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INDIAN BUREAU OF MINES

Monograph

on

CHINACLAY (KAOLIN)

भारतीय खान ब्यूरो
INDIAN BUREAU OF MINES
सतत कार्यरत
ON WITH THE JOB

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1. Introduction

The word 'Chinaclay' derives its origin from a hill named Kaoling in China from where it was first reported. The commercial term for chinaclay is kaolin. It is a white powdery mineral which consists principally of a micro crystalline compound approximately akin to the mineral kaolinite. It has a specific gravity of 2.6 and a fusion point of about 1735°C. It is distinguished from ordinary rock clay, principally by its plasticity, softness, extreme fineness of its ultimate particles, white colour and dispersion in water. Pure kaolin would contain 38.5% silica, 47.5% alumina and 14% water, but the commercial grades usually contain some amounts of impurities like quartz, oxides of iron and titanium and minerals containing calcium, magnesium together with alkalies of soda and potash.

The clay deposits have been formed primarily due to the alteration of granite gneisses in the remote past by hydrothermal action of aqueous solutions and later deposited in stratified layers as secondary deposits. The weathering of feldspar within the granite gnesis gave rise to the formation of kaolin. These deposits are known to occur in the ages ranging from Archaean to Tertiary rocks, but the industrially suitable deposits are occurring with the rocks of Gondwana and Tertiary periods. The different types of individual clay mineral groups viz. Kaolinite, Illite, Smectite' etc. are identified by X-ray Powder Diffraction Method, Differential Thermal Analysis or by Scanning Electron Microscopy.

Kaolin finds use in many ways in industries, such as paper, ceramic, calcined pigments, paints, plastics, rubber and other allied industries. Over the years kaolin has lost its market share to other white minerals particularly calcium carbonate and talc, but the paper industry's demand of kaolin for mineral coating and filler pigments still continues.

Prospecting and Exploration for clay deposits are mostly done by conventional method of pitting, trenching and rarely by shallow borehole drilling. Neither geophysical nor deep borehole drilling for identification of deeper and better quality deposits are practised as the shallow deposits continue to meet today's requirements. As a result, the information on world resources of kaolin lack authenticity. However in some of the countries the estimates were made. In India, the in situ reserves as on 1.4.1995 are nearly 1800 million tonnes.

Although chinaclay is found in abundance over many areas in India, the rich deposits are confined to the states of West Bengal (23%), Orissa (17%), Rajasthan (15%), Bihar (14%) and Kerala (9%). The rest 22% is distributed in all other states. However, the highest proved recoverable reserves are located in Rajasthan.

Though India is rich as far as the reserves of kaolin are concerned, it does not even account for 1% of the world's production.

In 1990, fifty-three countries in the world produced 23.2 Mt of chinaclay whereas in 1995 the number of kaolin producing countries came down to 32 with 24.5 Mt of production. The main producing countries of kaolin in the world are U.S.A., U.K., Germany, Czech Republic, China, Ukraine, Brazil, France, Spain, Australia, Indonesia, Thailand and Malaysia. In India, Rajasthan is the leading producing state followed by West Bengal, Kerala, etc.

The export market for chinaclay is in three forms viz. crude, refined and finished products. India's total export of kaolin during 1994 was 8658 tonnes which was 6% less than the previous year. In the year 1991, there were thirty-one exporting countries in the world which decreased to eleven during 1995. The main exporting countries were USA, United Kingdom, Brazil, Hong Kong, Czech Republic and France. In 1991, world export totalled 8.68 million tonnes which had a fluctuating trend and in 1995 this figure was 7.49 million tonnes.

There is a continuous rising trend in the world's import of kaolin from 1991 to 1993. This rising trend was discontinued subsequently, and a fall of 60% was noticed in the year 1995. The major importing countries are Taiwan followed by Germany, Hong Kong, Canada, Norway and Turkey.

The total world's import was 8.77 million tonnes in 1991 which rose to 10.10 million tonnes in 1993. The total imports were 9.7 million tonnes in 1994 which steeply declined to 3.77 million tonnes in 1995.

In India, chinaclay is mainly consumed in cement industry followed by ceramic, insecticide, refractory, paper, paint, cosmetic and rubber. The consumption in the refractory industry in the year 1985 was 33 thousand tonnes which had fallen down to 27 thousand tonnes in 1995-96. Whereas the consumption of kaolin in the paper industry had increased to 20 thousand tonnes in 1994-95 from 15 thousand tonnes recorded in the previous year. In the year 1995-96, the consumption of kaolin in paper industry was 16 thousand tonnes.

The price of kaolin depends upon its grade. The price of beneficiated kaolin during 1995 was in the range of $ 96 to 116 per tonne in United States of America.

Considering the resources, India can enhance the production of kaolin and could attempt the export of kaolin to neighbouring countries in near future by improving the quality as per customers' requirement.

2. Geology

2.1 General Geology

Generally, clays are found associated with almost all rock formations of all ages and are also being formed today. Clay is a colloidal substance formed by the process of weathering or by the action of solutions of igneous rocks. In either case, the alteration product is residual in character and is termed as 'residual clay'. The residual clays when exposed or sometimes removed and are redeposited elsewhere by a transporting agent like water, are described as 'transported clays'. These deposits are found in still water, running water, glacial deposits of boulder clays and wind deposits[1].

According to the American Society of Test Materials (ASTM), clay is an earthy mineral consisting essentially of hydrated silicates and alumina. It is plastic in nature when sufficiently fine grained, rigid when dry and vitrifying when fired to a high temperature. The different minerals of the clay are identified by chemical analysis or with petrological microscope and more precisely by X-Ray, Differential Thermal Analysis (DTA) and by Electron Microscope Studies. The methods like base-exchange, dye-absorption, infra-red absorption, staining properties, etc. have also been applied for the study of clay minerals.

The recent investigations have revealed that large workable deposits of kaolin of varying degrees of purity occur in Archaean rocks of Bihar, Karnataka, Kerala, Rajasthan, etc. The deposits of Rajmahal belts of Colgong (Pattarghatta), Bihar. of Orissa and West Bengal are also of much interest both as quality-wise and quantity-wise for the manufacture of porcelain. Similar deposits of a more restricted scale are found in Singhbhum district of Bihar state and the contemporaneous beds of other parts of the country.

The general geological succession of type areas along with the mineralogy, classification and origin are discussed in this chapter. Geologically, the area of Singhbhum district of Bihar falls under the Archaean Group of formation where these clays have been derived. The stratigraphic succession which lie towards the south-eastern part of Singhbhum district is as follows[2].

Stratigraphic Succession of Singhbhum (After Dunn)

Age	
	Kolihan series
	———Unconformity———
	Newer Dolerite
Archaean	Singhbhum Granite
	Arkasani Granophyre
	Chhota Nagpur Gneiss
	Dalma - Dhanjori Lava
	Dhanjori Sandstone
	———Unconformity———
	Iron Ore Series

The rocks of the Chhota Nagpur granite gneiss, Singhbhum granite, Arkasani soda granite & granophyre and the Newer dolerite are the instrusives into the Iron Ore series. The granitic rocks of South Singhbhum has given rise to K-clay belt which lies between Katepara-Karanjia and Raikaman-Putkarshai areas. This belt and the surrounding areas represent the undulating plains which have been formed by weathering of Singhbhum granite through geological ages. The granites has been intruded by a number of quartz veins and dolerite dykes. It is seen that the degree of weathering and alteration is intense near the western end of the belt, where the younger dolerite bodies are decomposed. Evidently, kaolin has been contributed considerably by the pegmatites and feldspars. The Singhbhum clay belt[3] consists of Katipara-Karinjia area on the west, Bhonda area in the middle and Raikaman-Putkarsahi area on the east. These areas extend to a length of about 22 km and found in stray pockets below the surface. Though the extent of quality and quantity vary from quarry to quarry, it is usually found up to a depth of 24 m.

The chinaclay is found associated with the rocks of various ages ranging from the Archaean to the Tertiary rocks in the Birbhum district of West Bengal[4]. The clay horizon in this district is overlain by coarse yellowish feldspathic sandstone, gritty ferruginous sandstone and finally lateritic cappings. The generalised geological succession of Birbhum district, West Bengal and properties of different clay minerals are given in Tables 2.1 and 2.2. respectively.

Table - 2.1 : Geological Succession of Birbhum District, West Bengal

Age	Formation	Lithology
Recent	-	Soil/Alluvium
Tertiary	Unclassified surfacial deposits	Lateritic soil gravel with petrified and associated chinaclay
	Unconformity	
	Rajmahal	Flow basalts with intertrappeans sedimentary beds
	Unconformity	
Upper Gondwana	Dubrajpur	Conglomerates, coarse and medium grained sandstone, siltstone, shale and its coal streaks
	Unconformity	
Lower Gondwana	Barakar	Fine to medium grained sandstone, carbonaceous shale, fine clay, grey, shale and coal seams
	Talchir	Greenish sandstone, siltstone, mottled clay and conglomerate
	Unconformity	
Archaean	Metamorphics	Granites, pegmatites and dykes

Table - 2.2 : Properties of Different Clay Minerals

Sl. No.	Group	Name of the mineral	Chemical composition	Physical properties	Optical properties α	β	γ	2V	Optic size	Origin	Remarks
1.	Kaolinite $(OH)_8Al_4$ Si_4O_{10}	Kaolinite	Al_2O_3 SiO_2 $2H_2O$	Monoclinic	1.563	1.569	1.570	24-50	(-) ve	W/H	
		Nacrite	Al_2 $Si_2O_5(OH)_4$	-	1.560	1.563	1.566	40-90	(+) or (-) ve	H	
		Dickite	Al_2 $Si_2O_5(OH)_4$	-	1.577	1.563	1.566	52-80	(+) ve	H	
2.	Montmorillonite $(OH)_4$ Al_4 $Si_8O_{10}XH_2O$	Montmorillonite	$(Mgca)OAl_2O_3$ $5SiO_2$ nH_2O	Orthorhombic	1.505	-	1.530	-	-	W	Insoluble in HCl
		Beidellite	Al_2O_3 $3SiO_2$ nH_2O	-	1.530	-	1.540	-	-	H	
		Nontronite	Si_7 $Al(Fe)_4$ O_{20} $(OH)_4$	-	1.575	-	1.610	-	-	H	
		Saponite	Mg_{18} Si_{22} Al_2O_{60} $(OH)_2$ Na_2	-	-	-	-	-	-	H	
		Heclorite	Li_2 Mg_{10} Si_{24} $O_{60}(OH)_{12}$ Na_2	-	-	-	-	-	-	H	
3.	Illite	Illite	K_2 $(AlFe\ Mg)Si_2$ A(.) O, OH	-	1.535	-	1.567	-	-	W	
4.	Halloysite	Halloysite	Al_2 $Si_2O_5(OH)_4$ $2H_2O$	-	1.561	-	1.549	-	-	W	Decomposed by H_2SO_4
		Anauxite	Al_2 Si_2O_5 $(OH)_4$	-	-	-	-	-	-	W	
5.	Allophane	Allophanite	Al_2O_3 SiO_2 nH_2O	Amorphous	1.496	-	1.470	-	-	W	Soluble in HCl
6.	Pyrophyllite	Pyrophyllite	Al_2O_3 $4SiO_2$ nH_2O	Crystalline	-	-	-	-	-	-	
7.	Leverrienite	Leverrienite	Al_2O_3 2 SiO_2 nH_2O	Monoclinic	-	-	-	-	-	-	Insoluble in HCl

W = Weathering, *H = Hydrothermal*

2.2 Mineralogy

The principal clay mineral group[5] namely kaolinite, montamorillonite, illite and sedimentary chlorites along with their mineral composition, physical and optical properties are presented in Table 2.3. The clay minerals are flaky, lathe, fibre like or hollow-tube shaped.

The minerals beidellite and allophanite are not usually present in clays. These are more closely related to the white micas and appear as decomposition products. A colloidal form of beidellite also probably exists. The property of plasticity depends on the presence of colloids. Neither the residual clays nor the pure mineral kaolinite is plastic.

In the early work on clay minerals, the name allophane was associated with amorphous constituents of clay. Studies however showed that only some of it was actually crystalline, but much of it was amorphous to X-Ray Diffraction. The term allophane can be used for all such amorphous clay mineral materials regardless of their composition.

(i) Kaolinite Group : Perhaps the best known clay minerals are those of the kaolinite group. Three distinct mineral species are represented by this group. They are kaolinite, nacrite and dickite. Anauxite has also been defined as a mineral with essentially the same attributes as kaolinite but with a higher silica-alumina molecular ratio. Early investigators believed anauxite as an inter-layer mixture of a double silica layer and a two layer sheet structure. X-Ray studies reveal that the material called anauxite is simply a mixture of kaolinite and quartz. Kaolinite group of minerals have the general formula Al_2O_3 $2SiO_2$ $2\ H_2O$ or $(OH)_8$ Al_4 Si_4O_{10}. Kaolinite is more stable than the minerals of the montmorillonite group. The kaolin group of minerals differ little in composition but have different crystal lattices with montmorillonite group.

Minerals occurring in kaolin are typically very fine grained (less than 4 microns) and therefore, it is difficult to separate them physically and study. Chemical analyses, study of optical properties and reactions due to heating for a long time were the principal methods of study for identification of minerals and now it is the X-Ray Diffraction (XRD) method. Three minerals have been identified by XRD in the kaolin group namely kaolinite, dickite and nacrite. The halloysite is a hydrated analogue of the kaolin group. The minerals dickite and nacrite are not as common as kaolinite.

(ii) Halloysite Group : Materials of the halloysite group are somewhat chemically similar to kaolinite, but have different structural attributes. There are two forms of the mineral halloysite. One form has the same chemical composition as kaolinite and the other is more hydrous with $4H_2O$ instead of $2\ H_2O$ in its composition. Unfortunately, there is no agreement among clay mineralogists regarding proper nomenclature for the halloysite minerals. Thus, the more hydrated form has been called endellite by some investigators and simply halloysite by others. The lower hydration form has been called metahalloysite by some and halloysite by others. It has been suggested that halloysite be used as a general term for all naturally occurring specimens of the mineral regardless of their state of hydration. When it is possible and necessary to describe the state of hydration, additional self explanatory qualifications should be used. The halloysite has the general formula Al_2O_3 $2SiO_2$ $4H_2O$ or $(OH)_{16}$ $Al_4Si_4O_6$. It loses water at 50°C. It was considered previously that it would alter to kaolinite at this temperature. This transformed product has now been recognised as meta-halloysite and the reaction is not reversible.

(iii) Montmorillonite Group : Montmorillonite has the characteristic of an expanding lattice structure, i.e. the property of adsorbing variable amounts of water between individual unit layers. Members of this group show considerable variation in the ratio of SiO_2 to R_2O_3. There can also be a replacement of aluminium by iron and magnesium. The iron rich montmorillonite is called nontronite and the magnesium rich variety is known as saponite. Montmorillonite group of minerals have general formula $(OH)_4$ Al_4 Si_8 O_{20} XH_{20}. Beidellite is often placed in this group.

(iv) Vermiculite Group : Vermiculites also has an expanding lattice structure. It differs from montmorillonite in only a limited degree of expansion and its particle size. Once, vermiculites were thought to be closely related to micas, but now they are recognised as clay mineral constituents.

(v) Illite Group : The term illite refers to any mica type clay mineral which shows no expanding structural characteristics. Illites include both trioctahedral and dioctahedral types of clay mineral micas. The illite group of minerals are very similar to the white micas except in containing less potash and more water. The general formula for illites is $(OH)_4 K_y (Al_4 Fe_4 Mg_4 Mg_6) Si_{8-y} Al_y O_{20}$ (the value of 'y' varies from 1 - 1.5). Most illites contain an excess of iron or magnesium and the aluminium is replaced by iron or magnesium. The mineral glauconite is considered to be very similar to illite.

(vi) Chlorite Group : The chlorites is a group of green hydrous silicates which contain ferrous iron and are closely related to micas. Structurally, they are regular interstratifications of single biotite mica layers and brucite layers, but they have been recognised as important constituents of clay materials. The identification of chlorite is particularly difficult when kaolinite is present in the same clay material.

In addition to the principal groups listed above, there are some clay minerals of less common occurrences and somewhat different in crystal structure. These include halloysite together with less hydrated metahalloysite and allophane. In some clays, vermiculite and palygorskites (sepiolite and attapulgite) are noticed but none of these minor clay minerals are to be found in shales or related rocks. The minerals para-montmorillonite and parasepiolite are considered to be the forms of montmorillonite and sepiolite, while leverrienite is considered to be a mixture of kaolinite and smectite or a mixture of nontronite and kaolinite. Whereas the exact nature of some minerals such as monothermite, kerffekillite, gedroizite, bravaisite, abbrusite, ablykite, doubassite, etc. are yet to be known.

(vii) Chain Structure Types : Attapulgite, sepiolite and palygorskite are clay minerals with chain structures similar to hornblende. These minerals are not yet completely understood. They can easily be missed in clay mineral analyses and may be much more abundant than is considered to be.

(viii) Mixed-Layer Combinations : Many clays are composed of more than one clay mineral. These clay mineral components are often random mixtures of discrete units so that there is no preferred geometric orientation. In another type of mixing, the layer type clay minerals are interstratified. This is because of their structural similarity. There are two different types of such mixed layer structures. In one type there is a regular repetition of layers which are stacked along the 'C' axis. The other type of mixed layer structure is a random, irregular interstratification of layers without any uniform repetition of layers. Mixed layers of illite, montmorillonite, chlorite and vermiculite are particularly common in clay materials and can only be detected by careful X-Ray Diffraction techniques. All the clay minerals except the palygorskites belong to monoclinic system with a pronounced basal cleavage.

2.2.1 Properties

The varied properties of clay minerals are important because they govern the economic use of clay materials[6].

(a) Ion Exchange : The ability of clay minerals to hold certain cations and anions which are readily exchangeable for other cations and anions is most significant. The commonest exchangeable cations in clay materials are Ca^{2+}, Mg^{2+}, H^+, K^+, NH^{4+} and Na^+. The more common exchangeable anions are SO^{2-}, Cl^-, PO^{3-} and NO_3.

There are two major causes for the exchange capacity of the clay minerals. Broken bonds around the edges of silica-alumina units give rise to unsatisfied charges which are balanced by absorbed cations and substitutions within the structure result in unbalanced charges satisfied by exchangeable cations. In addition, some anions may be absorbed by replacement of exposed hydroxyl ions and because of the structural bondage of some of them with tetrahedral units.

(b) Clay-Water System : Another important property of clay materials is their ability to hold water. This water is of two types, low temperature water and OH structural water. The low temperature water trapped in pores, on the surfaces and around the edges of the minerals composing the material is driven off by heating to 100-150°C. It is also the inter layer water between the unit cell layers of minerals such as montmorillonite. The water which occupies the tubular openings between the elongate structural units of the sepiolite-attapulgite-polygorskite minerals is also of this type.

Abundant evidence shows that there is some sort of definite configuration of the water molecules initially adsorbed on the surfaces of clay materials. However, there is no agreement regarding the precise nature of the structure of this initially adsorbed water. The configuration of this low-temperature water and the factors controlling it largely determine the plasticity, bonding, suspension, compaction and other properties of clay materials, which in turn govern the economic usage.

(c) Dehydration : When clay materials are heated, dehydration occurs. Thus, there is a loss of any water (adsorbed, interlayer, or structural OH water) held by the clay minerals. The heating of clay materials also causes changes in the clay mineral structures. At relatively high temperatures these structural changes facilitate the formation of new mineral phases. These structural modifications are particularly important in the firing of clay materials.

(d) Clay Mineral Organic Reactions : Another property of the clay minerals is their ability to react with organic materials. Clays with a high adsorbing capacity are used in decolourising oils, while others are used as catalysts in the cracking of organic compounds.

Some techniques for the analysis of clay materials are based on clay mineral organic reactions. For example, the identification of montomorillonite by X-Ray Diffraction is greatly simplified by treating the material with glycerol or ethylene glycol which substitutes for water in the inter-layer position and causes measurable expansion of the lattice along the 'C' axis. Some organic materials are also used in the identification of clay minerals by staining techniques.

(e) Optical Properties : The optical properties of clay minerals are usually difficult to determine because of their extremely small size, and their inherent variations. Replacements within the structure and variations in the amount of inter-layer water are reflected by changes in the optical properties. .

2.2.2 Identification

The different clays namely kaolin, ballclay, fireclay, flint, cornstone and diaspore clay can be distinguished by their colour, degree of plasticity and grain size. Colour of the mineral is attributed due to the presense of impurities. Kaolin is white coloured and white burning with low plasticity, and is characterised by high degree of colloidal suspension. Ball clays are dark-grey or black in colour and occur in the form of balls. They are highly plastic and refractory upto 1100°C. The fireclays have very low iron and alkali contents and can withstand high temperatures upto 1450°C whereas the lithomargic clays which are formed beneath the lateritic formations have poor suspensibility in water.

2.3 Classification

There is no complete satisfactory classification of the clay minerals available as yet. Classification is difficult because the clays often are of complex mixtures of minerals of such poor crystallinity that individual components can not be adequately characterised. Also there seems to be a continuous gradation between some of the types.

The following are the classifications based on crystal structure utility and origin. A major sub-division into amorphous and crystalline groups is made even though the amorphous components are relatively rare and of little importance[6]

2.3.1 Classification Based on Crystal Structure

I. Amorphous - Allophane group

II. Crystalline

A. Two-layer type (sheet structures composed of units of one layer of silica tetrahedrons and one layer of alumina octahedrons)

1. Equidimensional Kaolinite group : Kaolinite, nacrite, dickite etc.

2. Elongate Halloysite group

B. Three-layer type (sheet structures composed of two layers of silica tetrahedrons and one central dioctohedral or trioctahedral layer)

1. Expanding structure :

   a) Equidimensional Montmorillonite group : Montmorillonite glauconite and vermiculite, etc.

   b) Elongate Montmorillonite group : Nontronite, saponite, hectorite

2. Non-expanding structure :
   Illite group

C. Regular mixed layer type
(ordered stacking of alternate structural type)
Chlorite group

D. Chain-Structure type (similar to hornblende chains of silica tetrahedrons linked together by octahedral groups of oxygens and hydroxyls containing Al and Mg atoms) : Attapulgite, sepiolite, palygorskite

The three-layer minerals are divided into the expanding and non-expanding types in this classification. Though this sub-division is made there may be a continuous gradation between the two types. The expanding attribute is a readily determinable diagnostic property, since it imparts some unique physical properties to the clay materials composed of these minerals. The expanding minerals are divided into equidimensional and elongate divisions, because shape is readily recognizable characteristics that probably reflects structural attributes. Clay is also classified in terms of particle size. On the Wentworth scale, clay is reckoned to be 4 microns[7].

2.3.2 Classification Based on Utility

Clay is classified on the basis of its utility, whether it is refractory or non refractory.

(i) Fireclay : It is a refractory sedimentary clay with a low alkali content. It is usually associated with coal measures. The term is extended to include refractory kaolin having different modes of origin and containing such minerals as kaolinite, hydromica, dickite and halloysite in varying proportions.

(ii) Diaspore Clay : Diaspore clay is a rock consisting essentially of diaspore bonded by fireclay. Refractory clays are those which have a fusion point above 1605°C. These are normally poor in fluxes (less than 5%), the SiO_2 content ranges from 43 to 55% while the Al_2O_3 content is 30 to 40%. Kaolinitic clays containing 46% SiO_2 and 39.50% Al_2O_3 are also used as refractory, provided the fluxes are low. An increase of silica in such clays lowers the temperature of fusion, while an increase in alumina does not affect the fusion temperature, as in diaspore clays where the basic flux content may be about five per cent. In general, fireclays are of two types (a) plastic and (b) non-plastic. The plastic fireclays resemble ball clays and may be siliceous, kaolinitic or aluminous[8].

(iii) Kaolin Clay : Kaolin was originally used to signify a clay consisting essentially of the mineral kaolinite, which includes various other types, such as chinaclay and chinaclay rock as well as certain types of sedimentary clays. In chemical composition, kaolin differs rather widely, especially in regard to the silica and alumina contents. The term chinaclay is commonly used to designate materials having apparently characteristics similar to kaolin, but it is generally used to signify the washed and purified material derived from chinaclay rock.

(iv) Chinaclay Rock : Chinaclay rock is a completely kaolinised granite. It is white, light grey or cream coloured, easily broken and crushed between the fingers. This yields chinaclay on crushing and washing.

(v) Ballclays : Ballclays are white or light cream coloured with high plasticity. Its name has been derived from the shape of the marked product. These occur in the form of large lumps or balls. The material is often in dark grey or black in colour and is associated with peat bogs or swamps. Usually the clay is poor in alumina, rather siliceous, with low iron and alkali content. These clays possess a high binding power and tensile strength. Ballclays vitrify between cones six and eight and form dense impervious bodies, showing considerable shrinkage. Ballclays are similar to kaolin in mineral composition, but are slightly richer in silica and iron content. Commonly ball clays are of sedimentary origin with extremely fine-grained and carbonaceous. Most ballclays require 40-65% water of plasticity, and the dry strength will be of the order of 70.3 Kg/sq.cm. On firing, ballclays yield a vitreous mass at a lower temperature than kaolins.

(vi) Flint : Flint is a compact refractory of stone. The clays are non-plastic, but fine grinding increases the plasticity. Bond fireclays is a material having sufficient natural plasticity to bond non-plastic material. They generally have a long vitrification range. They usually burn to a colour darker than normal fire-clays, and sometimes have a comparatively higher silica content.

(vii) Cornish Stone : Cornish stone is kaolinised granite, hard and more compact than chinaclay rock. The term is sometimes used to signify a rock that is directly used in ceramic industries, but in general, cornish stone consists of feldspathic minerals and quartz together with other accessory minerals. This material forms a white flint when heated to a sufficiently high temperature. Certain types of clays carry names designating their use, such as clip clay, pottery clay, retort clay, earthernware clay, terra cotta, pipe clay, bleaching clay, bonding clay, foundary clay, sagger and rubber clays.

(viii) Pottery Clays : Pottery clays have the properties of high plasticity, free from grit and low iron content. It vitrifies at 1205°C. It is capable of being heated or dried without the addition of grit, and it is also free from carbonates, sulphates, etc. which may cause blisters.

(ix) Other Varieties : Bentonites are clays in which the mineral montmorillonite is predominant. Since the properties of the mineral vary greatly with the nature of the exchangeable base, bentonites are of various types. The main types are (a) swelling and (b) non-swelling. With addition of water, the swelling types increase in volume from 1 to 15 times. Sodium being predominant, these are characterised by high alkali content. In the non-swelling type, the main exchange base is calcium, which is replaceable by sodium. This exchange of bases transforms the non-swelling bentonite to a swelling type. The non-swelling bentonites, after digestion with acids, can be used for purifying petroleum oils, vegetable oils, etc.

2.3.3 Classification Based on Origin

The logical classification of clay materials from the geologic viewpoint is based on their origin. In such a classification there are three major sub-divisions. Residual clays remain after the solution of argillaceous limestone, or are formed by chemical decomposition. Alteration clays or bentonites are produced by the weathering and devitrification of volcanic tuff or ash[9]. Transported clays include those laid down in stream courses, lakes, swamps, lagoons, deltas and seas. Most transported clay and shale are of mixed origin, having first formed as residiuum, or as bentonite, before removal and deposition as sediment. Clay materials deposited by wind (some loess) and by glacial ice (boulder clay) are not of much commercial importance. Clays are broadly classified into In situ, Residual and Transported clays.

(i) In Situ Kaolin Deposits : In situ type of deposits are found at or near the host rock and are generally deep seated. Rocks rich in feldspar content undergo decomposition by the action of circulating acidic solution. These solutions attack potash, soda lime, magnesia and iron. The compounds formed due to the action of acids on the above are removed and deposited elsewhere leaving behind the in situ or residual kaolin mixed with quartz. If the water circulation is poor and solutions becomes saturated, most of the bases will be redeposited, either as a silicates or salt or both. The in situ or residual kaolin are usually coarse grained with less plasticity. The deposits are derived from igneous and sedimentary rocks. Feldspar bearing sandstones are the main source among the sedimentary rocks.

(ii) Residual Clays : The residual kaolin deposits occur away from the source of formation. These are transported from their source of origin by agencies such as wind, water, and ice and finally deposited in basins, lakes or places of depressions. During the process of transportation, other constituent minerals also get transported and finally deposited with them. Because of this reason the transported kaolins are less pure as compared to in situ kaolin. During this process sorting is maintained. The finer sediments are deposited separately as compared to coarser size sediments. Depending on the intensity of transporting agency, layers of clays and sandstones are formed.

Most residual clays are formed either (i) from the solution of argillaceous limestone or dolomite leaving the clay behind as a residue, or (ii) from the decomposition of feldspar-rich, such as granite and pegmatite. Clay formed due to (i) is a common material in humid regions underlain by carbonate rocks.

This type of clay is not used commercially, because it is likely to contain undesirable materials such as ferric oxide, sand and chert. It usually rests on an irregular rock floor, characterised by dumps, chimneys and deep solution pits and is therefore difficult to extract. The various types of transported clays are as follows :

A. Transported Clays : Surficial

Clays of commercial interest that do not form a part of the bedrock succession are mostly of stream and glacial lake origin. Although many deposits are worked in all parts of the country, surficial clays do not form bulk in size. Since they are practically common or of miscellaneous variety, being utilised for structural clays, their production value is also relatively low. These clays contain admixed sand, organic matter and other non-clay materials. These are not necessarily deleterious, as they reduce shrinkage and lower the firing point. Although a strong downward increase in the proportion of sand marks the cut-off limit of exploitation, deleterious substances may include coarse limestone particles, and various soluble sulphates.

B. Transported Clays : Swamp

Clays of present day swamps are of negligible, but an enormous tonnage is taken annually from the ancient swamps, chiefly the 'under clays' of Pennsylvanian system in the central and eastern United States. The term 'under clays' means the clay beds lying immediately beneath the coal beds. They are integral parts of the Cyclothems of Pennsylvanian strata, and are much interested in sedimentation and stratigraphy. The commercially important 'under clays' are found chiefly in the lower part of the Pennsylvanian system, in the Pottsville and Allegheny series. A few exceed 4 to 5 m in thickness and most mined clays are in 1 to 3 m range. 'Under clays' are commonly described as 'massive' or 'structureless' and lack lamination. Both plastic and flint clays are commonly coated with a thin films of organic matter. They may be the result of differential movement within the clay after leaching of included organic matter.

C. Transported Clays : Lagoon and Delta

A number of commercial clays were deposited in lagoonal and deltaic environments, of Cretaceous and Tertiary seams under tropical and subtropical climates. The clay beds tend to accumulate either lenticular or subrounded in shape with simultaneous deposition of extremely fine clays and coarse sands. Plant remains, generally as fragments or lenses of lignite, are commonly found. The lagoon and delta clays of Georgia, South Carolina, kaolin lenses in the Tuscaloosa formation (Upper Cretaceous) are the well known examples of this type.

D. Transported Clays : Marine

Commercial clays of marine origin are found in the Atlantic and Gulf Coastal plains. Most of these clays are put to adsorbent uses, as they are either naturally active or readily activated by acid treatment. These clays are derived from volcanic ash. The deposits of Porters Creek, south-eastern Missouri and southern Illinois and across Kentucky, Tennessee and Mississippi are the examples of this type.

2.4 Structure

The atomic structures of the clay minerals[6] show combinations of two basic structural units. One unit consists of silica tetrahedrons, in which each tetrahedron is made up of a silicon atom equidistant from four oxygen atoms or hydroxyl ions arranged in the form of a tetrahedron with the silicon atom at the centre. The silica tetrahedral groups are arranged to form a hexagonal network, which is repeated in two directions to form a sheet, with the composition $Si_4O_6(OH)_4$. The tips of all tetrahedrons point to the same direction and their bases are all in the same plane. The composite structure of this unit may be viewed as a perforated basal plane of oxygen atoms, a plane of silicon atoms forming a hexagonal network, and a plane of hydroxyl atoms with each hydroxyl positioned at the tip of the tetrahedron, directly above the silicon. The other structural unit consists of two sheets of closely packed oxygen atoms or hydroxyl ions in which aluminium, iron, or magnesium atoms are octahedrally coordinated. When aluminium is present, only two-thirds of all the possible positions are filled to balance the structure. This is the dioctahedral gibbsite structure and has the formula $Al_2(OH)_6$. If all the positions are filled, when magnesium is present, the trioctahedral brucite structure is formed with the formula $Mg_3(OH)_6$. Because of the sheet like nature of their structural units, most of the clay minerals are flake shaped. Some of the flakes have a distinct hexagonal outline. A few of the clay minerals are tubular or elongate, or both. Some are fibrous and are composed of structural units different from those listed above. The sepiolite, palygorskite and attapulgite minerals have structural characteristics similar to the amphiboles.

The clay minerals belong to phyllosilicates. They have a sheet structure, somewhat like that of micas. They consist essentially of two types of layers. One is a silica tetrahedral layer consisting of SiO_4 groups linked together to form an hexagonal network of the composition SiO_4 repeated indefinitely. The other type of layer is the alumina or aluminium hydroxide unit, which consists of two sheets of close packed oxygens or hydroxyls between which octahedrally coordinated aluminium atoms are embedded in such a position that they are equidistant from six oxygens or hydroxyls. Actually only two-thirds of the possible aluminium positions are occupied in this layer, which is the gibbsite structure. The mineral brucite has such a structure except that all possible aluminium positions are occupied.

The clay minerals belong to two contrasting groups. In kaolinite group, the mineral is characterised by a two layer lattice consisting of a gibbsite sheet and a silica tetrahedral sheet. This lattice does not expand with varying water content and no replacements of iron or magnesium in the gibbsite layer are known. The other group of clay minerals is characterised by a three layer lattice. In this type of lattice, there are two layers of tetrahedrally coordinated silica ions between which is sandwitched a gibbsite layer of octahedrally coordiated aluminium ions. Several important clay minerals belong to the three layer group. In montmorillonite there are three layer units loosely held together in the 'C - direction' with water between them. The three layer unit may also be held together by pottasium which owing to favourable ionic radius and coordination capacity builds the structure together so tightly that expansion is impossible. The clay mineral thus formed is illite.

2.5 Origin

Many of the clay minerals have been synthesised in the laboratory under conditions varying from room temperature and atmospheric pressure to elevated temperatures and pressures. From these experiments the environmental conditions favourable for the formation of the individual minerals are known. At low temperatures, acid conditions favour the formation of the kaolinite type of mineral, whereas alkaline conditions favour the formation of montmorillonite, in the presence of magnesium and potassium. At elevated temperatures, such generalities do not always hold good and the formation of minerals depends upon the ionic concentration, temperature and the Al_2O_3/SiO_2 ratio. Many of the clay minerals are of hydrothermal origin. With the possible exceptions of attapulgite, palygorskite and vermiculite have been reported in hydrothermal bodies, frequently with metalliferous ore deposits. Some hydrothermal clay deposits are monomineralic, but mostly consists of a mixture of clay minerals. Kaolinite has been produced[10] experimentally between 200 and 400°C. Kaolinite and montmorillonite occur in the halo of hydrothermal rock alteration that surrounds many sulphide deposits. The mineral sericite is formed in alkaline solutions at 300°C, but kaolin develops in acid solutions in less intense zone.

Clays are also formed due to chemically weathered aluminous rocks. These are carried off and deposited as ordinary argillaceous sediments[11]. The residual clays are derived from crystalline rocks, more especially granites and gneisses. Feldspar-rich pegmatites yield dikeless masses of high-grade white kaolin that is generally very low in iron and other impurities deleterious to chinaware manufacture. Syenites also yield excellent clay. Limestone, after long-continued solution erosion, leave a mantle of insoluble clayey impurities that are used for brick clays.

The in situ clays were formed by weathering while the transported clays of marine, lacustrine, flood plain, estuarine, delta, etc. result from a combination of processes. The process of sub-aerial weathering has also been accepted as one of the agencies for the formation of kaolin from felspathic rocks. The amount of decomposition depends on the factors such as climate, structural features, textural features and geological history, etc.

Decomposition of host rocks and deposition of clay may be brought about by hypogene or supergene enrichment processes. In hypogene process of origin, the chemical decomposition is brought about by the action of gaseous, vapours and solutions that orignates below and force their way upwards through rocks of earths crust. Alteration at depth is intense and complete within the sphere of gas and vapour action under high temperature and pressure. This type of alteration produces very irregular isolated masses of kaolin often surrounded by unaltered feldspathic rock. This irregularity has been attributed to the fact that "some portions of the original molten mass were more juicy than others and that in some places the gaseous matter escaped more readily". In this type of origin, it is noted that extent of kaolinisation varies directly with depth.

In supergene process kaolin is formed at or near the surface by the action of acidic water like carbonic and sulphuric acids. Percolating solutions of these acids react with the rocks and converts feldspar contents into kaolin. As soon as mineralised rock is exposed to air, oxidation process begins and sulphuric acid is generated by the action of oxygen on sulphides. The resultant sulphuric acid with surface water converts the sericitised rocks into kaolin mixed with lucite and other oxygen products. In such cases of surface weathering, it is observed that the extent of kaolinisation varies inversely with depth.

The action of water descending from swamps has also been considered as an agency for kaolinisation. This is supported by the association of kaolin deposits with the tertiary coal bearings and peat bogs, etc. Kaolin is produced by the action of water containing CO_2 of post-magmatic origin and is also attributed to post-magmatic emanations, such as gases, vapours and super-heated steam, which are given out at the last stage of a cooling magma. The occurrence of kaolin with metalliferous sulphides has been attributed to the action of sulphuric acid and H_2S. The hydrolysis of feldspathic rocks has also been cited as means of formation of kaolin. With the crystallisation of batholiths, fractures developed in the roof provides easy access to aqua-igneous rich in volatiles which may allow crystallisation of alumina as kaolinite instead of feldspar. Residual deposits of kaolin after leaching of the soluble portion of limestone have also been noted in some areas. Kaolin has also been reported as a replacement deposit after quartzite.

2.5.1 Lateritisation

In temperate climates, the silica of silicate rocks is not extensively removed but remains behind to form clay along with hydrous oxides of iron and residual grains of quartz. Thus, clayey soils are the common products of weathering of such rocks in all temperate climates. The tropical and sub-tropical climates are characterised by alternate wet and dry seasons. Under favourable circumstances, rock decaying is carried out and leaching is more complete. The silicates are more thoroughly decomposed to remove silica in solution. The result is a laterite soil, which is a mixture of hydrous oxides of aluminium and iron with some silica and other impurities. Instead of the hydrous aluminium silicate (clay) of temperate regions, it is hydrous aluminium oxide (bauxite) in other regions. Laterites are high in iron and low in alumina(10). Normally, on weathering, a silicate rock low in iron may leave a residue of good quality clay(11).

2.5.2 Kaolinisation

The process of formation of kaolinite is called kaolinisation. The deposits originated from volcanic ash are transported by wind from the coast and washed into valley and lagoons where it is first weathered into montmorillonite and later into kaolinite. The alteration of feldspar takes place by hydrothermal action of aqueous solution. This process of alteration is known as kaolinisation and can be shown by the following reaction.

$$K_2O\,Al_2O_3\,6SiO_2 + 2H_2O \longrightarrow Al_2O_3\,2SiO_2\,2H_2O + 4SiO_2 + K_2O$$

Feldspar + Water → China clay + Silica + Potash oxide

From the above equation, the silica (SiO_2) and potassium oxide (K_2O) are washed away during the process of weathering, leaving behind chinaclay.

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3. Prospecting, Exploration and Reserves

3.1 Objectives and Methods

The term prospecting in geological parlance is defined as the branch of science which on its application in quest of minerals/ores can lead to identify the location of mineral deposits on surface or underneath the earth's crust. Prospecting does not end with the discovery of a deposit. In practice, prospecting is immediately followed by exploration. The exploration can be defined as a science of prospecting in which sophisticated tools and equipments are used in qualitative assessment of mineral/ore in a prospect earlier identified[1]. It is a fact that prospecting discloses information about ore occurrence and mineralisation depicting the geological picture. Thus simultaneous prospecting and geology are reciprocally beneficial to each other. The general idea about the prospecting area, such as study of a reconnaissance map, obtaining information about roads, temples, etc. is very useful to mark the most promising areas on the map. In prospecting, the recommended procedure is to look for several associated minerals simultaneously and collect specimens to ascertain the geological structure of the planned prospecting area. Such groundwork is inevitable since it gives general idea of the geology and the topography of the area[2].

Before starting on a prospecting expedition, it is important to have all details of the route and a clear plan so that not a single outcrop of bedrock or natural or artificial exposure is missed. A topographic map will be of great help in planning the traverse. Any section on the map with a considerable thickening of the contour lines, which indicates the steepness of a slope, merits special attention[3]. The major objectives of exploration of minerals/ores today are :

1. To recognise and locate potential ore/mineral bodies or areas favourable for ore/mineral localisation.

2. To estimate the quantity and quality of the ore/ mineral in ground.

3. To ascertain the broad economic workability of the deposit and its industrial use.

It, therefore, assures a steady supply of mineral raw material to the established industries and promotes industrial growth by setting up mineral based industries.

3.2 Stages of Prospecting

The general practice for prospecting is to sink a few trial pits based on the information collected by the exploration agencies like Geological Survey of India, State Directorates of Mines & Minerals, etc. In some cases, pits are excavated based on observations made of river/nallah cutting or nearby wells. In the cases, where clays of workable grade with sufficient width are encountered, pits are made to exploit the clay deposits. Predominantly, deposits are found at shallow depths, and are worked by conventional opencast methods involving manual mining. The overburden and clay are soft, the scale of operations are being of lower order, where simple working tools are used for excavation[4].

The lessee usually concentrates on a single pocket for exploitation and have little knowledge about the actual content and depth of the deposit. Mining operation cease only after the pocket is completely exhausted. This approach of unsystematic mining is uneconomical for mining at greater depths.

Prospecting of chinaclay deposits are similar to bauxite prospecting because both are residual weathering products. In selecting large areas for initial prospecting of chinaclay, it is better to confine attention to areas which have a known history of residual weathering and contain acidic rocks like granite and pegmatites. In aerial photographs, clay and clayey soil give a very dark tone because of high moisture supported generally by good growth of vegetation. Swamps, marshy lands, water-filled depressions, etc. may also indicate the presence of chinaclay. Rapid reconnaissance with random pits and auger drilling help to locate specific targets for detailed search. Chinaclay deposits usually occur near the surface. Therefore, the methods of exploration practised are mapping, pitting, drilling, etc. Since clay is a soft material, conventional wet core drilling may not be suitable. Dry drilling, auger drilling or pitting are usually adopted[6].

The prospecting for chinaclay deposits require the following stages to be followed for better results.

(i) Prepare geological maps of the area on suitable scales to study the geological background of the area.

(ii) Survey and prospect the clay bearing areas by pitting and sinking boreholes by hand-augers.

(iii) Collect samples of chinaclay from the trial pits and study their physical properties. Also conduct field test to establish the recovery percentages of the chinaclay.

(iv) Despatch bulk samples of chinaclay to various chemical laboratories to conduct suitability tests for their applications in various industries, particularly in ceramic industry[7].

The first step in the process of systematic prospecting for clay is to prepare a geological map on a suitable topographic plan on a sufficiently large scale, say 1:1000 or 1:2000, depending on the size of the leasehold. The map should show all physiographic features such as high ground, flat and low lying areas, main drainage channels, all outcrops and structural features together with indications of degree of weathering and/or kaolinisation and all abandoned and existing pits and quarries. It may be possible from an understanding of the local geological and interpretation of data to infer the possible clay bearing areas. The next step is to delineate further the more promising sections of the area so demarcated by systematic boring and/or pitting. Such boreholes and pits should give reliable idea of the quality and grade of clay and enable to draw a bulk sample for chemical and washing tests. For this purpose, the following methods may be adopted. It is desirable to adopt a combination of methods involving both shallow drilling and test pitting to demarcate clay pockets. The clay deposits are demarcated to facilitate the determination of the quality of clay. Where the overburden is soft and has been known to be generally thin (upto 5 m) from the data obtained from pits, quarries and excavations in a developed area, a suitable type of shallow drilling equipment is the hand auger used in soil sampling. This equipment has a capacity of about 6-7 m which means that 1 to 2 m of the clay sample can be obtained when the overburden is about 5 m thick. It should be stated however, that the thickness of overburden has been known to be more than 5m in a number of regions where adoption of this method is likely to lead to misleading result. There are areas, in Singhbhum and Mayurbhanj districts where this equipment can be used with advantage. Even in these areas there may be certain sections where the overburden may exceed 5 m and this method will not be reliable. To overcome this difficulty, it may be necessary to carry out initial drilling programme to a greater depth. For this, hand operated auger drilling is used which is capable of drilling 50 mm diameter holes upto a depth of 30 m. After the location of the sizeable pockets of clay is demarcated by drilling on a grid pattern at 30 m intervals, it is necessary to put down pit again on a grid pattern and at suitable intervals to obtain necessary data in respect of lithology, percentage of different types of clay, colour, mineralogical composition, etc. and wherever possible the recovery after washing and the colour of the washed product. These data should be recorded for every pits and indicated on the geological map. The pit records should also show variations, if any, in the quality and colour of the clay with depth. The interval between the pits may be varied to suit local conditions, proving operations can be carried by pitting or borehole drilling directly on a grid pattern at intervals of 30 m[5].

3.2.1 Prospecting in Czechoslovakia

All prospecting and exploration works carried out earlier in that area indicate that kaolinisation has an aerial development on an ancient surface of feldspathic rocks, and that it decreases downwards at a different rate at different localities. In locating geophysical (resistivity & seismic) and boring profiles it is necessary to observe the direction of morphological depressions that can be of tectonic origin, particularly those extending beneath the residual cover, and the directions of the greatest variability in the chemistry of the parent rock. In positive boreholes, only chip samples are taken for geochemical analysis. Basic sampling is made in segments. Those which should be examined as one sample are determined according to macroscopic appearance (colour, structure). A large homo-geneous kaolin core is divided into 1 m long segments. In Karlovy - vary district rotary, boring with hard-metal bits and bentonite mud is used. The final core diameter is minimum of 137 mm and the core recovery amounts to 80-90% in kaolin. The bentonite coating has to be removed from the core surface before further treatment. The deposit must be bored down to a kaolinised parent rock with less than 10% of washed kaolin. In Plzen district, a spiral boring rig with 100 cm diameter is employed and in Znojmo area a rig with double core barrel is used for wet drilling. On the basis of geological map, geophysical measurement and reconnaissance boring, the inferred reserves can be calculated. Particularly, promising reconnaissance boreholes (relating to thickness and quality of kaolin) have to be verified by two additional boreholes spaced 5 to 15 m from the primary holes. It is very often found that only a kaolinised fault zone of a small width was encountered. Every subsequent borehole is located according to the results of the preceding boreholes[9].

3.3 Statewise/Districtwise Prospecting and Exploration Work Done - 1990 to 2000 (Ref. IMYB)

3.3.1 Chinaclay Prospecting in Assam

From the year 1990 to 1992, DGM, Assam carried out exploration work as below.

In 1990, DGM, Assam carried out exploration in Silanijan area of Karbi Anglong district by mapping 25 sq. km. and drilling 210 m in ten boreholes. Clay beds of varying thickness were encountered in almost all the boreholes, maximum being 3.5 metres. In Deopani area of Karbi-Anglong district, detailed mapping covering 0.5 sq. km. was carried out and kaolin beds of 1.5 to 8.5 m thickness were delineated over 0.18 sq. km. area by drilling 200 m in 18 boreholes.

In the year 1991, DGM, Assam carried out exploration in Silanijan area of Karbi-Anglong district by detailed mapping of about 2 sq. km, digging 13 pits and drilling 157 m in 8 boreholes. In Deopani area of Karbi-Anglong district, DGM also carried out investigation by detailed mapping of 1.1 sq. km., digging a pit and drilling 232 m in 15 boreholes.

In 1992, DGM, Assam carried out exploration in Silanijan areas of Karbi-Anglong district by detailed mapping about 5.5 sq. km., digging 70 pit, drilling 302 m in 20 boreholes and drawing 100 samples. In Deopani area of Karbi-Anglong district, DGM also carried out investigations by detailed mapping over an area of 0.23 sq. km., digging 5 pit, drilling 105 m in 7 boreholes and drawing 40 samples[10].

3.3.2 Chinaclay Prospecting in Andhra Pradesh

In the year 1998-99, DGM, Andhra Pradesh has taken up mapping for delineation of white clay deposit in Adilabad district and also to identfy clay deposits in Adilabad district[10].

3.3.3 Chinaclay Prospecting in Bihar

In 1992, DGM, Bihar carried out exploration in Harnak-Mahonatara area in Hazaribagh district by mapping about 80 sq. km., drawing 38 samples and drilling 137 m. In the same area DGM, Bihar in the year 1993 carried out mapping about 80 sq.km drawing 44 samples and drilling 102 m[10].

3.3.4 Chinaclay Prospecting in Gujarat

In 1990, DGM, Gujarat carried out preliminary survey to locate white clay around Valia and Kajan river valley in Bharuch district. In the year 1993, DGM, Gujarat, carried out reconnaissance survey by mapping over an area of 116 sq. km. in Bhachau Roper taluk of Kachchh district and detailed mineral survey by mapping over an area of 99 sq. km. in Mangaral and Ganderi areas of Surat and Valsad districts[10].

3.3.5 Chinaclay Prospecting in Haryana

In 1993, DMG, Haryana carried out preliminary survey by mapping over an area of 843 sq. km. in Shivalik Hills of Ambala district[10].

3.3.6 Chinaclay Prospecting in Karnataka

In 1995 & 1996, the Mysore Minerals Ltd. carried out exploration to ascertain lateral depth extension of clay deposits in Devangi area in the Company's Thirthahalli Clay Mines in Shimoga district. Trial pits were dug and 22 samples collected. In the year 2000, DMG, Karnataka has carried out investigations for clay around Majjur village, Shirahatti Taluk, Dharwar district. An area of 110 hectares was covered on a scale of 1:1000[10].

3.3.7 Chinaclay Prospecting in Kerala

In the year 1991, DGM, Kerala carried out exploration in Taliparamba area of Cannanore district by putting 103 augur drill holes. It also carried out exploration for Kerala Clays & Ceramic Products Ltd. in Pudukai-Kasargod area by mapping over 0.75 sq. km. and drilling 328 m in 15 boreholes. In the year 1995, DGM, Kerala carried out investigations on workable kaolinitic clay deposits in Mangalapuram and Melthonnakkal in Tiruvananthapuram district. In the year 1996 Geological Survey of India carried out detailed exploration in Thiruvananthapuram and Kasargod areas to demarcate the potential area. The resource potential of all types of clays was likely to be of the order of several million tonnes. There is also a possibility of getting coating grade kaolin for paper industry. In 1997, Geological Survey of India also continued preliminary appraisal of clay deposits in Kollam and Kasargod districts, Kerala. About 150 sq.km. area has been mapped in Kollam district and good quality clay has been recorded at Chavakad, Kovur, Panayara, Muttaram, Akattumuri, Onampalli, Cherunniyur, Palachina and Tettikulam. In Kasargod district, promising blocks have been identified at Kuttapanayddu-konam (1 sq. km), Poinechi (2 sq. km.) and Perrya (4 sq. km.). As per IMYB 1998-99, GSI has conducted exploration work during 1994-95 to 1996-97 in the following areas in Kerala state.

(a) Area between Kollambalam and Chattanur villages in Thiruvananthapuram and Kollam districts : Chinaclay associated with ballclay and carbonaceous clay was identified to a depth of 8 to 10 m in this area. Geological mapping was also carried out on a scale of 1:25,000 over an area of 155 sq. km.

(b) Area between Chalamchal and Periya villages in Kasargod district : A clay horizon was identified with 0.5 to 8.5 m. thickness upto a depth of 20 m. over an area of 18 Sq. km. Geological mapping was carried out on a scale of 1:25,000 over an area of 155 sq. km.

(c) Area between Chattanur and Kundara in Kollam district (coastal track) : Carbonaceous clay & ball clay bands with a width of 1 to 10 m. and a depth of 10 to 20 m were located into strike of NNW-SSE with a steep dip towards west. Geological mapping was carried out on a scale of 1:25,000 over an area of 155 sq. km. and 160 samples were analysed.

(d) Clay deposits identified between Chalamchal and Periya, Kasargod district, Kerala : It has an average thickness of 2 to 4m over an area of 18 sq. km. Geological mapping was carried out on a scale of 1:25,000 over an area of 155 sq. km. in 11 promising chinaclay bearing blocks. Besides, 30 promising clay bearing blocks have been identified.

Department of Mines & Geology, Thiruvananthapuram, Kerala drilled 19 boreholes with a total drilling of 590 m and collected 158 core samples in Veilur, Sasthavattom, Mangalapuram, Thiruvananthapuram districts of Kerala. Besides, GSI carried out geological mapping over an area of 120 sq.km. during 1995-96 field season in Kollam and Kasargod districts of the state. Large scale mapping in part of Kollam, Kasargod and Thiruvananthapuram districts helped in delineating 70 promising blocks with good quality of chinaclay having recovery of 40%. During 1996-97, Kerala State Mineral Development Corporation Ltd. (a Govt. of Kerala Public Undertaking) received a detailed project report from M/s. Water and Power Consultancy Services (India) Ltd. with potential estimation of Chinaclay. In the year 2000, GSI carried out exploration in Nileshwar Tehsil, Kasargod district, Kerala by drilling 20 boreholes with an average depth of 42 m on 200 m space interval and about 180 core samples were collected[10].

3.3.8 Chinaclay Prospecting in Madhya Pradesh

In the year 1992, DGM, Madhya Pradesh carried out reconnaissance survey to update the information on mineral occurrences in Bastar, Mandsaur, Narsinghpur and Raisen districts. In Bastar district, reconnaissance Survey was carried out over an area of 910 sq. km. in Rajkot, drawing 159 samples. Reconnaissance Survey was carried out covering about 2720 sq. km. in Thiran area in Mandsaur district, 1275 sq. km. in Gotitorai, Talai, Kakripani and Baragaon in Narsinghpur district and 2275 sq.km. in Bhilwani area in Raisen district.

In the year 1993, DGM, Madhya Pradesh carried out reconnaissance Survey by mapping over an area of 1760 sq.km. in Kakrapani and Shyam Nagar for preparation of mineral inventory of Narsinghpur district[10].

3.3.9 Chinaclay Prospecting in Meghalaya

In the year 1991, Directorate of Mines and Minerals, Meghalaya carried out detailed exploration in Mullich, Jaintia hills district by drilling 424 m in 10 boreholes and on washing 20 to 30 % white clay was recovered.

In the year 1994, Directorate of Mineral Resources, Meghalaya carried out detailed investigations of kaolin deposit around Nongbah village along Jowai Nartiang Road in Jaintia hills district. Two kaolinised granite blocks were located near Nongbah village where 16 boreholes were drilled on a 30 m square grid pattern. About 72 samples were collected and chemical analysis carried out.

In the year 1995, the Directorate of Mineral Resources, Meghalaya carried out detailed investigations of kaolin deposit around Nongbah village along Jowai Nartiang Road in Jaintia hills district. Two blocks of kaolinised granite were selected for detailed mapping and drilling where 306 m drilling was completed and 26 samples were collected. From drilling data, it is ascertained that granite rocks are partially kaolinised and general thickness of kaolinised rocks varies from 5-10 m and recovery of clay fraction after washing ranges from 10-30%. One bulk sample was tested at CGCRI Calcutta. The chemical analysis of Grade I clay revealed SiO_2 45.90%, Al_2O_3 35.97% and Fe_2O_3 0.96%. This clay cannot be used in making porcelain type hardware, but may find good uses in stoneware or other types of products where white colour of the body is of little importance[10].

3.3.10 Chinaclay Prospecting in Orissa

DGM, Orissa carried out investigations around Ramchandrapur in Mayurbhanj district in 1990, by mapping 58 sq. km. and drilling 525 metres of four blocks in the area. Block A was found to be the most promising where 3 to 4 m thick grit free white clay beds occur. In the year 1991, DGM, Orissa carried out investigations in Kathakaranjia area of Mayurbhanj district by mapping 2 sq. km. where thickness of white clay varies from 2.7 to 19 m[10].

3.3.11 Chinaclay Prospecting in Rajasthan

In the year 1991, DMG, Rajasthan carried out preliminary investigations by mapping 120 sq.km. near villages Bhithe-ka-Gaon and Mandli in Jodhpur district locating white plastic clay over a strike length of 7 km. having 150 m width and exposed thickness of 2 metres. In the year 1992, DMG, Rajasthan carried out preliminary investigations by mapping areas in Bikaner and Jodhpur districts. In Bikaner district, reconnai-ssance survey carried out over an area of 30,559 sq. km. along with other economic minerals in Gody-Modayat revealed clay around Jaitanga-ki-Dhani. DMG also carried out investigations by mapping 160 sq. km. near villages Bhithe-ka-Gaon and Mandli in Jodhpur district to find out potentiality of clay. In the year 1993, DMG, Rajasthan carried out preliminary investigations by mapping in Chittaurgarh and Jhalawar districts. In Chittaurgarh district, reconnaissance survey was carried out around Bhimgarh, Gujar-ka-khera, Raghunathpur, Nasura, etc. and covered an area of 30 sq. km. In Jhalawar district reconnaissance survey was carried out for high grade intertrappean limestone and clay was associated with volcanic rocks around Sarwar, Unhal, Rampura, etc. and covered an area of 100 sq. km. In the year 1994, DMG, Rajasthan carried out assessment and resource inventory of 15 leases in Bhilwara and Chittaurgarh districts and estimated reserves in Bihaykhera area, Bhilwara district. In the year 1996, DMG, Rajasthan carried out levigation, of clay marked in the Gurah area in Bikaner district of Rajasthan. In the year 1997, Directorate of Mining and Geology, Govt. of Rajasthan conducted regional geological mapping for white clay deposits in Sata, Tarla, Parma, Khari, Ogala, Sanvalsi, etc. villages in Barmer district. In the year 2000, DMG, Rajasthan, has located low grade siliceous ballclay in Boa/Nedai area. The deposit is pockety and associated with ferruginous sandstone. The thickness of clay bed varies from 0.50 to 2m. The chemical composition of clay is Al_2O_3 - 10 to 18% and SiO_2 - 70 to 72%. Investigations by mapping 10 sq. km. on 1 cm = 100 m scale for chinaclay around village Sonari and Uttam-Singh-ki-Dhani, district Barmer, was taken up in 1997-98. Chinaclay is exposed on the surface and also occurs below 0.10 to 0.3 m soil cover. The area covered is about 0.36 sq. km. The thickness was approximately 1.5 m. probably continuing further at depth. Chemical analysis of 13 samples revealed that chinaclay is of moderate quality. Clay occurrence was found near Mainpura village by mapping the area of 15 sq. km. on 1:10,000 scale in Sawai Madhopur district by DMG, Rajasthan. Six samples were collected for chemical analysis[10].

3.3.12 Chinaclay Prospecting in Tamil Nadu

In the year 1990, DGM, Tamil Nadu carried out exploration in Theranipalayam area of Thiruchirapalli district by drilling 195 m in 13 boreholes. DGM, Tamil Nadu also carried out 66.26 mm augur drilling in eight boreholes in Mummudisivampatti, Vitteven and Paragudi areas around Sivaganga in Pasumpan Muthiramalimgam district. In the year 2000, DGM, Tamil Nadu has carried out exploration at Adigattur, Mel Nallattur and Keel Nellattur in Tiruvallur district by mapping 11 sq. km., digging 24 pit and collecting 48 samples for chemical analysis[10].

3.3.13 Chinaclay Prospecting in Uttar Pradesh

In the year 1994, DGM, Uttar Pradesh carried out preliminary investigations of clay deposits in Sonbhadra district by mapping about 2 sq. km., drawing 75 samples and drilling 386 m. In the year 1996, DGM, Uttar Pradesh carried out preliminary search for chinaclay and associated minerals in Jourukhar, Bagisoli and Garda in Sonbhadra district of Uttar Pradesh. The objective of exploration was to work out the potentiality of clay deposit in the area. Extension of pocket at two sites was established and 180 samples were collected. DGM, Uttar Pradesh explored for chinaclay in Jourukhar Makoli, Ramgarh, Bagisoli and Garda areas of Sonbhadra district. Extension of pockets and 2 sites have been established by digging 6 pits and 2 trenches of 203 cu m[10].

3.3.14 Chinaclay Prospecting in Tripura

In the year 1994, GSI estimated 8.50 million tonnes of plastic clay in Tripura west and Tripura North districts. Occurrences of clay were reported in Gumati and Mutiari river basins and Lunga area. It was proposed to take up bulk sampling of Katkari and Sonaimunri areas in South and North Tripura districts[10].

3.3.15 Chinaclay Prospecting in West Bengal

In the year 1991, DMM, West Bengal carried out exploration by drilling 60 m in a borehole and established dark grey coloured clay having floating properties near Khariduria in Purulia district. DMM also carried out investigations for chinaclay in Manipur, Ramgarh, and Tipam areas of Bankura district by digging 51 pits and drawing 42 samples. In the year 1992, Directorate of Mines & Minerals carried out exploration by drilling 165 m. in a borehole and established two types of clays, white and dark colour clays, near Khariduria village in Purulia district. DMM also carried out investigation of clay by reconnaissance survey over an area of 3 sq.km. to assess the quality and reserves of clay by pitting in Hankas area in Purulia district[10].

3.4 Indian Reserves

3.4.1 Categorisation of Reserves

The reserves are known mineral assets readily available for exploitation. It implies quantity and quality available within certain dimensions. For the estimation of reserves, it is necessary to have qualitative picture of a deposit besides tonnage available within its dimensions. Qualitative picture is obtained by sampling. A careful assemblage of the sampling data helps in blocking out areas with particular grade. The degree of assurance depends both on the frequency of sampling and geological nature of the deposit[11].

The reserves of kaolin have been categorised as proved (measured), probable (indicated) and possible (inferred). When the estimate is based on sufficient data, it will not vary much from the actual tonnage and grade when mined. The reserves thus estimated are categorised as proved (measured) or probable (indicated), carrying a lesser degree of assurance and is based on a limited data of sampling. In case of uniform deposits, probable reserves are estimated from a limited number of widely spaced pits or boreholes. The reserve estimation made from extrapolation of sampling data to areas where there is no data of sampling available, is termed as possible reserves (inferred reserves). The above classifications of proved, probable and possible reserves equivalent to measured, indicated and inferred reserves, respectively, in estimating mineral reserves are universally accepted. The terminology under the latter category was first used by the U.S. Geological Survey in 1943. Sometimes 'Prospective' reserve is found to be used, instead of 'Possible'. More frequently 'quarriable' or 'mineable' reserves are used to differentiate those from the reserves in situ[11]. Keeping in view the recommendations of the Working Group of Mineral Exploration Committee, set up the by Government of India, the two other categories have been included. These are conditional resources and prospective resources.

Conditional resources is a part of 'identified resources' which will become 'reserves' with favourable changes in economic and legal conditions, such as cost of production, selling price, technology, market and infrastructural facility.

Estimation of reserves of any mineral is a difficult problem. Such estimate involves two parameters. One of them relates to the physical existence of the material which is estimated by a knowledge of shape, size, extent, distribution, etc., which are controlled by geological factors and revealed by the results of operations like drilling, pitting, trenching, mapping, etc. The other relates to economic mineability controlled by factors like mineralogical composition, recovery, amenability to washing, quality of the end products and the cost of producing within the prevailing sale value of the end products. There are, thus, two indeterminates involved in the computation of reserves, namely, physical indeterminate and economic indeterminate. The degree of uncertainties in respect of each of these inderminates vary with the nature, extent and reliability of the exploratory operations carried out and the extent and results of laboratory tests and estimates of cost and prices of end products. The degree of reliability required is related to the purpose for which the estimates are made. For example, the degree of reliability required for developing a particular block of area for exploitation is much higher than that required for regional assessments. On the other hand, regional assessment can not form a basis of selection for immediate exploitation, but these data give a broad idea regarding the overall potentiality and quality of the region as a whole which will enable the Government to decide the need for any further development programme and selection of block for detailed operation[12].

The degree of uncertainties in respect of physical existence are qualified by the use of conventional expressions such as proved, probable and possible reserves in case of specific properties and measured, indicated and inferred reserves in case of regional appraisal.

Table - 3.1 : All-India Chinaclay Reserves (As on 1.4.1995)

(In thousand tonnes)

Sl.No.	Status	Proved	Probable	Possible	Total
A. In situ Reserves					
1.	Textile/Paper Coating	0.00	0.00	120.92	120.92
2.	Insecticide	1877.76	2355.32	24881.47	29114.55
3.	Chemical	629.23	50.55	6508.50	7188.28
4.	Ceramic/Pottery	45449.46	48278.52	146170.02	239898.00
5.	Paper filler	2395.26	522.74	1058.54	3976.54
6.	Rubber	190.44	1779.87	4264.60	6234.91
7.	Mixed Grade	5536.46	91543.32	197388.84	294468.62
8.	Others	1596.18	9271.92	20078.86	30946.96
9.	Unclassified	1693.39	1798.77	25025.74	28517.90
10	Not Known	6345.02	383505.14	767966.43	1157456.59
	Total	**65352.20**	**539106.15**	**1193463.92**	**1797923.27**
B. Recoverable Reserves					
1.	Textile/Paper Coating	0.00	0.00	89.58	89.58
2.	Insecticide	1494.52	1911.64	19728.32	23134.48
3.	Chemical	526.32	45.83	5235.00	5807.15
4.	Ceramic/Pottery	31982.61	25188.85	93580.72	150752.18
5.	Paper filler	2193.03	428.58	820.49	3442.10
6.	Rubber	134.10	1247.18	2596.29	3977.57
7.	Mixed Grade	4108.21	45719.38	92878.08	142705.67
8.	Others	1162.44	6956.61	12964.74	21083.79
9.	Unclassified	502.40	741.29	11137.60	12381.29
10	Not Known	3729.62	219375.31	455989.14	679094.00
	Total	**45833.25**	**301614.67**	**695019.96**	**1042467.88**
C. Conditional Resources					
1.	Ceramic/Pottery	2.89	5.28	26.28	34.45
2.	Mixed Grade	0.00	23.00	203.00	226.00
3.	Others	0.00	104.00	555.00	659.00
4.	Unclassified	0.00	0.00	1273.00	1273.00
5.	Not Known	2.11	3171.69	591.00	3764.80
	Total	**5.00**	**3303.97**	**2648.28**	**5957.25**

All India total In situ Reserves 1797923.27 thousand tonnes.
All India total Recoverable Reserves 1042467.88 thousand tonnes.
All India total Conditional Resources 5957.25 thousand tonnes.

3.4.2 Analysis of All-India Chinaclay (Kaolin) Reserves

The analysis of reserves of kaolin in India in this chapter is based on the reserve figures as on 1.4.1995 compiled by the Mineral Inventory Cell of Indian Bureau of Mines[13]. The different grades (categorywise) of all India kaolin reserves as on 1.4.1995 are presented in Table 3.1. From this table, it is clear that the total of all the grades of in situ reserves are 1797923 thousand tonnes, recoverable reserves are 1042467 thousand tonnes and the conditional resources are 5957 thousand tonnes.

Out of the total in situ reserves the proved category is 65352 thousand tonnes (6%), the probable category is 539106 thousand tonnes (29%) and the possible category is 1193463 thousand tonnes (65%). Out of 1797923 thousand tonnes of total in situ, the category of "not known" is 1157456 thousand tonnes which is amounting to 64% and the remaining 36% (640467 thousand tonnes) is categorised into insecticide, chemical, ceramic/pottery, paper filler, rubber, mixed grade, others and unclassified.

Out of the total 640467 thousand tonnes (excluding not known category) the ceramic/pottery grade is 239898 thousand tonnes (37%), the mixed grade is 294468 thousand tonnes (46%), insecticide 29114 thousand tonnes (4%), chemical 7188 thousand tonnes, paper filler 3976 thousand tonnes, Rubber 6234 thousand tonnes, others 30946 thousand tonnes (5%), Unclassified are of 28517 thousand tonnes (4%) and textile/paper coating 120 thousand tonnes.

Out of the total in situ reserves of 1797923 thousand tonnes, the recoverable reserve is of 1042467 thousand tonnes, which amounts to 58% (Table 3.1). Amongst 1042467 thousand tonnes of recoverable reserve 150752 thousand tonnes (14%) is of ceramic/pottery, the mixed grade is 142705 thousand tonnes (13%), the 'not known' category is 679094 (66%), insecticide 23134 thousand tonnes (2.8%), chemical 5807 thousand tonnes (0.48%), paper filler 3442 thousand tonnes (0.28%), Rubber 3977 thousand tonnes (0.28%); others 21083 thousand tonnes(2%) and unclassified is 12381 thousand tonnes (1.15%). Out of 15075 thousand tonnes of ceramic/pottery grade the proved category is 31982 thousand tonnes (21%), probable is of 25188 thousand tonnes (17%) and the possible category is 93580 thousand tonnes (62%). Out of the mixed grade of 142705 thousand tonnes, the proved category is 4108 thousand tonnes, probable is 45719 thousand tonnes and the possible is 92878 thousand tonnes. Out of the total 1042467 thousand tonnes of recoverable grade, the proved category of all mine status together is 45833 thousand tonnes (7%), probable category is 301614 thousand tonnes (28%) and the possible category is 695019 thousand tonnes (65%).

Table - 3.2 : All-India Leasehold Chinaclay Reserves (As on 1.4.1995)

(In thousand tonnes)

Status	Type	Grade	Proved	Probable	Possible	Total
L/H	In situ	All grades	52856.77	145988.22	400248.07	599093.08
L/H	Recoverable	All grades	37680.21	72270.84	142160.38	252111.43
L/H	Conditional	All grades	5.00	130.72	1718.28	1854.00

L/H = Leasehold

Table - 3.3 : All-India Freehold Chinaclay Reserves (As on 1.4.1995)

(In thousand tonnes)

Status	Type	Grade	Proved	Probable	Possible	Total
F/H	In situ	All grades	12496.43	384117.93	792995.25	1189609.61
F/H	Recoverable	All grades	8153.04	223943.83	552663.54	784760.41
F/H	Conditional	All grades	—	3173.25	930.00	4103.25

F/H = Freehold

The conditional resources (Table 3.1) are of 5957 thousand tonnes consisting of ceramic/pottery, mixed grade, others, unclassified and not known categories. Out of 5957 thousand tonnes of total, nearly 3764 thousand tonnes belong to 'not known' category(63%).

3.4.3 All-India Leasehold Reserves

All India Leasehold kaolin reserves as on 1.4.1995 is presented in Table 3.2. From this table it is seen that the different categories of the in situ total leasehold is of 599093 thousand tonnes, the recoverable reserves are of 252111 thousand tonnes and the conditional resources are of 1854 thousand tonnes. Out of the total leasehold in situ reserves the proved category is 52856 thousand tonnes (9%), the probable category is of 145988 thousand tonnes (24%) and the possible category is of 400248 thousand tonnes (67%). Out of the total recoverable reserves 252111 thousand tonnes, the proved category is of 37680 thousand tonnes (15%), probable cateogry is of 72271 thousand tonnes (29%) and the possible is of 142160 thousand tonnes (56%), whereas most of the conditional resources i.e. 1718 thousand tonnes (93%) are belong to the possible category (Table 3.2).

3.4.4 All-India Freehold Reserves

The All India Free hold reserves as on 1.4.1995 are given in Table 3.3. It is clear from this table that the in situ freehold of all the grades and categories is of 1189609 thousand tonnes, the recoverable reserves are 784760 thousand tonnes and the conditional resources are of 4103 thousand tonnes. Out of the total in situ freehold reserves 12496 thousand tonnes (1.05%) are of proved category, 384118 thousand tonnes (32.2%) are of probable category and 792995 thousand tonnes (66.6%) are of possible category. Whereas in the recoverable reserve the total of all the grades and categories are of 784760 thousand tonnes in which 8153 thousand tonnes (1.03%) are of proved category, 223944 thousand tonnes (28.5%) are of probable category and 552663 thousand tonnes (70.4%) are of possible categories only. In case of conditional resources out of the total 4103 thousand tonnes, 3173 thousand tonnes (77.3%) belong to probable category. The rest of 930 thousand tonnes (22.6%) are placed in the proved and possible categories. The All India statewise freehold and leasehold china clay reserves of India as on 1.4.1995 are given in Table 3.4.

3.4.5 All-India statewise distribution of In situ Reserves

The statewise distribution of in situ reserves of chinaclay as on 1.4.1995 is given in Table 3.5. From this table, it is known that the total in situ reserves of all grades comes to 1797923 thousand tonnes, which are distributed in 19 states. Out of these total reserves, 418088 thousand tonnes (23.25%) belongs to West Bengal, 311157 thousand tonnes (17.3%) to Orissa, 273055 thousand tonnes (15.18%) to Rajasthan, 259815 thousand tonnes (14.45%) to Bihar, 164242 thousand tonnes (9.13%) to Kerala and the lowest of 16 thousand tonnes to Goa.

Table - 3.4 : All-India State-wise Leasehold (L) and Freehold (F) Chinaclay (Kaolin) Reserves of India (As on 1.4.1995)

(In thousand tonnes)

State	Type	Status	Proved	Probable	Possible	Total
Andhra Pradesh	In situ	F/H	-	-	48705.15	48705.15
	Recoverable	F/H	-	-	38415.08	38415.08
	In situ	L/H	866.53	4642.58	11717.09	17226.20
	Recoverable	L/H	768.35	3887.04	9434.25	14089.64
Assam	In situ	F/H	3752.00	-	160.00	3912.00
	Recoverable	F/H	2923.00	-	96.00	3019.00
	In situ	L/H	218.00	-	-	218.00
	Recoverable	L/H	131.00	-	-	131.00
Bihar	In situ	F/H	952.92	4885.52	19784.17	25622.61
	Recoverable	F/H	104.97	496.71	2978.89	3580.57
	In situ	L/H	6325.09	21291.98	206575.44	234192.51
	Recoverable	L/H	4319.18	8333.62	29696.74	42349.54
	Conditional	L/H	-	-	14.00	14.00
Delhi	In situ	F/H	857.32	629.65	2539.05	4026.02
	Recoverable	F/H	785.70	547.35	2322.51	3655.56
	In situ	L/H	19.64	63.27	1184.42	1267.33
	Recoverable	L/H	18.66	60.11	1125.20	1203.97
South Goa	In situ	F/H	-	16.00	-	16.00
	Recoverable	F/H	-	15.00	-	15.00
Gujarat	In situ	F/H	-	-	29275.05	29275.05
	Recoverable	F/H	-	-	23247.69	23247.69
	In situ	L/H	4557.00	18377.65	8992.89	31927.54
	Recoverable	L/H	1182.50	4677.60	2230.32	8090.42
Haryana	In situ	F/H	13.15	34.40	123.20	170.75
	Recoverable	F/H	3.98	15.60	66.00	85.58
	In situ	L/H	9604.00	2024.00	2996.00	14624.00
	Recoverable	L/H	7593.00	1179.00	1711.00	10483.00
Jammu & Kashmir	In situ	F/H	-	-	28105.60	28105.60
	Recoverable	F/H	-	-	19640.00	19640.00
	In situ	L/H	-	-	16.00	16.00
	Recoverable	L/H	-	-	13.60	13.60
Karnataka	In situ	F/H	27.00	2192.10	5040.69	7259.79
	Recoverable	F/H	24.00	1744.34	2691.15	4459.49
	In situ	L/H	247.29	1725.85	10104.90	12078.04
	Recoverable	L/H	201.18	1073.53	7122.77	8397.48

(Contd.)

Table - 3.4 : (Concld.)

State	Type	Status	Proved	Probable	Possible	Total
Kerala	In situ	F/H	-	2102.50	150457.81	152560.31
	Recoverable	F/H	-	1595.87	115162.10	116757.97
	In situ	L/H	7070.34	1141.61	3470.51	11682.46
	Recoverable	L/H	6506.04	1043.07	3173.02	10722.13
Madhya Pradesh	In situ	F/H	600.00	31.30	13913.18	14544.48
	Recoverable	F/H	500.00	25.06	11343.11	11868.17
	In situ	L/H	1596.67	2167.70	1102.61	4866.98
	Recoverable	L/H	1230.62	1674.68	769.55	3674.85
Maharashtra						
	In situ	F/H	-	183.90	4512.54	4696.44
	Recoverable	F/H	-	155.51	2911.48	3066.99
	In situ	L/H	154.89	793.42	453.81	1402.12
	Recoverable	L/H	135.46	696.77	377.91	1210.14
Meghalaya	In situ	F/H	2750.00	3740.00	80772.30	87262.30
	Recoverable	F/H	1650.00	2110.00	48603.10	52363.10
Orissa	In situ	F/H	-	38987.00	87231.83	126218.83
	Recoverable	F/H	-	23262.00	42317.57	65579.57
	Conditional	F/H	-	-	254.00	254.00
	In situ	L/H	672.24	72818.44	111447.78	184938.46
	Recoverable	L/H	470.90	36742.68	55476.58	92690.16
	Conditional	L/H	-	-	1335.00	1335.00
Pondichery	In situ	F/H	-	-	2940.00	2940.00
	Recoverable	F/H	131.00	-	2352.00	2352.00
Rajasthan	In situ	F/H	3538.04	2276.95	204195.83	210010.82
	Recoverable	F/H	2156.59	1447.57	159876.60	163480.76
	In situ	L/H	19667.55	18037.07	25339.56	63044.18
	Recoverable	L/H	13756.91	10877.29	17002.86	41637.06
	Conditional	L/H	-	104.00	340.00	444.00
Tamil Nadu	In situ	F/H	-	-	41873.07	41873.07
	Recoverable	F/H	-	-	31795.74	31795.74
	In situ	L/H	-	198.30	14715.04	14913.34
	Recoverable	L/H	-	138.81	13012.90	13151.71
Uttar Pradesh	In situ	F/H	-	-	17.78	17.78
	Recoverable	F/H	-	-	12.45	12.45
West Bengal	In situ	F/H	6.00	329038.61	73348.00	402392.61
	Recoverable	F/H	4.80	192528.82	48832.07	241365.69
	Conditional	F/H	-	31173.25	676.00	31849.25
	In situ	L/H	1857.57	2706.35	2132.02	6695.94
	Recoverable	L/H	1366.41	1886.64	1013.68	4266.73

Table - 3.5 : Statewise and Categorywise Distribution of In situ Chinaclay (Kaolin) Reserves (As on 1.4.1995)

(Reserves in thousand tonnes)

Sl. No.	Name of State	Proved	Probable	Possible	Total	Grade
1.	Andhra Pradesh	866.53	4642.58	60422.24	65931.35	All Grades
2.	Assam	3970.00	-	160.00	4130.00	"
3.	Bihar	7278.01	26177.50	226359.61	259815.12	"
4.	Delhi	876.96	692.92	3723.47	5293.35	"
5.	Goa	-	16.00	-	16.00	"
6.	Gujarat	4557.00	18377.65	38267.94	61202.59	"
7.	Haryana	9617.15	2058.40	3119.20	14794.75	"
8.	Jammu & Kashmir	-	-	28121.60	28121.60	"
9.	Karnataka	274.29	3917.95	15145.59	19337.83	"
10.	Kerala	7070.34	3244.11	153928.32	164242.77	"
11.	Madhya Pradesh	2196.67	2199.00	15211.39	19607.06	"
12.	Maharashtra	154.89	977.33	4966.35	6098.56	"
13.	Meghalaya	2750.00	3740.00	80772.30	87262.30	"
14.	Orissa	672.24	111805.44	198679.61	311157.29	"
15.	Pondicherry	-	-	2940.00	2940.00	"
16.	Rajasthan	23205.59	20314.02	229535.39	273055.00	"
17.	Tamil Nadu	-	198.30	56613.11	56811.41	"
18.	Uttar Pradesh	-	-	17.78	17.78	"
19.	West Bengal	1863.57	340744.96	75480.02	418088.55	"
	Grand Total	**65352.80**	**539106.15**	**1193463.92**	**1797923.27**	

CHINACLAY (KAOLIN)

Table - 3.6 : Statewise and Categorywise Distribution of Recoverable Chinaclay (Kaolin) Reserves (As on 1.4.1995)

(Reserves in thousand tonnes)

Sl. No.	Name of State	Proved	Probable	Possible	Total	Grade
1.	Andhra Pradesh	768.35	3887.04	47849.33	52504.72	All Grades
2.	Assam	3054.00	-	96.00	3150.00	"
3.	Bihar	23.15	12.23	199.63	235.11	"
4.	Chhatisgarh	1730.02	1242	2936	5909	"
5.	Delhi	804.36	607.46	3447.71	4859.53	"
9.	Goa	-	15.00	-	15.00	"
7.	Gujarat	1182.50	4677.60	25478.01	31338.11	"
8.	Haryana	7596.98	1194.60	1777.00	10568.58	"
9.	Jammu & Kashmir	-	-	19653.60	19653.60	"
10.	Jharkhand	4401	8818	32476	45695	"
11.	Karnataka	225.18	2817.87	9813.92	12856.97	"
12.	Kerala	6505.07	2638.94	118335.12	127480.00	"
13.	Madhya Pradesh	-	457.74	9352.70	9810.06	"
14.	Maharashtra	135.46	852.28	3289.39	4277.13	"
15.	Meghalaya	1650.00	2110.00	48603.10	52363.10	"
16.	Orissa	470.90	60004.68	97794.15	158269.73	"
17.	Pondicherry	-	-	2352.00	2352.00	"
18.	Rajasthan	15913.50	12324.84	176879.46	205117.82	"
19.	Tamil Nadu	-	138.81	44828.64	44967.45	"
20.	Uttar Pradesh	-	-	12.45	12.45	"
21.	West Bengal	1371.21	199815.46	49845.75	251032.42	"
	Grand Total	**45833.25**	**301614.67**	**695019.96**	**1042467.88**	

3.4.6 All-India Statewise Distribution of Recoverable Reserves

The statewise and categorywise distribution of recoverable reserves of chinaclay are given in Table 3.6. The total recoverable reserves of all grades of the 19 states put together is of 1042468 thousand tonnes. Rajasthan 205118 thousand tonnes (19.67%), West Bengal 251032 thousand tonnes (24%), Orissa 158270 thousand tonnes (15.18%), Kerala 127450 thousand tonnes (12.22%), Andhra Pradesh 52505 thousand tonnes(5.03%), Bihar 45930 thousand tonnes (4.4%), Meghalaya 52363 thousand tonnes (5.02%), Tamil Nadu 44967 thousand tonnes (4.3%) and Gujarat 31338 thousand tonnes (3%). The rest is in other states. Out of the total all India proved reserves the highest proved reserves of 15913 thousand tonnes (35%) are in Rajasthan followed by Haryana 7597 thousand tonnes (16%), Kerala 6505 thousand tonnes (14%), etc. and the lowest 135 thousand tonnes are in Maharashtra, whereas in Orissa the probable category are of 60005 thousand tonnes which is 20% and the possible category is of 97794 thousand tonnes(14%) of the total recoverable reserve of the state. Out of the total recoverable reserved, the highest possible reserves of 199815 thousand tonnes (66%) are West Bengal.

3.4.7 All-India Statewise Distribution of Conditional Resources

The statewise and categorywise distribution of the conditional resources are given in Table 3.7. These resources are distributed in four states namely, Bihar, Orissa, Rajasthan and West Bengal. Out of the above, 5 thousand tonnes are estimated only in West Bengal in the proved category, whereas in Bihar and Orissa 14 and 1589 thousand tonnes, respectively, are estimated in possible categories. The highest conditional resources of 3910 thousand tonnes are in West Bengal.

Table - 3.7 : Statewise and Categorywise Distribution of Conditional Chinaclay (Kaolin) Resources (As on 1.4.1995)

(Reserves in thousand tonnes)

Sl.No.	Name of State	Proved	Probable	Possible	Total	Grade
1.	Bihar	-	-	14.00	14.00	Mixed
2.	Orissa	-	-	1589.00	1589.00	"
3.	Rajasthan	-	104.00	340.00	444.00	"
4.	West Bengal	5.00	3199.97	705.28	3910.25	"
	Grand Total	**5.00**	**3303.97**	**2648.28**	**5957.25**	

3.5 World Reserves

The World reserves of chinaclay of all the countries are not available. But in few cases reserves of some countries are available, which are given below. According to United States Bureau of Mines the total world reserve of kaolin estimation is 13000 million tonnes[15]. The deposits of primary and secondary types are currently centred on eight geographic areas, out of which the most important reserves being in Brazil, United States of America, Australia, China, Japan and United Kingdom. China hosts large resources of kaolin followed by USA and CIS countries. Till 1991, about 218 kaolin occurrences spread over 19 provinces of China, whose overall reserves exceeded 2500 million tonnes. New mineral occurrences are discovered continuously in other provinces and regions of China[14].

Resources of kaolin in Georgia, USA are estimated to be 5 to 10 billion tonnes[16]. The kaolin reserves in Brazil are 150 million tonnes as estimated in the year of 1994, which is sufficient for more than 150 years[17].

In Japan, investigations have been carried out by the Mineral Resources Investigation Branch of Ministry of International Trade Industry for the estimation of reserves. As per the survey, the mineable quantities of clays in Kibushi and Gairome areas of Crude Province are as follows.

Reserves of Kibushi and Gairome Clays of Japan in 1997

	Ore Reserve (Tonnes)	Minable Reserve (Tonnes)	Mine life (Year)
Kibushi Clay			
Proven Reserves	7,747.6	6,101.3	7.5
Presumed Reserves	10,300.1	10,120.3	20
Estimated Reserves	24,510.1	23,173.1	49
Total	**42,557.8**	**39,394.7**	
Gairome Clay			
Proven Reserves	11,941.9	10,001.9	18.25
Presumed Reserves	5,648.9	5,028.4	27.40
Estimated Reserves	18,876.3	17,693.5	59.70
Total	**36,467.1**	**32,723.8**	

From the above table, it is known that the current extraction rate of Kibushi clay has approximately lost for a further 7.5 years on its proved reserve base, which may increase to 20 years if the estimated reserves are also taken into account.

Some of the common problems with clay mining are that the pit reach the bottom of the deposits, the removal of overburden rises yearly and the usual environment problems. In Japan with its relatively small land area; and rapidly advancing urbanisation, there are strict regulations against environmental pollution caused by mining and most mines are anxiously raising funds for addressing such problems. With this in mind, it is not inconceivable, therefore, to say that even though the estimated reserves are 23 million tonnes, legislation may severely impact the tonnage available for extraction. Local tile manufacturers are consuming plenty of clay. They are storing waste clay accumulated from the past and from this storing waste clay they extract more clay. From the housing sites the clays are carefully extracted and utilised. For Gairome clay, the life of reserves is shown to be 18-27 years on the basis of proved or presumed reserves but mining conditions are worse than that of Kibushi clay. Recently, for example, cheaper high purity silica sand has been imported from Australia and South East Asia, causing many of the region's silica sand mines to go out of business. Since Gairome clay is produced as an accompanying mineral to silica sand, this drop in production has had a knock on effect for clay output in the area[18].

In south west England, the kaolinised zones are either funnel shaped or trough like in form and desend to depths of more than 200m in places. The original kaolin resoure was probably in excess of 200 million tonnes[19]. The recent investigations in one of the kaolin deposits at Ballinge, Sweden indicated kaolin reserves of 20 million tonnes with 15 to 40% kaolinite[20].

In Brazil, the Greenfield Project which is situated in Amazone region is having 150 million tonnes of Crude reserves of kaolin[21].

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4. Indian Deposits

4.1 Description and Distribution

The occurrences of Chinaclay deposits have been reported from almost all the states of the country[1,2]. The major deposits of economic value belongs to the rocks of Archaean age followed by Gondwana and Tertiary ages. The workable deposits in the country belonging to the Archaean age occurs in the states of Andhra Pradesh, Assam, Bihar, Himachal Pradesh, Karnataka, Kerala, Rajasthan and West Bengal. Apart from this the scanty occurrences are known from the states of Haryana, Orissa, Punjab and Uttar Pradesh. The Chinaclay of sedimentary origin of the Gondwana formations are in the states of Andhra Pradesh, Bihar, Madhya Pradesh, West Bengal and with a limited extent in Maharashtra. The deposits which occur in the Tertiary rocks are in the states of Kerala and Tamil Nadu.

The mode of origin of the clay deposit plays a vital role in knowing its quality. On the basis of its origin, clay deposits are classified into two categories. The in situ or residual deposits which are found at or near the host rock are formed due to decomposition and disintegration of the feldspathic content present in the host rocks. These clays are coarsely grained with low plasticity. Whereas the secondary category of transported deposits occur away from the source of formation. These clays are fine grained with high plasticity. The transported kaolin are pure as compared to in situ deposits.

Even though the economically workable deposits are basically restricted to Archaean rocks, the possibility of having good sources of economical deposits in sedimentary rocks cannot be ruled out, as clay beds constitutes the main lithounit along with sandstone, shale, coal, etc. In sedimentary basins deposition has taken place in a number of cycles with certain time gap and with a sequence of alternating clay and sandstone beds. At present, mostly the shallow occurring deposits are being worked out and the probable deep seated deposits are in the earth's crust as it is. So the systematic planning for exploitation of deep seated deposits is the need of the hour. The important deposits statewise upto district level are described alphabetically hereunder.

4.2 Andhra Pradesh

In this state the important deposits occur in Adilabad, Cuddapah, East Godavari, Kurnool, Nellore, Vishakhapatnam, Warangal and West Godavari districts. These are as follows :

4.2.1 Adilabad

Rampur-Rallapet area of Adilabad district of Andhra Pradesh has a group of clay mines. These are located at 10 km south west of Sirpur-Kaghaznagar town. In this area, as many as 18 deposits are identified. The area occupied by Deccan traps which are underlain by sedimentary Gondwana formations. The kota sandstone and Maleri shales belonging to the upper Gondwanas are exposed in and around Rampur-Rallapet area. The chinaclay beds are confined to Maleri horizon, and extends in an area over 3 sq.km within the limits of Rampur-Rallapet area. In this area 4 clay bands with a cumulative thickness of upto 3 m are found. It is intercalated with sandstone and overlained by soil and ferruginous clays. The clays of this area are composed of mostly kaolinite with low alumina content. It is plastic and white to cream in colour[3].

The Pachgaon deposit occurs in Asifabad taluka at about 1.6 km south of Pachgaon village with an average thickness of 1.8 m. The dips of the beds are almost flat and occurs horizontally below the coarse grained ferruginous sandstone beds of upper Gondwana age. The Kodtarala deposit occurs at about 9 km northwest of Asifabad Railway station. The clay band is of 5 m thick and is exposed in a cliff section under the soil cover of 6 m. The Butemal deposit is located about 19 km northwest of Asifabad town. It is soft, pale, pink and somewhat shaly with 2 m thick and is found exposed along the course of the Baternal nala. Small deposits of chinaclay are also reported to occur in the vicinity of villages Dhauora and Chanka.

4.2.2 Cuddapah

The white coloured good quality clay with pinkish streaks, highly plastic, with firing shrinkage of 30% is 0reported to occur at the south eastern part of the hillock lying west of Hastavaram. The gritty matter in the clay is upto 37 percent. The greyish and pinkish coloured clays are known to occur in the Manikonda hills, about 1.6 km west of Tallapaka. The white colured, highly plastic, occurs south of the tank of Vellurupalli near Pullampet at shallow depth underlain by Archaean shales.

At about 3 km east of Obali near Singareddipalle, white clays are exposed. At about 3.2 km west-north-west of Pature, buff coloured clays are exposed. Both the clay varieties vitrifies at 1300°C and burns to a grey colour.

At Bhakrapeta white coloured shaly clays occur near 3 km west-south-west of this locality. The white coloured, calcareous clays are exposed at a distance of about 200 m west of Rampatadu under the soil cover attains thickness of 1.8 m. The material burns brown and fuses at 1250°. Similar type of clays occur on both the banks of river Sagribru at about 3 km west of Porumamilla area.

4.2.3 East and West Godavari

To the south and southwest of Kotta Bommuru the white coloured clays occurs intercalated with Rajahmundry sandstones. The material is plastic, grey burning when it vitrifies at 1300°C with total shrinkage of 45 percent. The purple and stained bluish white clays occur at Rasale are hard at the base of the hill. Further in the east-north-east of Rasale these clays are underlyingly ferruginous sandstones and grits. Similar type of deposit also occurs along the slope of hillock to the south of this village. A bed of white coloured clay 3 m thick occurs near Punyakshetram below the cover of 9m thick Rajahmundry sandstone. At about 1.6 km west of Peddapuram, a white coloured, 3 m thick clay bed occurs at a depth of 4.5 m below Rajahmundry sandstone. The total clay content of the crude rock is 60 percent. A large quantity of white coloured clay occurs at about 2.5 km west of Jaggampeta. The clay is white burning, hard and does not vitrify. At about 3 km north of Jaggampeta, highly Kaolinised felspathic gneiss is exposed in a quarry. The rock contains 30 percent clay matter, the rest being semi decomposed feldspar, quartz, mica and graphite. The beds of white clays are also reported to occur in Bommuri Metta Hill, near Rajahmundry. The material is plastic and burns white. In Dwaraka-Tirumala the clay deposit is confined to Raghavapuram shale of upper Gondwana age. These clays are buff in colour, non gritty, crumbles easily in water with kaolinitic composition.

4.2.4 Kurnool

White clay containing bands of yellow ochre occur at 2 km north-east of Ramallakota up to a depth of 7.6 m. At about 500 m south east of Betamcherla Railway station a good quality of white clay occurs in a hill. The clay is plastic and does not vitrify.

White clay with purple streaks occurs at half a kilometre south of Ambapuram.

At about 5 km south east of Gani and 18 km north of Panyam Railway station a small deposit of white clay with purple streak occur. The white colored clays also occur at about 800 m south-east of village Pracma. The patches of white coloured clay occur at about 200 m east of Puricherla. The white and buff coloured clay derived from the rocks of phyllites and gneisses are reported to occur at 1.6 km south of Peddapadu, west of Lanjabhavi and near Naglavaram. Kaolin derived from the weathering of granite rock is reported to occur south of Kasanapale. The depth of the deposit is reckoned to be about one metre and the material is rather gritty.

4.2.5 Nellore

A 1.5 m thick bed of buff and purple coloured clay of sedimentary origin belonging to Gondwana rock formation, dipping towards east, is exposed in the inflow channels of the tanks near Janakamnapeta. The clay is fairly plastic, gritty, micaceous, buff burning and it shows incipient fusion at 1200°C. At about 3 km south-east of Naraspuram a 4 m thick bed of white clay occurs close to the Karavali-Peddavani road. The clay is fairly plastic and burns to a cream-white colour. The china clay occurs in a small ridge north of Kistana Konda near Prabhagiripalyam. The material is plastic and white burning. Appreciable quantity of plastic china clay occurs at a depth of one metre to the north-east of Vobulayepalle. A deposit of kaolin is reported to occur near Kasumura near Gudur, on the Singurammalla hillock. This is reported to be white in colour with moderate plasticity. In Gotpalem a plastic kaolin resulting from decomposition of a pegmatite is reported to occur near this village. Kaolin resulting from the decomposition of a pegmatite body associated with quartzite is reported to occur near mallatippa, 800 m north of the mica deposit. A small deposit of chinaclay occurs in a ridge of quartzite, just on the Podalakur-Manubolu road near Valdapudi area.

4.2.6 Visakhapatnam

Kaolin occurs in a few places near Chodavaram. On washing the clay, the recovery is found to be 25% and the product has yellowish tint. The hill near Bhogapuram contains an extensive deposit of gritty white clay, which burns light buff in colour. Kaolin resulting from decomposition of pegmatite rock is reported to occur in the reserved forest near Yerravaram, 90 km from Narsipatnam. A deposit of white plastic clay is reported to occur near Dasannapeta. Further clay occurs in pocket in the manganese mine at Kodur. In a hill near Rajapalem, 1.2 km from Thada railway station, exposures of good china clay are known. The pale yellowish clay with white patches occurs at about 6 km west-north-west of Bodiguda. The surface is covered with laterite and depth of decomposition varies from 3-4.5m. The material has high plasticity and shrinkage of 19 percent and burns brown or cream white. Two occurrences of yellowish clay have been noticed near Rangar. The material is fairly plastic with shrinkage of 23 percent. Lithomarge clays are reported from Buyada Gedda stream section about 1 km east of Araku, Anjada, Kontabansaguda, Sarabaguda, Dalpaliguda, Mandagor and Modiguda areas. These occurrences appear to be patchy and superficial. They are derived from the alteration of garnetiferous gneisses.

4.2.7 Other Districts

Extensive beds of lithomarge are found to occur in the western part of Andola taluk at the contact of Deccan Trap and Bhima shales in Warangal district. A small deposit of white clay occurs associated with phyllites at about 1.6 km south-east of Maddagudem in Narasmpet taluk and near Miryalpenta in Yellandu taluk in Warangal district.

At 1.2 m below the surface, a white coloured plastic clay reported to occur at about 200 m west of Balapuram village in Anantpur district. A fairly small deposit of white coloured clay occurs near Macherla Railway station. White and yellow coloured clay in small quantity also occurs in association with calc tufa in south west of Vinukonda village in Guntur district.

The Srirangapur kaolin deposit falling in Pargi taluk of Mahabubnagar district is located at about 14 km from Farruknagar Railway station. This occurrence is on the Shadnagar - Farruknagar-Pargi road. The Kaolin is reported to be derived from decomposition of granite and pegmatite rocks along their contact with the Deccan trap rock. The crude material is gritty and yields about 50 percent white clay after washing. The Gambirpur deposit fall under Saddipet taluk Medak district. The kaolin occurs in partially decomposed granite in the form of small pocket and veins at about 1 km north of Gansirpur. The Chintriyal deposit is situated on the north bank of Krishna river about 32 km south east of Huzurnagar in Nalgonda district. The clay is compact, pure white to yellowish white in colour, often showing bedded structure.

4.3 Assam

The kaolinised clays occur in five districts of Assam viz. Garo, Jaintia-Khasi, Lakhimpur, Maria-North Cachiar and Sibsagar. The description of these districts is as follows.

4.3.1 Garo Hills

In this district the important deposits are found at Sohrarim, Narringgiri and Siju Songnong areas. Apart from these deposits a pinkish cream coloured clay of smaller size occur 4 km away from Shillong city on the Shillong-Cherrapunji road. The greyish white coloured clay deposit occurs near 24th kilometre stone on the same road of the extension. The white or light buff coloured kaolin also occurs near Tura area with pisolitic appearance resting on gneisses. The kaolinised gneisses also reported from Nangkhara, Agalgiri, Rongdingiri, Dobu, Boldakgithin and Laitksay areas of this district.

4.3.2 Jaintia and Khasi Hills

Thin deposits of lithomarge are reported to occur at the contact of Cherra sandstones and gneisses in the Jaintia hills, between Samasi and Mynthlu. Pure, white kaolin have been reported from several places in and around Sutnga and Laikesh areas. These deposits are of iron stained at some places.

4.3.3 Lakhimpur

A thick deposit of kaolin has been reported to occur at a distance of 6 km from the course of Dora river in Lakhimpur district.

4.3.4 Maria hills and North Cachiar

At the foot of Jamuna fall near Silbatla, a gneiss is overlained by a band of decomposed trap rock which in turn, overlain by a bed of white clay. This is nodular at bottom, but stratified at the top with a gentle dip towards south-east and attains a thickness of 6 metres. The topmost portion is composed of nummulitic limestone.

4.3.5 Sibsagar

A small exposure of kaolin occurs within a granitic rock in the Koilajan stream near Koilapahar. Lithomargic clay derived from trap rock also occurs to the north of the above locality. An extensive deposit of kaolin occurs on either banks of the Degaroo river in upper Brahmaputra region and at the fall of Nambor river, on the Dhansivi river at Bor Pathar area.

4.4 Bihar

Bihar is the leading producer of chinaclay in the country. The occurrences of chinaclay deposits in this state belong to the rock formations of Archaeans and Gondwana ages. These are mainly in the districts of Bhagalpur, Monghyr, Palamau, Ranchi, Santhal Parganas, Singhbhum, Dhanbad and Hazaribagh.

4.4.1 Bhagalpur[2]

Harankori Clay Deposit has been worked out over a considerable period. The clay occurs in a pegmatite vein which cuts quartz mica schist along the strike. The vein is about 7.6m wide in the northern part but it branches out into three in the southern part. The material is moderately plastic, with shrinkage of 22 percent, showing any vitrification. Gobardana clay deposit occurs in two sections in a pegmatite rock with a thickness of 1.5 m in the district. The Jharna deposit occurs at about 300 m east-south-east of Jarna is similar to that of Harankori clay. It occurs along the pegmatite vein. The clay is gritty and the proportion of the fine clay available after washing is 25 percent[2]. A 6 m wide deposit is located at about 600 m north-west of satletwa village in an altered pegmatite. The clay is fairly white but contains large proportion of quartz grains, with average 40 percent clay. Kaolin derived from the alteration of granites and gneisses is reported from a hill near Patharghatta or Bathesarthan. The alteration of feldspar from granites and gneisses have produced a coarse china clay deposit which is overlain by sandstones. The Kasri clays are of sedimentary origin and belongs to the rock formation of upper Gondwana age located about 6.4 km from Colgong. It is well exposed along the western flanks and baked into porcellanite at the contact with trap rock. The clay is fossiliferous and of good quality with high plasticity. At south of Gandeswari Pahar and east of Pachurki area about 3 m thick kaolin deposits are exposed in an abandoned pit.

4.4.2 Hazaribagh

A few pockets of chinaclay are noticed in gneissic rocks at Barki-Saria and minor occurrences of kaolin have been reported from 1 km north west of Kuntur-Lowa of this district. The Ossam area is located 45 km from Ramgarh where the kaolinised sandstone formations were encountered in the nallahs lying between the two hillocks trending east-west. The kaolinised beds show moderate dips with varying depths. The decomposition of sand-stone and formation of chinaclay are thought to be brought by hypogene or supergene processes. The formation of china clay beds in the antiform structure, reveals the possibility of circulating vapours at high temperature and pressure along the fold axis. The kaolinisation within the sandstone beds is more or less uniform, with the degree of kaolinisation getting intense at depths below 4 m.

4.4.3 Monghyr

Several deposits of chinaclay are reported to occur in the vicinity of Simultala area. The Bhandaru deposit occurs at about 600 m to the south-west of Bhandaru village and in the south of Badua nalla in a decomposed pegmatite rock. The kaolin bearing pegmatite strikes[2A] in an east-west direction. It has low to moderate plasticity with 20 percent shrinkage. The Pathalchapti clay results due to alteration of aplitic vein occurring within granite gneiss at this place. The Chiraya deposit is located at about one kilometre north-west of Chiraya and is associated with pegmatite rock mass which strike ESE-WNW. The material is pale cream in colour and possesses good plasticity. Baghwa deposit is located at about a kilometre in the south-east of Baghwa within a pegmatite rock and occurs at about 3 m from the surface. In Kharapur hills the pinkish white clay has been reported to occur on the hill tops of Khapra, Maruk and Maira located in the Kharapur hill range. The material is fine grained soapy and is fairly extensive. A good quality of kaolin is reported to occur in Niwadih area also.

4.4.4 Palamau

The Letehar clay deposits of this district are of sedimentary origin and occurs in rock formation belonging to Barakar series of Lower Gondwana age. These are found in two areas : (i) north of Tupukalan (ii) north of Mungar. The beds at Tupukalan strikes in the east west direction with 16° dip towards south. The clays are greyish white in colour, smooth and sectile. The material at North of Mungar is greyish white with yellowish specks. The beds strike east-west and dips 12° towards north. The clay is fine grained and free from grit but slightly micaceous.

4.4.5 Ranchi

The Ulatu deposit occurs at about 10 km from Ranchi, which is believed to be derived from the alteration of phyllitic rocks. The material is white and has a moderate plasticity. Another kaolin deposit occurs at 2.4 km north-west of Bagru and about 9 km west of Lahardaga areas. The material is milky white with intermittent bands of yellow, red and brown colour. It is fine grained and fairly plastic, and it occurs underneath the bauxite layer.

The white coloured clay derived from the decomposition of feldspathic gneisses is reported to occur at about a kilometre east of Haridih. The material is hard and compact. It requires crushing after washing. It is overlained by yellowish loam varying from 1.5 to 3.0 m. The clay has a good plasticity and about 17 percent shrinkage. The Sursu clay deposit is apparently derived from the decomposition of gneisses and pegmatites and occurs at about 2 km south-west of Sursu. It is white, gritty and contains partially decomposed matrix. A workable quantity of lithomarge is reported to occur at the base of laterite in the areas of Dumalipal and Serendag areas. A clay deposit having less extent occur below the laterite capping in Serangdhe plateau, south-west of Banjaripattoli.

4.4.6 Santhal Parganas

A Chinaclay deposit is located near Karanpura about 5 km from Kalikund on the Dumka-Patna road. The clay is restricted in the bands of altered gneisses which strike NW-SE and dips towards north-east. The altered rock is pale greenish in colour and somewhat gritty. Dudhani deposit occurs in the form of small pockets in association with decomposed gneiss having strike direction east-west. Simra deposit is found at about 1 kilometre north-west of Simra in the form of pockets within the decomposed granite gneiss, which strike NW-SE and dips 60° towards north-east.

The Bhurkunda deposit of chinaclay near Bhurkunda village occurs in a pocket within altered gneiss having strike almost north-south and dip towards east. The depth of the alteration is upto 2.4 m from the surface and is exposed in the nalla section. Asanboni and Jiradih chinaclay occurs in the form of pockets with the altered streaky gneiss having strike NNW-SSE. Gobindur deposit is located at about a kilometre to the north-west of Gobindur village where partially kaolinised gneisses were exposed. It is mixed with green material derived from hornblende and mica schist. It is gritty and plastic with 20 percent shrinkage. When fired, the colour appears cream without any vitrification. The kaolin occurring near Mangal Hat, at about 64 km to the east of Taljari Railway station, is associated with sandstones of Gondwana age.

Further the kaolin associated with Gondwana rock formations have been reported from Amjhari and surrounding areas covering boundaries of Dhamai and Hura Coalfields with the villages of Alabaru and Chilgo, respectively, in this district.

The kaolinised sandstones about six metres thick occurs in a fair abundance at Pond Dongri (Phulberia) and its neighbourhood. The clay possesses good plasticity and shrinkage of 13 percent. A bed of kaolin bearing sandstone, about 2.4 m thick occurs in Paharpur coal pit near Gandheshwari Pahar. The clay possesses a good plasticity and a shrinkage of 19 percent. It fires light blue with slight vitrification. The clay deposit of Hiranpur area is light bluish white in colour and covers a large area. It is plastic, shows 16 percent shrinkage and fair vitrification. The colour on firing is drab or brown.

4.4.7 Singhbhum

A white coloured clay deposit occurs in the south of Pundihasa appears promising because of its shallow nature. The depth of intersection varies from 1.8 to 2.4 m from the surface. The Karanjia deposit is situated at about 11 km from Kendposi Railway station, where the exploitation of chinaclay is being carried out through a number of pits. Another chinaclay deposit is situated little south of Darbasi. It is associated with fairly altered granitic rocks. Chinaclay has also been reported in Naumundi basin[4]. The Maharaja-Kasimbazar deposit is situated at about 6 km west of Karanjia. The clay occurs in association with altered granite rock with variable percentage of grit content. In western part, the granite is less altered and occurs in irregular patches. On valley portion clay is rather gritty.

Rungta chinaclay mine is located by the side of Chaibasa-Keonjhargarh road at about 1 km in the south-west direction of Karanjia. It occurs within highly kaolinised feldspathic granite rock, covering an extensive area. The Diamond chinaclay deposit is situated at about 200 m east of main road from Chaibasa to Keonjhargarh near the 27th kilometre. Clay is associated with quartz veins in the west and dolerite dyke in the east.

At Dumaria a fairly large size kaolin deposit occurs near the confluence of the two streams. Few abandoned chinaclay pits are also located near the miniature ravine and north of Landusai. At about 1.6 km east of Dumaria a good quality chinaclay deposit is reported.

In Chota Rajkhamon area chinaclay occurs in between two dolerite dykes. One dyke passes through Raikhomon and another runs south of Chota Rajkhomon area. The granitic rock is fully kaolinised. It is overlained by a 3 m thick detrital soil and foliated granite gneiss. The clay is fairly white and at few places slightly contaminated due to the presence of ferruginous material which imparts pinkish to buff colour.

Balidaskand kaolin deposit is located at about a kilometre west of Balidaskand village and occurs with a coarse grained banded granite. The clay is of gritty nature. The Gondkida clay deposit is situated to the south of village Gondkida and occurs within a decomposed granite rock at a depth of 2 m below the surface. A 6 m thick kaolin deposit occurs just north of Duhari village below the cover of 3 m thick laterite. The red staining is due to the presence of lateritic soil which is the characteristic feature of this deposit. Joldiha deposit is situated at about 6 km north of Raikhomon. The presence of clay is mostly confined to the nallas flowing in this area. In Tirilpi, a good quality of clay having 20 percent recovery was reported. At Bhonda, the china clay occurs in an altered granite which strike north-south. In southern part the clay is rather sandy, but in northern part it bears good quality with fineness. In the eastern side it extends further below the cover of soil. The average clay content is 25 percent.

At about 1 km south of Telaipi area the chinaclay occurs under a 2m thick laterite capping within a kaolinised granite. The chinaclay derived from decomposition of granite rock occurs on elevated ground as well as in the valley portion east of Kendposi. On systematic prospecting, there is a possibility of having good quality of chinaclay in Sarapia area.

The pocket type of clay deposit at Boraguli occurs on the eastern side on high ground around 400 m from Boraguli locality under the cover of laterite. It has been developed due to the alteration of feldspar bearing granite rock and are bounded by two eastward flowing nallas. The Pandrasali deposit is located about 800 m from Pandrasali Railway station. The clay is white to yellowish and gritty with 20 to 30 percent clay content. Madhkamhatu is located at about 2 km to the south of Chaibasa. The clay is very fine, soft, soapy and is free from grit. A kaolin bearing, massive bedded rock is exposed below the cover of 2 m soil at about a kilometre southwest of Gundiposi area.

At about 1.6 km northwest of Rajkarsawan Railway station and 400 m west of Chota Amda white coloured clay occurs under the cover of laterite. In Majri area, the Dharadhi deposit is located on the border of Singhbhum and Manbhum districts. These clays are of sedimentary origin and are shaly in nature. The strike of the beds are NNE-SSE. The Khari Dungri area is easily accessible from Gidhi Railway station on the Calcutta-Mumbai main line. The clays are whitish to pinkish in colour and appears to be formed due to alteration of basic rocks. These clays are of fine grained, compact, homogenous and of concretionary nature. Dante and Matiabandi areas also consists chinaclay. In Saraiketa area the Gangeruri clays are of sedimentary origin. Occurring within the feldspathic sandstone, it has undergone intense kaolinization to a greater depth. A kaolin of better quality is reported to occur in the vicinity of Bharatpur. Further the presence of white coloured clay is also reported from Mundakati, Samran, Ghagi, Urga, Rangamatia, Jaspur, Raghunathpur areas of Singhbhum district.

4.4.8 Sahebganj

The chinaclay is being exploited at six places in Rajmahal areas. These are namely Rajmahal, Rabazar, Mangalhat, Saidpur Bujrug, Jainabad and Kasba. The rocks in this area belong to Barakar stage of lower Gondwana system. The chinaclay is found to be distributed throughout the kaolinised sandstone formation. The joint planes are filled with ochurous, limonitic and ferruginous kaolin. It is believed that the vadose water passes through the cavities in the sandstone and later the materials carried-out by this water are deposited as thin bands/ layers of clay in the sandstone bed. It is found that the occurrence of chinaclay in kaolinised sand is about 11% and it is being recovered about 90 to 95% of its occurrence.

4.5 Gujarat

The white coloured clay occurs at Matahitekri near Naroti in Baroda district. It is highly aluminous and is being associated with the lateritic material in the beds of Eocene age, overlying the Deccan traps[5]. In Bhavnagar district, white and bluish coloured clay upto 1.2 m thick occurs at Bhudd and Thoradi areas. The material is soft and is absolutely free from grit.

4.5.1 Broach

On the right bank of Amravati river at about 800 m south-east of Bhilod, small lenses of white to grey coloured clays with 0.4 to 1.2m thick occurs overlying the limestone formation. The grey coloured clay also occurs in the nala section west of Dumlai. It is overlained by lateritic soil. The parent rock laterite dips 10° towards north-west direction. The exposed thickness above the nala bed varies from 0.9 to 1.5 m. A buff coloured clay occurs in a well section at Kondh in the Valia Mahal taluka. The overburden is about 7.5 m thick and clay beds appear to be lenticular in shape. It is plastic, hard and somewhat calcareous.

A small deposit of kaolin having thickness of 1m occurs under black soil cover to the north-east of Bharan in Valia Mahal taluka. A white coloured, highly plastic, kaolin occurs associated with Tertiary rock formations at Kadoli. Similar clays are reported from Damlai near Rewa-Kantha area.

4.5.2 Junagadh

A deposit of white clay, about 1.5 to 2.4 m thick occurs under a thick soil cover, south of Panchala. An extensive deposit of clay of varying colours and grit contents occurs near Kadiali. There are three main types of clays, greyish white, red and buff clays.

4.5.3 Kuchchh

The Anjar, Bhuj, Lakpat, Mandvi, Nakhtrawa clay deposits associated with the beds of Bhuj series occur in eight localities of Rapur taluk. At Makhona dull white and grey clay, fairly plastic, showing shrinkage of 10 percent without any vitrification are reported. The light grey and buff coloured clay fairly plastic, 12-15 percentage shrinkage, with fair vitrification are found near Dagala, Khedai, Mammara and Fulra areas. The moderately plastic clay with 18 to 24 percent shrinkage showing vitrification are reported to occur from Ghuneri, Madh and Kotra localities of this district.

4.5.4 Mehsana

The clay deposit occurs at Virpur on the western bank of the river Sabarmati is an alteration product of granite rock covered by lateritic soil and alluvium. Another deposit of Kot-Ransipur is also similar in nature. These are white in colour with moderate plasticity. In Panch Mahal district the Rajpara deposit is associated with Infra-trappean beds. These show poor plasticity with no shrinkage.

4.5.5 Rajkot

Greyish white plastic clay is reported to occur about 3 km east of Wankaner Railway station. The aluminous clay associated with laterite is reported to occur in the neighbourhood of Panchala near Nururda. The quarries situated about 7 km west of Wankaner near Rati Devli are 5 m thick and are overlain by thin bed of sandstone. Another clay bed of 2 m thick occur at Vagadia is white, slightly gritty and non-plastic. Clay occurred at about 1 km north-west of Velala is 1.2 m thick and underlain by variagated sandstones. At Udepur near Makansar, a bed of about 1.5 m thick grey and highly plastic clay occurs over a large area. At Velala, grey-coloured clay occurred over a large area. This is upto 1.2 m thick, underlain by sandstones[5].

In Idar, chinaclay deposits are reported to be on the eastern bank of the river Sabarmati between Tachawa and Phudera. These clays are of about 8 m thick and are underlain by laterite and loess. These are believed to be derived from the alteration of granite rocks. Extensive chinaclay deposits in the areas of Eklara and Asroria covering a surface area of about 7 sq.km were noticed. These deposits overlies the granite gneisses and underlies the Ahmednagar sandstones. These have been formed by the decomposition of both the rock types. The clay is fine grained, white with uniform texture and plasticity.

The occurrences of chinaclay are also known from the areas of Himatnagar, Katwar and Hapa of this district. The clay deposit in these areas are light grey to pink in colour and upto 3 m thick and are found interbedded with Himatnagar sandstones. The dull white, grey and buff coloured clays occur near Khedoi, Manmara and Fulsa areas. These are moderately plastic, fires reddish brown with 20% shrinkage and shows fair or no vitrification. Similar types of clay occur near Pandra, Ghuner, Madh, and Koltra areas. The deposits which are associated with upper Bhuj series of Cretaceous age are Mokhana, Dagala, Kheddi, Mamuara, Madhapur and Asambia. In all these areas, soft and buff coloured clay beds occur under a thick cover of lateritic sandy soil. These clay beds are lenticular in Mamuara, banded in Madhapur and in other areas it is irregular in nature. In Panadhra and Mata-nu-Madh areas the clay beds are associated with Eocene rocks. About 4 m thick, soft and buff coloured clay beds occur in 1 km length, under 12 m thick laterite capping in these areas.

4.6 Haryana

In Haryana important deposits of chinaclay have been located in Faridabad and Gurgaon districts. These deposits are of low grade and hence after proper washing it is being used in paper and textile industries.

4.6.1 Faridabad - Gurgaon

The areas in these districts are occupied by hard and friable quartzites belonging to Alwar series and are intruded at places by post Delhi pegmatites. The feldspars in the pegmatites has given rise to deposits of chinaclay due to alteration and weathering of the parent rock. In planar and peneplained areas of Faridabad-Gurgaon districts, older and newer alluvium and their derivatives are exposed. The remnants of quartz and tourmaline are left as it is and mica is altered into sericite due to alteration of feldspar. In addition to this, the chinaclay has also developed in feldspathic quartzites at few places. Hence, the deposits in these areas are assigned to be of structurally controlled. Sai chinaclay, Anangpur leases in Faridabad and Sundh chinaclay deposit in Gurgaon district are of this type[6,7].

The chinaclay deposits in the Anangpur area of Faridabad district have developed within the intrusives of pegmatites and quartzites. The in situ chinaclay developed due to alteration of feldspar has given rise to kaolin while the remnants of quartz, tourmaline are left as it is, and mica is altered into sericite. At few places chinaclay has also developed from feldspathic quartzites. The chinaclay deposits in the belt are few and limited[6].

4.7 Karnataka

In Karnataka state, good quality of chinaclay deposits occur in Belgaum, Bidar, Dharwad, Kolar and Shimoga districts. Smaller occurrences are reported from Bellary, Hassan, Chikmagalur, south Kanara and Tumkur districts. The description of the different deposits in these districts are as follows :

4.7.1 Bangalore

In Gorpatya area, clay is plastic grey in colour and occasionally gritty with an average thickness of 1. m occurs in a low ground area. Another deposit in Agara a plastic greyish clay of large size is found in the bed of the tank. A kaolin deposit formed as a decomposition of granite-gneiss occurs at Golhalli. The Nandagudi, Venkatapur and Wabsandra are the other kaolin deposits of uniform grade and extends to a depth of 5 m. The smaller deposits are reported from Gazerigredde, Karubarhali, Kamblipur, Yeshwanthpur, Hettakki, Lingapur and Buvanhalli areas.

4.7.2 Belgaum and Dharwar

The kaolin deposits in these districts are reported from a number of localities, namely Ramgurwadi, Gollihalli, Karalaga, Garalgunj and Desur. Whereas in Dharwar district, Varvi and Majjur deposits are important[7]. The area belongs to Archaean group of rocks consisting of granite gneiss, schists, etc. Generally, clay occurs below a soil cover of 0.5 to 2 m thick. The chinaclay reported to occur 5 m below the hard country rock. The Ramgurwadi-Bacholi area is situated on an elevated mound. The clay is upto 10 m thick in this area. The upper part of the clay bed is brownish in colour. The lower part, below 5 m is brownish cream, while the bottom-most is of white in colour. The clay reported to occur in pockets.

In Gollihalli area, the clay occurs below 1.5 m thick soil cover. The clay is yellowish with pockets of white to violet colour clay. Towards eastern side of the pit greywacke/phyllitic type of rock is exposed with N 15° -S 15°E strike having nearly vertical dip. In Karalaga area at places the granitic gneisses are exposed in the eastern part, the upper 1 m part of the clay bed in the western side is harder, while the lower 3 m part is softer. Chemically, there is no difference between these two. It is known that the clay bed is continuing further in depth below the ground water. The Desur area situated in a slope of a hillock. The orebody is overlain by lateritic soil with the thickness of upto 1.5 m.

The Varvi area is located along the gentle slope of a hillock trending N-S. Buff to cream coloured clay is found below a soil cover of 2 m. The feldspathic gneiss occur within the clay zone causing impurity. The quartz veins and banded magnetite quartzite also disrupts the quality of the clay in the varvi area. Whereas the Majjur chinaclay deposit is located at the foot of the hillock. Main country rock is not weathered fully to form the clay but the weathered feldspathic gneiss has given rise to these clays. The deposits at Garalgunj are covered with soil and laterite upto 3 m thick, below which occurs the pockets of yellowish clay mixed with the unweathered feldspathic gneiss. The pure white clay reported to occur as pockets in Ramgurwadi area. Mineralogically the clays occurring in the area consists of clay with major amount of quartz. The feldspars (orthoclase and plagioclase) and iron hydroxide are found in minor amount. Apart from this, talc and carbonates are also found in minor amounts. The approximate percentage of different mineral constituents of Ramgurwadi-Bacholi and Varvi areas are as follows :

Mineral	Ramgurwadi--Bacholi (%)	Varvi (%)
Clay	65 - 70	55 - 60
Quartz	20 - 25	31 - 35
Iron hydroxide	3 - 4	1 - 2
Feldspars	5 - 7	-
Carbonate	-	3 - 5
Talc	-	2 - 3

These clays are generally non-plastic. The grit content appears to be comparatively more in the area of Shirhatti than that of the clay from the area of Khanapur. The clays of khanapur area are comparatively higher in alumina than in Shirhatti area. The chemical constituents of both the areas are presented hereunder.

Constituent	Shirhatti	Khanapur
SiO_2	58 - 67	64.71 - 78.18
Al_2O_3	16 - 19	10.76 - 13.06
Fe_2O_3	2.05 - 4.14	0.65 - 1.39

4.7.3 Bellary

A small occurrence of white clay fairly plastic have been traced in phyllites at about 1 km east of Kumaraswamy area. Another deposit occurs at about 5 km NNE of Sandur in association with purple and red phyllites.

4.7.4 Bidar

The deposits of white clay are found in a plateau near Kamthana about 11 km southwest of Bidar below the ferruginous laterite and lithomarge derived from the Deccan Trap formation. The whole sequence rests on a decomposed trap flow. It covers an area of atleast 4 hectares with an average thickness of 0.6 m. Another deposit Shekapur is located about 2 km SSW of village Shekapur on the Vicarabad-Bidar Railway line. The clay is white and about 3 m thick admixed with earthy impurities.

4.7.5 Chikmagalur

White decomposed gneiss is exposed in the high bank in Mottgoad near Bomlapur. The material contains quartz and occurs below 3 m laterite capping. The clay is highly plastic and free from mica. In the north of Hariharpur on the left bank of Tunka river, pure white clay occurs from decomposed granite. A whitish yellow decomposed granite-gneiss is exposed in the high bank of a local garden in Asagod at about 6 km south of Hariharpur. Occurrences of chinaclay of limited extent are reported from Kikri, Moskoppa, Malhalli, Kakkod, Haralkudge, Kaila-Kusugli and Kesave areas of this district.

4.7.6 Hassan

The Bageshpura clay deposit covers a large area and are produced from the alteration of gneisses and pegmatite rocks. The clays are slightly micaceous, light coloured with reddish and yellowish stains. Since the percentage of iron is not much, the kaolin from this area is considered to be of high grade. This deposit is spread in two areas namely Appenhalli and Nandihalli.

4.7.7 Mysore and Kolar

Pure white kaolin, containing varying proportion of white granular quartz and small specks of silvery white mica occurs in large quantities below the soil cover in several places at Melkote and to its north-west in Mysore district. A low grade siliceous clay occurs in the decomposed gneisses in the vicinity of Melur in Kolar district.

4.7.8 Shimoga

The deposit at Keremane-Thenkabylu occurs about 1 km east of Mellagi and probably extends towards north beyond the Thenkabyl cliff under a 6 m thick yellowish laterite. Another clay deposit with considerable amount of mica flakes occur at Ulve at about 1 km South-West of Mellagi on the Koppa - Tirthahalli road. The Jittenuthur, Makkimane, Jidikuni and Bikkalli are the other deposits occurring on the same road.

The deposits of Kaolin are also reported within a radius of 5 km from Anandpuram area in Shimoga district. Extensive deposits of clay of dull yellowish colour occur along Balagudi Railway cutting. Large outcrops of low grade kaolin of various colours occur in and around Avinhalli along the Hosnagar and Hirebhasgar roads. The deposit Garbyle occurs near Narsimharajapura. The kaolinised material is reported below 9 m soil and laterite cover. The Doramakki, Bennegundi, Belehonnur, Varkatte and Barsarahalli are the other deposits in this district, where the good quality of clay occur as thin bands. These appears to be an alteration product of pegmatite. Besides these kaolin deposits, at Maradi, Nagdevalli, Verali, Belekoppa, Salur, Boggarvalli, Krishnur and Malali areas the clays are reported in a smaller scale.

4.7.9 South Kanara

A five metre thick dull white and pink coloured clay covering 65 sq.m area occur below laterite cover at about 3 km from Kasargod-Jalsur road. A buff coloured clay with dull red patches, with 5 m thick covering an area of 1.3 sq.km occur near Periya. The material is fairly plastic with 26% shrinkage. A pale cream, buff and white clay about 1 m thick occur near Bolur. An extensive white clay occur near Hosadurg in the gneissic country rock. Indication of chinaclay are found below laterite near Urwa, Kedial-bail and Kadricolen. Chinaclay deposits are also reported from Bavar, Uppala, Mulipja, Kadibail, Kasargod, Ajanur, Bare, Madikai, Nileshwar, Kinapur, Kodakkat, Charavattur, Puthiyan ,Gadd and Madavi areas over a stretch qf 40 km below a laterite capping.

4.7.10 Tumkur

An extremely fine grained, soft, compact white clay occurs in large quantity in Karekurchi, Muskondi, Shivasadra and Janenar. The clay free from grit, has a greasy feel with 2 m thick lateritic capping. The Kondli deposit is located about 10 km to the north of Ansandra Railway station in a scattered form. A white coloured, highly plastic clay is reported from Dodgollahalli of this district.

4.7.11 Other Districts

An extensive deposit of chinaclay is exposed at Kalkod near Shravata river at 1.6 km east of Hanaswar and also at the foot of the laterite hill in the same area. White coloured chinaclay derived from gneisses occur at Hadinbal under a thick laterite cover. The deposit also extends westward upto Nagara. Besides above localities, kaolin is also reported from Shirali and Bengare areas.

4.8 Kerala

Clay beds in Kerala are intimately associated with laterite horizons. Along the coastal region, good clays of all types and suitable for many clay-based industries are reported to occur in many districts of Kerala State. Clay is known in 8 out of 14 districts. Out of which only 4 districts are having commercially viable deposits. As regards the occurrence of chinaclay, the various reports of investigations and field studies indicated two types clay viz. sedimentary and Residual clay in this state. The sedimentary clays are believed to have formed by a process of inheritance in a confined environment and the residual clay by alteration/kaolinisation of crystalline gneisses by the Neoformation. The kaolinitic clays are known to occur[8] from north to south in the districts of Kasargod, Cannanore, Palaghat, Trichur, Kottayam, Ernakulam, Quilon and Thiruvananthapuram. As regards the Alleppey district the lithologs maintained by CGWB shows the presence of alternating layers of clays with variegated, carbonaceous and fossiliferous shales at various depths underlying sand, laterite, limestone, etc., sometimes even beyond 200 m depth.

The chinaclay occurring extensively in the four districts viz. Kasargod Cannanore in north and quilon, Thiruvananthapuram in south are divided into two distinct belts namely northern and southern belts. In both these belts sedimentary and residual clays occur. However in these belts the sedimentary clay is of much importance as far as mining and economics are considered than residual clays. This may be because of the fact that residual clays are of low grade and occur at greater depth.

The clay zone is of 6 to 15 m thick in Kasargod, Cannanore, Quilon districts and 4 to 20 m in Thiruvananthapuram district. The maximum thickness of 20 m is found in the Melthonnakkal area in Thiruvananthapuram district. The Quilon and Thiruvananthapuram districts cover an area of roughly 256 sq.km of the deposit. The thickness of overburden (generally laterite, is upto 15 m in all the districts. The weathered feldspathic gneiss and charnockites are found to occur below 40 to 70 m depth. In Cannanore and Quilon districts the clay horizon is often interlayered with lignite and carbonaceous clay typical of Warkallai beds. In Thiruvananthapuram district three main zones have been demarcated in Melthonnakkal, Azhoor and Veiloor villages within which 14 hamlets are known to be mineralised. The occurrence of clay deposits have a relationship with the topography. In Kasargod, Cannanore and northern part of Quilon districts, the clay deposits are found on the elevated grounds and plateaus while the adjacent paddy fields, valleys and low-lying areas are known to be barren. whereas in Thiruvananthapuram district the flat grounds are potential.

In the area between Kundara & Warkala[7] a large quantity of excellent quality of chinaclay deposits were formed. These deposits are the products of decomposition of granite gneisses. Also important occurrences of china clay are found in a narrow zone in the fringes of Western Ghats near Pudukai, Koyan Kunmam (Hosdurg), Mulinja and Keyyuru areas.

4.8.1 Cannanore

In Cannanore district, best quality of chinaclay occurs at Kannapuram, Palayangadi and Nileshwar. The Kannapuram clay deposits are irregular in extent and are of gritty nature. Palayangadi clay deposit occurs below the laterite near the village Madai. The clay deposits occur at the depth of about 30 m. The thickness of clay bed is about 10 m having good quality. The overlaying 30 m horizon is comprised of intermittent beds of lignite and carbonaceous shale. The lignite seams and carbonaceous shales belong to Tertiary formation. This clay carries roughly about 45% of grit and is of fairly good quality. About 1.2 km east of Madai the same type of clay deposit occurs near village Eripuram changal. At Rampuram near Cheruthazhom railway bridge a small quarry of plastic clay occurs.

At Nileshwar the clay deposits having thickness of about 10 m overlain by 10-15 m thick Tertiary sandstones, (clay and laterite) are observed. This clay is pure white in colour with specks of pyrites. It is highly plastic and burns white at 1280°C. It has no air shrinkage and the fired shrinkage is 10%. About 2 km east of Nileshwar quarry, similar type of clay deposits are noticed. The clay of this locality is of sedimentary origin. Other sedimentary clays are noticed near Palayangadi, Madai and Kadamkote Mala in Cannanore district.

4.8.2 Ernakulam

A good quality of chinaclay deposits are found around Trikkakara-Majumel area. The clay is mostly white in colour with about 45-55% grit matter. On washing, the clay appears dull white and also burn dull white with high degree of plasticity.

4.8.3 Quilon

The chinaclay deposits of Kundara in (Kollam) Quilon district of Kerala has been formed from the weathering of granite gneiss. The clay layer is around 1 to 4 m thick and is covered by tertiary sandstone. Kundara clay mines of Kerala ceramics is one of the biggest clay deposits of south India. It is owned by Kerala Government and is a captive mine for its ceramic factory at Kundara. The white clay deposit is spread in 2.5 sq.km of area below 30 m laterites. The area belongs to Warkhali formation of tertiary age. The beds are horizontal and do not show any remarkable variation in dip. However, a small fault zone has been noticed in the centre of the deposit. The structures of current bedding and cross stratification is seen on top layers of sandstone. Since the thickness of Warkhali formation overlying the kundara area is not uniform, the chinaclay bed is also variable with its quality and thickness from place to place. The clays are plastic and shows 24% shrinkage. In Chattannur white kaolin occurs in varying thickness near Pasavur Railway station. At Kerivellur and Tiruchembran a poor quality of china clay is reported on a high ground below the laterite capping[9].

4.9 Madhya Pradesh

A number of clay beds[10] of fairly good quality are seen in the districts of Chhindwara, Durg, Jabalpur, Hoshangabad, etc.

4.9.1 Chhindwara

A grey sandy clay occurs about 2 km north east of Baghi in a nala. Similar occurrences are seen in Mandhi, Kodia and little southwest of mandhi areas. Three beds of clay belonging to Jabalpur stage occurs in Khirkighat and Rojhori areas. The uppermost bed is about 1.2 m thick having good quality of clay separated by 1.8 m sandstone followed by 1 m clay bed. Further, there is a possibility to continue these beds in the westward direction. In Chilak area, a number of fine grained fairly plastic clay beds with high vitrification occurs. 1.5 m thick, yellowish white, good quality clay occurs in Rajihni, Banskhera, Bhond, Khalla, Kotra, and Bamnikalon areas. Whereas in Kundali, a 3 m thick bed of white, non gritty clay occurs between decomposed santstone and trap. The clay is very hard and fairly plastic.

4.9.2 Durg

A white to pale cream coloured lens shaped clay occurs about 4 km north of Charbata in a pegmatite rock. The clay is fairly soft and highly plastic. At Hitapathar a clay bed more than 4 m thick occurs about 1 km east of Hitapathar village in NW-SE trending pegmatite. About 800 m NNE of the same locality a 3 m thick dull white clay bed occurs in an altered granite. In Kohka, Dhabarand and Markahasa areas a good plastic clay showing high vitrification is reported. These are derived from the decomposition of felsic prophyry.

4.9.3 Gwalior

The Bela-Ki-Bori chinaclay deposit, located about 15 km from Gwalior city on the western side of the Agra-Bombay road is 2.4 m thick and is stained with red and yellow colours. These clays are medium hard and highly plastic. Another deposit of white clay, about 3 m thick occur about 1.2 km north-west of Naogaon. Similar deposits occur at Mahabir-ki-Kho, Chkonra, Shivpur, Santow, Dhiroli Jorasi, Barovi, etc. areas. In the hillocks of north and northeast of Bandholi thick bed of pink clays are exposed in ferrugnious shales overlying limestone. The minor occurrences are also reported at Ramana about 1.6 km south of Behat, Ratwa, Sihari, etc. areas.

4.9.4 Hoshangabad

The clay bed about 0.75 m thick occurs at Gotiloria on top of a plateau. Another sandy clay bed of 2 m thick overlying the 2.4 m thick sandstone occurs in a trial pit within the vicinity of Gotiloria. Four different clay bands with varying thickness (upto 2 m) occurs north of Hingpani. Besides this, an occurrence of another band of about 1 km North-West of this deposit is known. These clays are very fine grained and compact with pale white colour. Thin beds of alternating grey and pink clays are exposed in the high cliff section of the Kokripani. Another clay bed about 1 m thick outcrops at a distance of 800 m west of Talaia.

4.9.5 Mandsaur

White coloured chinaclay bands of varying thicknesses upto 6 m occurs extensively at Piplia and Mandsaur in Binota shale formation. The other important quarries are located at Bandkheri, Bogilari, Giyardia, Daulatpura, Multanpura, Bhuniakheri, Dinyerakheri, Pithiakheri, Dunglaida, Bahi, Khera, Kanghatli, Supra Gurha Bala and Umaria. A calcareous white clay derived from decomposition of granite occurs at about 1.6 km north-east of Antri and extends upto Torasi. The clay is usually gritty and occurs within a few metres from the surface. It has fair hardness and good plasticity. Thin bands of white clay occurs in association with the grey and pink shales overlying the lower Bhander limestone at Sabalgarh, Moraig and Bhari areas. These are deposited in limited extent with poor quality and used locally for white-wash.

4.9.6 Jabalpur

A white clay deposit overlain by Lametas occur at the foot of Chui hill near Jabalpur. At Murwara laminated pink and white lithomarge occurs under a capping of laterite. The clay deposits at Patbara Ridge, Polipathar are situated at about 6 km south east of Jabalpur attains a thickness of 6 m with intermittant sandy clay partings. Two clay beds having thicknesses of 1.8 and 1.2 m are intervened by 1.2 m sandstone parting at Nayagaon area. The deposits at Garha located at about 4 km south west of Jabalpur are of 1.8 m thick and are highly siliceous. The Mahanadi, Mahgawan, Halbai, Khetanli, Berwani are the other deposits where clay beds intercalated with slightly micaceous and ferruginous layers. At about 400 m south of Lametas, on the northern bank of the Narsada river, white fine grained, clay occurs upto 9 m thick. The Bhaganavara, Kudri, Basari, Hardua and Bujbuja deposits are of bedded arenaceous associated with Sirbu shale series. These are of uniform quality with variable thickness upto 6 m. Apart from these the white and grey coloured clays belongs to Gondwana formation are located near Kherani, Singanpuri, Jharela, Bilgada, Parsl, Jamunchua and Bhamka areas of this district.

4.9.7 Other Districts

A greyish white clay occur near Kheri about 15 km to ENE of Begamganj. Another deposit at Tinsai is about 2 m thick, followed by Kunda, Barha, Sodarpur, Sambhapur, Bhanpur, Ventkata and Gaonras are the other deposits in Raisen district. The kaolin deposits of smaller nature occur in Vidinagar, Kisangarh, Joshipuba, Nardaspur in Dhar district. A limited quantity of white or pink clay is exposed at Jaganpur, Shivpuri and Rai areas of Guna district. A thin band of clay with limited extent occurs 1.6 km away from Hardaspur in Jhabua district. These are dull and gritty and associated with pink granite underlain by Lametas. The good quality of clays, interbedded with gently dipping white, soft and micaceous sandstone occurs in a nallah at Chindkhera in Narsingpur district. It is followed by Bhilmadhana where the clays are upto 2 m thick, sandy and occurs about 2 km south west of Bhilmadhana area. The Jogikhapa, Ranikhamar, Chindkhera and Jatipur areas also consists of sizeable deposits of chinaclay. In Khursia of Raigarh district, a good quality of chinaclay is reported. In Mukatata of Raipur district also, a similar quality of clay is known to occur in association with Chandarpur sandstone. The Chandalla and Jamthan clay deposits of Shahdol district are white in colour, fairly plastic, non-gritty and are found to be the products of decomposed sandstones of Gondwana age[10].

The mottled pink and white coloured clays occur below the Deccan Trap to the south of Koruda, Sambhar, Kajuria and Nivari hills in Sidhi district. White clays occur with red and yellow ochre in Amirti, Majhpara areas of Satna district. These are occurring under a cap of thick laterite and sandstone. The sedimentary clays which are found at Raikot, Manganpur and Kokel areas of Bastar district are white in colour and are being exploited.

4.10 Maharashtra

4.10.1 Amravati

The white clays occur as pockets and beds in Lamata sandstones in Bairanghat, Khakpisimpir, Belkhera and Pandhari areas.

4.10.2 Chandrapur

The low grade kaolinitic clays associated with Kamthi formation having average thickness of 2 m occur near Isapur, Ballarshah, Junana, Katali and Kothari areas. The material is poor in plasticity and has low linear shrinkage. The Gondwana clays are also found on Bhiusun hill near Adhari.

4.10.3 Kolhapur

A bed of lithomarge occurs beneath the laterite about 19 km north-west of Kolhapur. The material is white to pink and finely laminated with rich iron content. In Gudalkop area, a bed of kaolin, capped by laterite, are overlained by traps. The clay is white at places pisolitic and high in alumina content. The kaolin bed occurring near Bherdargarh is reported to be about 6 m thick.

4.10.4 Other Districts

White coloured inter-trappean chinaclays occur at Khapri, Chorkheri and Shemda areas of Nagpur district. The Kumbharmatt deposit in Ratnagiri district is of good quality and slightly plastic. The lime free plastic chinaclay is reported in a nallah north of Jalgaon area. In the scarps overlooking panchagani, laterite is reported to occur at a depth into a zone of lithomarge and then into a kaolinised trap. The white plastic clay occurs in association with sandstone in the vicinity of Nala-sapora and Honawar areas. The thickness of the clay bed is upto 6 m occurring in a length of about 1.6 km. The inferior quality of lateritic clay occurs in and around Gokhara near Base in road station in Thana district.

4.11 Orissa

In Orissa the china clay deposits are occurring in a belt extending from North to South for a distance of more than 60 km length and 35 km width. The eastern and western limits are demarcated by the Semlipal hill range and iron ore range respectively. The chinaclay bearing area is a wide peneplain table land of granite terrain. The granite is essentially coarse to medium grained and highly feldspathic. The granites have been intruded by a number of pegmatites and ultrabasics. The granitic plains are mostly covered by alluvial soil. Fairly large areas exhibit features of lateritisation. Capping of murrum or lateritic concretions upto 8 m thick are present over the gently elevated grounds. The china clay deposits are distributed in allmost all the districts of the state. The important districtwise deposits are described hereunder.

4.11.1 Balasore and Bolangir

White coloured plastic clay of 3 m thick occur below laterite capping/north of Girdihi and Arabandha areas of Balasore district. The small pockets of Kaolin occurs in Sargod, Bhaludongri and Mendah areas of Bolangir district. The highly siliceous kaolin noticed at Narayanpur in Bolangir district is found to be derived from the rocks of granites and anorthosites.

4.11.2 Cuttack

A white clay occurs as beds in association with Gondwana rocks on the banks of the river Mahanadi. It varies the thickness upto 2 m under a 4 m thick laterite capping in Nirej and neighbourhood of Khurda areas of this district. Small occurrences of white, gritty kaolin occurs at Baideswar hill, in a nallah 2 km NNW of Brahmanbil, Banrapal, Raijharan, Chandipada and Sampoda areas.

4.11.3 Dhenkanal

In Hinjipider Ghati white chinaclays occur in association with sandstone and covers a large area. The clays at Sibulupose are yellowish in upper but white in lower portion, and occurs at about 1.6 km North of Sibulupose village are derived from the decomposition of feldspathic gneisses. The material is fairly plastic, gritty and occurs at 12 m depth. Similar type of clays occur at Mendhapoda in this district.

4.11.4 Ganjam

Stained and gritty Kaolin derived from the decomposition of feldspathic granite gneiss occurs near Sorongoda. Small deposits of kaolin occur at east of Siringia, Dwargam, Antarpalli, Jillinda, Satrusola, Bramarapur left bank of Haribhang river opposite to Adara, etc. areas in this district.

4.11.5 Keonjhar

The Keonjhargarh deposit falls about 1.6 km west of the town Keonjhar. Kaolin occurs on the slopes of the hill, in two patches separated by a band of weathered epidiorite and the reserves are of very high order. The Taranipukuri and Amuapara deposits occur at about 2.4 km north of the village Piparia on the Keonjhargarh-Jaipur road. The chinaclay is also exposed in the cuttings of Kasainala area. The depth of workings varies from 9-15 m in this area. The Sundi Mursua deposit lies between Keonjhargarh and Chaibasa.

4.11.6 Koraput

An extensive deposit of Kaolin is reported to occur at about 4 km east south east of Koraput near Oduguda. The clay is slightly gritty, fairly plastic and pinkish white in colour. Other smaller deposits are Musoriguda, Pukkili, Jodiguda, Naugaon, Madhupur, Ladipanga, Pittukond, Singarajukunta, etc.

4.11.7 Mayurbhanj

China clay deposits of Mayurbhanj[11] district are of primary type and are the in situ alteration products of granites caused by hydrothermal solutions and gaseous emanations. The clay belt which extends to a length of about 6 km with an average width of about 35 km aligns in North-south direction. The clay horizon extends beyond 30 m in depth as evidenced from the boreholes. The clays are associated with grits, mostly undecomposed quartz of aplite and pegmatite veins. They are in general pale cream to pale white in colour. These are occurring below a soil/laterite cover of upto 4 m thick. The working areas in this district are Jamkeshwar, Nanua, Joshipur, Jamda, Kadodia, Dumuria, Chanchboni-Purnapani and Gudidiha. These areas are a part of the wide peniplain table land of granite terrain.

Jamkeshwar chinaclay deposit is located [11] about 5 km east of Joshipur-Rairangpur main road. In this area as many as 8 quarries of various shapes and sizes were opened. The clay zone with ferruginous shalley partings, was exposed below 0.5 m thick soil cover. The top 2 m clay was yellowish in colour, which improved at depth. It is of medium grade clay.

The Nanua chinaclay deposit is situated near village Nanua, about 10 km west of Joshipur. The chinaclay zone was exposed below a 5 m thick cover of soil and a 4 m thick laterite. The clay is yellowish in colour at the upper part and the colour improved at depth. The quality of clay produced from this pit is reported to be of pottery grade. The recovery of crude chinaclay from this quarry reported to be about 40%.

The Joshipur deposit is located about 2 km south of Joshipur, on the western side of the NH-6 Highway. Chinaclay in this area occurs in the form of pockets below a cover of soil/lateritic overburden. The thickness of this overburden varies from 8 to 10 m of which top 5 m is hard lateritic soil followed by 3 to 5 m thick admixture of clay and murrum. The area does not reflect any major structural disconformity. The Joshipur deposit covers an area of about 121 hectares. The clay zone was found to extend NW-SE direction. It is extending upto a depth of about 15 m.

The Jamda area is approachable by a 3 km long fair weather road taken off from the NH-6 about 2 km south of Joshipur town. Chinaclay in the area occurs in the form of pockets, below the soil/laterite overburden cover. The thickness of this overburden is about 4 m.

The Kadodia area[11] reflects a plain topography with occassional narrow, low lying ridges of dolerites. The dolerite dykes occurs as a parallel to sub parallel ridges towards the eastern and northern parts of the area. The plains are mostly covered with alluvial soil. Chinaclay occurs below the soil/laterite cover and is an alteration product of granitic rock. No structural disconformity has been observed in the area. It is located in the plain area to the east of Kadodia village. In Kadodia area, three different grades of clay are being produced.

The deposit Dumura is located about 8 km west of Karonjia. It is more or less undulating ground, with small mounds of laterite and other quartz-feldspathic rocks. The small valleys between the mounds are good prospects of chinaclay. The chinaclay occurs below the soil/laterite cover and is an in situ alteration product of quartz - feldspathic rocks which does not reflect any structural disconformity. Sampling and analysis of clay obtained from the exploratory work resulted in five different grades of availability, i.e. pharmaceuticals, super textile, pottery, paper and insecticide grades.

Chanchboni and Purnapani are the two adjoining deposits located at 2 km west of the Joshipur-Karonjia road. These two deposits together are spread in an area of about 184 hectares. The chinaclay occurs below the soil/laterite overburden seems to have not been affected by any structural disturbances. The clay zone exposed shows that the top layer is yellowish in colour, at depth it improves its colour as evidenced from pitting and adjacent quarrying. The chinaclay produced from these areas are reported to be of good quality with two varieties.

The Gudidiha deposit extends in an area of about 207 hectares, located around Panaspol and Gudidiha villages . The clay occurs below a hard laterite of 0.5 m thick. Clay is associated with pegmatites, quartz veins and is having a yellow tint. But at depth it becomes whitish. A considerable quantity of pale cream coloured clay occurs in Borisabari, Karalia, Kurma, Bisai and Baripada areas of this district.

4.11.8 Puri

The white clay beds, gently dipping with 1.2 m thick occurs in association with Gondwana rocks in Barthalimundia, Bharatpur, Jagannathprasand and Patharkata areas. The material is soft and plastic with a lateritic capping of upto 3 m.

4.11.9 Phulbani

A bed of white clay, about 3 m thick derived from decomposition of gneisses occurs at Karanda and adjacent areas. Another deposit in Bahandh area is also reported. The other small deposits occurs at Deogarh, Tuljeri, Ratakandi, Dudurkot, etc. areas in this district.

4.11.10 Sambalpur

The white fairly plastic, gritty, free from ferruginous clays occur in association with Gondwana rock at about 2.4 km north-east of Rail. The chinaclay stained red and yellow derived from weathering of gneisses is reported to occur near Ghichamura. Similar types of clay are reported from Sagunpali and Chuhukitikra areas. Whereas in Baresinghari the clays are derived from the alteration of quartz-sericite-schist, which strike NNW-SSE and dips steeply toward, ENE occurs about 1.6 km south west of this place. A deposit of lithomarge occurs in banded form about 800 m northwest of Akhradand on a laterite ridge which trends WNW-ESE. A bed of white clay occurs in association with quartzites and sandstones of Cuddapah age in the south-east of Khola. In addition to the above mentioned localities, the occurrences of chinaclay are reported from khenda, Metapali, Erapali, Banjipali, Piplipali, Katapali and Donga Chhuncha areas.

4.11.11 Sundargarh

An extensive deposit of white clay suitable as a filter in paper idustry occurs near Banjipali. The chinaclay deposit occurs as pockets in Pegmatite veins at Manjapara. The kaolin clay occurs in Barakar sandstone of Gondwana rock formation at Amadpani. Besides, a band of white coloured clay occurs along Deo river near Kundraughttul, Kardaga, Baraibera and Birmitrapur areas.

4.12 Rajasthan

Good quality of chinaclay deposits[12] occur in Ajmer, Barmer, Bikaner, Jaipur, Jaisalmer, Jodhpur Nagaur, Sawai Madhopur, Pali and Udaipur districts of Rajasthan. These deposits are believed to be derived through hydrothermal alteration process of feldspars from the granite gneisses. All these deposits cover an area of 567520 Sq.m. It is found that the altered granite zone extends upto a depth of 68 m in some places.

4.12.1 Ajmer

The stained kaolin deposit occurs at Goredung believed to be formed due to the decomposition of granite and pegmatite rocks upto a depth of 9 m below the surface. At Laungia the clay is white, non plastic and slightly gritty due to the presence of undecomposed feldspars. The Mailan clay deposit occurs in the Machla hill, 1.2 km south west of Mailan, on the Ajmer-Berar road. It is plastic and stained.

4.12.2 Barmer

A bluish white 3 m thick clay inter bedded with Barmer sandstone occurs at 2.4 km west of Barmer, on the slope of the hill. In Botia area, six clay seams interbedded with varying thickness occurs in a nallah bed about 2.4 km south west of Botia village. These clays are white in colour and fairly plastic with smooth texture.

4.12.3 Bikaner

The clay deposits of Bikaner district are mainly confined to Kolayat area. Based on the occurrence of clay and concentration of the deposits, these are locally grouped into five major blocks viz. Murh, Gurha, Kotri, Indoka Bala and Chandi blocks. The Murh-Gurha area is about 50 km from Bikaner and is connected by National Highway towards Jaisalmer. The area is located in Thar desert. The rock formations in this area lie on part of shallow synclinal basin having E-W axis. Clay deposit occur as thin alternating beds having thin partings of ferruginous sandstone. Average thickness of individual clay beds is about 2 m except the places like shankhala Ki Basti and Mudh where the thickness has reached upto 6 m. In Murh block three beds and in Gurha block eight clay beds were reported. However the cumulative thickness of clay deposit at Muh block is more than Gurha block.

The rock formations which has been encountered in Bikaner district are of sedimentary origin and belong to four major formations such as Palana, Modh, Jogira and Kolauyat formations. In Muh block three main beds of clay separated by two ferruginous sandstone beds are termed as upper, middle and lower beds. The three clay beds are comparatively thicker than the interbedded sandstone bed.

The upper clay bed is the thickest upto 7 m. The quality of clay has been affected due to surface coatings of ferruginous material on the surface of the clay. The occurrence of clay in Gurha block is also similar to Muh block except the number of layers. Though some isolated small pockets of clay deposits occur near village Goleri, Jhaju, etc., the main clay deposits are located at Kolayat, Chandi, Indo-Ka-Bala, Kotri, Mudh, Deh, Shankhala-Ki-Basti and Gudha areas. The clay deposits of Kolayat area extends over 23 km length from village Chandi to Gudha and over 13 km in width from Kolayat town to village Gangapura.

4.12.4 Other Districts

The chinaclay deposits are reported to occur near Bodana Khanda and Sirol in Kota district are of good quality. The deposits are also found at Gehain in the Malani area of Jodhpur district. Minor deposits, in the form of pockets are found near Vagda, Deulwadi and Hiala areas. The Beds of whitish to pinkish coloured low grade chinaclay occurs below 15 m thick sand at Nagurda, Gunga, Kharadia, Nimla, Bhopa-Pamer-Ki-Dhani, Sonri and Bhadres areas of the district.

Chinaclay of varying thicknesses upto 4.2 m occur below the overburden of grit and sandstone near Kotri area of Bundi district. A small quantity of gritty and impure kaolin occurs at Buchara and Rasna areas of Jaipur district. A deposit of white clay derived from upper Vindhyan shales occur in two sections, overlain by sandstones at about 800 m, south-east of Basu in Sawai Madhopur district. The clays are pale yellow with medium plasticity. Besides, kaolin deposits are also reported from Phalodi located near Ravanjna Dungar Railway station and Mathasu areas. A white clay bed of 1 m thick occurs in association with the sandstones of Lathi stage at Kita and Divikot areas of Jaisalmer district. An extensive deposit of clay upto 1.5m thick stained occurs in the Vindhyan sandstones about 200 m west of Khajwana area in Nagaur district. Other known deposits are at Rolchandawatan, Saradana, Mundwa, Indawar, Huladah, Namri and Chandawatan areas in the district. The white and brown clays derived from alteration of granitic rocks are found near Kairale and Cholila areas of Pali district. A new deposit of chinaclay has been discovered near Karabaria-ka-Genta in Udaipur district. This is located at 7 km south east of Udaipur city. A bed of greyish white clay about 3 m thick, occurs under a capping of decomposed limestone and sandstone at 400 m east of Leetariya in Pali district. Clays in association with laterite, overlying sandstones with light grey to buff patches, fairly hard and plastic occurs at Bararo and Sherol Khara areas of Kotah district.

4.13 Tamil Nadu

In the state of Tamil Nadu[13] fairly good quality of chinaclay is available near Panruti, Trivendipuram, Tiruvakkari and Kumalampattu of South Arcot district. A small deposit of chinaclay occurs near Cherangode in Nilgiri district. White clays occasionally stained by iron solutions are found upto 9 m thick at Koppur, Kilacheri and Kannantangal areas of North Arcot district.

4.13.1 Chenglepet

The grey, plastic, low grade chinaclays occur about 600 m south west of village Viyapur in this district. Other known areas are Vallakkothi, Vallam, Tattanus, Sriperumbudur, Kannantangal, Gunakarambakkam, Ethkutlumedu, Mappedu, Kilachcheri, etc. These are of hard white to buff coloured occur below a thin cover of laterite. The white clays occur below laterite gravel south of the river Cauveri at Avivattur, Vengattur, Koppu, Palanjur, Tirumallaivayal, etc. areas. Whereas in Ambattur light grey Gondwana clays occur on either side of Railway line. These clays are intercalated with thin sandstone bands.

4.13.2 Other Districts

A thin kaolin bed occur about 25 km away from Madurai city on the Cochin-Kodai road. Thick beds of porcelain clay derived from decomposition of pegmatite veins occur in and around Doddabetta area in Nilgiri district. The white clays used for manufacture of the glazed tiles are occurring in Kanigiri, Pappantangal, Dusi, Pillur areas in North Arcot district. The white and buff clays occur in the area lying between Muthupatti, Madalampatti and Siruvayal areas. Similar type of clays are also found in and around Panamangudi, Sakkiravathi, Urali, Nattapurakki, Vitteneri and Pudukkudi areas of Ramnad district. Irregular and white clays are exposed at Gudilam river section of Pannikuppam area in South Arcot district. Minor occurrences of clays are reported to occur in and around Siranguppam, Melambattu, Maligambattu, Palaiyam, Vanamadevi, etc. areas of south Arcot district.

The deposit near Perambalur in Tiruchirapalli district is narrow and elongated and running NNE-SSW parallel to the Madras-Tiruchirapalli road occur below 30 m depth and is traversed by gypsum veins. The Gondwana clays also occur in the same district near Karai, Terani, Ottattur and Vellamu-Lante areas.

4.14 West Bengal

The chinaclay industry is one of the leading non metallic mining industry in West Bengal. The economically workable deposits in West Bengal are mainly restricted to Bankura, Birbhum, Midnapur and Purulia districts. Deposits of prime importance are confined exclusively in Chandidaspur, Mahammad Bazar and Rampurhat areas of Birbhum district. The chinaclay occurrence in Birbhum district is generally identified as a belt about 50 km long and 6 km wide within which the exploitation is being carried out. Tertiary sedimentary clay bearing basins also cover large areas of Birbhum district. The chinaclay in the state is found associated with rocks of granites and pegmatites within the phyllites of the iron ore series as a bedded deposit in the Raniganj area, and in some places underlying laterites, etc. Chinaclay deposits are reported from the Kharidungri-Jhariakech areas in Raniganj district. The recent investigations of chinaclays are from Kharia, Kamarpur, Mukhdumnagar, Chaubatta, Damra, Ramparhat and

Marra areas of this state. Occurrences of light brown and white clays have been noticed in several localities in Darjeeling and Jalpaiguri districts. Smaller occurrences are reported from Midnapur district. Residual type of chinaclay occur in Purulia district.

4.14.1 Bankura

In this district a number of small and scanty deposits are located. As per the published literature 25 clay bearing areas belonging to Archaean rocks and 33 clay bearing areas belonging to Tertiary rock formations are being worked in this district. These are divided into four categories based on their mode of origin (a) clays formed by decomposition of soda lime feldspar of the anorthosite (b) clays formed due to alteration of granitic rocks (c) clays formed by leaching of phyllite and other rocks (d) clays associated with Tertiary rocks. The first category was developed mostly in the north-western part of the district. These are located at Beriathol, Telidi, Katabaid, Dhatala and Rampur areas. These clays are highly plastic with little gritty and pale cream to pale buff in colour with slight vitrification. The second and third category of clays are found at Jemua, Shyampur, Saragdih, north-eastern part of Beriathol and the southern border of Raniganj Coal Fields of this district. The bedded clay deposits formed by kaolinisation of feldspathic sandstones of Tertiary age are found at Chutgarya and Saharjora areas.

The clay deposits are also located about 2 km north east of Rampur village in the same district. These are locally known as Kharichanda. The Kanchanpur, Swargabatti, Teliberia, Chandabila and Kurkutia are the other clay deposits occurring under a thick laterite covering. Dull white and buff colour clay occurs at Birsinhapur and Sonergram areas on the Durgapur-Bankura road. The low grade clays occur at Jharia and Pabyan areas under a 3 m thick lateritic soil. The deposit Datle was formed from the alteration of feldspathic quartzite which is exposed on either banks of Adali nallah, located 8 km north-west of Jantipahari Railway station. The effect of kaolinisation on feldspar is confined to very shallow depth. The Tilasule, Beledanga, Belbuni, Khaerkanali, Madhabpur, Dhunara, Kharigara, Bhedua, Baidkona are the bedded type of deposits occcurring under 3 m thick laterite capping. The clay is pale pink to pale cream in colour, non gritty and highly plastic covering large areas. Small patches of good quality of chinaclay upto 1.5 m thick occur at Dalambhiya, Bagjabra, Champaboni, Radhamadha-bkunjagarh, Raipur-Hariharganj, Tunji, Matgoda, etc. The kaolin deposits with high titanium content and appreciable amounts of iron and lime occur at Kharidungri, Jariakocha areas located about 45 km from Bankura railway station. These deposits measuring about 300 m length, 45 m width and upto 10 m thick occur below the hill slope as a vertical band. Other known areas are Dhansimla, Bholarkap, Banskanali, Kichka-kadamara, Bauridanga, Patalpur, Loharara, Kalyani, Sirbada, Kumardaha, Agarda, Mukundapur, etc. where the clay beds attain a thickness of upto 2 m under a laterite capping.

4.14.2 Birbhum

Birbhum district of west Bengal[14] state covers an area of 4545 square kilometres. It consists of 19 blocks, with the district head quarter at 'Suri', about 200 km away from Calcutta. Clay belts in the district are found in three blocks viz. Mohammad Bazar, Dubrajpur and Rampurhat. In Mohammad Bazar block, the chinaclay mines are mostly located in Kharia, Angarberia, Saldaha and Kamarpur mouzas. The non-plastic kaolinitic clay is found at Adda, Chanbatta, Chaknuria and Tumbuni areas of the district.

The Kharia deposit is situated 3 km west of Mohammad Bazar town. The deposit occurs under a cover of alluvium and laterite whose thickness is upto 10 m. The beds are almost horizontal with many intercalations of sandy layers within the chinaclay beds. This has resulted in deterioration of the grades. This deposit covers a part of Angarbaria Mouza in Mohammad Bazar Thana and occurs under a 4 m thick cover of alluvial soil. The deposit Saldhana covers about 40 hectares and is situated on the south of Mohammad Bazar-Sainthia road at a distance of 3 km from Mohammad Bazar town. All along the western boundary, runs the irrigation canal. The terrain is flat with a few small lumps of laterite. The chinaclays are covered under a blanket of alluvium soil and at places laterites. Komarpur deposit extends[14] about 30 hectares in Kharia mouza area. This is located on the north of the Mohammad Bazar-Sainthia road. It is covered by alluvium and laterite. Komarpur and the surrounding areas have been explored by GSI during 1958-59 and located 20 potential kaolin bearing areas. Originally, the area was a low lying flat topped hillock and bounded on the south by an irrigation canal. Three grades of chinaclay are being produced from this deposit.

Makdumnagar deposit extends in an area of 16 hectares falling in between Makdumnagar and Tentulberia mouza areas. The area is flat with most of the part covered by laterite. From the trial pits and quarry faces, the subsoil thickness varies upto 8 m. Below this overburden there is a layer of fireclay followed by chinaclay horizon of about 9 m thick. The Mandela deposit extends in 10 hectare area, situated 8 km west of Rampurhat on Rampurhat-Dumka road. The clay beds are covered by 2.5 m thick lateritic morrum. The thickness of chinaclay beds vary from 1.5 to 3 m. The details of analyses of china clay (white and creamish type) are as follows[1] :

Radicals	White Chinaclay	Creamish Chinaclay
Silica	44.4	45.91
Alumina	37.13	37.40
Fe Oxide	1.78	1.50
TiO_2	1.60	1.59
Lime	0.06	Traces
Magnesia	0.08	0.19
Soda	0.26	0.11
Potash	0.14	-
LOI	14.42	13.05
Undetermined	0.13	-
Sp. Gravity	2.73	-
pH of Aquous solution	7.50	7.08

Masra deposit is distributed in 10 hectares each in two separate blocks. The Mobalia deposit with an area of 50 hectares is situated in Mobalia Mouza at a distance of 20 km from Mohammad Bazar town. The area is mostly flat with slope upwards in the form of mounds on the western side of the deposit. The clays occur under a lateritic morrum and pink clay cover of 6 m from surface. Thereafter yellow type clay occurs with a varying thicknesses of 1.5 to 2 m. Below this is the chinaclay horizons whose thickness varies from 2 to 3 m and its bottom is marked by the appearance of reddish clays[14].

The deposits Nischintapur and Harinsingha covers an area of about 7 and 6 hectares, respectively., The Nischintapur deposit is located at a distance of about 5 km from Pachami on Mohammad bazar-Rampurhat road and

Harinsingha is located 1.5 km west of Nischintapur. The deposit is mostly grey coloured semi-plastic in nature. In Nischintapur deposit, most of the clay has been burnt due to lava activity. However, a thin layer of chinaclay whose thickness rarely goes upto 1 m. is noticed. The Chandidaspur deposit is located about 2 km from Dubrajpur. The entire deposit is covered with a thin mantle of soil, talus and lateritic nodules. The clay band is interbedded with sandstone beds. The clay is of white to greyish in colour with minor tints of fawn or light yellow. It is medium to coarse grained and compact. The clay zone show bedded character and is almost sub-horizontal in attitude. At places it shows a very low dip towards west. The sandstones and the interbedded kaolins shows a conformable relationship.

4.14.3 Midanapur

Grey to white coloured clay beds occur over a 3 m thick along a stream section south west of Fuldihi area. Similar type of clay exposed on the south bank of the river Subarnarekha at Ghorapincha area. Milky white non plastic clays are exposed in the south of Raikand village. Massive white clays occur at Katachua area formed by the decomposition of feldspar in granites. The clay shows poor plasticity with drying shrinkage of 3%. it is distributed in an area of 5000 square metres with 25 m thickness. The Burijhor-Kadamdoha deposits occur about 6 km north west of the village Katachua. These are proved upto a depth of 7 m covering in discontinuous patches over a length of 1 km. White clays occur at Dhrapahari under a thick laterite cover located 2 km north-east of Silda. Another deposit about 9 km west of this deposit at Belpahari, a gritty clay occur in a well section. The thickness is about 5 m with low plasticity.

4.14.4 Purulia

The chinaclay deposits at Amtor situated near Dhatara village are of white and are believed to be formed by the action of meteoric water on feldspars of the soda granite rock. The pocket deposits derived from the weathering of graphic granite are found between Kalabori and Kalajhor areas. Similar type of clays with greenish tints are found in Mahatamara, Taldi and Hankasara areas. The white to buff coloured residual type of clay lying along an east-west trending belt, upto a thickness of 8 m, occur at Matli-Barachatarma areas. The lenticular bodies of white clay occur at Dandudih-Khariduara-Sialdanga areas alongwith phyllites and quartzites. The clay deposit at Sialdanga is 200 m long and 61 m wide extends upto a depth of 15 m. The clay beds at Gagriabad, Sravandih, Rajabasa and Megdaha are smaller in nature in the district.

4.15 Other States

In Delhi a large deposit of chinaclay is located near Kusunpur, which is being exploited by a number of agencies. A good quality of chinaclay is also being mined in Mehrauli area of Delhi. The Camarconda and Colem areas of Goa consists of crude clay in large quantity. In Banda district of Uttar Pradesh, lenticular bands of white clay occur on Bema hill near Lakhanpur. White clays in small quantities are reported to occur from Sitapur and Kolgadhaya areas of the same district.

In Manipur a thin bed of bluish grey clay is noticed in the Kongwai Turel stream about 2 km west of Kongwai village. A good quality of white, pale grey or cream coloured clays occur in the areas of Jagalgati and Cherial in association with the bauxite-series in the same state. This is locally known as 'Makol'. These are low in plasticity and powdery in nature with high alumina content. A bed of cream coloured highly plastic clay occurs at the base of the low lying hills in the neighbourhood of Baldakhal and Champanura areas at a distance of 6 km southeast of Agartala in Tripura state. The clay bed is nearly horizontal upto 2 m thick and overlain by 3 m thick ferruginous sandstone of Tipam series. About 50,000 tonnes of high quality clay may be expected from each of these areas.

In Punjab a small deposit of white clay is found in bed of a nallah near Sikindarpur on the Delhi-Gurgaon road. In Himachal Pradesh, minor occurrences of chinaclay are known. The chinaclay derived from granitic rocks are noticed near Nahrona in the Kangra district. A few pocket deposits of chinaclay which are the products of kaolinization are recorded from the Karsog area of Madi district. Two potential deposits of chinaclay derived from alteration of granites, gneisses and pegmatite rocks are reported to occur at Asrang and Lipya areas of Mahasu district. Two beds of clays are exposed in the nallah within siwalik formation. Each bed is 3 m thick. The material from the upper bed is hard, light grey and compact white while the lower one is soft. At Mehi and Kenti, clay occurs in the Haunsar quartzites of Sirmur district. The decomposed sandstone near Rajpur also contain kaolin in the same state.

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5. World Deposits

5.1 Distribution

Geographically, kaolin deposits are widespread all over the world, and are known to occur in the rocks ranging from Archaean to recent. However, the deposits are confined to three geological periods namely Carboniferous, Cretaceous and Tertiary.

The term kaolin is applied to kaolinitic clays used in applications in which the whiteness of the clay is important, whether in its natural or fired state. 'Chinaclay' is a local term used for kaolin produced from kaolinised granites in southwest England. Kaolinite is very much a mineral of the land, often occurring as the dominant mineral product of chemical weathering under humid tropical conditions, which makes it ubiquitous under the warmer and wetter parts of the planet's land surface. This mineral is being reported from 56 countries in the world. Among those United States of America is having the highest reserves followed by United Kingdom, Columbia, Republic of Korea, Ukraine, Brazil, Federal Republic of Germany, Czechoslovakia, etc. The various deposits are desc ribed continent-wise in this chapter(1).

5.2 Africa

In Africa the deposits are smaller in nature and the known deposits are in Botswana, Algeria and South Africa. An interesting residual kaolin deposit in South Africa is located near Graham's town in south-eastern Cape Province. Kaolin is believed to be derived from Permian tillites and carboniferous shales. The Wood Hall clay deposit at Lobatse is located about 70 km. south-east of Gaborone, Botswana, followed by another deposit at 250 km north-east where it is being operated by Makoro(1). In Algeria, El Milia located 20 km. north of Tamazert is also a sizeable known deposit of chinaclay.

5.3 North USA and South America

The sedimentary deposits of Late Cretaceous/ early Tertiary age in Georgia and adjoining states in USA are producing the highest grade ore. In South America the main interesting areas are the Amazon Basin, Rionari, Cadam etc. The Kaolin deposits(2) suitable for paper coatings are located at Rixapim.

5.3.1 United States of America

Clay occurrences are known in almost all the states in USA except six states namely Alaska, Delaware, Hawaii, Rhode Island, Vermont and Wisconsin.

Hydrothermal Kaolin deposits occur at several localities in the western United States. In the little Antelope Valley district in California, rhyolites have been altered to kaolinite and quartz. The alteration zone consists of a core of clay that grades outward into country rock. Deposition of silica by thermal solutions has caused the contamination of clay in some places.

The sedimentary kaolins in Georgia and south Carolina are the most extensive secondary kaolin deposits in the world. These kaolins occur in Late Cretaceous and Early Tertiary rocks which were derived from deeply weathered crystalline rocks and gneisses on the Piedmont plateau. The Cretaceous kaolins are relatively unconsolidated and lenticular with various kaolinitic cross-bedded sands. Whereas the Tertiary kaolins are more persistent and thicker than the Cretaceous kaolins. The investigations indicate that the deposits of Georgia and South Carolina are derived from granites and gneisses of the Piedmont plateau. However, others believe that the kaolins were transported and deposited.

In California the Ione formation is divided into two parts. The lower bed contains clay which may be further divided into three layers. The one at the base consists of reworked laterite and isolated lenses of low grade kaolin. This is overlain by lignite coal in the middle. The upper layer contains thick beds of kaolin from which the exploitation is being done.

5.3.2 Brazil

A large sedimentary kaolin deposit is located in the territory of Amapa in northern Brazil on the bank of Jari river. It belongs to Barreiros series having a sequence of unconsolidated sands and kaolin of Pliocene age. The kaolin is at the top of this sequence and is called as Balterra clay. A light coloured kaolin layer also occur below the highly stained lateritic zone at Amazonia region. It is believed that these clays are derived from weathered granites on the Guyana shield and deposited in a lacustrine environment. The Rio Capim region of northern Brazil is also exploring kaolin deposits.

5.3.3 Mexico

Kaolin is mined from districts of Zacatecas, San Luis Potasi, Gaudalajara, Mexico D.F., Queretaro, etc. The San Luis Potasi is locally known as General Zaragosa. Kaolin was formed by hydrothermal argillation of rhyolite flow-breccia and probably from welded tuffs in this area.

5.3.4 Other Countries in America

In Argentina, the southern Patagonia region consists of extensive residual kaolin deposits. These might be resulted from the pyroclastic rocks of Jurassic age. The deposits located along the Chubet River Valley are considerably thick with high quality. In Columbia the only known workable kaolin deposits are located in between Bogota and Paz del Rio areas.

Kaolin occurs in various provinces of eastern and central Canada like Nova Scotia, New Brunswick, Ontario, etc. Kaolin deposits are also known in various areas of Quebec, namely, Papineau, Montmorency and Gatineau. The extensive deposits of a kaolinized sand mixture occur along the Missinaibu and Mattagami rivers south-west of James Bay in northern Ontario. In Western Canada, kaolin deposits of Manitoba are found on Deer Island, in the Pine River area near Arborg, and in Phanerozoic Sylvan strata. The kaolinitic shales occurring in the Kergwenan and Ste. Rose du Lac areas contain clay deposits. The kaolinitic clay resources of southern Saskatchewan occur as white mud deposits at Wood mountain, Knollys, Cypress hills, Moose Jaw and in Weyburn areas. The Eastend-Shaunavon area along the French-man river also contain kaolin deposits. The low grade kaolin deposits occur in Wabamun and Alberta areas. Other known deposits are along the Fraser river near Prince George and Sumas mountain in the country. The common clay deposits which are associated with shales are near corner Brook in New Brunswick, Havelock in Kings county and at Chipman areas. The deposits at Lantz in Nova Scotia, Laprairie in Quebec, Beauport and Deschaillons, Wood Stock, St. Marry, Regina, Estevan, Rockglen. Flintoft and Readlyn are the other important deposits in Canada. In British Columbia there are several active deposits occurring at Sumas mountain near Affotsford and Long Bay in south western portion of the province.

5.4 Asia

Kaolin deposits are distributed all along China, CIS, Indonesia, Japan, etc. These are described below.

5.4.1 China

One of the largest and highest quality of hydrothermal kaolin deposits in China are located near Suzhou in Jingsu province. The area consists of Carboniferous, Permian and Triassic carbonate and clastic rocks with multi stage acid igneous dikes and are associated with high angled faults. As a result of multiple intrusions of granitic rocks and Jurassic volcanism, intermediate and low temperature hydrothermal alteration is very wide-spread. Kaolinization of many rock types result in several types of kaolin deposits and are classified as compact, banded and sandy kaolin with relict phenocrysts. The Suzhou kaolin deposit is very large with proven reserves[3].

The deposit located at Gaoling near Jingdezhen is of residual nature and formed by weathering of granites.

Kaolin deposits are distributed[3] in China's six administrative regions. These deposits are abundant in east, south central and north regions located at Jingdezhen, Liling, Hunan province, Foshan, Guangdong province, Yixin, Jiangsu province, Zibo, Shandong province, Tangshan, Handan and Hebei province.

Deposits of Gaolin, Xingzi and Shaziling areas of Jiangxi. Jiepai Ganchong of Hunan province are of stratauoid and lentiform type and are formed by residual weathering. The deposits at Xuyong, Gulin, Weiyuan, Xishui, Yangquan and Shanxi are of nested and irregular type formed by weathering and leaching. The deposits at Changbai, Qiongtian, Zeijiang, Guanshan, Yanxi, Yangdong, Baishanlin, Jiangsu are of strataoid vein, lentiform, irregular type and were formed by hydrothermal alteration. The kaolin deposits at Yangbajing of Tibet, Tengchong, Yunnan province are also of strataoid vein type formed by low temperature hot spring alteration. The deposits Datong, Shanxi, Zibo, Shandarg, Tongchuan, located at Quingyuan, Guangdong, Shuiquliu, Jilin, Huanghua and Heilongjiang province are of strataoid and lentiform type formed by sedimentary origin. Guanshan, Yangxi, Jiepai, Liling, Maomin, Shandai, Donggongxia, Daquito kaolin, Xingzi, Beishan, Xuyong, Datong and Changbai are the other known kaolin deposits. In the south-west, north-west and north-east regions of China, Xuyong kaolin of Sichuan province is the most popular. High quality of kaolinite claystone along with dirt band of coal seams occur in Tongchuan district of Shanxi province. The Belitung Kaolin is formed from the weathering of the Cretaceous rocks.

5.4.2 India

In India the chinaclay deposits are occurring in as many as nineteen states. The important deposits are in Kerala, Bihar, West Bengal, Rajasthan, Gujarat, Orissa, Karnataka, Maharashtra and Andhra Pradesh. These deposits are ranging from Gondwana to Tertiary age. It is believed that these deposits are derived from granites, pegmatites and phyllites of Archaean age. In most of the places the clay deposits are overlain by laterites and alluvium. About 1797 million tonnes of reserve have been estimated as on 1.4.1995 in the country. The details have already been presented in the preceding chapters.

5.4.3 Indonesia

Kaolin is reported on the islands of Belitung and Banka in the Java sea. A porphyritic biotite granite on Belitung has altered to kaolinite. The mineralogical and chemical changes indicate that the feldspars have been altered to klaolinite and halloysite. Belitung kaolin is classified as Primary Kaolins which has been formed from weathering of Cretaceous rocks.

5.4.4 Japan

Hydrothermal kaolin deposits[4] are very common in Japan. The largest kaolin clay deposit in Japan is at Itaya located in Okayama Prefecture where 'Rosecki' is mined. The name 'Rosecki' is applied to compact clays comprised largely of minerals such as pyrophyllite, kaolinite and diaspore. The deposits were formed by alteration of pliestocene volcanic and pyroclastic rocks.

Eastern Mino district, Tajimi, Toki and Mizunami-cities are known for clay deposits. The other areas in Japan are Arita district in Kajushu island and Tokai district in Nagoya where these are represented by Noritake, Seto and Mino deposits. In Arita district the deposits of Toseki occur at Izumi-Yama, Amakusa islands and Kumamoto areas. These deposits occur under a thin bed composed of iron hydroxide. The known Kibushi and Gairome clay deposits are located at east mino district[5] where the clay layer contains large grains of quartz giving the clay a shiny appearance. The Gairome clay was deposited during the Pliocene period and was formed from granites. At present there are 34 mines in operation - out of which fourteen in Aichi, eight in Gifu, eight in Mie and four in other prefectures. The Amakusa Toseki is also composed of clays. The areas Sino and Orife are in Tokai district and Kibushi and Gairome clays are in east Mino district.

5.4.5 Ukraine

The deposits of pro syanovskoe, Glukhovetskoe, Veliko-Gradominetskoe and Turbovskoe deposits are being exploited. These deposits are believed to be formed from granites of Mesozoic age. The other deposits such as prosianaya and Gluknovetsk in Ukraine were formed due to the alteration of pre-cambrian gneisses.

5.4.6 Other Countries in Asia

In Malaysia, deposits of chinaclay are known to occur at seventeen places from Topa-Bidor, Perak, Jemaluang and Johore areas. Among these two high grade deposits are from Bidar area.

5.5 Australia

Residual Kaolinitic clays altered from granite occur in Ballarat and Pittong regions, north-west of Melbourne. The parent granitic rocks are of Devonian age and the kaolin deposits are found in gently undulating topography. The depth of alteration of the acidic rocks ranges upto 30 m. The Weipa kaolin deposit is located on the west coast of the Cape York peninsula in north-east Queensland. The sedimentary kaolinitic sands at Weipa are overlain by thick lateritic bauxites of Tertiary age. Below the bauxite is an interval called the "Pallid Zone" which contains iron stained mottled kaolin. The kaolin occurs in a sand matrix with coarse quartz and is of late Cretaceous age some believe as early as Tertiary age. The kaolinite is of 12 m thick and occur as platy in shape[4].

The high grade deposits in western Australia is very promising since the Yilgarn Granite-Greenstone province covers vast areas of the southern interior of the state. At Greenbushes in the south- west of the state, Gwalia kaolinisation has occurred in a hydrothermally altered pegmatite. Other potential high grade residual kaolin deposits in the southern part include Gabbin and Jubulk, about 200 km east-south-east of Perth. The mount Gibson near lake Moore, Mullewa, east of Geraldton and Tambellup, north of Albany are the other known deposits. A series of clay pans are occurring in an area north of Watheroo about 40 km north of Moora.

5.5.1 New Zealand

At Matauri Bay in the north of the island chinaclay deposits are being mined. A major deposit occurs in the Harper hills about 60 km. west of Christchurch. The Coalgate beds overlie a basalt flow and have probably formed from a glassy, volcanic ash. The above kaolin deposits were formed by low temperature hydrothermal alteration of acid volcanic rocks in the northern island of New Zealand.

5.6 Europe

In Europe, the chinaclay deposits are known in more than 12 countries. Among these, United Kingdom, Germany, Czechoslovakia, France, etc. are having thick deposits of high quality kaolin. These are of hypogene origin which occur in association with granite and are also capped by an unaltered granite layers at the surface. The sedimentary kaolin deposits[5] of Bavaria in Germany are derived from arkose sandstone underlying lignite beds and constitute potential sources of valuable paper class[6].

5.6.1 Austria

Kaolin deposits in Bohemian Massif of Austria are divided into two groups, namely, Kriechbaum and Weinzierl deposits. These are located in upper Austria near Schwertbeng, about 25 km east of Linz. The deposits of Mallersbach and Niederfladnitz are located near the town of Retz in Lower Austria. The deposits of Kriechbaum and Weinzierl are situated in the formations of Hercynian granite where the kaolinisation is 40 m thick. The Mallersbach and Niederfladnitz deposits are situated in the rocks of granites and gneisses of pre-Devonian age, with 44 % kaolinite content. Apart from these deposits, the kaolinised rocks, kaolinitic clays and sands at various places in the country are partly exploited for ceramic industry[5].

5.6.2 Czechoslovakia

In Karlovy-Vary area of Bohemian Massif, the residual kaolin deposits are associated with feldspathic rocks. In Plzen basin and Podborany region the deposits are occurring with arkosic sandstones of Carboniferous age. In Kadan and Znojmo areas the kaolin deposits are occurring with gneisses. With the exception of a small kaolin occurrence near mineral water springs at Kyselka, all the deposits were formed as a result of hot and humid climates during the Carboniferous, Mesozoic and Tertiary periods. The high grade kaolin deposits are being worked in the Sedloc, Bohemia, Podlesi, Bozicany, Zimlikov, Hajek, etc. areas. The Kadan deposit was believed to be originated through kaolinisation of gneisses during Tertiary period. In Podborany deposits the parent rock of the arkosic sandstones are of Permo-Carboniferous age and the high grade kaolin restricts in the upper 30 m layer. About twenty kaolin deposits have been known in Plzen basin. Among those, Chhimcany, Horni Briza and Kaznejov are being mined in huge open pits. All the deposits have originated from carboniferous arkoses. These are represented by large lenses upto a depth of 30 m, and are of non plastic in nature. In the southern Moravia, the Znojmo deposit resulted from the combination of granites of the Dyje massif and the orthogneiss of Bites type. All the Bohemian and Moravian kaolins are of porcelain type with above 20% grade.

In Kladno-Rakovnik basin the deposits are associated with Lubrenec coal seam which occur in the Upper Carboniferous period. The commercial deposits are known in several mining districts that extend mostly north-east of Rakovnik. Numerous fresh water clay deposits are known from Moravia and also from eastern Bohemia. The other deposits, namely Brezina, Malonin, Hrebec, Kunstat, etc. are known in the Cretaceous beds in the neighbourhood of the Permo-Carboniferous Boskovice furrow. The significant Cenomanian fresh water clays occur around Prague and Loung areas namely, Cerny Kostelec, Vysehorovice, etc.

The Oligocene and Miocene clays are being mined from Borovany, Ledenice, Mydlovary, etc. areas in the Bude Jovice and Trebon basins. The large Kysice deposit is located in the Plzen and Pisek. In western Bohemia the best quality clays lie near Skalna and Nova Ves in the Vildstejn series of the Cheb basin. In the Sokolov basin the clay deposits are associated with coal seams. The deposits at Biela Hora near Michalovce is a leaf shaped deposit occurring in the eastern Czechoslovakia with volcanic rocks of Pliocene age.

5.6.3 France

France has two great Tertiary basins - Paris and Aquitaine Basins where clay deposits are found. In Paris Basin Eocene clays are found on the south-eastern side of Province area.

The occurrences of kaolinitic sediment in the Aquitaine Basin are on the north side of the basin. These are the equivalents of sedimentary kaolin deposits in Georgia. Europe clay is also being worked in Charente area.

Kaolin deposits derived from the granite massifs in Brittany are most actively exploited in France. The largest deposit is at Quessoy. Another deposit in the northern area of Brittany is Plemet. In the southern and south-western parts of the peninsula the Ploemeur and Charante are the other known deposits, respectively.

The deposits found near Limoges, St. Yrieux and Limonsin are extremely pure and are derived from gneisses, whereas the deposits at Brittany are in the granite mountains of Pyrenes.

5.6.4 German Democratic Republic

Residual kaolin deposits are found in several localities in the southern part of the country. These are in Kemmlitz area of the north-west Saxony between Dresden and Leipzig. The parent rocks of kaolin in Kemmlitz area are volcanic ignimbrites and porphyrytic andesites. The thickness of kaolin ranges upto 40 m. Other rock types that are found in the southern part belong to Bohemian Massif. The deposits at Seilitz, near Meissen, are the oldest known deposits, which may be derived from pitchstone, felsite and quartz porphyry.

A Kaolin deposit is located in Bavaria near Hirschau where an arkosic sand of Triassic age has been kaolinised in an area of nearly 6 km. The Tirschenreuth is a pocket deposit occurring beneath Falkenberg granite. The kaolinisation reaches upto a depth of 30 m. A kaolinised belt approximately 400 m wide and more than 60 km long with 35 m thick occur in between Hirschau and Schnaittenbach areas. In part the underlying Kulmbach conglomerate is also kaolinised. In Rheinische Schiefergebirge, feldspar-rich rocks were intensively kaolinised during the Upper Cretaceous and the Lower Tertiary periods. The Tertiary feldspars in Lohrheim, south of Dietz on Lahn and in Geisenheim in Rheingau are kaolinitised. Greywackes in Oedingen, west of Oberwinter on the Rhine, as well as chlorites in Niederdresselndorf, 20 km. SSE of Siegen, were also kaolinitised. The pegmatite sand of the Weiden Bight, Bavaria and partially kaolinised porphyry at Birkenfeld on Nahe are also economically workable. Along the Naab valley and at the southern edge of Bavarian forest of Mitterteich area, kaolinitic clays are associated with Tertiary coals. In Westerwald, the mountainous region between Lahn, Wied Siegerland to the east of the Rheinische Schiefergebirge and several small occurrences of Tertiary clays are known. To the north of Hirschau, a worth mentioning deposit was found in Ehenfeld clay. In the region of Coburg, 60 km. to the north of Bayreuth, high quality clays are noticed. The high quality fine ceramic clays of the Tertiary are extracted to the west and south-west of Euskirchen and Ville areas, south of Siegburg. Rhineland-Pfalz (Palatinate) area of Eisenberg-Grunstadt, 25 km to the north-west of Ludwigshafen in the Neuwied basin and in its western marginal regions, as well as in Hesse near Grobalmerode, 20 km. east-south-east of Kassel and in the Spessart near Klingenberg are the important deposits in the country.

5.6.5 Spain

Kaolinitic sands of Cretaceous age are found from the Guadalajara to Valencia region in Central Spain. The kaolinite thickness in Wealdian and Utrillas ranges upto 30 m. The Onverdacht series in the Moengo area of eastern Suriname is divided into two - the upper Onverdach is composed of bauxite while the lower Onverdacht is composed of kaolinite. The age of the Onverdacht series is Eocene and kaolin has been derived from the Guyana shield. In the north western part of Spain kaolin deposits were formed by hydrothermal alteration from the pre-Hercynian granites. The other source of kaolin deposits in the eastern Spain was from the weathering of crystalline rocks of the lower cretaceous age. Between Madrid and Valencia these represent the arkosic sands that were subsequently kaolinised by circulating ground waters.

5.6.6 United Kingdom

The largest and highest quality primary kaolin deposits in the world is located in Cornwall region of south-eastern England. It is believed that kaolin is derived from St. Austell granite. The kaolinite content in the altered granite ranges between 10 to 20 percent. The kaolin body is funnel or trough shaped with tin, copper and tungsten indicating hydrothermal activity.

Many clay deposits are located between Dorset and Devon areas in the south-west of United Kingdom. The English Chinaclays PLC (ECC) is the largest producer of kaolin from twenty deposits located in Cornwall. Loporte, Widens and Cheshire are the other areas where kaolin is being reported. In the southwest of England larger primary kaolin deposits with high quality are found. The deposits of Redhill, Clophill, Baulking, Woburn areas are the known deposits in this country. In Devon area the lower Ninestones, Watts, Blake are being explored.

5.6.7 Other Countries in Europe

The kaolin deposits are scattered around Europe at a number of places. These include kaolinitic sands in solution pockets in the carboniferous limestone of the Ardennes. Similar kaolinitic sands in large solution pockets in limestone are found in the north-east Bulgaria and Derbyshire areas.

Extensive kaolin deposits in Scania, southernmost Sweden, have been the subject of much interest, although they are of relatively poor quality. These Scania deposits and a similar one on Bornbholm, were formed by Mesozoic weathering and are overlain by cretaceous sediments[5].

Deposits of kaolinised metamorphic rocks, probably remnants of deep weathering in the Mesozoic, have recently been discovered in Finland. Though none of these Scandinavian deposits has been explored yet, there is currently much interest in the deposit at Virtasalmi in Finland.

Jordan possesses abundant resources of clay. However, its exploitation is little. The Kurnuf formation is a terrestrial series of upper Jurassic and Lower Cretaceous age. One of the best source of kaolin deposits occur as thin beds and lenses and are worked at Mohis, about 17 km west-north-west of Amman where the kaolinitic deposit is 4 m. thick.

The Machtesh Ramon is a known deposit in the southern Israel. In Portugal the Cauliminas and Saibrais operates two mines, one situated at Mosteiros near Alcanede and the other at Bracais near Obidos. In the Island of Boruholm in Denmark, kaolin is located south of the Hasle at river Bagaa. Other deposit is at Olst, south of Randers in eastern Jutland of Israel.

In Belgium the workable kaolin deposits are located between Haut-Fays to Luhin, in a 20 km long band. These deposits were formed from weathering of arkoses, feldspathic sandstones and schists of Palaeozoic age. Small occurrences are also located between Louette-St-Pierre to Bras, Libramont and the Serpont of Cambrian ages. The ore deposit is associated with fine grained argillaceous sands that fill Karstic holes in Dinantian limestones formed by sedimentary origin. The Transinne and Malvoisin are the other known deposits.

The kaolin deposits have been discovered at several places in Egypt in recent years including those worked in the Budra area, about 26 km south-east of the Port of Abu Zenima. These deposits which are of upper cretaceous age (Nubia formation) consist of four lens-shaped bodies in moderately dipping quartzitic sandstones upto 80 m thick. Kaolinitic clays of the same age occur just north of Aswan and are reported to be upto 18 m thick near Abu-El-Rish Bahary. The clays which are produced from the great natural 'crater' of Makhtesh Ramon in southern Negev are from the pockets of cretaceous Nubia sandstone. The kaolinitic clays are also occurring in formations of Hamakhtesh Haqatan further to the north-east, close to the southern end of the Dead Sea.

The deposits in Cyprus occur extensively around the Troodos massif of the south-eastern island. Two deposits are located close to Vasilico city. The clay exploited is brown and grey in colours and belongs to the Athalassa formation of Pliocene age. The residual clay deposits which were found at Troodos in the Arakapas Valley lies north of Limassol town. The deposits in the Nicosia district are of pliocene age.

The largest kaolin deposit in Italy is at Locchera on the island of Sardinia. Kaolin is derived from hydrothermal alteration of tertiary rhyolites, ignimbrites and andesitic basaltic lavas. The major kaolin mineral is kaolinite followed by dickite, halloysite with sulfates, residual feldspar and smectite. Unimin S.P.A. is the leading producer and its deposits are located near Massa in Carrara area. The Pedra-de-Fogu and Puntenuova kaolin areas are also in Sardinia island. The deposit S'Aliderru is located in the north-western Sardinia. Small occurrences are found at Foggia in Puglia district, and at Pietracuta-di-S Leo in the Pesaro district. The other important deposits are located at Lozzola near Gattinara in the Vercelli province and Cagliari in Nuora Province.

The kaolin deposits in Poland occur in lower Silesia within Variscan granite massifs and, in particular, within Strzelin massif. The kaolin deposits were formed during Tertiary as a result of weathering of the granite massifs and other formations. The deposits at Zarow, Kalno, Smialowice, Boleslawice. Wyszonowice are occurring under the tertiary sediments. The Zerow and Wyszonowice deposits were formed on granites. They yield upto 50 m thick white grey and cherry-red kaolins. The mechanism of kaolin weathering is connected with warm and humid climate that prevailed in the Palaeogene and Neogene times. The activity of acid waters associated with brown coal played an important role in removing iron and bleaching kaolin[5].

The secondary kaolins were formed in the Oligocene and Miocene as a result of washing out of the primary weathering kaolin. The deposits of this type occur in the marginal zone of the western part of Strzegom-Sobotka granite massif. This type of secondary accumulation representing the Dzierzkow deposit, occurs in tertiary sediments. The kaolinitic sandstone deposits exploited in Boleslawiec basin represent the Senonian age of sedimentary type. These are delta shaped accumulations formed at the foot of weathering of granite massifs. The Czerna deposit is a bed of sands and friable kaolinitic sandstone of 24 m thick. The Zebrzydowa deposit has a 32 m thick kaolinitic sandstone. Czerwona Woda deposit has 18 m thick kaolinitic band. Upper Silesia, Radzionkow, Zagorze near Sanok and Grybow are in the sediments of the carpathian Flysch and Miocene. In the localities of Jawor, Gorki and Chmielnic. the clays are associated with a Tortonian Pyroclastics.

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6. Mining in India

6.1 Background

Kaolin mining in India is about two centuries old but the mining work has accelerated after independence when the industrialisation boosted up for the development of the country. The mining of kaolin is being carried out in almost fourteen states throughout the country. Major kaolin producing states are Rajasthan, West Bengal, Kerala, Gujarat, Andhra Pradesh and Bihar which are producing 90% of the total India's production[1]. A number of mines remain closed during sowing and harvesting season as most of the labourers are mainly engaged in agriculture. Few mines are working regularly, systematically, maintaining quality and production level.

6.2 Method of Mining

The kaolin deposits being mined are found at a shallow depth. Being low valued mineral and shallow depth the method of mining is usually adopted is opencast method. Very few mines viz. Patharghatta Mine in Bhagalpur district (Bihar) and Anteli mine in Jaipur district (Rajasthan) have started working by underground method but afterwards they switched over to opencast workings due to low recovery from underground workings[2].

Normally, the mining is started by putting small pits, on the exposure wherever exposed, as exploratory pits. These pits are deepened and also extended in all sides till kaolin is found[3]. The working is carried out manually by using crowbars, pickaxes, hammers, chisels, spades, etc. Being soft, the drilling and blasting are not required. The removal of overburden which is also comparatively soft, is also done manually. Now with the advent of mechanisation the trend is changing and the overburden is removed at some of the mines by deploying earthmoving machinery like Porcelain excavator, loader, dumper and trucks specially in the mines in Rajasthan. These machineries may be owned by the mine owner or taken on hire basis. At most of the mines, height of the benches are not kept regular and also not kept proportionately which resulted in collapsing in the rainy season. Trend is now changing to systematise mining operations at number of mines.

The labourers are paid daily but at some places the mining or extraction of kaolin is done on contract basis which results in the non-excavation of ore burden and height of the benches becoming very high and dangerous for working and also not in favour of conservation of kaolin[4]. The attendance of labourers is irregular as their main trade is farming. During sowing and harvesting seasons they mostly remain absent.

The broken material is hand sorted in the pit bottom or at the face itself and transported manually by hand to the pit top. With increase in depth of the mine, this is now being done by truck/ tractor trolly also. The waste material and overburden are generally dumped by the side of the pits which has to be rehandled. Such dumping was also not done systematically on a proved barren ground. Some times the waste is dumped in the pit bottom itself without extracting all the kaolin which is against conservation of the mineral deposits. Now with the use of excavators for removal of overburden (specially in Rajasthan), overburden (waste) dumps are away from the pits either in the non-mineralised ground or near the lease boundary on the barrier. In numbers of cases, backfilling has also been started after winning all the clay bed present in the pit. The broken material/kaolin is being manually sorted out as per grade and kept ready for despatch by trucks to the consignee's destination or to the beneficiation/grinding unit at the mine.

In Bihar area, the most of the mine owners have got their own beneficiation plant in the lease area or out side the lease area but near to the mine site. Beneficiated kaolin is marketed in a cake form in bags[5].

As there is more margin of profit in marketing good quality of kaolin, selective mining is also done in some mines which is again against the conservation principle.

There is a lacuna in top soil management in almost all the mines. It is neither been mined separately nor being stacked for future use. The backfilling of the mined out area is also followed in a few cases. The plantation in the lease area or outside the lease is, however, now being started and good results are found in kaolin mining area, specially in Rajasthan.

At some of the mines the waste material is dumped in huge quantity forming very big dumps like hillocks. This requires proper management to make them stable, reclaim and rehabilitate in due course to help in improving the environment.

6.3 Status of Mines

All the kaolin mines in India are opencast and about 80 percent are small and yield low production (upto 5000 tonnes per year). 15 percent mines are medium (producting 5000 to 15,000 tonnes per year) and rest of the mines are high productive mines (producing above 15,000 tonnes of clay per year).

Group-wise and State-wise production of kaolin is given in the Tables 6.1and 6.2, respectively.

From Table 6.1 it can be seen that in 1990-91, there were 182 working mines for kaolin in India. In 1991-92, the working mines decreased to 159 whereas in 1992-93, the working mines were 162 which were further increased to 167 in the year 1993-94.

It can also be seen from the table that the group of mines producing 15,000 tonnes and above kaolin are varying from 4 to 6 percent of the total working mines but they are producing almost 35 to 55 percent of India's total production. All these mines are semi-mechanised and regular productive mines.

Table - 6.1 : Group-wise Production of Kaolin (Natural)

(Quantity in tonnes)

Production Group (in tonnes/yr.)	1990-91		1991-92		1992-93		1993-94		1994-95		1995-96		1996-97		1997-98		1998-99	
	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production	No. of Mine	Production
Total : All Grade	182	615,055	159	699,273	162	531,874	167	505,644	154	551,883	162	643,368	166	592,211	152	624,349	139	539,422
Upto 500	85	13,951	62	11,692	73	8,948	74	11,390	64	8,193	61	8,816	55	8,992	51	7,886	49	7,667
501 to 1000	20	15,022	18	13,555	17	14,504	11	7,998	18	13,604	16	11,445	26	18,373	23	16,558	14	11,110
1001 to 2000	22	31,492	22	34,364	19	26,718	22	31,559	16	22,000	16	24,619	16	22,808	21	29,965	14	19,790
2001 to 3000	15	37,469	9	22,153	10	24,859	10	25,192	9	22,021	14	31,717	12	30,021	13	31,698	16	39,073
3001 to 4000	13	44,879	8	26,447	6	20,071	11	40,605	7	24,162	8	28,034	12	41,125	7	23,477	11	38,635
4001 to 5000	5	22,327	11	48,833	9	40,149	11	48,546	5	22,665	8	35,838	7	33,228	9	40,322	6	26,016
5001 to 10000	8	61,262	15	104,849	15	99,387	17	122,172	19	128,380	22	149,168	20	146,124	13	98,894	13	97,688
10001 to 15000	6	70,052	4	45,534	6	80,829	3	36,739	8	93,774	6	69,590	9	101,592	4	47,235	9	111,093
More than 15000	8	318,601	10	391,846	7	216,409	8	181,443	8	217,084	11	281,141	9	189,948	11	328,314	7	188,350

Table - 6.2 : Statwise Production of Kaolin from 1990-91 to 1998-99

(Quantity in tonnes. Value in Rs. '000)

State	1990-91		1991-92		1992-93		1993-94		1994-95		1995-96		1996-97		1997-98		1998-99(P)	
	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value
India	723,703	1,58,042	799,242	1,81,969	649,056	2,64,514	645,080	32,92,89	732,233	47,12,78	831,098	44,95,42	775,283	47,87,30	790,802	478,753	708,503	502,318
Andhra Pradesh	51,272	33,13	50,420	31,99	53,454	31,95	40,729	32,36	69,904	47,66	72,804	51,88	87,707	62,13	121,434	9,077	96,690	7,948
Bihar	37,887	1,39,33	38,843	1,44,18	29,554	1,39,98	36,524	1,26,77	46,064	1,89,98	53,615	2,28,15	62,932	2,79,87	58,578	31,209	30,444	26,049
Delhi	59,754	30,64	76,320	48,55	40,168	27,01	-	-	-	-	-	-	-	-	-	-	-	-
Gujarat	66,770	96,37	58,925	1,01,03	58,004	1,23,90	95,392	1,59,73	81,903	1,50,52	105,255	1,92,19	107,565	1,87,79	118,993	21,748	93,229	17,493
Harayana	19,633	1,401	28,725	20,74	47,164	44,33	11,176	8,91	33,317	27,84	83,221	69,57	3,576	3,47	1,994	209	14,183	1,321
Jammu & Kashmir	51	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karnataka	6,263	8,64	7,192	10,69	9,598	23,81	16,678	41,85	12,242	50,23	15,184	60,31	15,805	61,21	18,334	9,465	11,974	5,789
Kerala	91,348	9,50,28	102,775	10,99,15	111,502	19,81,53	145,635	24,15,40	124,683	34,56,64	154,557	31,33,29	173,666	34,56,83	163,813	344,286	193,685	396,392
Madhya Pradesh	27,483	11,96	28,983	15,00	29,967	9,87	20,870	10,95	31,064	16,85	32,623	18,71	29,447	16,84	24,374	1,576	26,320	2,008
Maharashtra	2,519	94	4,211	1,67	3,984	2,18	6,374	4,17	2,286	1,44	4,654	4,31	7,860	6,57	1,770	192	700	42
Orissa	17,442	29,71	16,268	29,26	15,312	24,91	12,693	25,92	6,347	18,03	16,816	37,75	17,690	28,35	14,835	2,123	7,680	1,013
Rajasthan	217,960	68,81	265,686	85,20	153,559	66,22	149,098	1,04,75	204,198	1,27,33	181,067	1,37,04	166,192	1,56,41	156,704	15,320	153,880	17,727
Tamil Nadu	2,985	2,84	715	68	1,160	1,45	-	-	-	-	-	-	-	-	-	-	-	-
West Bengal	122,336	1,93,50	120,179	2,31,55	103,630	1,68,00	109,911	3,62,08	120,225	6,26,26	111,302	5,62,22	102,843	5,27,83	109,973	43,048	79,718	26,536

In case of Medium group of mines i.e. producing 5000 to 15000 tonnes per year, they are 8 to 15 percent of the total working mines in India for kaolin but producing almost 20 to 30 percent of áthe country's production. These are manual mines.

In case of low productive group of mines i.e. producing up to 5000 tonnes kaolin in a year, they are almost 80 percent of the total working mines but producing only 30 percent of the country's production. All these mines are manual with irregular workings.

6.4 Production

6.4.1 India

The production of chinaclay in India during 1990-91 was 723,703 tonnes. This production comes from fourteen states. The production of chinaclay increased by 10 percent and reached upto 799,242 tonnes in the year 1991-92 which was produced by thirteen states. There was no production in Jammu & Kashmir state from 1991-92 to 1997-98. The production of chinaclay decreased by 19 percent in 1992-93 which came down to 649,056 tonnes which was further decreased by about 1 percent in 1993-94 when the production was 645,080 tonnes of chinaclay. In the year 1994-95, the production was 732,233 tonnes which was further increased to 831,098 tonnes in 1995-96. However, this increasing trend discontinued in 1996-97 when the production was 775,283 tonnes which was less by 6.7 percent than the previous year. In the year 1997-98, production was increased by 2 percent than in 1996-97. However, provisional figures for the year 1998-99 showed that there was 10% less production than the previous year.

The state-wise and year-wise production of chinaclay for the period 1990-91 to 1998-1999 is given in the Table 6.2.

From the table, it can be seen that Rajasthan, West Bengal, Kerala, Gujarat, Andhdra Pradesh and Bihar are the main kaolin producing states in India. Details of the kaolin production (state-wise) are given below.

6.4.2 Rajasthan

Rajasthan is the pioneer producer of kaolin in India. Principal districts for kaolin mining in Rajasthan are Bikaner, Bhilwara, Chittaugarh, Jaipur and Alwar. There are 26 kaolin mines in the state producing about 150,000 tonnes of kaolin per year which is almost 23 percent of the total production in India. Bikaner kaolin grade is the best in India.

In 1990-91, the state produced 217,960 tonnes kaolin which was 30 percent of the country's production. The production considerably increased (by 21 percent) during the year 1991-92 which reached to 265,686 tonnes. However, this rising trend discontinued in the year 1992-93 and kaolin production in the state was only 153,559 tonnes which was 24 percent of the country's production and about 42 percent less than the previous year. This was the year when production of chinaclay in the country was low probably due to decrease in the demand. The production further decreased to 149,098 tonnes in 1993-94 which was 23 percent of the country's production of kaolin. During the year 1994-95, the production was 204,198 tonnes which was about 28 percent of the country's production. In the year 1997-98, the production was 156,704 tonnes which was 19 percent of India's total production. In Bikaner district, the mining is mainly concentrated around Kolayat village which is 65 kms from Bikaner. There are about 72 mining leases of clay. Most of them are working. Out of these, four are for chinaclay (Kaolin). However, the deposit and grade of clay from all these mines are almost same.

6.4.3 West Bengal

West Bengal is the second largest producer of kaolin in India. Major kaolin producing districts are Birbhum and Bankura. In 1990-91, West Bengal produced 122,336 tonnes of kaolin which was 17 percent of total production of kaolin in India. In the year 1991-92, the production was slightly down to 120,179 tonnes which was 15 percent of the total production in India. There was a considerable decrease in production in 1992-93 which came down to 103,630 tonnes which was 16 percent of India's total production in the year. However, there was a marginal rise in production in the year 1993-94 (109,911 tonnes) and further rise in 1994-95 (120,225 tonnes) which were 17 & 16 percent of the India's production in 1993-94 and 1994-95, respectively. In the year 1995-96, the production was less by 7 percent than the production of previous year which downed to 111,302 tonnes and was 13 percent of the country's production. The production was further decreased to 102,843 tonnes which was also 13 percent of the country's production in 1996-97. In 1997-98, the production was slightly increased and reached to 109973 tonnes.There was sudden decrease in the production during the year 1998-99 to 71105 tonnes. The production in the year 1999-2000 was 79520 tonnes. Clay produced from Bankura district is being despatched to paint, pesticides, potteries, sanitaryware and ceramic industries.

6.4.4 Kerala

Kerala is the third important state in respect of production of kaolin in the country. Cannanore, Kasargod, Kollan and Thiruvananthapuram are the major kaolin producing districts in Kerala. The kaolin produced from Nileshwar Mines and Kundara mines are equally good in case of grade as Bikaner clay.

There are 22 mines which produce kaolin in the state. The production of kaolin in the year 1990-91 was 91,348 tonnes which was 13 percent of the country's production. The production of kaolin during the year 1991-92 was increased to 102,775 tonnes and was again 13 percent of the country's production. The production was further increased to 111,502 tonnes in the year 1992-93 which was 8 percent more than the production in the previous year. In the year 1993-94, the state produced 145,635 tonnes which was 23 percent of the country's production and was 30 percent more than that in the previous year. The production level of kaolin has gone down by 15 percent and reached to 124,683 tonnes during 1994-95 which was 17 percent of the country's production. However, there was 23 percent rise in production in 1995-96 which reached to 154,557 tonnes (19 percent of country's production). The rising trend continued in 1996-97 also, producing 173,666 tonnes (12 percent more than the previous year's production) and was 22 percent of the country's production. The production in 1997-98 was 163813 tonnes which was 6 percent less than the previous year.

6.4.5 Gujarat

Gujarat is the fourth largest producer of kaolin in the country. The major kaolin producing districts are Banaskantha, Kuchchh and Mehsana. There are about 15 working mines in these three districts. The major kaolin deposits are in Kuchchh district. The production of kaolin in 1990-91 was 66,770 tonnes which was 9 percent of the country's production. The production was decreased in 1991-92 and reached to 58,925 tonnes which was 7 percent of total production in the country. In the year 1992-93, the production level was almost same (58,004 tonnes) but this was 9 percent of the total production of the country. There was a steep rise in production of kaolin in the year 1993-94 which went up to 95,392 tonnes and was 15 percent of the India's production. In the year 1994-95, the production was decreased considerably (by 14.15%) and recorded 81,903 tonnes which was 11 percent of the country's production during the year. However, there was a considerable rise in production in 1995-96 and 1996-97 which had gone up to 105,255 tonnes and

107,565 tonnes respectively (13 and 14 percent of the country's production). There was a slight rise in production during 1997-98 when it rose to 118,993 tonnes which was 15% of India's production of kaolin.

6.4.6 Delhi

Delhi was the fifth largest kaolin producing state in the country. Major kaolin deposits were found in Kussumpur area. The production of kaolin during 1990-91 was 59,754 tonnes which was 8 percent of the India's production. The production was considerably boosted by 21.7% to 76,320 tonnes in 1991-92 and which was 10 percent of the total production of the country. This rising trend discontinued in the year 1992-93 and the production was 40,168 tonnes (down by 47.37%) which was 6 percent of the total kaolin production of the country. The production stopped since 1993-94 as the mining area/lease has been taken over by Delhi Development Authority by whom mining has been restricted. About 7,29,000 tonnes of chinaclay is lost forever as it could not be extracted due to blockage under the extended urban area. This incidentally is almost equal to the total production in India in a year[6].

6.4.7 Andhra Pradesh

Andhra Pradesh is the sixth largest producer of kaolin in the country. The major kaolin producing districts are West Godavari (19 mines), East Godavari (14 mines) and Adilabad (5 mines). The production during 1990-91 from the state was 51,272 tonnes which was 7 percent of the country's production. The production was slightly decreased to 50,420 tonnes in 1991-92 and was 6 percent of the India's production. In the year 1992-93, the production was raised to 53,454 tonnes which was 6 percent more than the previous year and was 8 percent of the country's production. The production came down by 24 percent in 1993-94 and was 40,729 tonnes (6 percent of country's production). However, in 1994-95 the production was raised to 69,904 tonnes which was 7 percent of the country's production. The production further raised by 4 percent in 1995-96 and was 72804 tonnes which was 9 percent of the country's production. This rising trend continued for 1996-97 also and the production was increased to 87,707 tonnes which was 11 percent of the country's production and 20 percent more than that of the previous year. In the year 1997-98, the state was third largest producer of kaolin in the country when it produced 121,434 tonnes which was 15 percent of India's production. The kaolin produced is despatched to refractory and ceramic industries.

6.4.8 Bihar

Bihar is the seventh largest state for producing kaolin in India. Rajmahal area of Sahebganj district is an important centre for mining of chinaclay. It is actually kaolinised sandstone from which both quality chinaclay and silica sand are recovered. The total reserves of the area are estimated at 19 million tonnes. The production of kaolin in 1990-91 was 37,887 tonnes which was 5 percent of India's production. The production during the year 1991-92 was slightly raised to 38,843 tonnes which was 5 percent of the country's production. However, the production decreased in the year 1992-93 and came down to 29,554 tonnes) down by 23.9%. In the year 1993-94, the production increased considerably by 23.58% and gone up to 36,524 tonnes and further rose to 46,064 tonnes by 14.76% in the year 1994-95. However, the percentage of production was almost steady by producing 6 percent of India's total production during both the years. The production during 1995-96 considerably increased by 16 percent more than the previous year and gone up to 53615 tonnes which further rose to 62932 tonnes in 1996-97. In 1997-98, the production was decreased to 58,578 tonnes which was 7 percent less than the previous year. A list of the Principal producers of kaolin during the year 1997-98 is given in Table 6.3.

Table - 6.3 : Principal Producers of Kaolin during the year 1997-98

Name and address of the producer	Location of the mine	
	State	District
English Indian Clays Ltd., P. O. Veli, Distt. Thiruvananthapuram, Kerala - 695 021.	Kerala	Thiruvananthapuram
Patel Nagar Minerals & Industries Pvt. Ltd., P. O. Mohammad Bazar, Patel Nagar, Distt. Birbhum, West Bengal.	West Bengal	Birbhum
Md. Sherkhan Pathan P. O. Sawa, Distt. Chittaurgarh, Rajasthan - 312 613.	Rajasthan	Chittaurgarh
Shivshakti Minerals, Bansliya Chinaclay Mines, P. O. Iswal, Tq. Girwa, Distt. Udaipur, Rajasthan.	Rajasthan	Udaipur
Dinesh Chandra Soni, Sri Ambica Minerals, Near Nehru Park, P. O. Nimbahera, Distt. Chittaurgarh, Rajastshan - 312 601.	Rajasthan	Chittaurgarh
Shankarlal Gangaram Thakkar, P. O. Śanthalpur, Distt. Banaskantha, Gujarat - 385 350.	Gujarat	Kachchh
K. T. Mines (Kamakshi Threteswara), Post Patur, Nandalur Mandal, Distt. Cuddapah, Andhra Pradesh.	Andhra Pradesh	Cuddapah
Durga Prasad Bansal, Pilikothi, Hissar Road, Rohtak - 124 001, Haryana.	Haryana	Faridabad

(Contd.)

Table - 6.3 : (Contd.)

Name and address of the producer	Location of the mine	
	State	District
Sri Satya Sai Mines & Minerals, P. O. Dwarkatirumala, Distt. West Godavari - 354 426.	Andhra Pradesh	West Godavari
Mangilal Deedwaniya P. O. Kotri, Distt. Bhilwara, Rajasthan.	Rajasthan	Bhilwara
G. D. Mishra, P. O. Mohammad Bazar, Distt. Birbhum, West Bengal.	West Bengal	Birbhum
Shri Modi Lavigated Kaolin (P) Ltd., P. O. Nim-ka-Thana, Distt. Sikar, Rajasthan - 332 713.	Rajasthan	Jaipur
E. A. Rasheed Thiruvananthapuram , 38/ 1058, Power House Road, Thiruvananthapuram, Kerala.	Kerala	Thiruvananthapuram
Popular Minerals, Prop. Md. Sherkhan, P. O. Sawa, Distt. Chittaurgarh, Rajasthan - 312 613.	Rajasthan	Chittaurgarh
The West Bengal Projects Ltd., Silpa Bhawan, 1st Floor, 2 & 3 Black Burn Lane, Calcutta - 700 012.	West Bengal	Birbhum
Md. Yusuf & Brothers, P. O. Rajmahal, Distt. Sahibgunj, Bihar.	Bihar	Sahibgunj

(Contd.)

Table - 6.3 : (Concld.)

Name and address of the producer	Location of the mine	
	State	District
Ghisulal Ojha, P. O. Pipland, Tq. Jahazpur, Bhilwara, Rajasthan.	Rajasthan	Bhilwara
Jitendrakumr S. Jobanputra P. O. Santalpur 385 350, Distt. Banaskantha, Gujarat.	Gujarat	Kachchh
Kerala Clays & Ceramics Products Ltd., P. O. Pudukai Nileswar, Distt. Kasargod, Kerala.	Kerala	Cannanore, Kasaragod
Progressive Mineral Corpn., Patel Nagar, P. O. Md. Bazar T. S. Distt. Birbhum 731 132, West Bengal.	West Bengal	Birbhum
Kerala Industrial Polymers Ltd., 'Padmasree', Vellayambalam, Distt. Thiruvananthapuram, Kerala - 695 010.	Kerala	Thiruvananthapuram
Rajmahal Quartz Sand & Kaolin Co., 1 No., N. S. Road, Calcutta - 700 001.	Bihar	Sahibgunj
Bhaskar Stoneware Pipes (P) Ltd., Amar Nagar, Faridabad, Haryana.	Haryana	Faridabad
The Kerala Ceramics Ltd., P. B. No. 2, P. O. Kundara 691 501. Distt. Quil/Kollam, Kerala.	Kerala	Kollam
Kunjilal Ishwari Prasad Agrawal P. O. Jaitwara, Distt. Satna 485 221, Madhya Pradesh.	Madhya Pradesh	Satna

6.5 Important Kaolin Mines

In India, there were about 159 mines which were producing kaolining the year 1999-2000. These mines are located in eleven different states in a pocket like deposits. The main kaolin mines are in Kerala, Andhra Pradesh, Rajasthan, West Bengal, Gujarat, and Bihar. Different kaolin mining system is adopted at different places though the method of mining is opencast. Some selected mines are described below and these are selected on the basis of production which are producing around 10,000 tonnes kaolin in a year. These mines are also selected on the basis of their different occurrences in different states which are producing major part of India's kaolin production.

6.5.1 Mine 'A'

The mine is located near village Rajmahal in Sahibganj district of Bihar state. The lease area is 8.01 hectares and expiring in 2002. No systematic exploration in the area has been carried out.

The mining operations are carried out by opencast method. There are four main working pits. The max. length of the pit is 120 m, width 100 m and depth 40 m. The total area under mining operations is about 4 hectares. The working is carried out manually and no mechinery is deployed.

During the year 1996-97, the production was 21,783 tonnes. the mine was worked for 301 days during the year at one shift.

The chemical analysis of the sample of mineral contains alkalies 0.20%, LOI - 12%, SiO_2 - 47%. TOP_2 - 0.40% Fe_2O_3 - 1.40% and Al_2O_3 - 37.69%.

6.5.2 Mine 'B'

The mine is located near village Rajmahal in Sahibganj district (Bihar). The mining lease area is of 5.04 hectares.

The mining is carried out by opencast method. There are two main working pits. The maximum length of the pit is 150 m and depth of 12 m. The maximum width of the pit is 70 m. The total area covered under mining is about 1 hectare. No machineries are deployed.

During the year 1996-97, the mine worked for 169 days only in one shift per day. The production was 4850 tonnes. The clay is of pottery and ceramic grades.

The chemical analysis of the sample from this mine contains SiO_2 - 478%, Fe_2O_3 - 2.43% and Al_2O_3 - 35.50% and LOI 13.70%.

The chinaclay produced from this mine is sold to pottery and ceramic industries.

6.5.3 Mine 'C'

The mine is located near village Rajmahal in Sahibganj district in Bihar. The area of the lease is 62.50 hectares in 4 blocks.

The mining is carried out by opencast method. There is only one main working pit having size of 120 m length, 80 m width and 20 m depth. The chinaclay occurs along with silica sand and the percentage of chinaclay to silica sand is 10 and 90 respectively. The overburden is removed by shovel and minerals are excavated manually. The mining operations are carried out in about 5 hectares of area. The thickness of the mineralised zone is 15 m.

During the year 1996-97, the mine worked for 287 days in one shift per day. The production was 3429 tonnes of chinaclay and 29,808 tonnes of silica sand. The average employment was 338 persons. They have approved Mining Plan. They have deployed 2 excavators, 4 trucks and 1 tractor of 40 H. P. for excavating mainly overburden. Besides, 7 pumps and 4 diesel generators are also deployed.

The chemical analysis of the sample from this mine contains (in percentage) Al_2O_3 - 35.14%, Fe_2O_3 - 0.51%, SiO_2 - 50%, TiO_2 - 0.60%, CaO - 0.06%, MgO - 0.10%, K_2O - 0.21%, LOI 13.04% and undetermined - 0.26%.

They mainly face the problems of irregular supply of electricity, storage of diesel and irregular availabilty of labours.

6.5.4 Mine 'D'

The mine is located in Ranchi district of Bihar. The lease area is 96.84 hectares out of which 41 hectares are forest land. In situ reserves are 6.2 million tonnes. The thickness of clay is up to 15 m proved by drilling and still persisting as bottom has not been touched.

The mining is carried out by opencast method. CK-90 loader and two Terex dumpers of 25 tonne capacity are deployed for the mining for removal of overburden. The mine is mainly worked for bauxite since last 50 years.

During the year 1996-97, the mine was worked for 355 days and produced 694 tonnes of chinaclay. The raw clay is washed and beneficiated. The production of processed clay was 184 tonnes.

The clay sample of this mine contains SiO_2 - 43%, Al_2O_3 - 38%, Fe_2O_3 - 1.6%, TiO_2 - 2.7% and LOI - 13%.

6.5.5 Mine 'E'

Mokdumnagar mine is located near village Mokdumnagar in Suri Sadar Tahsil of Birbhum district, West Bengal. There are two leases covering a total area of 29.20 hectares. Total estimated reserves are 12.40 million tonnes.

The mining is carried out in only major pit sizing 100 m x 80 m and depth reached to 20 m. maximum. There are separate benches in overburden and in mineral. The height of the bench is kept 1.5 m. The working is carried out in only one shift. In the year 1996-97, the working days were 301. In 1996-97 the production was 12,147 tonnes and PMV was Rs.175/- per tonne.

Kaolin contains Al_2O_3 - 37.40%, Fe_2O_3 - 1.78%, SiO_2 - 45.9%, TiO_2 - 1.60%, CaO - 0.60%, MgO - 0.06%, Na_2O - 0.26% and LOI - 14.42%.

The beneficiation plant is located about 1 km from the mine which is outside the lease hold.

6.5.6 Mine 'F'

The mine is located near village Thonnakkal in Thiruvananthapuram district of Kerala state. The lease area is 8.23 hectares in three blocks. The china clay is found under 6.5 m thick soft laterite which is convered by 1.5 m thick top soil. Clay thickness is 7 m.

The mining is carried out by opencast method by forming proper benches. There is only one main working pit in the area. Hydraulic excavator is used for mining. The length of the bench is 160 m in overburden and 120 m in ore. The height of the bench is 6 m in overburden and 4.5 m in ore. The maximum depth of the pit is 20 m. The mine has also deployed 7 pumps having 5 hp capacity each.

During the year 1996-97, the production from this mine was 1,36,195 tonnes of raw clay. The mine was worked for 299 days in two shifts. The average employment of labours was 25 persons.

The mineral from this mine contains Al_2O_3 - 40%, Fe_2O_3 - 0.32%, SiO_2 - 45%, TiO_2 - 0.60% and LOI - 14.10% indicating very good quality of clay.

6.5.7 Mine 'G'

The mine is located near village Devengi, Tah.- Thirthahalli of Shimoga district in Karnataka state. The lease area is in three blocks covering 33.99 hectares which was to expire in November 1998 and must have been renewed.

The mining is carried out by opencast method. Three tractors with 4 tonne tipping trollies capacity each are deployed for transporting overburden and mineral. Besides this, 2 diesel engines (5 hp each) and four electrical pumps are also deployed in the mine. The mined out area is reclaimed by backfilling overburden and waste material. Such reclaimed area is about 0.43 hectares.

During the year 1996-97, the production from this mine was 12,612 tonnes. Average daily labours employed was 87.

6.5.8 Mine 'H'

The mine is located near village Nileshwar, P.O. Puthariyadukkam in Kasargod district of Kerala state. The lease area covering 2.925 hectares expiring in 2002. Total mineable reserves are 0.5 million tonnes.

The mining is carried out by opencast method. All the mining operations are done manually. Clay washing plant is nearby the mine.

One pump of 5 hp capacity is deployed at the mine site. At the washing plant, 2 filter press (50 chamber & 5hp capacity each), 2 electric motors of 5 hp capacity each, 1 cyclone separator 25 hp capacity, one pulveriser one pump of 15 hp capacity are deployed.

During the year 1996-97, the production of processed clay was 4650 tonnes. The mine worked for 215 days during the year, giving average employment for 79 persons per day. The clay produced from this mine is sold to Ceramics, Refractories, Pesticides, Chemicals and Rubber industries.

6.5.9 Mine 'I'

The Kotri mine is located nearby Kolayat village in Bikaner district of Rajasthan. The lease area of the mine is 38.94 hectares.

The mining is carried out in a single working pit sizing about 400 m x 200 m and reached to a maximum depth of 20 m. There are separate benches in overburden as well as in mineral also. The overburden is removed by hydraulic shovel and loaders. The kaolin is of good quality and is despatched to ceramics and cosmetic industries.

Mining is carried out systematically under the guidance of qualified Mining Engineer. The lessee has prepared a mining plan for the mine.

6.5.10 Mine 'J'

Indaka Bala Mine is located near village Kolayat in Bikaner district of Rajasthan. The lease area is 123.86 hectares. In Kolayat area there are three blocks mineralised for clay and Indaka Bala is the eastern block of Kolayat area.

Mining is carried out by opencast method and manual work has been carried out. Separate benches in overburden and in minerals are formed. The overburden is occasionally being excavated by earth moving machinery on hired basis.

The quality of the clay reported is not good (lowest in three working blocks). The chemical analysis reported indicates around 55% SiO_2, 28.45% Al_2O_3, 2.65% TiO_2, 1.09% Fe_2O_3 and 10-12% LOI.

6.5.11 Mine 'K'

The mine is located near village Chandpura in Bhilwara district. The lease area is 32.37 hectares and was to expire on 19.10.1999.

Mining is carried out by opencast method. Benches in overburden and clay mineral are developed. Overburden removal is mechanised with the use of excavator and tipper trucks dumpers.

In the year 1996-97, the mine was worked for 233 days in one shift. Average daily employment was 8 persons. The production from this mine during 1996-97 was 20,592 tonnes.

There is a beneficiation washing plant for processing of clay outside the lease area. The over burden is of soil and is stacked separately for future use. The used water in washing plant is discharged in the Banas river which is nearby lease area. Previously (originally) the lease was for soapstone only the but lessee had added chinaclay afterwards and presently mining of chinaclay is a major operation. The soapstone is rarely produced.

The mine owner is stacking sub-grade mineral for future beneficiation use (if possible). The waste is being dumped away from pit in proper manner which is in between pit and Banas River. Care is taken that no waste is transported along with mine water being pumped or rain water. Mine water also goes to the river through drains with no solids in suspension.

The mine owner has also planted a number of trees to make the area green and looking after the same properly for its good survival.

6.6 Conservation Problems in Kaolin Mines

As kaolin mining is being carried out in different states and being a different type of deposit, every area has got its own conservation problem. These problems are described below (statewise/areawise).

6.6.1 Bihar

i) In Rajmahal area, it has been observed that the rejects generated after washing the kaolinised sandstone are being stacked separately in an unsystematic manner as coarse and silt reject for utilisation in future. Such stocks should be made in a proper way/place which should not be mixed with waste due to natural agencies [5].

ii) Huge quantity of coarse rejects is lying in each leasehold. At least 75% of these material may be possible to make suitable for market by simple grinding with the help of pulveriser [5].

6.6.2 Delhi

i) There are number of mines which are located nearby city/cities. The urban limit is increasing day by day and localities are comming in to the mine area due to which the mines are closed. The valuable mineral is becoming unrecoverable due to extension of urban areas over the mineralised ground.

6.6.3 Kerala

i) Around 34 lease areas have been identified as potential by reconnaissance survey. Intensive exploration has been done by DMG and KMEDP in a few areas like Nileshwar of Kasargod district, Mulavana of Quilon district, Melthonnakkal of Thirvananthapuram district, and Payangadi and Cheruthazhan of Cannanore district. In order to suggest measures of conservation to the State Government, more areas of the 34 identified areas as potential, need to be explored[17].

ii) There are a number of small leases where clay could not be worked out to its full extent. Large areas (minimum 5 hectares) may be made available for mining lease so that optimum exploitation of the mineral can be carried out with environment friendly mining[7].

iii) In Quilon and Thiruvananthapuram districts, mining ends when the sandy zone is encountered below the sedimentary clay. Refilling is also done when the mining of clay ceases. It is necessary to explore the area below the sand zones also for the possibility of encountering and working parallel clay bed, if any[7].

6.6.4 Rajasthan

i) In Bikaner district, though the kaolin mining has been started before 30 years or so, no systematic exploration has been carried out in the Kolayat area where kaolin deposit is located. In the interest of the conservation of mineral, it will be helpful if the pits/boreholes on grid pattern are made up to the bottommost kaolin bed and mining should be carried out up to the optimum/maximum depth before starting back filling.

ii) In most of the mines, higher grade clay had been mined out to get higher margin of profit. Such selective mining should be avoided in view of the conservation aspect[4].

iii) In opencast workings, the mining is carried out without formation of proper benches. At many places the height of the bench is as high as 8 m in overburden and 4 m in clay. The width of the benches has not been kept in proportionate to the height, resulting in collapsing of the faces during rainy season. To extract the mineral to its maximum possible extent, it is necessary to work the deposit by opencast method with systematic formation of benches in overburden as well as in clay[4].

iv) Number of small streams lead to Kolayat Talab. During rainy season, these streams carry water to this Talab. Mining area in Bikaner district contains these small streams having a very good accumulative effect for this important Talab of the area. Due to mining, this natural water drainage system has been disturbed. It becomes necessary to direct these natural streams so that these do not die in the pits or blocked by the waste dumps. Blocking of these natural water ways has resulted in less water carried to Kolayat Talab reducing water in this Talab.

6.6.5 West Bengal

(A) Bankura District

i) In almost all the mines, normal practice is to dump mine spoils on the grounds adjacent to the quarry workings and also within the quarries without ascertaining the potentiality of such dumping grounds or below the floor level of the quarries.

ii) In some of the mines, formation of proper benches is not being carried out. In most of the cases attempts have been made to form benches which fail during rainy season and the very purpose of the formation of benches gets defeated, affecting the conservation of mineral and development of mines. At times, the benches in overburden are not kept sufficiently advanced from the clay benches and as a result the clay gets contaminated by partial failure of benches due to rains and the overburden material gets mixed with the clay by which valuable clay is lost. Diversion of rain water on surface away from the pit should be done to avoid such situation.

iii) As there is a demand for good quality of kaolin, only selective mining is carried out and low grade kaolin is kept unmined. This results in unsystematic mining.

iv) Overburden and waste material obtained during mining operations are allowed to be mixed with non-saleable or sub-grade kaolin. It is not being dumped on separate ground earmarked for the purpose. Thus, the clay which could be recovered by levigation in future, is lost forever[3].

(B) Birbhum District

i) In many of the quarries, the china clay zone has not been exposed to its full thickness. Further deepening of the quarries and auger drilling on the floor of the quarry may reveal underlying clay zone.

ii) Selective mining can be avoided. If areas with poor recovery/grade/depth are worked simultaneously with better areas judiciously, it will help in conservation of kaolin[8]. Poor grade clay, wherever possible may be blended with high grade clay. Alternatively, when quality is more, levigation may be thought of.

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7. Mining in other Countries

7.1 Background

In 1990, there were 56 countries producing kaolin. This number reduced to 52 in 1996. In regards to production, USA is the pioneer country followed by U.K., Korea and Brazil[1]. Erstwhile USSR was the third largest producer of kaolin in the world in 1990. After formation of CIS, Ukraine which was main kaolin producing state of USSR, produced 1 million tonnes[1] of kaolin in 1992.

7.2 Method of Mining

Throughout the world, Chinaclay mining is generally carried out by opencast method except some underground mines viz. Yangxi area of Wuxian country, Suzhou city (China). In many of the mines, hydraulic excavators and dumpers are being used for removing Chinaclay. In German, overburden removal and transportation are fully mechanised and mining is done with pneumatic spade, electric slicing machine, power shovel front end loaders, paddle shovels and draglines by open cast method mining.

The other way to obviate the handling of crude clay by manual or mechanical methods is by hydraulicking and pumping wherever feasible. Hydraulicking is applied to excavation by streams of water under pressure from nozzle. Water is generally impounded from reservoirs and diverted from streams and conducted through ditches and pipes to an elevated point above the deposit and hence to the working face through pipes. Giants or Monitors are used to control the direction of jet. The rock of mineral bearing ground is broken partly by direct impact of jets and partly by undercutting and forcing the banks to come out. Water flow away from the face along with suspended rock/ mineral fragments to be discharged or dumped in slices or settling tanks. This method is used in U.K. (Cornish Mines).

In USA, in most of the mines, bucket elevators are used where hydraulic mining is practised for conveying clay from pit to bottom to the surface. In some cases, plunging is done in the pit for keeping clay in suspension and the clay slurry is transported to washing plants by pipe line transportation through rubber lined pipes.

Most of the countries in the world use opencast method of mining for producing kaolin. Large producers of kaolin use Hydraulic excavators. Main producers are having their own levigation plants nearby mine/kaolin producing area. As the kaolin being low valued mineral compared to metallic minerals, the literature is also rarely available. However, the kaolin mining in situ in respect of nine countries are described in this chapter.

7.3 Australia

Australia produced about 0.36 million tonnes of kaolin in 1990 which came down to 20 million tonnes in 1994 accounting for twelfth in rank in respect of kaolin production. The production was slightly more by 10,000 tonnes in 1995 i.e. 210,000 tonnes.

The major kaolin producing area is Cape York Peninsula in Queensland. The mine is operated by M/s Comalco. Kaolin used is of paper coating grade. Kaolin is mined from a layer under bauxite. Production is planned for 150000 to 300000 tonnes per year. All coating clay produced is mainly exported. In the area, another kaolin project is also under consideration[2].

7.4 Brazil

As per the world's kaolin production figures, Brazil is the fourth largest producer of kaolin. It produced 1.32 million tonnes of kaolin in the year 1994 which was slightly decreased to 1.26 million tonnes in the year 1995.

Greenfield Project

Considering the heavy demand of pigments in paper industry throughout the world, Greenfield Project has been developed by M/s Para Pigments SA in August 1996. This project is located in Amazon region of Brazil. The deposits in this region are well known in kaolin industry and are highly regarded because of their unique in situ brightness.

The company estimates the cost of the project at \$ 180 m to produce 1 m tpa. The company Para Pigments was established in Brazil in March 1992 with the purpose of exploring the development of a mining operation in the Rio Capin region of northern Brazil in Para state. The Barcarena port is joined with pipeline, from the plant location.

Greenfiel.d Project is a completely new project in an undeveloped area and in a remote location where no infrastructure is existing. The future cost and reserve estimations lead to the view that the Brazilian deposits will have an important role to play in the twenty-first century[3].

7.5 China

The term kaolin is used commercially to describe near white clay deposits containing primarily the mineral kaolinite. The term was derived from the Chinese kaoling, measuring high ridge, and "Chinaclay" has been used as a synonym for kaolin for many years. In fact, the chinaclay was first mined some 3000 years ago at a hill near Joucha Fu in Jiangxi province[4].

7.5.1 Jiepai Mine

The mine is located in Hunan province of China. The type of the deposit is boundary migmatite altered kaolin deposit. The kaolin occurs in weathered zone of migmatite, stratiform, strataoid. The thickness of clay bed ranges from 6.73 to 35 m. The deposit is having a depth of 100 m and the inclination is 0.32%. The mineral consists of halloysite, kaolinite, quartz, albite and limonite. The composition is SiO_2 > 65-72%, Al_2O_3 16.5-23.5% and Fe_2O_3 0.22-1.5%. The clay produced from this mine is used for the porcelain industry. The mine is having kaolin producing capacity of 150,000 - 2000,000 tpa which is the largest one in the country[1].

7.5.2 Datong Mine

Datong kaolin mine is located in Shaanxi province of China. The kaolin deposit is of coal bearing tectonic sedimentary type. It occurs in carboniferous permian system. This mine has a long history of development. There are six natural types of ore, composed of sparry kaolinite, hydromica, gibbsite, etc. The chemical composition is closed to the theoretical content of kaolin with negligible impurities having Fe_2O_3 < 1%. The production capacity is 50,000-100,000 tpa. The material produced from this mines is being used for ceramic and refractory industries[4].

7.5.3 Donggongxia Mine

Donggongxia mine is located near Longyan city in Fujian province. Kaolin deposit is a granite weathered type deposit. It occurred in weathered zone of adamellite and strataoid. The length of the deposit is almost 1.5 km and width is 500 m. The mine is owned by M/s Minxi Kaolin Company. The kaolin is composed of white, halloysite, kaolinite, quartz, illite, etc. The chemical composition is SiO_2 65-73%, Al_2O_3 15-18% and F_2O_3 1.5 - 2%. There are 11 ore dressing plants for the mineral processing which is produced from this mine. The production capacity of this mine is 30,000-50,000 tpa which is the third largest kaolin producing mine in the country[4].

7.5.4 Xingsi Mine

Xingsi mine is located near Jingdezhen which is a well known ceramic production location in Jiangxi province of China. Kaolin deposit is of granite pegmatite weathered type deposit. The ore body is striking N-E direction. The length of the deposit is 600 m, width 100 m. and depth 20 m. Pegmatite ore is of good quality. Kaolin contains kaolinite halloysite. The chemical composition of kaolin from this mine is SiO_2 51-58%, Al_2O_3 26-32% and Fe_2O_3 1.3-2.3%. Pegmatite type kaolin is having chemical composition of SiO_2 50-55%, Al_2O_3 29-34% and Fe_2O_3 1.3-1.7%. The kaolin produced from this mine is being used for ceramic industry. The production capacity is of 10,000 tps of kaolin[4].

7.5.5 Liling mine

Liling mine is located in Hunan province which is a well known ceramic producing location in China. Kaolin deposit is of quartz porphyry, weathered type deposit. It occurs in weathered quartz porphyry zone. The length of the deposit is 1 km and width 800 m. The thickness of the kaolin deposit is 30-50 m. The mineral composition is of kaolinite, quartz, hydromica, etc. The chemical composition is SiO_2 > 70%, Al_2O_3 14-15%, Fe_2O_3 < 0.93% and K_2O > 4%. The mine has a long history and is one of the oldest mines in the country. The production capacity of the mine is 10,000 tpa of kaolin.

Other important kaolin mines in China are given in Table 7.1[4].

Table - 7.1 : Important Kaolin Mines in China

Mining area	Type of the Deposit	Ore body	Mineral composition	Development & utilisation
Daquito kaolin deposit of Yongchun, Fujian province	Granite porphyry rocks & volcanic detrital rocks weathered kaolin deposit	Occured in weathering plane of ore-forming protolith, strataoid, orebody 1,100m. long, 150 m. wide, 40m. thick whiteness 58.8-67.2%	Kaolinite, illite quartz, feldspar, goethite, etc. SiO_2 72-76%, Al_2O_3 15-18%, Fe_2O_3 1.09-1.55%, TiO_2< 0.6%;	20,000 tpa supply to ceramic industry
Beishan kaolin of Qingtian country, Zejiang province	Crystal-vitric welded tuff, hydro-thermal alteration	Lentiform, strataoid 150m. long, 200m. inclined 1.75-5.58m. thick, dip 100°-130°, dip angle 15°-20°.	Kaolinite, dickite, quartz, pyrophyllite, etc. SiO_2 67-74%, Al_2O_3 19-24%, Fe_2O_3 0.07-0.82% and TiO_2 0.3-0.6%.	Small scale production for ceramic industry, etc.
Xuyong kaolin of Sichuan province	Denuded surface weathering and leaching kaolin deposit	Occurred in Permian system limestone and pyrite-bearing kaolinite clay-rocks, interrupted planer dispersion, nested occurrence, up to several metres thick	Halloysite, kaolinite, gibbsite, organic matter, SiO_2 36-48%, Al_2O_3 34-38% and Fe_2O_3 0.12-2.47%	Long history of small-scale mining
Changbai kaolin deposit, Jilin province	Tuff, hydrothermal altered kaolin deposit	Occurred in Jurassic system tuff. 4 ore-bodies, NW, NNW tendency, dip angle NE 20°-50°. 200-300m. long, 18 - 45m. wide, lentiform, irre-gular, roof and floor are rhyolite tuff	White, soft, compact blocks, dickite, alunite, pyrophyllite, etc. flake structure, high hardness, SiO_2 43.59-45.96%, Al_2O_3 39-40.77% and Fe_2O_3 0.17 - 0.20%	5,000-10,000 tpa
Guanshan area of Xushuguan, Suzhou city	paleovolcanic tuff hydrothermal alteration	Ocurred in interplanes of unconformity of Permian Triassic systems and Jurassic igneous rocks. Stratiform, E-W 1700 m, S-N 1 240 m.	Halloysite with kaoli-nite, pyrite alunite, organic matter as secondary Al_2O_3>30%, SiO_2<65%, Fe_2O_3<4% and SO_3<4.5%	By China Kaolin Co. producting refined kaolin for paper-making electronic and rubber industries

(Contd.)

Table - 7.1 : (Concld.)

Mining area	Type of the Deposit	Ore body	Mineral composition	Development & utilisation
Yangxi area of Wuxian country, Suzhou city	Paleoothophyre vein hydrothermal alteration	Occurred in reversed fault planes of Permian system and Devonian system sandstone. Stratiform, strataoid, gigantic veined structure, 500m. long & 20-100m. wide	Kaolinite and halloysite, rutile, pyrite, alunite, etc. as the secondary. Al_2O_3>24%, SiO_2 50-70% and Fe_2O_3 +/-3%	China Kaolin Co. developed by shaft. Products for paper-making, electronic, refractory materials and fillers
Yangdong area of Xushuguan, Suzhou city	Paleokarst denudation cave fillings, altered kaolin deposit	Occurred in caves of Permian system limestone. 150-300m. long, 50-100m. wide and 70-130m. deep	Halloysite, kaolinite, pyrite, etc. Al_2O_3>33%, SiO_2<46%, Fe_2O_3<3% and SO_3 2-3%	Long history mining, product for catalyst, paper-making and rubber industry
Maomin deposit, Guangdongdong province	Arkosic & quartz sandstone weathered residual kaolin	In Tertiary system, granule gravel, feldspar & quartz weathered into kaolin deposit. Dip NE-SW, dip angle : 4-12°, total thickness : 21.29m.	With hexagonal kaolin, halloysite, quartz, feldspar, mica, etc. SiO_2<83%, Al_2O_3>11%, Fe_2O_3 0.93% and TiO_2<0.32%	Discovered in 1989, 10 ore sites mined, product for paper-making
Shandai deposit of Zhanjiang city, Guangdong province	Granite weathered kaolin deposit	Occured in granite weathered zone, planer dispersion, flattish occurrence, NW-SE extension, 1,300m. long, 509m. wide, 13m. deep. -2μm, 28.35-62.82%	Composed of kaolin, halloysite, quartz, hydromica, feldspar. Al_2O_3 27-38%, Fe_2O_3 0.25-2.35%, TiO_2 0.02-0.93% and Whiteness 65-88%	By developing company of Zhanjiang Kaolin. Capacity 10,000 tpa.

7.6 France

France produced 330,000 tonnes kaolin in 1994 which increased to 3,45,000 tonnes in 1995. There are six major producers of kaolin in France which are having the production capacity of 3,60,000 tonnes.

7.6.1 Charentes Basin

Charentes basin mines are operated by M/s Argile & Minerau AGS. There are several deposits of clays on 1000 Km^2 of the old deltaic area. The production of crude kaolin is 500,000 tpa. The clays are processed at Clerac (calcination, chemical, grinding, homogenisation) for use in refractories, tiles, earthenwares, sanitarywares and foundry industry. Around 35-47% Al_2O_3 grades are produced and the commercial production is around 400,000 tpa.

Other important mines namely Kaolin de Arun (300,000 tpa) and Kaolin de Beanvoir (150,000 tpa), are operated by M/s La Source Compagnie Miniere.

Kaolin du Morbihan and Kaolin du Finistere are operated by M/s Harwanne Group and having production capacity of 500,000 tpa of ore. The ore is processed at Lanvrian plant for ceramic, fibreglass and fillers industries[5].

7.7 Japan

The representative ceramic producing districts in Japan are Arita district in Kyushu Island and Tokai district. Arita district is the birthplace of Japanese porcelain. It is said that the producing technique of the blue and white porcelain was developed early in Tokugama era (about 1615). In Arita district, the ceramic industry is thriving because of the excellent and unparalleled Toseki reserves which is covered with a brownish thin skin of iron hydroxide. The porcelain fired from Toseki is easily formed, of less burning shrinkage, fitted to delicate works and easy to be conveyed. The first step towards porcelain was taken in 1904 by M/s Japan Earthenware Unlimited Partnership. After the end of second world war in 1945, the mass production of porcelain was started in Seto and Mino districts. The turning point came in 1975 when kaolin from New Zealand was added to Gairome clay and found to produce porcelain with higher strength, whiteness and translucency than Arita wares[6].

Japanese pottery has developed owing to the excellent clay that occurs in Kibushi and Gairome areas which are described below

7.7.1 Kibushi Area

This is one of the most important and typical plastic clays occurrence in the Seto district. The bodies made from the clay are formed easily, have excellent plasticity and is recognised as unique in the production of "Hakaron" - a "Keep Warm" device.

There are about 25 mines in operation in Gifu prefecture, 15 in Aichi, 6 in Mie and one in another prefecture. Out of 47 mines, about 98.7% of the country's clay is produced in 3 prefectures of Tokai district. Amongst the producing mines are Hotoku mine in Yagusa district, Ceramic Guild Silica Sand Industry Mine in Seto district in Aichi area, Inagaki Clay Mining (Estubora Mining) in Gifur prefecture, Onada Mining in Tajim city, Obora Mining in Toki city and Sanko Mining in Igaueno. The life span of these mines ranges from 15-20 years.

At present, there are many difficult problems associated with the mines - particularly pollution. Tree planting in mining areas accompanied with urbanisation and development of housing sites etc. has begun to limit the amount of clay available. Consequently, there is a danger that the excellent clays could become exhausted and overall level of production is dropping[6].

7.7.2 Gairome Area

This is the second and most important typical plastic clay occurring in East Mino districts. The clay layer contains considerably large grains of quartz giving the clay a shiny appearance. Gairome clay was deposited during the Neogene Pliocene period (2-6 million years ago) and was formed from granite. The main components are kaolin and silica sand and its standard composition is clay 20%, silica sand 60% and 'Kira' (muscovite, biotite or Hydromica) 20%.

There are now 34 mines in operation – 14 in Aichi prefecture, 8 in Gifu prefecture, 8 in Mie prefecture and 4 in other prefectures. About 98% of the whole clay is produced in three prefectures of Tokai district[6].

7.8 Sweden

From late 1970s to mid 1980s, the Geological Survey of Sweden on behalf of the state Mining Property Commission performed investigations with reference to kaolin. In Scania, the most southern part of Sweden kaolin was found in a number of places. Detailed studies including drilling demarcated ten localities with in situ weathered bedrock more or less altered to kaolin[8].

7.8.1 Billing Mine

Billing mine is owned by M/s Warmland-Guldorytning AB. The company has started to design the mine area and is in development stage. The weathered bedrock is a slightly reddish granite consisting mainly of feldspar, quartz and small amounts of mica with an iron content of less than 1%. Pilot tests shows that after concentration by hydrocyclones and magnetic separation a good recovery of both filler and coating grades are possible[8].

7.9 Ukraine

The principal kaolin deposits of the former Soviet Union are in Ukraine. It produced about 1 million tonnes kaolin in 1992. The main production centres of kaolin are Prosianaya and Glukhoretsk. Combined production from these two centres is thought to be 1 million tonnes in 1995 which was wholly consumed by CIS countries and very little had ever been exported. Deep Mesozoic chemical weathering of the rocks of Ukrainian shield is wide-sprayed and kaolin deposits have been formed by the alteration of Precambrian leucogranintes and gneisses poor in dark minerals. Both of the principal deposits are capable of yielding paper filling and coating kaolins.

The possibility arises that an exportable surplus of kaolin will emerge from these Ukrainian operation. The distance of markets in Western Europe is more than 2000 km and rail distribution system is having problems. Export by sea or waterway is also difficult.

The Ukrainian Kaolin Industry will shortly be fully occupied meeting demand from within the CIS[2].

7.10 United Kingdom

United Kingdom is the second largest producer of kaolin in the world after USA. The production of kaolin during 1990 was 3.03 million tonnes which fell to 2.57 million tonnes in 1993 but slightly increased to 2.65 million tonnes in 1994.

At present, most of the production of kaolin comes from the Western part of the country. The significance of the chinaclay deposit of Devon and Cornwall was first realised in 1746 by Cookworthy who built a kiln in plymouth in which he produced the first time hard porcelain to be made in Britain.

The primary chinaclay deposits of south west of England have been produced by the alteration of the granites that were intruded shortly after the culmination of Varisear orogeny. The kaolinised zones are either funnel shaped or trough like in form and descend to depths of more than 200 m in places. The original size of the kaolin resource was more than 20 million tonnes[2].

The major mines/area which are pioneer in producing kaolin in the country are described below.

7.10.1 Austell and Dartmoor Mines

St. Austell mines carried out mining operations in 14 pits in St. Austell area of Cornwall and 2 pits on the south western side of Dartmoor in an area known as Lee Moor. These mines are operated by M/s. English Chinaclay International Europe which is the best known producer of kaolin in United Kingdom.

The production capacity of these mines is 2.5 m tonnes of dry kaolin which represents around 90% of the production in UK. Out of these production, almost 80% material is exported via ports in both the Austell area (Fowey and Par 50% and 30% respectively, and Plymouth 15%. Only 1% of the exports is destined for non - European customers with 45% leading to northern Germany and Scandinavia; 34% to France, Beneflux and the Rhine area and the remaining 20% bound for southern Europe and Mediterranean countries.

Kaolin of these mines is extracted by using hydraulic machines, whereby high power water cannons or monitors blasts the quarry face. The resultant slurry which contains kaolin, silica and mica is then collected, refined and dried. The majority of kaolin is supplied in lumps form at 10% moisture (preference paper industry) or to the lesser extent 18% water. Small amount of the production from these mines is milled and dried for sale to the rubber industry. Additionally, some kaolin is also sold to the paper industry in slurry form. The company estimates that 75-80% of its production is used in paper sector, with only 15% used in ceramic industry. The remaining 5-10% of production is marketed by their speciality Businesses Group to rubber, plastics and paint industries. Some of the less obvious products that contain kaolin are video and audio tapes, cork, horticultural fibers, flea powders and pharmaceuticals[7].

7.10.2 Goonvean and Rostowrack Mines

There are five kaolin mines viz. Goonvean, Rostowrack, Prosper, Bodelva and Greensplatt. Before 1995, there were only three mines in this group which were producing 110,000 tpa. But at present, the kaolin producing capacity of this group of mines is nearly doubled i.e. 230,000 tpa which is actually being achieved.

These mines are located in the St. Austell region of Cornwall and in the south-west portion of the country. These mines are operated by M/s Goonvean and Rostowrack Chinaclay Company Limited. Before 1995, Boldeva and Greensplatt mines were owned by M/s Redland Minerals.

The developmental work nearby Trelavour is being carried out which will add in the production capacity of this group of mines.

About 70% of the production is being exported mainly to European market although some material is shipped to the middle east and far east.

The biggest market for the production from these mines is paper sector which accounts for around 60% followed by ceramics and other applications for (40%). Other applications include paints, rubber, plastics, fibreglass and pharmaceutical industries.

These mines are producing a variety of filler and coating clays for paper industry as well as ceramic grades for sanitaryware and tableware industries. These mines produce almost twenty grades of kaolin[7].

7.10.3 Devon Mine

The mine is operated by M/s Watts, Blake and Berne & Co. Pvt. Ltd. There are two mines and are located near Cornwood in west Devon. The producing capacity of these mines is 1,40,000 tpa of kaolin. The mining is carried out by hydraulic machines. Material excavated from the mines is processed at their Cornwood plant before it is despatched in either bags or bulk tankers to the ceramics and paper industries[7].

7.11 USA

The USA is the world's largest producer of kaolin accounting for about one third of total world output. The vast majority of this output is sourced from the famous kaolin mining districts of the south-east USA. In 1995, production of kaolin was 9.4 m tonnes.

Total consumption of kaolin by North American paper producers in 1995 was around 3.7 m tonnes, 2.7 m tonnes for coating and around 1 m tonnes for filler grades. Fibreglass industry consumed about 3,90,000 tonnes of kaolin in 1995. The grade of kaolin for fibreglass industry consists of 44% SiO_2, 37% Al_2O_3, 0.6% CaO, 2% Na_2O, 1% Fe_2O_3 and 1% H_2O. Around 570,000 tonnes of Georgia kaolin was used by ceramic industry in 1995. Refractory makers consumed about 580,000 tonnes of kaolin having a grade of high alumina and calcined, which is produced from famous Georgia belt.

Georgia belt runs about 50 km wide and 400 km long through Alabama (AL), Georgia (GA) and

South Carolina (SC). This belt produced about 7.8 m tonnes of kaolin in 1995[9].

There are 14 producers in the Georgia kaolin belt producing calcined, air fleet and waterwashed products as well as two refractory grade producers out of six extraction districts in the three belt states viz Aiken, Wrens, Sandersville, Gordon, Andersonville and Eufala.

Some of the important mines in Georgia belt are described below.

7.11.1 Hepzibah (GA) and Aiken (SC) Mines

These mines are owned by M/s Albion Kaolin Co a subsidiary of United Catalysts Inc. The production from Aiken mines is despatched to Hapzibah for processing. The company has added around 100,000 tpa to its airfloat and slurried kaolin capacity, estimated at around 400,000 tpa in total. The material of these mines is sold to rubber, fibreglass, ceramics, building materials, paint, paper and refractory industries[9].

7.11.2 Andersonville (GA) and Eufala (AL) mines

These two mines are owned by M/s. C-E Minerals which is the only other refractory grade calcined kaolin producer in the Georgia belt. The production capacity of these mines is 500,000 tonnes per annum.

7.11.3 Sandersville and Wrens Mines

These mines are operated by M/s English Chinaclay International. The production from these mines is 2.2 m tonnes of levigated kaolin. All production is earmarked for paper industry. The company estimates reserves for 25 years and the processing capacity is currently operating at 90%. The company has added 50,000 tonnes of calcined kaolin in 1996.

7.11.4 Aiken (SC) mine of M/s National Kaolin Products

National kaolin products a part of WR Grace & Co's Grane Davison Division is operating this mine for hard clay. Production has increased by 25% during 1994 and 1995 and reached upto 140,000 tonnes per annum with improvements to classification systems using new equipment.

The plant is currently operating at 85% of its capacity. In 1996, around $ 500,000 has been spent to improve the drying process.

The Company keeps half of its production for its own fluid cracking catalyst used by petroleum industry. The other half is for the merchant market where it is predominantly used by rubber compounders, roofing granules and refractory manufacturers.

7.11.5 McIntyre (GA) Mine

This mine is operated by M/s Evans clay with a production capacity of 300,000 tpa. The reserves of kaolin are sufficient for 50 years. If the demand grows, company has a planned programme to increase the production by 50,000 tonnes.

7.11.6 Nord Mine

Nord mine is owned by M/s Nord Kaolin Co. which is one of the few kaolin companies not expanding capacity in Georgia. Company sells water washed kaolin based composite pigments that incorporate other mineral into hybrid pigments like TiO_2 which is used almost exclusively in the paper segment. The company claimed that it is the world's largest producer of such pigments.

The production from the mine is 300,000 tpa and has 31 m tonnes of estimated recoverable reserves.

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8. Beneficiation

Natural occurrences of kaolin clay contain not only wide varieties of impurities (gangue minerals) but pH of clay also varies from deposit to deposit. Most of the gangue must be removed in order to make it a commercially useful clay product. The coarser impurities generally may be quartz, mica, iron bearing minerals and heavy minerals. The iron bearing minerals, TiO_2, pyrite, organic matter, illite, montomorillonite, smectite, etc. usually occur in very fine forms even in micron size alongwith fine kaolin clay. Removal of these impurities in an economical manner has been subjected to much research and process equipment development in the industry. This will enable the production of kaolin products scientifically and technically of remarkable purity from clay deposits which are regarded as too impure to be used by various consuming industries.

IMPURITIES, INFLUENCE AND REMEDIES

Following are the generally occurring impurities along with clay, their influence and probable remedies :

Sl. No.	Impurities	Influence	Remedies
1.	Excess SiO_2	i) Abrasion problem in paper ii) Reduces plasticity, shrinkage and tensile strength	i) By proper milling ii) Production plus 80% minus 2 microns product by cycloning and deflocculation
2.	Iron oxide	i) Impart colour and reduces brightness	i) High gradient magnetic separation (cryo filter)
3.	TiO_2		
	a) Rutile	Act as a flux and pigment	High Gradient Megnetic Separator (HGMS), Ultraflotation, carrier flotation or gravity
	b) Calcium & TiO_2	Impart yellow colour and reduces brightness	HGMS
4.	Soluble Salt	i) Produces scum on the surface ii) produces irregular wears iii) consume more electricity during casting	i) Wet blunging or ii) Barium carbonate reaction
5.	Organic impurities	i) Change in colour before and after firing. ii) Increases plasticity iii) Increases porosity after firing	Oxidation by oxydents

CLAY PROCESSING IN GENERAL

Kaolin is an extremely useful mineral. Its properties of white colour, softness, small particle size and chemical inertness make it suitable for a number of industrial applications. The desired properties of kaolin vary greatly in these applications. What might be a good clay for paper coating might not be an acceptable clay for use as filler in rubber. End use to which clay is to be taken is therefore very important while beneficiating clay. Specification of clay required for a specific use is to be kept in mind while selecting beneficiation method.

The primary step in clay processing is to separate the abrasive minerals like quartz and undesirable minerals such as mica. The process is simpler in case of secondary deposits which have undergone natural classification during transportation, whereas the separation of kaolin from primary deposits is more difficult due to the presence of a high proportion of abrasive minerals that have survived the alteration process.

There are two basic methods of clay processing which are as follows :

1. Dry Process
2. Wet Process

Dry Process

The dry processing of kaolin is relatively simple, has lower costs, lower yields and lower quality products than the wet process. The general flow sheet utilized in dry process is as follows :

CRUDE ORE BLENDING
|
CRUDE ORE CRUSHING
|
CRUDE ORE DRYING
|
PULVERISATION
|
AIR CLASSIFICTION
|
REJECT — MARKETABLE PRODUCT

The essential feature of the dry process is to dry the crude clay so that it can be pulverised. The crude clay is crushed to relatively small pieces. At this stage, in general, it contains 20-25% moisture which is removed in rotary drier. Dried clay is pulverized in a roller mill and is fed to grinding section of the mill where plows lift the clay into the area where roller grinds it against the grinding ring. This disintegrated kaolin is then air classified whereby the finely ground product is lifted through the top of the machine to the outlet duct. In the outlet duct, the particles encounter the whizzer which separates by size. The light weight particles travel up through the whizzer and are collected separately. The coarse particles which lack the speed to escape the whizzer are rejected through the ports on the side of the mill. This reject may be subjected to further grinding and classifying to recover additional quantities of previous unliberated clay.

Wet Process

The wet processing of kaolin clay is more complex than the dry process technique. The water wash process scheme for kaolin beneficiation in general is as follows :

CRUDE CLAY BLENDING
|
DEGRITTING
|
FRACTIONATION
|
BENEFICIATION STUDIES
|
- * BRIGHTNESS
- * FLOTATION
- * MAGNETIC SEPARATION
- * REDUCTION LEACHING
- * OXIDATIVE LEACHING
- * DELAMINATION

|
FILTRATION
|
SPRAY DRYING — SLURRY
|
BAGGING
|
MARKETING

The first step includes drawing of representative sample for chemical and mineralogical examination and to make the crude clay into slurry. In order to separate clay from unwanted impurities viz. quartz, feldspars, mica, etc., it is to be fractionated after degrittings into fines, medium and coarse fractions.

In order to separate the fine clay from coarse one, dispersing reagents such as sodium polyphosphate is added to separate the particles in the flocks. The degritted clay (after blunging) may also be classified by hydrocyclones of various sizes or by spiral classifier by screens into fine clay and coarse fraction (plus 45 mircons or +325 mesh) called grit. After removing the grit the fine kaolin slurry is stored into tanks where it is chemically, mineralogically and physically tested so as to mix with other batches to obtain the desired blend. The fine clay (-45 microns) is further fractionated to -2 microns so as to make suitable for paper coating either by hydrocycloning or deflocculation. The -45 micron fraction contaning high amount of TiO_2 or iron bearing minerals which imparts the colour is to be subjected to Wet High Intensity Magnetic Separation (WHIMS) or (HGMS) to remove these impurities. These impurities including mica, etc. can also be reduced by adopting ultra flotation techniques. After removing these colour imparting impurities either -45 microns (-325 mesh) or -2 microns clay is subjected to bleaching to improve the brightness by employing oxidising or reducing bleachants, depending upon the quality of impurities. Sometimes, to improve the brightness, delamination or calcination process is also employed. After bleaching, the clay slurry is subjected to filtration, drying, pulverising, bagging and marketing. Sometimes, filtered clay or even final clay slurry is also transported either by shipping or by trucks for marketing purposes.

In India, clay with water is first fed to a blunger where clay is separated from the gangue material by blunging action. It is then passed through screen (size depending upon size of gangue material to be removed) while clay is in suspension with water. Clay with water is then passed through channels. Length and gradient of these channels depend upon the quality and size of the heavy impurities to be removed. Catchers i.e. obstacles at the floor of these channels are placed to arrest the transport of particle settled. Washed clay along with water is then directed to settling tanks where clay settles at bottom and excess water is allowed to overflow for recirculation after giving sufficient time for settlement. This process may be carried out a number of times in a settling tank to get a sufficiently thick bed of washed clay in the form of thick slurry. It is allowed to sun dry. When sufficient water evaporates, this clay is cut into cakes in the settling tank itself using an iron strip tied to a bamboo, forming channels. This helps in speeding up of drying process. When these cakes become sufficiently dry and can be handled, these are put on a platform made for the purpose and broken into smaller pieces to speed up final sun drying. Channels are cleaned to remove unwanted material settled periodically so that material once settled here are not transported to the settling tank.

Alternately, where filter press is used, kaolin slurry after washing is stored into tanks (not settling tank), pumped to filter press. Clay cakes in the form of plates, are taken out from press, broken into pieces and allowed to sun dry on the platform. When washed clay is sufficiently dried, it is sold as it is or pulverised, bagged and marketed depending upon the demand of the consumer industries.

BENEFICIATION PLANTS ABROAD

I. UNITED KINGDOM (UK)

Kaolin output of about 3.0 million tonnes in U.K. makes it the world's second largest source of supply and the largest exporter of Chinaclay. The kaolin deposits are localized in south-west England with more activity in Cornwall and some in Devon. Companies like English Chinaclay (ECC, UK), Goonvean and Rostowrack Chinaclay Co.Ltd., Watts Blake Bearne Plc and Streetley Plc. ECC are actively engaged in mining kaolin and account for 90% of UK's output, making them the world's dominant corporate kaolin producers and exporters.

English Chinaclay (ECC, UK)

a) Mining : The first operation in the mining sequence is the removal of overburden and whenever possible, clay is washed from the open pits face using high pressure hoses called monitors which are operated at very high pressure of about 250 p.s.i. In order to maintain a consistent quality from the pit, an extensive drilling programme is carried out and the results of core samples are analysed by taking the daily samples. As such, material of low quality can be blended.

b) Refining : The first step in this operation is the removal of coarse sand from the clay slurry which is being done by spiral classification. The overflow (-250 microns) from spiral classifier is pumped to hydrocyclones in series so as to get cyclone overflow of -53 microns. The cyclone overflow is fed to the thickener and the underflow containing sand, mica and feldspar is rejected. In thickener, some flocculants are added. The underflow from thickener is fed to DORR OLIVER (D.O.) Refining Tanks. The D.O. refining tanks are nothing but hydro-separators which has been traditionally used in the industry because of the high efficiency of separation and low running cost. Normally, hydro-separators run in three stages in series, the underflow (U/F) from the first is fed to second and so on. The overflow (O/F) from the hydroseparators can either be thickened, filtered and dried or further refined depending upon end use of clay.

For production of finer grade clay (-2 microns), used in paper coating, it is necessary to use centrifugal separation rather than simple gravity separation. Deflocculated slurry is fed to the centrifuge and out in to the bowl through accelerator ports. The coarse material is deposited on the bowl surface and is screened to the residue discharge end of the machine. The finer material overflows the weir plates which contain 75% -2 microns, 0.5% -10 microns and 0.02% -53 microns. The coarse residue can further be treated to recover kaolin by introducing ultraflotation. For reduction of iron and titanium compounds the clay slurry can further be subjected to magnetic separation of the field strength of 20 K. Gauss. The magnetic separation not only reduces the iron/titanium compounds but also increases the brightness. For paper coating the clay can be bleached further by which the iron staining, which is not susceptible to magnetic separation, can be removed/reduced by a reductive bleaching process. The organic staining from humic acids can be removed using oxidative bleachants. The brightness can be improved from 87-90 ISO to 92 ISO by this process.

The clay slurry as it leaves the refining plant is not in a saleable form and has to be either thickened or dried before sale.

c) Drying : The conventional drying route is first to thicken the clay to about 20% solids to 70% solids by filter press. Coating clay is normally fed to a pug mill where the action of mill enhances the rheological properties of the clay. The clay containing about 8-10% moisture can further be dried by Rotary and Buell dryer which reduces moisture content to 1%. At 1% moisture content, the product is obviously dusty and has to be bagged.

d) Marketing : The methods for preparing clay for the market are energy intensive and in recent years considerable research has been made to reduce the energy cost.

The first and most obvious method is to sell the clay as a slurry by using deflocculants so as to make slurry with 65-70% solids. The slurry is transported to the customers by road or by rail tanker in UK and by specially constructed ships to the continent.

The second method is by using high pressure pressing techniques so as to produce filter cake having 25% moisture as compared to 30-35% moisture, hence direct feeding to the dryer is possible which reduces the energy cost. This requires a less complicated flowsheet without dry feed back.

The third development within English Chinaclay is the tube press. A tube of smaller diameter, drilled with filtrate channels and backer and filter cloth fixed on the outside surface is mounted co-axially with the outer tube. The inner tube or candle is able to move vertically within the outer tube. The clay slurry containing 25% solids is introduced into the tube press and the filter cake containing about 18% moisture is blown off the candle. The clay in this form is hard and handleable and acceptable as a dust free product.

The details of the ECC process are given in the flow sheet (Fig. - 1)

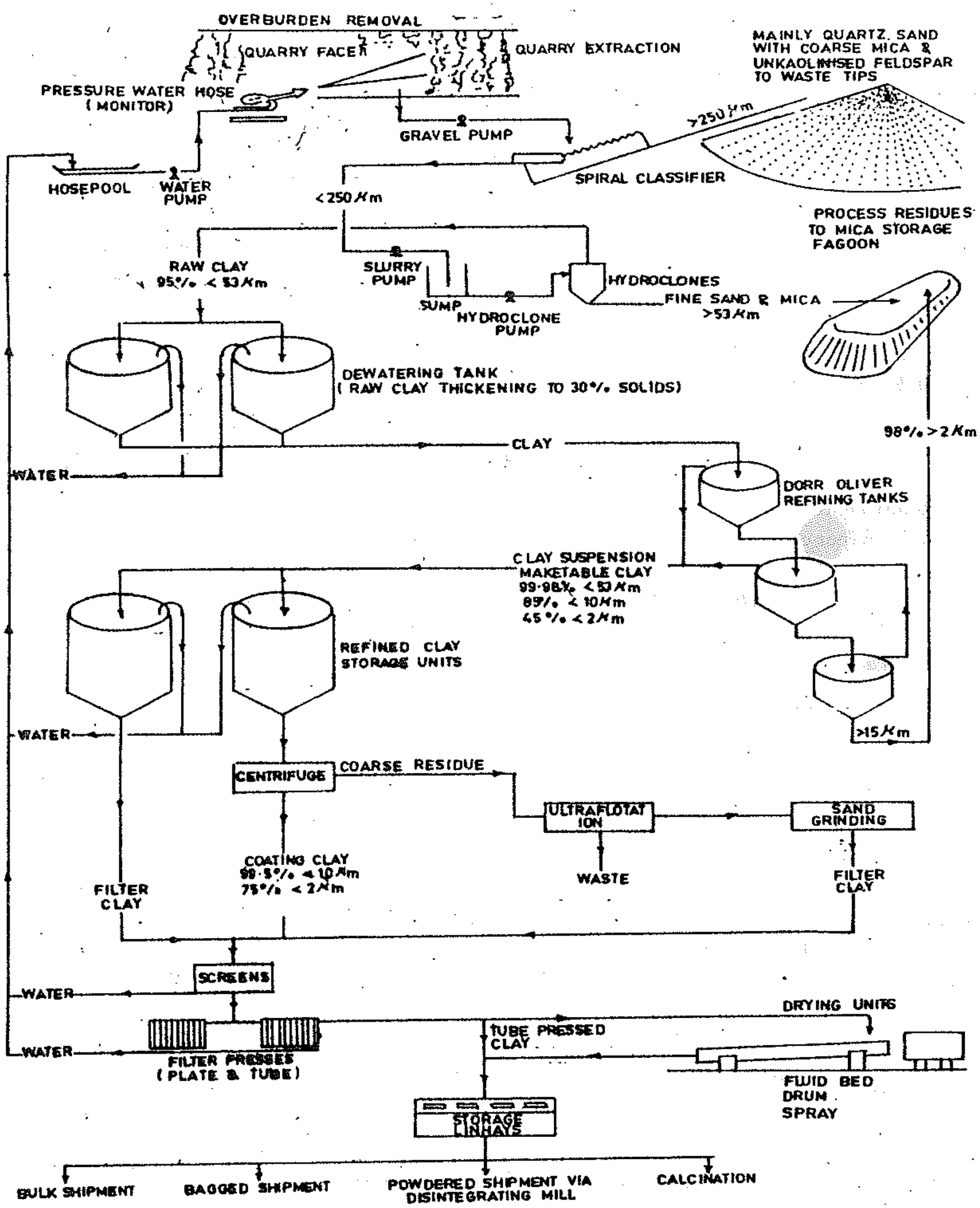


Fig. 1 : Flow Sheet of ECC Kaolin Process in U. K.

II. UNITED STATES OF AMERICA

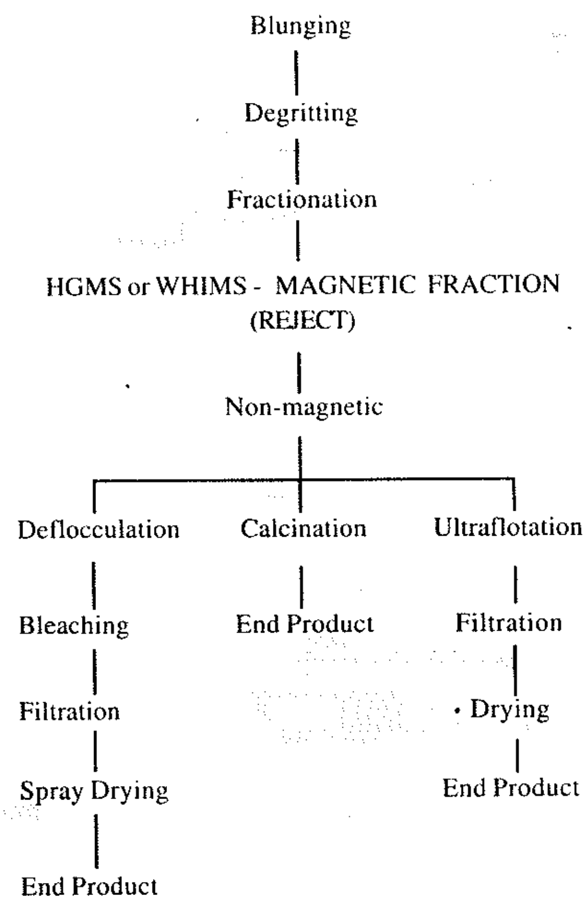
United States of America is the main source of kaolin accounting for about 35% of world production with an annual production of more than 9.0 million tonnes. The overwhelming majority of this is derived from the so called kaolin belt, which extends from South Carolina across Georgia and into Alabana represent the world's largest reserves of sedimentary kaolin and owing to their transported nature, the clay quality had been beneficiated naturally to give typical grades of about 90% kaolin.

Georgia Kaolin Company Inc. : This company is owned by Combuston Engineering Inc. and operates at Dry Branch, Sandersville, Wrens and Georgia with a total annual production of more than 1.6 million tonnes anticipating the increased demand for paper coating and filler grade kaolin as well as calcined kaolin as TiO_2 extender, the processes adopted are bluding, degritting, HGMS, flocculation, cycloning, bleaching delamination, calcination and even high speed centrifuges. The brightness could be achieved ranging from 85 to 93%.

ECC America Inc. : Is a wholly owned subsidiary of the UK's ECC International and till 1986 was known as Anglo-American clays. The company's processing operations are concentrated in Sandersville and is served by eleven open pit mines, situated through out the middle of the kaolin belt from Macon to Wrens. The process adopted is more or less same i.e. blunging, classifiction, HGMS, cycloning, bleaching delamination, calcination, etc. The delaminated Alphaplate fine coating clay is used for publication papers by Gravure and off-set. The total production is about 0.75 million tonnes.

J.M. Huber Corporation : Is one of the major US kaolin producers operating four extraction sites. The dominant product is paper coating and filler grade kaolin with all the major varieties processed including delaminated high brightness washed filler and calcined grades. The delaminated variety has a brightness of 88-90% with 88% -2 microns particle size. All the process clay has brightness of 83-93% with particular size ranging from 88-92% minus 2 microns.

Engelhard Minerals and Chemical Corporation : The company is having its head office at New Jersey and clay extraction in various locations in Wilkinson and Washington counties with processing is carried out at Mac Intyre, Gordorn and Attapulgus. The process flow sheet adopted is as follows :



PROCESS FLOW SHEET

Edger Plastic Kaolin Company, Florida

This company is also known as 'The Feldspar Corporation Edger Florida' and produced three products i.e. kaolin 6.30 m. tonnes/year, Glass sand (-30 mesh), 0.17 m. tonnes/year and Industrial sand (+30 mesh), 1.0 million tonnes./year (1984 data). The main impurities viz. Fe_2O_3 and TiO_2 are within tolerable limits. The beneficiation process adopted in the commercial plant to recover all the three above products is as follows.

Mining

The mining is being carried out in wet condition in the open pit. Top layer of about 5 meter thick is removed as overburden. The ore containing about 15% kaolin and about 85% sand is allowed to form very thin slurry by watering. The slurry appears to be in the form of lake of about 17 metres depth. A big pump pumps out the slurry of sand and clay at 70% pulp density. Recovery of useable sand is very poor.

PROCESSING/REFINING

1. Industrial Sand Separation

70% pulp density slurry from lake is pumped into surge bin (400 T capacity) where the water pressure is adjusted so that clear clay alongwith little fine sand (-100 mesh) comes out as overflow. The underflow from the surge bin is pumped to Dense Media Separator (FLOTEX TYPE) where automatic control permits variation of classification cut point while machine is in operation. This equipment has sharp, controllable classification in the particle size range of 20 mesh to 200 mesh. The DMS gives two products viz. overflow and underflow. The overflow containing mostly clay, joins the overflow of surge bin. The underflow from the DMS goes to rake/screw classifier. The underflow of rake classifier is transported by conveyor belt to the gas fired drier operated at 250°F. The dry product is then subjected to screening so as to get different size fractions viz. +8, +20, +30, +65, +100, +150 and -150 mesh.

2. Sand Separation

The overflow from the rake classifier, surge bin and Dense Media Separator (DMS) are fed to rake/screw classifier. The underflow from rake classifier (sand) containing heavy minerals viz. Fe_2O_3, TiO_2 etc. is fed to series of spiral classifier. The heavy minerals are removed by roughing and cleaning in the series of spiral classifiers so as to get clean sand of -30 mesh size. The -30 mesh sand product is fed to another rake classifier to remove the extra water into the overflow. The underflow contains about 10-15% moisture which is then dumped on the ground for sun-dry. Ultimately, it contains about 1-3% moisture. The product is suitable for glass making.

3. Clay Separation

The overflow from the rake/screw classifier of glass making sand is pumped to hydrocyclones. The hydrocyclone overflow is passed over 150 mesh screen kept at 45° to remove grass, organic compound, +200 mesh sand etc. The -150 mesh is almost 95% minus 325 mesh clay.

The clay fraction is fed to thickener, rotary drum type filter. The filter cakes contain about 45% moisture. The filter cakes are again fed to an extrusion device to get 1/4" dia and 1/2" length clay rolls for quick drying. These clay roles are dried in special type of driers where initial temperature is 1000° F and 250°F in the last. The dried product containing 1 to 2% moisture is pulverised to fine powder in a Ramond Mill. The dry clay powder is ready for sale.

A typical flow sheet, similar to this process, is given in Fig. - 2.

Annexure - B

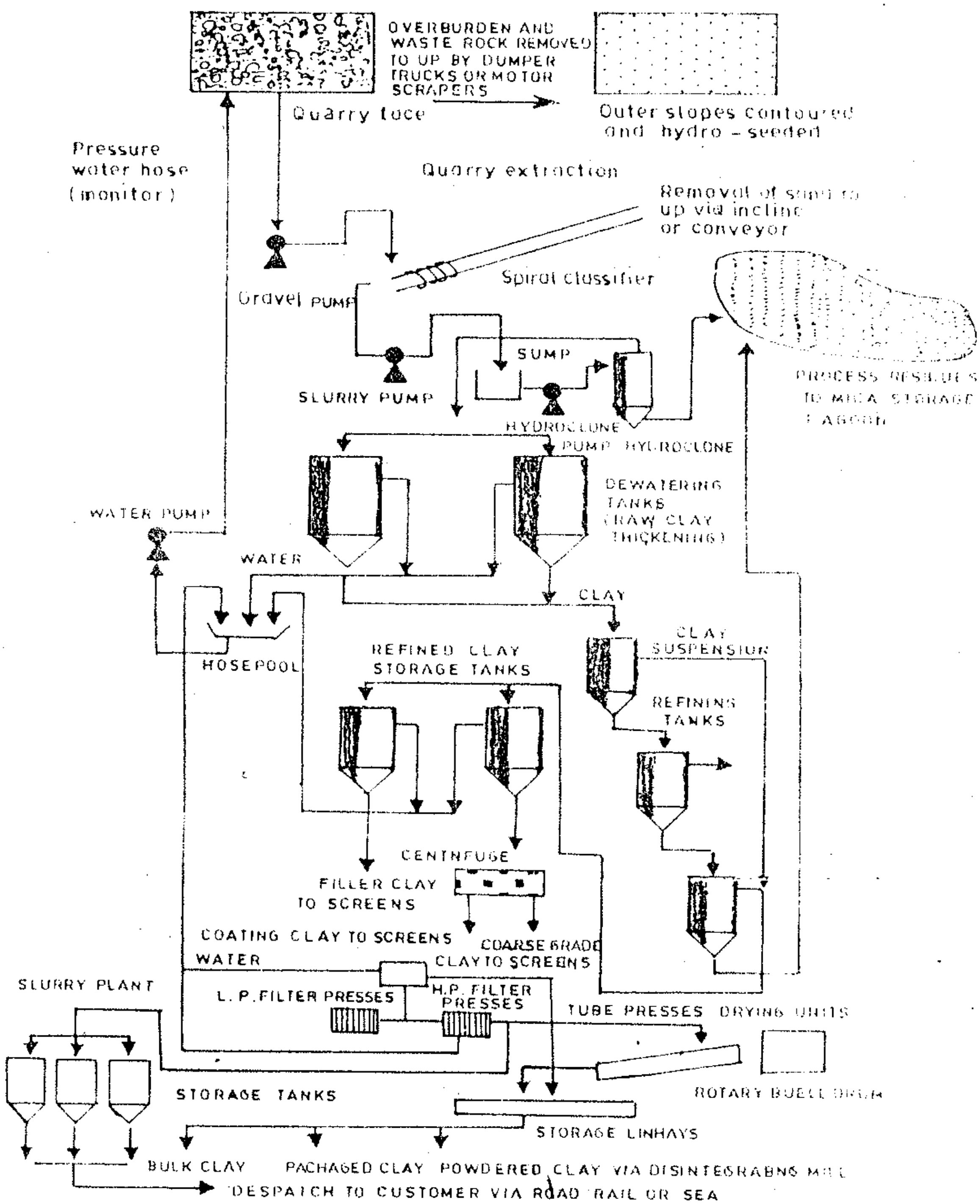


Fig. 2 : Typical Flow Diagram for Chinaclay Production

Nord Kaolin Company : Is a significant producer of coating grade kaolin. The annual production is about 0.3 m tonnes. The Nord's kaolin reserves are sufficient for another 25 years excluding low grade kaolin reserves which is beneficiated by employing Ozone as bleachant to improve the brightness required for coating grade clay.

Albion Kaolin Company : The annual production of this company is 0.2 million tonnes. This company has mine at Augusta, Georgia with processing plant at Hephzibah. The processed clay has brightness ranging from 75-80% with particle size 50-65% -2 microns. Most of the products are consumed within the domestic fibre glass, ceramics, soft rubber and refractory industries. The kaolin is shipped either in powdery form or as slurry.

Evans Clay Company : It is another company in USA having annual production capacity of 0.18 million tonnes. There are two extraction sites at Mac Intyre, Georgia, which have combined clay reserves of about 10.0 million tonnes. The washed material itself has brightness of 79% to 82% which can be improved to 82-84% with a particle size of 80-85% -2 microns. Selective mining of high grade material permits production of paper filler grade kaolin for domestic paper industry around 32%, ceramics 22%, adhesives 18% and rubber 14%.

C. E. Minerals : C.E. Minerals is the largest producer of refractory grade calcined kaolin in USA. The company operates mines at Andersonville, Georgia, Euyfla and Albama. Three refractory grade clays are produced with alumina contents in the range of 48-68% Al_2O_3 with 0.98-1.33% Fe_2O_3.

A.P. Green Refractories Company and Harbinson - Walkar Refractories Inc. : A. P. Green Refractories Company has two mines at Little Rock, Arkansas and Macon, Georgia and a kaolinite clay mine in Idaho. The process's end product is a calcined refractory grade clay.

III. LATIN AMERICA

In Latin America, Brazil and Mexico are the main producers of kaolin clay. Mexico produces about 0.28 million tonnes of clay much of which being consumed in the domestic ceramics and pigment market. Brazil produces a high quality paper coating grade clay of about 0.6 million tonnes.

Caulim da Amazonia S/A (CADAM), Brazil

This company has a mine processing plant and port facilities at Porto-de-Munguba on the Para-Amapo borders. The deposit being sedimentary is extremely high grade with 98% kaolinite. The final processed clay contains about 98% -2 microns having brightness about 86-88%. About 80% production is exported because of acceptance of clay for offset applications which is reported very good.

IV IBERIA - SPAIN

Spain is the Western Europe's second largest source of kaolin, supplying about 0.41 million tonnes to the market.

Caolines-de-Vimianzo SA (CAVISA)

This company is currently mining a primary kaolin deposit at Vimianzo, Cap Finisterre in Golicia, North West Spain and produces about 0.11 million tonnes of paper filler grade kaolin. The final processed clay contains about 35-40% -2 microns having 80-82.5% brightness.

Exploitaciones Ceramics Espanoles, SA (ECESA)

This company is the major supplier of kaolin having several high grade deposits around Burela, Lugo Province in North West Spain having annual production capacity of 0.07 million tonnes of two ceramic grades (-20) and (-30).

Compania Espanola de Caolines SA (CEDECSA) is a joint venture between Caobar SA and ECC International as the majority partner. This company produces about 0.05 million tonnes of processed clay out of which 0.03 million tonnes are of coating grade and 0.02 million tonnes are of filler grade.

V. WEST GERMANY

West Germany with its four companies produces 0.34 million tonnes annually.

Amberger Kaolinwerke (AKW)

The main kaolin supplier company in West Germany is AKW, produces about 0.15 million tonnes annually, 80% for coating and filler grade clay for paper manufacturer and remaining 20% for ceramics, paints and polymers absorbing. This company also imports about 0.15 million tonnes of kaolin annually from Georgia and about same quantum from Amazon 88 & from CADAM in Brazil. These clays blend typically to get brightness in range of 81.5-87.5% with particle size distribution of 50-98% -2 microns. Shipment is in the form of pellet, slurry or spray dried.

Eduard Kick and Quartz Sandwerke GMBH & Co.

This is the second largest clay producer company in West Germany producing about 0.135 million tonnes per annum of which more than 50% is used in paper making. Because of the low levels of alkali and fluorine, the clay finds particular demand in the reinforcement glass fibre and ceramic markets besides the traditional paint, polymer and pharmaceutical applications. The Chamotta, a calcined variety is utilised principally for ceramic glazes and in refractories.

Computerized blending facilities are available to satisfy customers' requirements.

Gsebruder Dorfner OHG Kaolin Und Kristallquarzsandwereke : This company also exploits a kaolin deposit in Hirschau region of Bavaria. Most of the clay is consumed in the paper industry. Three paper filler grades are blended with brightness of 75-85% with particle size of 50-72% minus 2 microns. In addition, a range of calcined and ceramic clays are sold together with a surface treated calcined clay for polymers.

VI. FRANCE

France produces about 0.314 million tonnes of clay besides several minor companies exploiting small deposits of kaolinitic sand in the Rhone valley. However, there are about six big companies based mostly in Brittany, Societe, Kaoliniere Armoddddddricaine (SOKA) mines chinaclay at Quessoy, Cotes-du-Nord.

Societe-des-kaolines du Finisterre S.A

This company is wholly owned by ECC International recording an annual production of 0.5 million tonnes of which about 60% is paper grade and about 40% is ceramic grade.

Societe-des-Kaolines de Beavoir

This company produced 0.017 million tonnes annually with the annual expansion capacity of 0.04-0.05 million tonnes of paper fillers grade. Kaolin from Beauvior granite possesses excellent fired whiteness combined with a low iron content mainly used in the manufacture of bone china, porcelain tableware, vitreous china and glazes.

VII. AUSTRALIA

Kaolin Australia Pty. Ltd.

The ECC International has got majority equity in this company. The mine is situated at Pittong near Linton in Victoria where clay production is about 0.04 million tonnes annually and mostly used in paper both for coating and as filler with some ceramic and polymer filler grade.

Australian China Clays Ltd.

This company produces about 0.045 million tonnes of kaolin from its two working mines viz. Stubbo and Tallawang. The Australian clay as a whole tends to have higher soluble salt contents. This factor alone mitigates in favour of wet processing. As a result of this, the new clay range will comprise three ceramic grade clays with fired colour/brightness in the range of 80 to 90%, iron content 0.46% to 0.59% and TiO_2 0.25% to 0.84%. The main markets for these clays will be in the whiteware ceramics industry, including porcelain and bone china. In addition to ceramic industry, three filler grades for paper, rubber and fibreglass are also produced.

Greenbushes Ltd.

Earlier, this company was shipping crude kaolin containing 40% kaolinite, 60% quartz and less than 0.1% combined Fe_2O_3 and TiO_2 to Japan. The company has intended to start the clay processing plant of 0.01 to 0.02 million tonnes capacity due to its low purity, colour and other impurities.

Comalco Aluminium Ltd.

A major deposit of premium quality kaolin is being developed by this company situated at Weipa in Northern Queensland to produce 0.1 million tonnes of clay annually. Only one commercial grade paper coating clay is produced. It reportedly compares in particle size with Brazilian paper coating kaolin product and is equivalent to US standard brightness Fine No.1 clay. The fine particle size gives higher paper gloss and is amenable to blending with calcium carbonate for coating purposes. Besides the domestic market, its proximity to major export markets in Japan, South Korea and Taiwan, undoubtedly is a logistical bonus.

Commercial Minerals Ltd.

This company operates a number of kaolin extraction sites throughout Australia. Gulgong in New South Wales is main site producing more than 0.03 million tonnes of clay annually from several locations. The clay produced is of ceramic and extender grade for consumption as catalysts, general ceramics, paints and polymers.

INDIAN SCENARIO

The Indian mineral industry markets more than 60 minerals valuing more than Rs.20.0 billion. They are broadly classified as fuel minerals, metal minerals and non-metal minerals. The fuel minerals are mainly coal and petroleum which contribute the bulk of the revenue. Useful metal minerals are iron, manganese, chromite, copper, lead, zinc, etc. and the least in terms of value are all the non-metal minerals, which have not been utilised to their maximum potential but hold great promise for the future. Clay is one of them.

Economic reforms initiated in 1990 resulted in the rapid growth in the Indian mineral sector in general and the industrial mineral sector in particular, despite enjoying the high priority status and support given to metallic and fuel minerals. The value of production of non-metallic minerals increased from Rs.799 crores in 1991-92 to an impressive level of Rs.1,343 crores in 1996-97, registering an increase of over 68%. The non-metallic mineral based products sector registered a growth rate of 12% in 1995-96 as against 8% in 1994-95 and 4.5% in 1993-94 which has amply reflected in growth in industries like cement, paper, rubber, plastic and chemicals which are the major consumers of industrial minerals.

The fact however remains that the production of industrial minerals in the country meets only about 50% of the domestic demand and with the likely expansion of demand, there is an urgent necessity of more investments in the industrial mineral sector. As far as clay is concerned there is good scope for value enhancement by levigation.

NEED FOR BENEFICIATION

(i) India is endowed with excellent and adequate reserves of a number of industrial minerals. The inadequate reserve position with respect to industrial minerals is partially due to a historical bias towards fuels, metallic and precious minerals in national development programme.

The special characteristic of an industrial mineral as distinct from metallic ores is that a single mineral can be put to a variety of uses. While the metallic minerals are valued for their metal content, the industrial minerals by and large are valued for physico-chemical properties. Most of the industrial minerals are used after some physical processing to make them acceptable by the end-user industry. Industrial minerals, therefore, call for special attention so as to prepare them to suit the requirements of various industries.

(ii) Industrial minerals also play a vital role in earning foreign exchange through export. The important non-metallic minerals being exported are barytes, bentonite, chinaclay, felspar, gypsum, quartz, etc. The value of export from these minerals excluding cut and polished diamond and other precious stone was of the order of Rs. 1,595 crores which constituted about 8% of the total export of all ores and minerals during 1996-97.

(iii) There has been a slowdown in industrial production in recent years, but this may be a passing phase. Beneficiation of clay is required to make it suitable for some specific use giving a value added product.

Clay Processing Practices in India

Most of the clay processing plants in India are adopting antiquated processing practices viz. blunging, wet screening, washing, levigation which involve passing the clay slurry through a series of trough or channels with different slopes. The levigated clay slurry is settled in tanks and supernatant water removed. Clay slurry is further dewatered by filtration employing plate and frame type filter cake, sun dried, pulverised and packeted for marketing.

a. The products are not of consistent quality

b. The recoveries are low

c. The scales of operations are small and discontinuous, involving much manual and laborious operations.

(iv) The Bureau of Indian Standard (BIS) Specification for paper coating clay, filler, textiles, rubber, insecticides, ceramic etc. are very stringent including the physical and chemical properties. Beneficiation is required to meet these requirements in clay.

(v) The rapid growth of paper and ceramic industries and also the growing application of kaolin in various other industries in recent years have buoyed up the demand for kaolin or white clay or White Gold.

(vi) Unwanted constituents are removed from the mineral by beneficiation. This enables the use of lower grade minerals after upgrading the same by beneficiation and in turn, practically, increasing the mineral resources of the country. Mineral which otherwise cannot be used can be used after beneficiation which helps in conservation of mineral.

A list of some of the Indian clay processing plants, location, process, grades, etc. is given in Annexure - 1.

ROLE OF INDIAN BUREAU OF MINES

Indian Bureau of Mines (IBM) is endowed with the responsibilities for ensuring conservation and scientific development of mineral resources. For this regular inspections/visits to mines, mineral beneficiation plants and mineral based industries are conducted.

Ore Dressing Division is one of the important Divisions of IBM and is a leading Research and Development (R&D) Centre for mineral processing in India. It has a Modern Mineral Processing Laboratory and Pilot Plant at Nagpur, Maharashtra (Central India) and two Regional Ore Dressing Laboratories and Pilot Plants at Ajmer, Rajasthan, (North India) and Bangalore, Karnataka (South India) with ancillary facilities for instrumental and chemical analysis as well as mineralogical studies having a team of more than 100 engineers and scientists. IBM undertakes laboratory and pilot scale investigtion work on almost all ores and mineals. The prime objective of the investigation is to develop the process know-how and flowsheet for beneficiation to obtain saleable products from the low grade ores and mineral rejects. More than 1800 investigations (laboratory and pilot scale) have so far been completed on different ores/minerals including ferrous, sulphide ores and industrial minerals (including clay) from different parts of the countries as well as from foreign countries and task have been completed successfully .

SALIENT ACHIEVEMENTS OF IBM IN CLAY PROCESSING

Taking cognisance of (i) extensive deposits of clay, (ii) growing application of clay in various industries, (iii) many current problems of industrial production, (iv) development of new products, (v) antiquated processing practices, etc., IBM improvised their Ore Dressing laboratories and pilot plants, with special facilities for clay beneficiation and processing. Thrust was provided to technology, quality, upgradation, improvement of recovery and grade, by- products, if any, as well as evaluation from the clay samples received on sponsored basis or collected from different deposits in the country. An officer was deputed to U.K., U.S.A., Canada and Finland to study the modern clay processing techniques both in laboratories and commercial plants. An expert from U.K. (Ex-English Chinaclay, Cornwall, U.K. expert) was engaged for providing in-house training to a group of engineers and scientists of Indian Bureau of Mines, in laboratory methodologies for process development and evaluation. United Nations Development Programme (UNDP) provided substantial support in addition to Government of India's support to the above efforts.

IBM carried out a number of beneficiation studies on clay samples received and drawn from different deposits in the country.

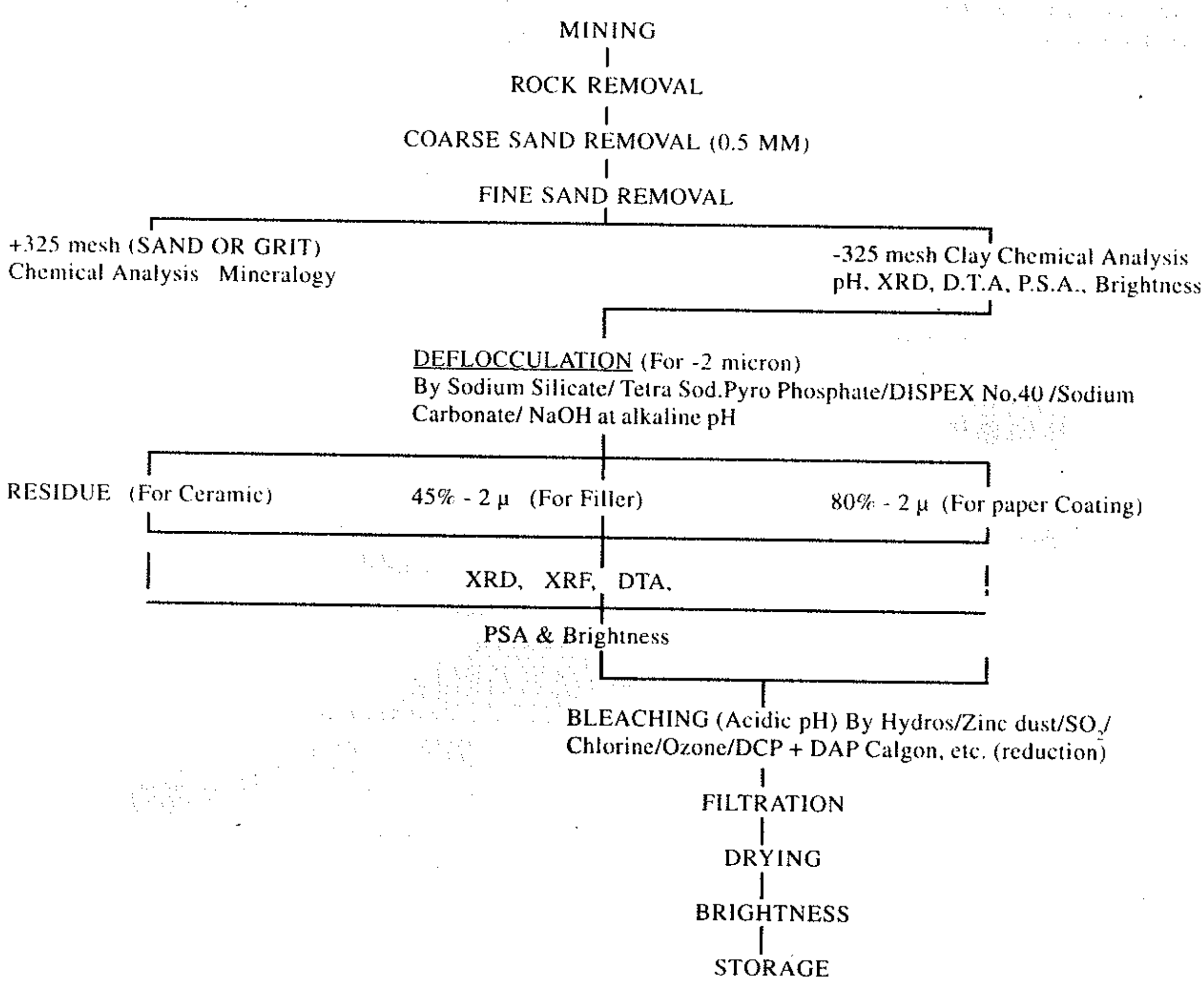
The object of the laboratory scale investigation is to develop a process for obtaining as much as possible clay product suitable for paper coating/paper industries which are in demand and highly priced and a secondary product suitable for ceramic and other industries. In some of the investigations, a silica sand fraction suitable for glass making industries and mica for mica user industries were also recovered as by-product. The results of beneficiation studies on clay samples received from different states are given in Annexure - II.

BENEFICIATION PROCESSES

There are various processes for clay beneficiation depending upon the nature of gangue minerals present and mode of their association with clay. The process route in general adopted by Indian Bureau of Mines for laboratory scale is as follows :

i. Blunging/agitation/attrition scrubbing.
ii. Wet sieving to obtain -325 mesh clay.
iii. Wet high intensity magnetic separation (WHIMS)
iv. Deflocculation to produce -2 microns clay
v. Bleaching to improve brightness
vi. Filtration
vii. Chemical analysis, mineralogical analysis by XRD, DTA and physical testing including particle size analysis (PSA) and brightness determination of all the products including received and beneficiated.

The flow sheet of clay processing in general is given below :



The salient results obtained by conducting the laboratory scale investigation in the laboratory of Indian Bureau of Mines, on the clay sample received from different States (1 to 16) are presented in Annexure - 2. In order to maintain confidentiality, the name, location and states have not been disclosed.

CLAY PROCESSING ON PILOT PLANT SCALE

Indian Bureau of Mines has conducted pilot plant scale studies on three samples (Sl. Nos. 13, 15 and 16 of Annexure - 2) received from different organisations. The objects of the studies were (i) to confirm the process and results of laboratory scale test carried out on the respective samples, (ii) to evolve a suitable process flowsheet for production of clay suitable for paper user industries, (iii) to obtain useful minerals viz. silica sand, mica, etc. as a by-product and (iv) to generate metallurgical and other data to be used for preparation of techno-economic feasibility report for commercial clay processing plant of 100-200 tonnes per day capacity.

The pilot plant beneficiation studies conducted in Indian Bureau of Mines on three clay samples (each sample weighing more than 10 tonnes) employing following unit operations :

1. Scrubbing/Tumbling
2. Classification
3. Wet High Intensity Magnetic Separation (WHIMS)
4. Hydrocycloning
5. Deflocculation
6. Bleaching
7. Thickening

The process flow sheet adopted during pilot scale studies by IBM on two samples are given in Fig.3 and Fig. 4 and the salient results of three samples are presented in Annexure - 2. A typical flow sheet for kaolin processing is given in Fig. 5 and that for a bleach plant is given in Fig. 6.

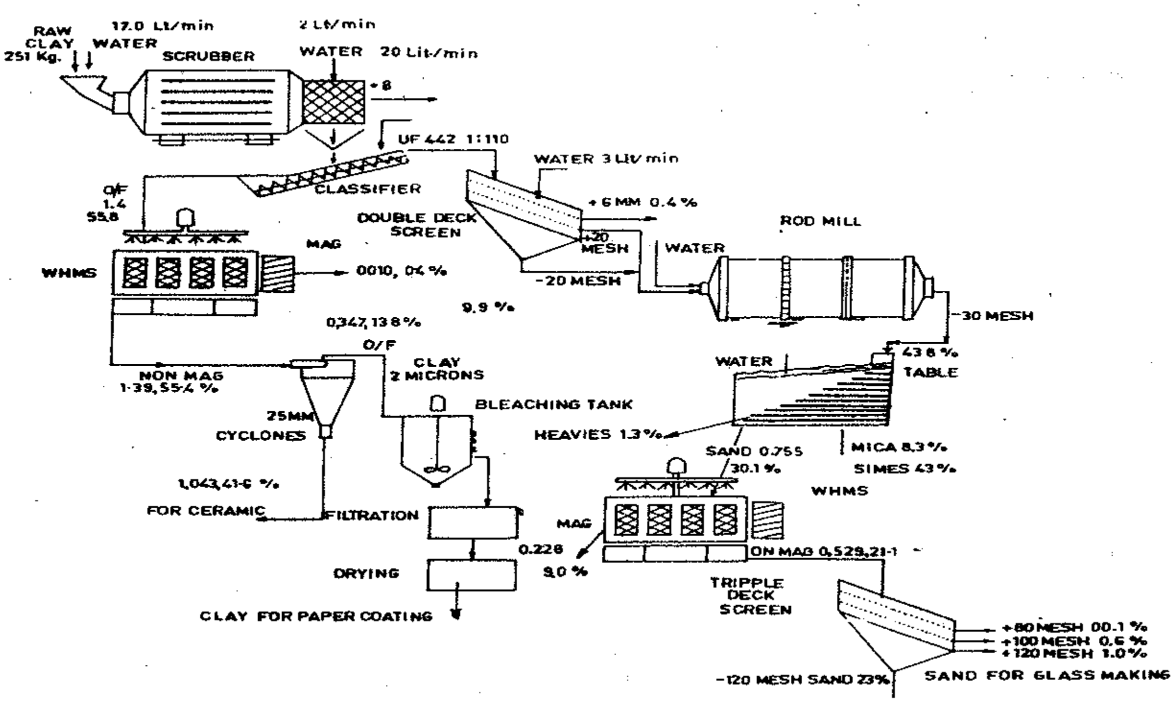


Fig. 3 : Pilot Plant Scale Beneficiation of Clay from India to Recover Clay Sand & Mica

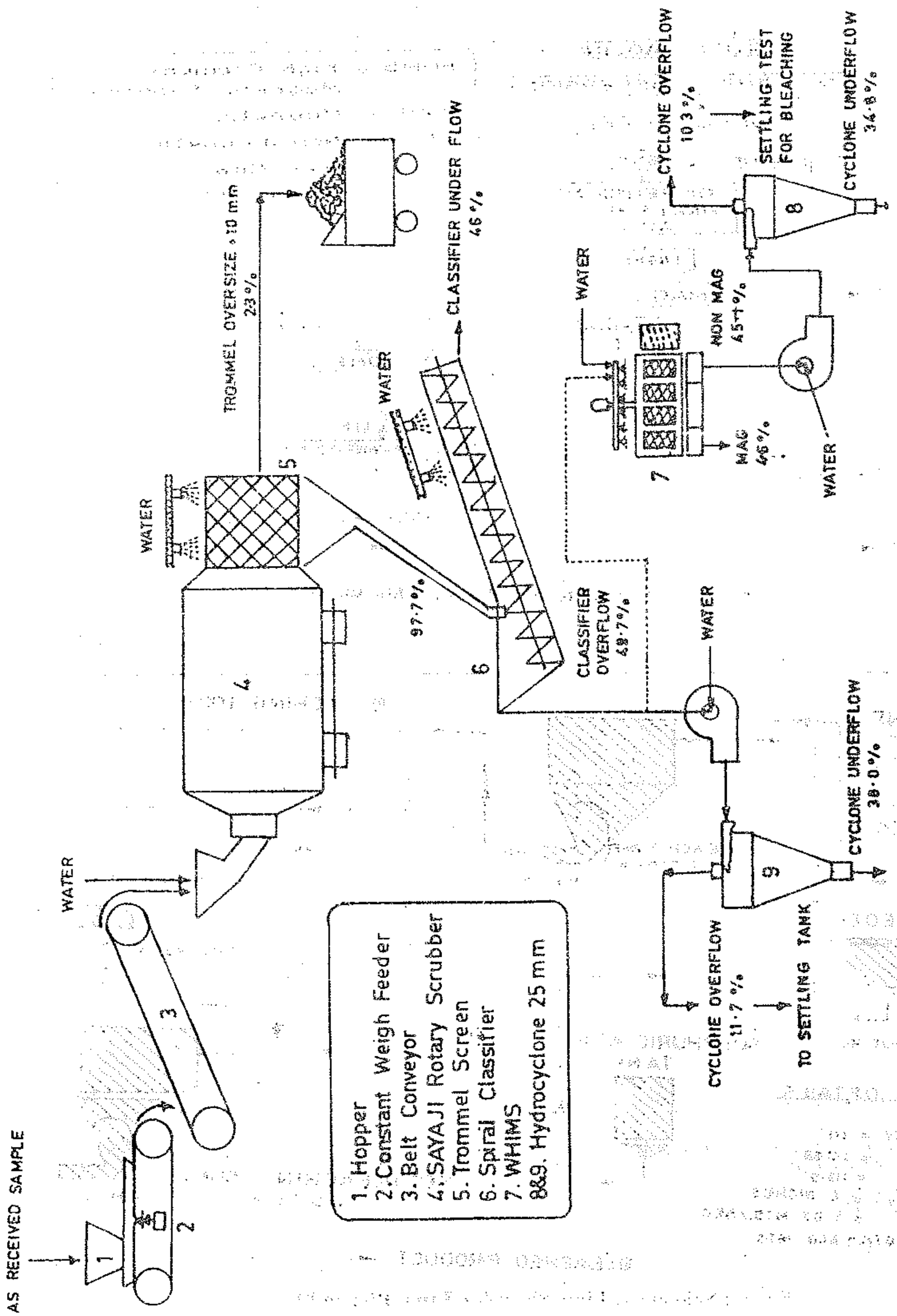


Fig. 4 : Process Flow Sheet for Pilot Plant Beneficiation Studies on Clay Samples

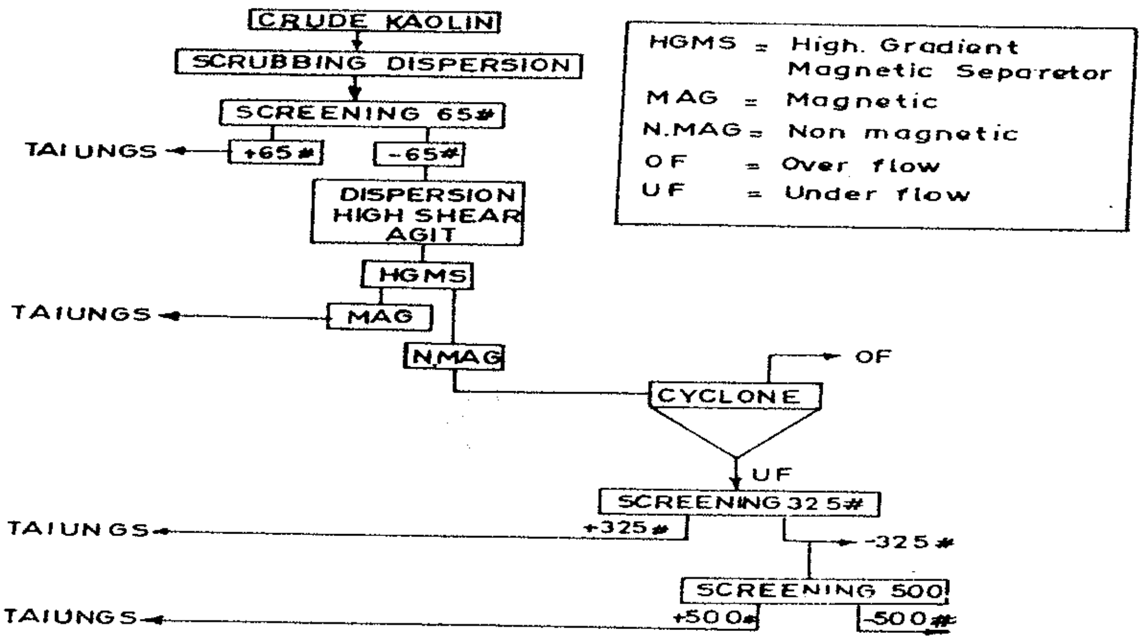


Fig. 5 : A Typical Kaolin Process Flow Sheet

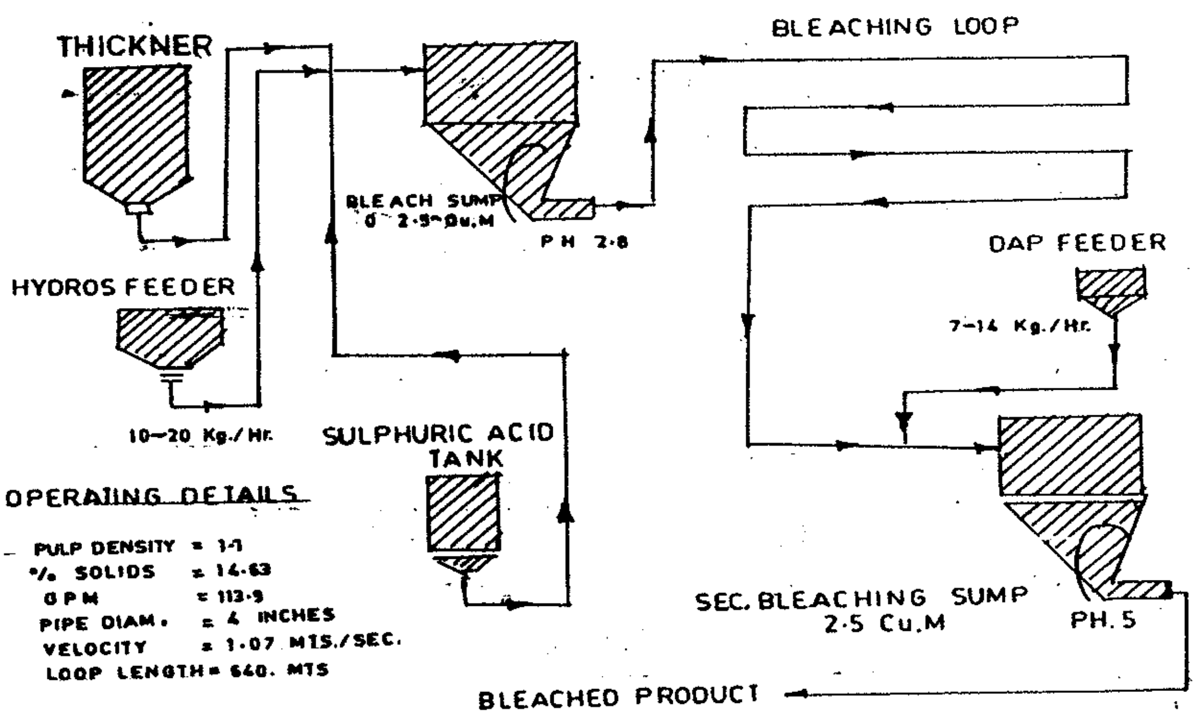


Fig. 6 : Schematic Flow Sheet for 5 tph. Bleach Plant

Annexure - 1

List of Levigation (Beneficiation) Plants In India

State	Name of the Plant	Installed Capacity
KERALA		
	1. English Indian Clays Ltd. Veli, Thiruvananthapuram.	9000 TPA
	2. Payangadi Clay Washing Plant of Kerala Clays & Ceramic Products Ltd. (KCCP). Dist. Kannur	30-35 tonnes/8 hours
	3. Nileshwar Chinaclay washing Plant of KCCP, Dist. Kasargod	105 tonnes/8 hours
	4. Kannapuram Chinaclay washing plant of KCCP. Dist. Kannur	40 tonnes/8 hours
	5. Kerala ceramics Ltd. Kundara, Dist. Quilon	18,000 TPY
	6. Southern Clays & Minerals Pvt. Ltd., Nileshwar Dist. Kasargod	3,000 TPY
	7. Vijaya Laxmana Clay Mine, Kundara, Dist. Quilon	250 kg/hour
	8. N. S. Babu, Bharathy Clays, Thiruvananthapum	N. A.
RAJASTHAN		
	9. Modi Levigated Kaolin Pvt. Ltd.	12.6 TPD
	10. V. K. & Sons Clay Beneficiation Plant, Dist. Jaipur	6 TPD
	11. Kuber Chinaclay Mine, Jaipur	4 TPD
	12. Deedwania & Sons, Dist. Bhilwara	7000 TPY
	13. Gopal Minerals Clay Beneficiation Plant, Dist. Bhilwara	6 TPD
	14. Godha & Company Clay Beneficiation Plant, Dist. Bhilwara	7-8 TPD
	15. Bhilwara Mineral & Grinders, Clay Beneficiation Plant, Dist. Bhilwara	7-8 TPD
	16. Prakash Industries, Clay Beneficiation Plant, Dist. Bhilwara	3-3.5 TPD
	17. Srinath Minerals.Clay Beneficiation Plant, Dist. Bhilwara	3.5 TPD
	18. Charbhuja Enterprises Clay Beneficiation plant, Dist. Bhilwara	N. A.
	19. Bileta Clay Beneficiation Plant, Dist. Bhilwara	5 TPD
	20. Bharat Minerals, Dist. Bhilwara	425 TPD

(Contd.)

Annexure - I (Contd.)

State		Name of the Plant	Installed Capacity
GUJARAT	21.	Amrapalli Mineral Development Corp., Nadapa, Dist. Kutch	20 TPD
	22.	Ashapura Chinaclay Mine, Dist. Kutch	30 TPD
	23.	Swastaik Minerals, Dist. Kutch	10 TPD
	24.	Kutch Ore Mandvi, Dist. Kutch	50 TPD
	25.	Sri Ram Minerals, Madhapar, Kutch	10 TPD
	26.	Sarswati Chinaclay Works	20 TPD
	27.	Anil Minerals, Dist. Kutch	10 TPD
	28.	Mamuaa Chinaclay Works, Dist. Kutch	10 TPD
	29.	Superfube Minerals Industries, Nadapa, Dist. Kutch	10 TPD
	30.	Nitin Minerals, GIDC Bhuj, Dist. Kutch	10 TPD
	31.	20 Micron, Mamuaa, Dist. Kutch	N. A.
	32.	Jayesh Mineral Industries, GIDC, Bhuj, Dist. Kutch	10 TPD
	33.	Minerals Oriental Industries, GIDC, Bhuj, Dist. Kutch	6,000 TPY
	34.	Eklera Trading Co. Idar, Dist. Sabarkantha	20 TPD
	35.	Amrapali & Co. Arsodia, Dist. Sabarkantha	50 TPD
	36.	Ambe Minerals, Davad, Dist. Sabarkantha	20 TPD
	37.	Oriental Praspecting Co. Kot, Ramsipur, Mehsana	30 TPD
BIHAR	38.	The Jain Chinaclay Mines, Dist. Chaibasa	1,500 TPY
	39.	Singhbhum Mineral Supply Co. Dist. Chaibasa	20,000 TPY
	40.	Gajadhar Mining Industries, Dist. Chaibasa	2000 TPY
	41.	Rai Bazar Chinaclay Mines, Rajmahat, Dist. Bhagalpur	N. A.
ORISSA	42.	J. C. Budhraja, Bhubaneswar	10,000 TPY

(Contd.)

Annexure - 1 (Concld.)

State		Name of the Plant	Installed Capacity
KARNATAKA	43.	Mysore Minerals Ltd., Thirthahalli, Dist. Shimoga	3000 T/month
MADHYA PRADESH	44.	Bagri Minerals & Chemcials, Dist. Satna	33,000 TPA
ANDHRA PRADESH	45.	Sri Satyasai, Dwarka, Tirumala	N. A.
TAMIL NADU	46.	Clay Washing Plant, Neyveli lignite Corporation, Neyveli	Plant closed
WEST BENGAL	47.	West Bengal Projects Ltd., Mokdum Nagar, Dist. Birbhum	18,000 TPA
	48.	Patel Nagar Minerals & Industries Pvt. Ltd., Dist. Birbhum	N. A.

Annexure - 2

Results of Beneficiation Studies on Clay Samples

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %		Mineralogy	Concentrate				Process Adopted
						Wt %	Assay %		Brightness %	
1.	1028	Limited tests on CLAY sample for M/s Bagri Minerals and Chemicals Ltd., Satna, M. P.	Al_2O_3 Fe_2O_3 SiO_2	34.08 1.19 46.22		70.20	Al_2O_3 Fe_2O_3 SiO_2	34.09 0.88 48.17	71 ISO	Wet High Intensity Magnetic Separation (WHIMS) Detailed studies are required
2.	1030	Limited Tests on CLAY sample from Rajnandgaon, Dongargarh dist. M. P. for M/s Madanlal Sharma	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 K_2O CaO MgO LOI	23.39 1.10 66.06 1.01 2.29 0.15 0.52 5.08		The sample could not be upgraded to the deisred limits				Scrubbing and WHIMS
3.	1057	Beneficiation of a CLAY sample from Bagru Hills, Bauxite Mine for Controller of Mines (CZ), IBM, Nagpur.	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 K_2O LOI	36.67 1.44 45.48 1.12 0.09 13.48	Val. Minerals Kaolinite Gangue : Quartz, Mica, Calcite, Rutile	27.05	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 K_2O LOI	37.15 1.18 45.65 2.05 0.04 13.77	61.33 ISO	Classification, Deflocculation and Bleaching
4.	1059	Tests on CLAY sample from Rajasthan area for M/s Bagri Minerals & Chemcials Pvt. Ltd., Satna, M. P.	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 K_2O CaO Na LOI	29.39 1.64 53.16 1.42 0.62 1.31 0.39 11.41	Val. Minerals Kaolinite Gangue : Quartz, Calcite	87.6 -325 Mesh	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 K_2O CaO MgO LOI	31.62 1.77 52.05 1.60 0.66 0.29 0.29 11.62	65.82	Classification, Due to alkaline pH of the as samples received further studies were abandoned

(Contd.)

Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
5.	1041	Beneficiation fo CLAY Sample from Payangadi Area, Kerala	Al_2O_3 24.57 Fe_2O_3 0.96 SiO_2 62.43 TiO_2 0.41 K_2O 0.36 LOI 9.81	Val. Minerals Kaolinite Gangue : Quartz Muscovite	50.9 -325 mesh	-325mesh fraction Al_2O_3 35.67 Fe_2O_3 1.41 SiO_2 47.12 TiO_2 0.41 LOI 14.63 CaO Traces	Brightness could be improved to 68.96 from 62.94 (ISO)	Classification, Deflocculation and Bleaching
6.	1060	Beneficiation of CLAY Sample from Chandrapur for M/s Central Potteries Ltd., Chandrapur, M. S	Al_2O_3 24.15 Fe_2O_3 1.52 SiO_2 64.98 TiO_2 0.96 K_2O 0.67 LOI 9.17	Val. Minerals Kaolinite Gangue : Quartz, Mica, Iron Oxides		Al_2O_3 29.89 Fe_2O_3 2.08 SiO_2 50.42 TiO_2 1.28 LOI 14.06	Brightness could be improved to 77 from 42.94(ISO) after bleaching and calcination	Classification, Deflocculation and Bleaching
7.	1073	Beneficiation of CHINACLAY Sample from Orampadu, Cuddapah dist., A. P. for Gimpex Private Ltd., Madras	Al_2O_3 19.65 Fe_2O_3 1.10 SiO_2 70.56 TiO_2 0.67 K_2O 3.00 LOI 4.22	Val.Mineral : Kaolinite Gangue : Quartz, Mica Calcite, Zircon, Tourmaline	32.70% (-2.2 micron overall 11.05	- 325mesh fraction Al_2O_3 21.56 SiO_2 69.13 Fe_2O_3 1.07 LOI 3.40	Brightness could be improved to 72.88 to 77.43 (ISO) after bleaching from 70.20	Classification, Deflocculation and Bleaching
8.	1076	Beneficiation of CLAY Sample No.T-75 from Tatera - Nimli area, Jaipur dist., Rajasthan for Shri Modi Levigated Kaolin Pvt. Ltd.	Al_2O_3 19.96 Fe_2O_3 0.63 SiO_2 71.07 K_2O 0.59 LOI 6.57	Val. Minerals Kaolinite Gangue Quartz,Mica, Calcite	39.0	- 325 mesh fraction Al_2O_3 37.10 Fe_2O_3 0.84 SiO_2 46.52 K_2O 0.34 LOI 13.89	Brightness of - 325 mesh fraction could be improved to 80.92 from 68.70 (ISO) after bleaching	Classification, Deflocculation and Bleaching
9.	1079	Beneficiation of CLAY sample from Belgaum, Karnataka for Indian Aluminium Co. Ltd.	Al_2O_3 34.84 Fe_2O_3 5.30 SiO_2 37.55 TiO_2 0.11 K_2O 0.04 CaO 0.11 MgO 0.09 LOI 15.40	Val. Mineral : Kaolinite Gangue : Gibbsite, Goethite, Calcite, Rutile	The sample is not amenable to beneficiation. Bleaching was not possible for this clay due to high amount of ironoxide as fine ultrafine inclusions & intermixing with kaolinite.			Deflocculation
10.	1085	Beneficiation of CLAY sample No. P-90 from Buchara area, Jaipur dist., Rajasthan for M/s Vishnukumar & Sons, Neem-ka-Thana, Rajasthan	Al_2O_3 23.74 Fe_2O_3 1.16 SiO_2 61.86 TiO_2 0.05 K_2O 0.14 CaO 2.11 MgO 0.11 LOI 10.08	Val.Mineral: Kaolinite Gangue : Quartz,Mica, Calcite,Rutile Goethite	33.40	- 325 mesh fraction Al_2O_3 35.00 Fe_2O_3 1.21 SiO_2 45.09 TiO_2 0.04 LOI 15.14	Brightness of final clay product could be improved to 74.14 ISO from 64.81 after bleaching	Classifiction, Deflocculation and Bleaching
11.	1086	Beneficiation of CLAY sample from Bagru Hills Bauxite Mines for Indian Aluminima Co. Ltd., Lohardaga, Bihar	Al_2O_3 34.46 Fe_2O_3 1.38 SiO_2 42.64 TiO_2 2.74 K_2O 0.12	Val.Mineral : Kaolinite Gangue : Quartz, Mica Iron	9.90	Al_2O_3 38.80 Fe_2O_3 1.18 SiO_2 43.09 TiO_2 1.72 K_2O 0.03	Brightness of decant slimes could be improved to	Classification, Deflocculation and Bleaching

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Annexure - 2 (Contd.)

Sl. No.	R.I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
			CaO 0.08 MgO 0.10 LOI 13.76	Oxides, Felspar, Rutile		CaO 0.18 MgO 0.10 LOI 14.42	71.90 from 68.52 (ISO) after bleaching	
12	1095	Beneficiation of CLAY sample from Cannanore dist. Kerala for Kerala Clays and Ceramics Products Ltd	Al_2O_3 22.30 Fe_2O_3 0.90 SiO2 66.41 TiO_2 0.51 K_2O 0.43 CaO 0.01 MgO 0.04 LOI 9.00	Val.Mineral : Kaolinite Gangue : Quartz, Mica, Iron Oxides, Amphibore, Zircon Rutile	53.28	- 325 mesh fraction Al_2O_3 35.66 Fe_2O_3 0.84 SiO_2 47.32 TiO_2 0.73 LOI 14.53	Brightness of decant product could be improved to 70.05 from 66.93 (ISO) after bleaching	Classification, Deflocculation and Bleaching
13	1106	Beneficiation of CLAY sample from Adari Mines, Warora Range, Chandrapur Dist.,M.S for M/s Vidarbha Clays, Chandrapur	Al_2O_3 38.33 Fe_2O_3 0.75 SiO_2 43.42 TiO_2 2.32 K_2O 0.07 CaO 0.13 MgO 0.11 LOI 13.84	Val.Mineral Kaolinite Gangue : Mica, Felspar Goethite	89.0 (of decant)	Decant (Non mag) (After bleaching) Al_2O_3 37.52 Fe_2O_3 0.14 SiO_2 44.60 TiO_2 0.83 K_2O 0.07 CaO 0.30 MgO 0.10 LOI 14.39	After bleaching, brightness could be improved from 75.23 to 80.85 ISO	Classification, Mag. Sep. Deflocculation and Bleaching
14.	1111	Beneficiation of CHINACLAY sample from M/s Kasimbazar China Clay Pvt. Ltd., Calcutta	Al_2O_3 29.97 Fe_2O_3 2.42 SiO_2 50.12 TiO_2 0.17 K_2O 0.74 CaO 1.90 MgO 0.22 LOI 14.28	Val.Mineral: Kaolinite Gangue : Quartz, Mica, Chlorite, Felspar Calcite	Overall Wt% 16.90	- 325 mesh fraction Al_2O_3 30.91 Fe_2O 2.35 SiO_2 48.57 TiO_2 0.17 LOI 13.76	After bleaching, the brightness could be improved from 66.92 to 70.59 (ISO)	Classifiction, Defloulation and Bleaching
15.	1149	Beneficiation of Crude CHINA-CLAY sample from Amrapali & Co., Ahmedabad, Gujarat	Al_2O_3 18.60 Fe_2O_3 0.67 SiO_2 70.06 TiO_2 0.28 CaO 1.39 LOI 7.61		45.9 (20.2) Overall St%	Decant Al_2O_3 37.82 Fe_2O_3 0.55 SiO_2 45.29 TiO_2 0.38 K_2O 0.04 LOI 14.85	Brightness of decant could be improved to 85.00 ISO from 82.07 after bleaching	Classification, Deflocculation and Bleaching
16.	1152	Beneficiation of CHINACLAY sample (New Prospecting Mix) from Sikar dist., Rajasthan for M/s Indo Modi Kaolin Ltd., Neem-Ka Thana, Rajasthan	Al_2O_3 24.50 Fe_2O_3 0.82 SiO_2 62.50 TiO_2 0.10 K_2O 0.59 CaO 1.92 MgO 0.52 LOI 9.28	Val.Mineral : Kaolinite Gangue : Quartz, Mica Calcite, Goethite Tourmaline, Felspar	13.78 Overall	Decant (Before bleaching) Al_2O_3 38.32 Fe_2O_3 0.88 SiO_2 44.72 TiO_2 0.09 K_2O 0.18 CaO 0.54 MgO 0.27 LOI 14.38	Brightness could be improved to 83.77 ISO after bleaching	Classification, Deflocculation and Bleaching

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Annexure - 2 (Contd.)

Sl. No.	R.I. No.	Title of the Investigation	Original Analysis %		Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
17.	1193	Beneficiation of CHINACLAY from Mamura-Bhuj Mine, Kutch Dist., Gujarat for INDEXTb, Gujarat	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 LOI	20.31 0.58 69.59 1.11 7.66	Val.Mineral: Kaolinite Gangue : Quartz, Calcite, Iron Oxides		(Non mag. Decant) - 325 mesh Al_2O_3 38.99 Fe_2O_3 0.16 SiO_2 45.26 TiO_2 0.18 CaO 0.11 MgO 0.19 LOI 14.18	Brightness 81.54 ISO after bleaching	Wet sieving, Deflocculation, Magnetic separation, Bleaching
18.	1194	Beneficiation of CHINACLAY from Arsodia Mines, Sabarkanta Dist., Gujarat for Industrial Extension Bureau, Govt. of Gujarat	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 LOI	19.91 0.43 68.77 0.44 8.40	Val.Mineral: Kaolinite Gangue : Quartz, Calcite, Iron Oxides	52.00	- 325 mesh fraction Al_2O_3 35.00 SiO_2 47.41 Fe_2O_3 0.41 TiO_2 0.74 LOI 14.21	Brightness of decant after 85.74 ISO after bleaching	Attrition scrubbing, Deflocculation, Bleaching
19.	1195	Beneficiation of CLAY sample from Manfara Mines, Kutch Dist., Gujarat Industrial Extension Bureau, Govt. of Gujarat	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 LOI	13.03 0.53 78.17 0.71 5.90	Val.Mineral: Kaolinite Gangue : Quartz, Calcite, Iron Oxides, Mica	34.4	- 325 mesh fraction Al_2O_3 36.95 SiO_2 45.44 Fe_2O_3 0.96 TiO_2 1.30 LOI 14.26	Brightness of decant 77.33 ISO after bleaching	Attrition scrubbing, wet sieving, Deflocculation, Bleaching
20.	1207	Beneficiation scale beneficiation studies of a CLAY sample (ROM) from Venkateswara clay project, Dwarka Tirumalai, W. Godavari Dist., A. P. for RCOM, IBM Hyderabad	Al_2O_3 Fe_2O_3 SiO_2 TiO_2 LOI	24.05 4.41 56.88 0.94 10.00	Val.Mineral: Kaolinite Gangue : Quartz, Calcite, Iron Oxides, Mica	45.60 (39.2 over-all)	- 325 mesh (78% -2.4 microns) Al_2O_3 31.24 SiO_2 51.58 Fe_2O_3 1.90 TiO_2 0.74 LOI 12.88	Brightness 46.08 ISO	Scrubbing, Screening, Deflocculation
21.	1215	Beneficiation of CLAY sample from Dwarka Tirumala Mines, A. P. for RCOM, IBM, Hyderabad	Al_2O_3 SiO_2 Fe_2O_3 TiO_2 CaO MgO LOI	21.16 53.60 11.23 1.39 0.75 0.44 11.32	Val.Mineral: Kaolinite Gangue : Quartz, Iron Oxides, Calcite Tourmaline	81.20	Non-Magnetic (-325 mesh) Al_2O_3 23.48 SiO_2 59.48 Fe_2O_3 4.48 TiO_2 0.42 CaO 0.50 MgO 0.26 LOI 11.78	Brightness 46.51 after bleaching	Attrition scrubbing, sizing, magnetic separation, bleaching, Deflocculation
22.	1216	Beneficiation of CLAY sample from Manfara, Bhuj, Kutch dist., Gujarat for M/s Kutch Minerals Ltd., Gujarat	Al_2O_3 SiO_2 Fe_2O_3 TiO_2 CaO MgO LOI	35.14 45.79 1.28 1.10 1.48 0.42 13.42	Val.Mineral: Kaolinite Gangue : Mica, Iron Oxides Garnet, Tourmaline Tremolite, Diaspore	95.10	Non-Magnetic (-325 mesh) Al_2O_3 35.78 SiO_2 45.84 Fe_2O_3 0.98 TiO_2 1.03 CaO 1.35 LOI 14.08 LOI 11.78	Brightness 73.65 ISO after bleaching	Wet Sieving, Deflocculation Bleaching, Magnetic, Separation
23.	1217	Pilot Plant scale recovery of silica sand and mica as a	Al_2O_3 SiO_2O_3	9.40 80.80	Val.Mineral: Kaolinite	93.10	(+80 mesh) Al_2O_3 0.65	Silica Clay	Classification, Sieve analysis, Flotation, WHIMS Acid

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Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
		by-product from CLAY sample New Prospecting Mix Mine, Sikar Dist., Rajasthan for Indo Modi Kaolin Ltd., Neem-Ka-Thana, Rajasthan (Analysis indicating silica sand containing clay)	Fe_2O_3 1.70 MgO 0.56 CaO 0.88 LOI 4.61	Gangue : Quartz, Mica Iron Oxides, Calcite		SiO_2 98.19 Fe_2O_3 0.06 CaO 0.10 MgO 0.08 LOI 0.20 (+80 mesh) Al_2O_3 31.86 SiO_2 47.67 Fe_2O_3 3.47 CaO 1.12 MgO 0.29 LOI 8.09		leaching, Sizing
24.	1218	Pilot Plant scale beneficiation studies on crude CHINACLAY sample from New Prospecting Mix Mines, Sikar Dist., Rajasthan for M/s Indo-Modi Kaolin Ltd., Neem-ka-Thana, Rajasthan	Al_2O_3 23.17 SiO_2 61.31 Fe_2O_3 1.91 MgO 0.50 CaO 1.12 LOI 9.27	Val.Mineral: Kaolinite Gangue : Quartz, Muscovite, Felspar, Iron Oxides	40.30	-325 mesh (74% -2.4 microns) Al_2O_3 35.91 SiO_2 45.82 Fe_2O_3 0.97 MgO 0.35 CaO 1.10 LOI 14.25	(Non Mag) Brightness 81.74 after bleaching	Screening, Scrubbing Classification, Wet, Screening, WHIMS, Deflocculation, Bleaching
25.	1238	Beneficiation of CLAY sample from Mamuara Mine, Bhuj, Dist., Gujarat for Industrial Extn., Bureau, Govt. of Gujarat	Al_2O_3 32.06 Fe_2O_3 1.79 SiO_2 49.50 TiO_2 2.70 CaO 0.29 MgO 0.63 K_2O 0.16 Na_2O 0.28 LOI 12.15	Val.Mineral: Kaolinite Gangue : Quartz, Calcite, Dolomite, Goethite Hematite, Felspar Diopside, Epidote Mica, Chlorite	34.60	-324 mesh Non Mag. Decant Al_2O_3 37.39 Fe_2O_3 0.60 SiO2 45.19 TiO_2 1.81 CaO 0.17 MgO 0.07 K_2O 0.01 LOI 14.01	Brightness 77.13 ISO after bleaching on decant	Attrition scrubbing, Magnetic separation, Deflocculation, Bleaching
26	1255	Pilot Plant beneficiation studies on CLAY sample from Arsodia Mines, Sabarkanta Dist., Gujarat for Industrial Extension Bureau, Gujarat	Al_2O_3 18.30 Fe_2O_3 0.87 SiO_2 67.29 TiO_2 0.82 CaO 2.63 MgO 0.48 K_2O 0.14 Na_2O 0.07 LOI 9.21	Val.Mineral: Kaolinite Gangue : Quartz, Felspar, Calcite, Iron. Oxides, Mica, Gypsum, Sodalite	21.90 (Over-all)	Decant (Non Mag.) Classifier of O/F 78.90% (-2.4 microns Al_2O_3 36.36 Fe_2O_3 0.29 SiO_2 46.35 TiO_2 0.47 LOI 14.87	78.77 ISO (before bleaching) 82.11 ISO (after bleaching)	Tumbling, Classification, WHIMS, Cycloning, Deflocculation, flollowed by bleaching.
					45.10 (over-all)	Non-Mag. of Classifier O/F 47.10% (-2.4 microns Al_2O_3 35.88 Fe_2O_3 0.81 SiO_2 45.29 TiO_2 1.08 LOI 13.68	76.58 ISO (before bleaching 81.00 ISO (after bleaching	Tumbling, Classification, WHIMS, Cycloning,
27.	1261	Pilot Plant beneficiation studies on CLAY sample No.1	Al_2O_3 32.19 Fe_2O_3 1.66	Val.Mineral: Kaolinite	20.90 (Over-all)	Decant (Non Mag.)	Before bleaching	Wet scrubbing/ Tumbling,

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Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
		from Mamuara Mines, Bhuj Dist., Gujarat for Industrial Extension Bureau, Gujarat	SiO_2 49.26 TiO_2 2.81 CaO 0.25 MgO 0.55 LOI 12.03	Gangue : Quartz, Goethite/Hematite, Calcite, Dolomite Felspar, Mica Chlorite	of CL O/F (84% (-2μ microns	Al_2O_3 36.88 Fe_2O_3 0.61 SiO_2 47.01 TiO_2 0.96 LOI 13.49	71.07 ISO) (after	Classification, WHIMS Hydrocycloning, Deflocculation, bleaching) Bleaching 76.11 ISO
28.	1264	Characterisation of 3 CLAY samples from Nungbi area, Ukhrul Dist., Manipur for Directorate of Commerce & Industries, Govt. of Manipur	Sample No. I/C to 5/C SiO_2 Al_2O_3 49.02 Fe_2O_3 15.50 CaO 11.70 MgO 3.26 TiO_2 1.11 LOI 1.06 14.96	Val.Mineral. Montmorillo nite. Kaolinite Gangue : Iron Oxides. Mica Quartz, Feldspar Calcite, Chlorite	The Clay sample consisting of mainly clay as contituents may be considered for beneficiation studies to reduce the free quartz, iron oxides so as to make suitable for clay user industries			XRD and Microscopic Studies.
			Sample No. Ultramafite "U" SiO_2 59.12 Al_2O_3 0.25 Fe_2O CaO 6.21 MgO 1.18 TiO_2 26.53 LOI 0.06 4.97	Val. Minerals : Montmorillo-nite. Kaolinite Gangue : Iron Oxides, Mica Quartz, Garnet, diopside, Chlorite, tremolite	The ultramafite sample which is talc (serpentine) based sample may not be suitable for beneficiation since this sample is a soapstone sample having talc and other minerals.			XRD and Microscopic Studies
			Sample No. Blended Material "CU" SiO_2 53.64 Al_2O_3 5.93 Fe_2O_3 CaO 10.24 MgO 1.14 TiO_2 17.46 LOI 0.36 8.04	Val. Minerals : Montmorillo-nite, Kaolinite Gangue : Iron Oxides, Mica Quartz, Feldspar, tremolite, Chlorite.	The sample Blended Material "CU" is the mixture of clay and ultramafic samples in certain proportions and thus need not be considered for beneficiation studies at this state.			XRD and Microscopic Studies
29.	1290	Bench Scale beneficiation on a Low Grade CHINACLAY sample from Kharia Mines of M/s Patel Nagar Minerals & Industries Pvt. Ltd., Birbhum Dist., West Bengal for RCOM, IBM, Ranchi.	Al_2O_3 36.23 SiO_2 45.32 Fe_2O_3 1.55 TiO_2 21.60 CaO 0.13 MgO 0.15 K_2O 0.14 LOI 13.65	Val.Mineral : Kaolinite Gangue : Iron oxides, Mica Quartz, Feldspar	53.68 - 325 Mesh	Al_2O_3 37.06 Fe_2O_3 1.56 SiO_2 44.63 TiO_2 2.01 CaO 0.06 MgO 0.21 LOI 14.39	Brightness : After Bleaching Decant - 77.00 ISO	Scrubbing, Deflocculation, Bleaching

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Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
30.	1302	Beneficiation of CHINACLAY Sample from Mukdam Nagar, Birbhum dist., West Bengal for the West Bengal Projects Ltd., Calcutta	Al_2O_3 36.71 SiO_2 45.66 Fe_2O_3 1.70 TiO_2 1.16 CaO 0.19 MgO 0.10 LOI 13.71	Val.Mineral : Clay(Kaolinite) Gangue : Quartz, Mica Felspar, Iron Oxides	Bleached Non-magnetic Decant Fraction (90.20) (90.20% -2.4 microns)	Al_2O_3 37.81 SiO_2 44.96 Fe_2O_3 1.12 TiO2 0.65 Brightness 80.94	ISO	Attrition scrubbing, Sizing, WHIMS, Deflocculation, Bleaching
31.	1360	Bench scale beneficiation studies on Manganiferrous CLAY sample from Gaval Sinshi Mine, Goa for M/s Sesa Goa Ltd.	Fe 40.00 Mn 9.30 SiO_2 10.70 Al_2O_3 5.80 TiO_2 0.20 P_2O_5 0.30 LOI 11.90	Val.Mineral : Goethite, Limonite, Wad, Psilomelane, Pyrolusite Gangue : Quartz, Clay Mica, Feldspar	Mineralogy indicated that the sample is not amenable to beneficiation			WHIMS
32.	1376	Specific surface area determination by BET technique on 8 CLAY samples for M/s 20 Microns Ltd., Baroda			Surface area determination BET Techniques clay samples is ranging between 5.09 to 32.01 sq.mt./gm.			
33	243 AJH	Physical and chemical analysis of clay sample of Shri Basant Kumar Mansinghka, Bhilwara, Rajasthan	SiO_2 50.27 Fe_2O_3 8.47 Al_2O_3 16.71 CaO 4.31 MgO 3.37 TiO_2 0.94 LOI 13.44			Gel formation Index-18 ml Plastic viscosity - 2.0		
34.	244 AJH	Physical and chemical analysis of clay sample of Shri Basant Kumar Mansinghka, Bhilwara, Rajasthan	SiO_2 50.29 Fe_2O_3 10.37 Al_2O_3 8.53 CaO 7.55 MgO 4.37 TiO_2 1.10 LOI 16.44			Gel formation Index-12 ml Plastic viscosity - 2.0		
35.	266 AJH	Performance test of Mozley Hydroclone Rig on CLAY sample from Bikaner Dist., Rajasthan (Departmental)	Particle size larger than 10.5 microns = 0.5% particle size less than 2.4 microns = 66.8%			Particle size less than 2.4 microns = 73.9% Particle size coarser than 10.5 micron = Nil		
36.	271 AJH	Characterisation of Clay sample from Gomtesh Granites, Beawar, Raj.	SiO_2 51.63 Al_2O_3 30.70 Fe_2O_3 1.48 TiO_2 1.26 LOI 11.25			pH of as received sample - 8.31 Brightness of as received sample - 73.1 ISO		Laser plot Brightness Tester
37.	272 AJM	Beneficiation of CHINACLAY sample from Banesti Mine, Chittorgarh dist., Rajasthan	SiO_2 70.69 Al_2O_3 18.54 Fe_2O_3 1.21 TiO_2 0.61	Val.Mineral: Kaolinite Gangue :	99.30	- 325 mesh of as received sample SiO_2 70.38		Size of deflocculation and bleaching

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Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
			CaO 0.28 MgO 0.50 Na2O 0.13 K2O 0.27 LOI 6.92	Quartz, Calcite, Iron odxide, Feldspar.	of -325 mesh 32.0 of -325 mesh	Al_2O_3 18.42 Fe_2O_3 0.93 TiO_2 0.87 LOI 6.96 Decant SiO_2 61.20 Al_2O_3 24.38 Fe_2O_3 1.58 TiO_2 1.36 LOI 7.61		
38.	274 AJH	Limited test on a clay sample from Kotri area, dist. Bhilwara., Rajasthan for M/s B. S. Mandwara, Jahajpur, Bhilwara	SiO_2 76.45 Al_2O_3 12.10 Fe_2O_3 0.44 TiO_2 0.77 LOI 2.69			Particle Size Analysis (By Malvern PSA) 100% - 45 Microns 99.4% - 33.7 Microns 81.6% - 10.5 Microns 51.9% - 5.0 Microns 9.0% - 3.0 Microns Brightness of -325 mesh fraction - 69.50 ISO		Attrition Scrubbing followed by wet sieving Leser phot brightness Tester
39.	277 AJH	Limited test on a CLAY sample from Madh area, Tah. Kalayat, for M/s Madhusudan Asopa, Bikaner, Rajasthan		Val. Mineral : Clay Gangue : Quartz, Felspar, Mica, Iron Oxide, Amphibole, Carbonate	87.8	-325 Mesh fraction SiO_2 58.89 Al_2O_3 24.84 Fe_2O_3 0.94 TiO_2 2.05 LOI 8.97		Attrition Scrubbing followed by wet screening
40.	266 BMG	Beneficiation of CHINACLAY sample from Ramgurwadi Mine of M/s Ceramic Products Ltd., Belgaum dist., Karnataka	Al_2O_3 24.90 SiO_2 57.41 Fe_2O_3 3.57	Val. Minerals : Kaolinite Gangue : Quartz, hematite, Calcite	41.2 (-325 mesh)	Al_2O_3 32.90 SiO_2 44.08		Sizing
41.	267 BMG	Beneficiation of china CLAY sample from Ramgurwadi Mine of M/s Ceramic Products Ltd., Belgaum dist., Karnataka	Al_2O_3 13.90 SiO_2 70.40 Fe_2O_3 1.50	Val. Minerals : Kaolinite Gangue : Montmorillonite, Calcite, Hematite, Quartz	67.6 (-325 mesh) PSA-2.5% of 2.4 microns	Al_2O_3 16.88 SiO_2 67.86 Al2O3	52.29 (ISO)	Sizing
42.	278 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/VL/S1)	Al_2O_3 25.72 Fe_2O_3 3.85 SiO_2 50.78	Val. Mineral : Kaolinite Gangue : Quartz, Goethite Hematite	Clay Content - 72% (DTA) Grit Content - 29% (Screening)		53.71	XRD, DTA, Screening & brightness test
43.	279 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/VL/S2)	Al_2O_3 26.19 Fe_2O_3 1.25 SiO_2 58.75	Val. Mineral : Kaolinite Gangue : Quartz, Goethite Hematite	Clay Content - 56% (DTA) Grit Content - 44% (Screening)		73.59	XRD, DTA, Screening & brightness test

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Annexure - 2 (Contd.)

Sl. No.	R.I. No.	Title of the Investigation	Original Analysis %		Mineralogy	Concentrate Wt %	Assay %	Brightness %	Process Adopted
44	280 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/VL/S3)	Al_2O_3 Fe_2O_3 SiO_2	26.09 1.45 57.15	Val. Mineral Kaolinite Gangue : Quartz, Hematite Goethite, anatase	Clay Content - 66% (DTA) Grit Content - 29% (Screening)		74.48	XRD, DTA, Screening & brightness test
45	281 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/VL/S4)	Al_2O_3 Fe_2O_3 SiO_2	52.16 1.59 10.58	Val. Mineral : Kaolinite Gangue : Quartz, Hematite Gibbsite, anatase (Gibbsite content more)	Clay Content 31% (DTA) Grit Content - 73% (Screening)		53.45	XRD, DTA, Screening & brightness test
46	282 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/Excel/S1)	Al_2O_3 Fe_2O_3 SiO_2	46.55 1.18 24.69	Val. Mineral Kaolinite Gangue : Gibbsite Goethite Hematite Quartz	Clay Content - 67% Grit Content - 30%		76.37	XRD, DTA, Screening & brightness test
47	283 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/Excel/S2)	Al_2O_3 Fe_2O_3 SiO_2	52.32 1.44 9.61	Val. Mineral Kaolinite Gangue : Quartz Hematite, Goethite Gibbsite	Clay Content - 30% Grit Content - 70.50%		60.37	XRD, DTA, Screening & brightness test
48.	286 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/ SUMM/S3)	Al_2O_3 Fe_2O_3 SiO_2	6.48 8.40 63.38	Val. Mineral : Kaolinite Gangue : Quartz, Hematite, Goethite	Clay Content - 11% Grit Content - 91%		27.72	XRD, DTA, Screening & brightness test
49.	287 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/ SUMM/S4)	Al_2O_3 Fe_2O_3 SiO_2	33.41 0.90 43.28	Val. Mineral : Kaolinite Gangue : Quartz, Goethite Hematite	Clay Content-84% (DTA) Grit Content - 12% (Screening)		60.01	XRD, DTA, Screening & brightness test
50.	288 BMG	Characterisation studies on CLAY sample from Kerala State for RCOM, Bangalore (IBM/KSP/ SUMM/S6)	Al_2O_3 Fe_2O_3 SiO_2	10.76 1.13 77.08	Val. Mineral : Kaolinite Gangue : Quartz, Goethite Hematite	Clay Content-21% (DTA) Grit Content - 75% (Screening)		47.36	XRD, DTA, Screening & brightness test

(Contd.)

Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %		Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
51.	318 BMG	Physical characterisation studies and chemical analysis of CLAY sample from Mallama-patti village, Mulag Warangal dist., A.P. for RCOM, IBM, Hyderabad	SiO_2 Al_2O_3 Fe_2O_3 TiO_2	38.14 32.68 3.65 7.67	The pH of the pulp was 6.67			52.62	pH and brightness
52.	215 AJM	Bench scale limited scrubbing test on CLAY reject sample from Bhinai Khera Mine	SiO_2 Al_2O_3 CaO LOI	29.20 23.60 19.90 23.60	Val. Minerals : 46.28 Clay. Gangue : Carbonates	SiO_2 Al_2O_3 CaO LOI	41.52 36.05 3.28 14.29	40.28 Brightness not	Scrubbing, Classification
53.	208 AJM	Particle size refining of R.O.M. Clay sample from Bhinani Khera Mine Bhilwara Dt., Rajasthan.	SiO_2 Al_2O_3 CaO Fe_2O_3 LOI	42.76 33.90 3.18 1.13 14.68	Val. Minerals : 63.7 Kaolinite Gangue : Muscovite, Feldspar, Quartz	Decant (-325 mesh) SiO_2 Al_2O_3 CaO LOI	44.26 35.87 0.75 13.20	Brithtness 76.0 ISO	Gravity & Hydrocycloning.
54.	229 AJM	Laboratory benefication of a CLAY sample from Mudh White Clay Mines, Bikaner Dt. Rajasthan.	SiO_2 Al_2O_3 Fe_2O_3 LOI	59.20 25.38 1.88 9.05	Val. Minerals : 49.30 Kaolinite montmorillonite Gangue : Muscovite, Goethite, Rutile			- 71.0 (ISO)	Classification, Deflocculation & bleaching
55.	230 AJM	Laboratory benefication of a CLAY sample from Mudh White Clay Mines, Bikaner Dt. Rajasthan.	SiO_2 Al_2O_3 Fe_2O_3 LOI	50.08 30.23 2.46 11.35	Val. Minerals : 70.60 Kaolinite montmorillonite Gangue : Muscovite, Goethite, Rutile			- 53.0 (ISO)	Classification, Deflocculation & bleaching
56.	234 AJM	Bench scale benefication studies on a CLAY sample No. KL/RMDS/1 Mud Block, A-Grade, Rajasthan	SiO_2 Al_2O_3 Fe_2O_3 LOI TiO_2	57.12 26.30 2.23 9.36 1.88	Val. Minerals : 80.00 Kaolinite montmorillonite Gangue : Mica, Quartz Calcite, Goethite	minus 2 Microns - 93.10		69.4 (ISO)	Classification, Deflocculation & bleaching
57.	235 AJM	Bench scale benefication studies on a CLAY sample No. JK/RMDS/3 Rajasthan.	SiO_2 Al_2O_3 Fe_2O_3 LOI	50.45 30.52 2.49 10.88	Val. Minerals : 53.60 Kaolinite montmorillonite Gangue : Mica,Quartz Calcite, Goethite	minus 2 Microns -	88.50	64.70 (ISO)	Classification, Deflocculation & bleaching
58.	92 Bang	Hydrocyclone test on a CHINACLAY sample for M/s. English India Clay Limited, Trivandrum.	Al_2O_3 SiO_2 Fe_2O_3 LOI	38.00 44.00 0.60 15.5		The test yielded 84% minus 2 microns size product		Brightness not mentioned	Hydrocylone.

(Contd.)

Annexure - 2 (Contd.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %	Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
59.	95 Bang	Limited tests of CLAY sample (1) from Sandur Taluk, Bellary Dt., Karnataka for RCOM, IBM, Bangalore.	Al_2O_3 18.00 Fe_2O_3 3.95 SiO_2 60.80 LOI 9.37	Val. Minerals : Clay Gangue : Quartz Carbonate, Felspar, Iron Oxide	53.60	- 200 mesh SiO_2 49.03 Al_2O_3 29.63 Fe_2O_3 3.90	Brightness not mentioned	West sieving
60.	96 Bang	Limited tests of CLAY sample (2) from Sandur Taluk, Bellary Dt., Karnataka for RCOM, IBM, Bangalore.	Al_2O_3 16.21 Fe_2O_3 1.69 SiO_2 69.70 LOI 4.71	Val. Minerals : Clay Gangue : Quartz Carbonate, Felspar Iron Oxide	36.50	- 200 mesh Al_2O_3 29.29 Fe_2O_3 1.31 SiO_2 50.22	Brightness not mentioned	Wet sieving analysis
61.	100 Bang	Hydrocyclone test on a CHINA CLAY sample for M/s. English India Clay Limited, Trivandrum.	SiO_2 44.0 Al_2O_3 38.0 Fe_2O_3 0.6 LOI 15.5			The test yielded a product with 86.2% minus 2 microns size particles with 25 mm size cyclone.	Brightness not mentioned	Hydrocycloning
62.	230 Bang	Sample prepparation and chemical analysis of FIRE-CLAY sample for RCOM, Goa	Al_2O_3 8.37 Fe_2O_3 6.50 SiO_2 61.70	The chemical analysis of the sample indicated that this type of sample is not suitable for industrial use in steel plant of manufacturing super refraction.				Crushing & sample preparation
63.	239 Bang	Bleaching of CLAY sample from Tumkur, Karnataka - for Rajasekhar Mines, Yeswantpur, Bangalore.	Brightness could be improved from 63.41 to 67.00					Bleaching
64.	253 Bang	Characterisation studies on a CLAY sample (VMS/CG/1) - for M/s. V. M. Salgaocar & Bros., Goa.	Al_2O_3 21.33 Fe_2O_3 3.83 SiO_2 60.87 LOI 9.36	Val. minerals Kaolinite-30% Gangue . 40% Quartz, Muscovite 10%	 61.00 86.5 97.0	Particle size Analysis - 2 microns - 10 microns - 53 microns		Anderson Pipette method
65.	260 Bang	Benefication of a CLAY sample No.CC-1 from Teethahalli Mine of M/s. Mysore Minerals Ltd., Shimoga Dt., Karnataka	Al_2O_3 36.93 Fe_2O_3 0.97 SiO_2 45.44	Val. minerals Kaolinite Gangue : Quartz, Muscovite Goethite Felspar			The Brightness could be improved from 78.46 to 85.23 (ISO).	Classification & Bleaching

(Contd.)

Annexure - 2 (Concld.)

Sl. No.	R. I. No.	Title of the Investigation	Original Analysis %		Mineralogy	Concentrate Wt %	Concentrate Assay %	Concentrate Brightness %	Process Adopted
66	264 Bang	Benefication of a CLAY sample No.CC-2 from teethahalli Mine of M/s. Mysore Minerals Ltd., Shimoga Dt., Karnataka	Al_2O_3 Fe_2O_3 SiO_2	35.28 1.20 44.82	Val. minerals Kaolinite Gangue : Quartz, Muscovite Goethite, Felspar			The Brightness could be improved from 74.43 to 85.66 (ISO)	Classification & Bleaching
67.	265 Bang	Benefication of a CLAY sample No.CC-3 from Teethahalli Mine of M/s. Mysore Minerals Ltd., Shimoga Dt., Karnataka	Al_2O_3 Fe_2O_3 SiO_2	36.66 1.27 45.89	Val. mineral Kaolinite Gangue : Quartz, Muscovite Goethite, Felspar			The Brightness could be improved from 75.24 to 86.06 (ISO)	Classification & Bleaching

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9. Environment

9.1 General

It is commonly said that mankind faces two certainties viz. death and taxes. The producers of industrial minerals face a third certainty in form of environmental problems. The extraction of rocks or minerals is not possible without disturbing the land. Water and air are also disturbed by mining. As a consequence, miners are not well liked. Today, starting a new pit or quarry or enlarging an existing one, is a subject to public hearing. Because of possible effect on air and water quality and land degradation of the property, the Government strictly imposed the requirements on extraction of the resources.[1] This is applicable to mining of all minerals including chinaclay.

To some degree, it is believed that we suffer from the heritage of public mistrust, which has developed from mining and allied activities resulting in water and air pollution in addition to degradation of land. Ideally, at the end of life of a mine, land disturbed should be brought to its original shape which is practically not possible and therefore land disturbed is to be put to best possible use to the society. This requires reclamation of the damaged land which should be done in phases to get back the maximum land for society's use at the earliest.

Now a days, special laws have been enacted for proper mine management with special emphasis on environment restoration practices. However, there are mine owners who operate their mines unsystematically.

In 1950s and 1960s, the province of Ontario, Canada underwent rapid growth and expansion resulting in demand for aggregates. Large pits and quarries were developed and in the absence of provincial regulations, many of them were operated in disregard to environmental impact, right of neighbours or obligations to restore the land. At the same time, people were moving from Toranto and other cities into the country, to form an increasing rural but non-farm population. As a result, towns began to enact local laws prohibiting new operations or expansions of old mines. By late 1960s the gravel and stone industries realised that they were in trouble and requested the provincial Government to take action, preferably in the form of legislation. This resulted in 'Pits and Quarries Control Act' for that province applicable to all pits and quarries including that of chinaclay.

In India, acute environmental problem was first faced in the middle of 1970s when the Supreme Court had given the directives for limestone mining of Dehradun area and mining activities were closed. Recently in Dec.1996 the Supreme Court again came in to picture ordering mining to be done in accordance with the provisions laid down in the Forest Conservation Act, 1980 to safeguard the forest land. As some clay mining areas are in the forest land, fully or partly, this is also applicable to chinaclay mining areas.

The National Ambient Air Quality Standards are given in Table - 9.1.

Table - 9.1 : Environment & Forests Central Pollution Control Board National Ambient Air Quality Standards, Notification dated 11.4.1994

S.O. 384 (E) - The Central Pollution Control Board in exercise of its powers conferred under section 16(2) (h) of the Air (Prevention and Control of Pollution) Act; 1981 (14 of 1981) hereby notify the National Ambient Air Quality Standards with immediate effect.

SCHEDULE - 1

Pollutant	Time weighted average	Concentration in ambient air			Method of Measurement
		Industrial Area	Residential (Rural) area	Sensitive Area	
Sulphur Dioxide (SO_2)	Annual average*	80 ug/m³	60 ug/m³	15 ug/m³	1. Improve Weste Gaeke
	24 hours **	120 ug/m³	80 ug/m³	30 ug/m³	2. Ultraviolet fluorescence
Oxides of Nitrogen as (NO_2)	Annual average *	80 ug/m³	60 ug/m³	15 ug/m³	1. Jacob & Hochheiser modified (Na) Arsenite method
	24 hours**	120 ug/m³	80 ug/m³	30 ug/m³	2. Gas Phase Chemilumines Scence.
Suspended Particulate Matter (SPM)	Annual average	360 ug/m³	140 ug/m³	70 ug/m³	High volume sampling. (Average flow rate not less than 1.1m³/minute)
	24 hours**	500 ug/m³	200 ug/m³	100 ug/m³	
Respirable Particulate Matter (RPM) (Size less than 10 um)	Annual average*	120 ug/m³	60 ug/m³	50 ug/m³	Respirable particulars matter & sampler.
	24 hours**	150 ug/m³	100 ug/m³	75 ug/m³	
Lead (Pb)	Annual average*	1.0 ug/m³	0.75 ug/m³	0.50 ug/m³	AAS Method After sampling using ERM 200 of equivalent filter paper
	24 hours**	1.5 ug/m³	1.0 ug/m³	0.75 ug/m³	
Carbon Monoxide (CO)	8 hours**	5.0 mg/m³	2.0 mg/m³	1.0 mg/m³	Non dispersive infrared Spectroscopy
	24 hours**	10.0 mg/m³	4.0 mg/m³	2.0 mg/m³	

* *Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.*

** *24 hourly/8 hourly values should be met 98% of the time in year. However 2% of the time, it may exceed but not on two consecutive days.*

Note :

1. *National Ambient Air Quality Standards : The levels of air quality necessary with an adequate margin of safety, to protect the public health, vegetation and property.*
2. *Whenever and wherever two consecutive values exceed the limit specified above for the respective category, it would be considered adequate reason to institute regular/continuous monitoring the further investigations.*
3. *The State Government/State Board, shall notify the sensitive and other areas in the respective states within a period of six months from the date of Notification of National Ambient Air Quality Standards.*

9.2 Kaolin Mining and its Impact on Environment

Mining activities create environment problems and kaolin mining is no exception. Environmental degradation resulting from kaolin mining (including its beneficiation) are under two main categories namely chemical and physical pollutions.

9.2.1 Chemical Pollution

Water discharged after beneficiation of kaolin is contaminated as a number of chemicals are used during the beneficiation process. This contaminated water is hazardous for human consumption and also affects crop production, if discharged into fields.

9.2.2 Physical Pollution

Kaolin mining is carried out mostly by opencast method and the environment may be effected in the form of :

i) Land Degradation

ii) Deforestation

iii) Noise Pollution

iv) Air Pollution and

v) Ophthalmic disorder

i) Land Degradation

The land degradation may result from the following type of conditions.

a) Land is degraded by opening a pit in the form of digging. If number of pits are opened, this will result in degradation of more land. Trenches made for exploration and drainage will also add to this.

b) Dump areas or piles result from opencast mines. More number of dumps will require more land, thereby degrading more land.

c) In some mines top soil is to be removed for winning chinaclay. Nature has taken 500 to 1000 years to impart fertility to the top soil in the form of biomass generation. By removing this top soil the time taken by nature is lost in a jerk. If it is not stacked separately or used elsewhere, loss is maximum. Further, if dumping is done on land containing fertile soil top, this soil is lost forever. Alternatively, if top soil is removed separately and stacked, its fertility is reduced. But in such case this can be used in best way and its fertility may be improved.

d) abandoned mine site : The basic operation of rock excavation by opencast mining has caused both direct and indirect land degradation in the mining belts. The direct degradations are excavations and overburden dumps which conflict with land use for agriculture, forestry, etc. The direct land degradation may be in the form of cutting due to mine water being disposed of.

(ii) Deforestation

The United Nations Scientific Working group forecasts that global temperature is likely to rise by 1°C by 2025 AD and the rate is higher than that seen during the last 10,000 years. The working group on climate change warns that if the addition of green house gas continues, the average rise in sea level will be above 6 cm a decade. The rise in temperature will lead to reduced rainfall and reduction in soil moisture in summer. Deforestation will also account for this drastic change in atmospheric conditions. In India deforestation accounts for 27% of the total added warning potential. Clay mining in forest area requiring deforestation is also responsible for this.

Forest is necessary for soil conservation, rechanging of underground water resources, supply of fuel and fodder, agricultural implements and raw material to the industry.

iii) Noise Pollution

Mechanisation in mining methods caused noise pollution which affects the health of the workers in the mine. In respect of chinaclay mining no mine is highly mechanized. In recent past, a number of clay mines in Rajasthan have adopted mechanisation for removal of overburden. Addition of excavator and dumpers/tipper trucks have resulted in noise pollution.

iv) Air Pollution

While carrying out the mining operations and excavations, the dust is produced which creates the air pollution in the mining area. In respect of chinaclay mining, most of the mines are opencast and small. The creation of dust is not much. However, the air pollution problem is faced in transport of more overburden/interburden waste by dumpers/trucks.

v) Ophthalmic Problem

As the chinaclay is white in colour and the mining is done by opencast method, it is but natural that the sunrays fall on the chinaclay which reflects the light and makes the dazzling effect on eyes. It becomes very difficult to look straight over chinaclay bed or stock after winning the same with naked eye in bright sun specially in case of mine with super/ snow white clay. The workers are exposed to such impact which may affect their eyesight.

9.3 Environmental impact in Bikaner & Bhilwara districts due to clay mining

Bikaner in Rajasthan is the major clay producing district. The other districts are Jaipur, Bhilwara, Sawai Madhopur and Pali. About 80% of the clay produced in Rajasthan come from Bikaner district. The main mineralisation of clay is located around Kolayat village which is 54 km WSW of Bikaner[2].

9.3.1 Land Degradation

The mining operations carried out by opencast method have caused both, direct and indirect land degradation. Direct degradations are excavations and overburden movements to external dumps. Huge piles of overburden dumps have been observed in all the four working blocks where mining is going on i.e. Indoka Bala, Kotri, Madh and Guda Blocks. In a number of cases it is observed that the mined out areas have not been restored and made available for agriculture purpose or for plantation though the mining is carried out upto the bottom most level of clay occurrence. The storage of dumps in past was irregular/unsystematic. Sometimes the overburden was dumped on both sides of the approach road which became obstacle for the transportation of material in a smooth way[3]. Now systematic dumping and even backfilling of worked out areas has been started.

Unsystematic dumping of waste in past had also blocked natural drainage of rain water to historical Kotayat Talab as almost all small natural drainage channels ultimately lead to this Talab.

9.3.2 Deforestation

The entire leases in Bikaner district are comprised of agricultural land or waste land. No lease area fall under the forest area and as such no forest has been damaged due to chinaclay mining in the district. However, at some places saplings and plants are being planted in the lease area, but survival is poor due to paucity of water. However, the number of plants are increasing due to the efforts now being made by the mine owner for plantation. The observance of Mines Environment and Mineral Conservation Weeks every year have also helped to increase plantation in the area.

9.3.3 Solid Waste Disposal

As stated earlier in 'Land degradation', waste dumping is now being done in systematic manner at number of mines including backfilling in to worked out areas. Now mine owners are understanding the importance of backfilling as it not only reclaims the area for putting the same useful for the society but also avoids dumping on mineralised ground. Most of the lease areas have hardly non-mineralised ground and therefore dumping on non-mineralised ground becomes a problem in this area. Backfilling, in addition, also helps in not blocking the natural water course by the dumps.

9.3.4 Mine Water Discharge

Water table in the area is very low and therefore it is not reached during mining. However, in the rainy season the water is collected in the old pits and used for drinking and other purposes by the labours. In some stray cases this stored rain water is also used for agricultural purposes.

9.3.5 Dust Control/Pollution

Mining is carried out by opencast method and the machineries being used produces dust. Sufficient water is not available at the mine site. Necessary steps are being taken by the mineowner to avoid health hazard due to inhalation of air borne dust by the labourers.

Air pollution was earlier observed at the dry processing plant at Chandi Mine of M/s Harish Clays. They have now taken necessary measures so that clay dust does not emit from the plant. However, due to scarcity of water for spraying on road, mine owners are facing difficulty in controlling dust formation over roads resulting from plying of trucks/dumpers. It may be noted that the mines in Bikaner district are in desert area.

In Bhilwara district of Rajasthan all the three main chinaclay mines are removing overburden with the help of excavators and dumping the same systematically. As these mines are in the vicinity of main river Banas, steps are now being taken up so that transport of these waste is not done with the rain water. Mine water is also discharged in such a way to avoid transport of solids along the same. All these mines have started doing plantation and some good green area is under development to improve the environment.

9.4 Preventive Measures Taken

9.4.1 Land Degradation

Since the development of the mine is done in a systematic and proper way, the over burden removal is carried out by using earth moving machinery. Dumping of over burden is done systematically and backfilling of worked out areas have been started in a number of mines. Because of this the area of the degraded land due to kaolin mining has been reclaimed considerably. However, mined out area is to be backfilled properly and rehabilitated to make the backfilled area useful to the society.

9.4.2 Deforestation

Mining in the entire leases of kaolin does not affect the forest. The participation in the Mineral Conservation Weeks celebrated by the mineowners has educated them in respect of environment. Many mine owners have started plantation in their lease area, thereby increasing the plantation area (which was almost nil before the start of mining operations), giving better environment than it was during pre-mining period.

9.4.3 Solid Waste Disposal

In almost all the mines waste consists of loose alluvial soil and friable sandstone. In the present practice mine owners are backfilling these material in the mined out area and keeping the same ready for the use of the society.

9.4.4 Mine Water Discharge

Being a very low water table in kaolin mining area in Bikaner district, the question of discharge of mine water does not arise. However, in Bhilwara district mine water is discharged which ultimately leads to the Banas river which is nearer to the lease area. Such discharge is planned in such a way that solids of waste are not transported along with water. This is done by first directing pumped water into a settling tank and then allowing the overflowing clear water to go to the main stream leading to Banas river.

9.5 Environmental Impact in Birbhum District (West Bengal) due to Clay Mining

9.5.1 Land Degradation

There is an obvious change in the landscape in the area as the mining activity has caused damage to natural cover and topography. The basic operation of rock excavation by opencast mining has caused both, direct and indirect land degradation in the mining areas. The direct degradations are excavations and overburden movements to external dumps which conflict with land use for agriculture, forestry, destruction of soil and vegetation. The indirect ingredients are drainage of water from aquifers in surrounding areas resulting in depletion or drying up of springs/streams and swamps/pastures. There are evidences of direct land damage by way of extensive mining excavations, overburden/waste rock dumps and associated activities.

The total land degradation was around 16 percent of the entire chinaclay lease areas up to 1990, out of which 21.5 hects was agricultural land accounting for about 7% of the total lease area.

9.5.2 Deforestation

The entire lease-holds of chinaclays in the district comprised of either waste land (locally termed as DANGA) or agricultural land and nothing falls within forest area. Thus, the mining operations have not contributed towards deforestation rather supplemented by afforestation programme to certain extent by way of planting saplings either within or outside the leasehold area.

9.5.3 Solid Waste Disposal

Overburden and waste rocks consist of alluvial soil, subsoil mixed with morrum and laterite. Overburden and waste rocks removed from quarries are dumped on the surface at different places. It can be presumed that on an average 2 tonnes of waste rock or overburden can be taken to be generated per tonne of chinaclay in this area. It was assessed that 6.34 lakh cubic metres of overburden rock are removed per annum. These dumps are scattered over an area of 12 hactares. Besides, land degradation, these dumps and stock piles have become major visual eye soaring features of the local landscape and there is an obvious change in the natural topography.

9.5.4 Mine Water Discharge

Water discharged from mines and beneficiation plants is not properly treated to deslime it in the mining areas. It has been observed that water pumped from the pits and the water discharged from the beneficiation plants contains some slime in the form of fire clay mineral. The clay mineral in suspension is not congenial to cultivation. There are river streams, nallahs, ponds and water pools containing clear water either adjoining the leasehold or within the leasehold in the mining areas. Water from these source is used for various purposes like drinking, bathing, irrigation, etc. Therefore, it is essential that only clear water should be allowed to mix in these sources to maintain ecological balance.

9.6 Preventive Measures Taken

9.6.1 Land Reclamation/Land Rehabilitation

An effort has been made by the mining lessees in the area to reclaim or rehabilitate land affected by various operations. The total area of land reclaimed or rehabilitated in different mines is around 7.11 hactares which constitutes only 18 percent of the total land degraded due to mining operations. The mined out area is reclaimed by backfilling of waste dumps into the worked out pit area.

9.6.2 Afforestation

Kaolin mining in this area does not affect the forest as no lease falls under the forest area. The participation in the Mineral Conservation Weeks celebrated by the mine owners has educated them in respect of environment and many mine owners have started plantation in their lease area, thereby increasing the plantation area.

9.6.3 Solid Waste Management

The concept of solid waste management was found lacking among the mine owners in the area. Overburden and waste rocks removed during mining operations have been dumped at different places within the leaseholds. The total area occupied by such dumps was about 12 hactares which comes to 4 percent up to 1990. The selection of dumping sites was done arbitrarily. Stabilisation of dumps and vegetation on it were not observed. Thus, it leaves a wide scope for environment friendly solid waste management. This can be done with proper planning to work up to full depth of occurrence of the chinaclay and back filling the pits. Dumps outside pits may also be planned properly so that phased reclamation and rehabilitation can be undertaken.

9.6.4 Treatment of Water Discharged from Mines and Beneficiation Plant

In the area waste water treatment is not practised. It has been observed that waste water discharge in the area contains the following.

i) Coagulation of finer (colloidal) particles of kaolin

ii) Fine grained particles of other clay minerals, quartz, felspar, mica & sand minerals

iii) Coarse grained particles of quartz, felspar and mica, etc.

Water discharged from mines as well as beneficiation plants contains the above in the form of slimes which is not congenial to agriculture field. Therefore, the water discharged is to be treated to deslime it. Only clear water should be allowed to flow out from the mines. The best way of treatment of such waste water is to pass the same through settling tanks where the fine grained and coarse particles would settle at the bottom of the tank leaving the clear water to overflow from the top of the tank.

Secondly, the waste water shall be pumped and diverted to a storage sump, any solids left shall be allowed to settle down. The overflowing water of the settling sumps would be clear and can be diverted to some useful purpose like agriculture. Water from processing plants may be recirculated for levigation purposes.

9.6.5 Top Soil Management

This concept is completely lacking. Top soil has neither been stacked separately nor been utilised. Top soil is always fertile as biomasses develops in this part of the soil. Nature takes about 500 to 1000 years in imparting this property of the top soil which during mining is mixed with other waste resulting in deterioration of the top soil rendering it useless for agricultural purposes.

9.7 Conclusion and Recommendations

9.7.1 Landscape

As a considerable area is affected by mining, causing damage to natural cover and topography in Bikaner district (Rajasthan) and also in Birbhum district (West Bengal), it is recommended that the mined out area should be backfilled properly after mining to full depth of occurrence of mineral so that it can be utilised for agricultural or other useful purposes by the society. Alternatively, where it is not possible to backfill the area due to paucity of material for the same, the pits formed may be used as water reservoir from where water can be drawn for any useful purpose or it may alternatively be used for pisciculture. In case of big pits filled with water boating arrangements may be made to attract visitors/ tourists. Green belt can be developed around such ponds making the same an aesthetic beauty point and a picnic spot.

9.7.2 Solid Waste Disposal

It is observed in both the districts i.e. Bikaner in Rajasthan and Birbhum in West Bengal, that in a number of cases the solid waste disposal is made arbitrarily and no area has been earmarked for such disposal. The total area of land degraded due to such disposal was about 12 hectares in Birbhum district which is 4% of the lease area. It is recommended that such waste should be disposed of over a predetermined land in a systematic manner so that land degradation can be minimised. This can be planned in such a way that some part of it becomes inactive earlier and any dead dump (in-active dump) may then be rehabilitated in a phased manner to plant some trees over it so that scars made can be compensated. These do not hurt the eyes and becomes a part of green belt in the area. This will also improves the environment of the area, specially in Bikaner district of Rajasthan where there are no trees. Greenery will not only improve the environment but will also help in bringing up the ground water table which is very low at present.

9.7.3 Top Soil Management

As stated earlier the concept of top soil management is completely lacking in Bikaner and Birbhum districts. It should be removed separately and utilised for agricultural and plantation purposes. If it do not find immediate use, it should be stacked separately in such a manner that biomass continues to develop within the soil and same can be utilised whenever required for plantation/agriculture.

9.7.4 Treatment of Water from Mine and Beneficiation Plant

In Birbhum district of West Bengal, as the water discharged from the mine and beneficiation plant is not congenial to cultivation, it is recommended that the such discharged water should be treated suitably in settling tanks and only clean water should be allowed to leave the area and mix with the natural water sources. The water may also be used for clay washing in the plant by way of recycling before such discharge.

9.7.5. Ophthalmic Disorder

In the kaolin mining area of Birbhum district of West Bengal a dazzling effect on eyes was observed when the sunrays are reflected from the chinaclay spread on drying platforms specially in case of snow white clays. It becomes very difficult to look straight over chinaclay with naked eyes in the bright sun. It is recommended that in such cases use of sun glasses would be helpful to avoid ill effect due to this reason. Employees working in such area should be provided with dark glasses.

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10. Uses, Specifications and Consumption

10.1 Background

Chinaclay, also called Kaolin, falls under the kaolinite group of clays. It is formed by alteration of felspathic rocks with composition of Al_2O_3, $2SiO_2$, $2H_2O$[1]. It is a white powdery mineral when in pure form. Kaolin is named after the hill in China (Kaoling) from which it is mined for centuries. Samples from Kaoling were first sent to Europe by a French Jesuit Missionary around 1700 AD as materials used by the Chinese in the manufacture of porcelain[2].

In its natural state kaolin is a white soft powder consisting principally of the mineral kaolinite which under the electron microscope is seen to consist of roughly hexagonal, platy crystals ranging in size from about 0.1 micrometre to 10 micrometres or even larger and also in vermicular and book like forms. Occasionally, microscopic forms approaching millimetre size are found[2]. Naturally found kaolin usually contains varying amounts of other minerals such as muscovite, quartz, felspar and anatase. In addition crude kaolin is frequently stained yellow by iron hydroxide pigments. It is often necessary to bleach the clay chemically to remove the iron pigment and to wash it with water to remove other minerals in order to prepare kaolin for satisfactory commercial use[2].

10.2 Properties

Before finding out the commercial use and marketing possibilities of a mineral, its physical and chemical properties need to be determined[3]. As for instance, in case of asbestos, bentonite, mica, quartz crystals (piezo-electric), talc and vermiculite the physical properties are most important whereas for bauxite, fertilizer minerals, fluorite, limestone and sulphur, the chemical properties are of prime consideration. Both physical and chemical properties are of paramount consequence for barytes, graphite, glass sand, kyanite, SMS grade limestone and magnetite[3].

Minerals are graded for various intended uses on the basis of their physical characters and chemical composition[3]. Chinaclay or kaolin is a white powdery mineral with the predominance of a micro-crystalline compound approximately to the mineral kaolinite (Al_2O_3, $2SiO_2$, $2H_2O$). The impurities associated with it are mostly free sililca, unaltered felspar, alkalies oxides of iron, Titanium, calcium, magnesium, etc. It is distinguished from ordinary rock clays by its whiteness in colour, low plasticity, softness, ease of dispersion in water and other liquids and extreme fineness of ultimate particles. Electron micrographs of kaolinite show well formed, six sided flake-shaped units frequently with predominant elongation. It is often seen that the edges of the particles are bevelled instead of being at right angles to the flake surfaces. The maximum lateral dimensions of flake surfaces range from about 0.3 to 4 micron and thickness from 0.05 to about 2 micron[4].

10.2.1 Chemical properties

The chemical properties depend upon the nature and the amount of impurities present and its physical properties depend upon both chemical composition and factors.

Ries noted that "All the constituents of clay influence its behavior in one way or another, their effect being often noticeable when only small amounts are present"[5].

Specifications are based on methods of preparation for end use and are described elsewhere in this chapter.

The composition of kaolinite is Al_2O_3 39.8%, SiO_2 46.3% and H_2O 13.9 percent. The chemical composition of a clay is little indication of its physical properties or of its volume, except in a general way. The chemical analysis may reveal the presence of impurities[5].

PRINCIPAL IMPURITIES

Some of the common impurities that exercise an important influence on the behaviour of a clay are noted below.

Silica (SiO_2) always present either in the form of quartz or in silicates has an important influence but is not deleterious for certain uses, except in very large amount.

Compounds of iron, such as oxides, limonite and hematite, carbonate, siderite and sulfide, pyrite act as colouring agents and as fluxes. Lime present as carbonate or as silicate (lime feldspar) or as sulphate (gypsum), is usually considered a very injurious impurity for most uses. Ordinarily, it is permissible only in low grade clay products.

Compounds of alkalies (Na_2O and K_2O), are powerful flaxes, vitrification is impossible if they are absent.

Compounds of manganese are rarely present, except sometimes in brick clays, when they act as colouring agents.

Water is present in two forms, as mechanically held moisture and chemically combined water. Mechanical water has an important influence on drying, shrinkage and cracking. Excessive combined water gives a high fire shrinkage and tends to cause warping and cracking.

Carbonaceous matter gives a grey or a black colour to the raw clay but usually burns out. It may cause difficulties on burning.

Soluble salts, usually sulphates but sometimes carbonates are occasionally present. They are undesirable. Since they may cause an efflorescence on the finished products[5].

10.2.2 Physical properties

The physical properties of the clay materials depend to some extent on the nature of the absorbed exchangeable ion carried by the clay mineral components[4].

The physical properties of kaolinite and the principal constituent of chinaclay are as follows.

i)	Specific gravity	2.60 to 2.63
ii)	Bulk density in Kgs/Cu.m.	0.33 to 0.66
iii)	Hardness (Moh's Scale)	2.0 to 2.5
iv)	Refractive Index	1.56 to 1.58
v)	Oil absorption (c.c. per 100 gm)	25 to 50
vi)	Reaction (pH)	4.5 to 7
vii)	Water of plasticity in percent by weight	8.9 to 56.3
viii)	Green strength in kg per sq.cm.	0.34 to 3.20
ix)	Dry strength in kgs per sq.cm	8 to 575
x)	Linear dry shrinkage in percent	3 to 10
xi)	Linear firing shrinkage in percent	2 to 17
xii)	Cation exchange capacity (milli equivalent per 100 gm)	3 to 15
xiii)	Fusion Temperature (°C)	1650 to 1775

According to Edwart P. MacNamara, plasticity in kaolin seems to be dependent chiefly on grain size and their strength varies directly with the plasticity. The drying shrinkage of plastic kaolin is also greater than non-plastic kaolins.

The physical properties for use of chinaclay in ceramic industry are (a) plastic properties (b) drying properties (c) firing properties and (d) miscellaneous properties like firing colour, etc. In the manufacture of insulators, electrical properties such as conductivity, dielectric content, power factor, and other are also important.

(a) Plastic Properties

Plasticity : It is defined as the property of the material which permits it to be deformed under the stress without rupturing and to retain the shape produced after the stress is removed. There is no direct method which can measure the property of plasticity and can be of any significance. The most widely accepted method is now the "Water of plasticity" i.e. the amount of water necessary to develop optimum plasticity. In the making of ceramic products a lower value of water plasticity is preferred. Provided it is consistent with the formation of good shape which will not crack on drying, can withstand handling and does not require intense forming pressure. Higher water of plasticity causes higher shrinkage because relatively higher quantity of water must be driven off during drying. In natural clay materials, non-clay mineral components, soluble salts, organic compounds, degree of crystallinity of clay minerals, their texture and exchangeable cation composition influence the water of plasticity.

Green strength : This refers to "those properties developed by a clay body after it has been rendered plastic by the addition of water and shaped with a definite form and has not been dried".

With continuous addition of water to a dry clay, it has been found that the green strength increases to a maximum amount and then decreases. The strength of water of plasticity is in general lower than the maximum volume because water in this case is in excess of that required for maximum strength. The range of green strength of kaolinite varies from 0.34 to 3.2 kg per sq.cm and is due to particle size and perhaps other factors, such as crystallinity. The presence of considerable quantities of non-clay minerals reduces the green strength. High content of well-sorted fine silts makes the clay difficult for ceramic use because of the resultant low green strengths to handle the shaped clay material safely without causing deformation[4].

(b) Drying Properties

Drying shrinkage : It is the reduction in size, measured either in length or volume of a mass of shaped clay, which takes place when the mass is dried so as to drive off the pore water and absorbed water. In practice the measurement is made on a test piece after drying at 105°C for atleast 5 hours[4].

In general, drying shrinkage increases with the increase of water plasticity. Harman and Fraulini showed by the table given below that the drying shrinkage of kaolinite increases with the decrease of the particle size.

Particle size (micron)	Linear drying shrinkage (percent of dry length)
10 - 20	1.45
5 - 10	1.89
2 - 4	2.19
1 - 0.05	2.35
0.05 - 0.25	2.69
0.25 - 0.10	3.70

The drying shrinkage is reduced with the presence of non-clay minerals in amounts varying with their shape, particle size distribution and quantity. According to Grim, the presence of some ± 25% non-clay mineral component is generally desirable in the ceramic body to improve its shrinkage characteristics, provided this amount does not adversely affect the other ceramic properties.

Dry strength : It is measured as a transverse breaking strength of a test piece after it has been made dry of all the pore and absorbed water, usually at 105°C for about 5 hours. The wide range of values obtained between 7 to 500 kg per sq.cm is due to variations in particle size distribution, perfection of crystallinity and the nature of exchangeable well sorted particles of non-clay components, which if present in large quantity, tend to reduce the dry strength. The particle size appears to be the main controlling factor for dry strength. Dry strength of kaolinite in relation to the particle size is given below. (after Anonymous, "Kaolin clays and their Industrial uses, Huber Corporation, New York, 1955)"[4].

	Dry strength Kgs. per sq.cm.
Whole clay	170
Coarser clay	18
1 - 0.25 micron	62
Finer than 0.25 micron	525

The table given below shows that the plastic kaolines have more strengths than the less plastic Kaolines.

	Compression Kg/Sq.cm	Tensile Kg/sq.cm	Transverse Kg./sq.cm
Plastic Kaolin	319-377	73-103	167-228
Less Plastic kaolin (Primary)	144-244	23-48	52-116

(c) Firing Properties

Linear Firing Shrinkage : The linear firing shrinkage in kaolinite varies from 2 to 17% due to variations in size and shape of the mineral particles. Firing shrinkage varies with particle size distribution tending to increase as sorting increases.

Fusion temperature : According to Norton kaolinite fuses at 1650°C to 1775°C. This variation is due to varying components of clay minerals belonging to kaolinite group. In general, the fusion point of commercial kaolins ranges from 1000°C to 1500°C. The lower values are found in materials rich in magnesium, calcium, titanium, alkalies and alkaline earths which act as fluxes[4].

Vitrification Range : The temperature interval between the begining of the development of a vitric bond in a ceramic body and the fusion of so much of the body that the shape of the ware is lost, is known as the vitrification range. A long vitrification range is always preferable because there could be better scope of safe controlling of the firing process as per requirements. The presence of relatively large particles and a wide particle size distribution tends to widen the vitrification range since the rate of fusion varies with the particle size[4].

(d) Firing Colour

The tendency to develop objectionable colour in a ceramic body under increasing temperature is usually due to non-clay minerals, particularly iron oxide. White burning clays contain less than 1% iron oxide, ivory or yellow burning clays contain 1 to 4% and red burning ones between 4% to 7%. Colour due to presence of coal and vegetable matter can be easily controlled by maintaining an oxidizing flame in the kilns, if the knowledge of their presence is known beforehand[4].

Tensile Strength : The tensile strength of unburned clay is important. A clay of too low tensile strength may be too weak to stand the necessary handling after molding[5].

Slaking : Slaking when applied to clay, refers to the physical disintegration of clay in water. It is not true slaking, as the term applied to lime, for no chemical action takes place. The rate and extent of slaking are of practical importance in the tempering of clay.

Porosity : Porosity is the amount of pore space between the clay particles, expressed as a percentage of the total volume of the clay. It depends on grain size and shape and has an important influence on the drying and burning behaviours of a clay.

Behaviour during and after burning : When a clay is burnt, a number of changes take place, some physical and some chemical. The temperatures at which these changes occur, the behaviour of the clay during these changes, and the properties of the finished products are all important factors.

The dehydration period (called water smoking by brickmakers) is the period at the beginning of the burning process during which the moisture is driven off.

The oxidation period is the second period reached in burning as the temperature is increased. During this period the organic matter sulfur and carbon dioxide are driven off and ferrous iron is oxidised to the ferric state.

The vitrification period follows oxidation as temperatures are further increased. Vitrification is the result of complete destruction of the original clay texture and structure by at least particle fusion and by chemical reaction between the constituents. The temperature of vitrification and the vitrification range, that is, the temperature range between incipient vitrification and the point of viscosity or complete fusion to a soft, viscous mass, are factors of utmost importance. If a vitrified product is to be made and the vitrification range is too short, it is possible to control the kiln temperature so closely that the ware will not melt and lose its shape.

The burnt clay, depending upon the nature of its intended use, must be tested for some or all the following properties; the percentage of fire shrinkage, tensile strength, porosity, absorption, tendency toward cracking, warping, blistering and so on; colour, translucency, hardness and toughness. If the clay is to be used in a mixture with other ingradients, such as feldspar and silica (as in a porcelain body), its behaviour may also be tested in a standard mixture.

10.3 Uses and Specifications

The uses of chinaclay can be broadly classified into two categories.

(A) Ceramic industry, where high temperature treatment is necessary.

(B) Non-ceramic industries where chinaclay is used in unburnt state.

10.3.1 (A) Ceramic Industry

Chinaclay is an essential constituent in the manufacture of porcelains, like white-ware, electrical insulators and sanitary wares. A typical porcelain would be with the following composition[1].

Kaolin - 40%

Ball Clay - 10%

Flint (Ground quartz) - 20%

Felspar or other white burning material e.g. talc and nepheline 30%.

Kaolin is used extensively in the ceramic industry, where their high fusion temperature and white burning characteristics make them particularly suitable for the manufacture of white-ware (china), porcelain and refractories. The absence of iron alkalies or alkaline earths in the molecular structure of kaolinite confers upon it, the desirable ceramic properties. In the manufacture of white-ware the kaolin is usually mixed with approximately equal amounts of silica and feldspar and a somewhat smaller amount of plastic light burning clay known as ball clay. These components are necessary to obtain the proper properties of plasticity, shrinkage, vitrification, etc. for forming and firing the ware[2].

Plasticity, shrinkage after drying and firing, colour after firing and refractoriness are the main properties sought after in chinaclay for the manufacture of ceramic product. The presence of grit upto 2% is not deleterious for the manufacture of ceramic ware.

Good quality chinaclay should have water plasticity of about 32%, shrinkage after drying should not be more than 7% and total shrinkage after firing at a temperature of 1300°C should not be more than 10 to 14%. The colour should be perfectly white after firing and it should not fuse below the firing temperature, i.e. 1300° C[6].

In the manufacture of high class ceramic products, the presence of lime, magnesia, iron oxide, alkalies and other impurities in chinaclay upto 2% is not harmful. The excess of iron, however, may colour the final product.

For common chinaware, the proportion of plastic clay may be increased to 30 percent and the proportion of chinaclay decreased to 10 percent. To manufacture different chinaware the blunged (kneaded) material of required plasticity is cast into different moulds, dried and fired in the kiln. Firing is done in two stages (a) after sun-drying and (b) after glazing. The dried material is passed through a spray of slurry, the glazing material containing mixtures of fine chinaclay, quartz and felspar power and a pinch of certain chemicals, which is kept as a trade secret by the different manufacturing units. The fired material soaked in slurry is fired at a higher temperature of about 1400°C to acquire the proper glaze on the surface[7]. In small plants for making potteries instead of spraying the solution, the sun dried mould is dip in to the solution and again sun dried before firing. To give coloured design on chinaware, design is either made by hand using ceramic paints or specially made ceramic design stikers are put on the chinaware and it is again fired at a temperature of around 900 to 1100°C. This will give proper colour to the design and make the same almost permanent on the chinaware.

In general the following specifications of chinaclay are required for ceramic industry.

i) Plasticity - Good
ii) Fired colour at 1200° C - Off white to white
iii) SiO_2 - 40-49 (occasionally 60 - 70%)
iv) Fe_2O_3 - 0.5% (max)
v) Size - 200 - 300 mesh
vi) PCE - 21 - 26
vii) Al_2O_3 - 38-40% (Occasionally below 38% but not less than 30%)
viii) LOI - 11 - 14%

For use in pottery and porcelain plasticity, fired colour, dry and fired strength, shrinkage during and firing and vitrification range are important[3]. As per I.S. 2840/1965 the required specifications for Ceramic Industry in India and UK are as follows[8].

Table - 10.3.1-A : Specifications of Chinaclay for Ceramic Industry

Sl.No.	Characteristics	Grade I	Grade II	Grade III
1)	Fineness (residue on 44 micron IS Sieve) Percent by weight (max.)	0.5	1.0	2.0
2)	Loss on ignition percent by weight (mini.)	13.00	12.00	10.50
3)	Alumina (as Al_2O_3) percent by weight (mini.)	37.0	34.00	32.00
4)	Oxides of iron (as Fe_2O_3) percent by weight (max.)	0.8	1.0	1.5
5)	Titanium oxide (as TiO_2) percent by weight max.	0.7	0.8	1.0
6)	Oxide of iron (as Fe_2O_3) and titanium oxide (as TiO_2) together percent by weight, (max.)	1.5	1.8	2.5
7)	Water & Plasticity percent (mini.)	32.0	35.0	38.0
8)	Shrinkage, linear :			
	a) Dry shrinkage (at 110°C) percent (max.)	6.0	7.0	8.0
	b) Total fired shrinkage (at 1350°C) percent (max.)	16.0	17.0	18.0
9)	Particle size distribution percent by mass (max.)			
	a) Coarser than 25 micron	5.0	7.0	10.0
	b) Coarser than 10 micron	15.0	20.0	25.0
	c) Finer than 2 micron	70.0	65.0	60.0
10)	Plasticity by hand feel test	Very Good	Good	Fair
11)	Attenburg Number (min.)	14.0	12.0	10.0
12)	Fired Characteristics at 1350°C	Should be free from black specks/ spot and cracks		
13)	Water absorption (maturity) Percent by mass (max.)	17.0	15.0	13.0
14)	PCE value in Orton (min.)	34.0	32.0	28.0
15)	Colour	White	Cream	Light buff
16)	Green MOR, Mpa (on drying at 110°C) (min.)	1.0	0.7	0.6
17)	Apparent porosity	28.0	23.0	21.0

Table - 10.3.1-B : Specifications of Chinaclay used in Ceramics by U. K. Industries

Chemical constituents	Wt. %
SiO_2	48 to 48.8
Al_2O_3	36.1 to 37
Fe_2O_3	0.62 to 1.0
CaO	0.06 to 0.12
MgO	0.30 to 0.35
Na_2O	0.10 to 0.14
K_2O	1.60 to 2.60
TiO_2	0.02 to 0.10
Loss on ignition	11.20 to 12.5
Particle size distribution	**%**
< 2 micron	40 to 70
> 10 micron	4 to 18
> 53 micron	0.03 to 0.15
Modulus of rupture (MOR) at 110°C (kg f/cm^2)	7 to 31.7
Brightness at 1180°C	86 to 91 (at effective wave length of 457 nm) 85 (at effective wave length of 464 nm) 83 (at effective wave length of 495 nm)
Brightness at 1280°C	86 to 88 (at effective wave length of 457 nm)
Brightness at 1410°C	75 (at effective wave length of 457 nm)

10.3.2 (B) Non - Ceramic Uses

Non - ceramic uses of chinaclay are many and they are as follows.

i) As a filler for paper and also for paper coating to manufacture "Stick paper" used by magazine industry and by other consumer.

ii) As a filler in all grades of rubber goods like automobile tyres, pressed and moulded goods and hard goods.

iii) As a filler in many products - phonograph, white celluloid goods, soap, wall plasters and insecticides.

iv) As a additive in a cement industry.

v) As a filler and stiffner for cotton Cloth and textile fabrics.

vi) In linolium and oil cloth as a filler and surface coating.

vii) In paint, an inert extender, in white wash and in distemper paints.

viii) As a mild abrasive in polishes, tooth powders, cleaning soaps.

ix) In the manufacture of coloured chalk and crayons.

x) In the manufacture of ultra-marines.

xi) In medicines and pharmaceuticals as a purifier and adsorbent.

i) Paper Industry

In paper industry, china clay is used to give a smooth and even surface and impair glaze[6]. Various grades of china clay are used in paper making according to the quality of the final product. To make the paper suitable for high fidelity of printing, it is necessary to correct the deficiencies like transparency and irregularities of the surface by addition of binding agents, such as starch and resin and by mechanical incorporation of mineral fillers into the paper fibres[1]. But ordinary filled papers lacks the perfection of surface smoothness required for accurate production of the tiny ink dots in halftone printing. To enhance the smoothness of surface it is necessary to coat the surface of paper with a thin film of finely divided mineral pigment suspended in an adhesive mixture like starch and casein. Chinaclay is preferred for use in high grade paper because of its (i) freedom from grit and micaceous impurity, (ii) whiteness having high brightness, (iii) fineness of particles, (iv) uniformity, (v) high percentage of retention in the finished clay, (vi) softness of texture and (vii) chemical inertness. Further the coating preparation must penetrate and bond satisfactorily to the surface of paper, it must flow enough to permit the required degree of spreading at the machine speed; it must have the proper levelling and settling characteristics after being applied to the surface of the paper, and on drying, smooth surface must develop that can be calendered to produce a gloss without the application of undue pressure. The rheological properties of coating kaolin are extremely important.

Requirements for Light kaolin and Indian Standard Specifications for Chinaclay for Light kaolin (IS : 505-1995) and specifications of china-clay used in paper making by U. K. Industries are given as follows.

Table - 10.3.2-A : Requirements for Light Kaolin

Sl. No.	Characteristic	Requirement for Grade 1*	Requirement for Grade 2*	Method of Test. Ref to Cl No. in Annex A of IS 505:1995
1.	2.	3.	4.	5.
i)	Coarse particles or grit represented aa residue on 53-micron IS sieve (see IS 460: 1985), percent by masss, Max	0.8	1.0	A-2
ii)	Particles larger than 10 microns in diameter, percent by mass, Max	5.0	15.0	A-3
iii)	Particles smaller than 10 microns in diameter percent by mass. Min	75	60	A-4
iv)	Relative density at 27/27°C	2.5 to 2.9	2.5 to 2.9	A-5
v)	Loss on drying, percent by mass, Max Lump Powder	10 2	10 2	A-6
vi)	Loss on ignition, percent by mass, Max	14.0 15.5	14.0 (max) 15.5	A-7
vii)	Matter soluble in water, percent by mass, Max	-	0.5	A-8
viii)	Matter soluble in hydrochloric acid, percent by mass, Max	0.5 to 1.0	1.5 to 2.5	A-9
ix)	Copper (as CuO), percent by mass, Max	-	0.007	A-10
x)	Arsenic (as As_2O_3), parts per million, Max	-	10	A-11
xi)	Iron (as Fe_2O_3), percent by mass, Max	0.6	0.75	A-12
xii)	Manganese (as MnO), percent by mass, Max	-	0.013	A-13
xiii)	pH value (of aqueous extract)	4.5 to 7.5	4.5 to 7.5	A-14
xiv)	Oil absorption, ml per 100 g, Min	-	50	A-15
xv)	Colour reflectance to blue light of wave length 5040 A°, percent	80 to 85	As agreed to between the purchaser and the supplier	A - 16

* *Grade 1 - Suitable for paper industry*
* *Grade 2 - Suitable for use as general filler*

Table - 10.3.2-B : Specifications of Chinaclay used in Paper Making by U. K. Industries

Chemical Constituents	Coating %	Filler %
SiO_2	47.8	47.7
Al_2O_3	37.0	36.0
Fe_2O_3	0.58	0.82
CaO	0.04	0.06
MgO	0.16	0.25
Na_2O	0.10	0.10
K_2O	1.10	2.12
TiO_2	0.03	0.05
Loss on ignition	13.10	11.19
Particle size distribution	%	
< 2 micron	75 - 94	25 - 48
> 10 micron	0.5 max	12 - 25
> 53 micron	0.02 max	0.05 max
Brightness	85-88%	76.5 - 84%
Yellowness	4.2-4.7%	-
Viscocity concentration	68-72%	-
Mean typical surface area (m^2 g^{-1})	10.5 - 12.5	6 - 8

Paper making can use chinaclay in two ways[9].

a) As a filler, added to the mixture of fibre and water in the head box at the beginning of paper making process.

b) As a coating pigment, applied with a binder, in the form of slurry to the base paper at the end of the paper making process, usually by means of a high speed blade.

In both the applications, minerals are used to improve the printing properties of paper in terms of gloss, smoothness, brightness, opacity and ink receptivity. In general, for high quality printing (especially four colours), better quality of mineral is used. For example, newsprint may contain little or no mineral filler, uncoated super calendar paper for colour supplements may contain over 25% of filler and uncoated paper for magazines or brochures may have 25-30% of coating pigment.

Minerals for coating are generally finer and brighter than minerals for filling[9].

Good and bright quality of chinaclay should have a brightness (GE photo volts) of above 65 and colour reflectance to blue light of wave lengths 5040 A (5040 is the wavelength of mercury; A = Angstrom, unit of the measurement of light) not less than 78%.

ii) Textile Industry

Chinaclay is utilised in textile industry as sizing and backing material. Grit-free china clay in white quality is an extremely desirable prerequisite for its use in the textile industry[7]. Chinaclay generally mixed up with some sort of adhesives are used. For this purpose, Chinaclay should be pure white in colour and free from any yellowish tint or added colouring matter such as ultramarines. Very fine size particles ranging from 2 to 5 micron are commonly used[4]. Grit is most objectionable as it reeds and threads. The clay should be white in colour in that tinting.

Oxides of iron and magnesium should be as low as possible (not more than 1 percent), preferably in traces only. Dull white clay is utilised in making coloured and Khaki cloth[7].

Indian standard specifications are same as those for paper industry with a special requirement under microscope. The material shall not show any definite structure and shall be free from any felsparic clay.

iii) Rubber Industry

In rubber, chinaclay is used as filler because of its colour, easy wettability and dispersability, reinforcing and stiffening properties and low cost. Chinaclay is mixed with rubber before casting. To a rubber technician chinaclay is distinguishable as "hard" chinaclay and "soft" chinaclay. Hard chinaclay produce a high nodules of rapture high tensile strength and good resistance to abrasion and stiff unused compounds. To impart the reinforcing properties to such rubber compounds, chinaclay should be as low as possible in coarse materials held on 325 mesh screen and must contain high percentage of particles finer than 2 micron. The mineralogical nature of the clay minerals and its crystallinity with regular shape is also important. Excessive grit reduces tensile strength, causes pre-mature flex cracking, dulls the knives of trimming machines and causes weak or dies and rubber mixing machines. Grit is also a source of dielectric failures in insulated wire compounds. The maximum amount of plus 325 mesh material in rubber grade clays is 3.5% and in high grade clays is less than 0.3%. 'Hard' kaolins are used in compounds for shoe heels and soles, wire insulation, gloves, tyres and tubes etc[4].

'Soft' kaolins produce lower nodules and tensile strength, low resistance to abrasion and soft uncured compounds. Products compounded with 'soft' kaolins are household goods, blown sponge, hard rubber toys and novelties.

Certain compounds of manganese, iron and copper affect the aging properties of natural rubber compounds. When kaolins showing the presence of the above metallic compounds, are used in the formulation of rubber compounds it is the usual practice to run aging tests on such rubber in order to be sure of harmless effects of these compounds[4].

Table 10.3.2-C mentioned below will give an idea of the particles size distribution of some kaolin used in rubber compounds prepared by American Rubber Industries and also some of the properties of rubber compounded with kaolin.

Table - 10.3.2-C : Particle size and Distribution of Chinaclay (Percentage)

Diameter in micron	Hard	Soft		
		A	B	C
Above 10	0.1	8.3	6.6	1.2
10 - 5	2.8	12.4	9.2	8.2
5 - 4	1.5	4.5	4.2	4.2
4 - 3	2.3	6.3	5.7	6.5
3 - 2	3.4	8.6	8.9	9.4
2 - 1	9.0	17.1	18.4	15.4
1 - 0.5	19.0	17.2	16.2	16.0
0.5	61.9	25.1	30.8	39.0
Above 5	2.9	20.7	15.8	9.4
Under 2	89.9	54.4	65.4	70.5

Specifications - Indian Standard Specification for chinaclay for rubber industry is as follows (IS 505 - 1995).

1. The material shall be the natural mineral consisting essentially of hydrated aluminium silicate, suitably treated where necessary and free from added substances.

2. Properties in rubber compounding the material shall pass such vulcanizing tests as agreed to between the purchaser and the vendor.

3. The material shall also comply with the requirements laid down in IS 505/1958 when tested in accordance with the methods prescribed in Appendix B of the ISI specifications. References to the relevant clauses in Appendix B are given in Col. 5.

(iv) Paint Industry

The properties like anti-setling, tinting effect, colloidal in nature and softness in some qualities of chinaclay makes it suitable for use in paint and distemper manufacture. Colloidalness of the particles is an important factor for the suitability of chinaclay for the paint industry. It is used as an extender or suspending agent in the manufacture of white paint and white tint. It acts as an inert pigment or extender.

The desirable properties of kaolinitic clays for the paint formulations are :

i) Impart desirable and controllable surface characteristics necessary to attain any desired sheen in the paint formulations.

ii) Permit high pigment loading, this is particularly true in semi gloss paints where there is gradual loss of gloss with increased loading.

iii) Rapidly and completely wettable in many vehicles. Actually, kaolin seem to improve the dispersability of other pigments which are difficult to incorporate in paint.

iv) Non-abrasive and provide good brushability good flow and levelling properties.

v) Have satisfactory oil absorption power

vi) Kaolins add to hiding power. This has been specially shown in water paint and alcoresinous paints

vii) Have good suspension properties, which reduce settling on storage

The average particles sizes of kaolins used in the paint trade vary from 0.5 to 5 micron and should have only a trace of residue on a 352 mesh sieve.

The amount of kaolin in paint formulations varies with the type of paint. In case of some enamelling where kaolin is used as suspension aid and to assist in the prevention of flooding, the amount may vary from 2 to 5% whereas in some inferior wall paints, about 50% of the total volume may be kaolin. House paint contain 1 to 1.5 kg of clay per gallon i.e. about 25% of the clay by weight.

Indian standard specification (IS: 68-1979) has laid down the following requirements for use of kaolin in the paint trade

1. The material shall be a natural product consisting essentially of hydrated aluminum silicate.

2. The material shall contain carbonate not more than 1.0 percent expressed as carbon dioxide.

3. When lead free kaolin is required, it shall contain not more than 0.05 percent of lead or compounds of lead (calculated as metallic lead) when tested by the method specified under 19 of IS: 68 - 1950.

4. Volatile matter shall not be more than 2%, residue on sieve not more than 0.5%, matter soluble in water not more than 1%, acidity not more than 0.1% and alkanality not more than 0.1%. The method of testing these have been specified in IS 33 - 1950[9].

The presence of sulphur is an important factor in forming the colours. With less sulphur it turns greenish and with more sulphur it becomes reddish[10]

Table - 10.3.2-D : Requirements of Kaolin for Paints

Sl. No.	Characteristics	Requirement		Method of Test	
		Grade 1*	Grade 2*	Ref to Cl. No. in IS:68:1979*	Appendix
i)	Volatile matter, percent by mass, Max	2.0	2.0	7	-
ii)	Residue on sieve, percent by mass, Max	0.5 on 63-microns IS sieve	0.5 on 40-micron IS sieve	8	-
iii)	Oil absorption**	25 to 40	25 to 40	9	-
iv)	Colour	Close match to approved sample		10	-
v)	Matter soluble in water, percent by mass, Max	1.0	1.0	17	-
vi)	pH value of 5 percent aqueous extract	6.0 to 8.5	6.0 to 8.5	19	-
vii)	Loss of ignition, percent by mass	10 to 14	10 to 14	-	B
viii)	Settling tendency	To pass the test		-	C
ix)	Flow point and stiff point	As agreed to between the purchaser and the supplier		-	D

Grade 1 - Ordinarily ground (63 micron) and*
Grade 2 - Micronized (Finely ground) 40 micron.*
** Method of sampling and test for inorganic pigments and extenders for paints (second revision).*
*** This shall, however, be within ± 10 perent of an approved sample, if any.*

Table - 10.3.2-E : Requirement of Chinaclay for Paint
(B. S. 1795 : 1952)

Sl. No.	Characteristics	Grade I	Grade II
1)	Total residue on sieve :		
	i) 100 mesh B. S. sieve	0.02% (max)	0.1% (max)
	ii) 240 mesh B. S. sieve	0.1% (max)	0.5% (max)
2)	Matter soluble in water	0.5% (max)	0.5% (max)
3)	Matter volatile at 98-102°C	2% (max)	3% (max)
4)	Acidity or alkalinity (Calculated as H_2SO_4 or Na_2CO_3)	0.01% (max)	0.01% (max)
5)	Loss on ignition (of dried mateiral) at 900°C	12% (min)	11% (min)

v) Plastics, Linoleum and Oil Cloth Industry

According to Willcox, fillers are used in plastics to aid in producing smooth surface finish, to reduce cracking and shrinkage during curing to aid in obscuring the fibre pattern to the gloss reinforcement, to contribute to high dielectric strength and to aid in resisting chemical action and weathering. For these, the clay should "Slake" easily to a thin cream without leaving lumps, be free from grit, have a good white colour and relatively low oil absorption. Kaolins with the finest particle size tend to increase the viscosity, but this property can be somewhat controlled by the selection of the proper particle size distribution. The exothermic reaction experienced during curing of polyster resin is reduced in intensity by the use of kaolin fillers. The chemical inertness of kaolin's imparts high dielectric strength and desirable electric properties so that plastics with kaolin filler may prove better for electrical insulation. Flexural strength of polyster resins with kaolin is somewhat larger than that attained with other commonly used fillers. The low specific gravity of kaolinite and its easier dispersion in resin prove advantageous over other mineral fillers[4].

vi) Cosmetics, Medicines and Pharmaceuticals

Super fine chinaclay is utilised for the manufacture of products like adult powder, adhesive, surgical plaster, lotion and ointment for external use and porcelain for dental preparation. Clays are believed to function by absorbing toxins and bacteria responsible for various types of internal infections; hence kaolin is used in therapeutic intestinal absorbent preparations. Kaolins used for medicinal purpose must be free from heavy metals and any other substance that the body will not tolerate. Chinaclay for medicinal purposes must be free from lead arsenic and other metal which the human body will not tolerate. It must not contain lead more than 5 parts per million and arsenic more than 2 parts per million. Such kaolins must be free from grits and should not impart an abnoxious taste and odour to the preparations. The suspending, gelling and absorptive properties of kaolinite are valued for preparation of pastes, ointment and lotions for external use[4]. It should have no frothing. Particle size, frothing and sedimentation volumes are the three important factors considered in the selection of chinaclay for pharmaceutical purpose. The frothing test is carried out by taking one ounce of the sample made into a paste with one ounce of glycerine containing 1 gm of boric acid and the mixture allowed to stand for four hours. If there is no frothing the particular chinaclay is regarded suitable for medical purposes. Higher sedimentation volume in the range of 16-22 cc is regarded as an added property in chinaclay which helps in forming a good paste and a fine poultice. Chinaclay having fine micron size particles, each below 2µ, usually provides better sedimentation volume[7].

Type	Sedimentation
British	16-22 cc
Indian	6-7 cc

Kaolin is used by medical profession in analysis where its selective absorptive properties make them of value. According to Fischer and Iwanoff, kaolin is being used in the purification of substances like caffeine, cantheridin and santonin in toxicological analysis[4].

Requirements of kaolin for cosmetic industry are given in Table 10.3.2-F.

Table - 10.3.2-F : Requirements of Kaolin for Cosmetic Industry

Sl. No.	Characteristic	Requirement	Method of Test (Ref to Cl. No. In Appendix A) of IS 1463:1983
i)	Identification test	To pass the test	A-2
ii)	Fineness :		
	a) Retained on 90-micron IS Sieve, percent by mass, Max	0.1	A-3
	b) Retaind on 45-micron IS Sieve, percent by mass, Max	2.0	
iii)	Matter soluble in dilute hydrochloric acid, percent by mass, Max	2.0	A-4
iv)	Heavy metals (as Pb), ppm Max	5	A-5
v)	Arsenic (as As_2O_3), ppm, Max	2	A-6
vi)	Bulk density	As agreed to between the purchaser and the supplier	A-7
vii)	Loss on ignition, percent by mass, Max	15.0	A-8
viii)	Iron	To pass the test	A-9
ix)	Carbonate	to pass the test	A-10

(vii) Ink

Kaolinite type clays are used largely in printing inks. The whiteness of kaolins is an important advantage. Satisfactory clays must be free from grit and should be very fine grained. To meet these demands water washed and chemically bleached products are generally required. Fine particle size kaolins with all particles smaller than 2 micron are being used in letter press and carbon inks.

(viii) Ultramarine

Kaolins should be low in iron oxide and lime and shall not contain any large amount of free silica[4]. Chinaclay is an important ingredient in the manufacture of "Ultramarine blue". Sulphur, silica, chinaclay and soda ash are calcined at 1500° C for 24 hours to produce ultramarine blue. For every tonnes of ultramarine blue nearly 0.8 tonnes of good quality chinaclay is required. The Fe_2O_3 contain in such clay should be below 1% and MgO should be very low[7].

(ix) Insecticides

Chinaclay is probably the most widely used as distributing agent for insecticides. It is valued for this purpose on account of its fineness, non-abrasive and floating properties and its freedom from harmful constituents such as arsenic[4]. Chinaclay is used in the manufacture of disinfectants like DDT as a distributing agent[7].

(x) Other Uses

Chinaclay is used in the manufacture of white cement where it is added alongwith gypsum to provide the effect of white colouration[7]. Coarse chinaclay from the sedimentation tank is used in the manufacture of refractory bricks for use in the glass and ceramic industry[7]. Presently another important use of chinaclay has been found out which can be considered as a major technological breakthrough in industrial application of kaolinetic clay to manufacture "synthetic zeolite". Synthetic zeolite finds use in refineries and petrochemical industries. It is also emerging as a catalytic material[10].

Chinaclay is also used in explosive and pyrotechnic industries. The specifications for the same are required as under :

Table - 10.3.2-G: Requirement of Chinaclay for use in Explosive and Pyrotechnic industries :

Sl.No.	Characteristics	Requirement
1.	Loss on drying, percent by mass, Max.	1.5
2.	Loss on ignition, percent by mass, Max	14
3.	Matter soluble in dilute hydrochloric acid, percent by mass, Max.	1.5
4.	Matter soluble in water, percent by mass, Max.	0.5
5.	Grit, percent by mass, Max.	0.001
6.	Fineness (material retaind on 63 micron IS sieve), percent by mass, Max.	1.0
7.	Bulk density, g/ml	0.65-0.90
8.	pH (of aqueous extract)	6.0-7.5
9.	Oil absorption, ml per 100 g.	35.45

10.4 Consumers' Specifications

Though there are a number of standard specifications for different industrial use of chinaclay as mentioned earlier, the consumers often stipulate their own specifications to suit specific requirements. Some of these specifications from Indian consumers for different industries are given in Table 10.4.

Table - 10.4 : List of units Consuming Chinaclay

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
***CEMENT**				
Associated Cement Companies Ltd., Cement House, 121, Maharshi Karve Rd., Bombay - 400 020	Kymore Dist. Jabalpur, Madhya Pradesh	To provide SiO_2 for combination with CaO in Kilns	SiO_2 - 66.3% Al_2O_3 - 13.4% Fe_2O_3 - 3.7% MgO - 0.1% CaO - 2%	Captive Mine
Associated Cement Companies Ltd., Cement House, 121, Maharshi Karve Rd., Bombay - 440 020	Wadi Junction Dist. Gulbarga, Karnataka	To provide SiO_2 for combination with CaO in Kilns		
Associated Cement Companies Ltd., Cement House, 121, Maharshi Karve Rd., Bombay - 440 020	Surajpur Dist. Ambala, Haryana	To provide SiO_2 combination with CaO in Kilns	CaO - 2.1% SiO_2 - 76.1% MgO - 1% Fe_2O_3 - 3.9% Al_2O_3 - 11.7%	M/s. Karam Singh Mehal Singh, Chandimandir Area M/s. Hardeo Singh, Chandigarh.
Cement Corporation of India Ltd., Core - 5, Scope Complex, 7 Lodhi Road, New Delhi - 110 003.	Nayagaon Dist. Mandsaur Madhya Pradesh	- do -		
H.M.P. Cements Ltd., 4 Fairlie Place, Kolkata - 700 001, West Bengal	Porbandar Dist. Junagadh, Gujarat	- do -	SiO_2 - 30-45%	Various Contractors
Krishna Cement Pvt. Ltd., H-3, Civil Lines, Mandiakudar-769 004 Dist. Sundergarh, Orissa	Mandiakudar Dist. Sundergarh, Orissa	- do -	SiO_2 - 62%	Captive Mine
Lakshmi Cement Jaykaypur Rayagada 765017 Orissa	Jaykaypuram Sirohi, Rajasthan	To provide SiO_2 for combination with CaO in Kilns		Sri Ambika Minerals, Nikum, Rajasthan Popular Minerals, Rajasthan

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Mangalam Cement Ltd., 93, Dashera Scheme, P. O. Dadabari, Kota - 324 009 Rajasthan	Morak Dist. Kota Rajasthan	For maintaining Silica nodule in Cement	SiO_2 - 60.65% Fe_2O_3 - 2.96% CaO-3.8% Al_2O_3 - 31.99%	
Mysore Cement Ltd., Industry House, 45, Race Course Rd., Bangalore 560 001 Karnataka	Ammasandra Dist. Tumkur Karnataka	-do-	Silica - 60% Iron - 3.5% Alumina - 25-30%	Captive Mine
Narmada Cement Company Limited, 2-C, II Floor, 462, Phoenix Mill Compound, Senapati Bapat Marg, Lower Parel, Bombay - 400 013.	Magdalla Dist. Surat Gujarat	-do-		
Narmada Cement Company Limited, 2-C, II Floor, 462, Phoenix Mill Compound, Senapati Bapat Marg, Lower Parel, Bombay - 400 013.	Zadgaon Dist. Ratnagiri Maharashtra	-do-	Burut SiO_2 - 40% min CaO - 10% max MgO - 3% max.	
Saurashtra Cement & Chemical Industries Ltd., Near Rly Station, P.O. Ranavav 360560 Gujarat.	Ranavav Dist. Junagadh Gujarat	-do-	SiO_2 - 55%	Local Supplier
Shriram Fertilizers & Chemical, 5th Floor., Kanchenjunga Bldg., 18, Barakhamba Rd., New Dehil 110 001.	Kota Dist. Kota, Rajasthan	-do-		Annupam Ashis Vyas, Chittaurgarh, Rajasthan

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Shree Cement. Bangur Nagar. P.B.No. 33. Beewar. Rajasthan	Beawar. Dist. Ajmer. Rajasthan	For maintaining Sillica module in Cement		
Vikran Cement Mandsaur. Madhya Pradesh	Mandsaur. Madhya Pradesh	-do-		
Udaipur Cement Works. Udaipur. Rajasthan	Udaipur	-do-		
*** CERAMIC**				
Anant Raj Clay Producers Ltd., H - 65. Connaught Circus. New Delhi 110 001	Bhudla Dist. Rewari Haryana	As the main body constituent	B.M. Minerals. Calcutta	
Bihar Industrial Corpn. Madhupur 815 353 Dist. Deoghar (E.Rly) Bihar	Madhupur Dist. Deoghar Bihar	-do-	Cossimbazar Chinaclay Mines (P) Ltd., P.O. Hatagamaria. Dist. Singhbhum. Bihar	
Bengal Potteries Ltd., Thapar House. 25. Brabourn Road. G.P.O. Box No. 2196 Calcutta 700 001	i) 45 Tangra Road. Calcutta ii) 3 Pagaldanga. Calcutta West Bengal	-do-	Washed Clay Size : 200 mesh	
Bawa Potteries. 6 Haidley Road. New Delhi	Kishangarh Mehrauli New Delhi	As the main body constituent		
Bharat Heavy Electricals Ltd. Bangalore. Karnataka.	Bangalore Karnataka	-do-		
Bharat Heavy Electricals Ltd., (Insulator Plant). Sultanpur. Uttar Pradesh	Sultanpur Uttar Pradesh	For imparting better dielectric Value and thermal shock	SiO_2 44-48% Al_2O_3 36-38% $Fe_2O_3 + TiO_2$ 2.5% max	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Ceramic Products Ltd., P.Box No. 2, Khanapur, 591 302 Dist. Belgaum Karnataka	Khanapur Dist. Belgaum karnataka	For the manufacture of stoneware, salt glazed pipes and fittings & refractory bricks	Al_2O_3 >25% Fe_2O_3 < 3%	
Decora Ceramics, Surendranagar Gujarat	Surendranagar Gujarat	As the main body constituent		
E.I.D. Parry Ltd., Dare House, P.B. No. 12 Madras 600 001	North Arcot Tamil Nadu	-do-		
Eastern Ceramics Ltd., Mahatama Gandhi Rd., Goregaon (West) Bomday 400 062	M.G. Road Goregaon(West) Bombay Maharashtra	-do-	Washed Lumps	
Ferro Coatings & Colours Ltd., P.O. Joka 24 Parganas, West Bengal	P.O. Joka Dist. 24 Paraganas West Bengal	As the main body constituent		
Gwalior Potteries P. Box No. 18, Kampoo Road, Gwalior 474 009 Dist. Gwalior Madhya Pradesh	Kampoo Road Lashkar Dist. Gwalior Madhya Pradesh	for the Manufacture of Insulators, Sanitary wares & Crockery		
Hindustan Sanitaryware & Indus. Ltd., 2, Red Cross Place Kolkata 700 001 West Bengal	Bahadurgarh Dist. Rohtak Haryana	For the manufacture of Sanitary Ware		
High Tension Insulation Factory, Bandar Bagicha, Patna 800 00, Bihar	P.O. Numkum Ranchi Bihar	As the main body constituent	Green bonding Strength about 5-10 Kg/cm² & 40 kg/cm² Clay Content 96% and 92% Iron < 1.5% & 0.5%	

(Contd.)

Table - 10 .4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
M. & R. Johnson (India) Ltd., Manabhoy Mansion Sir P.M. Road Bombay 400 001	Thane, Dewas & Kunigal Maharashtra, Madhya Pradesh & Karnataka	As the main body constituent	White Al_2O_3 - 3% Min. Fe + Ti 1% Max. (Oxides)	
Hitkari Potteries, Faridabad Haryana	Faridabad Haryana	-do-		
Jayashree Insulators, Veraval Junagarh Rd., Veraval 362 266 Gujarat	Rishra Dist. Hoogli West Bengal	For the manufacture of high & low tension insulator and bushing	Lump Al_2O_3 -30% min Fe_2O_3 -1.5% min TiO_2-1.5% max LOI - 10.5% min	Rajkamal Quartz Sand & Coal Co. M.S Road, Calcutta karanpara Mining Corpn. Rajmahal, Bihar.
Jayashree Insulators, B.N. Chambers, 3rd Floor, R.C. Dutta Road, Baroda - 390 005 Gujarat	Post Meghasar Via Kalol Panchmahals Gujarat	For the manufacture of electrical insulators	SiO_2 - 48.52% Al_2O_3 - 36. 1%	
Khodiyar Pottery Works Ltd., Sihor, Dist. Bhavanagar Gujarat	Sihor Dist. Bhavnagar Gujarat	As the main body constituent		
Kerala Ceramics Ltd., Kundara 691 501 Dist. Quilon Kerala	Kundara Dist. Quilon Kerala	For the manufacture of types of processed chinaclay	SiO_2 - 45.15% Al_2O_3 - 37. 59% TiO_2 - 0.50% MnO-Trace CaO - 0. 22% K_2O - 0.07% MgO - 42% Fe_2O_3 - 3-0.5%	Kerala Ceramics Ltd., Kundara, Kollam, Kerala
Klayman Porcelain Ltd., 7th Floor, Raghav Ratna Towers, Chirag Ali Lane, Hyderabad 500 001	Nandigaon Mehboob Nagar Andhra Pradesh	As the main body constituent		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Lustre Tiles Limited. A 65-66 RIICO Industiral Area. Bhiwadi 301 019 Rajasthan	Bhiwadi Alwar Rajasthan	For the manufacture of glazed tiles	D.M. Minerals (P) Ltd., 21 R.N. Mukherjee Rd., Calcutta 700 001 West Bengal	
Mysore Porcelains Ltd. P. Bag No. 1245 Bangalore 560 012 Karnataka	G.P.F. Premises Bangalore karnataka	-do-	Free from red ochre size : 10 micron Fe_2O_3 - 0.15 to 1.25%	
Madhusudan Ceramis (CERA) Kadi Mehsana, Gujarat	Kadi Mehsana Gujarat	-do-		
Neycar India Ltd., P.O. Vadalur Dist. South Arcot Pin 607 303 Tamil Nadu	Vadalur Dist. S. Arcot Tamil Nadu	-do-	White buring chinaclay Al_2O_3 - 40%	Tiruvanathapuram, Kerala Wankaner, Gujarat
Punjab Potteries New Delhi	New Delhi	As the main body constituent		
Parshuram Pottery Works Co. Ltd., Morvi, Gujarat	Wankaner Dist. Rajkot Gujarat	For the manufacture of glazed tiles		
Parshuram Pottery Works Co. Ltd., Morvi Gujarat	Morvi Gujarat	For the manufacture of glazed tiles		
Parshuram Pottery Works Co. Ltd., Morvi Gujarat	Thagadh Surendra Nagar Gujarat	For the manufacture of Sanitary Ware	SiO_2 - 48.60% Fe_2O_3 - 1.70% TiO_2 - 2.50% MgO - 0.80% CaO-2.42% K_2O - 0.83% Al_2O_3 -30.75% Na_2O-0.90%	Eklera Chinaclay, Ahmedabad Dayanand Minerals, Wankaner Anand Minerals, Wankaner Gujarat

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Rajniklal Ceramics (P) Ltd. 10 Portughese Church Road, P. Box No. 931 Calcutta 700 001 West Bengal	46 B Muraripukur Road. Calcutta West Bengal	For the mnufacture of Tableware. N.O.S., water filter candle, filter		Mines, Shabgani
Somany - Pilkington's Ltd., Kassar 124 507 Rohtak, Haryana	Kassar Dist. Rohtak Haryana	For the manuacture of glazed tiles		
Spartek Ceramics India Ltd., 52, Chamiers Rd., Madras Tamil Nadu - 600 028	Narsingapuram Dist. Chittor Andhra Pradesh	For the manufacture of Glazed tiles		
U.P. Ceramics & Potteries Ltd., Vandna, 11th Floor, 11 Tolstoy Marg New Delhi 110 001	G. T. Road Ghaziabad Dist. Meerut Uttar Pradesh	-do-	SiO_2 - 55% Al_2O_3 - 42%	
W.S. Insulators of India Ltd., Dhun Building, 175/1 Mount Road. Madras.	Porur Madras Tamil Nadu	As the main body constituent	SiO_2 - 44-45% Al_2O_3 - 39-40% $Fe_2O_3 + TiO_2 = 0.7\%$ $CaO + MgO = 0.5\%$	
PAPER				
Ballarpur Paper & Straw Board Mills Ltd., Ballarpur Dist. Chandrapur Maharashtra	Yamuna Nagar Dist. Ambala Haryana	As a filler		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Bhadrachalam Paper Board Ltd., 106, Sardar Patel Road, Secunderabad Andhra Pradesh	Sarpaka Dist. Khammam Andhra Pradesh	-do-	Fe_2O_3 - 0.7%	English Indian Clays Limited. Cathedral Road, Madras
Circar Paper Mills Ltd., H.No. 8-2-696 Banjara Hills Hyderabad 500 034 Andhra Pradesh	Gudipallipadu Nellore Andhra Pradesh	Filler material & brightness improvement	SiO_2 - 44% Al_2O_3-38%	Eng. Indian Clays Ltd. Tiruvananthapuram Kerala
Rohit Pulps & Paper Mills., Khadki-Udvada Valsad Gujarat	Khadki Dist. Valsad Gujarat	As a filler		
Shri Vindhya Paper Mills Ltd. Nasik Maharashtra	Nasik Dist. Nasik Maharashtra	As a filler		
Sirpur Paper Mills Ltd., Lingapur House, Himayat Nagar Rd., Hyderabad Andhra Pradesh	Sirpur Kagaznagar Dist. Adilabad Andhra perdesh	-do-		
Star Paper Mills Ltd., Saharanpur Uttar Pradesh	Saharanpur Uttar prdesh	-do-		
Triveni Tissues Ltd., 3 Middletone St. Calcutta 700 071	Triveni Dist. Hoogly West Bengal	-do-		
Union Paper & Board Mills Co., Kalicharan Ghosh Road, Sinthee Calcutta-700 050 West Bengal	Calcutta West Bengal	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
TEXTILE				
Ajudhia Textile Mills, (A Unit of NTC) Vandana Bldg., Tolstoy Marg, New Delhi 110 001	Azadpur Delhi - 110 033	As sizing & Finishing material (for preparing Starch Paste for cloth)		
Bengal Nagpur Cotton Mills, Rajnandgaon Madhya Pradesh	Rajnandgaon Dist. Rajnandgaon Madhya Pradesh	-do-		
Binny Ltd., 7 Armenian Street, P. B. No. 66 Madras 600 001	Madras Mill Perumbur Barracks P. B. No. 951 Madras - 600 012 Tamil Nadu	-do-		
Bharat Cotton Mills 24 Parganas West Bengal	24 Parganas West Bengal	-do-		
Bowreah Cotton Mills Co. Ltd., 21 Strand Road Calcutta 700 001	Bawria Dist. Howrah West Bengal	-do-		
Century Textile & Industries, Pandurang Bhudkar Marg, Worli, Bombay-400 025 Maharashtra	Bombay	-do-		
Digvijay Textile Mills, Lalbagh, Parel Bombay - 400 033	Lalbagh Parel Bombay Maharashtra	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Edward Mills Beawar 10th Floor. Vandana Bldg.. 11 Tolstoy Marg. New Delhi	Beawar Dist. Ajmer Rajasthan	As sizing & finishing materials (for preparing starch paste for cloth)		
Elgin Mills Co. Ltd.. 11/6 Smt. Parbati Bagala Road. Kanpur 208 001 Uttar Pradesh	Mill No. 1 Civil Line Kanpur Uttar Pradesh	-do-		
Hope Textile Mills Ltd.. Indore Madhya Pradesh	Indore Madhya Pradesh	-do-		
Kesoran Inds & Cotton Mills Ltd.. 9/1 R.N. Mukherjee Rd.. Calcutta 700 001	42 Garden Reach Road Calcutta - 700 024 West Bengal	-do-		
Kohinoor Mills Co. Ltd.. Home Street. Fort Bombay - 400 001	i) No. 1 & 2 Naigum Cross Rd.. Dadar. Bombay ii) No. 3 Mill Lady Jamshedji Road. Dadar. Bombay Maharashtra	-do-		
Mahalaxmi Mills. 9th Floor. Vandana Bldg.. 11 Tolstoy Marg. New Delhi 110 001	Beawar Dist. Ajmer Rajasthan	-do-		
Nanded Textile Mills Nanded. Maharashtra	Nanded Maharashtra	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Pulgaon Cotton Mills Ltd., 59 Bombay Samachar Marg., 2nd Floor, Fort, Bombay 400 001.	Pulgaon 442 302 Dist. Wardha Maharashtra	As sizing & finishing materials (for preparing starch paste for cloth)	Pioneer Pharmaceuticals Indore Madhya Pradesh	
Pratap Spg. Wvg. & Mfg. Co. Ltd., Pratapnagar Amalner Dist. Jalgaon Maharashtra	Pratapnagar Amalner Dist. Jalgaon Maharashtra	-do-	Pioneer Pharmaceuticals Indore Madhya Pradesh	
R.B. Bansilal Abirchand Spg. Wvg.Mills. N.T.C. House 15 N. Morarjee Marg. Bombay 400 038.	P.B. No. 6 Hinganghat Dist. Wardha Maharashtra	-do-		
Sri Bharti Mills. P.B.No. 10., Pondicherry Pin 605 004	Mudaliarpet Pondicherry	-do-		
Shree Subhalaxmi Mills. Cambay Gujarat	Station Road. Cambay - 388 620 Kaira Gujarat.	-do-	From Ahmedabad & local market	
Technological Institute of Textiles. P.O. Birla Colony Bhiwani - 125 022 Haryana	Birla Colony Bhiwani 125 022 Haryana	-do-	As sizing & finishing materials (for preparing starch paste for cloth)	
RUBBER				
Acron Rubber Industries. 134 Dhirubhai Parikh Marg. Kalbadevi Bombay 400 002 Maharashtra	Bhiwandi Dist. Thane Maharashtra	As a filler & reinforcing agent.	Commercial Grade	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Apolo Tyres Ltd., Jos Annexe, M.G. Road, Cochin 682 016 Kerala	Perambra Dist. Trichur Kerala	As a filler reinforcing & as a compounding ingredient for for anti-sticking solution	Commercial Grade	
Anico Rubber Industries Goregaon (E) Bombay 400 063 Maharashtra	Goregaon (E) Bombay Maharashtra	As a filler & reinforcing agent		
Aliga Rubber Works, 84/8 Fazalgunj Kanpur Uttar Pradesh	Fazalgunj Kanpur Uttar Pradesh	-do-	Powder Size: 250 Mesh	
Asha Rubber Industries, L.B. Shastri Marg, Mulund (W) Bombay 400 080 Maharashtra	L.B. Shastri Marg, Mulund (W) Maharashtra	-do-	Fine Powder free from metallic salts	
Associated Rubber Industries Ltd., Union Bank Bldg., 4th Floor, Apolo Street Bombay 400 001 Maharashtra.	Gogo Road Dist. Bhavnagar Gujrat	-do-		
Bata India Ltd., 30 Shakespeare Sarani, Calcutta 700 017 West Bengal	Batanagar Dist. 24 Parganas West Bengal	-do-	Powder Moisture 1.5% pH 4.5-6%	
Bedrock Tyre & Rubber Co., 16 Homi Mody St. Masjid Manor, Fort, Bombay - 400 023 Maharashtra	Goregaon(W) Bombay 400062 Maharashtra	-do-	Size: 350 Mesh Free from Carbonate pH 7	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Bombay Rubber Works Pvt. Ltd., Saki Vihar Road., Bombay 400072 Maharashtra	Saki Vihar Road Bombay Maharashtra	As a filler & reinforcing agent	Fine Powder	
Bengal Waterproof Ltd., S.M.Bose Road, Panihati 743 176 24 parganas West Bengal	S.M. Bose Road. Panihati, Dist. 24 Parganas West Bengal	-do-		
Ceat Tyres of India Ltd., 463 Dr. Annie Besant Rd., Bombay - 400 025 Maharashtra	Bhandup Bombay & 82 MIDC Satpur Nasik, Maharashtra	As a filler	Size:200-350 Mesh Purity 99.5 to 99.9%	
Cenara Rubber Products Pvt. Ltd., Mahabaleswar, Kadri Road, P.B.No.732 Mangalore - 575 003 Karnataka	Kulshekar Mangalore Dist. S. Canara Karnataka	As a filler & reinforcing agent	As per I.S. Specifications	
Cosmos India Rubber Works Pvt.Ltd., P.B.No.107, 7 Namji Street, Fort, Bombay 400 001 Maharashtra	i) Dr. Choitram Gidwani Road, Chembur Bombay ii) Plot No. 25 MIDC, Trimbak Road., Nasik Maharashtra	-do-	Moisture 1% Max Size:+200 Mesh Sp. Gr. 2.6 Ac Ins. 95%Min No Carbonates Cu-Nil. Mn-0.004% Al_2O_3-30% Min LOI-11-14%	
Carona Sahu Co. Ltd., 221 Dr. D.N. Road, Bombay 400 001 Maharashtra	Caves Road, Jogeshwari Bombay 400060	-do-	Size:300 Mesh Free from moisture	
Centreads Pvt Ltd., South Canara Karnatka	South Canara Karnatka	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Dunlop India Ltd., Dunlop House 57 B Mirza Galib Street, Calcutta 700 016 West Bengal	i) Shahagunj West Bengal ii) Ambattur Tamil Nadu	As a filler & reinforcing agent	Rubber Grade	
Eagle Rubber Industries Ghatkopar Inds. Estate, L.B. Shastri Marg, Ghatkopar Bombay 400 086 Maharashtra	L.B. Shastri Marg, Ghatkopar Bombay	-do-		
Enkay (India) Rubber Co.Pvt.Ltd., 2/8 Roop Nagar, Delhi 110 007	Basai Road Dist. Gurgaon Haryana	-do-		
Falcon Tyres Limited Mysore Karnataka	Mysore Karnataka	-do-		
Hind Rubber Industries Pvt.Ltd., Tardeo Road, Bombay 400 034 Maharashtra.	Tardeo Road Bombay Maharashtra	-do-	Powder	
Hindustan Rubber Works, Vir Savarkar Marg, Bombay, Maharashtra	Vir Savarkar Marg, Bombay Maharashtra	-do-		
Hilton Rubbers Pvt.Ltd., 209 Ansal Bhavan Kasturba Gandhi Marg, New Delhi 110 001	Rai Dist. Sonepat Haryana	-do-	As per I.S. Specification No. 505, 1968	
I.C.I. Ltd., (Chemical Divn.) Rishra Dist. Hoogly West Bengal	Rishra Dist. Hoogly West Bengal	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Incheck Tyres Ltd., Leslie House 19 J.N. Road, Calcutta 700 013 West Bengal	Kankinara Dist. 24 Parganas West Bengal	As a filler & reinforcing agent	Size: 200 Mesh Moisture 2% Solubility 0.5%	
Inarco Limited. Advent 12 A, Foreshore Road, Bombay 400 021 Maharashtra	2nd Pekhran Rd., Majiwada Thana Maharashtra	-do-		
Kedar Rubber Ltd., 46 B Shakespeare Sarani, Calcutta 700 017 West Bengal	92 Narkeldanga Main Road Calcutta West Bengal	-do-	Powder	
Lattia Rubber Mfg. Co.Ltd., Kurla-Andheri Road, Bombay 400 059 Maharashtra.	Bombay Maharashtra	-do-		
Modak Rubber Products Ltd., Kondivate Road, Opposite Marol Bazar Andheri-Kurla Rd. Bombay 400 059 Maharashtra	Andheri Bombay Maharashtra	-do-	Size: 300 Mesh As per I.S. specification No. 505	
Madras Rubber Factory Ltd., Dhun Building, 1/5/1 Anna Salai Madras 600 002 Tamil Nadu	1) P.B. No.1 Ponda (Goa) 2) T.H. Road Tiruvottiyur Tamil Nadu 3) Vadavathoor Kottayam Kerala 4) Ichiputtur Arkonam Dist. Tiruttani Tamil Nadu	-do-	Size : 325 Mesh Sp. Gr. 2.58-2.62 pH 4.5-6.5 Al_2O_3 - 38-41% SiO_2 43-46% Fe_2O_3 - 1% Max Mn-0.0025% Max Moisture 1% Max L.O.I 15% Max	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Modi Rubber Ltd. New Friends Colony, New Delhi	Modipurm Dist. Meerut Uttar Pradesh	As a filler & reinforcing agent	White to Cream Powder Size : 325 Mesh Moisture 1% Max. L.O.I. at 950° 15% Max pH 5.5 to 7.5 Sp. Gr. 2.5 to 2.6 Fe_2O_3 - 0.5% Max.	
National Engineering Industries Ltd., 2, Beerpara Lane Kolkata 700 030 West Bengal.	Dum Dum Calcutta West Bengal	-do-		
Patco Industrial Suppliers, 177-178 Industrial Estate, Dist. Sangli Maharashtra	Sangli Dist. Sangli Maharashtra	-do-		
Perfect Oil Seals & Industrial Rubber Products Plot No. 84, Bhosari Industrial Area, Pune - 411 026 Maharashtra	Bhosari Pune Maharashtra	-do-		
Premier Tyres Ltd., Merchant Chambers 41, New Marine Lines, Bombay 400 020	Kaasmssery Dist. Ernakulam Kerala	-do-		
Precision Rubber Co. (India) P.B. No. 7718 Jaya Cinema Bldg. Borivli (W) Bombay 400 092	Sree Manor Rd. Palghar Dist. Thane Maharashtra	-do-		
Rubber Industries (India) 87, Sir M.V. Road, Andheri, Bombay	Andheri (E) Bombay	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Satish Industries Laxmi Vishnu Sadan Maharshi Karve Road, P. B. No. 209 Naupada Thane 400 602 Maharshtra.	Thane Maharashtra	As a filler & reinforcing agent		
S.G.R. Industries Pvt. Ltd., 10 The Mall Dum Dum Calcutta 700 028	10 The Mall Dum Dum Dist. 24 Parganas West Bengal	-do-	Rubber Grade	
Swastik Rubber Products Ltd., Swastik House Khadki Pune 411 003 Maharashtra	i) Khadki ii) Chinchwad Pune Maharashtra	-do-		
Tyre Corporation of India Ltd., 19, J. N. Road, Calcutta 700 087 West Bengal	127 Katdanga Road, Kankinara 743 129 Dist. 24 Parganas West Bengal	-do-		
Vidyut Cable & Rubber Industries Plot No. 66 Govt. Inds. Estate Kandivli (N) Bombay 400 067.	Kandivli (W) Bombay Maharashtra	-do-		
Vikarsco Rubber Products (India) Santacruz Bombay	Santacruz Bombay Maharashtra	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
PAINTS				
Amar Paints & Allied Industries M. M. Inds. Estate Yediyur Bangalore 650 011 Karnataka	M. M. Inds. Estate Yediyur Bangalore Karnataka	As extender	Size : 30 mesh	
Assam Paints & Chemical Works Tinsukia Dist. Dibrugarh Assam	Tinsukia Dist. Dibrugarh Assam	-do-	-	
Advance Paints Pvt. Ltd., 125, Nagindas Master Rd., Fort Bombay 400 023 Maharashtra	47 Maker Chambers, 3, Nariman Points Bombay	-do-		
Bombay Paints & Allied Products Ltd., Corrider Road Gavanpada Chembur Bombay 400 047 Maharashtra	Corrider Road Gavanpada Chembur Bombay Maharashtra	-do-	As per I.S.68	Bargi Minerals & Chemicals Ltd., Dadar, Bombay
British Paints, 32 Chowringhee Rd., Calcutta 700 071 West Bengal	32 Chowringhee Road, Calcutta West Bengal	-do-	-do-	
Comet Paints Ltd., Anand-Sojitra Road, Vallabh Vidyansagar Dist. Kaira Gujarat 388 120	Vallabh Vidyansagar Dist. Kaira Gujarat	-do-	Suitable for paint indsutry	
Chemi Chrome Industries (P) Ltd. 84/79 G. T. Road Kanpur 208 003 Uttar Pradesh	84/79 G. T. Road, Kanpur Uttar Pradesh	-do-	-	

(Contd.)

Table - 10.4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Commercial Paint & Chemical Works 48-C Laxminagar Inds. Estate Indore 452 002 Madhya Pradesh	48 C Laxmibai Nagar Indore Madhya Pradesh	As extender	-	
Esdee Paints Kolshet Road, Thane 400 607 Maharashtra	Kolshet Road, Thane 400 607 Maharashtra	-do-	-	
Elphinstone Paint & Colour Mfg. Co., 50 Elphinstone Road, Bombay - 400 013	Elphinstone Road Bombay Maharashtra	-do-	Paint Grade	
Garware Paints Ltd., Rustom Bldg. 29, Veer Nariman Road, P.B. No. 63 Bombay 400 023 Maharashtra.	Patlipada Thane Maharashtra	-do-	-	
Goodluck Oil & Paint Co. Khanderao Road P. B. No. 120 Oppo. Jawahar Society Baroda 390 001 Gujarat.	Khanderao Rd., Baroda Gujarat	-do-	-	
Goa Paints & Allied Products Dempo House Campal, Panji 403 001 Goa	Panaji Goa	-do-	-	
Goodlass Nerolac Paints Ltd., P. B. No. 16322 Ganpatrao Kadam Marg, Lower Parel Bombay 400 013 Maharashtra	Lower Parel Kavesar Bombay Maharashtra	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Hardcastle & Waud Mfg. Co., Ltd., Brabourn Stadium 87 Veer Nariman Rd., Bombay 400 020 Maharashtra	Netivali Baug Kalyan - 421 326 Thane Maharashtra	As extender	Size : 300 mesh	
Hoyles Paints Ltd., Konnagar Dist. Hooghly West Bengal	Konnagar Dist. Hooghly West Bengal	-do-		
I.C.I. Ltd., (Chemical Divn.) Rishra Dist. Hooghly West Bengal	Rishra Dist. Hooghly West Begnal	-do-		
India Paint Colour & Varnish Co. Ltd., 14 Netaji Subhash Rd., Calcutta 700 001 West Bengal	Tollygunj Calcutta West Bengal	-do-		
Jyoti Oil & Paint Co. L. T. Road, Borivli (W) Bombay - 400 092	L. T. Road Borivli Bombay Maharashtra	-do-		
Laxmi Paint Works 14/2 Old China Bazar Street, P. Box 2574 Calcutta 700 001 West Bengal	Lilooah Dist. Howrah	-do-		
Modi Paint & Varnish Works Modinagar Dist. Meerut Uttar Pradesh	Modinagar Dist. Meerut Uttar Pradesh	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Mysore Lac & Paint Works P. Box No. 82 Mysore 570 001 Karnataka	Thilak Nagar Mysore Karnataka	As extender		
Nagrath Paints Pvt. Ltd., 2 Tolstoy Marg New Delhi	46 Fazalganj Kanpur Uttar Pradesh	-do-		
N. Choudhury Bros. Pvt. Ltd., Kolkata West Bengal	Calcutta West Bengal	-do-		
P. C. Chand & Co. Pvt. Ltd., Budge Budge Road, Calcutta 700 060 West Bengal	Budge Budge Rd. Calcutta West Bengal	-do-		
Punjab Paint Colour & Varnish work 123/529, Fazalgunj Kampur - 200 012 Uttar Pradesh	123/529 Fazalgunj Kanpur Uttar Pradesh	-do-		
Ravi Paint & Chemicals Ltd., P. Bag No. 5050 26 Armenian Street Madras 600 001 Tamil Nadu	85/87 Armenian Street Madras	-do-		
R. T. Paint India Pvt. Ltd. Bhandup Bombay 400 087 Maharashtra	Bhandup Bombay Maharashtra	-do-		
Synpro Industries, Industrial Estate Indore Madhya Pradesh	Indore Madhya Pradesh	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Sigma Paint Ltd., 221 Dr. D. N. Road, Bombay 400 001 Maharashtra	Old Nagardas Rd. Mogra Andheri (E) Bombay Maharashtra	As extender		
Snowcem India Bombay 400 001 Maharashtra	Bombay Maharashtra	-do-		
Shalimar Paints Ltd., 13 Camac Street Calcutta 700 017 West Bengal	Gobaria P. O. Botanical Garden Dist. Howrah West Bengal	-do-		
Singhal Paints Pvt. Ltd., 1 Ajahbagh Road Lucknow 226 004 Uttar Pradesh	Lucknow Uttar Pradesh	-do-		
The Oudh Sugar Mills Limited 18 Radhanath Choudhury Road, Calcutta	Calcutta West Bengal	-do-		
COSMETICS/SOAP				
Lakme Ltd. Bombay House, 24 Homi Modi St. Bombay 400 001 Maharashtra	Deonar Bombay Maharashtra	As a filler in cosmetic preparations		Bimal Chemicals (I) Ltd., Santacruz (W) Bombay
Swastik Household Industrial Products, Ambarnath Dist. Thane Maharashtra	Ambarnath Dist. Thane Maharashtra	-do-		-do-

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
The Tata Oil Mills Co. Ltd., Bombay House, 24, Homy Modi St. Fort, Bombay 400 001 Maharashtra	Kozhikode Kerala	As a filler in making soap	Al_2O_3 - 35% Fe_2O_3 - 1%	Ernakulam Kerala
The Tata Oil Mills Co. Ltd., Bombay House, 24, Homy Modi St. Fort, Bombay - 400 001 Maharashtra	Kochi-682014 Ernakulam Kerala	As a filler in making soaps, glycerine & toilet production	Alumina 30-35% Iron 1%	White Field Minerals Anjiparambil Complex Kochi-682 016 Sheeba Enterprises Quilon, Kerala Quilon Rubber Filler & Allied Industries, Quilon, Kerala
GLASS				
FGP Ltd. 9 Wallace Street, Bombay 400 001	L. B. Shastri Marg, Thane Maharashtra	For fibre glass making	SiO_2 - 47.5% Fe_2O_3 - 0.5% TiO_2 - 0.5% Al_2O_3 - 37.5%	English Indian Clays Veli, Tiruvananthapuram Kerala
Bharat Ophthalmic Glass Ltd., Durgapur Dist. Burdwan West Bengal	Durgapur Dist. Burdwan West Bengal	For fibre glass making		
Ceat Tyres of India Ltd., (Glass Fibre Division) Hyderabad Andhra Pradesh	Hyderabad Andhra Pradesh	-do-	SiO_2 - 44% Fe_2O_3 - 0.6% TiO_2 - 0.45% Al_2O_3 - 38%	
U. P. Twiga Fibreglass Ltd., 9 Industrial Area Bulandshahar Uttar Pradesh	Buland Shahar Uttar Pradesh	-do-	-300 mesh SiO_2 - 46% max Al_2O_3 - 395 min.	Engineering India Kerala

(Contd.)

Table - 10.4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
INSECTICIDES				
Agromore Ltd. Mysore Road. Bangalore Karnataka	Mysore Road Bangalore Karnataka	As a filler/ carriers for pesticides & insecticides formulation		
Gharda Chemicals Pvt. Ltd., Bandra. Bombay Maharashtra	Bandra Bombay Maharashtra	-do-		
Hindustan Insecticides Ltd. C 255 Defence Colony. New Delhi 110 003	Indus Area Rohtak Road Post Box 623 New Delhi 110 015	-do-	Soft washed lumps. creamy White Wett-ability within a minute compact sedi-mentation within 30 minute Carbonate-Nil pH 7-7.05 Bulk density 0.56 gm/cc Moisture <1.%	
Hindustan Insecticides Ltd. C 255 Defence Colony. New Delhi 110 003	Udyogmandal Eloor Panchayat Varapuzha Vill. Dist. Erna-kulam Kerala	-do-	Soft washed lumps. creamy white wett-ability within a minute compact sedi-mentation within 30 minutes Carbonate-Nil pH 7-7.05 Bulk density 0.56 gm/cc Moisture <1.%	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Hindustan Insecticides Ltd. C 255 Defence Colony, New Delhi 110003	Rasayani Raigarh Maharashtra	As a filler/ carriers for pesticides & insecticide formulation	Soft washed lumps, creamy white wett-ability within a minute compact sedi-mentation within 30 minutes Carbonate-Nil pH 7-7.05 Bulk density 0.56 gm/cc Moisture <1.%	
Jayalakshmi Fertilisers (Pesticide Divn.) Venkatarayapuram P. B. No. 5 Tanuku, Dist. West Godavari Andhra Pradesh	Tanuku, Dist. West Godavari Andhra Pradesh	-do-	Lumps free from iron, Moisture etc. pH - 7 to 7.5	Kerala Clays & Ceramic Products Ltd., Pappinisseri Kerala
National Pesticides 5 Inds Estate, Vidisha Madhya Pradesh	Inds Estate Vidisha Madhay Pradesh	-do-	White cream coloured lumps	
Pesticides India Post Box No. 20 Udaipur 313 001 Rajasthan	Udisagar Rd. Udaipur Rajasthan	-do-	Whiteness 78% SiO_2 - 40-50% Al_2O_3 - 20-40% Fe_2O_3 - 0.3-0.7%	
Penta Chem. Plot No. 20/23 Inds Estate	20/23 Inds Estate Kedgaon	-do-	-	
Kedgaon Ahmednagar 414 001 Maharashtra	Ahmednagar 414001 Maharashtra	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Rallies India Ltd. Ralli House 21 Ravelin Street Fort, Bombay Maharashtra	431/4 Panchpakhadi Village Wagale Indl Estate, Thane Maharashstra	As a filler/carrier for insecticides & Pesticides formulation	Soft lumps free from grit Moisture 0.5%	
Rallies India Ltd. Ralli House 21 Ravelin Street Fort, Bombay Maharashtra	Palghat Kerala	-do-	Soft lumps free from grit Moisture 0.5%	
Rallies India Ltd. Ralli House 21 Ravelin Street Fort, Bombay Maharashtra	Ambattur Dist. Chingle-put Tamil Nadu	-do-	Soft lumps free from grit Moisture 0.5%	
Rallies India Ltd. Ralli House 21 Ravelin Street Fort, Bombay Maharashtra	20 Howrah Rd. Salkia Howrah 711 106 West Bengal	-do-	Soft lumps free from grit Moisture 0.5%	
Scientific Insecticides Co., 13/14 Second Line Beach Madras Tamil Nadu	447/1 Mang-alagiri Road P. B. 80 Guntur Andhra Pradesh	-do-		
Sandoz (India) Ltd Sandoz House Dr. Annie Besant Road, Worli, Bombay 400 018 Maharashtra	Kolshet Road Dist. Thane Maharashtra	-do-		
Southern Pesticides & Fertilizer Ambattur Dist. Chinglepat Tamil Nadu	Ambattur Dist. Chinglepat Tamil Nadu	-do-		

(Contd.)

Table - 10.4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Southern Pesticides Corpn. Ltd., West Godavari Andhra Pradesh	West Godagari Andhra Pradesh	As a filler/carrier for inscecticides & Pesticides formulation		
Tarapur Chemicals & Pesticides E-47 MIDC Boisar Thane Maharashtra	E-47 Tarapur Industrial Area Boisar Dist. Thane Maharashtra	-do-		
Travancore Chemical & Mfg. Co.Ltd., Kalamassery Alwaye Dist. Ernakulam Tamil Nadu	Kalamassery Alwaye Dist. Ernakulam Tamil Nadu	-do-		
Union Carbide India Ltd., 1 Middleton St. Calcutta 700 018 West Bengal	Bhopal Madhya Pradesh	-do-		
Yawalkar Pesticides Pvt. Ltd., 52, Bajaj Nagar Nagpur, Maharashtra	50 Uppalwadi Kamptee Nagpur 440 026 Maharashtra	-do-	-	
OTHER ABRASIVES				
Grindwell Norton Ltd., Army & Navy Buldg., Mahatama Gandhi Rd. Bombay 400 023	Mora (Uran) Dist. Kolaba Maharashtra	As bonding material	-	
Hanuman Prasad Pragdas Chandra Shekhar Azad Road, Mirzapur Uttar Pradesh	Hanumana Dist. Rewa Madhya Pradesh	As bonding material	-	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Krishnalal Thireni & Co. Ltd., 1 & 3 Brabourn Rd., Calcutta 700 001	125 B. T. Road Dunlop Bridge Calcutta - 700 035 West Bengal	As bonding material	White hard Lump SiO_2 - 45% Al_2O_3 - 40% $Na_2O + K_2O$ - 4% Fe_2O_3 - 0.8%	
ASBESTOS PRODUCTS				
Dutta Bros. & Co., 34 Netaji Subhas Rd., Kolkata 700 001 West Bengal	Dubaco Bhuban 39/4 Abhoy Kumar Mukherjee Road, Calcutta 700 050 West Bengal	As bonding material/ filler	-	
Hindustan Ferodo Ltd., P. Box No. 9213 Ghatkopar Bombay 400 086	Lal Bahadur Shastri Marg Ghatkopar Bombay Maharashtra	As bonding material/ filler	-	
Newkem Products Corporation Harganga Mahal, Khodadad Circle, Dadar - 400 014 Bombay Maharashtra	Bhandup Bombay Maharashtra	For mfg. insulation powder, etc.		
BATTERY/DRY CELL				
Bharat Battery Mfg.Co. Pvt. Ltd. 238 Acharya Jagdish Chandra Bose Road, Calcutta 700 020	238 A Acharya Jagdish Chandra Bose Road, Calcutta West Bengal	Used in rubber, mixed as filler	Size - 200 Mesh Sp. Gr. - 2.6 L.O.I. - 13% Fe - 0.5% Cu - 0.01% Max. Mn - 0.01%	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
UB MEC Batteries Ltd., P. B. No. 2231 Yeshwantpur Bangalore 560 022 Karnataka	Bangalore Karnataka			
CHEMICALS				
Indian Explosive Ltd. Giridih, Bihar	Giridih Bihar	As one of the ingredients in the manufacture of explosives		
Mineral & Chemical Products Chaibasa - 833 201 Dist. Singhbhum Bihar	Near Kendposi Railway Stn. Dist. Singhbhum Bihar	Used for calcination	Cossim Bazar Chinaclay Mines Dist. Singhbhum, Singhbhum Minerals Chaibasa, Bihar	
ELECTRICAL				
Cable Corporation of India Ltd. Laxmi Building, 6 Shoorji Vallabdas Marg, Bombay - 400 038	Bombay Maharashtra	As a filler for making PVC compounds	Size - 30-40 Micron Al_2O_3 - 40-45% SiO_2 - 40-45% L.O.I. - 12-15% Moisture - 0.9% Max.	
Fort Gloster Industries Ltd., (Cable Divn.) 21 Strand Road, Calcutta 700 001 West Bengal	Fort Gloster Dist. Howrah West Bengal	As a filler in rubber compounds	I.S. Specification	
Indian Cable Co. Ltd., Jamshedpur Dist. Singhbhum Bihar	Jamshedpur Bihar	-do-		
Incab Industries Ltd., 9 Hare Street, Calcutta 700 001 West Bengal	P. O. Box 22 Hardaspur Indl. Estate Pune Maharashtra	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Mahendra Electricals Ltd.. Kamala Mansion Road. Nadiad P. Box. 43. Dist. Kaira. Gujarat	Kamala Mansion Rd.. Nadiad. Dist. Kaira Gujarat	As filler in rubber Compound		
Univeral Cables Limited. Birla Colony. Satna Madhya Pradesh	Satna Dist. Satna Madhya Pradesh	As filler		
ELECTRODE				
Ahura Welding Electrode Mfg. Co. Ltd.. 35 Ramchandra Rd.. R. S. Puram. Coimbatore 641 022 Tamil Nadu	Thirumalayam-palayam Dist. Coimbatore Tamil Nadu	As a binding material	Powder Al_2O_3 - 30% K_2O - 4% min. S & P - .001% max	
A. S. Jain Electrode Painpat Haryana	Panipat Haryana	As a binding material		
D & H Secheron Electrodes Pvt. Ltd.. 44/46 Inds Estate Fort. P. Box 69 Indore 452 004 Madhya Pradesh	Indore Madhya Pradesh	As a binding material		
Esab India Ltd.. Thane Maharashtra	Thane Maharashtra	As a binding material		
EWAI Alloys Ltd.. L & T House Bombay Maharashtra	Bombay Maharashtra	As a binding material		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
General Electrodes and Equipments Ltd., Jiji House, Raveline Street, Bombay 400 001 Maharashtra	Thane Maharashtra	As a binding material		
Lithothermic Electrode (I) Ltd., (Western Rly) Baroda Gujarat	Baroda Gujarat	As a binding material		
Modi Arc Electrodes Modinagar, Dist. Meerut Uttar Pradesh	Modinagar Dist. Meerut Uttar Pradesh	As a binding material		
Philips India Ltd., 7 Justice Chandra Mahab Road, Kolkata 700 020 West Bengal	Kalwa-Thane Dist. Thane Maharashtra	As a binding material	SiO_2 - 40-50% Al_2O_3 - 35-40% S < 0.03% L.O.I. - 12-15%	
Rockweld Electrodes India Ltd., 29 Inds Estate Ambattur Madras 600 028 Tamil Nadu	29 Inds. Etate Ambattur Madras Tamil Nadu	As a binding material	SiO_2 - 50% Al_2O_3 - 35%	
R. Gac Electrodes Ltd., Kawdiar, Trivandrum Kerala 695 041	Thiruvananthapuram Kerala	As a binding material		
Special Machines Bye-Pass Kunjpura Crossing Karnal, Haryana	Karnel Dist. Karnal Haryana	-do-		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Southern Electrodes M. A. Road. Hyderabad Andhra Pradesh	Hyderabad Andhra Pradesh	As a binding material		
Welding Rods Mfg. Company. P. O. Box 20 Industrial Estate Udhna. Surat. Gujarat	Udhna Surat Gujarat	-do-	SiO_2 - 46.5% Al_2O_3 - 39.5% L.O.I. - 14%	
FERTILIZER				
Maharashtra Agro Inds Dev. Corpn.. Shivani. Akola Maharashtra	Shivani Akola Maharashtra	As a coating agent		
South India Chemiclas & Fertilizers Kottayam Kerala	Kottayam Kerala	As a coating agent		
FOUNDRY				
Anglo-India Jute Mills Co. Ltd.. Jagatdal 24 Parganas West Bengal	Jagatdal 24 Parganas West Bengal	For furnace lining		
REFRACTORIES				
A.C.C. Ltd.. Cement House 121 Maharshi Karve Road. Bombay 400 020	Katni Fire-bricks & Pottery Works. Katni Madhya Pradesh	As the main body constituent	Al_2O_3 - 30-31% Fe_2O_3 - 3.5% CaO - 0.5% P.C.E. 31 Orton Cone	
Bharat Minerals & Ceramic Inds. P. O. Mahilong Dist. Ranchi Bihar	Mahilong Dist. Ranchi Bihar	For the manufacture of refractory materials. insulating bricks. acid proof bricks. etc.		

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Bharat Firebricks & Pottery Works Pvt. Ltd., Jharia Dist. Dhanbad, Bihar	Jharia Dist. Dhanbad Bihar	For the manufacture of refractory materials, insulating bricks, acid proof bricks, etc.		
Bharat Heavy Electricals Ltd., BBHEL House, Siri Fort, New Delhi 110 049	Jagdishpur Industrial Area Sultanpur Uttar Pradesh	For manu-facturing insulators		
Bharat Refractories Ltd., Bhandaridah Refractories Plant Bhandaridah 829 132 Dist. Bokaro, Bihar	Bhandaridah Dist. Bokaro Bihar	For the manufacture of refractory bricks, mortars, taphole & runner mass		
Bhupal Mining Works Bhilwara 311 001 Dist. Bhilwara Rajasthan	Pansal Road Bhilwara Rajasthan	For the manufacture of insulation bricks & mortars		
Haryana Refractories Pvt. Ltd., 17 Ganesh Chandra Avenue Calcutta 700 001 West Bengal	Plot Nos. 65 & 66 Sector 25 Ballabgarh Dist. Gurgaon Haryana	As the main body constituent	Al_2O_3 - 30% Fe_2O_3 - 1.5%	

(Contd.)

Table - 10. 4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Imperial Refractories Kalipahari Assansol Dist. Burdwan West Bengal	Kalipahari Dist. Burdwan West Bengal	For the manufacture of refractories		
India Fire Bricks & Insulation Co.. Central Avenue Sector IV. P. Bag No. 2 Bokaro Steel City Bihar 827 004	Marar Dist. Hazaribagh Bihar	For the manufacture of Refractory bricks and mortars		
Ipitate Refractories Limited. Ipitate Nagar Dhenkanal - 759 013 Orissa	Dhenkanal Orissa	For the manufacture of refractories	20 Orton Cone Al_2O_3 - 20% Min Fe_2O_3 - 1% Max	
Kumardhubi Fireclay & Silica Works Ltd.. Chartered Bank Building Calcutta 700 001 West Bengal	Kumardhubi Dhanbad Bihar	For the manufacture of refractories		
Modern Refractories. Shed No. 8-29 & 30. M. I. D. C. Industrial Area Hingna Road. Nagpur 440 016 Maharashtra	M. I. D. C. Indus. Area Dis. Nagpur Maharashtra	For the manufacture of fire bricks, insulation bricks & high alumina fire clay powder	Al_2O_3 - 40%	V. C. Minerals, Mysore
Mahaveer Industries Pvt. Limited. Bhilwara Rajasthan	Bhilwara Rajasthan	For the manufacture of refractories		

(Contd.)

Table - 10 .4 (Contd.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Maithan Ceramics Pvt. Ltd., 36/2 Vivekanand Rd., Calcutta - 700 007 West Bengal	Maithan Road Dist. Dhanbad Bihar	As the main body constituent		
New Bharat Refractories Bhareech Nagar Bihar 829 122	Bhareech Nagar Dist. Hazaribagh Bihar	For the manufacture of refractories		
Nutech Refractories Refractories (P) Ltd., 43 Sanjay Marg, Goapl Bari, Jaipur 302 001 Dist. Jaipur	Bhilwara Rajasthan	For the manufacture of insulation bricks	PCE 29 Alumina - 30% Iron 2% max	Deedwaniya & Sons, Kotri, Rajasthan
Orissa Cement Ltd., Rajganpur 770 017 Dist. Sundergarh Orissa	Rajgangpur Sundergarh Orissa	For the manufacture of refractories	Al_2O_3 - 17-18% Fe_2O_3 - 1.5% max	Lakhanpur, Orissa
Pratap Steels Ltd., A-4 Kalindi New Delhi	Ballabgarh Dist. Faridabad Haryana	For the manufacture of high alumina refractories fire clay Gr. stopper heads, basic refractories	Al_2O_3 - 35-37% Fe_2O_3 - 1-1.5%	K. C. Pradhan, Rourkela, Orissa
Stoneware Pipes (Madras) Limited, 89, Broadway 5th Floor, Madras 600 108 Tamil Nadu	Trivellore 602 001 Tamil Nadu	For the manufacture of high alumina refractories fire clay Gr. stopper heads, basic refractories		

(Contd.)

Table - 10. 4 (Concld.)

Name and address of consumer	Location of plant	Purpose of use	Specification	Source of Supply
Shri Natraj Ceramic & Chemical Industries Ltd. Dalmiapuram Pin 651 621 Dist. Trichy Tamil Nadu	Dalmiapuram Dist.Tiruchira-palli Tamil Nadu	For the manufacture of fire bricks, mortars. castbles stoneware pipes & fittings	Al_2O_3 - 35% Fe_2O_3 - 1.5%	Bharathy Clays & Standard clays, Trivandrum Kerala
Tata Refractories Ltd., P. O. Belpahar Sambalpur 768 218 Oirssa	Belpahar Sambalpur Orissa	For the manufacture of refractories	Al_2O_3 - 30% min Fe_2O_3 - 1.5% min TiO_2 - 1.25% max	Kendposi, Singhbhum Bihar
The Chalakudy Refractories Ltd., R. S. Road, P. B. No. 25 Chalakudy 680 307 Dist. Trichur Kerala	R. S. Road Dist. Trichur Kerala	For the manufacture of refractory mortar		
Valley Refractories Limited, 4, Ho Chi-Minh Sarani, Calcutta 700 071 West Bengal	Maithan Road Chirkunda Dhanbad Bihar	For the manufacture of refractory bricks & shapes, mortar	P.C.E. - 29-33 Al_2O_3 - 38-40% Fe_2O_3 - 1.5%	K. B. Traders & M. K. Traders, Chirkunda, Dhanbad Barakar Minerals Corpn. Barakar Bihar

10.5 Consumption

Chinaclay is mainly consumed in cement, ceramics, insecticides, refractory, rubber and paint industries. Table 10.5 shows the consumption of chinaclay (industry-wise/year-wise) :

Table 10.5 Consumption of Chinaclay
(By Industries)

Industry	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
All Industries	**393,000**	**355,000**	**270,800**	**268,400**	**353,800**	**318,700**	**253,900**	**256,600**
Cement	293,000(12)	260,000(13)	150,400(15)	138,100(16)	205,400(16)	176,000(12)	114,700(9)	119,000(9)
Ceramic	41,000(35)	41,000(35)	52,600(33)	58,200(33)	64,600(32)	56,100(30)	57,100(33)	54,700(33)
Insecticide	11,000(20)	11,000(20)	23,500(20)	25,300(19)	26,300(17)	25,900(16)	26,100(20)	26,200(20)
Paints	4,000(35)	4,000(35)	3,400(33)	3,600(31)	7,700(35)	8,500(17)	9,100(20)	9,100(20)
Paper	11,000(10)	6,000(10)	7,400(12)	15,000(16)	19,200(16)	16,700(16)	15,400(18)	16,200(18)
Refractory	17,000(24)	17,000(22)	18,800(22)	14,500(21)	18,300(24)	22,100(23)	22,100(22)	22,200(22)
Rubber	7,000(45)	7,000(46)	6,900(41)	5,600(42)	5,100(39)	2,100(30)	2,300(33)	2,100(33)
Cosmetics	-	-	-	-	1,900(4)	5,900(4)	2,400(4)	2,400(4)
Others	9,000(64)	9,000(64)	7,800(60)	8,100(60)	5,300(48)	5,400(43)	4,700(43)	4,700(43)

Others includes : Abrasive asbestos products, drycell battery, chemical, cosmetics, electrical, electrode, fertilizer, foundry, glass and textile.

1. *Figures rounded off.*
2. *Figures in parentheses denote the number of reporting units in organised sector reporting consumption.*
3. *In addition, three units processed crude Chinaclay to the tune of 153,500 tonnes, 158,600 tonnes and 160,900 tonnes during 1992-93, 1993-94, 1994-95 and 45,300 tonnes, 48,800 tonnes and 48,300 tonnes during 1995-96, 1996-97 and 1997-98, respectively, for supply of refined Chinaclay to consuming industries.*

Source *: Indian Minerals Yearbook 1995 and 1996 & ME Division.*

From the above table it is seen that the consumption of chinaclay is more in cement industry than in ceramics industry.

Taking into consideration the India's consumption of Chinaclay during 1995-96, the total consumption of chinaclay by all industries was 318,700 tonnes out of which 170,000 tonnes was consumed by twelve cement industries, which amounts to 55 percent. Consumption of chinaclay in ceramic industries was 25,900 tonnes by 16 industries (18 percent of the total consumption). Insecticide industries with a consumption 25,900 tonnes of chinaclay by 16 industries stood third which amounts to 8 percent of total consumption. There is 10 percent less consumption of chinaclay during 1995-96 as compared to 1994-95. The main causes may be less consumption of about 15 percent in cement industry and 13 percent in paper industry and 60 percent fall in rubber industry. However, there was a rise in consumption of chinaclay in refractories by almost 20 percent.

Other industries consuming chinaclay are refractories 7 percent (22,100 tonnes) paper about 5 percent (16,700 tonnes) and paints and rubber.

From the table it is also seen that the consumption of the chinaclay is reducing year by year from 1990-91 to 1994-95. In 1990-91, the total consumption of chinaclay was 393,000 tonnes which decreased to 355,000 tonnes in 1991-92 and further decreased to 270,800 tonnes in 1992-93. This decreasing trend continued up to 1993-94 and was almost steady at 268,000 tonnes in 1994-95.

However, during all these five years, cement, ceramics and insecticide industries were maintaining their trend using almost about 50, 20 and 10 percent, respectively.

In the year 1996-97, the consumption of kaolin was 253,900 tonnes which was 20% less than the consumption in previous year 1995-96. The consumption rose slightly by 1% during the year 1997-98 and reached to 256,600 tonnes. Out of these, 119,000 tonnes (46% of the India's total consumption) was consumed by 9 cement industries. The consumption of kaolin by 33 ceramics industries was 54,700 tonnes which was 21% of the total consumption. The consumption by 20 insecticides industries was almost steady. 10% of the total consumption during 1996-97 and 1997-98 was around 26,200 tonnes in each year. Other main consumers were refractory 9%, paper 6% and paint industries 4% of the total consumption of kaolin in India in 1997-98 which was 22,200 tonnes, 16,200 tonnes and 9,100 tonnes, respectively.

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11. World Trade and Future Outlook

11.1 World Trade

The export market for chinaclay is in three forms viz. (a) as a raw material (crude), (b) as processed (refined) material and (c) as finished products with its use such as ceramics, etc. The raw material (crude) is in demand in those countries which are industrially well advanced viz. Japan, Finland, Germany, etc. where beneficiation is undertaken and finally utilise it to manufacture finished products. Since the crude will be in high bulk with low cost, no country will evince interest for it unless it is geographically well placed with respect to exporting country.

In respect of processed clay the market potentiality will be identified in the countries which are industrially well developed so as to bridge up the gaps in needs for utilising products obtained from chinaclay. The developing countries which have less means to utilise the raw or refined clay can only depend on import of finished products for which India can have better possibilities. In India, crude chinaclay is normally processed outside the lease area. It is generally washed by adopting levigation and sedimentation. Though there are number of washing plants in the country, those of Kerala Ceramic Ltd. and Indian Clays Ltd. are considered to be the modern[2].

11.2 Export of Kaolin

In the year 1991, thirty - one countries exported kaolin to the tune of 8.68 million tonnes to different countries in the world. USA was the pioneer for exporting kaolin of 2.88 million tonnes which was 33 percent of the total exports of the world. During 1992, there was 8.40 million tonnes of total exports which was 3 percent less than that in the year 1991. However, there was about 5 percent increase in the world exports of kaolin in 1993, which reached up to 8.84 million tonnes. This rising trend continued in 1994 also with a 3 percent increase and the exports were the highest (9.14 million tonnes). There was a considerable decrease in kaolin export in the year 1995 (7.49 million tonnes) which was 18 percent less than that in the previous year. Country-wise and year-wise export of kaolin for the period from 1991 to 1996 is given in Table No. 11.1.

It can be seen from the table that in 1991 there were 31 countries exporting kaolin. In the year 1992, Russia and Slovenia reported 5700 tonnes and 6700 tonnes of export, respectively and total exporting countries were 34 which increased to 35 in the year 1993, where the export of kaolin was also increased by 20 percent. In 1994, only thirty-four countries exported kaolin (9.37 million tonnes). In the year 1995 also only thirty-four countries exported kaolin with an export of 9.47 million tonnes. In the year 1995, main exporting countries were USA, United Kingdom, Brazil, Hong Kong, China, Czech Republic and France.

The description of the major exporting countries is given below.

11.2.1 United States of America : United states of America is the pioneer exporting country of kaolin. In 1991, it exported 2.88 million tonnes of kaolin which was 33 percent of the total export in the world. In 1992, the export increased by 4 percent than the preceding year and reached to 3.00 million tonnes which was 36 percent of the total export of kaolin in the world. However, there was a slight fall in the year 1993, when the export was 2.99 million tonnes accounting for 34 percent of the total export of kaolin in the world. Incidentally, it was one percent less than that in the previous year. In 1994, the country exported 3.18 million tonnes of kaolin which was 35 percent of the world's total export. This was 7 percent more than the country's export during 1993.

There was a further rise in the export of kaolin in 1995 by 2 percent when it reached to 3.24 million tonnes accounting for 43 percent of the total export of kaolin in the world.

Table - 11.1: Exports of Kaolin

(Tonnes)

Country	1991	1992	1993	1994	1995	1996
Austria	34931	28270	15716	9353	10800	—
Belgium-Luxembourg	123909	139226	165759	100191	197923	250146
Denmark	504	491	337	421	598	517
France	247032	256761	244852	273975	281358	—
Germany	262325	279886	267435	496760	354103	196066
Greece	34620	24179	9402	21095	12941	—
Italy	35324	31178	61064	37567	34831	—
Netherlands	166336	170451	158258	227888	157631	102372
Spain	144875	147504	94163	117571	138647	—
Sweden	974	1412	904	4088	10600	13753
United Kingdom (d)	2518303	2168572	2125129	2173888	2222316	1957761
Bulgaria (a)	20400	19000	29500	40000	47400	—
Czechoslovakia	366000	440000	—	—	—	—
Czech Republic	—	—	426488	345423	383498	361858
Hungary	—	2572	4398	4059	5529	4403
Poland	—	1866	1834	10220	11015	—
Russia (a)	—	5700	3700	—	100	—
Slovenia (a)	—	7200	4400	1900	1000	—
Soviet Union (a)	1200	—	—	—	—	—
Switzerland	245	257	10895	7089	143	286
Turkey	50761	63994	84666	189425	256907	190761
Ukraine (a)	—	—	9100	11800	17900	—
USA	2887608	3003994	2990206	3189995	3246515	3246749
Brazil	343006	335476	601337	524877	579810	601822
China (a)	683400	376978	419552	485721	439439	882146
Hong Kong	323580	400154	533300	479702	457193	261578
India (b)	25727	18175	9142	8658	6242	—
Indonesia	125125	137851	126146	157866	192983	—
Israel	10818	14572	5307	(a) 5200	—	—
Japan	11353	11245	10252	12769	10860	8108
Jordan	—	1102	522	1078	800	—
Korea, Republic of	37660	34419	65476	123510	108337	53579
Malaysia	131305	111952	161296	110784	125354	—
Taiwan	8779	6706	7263	6997	7486	—
Thailand	13117	16952	38098	26793	27281	—
Australia (c)	149647	132262	154487	145000	130000	—
New Zealand (c)	24107	18692	18206	19306	17787	15047

(a) BGS estimates, based on known imports into certain countries
(b) Years ended 31 March following that stated
(c) Years ended 30 June of that stated
(d) Dry weight

11.2.2 United Kingdom : United Kingdom is the second highest exporter of kaolin in the world. In 1991, the export of kaolin was 2.51 million tonnes which was 29 percent of the world's kaolin export during the year. There was a considerable decrease in the kaolin export in 1992 which was 14 percent less than that in 1992 and was 2.16 million tonnes. It was 26 percent of the world's export in 1992. There was a slight fall in export in 1993 by 2 percent to 2.12 million tonnes which was 24 percent of the world's total export of kaolin. The export of kaolin increased by 2 percent in the year 1994 and reached to 2.17 million tonnes which was 23 percent of the world's total export. The rise continued in the year 1995 by 2 percent and the export was 2.22 million tonnes, which was 23 percent of the world's export during 1995.

11.2.3 China : China is the third highest exporter of kaolin in the world. China exported 6,83,400 tonnes kaolin in the year 1991 which was 8 percent of the world's total export. The export was decreased by 45 percent in 1992 and was 3,76,978 tonnes which was 4 percent of the world's total export of kaolin. However, there was 11 percent rise in export of kaolin in the year 1993 and reached to 4,19,552 tonnes which was 5 percent of the world's total export in 1993. This rising trend continued in the year 1994 when the country exported 4,85,721 tonnes of kaolin accounting for 5 percent of the world's total export and was 15 percent more than the country's export in 1993. There was 10 percent fall in the country's export in the year 1995 when it exported 439,439 tonnes which was also 5 percent of the world's total export in the year.

11.2.4 Czechoslovakia : Czechoslovakia exported 3,66,000 tonnes of kaolin in the year 1991 which was four percent of the world's total export and fourth highest in the world. The export considerably increased in the year 1992 reaching 4,40,000 tonnes (increase of 20 percent) which was 5 percent of the world's total export. The export of kaolin was not recorded after the year 1992.

11.2.5 Hong Kong : Hong kong was the fifth highest exporter of kaolin in the world in 1991. There was 3,23,580 tonnes export of kaolin in 1991 which was almost 4 percent of the world's total export. The export increased to 4,00,154 tonnes (24 percent increase) and was 5 percent of the world's total export in 1992 The export was further increased to 5,33,300 tonnes in 1993 which was 6 percent of the world's total export and was 15 percent more than the country's export in the previous year. In the year 1994, the country's export decreased by 10 percent and was 4,79,702 tonnes which was 5 percent of the world's total export. The export was further decreased by 5 percent and reached to 4,57,193 tonnes which was 6 percent of the world's total export in 1995. In the year 1995 Hong kong became the third highest exporter of the kaolin in the world by exporting 4,57,193 tonnes of kaolin.

11.2.6 India : India exported 25,727 tonnes kaolin to different countries in the year 1991 which slumped in 1992 to 18,175 tonnes, which is 30 percent less than that in the previous year. This decreasing trend continued in 1993 and 1994 also when the export was 9,142 tonnes and 8658 tonnes, respectively. It exported only 6242 tonnes of kaolin in the year 1995.

11.3 Imports

In the year 1991 there were 52 countries in the world which imported kaolin amounting to 8.77 million tonnes. The main importing countries were Japan, Finland, German Federal Republic, Taiwan, Canada, etc. In the year 1992, three more countries recorded their import of kaolin; these were Croatia, Hungary and Slovenia. But Morocco and Peru had not recorded their import during 1992. In the year 1993 only 51 counties imported kaolin which further reduced to 42 countries in 1994 and only 14 countries in the year 1995.

Table 11.2 shows the country-wise and year-wise imports for the period from 1991 to 1996.

Table - 11.2 : Imports of Kaolin

(Tonnes)

Country	1991	1992	1993	1994	1995	1996
Austria	183517	214418	202896	222474	249000	—
Belgium-Luxembourg	405980	438736	499788	714738	644275	646593
Denmark	22703	15910	9776	9987	14587	16037
Finland	937236	1017452	1175689	1328205	1378081	—
France	418671	401173	399983	438057	444127	—
Germany, Federal Republic of	889568	918086	830079	741120	717388	633467
Greece	25078	28917	25114	32681	57137	—
Italy	703283	752479	751278	855168	886062	—
Netherlands	496870	545943	568795	596674	523965	509753
Portugal	56695	63211	41455	54935	76766	95805
Spain	281997	361606	330858	368212	453490	—
Sweden	399834	350992	360063	340208	400921	342964
United Kingdom	27463	24520	23273	21693	17377	37800
Croatia	—	25744	13992	9400	16213	14193
Czechoslovakia (c)	2300	700	—	—	—	—
Czech Republic (c)	—	—	1353	3963	3825	5846
Hungary	—	20428	30027	22554	26145	34027
Macedonia (c)	—	—	—	1100	900	—
Norway	102280	93813	145805	180269	252658	224811
Poland	58006	77379	75495	91997	91409	—
Romania	16883	17633	38733	47699	41602	54330
Slovenia (c)	—	27400	22800	21900	19600	—
Switzerland	87827	76765	75852	75601	78243	74682
Turkey	22262	32510	43044	61194	84717	85789
Yugoslavia (d)	(f) 14285	10363	—	—	—	—
Morocco	10559	—	—	—	—	—
South Africa	20904	24426	22969	36985	35081	—
Tunisia	34036	45176	38700	46590	44900	—
Zimbabwe (d)	1139	825	513	568	926	—

(Contd.)

Table - 11.2 : (Concld.)

Country	1991	1992	1993	1994	1995	1996
Canada	520562	530735	531079	626718	621166	599842
Mexico	114174	111189	128117	172002	151604	—
USA	3373	4221	7626	10786	12017	13728
Argentina	18146	20463	28692	24992	30924	—
Brazil	1194	1119	1628	2044	2372	—
Chile	10334	14307	10255	15462	22152	16463
Colombia	9750	12469	9732	11944	7899	—
Ecuador	4054	756	1937	7729	7946	—
Peru	1035	864	1395	2234	2369	—
Uruguay	4770	5682	5481	6436	5492	—
Venezuela	21153	31085	33413	27240	29365	—
Bangladesh (b)	9144	7702	9594	—	—	—
China	10500	10310	16844	25639	30805	37211
Cyprus	17850	7876	9926	16126	8393	16361
Hong Kong	274369	310295	556138	548899	405245	175803
Indonesia	56301	69595	74638	75597	132108	—
Iran (a)	25751	31670	17175	19214	—	—
Israel (c)	10000	10400	6900	10000	8800	—
Japan	1253735	1153223	1189611	1283769	1265419	1399224
Korea, Republic of	222853	205494	225961	249641	274433	264587
Malaysia	24366	27787	29270	34455	44200	—
Pakistan (b)	6715	9526	7883	8796	—	—
Philippines	21676	21996	39967	33804	34307	—
Saudi Arabia	4092	6385	4453	9749	—	—
Taiwan	844865	1015464	1361737	1722616	1468705	—
Thailand	40742	44628	121972	41751	45990	—
Australia (b)	11331	7119	11965	—	—	—
New Zealand (b)	8780	9045	8133	8657	10360	—

(a) Years ended 20 March following that stated
(b) Years ended 30 June of that stated
(c) BGS estimates, based on known exports from certain countries
(d) As from 1992 data is for Serbia and Montenegro only
(e) Including fuller's earth
(f) Data for the Federal Republic of Yugoslavia only

The total imports of kaolin in the world during 1991 was 8.77 million tonnes and Japan was the pioneer in importing kaolin during the year. In 1992 the imports was further increased by 5 percent than the previous year and it was 9.22 million tonnes. This rising trend continued in 1993 also when the world's total imports was 10.10 million tonnes which was almost 10 percent more than the total imports of world in the previous year. This rising trend discontinued in 1994, when the world's total imports was 9.7 million tonnes which was 3 percent less than that in 1993. There was a steep rise in kaolin imports in the world which went up to 11.19 million tonnes, almost 15 percent more than the world's total imports of kaolin in 1994.

The position of main kaolin importing countries in the world is described below :

11.3.1 Japan : Japan stood first in kaolin importing countries in the world during 1991 when it imported 1.23 million tonnes of kaolin which was 14 percent of the total kaolin imported in the world. This was decreased in the year 1992 by 8 percent when the imports was 1.15 tonnes and was 12 percent of the world's total imports. In the year 1993, Japan imported 1.18 million tonnes which was 3 percent more than the imports in 1992 and was 12 percent of world's total imports in 1993. There was a considerable rise in imports of kaolin in 1994 which rose to 1.28 million tonnes, about 8 percent more than the imports in the previous year and was 13 percent of the world's total imports during the year. However, the imports in 1995 was 1.26 million tonnes. Japan continued to lead the imports during this period.

11.3.2 Finland : Finland imported 9,37,320 tonnes of kaolin in 1991 which was slightly more than 10 percent of the world's total imports of kaolin during the year and was second highest in the world. The imports were 9 percent more in the year 1992 and was 11 percent of the world's total imports. The country imported 1.01 million tonnes of kaolin in 1992. This rising trend continued in 1993 also and the imports reached to 1.17 million tonnes which was 12 percent of the world's total imports in 1993. This import was 10 percent more than the import in 1992. The imports in the years 1994 and 1995, were 1.32 million tonnes and 1.37 million tonnes, respectively.

11.3.3 Germany, Federal Republic : Germany was the third highest importer of kaolin in the year 1991. It imported 8,89,568 tonnes of kaolin which was 10 percent of the world's total import in the year. There was 3 percent increase in import of kaolin in 1992 which reached to 9,18,086 tonnes accounted for almost 10 percent of the world's total imports in the year. However, there was 10 percent fall in the import of kaolin in the year 1993 which was 8 percent of the world's total imports and reached to 8,30,079 tonnes. This decreasing trend continued in the years 1994 and 1995 when it imported 7,41,120 tonnes and 7,17,388 tonnes of kaolin, respectively.

11.3.4 Taiwan : Taiwan was the fourth highest country in the world in respect of kaolin imports in the year 1991. The imports of kaolin by Taiwan was 8,44,865 tonnes which was slightly less than 10 percent of the world's total imports in the previous year. There was a considerable rise in import of kaolin in the year 1992 which increased by 20 percent and reached to 10,15,464 tonnes which was 11 percent of the world's total imports. There was a further rise in imports of kaolin in 1993 and 1994 reaching 13,61,737 tonnes and 17,22,616 tonnes, respectively and which were 8 percent of the world's total imports. However, the imports decreased by 15 percent than the previous year which was 14,68,705 tonnes in the year 1995. Even then Taiwan was the topmost importing country of kaolin in the world during 1995.

11.3.5 Canada : Canada imported 5,20,562 tonnes of kaolin in the year 1991 which was 6 percent of the world's total imports in the year. It imported 5,30,735 tonnes of kaolin in the year 1992 which was 2 percent more than that in the previous year and was six percent of the world's total imports in 1992. There was again a slight rise in imports in the year 1993 when the country imported 5,31,079 tonnes of kaolin which was 5 percent of the total imports of the world in the year. The rising trend of the kaolin import was continued in the year 1994 when import was 6,26,718 tonnes accounting for six percent of the world's total imports. However, there was a slight fall in the imports of kaolin in the year 1995 when it imported 6,21,166 tonnes, about one percent less than the imports in the previous year. However, this was the seventh highest importer in the world in 1995.

11.4 World Production of Kaolin

There were 56 countries which produced 23.2 million tonnes of kaolin in the year 1990. The production of kaolin increased to 24.1 million tonnes in 1991 from 54 countries. The production of kaolin decreased to 22.3 million tonnes in the year 1992 which is 3% less than that of 1991. This decreasing trend discontinued in 1993 when it rose to 22.8 millions tonnes. Further, it was slightly increased to 25.1 millions tonnes produced by 52 countries in 1995. Thus, there was a regular fall in the number of countries producing kaolin.

The production of kaolin both country-wise and year-wise is given in Table 11.3 (World Mineral Statistics 1991-1996).

It is seen from the table that the main producing countries of kaolin were USA, United kingdom, Korea, Brazil, Soviet Union and China. These countries altogether have produced chinaclay to the tune of about 72 percent of the total world production in the year 1994.

Table - 11.3 : Production of Kaolin

(Tonnes)

Country	1990	1991	1992	1993	1994	1995	1996
Belgium	175000	260000	325000	300000	300000	300000	300000
Denmark	17423	17057	3503	3500	3500	3500	3000
France	370130	343800	334000	295000	330000	345000	326000
Germany	601000	598000	578000	544000	600000	570000	550000
Greece	169986	189235	201705	89473	117254	66682	—
Italy	67321	57871	33017	76000	74608	87920	126000
Portugal (n)	108392	149788	194090	178285	181933	192530	200000
Spain (k)	423357	413000	305000	284382	337339	399248	340000
United Kingdom (a)	(i) 3037486	2911484	(l) 2502224	(l) 2460632	2530277	2585881	2281438
Albania	8256	2000	500	—	—	—	—
Austria	81265	72361	64733	64381	65837	56789	50000
Bosnia & Herzegovina	-	-	3000	3000	3000	3000	3000
Bulgaria	186467	106000	104000	110000	115000	115000	115000
Czechoslovakia (h)	533000	526000	598000	—	—	—	—
Czech Republic (h)	—	—	—	702000	651790	757949	741000
Finland	7026	6879	6700	8156	8156	12392	17204
German Democratic Republic	115000	—	—	—	—	—	—
Hungary (c)	22000	19000	7000	15000	12000	5000	—
Poland	48100	44100	42400	47900	52600	52965	71665
Romania	250000	250000	150000	200000	200000	150000	150000
Slovenia	—	—	15000	10000	10000	10000	—
Soviet Union (n)	1800000	1600000	—	—	—	—	—
Turkey	251182	219211	185675	138989	179775	489635	288238
Ukraine	—	—	1000000	1000000	1015000	950000	1000000
Yugoslavia, Federal Republic of	198513	190000	111782	37627	69927	56926	68460
Algeria	17993	21460	20844	27300	17000	24068	25000
Burundi	5281	6567	9668	5318	2331	4766	4500

(Contd.)

Table - 11.3 : (Concld.)

Country	1990	1991	1992	1993	1994	1995	1996
Egypt (d)	149000	151548	95693	78107	54175	70597	115409
Madagascar	485	496	756	700	700	1545	...
South Africa	132421	134485	131765	147349	131863	146587	144777
Tanzania	2021	1738	1360	477	541	596	1332
Mexico	156140	167238	144121	215510	193034	221685	253602
USA (e)	9143000	9574900	8735204	8830000	8770000	9480000	9530000
Argentina	33684	47115	43722	42052	50471	40010	44200
Brazil (b)	765826	850000	900000	1031100	1323443	1269468	1300000
Chile	32416	63083	59083	66939	73081	10845	--
Colombia (j)	540000	900000	900000	900000	--	--	--
Ecuador	7883	12015	18395	4230	6623	8000	7000
Paraguay	74000	74000	74000	74000	74000	66300	74000
Peru	8000	7100	5500	4778	7908	8233	14295
Venezuela	14636	35000	40811	32000	10345	6000	8000
Bangladesh (d)	7223	7338	2317	1637	2753	6597	7000
China	600000	700000	700000	800000	850000	900000	950000
India (i)	104000	113000	110000	129000	134000	160000	160000
Indonesia	160098	139915	230550	42365	53236	14373	15000
Iran	150000	150473	264083	254413	227650	265591	--
Israel	42212	53000	53000	40000	40000	40000	40000
Japan	164802	129942	122948	110318	138412	182122	141230
Jordan	38800	46200	34446	47174	47200	65998	--
Korea, Republic of	1446598	1755225	1856157	2328921	2675485	2792139	2800000
Malaysia	152972	186699	244573	254345	312628	404336	--
Pakistan	46947	44738	42180	37179	47894	30746	54860
Sri Lanka	7734	7622	14000	16000	7800	16000	7700
Taiwan	105084	92970	103071	126752	102822	20406	25083
Thailand (h)	208348	256276	304480	404029	425567	460629	554000
Australia (c) (d) (f)	363000	376000	250000	180000	200000	210000	190000
New Zealand	25435	21338	27520	26543	40720	13662	15000
World total	**23200000**	**24100000**	**22300000**	**22800000**	**23800000**	**25100000**	**24800000**

Notes :

(1) *In addition to the countries listed, Lebanon and Vietnam are believed to produce kaolin*
(a) Sales
(b) Including beneficiated and directly shipped material
(c) Including beneficiated material
(d) Years ended 30 June of that stated
(e) Sold or used by producers
(f) White clays; including kaolin and ball clay
(g) Washed and dried
(h) Beneficiated
(i) Beneficiated, excludes directly used natural kaolin
(j) Crude
(k) Washed
(l) Dry weight
(m) Includes lower quality kaolinite and halloysite
(n) Includes washed and unwashed kaolin

Source - World Mineral Statistics - 1991-1996.

The year 1996 was highly insignificant for the world kaolin industry even though it was marked by the arrival of two new major projects in Brazil. However, the production could not be increased and was 24.8 million tonnes in 1996.

The main producing regions for refined kaolin are from USA, UK, Germany, Czech Republic, Ukraine, China and Brazil. Other significant producing countries include France, Spain, Australia, Indonesia, Thailand and Malayasia[6].

11.5 World Scenario

During 1994, the major producing countries were United States of America, United Kingdom, Korea, Republic of, Brazil, Soviet Union, China, Thailand, France, Belgium and Spain with a total production of 22.8 m tonnes of kaolin. United States of America produced 8.7 million tonnes of kaolin which was 39% of the total world production during this period. Second largest producing country was United Kingdom which produced 2.6 million tonnes contributing to about 12% of the world's total production. Third largest producing country was Korea Republic with a production of 2.6 million tonnes of kaolin. Other important producing countries were Brazil and Soviet Union followed by Thailand and France. From the table 11.1 it is clear that Korea, Republic of, Brazil, China and Thailand had the rising trend in production of kaolin during 1990 to 1994. Colombia, Czechoslovakia and Spain had also produced kaolin during this period.

The country-wise description is given below.

11.5.1 United States of America

USA is the pioneer kaolin producing country in the world. The working of kaolin in USA began in the 17th century in North Carolina. Though USA is the largest producing country of kaolin, it is also the largest importing country indicating highest consumption of kaolin in that country.

In the year 1990, the production of kaolin was 9.14 million tonnes which was 39 percent of the total world production. The production rose to 9.5 million tonnes in the year 1991, followed by 8.73 million tonnes in 1992, but slightly improved to 8.83 million tonnes in 1993, which again came down to 8.77 million tonnes in 1994. Though there was a fluctuation in the production USA almost produced 39% of the world's total production throughout the period of 5 years.

USA imported 4221 tonnes of kaolin in 1992 which rose to 7626 tonnes in 1993, 10786 tonnes in 1994, 12017 tonnes in 1995 and 13728 tonnes in the year 1996. Import sources were Mexico 31%, China 20%, U.K. 20%, Canada 15% and other 14%[8]. The price of kaolin in USA was 115 dollar per ton in 1995.

11.5.2 United Kingdom

United Kingdom was the second largest kaolin producing country in the world during 1990 to 1994. It produced three million tonnes in 1990 which was 13% of the total production in the world. It slightly decreased to 2.9 million tonnes (12 percent in 1991, and further decreased to 2.50 million tonnes in 1992. However, it was slightly increased to 2.57 millions tonnes in 1993 and 2.65 million tonnes in 1994, maintaining the level of 12 percent of the world production during this period.

United Kingdom was also the second largest importer during 1990 to 1994. In 1992-93, it imported 92 tonnes of kaolin (41% of world's total imports), which rose to 110 tonnes in 1993-94 and 336 tonnes in 1994-95 (43% and 61% of the world's total imports, respectively). However, there was a sudden fall of imports of kaolin to only 59 tonnes in 1995-96 which was 14% of the total imports of kaolin in the world. The kaolin deposits in Cornwall in England are considered to be typical representatives of hydrothermal type.

11.5.3 Korea, Republic of

Considering the production of kaolin in the world in 1994, Korea, Republic of stood the third largest, whereas it was the fourth in 1990 after Soviet Union. This country had almost rising trend in the production during 1990 to 1994. The production of kaolin in 1990 was 1.44 million tonnes which was 6 percent of the total world production in 1990 which rose to 1.7 million tonnes (7%) in 1991, 1.85 million tonnes (8%) in 1992, 2.33 millions tonnes (10%) in 1993 and 2.6 millions tonnes (11%) in 1994.

From the import and export Table, it is seen that the Korea, Republic of is just a self-sufficient country in kaolin as it neither import nor export kaolin i.e. producing kaolin to their internal demand only and conserving the rest for use in future.

11.5.4 Brazil

Brazil was the 5th largest kaolin producing country in 1990. The production of kaolin in 1990 was 7,65,826 tonnes which was 3 percent of the total kaolin production in the world. The production of kaolin in the year 1991 increased to 8,50,000 tonnes (3.5%) further rose to 90,000 tonnes in 1992, 9,50,000 tonnes in 1993 and 1 million tonnes in 1994. Brazil continued to produce almost 4 percent of the total world production of kaolin during 1990 to 1994 and stood fourth largest kaolin producing country in the world as per the world production. The country was also known as self-sufficient country in respect of kaolin as it never imported or exported kaolin.

11.5.5 China

Kaolin is known as chinaclay and China is the first country using kaolin for ceramics. During 1994, in the production of kaolin, China stood sixth in the world. In the year 1990, it produced 6,00,000 tonnes of kaolin which was only 2.5 percent of the world production and 7,00,000 tonnes in 1991 (3 percent). The same trend continued for 1992, 1993, and 1994 also which accounted for 3 percent of the world's total production. Though China was exporting kaolin in the second half of the 19th century, recent figures for its export are not available.

11.5.6 Thailand

Thailand produced 2,08,348 tonnes of kaolin during 1990 which was only 1 percent of the world's total production and the production rose to 2,56,276 tonnes in the year 1991 with a marginal rise. This trend was continued in the year 1992 with production of 3,04,480 tonnes giving 1 percent of the world's total production of kaolin. In the year 1993, the production was considerably higher and reached to 3,97,000 tonnes which was 2 percent of the world's total production. In the year 1994, there was a record highest production which was 2 percent of the world's total production and accounted for 4,15,000 tonnes.

11.5.7 India

Though India has a sufficient reserves of kaolin in consideration of the world's deposit, it was not producing even 1 percent. In the year 1990, the production was 1,04,000 tonnes which rose to 1,13,000 tonnes in 1991, slightly decreased to 1,10,000 tonnes in 1992 and again had a marginal rise in the year 1993 producing 1,29,000 tonnes. This rising trend continued in the year 1994 when the production rose to 1,50,000 tonnes.

Considering the resources, India can enhance the production of kaolin and could attempt to export kaolin to nearby countries, if it improves the quality as per the customers' requirement.

'Indal' decided to develop a new kaolin project at the Bagru plateau of Lohardaga in Bihar state, which will supply kaolin for paper, plastics, refractories and paint markets[3].

India also exported 25,727 tonnes kaolin in 1991 and 18,175 tonnes in 1992, respectively which is 30 percent less than that in the previous year. The decreasing trend continued in 1993 and 1994 also when export was 9,142 tonnes and 8658 tonnes, respectively. It exported 6242 tonnes of kaolin in the year 1996.

11.6 Prices

The price of kaolin is based on the grade, its washed quality or refineness. Grading is primarily based on whiteness and grit content. The prices of kaolin during the period 1992-93 to 1994-95 are given in Table 11.4.

Table - 11.4 : Prices of Kaolin, 1992-93 to 1994-95

(In Rs. per tonne)

Grade	Market	1992-93	1993-94	1994-945
Washed Clay Grade I (Lump)	Ex-Factory, Sarojininagar, Delhi	710	870	970
Washed Clay Grade II	---"---	125	110	140
Processed				
Jyoti Ist	F.O.R. Nileswar (Kerala)	1050	1050	1100
Neelex Ist	---"---	1160	1280	1400
Neelex W. I.	---"---	1500	1500	NQ
Jyoti W. I.	---"---	1250	1250	1250
Super fine lump (Bagged)	F.O.R. Suri/Sainthia (West Bengal)	710	830	830
Super White Power No. I (Bagged)	---"---	1500	1620	1620
Super White Powder No. II	---"---	1200	1320	1320
Super fine Powder (Bagged)	---"---	950	1070	1070
T. T. 75 Washed lump	Ex-Factory Antela (Rajasthan)	1230	1400	1700
Ceramic Grade	F.O.R. Kundara (Kerala)	550	550	550
Powder	---"---	900	900	900
Natural dried	---"---	4000	4000	3800
76 Special	F.O.R. Kochuveli (Kerala)	3950	3950	3950
BCK Powder	---"---	3700	3700	3700
KCG lump	---"---	2800	2800	2800
Kerala special	Exmine Nileswar (Kerala)	1400	1500	2000
Indian Clay	---"---	1150	1250	1600

Source : Indian Minerals Yearbook, 1997.

The prices of kaolin in U.S.A. during 1991 to 1995 were 96, 107, 107, 116, and 115 dollars per tonne, respectively[8].

The prices of kaolin in United Kingdom during 1996 are given below :

Refined. FOT, ex Cornwall	Price per ton
Filter	£ 50-75
Coating	£ 75-120
Ceramic Grade	£ 40-80
Porcelain Grade	£ 80-125
Ex Georgia Plant - Filler,	
bulk	£ 75-92
Coating-bulk	£ 89-174
Sanitary ware grade, bagged	£ 55-65
Tableware Grade, bagged	£ 120
Calcined bulk	£ 405-465

Sources : *Industrial Mineral, May 1995*[5].

11.7 Future Outlook

11.7.1 World

The paper industry continues to be the major consumer of refined kaolin accounting for 80% of total consumption in the major consuming regions. Over the years kaolin has lost market share to other white minerals particularly calcium carbonate and talc, but the paper industry's demand for mineral coating and filler pigments has been sufficiently strong to provide continuing growth for kaolin producers [7].

Only a small number of deposits are suitable for the production of high quality paper coating grades of kaolin and thus the major producers and exporters in US, U.K., Brazil and until recently Australia can be considered as members of an elite club. The International Monetary Fund, although constantly revising short term forecasts, still maintained GDP growth of industrial countries to be 2.5% and transition economies 4% to 5% and overall world growth to be around 4.0% for the remainder to this decade[8]. Paper and board requirement is predicted to increase by over 3% per annum in the world up to 2010 with printing and writing work growing at almost 4.5%[9].

World demand of coating kaolin is predicted to increase to a figure approaching 10.6 millions tonnes by the year 2005. This means an additional kaolin requirement of 3.5 million tonnes[9].

11.7.2 India

Considering the increasing population in India, its demands will increases in ceramics day by day besides increase in demand from cement industry also.

A projection of demand on the basis of current consumption rate of 6% per annum up to 1996-97 and at a growth rate of 7% per annum from 1997-98 to 2001-2002 has been made[7].

Expected Trend of Demand for Kaolin

(In tonnes)

Year	1997-98	1998-99	1999-2000	2000-2001	2001-2002
Demand	433,801	464,167	496,659	531,425	568,625

Demand projections for the year 2006-07 and 2011-12 are 79,526 and 1118,571 tonnes, respectively.

In India mostly simple techniques of levigation and sedimentation in a series of tanks are adopted with a view to degrit the material and produce the required products.

In recent years, significant developments have taken place in processing of kaolin and some of the plants abroad are adopting even cryogenic magnetic separation, air flotation, etc. Some special processing like delamination, calcination and chemical surface treatment are also adopted to produce special products. Detailed laboratory test work is essential to develop suitable process for removing the grit and other deleterious impurities and to bring about improvement in physical properties like brightness, whiteness and also in particle size distribution. It is strongly recommended that kaolin industry should adopt modern techniques of mineral beneficiation and produce high quality clay products including collined and surface coated varieties which will fetch higher revenue.

Indian Bureau of Mines, Central Glass and Ceramic Research Institute and Indian School of Mines (Dhanbad) have carried out test work through beneficiation on a number of samples and obtained high quality products. These facilities need to be supplemented with modern evaluation equipments and instruments. Hybrid products of kaolin with other minerals are also produced for application in paper industry. In fact commodity grades are giving way to value added products.

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