The analysis of clay materials for use in a ceramic studio

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Thesis (M.Dip.Tech.)

Technikon Witwatersrand

1994.

ACKNOWLEDGEMENTS

- The Foundation for Research Development and the Technlkon Witwatersrand research fund for their generous funding of this project;

- Prof. Sylvana Luyckx, Supervisor of the project, for her patience assistance and encouragement;

- Eugene Han, Co-supervisor of the project and Christopher Smart, my fellow lecturers for their discussions. suggestions and help;

- Prof. Olaf Heckroodt for his interest and valuable suggestions;

- Prof M.Witcomb and the staff of the Electron Microscope Unit for their advice and assistance;

- Friedel Sellschop my husband, for introducing me to research and for his valuable input and assistance;

- Jack Sellschop for the encouragement:

- Richard Sellschop for all the assistance with the computer;

ABSTRACT·

The research project entitled: *The Analysis* of *Clay Materials for use in a Ceramic Studio* was undertaken in order to give a quantitative base to the understanding ot clay materials and their role in clay bodies. The project consists of analysing the clay materials as they are supplied, using technically sophisticated equipment. A set of data for each of the nine chosen clays was assembled and then correlated for easier comparison.

The clay materials were then mixed into clay bodies using a set proportion in order that a comparison of the nine clay bodies could be made and related to the data assembled for the clay materials.

The data collected, as well as the ceramic calculations used in the research project were entered into the "Insight" Ceramic software programme for use in the studio. This data base will be the foundation for ongoing research into ceramic materials.

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CHAPTER 1

INTRODUCTION AND RESEARCH OBJECTIVES

This research project was undertaken in the Ceramic Division of the Department of Three Dimensional Design TWR., in order to give a quantitative base to the understanding of clay used in the Department. This project analyses the clay materials as they are supplied, using sophisticated technology gives quantitative results that can be correlated with the known requirements of the clay bodies.The clay mining companies and distributors should be able to supply an updated analysis of the clay materials with every batch supplied but it is only in rare instances that this is in fact given. This lack of information is one of the prime reasons for undertaking this research project.

Ceramics is peculiar in the field of Art and Design in that it is essential to understand the technology of clay both in its unfired state and as a component of a ceramic body if there is to be control of the final product. This is of particular importance in a Technikon where technology and its transfer are vital to the structure of the Programme. All the distinguishing features of good design and formal aesthetics are taught as well as a variety of production techniques and surface treatments, but, if the quality of the finished ware is not technically sound the product is seriously diminished in worth.

The quest for quality is of paramount importance in South Africa at this time as the current employment route is leading towards small businesses producing limited numbers of up-market, designed objects for both the local buyer and export. Ceramics is ideally suited to small batch production but only if the number of rejects can be kept to a minimum by stringent material controls. The information collected in this project should be regularly updated and be made available to production potters who have ventured into the self-employment territory. The information will be stored in the form of a Data Base (2.6) designed for the easy access to the composition of the materials as well as to the calculations required for the formulation of the materials into clay bodies by.all interested parties.

The clay bodies used to date have generally been supplied in pre-mixed form from one of the large ceramic supply companies. These materials have served a purpose in giving freedom to the students and staff of the Ceramic Division to

develop form, style and concept without too large an output of energy in the area of material research. However these clay bodies have proved to be the cause of problems that need to be addressed. It therefore becomes imperative that a clay body that is controlled and regularly tested should be formulated and mixed for use in the Ceramic Division. In this way the properties could be prioritised and adjusted to specific requirements. The information gathered in the course of this research project will be used for the formulation of the clay body.

Pottery making is one of the oldest techniques known to man. Sherds have been found from ancient civilisations in Asia dating back to 6500BC. It is the extraordinary properties of plasticity and sintering, making it possible to form the clay and then to render it permanent by firing, that has attracted man to this material. Clay vessels made for domestic uses such as carrying water, the storage of supplies and cooking pots have been produced by agrarian communities for centuries. Ritual vessels, for both secular and devout ceremonies were frequently made from clay, carefully and meaningfully crafted then decorated, endowing them with a spirit of creativity. The clay used for these vessels was selected for colour and workability and dug from riverbeds and prepared according to the traditions of the reqion. These preparations were tested empirically by the potters and the knowledge passed down through generations of crafts people. Even today traditional potters usually make use of materials within a limited radius of their workplace although they may combine materials in order to alter the properties of the body.

The concept of combining clays from different regions in order to fabricate a predetermined clay body was common practice in China as early as the Sung Dynasty (AD 960-1279). The potters of Jingdezhen combined the local ball clay with a particular clay from 'Gaolin', meaning High Mountain, to the North-East. A further important additive was 'petuntse', the colloquial name for a prepared crushed pegmatiteJ1] The three materials combined, produced a White, translucent porcelain that was the envy of the civiltsed world.. Enormous quantities of porcelain wares were made for export to Europe, Asia and Africa. The Portuguese were the first to trade in these wares, later the Dutch East India Company brought shiploads of porcelain to Europe where they were coveted by the gentry and envied by the potters. This competition led to considerable research into white clay bodies in Europe and throuqhout the Western world. It was not until 1710 that true porcelain was made.at Meissen. White tin glazed

majolica wares were produced in imitation of the Chinese porcelain until this discovery.

In the Eighteenth Century the Industrial Revolution and the resultant new middle class desired tableware of a high standard but, the imported wares were expensive. This newly opened market made the importation and blending of clays a viable proposition. Josiah Wedgwood for example built a canal to enable the transport of white clay from Devon to his factory, Etruria, in Stoke on Trent. His development and production of Creamware successfully competed with the imported porcelain. Today the importation and blending of clay in England and Europe is a highly sophisticated and scientifically controlled process guaranteeing a supply of clay to the manufacturer with a constant composition.

Post modernism's re-introduction of the use of brighter colours and decorative surfaces, after the constraints of minimalism and functionalism dictated by the Modernist movement in the 1950's and 1960's, required the development of white, low firing bodies. These bodies have to be fine-grained and low in iron to show off the coloured surface, and capable of maturing below $1200^{0}C$, as many of the available ceramic colours burn out at this temperature. The clays found in South Africa tend to be iron bearing, so, in order to produce a white body the clay materials must be blended in calculated proportions. It is essential to know accurately the composition of the various materials in order to perform this task. The materials required are readily available but are not always consistent in composition or tested regularly. These variations can cause faults such as dunting of the body or crazing in the glaze. This research project provides accurate means of examining clay materials in order to prevent such problems from occurring. It should be noted that this information and the means of formulating a clay body can be used to develop any required ceramic body, fired in any temperature range.

The Ceramic Design programme presented at the TWR is essentially art-and-design based, teaching visually literate students the techniques and technology necessary to make quality ceramic wares. It was therefore felt that the data generated by this project should be visually meaningful as well as quantitatively accurate in order for the data to be of use in the production studio. It was for this reason that the Scanning Electron Microscope with EDAX analyser was chosen as the prime analytical tool to study the clay materials. Photographs of the morphology and graphs of the properties of the clays would make the differences

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in these materials visually apparent when studied in conjunction with the analytical data. The stereo-microscope with a camera attachment was used in order to reproduce the colour of the clay which is often of significant importance:

As a final comparative method of characterising the nine clay materials chosen for the investigation, the materials were mixed as "clay bodies" with a set proportion of feldspar and silica to give a standard. These bodies were then tested by throwing with them on the wheel in order to compare their plasticity as well as other physical properties. This comparison of the materials as components of "clay bodies" was related to the characterisation of the individual clay materials.

1.2 CLAY MATERIALS

Clay can be defined as a fine grained earthy mineral, made up of hydrous aluminium silicates, plus residual fragments of other minerals and colloidal matter[2]. Clay displays plasticity when wet, green strength when dry and is converted to a rock-like mass when fired to a high temperature.

Kaolinite is the most common member of the clay group[2] and is the major component of the white primary or residual clays remaining on the site of their formation, known as kaolin or china-clay. Kaolinite is formed as the result of the weathering and decomposition of acid igneous rocks such as granite. Large amounts of the resultant finely ground weathered material are transported, usually by water, over long distances and deposited in river beds and lakes, resulting in sedimentary ball clays that are plastic due to the finely ground particles, but usually soiled due to the pick-up of other fine particles such as iron, titanium and manganese and chemically altered due to the ion exchange that occurs en route.

The structure of the clay mineral is dependent on the mineralogy of the parent rock and the sequence in which the weathering occurs. If the weathering is such that the potash and magnesia are rapidly removed, kaolinite is formed. If the potash and magnesia remain in the weathering zone, smectite and illite are formed. Likewise Kaolinite is formed from basic igneous rocks if the magnesia is

removed as soon as it is released, or smectite is formed (2]. Further weathering of the sediments follows the same pattern as for the acid igneous rocks[2].

Clay minerals have been classified into eight groups according to their crystal layer type, the layer charge and the type of interlayer unit.[2][3][4][5] To the ceramist making wares from clay, the three important minerals are Kaolinite, a species of the Kaolinlte group, Montmorillonite of the Smectite group and Illite of the Mica group.

The clay minerals are hydrous layer-silicates, part of the larger family of phyllosilicates. "The structure of kaolinite (the most ordered of the clay minerals) is made up of two layers. One layer consists of silicon and oxygen ions in which each silicon ion is at the centre of a tetrahedron formed by four oxygen ions. The other layer consists of aluminium and hydroxyl ions, the hydroxyls forming the corners of an octehedron. When the two layers are combined a layer of kaolinite is formed."[3] These minute hexagonal plate-like crystals compress into concertina-like stacks.PI This form of crystal structure is known as a 1:1 layer.

Montmorillonite is composed of the same basic constituents as kaolinite but the ratio of silica : alumina is doubled. The layer of aluminium and hydroxyl ions is sandwiched between two silicon and oxygen layers known as a 2:1 layer.'Illite is also of this 2:1 layer formation.

Most physical properties of clay minerals can be related either to the very small size and plate-like form of the individual particles or to the significant surface. charge associated with these particles.[5]

There is a certain amount of ionic substitution in the clay minerals, particularly in the dis-ordered, form of Montmorillonite. As the substitution involves the replacement of cations by another ion of lower valency, the clay structure becomes negatively charged. Positive ions, e.g. K+,Na+;Mg2+.Ca^{2+} and H+. are absorbed on the edges of the clay mineral,'or in the layers, these ions are loosely held in the structure and can in turn be exchanged[31.

Clay mineral crystals lie within the colloidal range and therefore have colloidal properties and do not obey the ordinary sedimentation laws. Instead the particles are capable of remaining suspended in water and have, the ability to absorb cations and anions and retain them in an exchangeable state. [2] Water

molecules.become attached to the positive and negative crystal sites that are exposed when the crystal is fractured. This pore-water between the flakes is one of the contributing factors affecting the plasticity of clay. [6] The alkalis found in the clay materials are bonded to the kaolin platelets by the surface charge of the crystals. They can readily be replaced by one another thus affecting the stacking of the platelets and causing either flocculation or deflocculation depending on the charge.

The particle size ctstrlbunon of a material cannot be conveyed by a single fineness figure. especially in the/colloidal range of particles. Only those particles less than 2μm e.s.d.(equivalent size diameter) are considered to be clay. This is a geological convention but can give comparative information to ceramists. The varied shapes of clay particles, from platelets to tubes, makes the measurement' of size particularly difficult. More than one method is usually needed and the problem of compatibility of the results must be considered[2l.The use of the laser diffraction method of particle sizing used in this project can be used as a comparative value. A mix of particle sizes in a clay body gives the best plasticity as the packing density improves. This also improves the green strength of the wares made from the clay. [2][3][4][5)

The effect of heat on clay minerals resulting in sintering and ultimately vitrification is indirectly the result of this finely divided state of the particles. When the minimum temperature is reached to initiate solid state intercrystallisation without actually reaching the melting point of the individual body components a lattice arrangement is formed[4j. "During firing the kaolin takes part in a series of reactions which lead to the formation of a glass-rich phase that forms the vitreous bond in the ceramic body."[2j

The combined effect of these properties result in a unique and irreplaceable. material that' will continue to be utilised by mankind for the production of objects for ritualistic, domestic and structural uses.

1.3 FUNCTION OF THE CONSTITUENT OXIDES IN CLAY MATERIAL

The constituent oxides in a clay material individually affect the final ceramic structure. The commonly occurring materials are discussed in this section.

Note: The formula for the *Ideal clay Substance* is Al_2O_3. 2Si02. 2H20 [4][2], therefore, the theoretical weight % expressed in oxides is:-

Si02: 46.51 %.
Al_2O_3: 39.53%
H20: 13.95%

This theoretical composition can be used to give an indication of the amount and type of impurities in the clay material. Kaolinite of this composition does not occur naturally·[2]

The structural formula of kaolinite can be written

(OH)a Si4 Al4 010

a) Silica(Si02)

Silica (Si02) is the most abundant oxide found on the earth's' crust. It forms silicates with other oxides. Most ceramic raw materials are silicates e.g. clay, feldspar, talc.

Silica occurs in clay in the free state as quartz or combined in the structure of minerals. The effect of free silica in a clay is to reduce the plasticity, drying shrinkage and dry strength.' Upon heating, free silica forms cristobolite and tridymite, two phases that contribute to the control of reversible thermal expansion and contraction of the fabricated clay body which is related to the glaze fit. Quartz is converted to crystobolite at $1470^{0}C$ but with the addition -of a flux, in particular lime, the reaction can occur sooner. Cristobolite is also 'derived from the break up of the kaolinite lattice. The silica content in a fabricated body can be between 70% and 75%[2].

b) Alumina (Al_2O_3)

Alumina occurs as combined aumino-silicates. High alumino content is associated with a high kaolinite content.12]

c) Iron Oxide (Fe_2O_3) and Titania ITi02}

These two oxides determine the colour of the clay. The combination of the two oxides should be less than 2% for the body to fire white.[2]

Titania is a white mineral but it enhances the staining power of Iron oxide.

Iron oxide can react with silicates and alumino-silicates to form "compounds that flux in the 11oooe range.

d} Lime (CaO) and Magnesia (MgO}(Alkali Earth Oxide)

These two oxides act as fluxes in low-fired clay bodies, forming eutectics and reducing the vitrification temperature. The alkali earths (Lime in particular) react with the silica in the clay body forming glass in a similar way to the feldspars but with a softening and melting range shorter than the feldspars. They are usually added in small amounts as the proportion of flux is higher than in Feldspars[3].

The presence of the alkali earths in a clay material can affect the plasticity. The small, multicharged ions can assist in the build-up of the water structure on the edge of a kaolinite crystal[6] .

Lime may act as a weak bleaching agent on iron.

Alkali earths can be used in the development of shock proof bodies and also in bodies requiring low shrinkage.I

e} Alkali oxides (K20 and Na2Q1

These oxides occur in the minerals feldspar and mica. They are powerful fluxes and combine with the silica and alumina during firing to form glasses of complex composition. The presence of potash and soda has a marked influence on the reversible thermal expansion and contraction of the fired body. Alkalies reduce the refractriveness and vitrification temperature of the clay.

Note on Loss on Ignition (LOI)

This is associated with the loss of hydroxyl ions in the clay structure (water of crystallization) as well as the loss of any organic matter that is present in the clay material.

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1.4 **PROJECT PLAN**

The project consists of the following three stages:

1.4.1. *Visual Information*

To examine the morphology and structure of the surfaces of the clays used in the studio on a microscopic scale and to present them photographically.

To record the variations in colour from one clay to another

1.4.2 Clay analysis

To examine the clays used in the studio and record their physical properties and composition for inclusion in a Data Base.

The interrogative techniques used to develop the Data Base are:

1.4.2.1 Physical measurements.

1.4.2.2 Chemical analyses.

1.4.3 Clay body

To fabricate "clay bodies" from the chosen clay materials in order to assess the physical properties of the clay materials in this form.

CHAPTER 2

MATERIALS AND EXPERIMENTAL TECHNIQUES.

The rationale on the choice of matsrtals and their preparation for analysis as well as the techniques used for the analyses are presented in this chapter. Some of the analytical techniques rely on results obtained from previous measurements in which case an explanation of the sequence of analysis is given. It should be noted that the term *clay material* is used for the "as supplied" clay, whereas the term *clay body* implies that the materials have been mixed into a clay body in combination with other materials.

2.1 CHOICE OF CLAYS

The clays in regular use in the Ceramic Division of the Technikon Witwatersrand were chosen to be tested in this project. These clays are commercially available and used for clay application by the students and staff. Occasionally a different clay will be introduced into the laboratory for research-based reasons such as a project on porcelain or white earthenware. Usually the choice is based on the required physical properties of the clay. Up to now the recommendation of the clay supplier has been the main criterion for the selection.

In the time span of this research project, two of the chosen clays, Western Province 8all Clay and 813, have been re-ordered. Samples from both the old and the new bags of clays have been analysed to show the variation in properties over a period of time.

CLAYS EXAMINED

Sail clays

- A Clay (Fire clay)
- 813
- C.Clay
- Moss clay
- PXX High cast (imported)
- Western Province Ball Clay

Kaolins

- G1 Kaolin
- Serena Kaolin
- S Kaolin

2.2 SAMPLE LABELING AND FIRING TEMPERATURES

The samples prepared for microscopic study, chemical analysis and the physical tests were labeled as shown in Table 2.1 according to the temperatures at which they were fired. These temperatures were chosen to closely match those used in the studio. As is usual in a working studio the glazes and clay bodies are formulated to mature at a specific temperature to simplify the firing schedule and to make sure that the kilns are fired full of wares as the cost per item must be accounted for.

TABLE 2.1 SAMPLE LABELING AND FIRING TEMPERATURES

Sample label	Firing Temp.	Orton cone number.	Firing Type
A	Unfired		
8	$1000^{0}C$	06 $(999^{0}C)$	Bisque temp.
C	$1100^{0}C$	03 $(1101^{0}C)$	Glaze temp.
0	$1200^{0}C$	4-5 $(1186^{0}C$-$1196^{0}C)$	Glaze Temp.

This system of firing and sample labeling has been used throughout the project. The A, or unfired sample was dried to 1100C in order to rid it of pore water. In the samples for the SEM this is necessary for the carbon coating to adhere to the surface and in the samples for the shrinkage and absorption tests it ensured that the Wet to Dry shrinkage was complete. The sample was not fired.

2.2.1 Samples for the microscopic studies and chemical analyses.

The microscopic studies were carried out by scanning electron microscopy (SEM) and the chemical analyses by energy dispersive X-ray analysis (EOAX). The samples examined on the SEMIEOAX were the A and 0 samples. To examine all four of the samples for each of the clay materials proved to be too time consuming and expensive. The results from the A and 0 samples were close, or even the same therefore it was assumed that the other two samples (8 & C) would also give very similar results.

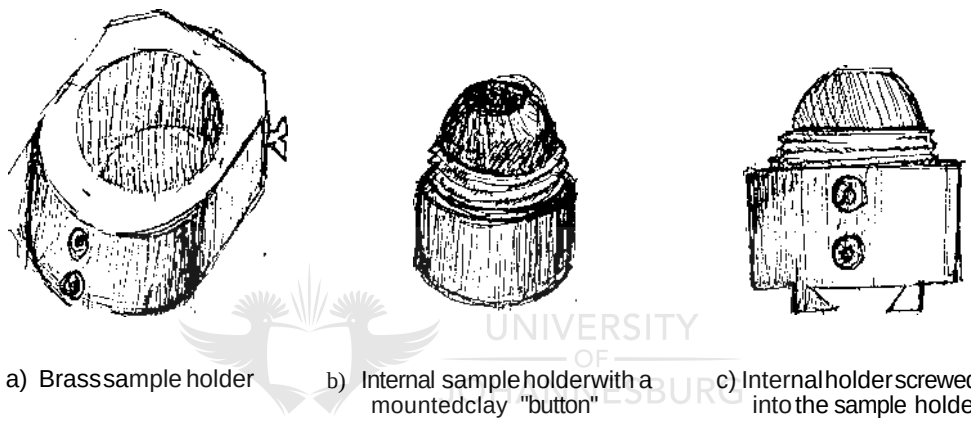
2.2.2 Samples for the physical tests

Samples fired to the four temperatures given in Table 2.1 were used for the physical tests. Where needed for the shrinkage and absorption tests, an additional sample was made and fired to $600^{0}C$. This is the temperature at which ceramic change becomes irreversible. The clay material is converted to a ceramic. The hydroxyl groups (OH) are removed from the clay lattice and the absorbed water. is removed from the fractured ends of the clay lattice·[7] (Section 1.2) This additional sample gave insight into the sintering properties of the clay materials.

2.3 METHOD OF SAMPLE PREPARATION

2.3.1 Samples for the SCanning Electron Microscope (SEM)

The requirements for samples for the SEM were examined. It is essential that the sample fit into standard brass holders (Fig.2.1) and that the top surface of the sample be flush with the top of the holder so that the electron beam strikes the surrace at 900 and the sample position is known. The internal holder (Fig. 2.1) should be firmly tightened with the grub screw.



a) Brass sample holder b) Internal sample holder with a mounted clay "button" c) Internal holder screwed into the sample holder

FIG. 2.1 STANDARD BRASS SAMPLE HOLDERS.

2.3.1.1 First set of samples

a) The very first samples made were broken from a larger test piece. These irregularly shaped shards proved difficult to mount correctly. An attempt to mount a small clay fragment in a bakelite plug made conductive by the inclusion of iron, proved unsuccessful as the sample continued to "charge" when in the microscope, due to the accumulation of secondary electrons on the surface of the sample.

2.3.1.2 Second set of samples

a) A Plaster of Paris mold was made in the shape of an egg box to form the samples into the correct shape to fit into the brass sample holder. The clays were wet mixed and then dried in this mold before firing. Four samples of each clay were made. The rounded side of the clay "buttons" was ground flat on a marble slab to obtain a suitable surface for analysis. If the surface is left rough the electron beam is scattered in

scattered in many directions, and information is lost. Besides this the depth of penetration of the beam would not be the same at different orientations of the surface with respect to the beam, so secondary electrons and X-rays from different depths would be received, which would make it impossible to compare data from different samples.

b) The samples were carbon coated with the assistance of the Electron Microscope Unit of the University of the Witwatersrand. This coating makes the sample conductive thereby preventing the surface of the clay from "charging up" whilst being examined in the SEM.

c)The build up of charge on the surface of the samples proved to be considerable, especially on the A (unfired) samples, in spite of the carbon coating. It is essential to cover the samples with sufficient DAG, a suspension of graphite powder in acetone, in order to lead the charge to earth, leaving uncovered, (but coated with carbon) the area to be analysed.

2.3.2 Samples for the physical tests

There is a large number of books and publications giving techniques of clay evaluation and testing.[2][4][7J[a] The purpose of this research is to identify the techniques necessary for the evaluation and testing of clays in a studio situation.

The Physical Tests carried out were the following: (4)

a) Shrinkage
b) Water Absorption
c) Loss on Ignition (LOI)
d) Plasticity
e) Particle size
f) Colour comparison

The samples for the physical tests were prepared from the same clays as those prepared for examination in the SEM.

2.3.2.1 Method of sample preparation

art kilogram of clay was mixed with water to form a workable, plastic clay.

b)The clay was wedged thoroughly and formed into suitable test pieces for the tests described in 2.4.2.1.

c) Samples of the clay in powder form were prepared for particle size tests to be conducted at the Dept. Chemical Engineering
University of Witwatersrand. (courtesy of Prof. Moys)

2.3.3.Samp/es for the "Clay Body lltests

Clay materials are seldom used in their found state but are mixed with other materials to form clay bodies with the required properties for their particular use. In order to obtain a normalised assessment of the clay materials they were mixed into "clay bodies" and tested (Table 3.32) (Chapter 4).

a) The nine clay materials listed in 2.1 were combined with Feldspar and Silica in the following proportions and formed into "clay bodies".

Clay material	50
Silica	30
Feldspar	20
	100

b)The clay was wedged thoroughly and formed into suitable test pieces for the tests described in 2.4.2.1 .

c) Samples of feldspar and silica were analysed in the SEM/EDAX (Appendix E) in order to include their composition into the Materials Definition Table included in the."Insight" Ceramic Chemistry software programme (2.6.2).

2.4 EXPERIMENTAL TECHNIQUES

2.4.1 Scanning Electron Microscope (SEM) and Energy DIspersIve X-ray AnalysIs (EDAX)

2.4.1.1 Basic Principles of the SEM/EDAX.[9]

The SEMIEDAX was selected as the instrument of analysis as the imaging of the surface and the chemical analysis of the individual clay materials can be performed simultaneously. This complied with the project aiming at visual and analytical characterization of the clays.

The SEM produces an image from the sample being examined as a result of the impingement of a finely focused electron beam onto its surface. The instrument basically consists of three groups of components: the electron optical column, the vacuum system including the specimen chamber and stage and the EDAX signal detection and display systems. The electron gun is usually a heated hairpin, tungsten filament. The electrons from the stream emitted from the gun are focused as they travel down the electron column by electromagnetic lenses which focus the beam to a diameter less than 100 Angstrom when it strikes the sample surface. The beam is scanned by electromagnetic scanning coils in synchronisation with the cathode-ray display tubes. When the beam impinges on the sample, secondary and backscattered electrons, X-radiation, and cathodoluminescence are emitted[9]. For this research project the secondary electrons were used to image the surface (with occasional use of backscattered electrons) and the X-radiation was used to analyse the chemical composition of the samples.

The secondary electrons that are emitted from the surface of the sample when it is impacted by a primary electron beam travel in all directions. However, since secondary electrons have relatively low energies, about 20 electron volts, essentially all of the secondary electrons, regardless of the direction in which they are emitted, are easily attracted to a collector mesh that has a positive potential of about 200 volts. This means that all spots on the sample surface will be included in the final image. However, it also means that secondary electrons produced by either primary or backscattering (Le. reflected) electrons striking other parts of the microscope, for example the objective lens, will also contribute to the final image. It has been estimated that about 30% of the final image is derived from extraneous interactions of this type. This phenomenon unfortunately creates noise in the image. Since all the secondary electrons entering the collector at any instant come from the small spot on the sample where the primary beam is striking, there is no need to focus the emitted

secondary electrons. Behind the collector is an aluminium coated light pipe which is excited with a potential of about 12.5 kV. This pipe is a solid rod made of specially doped plastic. Electrons that strike the end of the light pipe penetrate the thin aluminium coating and excite electron-hole pairs in the light pipe. These combine to produce photons which travel through the light pipe to a photomultiplier which produces a current. Any electrons that happen to travel away from the photomultiplier will be reflected by the aluminium coating and their motion reversed towards the photo multiplier. The current produced by the photomultiplier is amplified and used to modulate the intensity on a cathode ray tube which creates the final image.

The resolution and the depth of field of an SEM are the features that permit both the peaks and valleys normally encountered on a rough surface to be imaged in focus even at relatively high magnification. (Although the surfaces of the samples were ground flat, at the high magnifications used they appeared as rough surfaces). The contrast observed on the secondary electron image on the cathode ray tube is dependent primarily on the topography of the surface. A small variation in the angle between the primary electron beam and the surface of the sample where it strikes causes considerable variation in the brightness of the final image. Sharp edges or corners appear brighter than adjoining regions of the sample because their geometry causes greater quantities of secondary electrons to be emitted from them [9].

The energy dipersive X-ray analyser (EDAX) analyses the X-rays that are emitted from the spot where the electron beam strikes the sample. These X-rays have wavelengths characteristic of the elements contained in this precise area in an intensity proportional to their quantity which is measured by the spectrometer. A quantitative chemical analysis is possible by comparing the wavelengths and the intensity with known standards. The mineral standards for this project were loaned by Mintek and installed into the analytical programme linked to the EDAX (Appendix D) The use of the SEM/EDAX proved to be an efficient, accessible technique for obtaining the composition of clay materials for use in the Ceramic Division, TWA.

2.4.1.2 Procedure for Analysis of Clays

The procedure for the analysis of the clay samples was developed with the assistance of the Electron Microscope Unit at the University of Witwatersrand(10).

a) The samples were prepared as described in paragraph 2.3.1.

b) The samples were analysed using a Co standard that calibrates the energy scale. A sample of pure Co is permanently mounted at the side of the standard brass holder where it can be accessed and analysed

between each of the sample analyses. The zero strobe is set on, or as close as possible to, zero. The Cobalt K line should fall on 6.9242 keV. Any displacement was calibrated and corrected.

c) Mineral standards selected to closely correlate with the minerals commonly found in clay were used with the permission of MINTEK. The virtual or theoretical standards and the mineral standards available could not be calibrated adequately to give accuracy for elements such as sodium and magnesium which appear low on the atomic scale. A list of the standards used appear in (Appendix D).

d) The microscope was focused on the Co standard at 39mm working distance (WD) and x2000 magnification. The count rate was set on 1900 cps varying the Probe Current for adjustment. The Gun Alignment Tilt was checked at regular intervals to minimise drift. The Co standard was analysed between each two sample analyses in order to ensure the correct calibration. This process was repeated for each sample. The spectrum, a stoichiometric analysis giving the oxide percentage of the elements and an apparent concentration analysis giving the concentration of the various elements in the clay material were recorded for each sample.

e)The data were collected with ZAF correction [10] (Appendix D)
i.e. correcting for:-

Z = Atomic number
A = Absorption
F = Fluorescence

2.4.1.3 Correlation of clay data.

The clay data acquired from the SEMIEDAX were collected in these forms:-

a) computer generated analysis sheets giving the concentration of the elements in atomic percent. (Appendix D)

b) computer generated analysis sheets giving the stoichiometrically normalised analysis l.e. the oxide concentration in weight percent or molar percent (Appendix D).

c) Spectra of the above analyses.

d) Photographs of the samples at selected magnifications.

The calculattcns required for the analysis and comparison of clay materials are discussed in secnon 2.5 under clay evaluation &calculations. The visual information obtained is reported in Chapter 3 together with the physical data of the materials. The data collected in the course of this project has been stored in the form of a data base accessible to the Ceramic Division (Section 2.6)

2.4.2 Physical Tests

2.4.2.1 Linear Shrinkage. Water Absorption. Loss on Ignition. Colour and Particle Size(4)(11)

a) Linear Shrinkage

The claymatertal was prepared as discussed in 2.3.3.1, rolled into flat slabs and cut into rectangular samples. A 10cm line was inscribed onto each sample before firing to the required temperatures (Table 2.1). The shrinkage was measured from the shortening of the inscribed line for each of these temperatures. The wet-to-fired shrinkage is shown in the charts for each of the nine clay materials.(Chapter 3) and in (Chapter4) wet-to-fired linear shrinkage is given by:-

[(wet length - fired length)/wet length] x 100%

b) Water Absorption.

The samples were prepared as discussed in 2.3.3.1 and fired to the required temperatures. (Table 2.1)

The fired samples were weighed (D), placed in a saucepan and boiled for five hours, wiped dry and weighed again (S). The % water absorption is calculated by the formula

[(Soaked wt - Dry wt)/Dry wt.] x 100 =% Water Absorption

The information gained from this test gives insight into the fluxing rate of the clay material. Graphs of the results of test a) and b) are included in the information on individual clays (Chapter 3) and in (Chapter 4).

c) Loss on Ignition:

100 grams of each clay was formed into a flattened disc which was allowed to dry for 24 hours, weighed (this weight will be indicated as *(a)* and the weights measured subsequently will be indicated as *(b)* and *(e))* and then heated to 11OOC in order to drive off the pore water. The sample was then weighed again. *(b)*

The sample was fired to $1000^{0}C$ and re-weighed.(c) The difference between *(b)* and *(e)* is the *Loss on Ignition. (LOI)*

100 - *(a)* = Weight of water of plasticity in a 100 gm sample.

(a) - *(b)* = Weight of pore water in a 100 gm sample

LO/=(b)-(c)

The result of the LOI test is included in the ultimate analysis calculation (2.5.1.1).

d) Colour. ,

The flat samples used in (c) were each photographed by means of the stereo-microscope at the Schonland Research Centre, University of the Witwatersrand. (Chapter 3)

e) Particle Size Test.

The "Malvern mastersizer" laser diffraction instrument was chosen as the method of analysis as it is capable of measuring colloidal particles accurately.

The Laser Diffraction particle size analyser in the Dept. of Civil Engineering, University of the Witwatersrand was used for these test, by courtesy of Prof. Moys.

The basic principles of operation are as *follows:-*

the clay material is dispersed in water by stirring and ultrasound. The clay particles are then passed through a laser beam. When the light beam is interrupted by particles which are of varying diameters, a series of diffraction light ring patterns are formed . Each light ring is spaced radially at a distance which is uniquely related to a particular particle size. If a photosensitive detector is then placed in the path of the diffraction patterns, and the detector output scanned, digitised and programmed in a micro-computer, then the size distribution of the particles can be determined.[4][12]

The percentage of particles less than 2 pm is given in the analyses of the individual clay materials (Chapter 3) and further analyses in (Chapter 4) The complete particle size analyses can be found -in Appendix C

2.4.2.2 Plasticity Tests(2)(4)

Clay materials are not often used in their found state but are combined into a clay body for manufacture. This test was therefore performed on the standard "clay bodies" that were mixed from the chosen clay materials in order to obtain a realistic result..

Plasticity has been defined as "That property which enables a material to be changed in shape without rupturing by the application of an external force and to retain that shape when the force is removed or reduced below a certain value."(4)
The factors affecting plasticity are:-

a) water content
b) size, shape and composition of the particles
c) electrolyte content
d) history and preparation methods of the clay.

The "clay body" was prepared as described above (2.3.3).
The throwing test was divided into two sections.
i) A 500gm ball of clay was thrown into a cylinder 8cm in diameter. The height was measured.
ii) A 500gm ball of the clay was thrown in any form that the potter found suitable for the particular "clay body".
The results were recorded on an increasing scale rated from 1-5 (Table 3.32) and in (Chapter 4).

2.5 CLAY EVALUATION & CALCULATIONS

2.5.1 *Clay analysis*

The proportion of elements present in the clay material samples were determined by EDAX *(204.1)* making use of a Cobalt standard. The composition was obtained as % element, atomic % and oxide% and the formula of the material. An example of the computer analysis is shown in (Table 2.2.) The oxide % is calculated stoichiometrically from the % elements and the atom %. It is convention to report the composition of silicates (oxides) in terms of the total oxides however this is a theoretical calculation assuming that all the elements are oxides and that the percentage weight added to the % elements is oxygen alone. The elemental analysis is more correct as the oxide (stoichiometric) basis could be interpreted as conveying the concept that the material is a physical mix of oxides. In fact the oxide minerals consist of a regular packing of oxygen atoms of the O-sublattice with the interstices filled with metallic or amphoteric elements in stoichiometric proportions [151.

2.5.1.1 Ultimate analysis

The chemical analysis given in terms of percentage composition. of oxides[4]

The Ultimate Analysis was carried out as follows:-
two areas from each sample were analysed and the average of the two sets of results was taken as the composition of the sample. For the purpose of this project the atomic % analysis (Table 2.2 CoIA) was entered into the data base ultimate analysis calculation table (Table 2.3). A description of the method of calculation appears below Table 2.3.

Alternatively the average of the two stoichiometric results (Table 2.2 Co1.6) could be used to obtain the ultimate analysis.

TABLE 2.2 EXAMPLE OF THE ANALYSIS PRINT-OUT FROM THE LINK PROGRAMME OF THE EDAX

WPBC(2) 0 (1 200⁰ C)

1	2	3	4	5	6	7

Spectrum:

Last e1mt by STOI CH..NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	: 2 1	.000	.178	.160	Na201	.240	.005
MgK	: 2 1	.014	.368	.316	Mg101	.610	.010
A1K	: 2	.939	18.774	14.382	Al203	35.474	.454
SiK	: 2	.775	26.667	19.400	Si102	56.403	.613
K K	: 2	.990	2.280	1.205	K 201	2.746	.038
CaK	: 2	.978	.274	.141	Ca101	.384	.004
TiK	: 2	.981	.996	.430	Ti02	1.661	.014
MnK	: 2	.873	.083	.031	Mn1oi	.108	.001
FeK	: 2	.890	1.660	.614	Fe203	2.374	.019
O K	: 0	.000	49.020	63.323			2.000
TOTAL			100.000	100.000		100.000	1.156

Column Description

1) **Element (K line)(2 = Link Programme giving the mineral standards 2.4.1.3**
2) **ZAF Correction. See 2.4.1.2 (AppendixD).**
3) **% Element by weight.**
4) **Atomic % of Elements**
5) **Oxides of the elements assumed to be present.**
6) **% oxides stoichiometrically calculated.**
7) **Formula of the clay.**

TABLE 2.3 EXAMPLE OF THE ULTIMATE ANALYSIS CALCULATION

C CLAY A (Unfired)

1	2	3	4	5	6	7	8
	Atomic % of Elements			Molecular content *		Oxide content	
	Analysis 1	Analysis 2	Average	Number of Molecules	Total Mol Weight	OxideWt +LOI	Oxide Wt% +LOI
Si (S102)	23.32	23.26	23.29	23.29	1,399.73	68.06	63.90
Al (A1203)	9.90	10.16	10.03	5.02	511.53	24.87	23.35
Fe (Fe203)	0.27	0.27	0.27	0.14	21.55	1.05	0.98
Ti (Ti02)	0.35	0.24	0.30	0.30	23.57	1.15	1.08
K (K20)	1.54	1.66	1.60	0.80	75.36	3.66	3.44
Na (Na20)	0.15	0.19	0.17	0.09	5.27	0.26	0.24
Ca (CaO)	0.22	0.15	0.19	0.19	10.38	0.50	0.47
Mg (MgO)	0.25	0.17	0.21	0.21	8.46	0.41	0.39
Mn(Mn02)	0.02	0.00	0.01	0.01	0.87	0.04	0.04
OXYGEN	63.97	63.89	63.93				
LOI						6.50	6.10
Total	99.99	99.99	99.99		2,056.72	106.50	100.00

Note * =Molecular content of oxides in 100 atoms of clay.

•=LOI was measured for the same clay fired to $1000^{0}C$

Column Description

1) Elements in oxides being analysed
2) Atomic % taken from Column 4 Table2.2 (First analysis)
3) Atomic % taken from Column 4 Table 2.2 (Second analysis)
4) Average of Columns 2 & 3
5) Number of molecules of the oxides per 100 atoms of clay.
6) Column 5 multiplied by the molecular weight of the oxide of the element.
7) Mass of oxides (in weight %) and mass lost on ignition by 100 weight units of clay material.
8) Normalised results of column 7. These results are used for the Rational Analysis calculation (Table 2.4)

2.5.1.2 Rational Analysis or Proximate analysis or Calculated mineralogy.

The approximate amounts of mineralogical constituents present in the clay material . calculated from the ultimate analysis. [4J

The calculation of the Rational analysis from the Ultimate analysis was first introduced by Seger in 1876. It is now understood that this calculation does not take the mineralogical composition of the clay materials into account. It is therefore not totally accurate, but nevertheless is of importance to the studio potter as an empirical method for the comparison of clay materials[8]. Some clays have their fluxing oxides present as mica and some as feldspar. Both the Feldspar convention and the Mica convention{4} calculations have been included in Table 2.4 One or other result would be used depending upon the mineralogical composition of the clay. The Feldspar convention, assuming that the clay material is felspathic, is usually used in the studio situation,

a) The feldspar convention which assumes that all the alkali oxides are present as soda feldspar and potash feldspar. The total of the K20 and Na20 should be low (2-4%)[4]

b) The mica convention assumes that all the alkali oxides are present as soda mica or potash mica.

It is therefore necessary to know whether feldspar or mica is present in the clay material. X-ray diffraction is the most usual source of this information recorded in published literature on the composition of clay materials.Pl Other clay minerals that may be present in the clay material such as smectite, chlorite, vermiculite and pyrophelite will not appear in the results on account of the assumption on which the calculations are based but may have an influence on the properties of the clay. [2]

A derivation of the calculations can be found in (AppendiX A). A concise explanation of the calculations can be found below Table 2.4.

TABLE 2.4 EXAMPLE OF RATIONAL ANALYSIS [9] (C CLAY A)

MATERIAL	ENTRY	FACTOR	RESULT	
FELDSPAR CONVENTION				
trotal alkalis	3.68	*5.92	21.79	%Feldspar
Feldspar	21.79	*0.183	3.99	AI203 in Felds (a)
Feldspar	21.79	*0.647	14.10	Si02 in Felds (b)
1A1203	23.35	"-a"*2.53	49.00	% Clay subst. (c)
IClay subst.	49.00	*0.463	22.68	Si02 in Clay (d)
Si02	63.90	"-(b+d)"	27.12	% silica
% WATER IN THE CLAY: % ORGANIC MATTER				
IClay Subst.	49.00	*0.140	6.86	Loss:H20 in Clay
LOI	6.10	-H20 in clay	000	Loss: C02 etc.
MICA CONVENTION				
K20	3.44	*8.47	29.14	Potash Mica
Na20	0.24	*12.32	2.96	Soda Mica
Potash Mica	29.14	*0.384	11.19	AI203 in K Mica (e)
Potash Mica	29.14	*0.452	13.17	Si02 in K Mica (f)
Soda Mica	2.96	*0.4	1.18	AI203 in Na Mica (9)
Soda Mica	2.96	*0.471	1.39	Si02 in Na Mica (h)
AI203	23.35	-(e+9)*2.53	27.8	Clay subst.
Clay subst.	27.8	*0.465	12.9	Si02 in Clay (i)
Si02	63.90	-(f+h+i)	35.91	Free Silica

Description of Columns

1) Material whose content must be determined. The information is taken either from the Ultimate analysis (Table 2.3) or from the results obtained in the calculation. The data from the "A" sample (as supplied) are used.

2) The data from column 8 of the Ultimate analysis is entered into this column. The entry column is completed as the calculation progresses. e.g. the Feldspar content in this column is taken from the result of the calculation described by the first line.

3) In the calculation column the symbols used are *derived* from the MACRO computer programme

* = X : " " = Not included in the formula.

Letters are used to explain the sequence of the calculations.

The calculation carried out according to The *Feldspar Convention* [4]

Total alkalis x 5.92 = **%** *feldspar*
%Feldspar x 0.183 = %A1203 in feldspar
%Feldspar x 0.647 = %Si02 in feldspar
(Total %A1203 - %A1203 in feldspar) x 2.53 = % *clay substance*
%Clay substance x 0.465 = %Si02 in clay
Total %Si02 - (%Si02 in clay + %Si02 in feldspar)= **%** *silica*

The calculation carried out for% *Water in the clay*

%Clay substance x 0.140 = loss due to water in the clay molecule.
(LOI - loss due to water in clay) = loss due to organic matter.

The calculation carried out according to *The Mica convention* [4]

%K20 x 8.47 = *%potash mica*
%Na20 x 12.32 = *%soda mica*
%Potash mica x 0.384 = %A1203 in potash mica
%Potash mica x 0.452 = %Si02 in potash mica
%Soda mica x 0.400 = %A1203 in soda mica
%Soda mica x 0.471 = %Si02 in soda mica
(Total %A1203 - %A1203 in micas) x 2.53 = **%** *clay substance*
%Clay substance x 0.465 = %Si02 in clay
Total %Si02 - (%Si02 in clay + %Si02in mica)= % *free silica*

4) The result of the calculation. The bold data is used for comparison of clays.

A full explanation of the above calculation is found in (Appendix A)
The explanation for use of the Data Base is given in Section 2.6.

2.5.2 The composition of the clay material.

The composition of the clay material and ultimately the clay body can be assessed from the above calculations. Tables of the data, compiled from the results of the ultimate analyses and the rational analyses, as well as additional comparative information, can be found in Chapter 4.

2.6 DATA BASE

2.6.1 Purpose 01 the Data Base

The information gathered in the course of this research project and any data that may be collected in the future must be collated in order to make it useful to the Ceramic Division, TWA.

2.6.2 Description 01 the Data Base

The computer software programme used for the purpose of storing the data is "INSIGHT Ceramic Calculations and Recipe Management Software for the Glaze, Clay and Glass sciences"(14)

The "tnslqht" programme does not contain calculations for the rational analysis of clays. Therefore the calculation Tables 2.3 and 2.4 were installed on a computer Macro worksheet that is accessible to the Illnsight" programme.

The materials entered in the Illnsight" Materials Definition Table (MDT) are American and Canadian but the table can be expanded to include additional materials.
In order to obtain the ultimate or chemical analysis and the rational analysis of a clay body using the'tnslqht" programme, the following steps must be followed:-

a) the chemical composition of the clay materials examined must be entered into the MDT making the analysis available for the theoretical blending of clay bodies (Table 2.5).

b) the materials can be recalled from the MDT and theoretically blended in the required quantities (Table 2.6).

c) The ultimate analyses and the formulae of the resultant clay bodies are obtained for comparative purposes.

d) The rational analysis can be calculated using the ultimate analysis (Table 2.7. See also Table 2.4) for additional comparison.

An explanation of Table 2.5 and 2.6 appears after the tables.

Table 2.5
EXAMPLE OF CLAY ENTERED INTO THE MATERIALS DEFINITION TABLE

MOSS CLAY MATERIAL	A	B
Si02		65.39%
Al203...		26.83%
Fe203		1.58%
Ti02..		1.36%
K20.		4.30%
Na20.		.24%
CaO		.03%
MgO		.24%
MnO		.02%
	94.31	100%
(LOI)	(5.70%)	

	E	F
	FORMULA	ANALYSIS
CaO	.00	.03%
MgO	.02	;23%
K20	.17	4.06%
Na20	.01	.23%
Fe203	.04	1.49%
MnO	.00	.02%
Ti02	.06	1.28%
*A1203	1.00	25.30%
Si02	4.14	61.66%

COSTIKG 0
L.O.I. 5.70%
RATIO 4.14
EXPAN 5.90
WEIGHT 403.20

Table 2.6
EXAMPLE OF CLAY MATERIAL BLENDED IN A CLAY BODY.

MOSS CLAY BODY	C	D
Moss Clay	50	50%
SA Silica	30	30%
SA KFelds	20	20%
	100	100%

The analyses for
SA Silica and SA K Feldspar
are included (Appendix E)

	G	H
	FORMULA	ANALYSIS
CaO	.00	.02%
MgO	.02	.12%
K20	.32	5.13%
Na20	.02	.26%
Fe203	.03	.81 %
MnO	.00	.01 %
Ti02	.05	:68%
*A1203	1.00	17.49 %
Si02	7.33	75.48 %

COSTIKG 0
L.O.\. nfa
RATIO 7.33
EXPAN 5.75
WEIGHT 583 05

The information gained from the"lnsight" programme is:-

a) .The clay recipe in *Standard Formula calculation* Shown in Table 2.5.and 2.6.

Column A: The ultimate analysis, calculated from the EDAX data This is, in effect, the "recipe" of the clay material. The LOI is entered in the programme and is accounted for in the calculation.

Column B: The ultimate analysis (recipe) including the LOI expressed as a percentage.

Column C: The clay body recipe

Column D: The recipe expressed as a percentage.

Column E: The formula of the clay in which the oxide mix is expressed according to the relative numbers of molecule types[141. This information can give insight into the molecular structure responsible for the firing behavior. The formula can be adjusted to show a single material or a group of materials as unity. In the case of clay it is convention to give Al_2O_3 as unity. This allows for comparison of materials.

Column F: The formula is multiplied by the atomic weight of each oxide and then brought to a percentage. In this instance it is similar to the ultimate analysis entered in Column A as the clay material is not blended. The LOI is not included.

Column G: The formula of the clay body.

Column H: The analysis of the clay body. This information can be entered into the rational analysis calculation (Table 2.4.)

. b)The *Detail Formula calculation* giving a detailed break down of materials into relative numbers of molecule types, or a *Mix ticket* giving the mixing instructions according to batch.slze, An example is not included of these two calculations as it is the same information as that in Column H in different format.

c) The "cost" has not yet been programmed.

d) The LOI taken from the results of the physical tests.

e) The Ratio of Silica to Alumina.

f) The thermal expansion of the clay theoretically calculated by the "Insight" programme.

g) The Molecular weight of the formula.

CHAPTER 3

RESULTS OF CLAY MATERIAL ANALYSIS

The results of the research into the composition of clay materials are included in this chapter. The analysis and summary of each of the nine clay materials is shown separately. It should be noted that the summary includes conclusions that will be repeated in Chapter 4 in order to make this chapter a complete reference of the clay materials. Details on the calculations included in this chapter are given in Appendix A, on the results of the physical tests in Appendix C, and the raw data from EDAX and ultimate and rational analyses can be found in Appendix D. The comparative tables of the results of the analyses are included in Chapter 4.

It should be noted in the Water Absorption and Linear Shrinkage tables that although the temperature is DoC the sample has in fact been fully dried to 11 OoC to rid the clay of the pore water and to complete the wet to dry shrinkage.

When giving the chemical composition of clays it is convention to list them as oxides and to include loss on ignition (LOI). In analysis done on calcined samples (e.g. Sample D) the LOI value is given. In such cases the analysis is adjusted to total 100 weight units.

It should be noted that the *clay table* and *spectrum* do not show the same information. The *clay table* shows the calculated ultimate analysis (Table 2.3) of the clay material in terms of the component oxides. The *spectrum* shows the relative amounts of elements in one of the two samples included in the ultimate analysis.

As the Rational analysis is based on the assumed mineralogical composition of the clay material (2.5.1.2) and as the results from the A and D samples proved to be similar, only the results of the A sample are included in the results for comparative purposes.

As a final comparative technique the nine clay materials chosen were combined with feldspar and silica in a known proportion and formed into clay bodies (2.3.3). The reason for this final comparison is that clay is seldom used in its found state but rather blended, to form a required body for use in the studio (1.1). These resultant clay bodies could be compared both quantitatively and empirically. The results of the plasticity tests appear in this chapter. The comparative table of the Ultimate analyses of the clay bodies can be found in Chapter 4 (Table 4.2).

BALL CLAY

3.1. A-CLAY

3.1.1. *Origin and Mineralogy*

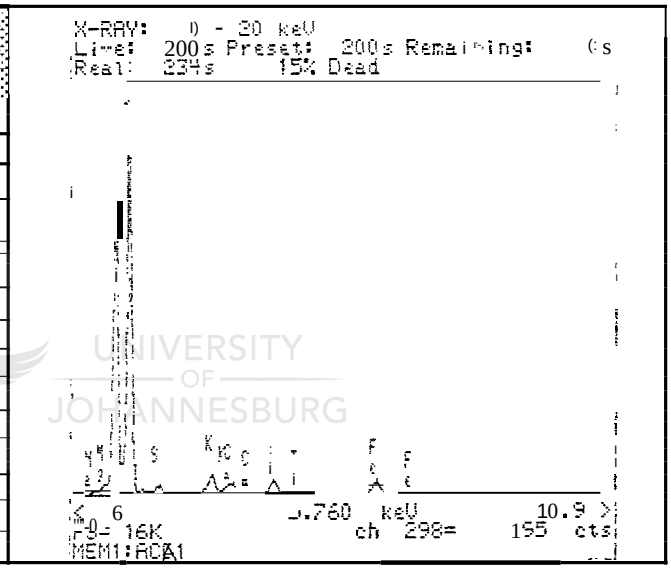
"A" clay occurs in the Vereeniging region. It is mined and supplied in an unaltered state.

3.1.2 *Clay analysis*

The Ultimate and Rational analyses were carried out from the data collected on the SEM./EDAX (2.5.1) (Appendix D). The results of the Ultimate analysis of A-Clay A can be found in (Table 3.1) and D in (Table 3.4) The results of the Rational analysis of A-Clay A can be found in (Table 3.5).

TABLE & SPECTRUM 3.1
COMPOSITION OF A-CLAY A

Oxide	Oxide Wt %
Si02	46.02
Al203	34.07
Fe203	3.53
Ti02	2.18
K20	1.37
Na20	0.20
CaO	0.91
MgO	0.50
MnO	0.07
SO	0.58
LOI	10.6
Total	100.00



A -CLAY A

Magnification X 2000

The individual hexagonal flat platelets can be seen. (Ch. 1)

FIG 3.1 EXAMPLE OF CLAY SURFACE A CLAY A

A -CLAY A

Magnification X 1160

This micrograph shows an individual, magnesium rich, particle
These isolated particles proved to be quite common in this clay. Needle-like particles can be seen around the magnesium particle.

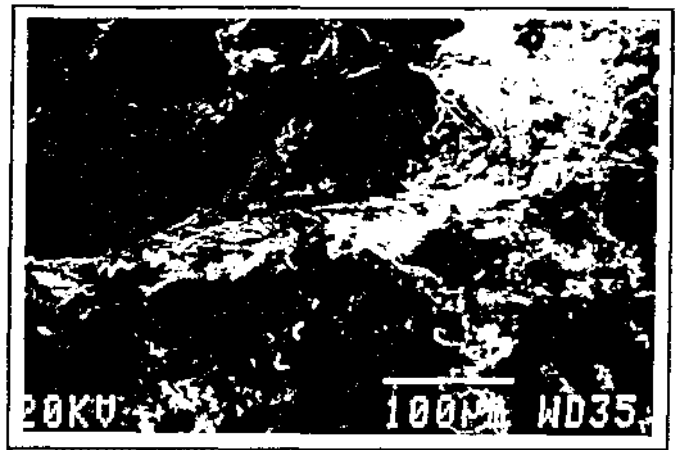
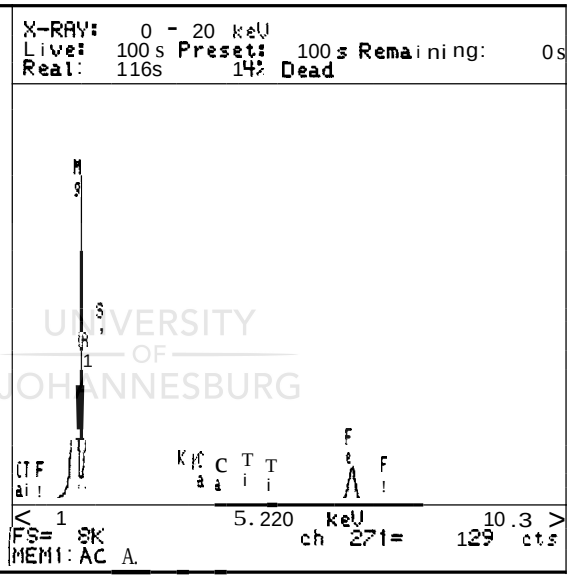


FIG 3.2 EXAMPLE OF CLAY SURFACE A-CLAY A

SPECTRUM 3.2 A-CLAY A

Composition of the particle indicated in Fig 3.2



SPECTRUM 3.3

This spectrum shows the composition of a particle found in A-Clay. This particle is high in Fe and proved to be common in this clay material.

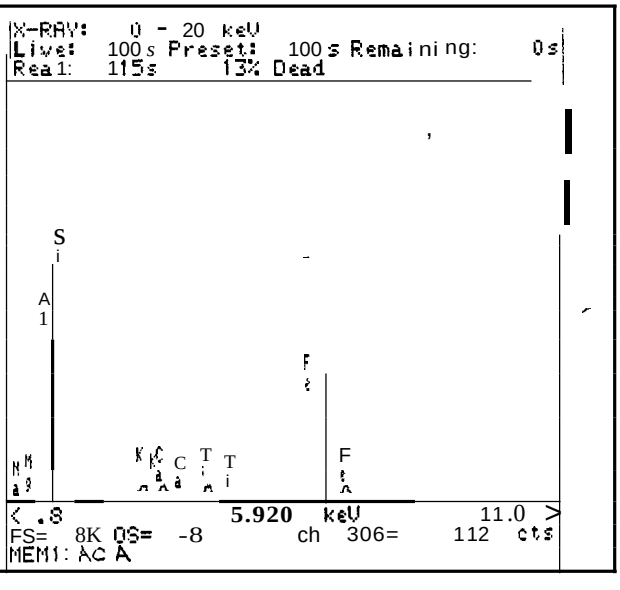
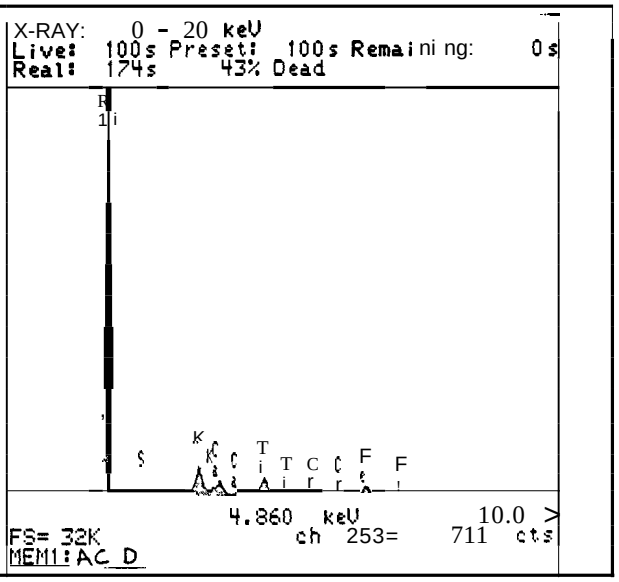


TABLE & SPECTRUM 3.4
COMPOSITION OF A-CLAY D

Oxide	OxideWt. %
Si02	49.82
Al203	33.57
Fe203	1.68
Ti02	1.93
K20	1.01
Na20	0.07
CaO	0.35
MgO	0.38
MnO	0.02
SO	0.58
LOI	10.6
Total	100.00



A-eLAYD

Magnification X 600

This is a micrograph of the surtace of the clay fired to 1200^{0}C

Large well fluxed particles can be seen. These particles are also visible in FIG 3.5

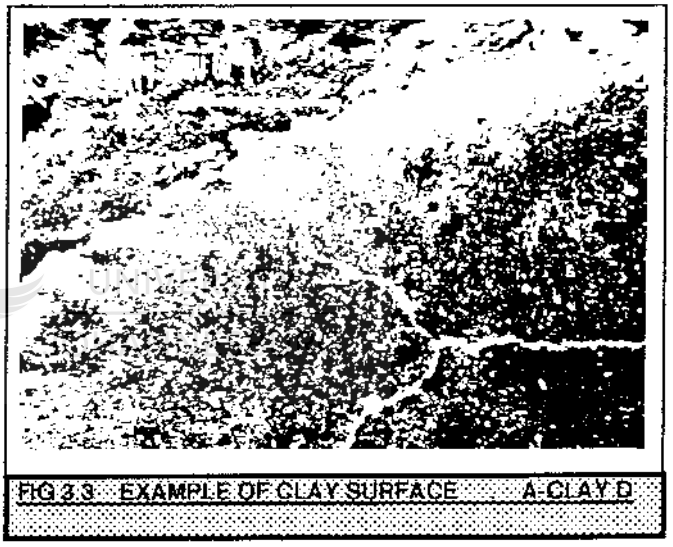


FIG 3.3 EXAMPLE OF CLAY SURFACE A-CLAY D

A -CLAY D

Magnification X 1200

This micrograph of the crack. in FIG 3.3 shows "ligaments" of fluxed material preventing the crack from splitting open.

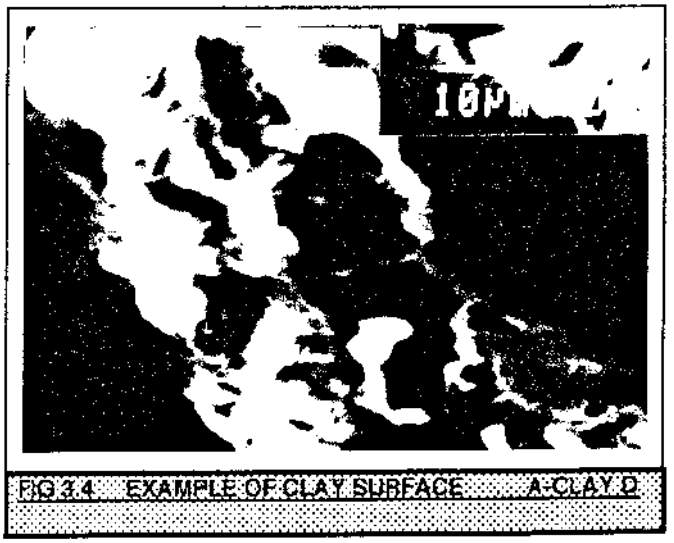


FIG 3.4 EXAMPLE OF CLAY SURFACE A-CLAY D

TABLE 3.5 RATIONAL ANALYSIS A -CLAY A	
FELDSPAR CONVENTION	
Material	Weight 00
Feldsoar	9.12
Clav substance	81.06
Free Silica	2.10
MICA CONVENTION	
Potash mica	11.43
Soda Mica	2.34
Clav substance	71.81
Free Silica	5.87
00 WATER IN CLAY : %ORGANIC MATTER	
Loss :H20 in Clay	11.35
Loss: CO2 etc.	0

The data in Table 3.5 is the result of the Rational Analysis calculation (Table 2.4)

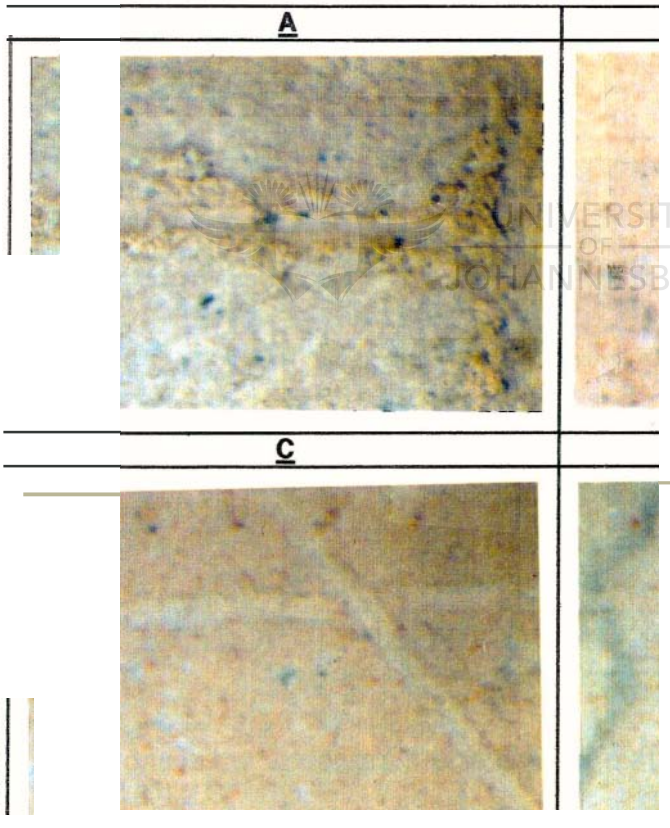


FIG 3.5

PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.1.3 Clay Properties

3.1.3.1 Water Absorption and Linear Shrinkage

A-CLAY

1 - -I Absorption
Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.

There is no value for the absorption test for A-Clay A as the sample is unfired and disintegrates in water.

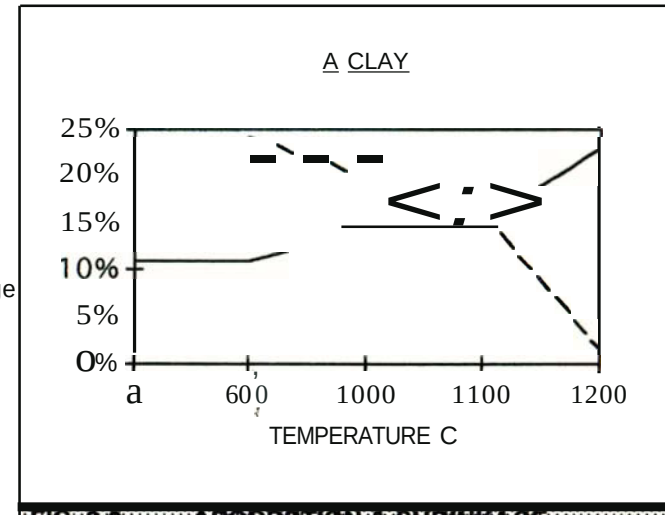


FIG 3.6 ABSORPTION & SHRINKAGE

3.1.3.2 Colour

A-CLAY

Photograph of A -CLAY fired to the selected temperatures. The change in colour can be clearly seen.

The colour at 11OOoC (C) is the palest.

FIG 3.7 COLOUR OF THE A-CLAY SURFACE

3.1.3 3 Particle Size

2 microns is the upper grain-size limit for materials to be classified as clay.[2] 2.4.2.3

PARTICLE SIZE :	The peak in the size distribution is at 20 μm and 3.9% of the particles are less than 2 microns in size .(Appendix C)

3.1.4 Summary and Preliminary Evaluation

A-clay is a plastic fire- clay from the clayfields of Vereeniging and Van der Bijl Park. Fire-clays are suitable for making oven ware.

A-clay has 5.71 % combined Fe+Ti (Table 3.1)The requirement for whiteware is 2% (2.5.2.1) With additions of Feldspar and Silica to make up a clay body. this clay could be useful for a slightly off-white ware fired to 1100^0 e The titanium content is the highest of all the clays tested (Table 4.1). This will enhance the staining power of the iron in the clay material.

The % particles below 2 microns is low (3.1.3.3) with the peak at the largest value in the particle size valuation at 20μm indicating that there is a fairly high proportion of large clay particle but a spread of particle sizes making the clay material very plastic when formed into a clay body.This clay material is high in Alkaline earths (Table 4.1 b) (1.2) a contributing factor to plasticity.l6)

The Alumina content is the highest among the selected clays materials making the material refractory. This will minimise the shrinkage and increase the firing range (Table 4.1).

The total of the fluxes = 3.0% (Table 4.1). The clay fluxes strongly after 1100^oe· (FIG3.S) The fluxing begins in small isolated pinheads (FIG 3.5)

Along with the fluxing the colour changes. (FIG 3.7)

BALL CLAY

3.2 B13 BALL CLAY

3.2.1 Origin and Mineralogy

The clay deposit is on the farm 8uffelsfontein in the Riversdale district. The material consists mainly of kaolinite, illite and quartz,l10j

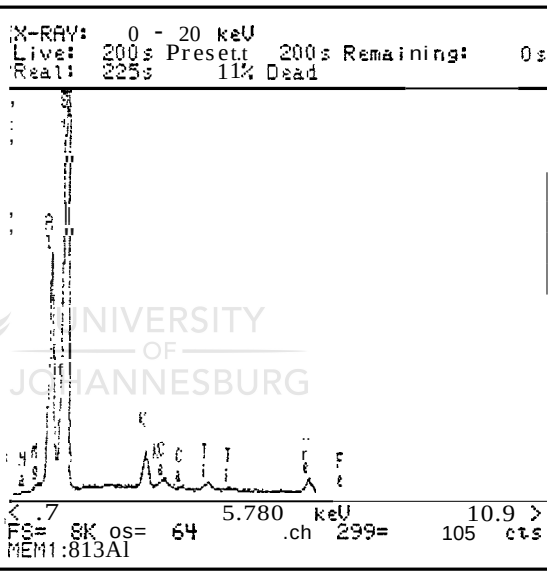
3.2.2 Clay Analysis

The Ultimate and Rational analyses were carried out using the data collected by the SEM./EDAX (2.5.1). The results of the Ultimate analysis of 813 Clay A can be found in (Table 3.6) and D in (Table 3.7). The results of the Rational analysis can be found in (Table 3.8).

Two samples of the clay were analysed as a new batch of clay was brought into the studio. (3.2.4)

TABLE & SPECTRUM 3.6
COMP. B13 CLAY (1 &2) A

Oxide	Oxide Wt o/o	
	1	2
Si02	61.29	61.15
Al203	24.19	24.91
Fe203	2.38	2.19
Ti02	1.12	1.08
K20	2.59	2.41
Na20	0.11	0.09
CaO	0.81	0.64
MqO	0.62	0.72
MnO	0.08	0.00
LOI	6.8	6.8
Total	100.00	100.00



813 CLAY A

Magnification X 2000

The individual hexagonal flat platelets can be seen. (1.2) This photo is taken of a rough patch where the particles are separate.

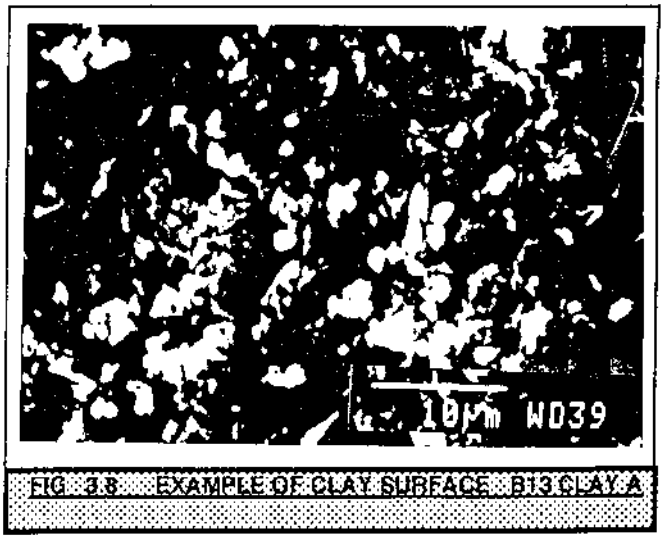


FIG. 3.8 EXAMPLE OF CLAY SURFACE B13 CLAY A

813 CLAY A

Magnification X 2000

Sample of 813 A in powder form. The flat flaky nature of the particles is shown.

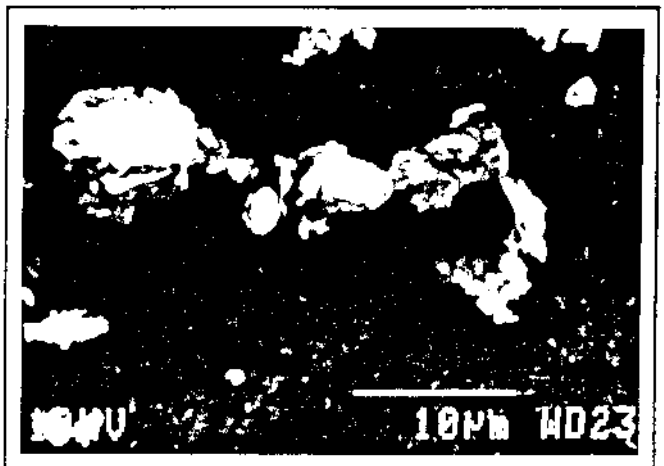


FIG. 3.9 EXAMPLE OF CLAY SURFACE. B13 CLAY A

813 CLAY 8

Magnification X 2200

This is the only example of a 8 sample in the SEM. The particles are still separated and unchanged in form after firing at this temperature. (Table 2.1)

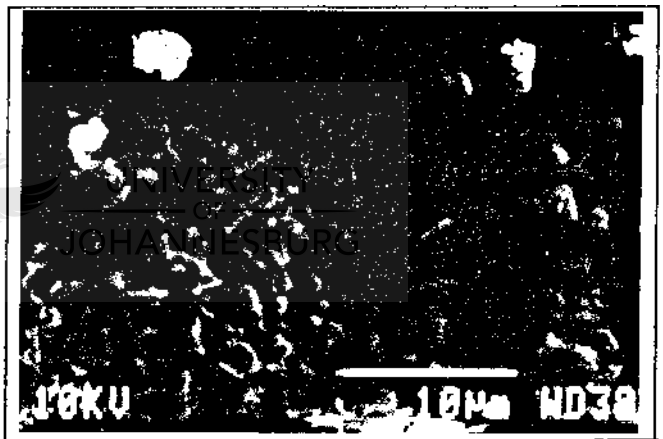
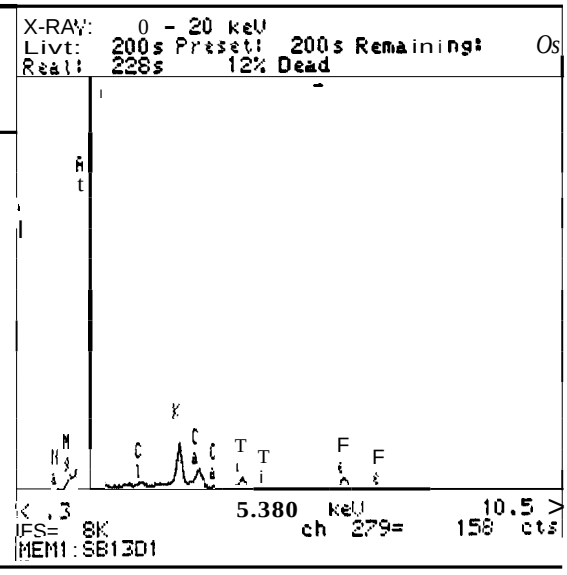


FIG. 3.10 EXAMPLE OF CLAY SURFACE. B13 CLAY B

TABLE & SPECTRUM 3.7
COMPOSITION OF B13 CLAY (1 &2) D

Oxide	Oxide Wt %	
	1	2
Si02	60.94	62.34
Al203	20.77	22.41
Fe203	2.07	2.03
Ti02	1.17	1.41
K20	2.26	2.37
Na20	0.16	0.13
CaO	3.33	1.76
MgO	0.59	0.68
MnO	0.00	0.08
+Cl &5	(1.91)	
LOI	6.8	6.8
Total	98.09	100.00



813 CLAY D

Magnification X 600

The sintered surface with separate particles is shown in this micrograph

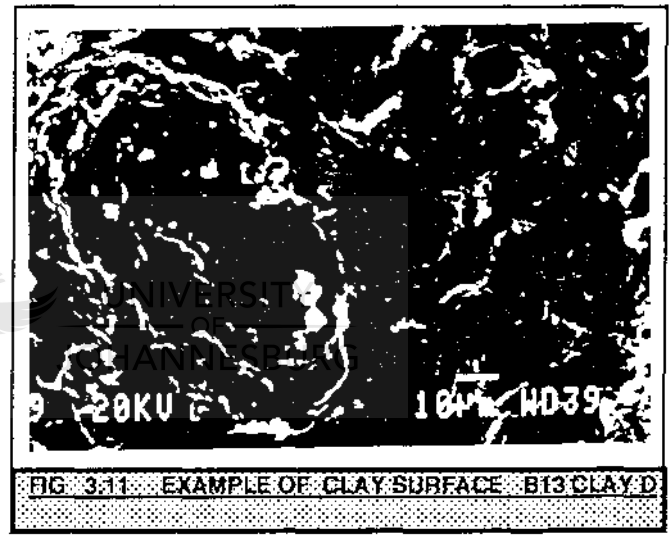


FIG 3.11 EXAMPLE OF CLAY SURFACE B13 CLAY D

813 CLAY D

Magnification X 600

The sintered surface of the clay material can be seen .

FIG 3.12 EXAMPLE OF CLAY SURFACE B13CLAY D

TABLE 3.8 RATIONAL ANALYSIS B13 CLAY(2) A	
FELDSPAR CONVENTION	
Material	Weight Percentage
Feldspar	15.98
Clay substance	53.8
Free Silica	26.04
MICA CONVENTION	
Potash mica	21.43
Soda Mica	1.23
Clay substance	37.69
Free Silica	32.05
00 WATER IN CLAY: %ORGANIC MATTER	
Loss H_2O in Clay	7.53
Loss: CO_2 etc.	0

The data in Table 3.3 is the result of the Rational Analysis calculation (Table 2.4)

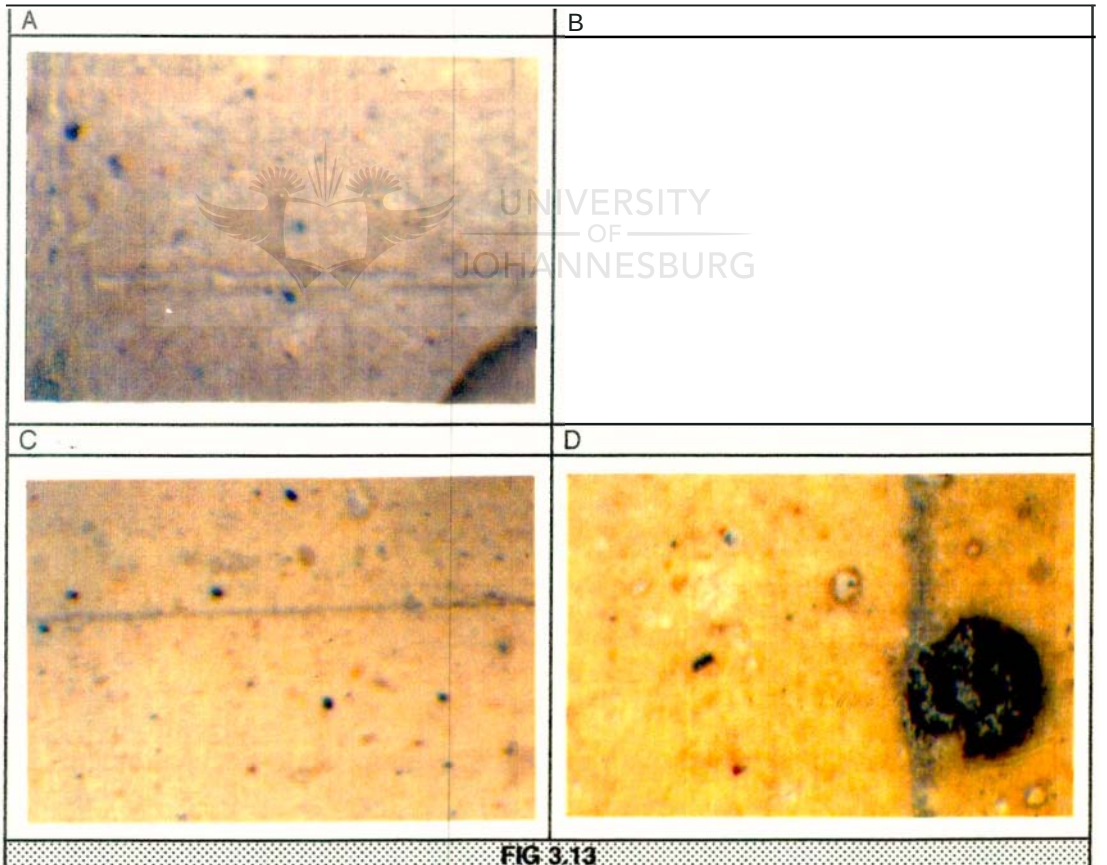
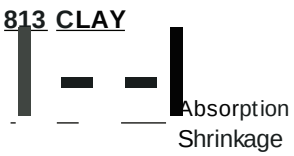


FIG 3.13

PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.2.3 *Clay Properties*

3.2.3.1 Water Absorption and Linear Shrinkage



The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.
The temperatures are those shown in Table 2.1
There is no value for the B13-A absorption test as the sample is unfired and disintegrated in water

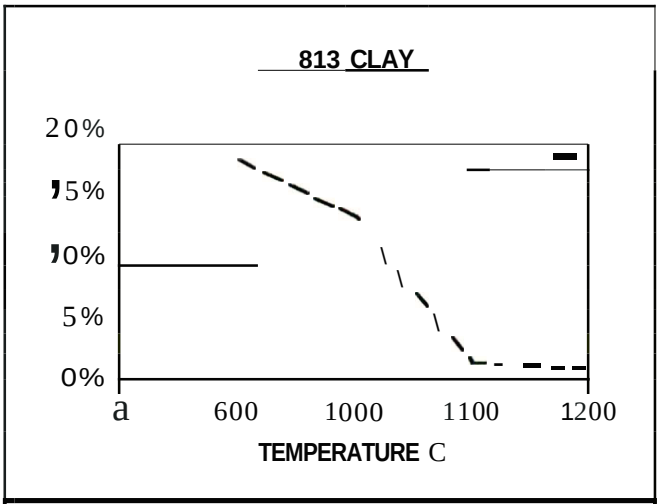


FIG 3.14 ABSORPTION & SHRINKAGE

3.2.3.2 Colour

813 CLAY

Photograph of B13 CLAY fired to the selected temperatures. The change in colour can be clearly seen.

The colour at 1100°C (C) is the palest.. At 1200° the colour is a yellow/green

FIG 3.15 COLOUR OF THE B13 CLAY SURFACE

3.2.3 3 Particle Size

2 microns is the upper grain-size limit for materials to be classified as clay.[2] (2.4.2.3)

PARTICLE SIZE	The peak in the size distribution is from 2μm to 7μm and 16.2 % of the particles are less than 2 μm in size (Appendix C)

3.2.4 Summary and Preliminary evaluation.

B 13 is a commonly used clay supplied by G&W Base Minerals.

On examination the clay appears fine particled but highly speckled. (FIG 3.13) The clay content is high 16.2% of the particles are below 2μm in size (3.2.3.3)

The clay mixed into a clay body was of average plasticity.

The Fe+Ti content is 3.2%. When combined with feldspar and silica to form a clay body the white wares requirement of 2% would be met. The clay has a characteristic green tinge at fluxing temperatures.(3.15) Fluxing occurs giving a biscuit-like surface.

Separate particles of iron, chromium, titanium and calcium were identified in the materiaL

The absorption curve shows that vitrification is almost complete by 11aaoe and the shrinkage is minimal from e to D. Le. 11OOVC - 12aOoe (Fig 3.14)

When comparing the two clay samples of B13 it was found that the iron content in sample 1 is almost .2% higher than sample 2 and the total flux content in sample 1 is 13.3% higher than in sample 2.and 44% higher than the supplier's analysis states. (Appendix B)

BALL CLAY

3.3 C-CLAY

3.3.1 Origin and Mineralogy

C-Clay (Crous clay) is mined at Peyneskraal in the Grahamstown district. The material consists mainly of illite with a small amount of kaolinite[11]

3.3.2 Clay Analysis

The Ultimate and Rational analyses were carried out using the data collected on the SEM IEDAX (2.5.1)(Appendix D)The results of the ultimate analysis of C-clay A can be found in (Table 3.9) and D in (Table 3.10) The results of the Rational analysis of C-Clay can be found in (Table 3.12)

TABLE & SPECTRUM 3.9
COMPOSITION OF C-CLAY A

Oxide	Oxide Wf%
Si02	63.90
Al203	23.35
Fe203	0.98
Ti02	1.08
K20	3.44
Na20	0.24
CaO	0.47
MgO	0.39
MnO	0.04
LOI	6.1
Total	100.00

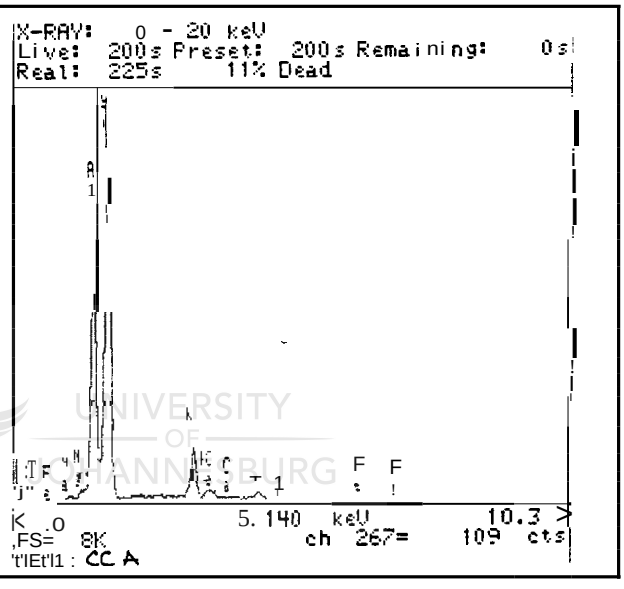
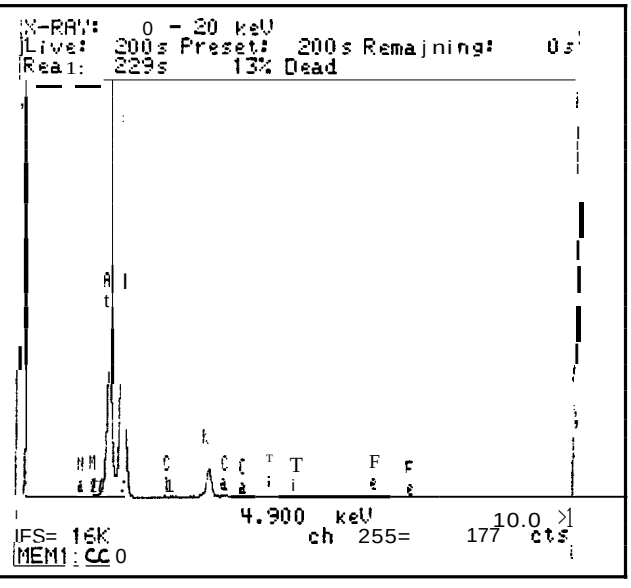


TABLE & SPECTRUM 3.10
COMPOSITION OF C-CLAY D

Oxide	Oxide %
Si02	64.61
Al203	23.93
Fe203	1.03
Ti02	0.93
K20	2.76
Na20	0.28
CaO	0.09
MgO	0.25
MnO	00.0
LOI	6.1
Total	100.00



c-eLAV 0

Magnification X 600

The individual hexagonal flat platelets can be seen. (1.2) The particles are beginning to sinter and coagulate.

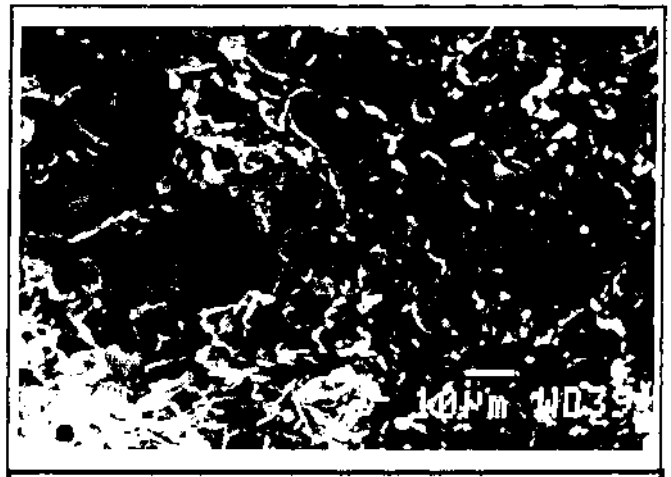


FIG 3.16 EXAMPLE OF CLAY SURFACE C-CLAY D

C-eLAVD

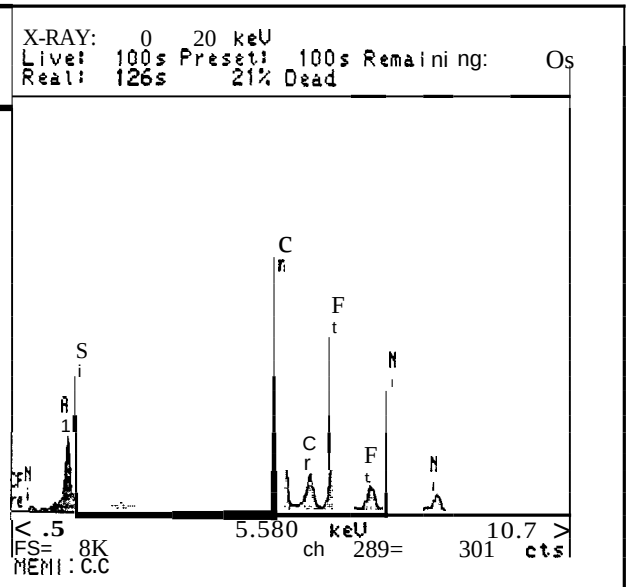
Magnification X 2000

The individual particles have run together forming a lattice on the surface.

FIG 3.17 EXAMPLE OF CLAY SURFACE C-CLAY D

SPECTRUM 3.11
COMPOSITION OF C-CLAY D

A example of an isolated particle rich in Fe Cr and Ni included in the clay material. (Fig 3.18)



c-eLAY D

Magnification X 600

The particle of Cr,Fe and Ni can be seen resting on the surface. the surrounding clay is sintered and congealed.(Spectrum 3.11)

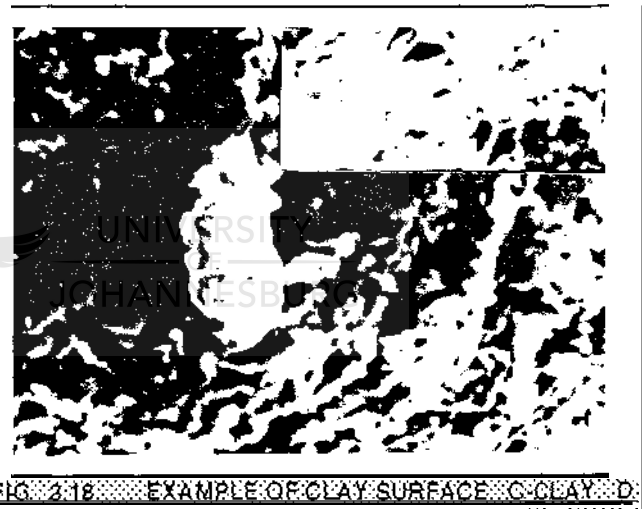


FIG 3.18 EXAMPLE OF CLAY SURFACE C-CLAY D

TABLE 3.12 RATIONAL ANALYSIS C-CLAY A	
FELDSPAR CONVENTION	
Material	Weight%
Feldspar	21.76
Clay substance	48.99
Free Silica	27.12
MICA CONVENTION	
Potash mica	29.14
Soda Mica	2.96
Clay substance	27.78
Free Silica	36.42
00 WATER IN CLAY: %ORGANIC MATTER	
Loss : H_2O in Clay	6.86
Loss: C0 2 etc.	0

The data in Table 3.12 is the result of the Rational Analysis calculation (Table 2.4)

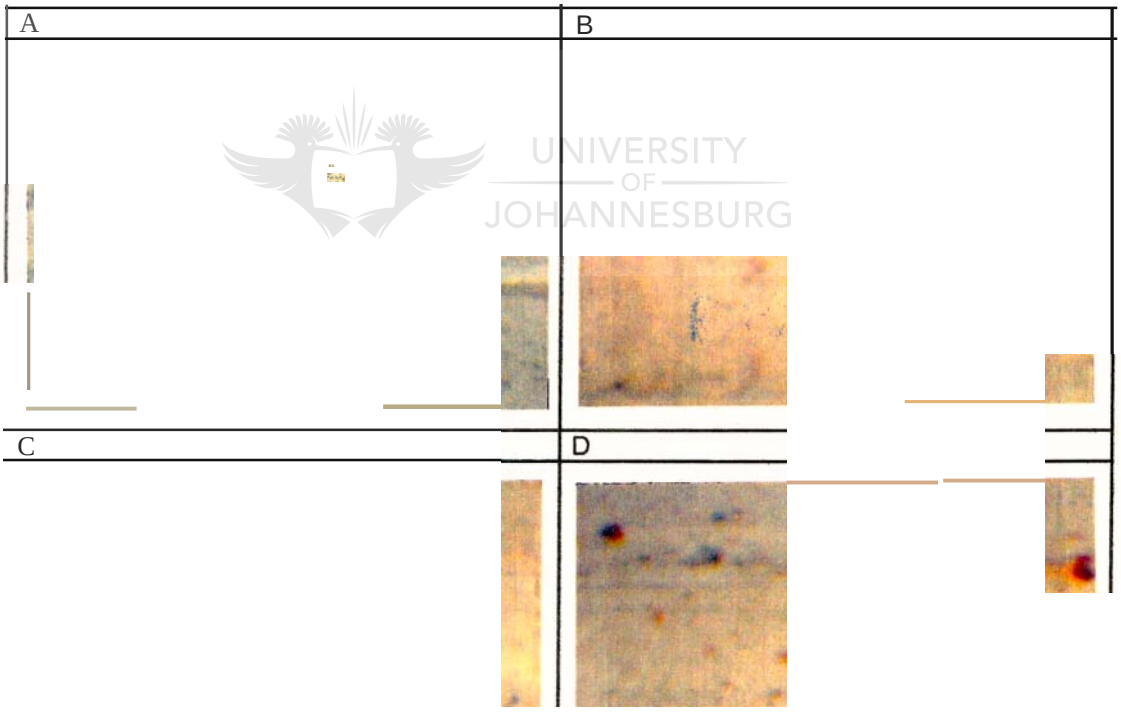


FIG 3.19

PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.3.3 Clay Properties

3.3.3.1 Water Absorption and Linear Shrinkage

C-CLAY

Absorption
Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.
There is no (A) or 600°C value for the absorption test as these samples disintegrated in water.

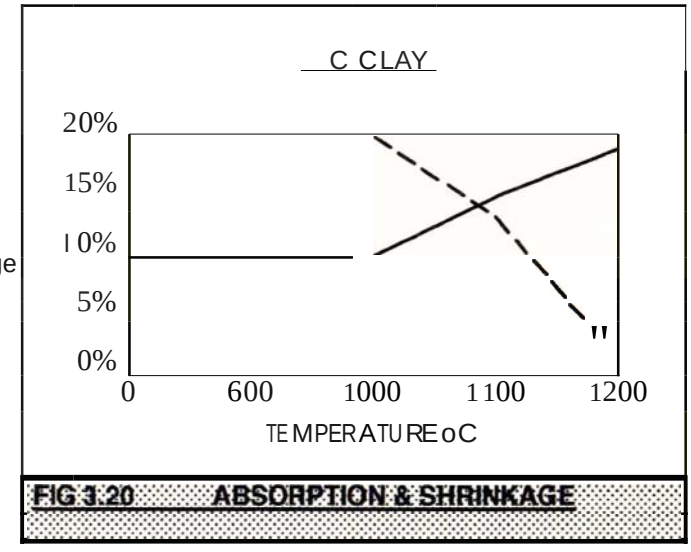


FIG 3.20 ABSORPTION & SHRINKAGE

3.3.3.2 Colour

C-CLAY

Photograph of C-CLAY fired to the selected temperatures.

This is a light coloured clay, even at high temperatures.

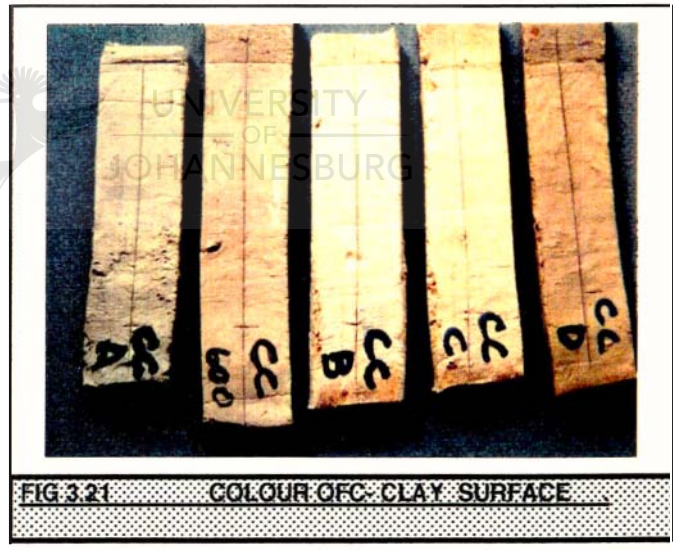


FIG 3.21 COLOUR OFC- CLAY SURFACE

3.3.3 3 Particle Size

2 microns is the upper grain-size limit for materials to be classified as clay.l2] 2.4.2.3

PARTICLE SIZE	The peak in the size distribution is at 8μm and7.4 % of the articles are less than 2 m in size A endix c)

3.3.4 Summary and Preliminary evaluation.

C-Clay is.amonq the whitest of the clays tested. The combined Fe+Ti value is 2.06% (Table 4.1 a) making it a suitable whiteware clay but the clay displays a tendency to dilate when combined in a clay body and the plasticity is mediocre.(3.32)

The Silica content is the highest of the tested clays and the Alumina the 10west.(FIG 4.1)

The total flux content is 4.58% which is high. The result of this can be seen in the total vitrification of the clay at 1200oe (FIG 3.20) but the clay was not sintered at 600oe causing the sample to disintegrate when boiled for the water absorption test.

The fluxing occurs in "chains" over the surface of the material. (FIG 3.17)

BALL CLAY

3.4 MOSS CLAY

3.4.1 Origin and Mineralogy

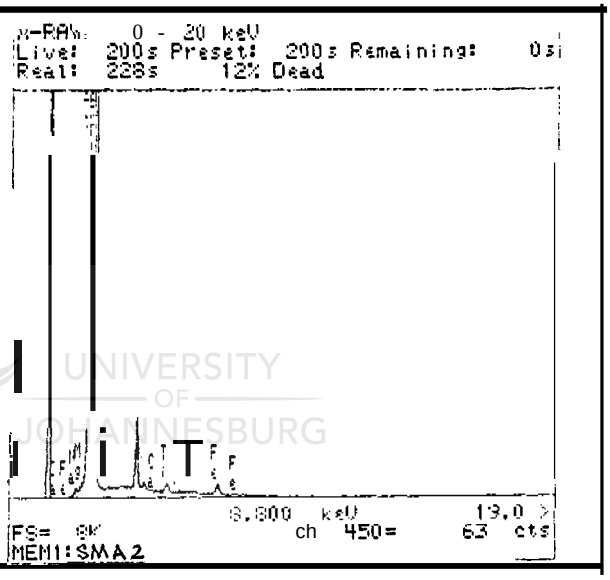
The deposit is on the farm Collingham in the Grahamstown district. The material consists mainly of kaolinite, illite and quartz with a little pyrophyllite and feldspar.[10]

3.4.2 Clay Analysis

The Ultimate and Rational analyses were carried out using the data collected on the SEM./EDAX (2.5.1) (Appendix D). The results of the Ultimate analysis of Moss clay A can be found in (Table3.13) and D in (Table 3.14). The results of the Rational analysis of Moss clay A can be found in (Table 3.16)

TABLE & SPECTRUM 3.13
COMPOSITION OF MOSS CLAY A

Oxide	Oxide Wt %
Si02	61.67
Al203	25.30
Fe203	1.49
Ti02	1.28
K20	4.06
Na20	0.23
CaO	0.03
MgO	0.23
MnO	0.02
LOI	5.7
Total	100.00



MOSS CLAY A

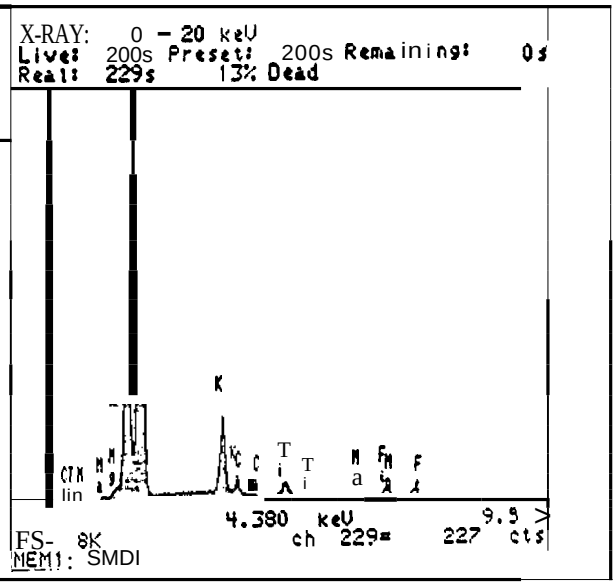
Magnification X 2000

The individual hexagonal flat platelets can be clearly seen. (1.2)

FIG. 3.22 EXAMPLE OF CLAY SURFACE MOSS CLAY A

TABLE & SPECTRUM 3.14
COMPOSITION OF MOSS CLAY D

Oxide	Oxide Wt%
Si02	56.88
Al203	29.21
Fe203	1.64
Ti02	1.38
K20	4.06
Na20	0.31
cao	0.01
MaO	0.27
MnO	0.53
LOI	5.7
Total	100.00



MOSSCLAY **0**

Magnification X 3500

The individual hexagonal flat platelets can be seen.

Moss clay exhibited the well known "stack of cards" structure

FIG.3.23 EXAMPLE OF CLAY SURFACE MOSS CLAY D

MOSS CLAY **0**

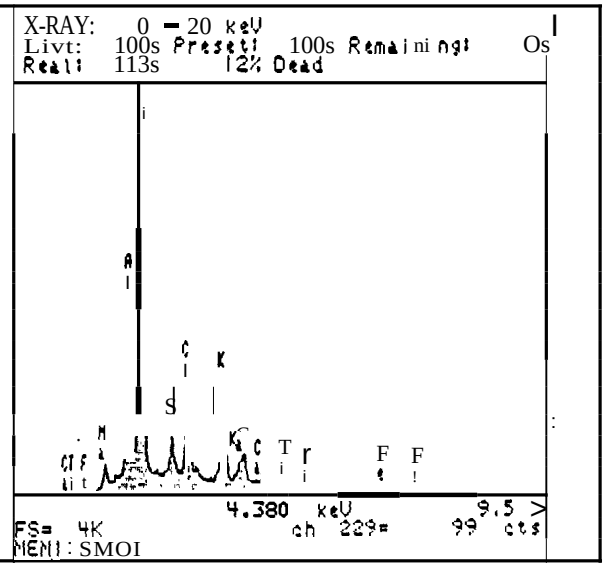
Magnification X 3500

The individual hexagonal flat platelets can be seen stacked on edge.

FIG.3.24 EXAMPLE OF CLAY SURFACE MOSS CLAY D

SPECTRUM 3.15
COMPOSITION OF MOSS CLAY D

This spectrum shows the occurrence of S and CI in the clay. The separate particles can be seen in
(FIG 3.25 and 3.26)



MOSS CLAY 0

Magnification X 750

The white particle can be seen on the surface of the clay.
See (Spectrum 3.15)

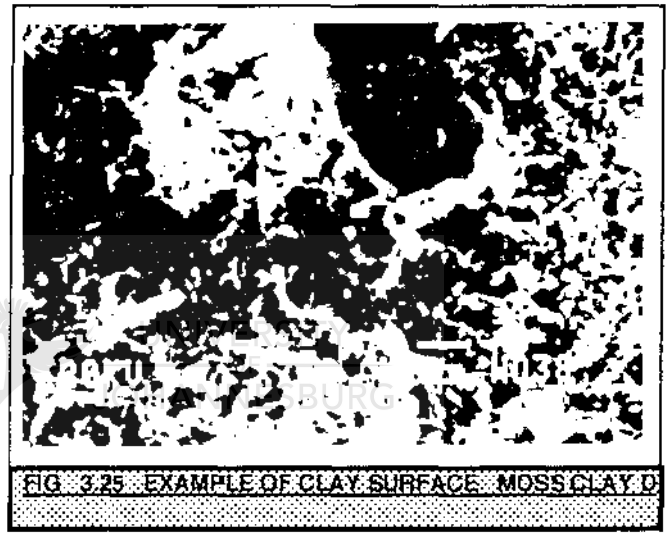


FIG 3.25 EXAMPLE OF CLAY SURFACE MOSS CLAY D

MOSSCLAY D

Magnification X 1500

This is an enlargement of FIG 3.25 . The string like attachments of the sintered particles can be seen

FIG 3.26 EXAMPLE OFCLAY SURFACE MOSS CLAY D

TABLE 3.16 RATIONAL ANALYSIS MOSS CLAY A	
FELDSPAR CONVENTION	
Material	Weiaht 0/0
Feldspar	25.40
Clav substance	52.25
Free Silica	21.04
MICA CONVENTION	
Potash mica	34.39
Soda Mica	2.83
Clay substance	27.73
Free Silica	31.90
0/0 WATER IN CLAY: %ORGANIC MATTER	
Loss H_2O in Clay	7.31
Loss: CO_2 etc.	0

The data in Table 3.16 is the result of the Rational Analysis calculation (Table 2.4)

3.4.3 ***Clay Properties***

3.4.3.1 Water Absorption and Linear Shrinkage

MOSS **CLAY**

Absorption

Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.

There is no (A) value for the absorption test

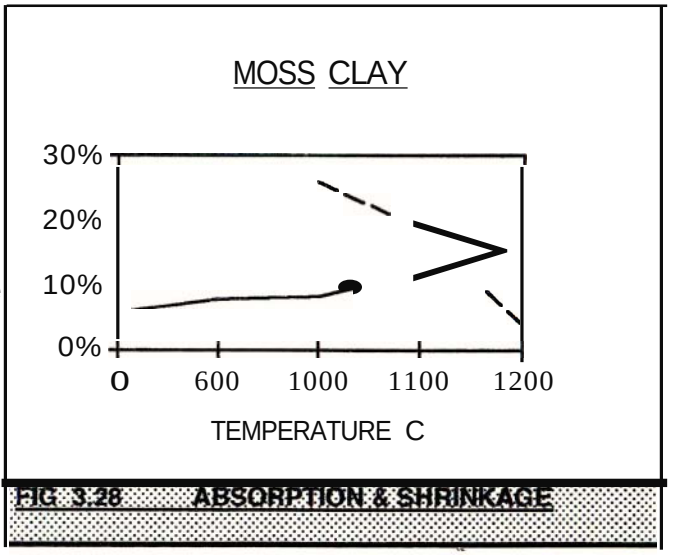


FIG 3.28 ABSORPTION & SHRINKAGE

3.4.3.2 Colour

MOSS CLAY

Photograph of A CLAY fired to the selected temperatures. the change in colour can be clearly seen.

The colour at 11*OOGC* (C) is the palest.

FIG 3.29 COLOUR OF THE MOSS CLAY SURFACE

3.4.3 3 Particle Size

2 microns is the upper grain-size limit for materials to be classified as clay.f[2] 12.4.2.3

PARTICLE SI

The peak in the size distribution is at 8.5μm and 5.1 % of the articles are less than 2 microns in size A endix C

3.4.4 *Summary and Preliminary evaluation.*

Moss clay is a readily available clay supplied by G & W Base Minerals.

This clay is close to fluxing point at 1200^0C but is still absorbent at 1100^0C.(Fig 3.28)

The particle size test showed that the peak at the largest value of the particle size valuation is below $10\mu m$ and there is an even spread of particle sizes. Although a low proportion of particles was clay material, in the throwing test this clay proved to be very plastic and firm to throw with.

Moss clay exhibits a matrix of varying sized particles.(FIG 3.22) and a non- compacted surface different to any of the other clay materials.

The combined Fe + Ti content is 2.77 %(Table 4.1) making it a possible clay for whitewares as this content will be less than 2% after blending, even in high proportions.

The total fluxes are 4.57% which is the highest along with C Clay (Table 4.1a) The particles show a spider-like fluxing pattern over the surface of the material at 12000C.

BALL CLAY

3.5 PXX BALL CLAY

3.5.1 Origin and Mineralogy

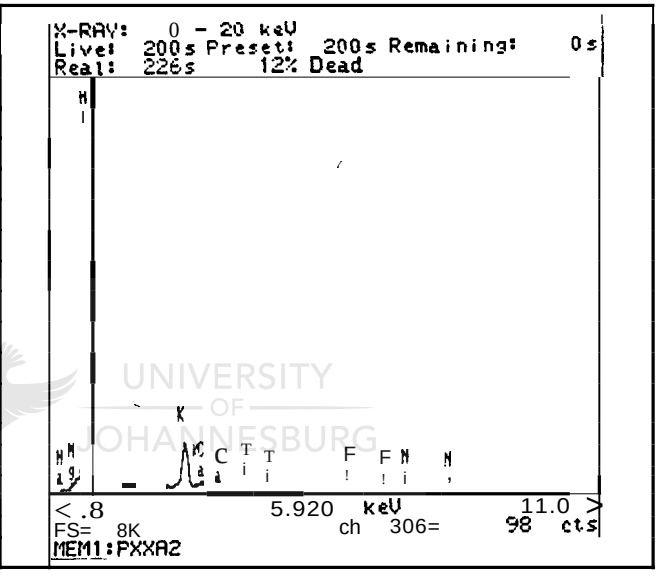
PXX is an imported Ball clay. Origin and mineralogy unknown

3.5.2 *Clay analysis*

The Ultimate and Rational analyses were carried out using the data collected on the SEM IEDAX (2.5.1)(Appendix D). The results of the Ultimate analysis of PXX-clay A can be found in (Table 3.17) and D in (Table3.18). The results of the Rational analysis of Pxx-Clay A can be found in (Table 3.19).

TABLE & SPECTRUM 3.17
COMOSITION OF PXX CLAY A

Oxide	Oxide WT%
Si02	53.29
Al203	32.62
Fe203	1.04
Ti02	0.97
K20	2.62
Na20	0.15
CaO	0.22
MgO	0.43
MnO	0.03
LOI	8.60
Total	100.0



PXXCLAY A

Magnification X 2000

The individual hexagonal flat platelets can be seen.

The clay is homogeneous.

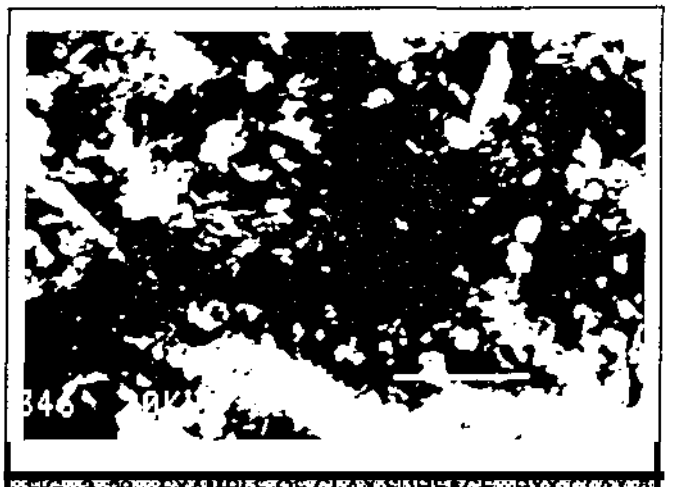
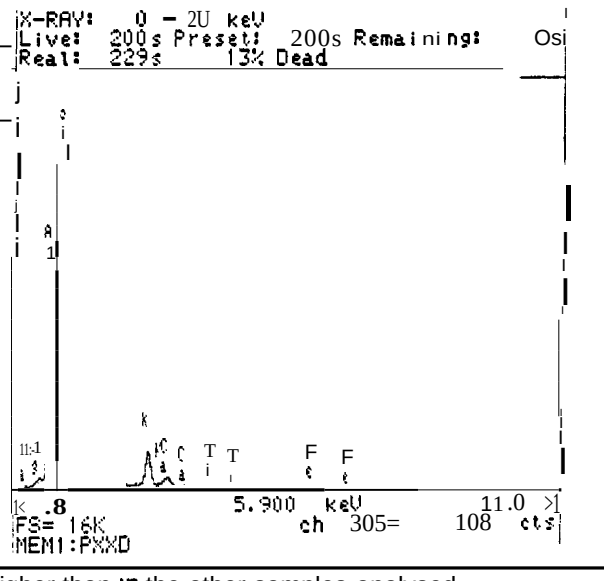


FIG 3.28 EXAMPLE OF CLAY SURFACE PXX CLAY A

TABLE & SPECTRUM 3.18

COMPOSITION OF PXX CLAY D

Oxide	OXide Wr %
Si02	49.07
Al203	29.59
Fe203	1.87
TI02	1.29
K20	2.75
Na20	0.23
CaO	5.52
MgO	1.07
MnO	0.02
LOI	8.60
Total	100.0



NOTE: The CaO in this sample is higher than in the other samples analysed

PXXCLAY 0

Magnification X1000

The sintered surface.

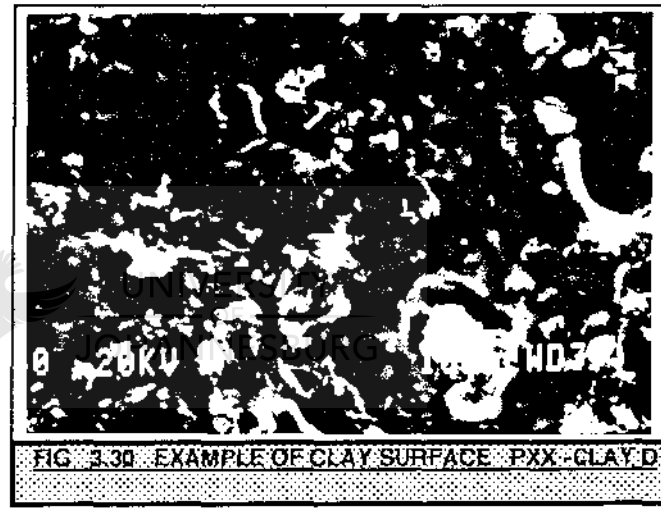


FIG 3.30 EXAMPLE OF CLAY SURFACE PXX-CLAY D

PXX CLAY 0

Magnification X12

The round sponge like particles can be seen.
The particles are of the same composition as the surrounding material.

FIG 3.31 EXAMPLE OF CLAY SURFACE PXX-CLAY D

3.5.4 Summary and Preliminary evaluation.

PXX Bait Clay is an imported clay used for white throwing and slip casting bodies. It was analysed in this project for comparison.

PXX Ball Clay is white at all temperatures (FIG 3.34) The combined Fe+Ti content is 2.01% which falls easily within the 2% white wares limit.
(Table 4.1)

The fluxing on the surface occurs in pinheads similar to those seen in the Kaolins

The total fluxes equal 3.45% (Table 4.1). The clay is close to vitrification at 11aaoc and the shrinkage is between 15% - 20%.(Fig 3.33)

This clay proved to be very plastic when formed into a clay body and thrown on the wheel.(Table 3.32) The clay content of the material is high, 74.85% as can be noted in (Table 4.3) The particle size distribution is evenly spread without any particular peak(Appendix C).

BALL CLAY

3.6 WESTERN PROVINCE BALL CLAY

3.6.1 Origin and Mineralogy

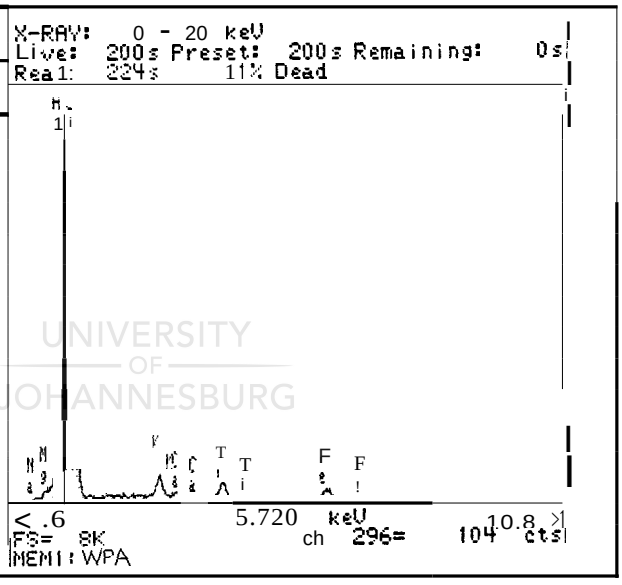
Western Province Ball Clay is mined near Kraaifontein in the Stellenbosch district. The material consists mainly of kaolinite with some quartz. The organic matter content is very high.[10]

3.6.2 Clay Analysis.

The Ultimate and Rational analyses were carried out using the data collected on the SEM IEDAX (2.5.1)(Appendix D).The results of the Ultimate analysis of WPBC-A can be found in (Table 3.20) and D in (Table 3.21).The results of the Rational analysis of WPBC-A can be found in (Table 3.22)

TABLE & SPECTRUM 3.20
COMPOSITION OF WPBC A

Oxide	Oxide Wt%	
	1	2
Si02	50.64	50.97
Al203	32.16	31.70
Fe203	1.73	1.74
Ti02	1.58	1.64
K20	1.15	1.13
Na20	0.08	0.06
CaO	0.19	0.18
MaO	0.58	0.59
MnO	0.00	0.10
LOI	11.90	11.90
Total	100.01	100.00



WPBC CLAY A

Magnification X 2000

The individual hexagonal flat platelets can be seen.

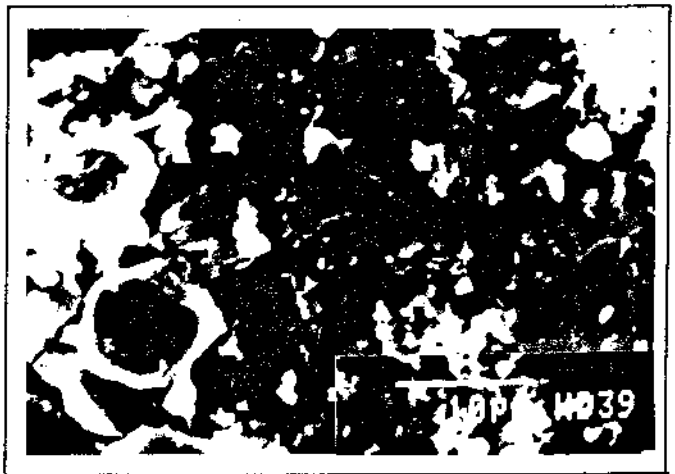
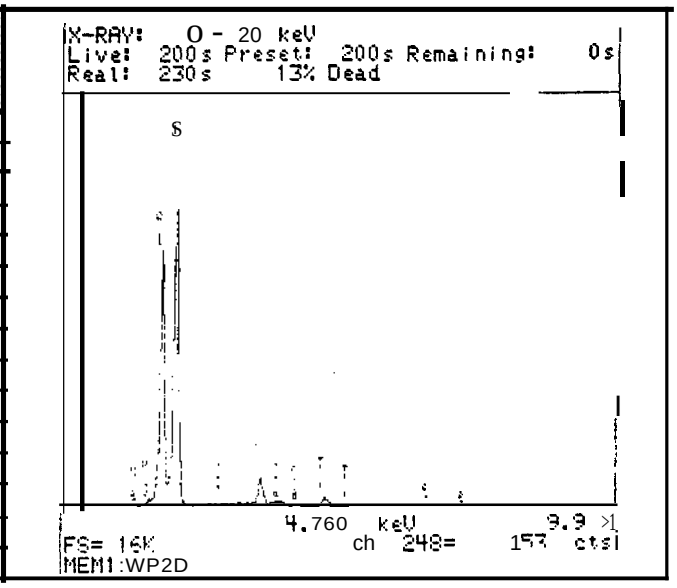


FIG. 3.35 EXAMPLE OF CLAY SURFACE. WPBC CLAY A

TABLE & SPECTRUM 3.21
COMPOSITION OF WPBC D

Oxide	Oxide Wt%	
	1	2
Si02	56.29	49.18
Al203	26.75	31.44
Fe203	1.61	1.98
Ti02	1.52	1.51
K20	1.19	2.44
Na20	0.13	0.28
CaO	0.13	0.42
MgO	0.39	0.73
MnO	0.08	0.12
LOI	11.9	11.9
Total	100.0	100.0



WPBC CLAY D

Magnification X 2000

The surface is sintered and has a lattice-Ike appearance

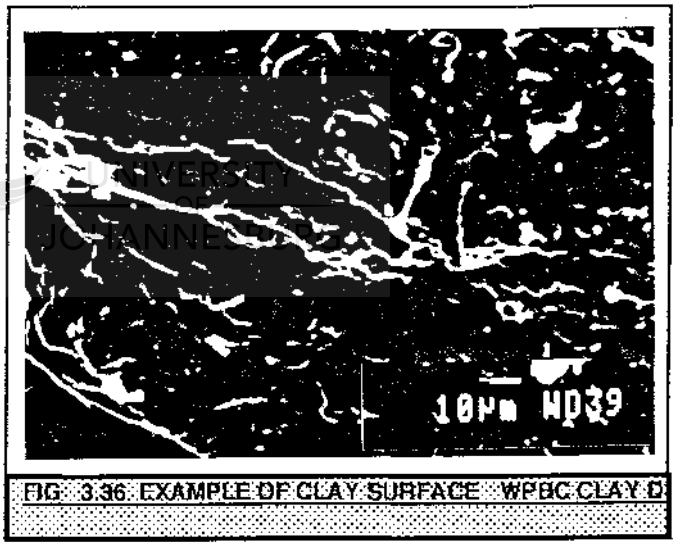


FIG 3.36 EXAMPLE OF CLAY SURFACE WPBC CLAY D

TABLE 3.22 RATIONAL ANALYSIS
WPBC A (1&2)

	1	2
FELDSPAR CONVENTION		
Material	Weight Percentage	
Feldspar	7.28	7.04
Clay substance	77.99	76.94
Free Silica	9.82	10.79
MICA CONVENTION		
Potash mica	9.74	9.57
Soda Mica	0.99	0.74
Clay substance	70.90	70.13
Free Silica	12.80	13.69
00 WATER IN CLAY: %ORGANIC MATTER		
Loss H_2O in Clay	10.92	10.77
Loss: CO_2 etc.	0.98	1.13

The data in Table3.22 is the result of the Rational Analysis calculation (Table 2.4)

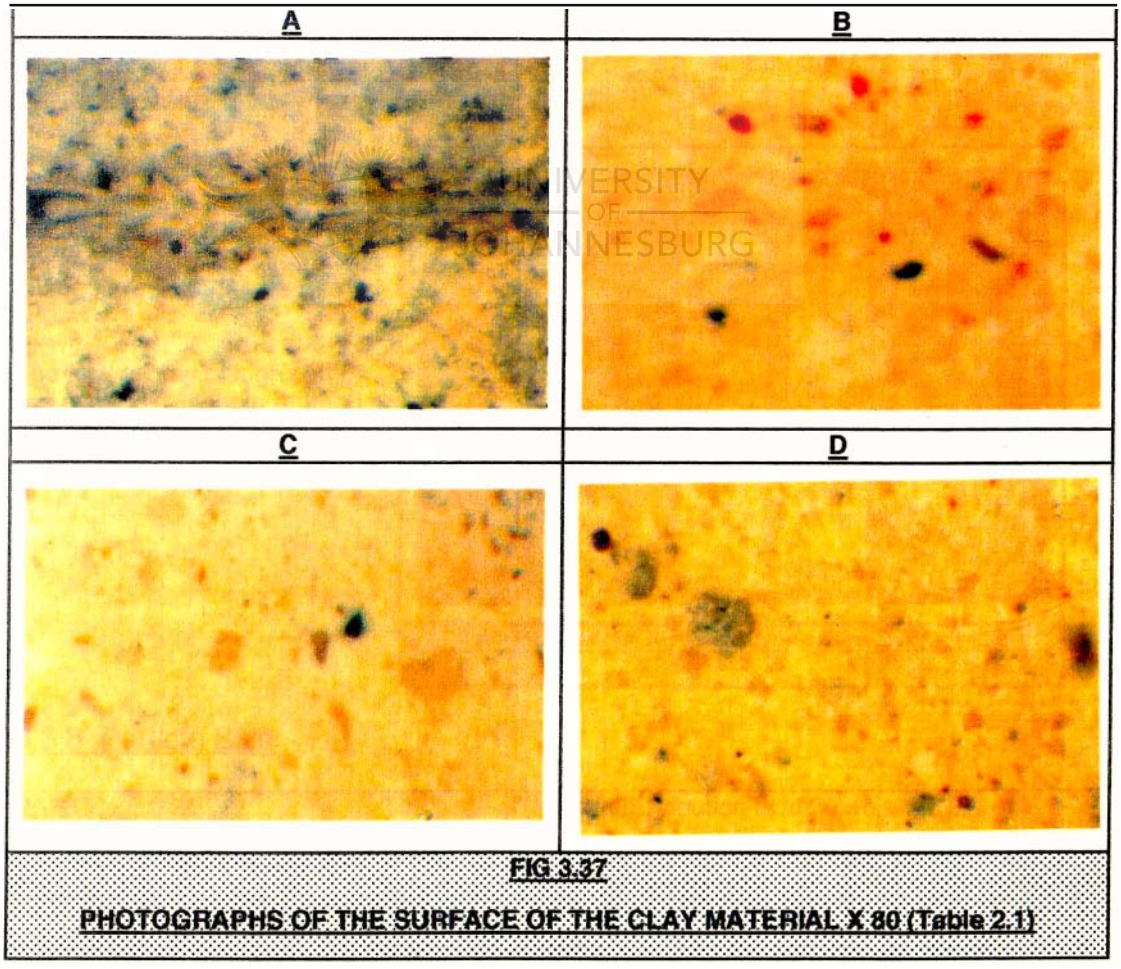


FIG 3.37

PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.6.3 ***Clay Properties***

3.6.3.1 Water Absorption and Linear Shrinkage

WPBC

Absorption
Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.

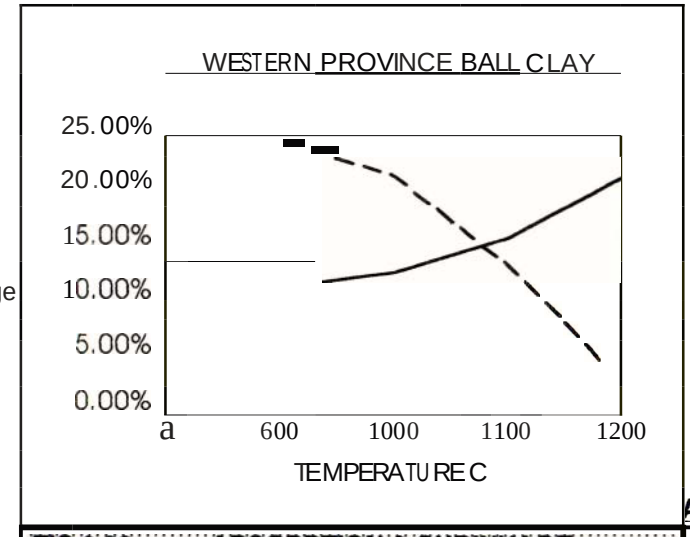


FIG 3.38 ABSORPTION & SHRINKAGE

3.6.3.2 Colour

WPBC

Photograph of WPBC fired to the selected temperatures. The change in colour can be clearly seen.

The typical gray of high carbon ball clays is evident in A. The body darkens when fired above 11*aaoc*

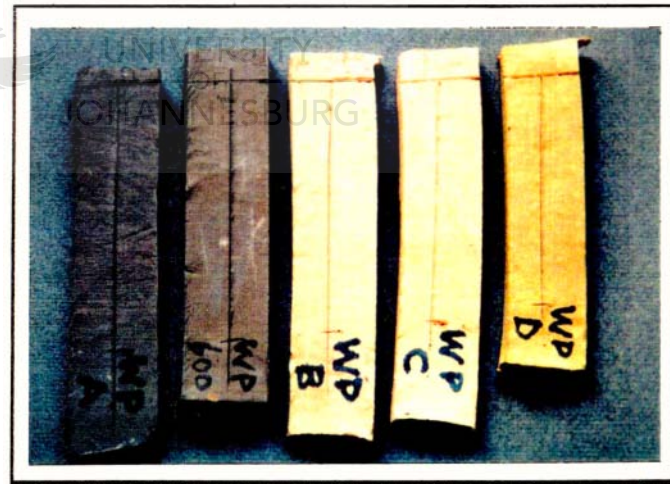


FIG 3.39 COLOUR OF THECLAY SURFACE WPBC

3.6.3 3 Particle Size

PARTICLE SIZE	The peak of the size distribution is at ZOSM and7.9% of the particles are less than 2μm in size (Appendix C)

3.6.4 Summary and Preliminary evaluation.

Western Province Ball Clay is supplied by G & W Base Minerals. It is plastic when blended in a clay body and with A-clay proved to be the most plastic of the chosen clays. (Table 3.32)

Two samples of this clay were analysed as a new order was brought into the studio. The two orders proved to be very similar in composition. (Table3.20)

The combined Fe + Ti content of this clay is fairly high - 3.38%
(Table 4.1a) -but it could be used as a constituent of a clay body in which the other materials are pale in colour.

The Potash content was 38% higher in the EDAX analysis than in the suppliers analysis. (Appendix B)

WPBC is low in fluxes.- 2.06% As a result of this the water absorption is high e.g.. 25% at 600^0 e (Fig.3.38). The material is high in clay substance 76.94% as can be seen in the Rational analysis (Table 3.2.2)(Table 4.3)

KAOLIN

3.7 G1 KAOLIN

3..7.1 *Origin and Mineralogy*

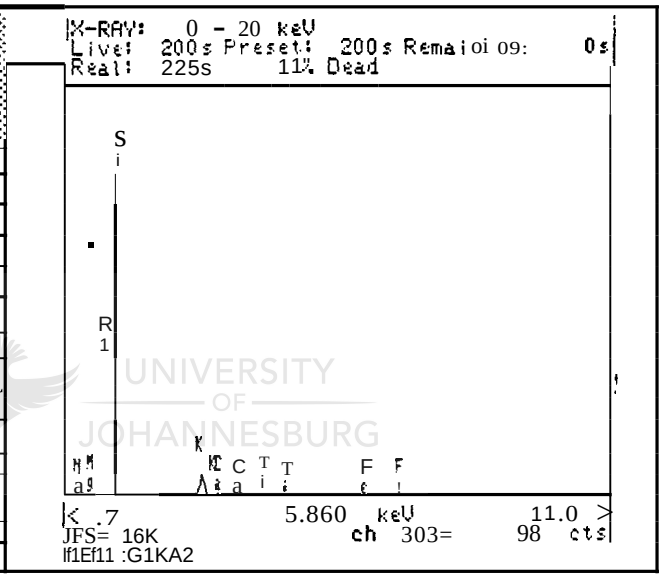
The deposit is on the farm Zyferfontein in the Grahamstown district. The material consists mainly of kaolinite and illite.f10]

3.7.2 Clay Analysis

The Ultimate and Rational analyses were carried out using the data collected on the SEM IEDAX (2.5.1) (Appendix D) the results of the Ultimate analysis of G1 Kaolin-A can be found in (Table 3.23) and 0 in (Table 3.24). The results of the Rational analysis of G1 Kaolin-A can be found in (Table 3.25).

TABLE & SPECTRUM 3.23
COMPOSITION OF
G1 KAOLIN A

Oxide	Oxide Wt %
Si02	64.28
Al203	26.24
Fe203	0.44
Ti02	0.62
K20	2.77
Na20	0.14
CaO	0.13
MgO	0.23
MnO	0.02
LOI	5.12
Total	100.00



G1 KAOLIN A

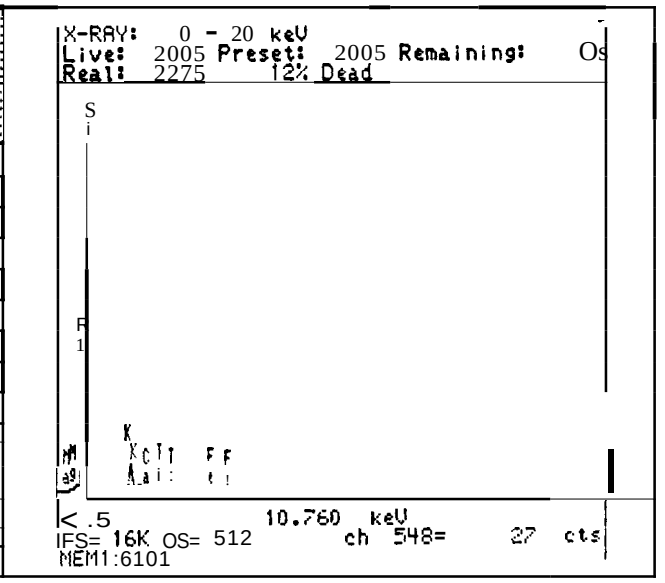
Magnification X 2000

Stacked platelets can be seen.

FIG. 3.40 EXAMPLE OF CLAY SURFACE G1 KAOLIN A

TABLE & SPECTRUM 3.24
COMPOSITION OF
G1 KAOLIN D

Oxide	Oxide %
Si02	66.51
Al203	23.84
Fe203	0.41
Ti02	0.72
K20	2.86
Na20	0.10
CaO	0.11
MgO	0.15
MnO	0.17
LOI	5.12
Total	100.00



G1 KAOLIN **0**

Magnification X 2000

The pinheads of fluxed clay material can be seen,
The analysis shows that there is no difference in composition in inclusions.

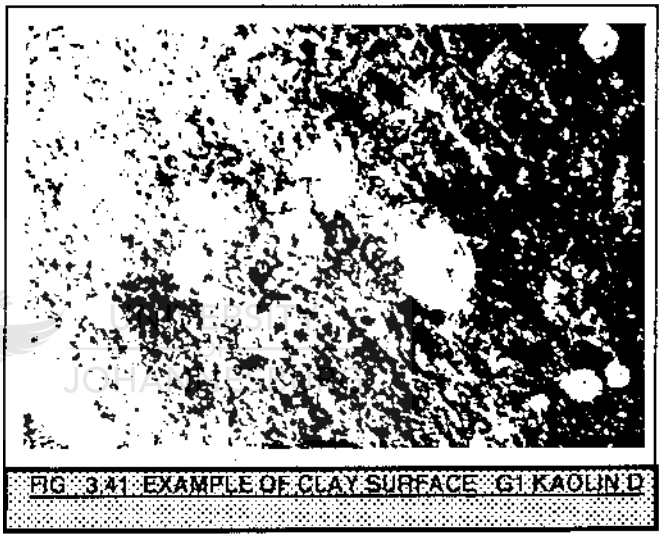


FIG 3.41 EXAMPLE OF CLAY SURFACE G1 KAOLIN D

TABLE 3.25 RATIONAL ANALYSIS
G1 KAOLIN A

FELDSPAR CONVENTION	
Material	Weight Percentage
Feldspar	17.23
Clay substance	58.41
Free Silica	26.09
MICA CONVENTION	
Potash mica	23.46
Soda Mica	1.72
Clay substance	41.85
Free Silica	33.40
%WATER IN CLAY: %ORGANIC MATTER	
Loss : H_2O in Clay	8.18
Loss: CO_2 etc.	0

The data in Table 3.25 is the result of the Rational Analysis calculation (Table 2.4)

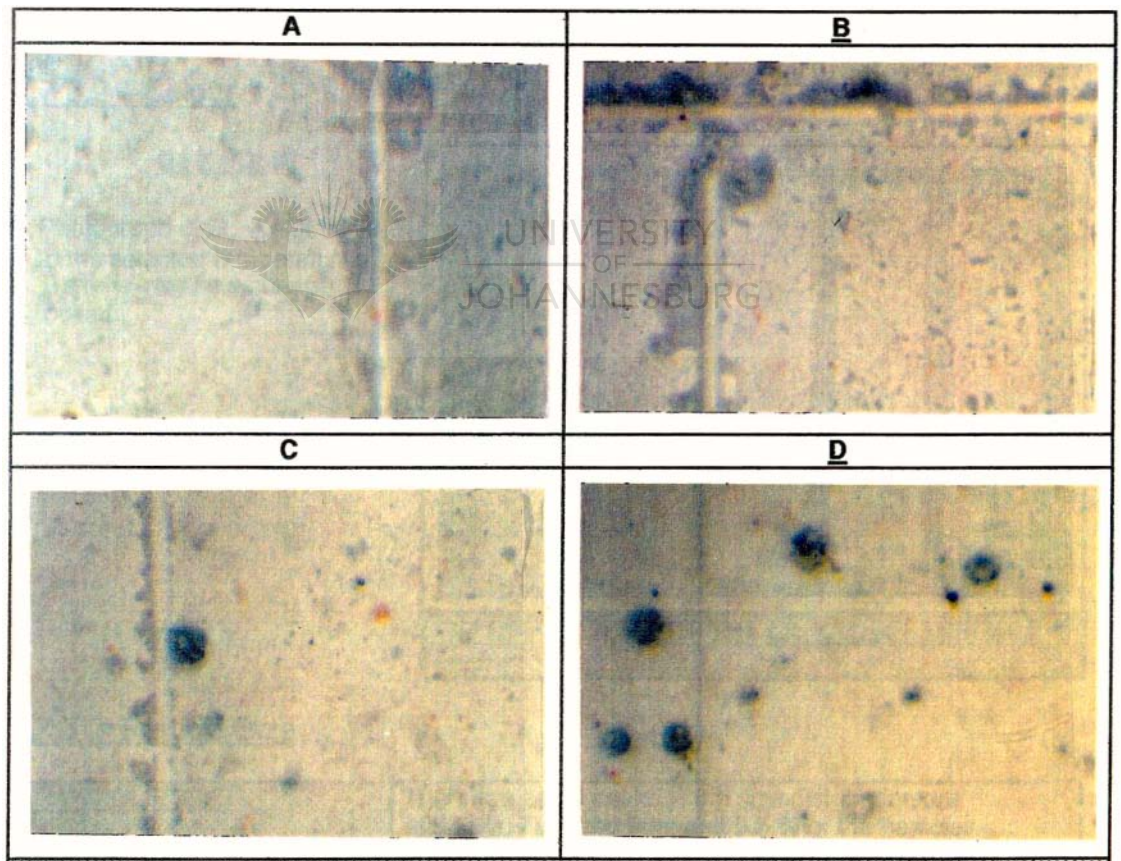


FIG 3.42

PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.7.3 Clay Properties

3.7.3.1 Water Absorption and Linear Shrinkage

GI KAOLIN

Absorption
Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.

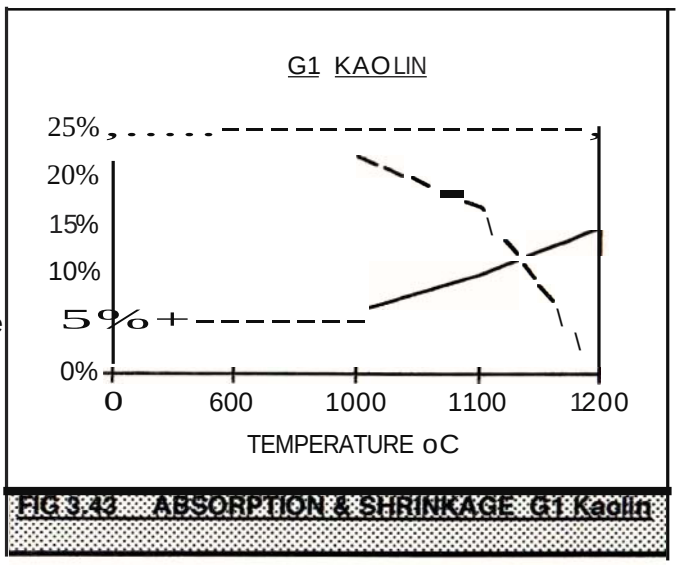


FIG 3.43 ABSORPTION & SHRINKAGE G1 Kaolin

3.7.3.2 Colour

G1 KAOLIN

Photograph of G1 KAOLIN fired to the selected temperatures. There is very little change in .colour.

FIG 3.44 COLOUR OF THE G1 KAOLIN SURFACE

3.7.3 2 Particle Size

PARTICLE SIZE	The three equal peaks in the size distribution are at 3.5μm, 7μm and 9μm and 9.5 % of the particles are less than 2 μm in size.(Appendix C)

3.7.4 Summary and Preliminary evaluation.

G1 Kaolin is a widely used clay material both for clay bodies and for glazes. The clay is supplied by G & W Base Minerals

The proportion of flux - 3.39%- is high for a kaolin causing the material to flux and vitrify at $1200^{0}C$. (FIG3.43)

The clay substance" in G1 Kaolin is low 58.41% for a kaolin and the Feldspar content high 17.23% as is the free silica content 26.09% (Table4.3) which should be taken into account when blending a clay body using this material as this combination may cause dunting of the wares due to an excess of free silica in the body.

The Fe + Ti content is well below the 2% limit for whitewares.

KAOLIN

3.8 SERINA KAOLIN

3.8.1 Origin and Mineralogy

Serina Kaolin is mined at Brakkloof in the Kommetjie-Fischoek valley on the Cape Peninsula.

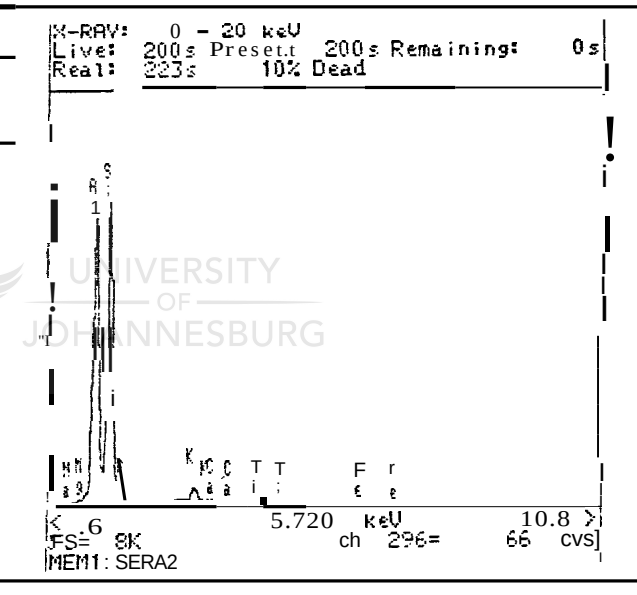
The Cape kaolins are formed *in situ* by weathering and hydrothermal action. The residual material consists mainly of kaolinite. quartz and mica with occasional inclusions of halloysite, and smectite-illite[2]

3.8.2 Clay Analysis

The Ultimate and Rational analyses were carried out using the data from the SEMIEDAX (2.5.1) (Appendix D). The results of the Ultimate analysis of Serina Kaolin-A can be found in (Table 3.26) and 0 in (Table 3.7). The results of the Rational analysis of Serina Kaolin-A can be found in (Table 3.28).

TABLE & SPECTRUM 3.26
COMPOSITION OF SERINA KAOLIN A

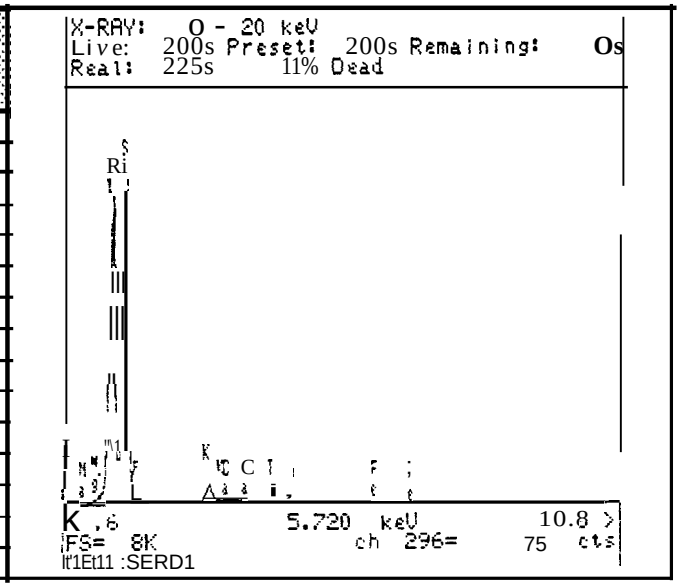
Oxide	Oxide %
Si02	47.43
Al2O3	38.04
Fe203	0.52
Ti02	0.42
K20	1.26
Na20	0.06
CaO	0.06
MoO	0.17
MnO	0.00
LOI	12.05
Total	100.00



NOTE: There is no micrograph of Serina Kaolin A (Fig 3.45) as the surface of the clay becam "charged up", by the electron beam, in spite of the precautions taken, making it tmpossible to focu on the surface of the sample.(2.3.1)

TABLE & SPECTRUM 3.27
SERINA KAOLIN D

Oxide	Oxide %
Si02	46.89
Al203	38.70
Fe203	0.43
Ti02	0.60
K20	1.18
Na20	0.02
CaO	0.03
MqO	0.08
MnO	0.01
LOI	12.05
Total	100.00



SERINA 0

Magnification X 2000

There is no sintering of the surface. The material is truly refractory

Platelets are evident in the clay structure.

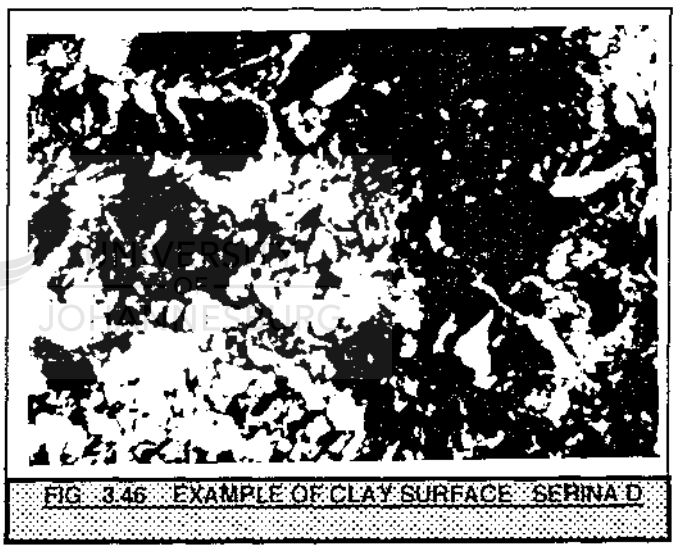


FIG 3.46 EXAMPLE OF CLAY SURFACE SERINA D

TABLE 3 28 RATIONAL ANALYSIS
SERINA KAOLIN A

FELDSPAR CONVENTION	
Material	Weight Percentaae
Feldspar	7.81
Clay substance	92.63
Free Silica	-0.51
MICA CONVENTION	
Potash mica	10.67
Soda Mica	0.74
Clay substance	85.12
Free Silica	2.67
% WATER IN CLAY : %ORGAN IC MATTER	
Loss : H_2O in Clay	12.97
Loss: CO2 etc.	0

The data in Table 3.28 is the result of the Rational Analysis calculation (Table 2.4)

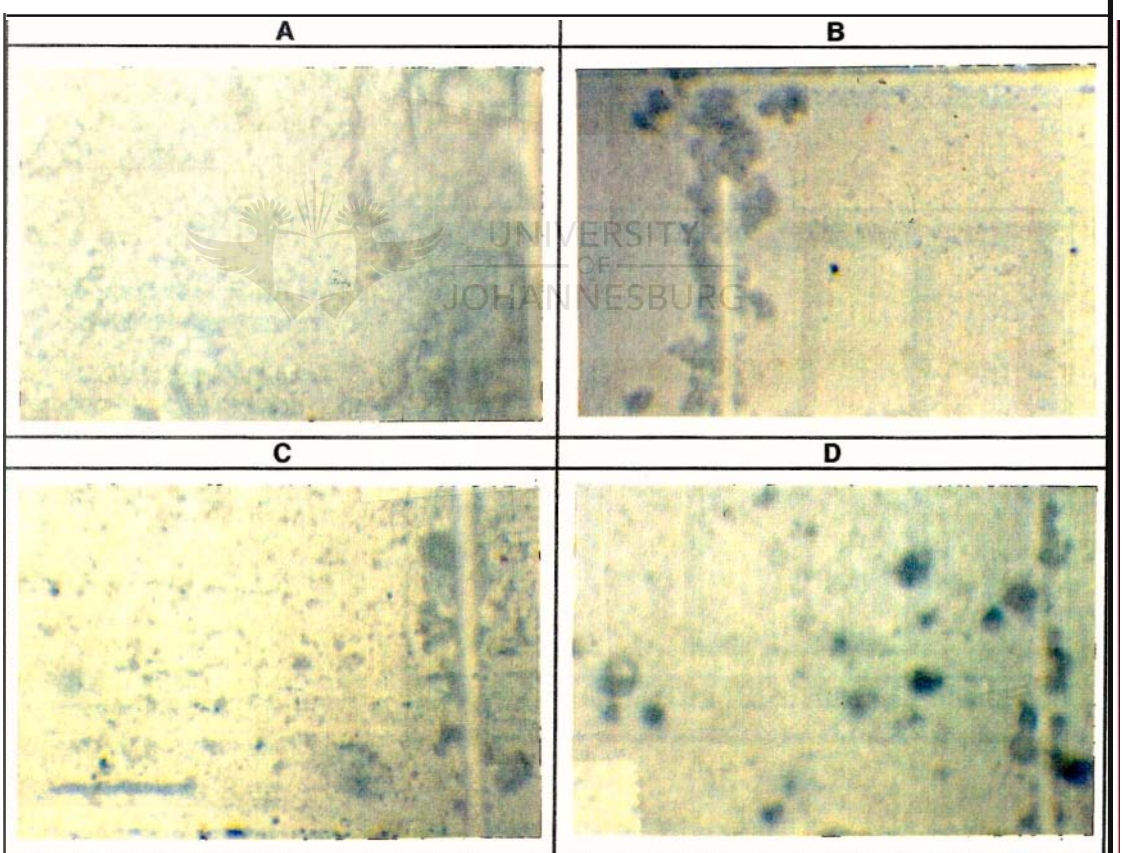


FIG 3.47
PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.8:3 *Clay Properties*

3.8.3.1 Water Absorption and Linear Shrinkage

SERINA

Absorption
Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.

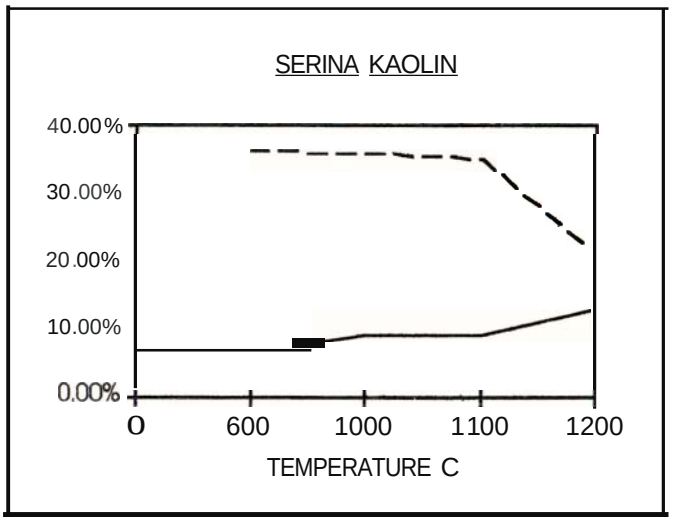


FIG 3.48 ABSORPTION & SHRINKAGE

3.8.3.2 Colour

SERINA

Photograph of SERINA fired to the selected temperatures.

the colour is constant at all temperatures as the Iron content is virtually nil.

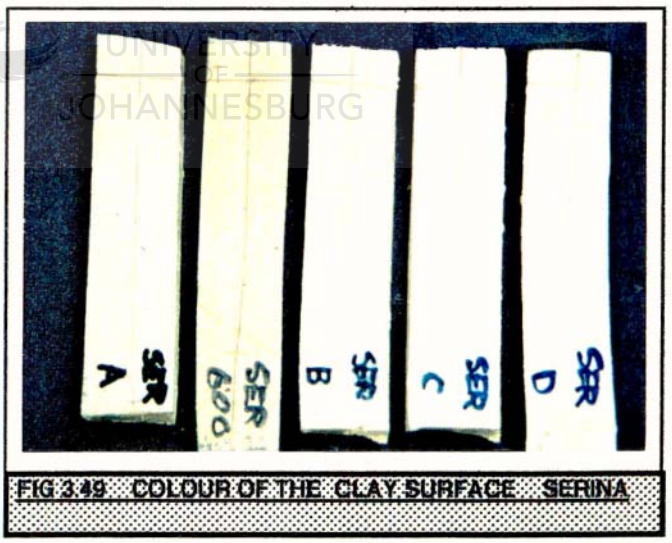


FIG 3.49 COLOUR OF THE CLAY SURFACE SERINA

3.8.3 3 Particle Size

2 microns is the upper grain -size limit for materials to be classified as clay[2) 2.4.2.3

PARTICLE SIZE	The peak in the size distribution is at *7fJm* and7% of the particles are less than2 *fJm* in size.(Appendix C)

3.8.4 Summary and Preliminary evaluation

Serina kaolin is mined and supplied by Serina (Pty) Ltd.

The kaolin is pure and refractory and easily beneficiated as the impurities are large enough to sieve out. The clay content is 92.63%.(Table 4.3) Serina Kaolin falls the closest of the clays tested to the theoretical composition of kaolinite:-

Si02.46.54 Al_2O_3 39.50 H20. 13.96

Composition otsenna Kaolin:-

Si02 . 47.43 AI203 . 38.04 LOI . 12.05

The shrinkage of Serina is low after the water of plasticity is removed (FIG.3.48)

The absorption curve does not approach the 0 line as the material is exceedingly refractory and retains absorbency. The peak at the largest value in the particle size valuation is below 10pm.

Serina kaolin is the most suitable material for whitewares and porcelain but is not always readily available.

KAOLIN

3.9 S. KAOLIN

3.9.1 Origin and Mineralogy

The deposit of S.Kaolin is in the Mossel Bay district on the farm Rondeheuwel.

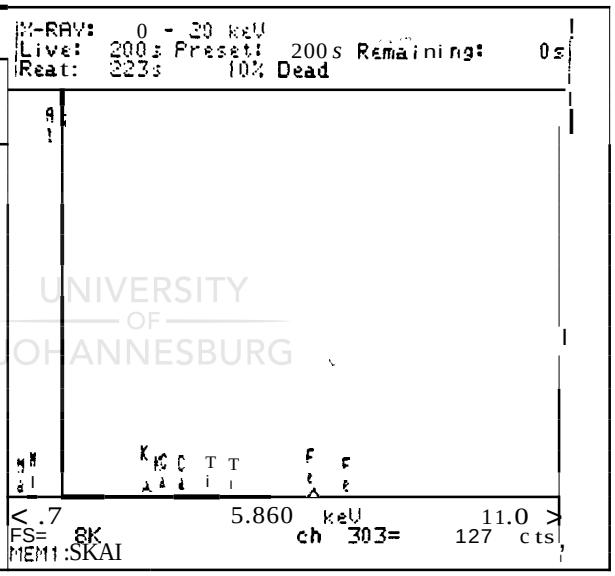
The material consists mainly of kaolinite with some quartz and rntca.Pl

3.9.2. Clay Analysis

The Ultimate and Rational analyses were carried out using the data collected on the SEM IEDAX (2.5.1)(Appendix D). The results of the Ultimate analysis of S-Kaolin-A can be found in (Table3.29) and D in (Table3.30). the results of the Rational analysis of S-Kaolin Acan be found in (Table 3.31

TABLE & SPECTRUM 3.29
COMPOSITION OF S KAOLIN A

Oxide	Oxide Wt 0/0
Si02	52.76
Al203	33.99
Fe203	1.88
Ti02	0.58
K20	0.51
Na20	0.09
CaO	0.03
MgO	0.27
MnO	0.11
LOI	9.8
Total	100.00



SKAOLIN

Magnification X 2000

The individual hexagonal flat platelets can be seen.

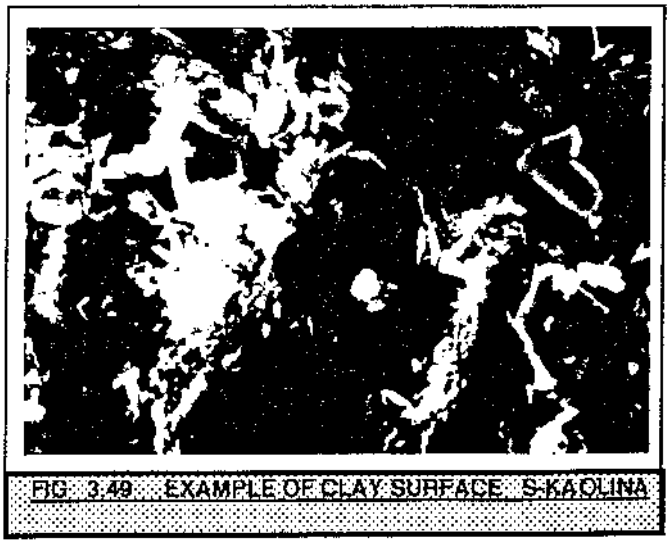
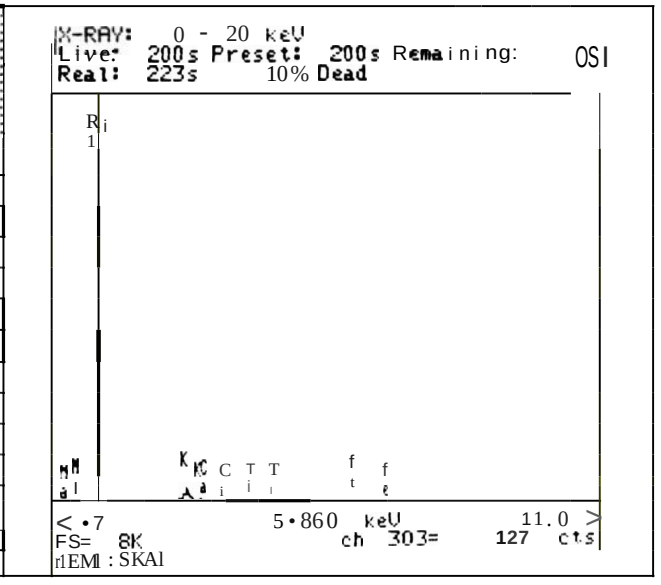


FIG. 3.49. EXAMPLE OF CLAY SURFACE. S-KAOLINA

TABLE & SPECTRUM 3.30
COMPOSITION OF S KAOLIN D

Oxide	Oxide Wt o/o
Si02	50.81
Al203	36.27
Fe203	1.42
Ti02	0.60
K20	0.64
Na20	0.06
CaO	0.06
MgO	0.35
MnO	0.00
LOI	9.8
Total	100.00



S KAOLIN D

Magnification X 2000

The individual hexagonal flat platelets can be seen.
The separate particles that appear on the surface do not differ in composition from the main body of material.

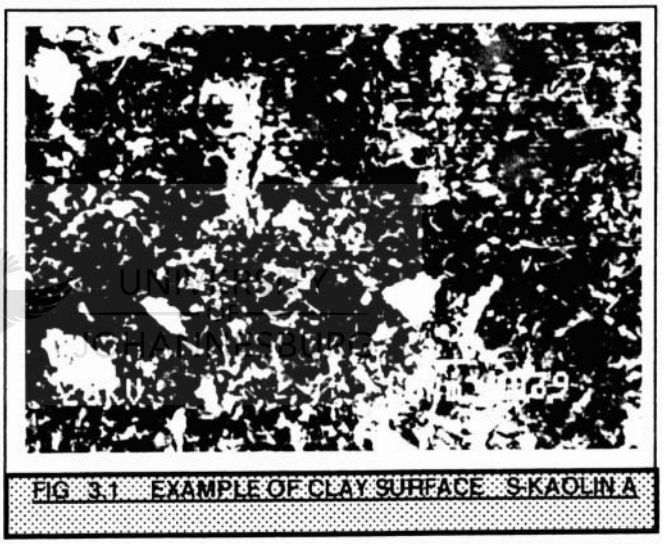


FIG 3.1 EXAMPLE OF CLAY SURFACE S-KAOLIN A

TABLE 3 .31 RATIONAL ANALYSIS S KAOLIN A

FELDSPAR CONVENTION	
Material	Weight Percentage
Feldspar	3.55
Clay substance	84.35
Free Silica	11.41
MICA CONVENTION	
Potash mica	5.42
Soda Mica	0.74
Clay substance	79.65
Free Silica	10.98
% WATER IN CLAY : %ORGANIC MATTER	
Loss : H_2O in Clay	11.81
Loss: CO_2 etc.	0

The data in Table 3.3 t is the result of the Rational Analysis calculation (Table 2.4)

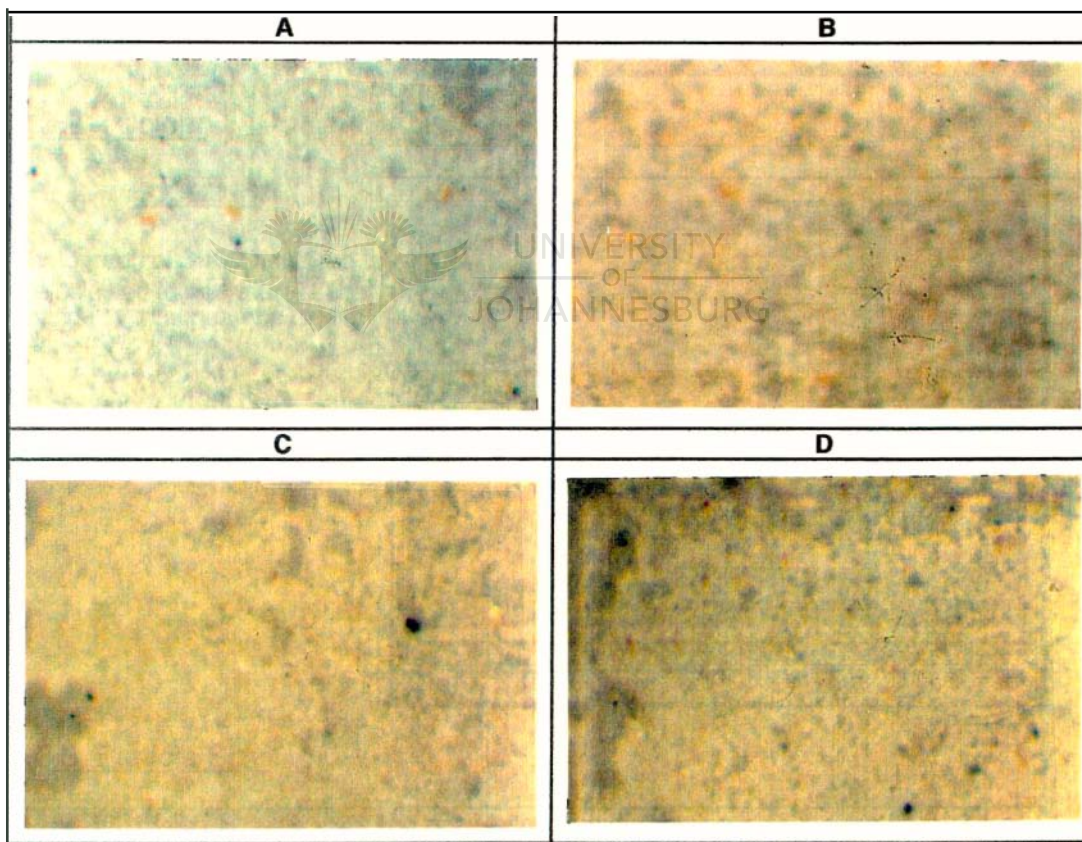


FIG 3 .51

PHOTOGRAPHS OF THE SURFACE OF THE CLAY MATERIAL X 80 (Table 2.1)

3.9.3 Clay Properties

3.9.3.1 Water Absorption and Linear Shrinkage

S.KAOLIN

Abscrption
Shrinkage

The results of the linear shrinkage and absorption tests (2.4.2) are shown in this chart.
There is no (A) value for the absorption test

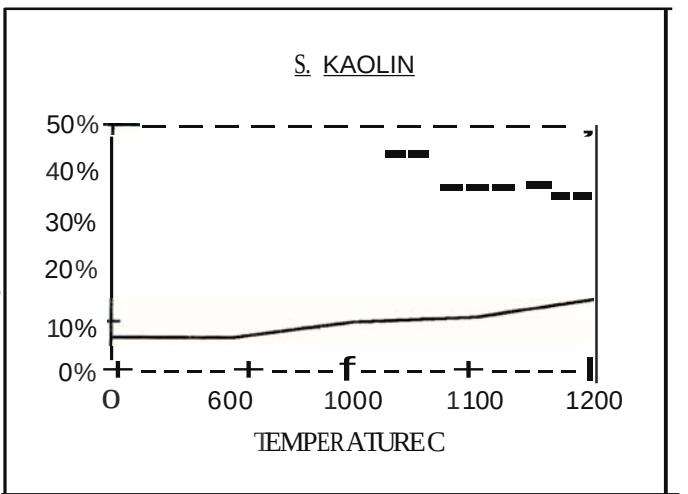


FIG 3.52 ABSORPTION & SHRINKAGE

3.9.3.2 Colour

SKAOLIN

Photograph of S KAOLIN fired to the selected temperatures. The change in colour can be clearly seen.

The colour at 1100° C (C) is the palest.

FIG 3.53 EXAMPLE OF CLAY SURFACE S-KAOLIN

3.9.3 3 Particle Size

PARTICLE SIZE	The peak in the size distribution is at *11.5Jlm* and 1.7% of the particles are less than 2 *utt:* in size. (Appendix C)

3.9.4 Summary and Preliminary evaluation.

S Kaolin is, a refractory material that begins to flux at $1000^{0}C$ but is far from vitrification at $1200^{0}C$. Craters appear in the surface as the material begins to flux.(Fig 3.51)

S Kaolin is a white material with very little plasticity when blended into a clay body (Table 3.37) The peak at the largest value in the particle size valuation is at *20pm* indicating that the particles are generally of a larger diameter than the other clay materials.

S Kaolin is closer to a pure kaolin than G1 Kaolin but not as pure as Serina kaolin.

S Kaolin is suitable as the kaolin component in a clay body but is no longer obtainable.

3.10.1 Clay body Analysis.

3.10.1.1 Plasticity.

As a final comparative technique the nine clay materials chosen were combined with feldspar and .silica in a known proportion and formed into clay bodies (2.3.3). The reason for this final comparison is that clay is seldom used in its found state but rather blended to form a required body for use in the studio (1.1). As stated in the introduction to this Chapter, the Ultimate analysis and the Rational analysis of the Clay bodies appear in Chapter 4

(Table 3.32) is compiled from the information obtained from three potters, each represented by a symbol (x, 0, 0) in the table. The clay bodies were prepared as described (2.3.3) and tested (2.4.2.2.) Each potter was given 500gms. of each of the prepared clay bodies which were thrown on the wheel and assessed for plasticity and workability. This is qualitative information as there is no definitive method of measuring plasticity but the information is never-the-less valuable as the experience of the potters chosen is considerable and the information can be comparatively applied.

The two clays identified by all three potters as being particularly plastic and easy to throw were A-clay and Western Province ball clay.

Moss clay was placed on the chart as being between *Good* and *Excellent.*

813 and PXX were similarly placed above *OK* but not outstanding.

C-clay was low on the scale as a plastic throwing clay possibly due to the low Alumina content in the clay material. (Table 4.2)

The three kaolins were understandably low in plasticity as the larger particles found in kaolins lower the plasticity and the green strength of a clay body. [4]

TABLE 3.32 RESULTS OF THE THROWING TEST FOR PLASTICITY

CLAY	CYL HGT	1 BAD	2 OK	3 GOOD	4 VGOOD	5 EXCEL	COMMENTS
1 A CLAY	10.0 14.0 13.4				X 0 0		Wet. Good tooth Moisture too high Firm, Did not absorb water.
2 B13	9.75 10.5 13.5		0 0		X		Good tooth. Smooth Sticky to wedge Slimy to throw Rubbery; pleasant colour; no form.
3 C CLAY	9.25 11.40 11.4	0		X 0			Spongy and dilated. Slimy , flabby. too wet. Stiff and floppy.
4 PXX	9.75 15.50 13.0		0		X	0	Firm. good tooth Very good. Hard and dry.
S MOSS	9.00 13.3 13.3			0	0	X	Firm and Strong. High water absorption ;dry Smooth; floppy; Slimy. Hard when stretched then flops.
6 WPBC	9.00 16.80 14.6				X 0 0		Dense. Similar to 613 Sticky - too wet Slimvand smooth. Easy to throw.
7 G1 KAOLIN	9.75 9.50 11.0	0	X 0				Wet / Dry cheesy Wet and short. Stiff and nooov Thirstv.
8 S KAOLIN	8.75 9.50 9.30	0 0	X				Less cheesy but no tooth Very short; sticky No binder; would not throw. (V bad)
9 SERINA	9.25 12.00 10.7	0 0	X				Less cheesy No tooth Short , sticky. Creamy; better than 7

CHAPTER 4

CORRELATION OF INFORMATION AND DISCUSSION.

The tables presented in this chapter include correlations of the results in Chapter 3 as well as additional tables prepared to assist in the comparison of the nine chosen clay materials and the "clay bodies" and thereby to identify the similarities and differences.

4.1 ULTIMATE ANALYSIS

The information in Tables 4.1 and 4.2 is compared in Tables 4.1 a and 4.2a in order to simplify the choice of clay to be used in a clay body. The tables show the Ultimate Analyses of the clay materials and the clay bodies. The proportion of the materials blended in a clay body can be adjusted using the INSIGHT software programme (2.6), and the Data Base.

1) The silica and alumina ratings show the clays in order according to the quantities of silica and alumina present in the bodies.
The amount of silica is an indirect indication of the behavior of the final clay body. Part of the Si02 becomes available as amorphous Si02 when clay breaks down, while Si02 as quartz is more refractory because of the larger particle size. In earthenware clay it can be considered a filler.
Al203 forms mulliteand takes part in the glassy phase of the clay vitrification process. The quantity of alumina can be used as an indication of the clay fraction in the Rational Analysis.

2) The Fe+Ti gives the total of these two materials which must be less than 2% when combined in a white clay body, Although the titanium is itself almost White, it enhances the staining power of the iron causing the clay body to be off-white. With the addition of silica and feldspar, or any other filler, to a clay body the proportion of the Fe + Ti is reduced. The result of this can be seen when comparing Table 4.2 (Clay material) with table 4.3 (Clay body).

3) The value of total fluxes is important to determine the vitrification and the thermal expansion of clay bodies. The thermal expansion of the clay materials is theoretically calculated by means of the Data Base.(Table 2.6)

4) The total of the secondary fluxes or alkali earth oxides gives information on the type of flux present in the clay. These fluxes are important for throwing clays as they can affect plasticity by altering the structure of the pore water layer[6!. The Ca reacts with the silica forming a glass at a relatively low temperature and thereby lowering the fluxing point of the clay body.

TABLE 4.1 TABLE OF THE ULTIMATE ANALYSIS OF BALL CLAYS AND KAOLINS

Oxide	A Clay	B13 Oay	C Clay	Moss Clay	PXX Ball cl	W.P.B.C lay	G1 Kaolin	Serena	S Kaolin
Si02	46.02	61.29	63.90	61.67	53.29	50.64	64.28	47.43	52.76
Al203	34.07	24.19	23.35	25.30	32.62	32.16	26.24	38.04	33.99
Fe203	3.53	2.38	0.98	1.49	1.04	1.73	0.44	0.52	1.88
Ti02	2.18	1.12	1.08	1.28	0.97	1.58	0.62	0.42	0.58
K20	1.37	2.59	3.44	4.06	2.65	1.15	2.77	1.26	0.51
Na20	0.20	0.11	0.24	0.23	0.15	0.08	0.14	0.06	0.09
Cao	0.91	0.81	0.47	0.03	0.22	0.19	0.13	0.06	0.03
MgO	0.50	0.62	0.39	0.23	0.43	0.58	0.23	0.17	0.27
MnO	0.07	0.08	0.04	0.02	0.03	0.00	0.02	0.00	0.11
Sulphur	0.55								
LOI	10.6	6.8	6.1	5.7	8.60	11.90	5.12	12.05	9.8
TOTAL	100.0	100.00	100.00	100.00	100.01	100.00	100.00	100.00	100.00

TABLE 4.1a [illegible]

Silica Rating	6	3	1	2	4	5	1	3	2
Al. Rating	1	5	6	4	2	3	3	1	2
Fe+Ti	5.71	3.5	2.04	2.77	2.01	3.31	1.06	.94	2.46
Total Fluxes	3.0	4.21	4.58	4.57	3.45	2.00	3.29	1.55	1.01
Ca+Mg+ Mn	1.41	1.5	.9	.28	.68	.77	.43	.23	.41

TABLE 4.2 TABLE OF THE ULTIMATE ANALYSIS OF CLAY BODIES

Oxide	A Clay	B13 Oay	CClay	Moss Oay	PXX Ball cl	W.P.B.C lay	G1 Kaolin	Serena	S Kaolin
Si02	74.06	75.73	76.63	75.48	71.74	72.08	76.60	70.46	72.07
Al203	19.69	17.02	18.07	17.49	21.72	21.70	17.93	24.86	22.33
Fe203	1.55	1.28	.39	.81	.15	.97	.27	.33	1.04
Ti02	.80	.60	1.05	.68	.79	.86	.34	.24	.32
K20	3.33	4.40	3.26	5.13	4.69	3.75	4.45	3.81	3.97
Na20	.17	.20	.31	.26	.76	.19	.21	.18	.05
CaO	.24	.41	.17	.02	.10	.10	.07	.03	.02
MgO	.16	.32	.11	.12	.05	.31	.12	.09	.14
MnO	0	00	00	.01	00	.05	.01	00	.06
TOTAL	100.00	100.00	100	100.00	100.00	100.00	100.00	100.00	100.00

TABLE4.2a ":COMPARATIVE INFORMAnON

Silica Ratino	4	2	1	3	6	5	1	3	2
Al. Ratino	3	6	4	5	1	2	3	1	2
Fe+Ti	2.53	1.77	1.44	1.49	.94	1.55	.61	.57	1.36
Total Fluxes	3.9	5.33	3.85	5.53	5.61	4.35	4.86	4.11	4.24
Ca+Mg+ Mn	0.4	0.73	0.28	0.14	0.15	0.16	0.2	0.12	0.16

4.2 **RATIONAL ANALYSES**

The Rational analysis of the ball clays and kaolins is shown in Table 4.3 and the Rational analysis of the clay bodies in Table 4.4.

The variation in the quantities of component materials can be clearly seen. The comparison of the clays illustrates the importance of knowing this information before substituting one clay material for another in order to retain the required proportions of Clay substance, Free silica and Feldspar or Mica in a clay body. Comparisons such as these are useful when deciding on the clay material to be included in a clay body. The recipe for the clay body can be calculated using the Insight programme and the calculations in the Data base. By adjusting the quantities of the various materials the proportions can be maintained.

In this project both the Feldspar and the Mica convention have been used for the assessment of the clay materials because the mineralogy of the clays had not been established directly. It could have been established by X-Ray diffraction if funds had been available. The mineralogical evaluations of the clay materials are referenced from scientific publications specialising in this technique. [2][5][15][16).

The Feldspar convention is referred to in the discussion as it Is the convention most frequently used in the studio situation, but the calculations based on both conventions are installed in the data base.

TABLE 4.3 TABLE OF THE RATIONAL ANALYSIS OF BALL CLAYS AND KAOLINS

Material	A Clay	B13 ClaY	C Clay	MOSS Clay	PXX Clay	W.P.B. Clay.	G1 Kaolin	Seren a	S Kaolin
Feldspar	8.22	15.98	21.76	25.40	16.58	7.28	17.23	7.81	3.55
Clay Subst	82.40	53.80	48.99	52.25	74.85	77.99	58.41	92.63	84.35
Free silica'	2.55	26.04	27.12	21.04	7.91	9.82	26.09	-0.5	11.41
Potash Mica	11.60	21.43	29.14	34.39	23.29	9.74	23.46	10.67	5.42
Soda Mica	2.46	1.23	2.96	2.83	2.83	0.99	1.72	0,74	0.74
Clay Subst	72.45	37.69	27.78	27.73	57.03	70.90	41.85	85.12	79.65
Free Silica	5.31	32.05	36.42	31.90	14.91	12.80	33.40	2.67	10.98
H20in Clay	11.35	7.53	6.86	7.31	10.46	10.92	8.18	12.97	11.81
LOI	10.60	6.80	6.10	5.70	8.60	11.90	5.10	12.05	9.80

TABLE 4.4 TABLE OF RATIONAL ANALYSIS OF CLAY BODIES.

Material	A Clay	B13 Clay	CClay	MOSS Clay	PXX Clay	W.P.B. Clay.	G1 Kaolin	Serena	S Kaolin
Feldspar	20.72	27.23	21.13	31.91	32.26	23.32	27.59	23.62	23.80
Clay subst	40.22	30.45	35.95	29.76	40.02'	44.10	32.59	51.96	45.48
Free silica	42.03	43.95	46.31	41.06	32.34	36.57	43.66	31.02	35.59
Potash Mica	28.21	37.27	27.61	43.45	39.72	31.76	37.69	32.27	33.65
Soda Mica	2.09	2.46	3.82	3.20	9.36	2.34	2.59	2.22	0.62
ClaySubst	20.29	4.36	15.03	0.00	6.88	21.67	5.69	29.30	21.55
Free Silica	50.58	55.70	55.36	54.89	46.17	46.54	55.70	41.20	46.54

4.3 SHRINKAGE AND ABSORPTION

The information shown in (Fig.4.1 and 4.2) was collated from the results of the shrinkage and absorption experiments (ChapterS) (Appendix C).The values for the individual clays materials are shown in the charts in the clay characterisation section. (Chapter3)

The clay bodies were submitted to the same test procedure as the clay materials and the results are presented in (Fig.4.3 and 4.4). The purpose of these clay body tests is to illustrate the changes that occur when materials are blended.

The linear shrinkage of the clay materials (Table 4.1) follows a shrinkage "pattern", with the wet to dry shrinkage being between 5% and 12% at $100^{0}C$ (in fact the samples were dried to 11OOC to ensure that the pore water had been driven off) and the shrinkage at $1200^{0}C$ falling between 12.5% and 22.5%. The three kaolins show the least shrinkage and the most plastic of the clays (A-clay and WPBC) (Table 3.32) show the greatest shrinkage.

In comparison the linear shrinkage of the clay bodies (Table 4.3) shows B13 Ball clay with the highest shrinkage followed by the remainder of the ball clays. Serena and S-kaolin predictably show the least shrinkage as they have a high clay substance level.(Table 4.5). The percentage linear shrinkage of the clay bodies, ranging between 9% and 16%.at $1200^{0}C$,is considerably lower than the clay materials shrinkage due to the silica and feldspar which act as fillers at this temperature. The shrinkage of the clay bodies is slightly less at the lower temperatures than that of the clay materials.

The tables of %water absorption show the wt.% water in a fired sample after boiling for 5 hours as described in Chapter 2. The porosity of ceramic materials is an .lndlcatlon of the state of flux that the body reached in the firing process. This can range from a highly porous earthenware to a totally vitrified porcelain with 0% absorption. The % water absorption is dependent on the composition of the material and the temperature of the firing.

The water absorption pattern (FIG. 4.2) of the clay materials fall into three distinct zones which are repeated in the clay body absorption charts (Fig 4.4) but with changes in the participant clays.

The clay material zones are:-

1) PXX clay and the 813 clay fluxing below 1000^0 C.
2) the rest of the ball clays and the G1 Kaolin fluxing below 1200^{0}C,
3)Serena and S- kaolins not approaching the fluxing point.

In comparison the clay body zones are:-

1) WP8C and Moss clay with 5% absorbency at 1100^{0}C and slightly less at 1200^{0}C.
2) the remainder of the ball clays plus G1 Kaolin ranging from 12%-17% absorption at 1100^{0}C and between 0%-5% at 1200^{0}C.
3) Serena and S-Kaolin not approaching the fluxing point.

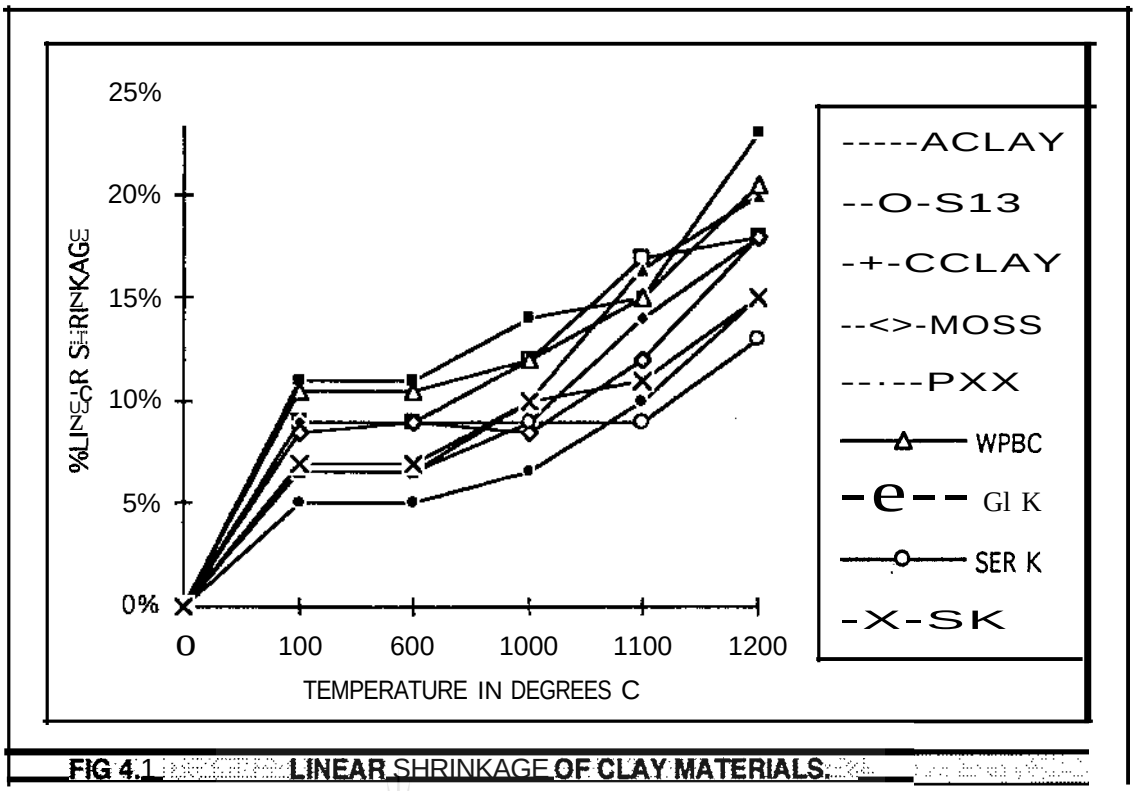


FIG 4.1 LINEAR SHRINKAGE OF CLAY MATERIALS.

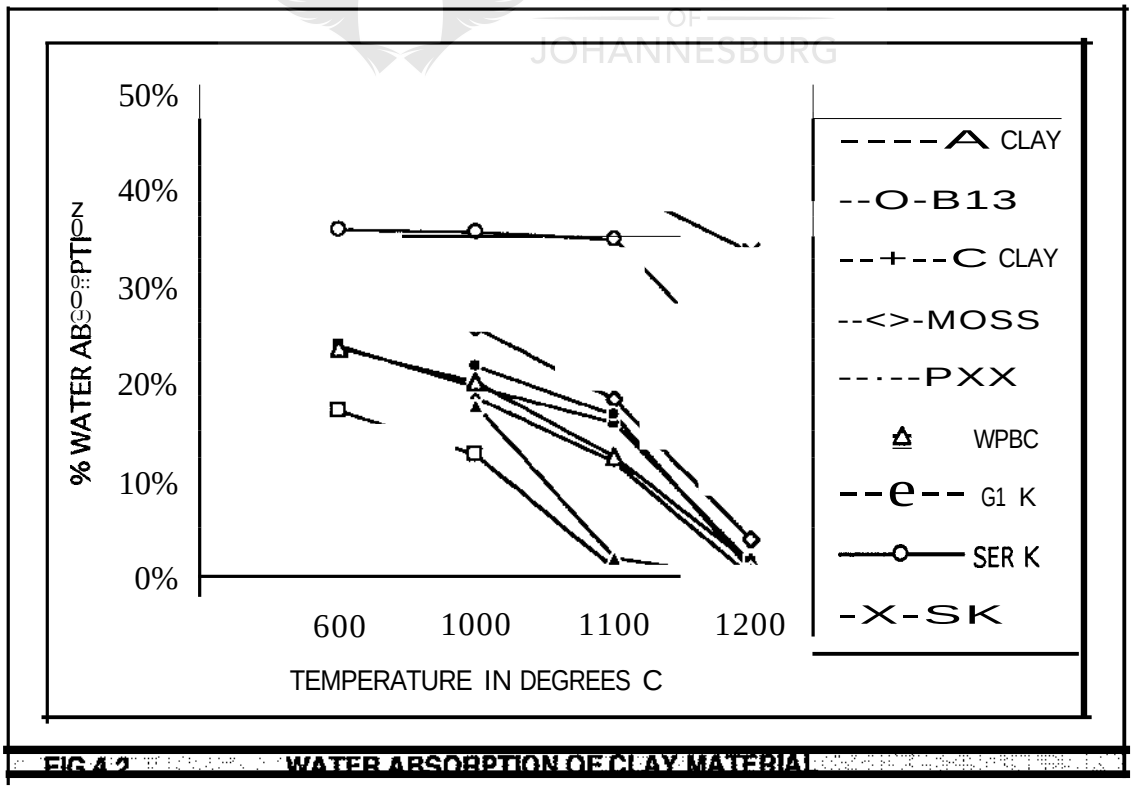


FIG 4.2 WATER ABSORPTION OF CLAY MATERIAL

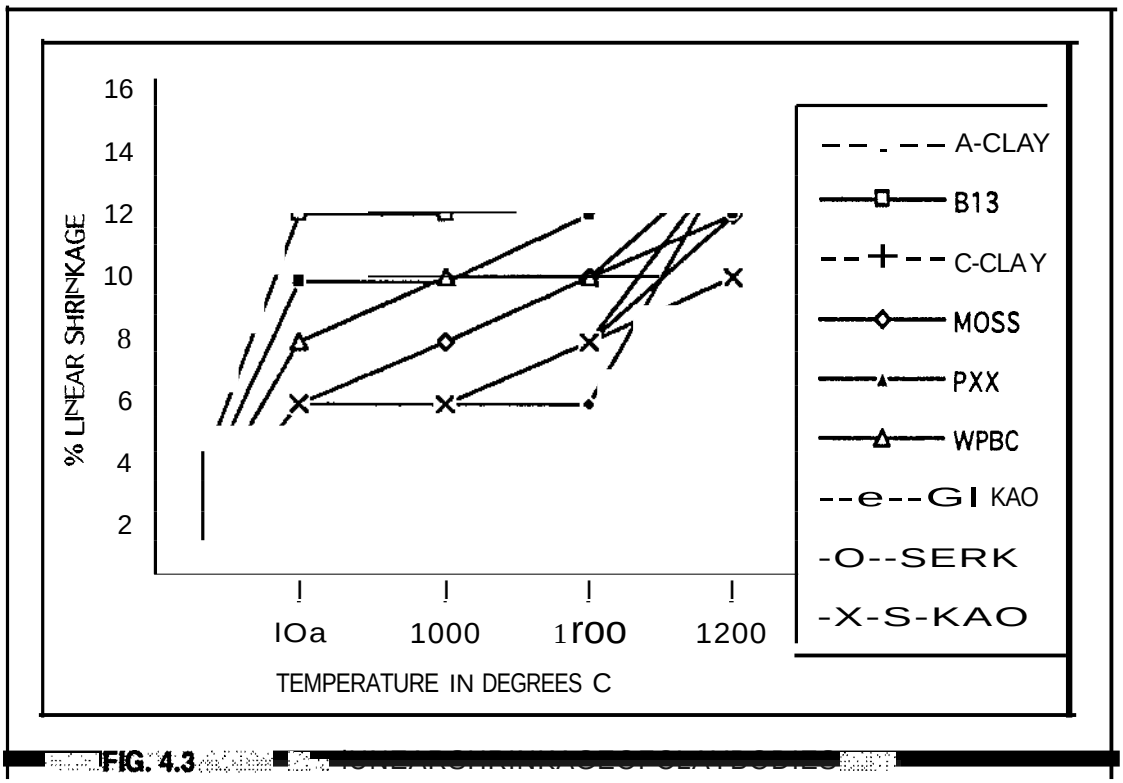


FIG. 4.3 LINEAR SHRINKAGE OF CLAY BODIES

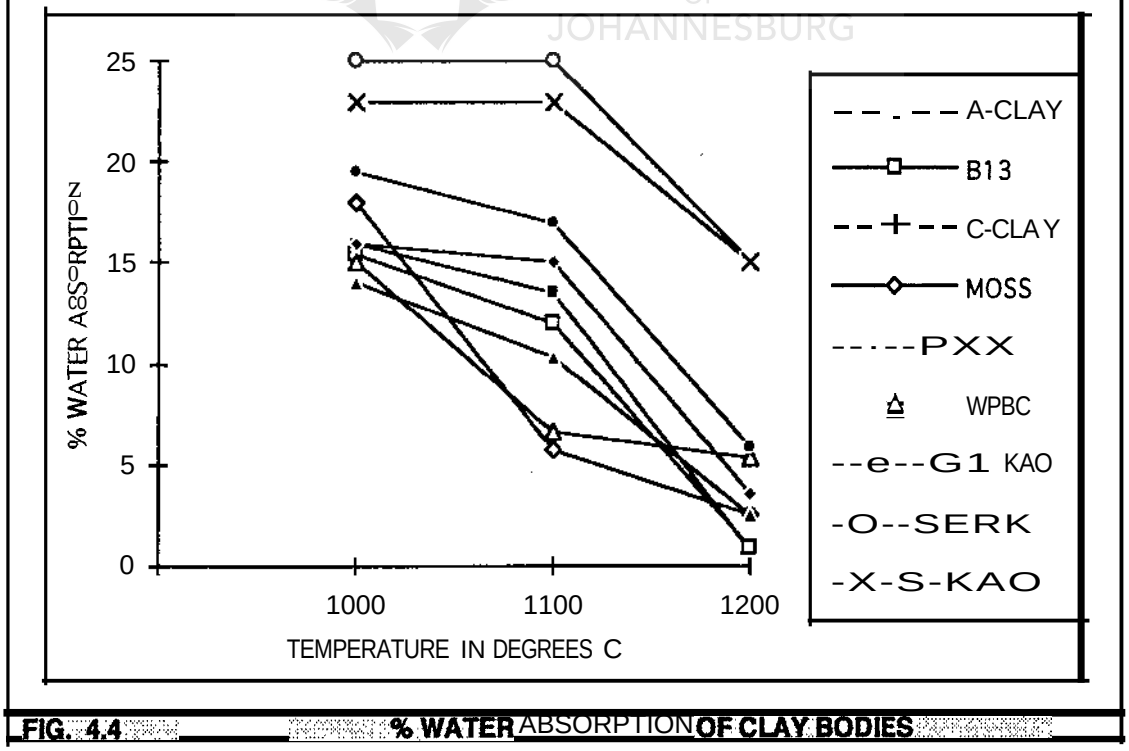


FIG. 4.4 % WATER ABSORPTION OF CLAY BODIES

4.4 **PARTICLE SIZE**

The particle size of the nine chosen clay materials was tested using the laser diffraction method on a Malvern "Microsizer" by courtesy of Prof. Moys, Dept. Chemical Engineering, Univ. of Witwatersrand. The data sheets and charts can be found in Appendix C.

It should be noted that particle size analysis is dependent on several parameters such as type of dispersant, method of analysis etc. and should be seen as a comparative method of assessing clay materials.

Particle size is of great importance to the plasticity of clay materials. As has been discussed in (1.2) a mix of particle sizes in a clay body gives the best plasticity as the packing density of the particles improves as does the green strength.

The following chart shows three series of data selected from the Malvern data sheets.

Fig 4.5 shows the % particles less than $2pm$ equivalent size diameter (e.s.d.) giVing the percentage clay in the material.[2] This is a geological size division of particles and the results should be seen as a comparative assessment of clay materials.

Fig 4.6 shows the peak of the particle size distribution chart giving the size of the particles that are present in the clay material in the highest percentage.

Fig 4.7 Shows the specific surface area in square meters of one gram of clay material. The smaller the average particles are the larger the surface area will be.

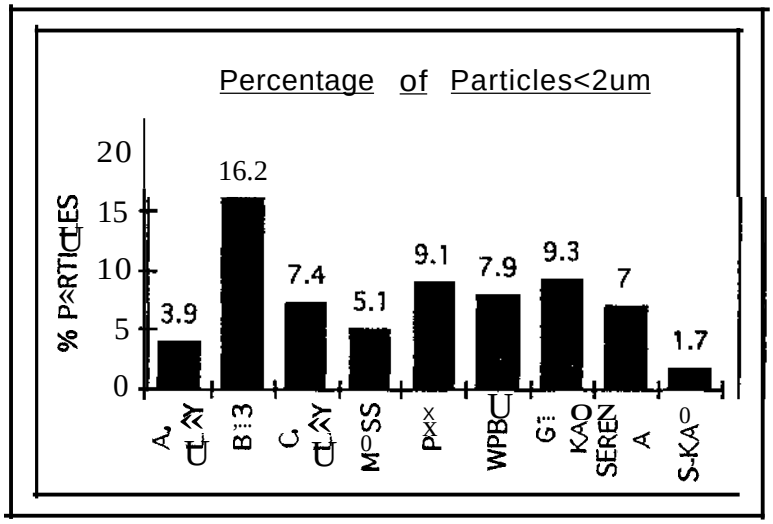


FIG. 4.5

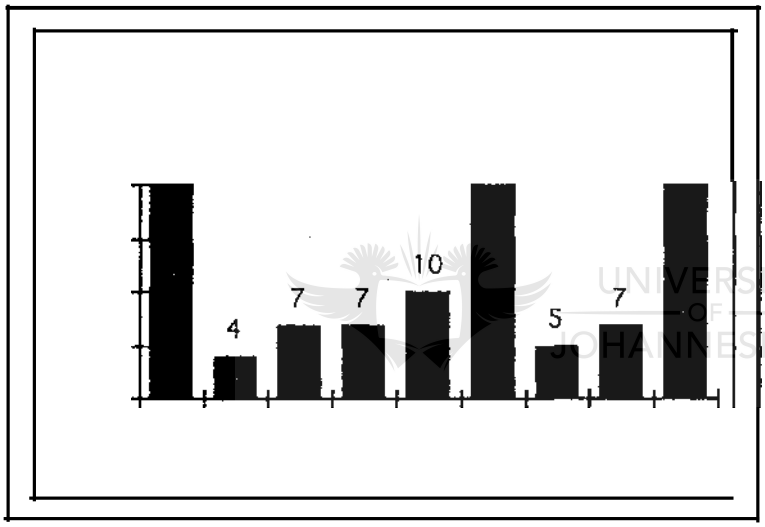


FIG 4.6

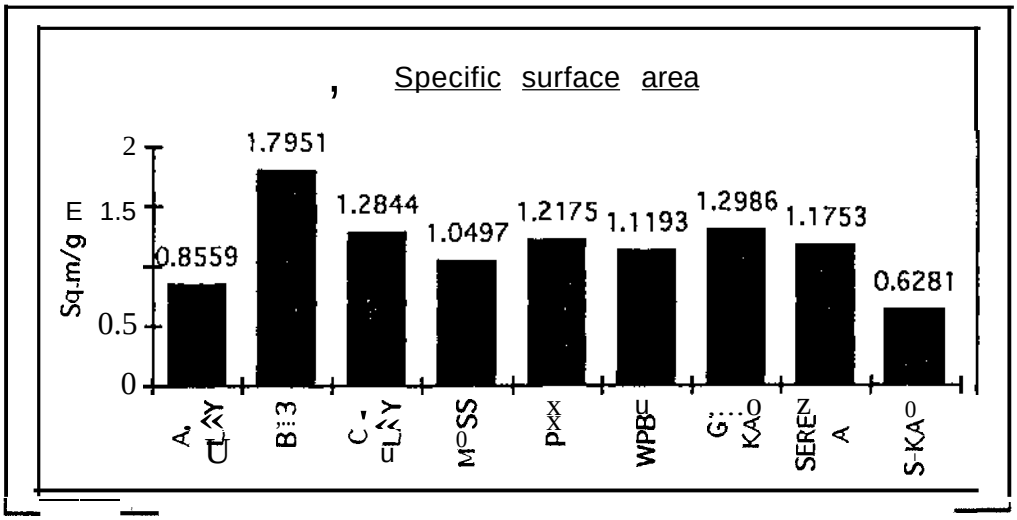


FIG 4.7

PARTICLE SIZE CHARTS

Fig 4.5 shows the percentage particles less than 2μm in size. This can be used to compare the quantity of colloidal particles present in the clay material.

Fig 4.6 gives an indication of the proportion of the coarser particles in the clay material. The chart shows the size of the particles present in the largest proportion.

Fig 4.7 gives an indication of the overall fineness of the material.

4.5 DISCUSSION

The charts and tables presented in this chapter can be compared and analysed, giving both qualitative and quantitative information on the properties of the nine clay materials and clay bodies.

For a clay body to be of use to a ceramist, whether a manufacturer or a studio potter, the required properties of the body must be considered. For instance, in the Ceramic Division, TWR, two types of whiteware are required:

1) a body for decorative art wares and fancy tableware. These wares frequently need more than a bisque firing followed by a glaze firing. Often a second glaze firing as well as a lustre or on-glaze firing is needed for the desired glaze effect and a non-vitrified body is necessary to prevent dunting in the last firing. The clay should be plastic in order to be thrown and have good green strength in order that the final surface treatment can be performed without fear of breaking. The choice of clays for inclusion in such a body should not approach the vitrification point at the regular firing temperature of the studio (1186°C) and should have a low silica content to avoid dunting. The ware should be white in order to enhance the colours applied to the surface.

2) a body for production wares that complies with the requirements for whitewares. The ware should be just short of vitrification at the chosen firing temperature in order to give mechanical strength and the body / glaze fit should be good to prevent delayed crazing. This body should be plastic for quick production throwing and preferably be compatible with a slip-ware body in order that sets, combining the two techniques, can be produced. (This thesis does not cover the SUbject of slipcasting bodies, but the information can be used for their assessment).

In both these cases, as in most others, the properties of workability and plasticity, colour, firing range and vitrification of the ware are of prime importance. It must be noted that any clay body can be formulated using the information supplied in this Data Base.

The information gained from the plasticity tests performed on the clay bodies shows that A Clay and Western Province Ball Clay (WPBC) are consistently the most plastic and easy to throw: On the particle size charts both these clays show a fair percentage of particles less than *2fJm* in size and a peak of particle size distribution at *20fJm* indicating a wide range of particle sizes.

If the similarities between these two clays are followed, it shows that they have the lowest % of total fluxes of all the chosen clays (Table 4.2) and are the lowest in free silica (Table 3.3). Both these clays are also among those with the highest combined iron and titanium content. If these two clays were combined in a white body that has properties as mentioned above(4.5), A-clay, WPBC and other white materials would have to be carefully balanced for the combined iron and titanium content to be less than 2% in order that the final clay body fire white.

The introduction of Moss clay in the place of A-clay would be more suitable for a whiteware body. After firing the clay body samples to $1000^{0}C$ and $1200^{0}C$ there was an indiscernible lightening of the A-clay in spite of the reduction in combined Fe+Ti to 2.53% (Table 4.2) but the WPBC and Moss clay fired considerably lighter at 11OOoC and slightly lighter at $1200^{0}C$.

It should be noted that neither Moss clay nor WPBC are fully fluxed at $1200^{0}C$ (Fig 4.4) making them useful clays for extending the vitrification range of a clay body without reducing the plasticity as would occur with the addition of kaolin. These two clays had the lowest absorption rate at 11 OOoC making them extremely useful clays for inclusion in whitewares intended to fire at temperatures below $1200^{0}C$.. There seems to be no outstanding factor to explain the. phenomena e.g. excess low temperature fluxes such as Na2D or CaD (Table 4.2).

813 clay shows the highest percentage of colloidal particles of all the clay materials tested (Fig 4.5), and the highest specific surface area (Fig 4.7) but the peak of particle size distribution fell below *5fJm* (Fig 4.6) caused the body to be sticky to throw on the wheel (Table 3.32. This could be attributed to the fact that the ranqe of particle sizes is too small.

On examination under the microscope 813 clay material appeared fine particled but highly speckled (Fig.3.13). Separate particles of iron, chrome, titanium and calcium were identified which are the probable cause of the characteristic green tinge of 813 at firing temperatures above 1100^{0} C. Examination of the fired clay body samples of

this clay show an indiscernible lightening of the clay body after the addition ·of silica and feldspar although the combined Fe+Ti content is 1.*n*% (Table 4.2).

813 , together with PXX clay, are the most vitrified of the clay materials at 11COoC (Fig.4.2) but with the addition of feldspar and silica to form a clay body the vitrification point was raised considerably (Fig 4.4). PXX is a useful white clay of average plasticity (Table 3.32). The clay fired lighter after the addition of silica and feldspar to the clay body but it is not superlorIn any way and it is doubtful that it should be used in the place of the local clay materials.

As has been stated in Chapter 3, C-Clay is among the whitest of the ball clays tested with a low combined Fe+Ti content of 2.06%(Table 4.1a) but the clay shows a tendency to dilate when combined in a clay body giving the clay body a low rating in the empirical throwing test (Table 3.32). This clay could be. introduced in small quantities to a clay body as a whitener. Neither the shrinkage nor the water absorption rates are excessive.

The addition of kaolin to a clay body is usual to increase the refractory materials and reduce the shrinkage of the clay body. Kaolin will also act to lighten the body. Of the three kaolins tested, Serena is far superior to the other two. As mentioned in Chapter 3 (3.8.4) this kaolin falls the closest of all the materials tested to the theoretical composition of kaolinite.

The silica content in Serena and S-Kaolin is low and high in G1 Kaolin. The fluxes follow the same pattern. S-Kaolin is the third clay material of those tested to exhibit a peak of particle size distribution at *20pm* (Fig 4.6) but a low percentage of the fine particles (Fig 4.5) and a low specific surface area (Fig" 4.7) suggest that it is a coarse, non-plastic material.

It is questionable whether G1 Kaolin should be considered a Kaolin or placed with the ball clays. Its analytical similarity to 813 clay is remarkable.

The information that can be gained from the correlation of data as is shown in this chapter, can assist in the choice of clays for specific bodies. For the two bodies outlined above (4.5) the 'choice of clay materials would be Moss clay and WP8C for their colour but more specifically for their fluxing power at $1100^{0}C$. As has been previously mentioned (1.2) for a body to have strength it should be just short of

vitrification: Both of these clays comply with this requirement. With the addition of Serena kaolin, feldspar and silica, a suitable body could be formulated. The second whiteware body mig.ht need the addition of a secondary flux to bring the fired body closer to vitrification point.

The data base and the comparative tables of clays can be updated with each new batch of clay brought into the studio. In this way the Ceramic Division of the TWR could establish a useful, comprehensive record of the composition and physical properties of the clay materials in use.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS.

The analyses and tests performed on the nine selected clay materials show the range of properties to be found in a handful of clay materials, a minute sample of all the claysround on Earth.

Tneclay mining companies and dlstrlbutors should be able to supply an updated analysis of the clay materials with every batch. supplled.but.ltlsontylnrare.lnstances that this is in fact given. This lack of information was one of the prime reasons for undertaking this research project. The available suppliers analyses can be found in Appendix B. A comparison of the EDAX data and the suppliers analysis shows that there are variations in composition, both greater and smaller. The analysis for Serena Kaolin, the most stable of the clay materials, is almost identical in the two analyses giving validation to the EDAX as an analytical tool. Generally the Al_2O_3 shows very little variation between the two analyses, the silica shows more but the Iron content and the fluxes vary considerably in percentage composition..

The techniques laid out in tnrs.thesls.can be used for testing any clay materials. As has been mentioned, the data should be frequently updated in order to be aware of changes in the composition of the clays in use and thus avert problems before any quantity of ware has been manufactured using material of unknown composition.

The Insight ceramic software programme combined with the ultimate and rational analyses calculations has proved to be efficient and accessible to the students of the Division. As long as the students have available the results from the analyses and the physical tests described here, they may enter them in the programme and "mix" the available clays theoretically, down to the final adjustments, until they obtain the clay body most suited to the type of ware required. This will eliminate the trials and errors of the past and, subsequently, the waste of time and materials.

Alternately, as discussed in detail in section 4.5, the potential of each new clay as a component of clay bodies can be assessed by means of the "Inslqht" programme by simply entering its chemical analyses in the programme and testing all possible recipes of clay bodies including the new clay material. As a result of this project, therefore, it will be much easier now to venture into new recipes.

Another important achievement of this work is that it has lead to a better understanding of the behavior of each clay. As has been discussed in section 4.5,

the behavior can be explained quite consistently in terms of composition and the rational analyses, particle size, fluxing temperature and colour. With further research into other clay materials: a useful body of information can be collected and made available to the students and staff of the Ceramic Division, TWA.

As far as suggestions are concerned, the main one is that the present knowledge of clays should be completed by X-ray diffraction analysis, perhaps in collaboration with another research group, which would lead to knowledge of the mineralogical composition of the clays. This would give another comparative means of assessing the physical properties and workability of the clay materials as well as the ability to determine whether the rational analysis should be based on the feldspar or mica convention.

APPENDICES

APPENDIX A

Rational Analysis

Copied from Whitewares Production, Testing and Quality Control byW. Ryan and C. Radford. Page 158 - 162

Example

SiO_2	61·30
Al203	20·20
Fe203	3·40
TiO_2	0·20
MgO	0·24
CaO	0'34
Na20	1·05
K_{20}	2·35
loss	10·90

To Calculate the Rational Analysis of a Clay

FELSPAR CoNVENTION

(1) Using this convention it is assumed that the alkalis (K_{20} and Na20) are derived entirely from felspars.

1 molecule K_{20} ≅ I molecule potash felspar

≡ K20.AI203·6Si02

94 parts K_{20} ≅ 556 parts potash felspar

1 part K_2O ≅ $\frac{556}{94}$ parts potash felspar

= 5·92 potash felspar or orthoclase

A similar calculation for soda spar (albite)

Na20.AI203·6Si02

yields a factor of 8·45. However, it is coinmon practice to take the sum of the percentage of K20 and Na20 and to use the factor of 5·92 to convert these oxides to mineral felspar. This treatment should only be applied to clays when the total alkalis are small (2-4%) and the amount of K_{20} is approximately twice the Na20 content.

Considering the ultimate analysis quoted at the beginning of the chapter,

(K20 2·35+Na20 1,05) = 3·40 total alkali content

3·4Ox5·92 = 20'13% felspar

(2) (a) 1 molecule K20.AI203.6Si02 ≅ 1 molecule AI203

556 ≡ 102

1 part felspar ≅ $\frac{102}{556}$ parts AI_{203}

= 0'183 AI203

20'13xO'183 = 3·68 parts AI203 in felspar

(b) Similarly, 556 felspar ≅ 6x60 $Si0_2$

1 felspar ≅ $\frac{360}{556}$ $Si0_2$

= 0'647 $Si0_2$

20·13xO·647 = 13·02 parts $Si0_2$ in felspar

(3) Total Al_2O_3 = 20·20 (ref. ultimate analysis)
.-Al_{203} in felspar = -3,68
16·52 = Al_{203} in clay substance

1 molecule Al_2O_3 ≡ 1 molecule A1203'2Si02'2H20
102 ≡ 258
1 part Al203 ≡ 102/258 parts clay substance
= 2'53 clay substance
∴ *16·52x2·53* = 41·79% clay substance

(4) 1 molecule Al2oi.2Si02.2H20 ≡ 2 molecules $Si0_2$
258 ≡ 2x60
1 clay substance ≡ $\frac{120}{258}$ $Si0_2$
= 0·465 $Si0_2$
Si02 in clay substance = 41·79xO·465
= 19-43% $Si0_2$ in clay substance

Free quartz = Total $Si0_2$
-($Si0_2$ in clay substance-l-SsOs in felspar)
= 61'30-(19,43+13'02)
= 28·85 % free quartz

Summary

Total alkalis x 5·92 = % felspar
FelsparxO'183 = Al203 in felspar
FelsparxO'647 = Si02 in felspar
(Total Al203-Al203 in felspar) X 2-53 = %clay substance
Clay substance x 0-465 = si_{02} in clay
Total Si02-(Si02 in clay+$Si0_2$ in felspar) = %quartz

Further information can be obtained from the percentage loss-on-ignition. The first step is to calculate the loss due to the chemically combined water in the clay molecule.

I molecule Al203'2$Si0_2$.2H20 = 2 molecules H20
258=2x18
36
I part clay ≡ 258 parts water
= 0·140 part water
41·78xO·14O = 5·83 loss due to H20 in clay molecule
(Total loss-loss due to H20 in clay) = loss due to organic matter, C02, etc.
(10'90-5·83) = 5·07% loss due to organic matter, C02, etc.

MICA CONVENTION

The mica convention is concerned with the minerals
. potash mica (K20.3AI203.6Si02.2H20)
and soda mica (Na20.3AI203.6Si02.2H20)

Using the ultimate analysis from the previous example:

(1) 1 molecule K20 ≡ 1 molecule K20.3AI203.6Si02.2H20
94 ≡ 796 .

$$1 \text{ part } K_2O \equiv \frac{796}{94} \text{ parts mica}$$

1 part K_2O = 8·47 parts potash mica

Similarly the factor for converting Na20 content to soda mica = 12·32.

K_2O = 2'35% (ref. ultimate analysis)
2·35x8·47 = potash mica = 19·91%
and 1·05x12·32 = soda mica - 12·93%

(2) 1 molecule potash mica ≡ 3 molecules AI203
796 ≡ 306

$$1 \equiv \frac{306}{796}$$

∴ 1 part potash mica = O'384 parts AI_2O_3
19·91 xO·384 = 7·64 = AI_2O_3 in potash mica
1 molecule potash mica ≡ 6 molecules SiO_2
796 ≡ 6x60

$$1 \equiv \frac{360}{796}$$

1 part potash mica ≡ 0·452 parts SiO_2
:. 19·91 xO·452 = 9·00 = SiO_2 in potash mica
Similarly for soda mica:
12·93xO·400 = 5·17 = AI_2O_3 in soda mica
12·93xO·471 = 6·09 = SiO_2 insoda mica

(3) Total AI_2O_3 (ref. ultimate analysis) = 20·20
- AI_2O_3 in micas (7'64+5'17) = -12,81
AI_2O_3 in clay substance = 7·39
7·39 x 2· 53 = 18·69% clay substance

(4) SiO_2 in clay = 18·69xO·465 = 8·69
Si02 in clay+Si02 in micas = (8'69+9'00+6·09)
=23,78
:. Free quartz = 61·30-23·78 = 37·52%

The final rational analysis is:

Potash mica	19.9
Soda mica	12·9
Clay substance	18·7
Quartz	37·5
Organic matter, C02, etc., by difference	6·9
Fe203	3·4
Ti02	0·2·
MgO	0·2
CSO	0'3

Summary

K20x8·47 = potash mica
Na20x 12·32 = soda mica
Potash mica x O'384 = AI_2O_3 in potash mica
Potash micaxO·452 = SiO_2 in potash mica
Soda micaxO'400 = AI_2O_3 in soda mica
Soda micaxO·471 = SiO_2 in soda mica
(Total AI_2O_3-AI_2O_3 in micas)x 2'53 = clay substance
.Clay substancexO'465 - SiO_2 in clay
Total SiO_2-(SiO_2 in clay+SiO_2 in micas) = Free quartz

APPENDIX B

Chemical Analy$es supplied by the distributors

CLAY TYPE	C CLAY	B13 CLAY	WPBC	PXX	A CLAY	KAOLIN Gl	KAOLIN S	SERENA K
Si02	56.8	58.9	48.5	54.5	55.85	65.5	53	47
AL203	23.6	24.9	31.6	33.5	28.9	22.5	31	37.5
Fe203	0.6	2.5	2.2	0.2	2.88	0.6	1.5	0.6
rTi02	1.8	0.9	1.4	1.5	1.5	0.5	0.9	0.68
MgO	0.2	0.3	0.5	0.1	0.3	0.1	0.1	0.18
CaO	0.3	0.2	0.16	0.2	0.45	0.04	0.1	0.1
Na20	0.3	0.4	0.1	1.2	0.05	0.6	0.2	0.3
K20	0.35	1.4	0.7	3.2	0.4	3.6	0.2	0.8
MnO				0.01				
LOI	6.7	9	12.9	5.4	10.6	5.7	11.7	13.3

APPENDIXC

RESULTS OF THE PHYSICAL TESTS

Loss* On *Ignition

Clay	A Clay	813	CClay	Moss	Pxx	WPBC	G1 Kaol.	Selina	S Kaolin
Drywt	73	70	71.5	70	78	69.5	75.	75.	73.25
110°C	72.4	74.5	69	67	73	65.5	72.5	69.25	67.00
1000^{0C}	61.10	67.7	64.8	63.2	66.7	57.7	68.8	60.9	60.4
LOI	10.9	6.8	6.1	5.7	8.6	11.9	5.1	12.05	9.8

Water* of *plasticity; Linear shrinkage; Water absorption.

CLAY MATERIAL

CLAY TYPE	C CLAY	B13	WPBC	PXX	A CLAY	G1 K	SK	SER K	MOSS
WATER OF									
PLASTICITY	38%	40%	42%	35%	44%	36%	47%	52%	45%
LIN.SHRINKAGE									
A	9%	9%	10.50%	6.50%	11%	5%	7%	6.50%	8.5%
600	9%	9%	10.50%	6.50%	11%	5%	7%	6.50%	6%
B	9%	12%	12%	10%	14%	6.50%	10%	9%	8.5%
C	14%	17%	15%	16.50%	15%	10%	11%	9%	12%
0	18%	18%	20.50%	20%	23%	15%	15%	13%	18%
ABSORPTION									
A									
600		17.60%	23.90%		24.20%			36.20%	
B	18.90%	13.10%	20.50%	18.10%	20%	22.10%	46.00%	35.90%	26%
C	12.20%	1.40%	12.80%	2.40%	16.20%	16.90%	40.90%	35.10%	18.7%
0	0.50%	0.70%	1.85%	0.20%	1.70%	1.10%	33.80%	21.10%	4.10%

CLAY BODIES

% LINEAR SHRINKAGE (WET-FIRED)									
	A-CLAY	813	C-CLAY	MOSS	PXX	WP8C	G1 KAO	SER K	S-KAO
W	0	0	0	0	0	0	0	0	0
0	9.9	12	6	6	6	8	6	6	6
1000	9.9	12	6	8	6	10	6	6	6
1100	12	14	6	10	8	10	8	8	8
1200	14	16	14	12	14	14	12	10	10

% WATER ABSORPTION									
	A-CLAY	813	C-CLAY	MOSS	PXX	WP8C	G1 KAO	SER K	S-KAO
1000	16	15.5	16	18	14	15	19.5	25	23
1100	13.5	12	15	5.7	10.3	6.6	17	25	23
1200	0.7	0.9	3.6	2.5	2.5	5.3	5.9	15	15

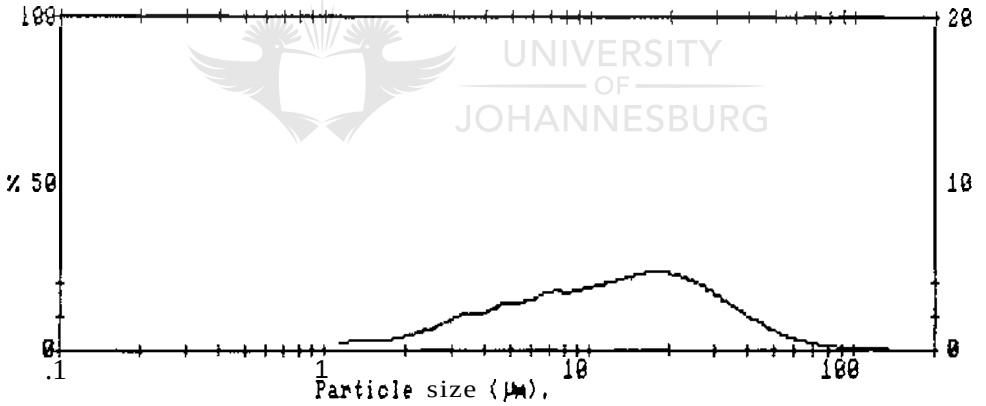
Particle size Analysis

A clay

MALVERN MASTERSIZER S2.01 Date 01-01-1980 Time 01:34

SAMPLE NO: 1 - AC

Dispersant	Water
Addltives	None
Ultrasound	Max
PUlP speed	80%
Stir speed	80%
Notes	



Upper Size	% in	Lower Size	% under	Upper Size	% in	Lower Size	% under
		600	100	31.0	6.7	25.5	79.6
600	0.0	492	100	25.5	8.0	20.9	71.6
492	0.0	404	99.9	20.9	8.6	17.1	63.0
404	0.0	332	99.9	17.1	8.3	14.1	54.6
332	0.0	272	99.9	14.1	7.7	11.6	46.9
272	0.0	224	99.8	11.6	7.1	9.48	39.8
224	0.1	183	99.8	9.48	6.5	7.78	33.3
183	0.1	151	99.7	7.78	6.3	6.39	26.9
151	0.1	124	99.5	6.39	5.5	5.24	21.4
124	0.2	101	99.3	5.24	5.1	4.30	16.3
101	0.4	83.3	99.0	4.30	4.2	3.53	12.2
83.3	0.7	68.3	98.3	3.53	3.8	2.90	8.4
68.3	1.2	56.1	97.1	2.90	2.7	2.38	5.7
56.1	2.2	46.0	94.9	2.38	1.8	1.95	3.9
46.0	3.5	37.8	91.4	1.95	1.3	1.6e	2.6
37.8	5.1	31.0	86.3	1.60	1.2	1.32	1.4

Result source=Salple
Record No. = 0
Focal length =300 mm.
Presentation =0903
Volule distribution
Beal length = 2.0 mm.
Obscuration =0.2092
Volume Cone. =0.0239 %
Residual = 0.113%
Model indp

D(Y,B.S) = 12.52 µm
DlY,9.9) = 35.60 µm
Dlv,".I) = 3.17 µm
D14,3) = 15.89 µm
D13,2) = 7.94 µm
Span =2.6
Spec. surf. area
0.8559 sq.I./gl.

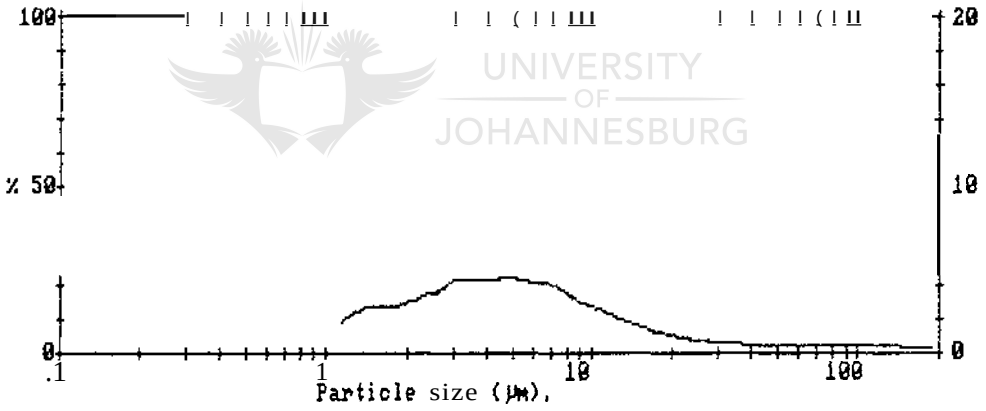
Particle size Analysis

8 13 8all clay

MALVERN MASTERSIZER S2.01 Date 01-01-1980 Time 00:13

SAMPLE NO: 2 - 813

Dispersant	Water
Additives	None
Ultrasound	Max
PUlP speed	80%
Stir speed	80%
Notes	



Upper Size	% in	Lower Size	% under:	Upper Size	% in	Lower Size	% under:
		600	100	31.0	1.3	25.5	90.3
600	0.0	492	100	25.5	1.6	20.9	88.7
492	0.0	404	100	20.9	2.2	17.1	86.5
404	0.0	332	100	17.1	2.8	14.1	83.7
332	0.1	272	99.9	14.1	3.8	11.6	79.9
272	0.2	224	99.7	11.6	4.9	9.48	75.1
224	0.4	183	99.3	9.48	6.0	7.78	69.1
183	0.6	151	98.7	7.78	7.5	6.39	61.6
151	0.8	124	98.0	6.39	8.0	5.24	53.6
124	0.9	101	97.1	5.24	8.3	4.30	45.3
101	0.8	83.3	96.3	4.30	8.0	3.53	37.3
83.3	0.9	68.3	95.4	3.53	8.0	2.90	29.3
68.3	0.9	56.1	94.5	2.90	7.1	2.38	22.2
56.1	0.9	46.0	93.6	2.38	6.0	1.95	16.2
46.0	0.9	37.8	92.7	1.95	5.2	1.60	10.9
37.8	1.1	31.0	91.6	1.60	5.1	1.32	5.9

Result source=Sample
Record No. = 0
Focal length =300 II.
Presentation =0903
Volume distribution
Deal length = 2.0 II.
Obscuration =0.1853
Volume Cone. = 0.0094 %
Residual = 0.375%
Model indp

D(v,0.5) = 4.81 µm
Dlv,0.9) = 24.33 µm
Dlv,0.1) = 1.55 µm
014,3) = 18.14 µm
013,2) = 3.70 µm
Span =4.7
Spec. surf. area
1.7951 sq.I./gl.

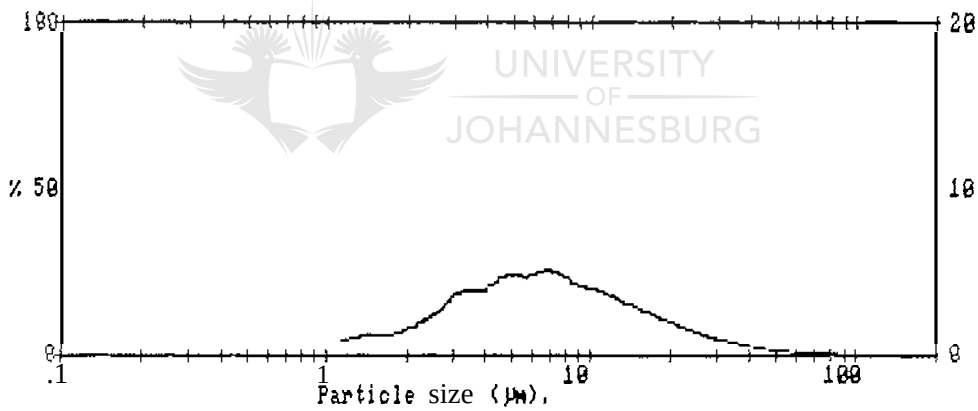
Particle size Analysis

C-Clay

MALVERN MASTERSIZER S2.01 Date 01-01-1980 TiMe 00:24

SAMPLE NO: 3 - CCLAY

Dispersant	Water
Additives	*None*
Ultrasound	Max
Pu.p speed	80%
Stir speed	80%
Notes	



Upper Size	% in	Lower Size	% under:	Upper Size	% in	Lower Size	% under:
		600	100	31.8	2.1	25.5	90.8
600	1.1	492	98.9	25.5	3.0	20.9	87.8
492	1.1	404	97.8	20.9	4.0	17.1	83.8
404	0.6	332	97.2	17.1	5.1	14.1	78.7
332	0.2	272	97.0	14.1	6.2	11.6	72.5
272	0.1	224	96.8	11.6	7.3	9.48	65.1
224	0.1	183	96.8	9.48	8.2	7.78	56.9
183	0.1	151	96.7	7.78	9.3	6.39	47.6
151	0.1	124	96.6	6.39	8.9	5.24	38.7
124	0.1	101	96.6	5.24	8.7	4.30	30.0
101	0.1	83.3	96.4	4.30	7.3	3.53	22.7
83.3	0.2	68.3	96.2	3.53	7.0	2.90	15.8
68.3	0.3	56.1	95.9	2.90	5.0	2.38	10.8
56.1	0.6	46.0	95.3	2.38	3.4	1.95	7.4
46.0	0.9	37.8	94.4	1.95	2.5	1.60	4.9
37.8	1.4	31.0	92.9	1.60	2.3	1.32	2.6

Result source=Salple
Record No. = 0
Focal length = 300 II.
Presentation =0903
Volule distribution
Beam length = 2.0 I••
Obscuration =0.2327
Volule Cone. = 0.0176 %
Residual = 0.165%
Model indp

D(v,0.5) = 6.72 µm
D(v,0.9) = 23.95 µm
0(v,0.1) = 2.29 µm
0(4,3) = 12.41 µm
0(3,2) = 5.15 µm
Span =3.2
Spec. surf. area
1.2844 sq.I./gl.

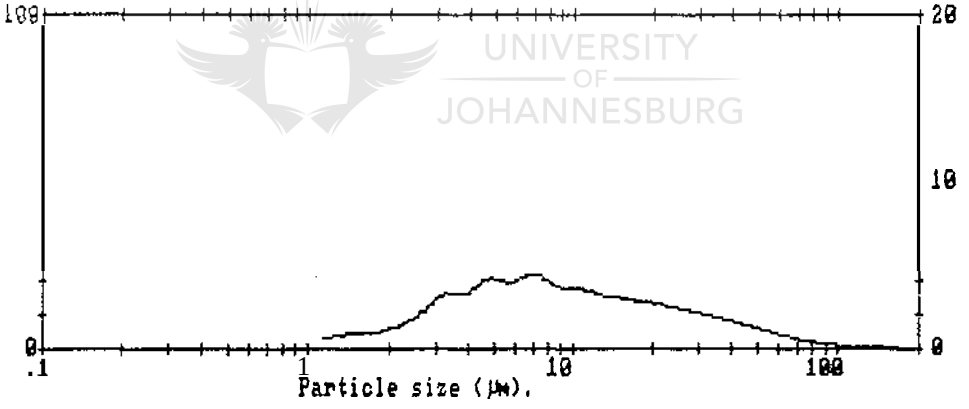
Particle size Analysis

Moss Clay

MALVERN MASTERSIZER S2.91 Date 01-01-1980 Time 00:44

SAMPLE NO: 5 - MOSS

Dispersant	Water
Additives	None
Ultrasound	Max
PUP speed	80%
Stir speed	80%
Notes	



Upper Size	% in	Lower Size	% under	Upper Size	% in	Lower Size	% under
		600			4.1	25.5	81.3
600	1.3	492			4.7	20.9	76.6
492	0.6	404			5.1	17.1	71.4
404	0.2	332			5.5	14.1	65.9
332	0.1	272			6.0	11.6	59.9
272	0.1	224			6.5	9.48	53.4
224	0.1	183			6.9	7.78	46.5
183	0.1	151			8.0	6.39	38.5
151	0.2	124			7.4	5.24	31.1
124	0.3	101			7.5	4.30	23.6
101	0.5	83.3			6.1	3.53	17.5
83.3	0.9	68.3			5.8	2.90	11.6
68.3	1.5	56.1			4.0	2.38	7.6
56.1	2.2	46.8			2.5	1.95	5.1
46.0	2.9	37.8			1.7	1.60	3.4
37.8	3.6	31.0			1.6	1.32	1.8

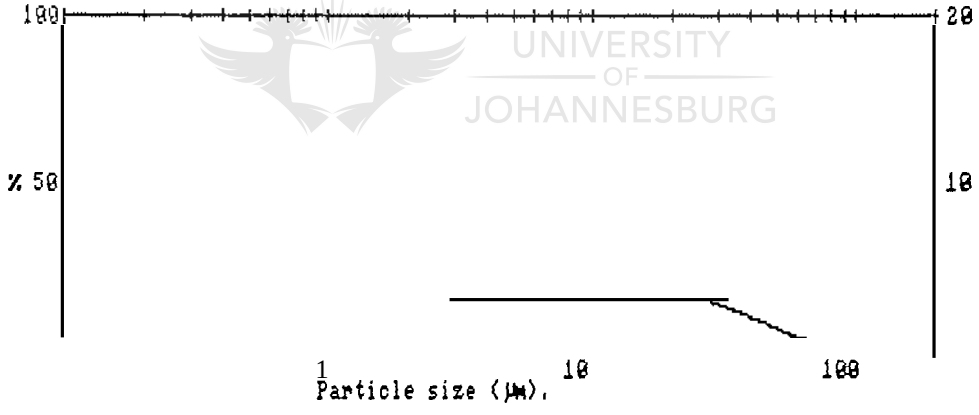
Particle sIze Analysis

PXX ball clay

MALVERN MASTERSIZER S2.01 Date 01-01-1980 Time 00:34

SAMPLE NO: 4 - PXX

Dispersant	Water
Additives	None
Ultrasound	Max
PUlp speed	80%
Stir speed	80%
Notes	



Upper Size	% in	Lower Size	% under:	Upper SIze	% in	Lower Size	% under'
		600	100	31.0	5.3	25.5	79.6
600	0.6	492	99.4	25.5	5.8	20.9	73.8
492	0.3	404	99.0	20.9	5.9	17.1	67.9
404	0.2	332	98.9	17.1	5.7	14.1	62.2
332	0.1	272	98.8	14.1	5.5	11.6	56.7
272	0.1	224	98.7	11.6	5.5	9.48	51.2
224	0.1	183	98.7	9.48	5.6	7.78	45.6
183	0.1	151	98.6	7.78	6.0	6.39	39.6
151	0.1	124	98.4	6.39	5.9	5.24	33.7
124	0.2	101	98.2	5.24	5.9	4.30	27.8
101	0.4	83.3	97.8	4.30	5.4	3.53	22.3
83.3	0.8	68.3	96.9	3.53	5.2	2.96	17.1
68.3	1.5	56.1	95.5	2.90	4.4	2.38	12.7
56.1	2.4	46.0	93.0	2.38	3.5	1.95	9.1
46.0	3.6	37.8	89.5	1.95	2.9	1.60	6.2
37.8	4.6	31.0	84.9	1.60	2.8	1.32	3.4

·Result source=SaIPle
Record No. = 0
Focal length = 300 mm.
Presentation =0903
Volume distribution
Beal length = 2.0 mm.
Obscuration =0.2887
Volume Cone. =0.0236 %
Residual = 0.122%
Model indp

D(Y,0.S) = 9.08 µm
D(y.0.9) = 38.80 µm
D(y.0.1) = 2.06 µm
D(4,3) = 14.99 µm
D(3,2) = 5.57 µm
Span =4.0
Spec. surf. area
1.2175 Sq.I.JgI.

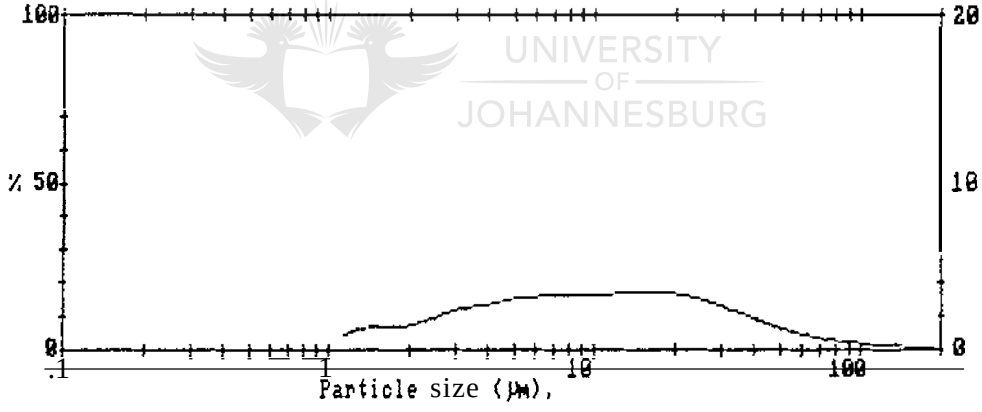
Particle size Analysis

Western Province Ball Clay

MALVERN MASTERSIZER S2.01 Date 01-01-1980 Time 00:55

SAMPLE NO: 6 - WPBC

Dispersant	Water
Additives	None
Ultrasound	Max
PUMP speed	80%
Stir speed	80%
Notes	



Upper Size	% in	Lower Size	% under:	Upper Size	% in	Lower Size	% under:
		600	100	31.0	5.1	25.5	78.8
600	0.2	492	99.8	25.5	5.8	20.9	73.0
492	0.2	404	99.6	20.9	6.3	17.1	66.7
404	0.2	332	99.5	17.1	6.4	14.1	60.4
332	0.2	272	99.3	14.1	6.3	11.6	54.1
272	0.2	224	99.1	11.6	6.2	9.48	47.9
224	0.3	183	98.8	9.48	6.1	7.78	41.8
183	0.4	151	98.5	7.78	6.1	6.39	35.7
151	0.5	124	98.0	6.39	5.9	5.24	29.8
124	0.6	101	97.4	5.24	5.5	4.30	24.3
101	0.8	83.3	96.6	4.30	4.9	3.53	19.4
83.3	1.1	68.3	95.4	3.53	4.6	2.90	14.8
68.3	1.7	56.1	93.8	2.90	3.8	2.38	11.0
56.1	2.4	46.0	91.4	2.38	3.1	1.95	7.9
46.0	3.3	37.8	88.1	1.95	2.5	1.60	5.4
37.8	4.2	31.0	83.9	1.60	2.4	1.32	3.0

Result source=Salple
Record No. = 0
Focal length = 300 mm
Presentation =0903
Volume distribution
Beam length = 2.0 mm
Obscuration =0.2255
Volume Conc. = 0.0194 %
Residual = 0.105%
Model indp

D(v,B.5) = 10.13 µm
D(v,0.9) = 42.01 µm
D(v,0.1) = 2.24 µm
D(4,3) = 16.59 µm
D(3,2) = 6.09 µm
Span = 3.9
Spec. surf. area
1.1193 sq.m/gm

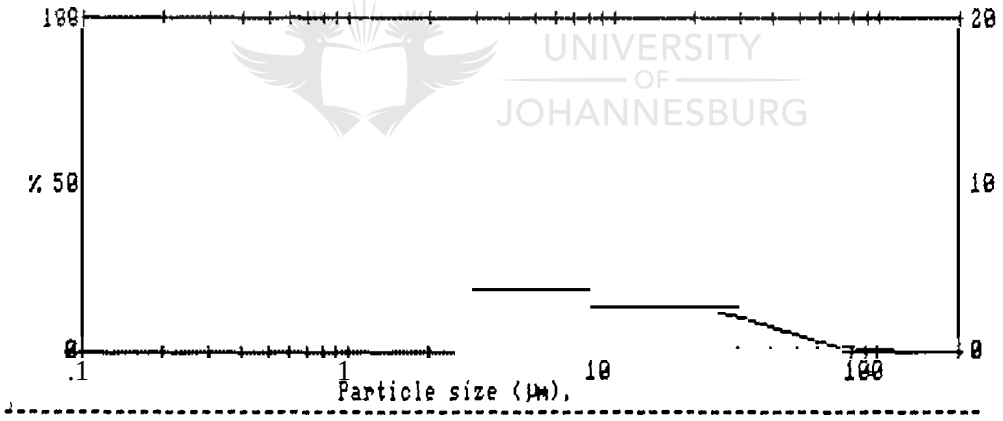
Particle size Analysis

G1 Kaolin

MALVERN MASTERSIZER S2.91 Date 01-01-1980 Time 91:25

SAMPLE NO: 9 - 61 K

Dispersant	Water
Additives	None
Ultrasound	Max
PUJP speed	80%
Stir speed	80%
Notes	.



Upper Size	% in	Lower Size	% under:	Upper Size	% in	Lower Size	% under:
		600	100	31.0	4.0	25.5	82.6
600	2.0	492	98.0	25.5	4.5	20.9	78.1
492	0.8	404	97.3	20.9	4.7	17.1	73.3
404	0.2	332	97.0	17.1	4.9	14.1	68.5
332	0.1	272	96.9	14.1	5.1	11.6	63.4
272	0.1	224	96.9	11.6	5.4	9.48	58.0
224	0.0	183	96.8	9.48	5.8	7.78	52.1
183	0.1	151	96.8	7.78	6.9	6.39	45.3
151	0.1	124	96.7	6.39	6.8	5.24	38.5
124	0.2	IBI	96.6	5.24	7.2	4.30	31.3
101	0.3	83.3	96.3	4.30	6.5	3.53	24.8
83.3	0.6	68.3	95.7	3.53	6.5	2.90	18.3
68.3	1.1	56.1	94.6	2.90	5.1	2.38	13.2
56.1	1.8	46.0	92.7	2.38	3.9	1.95	9.3
46.0	2.7	37.8	90.0	1.95	3.1	1.60	6.2
37.8	3.4	31.0	86.6	1.60	2.9	1.32	3.3

Result source=Sample
Record No. = 0
Focal length = 300 II•
Presentation =0903
Volume distribution
Beam length = 2.0 II.
Obscuration =0.3253
Volume Cone. = 0.0255 %
Residual = 0.108%
Model indp

Dlv,l!I.S) = 7.30 µm
Dlv,8.9) = 37.68 µm
Dlv,0.1) = 2.03 µm
D14,3) = 16.19 µm
D13,2) = 5.15 µm
Span = 4.9
Spec. surf. area
1.2986 sq.1./gl.

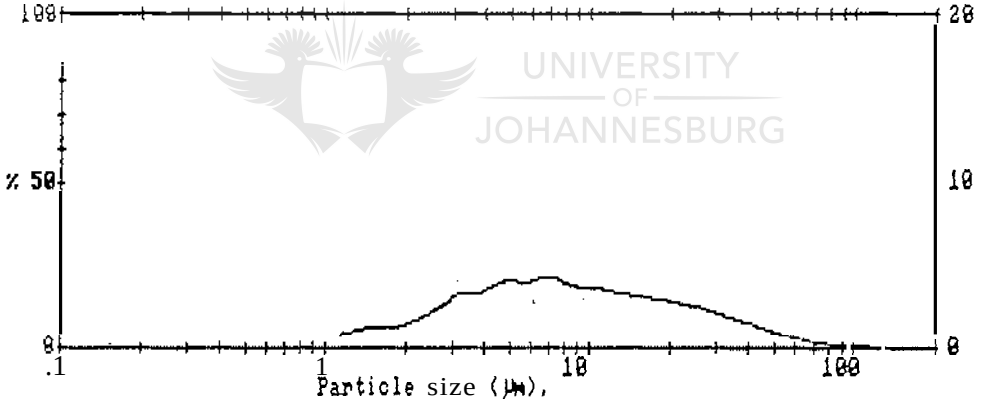
Particle size Analysis

Serena Kaolin

MALVERN MASTERSIZER S2.01 Date 01-01-1980 Time 01:04

SAMPLE NO: 7 - SER·

Dispersant	Water
AdditiYes	None
Ultrasound	Max
PUIP speed	80%
Stir speed	80%
Notes	



Upper Sue	% in	Lower Size	% under:	Upper Slze	% in	Lower Size	% under	Result source=Sample
		600	100	31.0	4.1	25,5	84.7	Record No. = 0
600	0.7	492	99.3	25.5	4.8	20,9	79.9	Focal length = 300 II.
492	0.4	404	98.9	20,9	5.4	17.1	74,5	Presentation =0903
404	0.1	332	98.8	17.1	5.7	14.1	68.8	Volule distribution
332	0.1	272	98.7	14.1	6.1	11.6	62.7	Beam length = 2.0 II.
272	0.0	224	98.7	11.6	6.6	9.48	56.1	Obscuration =0.2210
224	0.0	183	98.6	9.48	7.0	7.78	49.2	Volume Cone. = 0.0182 %
183	0.1	151	98.6	7.78	7.7	6.39	41.4	Residual = 0.118%
151	0.1	124	98.5	6.39	7.4	5.24	34.0	Model indp
124	0.2	101	98.3	5.24	7.3	4,30	26.7	
101	0.3	83.3	98.0	4.30	6.2	3.53	20.5	D(v,0.5) = 7.95 µm
83.3	0.6	68.3	97.5	3.53	5.9	2,90	14.6	DIY,B.9) = 32.95 µm
68.3	1.0	56.1	96·5	2,90	4.4	2.38	10,2	DIy,0.1) = 2.36 µm
56.1	1.7	46.0	94.8	2.38	3.1	1.95	7.0	D14,3) = 12.90 µm
46.0	2.5	37.8	92,2	1.95	2.3	1.60	4.7:	013,2) = 5.69 µm
37.8	3.4	31.O	88.9	1.60	2.2	1.32	2.5:	Span =3.8
								Spec. surf. area 1.1753 sq••• /gl.

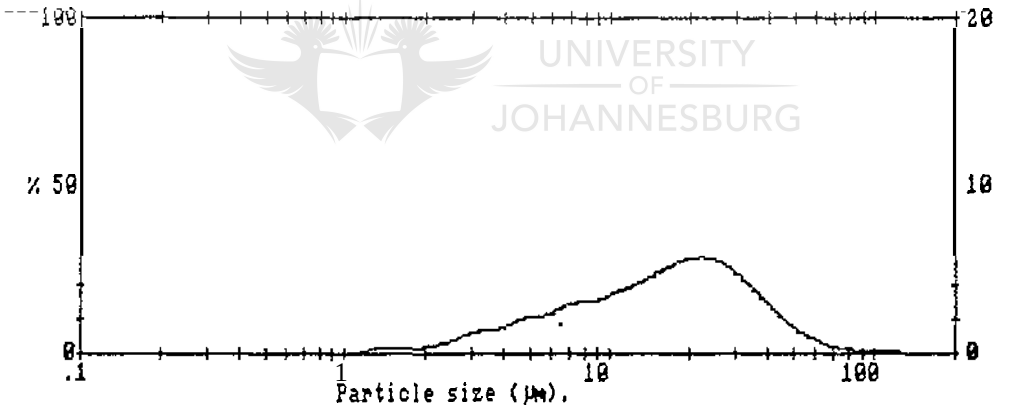
Particle size Analysis

S-Kaolin

MALVERN MASTERSIZER S2.IU Date 01-01-1980 Time 01:14

SAMPLE NO: 8 - S K

Dispersant	Water
Additives	None
Ultrasound	Max
PUlP speed	80%
Stir speed	80%
Notes	



Upper Size	% in	lower Size	% under:	Upper Size	% in	lower Size	% under
		600	100	31.0	9.4	25.5	72.8
600	0.1	492	99.9	25.5	10.5	20.9	62.3
492	0.0	404	99.9	20.9	10.1	17.1	53.2
404	0.0	332	99.9	17.1	9.0	14.1	43.2
332	0.0	272	99.8	14.1	7.7	11.6	35.5
272	0.0	224	99.8	11.6	6.7	9.48	28.8
224	0.1	183	99.7	9.48	5.8	7.78	23.0
183	0.1	151	99.7	7.78	5.4	6.39	17.6
151	0.1	124	99.5	6.39	4.3	5.24	13.3
124	0.2	101	99.4	5.24	3.9	4.30	9.4
101	0.3	83.3	99.0	4.30	2.8	3.53	6.6
83.3	0.7	68.3	98.4	3.53	2.5	2.90	4.1
68.3	1.4	56.1	97.0	2.90	1.5	2.38	2.6
56.1	2.7	46.0	94.3	2.38	0.9	1.95	1.7
46.0	4.8	37.8	89.5	1.95	0.6	1.60	1.1
37.8	7.3	31.0	82.2	1.60	0.5	1.32	0.6

Result source=Sample
Record No. = lll
Focal length = 300 II.
Presentation =0903
Volule distribution
Beal length = 2.0 II.
Obscuration =0.2558
Volume Cone. = 0.0423 %
Residual = 0.174%
Model indp

D(y,0.5) = 16.40 µm
Dlv.0.9) = 38.47 µm
Dlv.0.1) = 4.45 µm
D14,3) = 18.85 µm
D13,2) = 10.79 µm
Span = 2.1
Spec. surf. area
0.6281 sq.1./gl.

APPENDIX D

SEMIEDAX

Standards used for EDAX analysis.

The MINTEK standards used were:

Si - 23	Si02
AI- 5	AI203
Fe - 18	Fe203P
Ti - 2	Ti02P
Mg-1	MgOP
Si -12	CaOP
Si - 33	Na20p
Mn-4	Mn304
Si - 28	K20P

Explanation of *ZAF correction*

Z .The atomic number correction is required on account of two phenomena - electron backscattering and electron retardation, both of which depend on the average atomic number of the sample. If there is a difference between the average atomic number of the sample and that of the standard, an atomic number correction is necessary.
Variables affecting the Z correction are: operating voltage, take off angle and the mass absorption factor for the element of interest.

A The absorption correction is required since the x-rays produced by the electron beam are created at some non-zero depth in the sample, and they must pass through the sample on the way to the detector. On this journey, some of the X-rays undergo absorption due to interactions with the atoms of the various elements in the sample. Thus the intensity of the X-ray radiation finally reaching the detector is reduced in magnitude.
Variables affecting the A correlation are : respective mass absorption co-efficients, the critical excitation voltage Ec for K, Land M radiation from the element and the mean atomic number and mean atomic weight of the sample.
F The fluorescent correction is necessary if the energy of the X-ray peak from one element is sufficient to excite X-rays secondarily from another element. Thus more X-rays from the second element are generated than would have been produced by electron excitation alone.

CLAY MATERIAL ANALYSES

The stoichiometric analyses of the nine selected clay materials are presented in this section. The A*TOM%* column of the EDAX analysis was entered into the Ultimate analysis data base calculation (Chapter2).The Ultimate analysis for each clay material was entered into the Rational analysis data base calculation. The results of all three analyses are included in this appendix.

EDAX ANALYSIS

A-CLAY

Sample A 1

```
Specimen spectrum,                          FILENAME: ACD'l
ACD1                                          LIVETIME(spec.)=     200
 ENERGY      RES        AREA
    1.6    84.06     114853
TOTAL AREA=     287104
 ......
FIT INDEX=     .8'2
```

ELMT		APP.CONC	ERROR(WT%)
NaK	2	•185	.087
MgK	2	.426	•'109
AlK	2	24.0'10	.'187
SiK	2	23.730	•'14'1
K K	2	'1.463	.065
CaK	2	**.792**	.056
TiK	2	1.537	.077
MnK	2	.044	•07'1 * < 2 Sigma*
FeK	2	**2.737**	•'1'13
S K	0	.360	.044

```
...[ 3 ZAF'SJ

20.00 kV  TILT=   .00 ELEV=4o.00 AZIM=   .00 COSINE=1.000

Spectrum: ACD1

Last elmt by STOICH.,NORMALISED
```

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	.987	•'147	.133	Na201	.'198	.004
MgK	2	'1.005	•334	.284	Mg'101	.553	.009
AlK	2	.933	20.241	15.550	A1203	38.247	.492
SiK	2	.759	24.585	'18.140	Si102	52.59'1	•57't
K K	2	.99'1	1.161	.6'15	K *201*	'1.399	.0'19
CaK	2	.985	.632	**.327**	Ca'10'l	.885	.0'10
TiK	2	.985	'1.227	.53'1	Ti102	2.047	.0'17
MnK	2	.875	.040·	.015	Mn'10'l	.05'1	.000
FeK	2	.892	2.4'14	.896	Fe203	3.45'1	.028
S K	0	.733	.386	.249	S 101	.578	.008
0 K	0	.000	48.834	63.260			2.000
TOTAL			100.001	'100.000		100.001	'1.'162

EDAX ANALYSIS

A-CLAY

SampleA2

Specimen spectrum, FILENAME: ACA2
ACD2 LIVETIMECspec.)= 200

ENERGY	RES	AREA
1.4	83.41	117362

TOTAL AREA= 191190

FIT INDEX= .67

ELMT		APP.CONC	ERRORCWT%)
NaK	2	.140	.068
MgK	2	.273	.084
AlK	2	15.228	.147
SiK	2	'14.63'1	.1'11
K K	2	'I .'129	.055
CaK	2	.663	.049
TiK	2	'I .37'1	.069
MnK	2	.D39	.061* < 2 Sigma*
FeK	2	2.282	.'10'1
S K	0	.293	.036

•••C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: ACD2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	.·967	.'177	•'16'1	Na20'l	.238	.005
MgK	2	.989	.336	.289	Mg'101	.557	.009
AlK	2	.922	20.093	15.558	A1203	37.966	.493
SiK	2	.756	23.546	'17.512	Si102	50.370	.555
K K	2	.995	'1.380	.738	K 201	'1.663	.023
CaK	2	.988	.8'17	.426	Ca101	'1. '144	.0'14
TiK	2	.987	1.690	.737	*Ti'102*	2.820	.023
MnK	2	.875	.055	•02-1	Mn'10'l	.071	.001
FeK	2	.893	3.'1'12	'I •'164	Fe203	4.449	.037
S K	0	.738	.483	.315	S 101	.724	.0'10
0 K	0	.000	48.3'12	63.08'1			2.000
TOTAL			100.001	'100.000		100.001	1 .'171

EDAX ANALYSIS

A-CLAY

Sample D 1

CO calibration, FILENAME:SCOACD1
SCOACD1 LIVETIME= 200 *l/P* = 1883 cps

ENERGY	RES	AREA
.2	84.45	113522
6931.1	157.55	162801

TOTAL AREA= 376625 GF= 50.048

Specimen spectrum, FILENAME:SACD'1
SACD1 LIVETIMECspec.)'= 200

ENERGY	RES	AREA
.2	83.60	116211

TOTAL AREA= 243178

FIT INDEX= .55

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.086	.07'1* < 2 Sigma*
MgK	2	**.333**	.087
AlK	2	'19.636	•'156
SiK	2	**20.338**	.'120
K K	2	'1.04'1	.049
CaK	2	.298	.039
TiK	2	**-1.302**	.061
MnK	2	.025	.052* < 2 Sigma*
FeK	2	'1. '192	.076

••• C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=4o.oo AZIM= .00 COSINE='l .000

Spectrum: SACD'l

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	1 .0'1'1	.083	.074	Na201	.112	.002
MgK	2	'1.024	**.316**	.267	Mg101	.525	.008
AlK	2	.946	**20.224**	'15.398	Al203	38.2'13	.484
SiK	2	.764	25.920	'18.955	Si102	55.447	.596
K K	2	.988	'1.026	.539	K 20'1	**'1.236**	.0'17
CaK	2	.983	.295	.'15'1	Ca10'l	.4'13	.005
TiK	2	.983	'1.290	.553	Ti102	**2."152**	.0'17
MnK	2	.873	.028	.0'1'1	Mn101	.036	.000
FeK	2	.890	1.304	.480	Fe203	1.865	.015
0 K	0	.000	49.513	63.571			2.000
TOTAL			100.000	100.000		100.000	'1. '146

EDAX ANALYSIS

A-CLAY

Sample 02

Specimen spectrum, FILENAME:SACD2
SCOACD2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
.3	83.12	115846

TOTAL AREA= 244409

FIT INDEX= .49

ELMT	APP.CONC	ERROR(WT%)	
NaK	.034	.070*	< 2 Sigma*
MgK	.214	.086	
AIK	19.243	.155	
SiK	20.955	.'12'1	
K K	.867	.048	
CaK	.279	.038	
TiK	1.324	.061	
MnK	.005	.052*	< 2 Sigma*
FeK	1.222	.077	

••• [3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00COSINE=1.000

Spectrum: SCOACD2

Last elmt by STOICH.,NORMALISED

ELMT	ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	1.009	.032	.029	Na201	.044	.001
MgK	1.024	.203	.172	Mg101	.337	.005
AIK	.948	19.770	15.040	A1203	37.357	.472
SiK	.769	26.525	19.381	Si102	56.742	.608
K K	.987	.855	.449	K 201	1.030	.014
CaK	.983	.276	.141	Ca10'1	.386	.004
TiK	.983	1.311	.562	Ti102	2.187	.018
MnK	.873	.005	.002	Mn1'01	.007.	.000
FeK	.890	1.337	.491	Fe203	1.911	.015
O K	.000	49.686	63.734			2.000
TOTAL		100.000	100.000		100.000	1.138

ULTIMATE ANALYSIS TABLES

A-CLAY

A CLAY A (Unfired)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weioht	Oxide +LO	Oxide %
Si (5102)	18.14	17.51	17.83	17.83	1,071.34	51.47	46.02
Al(Al2O3)	15.55	15.56	15.55	7.78	793.25	38.11	34.07
Fe(Fe203	0.90	1.16	1.03	0.52	82.19	3.95	3.53
Ti (Ti02)	0.53	0.74	0.63	0.63	50.66	2.43	2.18
K (K20)	0.62	0.74	0.68	0.34	31.86	1.53	1.37
Na (Na20)	0.13	0.16	0.15	0.07	4.56	0.22	0.2C
Ca (CaO)	0.33	0.43	0.38	0.38	21.12	1.01	0.91
Mg (MgO)	0.28	0.29	0.29	0.29	11.55	0.55	0.5C
Mn(Mn02	0.02	0.02	0.02	0.02	1.56	0.08	0.07
5 (SO)	0.25	0.32	0.28	0.28	13.47	0.65	0.58
OXYGEN	63.26	63.08	63.17				
LOI						11.85	10.60
Total	100.00	100.00	100.00		2,081.57	111.85	100.00

A CLAY D (1200oC)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Average	Molecules	Mol weiaht	Oxide +LOI	Oxide %
Si (5102)	18.96	19.38	19.17	19.17	1,152.00	55.72	49.82
Al(Al2O3)	15.40	15.04	15.22	7.61	776.17	37.54	33.57
Fe(Fe203	0.48	0.49	0.49	0.24	38.74	1.87	1.68
Ti (Ti02)	0.55	0.56	0.56	0.56	44.54	2.15	1.93
K (K20)	0.54	0.45	0.49	0.25	23.27	1.13	1.01
Na (Na20)	0.07	0.03	0.05	0.03	1.60	0.08	0.07
Ca (CaO)	0.15	0.14	0.15	0.15	8.19	0.40	0.35
Mg (MgO)	0.27	0.17	0.22	0.22	8.85	0.43	0.38
Mn(Mn02	0.01	O.OC	0.01	0.01	0.56	0.03	0.02
5 (SO)			0.00	0.28	13.47	0.65	0.58
bXYGEN	63.57	63.73	63.65				
LOI						11.85	10.60
Irotal	100.00	100.00	100.00		2067.39	111.85	100.00

RATIONAL ANALYSIS TABLE

A-CLAY

RATIONAL ANALYSIS (A Clay A)					
FELDSPAR CONVENTION					
MATERIAL	ENTRY	FACTOR	IRESULT		
Total alkalis	1.39	*5.92	/8.22	%Feldspar	
Feldspar	8.22	*0.183	1.50	AI203 in Felds	(a)
Feldspar	8.22	*0.647	5.32	Si02 in Felds	(b)
AI2O3	34.07	"-a"*2.53	182.4	% Clay subst.	(c)
Clay subst.	82.4	*0.463	38.15	Si02 in Clay	(d)
Si02	46.02	"-(b+d)"	12.55	% Free silica	
% WATER IN THE CLAY: % ORGANIC MAnER					
Clay Subst.	82.4	*0.140	/11.53	Loss:H20 in Clay	
LOI	10.60	"(-H20 in clav)"	0.00	Loss: C02 etc	
MICA CONVENTION					
K20	1.37	*8.47	111.60	%Potash Mica	
Na20	0.20	*12.32	12.46	%Soda Mica	
Potash Mica	11.60	*0.384	4.45	AI203 in K Mica	(e)
Potash Mica	11.60	*0.452	5.24	Si02 in K Mica	(f)
Soda Mica	2.46	*0.4	0.98	AI203 in Na Mica	(g)
Soda Mica	2.46	*0.471	1.58	Si02 in Na Mica	(h)
AI203	34.07	-(e+g)*2.53	172.45	%Clay subst.	
Clay subst.	72.45	*0.465	33.89	Si02 in Clay	(i)
Si02	46.02	"-(f+h+i)"	15.31	%Free Silica	

EDAX ANALYSIS

813 Ball Clay

Sample 1 A1

```
CO calibration.                          FILENAME:SC01
SCOl                                       LIVETIME=    200 l/P=   2434 cps
 ENERGY      RES       AREA
     .3    85.81     112178
 6923.2   159.88     210775
TOTAL AREA=     486828 GF=   49.991


Specimen spectrum,                       FILENAME:813A1 FILE DOES NOT EXIST

Spectrum from Analyser, File or Real-time processor: Filel ?S
Specimen spectrum,                       FILENAME:S813A1
SB13A1                                     L.lVETIME(spec.)=    200
 ENERGY      RES       AREA
     .4    84.16     115484
TOTAL AREA=     279523
 ......
FIT INDEX=    .59

ELMT        APP.CONC      ERROR(WT%)
NaK   2        .057        .052* < 2 Sigma*
MgK   2        .398        .067
AlK   2      1'1.034       .'112
SiK   2      22.3'17       .'106
K K   2       1.744        .048
CaK   2        .452        .035
TiK   2        .494        .044
MnK   2       -.029        .044* < 2 Sigma*.
FeK   2       '1.174       .065
..[ 2' ZAF'SJ

20.00 kV  TILT=   .00 ELEV=40.00 AZIM=   .00 COSINE=1.000

Spectrum: SB13Al

L.ast elmt by STOICH.,NORMALISED

ELMT        ZAF     %ELMT     ATOM.%          %OXIDE      FORMULA
NaK   2   .998       .067      .060   Na20'1   .090        '.002
MgK   2  '1.0'14     .455      .385   Mg101    .754        .0'12
AlK   2   .940      13.601    "10.370 Al203   25.699       .324
SiK   2   .824      3'1.353   22.961  Si102   67.07'1      .717
K K   2   .985       2.050    '1.079  K 201    2.470       .034
CaK   2   .975        .538     .276   Ca'10'1  .752        .009
TiK   2   .978        .585     .25'1  Ti102    .976        .008
MnK   2   .87'1       .000     .000   Mn"10'1  .000        .000
FeK   2   .889       '1.531     .56't Fe203    2.'188      .0'18
0 K   0   .000      49.82"1   64.055                      2.000
TOTAL           100.00'1  "100.000          100.00'1      '1.'122
```

EDAX ANALYSIS

B13 Ball Clay

Sample 1 A2

Specimen spectrum, FILENAME:SB13A2
SB13A2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
.5	84.18	115427

TOTAL AREA= 267184

FIT INDEX= .41

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.067	.05-1 * < 2 Sigma*
MgK	2	.393	.066
AlK	2	-1-1.279	•111
SiK	2	19.977	.-101
K K	2	1 .815	.048
CaK	2	.349	.034
TiK	2	.651	.046
MnK	2	-.004	.044* < 2 Sigma*
FeK	2	-1.278	.066

[2 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum: SB-13A2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	.993	**.082**	.074	Na20'l	•11-1	.002
MgK	2	'1.0'10	'.475	.403	Mg'10-1	.787	.0-13
AlK	2	1.936	14.689	11.233	A1203	27.756	**.352**
SiK	2	.812	30.00-1	**22.036**	Si-102	64.'177	.690
K K	2	.987	**2.242**	1.'183	K 201	2.700	.037
CaK	2	.976	.436	**.225**	Ca'101	.6'10	.007
TiK	2	.979	.8-11	.349	Ti-l02	'1.353	.011
MnK	2	.872	.000	.000	Mn-l0-1	.000	.000
FeK	2	.889	1.753	.648	Fe203	2.506	.020
0 K	0	.000	49.5'12	63.849			2.000
TOTAL			100.00'1	'100.000		'100.001	1.132

EDAX ANALYSES

S13 *Sail Clay*

Sample 1 01

Specimen spectrum, FILENAME:Se.13AD1
S81301 LIVETIME(spec.)= 200

ENERGY	RES	AREA
.B	B5.31	116174

TOTAL AREA= 222152

Peak at 2.62 keV omitted?
FIT INDEX= .52

ELMT		APP.CONC	ERROR(Wr,,)
NaK	2	.'144	.060
MgK	2	.396	.077
AlK	2	10.393	.'128
SiK	2	24.139	.127
K K	2	1.911	.057
CaK	2	.711	.045
TiK	2	.595	.052
MnK	2	.064	.053*.< 2 Sigma*
FeK	2	1.178	.078

•• C 2 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum: S81301

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	"ELMT	ATOM."		%OXIDE	FORMULA
NaK	2	.993	.162	.145	Na201	.2'18	.005
MgK	2	*1.00B*	.437	.371	Mg101	.725	.012
AIK	2	.937	12.335	9.422	A1203	23.308	.294
'SiK	2	*.B36*	32.103	23.552	Si102	*6B.675*	.735
K K	2	*.9B6*	2.154	1.135	K 201	2.595	.035
CaK	2	.975	.811	.417	Ca101	1.135	.013
TiK	2	.977	.677	.:291	Ti102	1.129	'.009
MnK	2	*.B71*	*.OB2*	.031	Mn101	.'106	.00'1
FeK	2	*.8BB*	1.475	.544	Fe203	2.'109	.017
0 K	0	.000	49.763	64.093			2.000
TOTAL			99.999	100.000		99.999	1.120

EDAX ANALYSIS

B13 Ball Clay

Sample 1 02

CO calibration; FILENAME:SC02
LIVETIME= 200 l/P= 1790 cps

ENERGY	RES	AREA
1.1	83.94	113661
6929.7	157.86	154713

TOTAL AREA= 358002 GF=' 50.032

Specimen spectrum; FILENAME:SB13D2
LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.2	82.72	116571

TOTAL AREA= 220938

FIT INDEX= .47

ELMT	APP. CONC	ERROR(WT%)
NaK : 2	.112	.061* < 2 Sigma*
MgK 2	.348	.080
AIK 2	9.999	.128
SiK 2	23.326	.127
K K :,2	1.817	.058
CaK : 2	2.270	.059
TiK 2	.665"	.054
MnK 2	-.045	.052* < 2 Sigma*
FeK : 2	'1.256	.078
ClK .: 0	.134	.034
S K : 0	.339	.035

•• C 2 ZAF'SJ

20."00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT	ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK : 2	.982	.127	.114	Na201	.171	.004
MgK : 2	1.000	.386	.330	Mg101	.640	.010
AIK 2	.932	11.903	9.171	A1203	22.491	.288
SiK 2	.839	30.855	22.834	Si102	66.005	.716
K K : 2	.991	2.034	1.082	K 201	2.451	.034
CaK : 2	.977	2.577	1.337	Ca101	3.606	.042
TiK : 2	.973	.758	.329	Ti102	1.265	.010
MnK : 2	.870	.000	.000	Mn101	.000	.000
FeK : 2	.888	1.570	.584'	Fe203	2.245	.018
ClK : 0	.795	.188	.110	Cl102	.357	'.003
S K 0	.735	.511	.332	S 101	.767	.010
O K : 0	.000	49.087	63.777			2.000
TOTAL		99.996	100.000		99.996	1.136

EDAX ANALVSIS

B13 Ball Clay

Sample 2 A1

```
Specimen spectrum,                          FILENAME: 8'13A'l
B13A1                                         LIVETIME(spec.)=    200
 ENERGY      RES       AREA
    1.6    84.52    117692
TOTAL AREA=    162748

Peak at   2.60 keV omitted?
FIT INDEX=   .37

ELMT        APP.CONC     ERROR(WT%)
NaK   2        .070        .049* < 2 Sigma*
MgK   2        .248        .06'1
AlK   2       8.'192       .106
SiK   2      1'+.423       .097
K K   2       '1.472       .048
CaK   2        .305        .035
TiK   2        .406        .045
MnK   2        .040        •046* < 2 Sigma*
FeK   2       '1.0Lt3      .068
..C 2 ZAF'SJ

20.00 kV  TILT=   .00 ELEV=40.00 AZIM=   .00 COSINE='l .000

Spectrum: B13A1

Last elmt by STOICH.,NORMALISED

ELMT        ZAF     %ELMT     ATOM.%        %OXIDE     FORMULA
NaK   2    .988      •119      •'107  Na201   .'160       .003
MgK   2   1.005      .413       .352  Mg'10'l .686       .0'1-1
AlK   2    .934     '14.673   '1'1.250  A1203 27.725       .353
SiK   2    .81'1    29.745    2'1.906  8i102 63.63'1      .687
K K   2    .988      2.492     '1.3'19  K 201   3.002      .04'1
CaK   2    .975       .524       .270  Ca'10'l   .733     .008
TiK   2    .979       .694       .300  Ti102  '1.'157    .009
MnK   2    .872       .077       .029  Mn101   .099      .001
FeK   2    .890     -1.963       .727  Fe203  2.806      .023
0 K   0    .000     49.300    63.74'1                    2.000
TOTAL          '100.000  '100.000          '100.000     '1. '138
```

EDAX ANALYSIS

B13 Ball Clay

Sample 2 A2

Specimen spectrum, FILENAME: 8'13A2
B13A2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.5	84.62	117334

TOTAL AREA= 177666

FIT INDEX= .40

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	.033	.050*	< 2 Sigma*
MgK	2	.262	.064	
AlK	2	7.931	•'107	
SiK	2	17.464	•'105	
K K	2	'1.388	.048	
CaK	2	.466	.038	
TiK	2	.487	.046	
MnK	2	.018	.046*	< 2 Sigma*
FeK	2	.952	.067	

ZAF'SJ

20.00 kV TILT= .00 ELEV=40.o0 AZIM= .00 COSINE=1.o00

Spectrum: B13A2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	.99'1	.050	.045	Na20'1	.067	.001
MgK	2	1.009	**.393**	.334	Mg101	.652	.0'10
AlK	2	.938	12.792	9.775	A1203	24.'17-1	.305
SiK	2	.832	31.750	**23.303**	Si102	67.920	.727
K K	2	.987	**2.128**	**-1.'122**	K 201	2.564	.035
CaK	2	.975	**.723**	**.372**	Ca101	'1 .0'11	.012
TiK	2	.978	' .753	**.324**	Ti'102	'1.256	.010
MnK	2	.87'1	.03'1	.0'12	Mn101	.04-1	.000
FeK	2	.888	1.62'1	.598	Fe203	2.3'18	.0'19
0 K	0	.000	49.757	64.'1'15			2.000
TOTAL			99..999	'100.000		99.999	1.'1'19

EDAXANALYSIS

B13 Ball Clay

Sample 2 **02**

Specimen spectrum, FILENAME:S13D2813D2
S8'13D2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
.9	85.43	116518

TOTAL-AREA= 216002

FIT INDEX= .49

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.042	.060* < 2 Sigma*
MgK	2	.387	.078
AlK	2	10.807	.'128
SiK	2	**22.23[1**	•122
K K	2	'1 .*80B*	.056
CaK	2	1 .628	.053
TiK	2	.979	.057
MnK	2	•024	.05'1* < 2 Sigma*
FeK	2	1.232	.077

..C 2; ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: S813D2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	.983	.048	.044	Na201	.065	.001
MgK	2	1.003	•437	.373	Mg101	.724	.012
AlK	2	.933	13.1'14	'10.082	A1203	24.780	.3'16
SiK	2	.826	30.446	22.480	Si102	65.130	.704
K K	2	.992	2.063	1.094	K 201	2.485	.034
CaK	2	.979	1.883	.974	Ca'10'l	**2.634**	.031
TiK	2	.976	1.'135	.491	Ti'102·	'1.893	.0'15
MnK	2	.871	.031	.012	Mn10'l	.040	.000
FeK	2	.888	'1 .570	.583	Fe203	**2.244**	.0'18
0 K	0	.000	49.270	63.867			2.000
TOTAL			99.997	'100.000		99.997	'1. '131

ULTIMATE ANALYSIS

813 Ball Clay .

B13 CLAY A (Sarnole 1) (Unfired)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weioht	Oxide + LOI	Oxide %
Si (5102)	21.91	23.30	22.60	22.60	1,358.53	65.76	61.29
Al (A1203)	11.25	9.78	10.51	5.26	536.14	25.95	24.19
Fe (Fe203)	0.73	0.60	0.66	0.33	52.87	2.56	2.38
Ti (Ti02)	0.30	0.32	0.31	0.31	24.93	1.21	1.12
K (K20)	1.32	1.12	1.22	0.61	57.49	2.78	2.59
Na (Na20)	0.11	0.05	0.08	0.04	2.36	0.11	0.11
Ca (CaO)	0.27	0.37	0.32	0.32	18.01	0.87	0.81
Mg (MgO)	0.35	0.33	0.34	0.34	13.82	0.67	0.62
Mn (Mn02)	0.03	0.01	0.02	0.02	1.78	0.09	0.08
bXYGEN	63.74	64.12	63.93				
LOI						7.30	6.80
Total	100.00	100.00	100.00		2 065.92	107.30	100.00

B13 CLAY D (sample 1)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Average	Molecules	Mol weight	Oxide + LOI	Oxide %
Si (5102)		22.83	11.42	11.42	686.16	65.39	60.94
Al (AI203)		9.17	4.59	2.29	233.86	22.29	20.77
Fe (Fe203)		0.58	0.29	0.15	23.30	2.22	2.07
Ti (Ti02)		0.33	0.16	0.16	13.14	1.25	1.17
K (K20)		1.08	0.54	0.27	25.48	2.43	2.26
Na (Na20)		0.11	0.06	0.03	1.77	0.17	0.16
Ca (CaO)		1.34	0.67	0.67	37.50	3.57	3.33
Mg (MgO)		0.33	0.17	0.17	6.65	0.63	0.59
Mn (Mn02		0.00	0.00	0.00	0.00	0.00	0.00
Cl (Cl02)		0.11	0.11	0.11	5.67	0.54	0.50
5 (SO)		0.33	0.33	0.33	15.87	1.51	1.41
OXYGEN		63.78	31.89				
...01						7.30	6.80
Total		100.00	50.22		1,049.41	107.30	100.00

ULTIMATE ANALVSIS

B13 Ball Clay .

B13 CLAY (Samole 2) (Unfired)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	!Analysis 2	Averaoe	Molecules	Mol weioht	Oxide + LOI	Oxide %
Si (SI02)	22.96	22.04	22.50	22.50	1,352.16	65.62	61.15
Al (AI203)	10.37	11.23	10.80	5.40	550.88	26.73	24.91
Fe (Fe203)	0.56	0.65	0.61	0.30	48.36	2.35	2.19
Ti (Ti02)	0.25	0.35	0.30	0.30	23.97	1.16	1.08
K (K20)	1.08	1.18	1.13	0.57	53.27	2.59	2.41
Na (Na20)	0.06	0.07	0.07	0.03	2.08	0.10	0.09
Ca (CaO)	0.28	0.23	0.25	0.25	14.05	0.68	0.64
Mg (MgO)	0.39	0.40	0.39	0.39	15.88	0.77	0.72
Mn (Mn02)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bXYGEN	64.06	63.85	63.95				
LOI						7.30	6.80
Total	100.00	100.00	100.00		2 060.64	107.30	100.00

B13 CLAY (Sarnole 2) (1200oC)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weioht	Oxide + LOI	Oxide %
Si (SI02)	23.55	22.48	23.02	23.02	1,383.26	66.89	62.34
Al (AI203)	9.42	10.08	9.75	4.88	497.30	24.05	22.41
Fe (Fe203)	0.54	0.58	0.56	0.28	44.97	2.17	2.03
Ti (Ti02)	0.29	0.49	0.39	0.39	31.24	1.51	1.41
K (K20)	1.14	1.09	1.11	0.56	52.49	2.54	2.37
Na (Na20)	0.15	0.04	0.09	0.05	2.93	0.14	0.13
Ca (CaO)	0.42	0.97	0.70	0.70	39.02	1.89	1.76
Mg (MgO)	0.37	0.37	0.37	0.37	14.99	0.72	0.68
Mn (Mn02)	0.03	0.01	0.02	0.02	1.87	0.09	0.08
lOXYGEN	64.09	63.87	63.98				
LOI						7.30	6.80
Total	100.00	100.00	100.00		2 068.07	107.30	100.00

RATIONAL ANALYSIS

813 8a/l Clay .

RATIONAL ANALYSIS (813 Clay. A SAMPLE 1)				
FELDSPAR CONVENTION				
MATERIAL	NTRY	FACTOR	IRESULTI	
ITotal alkalis	2.70	*5.92	115.98 I%Feldspar	
Feldspar	15.98	*0.183	2.92 AI203 in Felds	(a)
Feldspar	h5.98	*0.647	10.34 Si02 in Felds	(b)
AI203	24.19	"-a"*2.53	153.80 1% Clay subst.	(c)
Clay subst.	53.80	*0.463	24.91 Si02 in Clay	(d)
Si02	61.29	"-(b+d)"	126.04 1% silica	
% WATER IN THE CLAY: % ORGANIC MATIER				
Clay Subst.	3.80	*0.140	17.53 ILoss:H20 in Clay	
LOI	.80	"(-H20 in clay)" 0	[toss C02 etc	
MICA CONVENTION				
K20	2.53	*8.47	121.43 I%Potash Mica	
Na20	0.10	*12.32	11.23 I%Soda Mica	
Potash Mica	21.43	*0.384	8.23 AI203 in K Mica	(e)
Potash Mica	21.43	*0.452	9.69 Si02 in K Mica	(f)
Soda Mica	1.23	*0.4	0.49 AI203 in Na Mica	(g)
Soda Mica	1.23	*0.471	0.58 Si02 in Na Mica	(h)
AI203	23.62	" - (e+g)*2.53	137.691%Clay subst.	
Clay subst.	37.69	*0.465	17.53 Si02 in Clay	(i)
Si02	59.84	"-(f+h+i)"	/32.05 1% Free Silica	

EDAX ANALYSIS

G-Clay

Sample A1

The data in Sample A1 and A2 was calculated using the Apparent concentration and not the stoichiometric analyses. The oxide weight was calculated for each molecule of material in the analysis and the total brought to a percentage.

Specimen spectrum, FILENAME: SCCA'1
LIVETIME(spec.)= :200

ENERGY	RES	AREA
.3	82.98	117598

TOTAL AREA= 182472

Peak at 2.30 keV omitted?
FIT INDEX= '1.20

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.'194	.065
MgK	2	.307	.083
AlK	2	11.502	.'.137
SiK	2	'19.86'1	**.'122**
K K	:2	2.056	.059
CaK	2	.299	.04'1
TiK	2	.600	.05:2
MnK	2	.038	.050* < 2 Sigma*
FeK	2	.508	•065 ▪

••• C 3 ZAF'S]

20.00 kV TILT= .00 ELEV=4o.0o AZIM= .00 COSINE=1.ooo

Spectrum:

All elmts analysed

ELMT		ZAF	%ELMT	ATOM.%
NaK	2	1.460	.133	**.423**
MgK	2	**'1.332**	**.230**	.695
AlK	:2	1.138	'10.105	27.480
SiK	2	.802	24.784	64.734
K K	:2	.905	**2.272**	4.263
CaK	:2	.901	**.332**	.608
TiK	2	.936	.641	.982
MnK	2	.859	.044	.058
FeK	:2	.882	.576	.75·6
TOTAL			39.1'16	100.000

EDAX ANALYSIS

e-c/ay

SampleA2

```
Specimen spectrum,                          FILENAME:SCCA2
                                              LIVETIME(spec.)=     200

 ENERGY      RES       AREA
     .2    83.35    118177
TOTAL  AREA=     176572
.......
FIT  INDEX=  1.25

ELMT          APP.CONC     ERROR(WT%)
NaK    2        .•235         .064
MgK    2        .201 .        .080
AIK    2      11.336          .135
SiK    2      18.822          .119
K K    2       2.124          .059
CaK    2        .198          .039
TiK    2        .386          .049
MnK    2       -.006          .050* < 2 Sigma*
FeK    2        .484          .067
....C 3 ZAF'S3

20.00 kV   TILT=    .00 ELEV=40.00 AZIM=    .00 COSINE=1.000

Spectrum:

All elmts analysed

ELMT          ZAF      %ELMT      ATOM.%
NaK    2  '1.475         .159       .53':1.
MgK    2  '1.339         .150       .474
AlK    2  '1. '146       9.895     28.126
SiK    2    .798       23.596     64.422
K K    2    .904        2.351      4.611
CaK    2    .898         .22'1      .422
TiK    2    .935         .412       .660
MnK    2    .860         .000       .000
FeK    2    .882         .548       •753
TOTAL                  37.332    '100.000
```

EDAX ANALYSIS

C-Clay

Sample 01

CO calibration, FILENAME:SC02
LlVETlME= 200 *l/P* = 1823 cp

ENERGY	RES	AREA
1.3	84.88	114315
6928.8	157.53	157210

TOTAL AREA= 364511 GF=' 50.024

Specimen spectrum, FILENAME:SCCD'1
LlVETlME(spec.)= 200

ENERGY	RES	AREA
1.4	83.74	116832

TOTAL AREA= 226914

FIT INDEX= .89

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.24'1	.065
MgK	2	.188	.080
AlK	2	'12.890	•'139
SiK	2	23.464	**.-127**
K K	2	2.373	.061
CaK	2	.062	.038* < 2 Sigma*
TiK	2	.588	.054
MnK	2	.004	.053* < 2 Sigma*
FeK	2	.828	.071

...[3 ZAF'S]

20.00 kV TILT= .00 ELEV=40.00 AZlM= .00 COSINE='1.000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.0'1'1	.256	**.229**	Na20'l	.345	.007
MgK	2	1.020	.198	.168	Mg10'1	.329	.005
AlK	2	.948	14.625	1'1.132	A1203	**27.634**	.348
SiK	2	.8'18	30.83'1	22.541	Si102	65.954	.706
K K	2	.985	**2.592**	1 .36'1	K 201	**3.'122**	.043
CaK	2	.972	.068	.035	Ca10'l	.096	.00'1
TiK	2	.977	.648	.278	Ti102	1.080	.009
MnK	2	.871	.005	.002	Mn'101	.007	.000
FeK	2	.888	'1.003	.369	Fe203	1.434	**.012**
0 K	0	.000	49.774	63.887			2.000
TOTAL			'100.000	100.000		100.000	'1. '13'1

EDAX ANALYSIS

C-Clay

Sample D2

Specimen spectrum, FILENAME:SCCD2
LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.5	83.19	116061

TOTAL AREA= 234406

FIT INDEX= .55

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	•'185	.063	
MgK	2	•'120	.080*	< 2 Sigma*
AlK	2	'1'1.205	.135	
SiK	2	**26.932**	.'134	
K K	2	2.'142	.059	
CaK	2	.069	.038*	< 2 Sigma*
TiK	2	.502	.052	
MnK	2	-.006	.053*	< 2 Sigma*
FeK	2	.446	.066	

▪-[2 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.·0'18	•'19'1	.170	Na20'l	.258	.005
MgK	2	1.027	**.'123**	.'103	Mg101	.204	.003
AlK	2	.954	12.343	9.346	A1203	**23.323**	.29'1
SiK	2	.845	33.5'13	24.374	Si102	7'1.690	.758
K K	2	.98'1	**2.295**	'1 .199	K 20'1	2.764	.037
CaK	2	.970	.075	.038	Ca10'l	.105	.001
TiK	2	.975	.54'1	.231	Ti102	.903	.007
MnK	2	.870	.000	.000	Mn'10'l	.000	.000
FeK	2	.887	.528	.'193	Fe203	.755	.006
0 K	0	.000	50.393	64.345			2.000
TOTAL			'100.002	'100.000		100.002	'1. '108

ULTIMATE ANALYSIS

c-Clay

C CLAY A (Unfired)							
	Atomic % of Elements			Molecular content *		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weioht	Oxide + LOI	Oxide %
Si (5102)	23.32	23.26	23.29	23.29	1,399.73	68.06	63.9C
Al (AI203)	9.90	10.16	10.03	5.02	511.53	24.87	23.35
Fe (Fe203)	0.27	0.27	0.27	0.14	21.55	1.05	0.98
Ti (Ti02)	0.35	0.24	0.30	0.30	23.57	1.15	1.08
K (K20)	1.54	1.66	1.60	0.80	75.36	3.66	3.44
Na (Na20)	0.15	0.19	0.17	0.09	5.27	0.26	0.24
ta (CaO)	0.22	0.15	0.19	0.19	10.38	0.50	0.47
Mg (MgO)	0.25	0.17	0.21	0.21	8.46	0.41	0.39
Mn (Mn02)	0.02	0.00	0.01	0.01	0.87	0.04	0.04
OXYGEN	63.97	63.89	63.93				
LOI						6.50	6.10
Total	99.99	99.99	99.99		2.056.72	106.50	100.00

C CLAY D (12000C)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaae	Molecules	Mol weloht	Oxide + LOI	Oxide %
Si (5102)	22.54	24.37	23.46	23.46	1,409.71	68.81	64.61
Al (AI203)	11.13	9.35	10.24	5.12	522.19	25.49	23.93
Fe (Fe203)	0.37	0.19	0.28	0.14	22.42	1.09	1.03
Ti (Ti02)	0.28	0.23	0.25	0.25	20.33	0.99	0.93
K (K20)	1.36	1.20	1.28	0.64	60.29	2.94	2.76
Na (Na20)	0.23	0.17	0.20	0.10	6.18	0.30	0.28
ta (CaO)	0.04	0.04	0.04	0.04	2.05	0.10	0.09
Mg (MgO)	0.17	0.10	0.14	0.14	5.46	0.27	0.25
Mn (Mn02)	0.00	0.00	0.00	0.00	0.09	0.00	0.0C
loXYGEN	63.89	64.35	64.12				
LOI						6.50	6.1C
Total	100.00	100.00	100.00		2.048.72	106.50	100.0C

RATIONAL ANALVSIS

C-Clay

RATIONAL ANALYSIS (C CLAY A)					
FELDSPAR CONVENTION					
MATERIAL	ENTRY	FACTOR	IRESULT		
frotal alkalis	3.68	*5.92	121.79	I%Feldspar	
Feldspar	21.79	*0.183	3.99	AI203 in Felds	(a)
Feldspar	21.79	*0.647	14.10	Si02 in Felds	(b)
AI2O3	23.35	"-a"*2.53	148.99	1% Clay subst.	(c)
Clay subst.	48.99	*0.463	22.68	Si02 in Clay	(d)
Si02	63.90	"-(b+d)"	127.12	1% silica	
% WATER IN THE CLAY: % ORGANIC MAITER					
Clay Subst.	48.99	*0.140	16.86	ILoss:H20 in Clay	
LOI	6.10	"(H20inclay)"	0.00	ILoss: C02 etc	
MICA CONVENTION					
K20	3.44	*8.47	r29.14	I%Potash Mica	
Na20	0.24	*12.32	12.96	1% soda Mica	
Potash Mica	29.14	*0.384	11.19	AI203 in K Mica	(e)
Potash Mica	29.14	*0.452	13.17	Si02 in K Mica	(f)
Soda Mica	2.96	*0.4	1.18	AI203 in Na Mica	(g)
Soda Mica	2.96	*0.471	1.39	Si02 in Na Mica	(h)
AI203	23.35	"(e+g)*2.53	127.78	I%Clay subst.	
Clay subst.	27.78	*0.465	12.92	Si02 in Clay	(i)
Si02	63.90	"-(f+h+i)"	136.42	I%Free Silica	

EDAX ANALYSIS

Masse/sy

Sample A1

The data in Sample A1 and A2 was calculated using the Apparent concentration and not the stoichiometric analyses. The oxide weight was calculated for each molecule of material in the analysis and the total brought to a percentage.

Specimen spectrum, FILENAME: SMA'1
LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.1	83.65	116411

TOTAL AREA= 231603

FIT INDEX= .80

ELMT		APP.CONG	ERROR(WT%)
NaK	2	.23'1	.065
MgK	2	•'152	.080* < 2 Sigma*
AlK	2	13.937	.138
SiK	2	20.972	•118
K K	2	2.795	.06:2
CaK	2	.0'18	.037* < 2 Sigma*
TiK	2	.822	.054
MnK	2	.026	.049* < 2 Sigma*
FeK	2	.7'17	.068

.••[3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

SpectrLlm:

All elmts analysed

ELMT		ZAF	%ELMT	ATOM.%
NaK	2	'1.442	.'160	.456
MgK	2	1.320	.115	.3'10
AlK	2	1.136	12.266	29.692
SiK	2	.784	26.749	62.'192
K K	2	'.909	3.076	5.139
CaK	2	.900	.020	.033
TiK	2	.939	.875	1.193
MnK	2	.861	.031	.036
FeK	2	.883	.8'11	.949
TOTAL			44.'105	100.000

EDAX ANALYSIS

Masse/sy

SampleA2

Specimen spectrum,
CO calibration,

FILENAME:
FILENAME: SCO'l
LIVETIME= 200 I/P= 1916 cps

ENERGY	RES	AREA
1.0	84.48	113327
6929.2	157.56	165063

TOTAL AREA= 383240 GF= 50.029

Specimen spectrum,

FILENAME:SMA2
LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.1	83.47	116548

TOTAL AREA= 220401

FIT INDEX= '1.04

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.216	.063
MgK	2	.182	.078
AlK	2	'13.355	.'135
SiK	2	'19.569	•115
K K	2	2.7'10	.061
CaK	2	.008	.036* 0(2 Sigma*
TiK	2	.494	.050
MnK	2	-.020	.050* < 2 Sigma*
FeK	2	.945	.070

•••C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum:

All elmts analysed

ELMT		ZAF	%ELMT	ATOM.%
NaK	2	'1.430	•'15'1	.453
MgK	2	1.312	.'139	.393
AIK	2	'1.'130	'1'1.820	30.'164
SiK	2	.778	25.'15'1	6'1.646
K K	2	.908-	2.983	5.253
CaK	2	.899	.009	.016
TiK	2	.939	.526	.756
MnK	2	.862	.000	.000
FeK	2	.884	'1.069	1.318
TOTAL			4'1.849	'100.000

EDAX ANALYSIS

Moss Clay

Sample 01

```
CO calibration,                          . FILENAME: SCO'l
                                           LIVETIME=    200  I/P=   1908 cps
 ENERGY      RES       AREA
     .8    84.26     113346
 6929.5   158.72     165794
TOTAL AREA=     381636 GF=   50.033
--------.-----------------------

Specimen spectrum,                       FILENAME: SMD'l
                                           LIVETIME(spec.)=     200
 ENERGY      RES       AREA
     .9    83.37     116150
TOTAL AREA=     232820

FIT INDEX= 3.33

ELMT        APP.CONC      ERROR(WT%)
NaK   2       .226          .064
MgK   2       .177          .078
AlK   2     '13.964         •'137
SiK   2     19.755          .116
K K   2      3.007          .064
CaK   2       .011          .038* < 2 Sigma*
TiK   2       .808          .055
MnK   2       .552          .063
FeK   2       .953          .074
...[ 3 ZAF'SJ

20.00 kV  TILT=   .00 ELEV=40.00 AZIM=   .00 COSINE='1 .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT        ZAF     %ELMT     ATOM.%          %OXIDE     FORMULA
NaK   2   .994      .255      .230    Na20'1    .343      .007
MgK   2  '1.008     .'196     •168    Mg101     .325      .005
AlK   2   .939    '16.664   '12. B'18 A1203   31.488      .405
SiK   2   .795    27.84'1   20.568    Si102   59.558      .650
K K   2   .990     3.401    1.B05     K 20'1    4.097      :057
CaK   2   .973      .013      .006    Ca'10'1   .0'18      .000
TiK   2   .980      .924      .400    Ti102    1.54'1      .0'13
MnK   2   .873      .709      .268    Mn101     .9'15      .008
FeK   2   .890    '1.200      .446    Fe203   '1.7'16      .0'14
0 K   0   .000    48.798    63.29'1                       2.000
TOTAL         100.000  '100.000          rqn.coo        '1. 160
```

EDAX ANALYSIS

Masse/sy

Sample D2

Specimen spectrum, FILENAME:SMD2
LIVETIME{spec.)= 200

ENERGY	RES	AREA
1.2	83.24	117204

TOTAL AREA= 202795

FIT INDEX= .66

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	.183	.058	
MgK	2	•119	.072* < 2	Sigma*
AlK	2	'1'1.556	.126	
SiK	2	17.398	.108	
K K	2	2.817	.06'1	
CaK	2	.006	.036* < 2	Sigma*
TiK	2	.615	.051	
MnK	2	-.004	.052* < 2	Sigma*
FeK	2	.835	.072	

.•C 2 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.005	.2't'l	.2'17	Na201	**.325** ,	.007
MgK	2	'1.0'16	•'155	**.132**	Mg10'l	.256	.004
AlK	2	.945	16.146	**12.382**	A1203	30.508	.391
SiK	2	.803	28.616	21.079	Si102	61.2'14 ,	.665
K K	2	.989	3.760	'1.990	K 201	4.529	.063
CaK	2	.970	.009	.005	Ca:l0'l	.0'12	.000
TiK	2	.977	.83'1	.359	*Ti102*	'1.386 .	.0'11
MnK	2	.872	.000	.000	Mn'101	.000'	.000
FeK	2	.889	'1.239	.459	Fe203	1.772	.014
0 K	0	.000	49.007	63.378			2.000
TOTAL			100.003	'100.000		100.003	'1. '156

••C 2 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum:

ULTIMATE ANALYSIS

Moss Clay

MOSS CLAY A (UNFIRED)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weloht	Oxide + LOI	Oxide %
Si (5102)	22.54	22.39	22.47	22.47	1,350.15	65.39	61.67
Al (AI203)	10.76	10.96	10.86	5.43	553.86	26.83	25.30
Fe (Fe203)	0.34	0.48	0.41	0.21	32.72	1.58	1.49
Ti (Ti02)	0.43	0.27	0.35	0.35	27.97	1.35	1.28
K (K20)	1.86	1.91	1.89	0.94	88.78	4.30	4.06
Na (Na20)	0.17	0.16	0.17	0.08	5.12	0.25	0.23
Ca (CaO)	0.01	0.01	0.01	0.01	0.56	0.03	0.03
Mg (MgO)	0.11	0.14	0.13	0.13	5.04	0.24	0.23
Mn (Mn02)	0.01	0.00	0.01	0.01	0.43	0.02	0.02
bXYGEN	63.76	63.67	63.72				
LOI						6.04	5.70
Total	99.99	99.99	99.99		2 064.62	106.04	100.00

MOSS CLAY D(1200oC)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Ayerage	Molecules	Mol weiaht	Oxide + LOI	Oxide %
Si (SI02)	20.57	21.08	20.82	20.82	1,251.49	60.32	56.88
Al (AI203)	12.82	12.38	12.60	6.30	642.60	30.97	29.21
Fe (Fe203)	0.45	0.46	0.45	0.23	36.11	1.74	1.64
Ti (Ti02)	0.40	0.36	0.38	0.38	30.32	1.46	1.38
K (K20)	1.81	1.99	1.90	0.95	89.37	4.31	4.06
Na (Na20)	0.23	0.22	0.22	0.11	6.93	0.33	0.31
Ca (CaO)	0.01	0.01	0.01	0.01	0.31	0.01	0.01
Mg (MgO)	0.17	0.13	0.15	0.15	6.05	0.29	0.27
Mn (Mn02)	0.27	0.00	0.13	0.13	11.64	0.56	0.53
bXYGEN	63.29	63.38	63.33				
LOI						6.04	S.7C
Total	100.00	100.00	100.00		2 074.82	106.04	100.0C

RATIONAL ANALYSIS

Moss Clay

RATIONAL ANALYSIS (Moss clay A)					
FELDSPAR CONVENTION					
MATERIAL	ENTRY	FACTOR	IRESULT	1	
rrotal alkalis	4.29	*5.92	125.40	I%Feldspar	
Feldspar	25.40	*0.183	4.65	AI203 in Felds	(a)
Feldspar	25.40	*0.647	16.43	Si02 in Felds	(b)
AI2O3	25.30	"-a"*2.53	152.25	1% Clay subst.	(c)
Clay subst.	52.27	*0.463	24.20	Si02 in Clay	(d)
Si02	61.67	"-(b+d)"	121.04	1% silica	
% WATER IN THE CLAY: % ORGANIC MAITER					
Clay Subst.	52.27	*0.140	17.31	ILoss:H20 in Clay	
LOr	5.70	"(H20inclay)"	0.00	ILoss: C02 etc	
MICA CONVENTION					
K20	4.06	*8.47	134.39	IPotash Mica	
Na20	0.23	*12.32	12.83	[Soda Mica	
Potash Mica	34.39	*0.384	13.21	AI203 in K Mica	(e)
Potash Mica	34.39	*0.452	15.54	Si02 in K Mica	(f)
Soda Mica	2.83	*0.4	1.13	AI203 in Na Mica	(g)
Soda Mica	2.83	*0.471	1.33	Si02 in Na Mica	(h)
AI2O3	25.30	"(e+g)*2.53	127.73	[Clay subst.	
Clay subst.	27.73	*0.465	12.90	Si02 in Clay	(i)
Si02	61.67	"-(f+h+i)	131.90	IFree Silica	

EDAX ANALYSIS

Pxx *Ball Clay* .

Sample A1

CO calibration, FILENAME:SC02
PXXA1 LIVETIME= 200 *l/P* = 1650 cps

ENERGY	RES	AREA
1.2	88.54	113706
6929.6	158.13	141690

TOTAL AREA= 329915 GF= 50.030

Specimen spectrum, FILENAME: PXXA'l
PXXA'l LIVETIMECspec.)= 200

ENERGY	RES	AREA
1.4	86.45	117266

TOTAL AREA= 178083

FIT INDEX= .50

ELMT		APP.CONC	ERRORCWT%)
NaK	2	.104	.068* < 2 Sigma*
MgK	2	.288	.084
AlK	2	14.790	•'147
SiK	2	'17.843	•119
K K	2	1.942	.059
CaK	2	.139	.039
TiK	2	.544	.053
MnK	2	-.016	.052* < 2 Sigma*
FeK	2	.586	.068

... [3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

SpectrLlm: PXXA1

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.023	**.'122**	•'109	Na2O1	.'164	.003
MgK	2	1.032	.335	**.283**	Mg'10'l	.556	.009
AlK	2	.952	'18.665	14.203	A1203	35.269	.448
SiK	2	.781	27.429	20.046	Si'102	58.676	**.632**
K K	2	.986	2.365	1.242	K 20'1	2.849	.039
CaK	2	.974	.'172	.088	Ca101	.240	.003
TiK	2	.978	.668	.286	*Ti102*	'1. '114	.009
MnK	'2	.872	.000	.000	Mn10'l	.000	.000
FeK	2	.889	.792	.29'1	Fe203	1.132	.009
0 K	0	.000	49.452	63.452			2.000
TOTAL			'100.000	100.000		100.000	1.'152

EDAX ANALYSIS

Pxx Ball Clay

SampleA2

Specimen spectrum, FILENAME:PXXA2
PXXA'l LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.3	85.14	117090

TOTAL AREA= 178198

FIT INDEX= .55

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	•'108	.069*	< 2 Sigma*
MgK	2	•'199	.085	
AlK	2	'15.074	.'149	
SiK	2	17.447	•'1'18	
K K	2	2.004	.059	
CaK	2	•'136	.038	
TiK	2	.492	.05'1	
MnK	2	.029	.052*	< 2 Sigma*
FeK	2	.591	.067	

... [3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE="1.000

Spectrum: PXXA'l

Last elmt by STOICH.,NORMALISED

ELI'1T		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.023	.'128	.114	Na201	.172	.004
MgK	2"	'1.032	.:232	.196	Mg101	.385	.006
AlK	2	.953	19.102	'14.543	A1203	36.094'	.459
SiK	2	.778	27.087	'19.807	Si102	57.944	.625
K K	2	•986	2.454	1.289	K 201	2.956	.04'1
CaK	2	.974	.'169	.087	Ca'10'l	.:237	.003
TiK	2	.978	.608	.26'1	*Ti'102*	1 .0'1 It	.008
MnK	2	.872	.040'	.015	Mn101	.052	.000
FeK	2	.889	.802	.295	Fe203	'1.'147	.009
0 K	0	.000	49.378	63.393			2.000
TOTAL			100.000	'100.000		'100.000	'1. '155

EDAX ANALYSIS

Pxx Ball Clay

Sample 0 1

CO calibration, FILENAME:SC02
LIVETIME= 200 '1/P= 1616 cps

ENERGY	RES	AREA
1.5	86.12	113918
6929.2	158.96	138934

TOTAL AREA= 323234 GF= 50.025

Specimen spectrum, FILENAME:PXXD
PXXD LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.3	82.91	116118

TOTAL AREA= 226015

FIT INDEX= .52

EL_MT	APP.CONC	ERROR(WT%)
NaK 2	.186	.079
MgK 2	.679	.101
AlK 2	17.981	.168
SiK 2	22.884	.'136
K K 2	3.349	.073
CaK 2	•-/22	.050
TiK 2	.807	.060
MnK 2	.031	.055* < 2 Sigma*
FeK 2	1.012	.080

...[3 ZAF/SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: PXXD

Last elmt by STOICH.,NORMALISED

ELMT	ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK 2	'1.0'10	•'170	.153	Na20'l	.230	.005
MgK 2	'1.022	.6'16	.524	Mg'10'l	1.021	.0'17
A1K 2	.94'1	17.708	'13.574	A1203	33.46'1	.430
SiK 2	.786	26.986	19.867	Si102	57.727	.629
K K 2	.990	3.'132	'1.657	K 20'1	3.773	.052
CaK 2	.973	.687	.354	Ca101	.96'1	.0'11
TiK 2	.976	.766	.331	Ti102	'1.277	.0'10
MnK 2	.872	.033	.0'13	Mn101	.043	.000
FeK 2	.889	'1.055	.391	Fe203	'1.508	.012
0 K 0	.000	48.848	63.'138			2.000
TOTAL		'100.000	'100.000		'100.000	1.168

EDAX ANALYSIS

Pxx Ball Clay

Sample 02

Specimen spectrum, FILENAME:PXXD2
PXXD LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.4	84.48	115634

TOTAL AREA= 273219

FIT INDEX= '1.00

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.2·18	.078
MgK	2	.900	•'10'1
AlK	2	'17.429	•'165
SiK	2	21.042	•'13'1
K K	2	2.198	.072
CaK	2	8.965	•'105
TiK	2	1.026	.070
MnK	2	-.017	.07'1* < 2 Sigma*
FeK	2	'1.846	.106

...[3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum: PXXD

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	.960	.'197	.182	Na20'l	.265	.006
MgK	2	"983	.795	.695	Mg'10'l	1.3'17	**.022**
AlK	2	.9'12	'16.57'1	13.069	A1203	31.3'12	.42'1
SiK	2	.784	**23.262**	'17.621	Si'102	49.762	.567
K K	2	'1.0'16	1.876	'1.021	*K 20'1*	**2.260**	.033
CaK	2	.992	7.839	4.162	Ca10'l	10.969	.134
TiK	2	.966	•92'1	.409	*Ti'102*	1.536.	.0'13
MnK	2	.869	.000	.000	Mn'10'l	.000	.000
FeK	2	.888	'1.804	.687	Fe203	2.579	**.022** .
0 K	0	.000	46.736	62.153			2.000
TOTAL			'100.001	100.000		'100.00'1	1.218

ULTIMATE ANALYSIS

Pxx Ball Clay .

PXX BALL CLAY A (Unfired)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weioht	Oxide + LOI	Oxide %
Si (5102)	20.05	19.81	19.93	19.93	1,197.58	58.30	53.29
Al (AI203)	14.20	14.54	14.37	7.19	733.02	35.69	32.62
Fe (Fe203)	0.29	0.29	0.29	0.15	23.30	1.13	1.04
tn (Ti02)	0.29	0.26	0.27	0.27	21.85	1.06	0.97
K (K20)	1.24	1.29	1.27	0.63	59.61	2.90	2.65
Na (Na20)	0.11	0.11	0.11	0.06	3.46	0.17	0.15
Ca (CaO)	0.09	0.09	0.09	0.09	4.91	0.24	0.22
Mg (MgO)	0.28	0.20	0.24	0.24	9.65	0.47	0.43
Mn (Mn02)	0.00	0.02	0.01	0.01	0.65	0.03	0.03
bXYGEN	63.45	63.39	63.42				
LOI						9.40	8.6C
Total	100.00	100.00	100.00		2.054.03	109.40	100.01

PXX BALL CLAY 0 (12000C)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Average	Molecules	Mol weiaht	Oxide + LOI	Oxide %
Si (5102)	19.87	17.62	18.74	18.74	1,126.51	53.68	49.07
Al (AI203)	13.57	13.07	13.32	6.66	679.40	32.37	29.59
Fe (Fe203)	0.39	0.69	0.54	0.27	43.01	2.05	1.87
Ti (Ti02)	0.33	0.41	0.37	0.37	29.56	1.41	1.29
K (K20)	1.66	1.02	1.34	0.67	63.07	3.01	2.75
Na (Na20)	0.15	0.18	0.17	0.08	5.19	0.25	0.23
Ca (CaO)	0.35	4.16	2.26	2.26	126.67	6.04	5.52
Mg (MgO)	0.52	0.70	0.61	0.61	24.56	1.17	1.07
Mn (Mn02)	0.01	0.00	0.01	0.01	0.56	0.03	0.02
bXYGEN	63.14	62.15	62.65				
LOI						9.40	8.60
trotal	100.00	100.00	100.00		2 098.55	109.40	100.01

NB The Ca is very high in this spectrum.

RATIONAL ANALYSIS

Pxx *Ball Clay* .

RATIONAL ANALYSIS (PXX Ball Clay A)				
FELDSPAR CONVENTION				
MATERIAL	ENTRY	FACTOR	IRESULTI	
rrotal alkalis	2.80	*5.92	116.58 I%Feldspar	
Feldspar	16.58	*0.183	3.03 AI203 in Felds	(a)
Feldspar	16.58	*0.647	10.73 Si02 in Felds	(b)
AI203	32.62	"-a"*2.53	174.85 1% Clay subst.	(c)
Clay subst.	74.85	*0.463	34.66 Si02 in Clay	(d)
Si02	53.29	"-(b+d)"	17.91 1% Free silica	
% WATER IN THE CLAY: % ORGANIC MATTER				
Clay Subst.	24.94	*0.140	/10.48 ILoss:H20 in Clay	(e)
LOI	8.60	"-(e)"	0 ILoss: C02 etc	
MICA CONVENTION				
K20	2.75	*8.47	/23.29 IPotash Mica	
Na20	0.23	*12.32	12.83 [Soda Mica	
Potash Mica	23.29	*0.384	8.94 AI203 in K Mica	(e)
Potash Mica	23.29	*0.452	10.53 Si02 in K Mica	(f)
Soda Mica	2.83	*0.4	1.13 AI203 in Na Mica	(g)
Soda Mica	2.83	*0.471	1.33 Si02 in Na Mica	(h)
AI203	32.62	"(e+g)*2.53 /57.03 [Clay subst.		
Clay subst.	57.03	*0.465	26.52 Si02 in Clay	(i)
Si02	53.29	"-(f+h+i)"	114.91/Free Silica	

EDAX ANALYSIS

Western Province Ball Clay

Sample 1 A 1

CO calibration, FILENAME: SC02
LIVETIME= 200 I/P= 1841 cps

ENERGY	RES	AREA
.1	83.79	113348
6932.8	156.88	158655

TOTAL AREA= 368138 GF= 50.061

Specimen spectrum, FILENAME:SWPBCA1
LIVETIME(spec.)= 200

ENERGY	RES	AREA
.5	82.77	118332

TOTAL AREA= 173057

FIT INDEX= .42

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.037	.060* < 2 Sigma*
MgK	2	.292	.074
AlK	2	13.080	.'130
SiK	2	'14.619	•'103
K K	2	.778	•044
CaK	2	.106	.033
TiK	2	.856	.054
MnK	2	-.028	.047* < 2 Sigma*
FeK	2	.9'11	.070

...[3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.0o AZIM= .00 COSINE=1.000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.008	.052	.047	Na20'l	.070	.00'1
MgK	2	'1.023	.400	.338	Mg'10'l	.663	.0'1'1
AlK	2	.944	'19.433	'14.792	A1203 '	36.7'19	.465
SiK	2	.77'1	26.606	'19.452	Si102	56.9'15	.61'1
K K	2	.987	1.'lOS	.581	K 20'1	**'1.332**	.018
CaK	2	.982·	•'15'1	.078	Ca101	**.2'12**	.002
TiK	2	.983	**'1.222**	.524	*Ti'102*	2.038	.016
MnK	2	.873	.000	.000	Mn101	.000	.000
FeK	2	.890	'1.435	.528	Fe203	2.052	.0'17
0 K	0	.000	49.596	63.66'1			2.000
TOTAL			'100.000	'100.000		'100.000	'1.'142

EDAX ANALYSIS

Western Provln.ce Ball Clay .

Sample 1 A 2

Specimen spectrum, FILENAME:SWPBCA2
LIVETIME(spec.)= 200

ENERGY	RES	AREA
.2	83.43	117339

TOTAL AREA= 193750

FIT INDEX= .24

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	.063	.064*	< 2 Sigma*
MgK	2	.334	.080	
AlK	2	'14.850	.139	
SiK	2	17.'156	.111	
K K	2	.853	.045	
CaK	2	.'124	.035	
TiK	2	.750	.053	
MnK	2	-.005	.048*	< 2 Sigma*
FeK	2	.954	.069	

•••.C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=4o.0D AZIM= .00 COSINE='l .000

SpectrLlm:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	1.014	.076	.068	Na20'l	.'102	.002
MgK	2	'1.026	.398	.335	Mg'10'l	.659	•011
AlK	2	.946	'19.'198	'14.582	A1203	36.276	.458
SiK	2	.774	27.'132	19.794	Si102	58.040	.621
K K	2	.986	1.058	.555	K 201	'1.275	•0'17
CaK	2	.981	.154	.079	Ca101	.216	.002
TiK	2	.982	.934	.400	*Ti102*	'1.558	.0'13
MnK	2	.873	.000	.000	Ml,'10'l	.000	.000
FeK	2	.890	1.311	.48'1	Fe203	'1.875	.0'15
0 K	0	.000,	49.739	63.707			2.000
TOTAL			tOO.OOO	'100.000		100.000	'1. '139

EDAX ANALYSIS

Western Provln,ce Ball Clay

Sample 2 A 1

CO calibration, FILENAME:SC02
LIVETIME= 200 *I/P* = '177'1 cps

ENERGY	RES	AREA
1.2	84.62	114103
6927.9	158.91	154072

TOTAL AREA= 354205 GF= 50.018

Specimen spectrum, FILENAME: SWP2A'l
LIVETIME(soec.)= 200

ENERGY	RES	AREA
1.4	83.05	117374

TOTAL AREA=' 191581

FIT INDEX= .42

ELMT	APP.CONC	ERROR(WT%)
NaK 2	.046	.066* < 2 Sigma*
MgK 2	.308	.083
AlK 2	'14.974	.143
SiK 2	17.583	•'1'14
K K 2	.869	.047
CaK 2	.100	.036
TiK 2	.914	.056
MnK 2	.020	.050* < 2 Sigma*
FeK 2	'1.0'14	.073

... [3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT	ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK 2	'1.0'10	.055	.049	Na20'l	.074	.002
MgK 2	'1.024	.360	.304	Mg'101	.598	.010
AlK 2	.945	'18.987	14.436	A1203	35.877	.453
SiK 2	.775	27.188	19.855	Si102	58. '16'1	.623
K K 2	.986	'1.056	.554	K 201	1.272	.0'17
CaK 2	.98'1	•'122	.063	Ca'10'l	•'17'1	.002
TiK 2	.983	'1.114	.477	Ti102	1.859	.015
MnK 2	.873	.028	.0'10	Mn101	.036	.000
FeK 2	.890	1.366	.502	Fe203	1.953	.0'16
0 K 0	.000	49.723	63.750			2.000
TOTAL		'100.000	100.000		'100.000	'1. '137

EDAXANALYSIS

Western Province Ball Clay

Samole 2 **A2**

Specimen spectrum, FILENAME:SWP2A:2
LIVETIME(spec.)= :200

ENERGY	RES	AREA
1.2	83.27	118293

TOTAL AREA= 173716

FIT INDEX= .51

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.035	.062* < 2 Sigma*
MgK	2	.345	.078
AlK	2	'13.598	.135
SiK	2	15.701	.108
K K	2	.798	.045
CaK	2	•-125	.033
TiK	2	.827	.054
MnK	2	.074	.050* < 2 Sigma*
FeK	2	.945	.073

••• C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='1 .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.008	.046	.041	Na20'1	.062	.00'1
MgK	2	'1 .0:22	.447	.377	Mg101	.74'1	.012
AlK	2	.943	19.'104	'14.540	A1203	36.097	.457
SiK	2	.773	:26.907	'19.669	Si102	57.559	.618
K K	2	.987	'1.072	.563	K 201	'1.291	.0'18
CaK	2	.982	•169	.086	Ca'10'l	.236	.003
TiK	2	.983	'1.'1'14	.478	Ti102	1.859	.0'15
MnK	2	.873	•112	.042	Mn'101	.144	.00'1
FeK	2	.890	1.406	.517	Fe203	2.010	.016
0 K	0	.000	49.624	63.687			2.000
TOTAL			100.000	100.000		100.000	'1.140

EDAX ANALYSIS

Westem Province Ball Clay

Samle 201

CO calibration, FILENAME:SC02
LIVETIME= 200 I/P= 1759 cps

ENERGY	RES	AREA
•7	84.80	114321
6925.7	158.23	152958

TOTAL AREA= 351810 GF= 50.006

Specimen spectrum, FILENAME:SWP2D
LIVETIMECspec.)= 200

ENERGY	RES	AREA
.7	82.93	116115

TOTAL AREA= 236256

FIT INDEX= .78

ELMT		APP.CONC	ERRORCWT%)
NaK	2	.'186	.074
MgK	2	.390	.093
AlK	2	18.442	.'160
SiK	2	**2'1.372**	.'126
K K	2	2.360	.062
CaK	2	.281	.D43
TiK	2	'1•022	.060
MnK	2	.076	.055* < 2 Sigma*
FeK	2	'1.546	.085

...[' 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.oo AZIM= .00 COSINE='l .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.000	.178	.160	Na201	.240	.005
MgK	.2	'1.0'14	.368	.313	Mg'10'l	.610	.0'10
AlK	2	.939	18.774	14.382	A1203	35.474	.454
SiK	2	.775	26.367	'19.400	Si102	56.403	.6'13
K K	2	.990	**2.280**	'1.205	K 201	2.746	.038
CaK	2	.978	.274	.141	Ca101	.384	.004
TiK	2	.981	.996	.430	*Ti102*	1.661	*.0'1 it*
MnK	.2	.873	.083	.03'1	Mn101	.108	.001
FeK	2	.890	1.660	.6'14	Fe203	2.374	.019
0 K	0	.000	49.020	**63.323**			2.000
TOTAL			'100.000	100.000		100.000	**1.**'158

EDAX ANALYSIS

Western Province Ball Clay

Sample 2 02

Specimen spectrum, FILENAME:SWP2D2
LIVETIME(spec.)= 200

ENERGY	RES	AREA
.9	83.50	117186

TOTAL AREA= 209380

FIT INDEX:: .7'1

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	.27'1	.070	
MgK	2	.595	.088	
AIK	2	'16.395	.150	
SiK	2	'18.385	.1'17	
K K	2	2.119	.060	
CaK	2	.370	.04'1	
TiK	2	.962	.059	
MnK	2	.077	.054* < 2 Sigma*	
FeK	2	1.226	.079	

•••r. 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l.000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	1.004	**.292**	**.263**	Na201	.394	.008
MgK	2	1.015	.635	.540	Mg101	1.053	.017
AlK	2	.935	18.995	'14.556	A1203	35.892	.46'1
SiK	2	.771	25.835	'19.0'15	Si102	55.267	.602
K K	2	.99'1	2.3'18	'1.225	K 201	2.792	.039
CaK	2	.978	.4'10	.2'11	Ca101	.574	.007
TiK	2	.98'1	'1.063	.459	Ti102	'1.773	.015
MnK	2	.873	.095	.036	Mn'10'l	.123	.001
FeK	2	.890	'1.492	.552	Fe203	2.133	.017
0 K	0	.000	48.865	63.'142			2.000
TOTAL			100.000	100.000		'100.000	'1.167

ULTIMATE ANALYSIS

Western Province Ball Clay I

WESTERN PROVINCE BALL CLAY D (Sample 1							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Average	Molecules	Mol weight	Oxide +LOI	Oxide %
Si (SI02)	19.45	19.79	19.62	19.62	1,179.34	57.47	50.64
AI(AI203)	14.79	14.58	14.69	7.34	749.04	36.50	32.16
Fe(Fe203	0.53	0.48	0.50	0.25	40.26	1.96	1.73
Ti (Ti02)	0.52	0.40	0.46	0.46	36.91	1.80	t.SS
K (K20)	0.58	0.56	0.57	0.28	26.75	1.30	1.15
Na (Na20)	0.05	0.07	0.06	0.03	1.78	0.09	0.08
Ca (CaO)	0.08	0.08	0.08	0.08	4.40	0.21	0.19
Mg (MgO)	0.34	0.34	0.34	0.34	13.56	0.66	0.58
Mn(Mn02	0.0e	0.0e	0.00	0.00	0.00	0.00	0.0e
OXYGEN	63.66	63.71	63.68				
LOI						13.50	11.90
Total	100.00	100.00	100.00		2.052.05	113.50	100.01

WESTERN PROVINCE BALL CLAY D (Samole 1)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaae	Molecules	Mol weiaht	Oxide +LOI	Oxide %
Si (SI02)	20.53	22.71	21.62	21.62	1,299.27	63.89	56.29
AI(AI203)	12.90	11.31	12.11	6.05	617.38	30.36	26.75
Fe(Fe203	0.55	0.38	0.47	0.23	37.15	1.83	1.61
Ti (Ti02)	0.47	0.42	0.44	0.44	35.20	1.73	1.52
K (K20)	0.66	0.51	0.58	0.29	27.53	1.35	1.19
Na (Na20)	0.11	0.09	0.10	0.05	3.07	0.15	0.13
Ca (CaO)	0.05	0.06	0.06	0.06	3.09	0.15	0.13
Mg (MgO)	0.26	0.19	0.23	0.23	9.09	0.45	0.39
Mn(Mn02	0.05	0.00	0.02	0.02	1.96	0.10	O.OS
bXYGEN	63.93	64.34	64.13				
LOI						13.50	11.90
Total	99.50	100.00	99.75		2 033.72	113.50	100.01

ULTIMATE ANALYSIS

Western Province Ball Clay I

WESTERN PROVINCE BALL CLAY A (Sample 2							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaae	Molecules	Mol weiaht	Oxide +LOI	Oxide %
Si (SI02)	19.86	19.67	19.76	19.76	1,187.70	57.85	50.97
IAI(AI203)	14.43	14.54	14.49	7.24	738.79	35.98	31.70
Fe(Fe203	0.5e	0.52	0.51	0.25	40.66	1.98	1.74
Ti (Ti02)	0.48	0.48	0.48	0.48	38.15	1.86	1.64
K (K20)	0.55	0.56	0.56	0.28	26.31	1.28	1.13
Na (Na20)	0.05	0.04	0.05	0.02	1.40	0.07	0.06
Ca (CaO)	0.06	0.09	0.07	0.07	4.18	0.20	0.1a
Mg (MgO)	0.30	0.38	0.34	0.34	13.72	0.67	0.59
Mn(Mn02	0.01	0.04	0.03	0.03	2.26	0.11	0.10
OXYGEN	63.75	63.69	63.72				
LOI						13.50	11.90
Total	100.00	100.00	100.00		2053.15	113.50	100.01

WESTERN PROVINCE BALL CLAY D (Sample 2)							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analvsis 2	Averaae	Molecules	Mol weight	Oxide +LOI	Oxide %
Si (SI02)	19.40	19.02	19.21	19.21	1,154.37	55.82	49.18
AI(AI203)	14.38	14.56	14.47	7.23	737.87	35.68	31.44
Fe(Fe203	0.61	0.55	0.58	0.29	46.52	2.25	1.98
In (Ti02)	0.43	0.46	0.44	0.44	35.52	1.72	1.51
K (K20)	1.21	1.23	1.22	0.61	57.23	2.77	2.44
Na (Na20)	0.16	0.26	0.21	0.11	6.56	0.32	0.28
Ca (CaO)	0.14	0.21	0.18	0.18	9.87	0.48	0.42
Mg (MgO)	0.31	0.54	0.43	0.43	17.19	0.83	0.73
Mn(Mn02	0.03	0.04	0.03	0.03	2.91	0.14	0.12
bXYGEN	63.32	63.14	63.23				
LOI						13.50	11.90
Total	100.00	100.00	100.00		2068.03	113.50	100.01

RATIONAL ANALYSIS

Western Province Ball Clay I

RATIONAL ANALYSIS WPBC A (sample 1)				
FELDSPAR CONVENTION				
MATERIAL		FACTOR	IRESULTI	
Total alkalis	1.23	*5.92	17.28	I%Feldspar
Feldspar	7.28	*0.183	1.33	AI203 in Felds (a)
Feldspar	7.28	*0.647	4.71	Si02 in Felds (b)
AI203	32.16	"-a"*2.53	177.99	1% Clay subst. (e)
Clay subst.	77.99	*0.463	36.11	Si02 in Clay (d)
Si02	50.64	"-(b+d)"	19.82	1% Free silica
% WATER IN THE CLAY: % ORGANIC MATTER				
Clay Subst.	76.94	*0.140	110.92	ILoss:H20 in Clay (e)
LOI	11.90	"(-e)"	1.20	[toss; C02 etc
MICA CONVENTION				
K20	1.15	*8.47	19.74	I%Potash Mica
Na20	0.08	*12.32	10.99	I%Soda Mica
Potash Mica	9.74	*0.384	3.74	AI203 in K Mica (e)
Potash Mica	9.74	*0.452	4.40	Si02 in K Mica (f)
Soda Mica	0.99	*0.4	0.39	AI203 in Na Mica (g)
Soda Mica	0.99	*0.471	0.46	Si02 in Na Mica (h)
AI203	32.16	"-(e+g)*2.53	170.90	I%Clay subst,
Clay subst.	70.90	*0.465	32.97	Si02 in Clay (i)
Si02	50.64	"-(f+h+i)"	12.80	I%Free Silica

RATIONAL ANALYSIS

Western Provln.ce Ball Clay I

RATIONAL ANALYSIS WPBC A (sample 2)				
FELDSPAR CONVENTION				
MATERIAL		FACTOR	IRESULTI	
Total alkalis	1.19	*5.92	17.04 I%Feldspar	
Feldspar	7.04	*0.183	1.29 AI203 in Felds	(a)
Feldspar	7.04	*0.647	4.55 Si02 in Felds	(b)
AI203	31.70	"-a"*2.53	176.94 1% Clay subst.	(c)
Clay subst.	76.94	*0.463	35.62 Si02 in Clay	(d)
Si02	50.97	"-(b+d)"	110.79 1% Free silica	
% WATER IN THE CLAY: % ORGANIC MAnER				
Clay Subst.	76.94	*0.140	110.77 ILoss:H20 in Clay	(e)
LOI	11.90	"(_e)"	1.20 ltoss: C02 etc	
MICA CONVENTION				
K20	1.13	*8.47	19.57 I%Potash Mica	
Na20	0.06	*12.32	10.74 I%Soda Mica	
Potash Mica	9.57	*0.384	3.68 AI203 in K Mica	(e)
Potash Mica	9.57	*0.452	4.33 Si02 in K Mica	(f)
Soda Mica	0.74	*0.4	0.30 AI203 in Na Mica	(g)
Soda Mica	0.74	*0.471	0.35 Si02 in Na Mica	(h)
AI203	31.7	"-(e+g)*2.53	170.13 I%Clay subst,	
Clay subst.	70.13	*0.465	33.6 Si02 in Clay	(i)
Si02	50.97	"-(f+h+i)"	113.69 I%Free Silica	

EDAX ANALYSIS

G1 *Kaolin*

Sample A 1

Data file values:
SNO= 107.49 SN1=-2.4341
CO calibration, FILENAME:SC02
LIVETIME= 200 *l/P* = 1616 cps

ENERGY	RES	AREA
1.5	86.12	113918
6929.2	158.96	138934

TOTAL AREA= 323234 GF= 50.025

Specimen spectI'um, FILENAME: G1K1
G'lK1 LIVETIME(spec.)= 200

ENERGY	RES	AREA
-1.5	84.69	117157

TOTAL AREA= 181433

FIT INDEX= .53

ELMT	APP.CONC	ERROR (WT%)
NaK 2	.105	.065* < 2 Sigma*
MgK 2	.125	.08'1* < 2 Sigma*
AlK 2	11.692	•-140
SiK 2	2'1.926	•'13'1
K K 2	2.036	.060
CaK 2	.084	.038
TiK 2	.2·16	.049
MnK 2	-.0'15	.052* < 2 -Sigma*
FeK 2	.229	.06'1

...C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum: G'lK'l

Last, elmt by STOICH.,NORMALISED

ELMT	ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK 2	'1.029	.122	.109	Na201	.165	.003
MgK 2	1.036	.'144	.121	Mg10'l	.239	.004
AlK 2	.959	'14.573	11.028	A1203	27.536	.344
SiK 2	.824	3'1.808	23.1'19	Si102	68.044	.722
K K 2	.98'1	2.48'1	'1.295	K 201	2.988	.040
CaK 2	.969	•'103	.053	Ca101	.144	.002
TiK 2	.974	.265	.113	*Ti102*	.442	.004
MnK 2	.870	.000	.000	Mn101	.000	.000
FeK 2	.887	.309	.113	'Fe203	.442	.004
0 K 0	.000	50.'195	64.050			2.000
TOTAL		'100.000	100.000		100.000	1.123

EDAX ANALYSIS

G1 *Kaolin*

SampleA2

Specimen spectrum, FILENAME: G1KA2
G1K1 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.4	84.68	117377

TOTAL AREA= 174362

FIT INDEX= .56

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.078	.064* < 2 Sigma*
MgK	2	•122	.080* < 2 Sigma*
AlK	2	1'1.6'13	•139
SiK	2	2'1.405	.129
K K	2	1.926	.059
CaK	2	.077	.037
TiK	2	.42'1	.050
MnK	2	.0'18	.050* < 2 Sigma*
FeK	2	.255	.059

... [3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: G1K1

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.025	.093	.082	Na201	.125	.003
MgK	2	'1.034	.143	•'121	Mg'10'l	**.238**	.004
AlK	2	.958	14.692	'11.'129	AI203	27.76'1	.347
SiK	2	**.822**	3'1.542	22.948	Si102	67.475	.716
K K	2	.982	2.376	'1.242	K 20'1	2.862	.039
CaK	2	.970	.096	.049	Ca'101	.'134	.002
TiK	2	.975	.524	**.223**	*Ti102*	.874	.007
MnK	2	.870	'.025	.009	Mn'10'l	.033	.000
FeK	2	.887	.348	.'127	Fe203	.498	.004
0 K	0	.000	50.'160	64.069			2.000
TOTAL			'100.000	'100.000		'100.000	'1.'122

EDAX ANALYSIS

G1 *Kaolin*

Sample 0 1

Specimen spectrum, FILENAME: G'lD1
G1 D'l . LIVETIME(spec.)= :200

ENERGY	RES	AREA
1.5	86.04	,117250

TOTAL AREA= 185479

FIT INDEX= .50

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	.08:2	.063*	< 2 Sigma*
MgK	2	.083	.079*	< 2 Sigma*
AlK	2	'10.952	.137	
SiK	2	22.947	**.132**	
K K	2	**2.232**	.062	
CaK	2	.077	.039*	< 2 Sigma*
TiK	2	.466	.053	
MnK	2	-.040	.053*	< 2 Sigma*
FeK	2	.286	.062	

[2 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: G'lD1

Last elmt by STOICH.,NORMALISE[I

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	1.021	.094	.084	Na20'l	.127	.003
MgK	2	1.031	.095	.080	Mg101	•'157	.002
AlK	2	.957	'13.494	**'10.232**	A1203	25.497	.319
SiK	2	.835	32.43'1	23.621	Si102	69.377	.736
K K	2	.982	2.680	'1.402	K 201	**3.229**	.044
CaK	2	.969	.094	.048	Ca101	.131	.001
TiK	2	.974	.564	.241	Ti102	.94'1	.008
MnK	2	*.B70*	.000	.000	Mn101	.000	.000
FeK	2	.887	.381	•139	Fe203	.544	.004
0 K	0	.000	50.'17'1	64.152			2.000
TOTAL			'100.004	'100.000		'100.004	'1.118

EDAX ANALYSIS

G1 *Kaolin*

Sample D2

Specimen spectrum, FILENAME: G'lD2
LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.6	85.27	116653

TOTAL AREA= 210400

FIT INDEX= .34

ELMT		APP.CONC	ERROR(WT%)	
NaK	2	.067	.068*	< 2 Sigma*
MgK	2	.099	.085*	< 2 Sigma*
AIK	2	12.490	•'147	
SiK	2	27.57·6	•'144	
K K	2	2.269	.063	
CaK	2	.067	.040*	< 2 Sigma*
TiK	2	.330	.053	
MnK	2	-.0'13	.054*	< 2 Sigma*
FeK	2	.202	.063	

.... [3 ZAF/SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum:

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.027	.066	.058	Na201	.088	.002
MgK	2	'1.036	.096	.08'1	Mg10'l	.160	.003
AlK	2	.961	'13.15'1	'9.938	Al203	24.850	.309
SiK	2	.839	33.229	24.119	Si102	71.083	.750
K K	2	.980	2.34'1	1.221	K 201	2.820	.038
CaK	2	.969	.070	.036	Ca101	.098	.00'1··
TiK	2	.974	.343	•146	Ti102	.57'1	.005
MnK	2	.870	.000	.000	Mn'101	.000	.000
FeK	2	.887	.230	.084	Fe203	.-329	.003
0 K	0	.000	50.474	64.318			2.000
TOTAL			100.000	'100.000		100.000	'1.110

ULTIMATE ANALYSIS

G1 *Kaolin*

G1 KAOLIN A							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysist	Analysis 2	Averaae	Molecules	Mol weiaht	Oxide +LOI	Oxide %
Si (SI02)	23.12	22.95	23.03	23.03	1,384.31	67.75	64.28
AI(AI203)	11.03	11.13	11.08	5.54	565.00	27.65	26.24
Fe(Fe203)	0.11	0.13	0.12	0.06	9.58	0.47	0.44
Ti (Ti02)	0.11	0.22	0.17	0.17	13.42	0.66	0.62
K (K20)	1.30	1.24	1.27	0.63	59.75	2.92	2.77
Na (Na20)	0.11	0.08	0.10	0.05	2.96	0.14	0.14
Ca (CaO)	0.05	0.05	0.05	0.05	2.86	0.14	0.13
Mg (MgO)	0.12	0.12	0.12	0.12	4.88	0.24	0.23
Mn(Mn02	0.00	0.01	0.00	0.00	0.39	0.02	0.02
bXYGEN	64.05	64.07	64.06				
LOI						5.40	5.12
Total	100.00	100.00	100.00		2,043.15	105.40	100.00

G1 KAOLIN 0							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis1	Analysis 2	Average	Molecules	Mol weiaht	Oxide +LOI	Oxide %
Si (SI02)	23.62	24.12	23.87	23.87	1,434.59	70.10	66.51
Al(Al2O3)	10.23	9.94	10.09	5.04	514.34	25.13	23.84
Fe(Fe203)	0.14	0.08	0.11	0.06	8.90	0.43	0.41
Ti (Ti02)	0.24	0.15	0.19	0.19	15.46	0.76	0.72
K (K20)	1.40	1.22	1.31	0.66	61.77	3.02	2.86
Na (Na20)	0.08	0.06	0.07	0.04	2.20	0.11	0.1C
Ca (CaO)	0.05	0.04	0.04	0.04	2.36	0.12	0.11
Mg (MgO)	0.08	0.08	0.08	0.08	3.24	0.16	0.15
Mn(Mn02	0.00	0.08	0.04	0.04	3.65	0.18	0.17
OXYGEN	64.14	64.32	64.23				
LOI						5.40	5.12
Total	99.99	100.09	100.04		2046.50	105.40	100.00

RATIONAL ANALYSIS

G1 *Kaolin*

RATIONAL ANALYSIS G1 KAOLIN					
FELDSPAR CONVENTION					
MATERIAL	ENTRY	FACTOR	IRESULT	1	
Total alkalis	2.91	*5.92	117.23	I%Feldspar	
Feldspar	17.23	*0.183	3.15	AI203 in Felds	(a)
Feldspar	17.23	*0.647	11.15	Si02 in Felds	ib)
AI203	26.24	"a"*2.53	158.41	1% Clay subst.	c
Clay subst.	58.41	*0.463	27.04	Si02 in Clav	Id
Si02	64.28	"(b+d)"	126.09	1% silica	
% WATER IN THE CLAY: % ORGANIC MATTER					
Clay Subst.	58.41	*0.140	18.18	ILoss:H20 in Clay	E)
LOI	5.10	"(- e)"	0.00	ILoss: C02 etc	
MICA CONVENTION					
K20	2.77	*8.47	123.46	1% Potash Mica	
Na20	0.14	*12.32	11.72	I%Soda Mica	
Potash Mica	23.46	*0.384	9.01	AI203 in K Mica	(e)
Potash Mica	23.46	*0.452	10.60	Si02 in K Mica	(f)
Soda Mica	1.72	*0.4	0.69	AI203 in Na Mica	(g)
Soda Mica	1.72	*0.471	0.81	Si02 in Na Mica	(h
AI203	26.24	"(e+g) 2.53	141.85	1% Clay substance	
tlay subst.	41.85	*0.465	19.46	Si02 in Clav	(i
Si02	64.28	"(f+h+)	133.40	1% Free Silica	

EDAX ANALYSIS

serena Kaolin

Sample A 1

CO calibration, FILENAME:SC02
SC02 LIVETIME= 200 *l/P* = 1682 cps

ENERGY	RES	AREA
1.2	92.56	113328
6927.6	164.06	145778

TOTAL AREA= 336374 GF= 50.016

Specimen spectrum, FILENAME: SERD'1 = SER A 1
SERD1 LIVETIME(spec.)= 200

ENERGY	RES	AREA
.7	97.64	116341

TOTAL AREA= 128785
.....
FIT INDEX= .41

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.047	.060* < 2 Sigma*
MgK	2	.049	.072* < 2 Sigma*
AlK	2	12.890	•'132
SiK	2	10.910	.095
K K	2	.689	.043
CaK	2	.033	.031* < 2 Sigma*
TiK	2	.164	.041
MnK	2	-.026	.044* < 2 Sigma*
FeK	2	.236	.053

...C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZlM= .00 COSINE=1.000

Spectrum: SERD1

Last elmt by STOlCH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.0"1'6	.078	.069	Na201	•105	.002
MgK	2	'1.05'1	.08'1	.068	Mg-10-1	. -134	.002
AlK	2	.966	22.968	-17.344	A1203	43.399	.547
SiK	2	.748	25.099	-18.205	Si102	53.692	.575
K K	2	.983	'1.206	.629	K 201	1.453	.020
CaK	2	.977	.058	.029	Ca-l0-l	.08-1	.00-1
TiK	2	.980	.:289	.-123	Ti102	.482	.004
MnK	2	.873	.000	.000	Mn-101	.000	.000
FeK	2	.890	.457	•167	Fe203	.654	.005
0 K	0	.000	49.764	63.367			2.000
TOTAL			100.000	-100.0.00		-100.000	-1 •-156

EDAXANALYSIS

Serena Kaolin

Sample A2

Specimen spectrum, FILENAME: SERA2 =A2.
SERA2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.1	93.48	117433

TOTAL AREA= 114281

FIT INDEX= .52

ELMT		APP.CONC	ERROR(WTX)
NaK	2	.0'10	.057* < 2 Sigma*
MgK	2	.087	.070* < 2 Sigma*
AlK	2	11.752	.126
SiK	2	'10.'122	.09'1
K K	2	.610	.039
CaK	2	.0'18	.028* < 2 Sigma*
rn:	2	•'148	.038
MnK	2	.001	.041* < 2 Sigma*
FeK	2	•'176	.047

...[ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=1.000

Spectrum: SERA2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.048	.0'17	.0'15	Na2O1	**.023**	.000
MgK	2	'1.053	•'156	.130	Mg101	.258	.004
AlK	2	.966	**22.806**	'17.208	A1203	43.093	.543
SiK	2	.750	**25.322**	'18.35'1	Si102	54.'168	.579
K K	2	.983	'1.164	.606	K 20'1	1.402	.019
CaK	2	.977	.035	.0'18	Ca101	.049	.001
TiK	2	.979	.283	.120	Ti102	.473	.004
MnK	2	.873	.002	.00'1	Mn10'l	.002	.000
FeK	2	.889	**.372**	•'135	Fe203	.531	.004
0 K	0	.000	49.843	63.416			2'.000
TOTAL			'100.000	'100.000		'100.000	1•'154

EDAX ANALVSIS

Serena Kaolln

Sample 0 1

Specimen spectrum, FILENAME:SERD2 = D1
SERD2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.4	89.63	116815

TOTAL AREA= 193222

FIT INDEX= 1.21

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.026	.075* < 2 Sigma*
MgK	2	-.'188	.091* < 2 Sigma*
AlK	2	20.072	.166
SiK	2	16.690	•116
K K	2	.983	.05'1
CaK	2	.046	.037* < 2 Sigma*
TiK	2	**.302**	.050
MnK	2	-.024	.052* < 2 Sigma*
FeK	2	.249	.06'1

..•C 3 ZAF'SJ

20.00 kV TLLT= .00 ELEV=4o.oo AZIM= .00 COSINE=1.o0o

Spectrum: SERD2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OX!DE	FORMULA
NaK	2	'1.049	.028	.025	Na201	.037	.001
MgK	2	'1.054	.000	.000	Mg10'l	.000	.000
AlK	2	.969	**23.234**	'17.530	A1203	43.901	.553
SiK	2	.747	25.061	.18.161	Si102	53.610	.573
K K	2	.983	**1.'122**	.584	K 20'1	'1.35'1	.0'18
CaK	2	.977	.053	.027	Ca101	.074	.00'1·
TiK	2	.979	.346	•147	Ti102	.576	.005
MnK	2	.873	.000	.000	Mn101	.000	.000
FeK	2	.889	.3'14	•114	Fe203	.449	.004
0 K	0	.000	49.843	63.413			2.000
TOTAL			'100.000	100.000		'100.000	1.'154

EDAX ANALYSIS

Serena Kaolin

Sample 02

Specimen spectrum, FILENAME: SERD3 = D2.
SERD3 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.3	90.26	116940

TOTAL AREA= 158706

FIT INDEX= .46

ELMT		APP.CONC	ERRORCWT%)
NaK	2	.010	.067* < 2 Sigma*
MgK	2	.092	.08-1* < 2 Sigma*
AlK	2	-17.083	•-150
SiK	2	-13.996	.-106
K K	2	.827	.045
CaK	2	-.006	.033* < 2 Sigma*
TiK	2	.350	.046
MnK	2	.0-1-1	.047* < 2 Sigma*
FeK	2	.25-1	.057

... (3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE=L 000

Spectrum: SERD3

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	-1.046	.0-12	.0-1-1	Na20'1	.016	.000
MgK	2	-1 .053	•116	.097	Mg10'1	•'192	.003
AlK	2	.966	**23.33'1**	17.6-15	A1203	44.084	.556
SiK	2	.745	24.790	-17.977	Si-l02	53.030	.567
K K	2	.983	-1.110	.578	K 201	1.337	.0-18
CaK	2	.978	.000	.000	Ca-l0'1	.000	.000
TiK	2	.980	.47-1	.200	*Ti102*	.785	.006
MnK	2	.873	.0-17	.006	Mn10'1	.021	.000
FeK	2	.890	.373	•'136	Fe203	.533	.004
0 K	0	.000	49.78'1	63.379			2.000
TOTAL			100.000	-100.000		'100.000	1.156

ULTIMATE ANALYSIS

serena Kaolin

SERINA KAOLIN A							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Average	Molecules	Mol weight	Oxide + LOI	Oxide %
Si (5102)	18.21	18.35	18.28	18.28	1,098.51	53.93	47.43
Al(Al203)	17.34	17.21	17.28	8.64	881.0S	43.25	38.04
Fe(Fe203	0.17	0.14	0.15	0.08	12.05	0.59	0.52
Ti (Ti02)	0.12	0.12	0.12	0.12	9.71	0.48	0.42
K (K20)	0.63	0.61	0.62	0.31	29.08	1.43	1.26
Na (Na20)	0.07	0.02	0.04	0.02	1.30	0.06	0.06
Ca (CaO)	0.03	0.02	0.02	0.02	1.32	0.06	0.06
Mg (MgO)	0.07	0.13	0.10	0.10	3.99	0.20	0.17
Mn(Mn02	0.00	0.00	0.00	0.00	0.04	0.00	0.00
OXYGEN	63.37	63.42	63.39				
LOI						13.70	12.05
Total	100.00	100.00	100.00		2037.08	113.70	100.00

SERINA KAOLIN 0							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Average	Molecules	Mol weioht	Oxide +LOI	Oxide %
Si (5102)	18.16	17.98	18.07	18.07	1,085.95	53.31	46.89
Al(Al203)	17.53	17.62	17.57	8.79	896.20	44.00	38.70
Fe(Fe203	0.11	0.14	0.13	0.06	9.98	0.49	0.43
Ti (Ti02)	0.15	0.2e	0.17	0.17	13.86	0.68	0.60
K (K20)	0.58	0.58	0.58	0.29	27.37	1.34	1.18
Na (Na20)	0.03	0.01	0.02	0.01	0.56	0.03	0.02
Ca (CaO)	0.03	0.00	0.01	0.01	0.76	0.04 ,	0.03
Mg (MgO)	0.00	0.10	0.05	0.05	1.95	0.10	0.08
Mn(Mn02	0.00	0.01	0.00	0.00	0.26	0.01	0.01
OXYGEN	63.41	63.38	63.40				
LOI						13.70	12.05
Total	100.00	100.00	100.00		2036.88	113.70	100.00

RATIONAL ANALVSIS

serena Kaolin .

RATIONAL ANALYSIS SERINA A				
FELDSPAR CONVENTION				
MATERIAL		FACTOR	IRESULTI	
Total alkalis	1.32	*5.92	/7.81 /%Feldspar	
Feldspar	7.81	*0.183	1.43 AI203 in Felds	(a)
Feldspar	7.81	*0.647	5.05 Si02 in Felds	(b)
AI2O3	38.04	"-a"*2.53	192.63 1% Clay subst.	(c)
Clay subst.	92.63	*0.463	42.89 Si02 in Clay	(d)
Si02	47.43	"-(b+d)"	1-0.51 1% silica	
% WATER IN THE CLAY: % ORGANIC MATTER				
Clay Subst.	92.63	*0.140	112.97 ILoss:H20 in Clay	(e)
LOI	12.05	"(-e)"	ltoss: C02 etc	
MICA CONVENTION				
K20	1.26	*8.47	110.67 IPotash Mica	
Na20	0.06	*12.32	10.74 [soda Mica	
Potash Mica	10.67	*0.384	4.10 AI203 in K Mica	(e)
Potash Mica	10.67	*0.452	4.82 Si02 in K Mica	(f)
Soda Mica	0.74	*0.4	0.30 AI203 in Na Mica	(g)
Soda Mica	0.74	*0.471	0.35 Si02 in Na Mica	(h)
AI2O3	38.04	"-(e+g)*2.53	185.12 [Clay subst.	
Clay subst.	85.12	*0.465	39.58 Si02 in Clay	(i)
Si02	47.43	"-(f+h+i)"	12.67 IFree Silica	

EDAX ANALYSIS

5-Ksolln

Sample A 1

CO calibration, FILENAME:SCO'1
G1K1 LIVETIME= 200 *I/P*= '1639 cps

ENERGY	RES	AREA
1.4	85.71	114300
6928.7	157.71	141292

TOTAL AREA= 327714 GF= 50.022

Specimen spectrum, FILENAME: SKA1
SKA1 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.4	84.21'	118427

TOTAL AREA= 150743

FIT INDEX:: .3'1

ELMT		APP.CONC	,ERROR(WT%)
NaK	2	.071	.063* < 2 Sigma*
MgK	2	.126	.076* < 2 Sigma*
AlK	2	13.989	•'140
SiK	2	'13.915	.106
K K	2	.439	.042
CaK	2	.027	.034* < 2 Sigma*
TiK	2	•271	.048
MnK	2	.095	.052* < 2 Sigma*
FeK	2	''1.006	.074

...[3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: SKA1

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXI[)E	FORMULA
NaK	2	'1.015	•'100	.089	Na201	•'135	.003
MgK	2	1.027	·'175	•147	Mg'10'l	.290	.005
AlK	2	.950	20.997	15.924	A1203	39.675	.501
SiK	2	.759	26.'144	19.044	Si'102	55.927	.599
K K	2	.984	.636	.333	K 20'1	.766	.0'10
CaK	2	.98'1	.039	.020	Ca101	•054	.001
TiK	2	.984	.392	.167	Ti102	.654	.005
MnK	2	.874	•'154	.057	Mn101	•'199	.002
FeK	2	.891	'1.609	.589	Fe203	2.300	.0'19
0 K	0	.000	-49.755	63.629			2.000
TOTAL			100.000	100.000		100.000	'1 .143

EDAX ANALYSIS

8-Kaolln

SampleA2

Specimen spectrum, FILENAME: SKA2
SKA2 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.5	84.23	118149

TOTAL AREA= 151767

FIT INDEX= .24

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.036	.063* < 2 Sigma*
MgK	2	.135	.077* < 2 Sigma*
AlK	2	'12.92.7	•'138
SiK	2	15.98'1	•112
K K	2	.207	.038
CaK	2	.00'1	.033* < 2 Sigma*
ri«	2	.278	.048
MnK	2	-.008	.049* < 2 Sigma*
FeK	2	.837	.070

••• [3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: SKA2

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.02'1	.049	.044	Na201	.066	.00'1
MgK	2	'1.032	•'182	.152	Mg'101	**.302**	.005
AlK	2	.954	18.874	'14.244	A1203	35.663	.445
SiK	2	.779	28.554	20.697	Si102	6'1.Q82	.646
K K	2	.981	.294	.'153	K 201	.355	.005
CaK	2	.980	.002	.00'1	Ca'10'l	.003	.000
TiK	2	.982	.394	.168	Ti102	.657	.005
MnK	2	.873	.000	.000	Mn101	.000	.000
FeK	2	.890	'1.310	.477	Fe203	1.872	.015
0 K	0	.000	50.34'1	64.064			2.000
TOTAL			'100.000	100.000		100.000	1.122

EDAX ANALYSIS

5-Kaolln

Sample 0 1

Specimen spectrum, FILENAME: SKD1
SKD1 LIVETIME(spec.)= 200

ENERGY	RES	AREA
1.6	84.89	114935

TOTAL AREA= 271362

FIT INDEX= .56

ELMT		APP.CONC	ERROR(WT%)
NaK	2	.079	.088* < 2 Sigma*
MgK	2	.368	•'108
AlK	2	27.200	.195
SiK	2	26.443	. '.146
K K	2	.906	,.056
CaK	2	.064	.044* < 2 Sigma*
TiK	2	.635	.063
MnK	2	-.081	.064* < 2 Sigma*
FeK	2	'1.486	.092

...[3 ZAF'SJ

20.00 kV TILT= .00 ELEV=40.00 AZIM= .00 COSINE='l .000

Spectrum: SKD1

Last elmt by STOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.025	.057	.051	Na201	.077	.002
MgK	2	'1.035	.266	.223	Mg'10'1	.440	.007
AlK	2	.953	21.299	16.119	A1203	40.245	.507
SiK	2	•757	26.063	18.945	Si102	55.754	.596
K K	2	.984	.688	.359	K 20'1	.828	.011
CaK	2	.98'1	.049	.025	Ca'lO'l	.069	.001
TiK	2	.983	.482	.206	Ti102	.804	.006
MnK	2	.874	.000	.000	Mn'10'1.	.000	.000
FeK	2	.890	'1.246	.456	Fe203	1.782	.0'14
0 K	0	.000	49.850	63.6'17			2.000
TOTAL			'100.000	'100.000		'100.000	'1. '144

EDAX ANALYSIS

5-Kaolln

Sample D2

Specimen spectrum, FILENAME: SKD2
SKD2 LIVETIMECspec.)= 200

ENERGY	'RES	AREA
1.5	85.55	116385

TOTAL AREA= 225754

FIT INDEX= .54

ELMT		APP.CONC	ERRORCWT%)	
NaK	2	.045	.082* < 2	Sigma*
MgK	2	**.234**	.'100	
AlK	2	22.874	.180	
SiK	2	**22.693**	.'136	
K K	2	.55'1	.049	
CaK	2	.046	.039* < 2	Sigma*
TiK	2	.339	.054	
MnK	2	-.073	.056* < 2	Sigma*
FeK	2	.962	.077	

••• C 3 ZAF'SJ

20.00 kV TILT= .00 ELEV=4o.0o AZIM= .00 COSINE='l .000

Spectrum: SKD2

Last elmt by 8TOICH.,NORMALISED

ELMT		ZAF	%ELMT	ATOM.%		%OXIDE	FORMULA
NaK	2	'1.033	.039	.035	Na20'l	.053	.00'1
MgK	2	'1.042	.200	.167	Mg'10'l	**.332**	.005
AlK	2	.959	**2-1.253**	16.034	A1203	40.159	.503
8iK	2	.760	:26.602	'19.276	Si'102	56.906	.605
K K	2	.982	.500	.260	K 20'1	.602	.008
CaK	2	.980	.042	.02'1	Ca101	.059	.00'1
TiK	2	.982	.308	•'13'1	TH02	.513	.004
MnK	2	.873	.000	.000	Mn'101	.000	.000
FeK	2	.890	.963	.35'1	Fe203	1.376	.0'11
0 K	0	.000	50.094	63.726			2.000
TOTAL			'100.000	'100.000		100.000	1.138

ULTIMATE ANALYSIS

5-Kaolln

S KAOLIN A							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaoe	Molecules	Mol weloht	Oxide +LOl	Oxide %
Si (5102)	19.04	20.70	19.87	19.87	1,194.22	58.49	52.76
Al(Al2O3)	15.92	14.24	15.08	7.54	769.28	37.68	33.99
Fe(Fe203	0.59	0.48	0.53	0.27	42.53	2.08	1.88
ln (Ti02)	0.16	0.17	0.17	0.17	13.18	0.65	0.58
K (K20)	0.33	0.15	0.24	0.12	" 45	0.56	0.51
Na (Na20)	0.09	0.04	0.07	0.03	2.06	0.10	0.09
ta (CaO)	0.02	0.00	0.01	0.01	0.59	0.03	0.03
Mg (MgO)	0.15	0.15	0.15	0.15	6.02	0.30	0.27
Mn(MnO2	0.06	0.00	0.03	0.03	2.48	0.12	0.11
OXYGEN	63.63	64.06	63.85				
LOl						10.86	9.8C
Total	99.99	100.00	100.00		2 041.82	110.86	100.0C

S KAOLIN 0							
	Atomic % of Elements			Molecular content		Oxide content	
	Analysis 1	Analysis 2	Averaae	Molecules	Mol weiaht	Oxide +LOl	Oxide %
Si (5102)	18.95	19.28	19.11	19.11	1,148.54	56.32	50.81
Al(Al203)	16.12	16.03	16.08	8.04	819.90	40.21	36.27
Fe(Fe203	0.46	0.35	0.40	0.20	32.20	1.58	1.42
Ti (Ti02)	0.21	0.13	0.17	0.17	13.46	0.66	0.6C
K (K20)	0.36	0.26	0.31	0.15	14.58	0.71	0.64
Na (Na20)	0.05	0.04	0.04	0.02	1.33	0.07	0.06
Ca (CaO)	0.03	0.02	0.02	0.02	1.29	0.06	0.06
Mg (MgO)	0.22	0.17	0.20	0.20	7.86	0.39	0.35
Mn(MnO2	0.00	0.0e	0.00	0.00	0.00	0.00	0.00
bXYGEN	63.62	63.73	63.67				
LOl						10.86	9.80
Total	100.00	100.00	100.00		2039.16	110.86	100.00

RAlIONAl ANALYSIS

5-Kaolln

RATIONAL ANALYSIS (S KAOLIN A)					
FELDSPAR CONVENTION					
MATERIAL	ENTRY	FACTOR	IRESULTI		
Total alkalis	0.60	*5.92	13.55	I%Feldspar	
Feldspar	3.55	*0.183	0.65	AI203 in Felds	(a)
Feldspar	3.55	*0.647	2.30	Si02 in Felds	(b)
AI2O3	33.99	"-a"*2.53	184.35	1% Clay subst.	(c)
Clay subst.	84.35	*0.463	39.05	Si02 in Clay	(d)
Si02	52.76	"-(b+d)"	'11.41	1% silica	
% WATER IN THE CLAY: % ORGANIC MATTER					
Clay Subst.	32.35	*0.140	'11.81	ILoss:H20 in Clay	(e)
LOI	9.80	"(- e)"	5.27	[toss: C02 etc	
MICA CONVENTION					
K20	0.64	*8.47	15.42	I%Potash Mica	
Na20	0.06	*12.32	10.74	I%Soda Mica	
Potash Mica	5.42	*0.384	2.08	AI203 in K Mica	(e)
Potash Mica	5.42	*0.452	2.45	Si02 in K Mica	(f)
Soda Mica	0.74	*0.4	0.30	AI203 in Na Mica	(g)
Soda Mica	0.74	*0.471	0.35	Si02 in Na Mica	(h)
AI203	36.27	"-(e+g)*2.53	179.65	I%Clay subst,	
Clay subst.	79.65	*0.465	37.04	Si02 in Clay	(i)
Si02	50.81	"-(f+h+i)"	'10.98	1% Free silica	

APPENDIX E

DATA BASE

The Ultimate analysis of the clay bodies was calculated by means of the "Insight" ceramic software programme. The results are presented in this appendix.

INSIGHT RECIPE CALCULATIONS.

***A** clay body*

A CLAY BODY

A CLAy.....	50.00	50.00%
SA SiLiCA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
		100.00

FORMULA & ANALYSIS

CaO ..	.00	.24%
MgO ..	.00	.16%
K20 ..	.03	3.33%
Na20 .	.00	.17%
Fe203..	.01	1.55%
Ti02...	.01	.80%
A1203..	.18	19.69%
Si02...	1.17	74.06%
RATIO	6.39	
EXPAN	5.35	
WEIGHT	94.70	

INSIGHT RECIPE CALCULATIONS.

813 Ball Clay Body

B13 BALL CLAY BODY

B13 Ball Clay.....	50.00	50.00%
SA SiLiCA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO ..	.01	.41%
MgO ..	.01	.32%
K20 ..	.05	4.40%
Na20 ..	.00	.20%
Fe203..	.01	1.28%
MnO ..	.00	.04%
Ti02 .	.01	.60%
A1203..	.16	17.02%
Si02...	1.22	75.73%
RATIO	7.56	
EXPAN	5.57	
WEIGHT	96.60	

INSIGHT RECIPE CALCULATIONS.

CClaybody

C Clay body

C CLAy.....	50.00	50.00%
SA SiLiCA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO....	.00	.17%
MgO....	.00	.11%
K20....	.03	3.26%
Na20...	.00	.31%
Fe203..	.00	.39%
Ti02...	.01	1.05%
AI203..	.17	18.07%
Si02...	1.23	76.63%
RATIO	7.21	
EXPAN	5.25	
WEIGHT	96.65	

INSIGHT RECIPE CALCULATIONS.

PXX Ball clay body

PXX BALL CLAY BODY

PXX BALL CLAy.....	50.00	50.00%
SA SiLiCA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO .	.00	.10%
MgO .	.00	.05%
K20 ..	.05	4.69%
Na20 ..	.01	.76%
Fe203..	.00	.15%
Ti02...	.01	.79%
A1203..	.21	21.72%
Si02...	1.16	71.74%
RATIO	5.62	
EXPAN	5.87	
WEIGHT	97.30	

INSIGHT RECIPE CALCULATIONS.

Moss Clay body

MOSS CLAY BODY

Moss Clay.....	50.00	50.00%
SA SILICA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO ..	.00	.02%
MgO ..	.00	.12%
K20 ..	.05	5.13%
Na20 .	.00	.26%
Fe203..	.00	.81%
MnO .	.00	.01%
Ti02 .	.01	.68%
A1203..	.17	17.49%
Si02...	1.22	75.48%
RATIO	7.33	
EXPAN	5.75	
WEIGHT	97.15	

INSIGHT RECIPE CALCULATIONS.

Western Province Ball clay body

Western Province ball clay Body

WPBC.	50.00	50.00%
SA,SILICA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO ..	.00	.10%
MgO ..	.01	.31%
K20 ..	.04	3.75%
Na20 .	.00	.19%
Fe203..	.01	.97%
MnO ..	.00	.05%
Ti02 .	.01	.86%
A1203..	.20	21.70%
Si02...	1.13	72.08%
RATIO	5.65	
EXPAN	5.47	
WEIGHT	94.05	

INSIGHT RECIPE CALCULATIONS.

G1 *Kaolin body'*

G1 Kaolin Body

G1 KAOLIN.....	50.00	50.00%
SA SILICA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO....	.00	.07%
MgO....	.00	.12%
K20....	.05	4.45%
Na20...	.00	.21%
Fe203..	.00	.27%
MnO....	.00	.01%
Ti02...	.00	.34%
A1203..	.17	17.93%
Si02...	1.24	76.60%
RATIO	7.26	
EXPAN	5.46	
WEIGHT	97.44	

INSIGHT RECIPE CALCULATIONS.

5erlna Kaolin body

SERINA BODY

Serina.....	50.00	50.00%
SA SiLiCA.....	30.00	30.00%
SA POTASH FELDSPAR..	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO .	.00	.03%
MgO .	.00	.09%
K20 ..	.04	3.81%
Na20 .	.00	.18%
Fe203..	.00	.33%
Ti02...	.00	.24%
A1203..	.23	24.86%
Si02...	1.10	70.46%
RATIO	4.82	
EXPAN	5.45	
WEIGHT	93.98	

INSIGHT RECIPE CALCULATIONS.

S Kaolin body .

S KAOLIN BODY

S Kaolin .	50.00	50.00%
SA SILICA. .	30.00	30.00%
POTASH FELDSPAR...	20.00	20.00%
	100.00	

FORMULA & ANALYSIS

CaO....	.00	.02%
MgO....	.00	.14%
K20....	.04	3.97%
Na20...	.00	.05%
Fe203..	.01	1.04%
MnO....	.00	.06%
Ti02...	.00	.32%
A1203..".21		22.33%
Si02...	1.14	72.07%
COST/KG	.04	
RATIO	5.49	
EXPAN	5.44	
WEIGHT	95.07	

EDAX ANALYSES

The analyses of SA Silica and SA K Feldspar are entered in the INSIGHT Materials Data Table (MDT).

Sa *Silica Analysis*

sa silica

Na20.....	.02	.02%
Si02.....	97.38	97.38%
AI203.....	1.93	1.93%
Fe203.....	.15	.15%
K20.....	.46	.46%
Ti02.....	.05	.05%
	100.00	

FORMULA & ANALYSIS

K20 .	.26	.46%
Na20 ..	.02	.02%
Fe203..	.05	.15%
Ti02...	04	.05%
*AI203..	1.00	1.93%
Si02...	85.60	97.38%

COST/KG .04
RATIO 85.60
EXPAN 3.72
WEIGHT 5274.25

Sa *Potash Feldspar*

SA POTASH FELDSPAR

Na20 .	.65	. .65%
Si02 ..	66.43	66.44%
AI203 ..	18.83	18.83%
K20 .	14.08	14.08%
	99.99	

FORMULA & ANALYSIS

K20 ..	.81	14.08%
Na20 .	.06	.65%
*AI203..	1.00	18.83%
Si02...	6.00	66.44%

COSTIKG .08
RATIO 6.00
EXPAN 8.42
WEIGHT 541.58