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CHARACTERISATION OF NAGAR PARKER CLAY

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Nagar parker clay has been studied with a view to its mineral characterisation and determination of physical and chemical characteristics . The study involves X-ray analysis, differential thermal analysis, IR absorption analysis, chemical analysis, particle size analysis, pyrometric cone equivalent etc. The results indicate it to be an excellent quality china clay.

INTRODUCTION

At present the only source of china clay which is being exploited is that of Swat china clay. This clay is a semi-weathered feldspathic material composed of anorthite, albite, kaolinite, free quartz, and mica [1]. Halloysite and montmorillonite have also been detected in this clay [2] Unfortunately, this clay has such impurities which are a great hinderance in way of its utilization for ceramic purposes. Presence of anorthite, in considerable quantities, makes it unfit for procelain. The low viscosity of anorthite at the firing temperatures for porcelain becomes the cause of warping and deformation. Defloculation and slip casting of this clay has also created problems due to the presence of feldspar and small quantities of montmorillonite. Due to these reasons all the major ceramic concerns are unwilling to use Swat clay. Even the paper manufacturers are not using this clay due to various reasons. All of these concerns are using imported china clay.

Nagar Parker china clay seems to be a ray of hope in the situation mentioned earlier, although there may be some difficulties in the economically feasible exploitation of Nagar Parker deposits. Nagar Parker area lies at the south–east corner of Sind province. The china clay 'rock' occurs as an alteration product of granite. The total reserves found so far are three million tons.

Present investigations have been based on four bulk samples received from Pakistan Mineral Development Corporation, as specified below:

Sample No.	Area	Pit No.
1.	Moti-Jo-Vandhio	T–78
2.	Dhedvero	D–121
3.	Parodhro	P–55
4.	Dungri	DG–71

These samples have been studied with a view to characterise the clay as regards its mineralogy and physico-chemical properties.

EXPERIMENTAL

Raw clay was mixed with water in a plastic basin and thoroughly hand blunged and then stirred mechanically to ensure the dispersion of the clay particles. The mixture was allowed to stand for 15 min. The top suspension was then passed through a 200 mesh B.S. sieve into another basin and allowed to settle down. The supernatent water was decanted and the sedimented clay was dried at 110°. Minus 200 mesh fraction is called washed clay and the residue is called coarse fraction in this presentation.

Chemical analysis was carried out using standard methods of silicate analysis [3]. The plasticity was noted by hand-feel method. Particle size analysis of washed clay samples was carried out by the Andreasen pipette method [4]. Differential thermal analysis and thermogravimetric analysis was done on the Derivatograph–a Hungarian Instrument with automatic recording of the curves. The heating rate was 10°/min.

IR absorption analysis was performed on Beckman IR5A.

Porosity. The test pieces for porosity determination were made by casting and the porosity was determined on weight percentage basis.

Reversible Linear Thermal Change. The bars of 2.5" length and 0.75" dia were prepared by the extrusion method and dried at 110°. These were then fired at 1250° in an electric furnace for 2 hr. The expansion was measured by a dilatometer designed by the British Ceramic Research Association.

pH Determination. The pH values of washed clay samples were determined with a glass electrode on suspensions containing 20 % of dry clay. The clay-water mixture was allowed to stand overnight to attain equilibrium. The suspensions were titrated against 0.1N NaOH soiution in 1 ml additions pH was plotted against the corresponding amount of alkali.

The colour of the raw as well as fired clay was noted. The Pyrometric Cone Equivalent (P.C.E) was calculated from chemical analysis according to the Schuens [4,5] formula:

$$\text{Seger Cone} = \frac{113+Al_2O_3-RO}{4.48}$$

This method is reported to have an accuracy of ±1 cone for clays containing 20–50% alumina.

For practical determination of P.C.E., sample cones were made in a steel die and fired along with standard seger cone after fixing them on a grog plaque.

RESULTS AND DISCUSSION

Simple water washing separates the clay fraction from the coarse material or grit completely. The clay fraction thus separated passes through 200 mesh B.S. Sieve. The amount of clay recovered from various samples is as follows:

Sample No.	Total weight kg	clay %	Coarse fraction, %
1.	14.2	41.5	58.5
2.	14.8	34.1	65.9
3.	24.5	29.1	74.9
4.	26.0	32.3	67.7

Chemical Analysis. Chemical analysis of raw clay, washed clay and coarse fraction or grit are reported in Table 1, 2 and 3. This data indicates that simple water washing separates the clay substance effectively from most of the impurities. Almost all the free quartz and most of the calcium and magnesium bearing minerals remain in the coarse fraction/grit while the washed clay carries small quantities of these impurities.

The iron content of all the samples is well below the tolerable limit. The clays containing 2% (TiO_2+Fe_2O_3) burn white or light coloured [6]. The sum of alkalies (Na_2O+K_2O) is 0.43, 0.37 0.20 and 0.33 for washed clay

Table 1. Chemical analysis of raw clay.

Constituents	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Loss on ignition	9.86	8.16	8.47	9.53
SiO_2	64.18	70.20	67.27	64.20
Al_2O_3	22.69	17.80	21.43	24.26
Fe_2O_3	0.53	0.35	0.30	0.35
CaO	2.85	3.12	1.85	2.37
MgO	0.51	0.15	0.36	0.50
Na_2O	0.09	0.23	0.10	0.11
K_2O	0.13	0.10	0.08	0.13

Table 2. Chemical analysis of washed clay.

Constituents	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Loss on Ignition	14.54	14.64	13.49	14.38
SiO_2	45.00	43.90	44.86	44.14
Al_2O_3	41.20	41.32	41.65	39.90
Fe_2O_3	0.47	0.32	0.38	0.80
CaO	0.06	0.08	–	0.16
MgO	0.02	0.08	–	0.12
Na_2O	0.15	0.16	0.09	0.10
K_2O	0.20	0.21	0.10	0.21

Table 3. Chemical analysis of coarse fraction.

Constituents	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Loss on Ignition	1.11	3.94	2.92	1.37
SiO_2	93.99	84.55	89.87	92.66
Al_2O_3	3.19	4.58	5.17	4.36
Fe_2O_3	0.13	0.08	0.10	0.14
CaO	2.20	6.92	2.60	2.19
MgO	–	0.18	0.09	0.09
Na_2O	0.04	0.07	0.04	0.07
K_2O	0.03	0.04	0.04	0.04

sample No. 1, 2, 3 and 4, respectively. While english china clays supplied by Watts, Blake, Bearne & Co., contain alkalies from 1.70 to 2.20%.

Particle size analysis of the washed clay samples is presented in Fig. 1. The results indicate that the clay is comparatively coarse grained. Samples No. 1 to 4 contain 34 %, 39 %, 52 % and 31 % particles below 3 microns.

Pyrometric Cone Equivalent (P.C.E.). The calculated value of P.C.E. for washed clay samples was seger cone 34 approximately, for all the four samples. The P.C.E. was also determined practically. The test cones were fired to the maximum attainable temperature (+1650°) in our laboratories. Seger cone 29 melted completely, but the sample cones did not show any change except a slight shine on the surface of the cones.

Reversible Linear Thermal Expansion. The results are presented in Fig. 2. It is clear that the reversible thermal expansion of all these samples falls within the range usually found for kaolin clays. The per cent expansion at 750° for sample No. 1 to 4 is 0.23, 0.17, 0.38 and 0.23 respectively.

Porosity. Porosity values on weight percentage basis were determined for the four washed clay samples at 1000°, 1100°, 1200° and 1300°. The results are presented in Fig. 4. The behaviour of sample No. 1, 2 and 3 is almost similar while No. 4 shows a sudden drop in prorosity at 1300°.

X-ray Diffraction Analysis. X-ray analysis data is presented in Table 5. Diffraction patterns of all the raw clay samples were almost identical, therefore, only one of them is presented in the Table. The same applies to all the washed clays samples and coarse fractions or grit samples. The data for one washed clay sample and one coarse fraction sample is also presented in this Table.

In case of raw clay, the diffraction lines suggest that the samples consist of α-quartz and kaolinite and the intensity of the lines suggests that α-quartz is the major phase. In case of washed clay samples α-quartz is present-

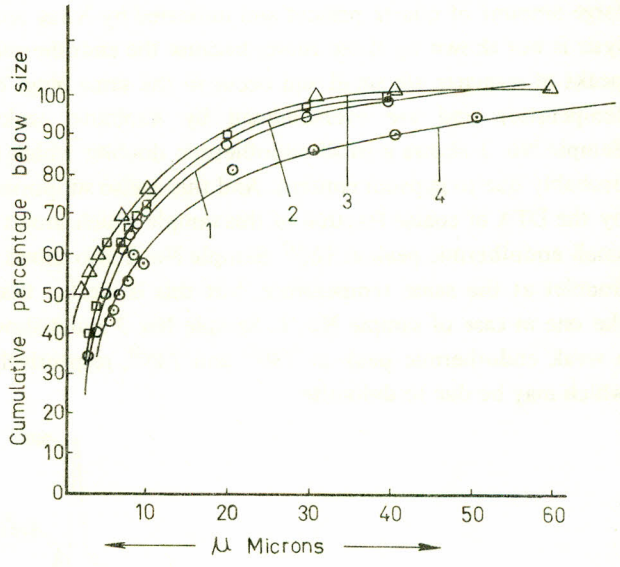

Fig. 1. Particle size.

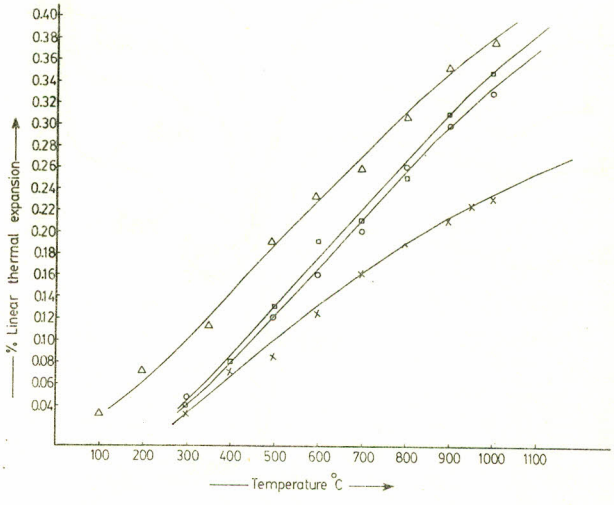

Fig. 2. Washed clay.

Table 4. Percentage porosity.

Temperature	1000°	1100°	1200°	1300°
Sample No. 1	45	43	32	31
Sample No. 2	42	42	26	25.5
Sample No. 3	38	38	21	19
Sample No. 4	44	46	30	17

in small quantities and the main phase is kaolinite. The coarse fractions contain mainly α-quartz.

Differential Thermal Analysis. The results are presented in Figs. 3, 4 and 5. Unwashed clay samples show a large endothermic peak between 570° and 610° and a large exothermic peak between 970° and 990°. This means that the sample contains kaolinite as a major constituent. The large amount of quartz present and indicated by X-ray analysis is not shown by these curves because the endothermic peaks of α-quartz are small and occur in the same range of temperature and are overwhelmed by kaolinite peaks. Sample No. 1 shows a small endothermic doublet which is probably due to gypsum content. And this is also supported by the DTA of coarse fraction of this sample which shows a small endothermic peak at 165°. Sample No. 2 also shows a doublet at the same temperature, but this is weaker than the one in case of sample No. 1. Sample No. 3 and 4 show a weak endothermic peak at 730° and 735°, respectively which may be due to dolomite.

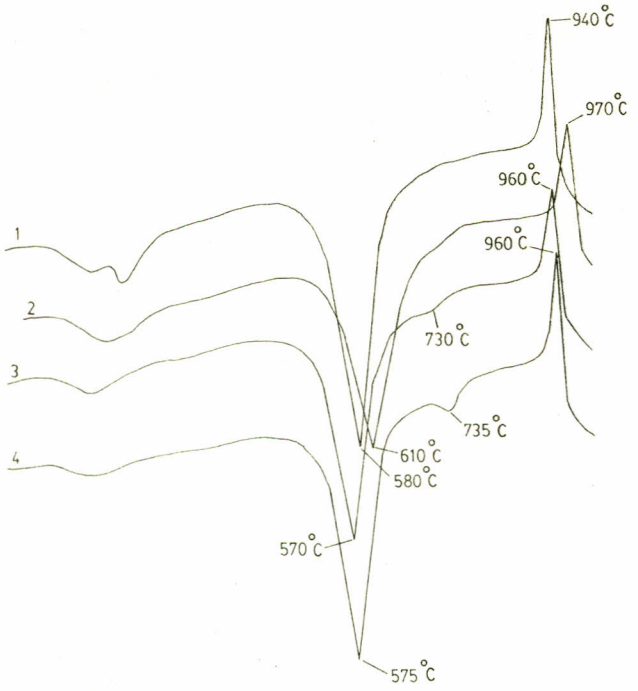

Fig. 3. Original samples of china clay from Nagar Parkar.

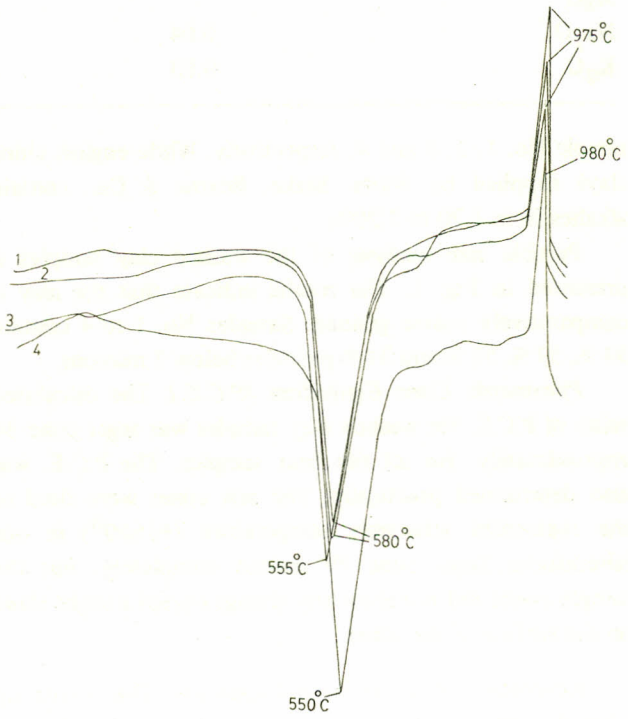

Fig. 4. D.T.A. of Nagar Parkar washed clay

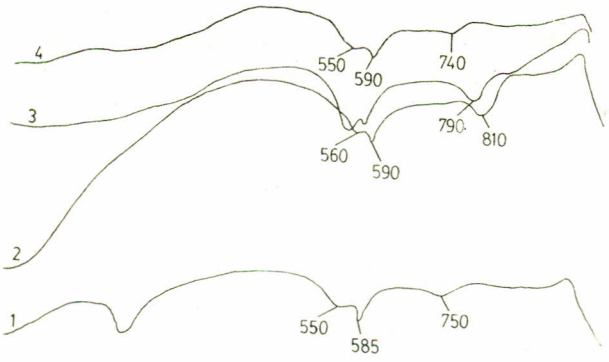

Fig. 5. D.T.A. of Nagar Parkar china clay grit samples.

In case of washed clay samples there is no peak in the range of 100–200°. These samples show typical kaolinite peaks. The endothermic peak is between 550 and 580° and the exothermic peak is at 975°. Sample No. 2, 3 and 4

Table 5. X-Ray analysis.

d in Å	Relative* Intensity	d in Å	Relative* Intensity	d in Å	Relative* Intensity
7.1	W	7.1	M	4.2	W
4.4	F	4.4	F	3.34	S
4.3	F	4.2	F	2.44	WF
4.2	MW	3.57	S	2.27	WF
3.57	MW	3.34	MW	2.24	F
3.34	W	2.55	W	2.13	WF
3.10	W	2.49	W	1.97	WF
2.55	F	2.37	MW	1.81	M
2.48	F	2.32	MW	1.67	WF
2.45	MW	2.28	W	1.54	M
2.34	W	1.97	F	1.45	WF
2.27	MW	1.82	F	1.42	F
2.24	WF	1.78	W	1.372	MW
2.17	F	1.66	W	1.288	W
2.13	MW	1.62	WF	1.256	W
1.97	F	1.58	F	1.229	W
1.81	MS	1.54	WF	1.199	W
1.67	WF	1.48	M	1.185	W
1.66	F	1.45	F	1.181	W
1.62	F	1.42	F	1.179	W
1.54	M	1.372	F	1.153	W
1.48	W	1.340	WF		
1.45	W	1.312	W		
1.42	F	1.285	WF		
1.38	MW	1.265	F		
1.372	M	1.201	F		
1.340	F	1.185	F		
1.312	F				
1.292	MW				
1.258	W				
1.230	W				
1.201	W				
1.999	W				
1.184	W				
1.181	MW				
1.154	MW				

*S = Strong. M = Medium. W = Weak. F = Faint. Ms = Medium strong. Mw = Medium weak. Wf = Weak to faint.

show a very small endothermic peak which may be due to the small quantity of dolomite.

All the grit/coarse fraction samples are mainly quartz and show a small but sharp peak at $585^{o}/590^{o}$. There is another small endothermic peak preceding this sharp peak. This is due to the residual clay substance sticking to grit particles. All these samples also show a small endothermic peak between $750–800^{o}$ which may be due to dolomite.

Thermogravimetric Analysis. The results are presented in Figs 6 and 7. The analysis has been used to calculate the clay fraction in the raw as well as washed clay. The loss of weight at the endothermic peak representing the loss of

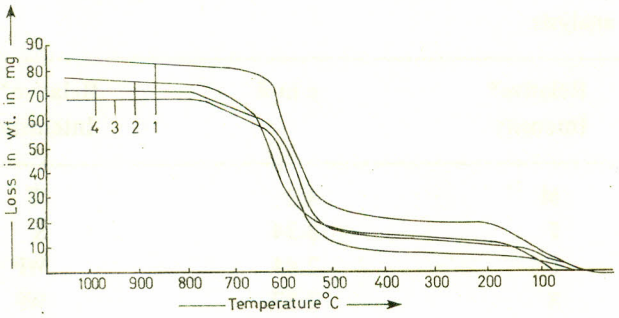

Fig. 6. Thermogravimetric analysis of unwashed clay.

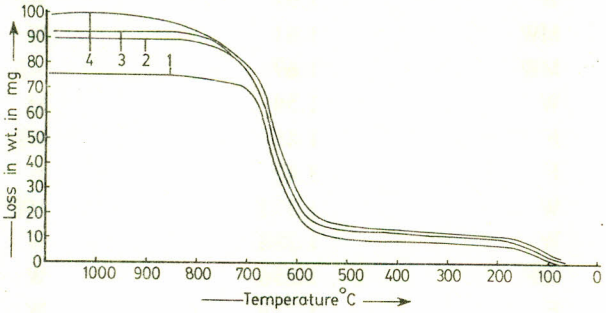

Fig. 7. Thermogravimetric analysis of washed clay.

crystalline water was made the basis of calculation.

The amount of clay substance in various samples was as follows:

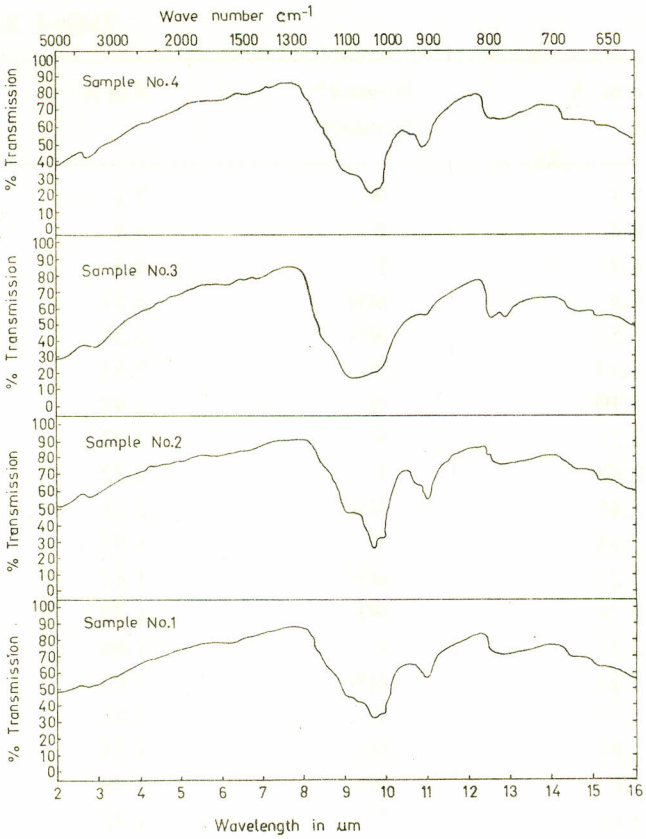

Fig. 8.

Sample No.	Raw clay: Weight of sample taken (mg)	Raw clay: Loss in weight (mg)	Raw clay: Clay fraction (%)	Washed clay: Weight of sample taken (mg)	Washed clay: Loss in weight (mg)	Washed clay: Clay fraction (%)
1	970	62	45.0	630	68	77.3
2.	990	60	43.0	660	77	63.6
3.	900	50	36.5	640	80	89.7
4.	985	54	39.2	690	87	90.4

IR Absorption Analysis. The results of the IR absorption for washed clay are presented in Fig. 8. These results confirm the findings of X-ray and DTA analysis.

Washed clay samples show the absorption bands for kaolinite. Raw clay samples show the absorption bands for quartz and kaolinite while grit samples show mainly quartz bands and carbonate bands.

pH of the Clay. All the four samples show an alkaline reaction. pH values for sample No. 1 to 4 are 8.15, 8.05, 8.35 and 8.35. The results of the titration with NaOH are presented in Fig. 9.

CONCLUSION

Nagar Parker china clay is fairly plastic and is a white firing clay. This shows an alkaline reaction. All the samples have been found to consist of kaolinite and α-quartz. Small

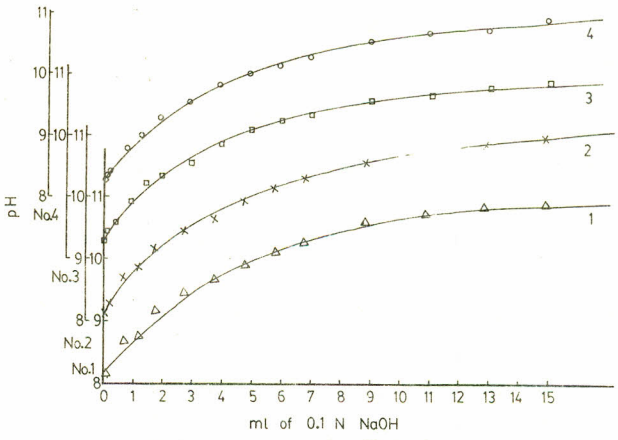

Fig. 9

quantities of gypsum and dolomite are also present in some of the samples. The clay substance can be separated from the coarse quartz fraction by simple water-washing and the impurities remain mainly in the coarse fraction. In view of its physical and chemical characteristics, this clay seems to be the best china clay found so far in Pakistan. The clay fraction contains only α-quartz as impurity in appreciable quantity. This clay should prove very useful for ceramic purposes in addition to its other uses.

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