Dr. John Convey, Director Mines Branch

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RELATION OF PHYSICAL PROPERTIES TO MINERALOGICAL COMPOSITION OF SOME CLAYS FROM THE CYPRESS HILLS AREA, ALBERTA

by

J. G. BRADY & R. M. BUCHANAN

MINERAL PROCESSING DIVISION

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RELATION OF PHYSICAL PROPERTIES TO MINERALOGICAL COMPOSITION OF SOME CLAYS FROM THE CYPRESS HILLS AREA, ALBERTA

by

J. G. Brady* and R. M. Buchanan**

SUMMARY OF RESULTS

The physical properties and mineralogical compositions of eighteen clay samples from three pits in the Cypress Hills area were determined for the Medicine Hat Brick and Tile Company Limited, Medicine Hat, Alberta. The relation of the mineralogical composition to physical properties and the variations in composition and properties of the various seams from pit to pit are discussed.

The majority of the samples are buff-firing stoneware clays from the Whitemud formation. Their mineralogical compositions were determined by X-ray diffraction analysis and differential thermal analysis. Kaolinite, montmorillonite, quartz, mica and feldspar were the principal minerals identified in them, although all of these minerals were not present in every sample. Quartz, and coarse mica, which was usually muscovite, were present in all samples. Kaolinite occurred in all of them except one from the Eastend formation.

The clays which contained the largest amounts of kaolinite and quartz and little or no montmorillonite, mica and feldspar were the most refractory. Clays containing montmorillonite were very plastic, were difficult to dry, and, in general, fired to a brown or red colour. The samples that contained substantial amounts of quartz, mica, and feldspar, and no montmorillonite generally lacked plasticity.

The clays from two of the pits contained more montmorillonite and less kaolinite and quartz than the materials from the third pit. Consequently, the clays from the third pit were generally more refractory, less plastic, and more easily dried than those from the first two.

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INTRODUCTION

Eighteen samples of clay from three newly-developed pits were submitted to the Mines Branch for investigation by the Medicine Hat Brick and Tile Company Limited, Medicine Hat, Alberta. The clays were principally from the Whitemud formation in the Cypress Hills region of Alberta, 45 miles southeast of Medicine Hat. Mr. L. O. Lindoe, Director of Research for the Company, requested particularly that information be provided on the refractoriness and mineralogical compositions of the samples. This information is required in order to assist the Company in the development and utilization of the clays in this area.

SAMPLES INVESTIGATED

The description and location of the samples provided by Medicine Hat Brick and Tile Company Limited are shown in Table 1.

PROCEDURE

The samples were crushed to pass a 16-M laboratory screen. They were tempered with water to a stiff plastic condition. The percentage of tempering water (water

TABLE 1

Location and Description of Samples

Lab. No.	Co. No.	Company Description
		Quarry 34
805	34A	Light to dark grey plastic shale, light buff firing, Battle formation, 3 to 5 ft.
806	$34B_1$	Salt-and-pepper, white weathering plastic sands, light buff firing, Whitemud formation, 6 to 8 ft.
	$34B_2$	Not sampled, yellow shale, red firing, 1 ft.
807	34C	Brown, black and purple-grey shale, light buff firing, darker at top, Whitemud formation, 3 ft.
808	34D (top) plastic	Pale yellowish and mottled grey, white weathering silts and sands, sandier at base, light buff firing, Whitemud formation, 6 to 7 ft.
809	34D (bottom) sandy	Same as above - sandy portion
810	34E	Pale ochrous sands and silts, light to dark buff firing, Whitemud formation, 3 to 9 ft.
		Quarry 45
811	45A	Light to dark grey plastic clay, salmon firing, Battle formation, 2 ft.
812	$45B_1$	Salt-and-pepper, white weathering plastic sands, light buff firing, Whitemud formation, 5 ft.
	$45B_2$	Not sampled, red firing, 1 ft.
813	45C	Brown, black and dark grey clay, red firing, Whitemud formation, 2 1/2 ft.
814	45D	Yellowish and mottled grey, white weathering clay and silt, dark buff firing, Whitemud formation, 7 ft.
815	$45E_1$ +	Black to olive clays, red firing, Whitemud formation, 3 ft.
	$45E_2$	Yellowish sands and silts, light red firing, Whitemud formation 2 ft.
816	45F	Grey clays and silts, red firing, low temperature, Eastend formation, 12 ft.
		Quarry 12
817	12A	Not sampled, Battle formation, 3 ft.
	$12B_1$	Salt-and-pepper, white weathering, plastic sands, light buff firing, Whitemud formation, 4 ft.
818	$12B_2$	Iron-stained, plastic clay, white weathering, red firing, Whitemud formation, 2 ft.
819	12C	Black to dark grey plastic clay, red firing, Whitemud formation, 3 ft.
820	$12D_1$	Pale grey clay and silt, white weathering, buff firing, Whitemud formation, 3 ft.
821	$12D_2$	Pale grey sand and silt, white weathering, light buff firing, Whitemud formation, 4 ft.
822	12E	Black to olive plastic clay, red firing, Whitemud formation, 3 ft.

of plasticity) was calculated. Test briquettes, 4 x $1\frac{1}{2}$ x $1\frac{1}{4}$ inches, were hand-moulded in steel moulds. A briquette from each sample was subjected to rapid drying conditions at 185°F and the effect noted. The remaining briquettes were dried at room temperature for 24 hours and then in a laboratory drier at 212°F; the drying shrinkage was calculated. The briquettes were fired at various temperatures, which in the majority of cases were cones 06 (1816°F), 02 (2014°F), 2 (2088°F) and 5 (2151°F). The fired colour, hardness, shrinkage, and absorption after a 24-hour soak in cold water were determined. The pyrometric cone equivalent (PCE) was obtained.

Representative samples were pulverized for X-ray diffraction analysis and differential thermal analysis (DTA). A Norelco X-ray Diffractometer was used to indicate their mineralogical compositions. In some cases X-ray powder photographs were taken to confirm the presence of kaolinite. When 14 angstrom (14A) peaks were observed, the sample was treated with ethylene glycol and a second diffractogram was obtained. A shift in the 14A peak to 16 or 17A indicated the presence of montmorillonite, which is the prominent clay mineral in bentonite. Samples giving 7A peaks were heated to 550°C for one hour and diffractograms were obtained from the heated materials. The heat treatment removed the 7A kaolinite peak but did not change any 7A peak produced by a chloritic clay mineral. A peak at 10A indicated the presence of mica. This mineral can occur in a non-plastic form such as muscovite, or in the plastic, clay-mineral form which is called illite.

Differential thermal analysis was used to confirm the presence of kaolinite, montmorillonite, and quartz, and to obtain quantitative estimates of the amounts. The samples were run in an air atmosphere at a scale setting of 40. A scale setting of 10, which produces peaks with 4 times the amplitude of scale 40, was used for sample 45F. The approximate amount of kaolinite was obtained by measuring the area under the endothermic peak at 1060°F. A second sample was heated to 1300°F to eliminate the very large kaolinite peak, cooled, and then reheated at a scale setting of 4. A very small endothermic peak caused by the inversion of quartz from the low to high form appeared at 1060°F. The area under this peak was measured to obtain the percentage of quartz.

The samples were washed through a 200-M screen and a visual (in some cases a microscopic) examination was made of the +200 mesh residue.

RESULTS

The mineralogical compositions determined by X-ray analysis and differential thermal analysis are shown in Tables 2, 3, and 4.

The differential thermal analysis curves are shown in Figures 1, 2, and 3. Endothermic peaks point down and exothermic peaks point up. The small endothermic peak at 250°F, such as the one on the curve of sample $34B_1$, Figure 1, is caused by the elimination of adsorbed water from kaolinite and micaceous material. Prominent peaks at 250°F, such as

TABLE 2

Mineralogical Composition of Samples from Quarry 34

Sample No.	Mineral	X-ray Diffraction Results	DTA Results
34A	kaolinite	7A peak, removed by heating	35%
	montmorillonite	Weak 14A peak, glycolation moved this to 17A	minor amount
	mica	Weak, diffuse 10A peak	
	quartz	Strong pattern	38%
$34B_1$	kaolinite	Diffuse 7A peak removed by heating	23%
	mica	Diffuse 10A peak	
	quartz	Very strong pattern	53%
	feldspar	Strong single peak at 3.24A	
34C	kaolinite	Distinct 7A peak, removed by heating	38%
	quartz	Strong pattern	30%
34D (plastic)	kaolinite	Weak 7A peak, removed by heating	23%
	mica	Distinct 10A peak	
	quartz	Very strong pattern	36%
	feldspar	Weak peaks at 3.26 and 3.21A	
34D (sandy)	kaolinite	Weak 7A peak removed by heating	22%
	mica	Distinct 10A peak	
	quartz	Very strong pattern	43%
	feldspar	Distinct peak at 3.24A	
34E	kaolinite	Weak 7A peak	15%
	mica	Doubtful 10A peak	
	quartz	Very strong pattern	42%
	feldspar	Distinct peaks at 3.25 and 3.20	

TABLE 3

Mineralogical Composition of Samples from Quarry 45

Sample No.	Mineral	X-ray Diffraction Results	DTA Results
45A	kaolinite	Weak 7A line on powder photograph	26%
	montmorillonite	Distinct 15-16A peak moved to 17A by glycolation	perhaps 15-20%
	quartz	Very strong pattern	40%
$45B_1$	kaolinite	Sharp 7A peak removed by heating	16%
	montmorillonite	Diffuse 14A peak, moved to 17A by glycolation	minor amount
	mica	Small but sharp 10A peak	
	quartz	Very strong pattern	46%
	feldspar	One small peak at 3.24A	
45C	kaolinite	Weak 7A line on powder photograph	27%
	montmorillonite	Double 15A peak moved to 17A by glycolation	perhaps 15-20%
	quartz	Strong pattern	27%
45D	kaolinite	Weak, indistinct 7A peak	20%
	mica	Small, moderately sharp 10A peak	
	quartz	Strong pattern	29%
	feldspar	Diffuse peak at 3.20A	
$45E_1$ + $45E_2$	kaolinite	7A peak removed by heating	24%
	montmorillonite	Broad diffuse 15A peak moved to 18A with glycolation	perhaps 15-20%
	mica	Small, sharp 10A peak	
	quartz	Strong pattern	33%
	feldspar	Small peaks at 3.19A and 3.24A	
45F	mica	Sharp, fairly strong pattern at 10A	
	quartz	Strong pattern	30%
	feldspar	Moderately strong 3.20A peak	

TABLE 4

Mineralogical Composition of Samples from Quarry 12

Sample No.	Mineral	X-ray Diffraction Results	DTA Results
$12B_1$	kaolinite	Small 7A peak	22%
	montmorillonite	Diffuse, weak 15A peak moved to 16.5A by glycolation	minor amount
	quartz	Very strong pattern	38%
	mica	Small 10A peak	
$12B_2$	kaolinite	Weak 7A line in powder photograph	21%
	montmorillonite	Very broad, diffuse 15A peak moved to 17A by glycolation	perhaps 15-20%
	mica	Weak, diffuse 10A peak	
	quartz	Strong pattern	30%
	feldspar	Two small peaks at 3.21 and 3.18A	
12C	kaolinite	Small diffuse 7A peak	28%
	montmorillonite	Diffuse 15A peak moved to 17A by glycolation	minor amount
	mica	Small but sharp 10A peak	
	quartz	Strong pattern	29%
	feldspar	One small peak at 3.20A	
$12D_1$	kaolinite	Small 7A peak removed by heating	22%
	mica	Small, distinct 10A peak	
	quartz	Very strong pattern	31%
	feldspar	Small, diffuse 3.2A peak	
	siderite	Small but distinct 2.79A	
$12D_2$	kaolinite	Weak 7A line on powder photograph	18%
	mica	Small 10A peak	
	quartz	Very strong pattern	
	feldspar	Double 3.2A peak	43%
12E	kaolinite	Weak 7A line on powder photograph	21%
	montmorillonite	Broad 14A peak moved to 17A by glycolation	perhaps 15-20%
	mica	Weak 10A line on powder photograph	
	quartz	Strong pattern	42%
	feldspar	Diffuse 3.2A peak	

the one on the curve of sample 45C, Figure 2, are caused by the loss of adsorbed water from a small amount of montmorillonite. This effect adds to the small peak produced by kaolinite and micaceous material.

The endothermic peak at 1060°F on the curves obtained at a scale setting of 40 is due, principally, to the expulsion of hydroxyl groups from the kaolinite lattice. These peaks hide the very much smaller endothermic ones that are caused by the breakdown of micaceous material and the inversion of quartz from one form to another.

The exothermic peak at 1670 to 1775°F is due principally, to a kaolinite reaction. Montmorillonite and micaceous material also affect this reaction and in general reduce the size and lower the peak temperature. Samples 45A, 45C, $45E_1$ + $45E_2$, $12B_2$ and 12E, which contain the largest amounts of montmorillonite in association with kaolinite, have an exothermic peak between 1670 and 1710°F. This peak is immediately preceded by a small endothermic one which is due to a typical montmorillonite reaction. Samples 34A, $45B_1$, $12B_1$ and 12C, which contain very small amounts of montmorillonite, have an exothermic peak in the 1725 to 1750°F temperature range. Clays containing kaolinite but no montmorillonite have an exothermic peak between 1740 and 1775°F.

Montmorillonite is a minor constituent in all samples in which it was identified. Consequently, no typical montmorillonite peak was observed at approximately 1300°F except on the curves for samples 45A and 45C, which have very small deviations at 1275°F.

Mineralogically, sample 45F, which is from the Eastend formation, is different from the other clays. It consists, principally, of an illitic clay mineral and quartz. The endothermic peak at 1025°F is due to an illitic clay mineral reaction, and the small sharp peak at 1060°F indicates that this material contains a substantial amount of quartz.

No quantitative estimates of the amounts of montmorillonite, mica and feldspar were made because of the great difficulties involved. A semi-quantitative estimate from DTA indicates the montmorillonite content in each of samples 45A, 45C, $45E_1 + 45E_2$, $12B_2$ and 12E is about 15 to 20 per cent. The quantity of mica and feldspar is small; the percentage of each mineral probably does not exceed 10 or 15 per cent.

Microscopic and megascopic examinations of the +200 mesh fraction show that coarse mica, principally muscovite, occurs in all samples. The amount is small in some samples, in which it was not detected by X-ray analysis. Yellowish-red aggregates in the +200M fraction of $12D_1$ were shown by X-ray diffraction to consist of quartz, mica and jarosite ($KFe_3(SO_4)_2(OH)_6$).

The physical properties are shown in Tables 5, 6, and 7.

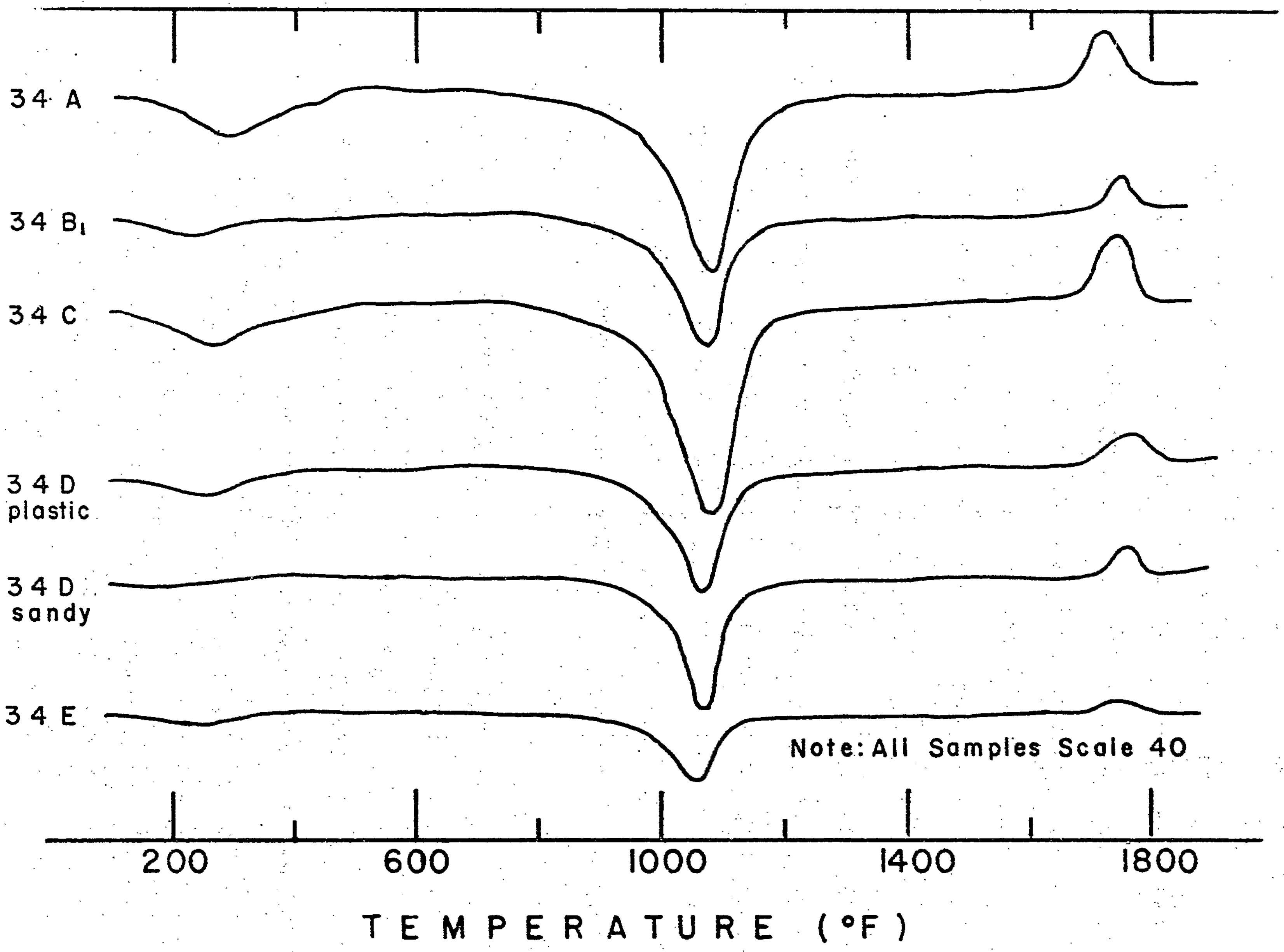

Figure 1. DTA Curves of Quarry 34 Clays

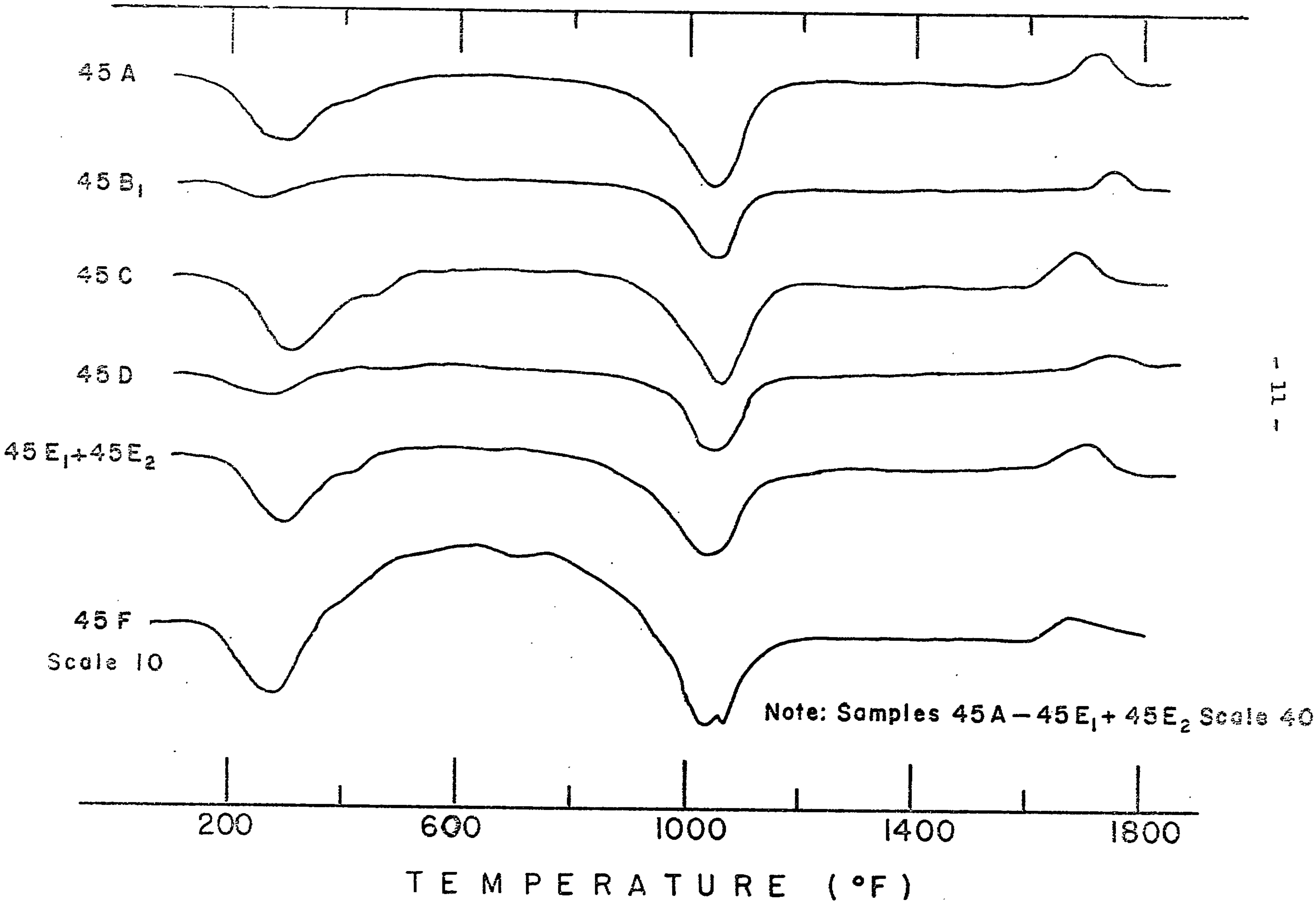

Figure 2. DTA Curves of Quarry 45 Clays

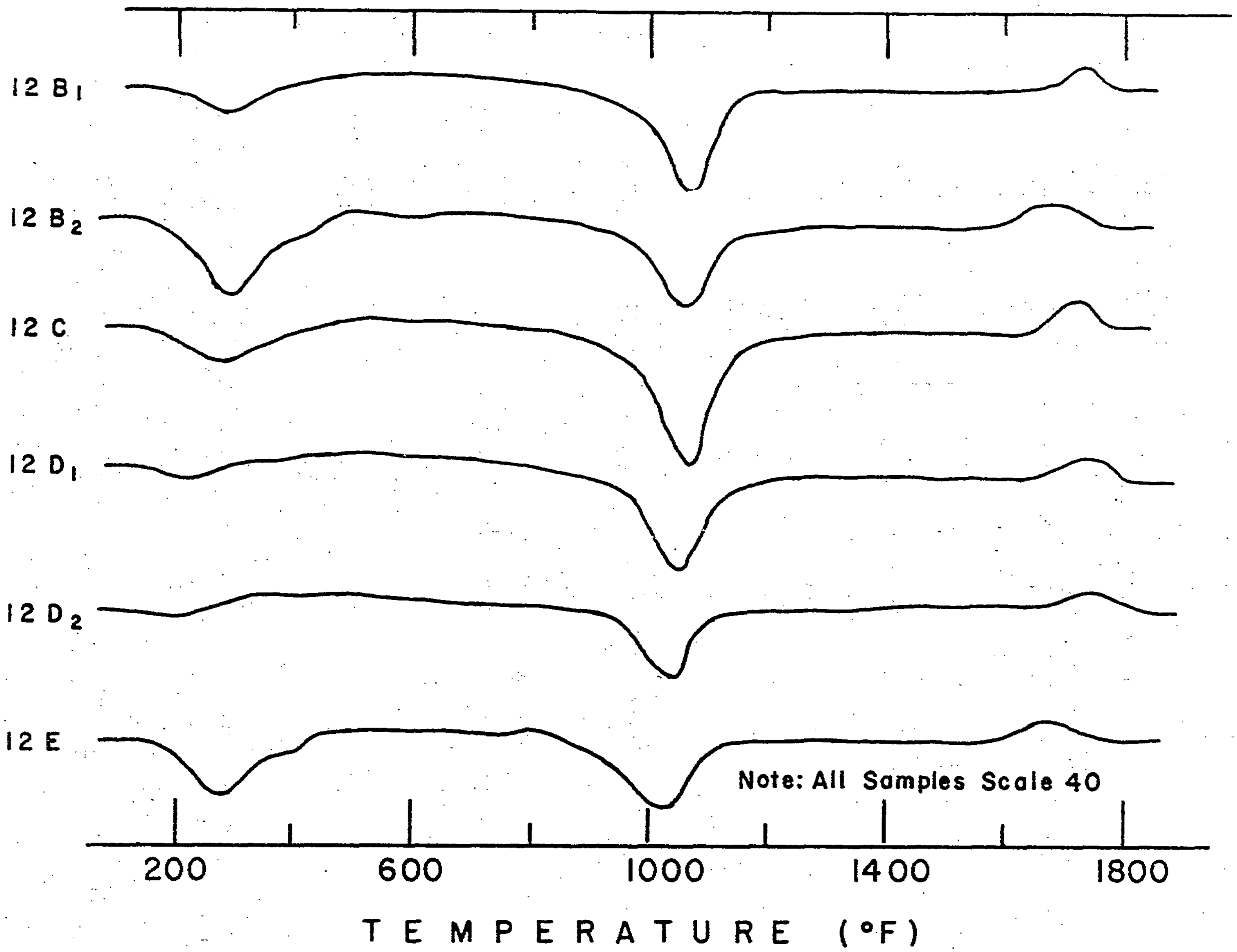

Figure 3. DTA Curves of Quarry 12 Clays

TABLE 5

Physical Properties of Clays from Quarry 34

Clay No.	UNFIRED CHARACTERISTICS	P. C. E.	FIRED CHARACTERISTICS Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	REMARKS
34A	Grey clay, very plastic and greasy, water of plasticity 26.7%, cracks in drying, drying shrinkage 7.6%.	23 (2887°F)	06	1.0	14.8	White	Fairly hard	Difficult to dry stoneware clay.
			02	3.3	10.0	Cream	Hard	
			2	4.0	8.8	Light buff	Very hard	
$34B_1$	Grey to white clay, fair plasticity, water of plasticity 18.1% slight cracks in rapid drying, drying shrinkage 4.8%, contains considerable grit.	20 (2808°F)	02	0.7	10.2	Light cream	Fairly soft	Open-firing stoneware clay which contains a high proportion of non-plastic material.
			2	1.0	9.1	Cream	Fairly hard	
			5	1.3	8.2	Cream	Fairly hard	
34C	Light brown to grey clay, good plasticity, water of plasticity 24.7%, slight tendency to crack with rapid drying, drying shrinkage 7.8%.	28 (2937°F)	06	1.1	14.0	White	Fairly hard	Refractory stoneware or low heat fireclay.
			02	3.5	10.2	Light cream	Hard	
			2	4.5	8.4	Cream	Very hard	
34D Plastic	White clay, plastic, water of plasticity 24.2%, cracks slightly with rapid drying, drying shrinkage 6.1%.	17 (2691°F)	06	0.2	13.9	White	Fairly hard	Stoneware clay.
			02	3.3	8.8	Cream	Hard	
			2	3.8	7.4	Light buff	Very hard	
34D Sandy	White clay, short and gritty, water of plasticity 21%, safe drying, drying shrinkage 5%.	19 (2768°F)	06	0	13.5	White	Fairly soft	Open-firing, non-plastic stoneware clay.
			02	0.7	11.5	White	Fairly hard	
			2	1.3	9.9	White	Fairly hard	
			5	1.8	9.0	Light cream	Hard	
34E	Light buff clay, non-plastic, water of plasticity 16%, safe drying, drying shrinkage 1.5%.	16 (2651°F)	02	0.3	18.5	Brown-buff	Soft	Non-plastic, sandy material.
			2	0.5	15.0	Brown-buff	Soft	
			5	1.3	15.0	Brown	Fairly hard	

TABLE 6

Physical Properties of Clays from Quarry 45

Clay No.	UNFIRED CHARACTERISTICS	P. C. E.	FIRED CHARACTERISTICS					REMARKS
			Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	
45A	Brown clay, tough plastic clay, water of plasticity 28.3%, cracks badly in drying, drying shrinkage 10.0%.	20	06	1.1	12.4	Light buff	Fairly hard	Very difficult to dry stoneware clay.
			02	2.5	9.5	Light buff	Hard	
			2	2.5	8.8	Buff	Very hard	
			5	3.5	8.2	Buff	Very hard	
$45B_1$	White clay, sandy material but inclined to be sticky, water of plasticity 17%, cracks in drying, drying shrinkage 2.0%.	18 (2732°F)	02	0.3	10.4	Light buff	Fairly soft	Difficult to dry, open-firing stoneware clay.
			2	0.3	9.9	Light buff	Fairly soft	
			5	2.0	9.4	Light buff	Fairly hard	
45C	Brown clay, very plastic, tough, and sticky, water of plasticity 34.7%, cracks in drying, drying shrinkage 11.7%.	16	06	2.5	10.5	Salmon	Hard	Very difficult to dry.
			02	5.7	4.4	Salmon	Very hard	
			2	6.3	3.6	Brown-red	Very hard	
45D	White clay, plastic, water of plasticity 25.8%, slight tendency to crack in drying, drying shrinkage 6.8%.	14 (2530°F)	06	0.8	14.1	Cream	Fairly hard	Stoneware clay with a medium firing range
			02	5.0	4.1	Light buff	Very hard	
			2	7.1	3.2	Buff	Steel hard	
$45E_1$ + $45E_2$	Brown to grey clay, very plastic and sticky, water of plasticity 37.5%, very difficult to dry, drying shrinkage 12.2%.	14	06	2.0	8.8	Light buff	Hard	Very difficult clay to dry.
			02	5.7	1.5	Brown-buff	Steel hard	
			2	6.3	0.6	Brown red	Steel hard	
45F	Grey to buff coloured clay, plastic, water of plasticity 24.4%, slight tendency to crack in rapid drying, drying shrinkage 6.8%.	9 (2300°F)	06	1.7	12.0	Salmon	Fairly hard	Common low fusion clay with a short firing range.
			02	7.3	0.6	Red	Steel hard	

TABLE 7

Physical Properties of Clays from Quarry 12

Clay No.	UNFIRED CHARACTERISTICS	P. C. E.	FIRED CHARACTERISTICS					REMARKS
			Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	
$12B_1$	Light grey clay, sandy, water of plasticity 23.6%, cracks badly in rapid drying, drying shrinkage 8.2%.	20 (2808°F)	02	0.7	11.1	Buff	Fairly soft	Open-firing because of sandy nature, difficult to dry stoneware clay.
			2	0.7	10.1	Buff	Fairly soft	
			5	1.0	9.9	Buff	Fairly hard	
$12B_2$	Buff clay, very plastic and sticky, water of plasticity 33.9%, cracks badly in drying, drying shrinkage 10.7%.	11 (2361°F)	06	6.5	9.8	Salmon	Very hard	Very difficult to dry.
			02	2.5	2.5	Brownish red	Steel hard	
12C	Light grey clay, very plastic and tough, water of plasticity 28.6%, cracks badly in rapid drying, drying shrinkage 8.2%.	19 (2768°F)	06	2.0	13.5	Cream	Hard	Difficult to dry stoneware clay
			02	5.7	5.5	Light buff	Very hard	
			2	6.8	2.1	Buff	Steel hard	
$12D_1$	Greyish white clay, good plasticity, water of plasticity 26.0%, very slight tendency to crack with rapid drying, drying shrinkage 7.1%.	15 (2595°F)	06	0.7	13.8	Cream	Fairly hard	Stoneware clay with a medium firing range.
			02	4.5	7.0	Light buff	Hard	
			2	7.0	1.0	Buff	Steel hard	
$12D_2$	White clay, gritty clay with poor plasticity, water of plasticity 23.6%, safe drying, drying shrinkage 4.5%.	16 (2651°F)	02	1.0	12.9	Cream	Fairly soft	Open-firing, non-plastic stoneware clay.
			2	1.7	10.5	Cream	Fairly hard	
			5	2.6	9.2	Dark cream	Hard	
12E	Very plastic, slightly sticky clay, water of plasticity 30.5%, cracks very badly in drying, drying shrinkage 10.2%.	15	06	0.7	13.0	Light salmon	Fairly hard	Very difficult to dry common clay.
			02	2.8	7.5	Salmon buff	Hard	
			2	4.1	4.6	Brown red	Very hard	

DISCUSSION AND CONCLUSIONS

Most of the samples are buff-firing stoneware clays. Kaolinite, montmorillonite, quartz, mica and feldspar are the principal minerals identified in them, although all five minerals do not occur in every sample. Quartz and mica are present in every clay, and kaolinite was identified in all of them except 45F.

Samples which contain the greatest amount of montmorillonite are very plastic, sticky, and impossible to dry without cracking because of their large drying shrinkage. The clays which contain a minor amount of montmorillonite are also difficult to dry. A very small amount of this mineral acts as a plasticizer, but a slightly larger amount makes drying difficult or impossible. Clays containing montmorillonite should be blended with non-plastic clays in proportions that produce a strong, easily-extruded body with suitable drying characteristics.

Samples 45C, $45E_1$+ $45E_2$, $12B_2$ and 12E, which are high in montmorillonite, are brown to red-firing clays. Sample 45A, which also contains an appreciable quantity of montmorillonite, is an exception and fires to a buff colour.

Quartz, feldspar and coarse mica are non-plastic ingredients. Samples $34B_1$, 34D (sandy), 34E, and $12D_2$ are relatively non-plastic because of a high content of these minerals and a low clay content. They have poor workability and would produce a weak body unless a plastic clay is added to them.

Samples 34A, $34B_1$, 34C, $12B_1$ and 45A have PCE's of 20 or higher because they have a high proportion of quartz and kaolinite which are refractory, and little or no montmorillonite, micaceous material, or feldspar. Conversely, the other samples, which are fluxed with micaceous material, feldspar, or montmorillonite in appreciable quantities, although they consist principally of kaolinite and quartz, are less refractory than cone 20. Sample 45F, which contains a illitic clay mineral, quartz, feldspar, and no kaolinite, is a typical, common, red-firing clay with a low PCE.

The clays from Quarries 45 and 12 contain a greater amount of montmorillonite than those from Quarry 34. The average content of kaolinite and quartz is higher in Quarry 34 than in Quarries 45 and 12. Consequently clays from Quarry 34 are generally more refractory, less plastic, and easier to dry than clays from Quarries 45 and 12.

Samples 34A and 45A have similar properties. They appear to be Whitemud clays rather than clays from the Battle formation.

Samples $34B_1$, $45B_1$, and $12B_1$ are open-firing stoneware clays which are difficult to dry. Each of them contains kaolinite and micaceous material, and has a high quartz content. Samples $45B_1$ and $12B_1$ contain montmorillonite and, consequently, would probably cause more trouble in drying than $34B_1$. Samples $34B_1$ and $45B_1$ contain feldspar, and $12B_1$ does not.

Clays $34B_2$, $45B_2$, and $12B_2$, of which only the last one was sampled, are red-firing, bentonitic materials, judging from the properties and composition of $12B_2$, and from certain tests performed by the company but not discussed here.

Sample 34C is a refractory stoneware clay, consisting of kaolinite and quartz. Samples 45C and 12C are very plastic, refractory materials which contain montmorillonite in addition to quartz and kaolinite. Sample 12C also contains micaceous material and feldspar.

Samples 34D (plastic), 45D, and $12D_1$ are stoneware clays having similar properties, although 45D and $12D_1$ have shorter firing ranges than 34D (plastic). They have similar mineralogical compositions except that $12D_1$ may contain a small amount of siderite.

Samples 34D (sandy) and $12D_2$ are open-firing, non-plastic stoneware clays with almost identical mineralogical compositions.

Samples 34E, $45E_1$+ $45E_2$, and 12E contain kaolinite, quartz, micaceous material, and feldspar. Montmorillonite is present in $45E_1$ + $45E_2$ and 12E, but there is none in 34E. This explains the different physical properties of 34E.