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EVALUATION AND MINERALOGICAL COMPOSITION OF CLAYS AND CLAY FRACTIONS FROM BURSTALL TOWNSHIP, ONTARIO

by

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MINERAL PROCESSING DIVISION

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EVALUATION AND MINERALOGICAL COMPOSITION OF CLAYS AND CLAY FRACTIONS FROM BURSTALL TOWNSHIP, ONTARIO

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J. G. Brady*, R. M. Buchanan**, K. E. Bell*** and H. Mercier****

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SUMMARY OF RESULTS

Twenty-four samples were submitted by Franc.R. Joubin & Associates Mining Geologists Limited, Toronto, Ont. The samples were of two series, marked GMA and GMB. Ten of the samples were designated 'clay' and fourteen 'sand'. The mineralogical composition and ceramic properties of the 'clay' samples and the clay components of the 'sand' samples were determined.

The series of 'clay' samples marked GMB was found to consist mainly of quartz, and members of the mica and kaolinite groups. They are common clays and might be useful for the manufacture of facing brick.

The 'clay' samples of the GMA series consist mainly of a kaolinite mineral and quartz. They are fairly refractory and possibly useful for low-duty and medium-duty fire-brick. With additions of fluxes, they might be useful for facing brick or sewer pipe.

The 'sand' samples contain only small amounts of clay, usually less than 10 per cent, which consist principally of a kaolinite mineral and small amounts of quartz. The raw colours are light and several show high reflectance values. All fired white or near-white at cone 10.

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INTRODUCTION

Ten samples of 'clay' and fourteen of 'sand' were submitted to the Mines Branch by Mr. Norman H. Ursel, P. Eng., Franc. R. Joubin & Associates Mining Geologists Limited, 111 Richmond St., West, Toronto, Ont. This report deals with the ceramic properties and mineralogical composition of the 'clays' and clay components of the 'sands'. An evaluation of the sands was carried out separately in the Non-Metallic Minerals Section under the direction of Mr. R. K. Collings.

The samples received were reported to be from Burstall township; the GMA series along the Missinaibi River, the GMB series along Coal Creek, a tributary of the Missinaibi. They are identified as follows:

Ceramic Lab. No.	Company Designation	Type of Sample
1304	GMA - 1	Sand
1305	GMA - 2	Clay
1306	GMA - 3	Sand
1307	GMA - 4	Sand
1308	GMA - 6A	Sand
1309	GMA - 6B	Sand
1310	GMA - 7	Clay
1311	GMA - 8	Sand
1312	GMA - 9	Sand
1313	GMA - 10	Sand
1314	GMA - 11	Sand
1315	GMA - 16	Clay
1316	GMA - 18	Sand
1317	GMA - 19A	Clay
1318	GMA - 19B	Sand
1319	GMA - 20	Sand
1320	GMA - 21A	Sand
1321	GMA - 21B	Sand
1322	GMA - 21C	Clay
1323	GMA - 23	Clay
1324	GMB - 1	Clay
1325	GMB - 2	Clay
1326	GMB - 3	Clay
1327	GMB - 5A	Clay

PROCEDURE

Sample Preparation

All of the samples were thoroughly dried at 104°C (220°F).

Preliminary treatment of the ten 'clay' samples consisted only of grinding to pass a 16 mesh Tyler standard screen. The fourteen samples of 'sand', however, were each separated into three fractions by wet-screening and settling procedures. In addition, the clay fraction was separated, by washing, from one light-coloured 'clay' sample (Lab. No. 1322, GMA-21C).

The washing procedures were carried out on 1000 gram, dry weight, portions of each sample of 'sand'. To each was added about one litre of water and approximately 0.4 grams of Calgon. The samples were thoroughly dispersed by stirring with a propellor-type mixer and then washed, with light brushing, through a 150 mesh Tyler standard screen. The coarse sands, retained on the screen, were oven-dried and weighed, and the percentage calculated on the basis of dry weight of sample. These samples were submitted to the Non-Metallic Minerals Section for evaluation.

The minus-150-mesh materials were separated into fine sand and clay fractions by repeated settling and decantation. Settling depths were eight inches and time intervals ten minutes. The settle-decant procedure was repeated until the supernatant liquids were essentially clear. The residues, consisting of fine sands plus some clay, were oven-dried and weighed, and the percentage of each was calculated. These samples appeared to contain most of the obvious impurities.

A few drops of glacial acetic acid were added to each of the clay suspensions remaining, which were then allowed to settle for one to two days. The clear liquids were withdrawn by syphon and the remainders thoroughly oven-dried at 104°C (220°F). The dry samples were weighed and the percentage of each calculated.

Ceramic Properties

The ten 'clay' samples were tested, with dilute hydrochloric acid, for calcium carbonate. The colour of each dry, ground 'clay' was noted. A weighed quantity of each ground material, sufficient to make eight briquettes, was tempered to a stiff-plastic condition and the amount of water required (water of plasticity) was recorded. The briquettes were hand-moulded in steel moulds measuring 4 x 1½ x 1¼ inches. The plasticity and workability of each material were observed and drying shrinkages were determined. One freshly-formed briquette of each material was submitted to rapid drying conditions at 85°C (185°F) and the results observed; the remaining briquettes were air-dried for about 24 hours and finally dried at 85°C (185°F) in a laboratory dryer. The pyrometric cone equivalent (PCE), or heat-softening point, was determined for each sample. Then the test pieces were fired at various appropriate temperatures. The fired colour, and hardness were observed and the fired shrinkages (based on wet length) were determined. The fired briquettes were weighed and immersed in water for 24 hours. The wet briquettes were weighed, the increase in weight recorded, and the percentage absorption calculated.

The ceramic properties of the clay fractions obtained from the fourteen samples of 'sand' and the one washed 'clay' sample were determined in the same manner. Since the quantity of washed clay for each sample was limited, only two briquettes were prepared and fired, to cone 10 (1285°C, 2345°F). Fired colours and firing shrinkages were determined. The PCE of each washed fraction was also obtained.

Raw Colours of Washed Clays

Comparative reflectance values were obtained for the dry, unfired, washed clay fractions. Measurements were made by the Non-Metallic Minerals Section, using a Welch optical-density meter with a magnesium basic carbonate standard (reflectance 100).

Differential Thermal Analysis (DTA)

Differential thermal analysis curves were obtained for the ten 'clay' samples and a few typical clay fractions from the 'sands'. The curves were obtained in an air atmosphere at a heating rate of 12 deg C per min. A semi-quantitative estimate was made of the kaolinite mineral content of the GMA 'clays' and the clay fractions washed from the 'sands', by measuring the area under the endothermic peak at approximately 600°C (1112°F). No quantitative estimate could be made of the kaolinite mineral content of the GMB series by DTA because another clay mineral (probably mica) gave peaks in the same general temperature regions.

X-Ray Diffraction Analysis (XRD)

Five clay fractions washed from the GMA series, and four of the GMB 'clays' were investigated by XRD. A portion of each of the samples was dispersed in distilled water. Small quantities of the suspensions were pipetted onto two glass microscope slides, one of which was pyrex. When the suspensions had been allowed to dry at room temperature, the resulting, well-oriented specimens were ready for analysis. Each specimen was scanned in a Philips X-ray diffractometer over a range of 60° (2θ). Several mounts on pyrex were heated at 600°C (1112°F) for one hour and rescanned to verify the presence of a kaolinite mineral.

Five of the impure, minus-150-mesh-sand fractions from the GMA 'sands' were also examined. Portions of each sample were analyzed by the X-ray diffractometer to identify the major constituents. Minor constituents were concentrated by heavy liquid (sp gr 3.33) and identified by XRD in 57.4 mm Debye-Scherrer cameras.

RESULTS AND DISCUSSION

Fractionation of the Sand Samples

While the primary interest in the fourteen samples of 'sand' lay in the sand fraction itself, the clay portions of the samples appeared of possible high quality, and thus their properties were investigated. The clay contents of the samples, shown in Table 1, were low, exceeding 10 per cent in only two cases.

TABLE 1

Mechanical Analysis of the Samples of Sand

Sample No.	% Sand +150 Mesh	% Sand -150 Mesh	% Clay
1304 (GMA- 1)	95.3	1.3	3.3
1306 (GMA- 3)	91.0	2.2	6.6
1307 (GMA- 4)	80.7	2.9	16.2
1308 (GMA- 6A)	89.4	3.0	7.5
1309 (GMA- 6B)	86.6	3.9	9.4
1311 (GMA- 8)	94.8	1.7	3.5
1312 (GMA- 9)	93.9	1.8	4.0
1313 (GMA-10)	90.6	2.5	6.9
1314 (GMA-11)	92.9	1.9	5.2
1316 (GMA-18)	93.9	1.9	4.0
1318 (GMA-19B)	88.5	4.2	7.2
1319 (GMA-20)	81.9	5.1	12.8
1320 (GMA-21A)	94.7	1.2	4.1
1321 (GMA-21B)	91.9	1.6	6.4

Ceramic Properties

The ceramic properties of the 'clay' samples are shown in Table 2, and those of the clay fractions washed from the 'sands' are shown in Table 3.

Except for the sandy samples such as No. 1322 (GMA-21C), the plasticity and workability of the GMA 'clays' are good. These samples are safe-drying with low drying shrinkages.

The PCE's of the GMA 'clays' vary from cone 23-26 to cone 30½. Two samples, No. 1317 (GMA-19A) and No. 1323 (GMA-23) have PCE's above cone 29 but less than cone 31½, which indicates that they are probably suitable for the manufacture of medium-duty fire-brick, or, in combination with a more refractory clay, for production of high-duty fire-brick. The refractoriness of the balance of the GMA 'clays' indicates that they might be suitable for low-duty fire-brick. All of the GMA 'clays', however, are open-firing and difficult to vitrify. Consequently, the addition of a refractory, easily-vitrified clay is likely necessary for the production of fire brick. They are much too open-firing for production of such clay products as facing brick and sewer pipe, unless combined with an easily-vitrified clay or some flux such as nepheline syenite.

The fired colours of the GMA 'clays' vary with the sample and the firing temperature through light shades typical of fire clays. Many of the fired specimens developed a yellow efflorescence that is attributed to soluble vanadium salts. This is a common occurrence with buff-firing clays of this type, particularly when absorptions are high.

The GMB 'clays' are of good plasticity and workability, but most have a tendency to crack upon rapid drying. Drying shrinkages (about 4 to 6 per cent) are slightly higher than for the GMA 'clay' samples.

The GMB samples are less refractory than the GMA 'clays'. Their refractoriness and fired properties indicate that they are common clays and may be suitable for such products as facing brick and sewer pipe. At temperatures where a hard, dense product is obtained, firing shrinkages are inclined to be high.

The fired colours of the GMB samples are generally darker than those of the GMA series. Several samples fire to a dark red at the higher temperatures.

The results of Table 1 show that the percentage of clay in the 'sands' is small, generally well below 10 per cent. The plasticity and workability of these clays are satisfactory. The drying shrinkages vary, but are mainly in the order of 4 to 5 per cent.

The PCE's of the clay fractions washed from the 'sands'

TABLE 2

Average Physical Properties of the Clay Samples

CLAY NO.	UNFIRED CHARACTERISTICS	P.C.E.	FIRED CHARACTERISTICS					REMARKS
			Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	
1305 GMA-2	Yellow, non-calcareous sandy clay, good workability and plasticity, water of plasticity 24.5%, safe drying at 185°F, drying shrinkage 4.6%.	Cone 23-26 approx between 2921-2950°F	02 (2014°F)	0.3	18.1	Light salmon	Very soft	Possibly suitable for low-duty fire-brick, very difficult to vitrify because of its sandy nature.
			5 (2151°F)	1.7	15.9	Light salmon	Very soft	
			10 (2345°F)	2.0	13.9	Pale pinkish buff	Soft	
			15 (2595°F)	3.2	12.1	Light brown, speckled	Fairly soft	
1310 GMA-7	Brownish red, non-calcareous clay, good workability and plasticity (greasy), water of plasticity 27.8%, safe drying, drying shrinkage 5.6%.	Cone 27 approx 2937°F	02	1.5	16.9	Pink	Soft	Slight vanadium scum, suitable for low-duty fire-brick, drying shrinkage slightly above normal.
			5	4.0	14.2	Pale pink	Fairly hard	
			10	5.6	10.9	Pale buff	Hard	
			15	6.5	6.5	Speckled brown	Very hard	
1315 GMA-16	Light red, non-calcareous clay, good workability and plasticity, water of plasticity 27.6%, safe drying, drying shrinkage 4.9%.	Cone 27½ approx 2946°F	02	1.9	19.0	Salmon	Soft	Slight vanadium scum, suitable for low-duty fire-brick, fairly difficult to vitrify.
			5	4.5	12.5	Dark salmon	Fairly soft	
			10	6.0	9.4	Pinkish tan	Fairly hard	
			15	7.4	7.4	Speckled brown	Hard	
1317 GMA-19A	Yellow buff, non-calcareous clay, good workability, fairly plastic (greasy), water of plasticity 28.9%, safe drying, drying shrinkage 3.9%	Cone 29½ approx 2966°F	02	2.0	22.3	Pale salmon	Very soft	Vanadium scum, suitable for medium-duty fire-brick, rather difficult to vitrify.
			5	4.0	17.9	Pale salmon	Fairly soft	
			10	6.0	14.2	Dark cream	Fairly hard	
			15	6.7	9.0	Speckled light brown	Hard to very hard	
1322 GMA-21C	Light cream, non-calcareous sandy clay, good workability, low plasticity, water of plasticity 20%, safe drying, drying shrinkage 4.0%.	Cone 28½ approx 2946°F	02	0.0	16.4	Nearly white	Very soft	Very slight vanadium scum, difficult to vitrify because of sandy nature, very close to being suitable for medium-duty fire-brick.
			5	0.2	15.7	Nearly white	Very soft	
			10	1.0	14.0	Nearly white	Soft	
			15	1.3	13.5	Cream, fine specks	Fairly soft	

TABLE 2 (cont'd)

Average Physical Properties of the Clay Samples

CLAY NO.	UNFIRED CHARACTERISTICS	P.C.E.	FIRED CHARACTERISTICS Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	REMARKS
1323 GMA-23	Salmon, non-calcareous clay, good workability and plasticity, (greasy), water of plasticity 29.4%, safe drying, drying shrinkage 5.4%.	Cone 30½ approx 3000°F	02	2.3	21.8	Light salmon	Very soft	Very slight vanadium scum, fire clay suitable for medium-duty refractories.
			5	5.0	14.2	Very light salmon	Fairly hard	
			10	7.4	10.9	Light buff	Hard	
			15	9.0	5.6	Speckled brown	Very hard	
1324 GMB-1	Cream, non-calcareous clay, (some hard lumps) good workability, very plastic, water of plasticity 32%, cracks with rapid drying, drying shrinkage 4.2%.	Cone 16, approx 2651°F	02	1.7	20.6	Cream	Medium hard	Stoneware type clay or very low-duty fire-clay
			5	5.8	12.3	Dark cream	Very hard	
			10	7.8	3.0	Mottled grey	Steel hard nearly vitrified	
1325 GMB-2	Brown, non-calcareous clay, (some hard greenish-yellow lumps contain sand) good workability, very plastic, water of plasticity 27.5%, cracks with rapid drying, drying shrinkage 6.5%.	Cone 12½ approx 2397°F	06 (1816°F)	3.3	15.5	Light red	Fairly hard	Common, red-burning clay, some difficulty with drying.
			02	8.5	5.7	Red to dark red	Very hard	
			5	9.8	1.8	Dark red	Steel hard	
1326 GMB-3	Brown, non-calcareous clay, good workability and plasticity (greasy), water of plasticity 29.2%, tendency to crack with rapid drying, drying shrinkage 6.7%.	Cone 12¾ approx 2404°F	06	3.7	12.5	Dark salmon	Hard	Same as comments as for GMB-2
			04 (1922°F)	6.3	7.2	Light red	Very hard	
			02	9.2	2.2	Red	Steel hard	
			6	7.7	0.4	Dark red	Vitrified (overfired)	
1327 GMB-5A	Yellow buff, non-calcareous clay, good workability and plasticity (greasy), water of plasticity 27%, safe drying, drying shrinkage 4.2%.	Cone 15 approx 2595°F	04	2.0	19.1	Pale salmon	Fairly hard	Common clay.
			02	4.5	13.7	Salmon	Hard	
			5	9.7	3.3	Dark brownish red	Steel hard	
			10	8.7	0.7	Dark brown, specks	Nearly vitrified (warped slightly)	

TABLE 3

Properties of Clay Fractions Washed from Sands

CLAY NO.	UNFIRED CHARACTERISTICS	P.C.E.	FIRED CHARACTERISTICS					REMARKS
			Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	
1304 GMA-1	3.3% clay, drying shrinkage 4.5%	Cone 34+ approx 3205°F+	10 (2345°F)	11.0	- -	Nearly white	- -	- - -
1306 GMA-3	6.6% clay, drying shrinkage 4.5%	Cone 34+	10	13.0	- -	White	- -	- - -
1307 GMA-4	16.2% clay, drying shrinkage 4.0%	Cone 34+	10	13.0	- -	Very slightly off white	- -	- - -
1308 GMA-6A	7.5% clay, drying shrinkage 4%	Cone 34+	10	15.0	- -	Nearly white	- -	- - -
1309 GMA-6B	9.4% clay, drying shrinkage 4%	Cone 34+	10	12.0	- -	White	- -	- - -
1311 GMA-8	3.5% clay, drying shrinkage 4.5%	Cone 32¼ approx 3115°F	10	14.0	- -	Light grey	- -	- - -
1312 GMA-9	4.0% clay, drying shrinkage 4.0%	Cone 34+	10	14.0	- -	White	- -	- - -
1313 GMA-10	6.9% clay, drying shrinkage 5%	Cone 34+	10	12.0	- -	White	- -	- - -
1314 GMA-11	5.2% clay, drying shrinkage 4.0%	Cone 32½ 3134°F	10	12.0	- -	Yellowish white	- -	- - -
1316 GMA-18	4.0% clay, drying shrinkage 2.5%	Cone 34+ approx 3205°F+	10	13.0	- -	Off white	- -	White at the bottom of briquette
1318 GMA-19B	7.2% clay, drying shrinkage 3.5%	Cone 32 3103°F	10	12.0	- -	Whitish grey	- -	- - -
1319 GMA-20	12.8% clay, drying shrinkage 4.0%	Cone 34- approx 3195°F-	10	12.0	- -	Slight off white	- -	- - -
1320 GMA-21A	4.1% clay, drying shrinkage 5.5%	Cone 34-	10	12.0	- -	Light cream	- -	White at the bottom
1321 GMA-21B	6.4% clay, drying shrinkage 7.0%	Cone 32½ 3134°F	10	13.0	- -	Light grey	- -	Warped in firing

are mostly in the neighborhood of cone 34, indicating that the samples contain principally a kaolinite-group mineral. The colours, when fired to cone 10, are white, cream or grey. This indicates that the washed samples have a fairly low iron content.

Sample No. 1322 (GMA-21C) contained 37.5 per cent clay, which is an off-white colour. The PCE is cone 33 and the sample, fired to cone 10, is off-white.

Reflectances of Raw Washed Clays

The reflectance values for the clay fractions washed from the 'sands' are given in Table 4.

TABLE 4

Comparative Reflectances of Dry, Unfired, Washed Clay Fractions

Sample No.	Reflectance	Sample No.	Reflectance
1304 (GMA- 1)	74.0	1314 (GMA-11)	55.0
1306 (GMA- 3)	73.0	1316 (GMA-18)	71.0
1307 (GMA- 4)	77.5	1318 (GMA-19B)	70.5
1308 (GMA- 6A)	77.0	1319 (GMA-20)	80.5
1309 (GMA- 6B)	83.0	1320 (GMA-21A)	71.5
1311 (GMA- 8)	71.5	1321 (GMA-21B)	64.5
1312 (GMA- 9)	80.5	1322 (GMA-21C)	75.5
1313 (GMA-10)	85.5	Magnesium Carbonate	100.0

The clays showing reflectance values of 73 or greater fire white or near-white. Those showing lower reflectances fire cream or light grey. Probably the reflectance values could be raised by chemical treatment.

Differential Thermal Analysis

The curves for the GMA 'clays' are shown in Figure 1 and those for the GMB series are shown in Figure 2. Curves for some selected clays washed from the 'sands' along with a kaolinite standard, American Petroleum Institute (API) kaolinite H-4, are shown in Figure 3. Endothermic peaks point down and exothermic peaks point up. The remainder of the washed-clay curves are similar to that of No. 1307 (GMA-4), Figure 3.

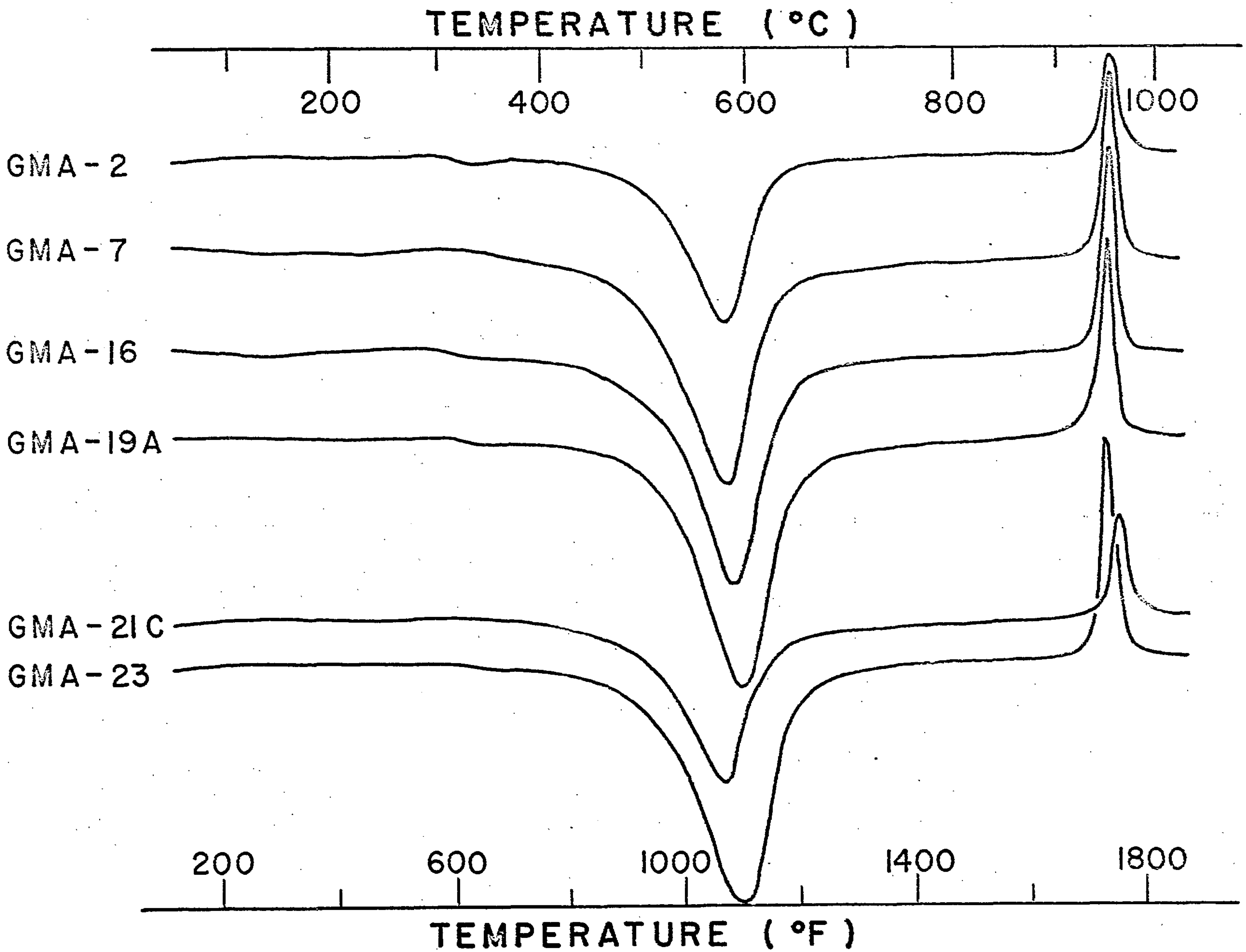

Figure I. DTA Curves of GMA 'Clays'.

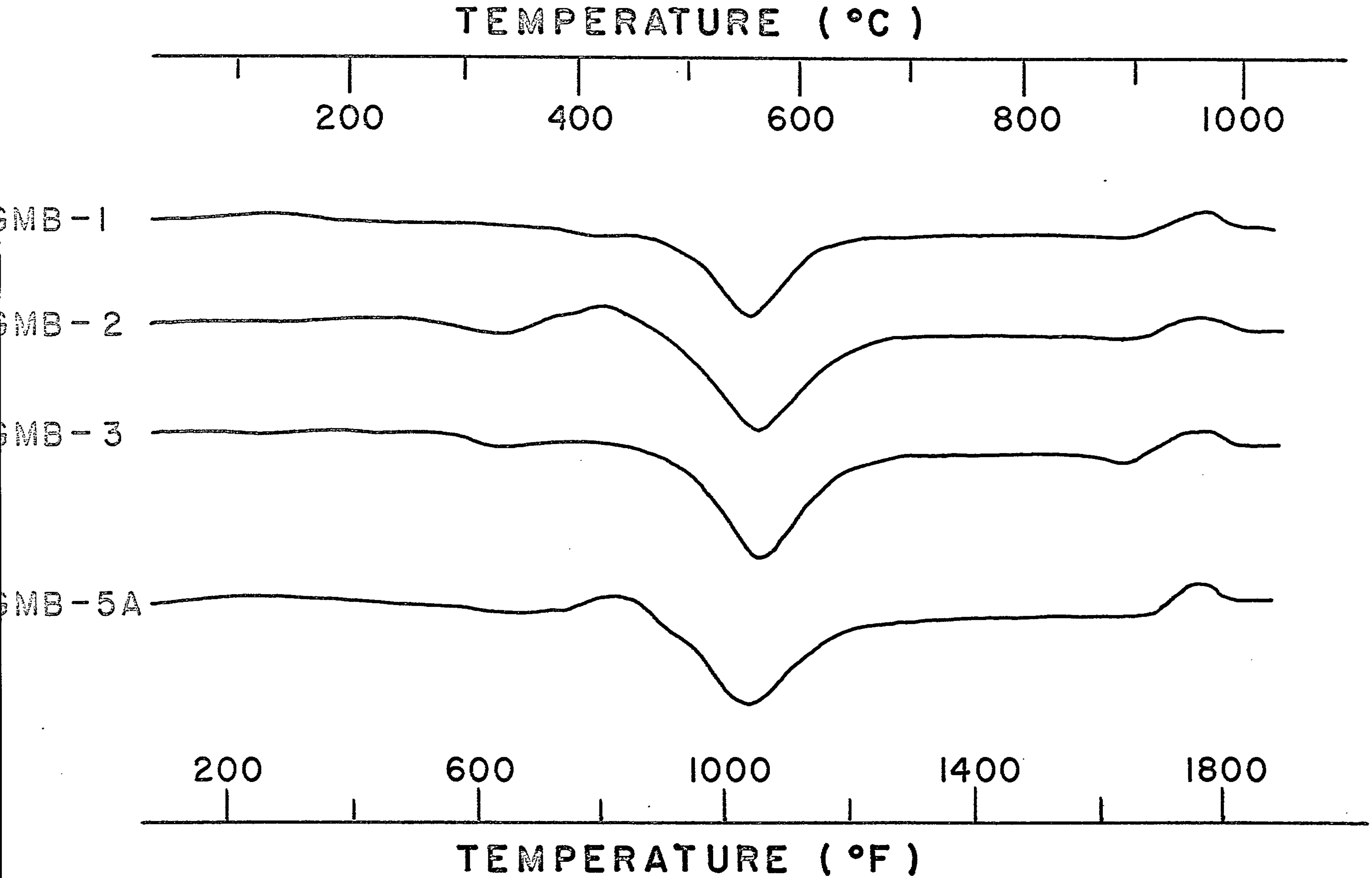

Figure 2. DTA Curves of GMB 'Clays'.

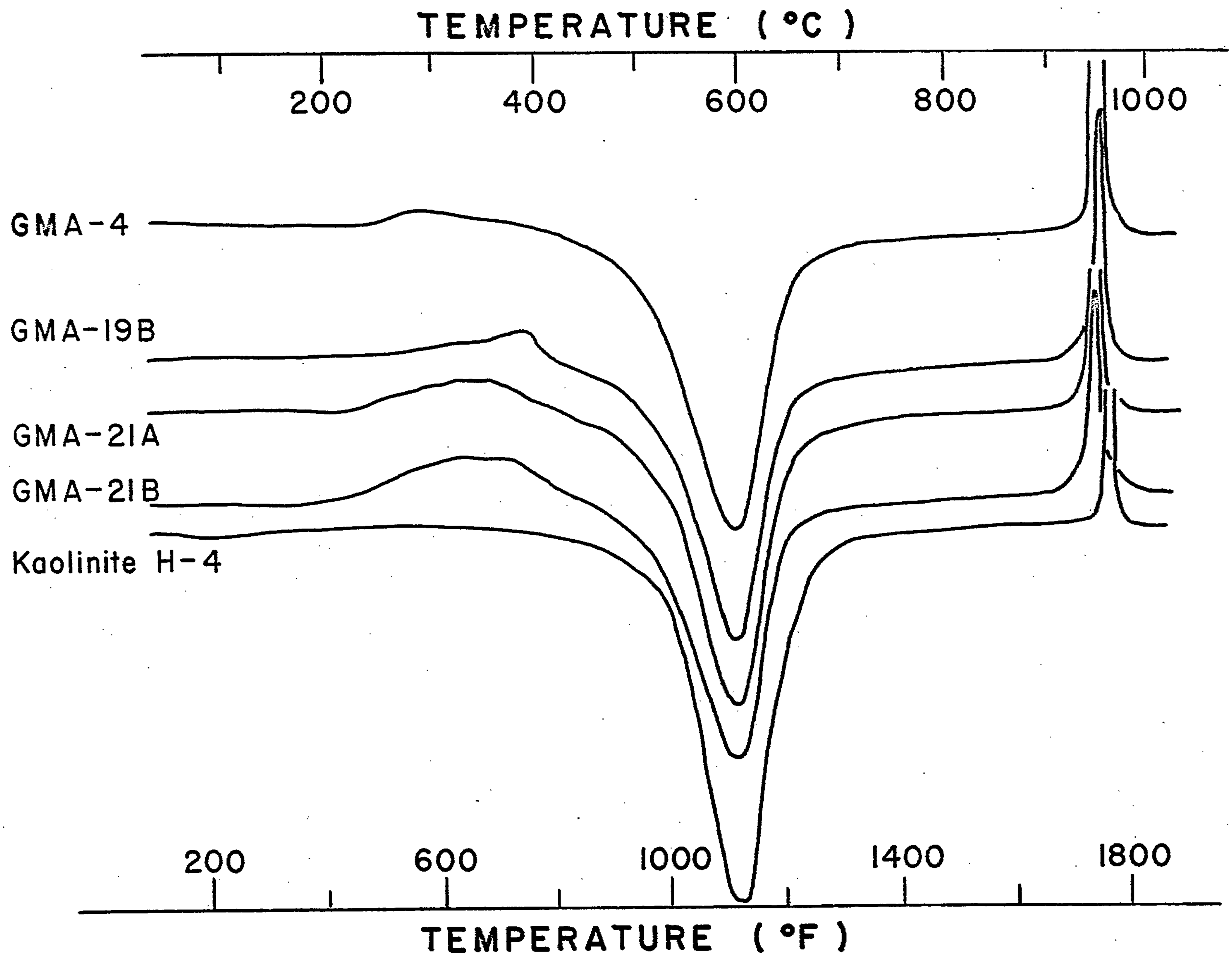

Figure 3. Selected DTA Curves of Clays Washed from Sands.

The peaks in Figure 1 and Figure 3, when compared with the standard H-4, indicate that a kaolinite-group mineral is a major constituent of the GMA 'clays' and particularly of the clay fractions from the 'sands'. The mineral is probably kaolinite. The diagnostic features for kaolinite are a broad endothermic peak at approximately 600°C (1112°F), an intense exothermic peak at approximately 950°C (1742°F) and a dull, small peak at about 130°C (266°F).

The peaks of the GMB curves in Figure 2 suggest that a small amount of kaolinite (or kaolinite-group mineral) may occur in association with a mica clay mineral, probably illite.

The curves in Figures 1 and 2 indicate that there are no materials such as pyrite or organic material present in quantities sufficient to cause difficulty in firing.

The clays cause endothermic peaks that obscure the very small peaks caused by the quartz inversion at 573°C (1065°F).

The estimated kaolinite contents of the 'clays' and washed clay fractions are shown in Table 5.

The clay fractions that have about 96 per cent or greater kaolinite have the highest reflectances in the raw state, about 77 or greater, and fire white or near-white. The clay sample washed from No. 1319 (GMA-20), which has about 87 per cent kaolinite and a reflectance of about 80.5, is an exception because it fires slightly off-white.

X-Ray Diffraction Analysis of Washed Clays

A quantitative interpretation was not attempted. The 7A° material that was destroyed by heat treatment is thereby identified only as a member of the kaolinite group. A sharp diffraction peak at 10A° is due to a member (or members) of the mica group.

The classification into major and minor constituents was made by comparison of diffraction peak heights with those obtained from reference materials. The results are shown in Table 6.

X-Ray Analysis of Fine Sand Fractions

The nature of the washing process was such that the impurities appear to be concentrated in the minus-150-mesh fraction. The results of the analyses of these fractions, shown in Table 7, are thus indicative of possible impurities present in otherwise undetectable amounts in the other fractions. Noteworthy is the apparent absence of magnetite and other iron-bearing minerals, and of feldspar.

TABLE 5

Semi-Quantitative Estimate of the Amounts of Kaolinite in GMA and Washed Clays

Sample No.	Per Cent Kaolinite	Sample No.	Per Cent Kaolinite
GMA 'Clays'			
1305 (GMA- 2)	36	1317 (GMA-19A)	57
1310 (GMA- 7)	50	1322 (GMA-21C)	33
1315 (GMA-16)	53	1323 (GMA-23)	62
Clay Fractions Washed from 'Sands'			
1304 (GMA-1)	83	1313 (GMA-10)	97
1306 (GMA-3)	95	1314 (GMA-11)	95
1307 (GMA-4)	96	1316 (GMA-18)	92
1308 (GMA-6A)	100	1318 (GMA-19B)	79
1309 (GMA-6B)	97	1319 (GMA-20)	87
1311 (GMA-8)	89	1320 (GMA-21A)	92
1312 (GMA-9)	100	1321 (GMA-21B)	75

TABLE 6

X-Ray Diffraction Analyses

Sample No.	Major Minerals	Minor Minerals
1307 (GMA- 4)(washed)	Kaolinite group	n.d.
1319 (GMA-20)(washed)	Kaolinite group	Quartz, Mica(?)
1320 (GMA-21A)(washed)	Kaolinite group	Quartz
1321 (GMA-21B)(washed)	Kaolinite group	Quartz
1323 (GMA-23)(washed)	Kaolinite group	Quartz
1324 (GMB- 1)	Quartz	Kaolinite group, Mica
1325 (GMB- 2)	Quartz	Mica, Kaolinite group
1326 (GMB- 3)	Mica, Kaolinite group, Quartz	
1327 (GMB- 5A)	Quartz, Mica	Kaolinite group

TABLE 7

X-Ray Analysis of Minus-150-Mesh-Sand Fractions from GMA 'Clays'

Sample No.	Major Minerals	Minor Minerals
1307 (GMA- 4)	Quartz, Kaolinite group	Rutile, Anatase
1313 (GMA-10)	Kaolinite group, Quartz, Mica	Rutile, Anatase
1314 (GMA-11)	Kaolinite group, Quartz, Mica	Rutile, Anatase
1319 (GMA-20)	Quartz, Kaolinite group	Rutile, Anatase
1321 (GMA-21B)	Quartz, Kaolinite group	Rutile, Anatase

CONCLUSIONS

The samples which are designated as 'clays' vary in plasticity due to variable amounts of non-plastic quartz. The GMB samples are more plastic than the GMA samples. The GMB samples may be classed as common clays and have possible uses as raw materials for facing brick and sewer pipe. The GMA 'clays' are fairly refractory, two of them having sufficient refractoriness for possible use in the manufacture of medium-duty fire-brick or possibly for combining with more refractory materials for high-duty fire-brick. The GMA 'clay' samples are difficult to vitrify, perhaps because of a high quartz content. Addition of fluxes to ease vitrification might make the 'clays' useful in facing brick or sewer pipe.

The GMA 'clays' are principally kaolinite and quartz while the GMB clays contain a kaolinite-group mineral, a mica mineral, and quartz.

The washed clay fractions from the 'sands' consist principally of a kaolinite-group mineral (likely kaolinite) and a small amount of quartz. The apparent absence of iron-bearing impurities and feldspars is worthy of note. Reflectance values are fairly high in a few cases. No standard coating clay was available for comparison with the washed samples. Their PCE's are mainly about cone 34.

The percentage of clay in most of the 'sand' samples is below 10 per cent.