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CERAMIC QUALITIES OF INDUSTRIAL CLAY DEPOSITS AT VIMTIM IN MUBI, NORTHEASTERN NIGERIA.

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Abstract

The possibility of using the extensive clay deposit at Vimtim in Mubi area, northeastern Nigeria for coarse ceramic manufacture was investigated. Relevant ceramic properties of the clays have been determined and their suitability is satisfactory. Results of the assessment reveal clays that are fine-grained (85.6-96% < 2μm), plastic (36-53% PI), and moderately dense (1200-1720 g/m^3). Mean values of other industrial properties include 6.9% shrinkage, 6.8% porosity, 34.5N/m^3 mechanical strength, 7.7% LOI, reddish yellow firing colours. Their average chemical composition includes 70.5% SiO_2, 17.04% Al_2O_3, 2.58% Total Fe oxides, 0.26% Na_2O 0.92% K_2O, 0.89% MgO and appreciable kaolinite content. These parameters suggest good clay raw materials for the manufacture of coarse ceramic products like earthenware, kitchenware, ornamental wares and scientific wares.

Key words: Clay deposit, Vimtim - Mubi, Nigeria, Ceramic qualities.

Introduction

Extensive deposits of clay occur in Mubi and its environs, especially in the peneplains surrounding or enclosed by the high rising basement blocks. Numerous occurrences are encountered within Mubi urban close to the riverside, kilometre 3 along Mubi - Maiha road, and 2.5km along Mubi - Michika road (Fig.1). Other occurrences are in Bahuli, Muchala, Mondanya, and Madugu etc. The indigenes of these areas engage in small-scale pottery making (including traditional pots and kitchenware). A large deposit of about 3sq km occurs at Vimtim (a settlement located at about 14km from Mubi town along Mubi - Michika road) from where the Mubi burnt bricks factory sources its raw materials. This research was undertaken to assess the ceramic properties of the clays at Vimtim, Mubi.

Geologic Setting

Vimtim clay deposit is located on a thick layer of old terraced alluvium of Quaternary age, enclosed within and bordering basement rock units. It is bounded on the north and east by the migmatite gneisses and on the south and west by the Older Granites (Fig 2). The area is underlain by basement rocks, which have been highly weathered to form the residual clay deposit. The major rock types include migmatites, gneisses (including pockets of dioritic gneisses), syntectonic granites and the alluvium.

Sediments exposed in the area are poorly sorted ferruginous detrital sandstones, thick sequences of mud and shale, and gray-coloured clays in association with bands of ironstone. The clays are overlain by thick overburden and underlain by ironstained gravelly units. The loose overburden sediments are yellowish to reddish brown in colour and are coarse to medium grained, consisting mainly of quartz grains. Lithologic section of the exposure at Mararaba Vimtim is given in Fig. 2b.

Three distinctive clay exposures were encountered at the factory quarry site behind

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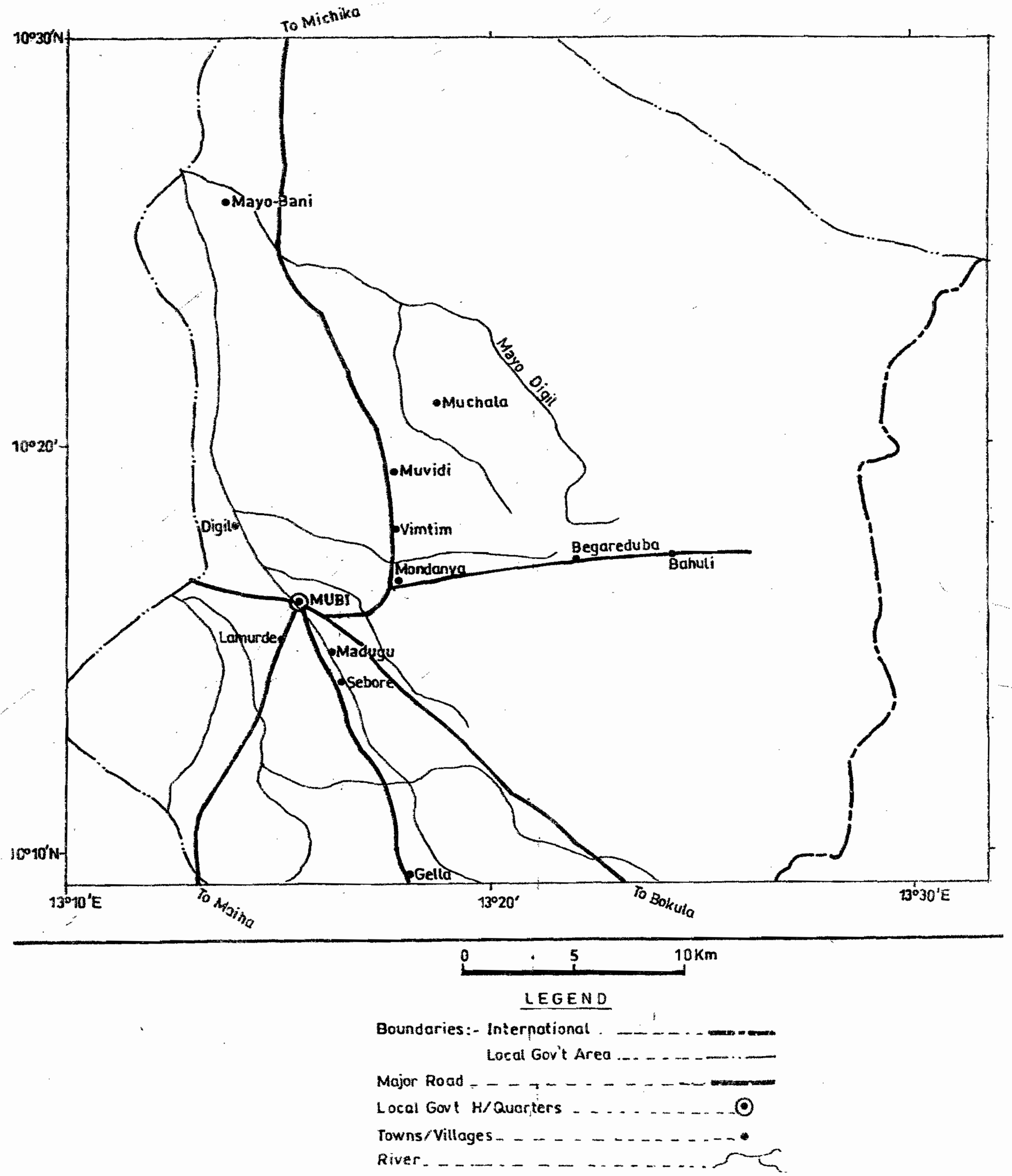

FIG. 1: LOCATION MAP OF MUBI AND ENVIRONS

Vimtim village. The clays are sandy, with the intercalating sands coarsening with depth. Generally, the clays are gray in colour, medium grained, plastic and sticky to touch. They occur in association with mud, fine-grained gravelly sands and thin ironstone beds. The associated sands are angular-shaped, depicting close provenance. The clay beds are mostly 0.2 - 0.4m thick at depths between 1 - 3m. However, a thick bed of about 1.6m occurs between 1.4 - 3m depth at Mararaba

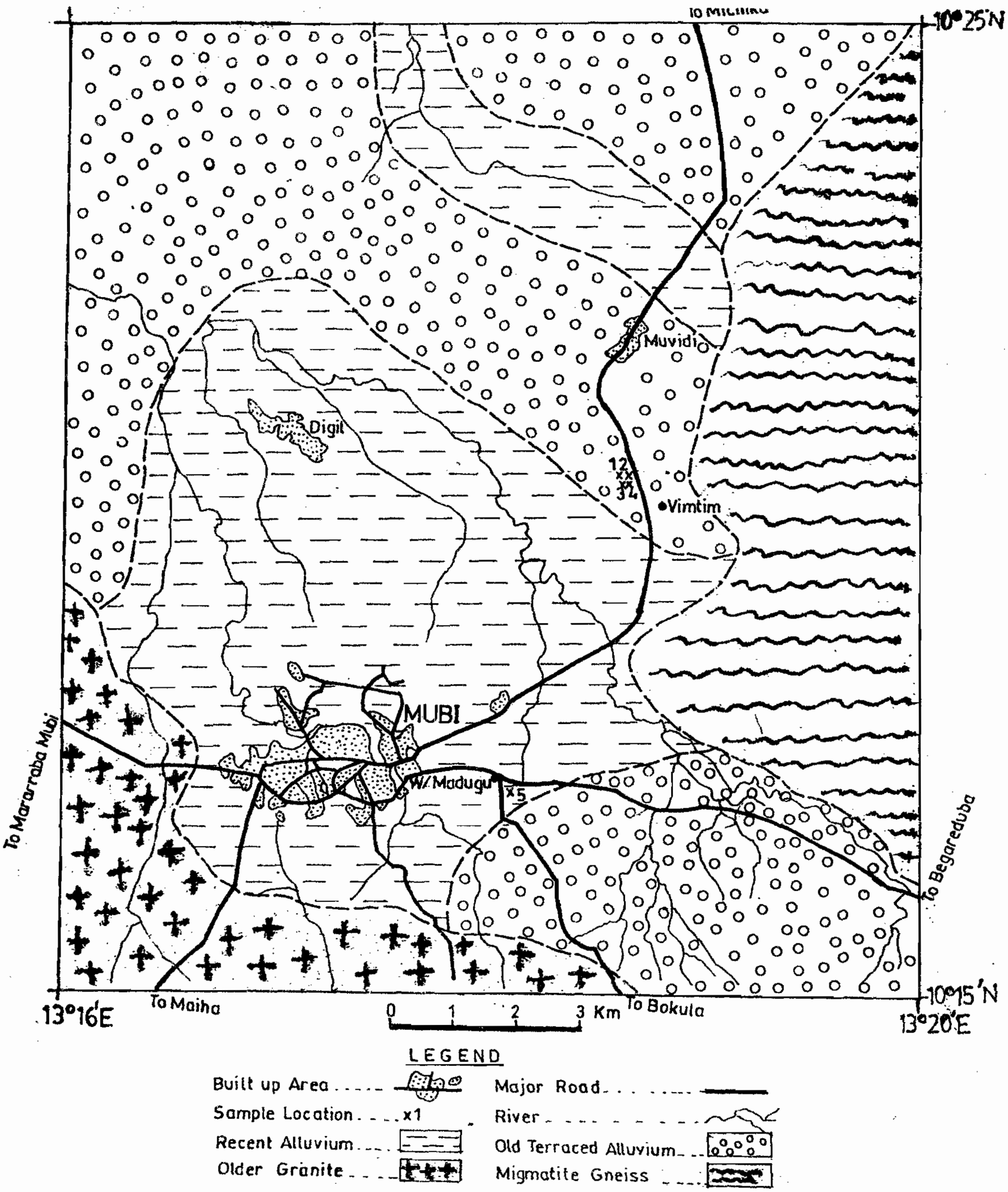

FIG. 2a GEOLOGIC AND SAMPLE LOCATION MAP OF THE STUDY AREA

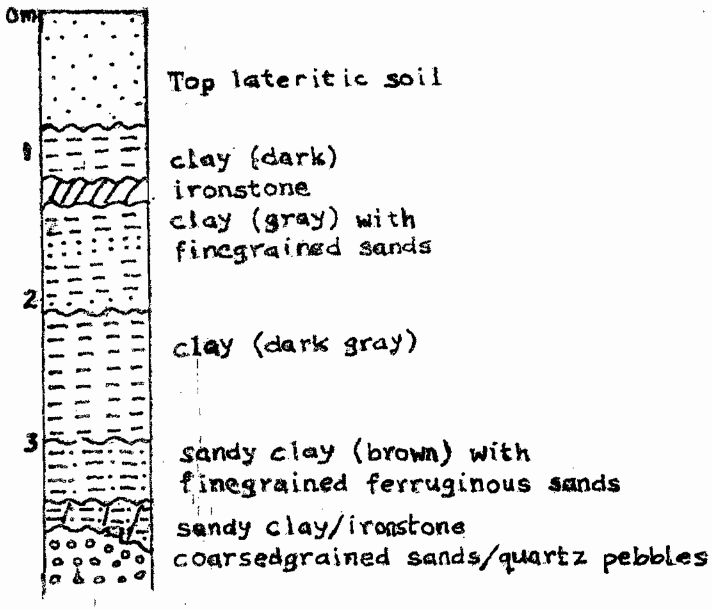

FIG 2b Vertical profile at Mararaba Vimtim

Vimtim. It is dark gray in colour, very smooth and sticky, very fine-grained and monolithic. Below the 3m depth the clay grades into thin bedded and brownish sandy clay mixed with fine-grained ferruginous sand, ironstone pebbles and thin ironstone bed at 3.4 - 3.6m depth interval. Underlying these is a thick bed of coarse-grained sands associated with large ironstained quartz pebbles.

Sampling and Analyses

Samples were collected from three sections of the quarry and from exposures in dry stream channels and hand dug wells. One hundred samples were collected at 1.5 to 3m-depth interval by means of a shovel and bouger digger. About two kilograms (2kg) of each sample was obtained.

Fifty representative samples were selected and used for the various analyses. A kilogram of each sample was pulverised, dried and powdered. Some quantities of the powdered samples were made into slurry and used for density tests while some were pelletized into 15 spherical-shaped tiles of 2 cm diameter size using a pressure gauge machine, and used for the determination of other physical properties. Part of the sample powder was also used for the chemical tests while the leftover coarse fractions from sieve analysis were made into slides for petrographic studies. Clay pastes were made into test bricks by vacuum extruder and used for compressive strength test.

Properties of the raw clay materials measured using standard methods include plasticity (Casagrande, 1932; Dumbleton & West, 1966; Bain, 1971), grain size of particles (by wet sieve procedure with BS 160, 230, 330 mesh sizes) and density. A standard oedemeter was used to measure the compressive strength of the brick specimens at Works Training School laboratory, Yola. Petrographic study of the samples was done using binocular microscope while XRD method (at Ashaka Cement factory physical laboratory) was used to determine the clay minerals content. Shrinkage, porosity, compressive strength, loss on ignition and colour were some of the industrial properties determined. The size, weight, resistance and colour of fresh sample pellets were noted, and then oven-dried for 45 minutes to 120^0 C and the parameters re-measured. The dried specimens were fired for 30 minutes at three different temperatures (950^0 C, 1050^0 C, 1100^0 C) and changes in each of these properties observed and measured using standard procedures at the temperature marks.

The chemical constituents (oxides of relevant elements) were determined using Atomic Absorption Spectrophotometer (for Si, Al, Ca, Mg, Na and K) and colorimeter (for Fe).

Results and Discussion

Results of the physical properties are given in Table 1. The clays have high plasticity within a range of 36 - 53%. The liquid limit values range from 55 - 72% while the plastic limits range from 15

Table 1 **Physical Properties of the studied clays**

Location	No. of samples	Grain size (%)		Plasticity (%)		Dry density (kg/m^2)	
		Mean	Range	Mean	Range	Mean	Range
Vimtim (quarry site)	15	87.08	85.6-89.7	41.02	36-48	1488.6	1300-1720
Vimtim (dry stream valley)	5	93.2	90-96	46.4	38-53	1466	1420-1510
Mubi (factory site)	5	89.1	87-94	42.2	38-49	1370	1200-1580
Egamini *	8	88.0	-	27.0	-	1624	-
Itu **	20	93.35	-	30.1	-	1403.5	-

Investigated ball clay deposits : *Alabo & Odigi,1989; **Elueze et al,1999.

Table 2 **Firing characteristics of the studied clays**

Location	No of samples	Temp °C	Shrinkage (%)		Porosity (%)		LOI (%)		Strength (N/m^3)	
			mean	range	mean	range	mean	range	Mean	range
Vimtim (quarry site)	15	950	2.8	1.7-4.5	15.5	12-19	14.7	13-18	50.8	30.7-62
		1050	4.9	2.3-7.5	13.3	9.8-16.2	17.5	16-19.2	81.8	62-95
		1100	6.2	3.8-9.2	7.2	4.2-10.3	23.2	22.6-24	111.3	96-116
Vimtim (dry stream valley)	5	950	3.5	2.6-4.3	17.0	13.7-19.6	14.8	13-16.5	52.9	40.2-65
		1050	4.9	2.5-7.2	13.7	10.7-15.8	17.7	16.6-19	77.8	66-92
		1100	7.3	3.8-9.6	6.9	6-9.4	23.2	22.7-23.8	105.7	90.3-125
Mubi (Factory site)	5	950	3.5	2.7-4.7	15.0	12.8-17	14.9	13-18.5	36.6	32.8-42
		1050	5.2	2.9-8	12.1	9.8-14.6	17.6	16.8-19.1	67.1	63-70
		1100	7.4	6.8-12.3	6.4	4.7-8.6	23.3	22.9-23.8	92.4	90.5-96.5
Egamini *	8	1100	6.67	-	9.52	-	28.58	-	22.86	-

LOI = loss on ignition

Investigated ball clay. *Alabo & Odigi. 1989; Elueze et al. 1999

Table 3 **Chemical composition of the studied clays**

Parameters %	Vimtim (Quarry site)		Vimtim (Dry stream valley)		Mubi (Factory site)		Itu *	London **
	mean	range	mean	Range	mean	range	mean	Mean
SiO_2	71.2	68.7-76	69.7	68.6-72.5	70.5	68.6-72	70.8	67.5
Al_2O_3	17.5	15.8-25	16.5	15.8-17.9	17.1	15.8-18.6	13.1	26.5
Fe_2O_3	2.8	1.5-4.2	3.6	1.9-6.8	3.3	2-4.6	2.8	0.85
FeO	1.7	0.4-4.0	2.4	0.9-3.9	1.74	0.6-3.2	-	-
CaO	2.7	1.8-5.5	3.14	1.9-4.2	2.84	2-3.2	0.64	0.24
MgO	0.71	0.1-1.8	0.86	0.3-2.1	1.1	0.6-1.9	0.16	0.15
K_2O	0.84	0.5-1.9	0.9	0.5-1.5	1.04	0.6-1.7	0.34	2.1
Na_2O	0.31	0.17-0.6	0.25	0.15-0.4	0.26	0.2-0.5	0.10	0.85

Known ball clay deposits : * Elueze et al,1999; ** Singer & Sonja,1971.

- 32%. The observed plasticity parameter indicates possible expansive clay with relatively low silt content. About 85.6-89.7% of the particles pass the finest sieve of 330 mesh size for quarry samples, and 90-96% for clays from dry stream channels. These percentages depict medium grained clays. The dry density of the clays range from 1300 to 1720g/m^3 for the Vimtim quarry samples, while the stream channel samples have 1420 to1510 g/m^3. These values indicate dense, and less viscous clays.

Microscopic examination of the coarse fractions reveals mainly quartz and feldspar with little amounts of mica and opaque minerals. They are angular to subangular in texture and brownish stained. The texture signify close provenance of the source materials while the brown stains indicate oxidation. XRD analysis of the clays was done with a Philips (model PW1710) diffractometer (using Cu radiations at scanning rate of 40KV and 20mA) and the interpretations were computer automated. The diffractogram is given in Fig 3. Results reveal the clays to generally contain mainly kaolinite (41%) and montmorillonite (11%). The factory site clay samples contain illite, which is somehow related to the appreciable iron content.

Table 2 show results of the firing properties. Areal shrinkage value of the fired specimens range from 1.7 to 4.5% at 950^{0}C, 2.3 to 7.5% at 1050^{0}C and 3.8 to 9.2% at 1100^{0}C for the Vimtim clays. Apart from reduction in size, no physical distortion or crack occurred on the clay specimens hence there would be negligible distortion in shape of its products. The porosity or water absorption capacity of the fired samples range from 12-to19% at 950^{0}C, 9.8 to 16.2% at 1050^{0}C and 4.2 to 10.3% at 1100^{0}C. The porosity values lessen remarkably at 1100^{0}C, probably due to vitrification of the clay particles. The dried bricks were quartered into 3cm^2 size test cubic bricks and fired. The compressive strengths were measured. Results in Table 2 show values ranging from 30.7 to 62 N/m^2 at 950^{0}C, 62 to 95 N/m^2 at 1050^{0}C and 96 to 116 N/m^2 at 1100^{0}C. The results show significant variation with increase in temperature but narrow variation range at each temperature (averaging 33 N/m^2). However, comparatively, the quarry samples are of a higher strength than the rest. The high values can be attributed to high contents of fluxes notably iron oxides. Remarkable

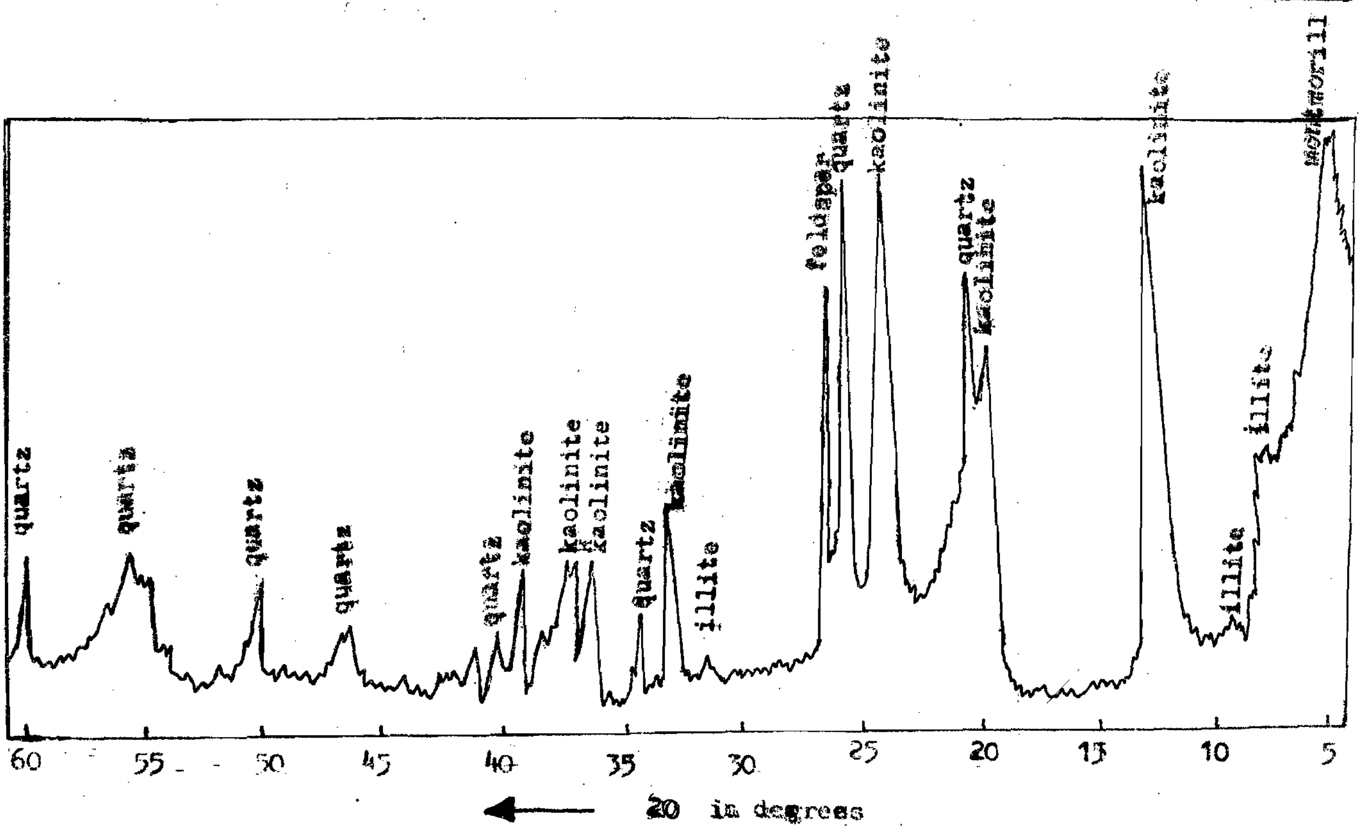

Fig. 3 X- ray diffractogram of Vimtim clays

colour change was noted with increasing firing temperature. The fresh samples were grayish brown but changed to brown when dried. On firing, the colour changed from rusty brown to various shades of reddish brown. The increasing reddish brown tint indicates moderate iron content. This brown firing colour is however good for bricks but can also give appealing colour for manufactured ceramic products. Loss on ignition values for the clays vary from 13 to 18% at 950^{0}C, 16 to 19.2% at 1050^{0}C and 22.6 to 24% at 1100^{0}C. The narrow variation range for Vimtim clays at 1100^{0}C indicates intense fusion of the pore spaces. This deduction is supported by the observed low porosity (4.2 to 10.3%) of the clays at that temperature.

Appreciable chemical contents determined include silica, alumina, iron oxide, alkalies, lime and magnesia (Table 3). Out of these, the first four are useful in ceramic materials (Cole, 1960, Freeman, 1964). Determined values show SiO_2 (68.6 to 76%), Al_2O_3 (15.8 to 25%), Fe oxides (2.6 to 10.7%), Na_2O (0.15 to 0.6%), K_2O (0.5 to 1.9%), CaO (1.8 to 5.5%) and MgO (0.1 to 2.1%).

Assessment of Ceramic Quality

Clay materials best suited for ceramic manufactures are the ball clays. Many workers (Boswell, 1952; Cole, 1960; Nurse, 1960; Keeling, 1962; Freeman, 1964; Grim, 1968; Decleer et al, 1988; Adegoke et al, 1989; Ntekim, 1992; Emofurieta et al, 1994) have studied and documented several of the industrial characteristics of such clays. According to these authors, ball clays are black or dark gray coloured in the field. Industrial specifications for ceramic clays include a reddish yellow, pale yellow or ash white firing colour; more than 80% of particles less than 2μm; medium to high density; high plasticity, compressibility and mechanical strength; low shrinkage and porosity. Also, such clays must contain mainly kaolinite, little montmorillonite and 10 to 40% non-clay (quartz, feldspar and mica) minerals; high silica and low alumina, alkalies, magnesia, lime and iron contents. The studied clays are dark gray in colour and contain quartz, mica and feldspar minerals. This field evidence depicts a residual clay deposit formed from detrital materials weathered from the surrounding crystalline rock units. XRD results (Fig 3) show that the kaolinite (ca 41%) dominates the mode with illite (ca 8%) and montmorillonite (ca 11%), and appreciable quartz (ca 33%) and minor feldspar (ca 7%). Average values of the physical properties (1460.4g/m^3 density, 42.5% plasticity index, 7.7% LOI, 6.7% shrinkage, 6.9% porosity, 35.5 N/m^2 mechanical strength and reddish yellow firing colour) and compositional characteristics (70.8% SiO_2, 17.24% Al_2O_3, 2.48% Total Fe oxides, 0.29% Na_2O, 0.89% K_2O, 2.84% CaO, 0.85% MgO and appreciable quantities of kaolinite (41%) and quartz with accessory feldspar and little smectites) fall within the known values for ball clays. The mean density, plasticity, strength, shrinkage, LOI and porosity indicate that the clays can withstand high shear stress and temperature, and would show no damage on exposure to heat. Therefore, they can be used for the manufacture of coarse ceramic products like earthenware such as flower vases, tiles, kitchenware, tableware, scientific wares (e.g. crucibles) etc. The high silica and low alumina and appreciable kaolinite contents depict good ball clays, while the little quartz and feldspars are useful fluxes needed in ceramics manufacturing.

Conclusion

Detailed laboratory examination has confirmed that the Vimtim - Mubi clay materials previously used for brick making is adequate for coarse ceramics manufacture. The observed high plasticity, density and strength, low porosity, shrinkage and LOI, coupled with the fine particle size (about 80% average < 2μm) make the clays good raw materials for ceramics products. It is therefore recommended that the existing factory should diversify its product base into pottery and other ceramic products manufacture.

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