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PRINCIPAL CLAY DEPOSITS

of

HYDERABAD STATE



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by

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PRINCIPAL CLAY DEPOSITS OF HYDERABAD STATE

INTRODUCTION

by

Syed Kazim

Clay is one of the most widespread and earliest substances to be utilised by man. Even so, it is difficult to offer a precise definition of clay. The term is applied to describe earthy substances consisting mainly of a group of hydrous aluminous silicates which are plastic in the wet condition and become stone like when heated to a high temperature.

Formation of clays.

Clays are found associated with almost all rock formations of all ages and are also being formed even today; they are the products of rock destruction due to the process of weathering and/or by the action of solutions of igneous or surface origin on fresh rocks. In either case the alteration product is residual in character and is termed *residual clay*. Ordinarily, *residual clays* are derived from (a) granite, gneiss, pegmatite, etc., (b) basic igneous rocks, e.g., Deccan Traps, (c) limestone or dolomite, (d) slate or shale, and (e) sandstone. The *residual clays* when exposed are sometimes removed and redeposited elsewhere by a transporting agent, like water. Such deposits are described as *transported*

clays. They may be (a) deposits in still water, *e.g.*, fire clays, shales, etc., (b) deposits from running water, *e.g.*, alluvium, loam, (c) glacial deposits such as the boulder clays, and (d) wind deposits such as loess. Obviously, clay is not a single mineral but a mixture of minerals, original or decomposed, with appreciable percentage of the substances in colloidal condition. Kaolinite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$), anauxite ($\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 2\text{H}_2\text{O}$), halloysite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot n\text{H}_2\text{O}$), montmorillonite ($\text{Al}_2\text{O}_3 \cdot (\text{Mg. Ca.}) \cdot 0.5\text{SiO}_2 \cdot n\text{H}_2\text{O}$), are examples of some clay minerals.

Classification of clays.

The geologist and the minerologist classify clays from the view point of their origin; they are primarily concerned with the processes leading to their formation. The metallurgist and the constructional engineer on the other hand, are interested in clays with regard to their refractory nature, *i.e.*, ability to resist high temperatures. The ceramist considers their working properties (plasticity, dry strength, etc.), drying behaviour (shrinkage, tendency to warp), and firing qualities (vitrification, colour, ability to take finish, hardness). The principal kinds of clays are kaolins, ball clays, bond clays, flint fire clays and low refractory buff burning clays.

The term kaolin or china clay is used to describe a group of clays consisting mainly of the mineral kaolinite. They are characteristic for their fine grain, bright white colour in the raw and fired condition and refractoriness.

Although kaolins occur sufficiently pure in nature, they are often subjected to a pre-treatment to ensure uniform quality. They are normally treated in a carefully controlled sequence of operations which include washing, addition of electrolytes,

centrifuging, elutriation and bleaching. These improved methods of treating kaolins give a product of excellent quality. They are mixed with ball clays to give the required strength.

Ball clays are sedimentary plastic clays. They are dark in the unfired condition due to the presence of organic impurities and fire to a dull or cream white colour. They are mixed with other clays to impart strength, improve their workability and aid in the vitrification process.

Flint fire clays contain a relatively high percentage of alumina. Their plasticity is low with ordinary tempering methods but is increased by wet pan grinding in water. They are used in the manufacture of refractory wares.

Bond clays have a high plasticity and a long range of vitrification. They find extensive use in the manufacture of graphite crucibles, glass refractories and similar products.

Low refractory buff burning clays are found in several grades. Their hardness varies from the hard shale like varieties to soft types. They are used in the manufacture of architectural terra-cotta.

Several clays have been given names designating their use, such as potter's clays, bleaching clay, pipe clay, retort clay, sagger clay, rubber clay, etc.

Uses of clays.

Clay products are of numerous types and play many essential as well as humble roles in the industrial and domestic life of a nation. They are indispensable in construction, in metallurgical practice, agricultural and chemical processes, sewage disposal, power transmission, heating appliances, and in

varied household uses. Raw clay finds extensive use as a filler in paints, paper, etc. A good deal of our industrial activity centres round clay.

It is obviously very difficult to completely list the various uses of clay and its products. Some of the requirements of the different categories of clay users are indicated below:—

Household uses.—Pottery, earthenware, art wares, containers, fire kindlers, porcelain stoves, scouring soaps, and oil cloth. Clay is sometimes used in medicines.

Building works.—Bricks, cement, roofing tiles, sanitary wares, drain pipes, floor tiles, wall tiles and pavers.

Heavy chemical industry.—Electrolytic cells, crystallisation dishes, acid proof tanks, chemical apparatus (such as crucibles, evaporating dishes, etc.).

Textile industry.—Fire bricks and refractories for boilers, acid proof tanks, thread guides, tension sleeves, winder guides, shuttle pins, and other porcelain accessories.

Glass and enamel works.—Special refractories for building furnaces, muffles, etc.

Iron and brass casting.—Cupola blocks, plumbago crucibles, fire bricks, silica refractories, refractory crucibles and high alumina refractories.

Electrical equipment.—Transformer housings, spark plugs, suspension insulators, pin type insulators, fuse cut-outs, coil forms, nails, knobs, tubes, cleats, outlet boxes, sockets, neon signs, etc.

Heating equipment.—Pyrometer tubes, ceramic burners and radiant heaters.

Miscellaneous uses.—Filler in cloth, paint, paper, rubber, soaps, oil cloth, crayons and card-board. Balls and bricks for grinding, dental porcelain, precision gauges, blasting nozzles, pressing and extrusion dies, rubber forms (for gloves) soda fountain accessories, humidifiers, battery cases, gas masks, etc.

The above data illustrate the multifarious uses of clays and their products. No effort would then appear to be too great when it is directed to study and utilise the available clay resources to the most appropriate uses. It is likely that no one clay may suit the requirements of all ceramic wares. Inferior grades of clay can be purified or admixed with others of better quality to give a material of the desired properties.

Clay deposits in Hyderabad and their development.

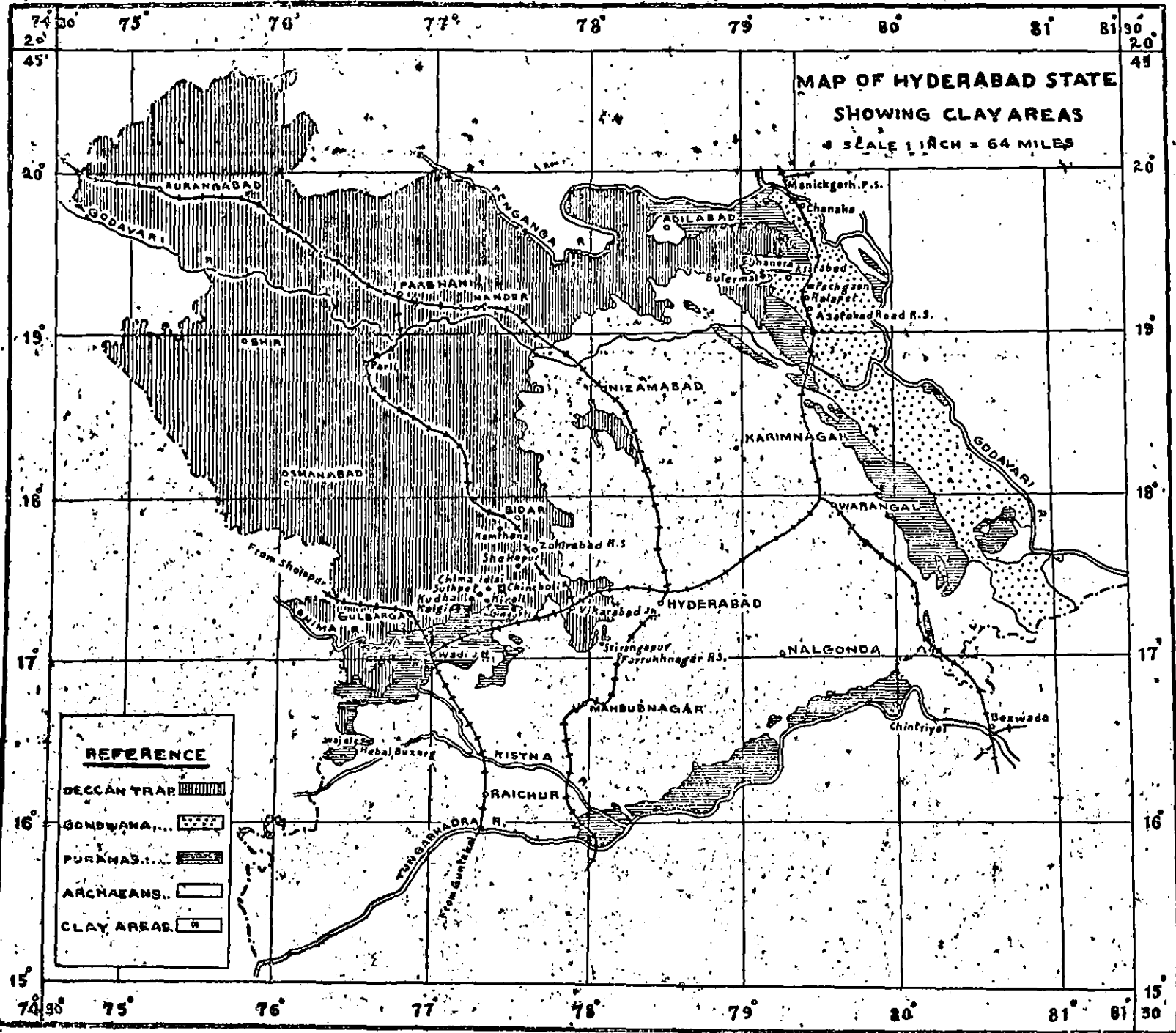
Several clay deposits were located during the course of the geological survey of the State. Preliminary prospecting was carried out by different officers of the department of some of the more important deposits, viz., at Pachgaon, Kamthana, Chintriyal, Shekapur and Srirangapur. The results of their inquiry and an estimate of quantities available are summarised by Mr. L. S. Krishnamurthy in Part I of this bulletin.

Some of these deposits were being worked by villagers in a small way for daubing houses or like purposes. Others were sought to be worked out by more enterprising persons without, however, any knowledge of their properties and their suitability for any particular industry. The local clays are

mostly used for the manufacture of pipes, sanitary-ware, porcelain and potteries. It was therefore, considered desirable to investigate the chemical and physical properties of the clays from the major deposits and publish them for the information of the general public. Dr. K. Venkateswara Rao has determined the working properties, drying behaviour and firing qualities for each of these clays and the results of his investigation are given in Part II of this bulletin. An attempt is also made to indicate the appropriate use to which each of the available clays may be employed.

In 1947, the Government in order to conserve the clays available for use in industries within the State issued an order prohibiting the export of clay outside Hyderabad State. The output of clay was 1885 tons in 1947 and 2439 tons in 1948. Some china clay is also imported every year from Travancore and U.P.

It is hoped that the information presented in this bulletin might help to establish new industries or extend or otherwise aid those already existing.



[To face page 7.

PART I.
GEOLOGY OF THE PRINCIPAL CLAY DEPOSITS OF
HYDERABAD STATE.

by

L. S. Krishna Murthy.

The origin, formation and classification of clays has been summarised in the introductory chapter (pp. 1-3). The geological classification of clays according to their origin, and their associated rock formations are referred to therein. Classification of clays according to their physico-chemical characteristics and utilisation has also been mentioned.

§1. *The principal clay deposits of Hyderabad are associated with the following formations:—*

A. Residual:—

1. Derived from Archæan rocks, granite and pegmatities—kaolin or china clay.
2. Derived from basic igneous rocks, *i.e.*, Deccan Trap—laterite and associated clays.

B. Transported:—

3. Associated with Purana sedimentary rocks.
4. Associated with the Upper Gondwanas (Kota-Maleri beds).

The accompanying map (Plate I) shows the principal clay deposits and the formations in which they occur.

A. Residual clays associated with Archaean rocks.

Coarse granites and pegmatites have in favourable places given rise to a white clayey material due to decomposition of felspars. Such sporadic occurrences are noted in numerous localities where the white clay is often mixed with calcarious material, giving rise to white calcarious earth. Due to aerid conditions there appears to be more disintegration than decomposition and the kaolinised felspar is invariably associated with fine disintegrated quartz and felspar grains and calcarious material resulting in a white calcarious gritty clay. Such alteration of the granites and pegmatites are particularly noted along the Deccan Trap contact and its immediate neighbourhood. Instances of such occurrences are in Nizamabad, Atraf-i-Balda and Mahbubnagar districts along the granite and Deccan Trap boundary.

§2.- *Srirangapur clay.*

One such principal occurrence of a kaolinised clay area was noted and prospected near Srirangapur, Pargi taluk, Mahbubnagar district, about 9 miles from Farruknagar Railway station on the Shadnagar (Farruknagar) Pargi road.

The clay deposit is in granite, about half a mile south of the Deccan Trap margin, and occupies a sloping ground about 520,000 sq. ft. in extent.* The clay is intimately associated with decomposed white

*S. K. Mukherjee—Unpublished report of the prospecting work done on Srirangapur clay deposits.

pegmatites and granites and also coarse pink granite. The granites are practically free from ferruginous constituents and small quantity of biotite, on decomposition, sometimes stains the clay in patches of brown. The other rocks to the north of the area are Deccan Trap, infra-trappean cherts, and laterite. The detrital lateritic red clayey material sometimes forms the overburden in some of the pits.

It is very probable, for the following reasons, that the white clay is a residual product of granite and pegmatite decomposition:

- (a) The clay occurs as a gritty unconsolidated mass without any bedded structure, the grits being undecomposed fragments of felspar and quartz.
- (b) Nearby all the pits reveal veins of decomposing pegmatite and large and small boulders of granite practically undecomposed at the core and increasingly decomposed and richer in clay towards the periphery.
- (c) The clay has not been found to occur in the absence of pegmatite.

It is very likely that in places, a quantity of colloidal silica derived from the chert beds to the north might have got mixed up with the white clay deposit, altering its composition and character from those of a typical kaolinised clay. Investigations reveal a poor bentonitic character in these clays and a high absorption value.

About 23 pits of various dimensions and depths were excavated in the area to obtain the necessary data for calculating the possible extent and quantity of clay available. It was found that the depth of

decomposition varied from 9' to 24' with an average of 11'4". The extent of the clay is practically limited to the east and south as the trial pits in these directions showed little decomposition and almost absence of clay. But towards N. and N.W., the clay occurs at various depths indicating further extent of the clay in the same direction with a rapid increase of overburden making quarrying expensive.

It has been estimated that the total quantity of clay available is about 36,27,972 c.ft. which with a foot tonnage of 20, would approximate to 1,80,000 tons of clay. The average thickness of the deposit is 11' 4" under an overburden of about 2'. As has been already pointed out the clay is gritty, and washing tests have given only about 50 per cent. yield of finer white clay.

B. Residual clays associated with laterites formed by the decomposition of Deccan Trap rocks *in situ*.

Laterite is a residual product of rock decay (Deccan Trap lava flows) in tropical climates subjected to alternating dry and wet seasons. Extensive areas of Deccan Trap rocks are capped by laterite in Bidar, Osmanabad, Nizamabad, parts of Atraf-i-Balda, Medak and Gulbarga districts. The Deccan Trap rocks are lateritised generally above 2000' contour and form broad plateau; the thickness of lateritic layer varies widely from a few feet to sometimes even more than a 100' as in the Ananthagiri and Bidar plateaux. The lateritic layer is composed of a scoriaceous looking ferruginous material at the top, grading downwards to purplish aluminous bole, lithomarge and other variegated clays and ochreous material, the whole resting on a decomposing trap flow. The lower zone of clays consists of light coloured clays and ochres, sometimes with layer of white or dull white clays.

The white clay is quarried as it finds a ready market in ceramic and other industries. Such extensive deposits of white clay are found near Kamthana about 7 miles S.W. of Bidar and near Shekapur about 6 miles S. of Zaheerabad, in Bidar district.

§3. *Kamthana, (Bidar) Clay.*

It has been estimated that near Kamthana kaolin or china clay occurs over an area of at least 10 acres and has an average thickness of 2'. The clay is worked by sinking pits 2½ ft. square about 30 ft. apart, to a depth of 28 ft. through the laterite. These pits are connected with each other by tunnels and cross cuts 3 ft. wide. A good quantity of the material has been extracted and the area may be expected to yield a further considerable quantity.

This clay appears to be a very good quality kaolin and should be reserved for high class ceramic industry and as a paper and textile filler.

§4. *Shekapur clay.*

The Shekapur clay area is about 1½ miles S.S.W. of the village, 6 miles south of Zaheerabad railway station on Vicarabad-Bidar line. The site is in a shallow depression at the base of a lateritic ridge forming the 2000' contour. An area of about 2 acres has been leased out for quarrying white clay which is mostly used in the Deccan Porcelain and Potteries Ltd., Tandur, about 28 miles south of the clay site. The white china clay occurs in laterite with an overburden of 8'-12' of coloured lateritic clays and ochres. The dull white clay band is about 10' thick as seen in the working tunnel. This layer of white clay is much impregnated with earthy impurities lightly coloured and dirty white material which have

to be separated while quarrying and the purer white clay stacked separately. No prospecting was conducted, but the area appears to be capable of yielding a very considerable quantity of the material.

C. Secondary or transported clays, associated with the Purana sedimentary rocks.

§5. *Chintriyaal clay.*

Chintriyaal ($16^{\circ} 38'$, $79^{\circ} 28'$) is situated on the north bank of the Krishna river, about 20 miles S.S.E. of Huzurnagar, the headquarters of the taluk of the same name, in Nalgonda district. The Krishna river here forms the southern boundary of Hyderabad State. About 8 miles south of Huzurnagar the granites are unconformably overlaid by the Palnad sedimentaries which extend up to the Krishna and beyond.

The rocks of area comprise sandstones and shales at the base, succeeded by limestones.* The sandstones which are usually coarse-grained and gritty occur at the base of the series and are overlain by shales which are grey, greenish or reddish in colour fairly compact and somewhat slaty. The limestones are light to dark grey in colour and compact and are intercalated with hard, compact shales or shaly limestones. The rocks have a general N.E./S.W. strike, with a S.E. or S.S.E. dip varying from 10° to 30° .

White clay occurs at some places in the shaly rocks, either in pockets and lenses, or as well defined and fairly consistent beds as near Chintriyaal. It

*P. V. Rao—Unpublished report of prospecting work on Chintriyaal clay area.

cannot be said with any certainty whether the bedded clay was formed due to alteration and partial leaching out of soluble constituents from some of the original rocks, or was deposited as such along with the other rocks.

The site prospected for clay is about 2 miles E.N.E. of Chintriyal. The area in which the clay bed occurs is undulating with low mounds rising above the cultivated fields. The principal rocks are limestones occurring as bands intercalated with thin hard shaly limestones and less frequently with shales. Quartz veins and blows are common. At the north end the clay bed is seen to have died out passing imperceptibly into earthy material, while at its south end the clay bed is faulted down by a normal fault.

The outcrop of the clay bed has been traced to over a length of 1200 ft. with an average workable thickness of 2 ft. The white clay bed is invariably overlain and underlaid by impure and mixed clay of varying thickness. The clay is compact and pure white or yellowish white in colour often showing laminated structure. The dip of the clay bed is 5°-8°, slightly steeper nearer the outcrop than away from it. The overburden should naturally increase along the dip. It has been estimated assuming that it should be possible to work the clay economically up to a depth of 30'-35' the total tonnage of clay will be about 32,000. It would be 80,000 tons if the greenish clay above or below the white clay bed is also included. Quarrying operations cannot be continued indefinitely along the dip as a point would soon be reached when further progress would be uneconomical.

Chintriyal clay has been characterised as good quality china clay.

D. Clay beds associated with the upper Gondwana beds.*

§6. Pachgaon clay.

Good fire clays are reported from the upper Gondwana, *e.g.*, Jubbalpore. Similar clays are found in the upper Gondwana (Kota-Maleri group) near Pachgaon in Adilabad district. The clay area is about a mile south of Pachgaon, about 4 miles N.E. of Asifabad Road station on the Kazipet-Balarshah line. The clay bed is reported to occur over an area of about a square mile with an average thickness up to 6 ft. The clay is pale grey to pale pink in colour, smooth, even grained and mostly free from grit.

The clay occurs in almost horizontal beds underlying coarse sandstone. The sandstone is sometimes ferruginous and the clay below may thus become stained and contaminated by iron impurities. In some of the pit sections it has been noticed that below an overburden of 5' of soil there is a bed of clay 2½' thick seamed with red stained ferruginous clayey material. Below this is a 5' bed of good clay, pale pink in colour. The upper portion of the clay bed contains embedded nodular iron stones widely distributed. A portion of the Pachgaon clay area which has been examined is estimated to contain about 80,000 tons of good clay. Taking the whole clay area and assuming the possible extension of the clay bed over an area of about 1 sq. mile, the reserves would approximate to 5 to 6 million tons.

This clay has been found to be suitable for the manufacture of refractory articles.

*S. H. Gowher—Unpublished reports on Pachgaon, Katrala, Butarnal and Dhanora clay areas.

Similar white clay deposits have been noted at Ralapet and Kattrala. A clay bed 1-1½ ft. thick, is found at the bottom of the cliffs cut by the Pedda Vagu, near Kattrala, about 5 miles N.W. of Pachgaon. But the heavy overburden about 25' thick makes it uneconomical to work.

Clay beds were also noted in the upper Gondwanas near Butarmal and Dhanora in Asifabad taluk. At Dhanora, the bed of clay is thin and not economical to work. Prospecting work near Butarmal about 12 miles N.W. of Asifabad has revealed the existence of a pale-pink to pale-yellow clay about 7' thick over an area of 12 acres. The overburden is about 8'. The total estimated quantity approximates to 2 lacs of tons.

A similar occurrence has also been reported from Chanaka, about 2 miles S.E. of Rajura railway station.

PART II

PHYSICO-CHEMICAL PROPERTIES OF THE CLAYS.

by

K. Venkateswara Rao.

Scope of the work.—The investigations herein described were carried out with a view to obtain a better picture than hitherto available of the physico-chemical properties of clays from the principal clay deposits in the State, *viz.*, at Pachgaon, Kamthana, Chintriyal, Shekapur and Srirangapur.

At the stage when the writer took up work on this subject, data about these clays was mostly confined to their chemical composition and a few remarks on their refractory nature. The necessity of a general examination involving the determination of their grain size, plasticity, modulus of rupture, porosity, breakdown potential, etc., was apparent. This could only be attempted as dictated by the limitations of the available accessories and not as required by the logical necessities of interpretation.

§1. Properties of the clays.

1. *Chemical composition of the clays.*

The clays were sampled according to standard practice. The chemical composition of the raw and washed clays was determined on a moisture free basis (after drying them in air oven at 105°C).

Results obtained by the writer are shown in the accompanying tables along with the data reported by others for purposes of comparison.

TABLE I.

Chemical composition of Pachgoan clay.

%	1	2	3	4	5
Loss on ignition ..	8.75	9.04	8.18	6.80	5.20
SiO ₂ ..	62.12	60.70	62.00	65.62	61.84
Al ₂ O ₃ ..	24.61	25.80	24.40	21.68	23.54
Fe ₂ O ₃ ..	1.90	1.17	2.80	1.71	2.70
TiO ₂ ..	..	..	..	1.10	..
CaO ..	0.90	1.00	1.00	..	1.80
MgO ..	0.95	1.20	trace	0.85	1.70
MnO ..	..	..	..	0.05	..
Na ₂ O ..	trace	trace	..	0.05	0.91
K ₂ O ..	1.10	1.21	..	2.17	1.08

1. Raw sample.....analysis by writer.
2. Washed sample..... do
3. Sample washed or raw (?).. analysis by Chief Chemist,
Government Industrial
Laboratory, Hyderabad.
4. do .. analysis by United Steel Co.,
Sheffield.
5. Raw sample..... analysis by Ceramic Research
Scholar, C.L.S.I.R., Hyder-
abad-Deccan.

TABLE II.

Chemical Composition of Kamthana Clay.

%	1	2	3	4
Loss on ignition..	13·86	14·01	15·10	9·73
SiO ₂ ..	45·51	45·27	44·20	44·38
Al ₂ O ₃ ..	39·47	40·17	40·20	36·90
Fe ₂ O ₃ ..	1·08	0·96	trace	2·00
TiO ₂ ..	..	..	..	..
CaO ..	0·16	0·12	0·20	1·42
MgO ..	0·09	trace	..	3·37
Na ₂ O ..	0·12	0·10	..	} 2·20
K ₂ O ..	0·20	0·18	..	

1. Raw sample analysis by writer.
2. Washed sample do
3. Sample washed or raw (?) analysis by Chief Chemist,
Government Industrial
Laboratory Hyderabad.
4. Raw sampleanalysis by Ceramic Research
Scholar, C.L.S.I.R., Hyderabad.

TABLE III.

Chemical Composition of Chintriyal Clay.

%	1	2	3	4
Loss on ignition..	5.0	6.8	8.70	..
SiO ₂ ..	68.7	62.2	60.50	69.80
Al ₂ O ₃ ..	28.0	24.8	22.89	26.10
Fe ₂ O ₃ ..	3.5	3.0	} 4.85	traces
TiO ₂ ..	..	..
CaO ..	2.5	2.2	1.82	0.80
MgO ..	1.8	1.5	2.40	0.50
Na ₂ O ..	} 0.9	0.4	} *	..
K ₂ O ..		0.8		

1. Raw sampleanalysis by writer.
2. Washed sample do
3. Raw sampleanalysis by Ceramic Research Scholar, C.L.S.I.R., Hyderabad.
4. Sample raw or washed (?) analysis by the Chief Chemist, Government Industrial Laboratory, Hyderabad.

* Value of alkali chlorides : 4.80%

TABLE IV.

Chemical Composition of Shekpur Clay.

%	1	2	3
Loss on ignition ..	12.28	12.84	9.10
SiO ₂ ..	38.01	38.82	34.08
Al ₂ O ₃ ..	45.24	48.11	42.27
Fe ₂ O ₃ ..	1.26	1.71	} 7.90
TiO ₂ ..	..	..
CaO ..	2.79	2.54	2.67
MgO ..	0.70	0.65	1.58
Na ₂ O ..	} 0.82	0.28	1.60
K ₂ O ..			0.26

1. Raw sampleanalysis by writer.
2. Washed sample do.....
3. Raw sampleanalysis by the Ceramic Research Scholar, C.L.S.I.R., Hyderabad.

TABLE V.

Chemical Composition of Srirangapur Clay.

%	1	2	3	4	5
Loss on ignition..	15.08	17.16	10.30	12.24	4.90
SiO ₂ ..	54.32	52.19	59.66	56.30	57.22
Al ₂ O ₃ ..	23.67	23.25	20.22	21.42	24.80
Fe ₂ O ₃ ..	} 8.22	} 8.08	8.50	8.69	} 1.90
TiO ₂ ..			0.83	0.42	
CaO ..	1.40	1.60	1.59	1.79	3.57
MgO ..	3.02	3.20	3.47	3.72	5.10
Na ₂ O ..	..	..	} 0.54	0.34	*
K ₂ O ..	..	..	

1. Raw sample analysis by writer.
2. Washed sample do
3. Raw sampleanalysis by Government Test House, Alipore.
4. Washed sample do
5. Raw sampleanalysis by the Ceramic Research Scholar, C.L.S.I.R., Hyderabad.

* Value of alkali chlorides : 0.65%

TABLE V (a).

Rational analysis of the clays calculated from the ultimate composition.

Clay	% Felspar	% Quartz	% Clay matter	% Rest
Pachgaon clay ..	7.58	26.92	65.5	..
Kamthana clay ..	2.20	..	97.80	..
Chintriya clay ..	5.16	36.54	58.30	..
Shekapur clay*	..	..	..	..
Srirangapur clay ..	2.04	23.71	74.25	..
Travancore clay†	1.70	..	97.6	0.70

* The alumina content in this clay is in excess of the silica percentage.

† Data quoted from pamphlet entitled "China Clay" issued by Messrs Associated Textile Engineers, 43, Forbes street, Bombay.

The chemical composition of the clay, by itself, at best gives only a rough indication of its nature and utility. Two clays which show marked resemblance in their chemical composition may show a wide contrast in their physical properties. Nevertheless, certain inferences can be drawn from the ultimate composition remembering, however, that some exceptions need not necessarily render the conclusions invalid.

The chemical composition of the raw and washed clays is given in Tables I-V. The generality of the results obtained by the writer are in close agreement with those of others. Washing of the clays appears to effect a slight increase in the alumina percentage

and a concomitant alteration (decrease) in the silica content. It will be seen from the results that the composition of the Kamthana clay (Table II) shows a percentage of silica and alumina approaching quite closely to kaolinite. It is also interesting to note that for the Shekapur clay (Table IV) the alumina percentage is greater than that required for the kaolinite composition. This excess alumina makes the clay very refractory. Ries remarks (5) that in such cases an adjustment of the silica alumina ratio gives a eutectic whose melting point lies at cone 26 (1575°C).

The total fluxes (Fe_2O_3 , FeO , CaO , MgO , Na_2O , & K_2O) are high for the Chintriyal clay (8.70%) and very low for the Kamthana clay (1.36%). Despite the greater flux percentage, the Chintriyal clay is found to be more refractory than the Srirangapur clay (Table 21); this is attributable to the texture and the distribution of the relative constituents in the clays.

Owing to the appreciable percentage of alumina in the Shekapur clay (Table IV), its extraction from the clay may offer interesting possibilities. The separation of silica by artificial means will be a handicap to a high alumina clay when used in competition with bauxite. But when the clay is used for the direct production of aluminium or an aluminium silicon alloy, the handicap may not be so serious. Results of experiments conducted by the Aluminium Co. of America (Badin) with a view to study this possibility have shown that aluminium can be obtained directly, by evaporation in the blast furnace, from the calcined bauxite. Further investigation on this process is, however, necessary to study the optimum conditions of manufacture and its commercial feasibility.

2. *Sieve analysis of the clays.*—An approximate idea of the percentage of silicious impurities in a clay may be had from its sieve analysis.

A representative portion of the sample was initially powdered to pass a 30 mesh sieve and 25 grams of it was kept for two hours at 110°C and then weighed. It was then placed in about 500 cc. of distilled water and allowed to stand for 2 hours. The gritty matter was separated from the clay by gently rubbing the material between the fingers under water. The suspension of clay in water was then screened through a 200 mesh sieve and the oversize particles washed thoroughly to remove the clayey matter completely. The residue on the mesh was then dried at 110°C and weighed.

The results for the different clays are given in Table VI.

TABLE VI.

Clay	% moisture loss at 110 C°	% impurities retained on the 200 mesh sieve	% pure clay
Pachgaon clay	1.4	4.0	94.6
Kamthana clay	1.3	20.0	78.7
Chinriyal clay	1.0	25.5	73.5
Shekapur clay	2.8	42.8	54.9
Srirangapur clay	8.5	48.6	42.9*

* The report of the Government Test House, Alipore, however, states that pure clay matter was found to be 75.55 per cent. This disparity may be due to the non-representative nature of the sample sent to them.

3. *Grain size analysis of the clays.*—A determination of the grain characteristics of the clay is very useful in computing the surface factor and estimating the properties of the non-plastic ingredients in it. Grain size is important in casting slips, since the larger particles settle earlier than the finer ones. The grain size of the various ingredients is generally adjusted to ensure uniform distribution and settling. The use of clay as a filler in textiles, etc., depends upon the fineness of its particles.* The particle size is also found to exert an influence on the base exchange properties of the clays.

The classification of small particles by water is based upon Stoke's law which states that a sphere will sink in a liquid at a velocity directly proportional to (i) the square of its diameter, (ii) difference in the densities of the sphere and the liquid and inversely proportional to (iii) the absolute viscosity of the liquid. It may be expressed as follows:—

$$r^2 = \frac{g}{2} \times \frac{uh}{gt(\Delta - \delta)}$$

where r : the radius of the settling particle (cm.)

h : the distance travelled by the particle (cm.)

u : the absolute viscosity of the liquid (poise)

t : time (secs.) for particle to fall h cms.

Δ : density of the falling particle

δ : density of the settling medium

g : acceleration due to gravity (980)

A shape factor has to be introduced if this relationship is to be applied to mineral grains. On the

*Hauser maintains that the hydration properties of the filler are relatively more important than its particle size in effecting greater retention by the paper stock [*Brit. Chem. Abst.*, 1937 (B) p. 1036].

assumption that the average density of the clay particles is 2.63* settling in water ($\delta : 1$; $u : 0.01$) and making allowance for the shape factor, the equation reduces to

$$d = \sqrt{v/700}$$

where d is the diameter of the settling particles and v their velocity. This equation has been verified and found to hold good in the case of quartz grains. The classification of the particles by water is effected either by (i) decanting or siphoning off part of the grains held in suspension after a given time of settling or (ii) elutriation at different water velocities. Both the methods have serious shortcomings and the simpler of them is as accurate as the other.

A dozen pyrex glass test tubes (1" x 12") are marked with a ring (on each) at the place determined by the meniscus when 20, cc. of water is placed in each of them. Another ring is marked on each of the tubes about an inch below the top and an even number of centimeters above the lower ring.

The clays to be examined were previously screened through a 200 mesh sieve, and the material passing through the sieve is evaporated to dryness and kept at 110°C for 5 hours. One gram of clay, thus dried, is separately weighed and placed in each of the tubes. To each tube is also added a few drops of ammonia to deflocculate the clay. The tubes are then filled to the upper ring with distilled water, shaken vigorously and let stand. At the end of a definite interval (2 minutes) the suspension in the first tube is siphoned down to the lower ring. The suspension in each of the other tubes is also likewise removed at different intervals. The residue left in

*These determinations are made before ascertaining the specific gravity of the clays. (Cf. Table XIII).

the tube is washed, evaporated to dryness and weighed.

Calculations.—

Let w : the number of grams of solid matter originally contained between the rings of a tube,

w_1 : number of grams of solid matter originally contained below the lower ring,

w_2 : number of grams of solid matter at the bottom of the tube after siphoning off the part between the rings.

Then

$w_2 - w_1$: amount of clay settled in time t

and

$\frac{w_2 - w_1}{w} \times 100$: percentage of solid matter that settled from the zone between the rings.

These percentages are plotted against their respective times and a smooth curve is drawn through the points. From each of these points a tangent to the curve is drawn and extended to intersect the ordinate. The scaled distances between the successive intercepts represent the percentage of material of the size range given by the Stoke's equation for the corresponding velocities indicated by the abscissa of the points from which tangents were drawn.

The amount of material sedimented (P) in a given time (t) comprises of (a) particles whose size would have permitted their reaching the bottom zone even if they had started from the upper ring, (b) particles which would reach the bottom zone only because they had started from some intermediate points. Since according to Stoke's law, the velocity of the particles is constant, the sediment

$$P=S+t \times dP/dt.$$

where S is the amount of sediment contributed by particles in (a) group and $t \times dP/dt$ is the amount of sediment given by particles in (b) group (plate II, Fig. 1). A typical example will now be considered. For the Pachgaon clay (Table VII), two points a and b on the curve give the following measurements:—

	a	b
Time (from origin) ..	8	16
Total percentage settled ..	15.8	81.9
Tangent intercept ..	8	42
Difference between tangent intercepts	34	

The distance between the rings of the tube is 230 mm., and the velocities corresponding to a and b are $230/8 \times 60 = 0.4792$ and $230/16 \times 60 = 0.2395$ respectively.

From the simplified Stoke's equation the particle size corresponding to these velocities is given by

$$d_1 = \sqrt{0.4792/700} = 0.02668 \text{ mm.}$$

$$d_2 = \sqrt{0.2395/700} = 0.01649 \text{ mm.}$$

The conclusion then is that there is 34 per cent. of material (difference between tangent intercepts) between the sizes 0.0267 mm. and 0.0165 mm.

The data, thus obtained, for the grain size of the different clays is given in Tables VII-XI.

[Statement.

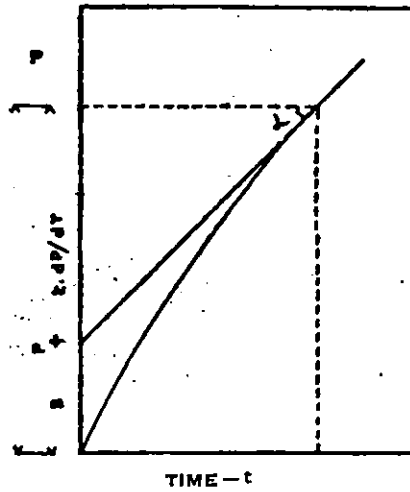


FIG. 1. GRAIN SIZE OF THE CLAYS.

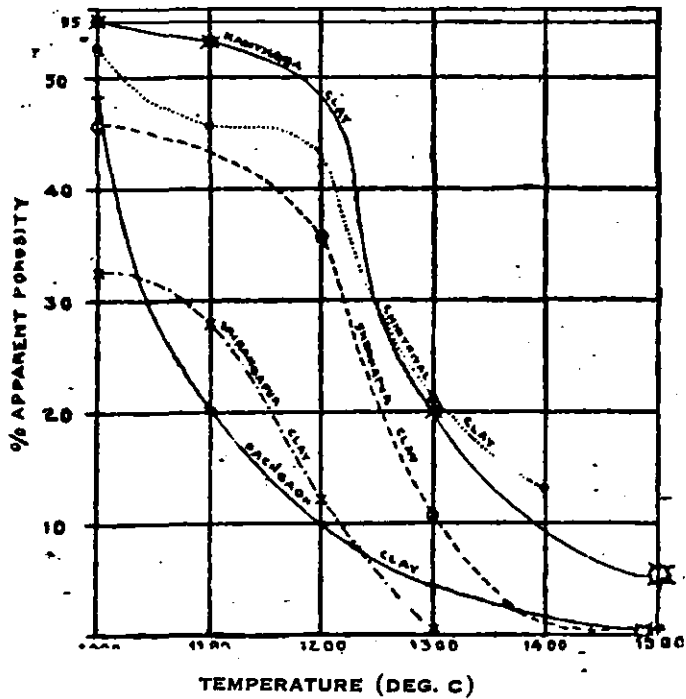


FIG. 2. VARIATION OF APPARENT POROSITY WITH TEMP. FOR THE CLAYS.

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TABLE VII.

Grain size analysis for Pachgaon clay.

No.	Time in minutes	Weight of clay settled	% of clay sedimented	Velocity (mm/sec) 280/t	Tangent intercept	Diameter (mm) $\sqrt{v/700}$
1	0	0.165	..	..	..	..
2	2	0.250	9.8	1.916	4	0.05281
3	4	0.274	11.9	0.9585	6	0.08701
4	8	0.30	15.8	0.4792	8	0.02668
5	16	0.85	81.9	0.2895	42	0.01649
6	32	0.88	85.6	0.1198	48	0.01808
7	48	0.90	88.8	0.07986	56	0.01069
8	64	0.95	94.1	0.0539	82	0.00878
9	120	0.99	98.7	0.0288	99	0.00642

TABLE VIII.

Grain size analysis for Kamthana clay.

No.	Time in minutes	Weight of clay settled (gms.)	% of clay settled	Velocity (mm/sec) 185/t	Tangent intercept	Diameter (mm) $\sqrt{v/700}$
1	0	0.2612	..	..	..	..
2	10	0.4934	31.4	0.215	10	0.0175
3	40	0.8744	88.0	0.056	65	0.00894
4	80	0.8948	87.5	0.028	82	0.00684
5	120	0.9214	89.8	0.019	90	0.00522

TABLE IX.

Grain size analysis for Chintriyal clay.

No.	Time in minutes	Weight of clay settled (gms)	% of clay sedimented	Velocity (mm/sec) 220/t	Tangent intercept	Diameter (mm) $\sqrt{v/700}$
1	0	0.2170	.. ..	..	..	..
2	2	0.2540	4.78	1.881	2	0.05116
3	6	0.3480	16.09	0.7005	5	0.03164
4	12	0.3700	19.54	0.3058	10	0.02088
5	24	0.4800	39.96	0.1526	14	0.01477
6	48	0.7500	68.06	0.0763	38	0.01044
7	165	0.8240	77.52	0.0222	77	0.00564
8	200	0.8840	85.17	0.0183	83	0.00512

TABLE X.

Grain size analysis for Shekapur clay.

No.	Time in minutes	Weight of clay settled (gms)	% of clay sedimented	Velocity (mm/sec) 180/t	Tangent intercept	Diameter (mm) $\sqrt{v/700}$
1	0	0.22	..	..	..	..
2	2	0.76	69.33	1.5	60	0.04629
3	6	0.94	92.3	0.5	86	0.02678
4	8	0.95	93.56	0.375	90	0.02314
5	16	0.96	94.86	0.189	96	0.01644
6	32	0.97	96.16	0.094	96	0.01159
7	48	0.97	96.16	0.062	96	0.00934
8	64	0.97	96.16	0.047	96	0.00819
9	120	0.97	96.16	0.025	96	0.00597
10	200	0.97	96.16	0.015	96	0.00468

TABLE XI.

Grain size analysis for Srirangapur clay.

No.	Time in minutes	Weight of clay settled (gms)	% of clay sedimented	Velocity (mm/sec) 180/t	Tangent intercept	Diameter (mm) $\sqrt{v/700}$
1	0	0.15	..	..	..	..
2	2	0.32	20.0	1.5	16	0.04629
3	6	0.38	27.06	0.5	18	0.02673
4	8	0.42	31.77	0.375	20	0.02814
5	16	0.49	39.91	0.189	22	0.01644
6	32	0.60	52.94	0.094	30	0.01159
7	48	0.64	57.65	0.062	32	0.00934
8	64	0.82	78.44	0.047	42	0.00819
9	120	0.84	81.17	0.025	76	0.00597
10	200	0.91	89.41	0.015	86	0.00468

4. *Purification of the clays.*—It will be seen from Table VI that the amount of clay matter (indicated by the quantity passing a 200 mesh sieve) varies for each clay over an appreciable range (94-42%). In many industries only clay of a high degree of purity can be employed. The purification of clay from silicious and other impurities is therefore a matter of much importance.

Clays may be purified by a variety of methods depending upon the use to which they are intended and the availability of the necessary equipment. Sifting, washing (levigation or elutriation), air-fotation and colloidal peptisation are the four methods usually employed for the purification of the clays. When one of the first two methods (mentioned above) is employed, the clay is always associated with fine particles of sand. Their complete removal (in the washing process) can only be accomplished

at the expense of some clay which also settles along with the fine sand. Peptised clay slips, on the other hand, remove the sand and other gritty particles, which do not go into suspension* and allow them to settle down more rapidly than in the case of ordinary water slips. Besides the process is relatively cheap. Some preliminary experiments were therefore conducted with a view to determine conditions of peptisation and flocculation under which the refining process could be carried out with advantage.

For each of the clays investigated the coarse impurities were removed by screening them through a 30 mesh sieve. The comparative effects of sodium carbonate, caustic soda and ammonium carbonate were examined. One gram of the clay was shaken thoroughly with 10 cc. of each of the aqueous solutions containing varying concentrations of the alkalis (mentioned above). The peptised slip was allowed to stand overnight, the supernatant liquid siphoned off, the residue dried and weighed. The percentage of peptised slip is calculated by difference. These results are given in Table XII. It will be seen that the effect of the peptising agents, under the concentrations studied is appreciable only in the case of Pachgaon clay. For others, more detailed investigations with the use of alkali concentrations varying over still smaller magnitudes (and controlling the pH of the dispersion medium) and some protective colloids may yield fruitful results.

The peptised clay slip is found to be flocculated by means of a 10% solution of calcium chloride or sodium chloride.

*The possibility of the colloidal silica passing into the slip cannot be ruled out.

TABLE XII.
Purification of the clays.

Percentage Concentration of Alkali	Percentage of clay peptised with		
	Na_2CO_3	NaOH	$(\text{NH}_4)_2\text{CO}_3$
<i>Pachgaon clay</i>			
..	88	83	88.
00·09	60	65	80
0·18	64	70	80
0·16	79	75	50
0·20	67	94	88
0·23	66	82	40
0·26	60	84	40
0·29	48	54	85
0·31	45	80	80
0·33	40	80	80
<i>Kamthana clay.</i>			
0	85	85	85
0·09	42	28	40
0·18	40	25	25
0·16	35	25	25
0·20	35	20	27
0·23	40	48	85
0·26	41	88	40

TABALE XII.—(contd.).

Percentage Concentration of Alkali	Percentage of clay peptised with		
	Na_2CO_3	NaOH	$(\text{NH}_4)_2\text{CO}_3$
0·29 ..	82	80	54
0·81 ..	80	80	53
<i>Chintriyal clay.</i>			
0 ..	10	10	10
0·09 ..	11	18	11
0·18 ..	14	15	11
0·16 ..	14	14	12
0·20 ..	20	23	11
<i>Shekapur clay.</i>			
0 ..	6	6	6
0·09 ..	8	12	10
0·18 ..	14	10	8
0·16 ..	20	15	12
0·20 ..	17	15	14
<i>Srirangapur clay.</i>			
0 ..	20	20	20
0·09 ..	17	15	10
0·18 ..	14	16	12
0·16 ..	12	20	12
0·20 ..	18	22	15

5. *Specific gravity and other properties of clays.*

TABLE XIII.

Clay	Colour of raw sample	Action of water	Specific gravity
Pachgaon clay	Pale grey	.. Crumbles to a fine powder, non-gritty.	2·606
Kamthana clay	White	.. Crumbles to a fine powder,	2·423
Chintriya clay	White	.. Does not crumble, greasy feel.	2·587
Shekapur clay	Light brown	.. Does not crumble, gritty.	2·368
Srirangapur Clay.	Light cream	.. Crumbles to a coarse powder*, no swelling.	2·352

* Similar observation was reported by the Government Test House, Alipore.

6. *Plasticity.*—Plasticity is the most obvious characteristic of a piece of wet clay. It is usually defined as that “property which enables a material to be deformed continuously and permanently without rupture during the application of a force which exceeds the yield value of the material.” So long as a clay contains an adequate quantity of water, it is plastic and may be moulded into articles of any desired shape. But once the water is removed completely, the clay loses its plasticity and is stone like.

Considerable divergence of opinion exists in regard to the causes which produce plasticity. The presence of water, in the combined as well as in the free state, the fineness of the particles, the molecular

attraction between clay and water, the existence of colloidal substances in clay have all been suggested as factors, operating individually or simultaneously, giving rise to plasticity. It has not been possible to assign any one single cause to plasticity.

There is also no generally agreed method for determining the plasticity. Several methods have been suggested from time to time; of these, the method adopted by Bingham (5, 6), appears to be the best. The writer could however determine only the Atterberg's Plasticity number and water absorption.

The difference between the water contents of the flow limit and the rolling limit give the Atterberg's Plasticity Number; the higher its value the more plastic the clay.†

The rolling limit is determined by rolling the clay in a stiff mud condition into threads between the hands; clay is added till the threads crumble. The water content (A) is determined by heating it to constant weight at 110° C for about three hours. The flow limit is determined by making the clay into a paste till it is so stiff that two separate portions barely touch each other when kept in a dish and sharply tapped against the hand. The water content (B) is again determined as before. The difference between A and B gives the Atterberg's Plasticity Number (Table XIV).

Water absorption is also considered as a measure of the plasticity. The sample under examination was accurately weighed before and after keeping in

†This method of determining the plasticity is very arbitrary since the personal equation is high. Besides "it does not put the proper distinction between the plasticity of clays which are workable in the stiff mud machinery and the sticky varieties which require large quantities of water to develop plasticity."

a desiccator, containing 10 per cent. sulphuric acid for 24 hours. Water absorption is calculated in terms of the dry weight of clay (Table XV).

TABLE XIV.

	ATTERBERG'S PLASTICITY NUMBER FOR	
	Raw sample	Washed sample
Pachgaon clay	10	13
Kamthana clay	21	40
Chintriyal clay	10	11
Shekapur clay	12	26
Srirangapur clay	22	44

TABLE XV.

	PERCENTAGE WATER ABSORPTION * BY	
	Raw sample	Washed sample
Pachgaon clay	1.7	2.0
Kamthana clay	1.5	1.7
Chintriyal clay	0.8	0.9
Shekapur clay	2.8	2.9
Srirangapur clay	2.0	11.0

* The average room temperature during these tests was 80° C.

7. *Permeability of the clays.*—The readiness with which a clay permits a liquid or gas to pass through it is known as permeability. It is measured by the rate at which certain liquids permeate through the substance of unit dimensions under unit pressure.

The permeability of clays to water is determined in an apparatus essentially similar to Schurecht's permeameter (10). It consists of a glass tube 2.5×20.0 cm.) fitted with rubber stoppers at either end. The clay to be tested is mixed with water to normal consistency and then pressed into a cylindrical hole of 1.0 cm. diameter in the lower rubber stopper. The tube is then filled with distilled water up to a definite mark and stoppered. The quantity of water permeated is obtained by noting the volume of water necessary to bring the water level to the original mark. It will be seen from results in Tables XVI and XVII that the permeability factor is far from being constant for the clays examined. The permeability, however remains constant for the first six days tends to increase, then decreases and finally increases to a certain value at which it remains practically constant thereafter (Plate III, Fig. 1). The magnitude of variation in permeability is maximum for Chintriyal clay and minimum for Pachgaon clay.

[*Statement.*

PLATE III.

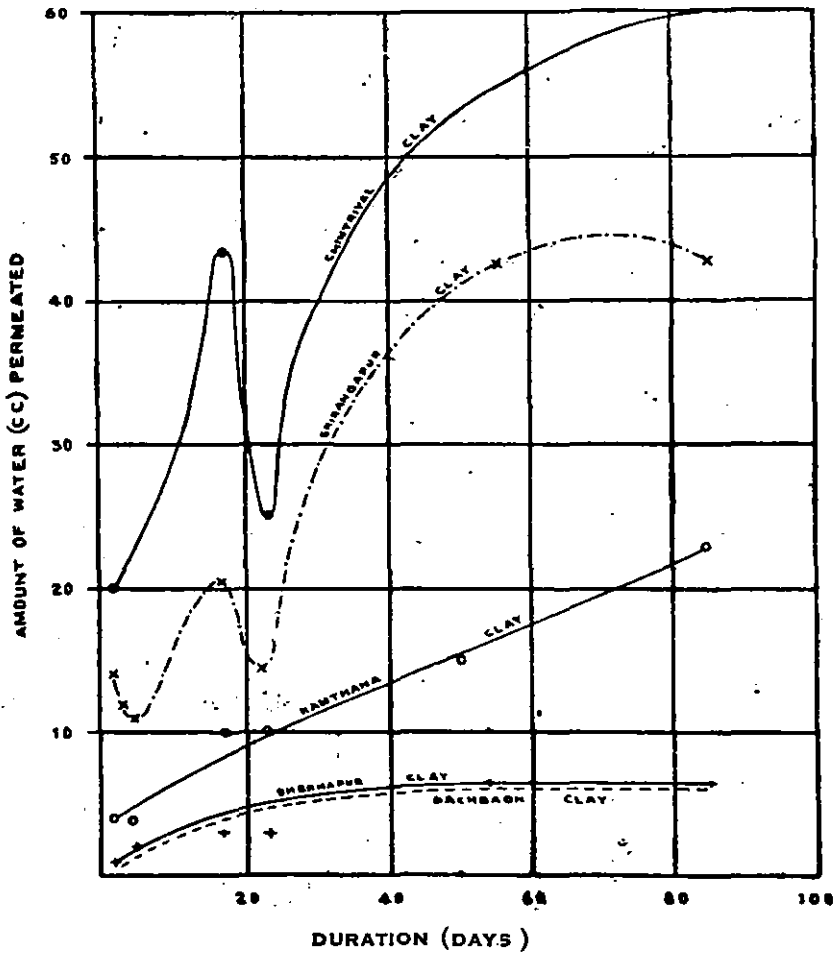


FIG. 1. PERMEABILITY OF THE CLAYS TO WATER

[To face page 39.]

TABLE XVI.

Permeability of the clays.

Duration in days	VOLUME OF WATER (IN C.C.) PERMEATED THROUGH				
	Pach- gaon clay	Kamthana clay	Chintriyal clay	Sheka- pur clay	Sriranga- pur clay
2 ..	1.2 (0.6)	6.0 (3.0)	20.0 (10.0)	1.6 (0.8)	15.8 (7.6)
4 ..	...	..	..	..	18.8 (8.5)
6 ..	1.8 (0.8)	6.0 (1.0)	22.8 (8.8)	1.7 (0.8)	11.0 (0.8)
16 ..	2.8 (0.17)	10.5 (0.6)	44.6 (2.8)	3.0 (0.2)	21.0 (0.8)
28 ..	2.5 (0.1)	9.8 (0.4)	25.7 (1.1)	2.5 (0.1)	16.5 (0.7)
58 ..	8.8 (0.16)	17.8 (0.8)	52.7 (1.0)	8.0 (0.15)	48.0 (0.8)
85 ..	8.8 (0.1)	28.6 (0.8)	60.0 (0.7)	8.9 (0.1)	48.6 (0.5)

NOTE.—Numbers in brackets indicate permeability factor (P) obtained from the expression $P=W/T$, where W is the amount of water passing through in T days.

TABLE XVII.

Permeability of the clays.

Clay	Volume of water (cc) originally introduced in the apparatus	Volume of water (c.c.) permeated in 85 days	Percentage of water permeated
Pachgaon clay	62·0	8·3	13·39
Kamthana clay	65·0	23·6	36·31
Chintriyal clay	60·0	60·0	100·0
Shekapur clay	61·0	8·9	14·59
Srirangapur clay	70·0	43·6	62·34

Shrinkage.—All clays shrink more or less on drying and heating. It is mainly but not entirely due to the removal of water from the clay by evaporation. The amount of contraction depends upon the rate at which the clay is dried; rapid drying tends to develop a crack in the dense clays. The use of acid waters is reported to reduce the shrinkage while the alkali waters increase it. It would appear that as the water is removed, any that remains draws the clay particles closer by means of surface tension into a smaller and denser mass. Usually the linear shrinkage of a clay may vary in different directions. For this reason it is desirable to know the volume shrinkage also.

Sand and like materials counteract the shrinkage and are generally added in clay ware for the purpose. The added material renders the mixture

relatively more porous and facilitates drying as well, and reduces the incident danger of cracking. It also allows the clay to keep its shape during burning but decreases its tensile strength.

8. *Linear air-shrinkage*.—A straight line is ruled on the bricklet* ($6'' \times 1'' \times 1''$) with two cross-lines at definite distance (8 cm.) apart. The clay is air dried and kept in an oven at 65°C for four hours. The distance between the two cross lines is measured; it is then kept at 105°C for 5 hours and the distance between the cross lines noted. The linear air-shrinkage is computed in terms of the wet length.

TABLE XVIII.

Clay	Wet length (cm.)	Length after keeping at 65°C (cm.)	Percentage of shrinkage at 65°C .	Length after keeping at 105°C . (cm.)	Percentage of shrinkage at 105°C .
Pachgaon clay ..	8.0	7.4	7.5	7.3	8.8
Kamthana clay..	8.0	7.5	6.0	7.5	6.0
Chintriya clay ..	8.0	7.9	1.0	7.8	2.5
Shekapur clay ..	8.0	7.8	2.5	7.8	2.5
Srirangapur clay	8.0	7.2	10.0	7.1	11.0

9. *Volume air-shrinkage*.—The volume of the freshly molded test piece ($6'' \times 1'' \times 1''$) is determined by the method of Schurecht using an instrument

*In all these experiments the raw clay is powdered to pass through a 30 mesh sieve, made into a paste with ordinary tap water and the mold wetted with a little kerosene.

similar to the direct reading overflow meter. The bricklet is thoroughly dried, soaked for 12 hours in kerosene of the same specific gravity as that used in the volume determination and its volume again determined.

TABLE XIX.

Clay	Percentage volume shrinkage.
Pachgaon clay ..	25
Kamthana clay ..	20
Chintriyal clay ..	6
Shekapur clay ..	11
Srirangapur clay ..	30

10. *pH value of the clays.*—The hydrogen ion concentration of the clay slips will be helpful in the purification of the clays by the method of colloidal peptisation. *pH* is defined as

$$pH = \log_{10} \frac{1}{[H]}$$

The *pH* value of the clays was determined with an L and N *pH* indicator assembly, using 0.5 per cent. clay slips.

TABLE XI.

Clay	<i>pH</i>
Pachgaon clay ..	5.0
Kamthana clay ..	5.1
Chintriyal clay ..	6.85
Shekapur clay ..	5.8
Srirangapur clay ..	5.6

11. *Porosity of the clays.*—The porosity of a clay is usually defined “as the volume of the pore space between clay particles, expressed in percentages of the total volume of clay and depends upon the shape, and size of the particles making up the mass.”

Following the classification of pores into open and closed pores two types of porosity are recognised: the true porosity and the apparent porosity. The former only represents the volume of the open pores, the latter includes both. The determination of the volume of the closed pores is carried out by indirect methods. The apparent porosity is easily determined.

Porosity of the fired clays determines their suitability for the manufacture of different articles; it has an important bearing on their mechanical strength and insulating properties. Porous substances are comparatively light and soft; vitrified ones dense and hard. In certain types of articles such as light sound proof partitions clays of high porosity are preferred. An important property of porous ware is their ability to dry readily without much risk of cracking.

The rate of vitrification is shown by a series of porosity tests on the material at different temperatures. The clay was molded into cones of form and shape similar to the Seger Cones, dried first at room temperature, and subsequently at 110°C for 5 hours. The samples were fired in a high speed electric furnace at definite temperatures,* soaked for 4 hours threat and the furnace switched off.

*The initial temperature of the furnace in all these determinations was about 450-500°C and the rate of heating was far from being uniform. A temperature of about 800°C was reached within 1½ hours of starting the furnace (even when it was started from the room temperature); it was 120°/hour thereafter. It was the minimum rate of heating at which the available furnace could be operated.

The samples were however retained in the furnace and allowed to cool gradually for 16 hours. The apparent porosity of the samples was next determined (Table XXI). The colour of the fired samples is given in Table 22.†

The pyrometric cone equivalent could not be determined for want of the standard cones and a furnace which could be operated at the rate prescribed by standard practice.

TABLE XXI.

Variation of apparent porosity with temperature for the different clays (cf. PLATE II, FIG 2).

Clay	1000°C	1100°C	1200°C	1300°C	1400°C	1500°C
	%	%	%	%	%	%
Pachgaon clay . . .	48·52	20·05	6·46	6·02	5·56	0·18
Kamthana clay ..	54·95	54·6	52·70	20·2	5·16	0·16
Chintrial clay ..	51·84	45·81	44·91	20·7	18·98*	..
Shekapur clay ..	45·68	42·21	36·98	10·6	0·7	0·7
Srirangapur clay ..	31·85	28·79	12·60	1·59*	..	..

† The refractory tests were carried out at M/S Praga Tools Corporation Factory due to the kind arrangement made by the Chief Technical and Industrial Adviser, Hyderabad Government.

* Fused.

12. *Variation in the colour of clays fired at different temperatures.*

TABLE XXII.

Clay	1000°C	1100°C	1200°C	1300°C	1400°C	1500°C
Pachgaon clay ..	Light Yellow	Yellow	Yellow	Yellow	Yellowish white	Yellowish white
Kamthana clay ..	Dull white	Dull white	Dull white	Dull white	Yellowish white	Yellowish red
Chintriyaal clay ..	Yellowish white	Yellowish white	Yellowish white	Yellowish white	Brownish white	..
Shekapur clay ..	do	do	do	do	Light green	Light green
Srirangapur clay ..	Light brick red	Brick red	Brick red	Red	..	..

Strength of the clays.—The strength of dry raw clay has an important significance in problems connected with the handling, molding and drying clay products. A strong clay withstands shocks and strains in handling. A knowledge of the clay strength enables us to estimate the quantity of the non-plastic material it can carry.

13. *Modulus of rupture of the clays.*—The traverse strength (or modulus of rupture) is the resistance which a clay bar offers to a load applied at right angles to its length.

The clay was ground to pass a 30 mesh sieve and the requisite quantity of water added to it to give a proper consistency. It was stored in a damp jar for

about 24 hours. A piece of the plastic clay was then cut from the lump, placed in a mold and firmly pressed into shape. The excess clay was removed with a knife. The molds were 7 inches in length and 1 inch in cross-section. The bars were dried first at room temperature, then at 65°C and finally at 110°C to constant weight. The bars were broken by adding weights to a holder fastened to a stirrup fitted at the centre of the test piece. The dimensions of the test piece were measured at the point of failure and the modulus of rupture (R) computed from the formula

$$R = 3wl/2bd$$

in which w is the load applied in pounds, l the distance between the supports in inches, b the breadth of the bar in inches, and d the depth of the bar in inches.

The results of these tests are given in Table XXIII.

TABLE XXIII.

*Modulus of rupture for the raw clays**

Clay. :	lbs./sq. inch.
Pachgaon clay ..	270
Kamthana clay ..	98
Chintriya clay ..	60
Shekapur clay ..	83
Srirangapur clay ..	63

14. *Crushing strength of the clays.*—The crushing strength is the force required to crack or break an article in compression. The clay samples were

*The author is indebted to Prof. Mohan Raj and Mr. G. Rama Rao for kind assistance in determining the mechanical properties of the clays at the Osmania Technical College.

made into cubes of about $1\frac{1}{2}$ inches side, air-dried and then fired at 1200°C . The side was accurately measured and the crushing strength determined.

TABLE XXIV.

Crushing strength of clays fired at 1200°C .

Clay.	lbs./sq. inch.
Pachgaon clay	4500
Kamthana clay	2240
Chintriya! clay	1840
Shekapur clay	2240
Srirangapur clay	1120

15. *Tensile strength of the clays.*—The tensile strength of a clay is the resistance it offers to rupture when pulled apart.

The tensile strength is measured by molding the kneaded clay into briquettes of form and shape similar to those made in cement testing, dried first at room temperature and subsequently at 110°C for 5 hours, and pulling them apart in a testing machine.

TABLE XXV.

Tensile strength of the clays.

Clays.	lbs./sq. inch.
Pachgaon clay	95
Kamthana clay	50
Chintriya! clay	45
Shekapur clay	48
Srirangapur clay	40

16. *Breakdown potential of the clays.*—The usefulness of clay products in the field of electricity depends upon their ability to resist the passage of an electric current. The insulating properties of a clay are determined by its breakdown strength, dielectric constant, loss factor and volume resistivity. The breakdown potential is the potential at which the insulator breaks down.

The samples were made into cubes of about 1" side. They were first air-dried, kept in an oven at 110°C for five hours and then fired at 1200°C. Each of the samples was then accurately measured and a high voltage applied across it till there was a flash over.*

TABLE XXVI.

Clay	Side in inches	Flash at k.V.
Pachgaon clay	0.918	18
Do	1.174	26
Kamthana clay	0.850	23
Do	0.866	25
Chinriyal clay	0.835	18
Do	1.290	26
Shekapur clay	1.010	19
Do	0.880	15
Srirangapur clay	0.801	15.5
Do	0.873	16
Travancore clay	0.886	16.5

§2. Pachgaon clay.

The Pachgaon clay is light grey in colour, free from grit, slightly acidic and has a low permeability. Its modulus of rupture is 270 lbs./sq. inch and has a linear shrinkage of 8.8%. It fires light yellow

*The author is indebted to Col. Paul, Principal, Engineering College, Madras for getting this data determined in their Electrical Laboratory.

and is fairly well vitrified at 1200°C. These and other properties (see Tables I, V-VII, XII and XIV-XXVI) suggest that it will find use in the manufacture of sanitary ware, chemical and other stoneware, terra-cotta and saggars. Its rather high fusion point is likely to make it serviceable in the manufacture of refractories.* From an examination of the linear shrinkage, and its ability to withstand a temperature of 1300°C, the Geological Survey of India also comes to the same conclusion. In the unburned condition the clay may be useful as a filler in the manufacture of rubber and oil cloth.

§3. Kamthana clay.

The Kamthana clay is dull white in colour and is free from grit. Its composition is similar to that of kaolinite (p. 18). The rational analysis of the clay shows that it contains 97.8% clay matter. In this and other respects it compares favourably with the Travancore china clay. The Travancore china clay is, however, whiter than the Kamthana clay. The Kamthana clay may be useful in the manufacture of white wares, such as china and semi-porcelain, filler in paints, paper, cloth, and rubber industries. Its breakdown potential at about 23 k.V. suggests that it can be used in the manufacture of spark plugs and other porcelain insulators.†

§4. Chintriyal clay.

The Chintriyal clay is characterised by its high permeability and low shrinkage. It is free from

*In general all fire clays are not particularly suited for all kinds of refractory wares. Some resist heat alone, others have resistance to corrosion, etc. Consequently, the manufacturer is obliged to select a mixture of clays which will give a material best adapted to the conditions of its use.

†It is necessary to determine the electrical conductivity of this clay at different temperatures since its variation is also an important factor to be considered in the manufacture of spark plugs.

grit and has a greasy feel. It fires yellowish white and fuses to a light yellowish green mass at about 1400°C. Admixed with another clay it may be useful for the manufacture of pottery, paving bricks, sewer pipes, etc. In the unburned condition it may find use as a filler in oil-cloth, paints, rubber and soft polishing compounds.

§5. Shekapur clay.

The Shekapur clay has a light brown colour, low permeability and shrinkage. It fires yellowish white and is fairly well vitrified at 1400°C. (see Tables IV, V (a), VI, X, XII-XXVI). The clay is likely to be useful for the manufacture of refractories.

§6. Srirangapur clay.

The Srirangapur clay is light cream in colour, slightly acidic, and crumbles to a coarse powder when kept in water. It is associated with nearly 48% silicious and other impurities and can be used with advantage only after purification. It has a high permeability, fires brick red and fuses at about 1300°C. Its linear shrinkage is about 11 per cent. (see Tables V, V (a), VI, XI, XXVI).

At one time it was suggested that the Srirangapur clay might be classed amongst good quality bentonites. Subsequent investigations at the Government Test House, Alipore showed that (1) it did not answer the settling test said to be applicable to bentonites, (2) it did not show the typical swelling characteristic of all good bentonites, (3) its composition is similar to that of some bentonites (cf. p. 21). On the basis of the above data it was inferred that it may not be possible to put it to the

various uses to which bentonites are generally employed, but that it may find use in the manufacture of porcelain ware and cosmetics. It was also remarked that swelling under the influence of water may not be taken as a criterion characteristic of bentonites since some low grades do not swell. The writer has found that it has no bleaching properties. Its high water absorption (Table XV) may render it useful for the dewatering of petrol. Its gritty nature, and permeability are detrimental to its use as filler. It may be useful for the manufacture of face brick and like articles after admixture with a clay such as the Shekapur clay.

Summary.

In a general examination of clays from five principal deposits in the State, *viz.*, Pachgaon, Kamthana, Chintriyal, Shekapur and Srirangapur the following properties were determined: chemical composition of the raw and washed samples, grain size, specific gravity, plasticity, shrinkage, pH value, porosity, colour on firing, modulus of rupture, crushing strength, tensile strength and the breakdown potential. Some preliminary experiments were also done in regard to their purification. The clays appear to be well adapted for the manufacture of several kinds of ceramic wares. They may also find extensive use as fillers in several industries, chiefly, paper, textiles, paints and rubber.

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