

3 Beneficiation of Ceramic Raw Materials in Ghana: Composition of Samples of Clay Materials

C.N.K. Kokoroko, MSc Ceramic Science

ABSTRACT

Study of the mineralogy, chemical composition, and physical characteristics of clays from selected clay deposits in Ghana was made. Appraisal of data obtained from this study testifies to the appropriate usage of these clays for ceramic products development.

Keywords: clays, composition, usage.

INTRODUCTION

Ghana has rich deposits of ceramic minerals among which are clays of various types. These clay deposits have not been exploited satisfactorily for ceramic products development. One reason being that there is no adequate information on the chemical nature and the physical properties of these raw materials.

Ghana's development of ceramic products is far below expectation which state of affairs is attributable to lack of interest in a thorough investigation into locally available raw materials in order to encourage exploitation. Physical properties and chemical constitution of ceramic raw materials are essential for efficient processing techniques in production.

Ceramic activity in brick production in the rural areas have died down and in the cities products, mainly brick and tiles, are of inferior qualities compared with acceptable standards. There is only one white-ware production unit in Ghana; this also closes down at random due to problems encountered.

It is the interest of the author to investigate the mineralogy and physical properties of clays in Ghana and assess their possible usages for specific product development.

EXPERIMENTAL PROCEDURE

Clay samples were taken from known deposits at Anfoega, Kpeve, Kibi, Saltpond, Abonku and Fomena from about 1m below the surface of

each deposit. Each sample was ground in an agate mortar and quartered to obtain representative sample of each.

In order to study the mineralogy of samples x-ray analytical techniques (ERD) were employed with $CuK\alpha$ radiation. The results give chemical analysis and mineral assemblages as shown in Table 1 and diffraction peaks in Figures 3-8. Also employed in the study of phase changes of clay the minerals are Differential Thermal Analysis (DTA) and Thermogravimetric (TG) analytical techniques.

Other investigations conducted were on particle size and pH values of samples. The plastic nature of the samples were also studied in accordance with JIS A1205 specifications as presented in Figure 1 and Table 2. Finally, samples were fired to 1250°C for 30 minutes in a box laboratory furnace for the study of effect of heat on them.

Table 1: Chemical composition (wt %) and mineral assemblage.

Raw Materials	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	TiO ₂	lg loss	Total	Mineral Assemblages
Anfoega Clay	69.2	19.8	0.5	0.5	tr.	1.1	1.1	0.6	6.6	99.4	Q, K>F, S
Kpeve Clay	79.6	7.7	3.8	2.2	0.1	1.0	tr.	0.6	4.6	99.6	Q>C, S
Abonku Clay	59.8	21.3	7.2	0.2	0.4	0.8	0.4	1.0	8.4	99.5	Q, K>S, OO
Fomena Clay	64.3	19.3	5.5	0.1	tr.	0.9	0.1	0.9	7.9	99.0	Q, K>S, OO
Kibi kaolin	45.8	38.2	0.7	tr.	tr.	0.7	tr.	1.6	13.2	100.0	K>S, Q
Saltpond kaolin	70.2	20.9	0.9	tr.	tr.	0.5	0.6	0.1	6.5	99.7	Q, K>S, PA

Q = quartz
C = calcite
K = kaolin
F = feldspar
S = sericite.
PA = paragonite
OO = goethite

C.N.K. Kokoroko
Dept. of Industrial Art
University of Science and Technology
Kumasi, Ghana



Table 2: Physical characteristics of fired clays.

Raw Material	Firing Temp. °C	Shrinkage %	Water Absorption %	Fired Colour
Anfoega clay	1230	7.5	8.9	White
Kpeve clay	1230	4.7	7.9	Brown
Abonku clay	1230	10.2	8.4	Brown
Fomona clay	1230	7.9	11.8	Brown
Kibi kaolin	1230	5.0	21.4	White
Saipond kaolin	1230	0.9	21.9	White

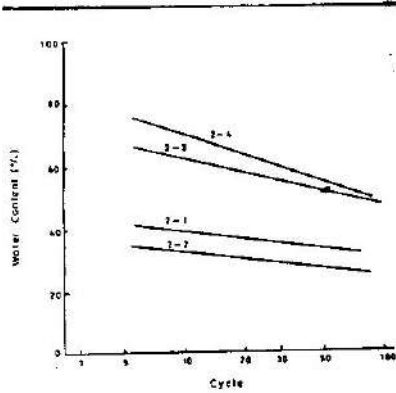
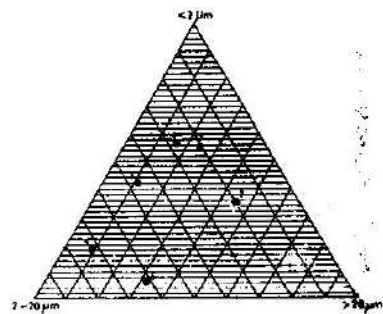


Fig. 1: Flow curve (by JIS A1205) for clays



Clay Serial No.	1	2	3	4	5	6
pH	7.2	7.6	4.8	4.4	4.6	4.6

- KEY
1. Anfoega Clay
 2. Kpeve Clay
 3. Abonku Clay
 4. Fomona Clay
 5. Kibi kaolin
 6. Saipond kaolin

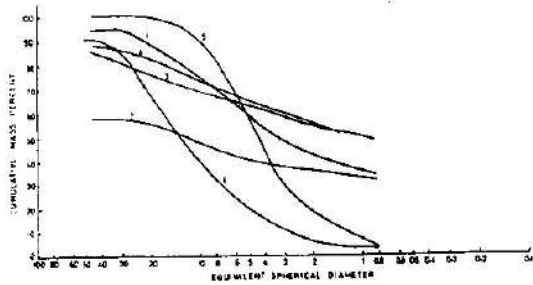


Fig. 2: Particle size analysis and pH of clays

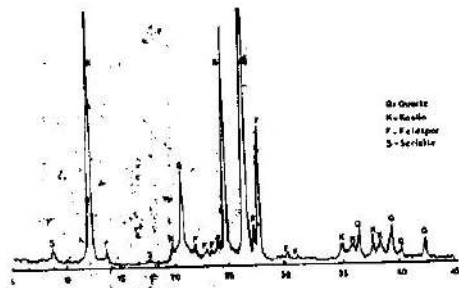


Fig. 3: Anfoega clay

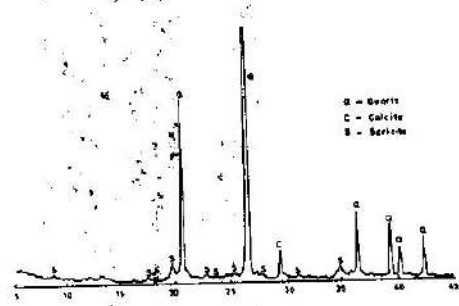


Fig. 4: Kpeve clay

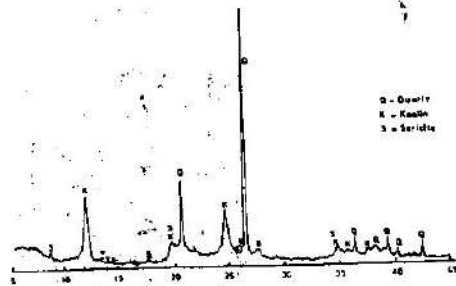


Fig. 5: Abonku clay

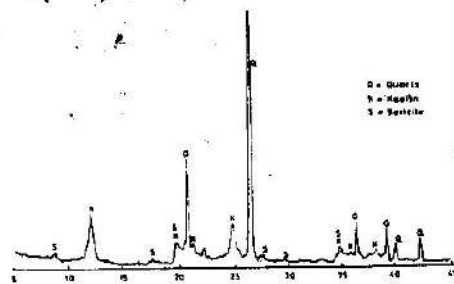


Fig. 6: Fomona clay

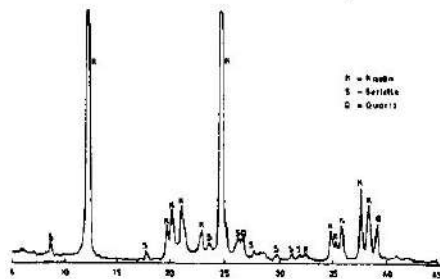


Fig. 8: Saltpond kaolin

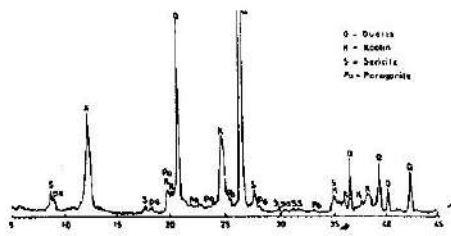


Fig. 7: Kibi kaolin

RESULTS AND DISCUSSIONS

Examination of DTA and TG results in Figures 9-14 shows that all clays behave essentially the same, except Kpeve clay which behaves abnormally with several endothermic peaks and with no crystallization peak characteristic of clays around 1000°C region. Comparing the DTA and TG results to XRD and chemical composition results in Table 1 and Figures 3-14, it may be concluded that this abnormality displayed by Kpeve clay is related to its mineral constitution.

The clays except the kaolins of Kibi and Saltpond show endothermic reaction below 200°C. This reaction is attributed to removal of water adsorbed on the surfaces of particles and possible interlayer water[1]. Between 500°C-700°C there occur a major dehydration curve associated with the expulsion of constitutional or crystalline water within the minerals lattice. On the dehydration curves, however, a corresponding weight loss is observed as the bulk of water is expelled from the samples. Kpeve clay exhibits a series of small endothermic peaks within this temperature range; this may happen as a result of residual crystalline water being removed.

Between 950°C - 980°C the DTA curves show an exothermic peak characteristic of the kaolin group. This phenomena agrees with Norton[2]. The

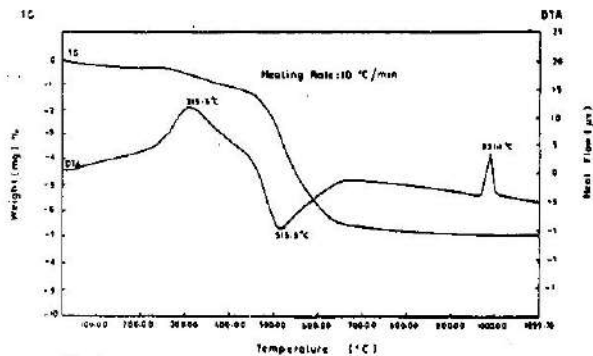


Fig. 9: Anfoega clay

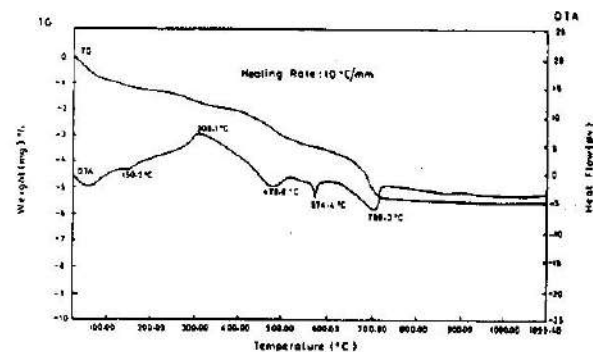


Fig. 10: Kpeve clay

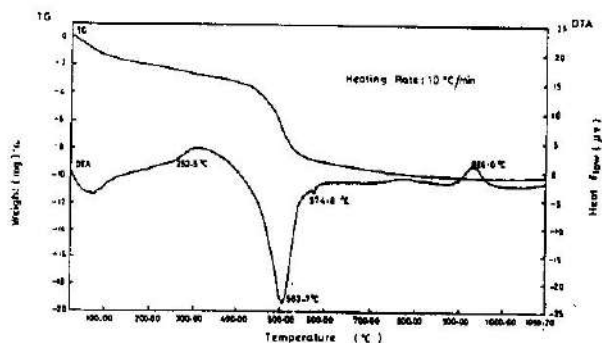


Fig. 11: Abonku clay

only exception in this study is the exothermic reaction of Abonku and Fomena clays which appears before 950°C. This behaviour could be caused by the heating rate of samples. Opinion differs in the significance of this exothermic reaction. Mellor and Holdcroft[3] considered it as a physical change in Alumina. Satoh[4] considered it as a polymerisation of Alumina. Mellor and Scott[5] regarded the reaction as structural arrangement of Al_2SiO_5 assumed to be formed with SiO_2 on the dehydration of kaolinite. In

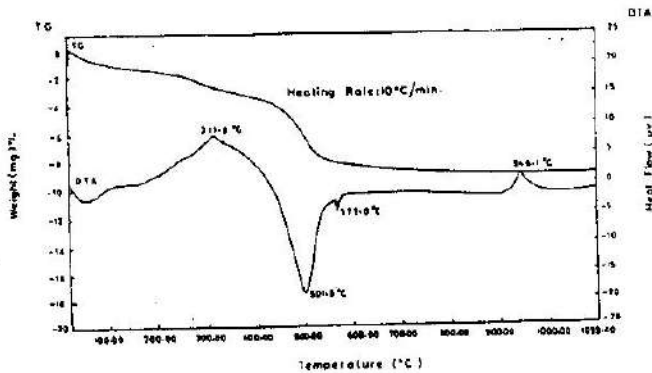


Fig. 12: Fomena clay

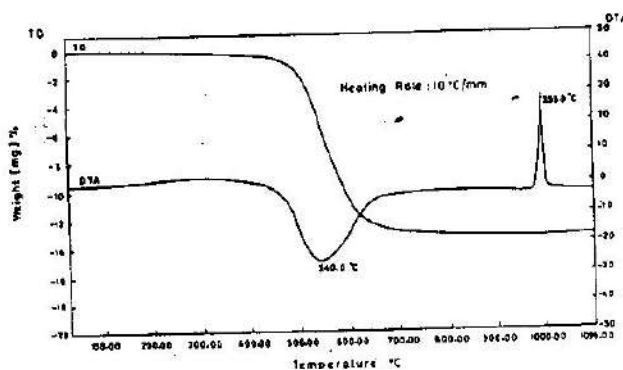


Fig. 13: Kibi kaolin

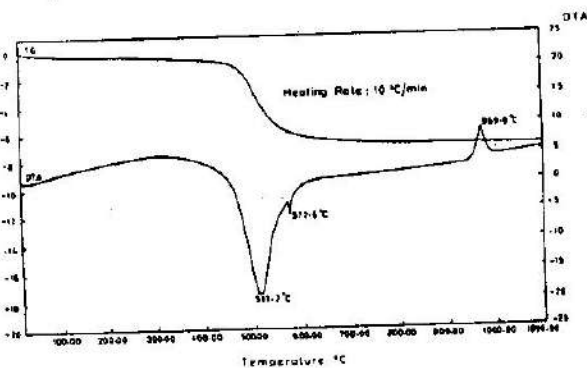


Fig. 14: Saltpond kaolin

this connection the statement of Hyslop and Rooksby[6] that sillimanite or mullite formation starts at 870°C deserves mention. Accordingly the exothermic reaction in this temperature range may be attributed to the conversion of α - Al_2O_3 to α - Al_2O_3 and to Alumina-silica formation. As this exothermic reaction is a combined reaction of Al_2O_3 and SiO_2 it may be deduced that the DTA curve of Kpeve clay

Table 3: Plastic behaviour of secondary clays (JIS A1205)

Serial No.	2 - 1	2 - 2	2 - 3	2 - 4
Material	Anfoega clay	Kpeve clay	Abonku clay	Fomena clay
Plastic limit (WPL)	23.2	14.7	21.2	25.0
Liquid limit (WLL)	36.0	29.5	37.5	61.5
Index of Plasticity (IP*)	12.8	14.8	36.3	36.5
Plasticity (P**)	1.55	2.01	2.71	2.46

* = $W_L - W_P$ ** = W_L/W_P

lacks this reaction because of the comparatively small Al_2O_3 content reflected in its chemical constitution in Table 1.

Mineralogy (Table 1), particle size analyses and pH (Figure 2), plastic behaviour (Table 2 and Figure 1), and physical characteristics on firing (Table 3) simultaneously reflect on the usefulness of the clays. From XRD, TGA and TG data (Figures 3-14) and chemical composition (Table 1) it is observed that Kibi and Saltpond kaolins are primary clays, the predominant mineral in Kibi kaolin being kaolinite while quartz and kaolinite dominate the mineral composition of Saltpond kaolin. These clays lack fluxing minerals, are non-plastic and fire white. Their pH values are quite conducive for ceramic production. Their chemical nature permits high temperatures for maturity hence they can be employed in the manufacture of aluminosilicate refractories. Being non-plastic they can be mixed with other clays and minerals to render them workable for whiteware products.

Anfoega clay fires white, while Kpeve clay fires brown because of its Fe_2O_3 component. The two clays have low plastic limit values with high pH values contrary to the normal pH values of clays which lie between 4.5 - 6.5. These clays could be mixed with other clays which are plastic for suitable body compositions. With a good workable composition, Anfoega clay could be employed in pottery, while Kpeve clay could be used for brick and tile production. Neither of these clays can be employed alone in traditional ceramic production.

Abonku and Fomena clays are the most plastic of all clays studied. They fire brown because of their Fe_2O_3 component, have suitable pH values and are therefore useful for casting processes in studio pottery and brick and tile production. Their water absorption values at 1250°C qualifies them for earthenware products only.

Effect of particle size distribution is observed in the Kpeve clay to let it have the least shrinkage values due to the presence of more coarse particles of quartz. It can also be discerned that Kibi kaolin has more fine particles than has

Saltpond Kaolin hence Kibi kaolin shrinks more than Saltpond kaolin.

CONCLUSION

Clay minerals from different deposits exhibit different qualities in composition. To achieve a meaningful product development with ease it is necessary to have a technological study of all clays in use in order to learn of their composition which influences industrial applications.

Possibilities exist for the use of these clays in pottery and brick and tile production. However to achieve strong bodies of low water absorption, fluxing minerals can be employed as admixture to these clays for stoneware bodies particularly within the classical ceramic products range.

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