EXPLORATION OF CLAY FROM ANKPA NIGERIA, FOR THE PRODUCTION OF EARTHENWARE AND STONEWARE CERAMICS.

BY

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DECLARATION

I declare that the research work in this thesis entitled "EXPLORATION OF CLAY FROM ANKPA NIGERIA FOR THE PRODUCTION OF EARTHENWARE AND STONEWARE CERAMICS" was carried out by me in the Department of Industrial Design, under the supervision of Prof. A.M. Ahuwan and Dr.V.Alkali.The information got from the literature has been duly acknowledged in the text and a list of References provided. No part of the thesis was previously presented or done for another degree or diploma at any university as far as is known to me.

_____ _____

Shaibu Alidu Philip Date

CERTIFICATION

This thesis, Title "EXPLORATION OF CLAY FROM ANKPA NIGERIA FOR THE PRODUCTION OF EARTHENWARE AND STONEWARE CERAMICS**",** by SHAIBU ALIDU PHILIP, meets the standard and regulations governing the Award of the Degree of Master of Arts of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to God Almighty that brought me to this point of my study, my wife Lilian Shaibu, My parents Mallam Shaibu Okodo and my mother, Mallama Adijetu Shaibu for her wisdom in sending me to school in the early 60s.and to my children Benjamin Shaibu, Lydia Yakubu nee Shaibu, Philomena Shaibu, David and Daniel Shaibu (The Ejima) Susan, Enyojo and Emmanuel Shaibu also share in this dedication.

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ABSTRACT

This study explored the workability of clay from Ankpa Kogi State of Nigeria for the production of earthenware and stoneware ceramics. This research investigated a manageable area around Ankpa with clay deposits that are locally put to use by local potters, but yet to be used in contemporary ceramic. This study started with preliminary investigation in order to get information on the clay deposit from the people of the area and was followed by field trip to clay deposit areas where clay samples were obtained. There are many clay deposits in and around Ankpa only three samples from Ankpa 1, Ankpa 2 and Odagbo were collected using the random sampling method. Physical and chemical analysis was carried out on the clay samples from the three deposits for their physical and chemical properties. The ceramics wares were produced using the methords of throwing, casting and hand-building. Sample wares produced were dried in the room atmosphere in the ceramics section of the Department of Industrial Design A.B.U Zaria. The wares were successfully fired up to glaze temperature of about 1260^0C using kerosene kiln in the ceramics section. The following finding were made, Ankpa 1 and Ankpa 2 clay samples are fire clay due to their non plastic nature. The tabular and dense nature of the Ankpa 1 and Ankpa 2 clay samples will not allow it to slake except the grain size is reduced. Odagbo clay sample is a secondary clay due to it plastic nature and high iron content. X ray diffraction analysis of Ankpa 1 and Ankpa 2 shows that they are brownish pink fireclay. The results of these analyses encouraged the utilization of the samples in the experimental production of earthenware and stoneware pieces. Clay body formulated from the clay samples was successfully used in the production of wares.

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DEFINITION OF TERM

Alumina	-	Occur in clay not only in form of clay mineral but also in feldspar, mica and other simple alumina silicates all of which are moderately fusible.
Clay	-	A clay for a special purpose
Earthenware	-	Pottery or other objects made from fired clay which is porous
Glaze	-	A thin glass layer fused on ceramics wares
Kiln	-	A structure built to conserve heat
Plasticity	-	The property of a material enabling it to be shape and to hold its shape
Stoneware	-	Pottery or other objects made from fired clay which is dense and vitrified
Vitricication	-	The furthest state to which a body can be taken in firing without deformation
Biscuit or bisque firing	-	A name given to once fired ceramic body on which there is no glaze usually to a temperature more than 950^0C.
Ceramics	-	(Greek Keramos) A general word for all pottery and used today in connection with industries such as glass and cement.
Crazing	-	An undesirable and excessive crack in the glaze, which penetrate through the glaze to the clay body.
Fire-clay	-	A clay having slight higher percentage fluxes than pure clay, used in manufacture of refractory material
Glaze	-	A liquid suspension of finely ground minerals that is applied by brushing, pouring dipping or spraying on a fired ceramic ware, when fire it turned glossy
Shrinkage	-	Contraction of the clay in either, drying or firing stage.
Modelling	-	Modelling is the process of creating or making an original (Prototype) figure by skilfully shaping the object either in clay or plaster of pairs, plasticine etc.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY.

Clay is a term that refers to a number of earthy materials that are composed of minerals rich in alumina, silica and water. Clay is not a single mineral, but a number of minerals; it is abundant in many places of the world. Clay is formed as a result of weathering of several kinds of rocks in a process that took thousands and millions of years as a result of the actions of environmental agents such as wind, rain, glacier, and freezing. In addition to the weathering process, clay deposits may be formed in a place as residual deposits in soil, however thick deposits usually are formed as a result of secondary sedimentary deposition process after they have been eroded and transported from their original location of formation.

According to Rhodes (1971) there are several types of clays. Clay is an important part of the earthy materials which make up the surface of the planet. It is the end product of weathering of feldspathic rocks. As mountains and hills are worn away by the action of water, the fine ground debris, resulting from the action of water, is finally laid down quietly in still estuaries or deltas, and separated out as it settles in the water to various particle sizes.

This type of clay deposit is common in formal glacial lakes. When glacial lakes are formed, there is very little movement of water that makes the lake, this water contained eroded soils which Settle on the lake bed. This allows such an even distribution on the

different layers of clay. The description above probably informed the reason why in most coal deposits fire clay is often found. Odagbo clay deposit is located in a coal mining site.The use of clay in Ankpa area is an age- long tradition. The people used clay for the buildings and decoration of houses, pots for cooking, storage of liquid, and farm products before the present era of contemporary building with cement and sand blocks and the use of modern utensils. Those who could not afford modern building still build and live in houses built with clayey materials

Ankpa is one of the Local Government Areas of Kogi State in Nigeria. The area has many deposits of clays which have not been investigated beyond geological survey; the need for informed research into this topic is the lack of verified information on the clay deposits in Ankpa. This research therefore is aimed at exploring some of these clay with the view to find suitable clay for the production of earthenware and stoneware ceramics.
Ahmed (1986) discloses that a good number of clay deposits in Nigeria have been investigated. However, greater percentage of the clay deposits in Nigeria has not been investigated beyond the level of geological survey. In view of the increasing demand for ceramic products in Nigeria, exploration and investigation into more clay deposits is necessary, thus investigation into clay deposit in Ankpa Kogi State Nigeria is timely and necessary.

According to Cardew (1956) ”Nigeria has almost unlimited reserves of all the major raw materials necessary for ceramic production and some are of excellent quality.” Considering the fact that Nigeria has all that it takes to be self- reliant in ceramic production, the Federal Government of Nigeria took the bold step of attaining self-

reliance by announcing a ban on importation of raw materials that have their substitutes in Nigeria through the Ministry of Commerce and Industries as reported in the Nigeria Concord Newspapers of August 22nd 1984. Subsequently, as a backup, on 26th October 1984, the Federal Government, as reported by New Nigeria Newspaper says that "the days of unlimited importation of raw materials were over, and industries must now find local raw materials as alternatives" As a result, The Ministry of Solid Mineral Development was created. Since then the government had ensured that the solid mineral sector takes off successfully. Opoku (2000) observes that, "to articulate this policy, government officials addressed seminars, workshops, visited developing countries and advanced countries to understudy their experiences in mineral developments with the aim of sensitising the business community and the government on the potentials of Nigeria's solid minerals."

Gukas (2003) reports that the Government of Nigeria then commissioned Zingg Consultant A. G. of Switzerland to carry out some analyses of clay deposits in some selected areas of the country.Further research works into available local raw materials were encouraged by the establishment of the following research Institutes:

Federal Institute of Industrial Research, (F. I. I. R. O). Oshodi.

National Steel Council (N. S. C.) Jos.

Project Development Agency (P. R. O. D A).Enugu.

Ministry of Solid Mineral Development was established in all the states of the Federation and the Federal Capital Territory.

Clay workers in the past were limited in techniques in the use of abundant clay materials and other ceramic raw materials that we have today such as kaolin, quartz, silica, feldspar, and so on due to limited knowledge and technology needed to harness these materials. With the effort of the Government and other individual effort toward the attainment of self-reliance in the local sourcing of industrial raw materials, a good example is the research carried out by Ahuwan (1997) in which he investigated a raw material he suspected to be clay in Darazo area of Bauchi State. The result of which he found out that, given a margin of error of 5 percent, a case of kaolin (primary clay) has been established from Dass A. and Dass B. early suspected to be kaolin .The result of his research inspired the exploration into clay deposits of Ankpa in Ankpa Local Government area of Kogi State.

1.2 Statement of the Problem;

There are clay deposits in many places of the world, Ankpa inclusive, however mere sighting of clay does not make it reliable for utilization in ceramics. Although potters in Ankpa had used clay in their area to meet their pottery needs long before now, the need to explore these clay for utilization in modern ceramics cannot be overemphasized.The problem of this study is to identify, procure and process clay from Ankpa in Ankpa Local Government area of Kogi State Nigeria and to analyse the properties of the clay samples to ensure its suitability for the production of earthenware and stoneware ceramics.

1.3 Aim of the Study

The aim of this study is:

to explore clay from Ankpa with the view to finding suitable clay for utilization in the production of earthenware and stoneware ceramics.

1.4 Objectives of the Study;

The objectives of this study are to**:**

1. to explore and identify the types of clay minerals from Ankpa for utilization in the production of earthenware and stoneware Ceramics

2 to carry out property test on the clay samples to ascertain their suitability for production of earthenware and stoneware Ceramics

3 to explore the forming ability of the clay into forms using the throwing, coiling and slip casting methods.

4 to determine the suitable temperature that could fire the clay products.

1.5 Research Questions;

In other to undertake a successful study, the following research questions were carefully drowned from the objectives of this study.

1 Are the explored and identified clay in Ankpa and its environs suitable for the production of earthenware and stoneware ceramics?

2 Are the properties of Ankpa clay samples indication of quality clay that can be used for the production of earthenware and stoneware Ceramics?

3 Are the clay samples of Ankpa suitable for techniques of ceramic production such as throwing, coiling and slip casting methods?

4. Are the sample clay products able to fire up to the desired temperature of 1000 ^{o}C to 1260 ^{o}C without deformity?

1.6 Delimitation of the Study;

The study is delimited to the exploration of clay samples selected randomly from Ankpa 1 ,Ankpa 2 and Odagbo in Ankpa of Ankpa Local Government Areas of Kogi State Nigeria.

1.7 Basic Assumptions;

The study started with the following basic assumptions

1 That the clay will mature at the maturing temperature of 500^{o}C to 900 ^{o}C for earthenware and 1000 ^{o}C to 1260 ^{o}C up wards for stoneware.;

2 That the chemical composition of the clay samples selected for this study will allow glaze to fit to body of sample wares produced from the clay samples for glaze firing after bisque firing.

3. It is assumed that all the equipment needed to carry out tests on the clay samples are available in the studio of Ceramic section of the Department of Industrial Design A.B.U, Zaria and Centre for Energy Research and Training, A.B.U. Zaria.

1.8 Justification of the Study;

The study would improve the utilization of clays from Ankpa by local pottery centres and encourage investors in modern ceramic business. It will also encourage the production of modern domestic utensils, sanitary wares, industrial products as well as modelling and production of instructional materials for schools. Considering the vast and multidimensional use of clay in our contemporary period, research into clay minerals, especially where clay is not known to have existed beyond geological survey (such as Ankpa) is necessary.

1.9 Significance of the Study;

Significance of this study could be seen from the following points of view;

Aesthetically: the importance of ceramics in the beautification of our environment and homes cannot be overstretched. The study will help acquire clay that could enhance the production of decorative wares, such as flower vases, floor tiles and ceramic sculptures.

Educational significance: the clay could be used in schools as medium of expression in modelling classes; Ceramic, Sculpture classes as well as other clay related subject in and around Ankpa area.

Economic significance: lack of clay had hindered the establishment of pottery centre and ceramics studios in Ankpa area, hopefully the explored clay will enhance the establishment of pottery centre's and ceramic studios that can provide employment for the unemployed.. It could encourage youths to go into burnt bricks business that provides cheap bricks for those who are interested in building with such bricks as it done in Benue State as a way of providing job for the unemployed.

Cultural significance: the clay could encourage the establishment of modern ceramic studio in the area which would help improve the production of cultural pottery wares of the people of the area, if modern techniques of ceramic production are introduced

CHAPTER TWO

2.0 REVIEW OF RELATED LITERATURE

The need to have workable clay that is tested for utilization in ceramics cannot be over emphasized. Clay as one of the major raw materials in ceramic production is of different types with different properties, it is therefore important to have proper knowledge of clay properties before using it in ceramics. The focus of this literature review is on the relevant literature that will form the theoretical framework for this research. The review therefore covers the following sub topics;

i Historical background

Ii Definition of clay

iii Prospecting and Mining

iv Classification of clay

v Earthenware clay and Stoneware clay

vi Characterization of clay samples

vii Physical and Chemical properties

viii Preparation of clay samples,

ix Drying and Firing

2.1 Historical background;

The art of pottery is said to be universal, it is one of the oldest craft on earth. According to Ahuwan (2003), traditional pottery in Nigeria is acclaimed world wide. In a related view, Ahuwan (2004), stated that the art of pottery is as old as iron age when fire was

discovered by the historic man in (3000 BC) he discovered that it could be used to turn a valueless" Mud" Into a hard metallic valuable material.

Green (1967) connected the discovery of the use of clay to the heat and basket theory .He stated that when a clay sealed utensils of basket which was meant to contain grain and liquid incidentally came in contact with fire, the basket got burnt off while the clay retained it shape and got harden because of effect of heat from the fire. That was probably how the art of pottery was discovered.

Kockar, Mustafa, Algun, Haluk, Haluk, Akturk (2012), observed that Clay is one of the oldest building materials on earth, among other ancient, naturally-occurring geologic materials such as stone and organic materials like wood. Between one-half and two – third of the world's population, in traditional societies as well as developed countries, still live or work in building made with clay as an essential part of its load- bearing structure .Clay is also a primary ingredient in many natural building techniques, clay is used to create adobe, cob, cordwood, and rammed earth structures and building elements such as wattle and daub, clay plaster, clay render case, clay floors and paints.

2.2 Definition of clay;

Manzuche, (2003) defines clay as a tenacious ductile earthy materials, hydrated aluminum silicate or earth crust . Kaolin or china clay is good example of pure clay.

Rhodes ,(1971) described clay as an earthy mineral substance, composed largely of a hydrous silicate of alumina, which becomes plastic when wet and hard and rock-like

when fired .Clay is soft when wet and hard when baked and is dry, it is used for making bricks and containers

Rhodes, (1971) described clay as earthy mineral substance that occurs naturally in a process that takes thousands and millions as rocks are broken down in tiny particles and are weathered thereby forming clay. Clay is composed largely of a hydrous silicate of alumina, which becomes plastic when wet and hard as rock .when fired

Saibu (2005) defined clay as a product of geological weathering of the earth surface as a result of geological disintegration of feldsparthic pigments and granite types of rock. Kaolin or china clay a good example of pure clay is a hydrous aluminum silicate with the chemical formula of (Al_2O_3, $2SiO_2$, $2H_2O$.).

Rhodes, (1971) "defined clay as an earthy mineral substance, composed largely of a hydrous silicate of alumina, which becomes plastic when wet and hard and rock-like when fired. Clay as described by Saibu (2005) is a product of geological weathering of the earth surface as a result of geological disintegration of feldsparthic pigments and granite types of rock.

Clay prospecting and Mining;

2. 3.1 Clay prospecting;

Prospecting or sourcing of clay simply means going out in search of clay. Before research on exploration of clay could be carried out in an Area where the clay has not been studied beyond geographical survey such as Ankpa, the need to go out and source

for clay is a necessary. Clay prospecting according to Saibu, (2005) is a channel through which relevant information about clay could be obtained. Clay can be sourced through cantact with Miners, Geographers, Builders etc.

Miners who are charged with the responsibility of digging great depth into the earth crust in search of valuable minerals such as coal, gold, diamond, tin and so on,exposed clay to the surface and are accessed by the potters or other people that do their business with clay.Other sources of information about clay are, activities of some of the following agents,

Geographers, Builders, Farmers in their agricultural activities, Trending along rivers banks or beds one could likely come across layers of clay; Contacts with natives of the places where clay is located could provide information on clay in their area. Civil engineering activities during road construction usually expose clay as they cut through areas where clay is deposited.

2. 3.2 Clay Mining;

Clay mining according to Jeanne (2015) was a major industry in West Virginia as far back as 1895 to 1915; the clay was mined from residual clay developed by the weathering of lime stone and shale and from transported clay deposits in rivers and swamps during the marine geologic age.Saibu, (2005) observes that clay can be mined using several methods of mining. Some of these methods he said are open pit method and underground mining method.

2.3.2.1 The open pit method is employed when the clay seam is not too deep. In operating the open pit method, the overburden of the soil is removed manually by using

shovels , excavators or bulldozers while digger or pneumatic shovels is used to dig out the underlying clay which is then transported to studio or clay pit by vehicle.

2.3.2.2 The underground mining method is employed where the clay deposits are located in the earth interior is as long as (12feet) or 3.6 metres or more. In this method, clay is hauled directly to the surface by mechanical excavator. The hydraulic mining technique is another method of excavating clay, this method involves the use of powerful jet of water to dislodge the clay particles from the deposit into settle pound where it settles and is extracted mechanically.

2.4 Classification of clay;

Rhodes, (1971) said that Clay may be classified in various ways depending on what properties are of interest to the classifier. One might classify clay according to colour as they exist in nature, use, or geologic origin. The classification also can be done based on plasticity or workability of the clay and its reactions during drying and firing

Saibu, (2005) observes that there are two major classes of clay namely; Residual or Primary clay and Sedimentary or Secondary clay.

2.4 .1 Residual or Primary clay; are clay that have not been transported from the place of its origin by natural agencies such as wind, frost and water, they are found side by side with unaltered igneous rock from which they are formed. Singer and Singer (1963) explained that Primary or residual clay is that clay which has been formed on the site of their parent rocks and has not been transported, either by water, wind, or glacier. In most cases they are left on the sport where they are formed by the disintegration of

feldspathic rock. Deposits of primary clay are often found large or coarse grain sizes, pure in colour and relatively non plastic.Primary clay as describe by Komolafe (1991) is a refractory material, which on heating as pure kaolinite looses it water as steam at 450^{oc} giving meta kaolin (Al_2O_3, $2SiO_2$) as the dehydration product

2.4. 2 Sedimentary or Secondary clay is clay which has not remained at their original site of formation. They have been transported by the action of running water or rain, wind, glacier, or frost from **the** site of parent rock to new deposit.

2. 5 Earthenware clay and Stoneware clay;

2.5.1 Earthenware clay:

According to Singer and Singer (1963) composition of ceramics bodies lies within certain limits, they are govern by a number of factors. firstly the shaping of wares which necessitates the inclusion of plastic materials, secondly the drying and firing of the wares without cracking which call for addition of non clay materials that stick during drying and firing-feldspar ,flints and so on.

Nelson (1971**)** states that earthenware bodies are fragile and are very porous in nature, they cannot be made vitreous because of the temperature limit. Any attempt to fire above $1150^{o}C$ may lead to deformity bloating and blistering. Encyclopedia Americana (1966) states that the advantage of earthenware bodies are that they are simple to handle, abundantly cheap and available everywhere for the production of both glaze and unglazed pottery.

Earthenware clay according to Rhodes, (1971) is common types of clay that are cheaply and abundantly found, they have variety of them in different places. They are impure clay with iron, calcium and feldspar; they are also called by these names; terracotta clay, gumbo clay and so on.

2.5. 2 Stoneware clay;

Stoneware clay according to Saibu (2005) is common of the sedimentary type and is found in seams or layer often associated with fire clay or coal. Stoneware clay is generally plastic and fire in a range from cone 6 to cone10. Any clay he added that can be fired to a temperature range of 1200 ^{o}C or about cone 7 and which as a result of the fire treatment is of serviceable hardness and density may be termed stoneware clay

2.6 Characterization of clay samples;

Physical nature of clay as observed by Rhodes (1989) is more obscure and our knowledge of it is less exact, than its chemical composition. The chemical composition of clay can be readily determined by routine analysis .The size and shape of the particles in clay and the forces which account for its plasticity can be known only through microscopic study and other types of analysis. Studies he added indicate that extremely small size of the grains of clay account for most of its physical properties.

Composition of Clay according Rhodes (1971) varies, depending on the source of the parent rock. In different location the igneous rock which gives rise eventually to clay may differ widely, some of it being more or less of iron, some containing much quart, and

some being loaded with iron oxide sometimes the debris from the erosion of very wide area will be brought together by some river system and deposited as clay in delta.

2.7 Chemical and physical properties;

2.7.1 Chemical composition;

The more pure light burning clays such as kaolin and ball clay have a relatively high percentage of alumina and low percentage of iron and other impurities. In tracing the chemical parentage of clay, it is important to look closely at the feldspar family of minerals, which are most abundant minerals and therefore enter, into the formation of any clay. Feldspars contain alumina (Al_2O_3) and silica (SiO_2) combined with more other oxides of an alkaline nature.

2.7. 2 Chemical properties of clay;

According to Rhodes (1989) Clay vary widely in chemical composition, the more pure light burning clays such as kaolin and ball clay have a relatively high percentage of alumina and low percentage of iron and other impurities. In tracing the chemical parentage of clay, it is important to look closely at the feldspar family of minerals, which are most abundant minerals and therefore enter into the formation of any clay. Feldspars contain alumina (Al_2O_3) and silica (SiO_2) combined with more other oxides of an alkaline nature.

Burnet (1976) revealed that the earth crust composed of rock, each of which is made up of minerals that are compound of several elements such as silica (Sio_2) which combine with other oxides to form silicate, the most common of which is feldsparSaibu (2005) explains that, during the processes of disintegration Soda Sodium oxide (Na_2O) Potash

(K_2O) and lime (CaO) being soluble are carried away by water leaving some hydrated after long exposure to water. The alumina and silica combined chemically with water as hydrated aluminium silicates with the chemical formula of (Al_2O_3, $6SiO_2$, $2H_2O$).this according to him constitute the pure clay koalinite clay.

2.7.3 Physical properties of clay;

Physical nature of clay as observed by Rhodes (1989) is more obscure and our knowledge of it less exact, than its chemical composition. The chemical composition of clay can be readily determined by routine analysis .The size and shape of the particles in clay and the forces which account for its plasticity can be known only through microscopic study and other types of analysis. Studies he added indicate that extremely small size of the grains of clay account for most of its physical properties.

Singer and Singer (1963**)** enumerate some of the following as the physical properties of clay. In order to ensure the workability of clay, it has to be tested for these properties Plasticity property, Shrinkage property, Porosity property, slaking property, Strength property, Colour property and so on

2.8 Preparation of clay body;

Before clay is put in to use in ceramic, it has to be processed. Opoku (2004) suggested that materials such shovel, framed screen, containers, and plastic bags are needed, the following steeps he added should be taken; slaking of clay in dry state, stir vigorously with water to tin cream stage, sieve through mesh, allow it to settle for some hours then

siphon the water, pour out the clay to dry or leader hard. Okoruwa (1986) used 50% of water to every 500grams of dry ingredient

Clay body as defined by Rhodes (1971) is a mixture of clays or clays and other earthy mineral substances which are blended to achieve a specific purpose. According to Saibu (2005), there are numerous methods of forming clay into an article or ceramics ware. Each of these forming methods requires specific clay. This means that clay bodies must not only be designed for a particular firing temperature so as to achieve the desire colour, texture, degree of hardness and density required, but bodies are also designed or compounded for specific or particular forming methods. Although several clay types according to Dickerson (1976) occur in nature, only a few are used alone.

Saibu , (2005) suggests two methods of clay preparation for clays prepared in a school situation 1 Manual preparation of clay and 2 Mechanical preparation of clay

2.8.1. Manual preparation of clay; In manual preparation of clay, clay from several locations is collected. The clay is dried, pounded into coarse powder and soaked in water for days or weeks to enable the clay particle to slake; it is then mixed thoroughly and passed through a 30-100 sieve mesh to remove the coarse particles and other impurities

2.8.2. Mechanical preparation of clay; the mechanical preparation of clay is the use of various machines such as plunger, pug milling machine and extruder to prepare clay .

2.9 Drying of wares;

Saibu (2005) said that drying is the process of exposing the wares to airflow from the kiln in order to eliminate the water of plasticity (the physically combined water). According to Scares (2005) When, clay becomes dry and fired in a kiln, it becomes firm and permanent, Physical and chemical changes occur. Because of these properties, clay is used for making pottery items, both utilitarian, and decorative wares.

2.9 .1 Types of drying;

2.9.1.1 Heated flow drying;

This is done by arranging the wares on the floor to allow the flow of hot air from kiln in order to eliminate the water of plasticity from the wares. It could be regarded as the removal of moisture from the wares, this process is carried out gradually and it usually leads to a reduction or shrinkage of the wares which is referred to as drying shrinkage.

2.9.1.1.2 Open air-drying;

Open air drying can be described as the process of drying which is done by exposing the ware to airflow in a room temperature to avoid cracking

2.10 Firing of wares;

According to Saibu (2005), firing brings about the completion of drying, which entails the elimination of both the physically combined water (water of plasticity) as well as the chemically combined water, which is part of molecular structure of the clay. Rhodes (1971) revealed that the first change which firing brings about in clay is completion of drying. This final drying must be brought about slowly; otherwise the formation of steam within the body of the clay may cause it to bust. This explosion in the kiln is usually

coursed by too rapid advance of heat in the early stages of firing or by pocket of air in the clay. Another change which occurs in the clay during the early stages of firing is all those components of clay which are not already in oxide form; these would include such organic maters as carbon and the inorganic carbonates or sulphates. The oxidation of these compounds is usually not complete until the temperature has advanced to about $900^{O}C$.

Rhodes (1989) said that when clay is fired, it is ranks as one of men's most important early inventions. The domestic life of the primitive man was enriched by the possession of fired clay vessels for storing grains, carrying water, cooking, and washing, holding food, ceremonial and purely aesthetic uses.Kashim (2003) stated that clay has played a dominant role in human life right from the moment, its usefulness was revealed through the heat and basket theories, when clay incidentally came in contact with fire.

2.10.1 Pre heating;

Is the stage of firing wares which is carried out slowly by heating slowly for one hour or more using socked bricks with kerosene and other combustible material to support burning within the temperature range of $0^{o}c$ to $350\ ^{O}C$ This stage helps in the elimination of moisture from the wares .The nest stage of firing is $350\ ^{O}C$ - $900\ ^{O}C$, this stage according to Garkida (1998), helps in burning or decomposition of the combustible materials in the clay as well as molecular water present would be driven out and combustible volatiles matters expelled.

2.10.2 Full firing stage;

The stage of full firing from $900^{O}C$ to $1350\ ^{O}C$ according Saibu (2005) brings about the transformation of various minerals, and as the firing is extended from $1350\ ^{O}C$ to 1400

^{O}C brings about the incipient fusion of the impurities filling up of the interstices between the solid particles by fused mass. The last stage in the firing processes is called cooling stage or annealing stage.

2.10.3 Cooling or **annealing stage**;

At this stage, the kiln is put off and the fired wares were allowed to cool gradually for about 18 hours in the kiln to prevent cracking of the wares Garkida (1998) observed that the rigidity and maintenance of size, shape, strength at operating temperature is the ability to withstand thermal shock such as cooling of furnace or in fluctuation which occurs during changing and normal operation.

CHAPTER THREE

3.1 RESEARCH DESIGN AND METHOLOGY

Research design according to Ali, Chukwuma and Mgbodile (1991) is a blueprint, or plan of activities to be implemented towards successful completion of the study. There are different kinds of research designs used in carrying out studies, some of these include;Descriptive designs, Comparative designs, Correlation designs and experimental designs. For this study, an experimental design is adopted. The main focus of this chapter therefore is on research methodology, sampling techniques, sample size, population of the study, pilot study, and property analysis of the clay, this process includes procurement, slaking and testing for mineralogical and chemical properties of the clay as well as testing for heat tolerance capacity.

3.2 Sampling techniques;

Study sample according to Maikudi (2011) can be obtained through any of the following steps, depending on the nature of population territory such as-;

- Systematic sampling techniques
- Sampling, sampling techniques
- Random sampling techniques
- Selection sampling techniques
- And, cluster sampling techniques

The random sampling technique was adopted in the selection of clay samples for this study. Samples were collected from Ankpa 1, Ankpa 2, and Odagbo clay deposits. These samples are located in the same geographical area of about 15 kilometres of radius.

3.3 Samples;

Samples were collected from three different sites in Ankpa, namely Ankpa (1), Ankpa (2) and Odagbo clay deposits in sacks by manual method of mining, using digger and shovel.All the clay samples collected for this study were collected from a coal deposit zone.



Plate i : Ankpa 1 clay sample:



plate ii: Ankpa 2 clay sample



Plate iii: Odagbo clay sample

3.4 Population of the Study;

Population of the study is the clay samples from three different sites in Ankpa, namely Ankpa 1, Ankpa 2, and Odagbo clay deposits all in Ankpa,Loccal Government area of Kogi State Nigeria

3.5. Pilot Study;

The pilot study of the research was conducted in two phases.The first was the collection of sample clays and obtaining of background history of the clay from the local folks by visiting the sites of the clay deposits. The second phase is the preliminary investigation into the collected samples of clay in the studio of Ceramic Section of Industrial Design Department of Ahmadu Bello University Zaria.

3.6 Research Instrument;

The research instruments are the equipment in the Ceramics Section of Industrial Design Department, Ahmadu Bello University, Zaria, such as clay slaking containers, working table, kerosene firing kilns, plaster moulds, throwing wheels, sieves and the facilities in the laboratory of Centre for Energy Research and Training Zaria and facilities in the laboratory of National Steel council Kaduna,that are used for analysing the clay samples.

3.7 Physical analysis of the clay;

The linear test procedure as suggested by Zauro (1988) and Saibu (2005) was adopted in carrying out the following physical properties test on the clay samples. in the Ceramics Section of the Department of Industrial Design, Ahmadu Bello University, Zaria .they are (i) Plasticity) (ii) Shrinkage (iii) Porosity (iv) Slaking property (v)) test for strength (vi) Colour and (vii) Residue test.

3.7.1 Plasticity test;

A simple test for clay plasticity was carried out on clay samples by simply looping a pencil or snake like roll of clay round a finger to see if coil of the clay would crack excessively, which simply imply that the clay is not plastic enough, usable clay mass prepared from the three clay samples one after another, were used to prepare coils, looped round the finger to see if it would crack easily. This test was carried out on the three clay samples and results were obtained.

3.7.2 Shrinkage test

Oyeoku (1984) observes that shrinkage test could be carried out by rolling out a plastic clay slab from a clay sample; the clay slab is then cut, marked and measured at green stage, when the slab is totally dried, a second measurement is taken and a final measurement after firing, at various stages of measurement; reduction in size of the slab were been observed and recorded



Plate iv: Test bar of Ankpa 1 clay sample



Plate v: Test bar of Ankpa 2 sample clay



Plate vi: Test bar of Odagbo sample clay

3.7.2.1 Procedure for Shrinkage test;

Linear test procedure as suggested by Zauro (1988) and Saibu (2005) was adopted.

Test labs from Ankpa Area 1, Ankpa Area 2 and Odagbo clay samples were made and measured in green stage still in plastic conditions .the slabs were dried under careful condition to avoid distortion to the slabs. The percentage shrinkage of Odagbo clay sample was determined as follows:-

$$\% \text{ Original } \frac{\text{lenght– dry length}}{\text{Original length}} \times 100$$

$$\frac{10 - 9.6}{10} \times \frac{100}{}$$

$$= \frac{0.4}{1} \times \frac{10}{1}$$

Dry shrinkage = 4%

$$\frac{10 - 9.4}{10} \times \frac{100}{}$$

$$\frac{0.6}{1} \times \frac{10}{1}$$

Fired shrinkage = 6%

The percentage shrinkage of Ankpa 1 clay sample was determined as follows:-

$$\% \frac{\text{Original length– dry length}}{\text{Original length}} \times 100$$

$$\frac{10 - 9.8}{10} \times \frac{100}{}$$

$$= \frac{0.2}{1} \times \frac{10}{1}$$

Dry shrinkage = 2%

$$\frac{10 - 9.7}{10} \times \frac{100}{}$$

$$\frac{0.3}{1} \times \frac{10}{1}$$

Fired shrinkage = 3%

The percentage shrinkage of Ankpa 2 clay sample was determined as follows:-

$$\% \frac{\text{Original length– dry length}}{\text{Original length}} \times 100$$

$$\frac{10 - 9.7}{10} \times \frac{100}{}$$

$$= \frac{0.3}{1} \times \frac{10}{1}$$

Dry shrinkage = 3%

$$\frac{10 - 9.6}{10} \times \frac{100}{}$$

$$\frac{0.4}{1} \times \frac{10}{1}$$

Fired shrinkage = 4%

3.7.3 Porosity test;

To carry out porosity test, bisque ware was weighed and recorded then It was soaked in water over night or 24 hours and wiped clean of the surface water and weighed second time. The percentage gain in weight stands for the porosity of the clay.

Using the Linear test procedure earlier adopted, test bars produced from the sample clays of Ankpa. Were bisque fired and weighed, soaked in water over night or for 24 hours. Wiped clean of the surface water and weighed the second time the weight gained was used to find percentage of porosity with following results odagbo clay sample has 8.3% Ankpa 1 clay sample has 10.8% while Ankpa 2 clay sample has 9%

Procedure for porosity test;

The percentage weight of Odagbo clay sample was determined as follows:-

$$\frac{\text{Saturated weight - after dry}}{\text{Weigh after dry}} \times 100$$

$$\frac{130 \text{ grams} - 120 \text{ grams}}{120 \text{ grams}} \times 100$$

$$\frac{10 \text{ grams}}{120} \times 100$$

Percentage weigh = 8.3 %

The percentage weight of Ankpa 1 clay sample was determined as follows:-

$$\frac{\text{Saturated weight - after dry}}{\text{Weigh after dry}} \times 100$$

$$\frac{133 \text{ grams} - 120 \text{ grams}}{120 \text{ grams}} \times 100$$

$$\frac{13 \text{ grams}}{120} \times 100$$

Percentage weigh =10. 8. %

The percentage weight of Ankpa 2 clay sample was determined as follows:-

$$\frac{\text{Saturated weight - after dry}}{\text{Weigh after dry}} \times 100$$

$$\frac{131 \text{ grams} - 120 \text{ grams}}{120 \text{ grams}} \times 100$$

$$\frac{11 \text{ grams}}{120} \times 100$$

Percentage = 9 %

3.7.4. Slaking property test;

Slaking according to Saibu (2005) is the ability of the clay to dissolve or brake into smaller fragments when soaked in water. All clay have the tendency to slake when soaked in water. The rate at which clay slake depends on the particle size. Clay with fine particles slakes slower than those with large particle due to the compressed nature of the clay. Clay samples from Ankpa clay sample 1, Ankpa clay sample 2 and Odagbo clay sample were soaked differently in water for about 24 hours under

observation to see the time that each of the clay would dissolves. Ankpa 1 and Ankpa 2 did not dissolve after 24 hours, it was left for one week more in the water, and it still did not dissolve easily but was soft. To bring about easy slaking, the clay particle sizes were reduced by pounding and sieving.



Plate vii ; Ankpa 1clay sample in coarse form



Plate viii: Ankpa

1clay sample in powder form



Plate ix: Ankpa 2 clay sample in coarse form.



Plate x: Ankpa 2 clay sample in powder form.



Plate xi: Odagbo clay sample is secondary clay that slakes easily.

3.7.5. Test for clay strength;

This property of clay provides the clay the capability to withstand handling during forming and the subsequent drying / firing of the wares. Clay has what could be regarded as green, drying and firing strength. According to Saibu (2005) Clay strength can be determined by breaking a bar supported on two knife-edges by means of load applied to the centre. The strength of Clay samples from Ankpa Area 1, Ankpa Area 2 and Odagbo clay, were determined by breaking of fired test sample bars made from each sample clay supported on two knife-edges by means of load applied to the centre. and results obtained were noted.

3.7.6. Clay colour;

According to Saibu (2005) colour is the property of clay that helps in the classification of clay either as primary or secondary clay. Colour of clay varies and this could be determined by the mode of formation, the degree of dispersion or transportation as well as impurity or oxides met in the course of movement from the parent rock. From observation, Ankpa clay samples appear in different colours at green stage and after firing. At green stage Ankpa 1and Ankpa2 appear as off white while odagbo sample appear to be light brown

3.7.7 Clay residue;

To determine clay residue, the clay is soaked in water for about twenty four hours. The long time exposure to water is to enable the clay dissolve or (slake) completely. The dissolved clay thereafter is passed through 120-sieve mesh and washed with water until the clay particles have passed through the sieve, the debris collected were dried and analyzed as clay residues.Clay samples from Ankpa Area 1, Ankpa Area 2 and Odagbo, were soaked in water seprately for at least one day or twenty four hours, amazingly only Odagbo clay sample could dissolve easily and completely Ankpa Area 1 and Ankpa Area 2 were left for more time under observation but could not dissolve.

3.7.8 Chemical Analysis; Chemical Analysis of the sample clays of Ankpa were carried out at the Centre for Energy Research and Training Zaria, using the Mini Pal compact Energy dispersive X-ray spectrometer to determine alumina and silica contents as well as other elements contained in the clay samples. X RD .of the clay was carried out at the National Steel council Kaduna to determine the type of clay.

3.8 Composition of experimental clay body sample;

Normally a number of clays are blended in a carefully designed composition called “a Clay body” to give optimum working qualities and maturation temperature. The clay body for the production of sample wares for this study was prepared from the clay samples of the tested clay samples of Ankpa, in Ankpa Local Government Area of Kogi State, Nigeria, namely Ankpa 1, Ankpa 2 and Odagbo.

The plastic nature of Odagbo clay samples makes it easy to be used alone, while Ankpa 1 clay samples,and Ankpa 2 clay samples could not be used alone due to their none plastic nature but were mixed with 30% plastic clay of Odagbo to improve their plasticity



Plate xii: Composition of clay **body** from Ankpa clay samples for production of samples wares

3.9 Production of Sample wares;

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3.9.1 Throwing techniques;;

Throwing on the potter's wheel is the most common of all studio production techniques. It is particularly suited to the formation of symmetrical hollow ware, such as jars, bottles flower vases, bowls, cups and teapots. The clay sample from Odagbo clay deposit was used to throw some wares alone on the throwing wheel and it came out well. The composed clay bodies from Ankpa 1 and Ankpa 2, clay samples were used for throwing sample wares and they came out well.



Fig1:Throwing wares with the composed clay body from Ankpa clay samples



Plate xiii: Some thrown wares with the composed clay body from Ankpa clay samples

3.9. 2 Slip casting techniques;;

Slip casting technique is the further application of plaster mould in pot making. Slip is a fluid consisting of suspension of clay particles in water. In the casting technique, plaster moulds are filled with a carefully prepared slip and allowed to stand full for a short time. During this period the plaster absorbs water from the slip and a layer of clay is deposited on the walls of the mould. Since the emphasis of this study is not on slip casting, existing (P.O.P) mould in the studio of ceramic section of Industrial Design Department, Ahmadu Bello University, Zaria was used to carry out the experimental slip casting. Prepared clay slip from the samples clay of Ankpa 1 and Ankpa samples clay 2 and Odagbo samples clay, were used to experiment how well these clay sample could be used for slip casting.



Fig.2: **Slip casting process with clay body composed from Ankpa clay samples**

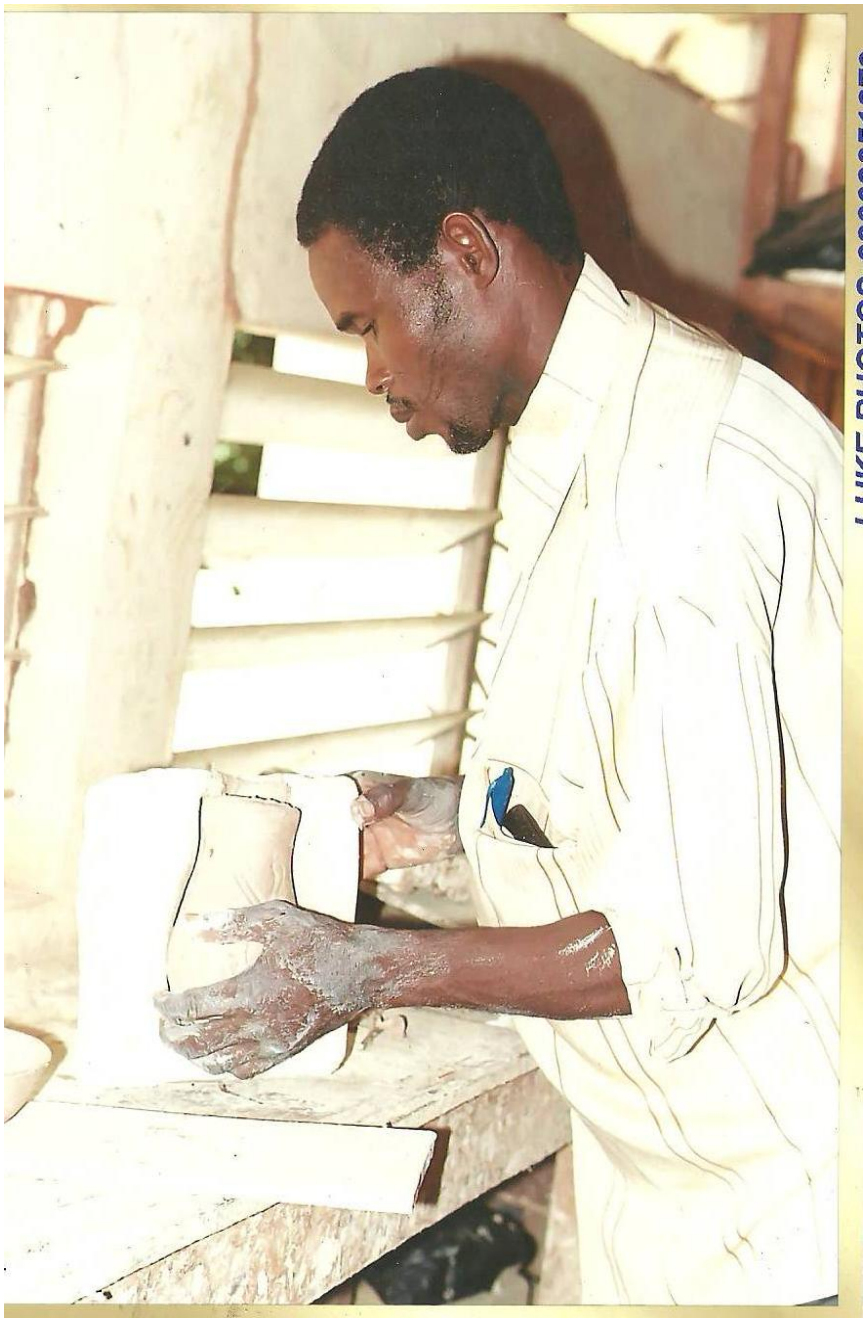


Fig 3 : Slip casting ware with clay body composed from Ankpa clay samples been detached from the mould.



Plate xiv: **Slip caste wares from clay body formulated from Ankpa clay sample**

3.9.3 Coiling techniques;

The technique of building up pieces of pottery from coil of clay is very ancient. Coil building may be used to make pots of any shape, but its most common application in the production of large asymmetric forms. Plastic clays are better options in coil building technique, thus Odabgo clay sample was a better option, the piece bellow is an experimental sample piece produced from Odagbo sample clay from Ankpa.



Plate xv Coiling techniques experimented with the sample clay of Odagbo

3.10 Drying of wares;

Drying of the sample wares produced from the explored clay from Ankpa was carried out by exposing the wares to open air in other to eliminate the water of plasticity. It can also be regarded as the removal of moisture from the wares. Dickerson (1976) observed that proper drying is vital to the production of pottery wares, while improper drying is responsible for problems encountered by potters. The final drying in clay he added must be brought about slowly; otherwise the formation of steam within the body of clay may cause it to burst. The sample wares were dried gradually in room atmosphere in the ceramic section of Industrial Design Department A B U Zaria.

3.11 Firing of ware;

The sample wares produced rom Ankpa clay samples were fired, bringing about the completion of drying of the wares which entails the elimination of both the physically combined water (water of plasticity) as well as the chemically combined water, which is part of molecular structure of the clay.

Rhodes (1971) revealed that the first change which firing brings about in clay is completion of drying. This final drying must be brought about slowly; otherwise the formation of steam within the body of the clay may cause it to burst. This explosion in the kiln is usually caused by too rapid advance of heat in the early stages of firing or by pocket of air in the clay. Another change which occurs in the clay during the early stages of firing is all those components of clay which are not already in oxide form; these would include such organic maters as carbon and the inorganic carbonates or sulphates. The oxidation of these compounds is usually not complete until the temperature has advanced to about $900^{o}C$.

Rhodes (1989) said that when clay is fired, it is ranked as one of mans most important early inventions. The domestic life of the primitive man was enriched by the possession of fired clay vessels for storing grains, carrying water, cooking, and washing, holding food, ceremonial and purely aesthetic uses.Kashim (2003) stated that clay has played a dominant role in human life right from the moment, its usefulness was revealed through the heat and basket theories, when clay incidentally came in contact with fire.

Firing o the wares was carried out slowly by heating slowly for one hour or more using socked bricks with kerosene and other combustible material to support burning within the

temperature range of 0^{o}c to 350 ^{o}C. This stage helps in the elimination of moisture from the wares. The nest stage of firing was 350 ^{o}C - 900 ^{o}C, this stage according to Garkida (1998), helped in burning or decomposition of the combustible materials in the clay as well as molecular water present would be driven out and combustible volatiles matters expelled.

The temperature was raised from 900 ^{o}C to1350 ^{o}C which according Saibu (2005) brings about the transformation of various minerals, and as the firing is extended from 1350 ^{o}C to 1400 bringing about the incipient fusion of the impurities filling up of the interstices between the solid particles by fused mass. The last stage of the firing is called the.

3.11.2 Cooling or annealing stage of firing;

At this stage, the kiln was put off and the fired wares were allowed to cool gradually for about 18 hours in the kiln to prevent cracking of the wares. Garkida (1998) observed that the rigidity and maintenance of size ,shape, strength at operating temperature is the ability to withstand thermal shock such as cooling of furnace or in fluctuation which occurs during changing and normal operation.

CHAPTER FOUR

4.0 RESULTS AND FINDINGS;

4.1 Results of Physical Analysis of the Clay Samples

Preliminary investigations were carried out on the clay samples to determine the following physical properties of the clay in the Ceramic Section of Industrial Design Department of Ahmadu Bello University Zaria.(i) Plasticity test (ii) Shrinkage test (iii) Porosity test (iv) Slaking property test (v) Strength test (vi) Colour test and (vii) Residue test. The following results below were obtained;

4 .1.1 Results of Plasticity test;

The prepared usable clay mass from the clay samples of Ankpa were looped and coiled round a finger, the clay samples length from Ankpa Aera 1 and Ankpa Aera 2 cracked easily, though not excessively which shows that the clay samples were not plastic.Anpka 1 clay sample and Anpka 2 clay sample are non plastic clays, while Odagbo clay sample is a plastic clay

4.1.2 Results of Shrinkage test;

Table 1:Shows results of shrinkage test of the three clay samples

Clay samples	Per. of dry shrinkage	Per .of fired shrinkage
Ankpa 1	2 %	3 %
Ankpa 2	3 %	4 %
Odagbo	4 %	6 %

4.1.3 Results of Porosity test;;

Using the linear test procedure earlier adopted, test bars produced from the sample clays of Ankpa were used to find percentage of porosity with the following results, Odagbo clay sample has 8.3%, Ankpa 1 clay sample has 10.8% while Ankpa 2 clay sample has 9% water Absorption respectively.

4.1.4 Results of Strength test;

The strength of Clay samples from Ankpa Area 1, Ankpa Area 2 and Odagbo clay, were determined by breaking of fired test sample bars made from each sample clay supported on two knife-edges by means of load applied to the centre. and the bar could not break easily .



Plate xvi : Fired test bars from Ankpa 2 clay sample

4.1.5 Slaking property test of Ankpa clay;

Clay samples from Ankpa Area 1, Ankpa Area 2 and Odagbo, were soaked differently in water for about 24 hours under observation to see the time that each clay sample would dissolve. Oagbo clay sample dissolved within 24 hours as expected. It was discovered that Ankpa Area 1 and Ankpa Area 2 did not dissolve and was allowed more days in the water

under observation for one week; it became soft but did not dissolve. To enable the samples clay be put to use for the research purpose, the researcher reduced the clay particles by pound to allow easy slaking.

4.1.5.1 Slaking property test results;

Anpka 1 clay sample and Anpka 2 clay samples could not dissolved after 24 hours of soaking while Odagbo clay sample dissolved within 24 hours of soaking. Anpka 1 clay sample and Anpka 2 clay samples were allowed more time in water for one week but could not dissolve; it was only softened due to their hard and rocky nature.

4.1.6 Colour;

The colour of Odagbo clay sample at green stage appears brown after firing, the colour changed to light brown, while Ankpa 1 and Ankpa 2 clay appear light pink at the green stage, after firing the clay appear to be light cream. The X-Ray Diffraction (XRD) of the clay shows that the clay is a of brownish- pink fire clay

4.1.6.1 Results of Colour test;

Anpka 1 clay sample and Ankpa 2 clay samples appears to be light pink and creamy in colour at the green stage, while ,Odagbo clay sample appears to be light brown in colour

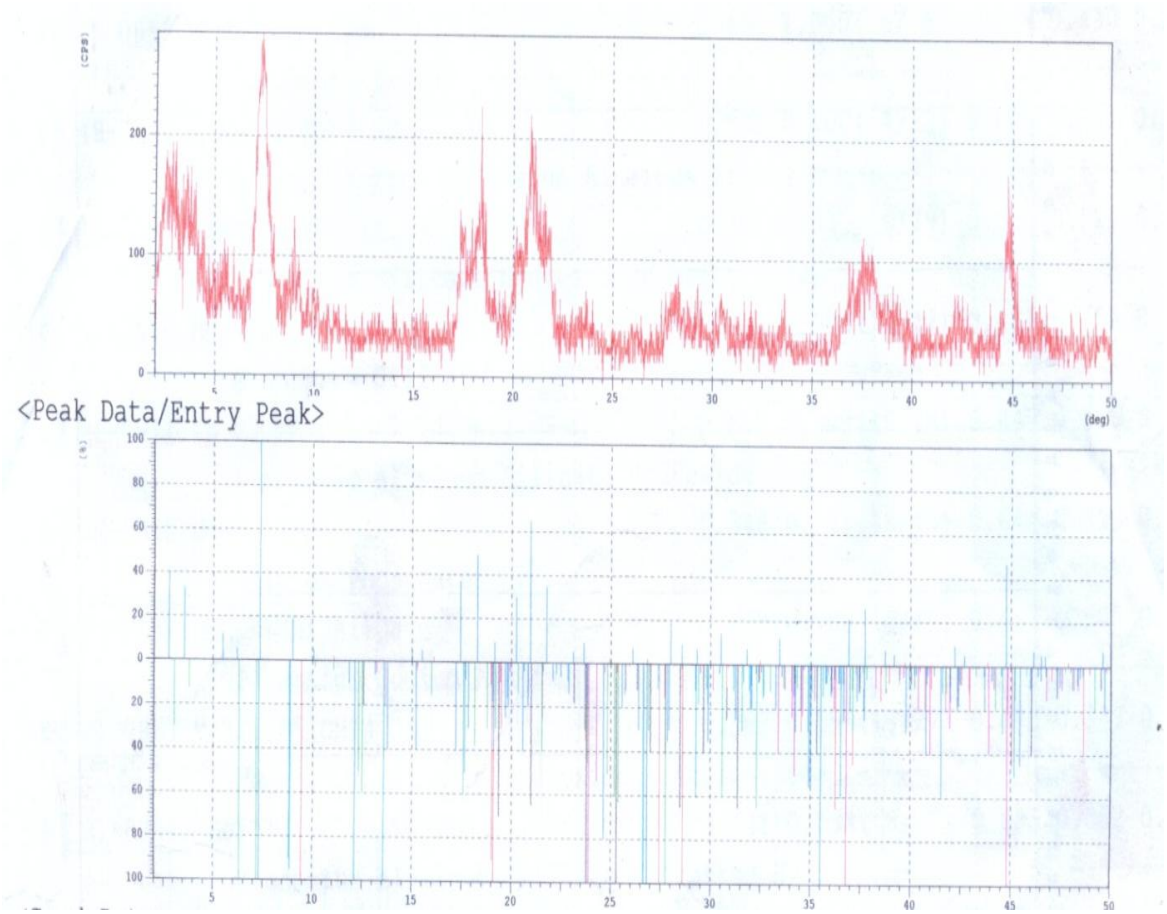


Plate xvii: Shows; X-ray Diffraction Analysis of the clay samples,

Plate xvii: X-ray diffraction analysis of the clay samples of Ankpa Area (1) and Ankpa (2) was carried out at the National Steel council Kaduna which determined that the clay is a brownish pink fireclay

4.1.7 Result of the clay residue test;

Residue test on Ankpa clay samples to determine the clay residue shows that the clay contains fewer particles that are considered to be impurity due to the tabular nature of the

clay. The particles collected were dried and analyzed it shows that the particles were sand and few tiny stones.

4.1.8 Result of drying the wares ;

The drying of the sample wares was carried out gradually in a room atmosphere to reduce the chance of cracking-but was how ever left open for free flow of air, to help facilitate drying. Drying was successful in all the samples produced**.**



Plate xviii: **Thrown sample wares ,drying in room atmosphere**

4.1.9 Result firing of the wares;

The wares were fired in the Ceramics Section of the Industrial Design Department of Ahmadu Bello University Zaria, using the kerosene kiln under full oxidizing atmosphere to the temperature of about1260^{o}C. The firing was done in stages of biscuit firing and glaze firing successfully



Plate xix: Thrown sample wares from Ankpa 1 clay sample



Plate xx: Thrown wares from Ankpa 2 clay sample



Plate xxi: Glaze fired wares produced from Odagba clay samples



Plate xxii: Glaze fired Slip caste wares, produced from the composed clay body of Ankpa.



Plate xxiii: More glaze fired sample wares of the clay sample



Plate xxiv: More glaze fired sample wares of the clay sample



Plate xxv: Firing of sample wares at the firing unit of Ceramic Section, Department of Industrial Design, Ahmadu Bello University Zaria.

4.2 Analysis of the result of Chemical analysis of Ankpa clay samples

Chemical analysis of the clay samples from Ankpa was carried out at the laboratory of Centre for Energy Research and Training Zaria, using the Mini pal Energy dispersive X-ray spectrometer design for detection and measurement of elements for characterisation of the chemical properties of the clay deposit. According to Rhodes (1989) Silica and alumina are the major essential element that makes up clay. Clay samples from Ankpa according to the elemental analysis conducted as stated in **Table** 2; above, shows that, the clay sample from Anpka 1 has 36.7 %, silica 29% alumina and 0.5% iron oxide contents. Anpka 2 clay

sample has 45.7 % silica, 26.4% alumina and 8% iron oxide contents, while Odagba clay has very low percentage of silica 24.17%, alumina of 18.14% and12% iron oxide respectively.

Other elements that are contained in the clay samples ranging from iron oxide to other oxides are considered to be impurities which are not needed in some clay body that are prepared for the production of white wares. Though Ankpa 1 and Ankpa 2 clay samples have high percentage of iron oxide to be considered high firing fire clay but the percentage of silica and alumina contents of the clay has raised them above ball clay.

The result compared with the Ultimate Chemical Analysis of a Typical Clay Specimen, in Ahuwan (1997) which has 46.60 silica and 38.30 alumina. Chemical Analysis Table above shows that, the clay sample from Anpka (1) has 36.7 % silica and29% alumina contents closed to the Chemical Analysis of Typical Clay Specimen which has 46.60silica and 38.30 alumina. Anpka (2) clay sample has 45.7 % silica and26.4% alumina contents, while Odagba clay has very low percentage of silica 24.17% and alumina of 18.14% respectively.

Anpka (2) clay sample has 45.7 % silica which is approximately the same as chemical analysis of the typical clay specimen which has 46.60 silica.it also has and 26.4% alumina contents which is about 2.5% lower than that of the standard Clay Specimen which is 38.30 alumina.

From these comparisons of the properties of tested clays such as English clay, Georgia clay and Bauchi clay as reported in Ahuwan (1997) with The Physical and Chemical analysis of the Ankpa 1 and 2 clay samples, shows that they are fire clay ,while the case of ball clay have been established in Odagbo clay sample .

The chemical analysis in **Table 2** shows that, the clay sample from Anpka (2) has **45.7%** silica (SiO_2) contents, Anpka (1) clay sample has. 36.9 while Odagbo clay sample has 24.17 respectively.Anpka (1) clay sample has alumina (Al_2O_3) contents of **28.5%,** Anpka (2) has 26.4%alumina (Al_2O_3) contents while Odagbo has 18.14% alumina (Al_2O_3) contents .Anpka 1 clay sample has iron (Fe_2O_3) contents of **0.50%,** Anpka 2 has **0.6**. iron (Fe_2O_3) contents while Odagbo has **6.10** iron (Fe_2O_3) contents

Odagbo clay sample is secondary clay in view of its colour, plastic nature and high ion (FeO_3) contents of **6.10 %.**

The result of the analysis shows that the clay is a brownish pink fire clay. The results of the elemental analysis of the Mini Pal compact Energy dispersive X-ray spectrometer of the clay samples is shown in table 2

Table 2:Chemical composition of the three clay samples from Ankpa

Ankpa 1 clay sample		Ankpa 2 clay sample		Odagbo clay sample	
Elements	percentages	Elements	percentages	Elements	percentages
SiO_2	36.9	SiO_2	45.7	SiO_2	24.17
Al_2O_3	28.5	Al_2O_3	26.4	Al_2O_3	18.14
TiO_2	9.11	TiO2	13.9	TiO_2	0.0
Fe_2O_3	0.5	Fe_2O_3	0.6.	FeO_3	6.10
CuO	0.058	CuO	0078	CaO	0.3
Sc_2O_3	0.05	Sc_2O_3	000	MgO	0.3
V_2O_5	0.39	V2O5	0.51	Na_2O	0.3
Cr_2O_3	0.18	CrO3	0.14	Cr	19.16
NiO	0.061	NiO	0.058	La	4.85
Ga_2O_3	0.12	Ga_2O_3	0.03	Na	12.35
MoO_3	000	MoO_3	1.00	Mn	27.44
Rh_2O_3	2.2	Rh_2O_3	2.0	K_2O	0.7
Rb_2O	14.00	ZnO	0.076	Zn	155.7
TeO_2	0.09	TeO2	0.25	Ce	108.4
CdO	2.3	Re_2O_7	0.25	Hf	14.34
P_SO_3	0.3	IrO_2	0.44	Th	10. 65

Table 3: Chemical composition of some tested clay.

Dass A		Dass B		Darazo		Georgia		English	
Elements	%	Elements	%	Elements	%	Elements	%	Elements	%
SiO_2	7.8	SiO_2	8.40	SiO_2	58.40	SiO_2	45.80	SiO_2	37.60
Al_2O_3	15.40	Al_2O_3	16.50	Al_2O_3	17.60	Al_2O_3	38.00	Al_2O_3	40.30
Fe_2O_3	0.0	Fe_2O_3	0.0	Fe_2O_3	0.0	Fe_2O_3	0.0	Fe_2O_3	0.5
MgO	2.56	MgO	2.77	MgO	2.50	MgO	0.0	MgO	0.0
CaO	4.75.	CaO	4.90	CaO	4.10	CaO	0.0	CaO	0.10

Source; Ahuwan (1997).

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Table 4; Chemical composition of Typical Clay specimen.

Elements	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Loss
percentages	46.60	38.30	0.1	0.4	0.3	0.3	0.3	0.7	13.0

Source; Ahuwan (1997).

. **4.3 Finding;**

1. Odagbo clay sample is secondary clay in view of its brown colour, plastic nature and high iron (FeO_3) contents of **6.10 %** since all pure clays are of low ion (FeO_3) contents, and usually white in colour.

2 .The clay samples of Ankpa1 and Ankpa 2 clay can also be regarded as Stoneware clay or secondary fire clay due to its firing temperature of 1260^oC. This can be supported by Rhodes view (1971) that "stoneware clays are clay which mature or become vitreous at the temperature of 1200^oC to 1300^oC

3. The chemical analysis shows that, the clay sample from Anpka (2) has **45.7%** silica (SiO_2) contents .this can compare with silica (SiO_2) contents of **46.60%** of a typical clay Specimen of Georgia Clay and Silica (SiO_2) contents of Bauchi clay with **45.80 %** . Though the alumina (Al_2O_3) contents of **28.5%** of Anpka (1) clay sample is low for it to be regarded as pure clay when compared with alumina (Al_2O_3) contents of **38.30%** of typical clay but its Silica (SiO2) content of 36.9% is higher than those of Dass A with 15.40 % Dass B 16.50 % and Darazo 17.60% respectively

4. Ankpa 1 and Ankpa 2 clay samples did not dissolve after 24 hours, it was left for one week more in the water, and it still did not dissolve easily but was soft. To bring about easy slaking, the clay particle sizes were reduced by pounding and sieving.

5. The clay samples of Ankpa (1)and Ankpa (2) are not pure white due to the high percentage of iron oxide in them (FeO_3 which is **0.5**% in the clay sample of Anpka (1) and (**0.6**%) in Anpka (2)

6. The X-ray diffraction analysis of the clay samples of Ankpa (1) and Ankpa (2) carried out at the National Steel council Kaduna to determine the type of clay shows that the clay is a brownish pink fire clay.

7. Anpka 1 clay sample and Anpka 2 clay samples could not dissolved after 24 hours of soaking even when left longer in water for a week due to the tabular and rocky nature. Before it was utilized, the grain size of the clay has to be reduced by pounding and sieving to enable it slake easily.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS;

5. 1. SUMMARY;

Exploration into clay from Ankpa was informed by the need for verified clay mineral, in and around Ankpa in Ankpa Local Government Area of Kogi State Nigeria that could be use for production of earthenware and stoneware ceramics. The experimental method of research was adopted in the course of the study to accomplish the objectives of the research. Random method of sampling was adopted in the selection of sampling for the research. At the preliminary, many clay deposits were visited. At the end of the visit, only three sites were selected for the study.

Clay samples were collected from the three different sites selected for the study and preliminary investigations were carried out on the samples as well as property test and elemental analysis of the clay samples. The XRD of the clay revealed that the case of brownish pink fire clay was established in Ankpa 1 and Ankpa 2 clay sample. Clay bodies were prepared from the tested clay samples for the production of experimental wares and test bars. Samples were produced from the clay samples and were fired up to 1260^{o}_{C} successfully.

5. 2 CONCLUSIONS.

The following conclusions were drawn;

The clay deposits from Odabgo clay sample is secondary clay of excellent quality for the production of earthen and stone wares ceramics because of its plastic nature. Experiments proved that Ankpa 1 and 2 clay samples could be modify with Odabgo clay samples to

have workable clay for the production of earthenware and stoneware ceramics. Proper beneficiation of Ankpa 1 and 2 clay samples could boost their use in the production of high firing ceramics wares such as insulators, refractory wares and tablewares.

The Ankpa clay samples were fired up to a high temperature of 1260^{o}C,which is a clear indication that the explored clay sample from Ankpa are of excellent quality for the production of earthenware and stoneware ceramics as well as other wares that can fire above1260^{o}C

5.3 RECOMMENDATIONS;

1 This study could encourage the setting up of clay related industries in Ankpa and it environment, thereby boosting the economic potential of the area.

2 The clay samples of Ankpa 1 and Ankpa 2 are tabular rocky like in nature which does not dissolve easily. It is therefore recommended that the grain size be reduce by pounding and sieving for easy slaking.

3 The clay samples from Ankpa 1 and Ankpa 2 are recommended for further study to unearth their full potential in view of their firing strength of 1260^{o}C,

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