AN ASSESSMENT OF THE SUITABILITY OF IBETO CLAY IN NIGER STATE FOR THE PRODUCTION OF TABLEWARE

BY

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DECLARATION

I, Andrew Yohanna, declared that the work in the thesis entitled "An Assessment of the suitability of Ibeto Clay in Niger State for the Production of Tableware" is solely the result of my work in the Department of Industrial Design, under the supervision of Professor A.M. Ahuwan and Professor U.A. Sullayman. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

_____	_____	_____
Andrew Yohanna	Sign	Date

CERTIFICATION

This thesis entitled An Assessment of the Suitability of Ibeto Clay in Niger State for the Production of Tableware by Andrew Yohanna meets the regulations governing the award of Master of Arts in Industrial Design of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memory of my parents, late Reverend and Mrs Yohanna Kubai.

ACKNOWLEDGMENT

My immeasurable gratitude goes to God Almighty for his mercy and divine protection throughout the period of my study.

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ABBREVIATIONS

cm	-	centimeters
fig.	-	figure
gm	-	gramme
km	-	kilometer
mm	-	millimeter
NA	-	Not available
^{0}C	-	Degree centigrade
^{0}F	-	Degree Fahrenheit
Ppm	-	Part per million
ABU	-	Ahmadu Bello University
AAS	-	Atomic Absorption Spectophotometer
DTA	-	Differential Thermal Analysis
PCE	-	Pyrometric cone equivalent
XRD	-	X – ray diffraction
XRF	-	X-ray fluorescence
APL	-	Attenberg Plasticity Index

SIGNS AND NOTATIONS

(±)	-	Plus, minus and bracket
x	-	multiplication
÷	-	division
=	-	equals to
%	-	percentage
+	-	plus
-	-	minus
( )	-	bracket

DEFINITION OF OPERATIONAL TERMS

Alkaline	A chemical term used in the classification that Sager created for materials in order to calculate the formulation of glazes. The most important alkaline elements to ceramics are sodium oxide, potassium oxide and lithium oxide.
Bisque firing:	The first firing of clays usually up to 900^0C with no glaze
Blunge:	To mix a slip
Body:	A clay for special purpose. It is created by blending different clays or by adding to clays other minerals, such as feldspar quartz and fluid, in order to produce a desired workable body.
Casting:	A method of making ceramic pieces in moulds, using slip that subsequently solidifies.
Cones:	Pyramid - shaped objects made of specially formulated ceramic materials that melts at a specific temperature in relation to a specific temperature rise.
Beneficiation:	This is the systematic process of refining raw materials in order to optimize their performance or make them useful in the manufacturing process.
Deflocculate:	The addition of electrolytes to slip to reduce the amount of water needed to make it pourable
Earthenware:	Pottery or other objects made from fired clay which is porous and permeable. Earthenware may be glazed or unglazed and is usually but not always buff, red, or brown in colour.
Flux:	A ceramic flux functions by promoting glass formation in clay bodies and glazes. It is used in glazes to lower the high melting point of Silica.
Glaze:	A layer of glass which is fused into place on a pottery body. The glaze provides a hygienic covering on pottery

	because it is smoother than the body it covers and it is non porous.
Leather hard:	Semi hard consistency of clays when they still retain some of their moisture.
Levigation:	Refining clay by water floatation.
Opacifier:	A raw material added to glazes to make them opaque. The most significant ones are tin oxide, zirconium silicate and titanium dioxide.
Oxide:	Any element combined with oxygen.
Plasticity:	The capacity of clay to absorb water, to be formed without rupture or cracking and to retain a shape.
Porcelain:	High temperature ware which is translucent and often white. The body is by mixing china clay, china stone and quartz together at definite rates.
Pottery:	Objects and especially vessels which are made from fired clay. The term "pottery" include earthenware, stoneware and porcelain
Refractory:	The ability of clay to withstand high temperature without distortion and / or melting.
Stoneware:	Pottery or other objects made from fired clay which is dense and vitrified. Stoneware is fired at temperatures above 1200^0C, it may be dark or light in colour but is not translucent.
Segar cone:	A small narrow cone of clay and refractory materials that collapses at a particular temperature. Cones are usually used in groups covering a range of temperatures to monitor furnace temperature.
Silica:	Oxide of silicon that occurs naturally in multiple forms: quartz, rock and sand. Size and purity vary.
Slip:	Liquid clay that is used to join clay pieces together or for casting ceramic wares.

Table ware:	A general term for ceramic products directly concerned with serving of food and drinks.
Translucence.	A characteristic of porcelain clay bodies. When the walls are very thin, they allow the passage of light but not clear vision, through them.
Temperature:	The intensity of heat as measured in degrees Fahrenheit or degrees centigrade
Thermal shock resistance:	A condition whereby devices or refractory products are subjected alternately to extreme heat and extreme cold.

CHEMICAL SYMBOLS

SiO_2	-	Silica
Al_2O_3	-	Alumina
Fe_2O_3	-	Iron oxide
MgO	-	Magnesia
CaO	-	Lime
Na_2O	-	Soda
TiO_2	-	Titanium oxide
MnO	-	Manganese oxide

TABLE OF CONTENTS

Title page i

Declaration..... ii

Certification iii

Dedication iv

Acknowledgment.....v

Abbreviations vii

Signs and notations.....viii

Definition of operational terms ix

Chemical symbols.....xii

Table of contents xiii

List of Tables.....xvii

List of figures.....xviii

List of Plates.....xix

List of Appendices.....xx

Abstract xxi

CHAPTER ONE

1.0 Introduction 1

1.2 Statement Of The Problem..... 3

1.3 Aims And Objectives Of The Study..... 4

1.4 Research Questions..... 4

1.5 Scope And Delimitation Of The Study 5

1.6 Research Limitation 5

1.7 Significance Of The Study 5

1.8 Justification For The Study 6

CHAPTER TWO

2.0 Literature Review 7

2.1 Clay Raw Materials 7

2.1.1 Origin Of Clay 7

2.1.2 Kaolin 8

2.1.3 Kaolin Sourcing 10

2.1.4 Ball Clay 11

2.15 Kaolin Mining 15

2.1.6 Processing Kaolin 17

2.1.7 Kaolin Deposits In Nigeria 18

2.2 Refractory Materials 19

2.2.1 Classification Of Refractories 19

2.3 Throwing (The Potters Wheel) 22

2.4 Sieving And Drying 23

2.5 Glazing 24

2.6 Firing 25

CHAPTER THREE

3.0 Research Methodology 26

3.1 Introduction 26

3.1.1 Experimental Procedure 26

3.1.2 Data Collection 26

3.13 Field Work..... 27

3.2 Chemical Analysis Of Ibeto Clay..... 27

3.2.1 Bulk Analysis By X-Ray Diffraction (Xrd) Analysis 28

3.2.2 Orient Analysis..... 29

3.2.3 Glycolation..... 30

3.2.4 Heat Treatment 30

3.2.5 Analysis To Determine The Physical Content Of The Clay 31

3.2.6 Test For Shrinkage..... 32

3.2.7 Absorption/Porosity Rate 32

3.3 Preparation Of Ibeto Clay For Table Wares Production..... 34

3.4 Throwing 35

3.4.1 Drying Of Finished Wares..... 35

3.5 Firing Clay Bodies..... 35

3.5.1 Bisque Firing..... 36

3.6 Glazing..... 36

3.6.1 Slips Application On Wares Before Glaze Firing..... 37

CHAPTER FOUR

4.0 Result, Data Presentation And Analysis..... 42

4.1 Sample Description 42

CHAPTER FIVE

5.0 Conclusion, Summary And Recommendation…… 59

5.1 Findings…… 59

5.2 Recommendation …… 61

References …… 62

Appendices ……64

LIST OF TABLES

Table 1: Clay Body Temperatures 25

Table 2: Chemical Analysis Of Ibeto Clay 28

Table 3: Recipe For Slip Application On Wares 38

Table 4: Physical Characteristics Of Ibeto Clay Compared With Other Clay Bodies In Nigeria 42

LIST OF FIGURES

Fig. 1: Beneficiation Of The Materials (Ibeto Clay). 34

Figure 2: Bulk Sample..... 44

Figure 3: Orient Sample..... 47

Figure 4: Glycolated-clay-sample.....52

Figure 5: Clay Sample Heated @500> 53

Figure 6: Clay Sample Heated @550>. 54

LIST OF PLATES

Plate 1: X – ray Diffractometer Schimadzu 600 Model - - 29

Plate 2: X – ray Fluorescence Advant'x 1200 model - - 30

Plate 3: Glazed Ceramic Bowl and Cup - - - - 40

Plate 4: Glazed Ceramic Teapot and Jug - - - - 40

Plate 5: A Set of Ceramic Teapot and Cups - - - - 41

Plate 6: A Set of Ceramic Teapot and Cups - - - - 41

LIST OF APPENDICES

Appendix I: Map showing Niger State - - - - 64

Appendix II: Certificate of Analysis - - - - - 65

Appendix III: Basic Data Process - - - - - 66

Appendix IV: Basic Data Process - - - - - 67

Appendix V: Basic Data Process (Bulk Sample) - - - 68

Appendix VI: Basic Data Process (Glycolated clay sample) - - 69

ABSTRACT

Lack of understanding of clay bodies hampers the art of pottery. This phenomenon is one of the problems militating against the growth of ceramic industry in Nigeria. The formulation of a clay body is a science which potters should pursue with vigour. The development of pottery depends on the understanding of the clay bodies needed in ceramic production. The discovery of Ibeto clay was a chanced discovery, coupled with the fact that Niger state is noted for pottery tradition that dates to many years. The need to study the physical content of Ibeto clay and to determine its suitability in tableware production has become necessary. In carrying out this research, the clay samples undergo chemical analysis which includes the use of X-Ray Fluorescence spectrphotmeter (XRF) and Bulk analysis by x-ray (Diffraction, XRD). Orient analysis was also carried out to determine whether the sample is a refractory material. The sample was also subjected to heat treatment to observe the behavioural pattern of the clay and also to determine refractory value. Other tests carried out were plasticity test, moisture content test, shrinkage test, and absorption test. Samples were made using the throwing wheel technique. The finished wares were both bisqued and glazed fired. The results of the study showed that Ibeto clay is a refractory clay and it does not swell. Two different glazes were formulated. The first glaze test consists of feldspar 40% quartz, 15% mixed wood ash 15% secondary clay 15% Ibeto Kaolin 15% and cobalt oxide or carbonate 0.2%. The result shows a translucent glaze enhanced by slip decoration. The second test consisted of Feldspar 40%, mixed wood ash 20%, secondary clay 16% and rice husk ash 24%. The result shows a milky bluish glaze it was also decorated with slip. During the firing in the gas kiln it was observed that at 600^0C, the process of quartz inversion commenced. At 1000^0C vitrification process and melting of glaze commenced. There was no any casualty recorded while the firing lasted.

CHAPTER ONE

1.0 INTRODUCTION

We depend heavily on ceramics products in our everyday life, whether they be delicate china tea cups, tableware, burnt bricks, tiles, glass or rough linings for high temperature industrial furnaces. It is astonishing when you consider that shapeless lumps can be made into some of the most exquisite objects in the world. This is where the art of the potter comes in, clay is the major raw material in ceramics production. How fortunate then, that clay, the essential raw material for ceramics production is so cheap and plentiful. Clay is found generally beneath the top soil, practically at most deposit sites in the world. There is a wide variety of different clays, but they all have to a greater or lesser extent, two basic properties that make them useful to us.

Firstly, they become plastic when moist. This means that they can be shaped and moulded without falling apart. Secondly, they become extremely hard and strong when they are exposed to great heat. Gukas and Datiri, (2001) reported that clay is formed because of the decomposition of an igneous rock of some geologic hypogenic actions that result from the mixture of gases and vapour in the interior of the earth's crust over a very long period which must be about some million years ago. Salmang, (1961) reported that, there are two views about the origin of clays, one preferred by geologist, the other by chemists. For the sake of this study, we shall concentrate on the former view held by geologists. Geologists believed that Kaolin is produced from feldspar under the influence of weathering or acidic water.

The Ceramist classified clay into two categories, i.e. primary clay and secondary clay. Because of the natural sedimentation, secondary clays are contaminated with

organic substances, these impurities include iron oxide, limestone etc. (Cochrane, 1969). The presence of iron oxide gives the clay its reddish colour, Norton, (1974) reported that the word Kaolin came from Chinese word Kaoliang, which is a mountain in China, is applied to most white burning clays. He classified Kaolin into two types, the first is residual deposit derived from altered rock, often of the pegmatite type, with the Kaolin remaining in Situ among the rock fragments not decomposed. The second is a sedimentary type in which fire rock and clay particles have been washed out of the original deposit and laid down in lakes and lagoons with some alteration during transport and after settling.

For almost two decades of my teaching career in a tertiary institution as a ceramic teacher, finding a new site of clay deposit that will be suitable for ceramic production is the underlying factor that motivates me to search within my locality for possible sites for clay exploration and the possibility of getting quality Kaolin for ceramics production.

Ibeto village is situated along Kontagora Yauri major highway. The town is located at some 30km South-West of Kontagora Emirate Council in Niger State Nigeria. Most of the inhabitants of the town are farmers with few traders. It is interesting to note that Ibeto clay, which derived its name from Ibeto village in Kontagora Emirate Council of Niger State, is a residual Kaolin deposit. In my personal interaction with Mallam Garba Ibeto a resident of Ibeto village, he told me that the clay was discovered accidentally, when the villagers were digging the ground to obtain clay for building their mud houses. Because of its whitish colour and its ability to dissolve in water easily, the people nicknamed it “Farin Kasa” meaning white earth. It was mainly used by the villagers for both interior and exterior decorations in form of wall painting. This

motivates me to go into research, to determine the suitability of Ibeto clay in the production of ceramic tableware.

1.1 Background Of The Study

The discovery of a white substance suspected to be a kaolin in a village called Ibeto in Niger State motivates further investigation, to ascertain the suitability of this clay for the production of tableware. So far there is no any known published work on the properties of this clay deposit.

1.2 Statement of the Problem

The problem of this study is the assessment of Ibeto clay in Kontagora Local Government area of Nigeria State and determining its suitability as a material for the production of tableware. The following problem will be address:

i. Procurement and beneficiation of Ibeto clay samples from Ibeto village in Niger State.
ii. When subjected to XRF analysis, what will be the physical properties of the clay samples.
iii. What will be the result when the clay is tested for the mineralogical properties through XRD.
iv. When combined with other clay bodies can we obtain workable body?
v. Can we obtain a good result when it is used for tableware production.
vi. What will be the outcome when this clay is used with other components in glaze preparation.
vii. What will be the result when it is subjected to both bisque and glaze firing?

1.3 Aims and Objectives of the Study

The aim of this study is to explore and characterize the physical and chemical properties of Ibeto clay and to use it to produce ceramic tableware.

Specific objectives of this study are:

i. Determine the physical qualities and properties of Ibeto clay.

ii. Determine the chemical and mineralogical composition of Ibeto clay through XRF and XRD tests.

iii. To find out how Ibeto clay can be mixed with Minna ball clay into suitable homogenous clay.

iv. Achieve stone ware temperature of 1280^0C from the clay body when fired in a gas kiln.

1.4 Research Questions

The following research questions were formulated:

i. Will the clay found in Ibeto be suitable for production of ceramic table wares?

ii. When subjected to beneficiation, will the material be of standard quality for ceramic production?

iii. When subjected to chemical (XRF) analysis will the clay pass the physical property of acceptable ceramic body?

iv. Will the clay pass the mineralogical property test to be determined by XRD and XRF test?

v. Will the clay pass shrinkage test, plasticity test and refractory tests?

vi. When combined with Minna ball clay, can we achieve a stone ware temperature of 1280^0C?

vii. What will be the outcome of the final result when the test is fired in a gas kiln?

1.5 Scope and Delimitation of the Study

The scope of this study will cover the physical characterization and utilization of Ibeto clay, its chemical and mineralogical properties, its suitability in the production of table wares will be tested when combined with other clay minerals. The method of production that will be employed is the throwing technique using a manual throwing wheel. While finished work will be fired in a gas kiln to obtain a result.

1.6 Research Limitation

The followings are limitations that confront this study:

i. Inadequate modern facilities for digging and transportation at the site of clay deposit constitute limitation.

ii. Lack of modern laboratory and facilities for processing and treatment of raw materials also constitute limitation.

iii. Kilns for firing the samples to required temperature are not available, hence the need to construct a gas kiln.

1.7 Significance of the Study

This research will contribute to the database of clay raw materials in Niger State. The state is noted for pottery tradition which dated back to more than 50 years with notable pottery centers such as Ladi Kwali pottery Centre, Al-habeeb pottery Centre and some

tertiary and secondary schools where Fine Arts is taught. The discovery of a new clay deposit will facilitate entrepreneurial development and promote local industries.

1.8 Justification for the Study

Many local industries are suffering due to lack of raw materials, and couple with the fact that Nigerian markets are flooded with cheap China products. How can this trend be arrested. The solution is to intensify effort in discovering sources of local raw materials for ceramic production. Yakubu (2009), opined that there is currently a high demand for industrial raw material in Nigeria to support the growing sector of the economy such as in the iron and steel, glass and cement industries. The discovery of a new source of raw material will enhance the drive for industrialization. The Quest to assess a suitable source of raw material for the promotion of teaching ceramic in any institution justify this study. The completion of this work will encourage and promote the development of local ceramic industries in Niger state.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Clay Raw Materials

Fire, earth and water are the primitive materials of pottery. In every simple terms, the potter's art is to mould clay with water and to harden it by fire or heat. Many thousand years ago early man made the simple discovery and realized that he could take advantage of it. He made objects such as bowls and pots out of wet clay and baked them in the sun. Where the sun did not shine very much, he baked them in fire. So began one of man's earliest crafts i.e. that of making pottery (Cochrame, 1969). The word ceramics is derived from the Greek word Keramos, meaning potter's clay. Ceramics as a term broadly means non-metallic, clay products baked by fire. This includes not only such things as pottery and porcelain, but also bricks, tiles, cement and glass. Clay is found beneath the soil. It is a mineral that is composed of alumina, silica and water. This is expressed scientifically with the formula Al_2O_3-Sio_2-$2H_20$ (Rhodes, 1973).

Ojie and Esosuakpo, (2008) stated that clay as a ceramic raw material is a malleable medium for artistic expression but fragile at bone dry or fired stage. It remains useful to the potter because of certain qualities, which it possesses. Qualities, such as its plastic nature, softness, ability to respond to shaping, drying, firing, blending and combining shrinkage, texturing and smoothness make it a peculiar medium for ceramic production.

2.1.1 Origin of Clay

Clay is a product of decomposition of rocks, particularly granite that is abundant all over the earth surface. Granite, which is also known as feldspathic rock, decomposed

through time in many different physical actions such as wind, rains, erosion, earth movement: earth-quake, volcanic eruption etc. and eventually become clay as we know it.

Bowers, et al (1984) in Mode & Amobi (2006) reported that, there are four geological processes which give rise to clay minerals formation:.

i. Weathering
ii. Precipitation from concentrated solutions (saline lakes and closed marine basins);
iii. Burial diagenesis (effects of chemical and thermal change) and
iv. Hydrothermal alteration (water rock interaction at higher temperature due to thermal effects of magnetic intrusion).

The water-rock ratio, the rock composition and the temperature at which the reactions take place, are the variables that control the four processes in the various clay minerals form. They range from conditions at the earth-air or earth-water interface which give minimum temperatures of 40C for ocean bottom formation and around 150C average for land occurrence to the upper limit at which clay minerals occur, which heat is 200^0C in young rocks. Burial depths are usually not greater than 6-7km (Velde, 1992 in Mode & Amobi, 2006).

2.1.2 Kaolin

Kaolinite is a clay mineral and part of the group of industrial minerals, with the chemical composition $A1_2SiO_2\ O_5\ (OH)_4$. It is a layered silicate mineral, with one tetrahedral sheet of alumina octahedral. Rocks that are rich in Kaolinite are known as Kaolin or China clay. The name is derived from Kao-ling (Chinese Gaoling), a village

near Jingdezhen. Kaolin also known as China clay is pure, soft white clay of variable but usually low plasticity that retains its white colour when fired.

Ibrahim & Na'Allah (2006), opined that pure Kaolin is necessary for the manufacture of porcelain and other China ware. Impure varieties are used in making pottery, stone-ware and bricks as filler for pigments and in the manufacture of paper.

Opoku, (2007) reported that Kaolin is the main versatile industrial raw material of wide applications in the ceramics industry. It is available in various parts of Nigeria with the largest deposit estimated at 769,000,000 tons located at Enugu. This is followed by the Kankara deposit which is estimated at 3,400,000 tons. The good quality of these deposits offers the mineral to prospective investors in such industries as paints, advanced ceramics, refractories, chemical and pharmaceutical industries, paper, rubber plastics and crayons. Kankara deposit is of a very high grade quality.

To substantiate the high quality of Kankara Kaolin. Sullayman (2006) opined that Kankara Kaolin can be directly substituted for foreign Kaolin. The result of his work using some selected raw material for porcelain slip casting and glazing of moulded ceramics. He formulated different bodies using the following recipes:

Feldspar

Kaolin

Quartz

Bomo Clay

The result was outstanding. He concluded by saying, the quality of Kankara Kaolin is high and can favourably be substituted with foreign Kaolin. He also used it in

the development of dense blast furnace refractory bricks as can be seen in Sullayman (2011)

2.1.3 Kaolin Sourcing

Kaolinite is one of the most common minerals, it is mined, as kaolin, in Brazil, Bulgaria, France, United Kingdom, Iran, Germany, India, Australia, United States, Nigeria and other countries.

Kaolin is predominant in tropical soils, It occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates- for example in tropical rain forest areas.

Ahuwan, (1993) reported that Kankara clay, a well-known Kaolin deposit is located at Danmarke, 5km South-East of Kankara town in Katsina State. The irregular deposits have been identified. The deposit is residual primary clay, poorly plastic with small amount of Zorcon, illemenite and tourmaline as impurities, the report went further to say about 30 meters below the surface and underlying the Kaolin deposit is the occurrence of white marble.

Ibrahim and Na'Allah, (2006) reported another source of Kaolin deposit in Alkaleri Local Government Area of Bauchi State, in North Central Nigeria, latitude 10'17' north and latitude 9' 45' east situated at 690, 20 meters above the sea level, located along the north-eastern edge of the Jos Plateau. There were high activities of illegal mining of Kaolin among the local inhabitants; the area is endowed with deposits of Kaolin forming about 75% of the total land area. Garkida, (1998) also reported deposits of Kaolin found in Edo, Kwara, Bauchi and Sokoto States. Tukur,(2006) reported that there is Kaolin deposit in Kaoje and Bauxite clay near Giro town. Kaoje Kaolin deposit is

located at Kasali hill South-East of Kaoje. The clay is pure kaolin with occasional coarse fraction of silica; the clay is white and possesses little or no impurities. The projected volume of the deposit is put at over 875 million cubic meters.

2.1.4 Ball Clay

Ball clays are Kaolinitic sedimentary clays that commonly consist of 20- 80% kaolinite, 10-25% mica, 6-65% quartz. Localized seams in the same deposit have variations in composition including the quantity of the major minerals such as lignite. They are fine-grained and plastic in nature.

In a simple word, ball clay is a secondary clay that has been transported from its place of formation and redeposited elsewhere. A good example is Bomo clay used in the department of Industrial Design, Ahmadu Bello University, Zaria and Chanchaga clay found in Minna used by the researcher.

Secondary Clay

Secondary clay has been transported far from their bedrock by water, atmospheric agents or other means and have been deposited in other places. The small particles of clay become grouped by size during the process and they may mix with the products of other decomposed rocks. The heaviest particles are deposited first as the transporting agent loses strength, while the lightest particles continue to travel and settle out, particularly in areas of calm or stagnant water.

These clays are non-plastic and very fine, although they may contain large quantities of organic matters and other minerals (Frigola, 2006).

Properties of Clay

Properties of clay include plasticity, shrinkage and under air drying, fineness of grain, colour after firing, hardness, cohesion and capacity of the surface to take decoration. On the basis of such qualities, clays are variously divided into classes or groups; products are generally made from mixtures of clays and other earthly substances.

Plasticity

This is a very complex quality that can be difficult to define. It is closely connected to the physical and chemical relationships among the particles in the clay, the water, and among the particles themselves. As a result, it is influenced by the following five factors:

- Size and shape of clay particles
- Electrical attraction
- Carbonaceous matter and bacteria
- Water
- Aging.

However, it is not enough to speak of the plasticity of clays from the chemical view point. Frigola, (2006) stated that, there is an easier way to define this characteristic. Plasticity is the capacity of clay to absorb water, to be formed without rupturing or cracking and to retain a shape. Plasticity refers to how flexible a clay or clay body is. Any particular clay's plasticity is greatly influenced by the clay's particle size, water content and aging. It is easy to find out how plastic clay is. Make a coil of the clay and then wrapped it around your finger. Plastic clay will not crack or break, non-plastic clays will.

Shrinkage

All clays shrink. But not all clays are created equal. Different clay bodies experience different amounts of shrinkage. It depends upon the clay's particle size and on how many and what type of impurities are present in the clay body. Frigola, (2006) said that the water that surrounds the clay particles and that makes the clay workable is water of plasticity. It makes up 2 to 35 percent of the weight of the wet clay. When the water evaporates, the particles of clay move closer together and the entire piece shrink. The smaller the particles, the greater the shrinkage and thus the greater the risk that the piece will become distorted or cracked. The final size of the work will be slightly smaller because it losses all of this water.

Ceramic work loses all of its water during two processes; the drying, in which the clay loses its water of plasticity and becomes leather hard; and during firing when the clay loses the remaining water, which is referred to as chemical water. During firing, the clay shrinks permanently.

Chemical and Mineralogical Composition

Clay minerals are hydrous aluminum phyllosilicates, sometimes with variable amounts of iron, magnesium, alkali metals, alkaline earths and other cautious. Clays form flat hexagonal sheets similar to the micas. Clay minerals are common weathering products (including weathering feldspar) and low temperature hydrothermal alteration products. Clay minerals are very common in fine grained sedimentary rocks such as shale, mudstone and siltstone and in fine grined metamorphic slate and phylite (Wikipedia, 2012). Clay minerals can be classified as 1:1 or 2:1, this originate from the

fact that they are fundamentally built of tetrahedral silicate sheets and octahedral hydroxide sheets as described in the structure section below:

1:1 clay would consist of one tetrahedral sheet and one octahedral sheet, examples would be Kaplit and Serpentine. 2:1 clay consists of an octahedral sheet sandwiched between two tetrahedral sheets, examples are talc, vermiculite and montuorillonite.

Sintering

Sintering is a method used to create objects from powders. It is based on atomic diffusion. Diffusion occurs in any material above absolute zero, but it occurs much faster at higher temperatures. In most sintering processes, the powdered material is held in a mold and then heated to a temperature below the melting point. The atoms in the powder particles diffuse across the boundaries by the particles, fusing the particles together and creating one solid piece. Because the sintering temperature does not have to reach the melting point of the material, sintering is often chosen as the shaping process for materials with extremely high melting points. Sintering is traditionally used for manufacturing ceramic objects but finds applications in almost all fields of industry.

Porosity

Porosity is the ability of clay bodies to absorb water after firing. A pore is a tiny empty space surrounded by particles of clay. If a porous piece is submerged in water, it will absorb a great deal of it. Frigola, (2006) opined that, the most important items to keep in mind about porosity are closely linked to firing, the higher the firing temperature the lower the porosity of the body. Porosity is common to all pieces fired at low temperatures, a fact that also affects glaze application. It is possible for porous objects to

absorb more glaze than others, and as a result, alter the colour or even cause the glaze to run.

2.15 Kaolin Mining

Kaolin clay mineral is kind of clay or clay rocks in which there is a certain amount of Kaolinite subfamily clay minerals. Kaolin has many excellent process performances which make the kaolin widely used in paper making ceramics, paint, rubber, plastics, refractories, chemicals, pesticides, pharmaceuticals, textiles, petroleum, building materials etc. And so mining kaolin is widely seen too in many industries, such as ceramic products.

Kaolin Mining Craft Process

According to Frigola, (2006), Mining Kaolin beneficiation process is divided into dry and wet processes.

The Process of Dry Method of Kaolin Mining is Mainly as Follows

Crude Ore taken out will be sent into Kaolin mining equipment that is crushing machine to crush till the fineness is about 25mm. Then the material will be transported by belt conveyor to secondary crushing equipment, such as impact crusher, cone crusher etc. to be crushed again. When its fineness is less than 6mm, the hot air in the Kaolin quarry equipment will absorb the water in Kaolin till the amount drops to **10%.** The crushed stone can be grinded in raymond mill which is equipped with centridge and cyclone dust collector, this will further grind the materials. The process can remove most of the sand and therefore is suitable to process ore minerals with white high ore, low gravel content,

the appropriate particle size distribution. The dry method of Kaolin mining is of low cost and products is commonly used in cheap filler of rubber, plastics and paper industries.

Kaolin Mining in Nigeria

One of the major problems hampering proper utilization of Kaolin deposit in Nigeria is lack of modern equipment for mining Kaolin. The mining and processing of this mineral if not properly handled can impact permanent damage to the environment, Ibrahim and Na'Allah, (2006) opined that Kaolin mining lives the environment not only covered with depression, holes, dents and collapsed ground, but also with large area of the ground covered with Kaolin dust which further increases environmental concerns and hinders agricultural activities. The first practical step in the mining process is to dig out the clay from its deposit, most clay is mined from open pits, Ahuwan, (1993) suggested three open cast mining methods:

i. Clay could be mined using modern surface mining equipment such as drag lines, power shovels and scrapper loaders. Although, the initial capital outlay on equipment may be large, this is compensated for in mechanical advantage and reduced labour cost.

ii. Some Kaolin may be extracted by hydraulic mining and dredging.

iii. Kaolin could also be mined using the cheap crude method i.e. engagement of human labour to dig the pits. Such labour may be expensive and hard to come by where there are no existing infrastructures. This is the method employed in mining Kankara Kaolin in Katsina State. Kankara Kaolin has been reputed to be of high quality. Sullayman, (1986) opined that Kankara Kaolin can be directly substituted for foreign kaolin. In his work using some selected raw

material for porcelain slip casting and glazing of moulded ceramics. He formulated different bodies using the following recipe:

Feldspar

Kankara Kaolin

Quartz

Bomo Clay

The result was, very good and he concluded by ascertaining that Kankara Kaolin is of good quality and can favourably be substituted for foreign kaolin.

2.1.6 Processing Kaolin

The dry process is simple and produces a lower quality product than the wet process. Dry-processed kaolin is used mainly in the rubber industry and to a lesser extent, for paper filling and to produce fibre glass and sanitary ware.

Wet processing of kaolin begins with plunging to produce a slurry, which then is fractionated into coarse and fine fractions using centrifuges, hydrocyclones or hydro-separators. At this step in the process, various chemical methods such as bleaching and physical and magnetic methods may be used to refine the material Chemical processing includes leaching with sulfuric acid, followed by the addition of a strong reducing agent such as hydrosulfite. Before drying, the slurry is filtered and de-watered by means of a filter press, centrifuge, rotary vacuum filler or tube filler. The filtered dewatered slurry material may be shipped or further processed by drying in apron, rotary or spray dyers.

Following the drying step, the kaolin may be calcined usually in a multiple heat furnace, for use as filler or refractory material.

Datiri and Yusuph (2004) reported that a method known as the wet processing approach could be applied in processing kaolin. It is called washing technique, this involves the use of water and it largely has to do with the process of either levigation or sieving, or it may combine both. The wet processing technique allows for use of much water which results in quick settling of coarse particles which are either silica or stones, while the lighter particles (pure kaolin) is delayed in suspension since they settle at slower speed. Jacobs (1971), further buttress that, another process used to produce value added products is calcinations, which was introduced in the early 1950s. Kaolin is processed to remove impurities and a fine particle size grey kaolin is preferred feed, the fine grain kaolin is spray dried, pulverized and then led to either rotary or large heat calcine and heated to as high as 1300°C. The highest temperature of 1300°C is used to produce granules for use in making refractory shelf's and bricks, Most of the pigment grade calcines kaolin is heated to a temperature between 1000°C and 1050°C.

2.1.7 Kaolin Deposits in Nigeria

Kaolin is one of the industrial minerals that can be found in commercial quantity, in fact Nigeria has an estimated reserve of about two (2) billion metric tones of Kaolin deposits scattered in different parts of the country to include Ogun, Edo, Plateau, Katsina, Kebbi and Nasarawa States.

Opoku, (2003) went further to give us a break down estimates. He reported that Kaolin is available in various parts of Nigeria with the largest deposit estimated at 769,000,000 tons located at Enugu. It is followed by the kankara deposit in Katsina State which is estimated at 3,400,000 tons. The good quality of these deposits offers the

mineral to prospective investors in industries such as paints, refractory, chemical and pharmaceutical, paper, rubber, plastic and crayons.

2.2 Refractory Materials

A refractory material is one that retains its strength at high temperatures, it is also defined as "non metallic materials having those chemical and physical properties that make them applicable for structures, or as components of systems, that are exposed to environments above $1{,}000^0$F (538^0C). Refractory materials are used in linings for furnaces and reactors. They are also used to make crucibles.

Refractory materials must be chemically and physically stable at high temperatures. Depending on the operating environment, they need to be resistant to thermal shock, be chemically inert and/or have specific range of thermal conductivity and of the coefficient of thermal expansion. The oxides of aluminum (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories. Another oxide usually found in refractories is the oxide of calcium (lime). Fire clays are also widely used in the manufacture of refractories.

2.2.1 Classification of Refractories

Refractories can be classified on the basis of chemical composition, method of manufacture, physical form or according to their application.

Based on Chemical Composition

Acidic Refractories

These are used in areas where slag and atmosphere are acidic. They are stable to acids but attached by alkalis. The main raw materials belong to the RO_2 group e.g. silica (SiO_2), Zirconia (ZrO_2), alumina, fire-clay refractories.

Neutral Refractories

These are used in areas where slags and atmosphere are either acidic or basic and are chemically stable to both acids and bases. The main raw materials belongs to, but not confined to R_20_3 group. The common examples of these materials are alumina (Al_2O_3), Chromia (Cr_2O_3) and carbon.

Basic Refractories

These are used on areas where stags and atmosphere are basic; they are stable to alkaline materials but react with acids. The main raw materials belong to the RO group to which Magnesia (MgO) is a very common example. Other examples include dolomite and chrome magnesia.

Bulk Density

Bulk density is a property of powders, granules and other "divided" Solids, especially used in reference to mineral components (soil, gravel), chemical substances (pharmaceutical) ingredients, foodstuff or any other masses of corpuscular or particulate matter. It is defined as the mass of many particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume and internal pore volume.

Bulk density is not an intrinsic property of a material, it can change depending on how the material is handled. For example, a powder poured into a cylinder will have a particular bulk density; if the cylinder is disturbed, the powder particles will move and usually settle closer together, resulting in a higher bulk density. For this reason, the bulk density of powders is usually reported both as “freely settled” (or “poured” density) and “tapped” density (where the tapped density refers to the bulk density of the powder after a specified compaction process, usually involving vibration of the container (Frigola, 2006).

Modulus of Rupture

Flexural strength, also known as modulus of rupture, bend strength or fracture, a mechanical parameter for brittle material, is defined as a material’s ability to resist deformation under load. The transverse bending test is most frequently employed in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol $\tilde{O}$ (Sullayman, 2011).

Thermal Shock Resistance

Thermal shock occurs when a thermal gradient causes different parts of an object to expand by different amounts. The differential expansion can be understood in terms of stress or of strain, equivalently. At some point, this stress can exceed the strength of the material, causing a crack to form. If nothing stops this crack from propagating through the material, it will cause the objects structure to fail.

Failure due to thermal shock can be prevented by:

1. Reducing the thermal gradient seen by the object, by

- Changing its temperature more slowly
- Increasing the materials thermal conductivity.

2. Reducing the material's co-efficient of thermal expansion.
3. Increasing its strength.
4. Introducing built-in compressive stress, as for example in tampered glass.
5. Decreasing its young's modulus.
6. Increasing its toughness by:

- Crack tip blunting, i.e. plasticity or phase transformation
- Crack deflection.

2.3 Throwing (The Potters Wheel)

The potter's wheel. In a process called "throwing" (coming from the old English word thrawan which means to twist or turn, a ball of clay is placed in the centre of a turntable, called the wheel-head, which the potter rotates with a variable-speed electric motor.

During the process of throwing, the wheel rotates rapidly while the solid ball of soft clay is pressed, squeezed and pulled gently upwards and outwards into a hollow shape. The first step of pressing the rough ball of clay downward and inward into perfect rotational symmetry is called centring the clay — a most important skill to master before the next steps:

Opening (making a centred hollow in the solid ball of clay), flooring (making the flat or rounded bottom inside the pot), throwing or pulling (drawing up and shaping the walls to an even thickness) and trimming or turning (removing excess clay to refine the shape or to create a foot).

At the wheel pressure is applied to the clay at a single point. If pressure is applied to more than one spot at a time, with a finger or a part of the hand, the shape registers this pressure and could move off centre.

Leaving to throw on the wheel demands a slow, continuous leaving curve (Frigola, 2006).

2.4 Sieving and Drying

Processing natural clay will take more than one day and will require table and floor space. You will probably want to do this somewhere like the garage or basement instead of the kitchen, as this is a messy and long term project.

Suggested Process

1. Spread the clay out on a clean sheet of paper covering a counter, table or a supported window screen to allow air flow from all sides. Let the clay dry out completely.
2. Wrap it in a piece of heavy canvas and pound on the canvas to break it up. Pound the clay until it is powdered. Remove rocks, sticks and other debris.
3. Sieve the powdered clay through a sieve or window screen, into a container double the size you would used to hold the current amount of powered clay.

Remove any extra unwanted debris, such as pebble so small bits of extraneous matter.

4. Pour water into the clay. Make sure there is enough water to cover the clay entirely. Let the clay sit for a couple of days without stirring or disturbing it. If the clay has soaked up all the water, add enough to cover the top of the clay by about 1 inch, This will allow all of the clay to become soft .and mushy, breaking up any hard chunks. Leave it alone until the clay has settled entire to the bottom and is thoroughly "slaked".
5. Stir the clay so that it becomes about the consistency of whole milk or cream. This is referred to as "slip".
6. Strain the slip through a sieve or window screen into another large container. This is the final "cleaning" of the clay, ensuring that there is no unwanted debris in the clay.
7. Allow the clay to settle to the bottom of the container so that there is clear water on top of the clay and the clay is a chunk of mush below the water surface.
8. Siphon or dip the water off of the top of the clay. (www.ehow.com).

2.5 Glazing

Glazes are used on clay bodies that are different in both physical and chemical properties and that also melt at different temperatures.' At the same time, clays and glazes display specific properties that will vary when they are fired, thus, it is not surprising that there are a great many different recipes for glazes.

Glaze: A layer of glass prepared from blends of different materials that combine evenly when they melt and attach firmly to a ceramic object. This object needs to be

insoluble and impermeable to liquids and gases. In general, these glazes are transparent and provide a glossy or matte finish (Frigola, 2006).

2.6 Firing

The proper firing temperature for a clay body depends on many factors, especially its chemical composition, the peak temperature and the length of soak, the duration of the tiring and the cooling. It is important to understand the concept of firing clay work to the correct temperature.

Maturity: This refers to the optimum point reached by clays during the final firing. All clay bodies have a specific shrinkage and absorption rate determined for their firing range. If the clay is not fired high enough, it will have a high absorption rate or remain porous. If it is fired higher, it will become vitrified with a lower absorption rate. If fired too high, it will slump or bloat, (Frigola, 2006). Below is the table of different clay body temperatures.

Table 1: Clay Body Temperatures

Clay Bodies	**Approximate Firing Range**	**Approximate Melting Temperature**
Terracotta	960^0C-1030^0C	1050^0C-1100^0C
Earth ware	960^0C-1050^0C	1080^0C-1150^0C
Stoneware	1200^0C-1300^0C	1325^0C-1350^0C
Porcelain	1200^0C-1300^0C	1325^0C-1350^0C

Source: Frigola (2006)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter is a documentary of how data was collected and analyzed. This research focused on determining the suitability of Ibeto Clay in the production of table wares. Various instruments and equipment were used in this research work,

Sample pieces of table wares, such as tea pots, tea cups were made using the throwing method. The finished work were glazed and fired to establish the Clay's behavioural characteristics. Other test's were also carried out.

3.1.1 Experimental Procedure

The study adopted the experimental method. This involves data collection, field work and chemical analysis.

3.1.2 Data Collection

There are available literatures related to this subject which guided the researcher to locations where materials are obtained. Norton, (1974) reported that majority of clays are mined in open pits stripping the overburden and taking out the useful clay. The stripping may be done by power shovels working on a face or, in some mines by bulldozers and power scrappers of large capacity.

Due to lack of modern equipment at the site, local equipments and manual labour were used for clay mining. The following tools were used for digging and transportation of clay from the site to the studio:

i. Shovels

ii. Head Diggers

iii. Cutlass

iv. Big and small hoes

v. Big and small hammers

vi. Head pan and Basins

vii. Wheel Barrow and

viii. Pick-up Van

3.13 Field Work

A pilot study was conducted on samples collected from various location of the clay deposit. The site of the clay deposit is located in Ibeto village, which is situated at North-West of Kontagora Local Government Area of Niger State. The town is located some 30km along Yauri-Sokoto road. The village is accessible by road. Many trips were made to collect samples. The secondary clay used in this study was found in Minna, capital city of Niger State. The clay pit is located at the outskirt of the town along Bida road.

3.2 Chemical Analysis of Ibeto Clay

Samples of Ibeto clay was collected and taken to National Metallurgical Development Centre, Jos for chemical analysis. In the XRF analysis, the finely ground raw clay mineral was pressed into a compact form and then fused with lithium tetra-borate flux in a glass bead. An x-ray beam from a tungsten xray gun was focused on the specimen.

The focused x-rays cause the elements present in the specimen to excite leading to the emission of secondary x-rays that are characteristic of the elements. The amount of emission is also directly proportional to the concentration of the element present in the sample. The x-ray spectrum of the sample was computer processed to determined the elements present and their individual concentrations. Below is the tabulated outcome of the test.

Table 2: Chemical analysis of Ibeto clay

S.N	Sample	% Al_2O_3	% SiO_2	% K_20	% CaO	% TiO_2	% Cr_20_3	% MnO	% Fe_20_3
1.	KAOLIN	35.20	50.90	0.15	0.21	1.47	ND	0.005	3.48
		% NiO	% CuO	% ZnO	% ZrO_2	% BaO	% MgO	% Na_20	% PbO
		0.008	0.03	ND	0.40	0.12	0.15	0.03	0.02

Key: % = Percentage
ND = Not Detectable

3.2.1 Bulk Analysis by X-Ray Diffraction (XRD) Analysis

Preparation of the Sample

The powdered whitish sample was oven dried at 600^0C for 1 hour to make it moisture free. After cooling, the sample was sieved using Tyler mesh 1.5μ to obtain 100 mesh particle size according to standard of sample preparation.

About 15gm was carefully weighed using metler balance (20kg capacity). This was loaded onto the sample holder and uploaded into the machine "XRD Schimadzu – 600 model. The data was tabulated and recorded.

3.2.2 Orient Analysis

This analysis required the analyst to obtain the clay independently by extraction treatment. The whitish sample was treated as follows:

i. About 3 – 5gm of the sample was put inside the “test tube” and turned into solution by addition of “distilled water”. It was properly mixed using clean “glass rod” and was later “centrifuged” at 6rpm for 20 minutes using “centrifuge equipment” for proper and even distribution. This was decanted about 8 times after which it was treated with 0.62% sodium hexametaphosphate.

ii. The clay went into complete “suspension” after 8 times of decantation.

iii. With the aid of “microdropper” about 10mls was applied on a clean slide and kept in an environment that was dust-free, and allowed to be air dried for 24 hours.



Plate 1: X-ray Diffractometer Schimadzu 600 Model



Plate 2: X-Ray Flourescence Advant'x 1200 Model

3.2.3 Glycolation

This is a confirmatory test to detect whether the clay is a swelling or non-swelling type. About 500ml of ethylene glycol was laid on the bottom of the dessicator. The clay-slide already prepared was placed on top of wire guaze over the ethylene glycol inside the dessicator. The covered dessicator was put inside the oven at 75^0C for 1 hour to be heated up. The dessicator was removed and allow to cool. The slide-clay was removed and was ready for analysis.

3.2.4 Heat Treatment

This is another confirmatory test to ascertain if such clay can withstand high temperature as a refractory agent.

The slide-clay already prepared was placed inside furnace – 1200^0C capacity and heated at 500^0C and 550^0C for 1 hour respectively.

This was removed and placed inside "silica gel lined dessicator" and allowed to cool. The slide-clay was then removed and was ready for analysis.

3.2.5 Analysis to Determine the Physical Content of the Clay

The clay under study is white in colour. It is coarse in texture and smooth when sieved. In a laboratory where the clay was studied under a microscope, the shapes of the particles are plate like and the size of each particle is about one micron.

Plasticity Test

To determine the plasticity content of Ibeto clay. A quantity was obtained in 50kg bag. The raw dried clay was soaked in a plastic bucket for two days to enable the lumps to dissolve properly. On the third day, it was sieved using 100 mesh siever to remove unwanted particles. The slurry was poured into a plastic container to allow it settle down and subsequently become leather hard after two days a piece of rolled thin clay was rolled and twisted round the finger. The result was recorded and documented.

Moisture Content Determination Procedure

A wet sample of Ibeto clay was weighed and recorded as W1, after drying the same sample was fired to 800^0C after firing the fired sample was weighed and recorded as W2. Calculation for moisture content according to Rhodes (1973) in Ojie and Esosuokpo (2008) is presented below:

W1 =

W2 =

$$= \frac{\text{Wet Sample-dry sample}}{\text{Wet Sample}} \times \frac{100}{1}$$

Therefore, W1-W2 =

$$\% \text{ moisture} = \frac{\text{moisture}}{\text{Dry sample}} \times \frac{100}{1}$$

3.2.6 Test for Shrinkage

Four bars of 12cm length and 4cm width was made. A line of 12cm was drawn at the centre when the clay bar was wet. The bars were fired to 800^0C the measurement was taken to determine shrinkage. Shrinkage calculation.

Wet length =

Fired length =

Therefore, $\frac{\text{wet length – fired length}}{\text{Wet length}} \times \frac{100}{1}$

3.2.7 Absorption/Porosity Rate

In order to enhance glaze application on wares made from the clay, its porosity or absorption rate was tested. The method proposed by Cross and Young (1948) was adopted. Four bars of 12cm x 4cm width were made from Ibeto clay. They were fired at different temperatures ranging from 800°, 1050°C and 1150°C. This is done in order to ascertain the right temperature of maturity of the clay. The specimen were then boiled for 1 hour 30minutes and allowed to cool to room temperature and their weights were recorded. The specimen were then removed from the container and excess water wiped off. They were weighed in air (w). The apparent porosity was calculated. The first bar

was fired in the kiln to 800°C after cooling, it was weighed and recorded as W1. After cooling, the same bar was dropped in a water for five minutes and weighed again as W2.

W1 =

W2 =

Calculation formula in percentage:

$$\text{Absorption rate} = \frac{\text{Wet weight-Dry weight}}{\text{Dry weight}} \times \frac{100}{1}$$

3.3 Preparation of Ibeto Clay for Table Wares Production

The processing of the raw clay was carried out in Al-Habeeb Pottery Centre, Minna in Niger State, Nigeria. Al-Habeeb Pottery Centre lacked some of the basic equipment found in a standard ceramic studio. Most of the process were carried out manually. The raw clay e. Ibeto Clay and Minna clay were mixed together in equal proportion that is 50-50. The raw clay was soaked in water for 4Shours. After mixing the two clay bodies to obtained hormogeneous body, the clay is sieved with a 200 mesh size. The sieved slurry were poured into locally made traditional pots and were placed outside for almost two weeks. Through the process of evaporation, the excess water in the lay was drained. The leather hard clay was spread on a plaster mould for a day to remove excess water. When the clay was ready, it was packed and stored in a clay pit for some days to aged.

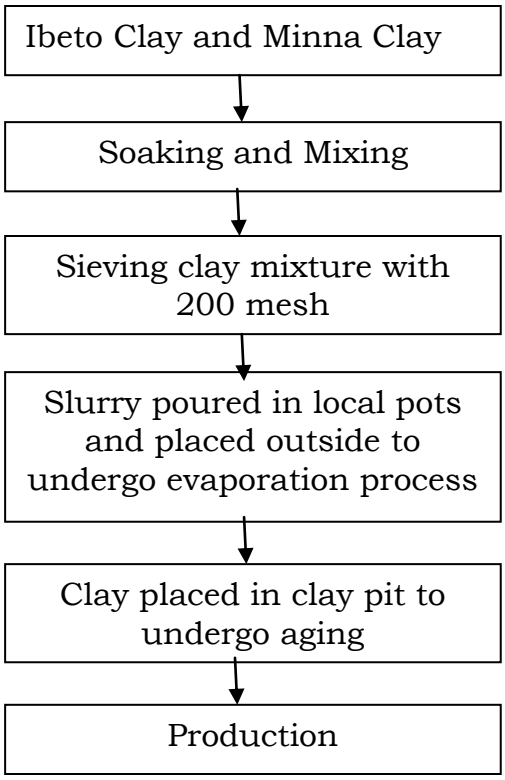


Fig. 1: Beneficiation of the Materials (Ibeto Clay).

3.4 Throwing

The practical thrown work was performed at Al-Habeeb pottery centre on a wooden kick wheel. When the clay was ready to be used, sizeable lumps were taken out of the clay pits. The lumps were wedged to obtained homogenous consistency. The next step was to throw the wedged lumps on the wheel. Centering the clay is one of the most of the important steps in throwing pottery, as such care was taken to ensure that each lump was properly centred on the wheel head to achieve a successful pulling. Most of the items made are: cups, jugs, tea pots, sugar pots etc.

3.4.1 Drying of Finished Wares

The finished wares that comprises of tea-cups, jugs, tea-pots, sugar pots etc. were placed on planks and covered with polythene to protect the wares from being over exposed so that they do not crack, warp or get distorted after a period of two weeks. By the third week, the wares were ready for bisque firing and glazing.

3.5 Firing Clay Bodies

The proper firing temperature for a clay body depends on many factors, especially its chemical composition, the peak temperature are the length of soak, the duration of the firing and the cooling.

3.5.1 Bisque Firing

Both the bisque firing and glaze firing were carried out in a gas kiln. It was a medium downdraft kiln with two burners. One of the advantages I observed using this kiln is that, the kiln can reach maximum temperature in eight to twelve hours. I was able to achieve reduction atmosphere when firing. The dried wares were loaded into the kiln and were fired approximately 900°C-960°C.

Pyrometric cones are made of a specially formulated ceramic material that melts at a specific temperature in relation to a specific temperature rise. They are placed inside the kiln at an 82 degree angle. That tilt allows the cones to bend as they reach the indicated temperature. The kiln was loaded with decorated glaze wares and firing commenced. At 1000^0C Cone 05a melted. The glaze matured at 1300^0C – at this temperature, Cone 10 melted.

3.6 Glazing

Frigola (2006) defined glaze as a layer of glass prepared from blends of different materials that combine evenly when they melt and attach firmly to a ceramic object. This objects needs to be insoluble and impermeable to liquids and gases. For the final glaze firing of the sample wares, two glaze recipes were formulated. From the Ibeo Kaolin and Minna ball clay the result shows that the mixture is a stoneware body. One of the determining factors in preparing stoneware glaze is the way in which they are applied. Their thickness varies between 1/16 and 1/8 inch (1.5 and 3mm). The ingredients are ground finely.

Two glaze recipes were formulated to be used on the resultant clay bodies. Below is the recipes for the two glazes that were use in the study:

Test 1: **Whitish Glaze**

Feldspar	40%
Quartz	l5%
Wood ash (mixed)	15%
Secondary Clay	15%
Kaolin	15%
Cobalt Oxide	0.2%

The addition of Cobalt Oxide gives the finished wares bluish colour.

Test 2:

Feldspar	40%
Wood ash (mixed)	20%
Secondary Clay	16%
Rice husk ash	24%

Stoneware glazes are generally made up of clays, silica, feldspars, carbonates and other components.

- Clays: white clays free of iron oxide
- Silica: Quartz
- Feldspar: sodium, potassium and lithium feldspar or nepheline syenite.
- Carbonates: calcium carbonate, magnesium carbonate, dolomite, talc, barium carbonate or strontium carbonate.

3.6.1 Slips Application on Wares before Glaze Firing

After mixing the glaze, before applying the glaze on the bisque wares it was decorated with slip. A slip is generally liquid clay, which can be applied to leather hard or bisque fired form. The application of white slip also helps brighten up the glazes. If

applied to a leather-hard form the slip must exhibit the same shrinkage as the clay body. Slips are basically made up of 60 to 70 percent ball clays or kaolin, 5 to 10 percent silica and 10 to 30 percent feldspar.

Below are the recipes of slip composition applied to bisque wares before glaze firing:

Table 3: Recipe for Slip Application on wares

	Recipe 1	**Recipe 2**
Ball Clay	62%	20%
Kaolin	-	40%
Feldspar	30%	30%
Whiting	8%	
Silica	-	10%

Source: Studio experiment

3.6.2 Firing

The proper firing temperature for a clay body depends on many factors, especially its chemical composition, the peak temperature and the length of soak, the duration of the firing and the cooling". It is important to understand the concept of firing clay work to the correct temperature (Frigola 2006). The final firing of the finished wares was carried out in a Gas Kiln. The temperature in the kiln was monitored through the use of pyrometric cones.

Maturity

This refers to the optimum point reached by clays during the final firing. All clay bodies have a specific shrinkage and absorption rate determined for their firing range. According

to Frigola (2006) If the clay is not fired high enough, it will have a high absorption rate or remain porous. If it is fired higher, it will become vitrified with a lower absorption rate. If fired too high, it will slump or bloat.

Pyrometric cones are made of a specially formulated ceramic material that melts at a specific temperature in relation to a specific temperature rise. They are placed inside the kiln at an 82 degree angle. That tilt allows the cones to bend as they reach the indicated temperature. The kiln was loaded with decorated glaze wares and firing commenced. The glaze wares matured at 2372°F/1300°C-At this temperature, Cone 10 melts.

At 1832°F/1000°C - At this temperature, Cone 05a melts.



Plate 3: Glazed Ceramic Bowl and cup



Plate 4: Glazed Ceramic Teapot and Jug

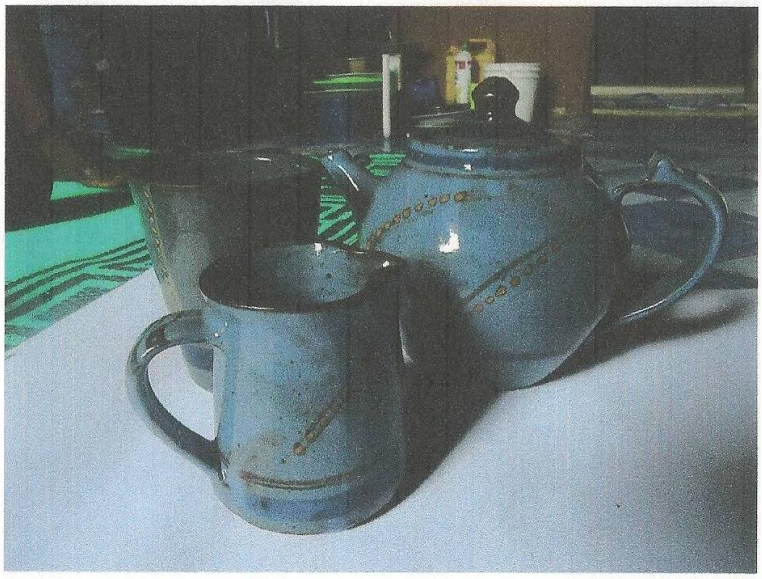


Plate 5: A set of ceramic teapot and cups



Plate 6: A set of ceramic teapot and cups

CHAPTER FOUR

4.0 RESULT, DATA PRESENTATION AND ANALYSIS

4.1 Sample Description

Ibeto clay varies in physical characteristics such as cream with some brown stain though not conspicuous. The lumps are hard with coarse texture. When crushed to powdery form it disintegrate into finer particles. It is a residual kaolin that is mined along the Ibeto- Yauri major highway. After pounding and sieving, it was observed that when mixed with water the substance became plastic, which suggests that Ibeto clay is kaolin as compared with other Kaolin from other locations in Nigeria (See the table below).

Table 4: Physical Characteristics of Ibeto Clay Compared with other Clay Bodies in Nigeria

CLAY	COLOUR	PHYSICAL FORM	LUMP SIZE AS MINED
Ibeto	Cream with brown stains	Hard lumps of coarse texture	5 – 15cm
Ahoko	Light grey	Moderately hard lumps with smooth touch	5 – 20cm
Onibode	Light grey	Hard lumps with smooth touch	30 – 40cm
Kankara	White	Soft, smooth, powdery lumps	Less than 5cm
Manjahota	Cream	Moderately hard, with soft touch	10 – 20cm
Warram	Ash grey	Very hard lumps with smooth touch	20 – 40cm
Nafuta*	Cream with brown stains	Hard lumps of coarse texture	5 – 15cm

Source: Ahmed (1986) in Yakubu (2009)

X-Ray Fluorescence (XRF) Analysis of Ibeto Clay

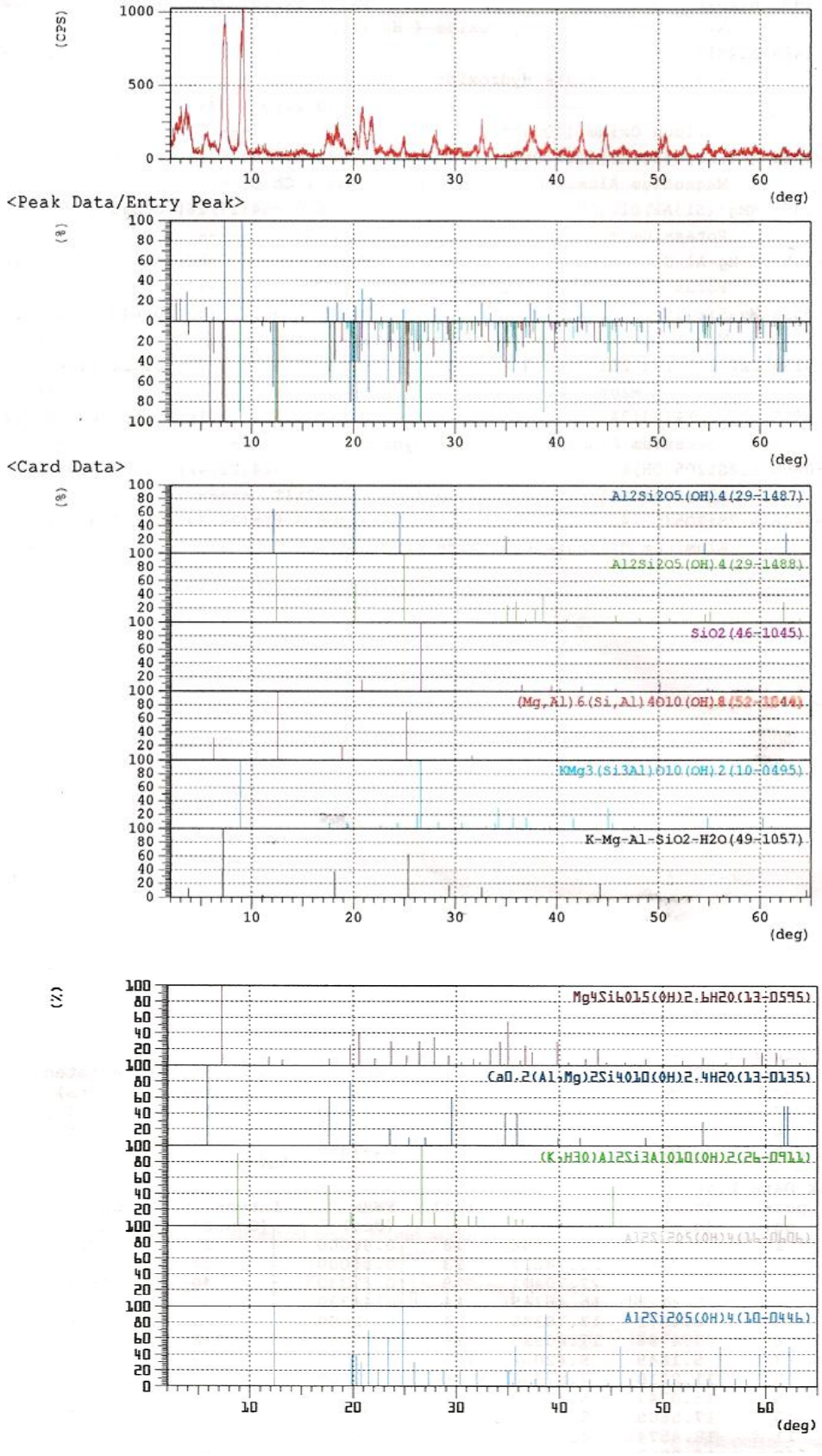
Result obtained from X-ray fluorescence analysis of the samples of Ibeto clay shows the oxides present to be alumina (Al_2O_3) and Silica (SiO_2). These two elements have the highest percent occurrences Al_2O_3 (35.20wt%) SiO_2 (50.90 wt%). Other elements appear in smaller quantities such as K_2O (0.15wt%) CaO (0.21wt%) TiO_2 (1.47wt%) MnO (0.005wt%) Fe_2O_3 (3.48wt%) NiO (0.008wt%) CuO (0.03wt%) ZrO_2 (0.40wt%) BaO (0.12wt%) MgO (0.15wt%) Na_2O (0.03wt%) PbO (0.02wt%).

These average values for alumina and silica make Ibeto clay to appear suitable for ceramic table ware production. The slight volume of silica in the clay shows that the sample obtained at the site was from the surface, if the mining could go deeper purer content with lesser silica content can be obtained. The slightly high content of iron Fe_2O_3 (3.48wt%) was responsible for the brown stain on the mineral at raw stage (Mauchaeus et al, 2002) in (Yakubu, 2009).

X-ray Diffraction (XRD) Analysis (Bulk Analysis)

The "gonometer" was preset to rotate between the angle 2^0 and 65^0 2theta at 4deg/min per step counts of the peaks expression. The x-ray light disperses at voltage of 40 – 45 (kv) and current of 30 – 40 (MA). This gave the crystallographic and microstructural / mineralogical details of the clay, as can be seen in the figure below.

Figure 2: Bulk Sample



XRD RESULTS INTERPRETATION (IBETO CLAY SAMPLE ANALYSIS)

The three major or strongest peaks found in the Bulk Clay analysis as expressed on the diffractogramm were at the following 2 theta Braggs angles viz.

The 1st strongest peak subtends at 2Theta braggs angle 9.1849 with corresponding intensity ratio of 100.

The 2nd strongest peak subtends at 2theta Braggs angle 7.4796 with corresponding intensity ratio 99 and.

The 3rd strongest peak subtends at 2Theta Braggs angle 20.9377 with corresponding intensity ratio 32 respectively.

"Auto-searching" and corresponding 'Manual Matching" of the analyzed sample and the 'card file data", resulted in the following detailed peaks expression tagged ENTRY DATA ACCEPTED PEAKS.

1. Columns 4,5,6,7, 9 and 11 have the 1st, 2nd and the 3rd strongest peaks corresponding to the 2 Theta Braggs angle 9.1849, 7.4796 and 20.9377 respectively.
2. Columns 4,5,6,7 and 9 have the 1st and 2nd strongest peaks corresponding to the 2Theta Braggs angle 9.1849 and 7.496 respectively.
3. Columns 3,4,6,8,10 and 11 have the 1st and the 3rd strongly peaks corresponding to the 2Theta Braggs angle 9.1849 and 20.9377 respectively.

4. Columns 3,5,7,9 and 11 have the 2nd and 3rd strongest peaks corresponding to the 2Theta Braggs angle 7.4796 and 20.9377 respectively.
5. Columns 4,6 and 7 have the 1st strongest peak corresponding to the 2Theta Braggs angle 9.1849 only.
6. Columns 5 and 9 have the 2nd strongest peak corresponding to the 2Theta Braggs angle 7.4796 only.
7. Columns 3,7,10 and 11 have the 3rd strongest peak corresponding to the 2 Theta Braggs angle 20.9377 only.

Close observation on the individual strongest peaks on the CARD FILE DATA have some RESIDUALS PEAKS (MINOR PEAKS)

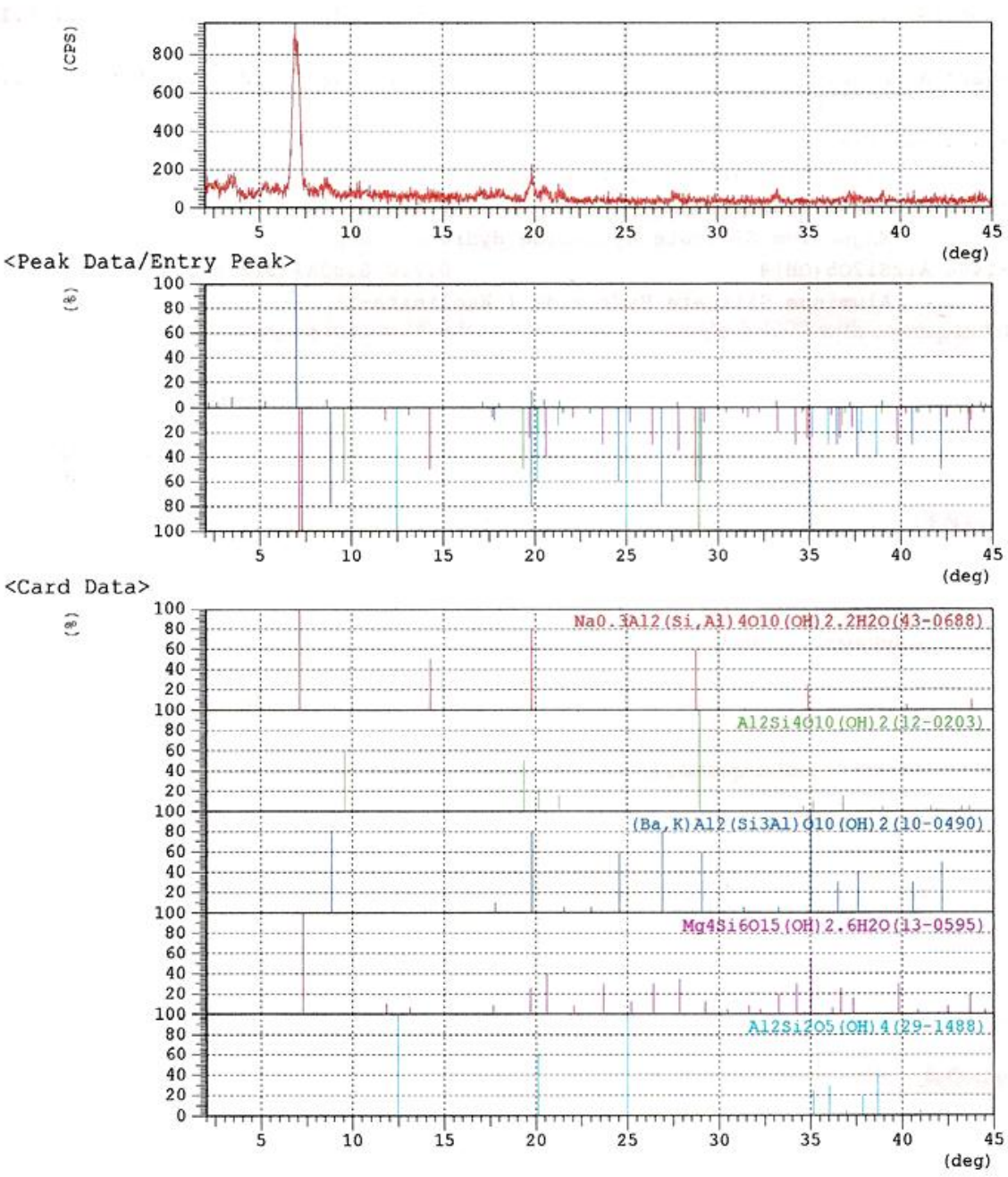
These are found at the 2Theta Braggs angle corresponding to angles .5.7128, 6.4072, 18.4574, 21.7979, 29.3242, 32.6602, 37.8254, 42.4422 etc.

CONCLUSION: The major minerals contained in BULK CLAY SAMPLE OF IBETO CLAY as confirmed by the various peaks against corresponding 2Theta Bragggs angle are: Kaolinite, Sepiolite, quartz, Montmorillonite, Hydrobiotite and Illite. The minor minerals found are: halloysite, Phlogopite and Nacrite etc.

Orient Analysis

The "Gomometer" was set at 2^0 and 45^0 2theta angle at 4deg/min per step counts of the peaks expression. The x-ray light disperses at 40 – 45kv and 30 – 40 (MA) for voltage and current respectively (see figure 9 below).

Figure 3: Orient Sample



Orient Sample Analysis (Ibeto Sample)

The three major or strongest peaks found in the Orient clay analysis as expressed on the diffractogram were at the following 2Theta braggs angles viz:

The 1st strongest peak subtends at 2Theta Braggs angle 7.1336 with corresponding intensity ratio of 100.

The 2nd strongest peak subtends at 2Theta Braggs angle 19.1931 with corresponding intensity ratio 13 and

The 3rd strongest peak subtends at 2theta Braggs angle 3.7272 with corresponding intensity ratio 8 respectively.

"Auto-searching" and corresponding "manual matching" of the analyzed sample and the "card file data", resulted in the following detailed peaks expression tagged Entry Data Accepted Peaks.

1. Columns 1,3,4 and 5 have the 1st and 2nd strongest peaks corresponding to the 2Theta Braggs angle 7.1336 and 19.9131 respectively.
2. Columns 1 and 4 have the 1st strongest peaks corresponding to the 2Theta Braggs angle 7.1336 only.
3. Columns 1,3,4 and 5 have the 2nd strongest peaks corresponding to the 2theta Braggs angle 19.9131 only.

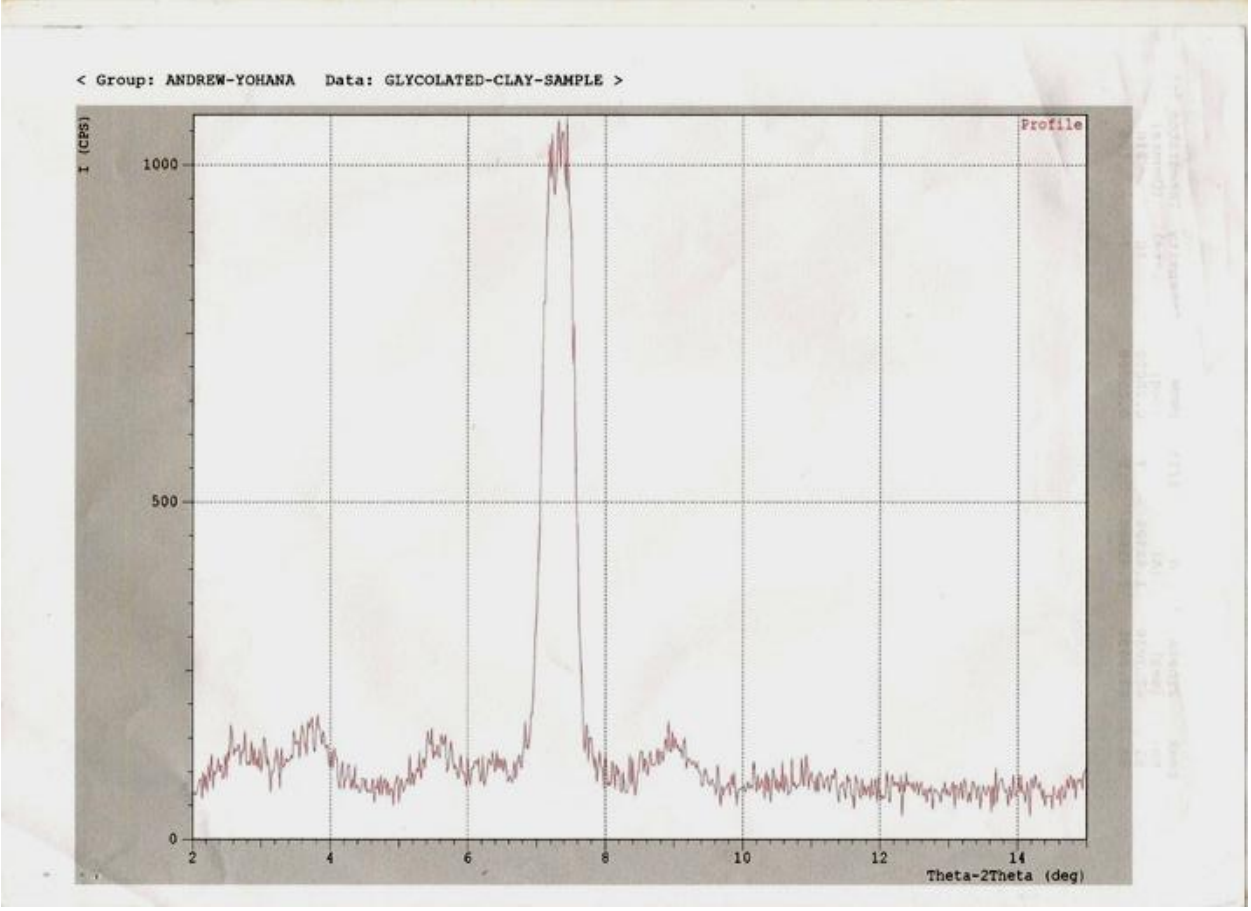
Close observation on the individual strongest peaks on the CARD FILE DATA have some RESIDENTIAL PEAKS (minor peaks). These are found at the 2Theta Braggs angle corresponding to angles 8.7907, 17.2296 correspond to angles 8.7907, 17.2296, 27.8313, 37.2659 and 39.0146 respectively.

CONCLUSION: the major minerals contained in orient clay sample of Ibeto clay as confirmed by the various peaks against corresponding 2theta Braggs angle are Illite, Musorite, Kaolinite and Sepiolite. The minor minerals are Beidellite, hydro-biotite and pyrophyllite etc.

Glycolation Analysis

This was set to rotate at gomometer angle 2theta of $2^0 – 15^0$ at 2deg/min per step counts of the peaks. The result indicates that the clay is not a swelling type, since no-dome shape was observed in the peak (See the figure below).

Figure 4: Glycolated-clay-sample



Glycolated Clay Sample Analysis (Ibeto clay)

This analysis is mainly a confirmatory test to categorize the sample whether it's a swelling or non-swelling clay. According to the results generated from ethynol-glycol oven treatment and XRD result, it indicate that the defactogramm peaks are not shifted from the origin hence the clay did not absorb the glycol and therefore can be classified as non-swelling clay.

Heat Treatment (Heating at 500^0C and 550^0C)

The gomometer was set to rotate at 2^0 – 15^0C 2theta angle at 2deg/min per step count. The voltage and current level were 40 – 45kv and 30 – 40MA respectively.

No effect of heat was observed except the cluster formation of peaks around the angle of 7.2 – 7.9. This result clearly shows that the clay is a refractory material (see figure below).

Figure 5: Clay Sample Heated @500>

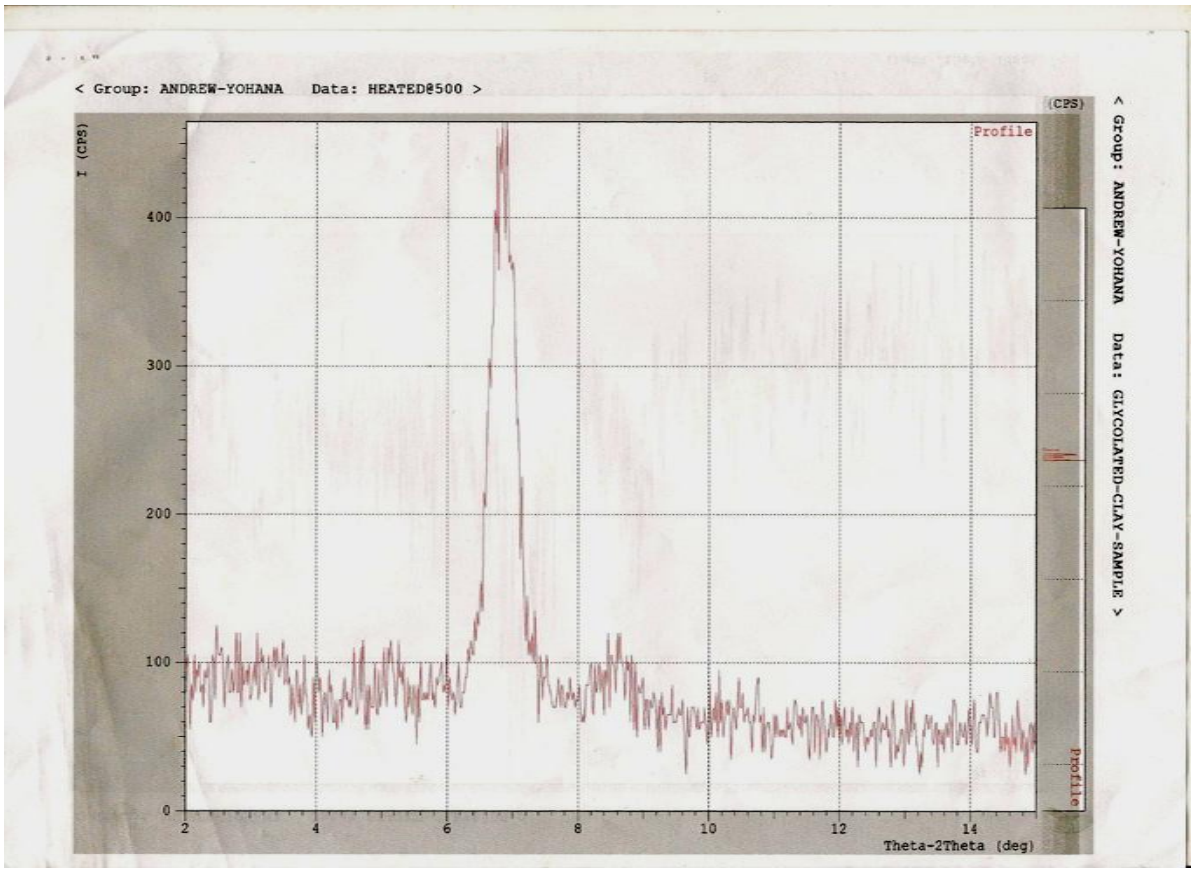
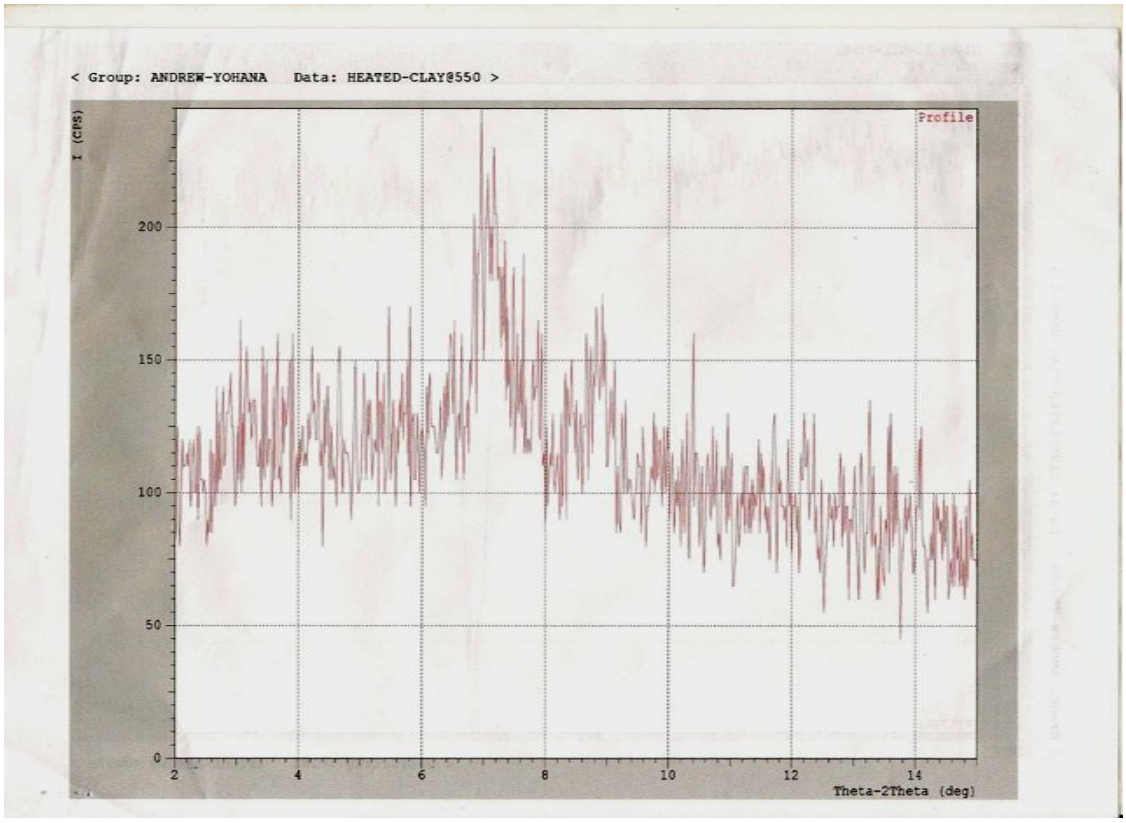


Figure 6: Clay Sample Heated @550>



HEAT TREATMENT

This analysis is to conform if the particular clay can easily be destroyed by heat at the temperature of 500 and 550^0C. From the result of the defractogramm obtained from XRD after furnace heating treatment, it was observed that no effect on the peaks at 500^0C. But at 550^0C according to the result some peaks disappeared. This disappearance of the peaks indicate that such clay cannot be destroyed if expose to temperature of 550^0C and above.

Plasticity Test Analysis

A piece of rolled thin clay coils was rolled and twisted round the finger. The result shows that the coils crack. This means that the clay is very short and will be difficult to work with. It will be good when combined with other clay bodies that are highly plastic.

Moisture Content Determination Analysis

A wet sample of Ibeto clay was weighed and recorded as W1, after drying the same sample was fired to 800^0C, it was weighed and recorded as W2. Calculation for moisture content according to Rhodes (1973) in Ojie and Esosuakpo (2008) is presented below:

W1 = 60

W2 = 51

$$= \frac{\text{Wet sample – Fired Sample}}{\text{Wet Sample}} \times \frac{100}{1}$$

Therefore, W1 – W2 = 60 – 51 = 9

$$\% \text{ moisture} = \frac{\text{Moisture}}{\text{Dry Sample}} \times \frac{100}{1}$$

$$= 9/51 \times 100/1 = 900/51 = 17.64\%$$

Therefore, the moisture content is 17.64%

Test for Shrinkage Analysis

Four bars of 12cm length and 4cm width were made. A line of 12cm was drawn at the centre when the clay bar was wet. The bars were fired to 800^0C, the length of the 12cm line was taken again after the firing. The following results was obtained:

Wet length = 12cm

Dry length = 11.4cm

% Shrinkage:

$$= \frac{\text{Wet length} - \text{Dry Length}}{\text{Wet Length}} \times \frac{100}{1}$$

$$= \frac{12 - 11.4}{12} \times \frac{100}{1} = \frac{0.6}{2} \times \frac{100}{1} = 5\%$$

Therefore total shrinkage is 5%.

Absorption/Porosity Rate Analysis

In order to enhance glaze application on wares made from the clay, its porosity and absorption rate was tested. The method proposed by Cross and Young (1948) was adopted. Four bars of 12cm x 4cm width were made from Ibeto clay. They were fired at different temperature ranging from 800^0C, 1050^0C and 1150^0C. The specimen were then boiled for 1hr 30 mins and allowed to cool at room temperature, and their weights were recorded. The first bars was fired in the kiln to 800^0C after cooling it was weighed and recorded as W1. The same bar was dropped in a water for 5mins and weighed again as W2. The following result was obtained:

W1 = 60gms

W2 = 85gms

Calculation formula in percentage

$$\text{Absorption rate} = \frac{\text{wet weight} - \text{dry weight}}{\text{Dry weight}} \times \frac{100}{1}$$

$$= \frac{W2 - W1}{W1} \times \frac{100}{1}$$

$$= \frac{85 - 60}{60} \times \frac{100}{1} = 41.66\%$$

The absorption rate of Ibeto clay is 41.66%.

Firing Clay Bodies

The proper firing temperature for a clay body depends on many factors, especially its chemical composition, the peak temperature and the length of soak, the duration of the firing, and the cooling.

Bisque Firing

The dried wares were loaded into the gas kiln and was fired to approximately 900^0C – 960^0C. The firing lasted for 9 hours. At the firing temperature of 400^0C chemical water was eliminated. As the firing progressed to 600^0C quartz invasion process commenced. Optimum temperature for bisque was reached at 960^0C.

Glaze Firing

The kiln was loaded with decorated glaze wares and firing commenced. The following behaviours were observed.

1000^0C – At this temperature cone 05 a melted

1300^0C – At this temperature cone 10 melted

The following observations were made at 600^0C. The process of quartz inversion commenced. At 1000^0C vitrification process and melting of glaze commenced. Through the pin hole, it was observed that cone 05a melted. By the time the kiln rose to 1300^0C cone 10 melted and the firing process was completed. The entire period for firing was 9 hours.

CHAPTER FIVE

5.0 CONCLUSION, SUMMARY AND RECOMMENDATION

5.1 Findings

The result obtained in this study showed that Ibeto clay is a kaolin and a refractory material. Orient analysis test, glycolation analysis and heat treatment showed that Ibeto clay, apart from being a refractory material that can be used in different ranged of ceramic production, it can also be used in road construction because it is a non-swelling clay. In the production of table wares the result obtained is satisfactory.

Based on the findings in this study the following observations were made:

1. The chemical composition of Ibeto clay showed the main oxides in the clay to be Al_2O_3 (35.20wt%) and silica (50.90wt%). This shows that the clay is kaolinite and a refractory material. The presence of iron Fe_2O_3 (3.48wt%) is responsible for the brown stains on the clay. XRD results confirmed this through the multiple peaks on the graph.
2. Ibeto kaolin is suitable for ceramic tableware production when combined in equal proportion with a good secondary clay. The outcome of the combination of Ibeto clay and Minna clay shows a homogeneous composition that resulted in a stoneware body. This was attested to by both the bisque and glaze firing that reached 960^0C and 1300^0C respectively.
3. The x-ray diffraction (XRD) analyses of the clay as shown by the crystals proved that the sample is a kaolinite mineral.
4. Ibeto clay is a Kaolin and a good source of ceramic refractory material.

5. Ibeto clay has up to 35.2% Al_2O_3 and up to 50% silica. The brown colour of the clay is due to the presence of iron and titanium totaling up to 4.9%.
6. Ibeto clay can be used for glaze.
7. The dominance of kaolinite mineral can be responsible for the low plasticity of the clay.
8. The effect of glaze on the finished glazed and fired wares shows that the absorption/porosity rate of the clay in relation to glaze application is good.
9. Shrinkage test conducted on the clay shows that the percentage of shrinkage is 5%.
10. Under the laboratory test for heat treatment. No negative effect of heat was observed, such as warping. This confirmed that the substance is a refractory material.
11. The two glazes formulated show the high quality of Ibeto kaolin. The recipe includes feldspar, quartz, wood ash (mixed), secondary clay and kaolin. The result shows a whitish glaze. The addition of cobalt oxide in a small percentage of 0.2% gives the ware its bluish colour. The second recipe that comprises feldspar wood ash (mixed), secondary clay and rice husk gives the glaze a milky colour.
12. After the firing range of 960^0C for bisque and 1300^0C for glaze. The final firing was successful without recording any breakage.

Contribution to Knowledge

The practical scientific aspects involved in clay sourcing for ceramics provides both the practical and scientific aspects of clay sourcing for ceramic production.

5.2 Recommendation

Based on the results obtained from this research findings, the following recommendations are proposed for further research:

i. Ibeto clay deposit should be further investigated to ascertain the quantity occurrence of the deposit, it is up to commercial quantity.

ii. Niger state government should set up entrepreneurial ship centre where pottery will be utilize for skill acquisition.

iii. To investigate the possibility of using this clay in combination with feldspar to determine if the fired properties of the porcelain body could be improved.

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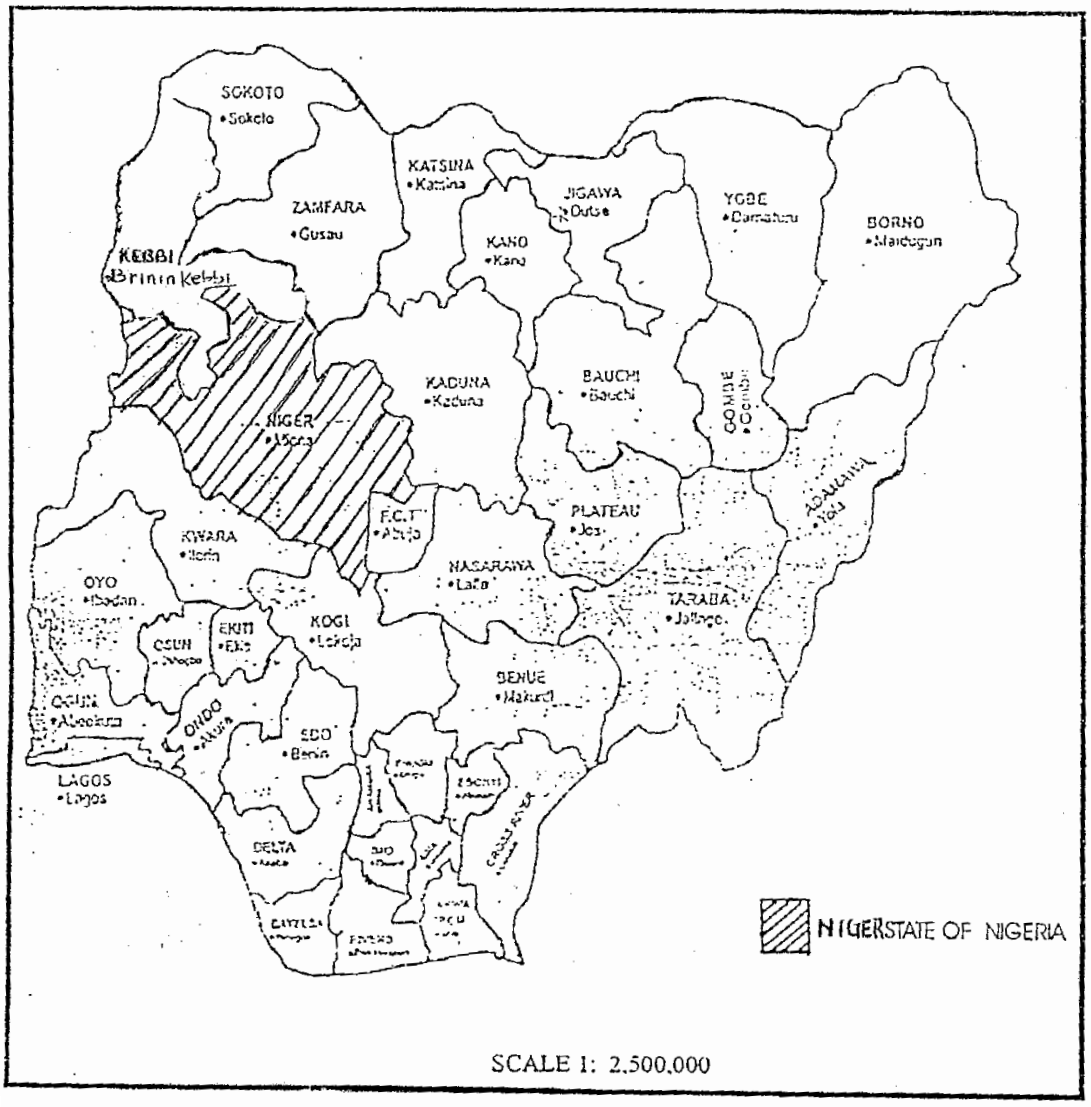
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APPENDIX 1



SOURCE: MINISTRY OF LANDS, HOUSING & URBAN DEVELOPMENT
NIGER STATE (2011)

APPENDIX II

NATIONAL METALLURGICAL DEVELOPMENT CENTRE

FAX: 073-613266
TEL: (073) 613267, 613264, 613271

PLOTS NO. BPG 179, PSG 390
ZARIA ROAD,
P.M.B. 2116,
JOS, NIGERIA

LETTER REF. NO. NMDC/TECH/179/429

DATE 16th July, 2010

CERTIFICATE OF ANALYSIS

CLIENT: Andrew Yohanna,
A.B.U., Zaria.

SAMPLE: Kaolin

JOB: Chemical Analysis

TEST RESULT:

S/N	Sample	% Al_2O_3	% SiO_2	% K_2O	% CaO	% TiO_2	% Cr_2O_3	% MnO	% Fe_2O_3
1	KAOLIN	35.20	50.90	0.15	0.21	1.47	ND	0.005	3.48
		% NiO	% CuO	% ZnO	% ZrO_2	% BaO	% MgO	% Na_2O	% PbO
		0.008	0.03	ND	0.40	0.12	0.15	0.03	0.02

Key: % = Percentage
ND = Not Detectable

NAME OF VERIFYING OFFICER: J. OBIY NWOSU

SIGNATURE: _____ DATE: 16TH JULY, 2010

APPENDIX III

```
        ***  Basic Data Process  ***

# Data Infomation
        Group                   : ANDREW-YOHANA
        Data                    : HEATED@500
        Sample Name             :
        Comment                 :
        Date & Time             : 03-31-12 11:11:02

# Measurement Condition
    X-ray tube
        target                  : Cu
        voltage                 : 40.0 (kV)
        current                 : 30.0 (mA)
    Slits
        Auto Slit               : not Used
        divergence slit         :   1.00000 (deg)
        scatter slit            :   1.00000 (deg)
        receiving slit          :   0.30000(mm)
    Scanning
        drive axis              : Theta-2Theta
        scan range              :    2.0000 - 15.0000 (deg)
        scan mode               : Continuous Scan
        scan speed              :    3.0000 (deg/min)
        sampling pitch          :    0.0200 (deg)
        preset time             :    0.40 (sec)

# Data Process Condition
    Smoothing                   [ AUTO ]
        smoothing points        : 25
    B.G.Subtruction             [ AUTO ]
        sampling points         : 25
        repeat times            : 30
    Ka1-a2 Separate             [ MANUAL ]
        Ka1 a2 ratio            : 50 (%)
    Peak Search                 [ AUTO ]
        differential points     : 25
        FWHM threhold           : 0.050 (deg)
        intensity threhold      : 30 (par mil)
        FWHM ratio  (n-1)/n     : 2
    System error Correction     [ YES ]
    Precise peak Correction     [ NO ]
```

APPENDIX IV

```
          ***  Basic Data Process  ***

# Data Infomation
        Group                 : ANDREW-YOHANA
        Data                  : ORIENT-SAMPLE
        Sample Nmae           :
        Comment               : CLAY
        Date & Time           : 03-31-12 07:37:38

# Measurement Condition
    X-ray tube
        target                : Cu
        voltage               : 40.0 (kV)
        current               : 30.0 (mA)
    Slits
        Auto Slit             : not Used
        divergence slit       :   1.00000 (deg)
        scatter slit          :   1.00000 (deg)
        receiving slit        :   0.30000(mm)
    Scanning
        drive axis            : Theta-2Theta
        scan range            :    2.0000 - 45.0000 (deg)
        scan mode             : Continuous Scan
        scan speed            :    5.0000 (deg/min)
        sampling pitch        :    0.0200 (deg)
        preset time           :    0.24 (sec)

# Data Process Condition
    Smoothing                 [ AUTO ]
        smoothing points      : 25
    B.G.Subtruction           [ AUTO ]
        sampling points       : 25
        repeat times          : 30
    Ka1-a2 Separate           [ MANUAL ]
        Ka1 a2 ratio          : 50 (%)
    Peak Search               [ AUTO ]
        differential points   : 25
        FWHM threhold         : 0.050 (deg)
        intensity threhold    : 30 (par mil)
        FWHM ratio  (n-1)/n   : 2
    System error Correction   [ YES ]
    Precise peak Correction   [ NO ]
```

APPENDIX V

*** Basic Data Process ***

Group : ANDREW-YOHANA
Data : BULK-SAMPLE

Strongest 3 peaks

no.	peak no.	2Theta (deg)	d (A)	I/I1	FWHM (deg)	Intensity (Counts)	Integrated Int (Counts)
1	7	9.1849	9.62062	100	0.43640	139	3001
2	6	7.4796	11.80980	99	0.47600	138	3346
3	14	20.9377	4.23938	32	0.41500	44	931

Peak Data List

peak no.	2Theta (deg)	d (A)	I/I1	FWHM (deg)	Intensity (Counts)	Integrated Int (Counts)
1	2.9236	30.19546	18	0.41340	25	789
2	3.2783	26.92918	22	0.00000	31	0
3	3.8886	22.70401	29	0.67330	40	1624
4	5.7128	15.45765	14	0.44330	19	452
5	6.4072	13.78385	4	0.32000	5	126
6	7.4796	11.80980	99	0.47600	138	3346
7	9.1849	9.62062	100	0.43640	139	3001
8	11.2210	7.87908	4	0.18000	5	120
9	15.0747	5.87242	4	0.12000	5	92
10	17.5689	5.04395	14	0.50000	20	602
11	18.4574	4.80310	19	0.54000	27	752
12	19.0857	4.64637	8	0.26000	11	202
13	20.2471	4.38240	15	0.33000	21	352
14	20.9377	4.23938	32	0.41500	44	931
15	21.7979	4.07399	23	0.44000	32	717
16	22.7956	3.89789	4	0.12000	6	67
17	23.7884	3.73741	3	0.35000	4	72
18	24.9711	3.56301	12	0.32000	16	295
19	28.0410	3.17952	13	0.59000	18	536
20	29.3242	3.04324	5	0.32000	7	180
21	30.4827	2.93017	4	0.36000	6	111
22	32.0209	2.79284	5	0.32000	7	135
23	32.6602	2.73961	19	0.30000	27	455
24	33.5193	2.67134	8	0.28000	11	183
25	36.9162	2.43295	4	0.24000	6	113
26	37.4358	2.40037	18	0.34000	25	500
27	37.8754	2.37351	12	0.24000	17	268
28	38.1752	2.35556	3	0.32000	4	91
29	39.2244	2.29494	7	0.38000	10	245
30	40.6934	2.21542	3	0.44000	4	101
31	41.7327	2.16261	3	0.08000	4	51
32	42.0925	2.14496	5	0.00000	7	0
33	42.4422	2.12809	19	0.42000	26	582
34	44.7925	2.02173	21	0.41670	29	642
35	45.7303	1.98243	3	0.12000	4	33
36	46.1701	1.96456	3	0.20000	4	58
37	46.4699	1.95259	5	0.16000	7	122
38	47.6393	1.90735	4	0.14000	5	56
39	50.2247	1.81506	10	0.20670	14	150
40	50.6829	1.79972	14	0.35000	19	378
41	52.6021	1.73848	6	0.31000	9	167
42	54.5663	1.68045	6	0.28000	8	147
43	54.9661	1.66917	6	0.32000	9	170
44	55.8458	1.64495	4	0.32000	5	81
45	56.1657	1.63633	6	0.48000	8	179

APPENDIX VI

```
          ***  Basic Data Process  ***

# Data Infomation
          Group                 : ANDREW-YOHANA
          Data                  : GLYCOLATED-CLAY-SAMPLE
          Sample Nmae           :
          Comment               :
          Date & Time           : 03-31-12 11:04:18

 # Measurement Condition
     X-ray tube
          target                : Cu
          voltage               : 40.0 (kV)
          current               : 30.0 (mA)
     Slits
          Auto Slit             : not Used
          divergence slit       :   1.00000 (deg)
          scatter slit          :   1.00000 (deg)
          receiving slit        :   0.30000(mm)
     Scanning
          drive axis            : Theta-2Theta
          scan range            :    2.0000 - 15.0000 (deg)
          scan mode             : Continuous Scan
          scan speed            :    3.0000 (deg/min)
          sampling pitch        :    0.0200 (deg)
          preset time           :    0.40 (sec)

 # Data Process Condition
     Smoothing                  [ AUTO ]
          smoothing points      : 27
     B.G.Subtruction            [ AUTO ]
          sampling points       : 27
          repeat times          : 30
     Ka1-a2 Separate            [ MANUAL ]
          Ka1 a2 ratio          : 50 (%)
     Peak Search                [ AUTO ]
          differential points   : 27
          FWHM threhold         : 0.050 (deg)
          intensity threhold    : 30 (par mil)
          FWHM ratio  (n-1)/n   : 2
     System error Correction    [ YES ]
     Precise peak Correction    [ NO ]
```