTRACT

Kaolin of sedimentary origin in the Abeokuta area, southwestern Nigeria was studied to determine its mineralogy and geotechnical properties as well as possible industrial applications. Samples of kaolin were collected from different mine sites in the Abeokuta area. Geotechnical test was also performed to determine the grain size parameters and plasticity of the kaolin samples. Samples were also subjected to mineralogical and morphological analysis using X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM). Results revealed that kaolin samples have clay, silt and sand fraction ranging from 7.3 -53.93%, 29.56 – 53.72% and 1.8 to 29.56% respectively. XRD and SEM results revealed that minerals in kaolin are kaolin, quartz, rutile and anatase. Industrial and geotechnical appraisal revealed that some of the samples with high content and low quartz content can be used in production of ceramics and paper while cannot be used in some industrial application such as pottery and production of ceramics due to the grain size geotechnical properties and mineralogy.

INTRODUCTION

Kaolin is a phyllosilicate mineral which is usually micron to submicron in size. They have found great applications industrially due to their physical and compositional characteristics. They are used in ceramics, paper filling and coating, refractory, water treatment fiberglass, cement, rubber and plastics, paint, catalyst, pharmaceutics, ceramics, cracking catalyst industries and agriculture (Jepson 1984; Bundy and Ishley 1991; Ekosse 2010; Diko et al. 2011). Kaolin belongs to the Kaolinite group which according to Murray, (2007) also comprises of halloysite, dickite and nacrite. These different minerals differ based on the manner of stacking and the number of unit layers (Murray 2007; Vaculíková et al. 2011).

Chemically, kaolin are hydrated aluminum silicates ($Al_2Si_2O_5(OH)_4$) which consist of 1:1 layers of combined silicate sheets (Si_2O_5) bonded to aluminum oxide/hydroxide [$Al_2(OH)_4$] layers, which are continuous in the a- and b-axis directions and are stacked one above the other in the c-axis direction and particles can vary from tens of nm to several µm. They are formed from in situ weathering of certain igneous rocks, diagenetic processes or hydrothermal alteration of suitable rocks. The properties of kaolin also depend on the degree of crystallinity or the degree of weathering which is a function of the source of the parent components of the material (Murray and Kogel, 2005). The morphological properties of kaolin are also important in determination of their industrial application especially in use as paper fillers and coating (Jepson 1984; Bundy and Ishley 1991). The physical characteristics also determine its ultimate application hence, the need to characterize the mineralogical properties of kaolin samples to identify the different mineral phases which may be present in them.

Depending on the source, kaolin may contain impurities such as quartz, feldspar, anatase, and muscovite. Iron hydroxide pigments may also be present and this will affect the color and industrial application of the kaolin. Industrial application of kaolin also depends on the range of particle size, particle shape and arrangement, crystallinity and specific surface area (Emofurieta et al., 1992). In this study, kaolin deposits around Abeokuta are examined to determine their mineralogy and possible industrial applications.

MATERIALS AND METHODS

Representative samples of kaolin were collected from working surfaces and pits in the Abeokuta area, the samples were air dried prior to analysis. Grain size analysis which involved sieve analysis and sedimentation analysis were performed for coarse and fine grains respectively. Specific gravity, natural moisture content and consistency limits were also determined. Analysis was carried out at the Department of Geology, University of Ibadan. 6 representative samples were subjected to X-Ray Diffactrometry (XRD) using a PANalytical Empyrical XRD equipment with a Cu-anode X-ray tube at the Department of Geosciences, University of Free State, South Africa. For morphology, 6 specimens were examined and analysed with a JSM-7800F Extreme-resolution Analytical Field Emission Scanning Electron Microscope (SEM). Analysis was carried out at the Centre for Microscopy, University of Free State, South Africa.

RESULTS AND DISCUSSION

Kaolin occurs as whitish to greyish to reddish beds which are overlaid by lateritic beds in some areas (Figure 1). In the kaolin beds, the upper section of the layers which are close to the lateritic beds are reddish compared to the lower beds indicating the presence of iron rich minerals in the upper section. They occur in discrete beds of different lengths, thickness; grain size also differs in the beds and locations.

Geotechnical analysis results revealed the specific gravity of the samples ranges from 2.49- 2.65g/cm^3. Grain size and hydrometer analysis revealed wide variation in particle size. The clay, silt and sand fraction in the samples ranges from 7.3 -53.93%, 29.56-53.72% and 1.8 to 29.56% respectively. The samples with the lower clay proportions are characterized by 47 - 53% sand and silt percentage of 41 - 47%, lower natural moisture content of 13-17% compared with samples with higher proportion of clay of 31 - 53.93% (Table 1, Figure 2). Natural moisture content ranged 13-25%, liquid limit ranged 57.5-76.8, plastic limit ranged 24 - 32, and plasticity index ranged 34-45 while linear shrinkage ranged 12.9-15.78.

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Figure 1: Field photographs showing sample collection points in the Abeokuta area

Kaolin samples with lower clay percentages are characterized by lower linear shrinkage values of 8.6 to 10 compared to kaolin samples with higher clay percentage with linear shrinkage values of 12.9-15.78 (Table 1).

Due to the lower proportion of clay materials in some of the samples, consistency limit values were not determined for the samples with low clay percentages. Samples with high clay percentages are characterized by values of 57.5-76.8, 24-32 and 34-45 for liquid limit, plastic limit and plasticity index respectively.

Table 1: particle size distribution, physical and geotechnical properties of studied samples

Sample number	Natural moisture content	Specific gravity (kg/m3)	Consistency limits				Grain size(%)		
			Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage	Sand	Slit	Clay
1	23	2.58	57.5	24	34	13.6	14.8	31.27	53.93
2	23	2.49	76.8	32	45	15.78	29.56	29.56	31.14
3	17	2.53	NP	NP	NP	10	52.1	40.57	7.3
4	15	2.62	NP	NP	NP	10	47.6	45.43	6.97
5	13	2.65	NP	NP	NP	8.6	47.1	46.92	5.98
6	25	2.59	64.3	31	34	12.9	1.8	53.72	44.48

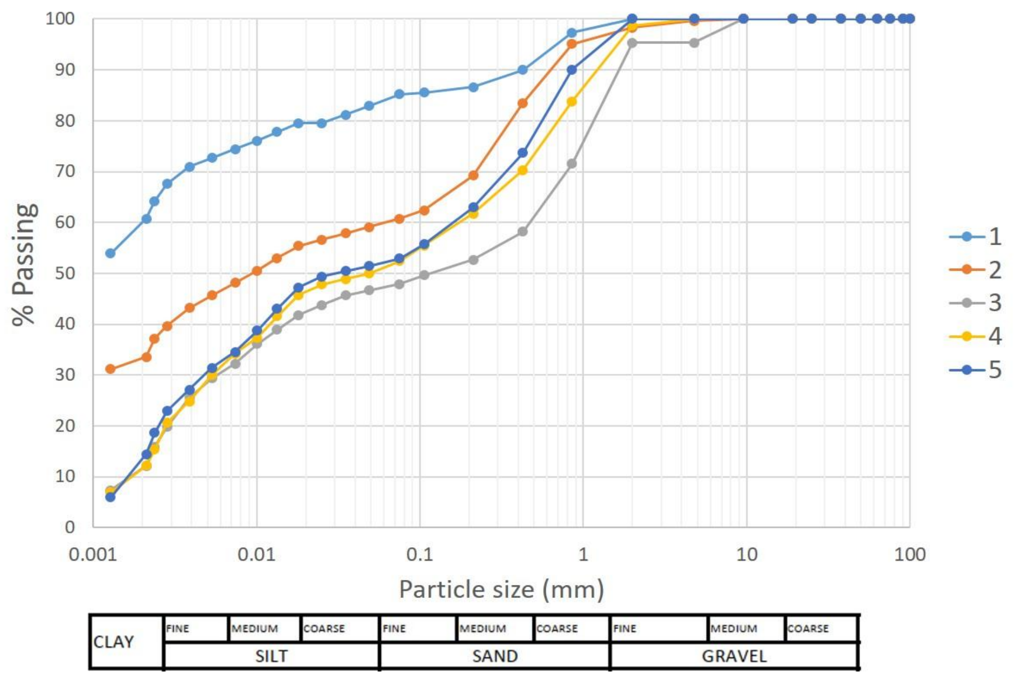

Figure 2: Grain size analysis of kaolin from Abeokuta area

Mineralogy and morphology

XRD results revealed the kaolin samples are composed majorly of kaolin and in some cases quartz, and accessory minerals such as mica, rutile and k-feldspar (Figure 3a and b). Morphologically, the kaolin is composed of regular to irregular platy sheet like stacks of kaolinite. The platy regular structures are visible at higher magnification. Some of the minerals revealed well developed euhedral crystal faces and some are characterized by irregular crystal surfaces elongated in one non uniform direction with matrix of finer particles on their surfaces while Some of the accessory minerals also occur as lath like and fibrous bundles (Figure 3c). The stacking and thin platy, non-uniform, irregular grain is typical of sedimentary kaolin and the absence of tubular shaped crystals denoted the absence of halloysite (Keller 1976; Joussein et al 2005; Garcia-Valles et al. 2020;).

Industrial appraisal

The physical and geotechnical properties of industrial minerals are of great importance in the determination of their scope of application for various industries. For clays, the plasticity, moisture content, porosity and permeability depends on the particle size distribution and ratio of clay/silt/sand size clasts.

An assessment of the clay/silt/sand fractions which controls porosity and permeability was carried out using the ternary diagram of McManus (1998). The studied kaolin samples plotted within the low porosity, low permeability field (Figure 4a) and this indicates low cohesion in the kaolin and inability of the kaolin to readily adsorb water and this will affect the use of the clays in ceramics.

The clay/silt/sand ratio determines the plasticity of the clays and higher proportion of clay and silt fractions will lead to higher plasticity while lower fractions will lead to low plasticity or no plastic clays (Daoudi et. al. 2014).

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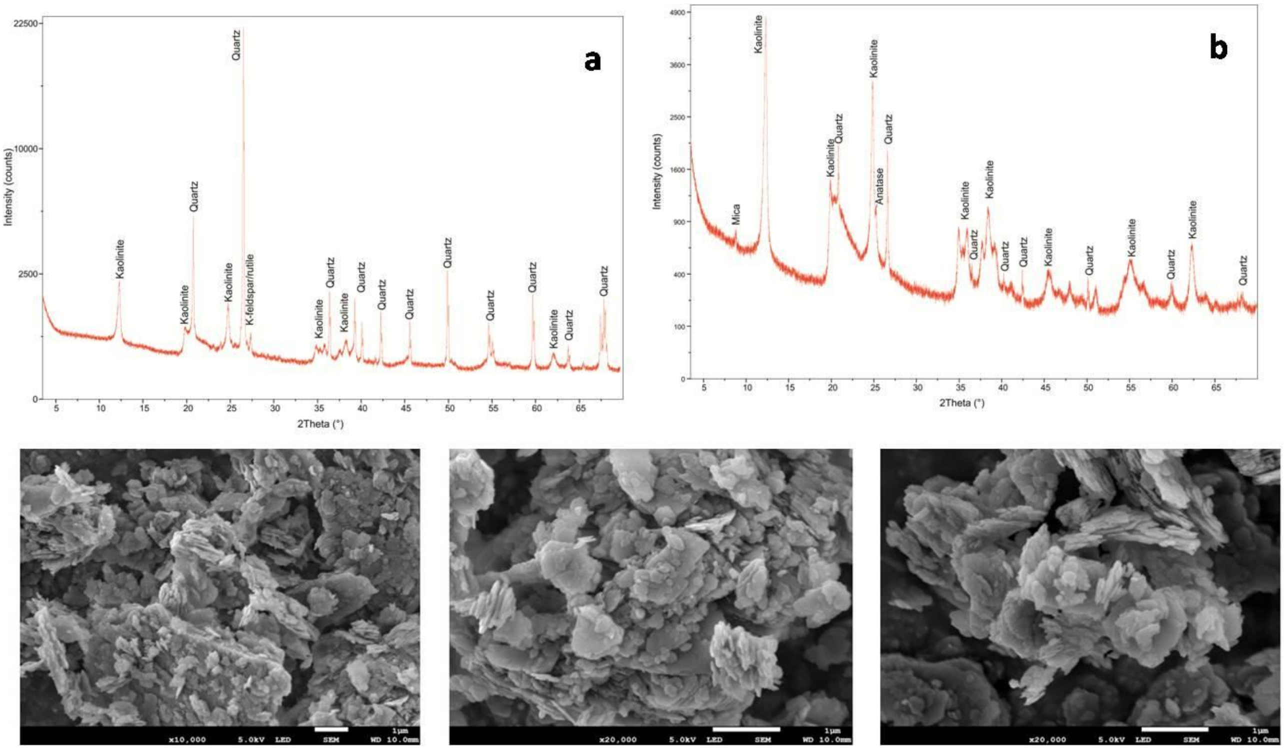

Figure 3: (a and b) Representative XRD of kaolin samples from Abeokuta area showing their mineralogical composition. (c) Scanning electron microscopy (SEM) micrographs showing the morphology of kaolin samples from Abeokuta area.

The potential for swelling can be estimate from the value of the plasticity index. Moderate values indicate a high potential for swelling and high values could indicate possibility of excessive shrinking. According to Abajo (2000); Vieira *et al*., (2008), kaolin with plasticity index below 10% are not suitable for use in ceramics production.

The plasticity index values for some of the studied kaolin are above this benchmark and this implies that they can be used in the production of structural clay products. However, based on the Casangrande chart (Figure 4b and c), the kaolin samples are not suitable for use in potteries and production of bricks as they mostly plot outside the optimum/acceptable region. Morphologically, the studied kaolins are composed of fine sized platy crystals which are suitable for production of paper as they will impart a smooth surface which will be receptive to ink (Murray 2007).

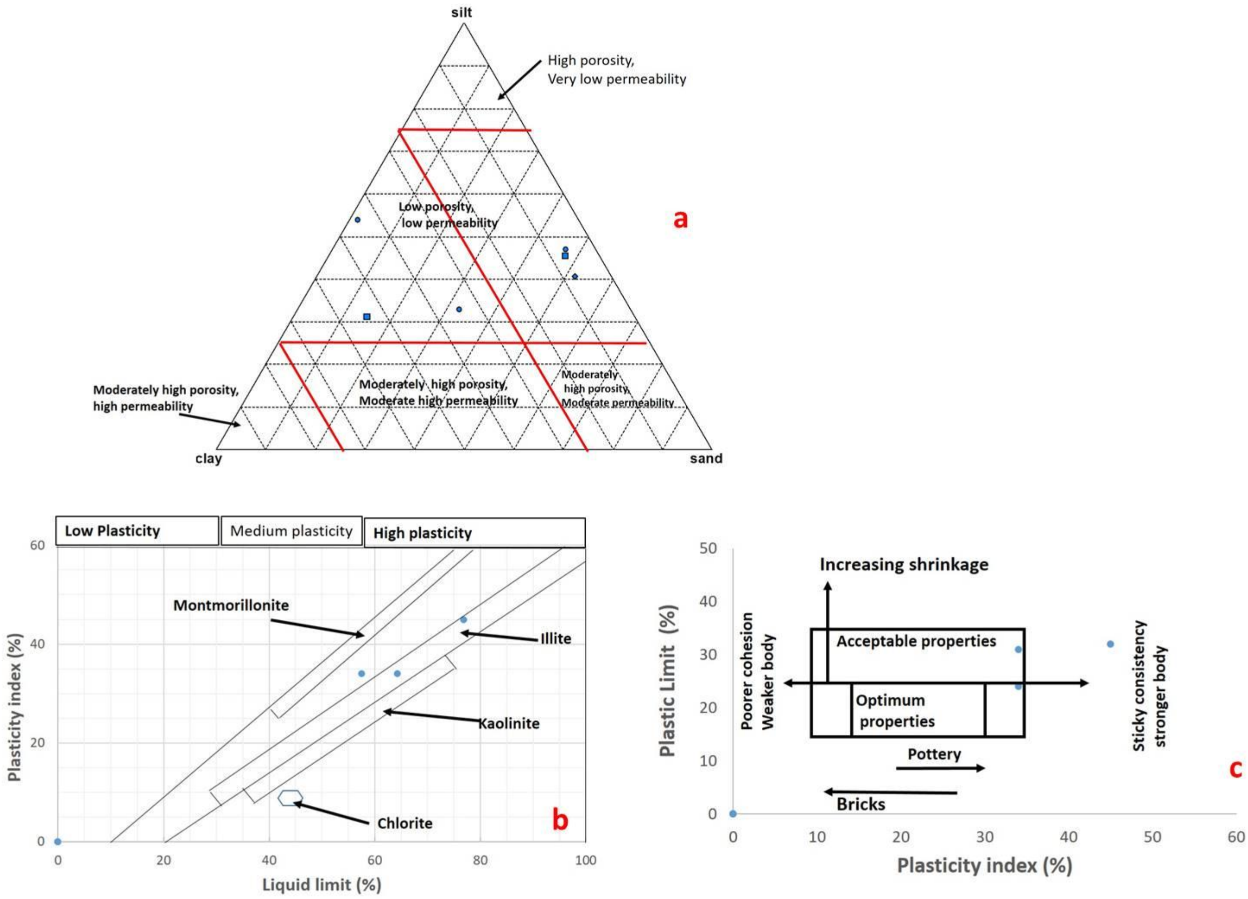

Figure 4: (a) Ternary diagram of studied kaolins based on their sand, silt, clay fraction percentages (Fields after McManus 1998), (b)Position of the studied kaolin samples on the Holtz and Kovacs (1981) diagram, (c) Clay workability chart (after Casagrande 1948)

CONCLUSION

The studied kaolin samples are composed primarily of kaolin and accessory minerals such as feldspar, and mica, their properties varies based on clay/silt/sand proportions, some of them are not plastic and may not be applicable in certain industrial applications such as ceramics. Some of the samples, based on plasticity index and particle size/shape can be applicable in production of ceramics, pottery, paper and similar applications.

REFERENCES

Abajo, M. (2000) Manual Sobre Fabricación de Baldosas. Tejas y Ladrillos; Beralmar S.A.: Barcelona, Spain.

Bundy, W.M and Ishley, J.N. (1991) Kaolin in paper filling and coating. Applied Clay Science 5:397-42

Casagrande, A. (1948) Plasticity chart for the classification of cohesive soils. Transactions of America Society of Civil Engineering113, 901

Daoudi, L.; Elboudour, E.H.; Saadi, L.; Albizane, A.; Bennazha, J.; Waqif, M.; El Ouahabi, M.; Fagel, N. (2014) Characteristics and ceramic properties of clayey materials from Amezmiz region (Western High Atlas, Morocco). Applied Clay Science102, 139-147.

Diko, M.L., Ekosse, G.E., Ayonghe. S.N. and Ntasin, E. (2011) Physical characterization of clayey materials from

Scientia Africana, Vol. 21 (No. 2), August, 2022. Pp 97-104 https://dx.doi.org/10.4314/sa.v21i2.10
© Faculty of Science, University of Port Harcourt, Printed in Nigeria ISSN 1118 – 1931

Tertiary volcanic cones in Limbe (Cameroon) for ceramic applications. Applied Clay Science, No. 51, 380-384. DOI:10.1016/j.clay.2010.11.034

Ekosse, G.E. (2010) Kaolin deposits and occurrences in Africa: Geology, mineralogy and utilization. Applied Clay Science, 50, No. 2, 212-236. DOI:10.1016/j.clay.2010.08.003

Emofurieta, W.O.; Kayode, A.A.; Coker, S.A. (1992): Mineralogy, Geochemistry and Economic Evaluation of the Kaolin Deposits near Ubulu-Uku, Awo-Omama and Buan in Southern Nigeria. Journal of Mining Geology, 28, 211–220.

Garcia-Valles, M.; Alfonso, P.; Martinez, S.; Roca, N. (2020): Mineralogical and Thermal Characterization of Kaolinitic Clays from Terra Alta (Catalonia, Spain). Minerals10, 142.

Holtz, R.D. and Kovacs, W.D. (1981): An Introduction to Geotechnical Engineering; Prentice-Hall, Inc.: Upper Saddle River, NJ, USA.

Jepson, W.B. (1984) Kaolins: Their properties and uses. Transactions of the Royal Society of London: A311:411-432.

Joussein, E.; Petit, S.; Churchman, J.; Theng, B.; Righi, D.; Delvaux, B. (2005) Halloysite clay minerals—A review. Clay Mineralogy:40, 383-426

Keller, W.D. (1976) Scan electron micrographs of kaolins collected from diverse environments of origin–I. Clay Mineralogy: 24, 107-113.

McManus, J. (1988) Grain size distribution and interpretation. In Techniques in Sedimentology; Tucker, M.E., Ed.; Blackwell Scientific Publications: Oxford, UK, 1988; pp. 63-85

Murray, H.H. (2007) Applied Clay Mineralogy. Occurrences, Processing and Application of Kaolins, Bentonites, Palygorskite–Sepiolite, and Common Clays, 1st ed.; Elsevier: Oxford, UK, p. 189

Murray, H.H. and Kogel, J.E. (2005) Engineered clay products for the paper industry. Applied Clay Science 19, 199-206.

Vaculíková, L., Plevová, E., Vallová, S. and Koutník, I. (2011) Characterization and differentiation of kaolinites from selected Czech deposits using infrared spectroscopy and differential thermal analysis. Acta Geodynamics and Geomaterials 8, No. 161, 59-67

Vieira, C.M.; Sa'nchez, R.; Monteiro, S.N. (2008) Characteristics of clays and properties of building ceramics in the state of Rio de Janeiro, Brazil. Construction and Building Materials 22, 781-787