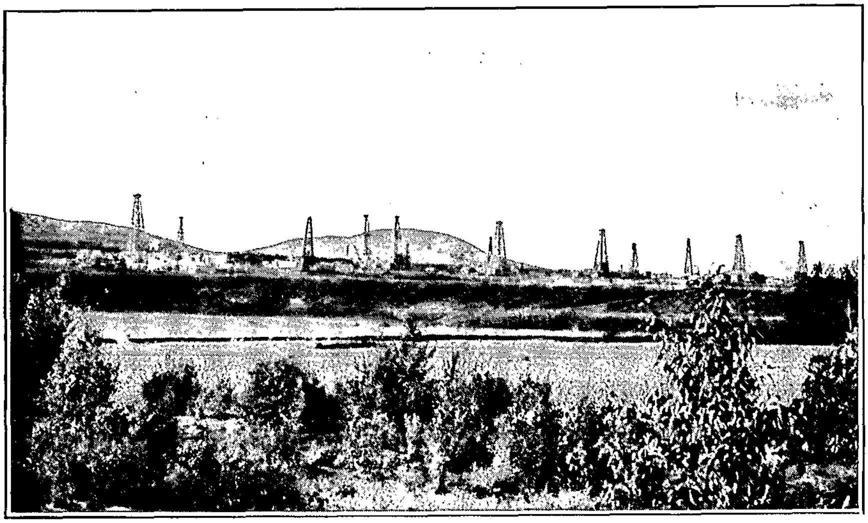
THE CLAY AND SHALE RESOURCES OF TURNER VALLEY AND NEARBY DISTRICTS

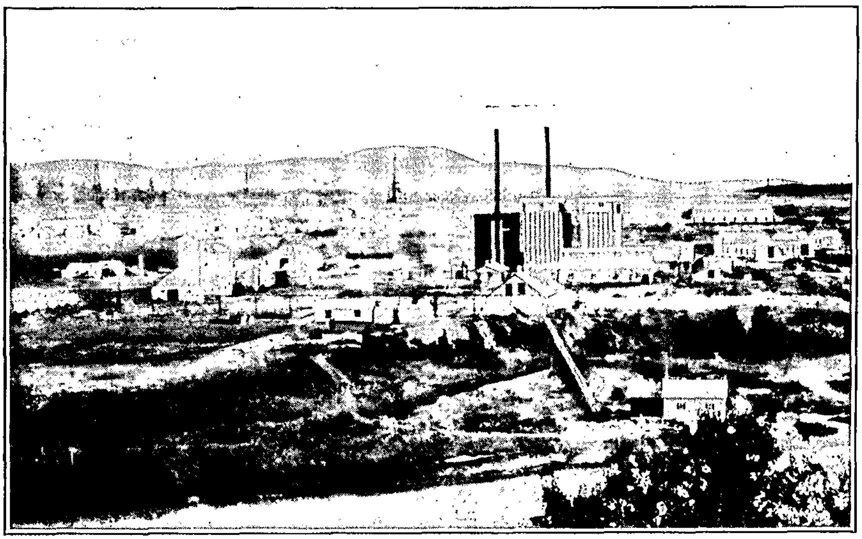
W. G. WORCESTER

MINES BRANCH
DEPARTMENT OF MINES
OTTAWA
1932

NO. 729



A. View of oil derricks in central Turner valley.



B. View of central Turner valley; scrubbing plant of the Imperial Oil Company, Ltd., in the foreground.

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BY

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F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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ILLUSTRATIONS

Photographs

Graphs of Absorption and Shrinkage Curves

PREFACE

The investigation of the clays and shales of Turner valley, Alberta, and adjacent districts, herein reported upon, was undertaken by Professor W. G. Worcester of the University of Saskatchewan. The work was done under the supervision of the Ceramic Division of the Mines Branch during the field season of 1929 and at the request of the Turner Valley Waste Gas Committee appointed by the Dominion and Alberta Provincial Governments.

This report which was submitted to the Turner Valley Waste Gas Committee is now published by the Mines Branch of the Dominion Department of Mines with the permission of the chairman and members of that Committee.

JOHN McLEISH,
Director, Mines Branch.

THE CLAY AND SHALE RESOURCES OF TURNER VALLEY AND NEARBY DISTRICTS

CHAPTER I

INTRODUCTION

The present report has been prepared in response to a demand for information relative to the ceramic possibilities of the several geological formations outcropping at or near the Turner Valley oil and gas field. It was hoped that there might be found clays or shales of a kind or quality to warrant their development along commercial lines, thereby assisting to provide a market for gas now going to waste.

The time allowed for the field study and collection of samples extended from August 15 to September 30, 1929. Obviously, work undertaken in so short a time could only be in the nature of a reconnaissance. However, sufficient information has been obtained to permit of stating quite definitely the types of clay and shale to be expected in the area studied. Furthermore, the information will prove of material assistance in directing new work to those formations and deposits of greatest industrial ceramic interest.

The survey has also shown that commercially important beds of clay and shale for the manufacture of clay products occur within the general district of the Turner Valley gas field; thus, in the event of suitable transportation becoming available, the conditions at Turner Valley would prove highly attractive to the building up of diversified ceramic industries at that point.

No attempt has been made in this report to deal with the origin of clays, their classification nor the general technology of clays, as those subjects were covered quite fully by Ries and Keele[1] in their extensive report on the clays and shales of the Western Provinces, and moreover, it was felt that a more complete discussion of the commercial possibilities of the numerous samples and deposits would prove of greater value at this time.

ACKNOWLEDGMENTS

The author wishes to express his indebtedness to G. S. Hume of the Geological Survey, for his valuable assistance in supplying information relative to the geology of the district and for the location of many of the outcrops examined and sampled; also to Dr. J. A. Allan, University of Alberta, Edmonton, for similar information; and to Mr. P. D. Moore, Geologist for the Imperial Oil Co., Ltd., at Turner Valley, for information and for the privilege of examining core samples from wells in the district.

In the field work the efficient and experienced services of J. W. Craig, Ceramic Engineer, and J. Cameron Worcester, are hereby acknowledged. In addition to his work in the field, Mr. Craig acted as full-time assistant in the conducting of all laboratory tests, and in the compiling of the tables.

[1] "Clay and Shale Deposits of the Western Provinces": Geol. Surv., Canada, Mem. No. 24.

COLLECTION OF SAMPLES

In planning for the collection of the samples for this investigation, the following objects were selected as being the most important to the supplying of immediate information relative to the commercial ceramic possibilities of the area under survey.

First, that of a careful sampling and study of the several geological formations known to outcrop in the selected area.

Secondly, that of collecting all samples from an industrial point of view, rather than from that of making a highly technical pyro-physical and chemical study of the innumerable strata or beds. Thus all deposits selected for sampling were, in most cases, beds of sufficient depth or thickness to provide material in commercial quantities, and under practical working conditions. In other words, thin isolated strata of shale were not included. Each deposit or bed in turn was sampled according to standard practice by first clearing the surface of all foreign material or overburden, followed by cutting a channel or trench sample across the stratum or deposit.

However, a slight departure from the usual channel sample practice was made in that objectionable bands of stone and concretions of appreciable size which would be discarded in actual operation were in all cases excluded from the samples; thus the samples as taken represent, in so far as possible, the actual material which would ultimately be used in the production of commercial wares.

AREAS OR DISTRICTS SURVEYED

Though the survey was intended primarily to cover only the Turner Valley district it was, for the following reasons, deemed advisable to extend the work to cover a greater area than that of the immediate vicinity.

First: Turner valley proper is approximately 11 miles from the nearest shipping point, thus in the absence of rail transportation the commercial possibilities for clay product manufacture in the valley or at the source of gas supply would prove unattractive if not wholly uneconomical.

Second: In that gas lends itself readily to transportation, at least within reasonable distances, it was considered advisable to extend the study to include adjacent territory on or near transportation.

Third: It was also considered essential to check possible lateral variations of the beds as well as those which might occur across or at right angles to them. For this reason work was started somewhat south-southeast of Turner valley and was carried north-northwestward along the general strike of the formations to the Bow river, west of Calgary.

The territory covered has for convenience, been divided into districts or areas as follows:—

Upper Highwood River Area

Included in this field were stretches along Highwood river, Bull creek, Ings creek, Sullivan creek, and Trap (or Flat) creek, all to the south and southeast of Turner valley. Many excellent exposures of Edmonton, Belly River, and Benton beds were seen.

Turner Valley (Central) Area

This district included areas along Sheep river from below the forks (the junction of Quirk creek and Sheep river), upstream to Black Diamond, Turner Valley, Lineham ford, Macabee creek, and outcrops on Quirk creek from the forks to Millarville and Kew.

North (Central) Area

The field work in this area covered deposits and outcrops at Priddis and upstream along Fish creek, then northwestward to Elbow river at Bragg Creek.

Bow River Area

This covered, in part, stretches along Bow river from Cochrane to Ghost river, on Spencer creek, Grand Valley creek, Jumpingpound creek, and at Bowness and Brickburn, short distances west of Calgary.

East Area

This field comprises the area east of Turner valley in the vicinity of Okotoks and Aldersyde where excellent outcrops of Paskapoo beds were examined and sampled along Highwood and Sheep rivers, and at Sandstone in Wilson coulée. Stretches along Pine and Fish creeks, near De Winton and Midnapore, were also studied.

GENERAL NOTES CONCERNING SAMPLES

The total number of samples collected during the field work was 82. The number collected from the individual fields or areas is given below.

Area	Number of samples	Per cent of total
Upper Highwood River area	14	17·3
Turner Valley (Central) area	33	40·2
North (Central) area	11	13·3
Bow River area	7	8·5
East area	17	20·7
Total	82	100·0

It will be noted that over 60 per cent of the samples was collected from Turner Valley and the East area (Okotoks-Aldersyde); these areas are most likely to become ultimate users of gas from the Turner Valley field.

A further division of the samples may be made geologically, in accordance with the formations or beds from which they were taken.

Formation	Number of samples	Per cent of total
Recent	3	3·6
Paskapoo	27	32·9
Edmonton	14	17·3
Bearpaw	1	1·2
Belly River	11	13·3
Benton	19	23·2
Blairmore	7	8·5
Total	82	100·0

Although many deposits were visited and sampled it is not to be assumed that others do not exist. The ones selected for test purposes were carefully chosen to provide representative samples of the formations within which they occurred. Time did not permit, nor was it thought necessary to collect material from all of the outcrops, in that a very large amount of repetition would have resulted. There may be other outcrops or material under cover, which may prove equally as attractive from an industrial point of view as the deposits here reported on.

LOCATION OF DEPOSITS

The accompanying table gives the legal location of each deposit sampled, and, in most cases, to the nearest quarter section. In addition to the legal locations which are given, brief general locations have been added. In addition, there has been added a column showing the geological formation from which each sample was taken. It is possible that, owing to some of the beds being much distorted and intermixed, a number of samples have been assigned to the wrong geological formation.

The geological ages of the samples were determined largely by reference to publications and maps of the Geological Survey of the Department of Mines; those most frequently used being by Cairnes[1], Slipper[2], Hume[3], and Rutherford[4]. G. S. Hume supplied advance (private) information concerning the geology along the Highwood river, Bull, Macabee, and Fish creeks.

[1] "Moose Mountain District"; Geol. Surv., Canada, Mem. 61.
[2] "Sheep River Oil and Gas Field, Alta."; Geol. Surv., Canada, Mem. 122.
[3] "Turner Valley Oil Area"; Geol. Surv., Canada, Sum. Rept. 1926, pt. B.
"Oil Prospects near Bragg Creek"; Geol. Surv., Canada, Sum. Rept. 1927, pt. B.
[4] Geology along the Bow River between Cochrane and Kananaskis. Geol. Survey Div. Alberta, Report No. 17.

TABLE I

Locations

Sample No.	Location					General Location	Formation
	Q.	S.	Tp.	R.	West of mer.		
2901	SE.	10	18	2	5	Highwood river, below Bull creek..........	Edmonton
2902	SE.	10	18	2	5	" " "	"
2903	SW.	9	18	2	5	Bull creek, near mouth......................	"
2904	SW.	9	18	2	5	" "	"
2905	NE.	36	17	4	5	Trap creek, near mouth.....................	Benton
2906	SE.	1	18	4	5	Highwood river, below Trap creek.........	"
2907	SW.	6	18	3	5	" " "	"
2908	SW.	6	18	3	5	" " "	Belly River
2909	SW.	20	18	3	5	Sullivan creek, near mouth.................	Benton
2910	SW.	20	18	3	5	" "	"
2911	SE.	8	18	2	5	Bull creek, near old mines.................	Bearpaw (?)
2912	SW.	8	18	2	5	" "	Belly River
2913	NW.	25	18	3	5	Highwood river, below Ings creek..........	Benton
2914	NW.	25	18	3	5	" " "	"
2915	SE.	17	20	2	5	Sheep river, near Black Diamond..........	Edmonton
2916	SE.	17	20	2	5	" " "	"
2917	SE.	17	20	2	5	" " "	"
2918	SE.	17	20	2	5	" " "	"
2919	SE.	17	20	2	5	" " "	"
2920	NE.	2	20	3	5	Sheep river, near Lineham.................	Belly River
2921	SW.	1	20	3	5	" "	"
2922	SW.	1	20	3	5	" "	"
2923	SW.	5	21	3	5	Quirk creek, west of Millarville.............	"
2924	SW.	5	21	3	5	" "	" (?)
2925	SW.	5	21	3	5	" "	" (?)
2926	NW.	5	21	3	5	" "	"
2927	SE.	7	20	2	5	Turner Valley, near small bridge, main trail.	Benton
2928	SE.	7	20	2	5	" " " ..	"
2929	SE.	7	20	2	5	" " " ..	"
2930	SE.	7	20	2	5	" " " ..	"
2931	SE.	7	20	2	5	" " " ..	"
2932	NE.	6	20	2	5	" east of Imperial Oil refinery..	"
2933	NE.	6	20	2	5	" " " ..	"
2934	NE.	6	20	2	5	" " " ..	"
2935	NE.	29	19	3	5	Sheep river, at mouth of Macabee creek.....	"
2936	NE.	29	19	3	5	" " "	"
2937	NE.	29	19	3	5	Macabee creek, near mouth................	Blairmore
2938	NE.	29	19	3	5	" "	"
2939	NW.	29	19	3	5	Macabee creek.............................	"
2940	SW.	12	21	3	5	Millar ranch, Quirk creek..................	Recent
2941	SW.	12	21	3	5	" "	"
2942	SE.	33	20	2	5	Freeman ranch, Quirk creek...............	Paskapoo
2943	SE.	33	20	2	5	" "	"
2944	SE.	33	20	2	5	" "	"
2945	NE.	21	20	2	5	Sheep river, below Black Diamond..........	"
2946	NW.	23	22	3	5	Priddis, Fish creek.........................	Edmonton
2947	NW.	23	22	3	5	" "	Paskapoo
2948	NW.	23	22	3	5	" "	"
2949	SE.	10	22	3	5	Fish creek, above Priddis..................	Edmonton
2950	NE.	4	22	3	5	" "	"
2951	S. ½	35	20	3	5	Near forks, Quirk creek....................	Paskapoo
2952	S. ½	35	20	3	5	" "	"
2953	SE.	18	20	28	4	Highwood river, near Aldersyde...........	"
2954	SE.	32	20	28	4	" near mouth of Sheep river..	"
2955	SE.	32	20	28	4	" " " ..	"
2956	SE.	30	20	28	4	Sheep river, east of Okotoks...............	"
2957	NE.	19	20	28	4	" "	"
2958	SW.	8	20	28	4	Highwood river, near Aldersyde...........	"

TABLE I—Concluded

Locations—Concluded

Sample No.	Location Q.	S.	Tp.	R.	West of mer.	General Location	Formation
2958A	SW.	8	20	28	4	Highwood river..........................	Paskapoo
2959	NW.	22	20	29	4	Sheep river, C.P.R. bridge, Okotoks........	"
2960	NE.	24	20	29	4	Sheep river, SE. of Okotoks................	"
2961	NE.	24	20	29	4	" "	"
2962	SE.	20	20	28	4	Sheep river, east of Okotoks................	"
2963	SE.	20	20	28	4	" "	"
2964	SW.	25	20	1	5	Sheep river, upstream from Okotoks........	"
2965	SW.	25	20	1	5	" " "	"
2966	SW.	29	20	29	4	" " "	"
2967	S. ½	2	21	1	5	Wilson coulée, Sandstone Station............	"
2968	S. ½	2	21	1	5	" " "	"
2969	S. ½	2	21	1	5	" " "	"
2970	SE.	11	23	5	5	Elbow river, Bragg Creek P.O...............	Benton
2971	NW.	12	23	5	5	" " "	Blairmore
2972	NW.	12	23	5	5	" " "	"
2973	NW.	12	23	5	5	" " "	"
2974	SE.	13	23	5	5	" " "	"
2975	NE.	19	23	4	5	Elbow river, Sarcee Indian reserve..........	Belly River
2976	NW.	17	26	5	5	Spencer creek, west of Cochrane............	Benton
2977	NE.	13	26	5	5	Grand Valley creek, west of Cochrane.......	Belly River
2978	NW.	5	5	4	5	Bow river, near C.P.R. bridge west of Cochrane.	Edmonton
2979	NW.	5	5	4	5	" " " ..	"
2980	NE.	33	25	4	5	Near mouth Jumpingpound creek...........	Recent
2981	SW.	26	24	2	5	Bow river, Tregillus Clay Products, Ltd. (dismantled)...........................	Paskapoo
2982	NE.	23	24	2	5	Bow river, Crandell Pressed Brick Co., Ltd.	"

*TABLE OF FORMATIONS

Age		Formation	Lithology	Deposit	Topographical expression	Thickness	Remarks
						Feet	
Tertiary		Paskapoo	Light, ash-coloured, massive sandstone beds, greenish clays and shales	Freshwater	Eroded into irregular hills and depressions	4,000	In certain places a conglomeratic sandstone with quartzite pebbles up to 3 inches in diameter is exposed at what is considered the base of the Paskapoo. Below the conglomeratic sandstone is green clay shale presumed to be Edmonton. The division is not made on fossil evidence
Cretaceous		Edmonton	Dark green clays with hard, greenish sandstones. A carbonaceous horizon at base	Brackish water	Underlies a broad depression formed in upturned beds east of Turner valley and extending northwestward to Priddis	1,300	
Cretaceous	Montana	Bearpaw	Black shales, carbonaceous in places	Marine			Not definitely known to be present in Turner Valley area
Cretaceous	Montana	Belly River	Light green clays and shales, light grey and greenish, massive, and thin-bedded sandstones. A coal seam at the top of the formation	Brackish water	Upturned beds form prominent ridges	1,800 to 1,900	
Cretaceous	Colorado	† "Benton"	Blue-black shales with several thin sandstone members	Marine	In contrast with the Belly River rocks these are easily eroded and form valleys	2,500 to 3,000	Fossils from the upper part of the "Benton" appear to be Montana in age, whereas lower down Colorado fossils are common.
Cretaceous		Blairmore	Thin-bedded, variegated shales, massive and thin-bedded, green and grey sandstones	Land and freshwater (plants)	Form ridges		In the Blairmore area there are two floras, an upper dicotyledon flora of Upper Cretaceous age and a lower cycad flora. Only the lower has so far been found in Turner Valley
Cretaceous		Kootenay	Coal, black shales, and hard sandstones	Continental	Does not outcrop in Turner Valley area		A conglomerate of varying thickness occurs at the base of the Blairmore. It is not known to have been recognized in well samples

* Table taken from Summary Report 1926, Part B, Geological Survey of Canada, "Turner Valley Oil Area," G. S. Hume.

† While the Benton formation may be divided into Lower Benton followed by Cardium sandstone and then Upper Benton, no attempt has been made in this report to divide the samples thus, largely from the fact that ceramically they are quite similar. Dr. G. S. Hume, of the Geological Survey of Canada, has now abandoned the term Benton and substituted Lower and Upper Alberta shale, *see*, Hume: Summary Report, 1929, Part B, Geological Survey of Canada.

CHAPTER II

TESTS AND TESTING PROCEDURE

The observations, studies, and tests made and conducted on the samples of this report may be divided into two general groups: First, those on the raw or unburned clays, and second, those on their burned trials. They were as follows:—

Plastic and Dry Properties—

Presence of carbonates.
General grinding properties.
Working properties.
Colour, wet and dry.
Drying behaviour.
Water of plasticity.
Shrinkage water.
Pore water.
Dry volume shrinkage.
Dry linear shrinkage.
Modulus of rupture.

Fired Properties—

Oxidation.
Volume shrinkage at various temperatures.
Linear shrinkage at various temperatures.
Apparent porosity at various temperatures.
Absorption at various temperatures.
Apparent specific gravity at various temperatures.
Hardness.
Colour.
Colour defects.
Modulus of rupture.
[1]P. C. E. (Fusion Tests).

PLASTIC AND DRY PROPERTIES

Presence of Carbonates

As carbonates may, in some cases, prove detrimental to the colour value of the burned ware, each sample was tested for the presence of free carbonate by applying drops of hydrochloric acid to the surface of numerous unground pieces of each shale or clay. The results are shown on page 15.

[1] P.C.E., or pyrometric cone equivalent, is the term adopted by the American Ceramic Society to designate the softening point of a clay in terms of a standard pyrometric cone.

Grinding and Preparation of Samples

Each sample was crushed in a roll crusher to pass a $\frac{1}{4}$-inch mesh, followed by a final pulverizing or sizing to pass 20 mesh in a rotary grinding mill, note being made as to its hardness and grinding properties. The ground samples were then thoroughly dried in a constant temperature oven at 70° C. It was thought that this plan would provide a more accurate measurement of the water necessary to produce plasticity than would be possible if each sample were tested as it came from the deposit.

Tempering

The water used for tempering was taken from the mains of the city, (South Saskatchewan river), and very likely corresponds quite closely to the average water available to the western clay products industry. Each clay or shale was tempered, in so far as possible, to its best working consistency, a condition rather difficult to obtain in some of the short and feebly plastic Benton shales. The tempering was followed by packing each sample in a jar and allowing it to age approximately 24 hours, thus permitting of a better distribution of the water and a greater degree of development of the latent plasticity.

Preparation of Trials

Upon removal from the ageing containers the soft plastic masses were thoroughly wedged until each became uniform as to consistency. Following the wedging process, rolls of clay slightly larger and longer than the mould box were prepared and then pressed or pounded into the mould[1] with the side of the hand.

Plasticity and Working Properties

An experienced worker of clays can readily judge their general degree of plasticity and working properties through feel and manipulation of the plastic mass in the hand, thus, if the same worker be permitted to study these properties in a number of samples his description or classification of them will be sufficiently accurate to satisfy the demands of the trade in general. In the present study all samples were tempered, wedged, and moulded by the same person; his classification and remarks are noted in Table II, columns 2 and 3.

Colouring and Drying Behaviour

The raw or unburned colour of a clay may give a clue to the presence of unoxidized materials like carbon and organic matter. It also reveals to some extent the degree of oxidation of the iron present. The colour of the wet and dry trials prepared for this report have been listed in Table II, columns 4 and 5.

Drying behaviour was determined according to the standard methods of the American Ceramic Society.[2] The test pieces being carefully examined for checks and cracks, and volume and linear shrinkage determined.

[1] The mould used was that described on page 445, Jour. Amer. Cer. Soc., June, 1928.
[2] Jour. Amer. Cer. Soc., June, 1928, p. 450.

Water of Plasticity

In the tempering of clay the water which is added to permit of working it into a plastic mass is described or designated as the water of plasticity. The percentage of water used for this purpose gives a fairly clear conception of the size of grain of the clay. For instance, a fine-grained ball clay may require 40 per cent or more of water to produce plasticity, while, on the other hand, a coarse-grained sandy clay may use only 20 per cent or less. As a rule those clays which show high water of plasticity will be found troublesome or difficult to dry safely.

In the present work the average of three trials, ($1\frac{1}{8} \times 1\frac{1}{8} \times 1\frac{7}{8}$ inches), was taken and the per cent obtained by the standard formula.

$$\text{Water of Plasticity: } T = \frac{Wp - Wd}{Wd} \times 100.$$

Where T = per cent water of plasticity.
Wp = weight of the plastic trial piece.
Wd = weight of the dry trial piece.

The results are shown in Table II, column 7.

Shrinkage and Pore Water

"Shrinkage water" is defined as that portion of the water of plasticity which is driven off up to the point where drying shrinkage ceases. "Pore water" is defined as that portion of the water of plasticity which is driven off from the point where drying shrinkage ceases until the clay piece has reached approximately constant weight at 110° C. Thus shrinkage water plus pore water equals the water of plasticity.

$$\text{Shrinkage water: } t_1 = \frac{Vp - Vd}{Wd} \times 100$$

Where t_1 = the per cent shrinkage water.
Vp = the plastic volume in c.c.
Vd = the dry volume in c.c.
Wd = the dry weight in grammes.
Pore water: $t_2 = T - t_1$
Where t_2 = the per cent pore water.

Results are shown in Table II, columns 8 and 9.

Dry Volume Shrinkage

The usual industrial method of obtaining shrinkage is that of making two marks or indentations on a plastic trial piece at a known distance apart. The piece is dried and the distance between the marks re-measured. The per cent of shrinkage is then easily determined. This method of determining shrinkage may prove quite unreliable, especially in cases where the trial piece becomes warped or twisted during the drying period. To guard against errors of this sort the adopted standard method calls for a determination of the actual volume of the wet plastic and dry trial piece, from the data thus obtained the linear and volume shrinkages may be readily obtained.

In testing the present samples the dry volume shrinkage was taken from trials prepared for the determination of the water of plasticity, by placing each wet plastic trial in a Goodner[1] mercury volumeter and measuring its volume. When removed from the volumeter each trial piece was

[1] Jour. Amer. Cer. Soc., April, 1921.

air-dried at room temperature, followed by drying in an oven held at 70° C. for 12 hours and finally at 110° C. to practically constant weight, then placed in a desiccator until cool and lastly re-measured in the volumeter for its dry volume. The per cent dry volume shrinkage was calculated by the standard formula.

$$b = \frac{Vp - Vd}{Vd} \times 100$$

in which b = per cent volume shrinkage.
Vp = the plastic volume.
Vd = the dry volume.

Results are shown in Table II, column 10.

Dry Linear Shrinkage

Notwithstanding the greater degree of accuracy obtained through measuring shrinkage by volume rather than by the linear method, it is usually found necessary to change the former into the latter by calculation at least prior to the ordering of dies or other equipment. In the present case the work has been done as an aid to the better understanding and convenience of the average clay-worker. The conversion was made by means of the shrinkage tables of A. E. R. Westman.[1]

Results are shown in Table II, column 11.

Dry Modulus of Rupture

The measure of this property of an ordinary clay in its unburned state is of assistance and value in determining its suitability for certain wares. For instance, in the production of thin-section wares clays of high modulus of rupture are sought as losses due to handling in the raw state are much less than would be the case with clays having low modulus of rupture.

In conducting the modulus of rupture tests on the raw trials three pieces of each clay, $1\frac{1}{8} \times 1\frac{1}{8} \times 7$ inches, were prepared. These were slowly dried at room temperature, then placed in an oven for 12 hours at 70°C., then raised to 110° C. until practically constant weight had been obtained. The trials were cooled in a desiccator and were taken out only as needed for the final test. The apparatus consisted of a special cradle upon which were placed rocker supports carrying rollers for the knife edges and spaced five inches on centres. The load was applied by means of a hand-power Tinius Olsen general testing machine. The average of the three trials has been recorded, the calculations being made by the following formula.

$$M = \frac{3\,Pl}{2bd^2}$$

where M = modulus of rupture (transverse strength) in pounds per square inch.
P = the load applied at the centre in pounds.
l = the span between supports in inches.
b = the breadth in inches.
d = the depth in inches.

Results are shown in Table III, column 2.

[1] Jour. Amer. Cer. Soc., September, 1928.

FIRED PROPERTIES

Oxidation

Most clays which carry unoxidized materials like organic matter, carbon, and sulphur compounds, require special care and treatment during the early stages of the burning. Otherwise, serious losses will result through a bloating or expansion of the ware due to a rapid evolution of gases in the interior and its non-escape at the surface. Fine-grained clays are more liable to the above trouble than are coarse-grained ones, even though in the latter case the per cent of unoxidized material in the raw clay may be higher.

Up to the present no standard test for measuring oxidation has been formulated. Many investigators have, however, adopted the method described below. Trials $1\frac{1}{4} \times 1\frac{1}{4} \times 2$ inches were moulded and dried in the same manner as those used for volume dry shrinkage. When dry they were placed on end in an oil-fired, muffle kiln, care being taken to so place them that one complete set of all clays could be drawn from the kiln at desired intervals; sufficient sets to permit of ten draws being provided. The temperature of the kiln was gradually raised to 750° C. in 7 hours. This temperature was then maintained as nearly constant as possible for 11 hours, one trial of each clay being drawn from the kiln at one-hour intervals during the earlier part of the test and at two-hour periods near the close.

The trials when cool were broken open and the progress of the oxidation noted. The results are shown in Table III, column 4.

Volume Shrinkage, etc.

The trials for the measurement of the volume changes taking place during the burning were prepared in the same manner and were of the same size as those used for dry volume shrinkage. As the oxidation study had shown several of the clays to be difficult of oxidation the following precautionary plan was followed to avoid their swelling or bloating during burning; all of the volume trials were placed loosely in open saggers which in turn were set in an oil-fired muffle kiln and the temperature slowly raised to 750° C. where it was held for several hours followed by slow cooling.

At the conclusion of the above oxidation treatment the saggers containing the trials were removed to an open, oil-fired, down-draught kiln and placed so that complete sets of the samples could be drawn from the kiln at desired temperatures—these temperatures being represented by cones 010–07–04–02–1–3, and 5. It should be mentioned that preliminary burns had been made to classify the clays roughly into groups according to vitrification ranges, and it was also found necessary to make two complete burns in order to accommodate the large number of trial pieces.

Upon removal from the kiln each set of trials was immediately placed in the chamber of a nearby kiln where the temperature was that of a clear red heat. When all had been transferred the kiln and its charge was slowly cooled to room temperature and the trials removed. Measurements and calculations were then made on them for volume shrinkage, linear shrinkage, apparent porosity, specific gravity, and absorption, the A. C. S. Standards, 1928, being used in each case, except that of linear shrinkage which was taken from the Westman tables, published in Journal American Ceramic Society, 1928.

The formulæ used were as follows:—

Volume change

$$b_1 = \frac{Vd - Vf}{Vd} \times 100$$

Apparent porosity

$$P = \frac{Sf - Wf}{Vf} \times 100$$

Absorption

$$A = \frac{Sf - Wf}{Wf} \times 100$$

Apparent specific gravity

$$G = \frac{Wf}{Vf - (Sf - Wf)}$$

Where b_1 = Per cent volume change.
Vd = Volume of the dry test piece in c.c.
Vf = Volume of the fired test piece in c.c.
P = The per cent apparent porosity.
Sf = Weight of the saturated fired test piece in grammes.
Wf = Weight of the fired test piece in grammes.
G = The apparent specific gravity.
A = Per cent absorption.

Results are shown in Table III, columns 6, 8, 9, and 10.

Hardness

This property was measured by means of a steel knife blade which was drawn, under hand pressure, across the surface of the several trials burned to the cones noted above. The first trial in the series to remain uncut or unscratched has been listed as steel hard. Results are shown in Table III, column 11.

Colour

In most cases the reporting of the colour changes noted on the average draw trials proves to be of little value, as the cooling time for such trials is too short and does not permit of the development of the true shades or colour values. In the present study, therefore, a complete separate burn to cone 02 was made in which the trials were allowed to cool down with the kiln, thereby approaching commercial kiln conditions as far as possible. While some of the samples were not at their best colour at cone 02, due allowance has been made for them in the final study.

Results are reported in Table III, columns 12 and 13.

Colour Defects

In studying the colour of the above trials note was made of all scummed trials, those with specks of foreign materials, and other conditions which tend to mar the commercial value of the burned ware. These conditions have been reported in most cases in the general description of each sample and also in Table III, column 14.

Fired Modulus of Rupture

At the time of preparing the trials for the raw modulus of rupture tests, 3 extra pieces of each clay were prepared in the same manner and under the same conditions. When dry they were placed in a muffle kiln, the temperature raised to 750° C. and then held for several hours under oxidizing conditions including the cooling of the kiln. The trials were then burned to cone 02, corresponding to a temperature favourable to a majority of the samples; however, a few of them would have shown higher strengths had they been burned somewhat above cone 02. Mention has been made of these under the description of the individual samples. The formulæ and method used to determine the modulus of rupture on the burned trials were the same as those for the unburned ones.

Results are reported in Table III, column 3.

Absorption and Shrinkage

In Chapter IV a number of typical absorption-shrinkage graphs have been inserted to illustrate the general types of clays found in each of the geological formations, and to assist in the making of comparisons between the clays of the several formations as a whole. It has not been the intention to set forward any particular clay or group of clays as models but rather to use them as types only: any or all of the ungraphed clays may be plotted for comparative purposes if desired.

P. C. E. (Fusion Tests)

A number of the samples which developed rather high percentages of porosity were further tested as to their fusion or softening temperatures, by preparing small test cones which were first lightly calcined and then tested according to the standard method described in Journal American Ceramic Society, September, 1928. A pot furnace fired with oil was used for the production of the necessary temperatures in each case. Care was exercised to muffle or protect the cones from the flame, and also to maintain oxidizing conditions.

The results are reported in Table IV.

PRESENCE OF CARBONATES

Four carbonates are commonly found in clays, viz.: carbonate of calcium (lime), carbonate of iron, carbonate of magnesium, and dolomite; they may be present singly or jointly and in any state of sub-division from finely divided particles to appreciable sizes. However, the one most usually looked for by the clay-worker is calcium carbonate; from experience he knows that clays which carry excessive amounts of this impurity develop properties, such that overfiring or fused wares can hardly be avoided, and, furthermore, the burned colour is usually an undesirable buff instead of red.

In addition to the above unfavourable reactions or conditions which may arise from the presence of carbonates in clay there may be mentioned that under certain conditions during burning they may so retard the oxidation of carbon, iron, and other ingredients of the clay that disastrous bloating or swelling of the ware may occur through a delayed evolution of gases which should have taken place prior to the surface of the ware becoming dense through vitrification.

Furthermore, though carbonates are virtually insoluble in water, they may, indirectly, be the cause of kiln scum[1], as during the early stages of

[1] An undesirable film on the surface of the ware.

the burning of clay water or steam is given off, this in turn through contact with sulphurous gas from the fuel may form sulphuric acid which readily attacks the carbonates, and converts them into sulphates which may be left as a film on the ware.

In view of the above unfavourable conditions which may arise directly or indirectly from carbonates, and through a desire to check their presence in the several geological formations studied, each sample was tested by applying drops of hydrochloric acid to the surface of unground specimens of shale or clay. The carbonates were readily detected through effervescence. As it is fully realized that the foregoing test gives little more than a rough measure of the amounts of carbonates present in the many samples it is felt that a more universal study and recognition of the carbonates in clays would prove valuable.

The results of the present tests are shown below.

Formation	Number of samples collected	Per cent of samples free of carbonates	Per cent of samples with carbonates present
Recent	3	....	100·0
Paskapoo	27	24·2	75·8
Edmonton	14	33·3	66·7[1]
Bearpaw	1	....	100·0
Belly River	11	81·1	18·9[2]
Benton	19	78·9	21·1[3]
Blairmore	7	71·4	28·6[2]
Total	82		

(1) In 25·01 per cent of the samples carbonates were present as surface scum only, the shale tested free.
(2) In small amounts only.
(3) In 10·55 per cent of the samples carbonates were present as surface scum only, the shale tested free.

It was observed in some of the samples that the carbonates were present in the form of a film or coating on the surface of the pieces, and, not as an ingredient in the sample, that is in some cases the application of acid to a freshly fractured surface failed to reveal traces of carbonates, though they were found present in the sample as a whole.

On account of the small number of samples collected from the Recent and Bearpaw beds, it is quite possible that the above percentages do not represent what would be found true of a larger number of samples. Thus, neglecting them, it is interesting to note that the upper formations, the Paskapoo and Edmonton, carry the highest percentages of free carbonates, while, on the other hand, the lower formations, the Belly River, Benton, and Blairmore, are reasonably free from same, the Belly River ranking highest in that respect.

In a study of the burned trials it is to be observed that surface scum or whitewash is high in the samples from the upper beds, namely, Paskapoo and Edmonton. Although the Benton shales tested low in carbonates they rank highest in the number of scummed burned trials.

MEASUREMENT OF TEMPERATURE AND FUSIBILITY

As the methods for determining temperatures in the ceramic field are so commonly known and generally used by the industry, it is thought unnecessary to enter upon details for this report, other than to say that the pyrometric cone method was employed throughout the work to determine the finishing points of all burning tests, and to measure heat-work.

The following list gives the cone numbers and temperatures ascribed to them, although incomplete it will be found to cover the temperature ranges employed in the present investigation.

Cone No.	Degrees Centigrade	Degrees Fahrenheit	Cone No.	Degrees Centigrade	Degrees Fahrenheit
010	890	1634	1	1125	2057
09	930	1706	2	1135	2075
08	945	1733	3	1145	2093
07	975	1787	4	1165	2129
06	1005	1841	5	1180	2156
05	1030	1886	6	1190	2174
04	1050	1922	7	1210	2210
03	1080	1976	8	1225	2237
02	1095	2003	9	1250	2282
01	1110	2030	10	1260	2300

It should be borne in mind that cones do not measure temperature with exactitude, but are used, as before stated, as a measure of heat-work produced in the kiln.

CHAPTER III

LOCATION, DESCRIPTION, AND WORKING AND BURNED PROPERTIES OF SAMPLES TESTED

UPPER HIGHWOOD RIVER AREA

Samples Nos. 2901 and 2902

Location and Description

These samples were collected on the east bank of Highwood river, approximately $1\frac{1}{4}$ miles below the mouth of Bull creek.

The strata dip northeasterly and are made up of alternating bands of buff to lead-grey sandstones, shales, hard nodular clay-ironstone, and in addition a single thin seam of coal was observed. Oxidation has proceeded downward from the surface as much as 40 feet in places. Some of the shales are quite soft and contain colloidal or bentonitic matter.

The overburden is not excessive. However, in working the deposit by the open-pit method difficulty from caving is likely to be encountered. Other methods of mining are likely to prove very expensive.

A cross-section taken at right angles to the dip is given below:—

	Feet	Inches
Overburden of soil, stone and gravel	5	
Coal	1	6
Shale	4	
Sandstone carrying fossils	3 to 4	
Hard rust-coloured sandstone	1	6
Sample No. 2901		
Shale, light and dark green	20	
Sandstone, soft and colloidal, nodular clay ironstone and hard shales (discarded)	6	
Sample No. 2902		
Shales, light grey, colloidal	25	
Nodular sandstone band (used as base)	1 to 3	

Working and Burned Properties

Sample No. 2901. In the raw state, the general colour of the clay is dark grey with some iron stain. On the whole the material is sandy and of medium hardness. When tempered (mixed) with water it becomes quite sticky, in addition to its plasticity, a condition due, no doubt, to the presence of bentonitic or colloidal substances. This conclusion is borne out by the unsatisfactory drying behaviour of the sample.

The percentage of shrinkage water indicates a material of medium-grain size, the drying shrinkage is slightly above normal for clays of this type. The modulus of rupture in both the raw and burned states is satisfactory. The time necessary to oxidize thoroughly is above the average of the other samples tested but is not excessive. The reactions or changes which take place during the burning are fair on the whole, though a sudden change in the rate of vitrification takes place between cones 04 and 02; overfiring takes place at cone 3, it becomes steel hard at cone 07 and burns to a fair red, although somewhat dimmed by an objectionable scum; this, however, could be overcome in commercial practice.

The data obtained indicates the possible use of this clay in the manufacture of building brick, hollow tile, land drain tile, and similar wares. In case of further investigations special attention should be given to its drying properties.

Sample No. 2902. The colour of the sample is a greenish grey; it is generally sandy though some parts are bentonitic. When dry it is easily crushed but it would prove troublesome to grind if wet or damp. Upon tempering it becomes sticky and highly plastic, the drying properties are poor in that it not only cracks, but twists and warps as well. The percentages of water of plasticity and of shrinkage are both high; the drying shrinkage is excessive. (*See* Fig. 15, p. 104.) Owing to the drying defects it was impossible to prepare trial pieces for the modulus of rupture tests.

The results obtained on this sample in the raw state were such that further testing of it is not to be recommended.

Samples Nos. 2903 and 2904

Location and Description

These samples were taken from Edmonton beds outcropping on Bull creek near its junction with Highwood river.

Sample No. 2903 was taken on the east side of the valley 100 yards from the mouth of the creek. The beds, which are much distorted and folded, are composed of dark grey to nearly black fissile shale.

Interspersed among the layers or bands of shale are many thin clay-ironstone seams; these, and a band, one to three inches thick, of a soft white substance near the centre of the fold could not be removed in commercial operations and were, therefore, included in the sample. In addition, the lower three feet of the outcrop was badly scummed or encrusted with salts. A crosscut of 25 feet was taken for the sample at the most favourable-looking part of the face. From a practical point of view this deposit does not appear promising for commercial development as the beds are badly disturbed and may not prove uniform nor continuous. Furthermore, the presence of soluble salts and clay-ironstone seams are decidedly undesirable.

Sample No. 2904 was taken from a small outcrop, in which the beds are folded, on the west side of the stream near the mouth, the shales being dark rusty in colour and somewhat more sandy than sample No. 2903. The cross-section is as follows:—

	Feet
Blocky, banded sandstone (capping)	4
Shale, dark and rusty	3
Shale, dark, fissile and softer	4
Stony zone, hardened thin layers (discarded)	1
Shale, greyish, sandy	3
Sandstone base	
Total shale	10

Working and Burned Properties

Sample No. 2903. The raw sample is greyish slate in shade, with small amounts of scum showing on cleavage faces. The sample is fine grained, and breaks down into sharp splintery pieces, easily crushed.

When tempered the mass becomes quite plastic and sticky; and although the drying shrinkage is high, serious loss through cracking did not result in the small trial pieces. In full-sized ware cracking would be expected. It has a high modulus of rupture in both the raw and burned state, the strength of the former being, no doubt, largely due to the bonding action of colloidal substances. Vitrification proceeds regularly up to cone 07, it then slows up until cone 04 is reached, from thereon it proceeds normally; overfiring occurs at cone 3.

The data obtained from this sample, with the exception of drying properties, would indicate that it has only fair possibilities for brick, tile, and other low-grade commercial wares. At present, at least, the distance from rail does not warrant further attention.

Sample No. 2904. This sample is slate-coloured, with some scum present on cleavage faces; the fracture is semi-conchoidal to irregular. When tempered it becomes a plastic mass of fair working properties. The drying shrinkage is high, resulting in checks or cracks which prevented the modulus of rupture trials. Oxidation was rather difficult. The vitrification changes are similar to those of No. 2903, though the actual percentages of absorption and shrinkage are slightly lower on the whole. The final colour is a red of only passable shade, in addition this is further marred by a thin coating of scum.

Taking all conditions into consideration the general prospects of this sample are not encouraging, especially as many clays of much better properties are recorded in this report.

Sample No. 2905

Location and Description

Trap creek (locally called Flat creek) is a small stream entering Highwood river from the west in the NE. ¼ sec. 36, tp. 17, rge. 4, W. 5th mer. From a short distance below the trail bridge to the mouth, the stream has cut a channel through the Benton beds.

About 100 yards downstream from the bridge, and on the south side, a very good exposure of the shales may be seen. They are thinly laminated or bedded, interbanded with clay-ironstone concretions of kidney shape, and many bands of hardened sandy shale one to two inches in thickness. They were included in the sample as they could not be removed commercially. The total face crosscut for the sample was 70 feet. The overburden varies from a few feet at the face of the exposure to greater depth farther back. The beds would prove difficult to work because of their vertical position.

Working and Burned Properties

The sample is a dark slaty material, which readily splits into thin pieces. It is somewhat hard to grind and produces little dust or fines. Therefore, although the material is normally fine grained, it grinds to a coarse-grained, non-plastic product. In order to produce sufficient plasticity to permit of moulding the trials it was necessary to age the newly tempered batch for several days, a procedure necessary with all samples collected from the Benton formation. At the end of the ageing period a sufficient degree of plasticity could be developed to permit of shaping the trial pieces, though much care had to be exercised. The lack of bond is clearly shown through the results of the modulus of rupture tests.

The dark colour of the sample indicates the presence of considerable carbonaceous matter, the time required to oxidize this material thoroughly proved excessive in comparison with other samples tested in this work. The burned colour is unattracoive and would be permissible only in low-grade wares.

On the whole this deposit is of doubtful commercial interest as it lacks plasticity, is low in bonding strength, high in carbonaceous matter, and burns to a poorly coloured body of high porosity. The latter property could be improved by higher temperatures, though at higher costs than would be warranted by the class of ware possible to produce from this material.

Sample No. 2906

Location and Description

Sample No. 2906 was taken from Benton beds at a point on Highwood river about one-half mile below the mouth of Trap creek. At this point the north bank of Highwood river is made up of nearly vertical beds of shale and hardened grit or sandstone zones rising nearly 150 feet above the river. The collecting of sample No. 2906 was commenced on a band of rusty conglomerate and continued westward across 80 feet of dark shales to a shaly sandstone zone. The beds sampled were dark slate to lead grey in colour, the easterly third being of a red-brown shade due to iron stain. The structure of these shales is more blocky and less thinly laminated than some beds of Benton sampled elsewhere.

While it would be possible to work these beds, certain practical difficulties would be encountered. Owing to the nearly vertical position of beds it would be difficult and expensive to win the material as the loading or shovelling floor would prove to be very rough and uneven, and great care would be necessary to maintain a uniform mixture.

Working and Burned Properties

The sample is of a greyish slate in colour and is much coated with iron oxide. The fracture is conchoidal and lamination is not well marked other than in the bed as a whole. It is quite gritty and hard, although upon grinding it produces more fines or dust than No. 2905. When tempered and aged it developed a fair degree of plasticity so that trial pieces were readily moulded from the mass. It dried safely without cracks. The strength of the raw sample is among the highest of the samples from the Benton formation, and the oxidation period was $4\frac{1}{2}$ hours which is not excessive. The burned modulus of rupture or strength is good. Shrinkage at cone 3 is below the average; the drop in absorption with increase of temperature was quite regular to normal for heavy clay products. The burned colour at cone 02 is a good dark red. At cone 010 the body becomes steel hard but the absorption is quite high.

The sample is worthy of further consideration for the manufacture of face brick, common brick, paving brick, hollow tile, and red terra cotta. The small amount of scum present could be overcome in commercial practice. The chief drawback is its distance from rail.

Sample No. 2907

Location and Description

This sample was taken about one mile downstream from No. 2906 close to a fault line. The beds are nearly vertical and are similar to those of the previous sample. A cross-section, starting at the downstream side and working upstream, is as follows:—

	Feet
Conglomerate rock, rusty	6
Dark shale, red-brown from iron rust (A few clay-ironstones present)	8
Black fissile shale	14
Thin parting seam of a sandy nature	
Grey to dark slate-coloured shale with a number of sandy streaks or bands	22
Hard sandy or grit zone.	—
Total shale	44

As shown above, 44 feet of shale was included in this sample. The strata are exposed 60 feet above the river and are covered with an overburden of rounded stones and gravel up to 8 feet in thickness. Working conditions here would be similar to those described under No. 2906.

Working and Burned Properties

The general colour of the sample is a light slate grey, intermixed with darker particles. Parts of it were heavily coated with iron rust. For the most part the fracture is conchoidal resulting in small angular pieces. Another portion of the sample is more sandy and breaks down into larger pieces with irregular fracture; lamination in the pieces is not well marked.

The sample is hard to crush yielding only a small amount of dust; however, after tempering and ageing, sufficient plasticity was present to permit of moulding. The drying shrinkage was quite within safe limits. The rate of vitrification is gradual and quite uniform from cone 010 to cone 3, where overfiring begins. At cone 02 it develops into a hard dense body of a good medium red, though partly masked by scum.

The tests indicate that the material appears to be suitable for the production of roofing tiles, face, common, and paving brick, in fact most any line of red heavy clay products. Absence of transportation is a drawback however.

Sample No. 2908

Location and Description

The two deposits just described as occurring in the Benton formation are separated by a zone of nearly vertical Belly River beds. As the colour and general physical properties are quite different to the flanking Bentons, little difficulty was encountered in making a proper division. A section of these beds which appeared promising was selected for No. 2908, the location being on the north side of the river and upstream approximately one-quarter mile from No. 2907. While the beds at this point are not well exposed it is thought that greater thicknesses occur in the benches to the north.

The cross-section of the deposit is given below, starting at the downstream side.

	Feet
Shale, yellowish green, massive	3
Shale, light grey of greenish tint	7
Shale, dark grey of greenish tint	18
Stone, greyish, hard, discarded	1
Shale, light yellowish green	4
Shales, dark grey, greenish tint	2
Total shale sampled	34

On the whole these shales are more massive, blocky, and less fissile than the Bentons, and are not so hard. For these reasons there would be less difficulty in working them.

Working and Burned Properties

The sample is greenish to buff-grey. Evidence of lamination is lacking; the pieces are large, irregular in shape and of uneven fracture. Considerable iron stain is present on the lamination faces. Tests with acid showed absence of carbonates.

It crushes readily, producing considerable fines, so that when tempered it is easily worked up into a plastic mass of good working properties. The oxidation period was rather long but it is not to be expected that commercial difficulties would be met with on this account. The modulus of rupture or strength of the burned trials indicates a hard strong body. Vitrification progresses in a gradual and safe manner, the best range being from cone 010 to cone 1, at which latter temperature the body starts to overfire. The burned colour is good being a dark red free from scum, and of pleasing colour.

The clay appears to be suitable for quarry tile, roofing tiles, terra cotta, face brick, and other similar lines of heavy clay products.

Sample No. 2909

Location and Description

Sullivan creek, near its junction with Highwood river, has cut a gorge 75 feet deep in the Benton shales. At this point the beds are pitching sharply eastward, in fact from an industrial standpoint they may be regarded as vertical. The creek at its mouth breaks through a stratum of very hard, rust-coloured stone varying in thickness from 3 to 8 feet.

Using this band as the eastern edge the shales were sampled upstream across their face for a distance of 250 feet, stopping at a zone of badly disturbed and intermixed shales. The first 135 feet is composed of red to brown rusty shales, stratified, hard, and slate-like; interbanded with these shales are 14 layers or bands containing clay-ironstone concretions varying in size from 3 inches up to 12 inches in diameter. For obvious reasons these were excluded from the sample which was listed as No. 2909.

Working and Burned Properties

In this sample of the Benton beds, the cleavage and fracture faces are badly iron-stained but show the shale to be dark slate-coloured. The pieces are angular and mostly of a conchoidal fracture with little evidence of lamination. The material is hard and difficult to grind, producing in relation to the whole only a small proportion of fines. It was found impossible to produce plasticity beyond a very slight degree. The water required to temper was naturally small, the drying shrinkage was obviously low, and the dry unburned body possessed but little strength. Oxidation progressed safely on account of the openness of the pore system permitting a free movement of oxygen into the interior.

Vitrification was uniform between cones 010 to cone 3. The body became steel hard at cone 07, which is quite low. The shrinkage at cone 3 is satisfactory, absorption at the same temperature is a little high though for ordinary heavy clay products would prove satisfactory. The burned colour is light red with some scum present.

The clay is of only moderate interest for further study of its commercial possibilities. The fact that it is non-plastic precludes its use in the manufacture of all stiff-mud wares. If very finely ground it might possibly be manufactured into bricks by the dry-press method.

Sample No. 2910

Location and Description

The remaining or upstream portion of 115 feet was selected for sample No. 2910, there being a general difference in the beds in that those taken for this sample were free of concretions, and broke down into smaller and thinner pieces. Soluble salts were noted on the face of the outcrop. The overburden of stone and gravel is light, stripping would, therefore, not likely prove expensive, although the vertical position of the beds would develop certain quarrying difficulties.

Working and Burned Properties

This sample is a continuation of No. 2909 and, other than that changes proceed a trifle more slowly, the remarks relative to its companion sample may be equally applied here.

Sample No. 2911

Location and Description

This deposit is located in the valley of Bull creek on L.S. 7, sec. 8, tp. 18, rge. 2, W. 5th mer., approximately ½ mile northeast of the present working coal mine. The beds are tilted quite sharply and are thought to be of Bearpaw age. The exposed face selected for sampling measured 10 feet high and 105 feet in length across the strata at right angles. The overburden is stone and gravel varying from 3 to 8 feet in thickness. The beds are dark grey, greenish and rusty brown with one part dark grey and nodular. The left or northern half of the exposure is more yellowish to olive green than the southern half. Some slickensided conditions were noted, as well as a few bands of well-oxidized clay-ironstone; otherwise the beds were fine-grained shales.

Other outcrops of the same shale occur nearby and in tributary coulées leading into the main valley. As the overburden is not excessive, and the beds are not pitching so sharply as others before noted, a time may come when they may prove of sufficient interest to warrant a further study of their extent and conditions in the valley sides and uplands.

Working and Burned Properties

The general colour of the sample is that of a brownish grey blended with darker shades. The fracture for the most part is conchoidal, accompanied by slickensided conditions; certain sandy members are hard and carry carbonates.

The sample as a whole crushed easily and when tempered with water disintegrated readily into a good working, plastic mass which developed a rather high drying shrinkage. It is notable that the modulus of rupture in the raw state is exceptionally high, being 1,035 pounds per square inch. Oxidation did not prove difficult though from the fineness of grain the opposite was to be expected. The changes taking place during the vitrification period are quite favourable, the rate progressing quite regularly. The body comes to its best condition between cone 02 and cone 1. The shrinkage is not excessive, the porosity and absorption percentages are both low; steel hardness is reached at the low temperature of cone 010. The modulus of rupture in the burned state is high, being well over 4,000 pounds per square inch, showing it to be one of the strongest clays tested in this investigation. The colour is of medium grade only and slightly marred by scum.

The fields for further investigation with this sample are those of roofing and quarry tile, face and common brick, building tile and possibly paving brick. Its high raw strength makes it of interest for thin-section wares like roofing tiles, and as a bonding material for certain of the Benton samples which have proved non-plastic. The drying property should be given special study prior to commercial investments.

Sample No. 2912

Location and Description

About 100 yards downstream from the old coal mine workings on Bull creek, sec. 8, tp. 18, rge. 2, W. 5th mer., there is an exposure of multicoloured Belly River shales, the predominating shades being yellowish green, grey-green, and light, dark and slate grey. The light grey and greenish shales break down into angular particles with little evidence of lamination, while the dark slate-coloured beds appear slickensided. A few bands of clay-ironstone were noted as well as a thin sandstone member containing fossils.

The sample was taken at right angles across strata for a distance of 100 feet. The overburden at this point varies from 3 to 8 feet though it may prove greater along the strike of the beds on the uplands. This deposit appears of commercial interest and, were rail transportation provided, further work in the matter of tracing the continuity of the beds would be worth undertaking.

Working and Burned Properties

The material comprising this sample is harder and of a lighter grey shade than No. 2911. Though generally hard, little difficulty was experienced in the grinding of the present sample; it tempered readily, forming a good working mass. Though the drying shrinkage is a little higher than is desirable, no difficulties were experienced through cracking. Its raw strength while slightly under that of No. 2911 is well above the average. The long period required to complete oxidation indicates the presence of fairly large amounts of unoxidized materials which are retarded in their oxidation by the fine grain or dense condition of the body.

Between cones 010 and 1 the progress of vitrification is slow and uniform. The body is steel hard at cone 010 and at cone 02 attains a shade of light red of fair quality.

The raw and burned physical properties of this sample correspond so nearly to those of No. 2911 that the remarks concerning that sample apply equally well although the unfavourable oxidizing conditions of No. 2912 should be carefully investigated. A possible solution would be the blending of the two clays.

Samples Nos. 2913 and 2914

Location and Description

These samples are from dark Benton beds on the north bank of Highwood river, approximately 2 miles downstream from the mouth of Ings creek, and only a short distance east of the Imperial-Highwood No. 1 well. The beds at this point are nearly vertical, thus the samples were taken horizontally across the face. As the banks of the river are largely covered with vegetation, the total thickness of the shale deposit could not be determined, although it no doubt corresponds very closely to the height of the main bank which is roughly 60 feet.

Sample No. 2913. This was started on a fault line and carried upstream across 86 feet of dark slate-coloured shale, which is hard and splits readily into thin slate-like pieces. A large number of thin bands of hardened sandy material are interbedded in the shale. These were included in the sample, while a few sandy concretions encountered were discarded.

Sample No. 2914. The dark slate-like beds of No. 2913 give way rather sharply to more thinly laminated ones of a red, rusty colour; these were taken as No. 2914. The total distance sampled was 55 feet not including a hardened sandy band 3½ feet thick. Quarrying conditions here would be the same as set forth under sample No. 2906.

Working and Burned Properties

Sample No. 2913. The sample is dark to nearly black in colour, the pieces are well laminated, clear of iron rust but are coated with a scum. The sample proved hard to grind and of very low plasticity and poor working properties.

The more important properties of this sample are so close in accord with those of No. 2905 that the remarks concerning that sample may be regarded as applying to the sample under discussion.

Sample No. 2914. This sample is of a red-brown to iron rusty shade not unlike that of sample No. 2909. It is well stratified and splits into thin, sharp slaty pieces, although certain parts are more blocky in structure. It is hard and quite non-plastic, although by means of ageing it was possible to develop sufficient plasticity to permit of proper moulding and the development of a fair raw strength; oxidation progressed favourably. The raw and burned shrinkages are both low, and like most other samples from the Benton beds, a slight expansion rather than shrinkage takes place at the lower temperatures. (*See* Fig. 25, p. 110.) Changes in absorption porosity are slow, the former being 10 per cent at cone 3, which is higher than desirable for the better classes of red wares. The burned colour is quite pleasing and would prove satisfactory for face brick, tile, and other heavy clay products.

On account of the low plasticity of this sample it is doubtful whether wares could be manufactured by the stiff-mud process, though by fine grinding, steaming, and ageing it is quite possible that satisfactory dry-pressed products could be manufactured from it. Were it near transportation, further investigational work would be justifiable.

TURNER VALLEY (CENTRAL) AREA

Samples Nos. 2915 to 2919

Location and Description

The deposits from which these samples were taken are in the Edmonton formation and are near Black Diamond bridge and northward along Sheep river. The exposures are low in the river bank not exceeding 10 to 12 feet above water level, and are lowest at the point downstream where they first emerge from under cover, the exposed thickness being but 5 feet.

The overburden of silts, gravel, and boulders, varies in thickness from 6 to 10 feet; this condition, in addition to the sharp pitch of the beds (*see* Plate IIIA) and their small exposure above water, presents problems that require careful engineering and industrial study to determine the feasibility of developing this deposit.

Sample No. 2915 was taken at the point where the beds are first seen; the shales are fine grained and generally greenish in shade and gradually pass into sandy shales. At 75 feet from the starting point a narrow zone of buff sandstone occurs which was used as the upstream edge of this sample. Interbedded in the sandy shales is a 6-inch, hardened, nodular ironstone band with a thin fossiliferous member to the left of it. The ironstone was discarded from the sample.

The buff sandstone marker gives way to 15 feet of hard shales, mostly bluish green, buff, and grey, with a very heavy rusty-coloured zone on the left, from which the shales merge rapidly into a second buff sandstone; this was used for the upstream or left-hand marker of *No. 2916*. From this marker the beds for the next 15 feet are made up of alternating thin strata of sandy shale, shale, and sandstone, all of which were discarded or unsampled as the average sample would prove too sandy for ceramic products.

Sample No. 2917. This sample was started at the upstream face of the above zone and continued for 100 feet in greenish iron-stained shale. Some portions were found to be more sandy than others and in addition, a number of thin bands of hard nodular ironstone were encountered and discarded. These shaly beds are terminated by a heavy zone of massive to blocky buff sandstone which was used as the dividing line between Nos. 2917 and 2918.

Sample No. 2918. This included 75 feet of dark green shales, fine grained to rather coarse grained and sandy. At the extreme left the deposit encounters a thin seam of coal which was made the upstream marker for the deposit. It was noted that a smaller number of ironstone bands occur in this deposit than in its companion No. 2917.

Sample No. 2919. From the coal seam and for a distance of about 150 yards the beds are of little ceramic interest because of the excessive interbanding of sandstones and shales. At a point opposite the gravel pit and screening plant there is a zone of soft, grey, slate-coloured shales, badly crumpled or disturbed and coated in part with a scum of soluble salts. These shales were avoided, but a section 50 feet wide was taken from a series of well-stratified grey to greenish iron-stained shales.

Working and Burned Properties

Sample No. 2915. The sample is yellowish green in shade, it breaks out in lumpy form with little evidence of lamination, the fracture is uneven to semi-conchoidal. The shale is hard, gritty, and is iron-stained on fracture faces or foliation planes. Grinding was quite easily accomplished, though owing to the sand or grit present the ground sample was quite short and low in plasticity. The raw strength as a result is also low, corresponding closely with figures obtained from the weaker Benton samples. The drying shrinkage is such that drying troubles would not be likely.

The changes taking place during burning are not entirely satisfactory as little or no vitrification takes place between cones 010 and 07. (*See* Fig. 16, p. 105.) Between cone 07 to cone 04 vitrification starts and continues at a gradual rate until cone 02 is reached, the rate then increases rapidly—a condition not desirable in commercial practice. The ware becomes steel hard at cone 04 and develops a final burned strength of over 3,000 pounds at cone 02. The burned colour is a dark red of good tone.

From data obtained this clay is likely to be restricted in its field of usefulness, as, in order to avoid difficulties during the burning, it would be necessary to stop the burning before low porosity conditions are reached, thereby confining its manufactures to stock and common brick. The semi-plastic condition would no doubt bar it from the manufacture of hollow or thin-section ware. Further investigation, if undertaken, should include the blending of this clay with one or more of greater plasticity.

Sample No. 2916. Although this sample was taken close to No. 2915 it varies from it in several respects: the general colour is light grey-buff to dark slate, somewhat iron-stained. The pieces show lamination and are generally flat or thin; the texture is also finer than No. 2915. Notwithstanding a certain degree of shortness the working properties are fair. It dried safely with some shrinkage. The raw strength and oxidation are quite satisfactory.

The changes taking place during burning are more favourable than are those of No. 2915. A gradual change takes place from cone 010 to cone 04 where a more rapid increase is noted, this increase continues to cone 3, where overfiring takes place. The burned colour and strength are both good.

Possible uses for this clay might include a general line of red ware and heavy clay products, such as building brick, tile, and possibly paving brick.

Sample No. 2917. The colour of the sample is a greenish buff. The clay is generally gritty, non-stratified, breaking out in irregular conchoidal lumps. It was of medium hardness, though it slaked sufficiently during tempering to develop into a body of fair working properties. The drying shrinkage is low, safe, and accompanied by a fairly high strength in the dried state.

The burned properties are quite satisfactory. (*See* Fig. 12, p. 103.) The body becomes steel hard at cone 010, and at 02 it has a modulus of rupture of nearly 4,000 pounds. The colour is a dark clear red suitable for the better lines of red clay wares.

Tests indicate that this clay could be used in the manufacture of a fairly wide range of clay wares, including paving, face, and common brick, quarry tile, roofing tile, hollow blocks, and drain tile. In the event of transportation becoming available the material represented by this sample will be worthy of further study.

Sample No. 2918. This is quite similar to No. 2917, although a heavy band of sandstone divides the two deposits. The general shade is a dark greenish grey in colour, the pieces are irregular in size and iron-stained, non-laminated, have uneven to conchoidal fracture and are quite hard and gritty.

When ground, the clay tempers into a plastic mass of fair working properties and it dries safely. The raw strength while sufficient, is lower than its neighbouring samples. A little longer time is also required for its complete oxidation. The properties developed during vitrification, i.e. the burned colour, etc., correspond so closely to those of sample No. 2917 that it is unnecessary to comment further on the present sample, other than to state that the two deposits could very well be worked as one commercially.

Sample No. 2919. Two general materials go to make up this sample, one is light grey, sandy, iron-stained and of a shaly structure, the second is darker in shade, iron-stained, finer in grain, not well stratified, of uneven fracture, and somewhat slickensided.

The plasticity and working properties are only fair, though better conditions are indicated by drying shrinkage which is quite normal for stiff-mud bodies. The dry strength is the highest of all samples collected in the same neighbourhood.

The burned properties are not quite so favourable, as the porosity is higher in general than the other samples, and the final colour is not so clear or good.

The general uses indicated for this clay by these tests would be in the manufacture of products like common brick, building and drain tile, and wares where low porosity and absorption are not of prime importance.

RECOMMENDATIONS

As the tests have shown the shales of samples Nos. 2915 to 2919 to be of merit, it is to be suggested that, in the event of transportation reaching them, a more extended survey be undertaken in an endeavour to trace the beds along their strike to higher ground where the overburden may become less and the thickness of shale above water somewhat greater.

Samples Nos. 2920, 2921, and 2922

Description and Location

These samples were all taken from Belly River beds on the west flank of the main Turner Valley anticline where it is cut by Sheep river just below Lineham ford. The shale beds at this point are steeply pitching and much interbanded with hardened sandstone layers.

Sample No. 2920. This was collected from nearly vertical beds on the north side of the stream and about 200 feet below the abandoned coal mine at the ford. The vertical exposure measured 30 feet. A crosscut 39 feet in width was taken starting on the right or downstream side, a cross-section being given below.

	Feet
Sandstone layers	5
Shale zone, bluish grey on the east, changing to greenish slate shade on the west	33
Sandstone (discarded)	2
Shale, green and reddish brown	4
Sandstone (base marker)	8
Black shales, disturbed	not taken
Total shale sampled	37

The deposit possesses industrial possibilities. However, as it is in a disturbed or folded zone it would be advisable to prospect thoroughly the extent and condition before proceeding with actual development.

The two last samples of the group were taken on the south side of the river about ¼ mile downstream from the one just described.

Sample No. 2921. This sample was started on the right or upstream side at a zone of banded sandstones, the cross-section being as follows:—

	Feet	Inches
Banded beds of sandstone......unmeasured		
Yellowish green shale	3	
Dark to nearly black shale	4	
Nodular hard stone (discarded)	1	6
Dark grey shale	4	
Nodular hard stone (discarded)	4	
Black fissile shale	5	
Nodular hard stone (discarded)	2	4
Dark shale	4	
Greenish grey sandstone (base marker)	20	
Total shale sampled	20 feet	

It is quite evident that this deposit would have to be worked largely by hand so that the undesirable materials might be removed; thus the winning costs would be increased materially.

Sample No. 2922. This was the last sample of the group, and was started at the east side of the sandstone used to mark the east face of No. 2921. It was carried downstream across the face of the strata a distance of 100 feet, or nearly to the fault line shown by Slipper.[1] The shales are dark in shade and quite heavily iron-stained. Near the middle of the deposit there is a zone of greenish rusty shale. Unfortunately, 6 bands of hard sandstone varying from 4 to 24 inches in thickness are interbedded in this deposit. While this deposit would prove more satisfactory to work than would No. 2920, care would have to be exercised to remove the objectionable bands of stone; this would have to be done largely by hand. As the deposit averages about 25 feet in depth there is a very considerable amount of available material above water level.

Burned and Working Properties

Sample No. 2920. In the main, this sample is dark grey, though some portions are lighter in shade and are iron-stained. Stratification is poorly developed in the individual pieces, which vary in shape and size and are semi-conchoidal to conchoidal in fracture.

The sample when pulverized produced a fair quantity of fines; these, with a considerable proportion of the coarse material of the ground sample, softened readily when tempered. The mass proved plastic and of free working properties, such that it was easily moulded into the trial pieces. The drying rate was safe without losses. The raw strength is above the average and should prove ample for all general classes of ware. The oxidizing time of 4½ hours indicates a clay not likely to give trouble in this respect.

[1]Slipper, S. E.: Sheep River Oil and Gas Field (Map No. 1724); Geol. Surv., Canada.

The pyro changes, while irregular in detail, are on the whole quite favourable, in that the total burning shrinkage is low and associated with it is that of a low absorption between cones 04 and 3. (*See* Fig. 18, p. 106.) These properties are accompanied by a clear dark red colour and a very high burned modulus of rupture or strength.

The data so far obtained indicate that the material is suitable for stiff-mud face brick, paving brick, quarry, or paving tiles, roofing tiles and other red wares of similar nature.

Sample No. 2921. The general appearance of this sample corresponds closely to that of the last sample. It is, however, more sandy, somewhat harder, some portions breaking down into splintery pieces. When tempered it is found to have slightly less plasticity than No. 2920, due partly to the higher proportion of sandy material and also to a slower or smaller amount of softening of the grains during the tempering process. The plasticity, notwithstanding, is ample to permit of proper and free moulding. In consequence of its sandy nature the drying shrinkage was not excessive. The raw strength is below the average; this, again, reflects the sandy nature or shortness of the body. No trouble was encountered during the oxidation period.

A study of the vitrification changes reveals a marked resemblance to those of its companion Belly River samples. However, samples Nos. 2921 and 2922 are slightly the more favourable, their vitrification range being wider prior to reaching overfired conditions. (*See* Fig. 17, p. 106.) The burned strengths of the two latter samples are high, being well above the average, though not quite so high as No. 2920. While the burned colour of the present sample and that of No. 2922 is of a lighter shade than No. 2920, it is a clear red of pleasing commercial value. Clays Nos. 2920, 2921, and 2922, all from the Belly River formation and in the same locality, are worthy of a more extensive study or consideration, especially so in the event of transportation reaching them.

Sample No. 2922. The raw and burned properties of this sample resemble so closely those of clay No. 2921 that reference is made to the remarks concerning that sample and to the tables for detailed particulars.

Samples Nos. 2923, 2924, 2925, and 2926

Location and Description

These samples were collected on Quirk creek a short distance above the mouth of Fisher creek, in sec. 5, tp. 21, rge. 3, W. 5th mer. With the exception of sample No. 2926 all were taken on the south side of the river where the best exposures are to be seen. The beds pitch sharply to the southwest and are exposed only 6 to 8 feet above the water level. (*See* Plate IV A.) In this respect they do not appear promising from an industrial point of view. However, it is quite possible that greater thicknesses may be found back from the river in the upper benches.

Sample No. 2923. This sample was started about 150 yards downstream from a fault line which crosses the area near the southwest corner of section 5. The beds are typical Belly River in that for the most part they are of light green shales and hardened sandstone members. The cross-section is given below.

	Feet	Inches
Sandstone (upstream marker)	unmeasured	
Shales, green slate-coloured and rusty with a hard nodular zone 1 foot thick near the starting point	48	
Sandstone (discarded)	5	
Shale, sandy, greenish and rusty	7	
Sandstone (discarded)	14	
Shale, greenish, rusty, and black	11	
Sandstone (discarded)	12	
Shales, greenish and rusty	23	
Sandstone (discarded)	3	6
Shales, greenish and rusty	30	
Sandstone, used as base	5	
Total shale sampled	119 feet	

In the event of finding beds in the upper benches having greater thicknesses, and of rail service being provided the deposit should be worthy of further study.

Downstream 200 yards from the above deposit the beds change in colour and general physical properties, they become darker and more slate-like, with reddish brown shades near the upstream starting point. There are three bands of hardened sandstone, one of which is 2 feet thick. The beds are nearly vertical and rise 6 to 8 feet above low water. An overburden, 4 feet thick, of loose stone and gravel rests on the upper edges of the strata. The total face crosscut for the samples was 190 feet.

The first, or upstream, 124 feet was taken for sample *No. 2924* and the downstream portion of 66 feet was sampled for *No. 2925.*

Sample No. 2926. This was the last sample of the general group, and was taken on the north side of the river a short distance downstream from the last two samples. The beds at this point are quite like those of No. 2923 in so far as colour and general physical properties are concerned; they are likewise interbanded with layers of sandstone. The cross-section is as follows:—

	Feet	Inches
Sandstone (upstream marker)	6	
Shale, yellowish, iron-stained	16	
Shale, light yellow, dark green	9	
Sandstone, blocky (discarded)	4	6
Shale, yellowish and green	4	
Ironstone, nodular (discarded)	1	4
Shale, yellowish and green	2	
Sandstone and shale (discarded)	2	6
Shale, grey	19	
Beds pass under cover here.		
Total shale sampled	50 feet	

Like No. 2923 on the other side of the river, these beds are not exposed more than 6 feet above low-water level. It would, therefore, be advisable to trace along the strike of the outcrop to the upper bench levels where greater thicknesses may be found. With transportation this deposit would be of commercial interest.

Working and Burned Properties

Sample No. 2923. The general shade is light green and the sample as a whole is easily crushed; considerable iron stain is present, stratification is evident in some pieces of the sample taken, but the fracture is uneven to semi-conchoidal. Tests showed the material to be free of carbonates. The plasticity and working properties are fairly satisfactory, drying of the trials proved safe, the total drying shrinkage corresponding with the Belly River samples taken on Sheep river.

The modulus of rupture of the burned trials is very high and slightly above that of sample No. 2920. All other properties resemble so closely those of clays Nos. 2921 and 2922 that attention is here directed to the discussion of those samples as applying in the case of the present sample.

Sample No. 2924 was slate grey with some iron stain, the pieces are splintery to angular, gritty, and possess but little evidence of lamination. In tempering, a lower degree of plasticity was produced than in the other samples collected in the same field; the working properties were rather poor, indicating a short sandy body. Drying and oxidation as a consequence, naturally, gave no trouble. The modulus of rupture of the raw clay is below the average although sufficiently high for the more ordinary red ware products.

During burning the changes are quite slow or inactive until cone 04 where the rate increases and continues steadily to cone 4, thus showing a body of sufficiently wide vitrification range for most purposes. The burned strength is quite satisfactory. The colour, while fair, is not so pleasing or bright as Nos. 2920 to 2923 inclusive.

The data obtained indicate the suitability of this shale for ordinary face or stock brick, common brick, and hollow building tile. Its colour when burned is rather below that required by the roofing and floor tile trades.

Sample No. 2925. The colour is dark slate and the material is harder and of more splintery fracture than the adjacent beds. The mass when tempered proved weak and deficient in plasticity, a condition to be expected from a body of this type. The strength of the unfired body is decidedly low.

The vitrification rate and other properties of this sample more nearly conform to those of certain Benton samples than they do to those of samples taken from the Belly River beds here studied. The chief difference is in the temperature at which active vitrification starts. In other Belly River samples it starts at comparatively low temperatures and extends over a wide range, whereas in the samples under discussion little evidence of vitrification is noted below cone 02, from that point on it proceeds quite rapidly until overfired conditions are reached. (*See* Fig. 21, p. 108.)

In a summary of the possibilities offered by the samples collected on Quirk creek, No. 2925 commands the least interest in that its burned colour is weak and its general physical properties are not of the best. The most likely field for further study would be that of its use in the manufacture of stock brick.

Sample No. 2926. This sample is distinctly different from No. 2925. Judging by the raw colours and other properties there is no doubt of the proper placing of these beds in the Belly River formation. This conclusion is further substantiated by a study of the fired properties. The sample is light buff to grey and shows that part of the iron has been oxidized naturally. It is generally gritty and the pieces non-stratified or shaly.

Though the body proved to be short, sufficient plasticity was developed to assist in an easy moulding of desired shapes, which dried safely. Its raw strength is above that of No. 2925 but on the other hand oxidation proved to be more difficult. The pyro changes start at cone 010 and proceed solwly to cone 04, the rate then increases and continues steadily for several cones, developing a sound body of good strength and colour. (*See* Fig. 19, p. 107.)

Reference is made to the discussions on Nos. 2920 and 2921 as applying to the commercial interests of the sample here described.

Samples Nos. 2927 to 2931

Location and Description

These samples were collected from Benton beds on the east flank of the main anticline at Turner Valley; thus these deposits are in close proximity to the gas supply and should, therefore, prove of interest whenever rail transportation reaches the district, providing of course that the shale proves suitable for the production of commercial ware.

The deposits sampled are located on the north bank of Sheep river, below the Black Diamond-Turner Valley trail and to the west of the prominent Belly River rock cut. The beds dip to the northeast (*see* Plate IVB) and rise but little more than 10 feet above low-water level in the river. Starting at the point where the shales first emerge from under cover the sampling was continued upstream to near the mouth of a small creek which enters Sheep river from the north. Sample divisions were made at points where the beds changed in colour or physically as pointed out below.

Sample No. 2927 represents 89 feet of the most easterly beds. The shales are quite slaty in nature and weather down into thin splintery pieces. A number of clay-ironstones were observed in this deposit though in less numbers than in some of the associated beds. This deposit gives way rather sharply to a zone of red-brown, iron-stained shale, well stratified and with many thin layers of harder sandy shale. This section was sampled for a distance of 57 feet to a 10-inch layer or band of calcareous stone and designated *No. 2928*. The upstream half of the deposit is more thinly bedded and carries fewer of the thin hard streaks than does the lower half.

From the 10-inch stone marker of the above sample, a span of 50 feet was not sampled as some of the beds were under cover, but where exposed they appeared to be the same as those of the previous beds.

Sample No. 2929. Starting at a point where the shales next appeared from under cover a section 48 feet was taken for No. 2929. In the upstream part of this section the shales are more sandy and interstratified with lenticular masses of fossiliferous stone. In general this section of shale is harder than the adjoining shales upstream.

Sample No. 2930. A little to the east of the mouth of the small creek previously mentioned, are beds of slate-coloured to nearly black Benton shales which rise 6 to 10 feet above the river. Considerable iron stain was present and the upstream half of the deposit was more sandy than the lower. From the creek the deposit was sampled downstream 75 feet and the material listed as No. 2930.

Sample No. 2931, consisting of a 66-foot section, was made to the north of the creek bridge where there is an open-cut bank of dark shales, heavily banded or charged with small nodular clay-ironstone. The concretions were discarded, though commercially their removal would not likely be practicable. It is, therefore, quite likely that this deposit would have to be avoided.

The other deposits of the whole group, although quite free from concretions, and of workable depths, could not be developed at the points sampled owing to their nearness to the public highway. The same beds no doubt exist north of the road and again in the bench lands to the southeast across the river, where sufficient room is available for a clay products plant, though access to rail must be provided.

Working and Burned Properties

Sample No. 2927. The sample as received at the laboratory is composed of two different materials; one is dark slate-coloured, and when crushed, breaks into angular flinty pieces, the other is more sandy and coarser grained, and breaks into larger and more blocky pieces. Iron stain and carbonates are both absent. When ground and tempered the mass is short and quite non-plastic, though through ageing a fair degree of cohesion developed resulting in a raw strength of slightly over 300 pounds per square inch.

The vitrification changes are quite favourable, the rate being slow and gradual resulting in a body of fair properties between cones 02 and 3, beyond the latter cone, however, overfiring takes place rapidly. The burned strength at cone 02 is good, the colour on the other hand is quite unsatisfactory.

While it was possible to mould small trial pieces from this shale it is doubtful whether it could be manufactured by any other method than that of dry pressing; this being the case, in addition to the unsatisfactory colour, its use will be for common and stock brick only. Extended testing, including that of blending with a more plastic clay, might show this clay to be of greater commercial interest.

Sample No. 2928. When tested this sample proved to have raw and burned properties so nearly in accord with those of the preceding sample, No. 2927, that reference is here made to the remarks and statements concerning that sample.

Sample No. 2929. The sample is hard, slate-like and thinly stratified; a small portion, however, is quite sandy and when broken, the pieces are angular to blocky in shape. The mass is very short and of poor working properties even after grinding, tempering, and ageing; it being quite evident that little or no disintegration of the shale particles had taken place; drying shrinkage was consequently quite low. A study of the changes which took place during the burning of the trials reveals that this clay is more refractory than the other samples of Benton collected from the same general outcrop. Although the absorption and porosity are quite high at cone 3 this condition could be improved by higher firing temperatures. (*See* Fig. 26, p. 111.) However, the burned colour, even at its best, is poor and would not prove suitable for other than common brick and tile. The lack of plasticity is another disadvantage; therefore, taking all properties into consideration the sample has little to recommend it from an industrial point of view.

Sample No. 2930. The surface colour of the sample is reddish brown due to iron stains, but fresh fractures show the original colour to be dark slate or nearly black. The fracture is semi-conchoidal and in weathering the shale splints into thin splintery pieces.

Pulverizing was fairly easy, considerable fines being produced. Sufficient plasticity was developed during tempering to ensure good working properties. The fine close texture of the body retarded the drying rate, and interfered with the oxidation. Consequently extreme care will be necessary in burning this clay to prevent losses through lack of complete oxidation.

The raw strength, 332 pounds, is sufficiently high for most wares.

The vitrification changes proceed quite rapidly from cone 010 to cone 02 indicating the presence of a fairly large amount of fluxing material, or a favourable proportion of them, such that rapid sintering or fusion takes place. Between cones 02 and 3 vitrification appears to be interrupted followed by sharp overfiring. (*See* Fig. 22, p. 109.) The burned strength is high, and the colour is a medium red of good value.

The physical and pyro-physical properties of this clay suggest that it is suitable for stock brick, common brick, and possibly paving brick and hollow tile. Attention, however, is again called to the long period required for the oxidation.

Sample No. 2931. In the raw state this shale is so similar to that of the last sample that a repeated description is unnecessary. The physical properties are slightly different in that when ground and tempered it is less plastic than No. 2930 but still possesses fair working properties. It dried safely, the raw strength being good; and the oxidation conditions are very much better than the preceding sample.

The sample reacts quickly to increase of temperature and overfires at cone 3. The total burned shrinkage, absorption, and final colour are all within commercial ranges. Therefore, this clay offers possibilities for use industrially, but more extended testing is advisable.

Samples Nos. 2932 to 2934

The remainder of the samples listed in the general group for this district were collected along the face of the high cutbank on the east side of Sheep river, opposite the Imperial Oil Company's scrubbing plant shown in Plate IB. The beds at this point pitch sharply to the northeast and are capped by 30 feet of overburden, largely clay, gravel, and stones—in other words, river wash.

Sample No. 2932. This was the first sample taken upstream; its position is above that of the two adjoining deposits. Sampling was started near the top of the shales at a hard yellowish sandstone ledge, 6 to 11 inches thick, and then carried 36½ feet across the face to a hard 3-inch layer of stone. The upper third of the deposit consisted of red-brown rusty shales which merged into a zone of dark grey hard shale, below which the colour was that of the upper beds—rusty red-brown.

Sample No. 2933. This sample was taken just below the preceding one, the division line being the thin hard stony layer at the base of No. 2932. Immediately below this stone there are 3 feet of dark slaty shale, a 1-inch ochreous seam, 5 feet of shale, a 1-inch greenish bentonitic streak, and then dark shale to a thin band of shale containing appreciable amounts of soluble salts which appeared on the surface as a white incrustation. The total depth or cross-section sampled was 54 feet. A number of irregular sized clay-ironstone concretions were noted in this deposit.

Sample No. 2934. This was taken from beds 57 feet thick and just below the last sample. The general shade or colour is that of a rusty brown. Some selenite was present in the lamination seams. Five irregular layers of nodular clay-ironstone were also noted. The shale of this deposit weathers down into smaller pieces than Nos. 2932 and 2933.

Working and Burned Properties

Sample No. 2932. The colour and general hardness of this sample are nearly identical with the two last samples. Considerable more iron stain and gypsum crystals are present.

The properties, raw and burned, are not so favourable, however, as it has lower strengths and the vitrification range is quite narrow or limited. (*See* Fig. 23, p. 109.) Overfiring occurs at cone 02. In addition the general burned colour is slightly marred by the presence of small yellow specks, due possibly to the gypsum noted in the original sample.

This shale would be restricted to wares permitting of a fair degree of porosity or absorption, as overfiring must be avoided. A possible use might be that of blending it with other clays in the district to lower their burning temperatures.

Sample No. 2933. This shale breaks into thick blocky pieces which show little stratification, the fracture is uneven, with gritty faces, the whole being heavily iron-stained. The batch after tempering and ageing proved short, and intermediate in working properties; shrinkage and strength are both low in the unfired state. Complete oxidation required a little more than the general run of Benton samples.

The changes occurring during burning are uniform and gradual. The absorption at cone 3 is a little higher than is desirable for outside structural clay wares. (*See* Fig. 24, p. 110.)

The burned strength is fair, but colour is below normal and the use of this clay would be limited to low-grade ware like common brick. Even these, due to the non-plastic condition of the sample, would have to be made by the dry-press method.

Sample No. 2934. This sample is nearly black in colour, heavily coated with iron rust and carries gypsum but is less hard than the other samples from the district. When tempered, it becomes rather smooth or fat to the feel and of fair working condition. The shrinkage during drying was normal and safe. The raw modulus of rupture is low due to short components in the sample.

Vitrification progressed more rapidly than in the previous sample but was within safe limits. The final colour is a medium red but of a value below that desired for claywares where colour is important.

Further testing would be necessary to determine the possibilities of manufacturing ware from this material by the stiff-mud process; should this method be impracticable the clay would be used only for simple dry-pressed forms, like brick.

Samples Nos. 2935 and 2936

Location and Description

On the north side of Sheep river and just below the mouth of Macabee creek, nearly vertical beds of Benton shale rise approximately 100 feet above the river. The downstream beds are red-brown to rusty, and weather into thin pieces with sharp edges.

Sample No. 2935 was started on the east side at a 6-inch band of dark conglomerate rock and carried upstream across the face of uniform beds 118 feet. Just east of the conglomerate marker and towards the top of the outcrop a number of large, yellowish cherty concretions occur. The red beds give way to a hardened zone of dark slate-like shale which was cut 40 feet for sample *No. 2936*. Near the parting line of this sample and the red beds of No. 2935 there was observed a 2-inch band of light bentonitic material. The overburden is slight compared to the great depth of the deposit, although the vertical position of the strata would detract somewhat from economical working conditions.

Working and Burned Properties

Sample No. 2935. The pieces were hard, thin, and slaty, with considerable iron stain on the surfaces. When crushed or pulverized, very few fines were produced, this condition followed by non-slaking or disintegration after tempering produced a body of low plasticity, such that moulding of the trial pieces was accomplished only with difficulty. Naturally the drying shrinkage and raw modulus of rupture were both low, the latter test gave a figure below that of any other sample tested.

During the early stages of burning period, the body expands reaching a maximum at cone 010. At higher temperatures it shrinks attaining its original dry volume at cone 04; the total burning shrinkage is 1 per cent at cone 4. The above shrinkage figure is very low and indicates a lack of vitrification with a correspondingly high absorption. As the burned colour is poor and the strength low this material has little to commend it for industrial purposes. A possible use for it might be as grog in clays or bodies where density and shrinkage are excessive.

Sample No. 2936. The pieces composing the sample are finely laminated and break down readily into thin flakes. Carbonates were noted in quite large quantities.

Testing showed the sample to be lacking in plasticity, of low strength, and of a poor burned colour. Furthermore, trial pieces fired at low temperatures expanded and burst open after being removed from the kiln for a few days, this condition being doubtless due to the hydration of free lime; therefore, this deposit has no commercial value.

Samples Nos. 2937, 2938, and 2939

Location and Description

These samples were obtained from nearly vertical Blairmore beds on Macabee creek. The first two were collected at the mouth of the stream and high up towards the top of the north wall of the canyon where red and green shale and hardened bands of stone outcrop. The first sample, *No. 2937*, is from a thin band of red shale, not over 12 to 15 inches in thickness; adjoining it on the west is a band of similar thickness of green shale which was sampled for *No. 2938*.

While these beds or strata rise 100 feet above the creek they do not offer great commercial possibilities in that the quarrying would prove somewhat difficult and the amount of material to be recovered is rather small. However, the two seams may be worked together as they are suitable for the same class of wares.

Upstream from the mouth of Macabee creek in a straight line approximately $\frac{3}{8}$ of a mile and about 100 feet downstream from the Benton-Blairmore contact a disturbed zone of thin shale bands and sandstone occur followed by shales which were selected for sample *No. 2939*. The cross-section taken was as follows:—

	Feet	Inches
Sandstone, hard	3	
Shale, grey	1	3
Hard nodular rock, used as cap	0	8
Shale, slate grey with light grey specks	4	
Shale, yellowish green	8	
Shale, green, hard	2	
Shale, slate grey	4	
Shale, green, glassy concretions	10	
Shaly sandstone, used as base	3	
Total shale sampled	28	

It will be noted that this deposit carries 28 feet of shale, and although the beds are nearly vertical, the deposit is such that it should receive further consideration in case rail transportation becomes available.

Working and Burned Properties

Sample No. 2937. The shale appeared to be dark red, though upon close examination it was found to be intermixed or mottled with greyish green; fracture being earthy to uneven. Stratification was practically absent, the shale breaking in one direction as readily as in another. Upon pulverizing, a fair proportion of fines or dust was produced, and in addition, a part disintegration or softening of the larger grains took place during tempering and ageing, all of which tended to give a body of good working properties, though slightly granular in texture. A low percentage of water was required for the tempering, followed by a low drying shrinkage. The modulus of rupture for the raw pieces is quite good.

The rate and range of the vitrification is favourable, at least up to cone 3, but above that point overfiring takes place. The burned strength is high and would prove sufficient for hard service wares.

Among the more outstanding properties of this clay is the bright red colour of the burned pieces. Very few clays or shales attain the particular shade and clearness of colour developed by this sample.

The physical properties in the unburned and burned state are such that it is of interest for use in the manufacture of face brick, quarry tile, roofing tile, red terra cotta, paving brick, red flooring tile, and pottery. There is, however, to be considered the apparent limited supply of the material at the point of sampling and its distance from rail transportation.

Sample No. 2938. The deposit although a direct continuation of the one just described differs from it in colour and texture. Sample No. 2937, as before mentioned, is red while No. 2938 is greenish grey. There is considerable interblending of the two colours so that a clear sharp cut division of the two cannot be made, though the latter material or shale is more gritty and harder, stratification is lacking and the fracture irregular. The sample proved hard to grind and only by long grinding was it possible to produce a fair proportion of fines. Tempering, followed by ageing, resulted in a short gritty body with fair working properties. The raw strength is a little under that of No. 2937 but its drying shrinkage is practically the same, oxidation is completed in a reasonable period of time. The pyro-physical changes are remarkably uniform and regular, the rate of change or vitrification being a little less than that of No. 2937, indicating a slower fusion of the materials present. The burned strength is rather low, although to develop the best strength the body should be burned at a somewhat higher temperature. The burned colour is a bright red with a slight yellowish tint.

Although the sample possesses good properties which would make it suitable for use in a wide range of red clay products, the quantity of material available as shown by the thickness of the beds is not large. Should rail transportation become available a more extended examination of the district might disclose thicker beds similar to this shale and to No. 2937.

Sample No. 2939. The colour varies from slate grey and yellowish green to nearly black. Some slickensided material is present as well as iron rust and a film of black shiny unknown substance on the faces of some pieces. On the whole the sample is gritty and proves to be short when tempered with water. However, the working properties are such that it could be manufactured into commercial wares. The raw strength is below the general average and oxidation proceeds rather slowly. These conditions are partly offset by the favourable changes which take place during the burning. The body becomes steel hard at cone 010. Above this the shrinkage increases slowly with a correspondingly uniform drop in porosity and absorption. (*See* Fig. 28, p. 113.) Its strength would prove sufficient for all lines of red ware. The colour, that of a medium bright red, is pleasing and of good value. A few black specks may be seen but these would not prove objectionable except in red ware pottery, floor and wall tile.

Notwithstanding the excellent properties of this sample, the distance from rail prevents its development.

Samples Nos. 2940 and 2941

Location and Description

Both samples were taken on the Millar ranch in sec. 12, tp. 21, rge. 3, W. 5th mer., and about one-quarter mile northeast of the ranch buildings. The general district is that of a flood plain through which Quirk creek has cut a meandering channel 40 feet deep exposing beds of glacial or boulder clay, 10 feet thick at the base or water level. The boulder clay is capped by 30 feet of fine-grained stratified clays; the upper parts of which are highly colloidal but the lower part is slightly silty.

Sample No. 2940 was obtained from the uppermost beds and *No. 2941* near the base of the deposit. The overburden of soil which is quite shallow could be cheaply removed and the clay could be recovered by mechanical means. Transportation is lacking at present though a surveyed and partially graded right-of-way for a railroad crosses the property.

Working and Burned Properties

Sample No. 2940. This sample represents material of Recent origin. It is a soft clay which breaks down when dry into hard granular pieces or pellets about the size of wheat grains; when tested with acid, the clay gave indication of being high in carbonates. On tempering the clay becomes very sticky and difficult to mould or work. Although small trial pieces dried safely, in view of its excessive drying shrinkage it is doubtful if the same results could be obtained in full-sized ware.

The clay is of special interest because of its very high raw strength and its slow rate of oxidation. (*See* Fig. 1, p. 96.)

The burning behaviour of the clay is quite unsatisfactory there being little or no sign of vitrification up to cone 04. Between that cone and cone 02 it vitrifies very rapidly ending in overfired conditions within narrow temperature changes. Furthermore all trials cracked during the burning period. Owing to this unsatisfactory behaviour the clay cannot be used alone in the manufacture of clay products, although it may be used as a bonding material for clays or shales having low plasticity, or poor working properties. This clay might be used as a raw material for "Haydite,"[1] as, unless very slowly oxidized during the burning, it will bloat or expand to abnormal sizes, the resulting mass being light in weight and highly vesicular or sponge-like. It is of interest to note that during the past, many tons

[1] "Haydite" is the trade name for a building material composed of bloated pieces of burned clay or shale for use as an aggregate in place of gravel in the making of concrete.

of it have been used in the raw state as a mudding or liquid sludge in the drilling of deep wells in Turner valley by the rotary method. The fine grain and very highly colloidal properties of clays of this type are such that a practically non-settling mud or slip is possible from them, especially if the "mud" is boiled or steam "cooked."

Sample No. 2941. Sample No. 2941 is a soft clay of Recent origin but has somewhat different physical properties from No. 2940. It is more yellowish to dark buff when dry, carries carbonates and in fracture is earthy to conchoidal, although the larger pieces show lamination lines. It crushes easily and tempers into a plastic mass of good working properties.

Small trial pieces required slow drying to prevent cracking. The raw modulus of rupture is high though not equal to No. 2940. The behaviour during burning is better than in the previous sample as the vitrification range is wider. (*See* Fig. 2, p. 96.) The burned colour is a medium red of low value, badly scummed, and shows yellowish specks. More extensive tests will be necessary to check its drying qualities in full-sized ware. The clay is of only moderate interest even for the more common wares, like common brick.

Samples Nos. 2942, 2943 and 2944

Location and Description

The samples were all taken from an outcrop of Paskapoo shales on the south bank of Quirk creek, three-quarters of a mile above its junction with Sheep river. The Freeman ranch buildings are a short distance northwest from this deposit.

The three samples taken were divided largely by colour, though commercially they would be treated as one clay. The lowest one, *No. 2942*, showed 4 feet of sandy grey shale, which in turn gives way to $3\frac{3}{4}$ feet of darker and finer grained shale which was sampled for *No. 2943*. Capping this is a sandstone layer 1 foot 10 inches thick, which was used as the base for the next sample. *Sample No. 2944* was taken from a bed of shale 5 feet thick, light grey near the base, light buff in the centre, and slate grey to nearly black in the upper third. A layer of sandstone 3 feet thick caps the whole.

The beds dip gently northeastward, and were it not for the interbanded and capping sandstones the deposit might prove to be of commercial interest.

Working and Burned Properties

Sample No. 2942. In the raw state the colour is light grey, stained with considerable iron rust; carbonates are present in fairly large amounts; the fracture is stony to irregular and the texture is gritty or sandy and generally dry.

Pulverizing was not difficult and resulted in a mixture which proved short in the plastic state. The drying shrinkage, raw strength, and oxidation were all within commercial limits. Owing to the sandy content the clay expands during the early part of the burn, and does not return to its original size until cone 03 is reached. Vitrification proceeds more rapidly from cone 02 to cone 3 and overfiring takes place prior to cone 5. (*See* Fig. 10, p. 101.) The burned colour is poor and unsuitable for other than common brick and tile.

Sample No. 2943. As the beds from which this sample was taken are just above the preceding sample the two could most likely be worked as a single deposit. However, the present sample is finer in grain and softer, though some portions are gritty, and considerable iron stain and carbonates are present.

The clay has good plasticity and working properties, and dries safely. The raw strength is satisfactory for heavy clay products; oxidation would not present any difficulties under ordinary burning practice.

During the burning the porosity and absorption remain high up to cone 04, from there on they drop uniformly to cone 3; above that temperature overfiring takes place rather quickly.

On the whole this shale has better ceramic properties than *No. 2942*, in that its absorption drops to reasonable percentages well in advance of overfiring. The burned strength is satisfactory. On the other hand the burned colour is a misty or greyish red suitable only for the more common lines of building products.

The interest in this shale lies in its use for common and stock brick, hollow building tile and similar wares, though in the absence of a clay yielding better red for face brick this shale might well be used.

Sample No. 2944. The two last samples and the present one are quite similar except that No. 2944 is slightly more sandy. The fracture is irregular without signs of stratification, and carbonates are present in small amounts. Owing to its sandy nature the sample grinds freely, and the drying conditions are good.

The raw strength is slightly better than No. 2943, the time necessary for oxidation being the same. Its vitrification changes are slow, uniform and exceptionally regular. Overfiring takes place between cones 3 and 5, with porosity still quite high. The burned colour, the commercial value, and uses of this material are quite the same as No. 2943.

Sample No. 2945

Location and Description

Sample No. 2945. This sample was taken from a deposit on sec. 21, tp. 20, rge. 2, W. 5th mer., approximately 2 miles downstream from the Black Diamond bridge over Sheep river. The deposit which is on the west side of the river is made up of shale and sandstone layers. (*See* Plate V B.) The following cross-section was sampled.

	Feet	Inches
Overburden	10	
Sandstone capping	1 to 2	
Shale, yellowish	2	8
Shale, light grey	2	1
Shale, slate grey	2	2
Nodular sandstone layer	0	10
Shale and concretions	4	
Shale, grey and iron-stained	2	
Massive sandstone for base.		
Total shale sampled	12	11

The above section is doubtless only a part of the entire deposit as the bank continues to rise and may contain more shale beneath the overburden. This deposit being near the gas fields should be more carefully investigated in case a railroad enters the district.

Working and Burned Properties

This sample in the raw state corresponds in colour, texture, and fracture to those of the three preceding samples. However, it is a little finer in grain and less sandy; these conditions being reflected in its raw strength, higher drying shrinkage, and longer oxidation period. Little vitrification takes place prior to cone 04 other than that indicated by its steel-hard condition at cone 010.

The burning shrinkage and absorption changes are safe and regular, both proving to be commercially safe at cone 3. The burned colour is fair for structural wares.

The suggested uses for this shale include face and common brick, and building tile. In addition, further testing may prove its usefulness for paving brick.

Samples Nos. 2951 and 2952

Description and Location

Both these deposits are in the Paskapoo beds where they outcrop on the north side of the Sheep river in sec. 35, tp. 20, R. 2, W. 5th mer., approximately 1½ miles below the junction of Sheep river and Quirk creek.

Sample No. 2951. A low exposure of dark shales rests on sandstone at water level near the east end of the outcrop. This part of the deposit was taken as sample No. 2951 as below. (*See* Plate VI B.)

	Feet	Inches
Cover, shales and sandstone	100	
Shale, light green, fine grained	1	
Shale, chocolate, sandy	1	
Shale, variegated green, sandy	1	
Shale and sandy shale	0	10
Shale, grey, sandy	2	10
Shale, bluish and iron-stained	4	6
Sandstone base.		
Total shale sampled	11	2

Owing to the heavy overburden and the steepness of the face of the outcrop the deposit would have to be mined or combined with the remainder of the shales in the bank and worked as an open face quarry. This would seem possible from a study of the cross-section of the next sample, which lies just above.

Sample No. 2952. The collection of No. 2952 was made at the west end of the general outcrop, about 20 rods upstream from the previous sample and constitutes nearly the entire vertical face of the bank. The section is as follows:

	Feet	Inches
Cover, soil and silts	10 to 20	
Sandstone layer	1	
Shale, green	1	2
Shale, black, rusty, fissile	3	
Shale, greenish, plastic	3	2
Shale, light green, sandy	7	2
Sandstone (discarded)	0	8
Shale, greenish, rust-stained	3	6
Shale, dark to black	5	1
Shale, grey and green and clay-ironstone concretions	9	6
Sandstone	2	6
Shale, grey, rusty, sandy	2	
Shale, greenish, fine grained	1	
Thin carbonaceous seam		
Shale, greenish, some concretions	2	8
Shale, light green, fine grained	5	3
Sandstone (discarded)	1	10
Shale, grey, sandy, some concretions	2	6
Shale, nearly black, fine to sandy	3	4
Shale, dark brown to green, plastic	1	4
Shale, brownish green, sandy	2	4
Shale, greenish, sandy	3	9
Talus material	40	
Total shale sampled	59	2

The large amount of shale in this deposit accompanied by the small amount of stone and concretions to be discarded, places this deposit in a position to command further attention should a railroad pass within reasonable distance of it. The gas at Turner Valley could no doubt be carried to this field at a reasonable cost.

Working and Burned Properties

Sample No. 2951. The pieces of shale vary from light to dark grey and in part are iron-stained, the dark portion is highly conchoidal in fracture, but that of the light portion is stony and irregular and is more gritty.

Grinding produced considerable fines and dust which in conjunction with a free disintegration of the larger grains produced good plasticity and excellent working properties. The dry shrinkage is slightly high, but not sufficient to develop drying troubles. Raw strength and oxidation are quite satisfactory in this material. Vitrification changes are all of a favourable nature and occur at reasonable burning temperatures for red wares. Overfiring occurs between cones 1 and 3.

The burned colour while not of the best shade of red would prove quite acceptable to the general trade. The uses for this shale would be the same as for the last sample. It is of interest to note that while this sample was collected in the Paskapoo beds its burned colour and general properties are such that its allocation to the Edmonton beds would be justifiable.

Sample No. 2952. The general shades of this sample are dark slate, grey, and rusty brown; the lighter material proved to be quite high in carbonates. While the sample in the dry state has a decidedly gritty feel certain parts are quite soft and fine grained. The mass as a whole becomes decidedly plastic when tempered and works freely into moulds. The drying shrinkage was quite satisfactory and safe.

The modulus of rupture is fairly high, the trial pieces breaking at 495 pounds; when burned at cone 02 the pieces broke at 2,230 pounds. The latter strength is only average, but could be increased materially by higher burning temperatures. Oxidation required only three hours, therefore little or no trouble need be expected from this source. The body becomes steel hard at the low temperature of cone 010; the burned colour is quite unattractive, being light greyish red.

The porosity and shrinkage data indicate this shale to be unlike the nearby sample, No. 2951, as its porosity is very much higher and the percentage of shrinkage lower until about cone 3, where both samples start to overfire. The vitrification changes are much too rapid as at no time during the burning does the porosity drop to a reasonable degree prior to overfired conditions. Therefore, in view of the poorly burned colour and the unsatisfactory changes taking place during the burning, but few lines of manufacture are open to this shale other than the more ordinary lines of common brick, building and drain tiles, where low absorption is unnecessary.

NORTH (CENTRAL) AREA

The samples from this general area are from Paskapoo, Edmonton, Belly River, Benton, and Blairmore formations.

Samples Nos. 2946 to 2950

Location and Description

All these samples are from Paskapoo and Edmonton beds near Priddis and above the settlement on Fish creek.

Sample No. 2946. The first one of the group, No. 2946, was taken from an outcrop at the mouth of a small valley which enters the main valley from the east at a point just south of the post office. This deposit may prove to be a slide, as the strata dip somewhat more sharply than those of the main outcrop to the north. This deposit has been listed as Edmonton because of its position at the base of the hill, and also because the colour is more like that of the Edmonton than Paskapoo; the classification, however, is uncertain.

The cross-section of the beds is as follows:—

	Feet	Inches
Overburden, shale and sandstones	8	0
Shale, sandy, yellowish	0	4
Shale, dark slate colour	0	6
Shale, iron-stained	3	0
Shale, light grey	1	8
Shale, dark and blocky	2	4
Shale, black	1	8
Sandstone base		
Total shale sampled	11	0

Sample No. 2947. This was taken from near the base of a high bluff on the east side of Fish creek opposite the post office at Priddis. The upper 25 feet of the exposed beds is a massive sandstone (*see* Plate VIA) and zones or layers of pebble and shale conglomerate with markings of lignite or plant remains along parting seams or bedding planes are present.

Beneath the massive sandstone is a bed of bluish green to dark coloured shale, 18 feet thick measured at right angles to the beds which dip toward the northeast. It would be necessary to mine the shale from this deposit by underground methods owing to the heavy ledge of sandstone above it. For this reason the beds above the sandstone should receive first attention.

Sample No. 2948. This sample is from beds which are exposed on the left bank of the ravine from which No. 2946 was taken. Here the beds rest on a massive sandstone which is doubtless the capping covering the shales of No. 2947. The cross-section was measured as follows:—

	Feet	Inches
Cover, unknown.		
Shale, sandy and yellowish	0	18
Shale, darker and finer grained	0	16
Shale, sandy, yellowish grey	4	8
Shale, grey to greenish	8	0
Sandstone base		
Total shale sampled	15	10

Should rail of transportation reach Priddis the deposit would be worthy of further study.

Sample No. 2949. This sample was taken two miles upstream from Priddis and on the east side of Fish creek.

The cross-section was as follows:—

	Feet	Inches
Glacial clay overburden	10 to 20	0
Sand, green	0	6
Shale, light grey and rusty	5	0
Shale, dark to black, fine grained	3	0
Total shale sampled	8	0

Unless greater thickness of shale having less overburden can be located there is little to commend this deposit.

Sample No. 2950. This sample was taken about two miles farther upstream from the previous sample, the location being in the NE. ¼ of sec. 10, tp. 22, rge. 3, W. 5th mer. and on the east side of the stream. The general cross-section is shown below:—

	Feet	Inches
Cover, unknown and soil.		
Sandstone, massive	10	2
Shale, dark and rusty	3	0.
Shale, light brown	4	0
Shale, dark grey	2	0
Shale, greenish brown	3	0
Sandstone, bluish, base.		
Total shale sampled	12	0

Transportation and fuel would place this deposit and general district in a position worthy of further study.

Working and Burned Properties

Sample No. 2946. This sample shades through buff, greyish green to dark slate in colour with some discoloration of iron rust. Some stratification is evident; and the material on the whole is fine grained. The shale crushes easily and develops a body of good plasticity and working properties. Safe drying of the small trials was accomplished only through care and a rather extended drying period. It is quite likely that warping and cracking would take place in the drying of full-sized ware owing to the high drying shrinkage. The raw modulus of rupture is above the average; on the other hand the burned strength is only medium; oxidation progresses slowly. Vitrification starts at cone 010 and continues steadily to cone 02 with overfired conditions taking place shortly thereafter.

It is to be noted that this shale becomes steel hard at cone 010 and reaches its best condition at cone 02. The burned colour is a dark red of good value though not quite so clear as that of samples from the same beds farther south.

The burned properties suggest the use of this shale for face, common, and paving bricks, roofing and quarry tiles, building tile, and similar wares. Although losses would undoubtedly be met with in the drying of commercial wares, these losses could probably be prevented by blending with clays of lower plasticity and drying shrinkage. There is also the possibility of producing brick from this sample by the dry-press method.

Sample No. 2947. The general shades of the shale when dry is buff to grey in colour, one portion being heavily iron-stained and rather gritty. On the latter account it proved to be rather short in its working behaviour. The grains of the sample are small as shown by the relatively high percentage of tempering water. The drying shrinkage is slightly over the average though not sufficient to prevent safe drying. Its raw strength is rather below the average though when burned the strength is very good. Oxidation was slow but should not prove troublesome under proper burning conditions. At cone 010 vitrification had progressed sufficiently far to produce a steel hardness in the body, but the absorption at the same temperature is too high for most commercial wares. However, the percentage drops slowly to cone 04, between that and cone 02 it decreases very sharply, then slows up to cone 3 where overfiring starts.

The burned colour is a clean light red quite suitable for face brick. If the deposit were near rail it would be worthy of further study for the production of common brick, building and drain tile.

Sample No. 2948. The shale is well oxidized and fine grained; one part of it is sandy, the remainder being more clayey. The sandy part shows some stratification but the clayey part breaks into irregular pieces. Carbonates are absent but the whole sample is badly iron-stained.

The shale grinds freely and, although it tempers into a mass somewhat short, the plasticity is quite sufficient for good working properties. All the trials dried safely, the drying shrinkage being low. Between cones 010 and 04 the porosity and absorption are both high, but before cone 02 is reached they drop rapidly, accompanied by a sharp increase in the burning shrinkage. At cone 3 there is a decrease in the rate of change, beyond which the rate again increases to an overfired condition. The burned colour is good. The body becomes steel hard at a comparatively low temperature, cone 010. Oxidation should not prove troublesome with moderate care during the early stages of the burning.

Although the colour of the ware made from this shale would permit of its use in exterior wares such as face brick and roofing tile, the fact that it requires burning to cone 3 at least to lower the absorption to a reasonable degree for these wares would mean an increase in the burning costs over that of other shales in the same general district, for example No. 2946. A blend of the two shales would be well worth trying in that No. 2948 would improve the drying properties of No. 2946; on the other hand the vitrification changes of No. 2948 would no doubt be materially improved.

Sample No. 2949. In the laboratory the dry sample shows iron stain on the fractured faces of irregular-shaped pieces but the general shades are buff and greenish dark grey. On the whole the material is finer grained and less gritty than the previous sample. These conditions become more evident in the tempered mass, which proved quite plastic and of good working properties. The trials dried safely notwithstanding a shrinkage somewhat above the average. Its raw strength is very good and would prove sufficient for thin-section wares. Owing to the close texture of this sample oxidation proceeded slowly, indicating that in heavy wares losses might occur unless care were exercised to oxidize properly during the early stages of the burning.

When burned the ware shows a very high modulus of rupture. The trial pieces were, however, slightly kiln-marked, indicating a condition of low viscosity during vitrification.

Vitrification proceeds steadily from cone 010 to cone 02, where the properties are at their best, thus indicating not only a safe burning shale but one requiring rather low temperatures to produce wares low in porosity, absorption, and fired shrinkage. The burning should not be carried beyond cone 02, otherwise losses will be incurred through overfired and kiln-marked wares. (*See* Fig. 14, p. 104.)

The burned colour is a clear medium red, commercially good. The general uses indicated are those of a fairly complete line of structural wares, also paving brick and quarry tiles, though more complete tests should be made prior to any industrial development of this deposit for the latter products. At present the outlook for this material entering the clay products field is decidedly negative owing to its distance from rail.

Sample No. 2950. This sample is dense and fine grained, breaks into sharp angular pieces which are partly conchoidal in fracture. There are two shades, one light grey and the other dark grey with some iron stain; carbonates were undetected.

The hardness is medium in so far as crushing or grinding is concerned. Upon tempering a smooth or fat plastic body is produced which lends itself readily to moulding or shaping. The drying properties proved favourable. Although the raw modulus of rupture is low it would be sufficient for all except very thin wares. Owing to some unoxidized material present and the fine-grained, dense condition of the body, the time required for complete oxidation proved to be excessive, so much so that special attention is drawn to it, in order that further study may be given in advance of money expenditures for industrial purposes.

The vitrification rate and range are both good and indicate that the shale has a slightly higher degree of refractoriness than No. 2949, as overfiring does not occur until cone 1 has been passed. The temperature necessary to produce the best quality of ware is low and would prove satisfactory for industrial practice. The burned colour is good and when considered with the other properties, including its burned strength, emphasis is given to the importance of this sample for use in practically all lines of red ware like face, common, and paving brick; roofing, floor, and quarry tile; and hollow building tile. Unfortunately, owing to lack of rail transportation it is wholly barred, at present, from development.

Sample No. 2970

Location and Description

Sample No. 2970 is made up of 41 feet of Benton shales, red-brown and rusty in shade with a single band of clay-ironstone near the centre. The location is on the east side of the Elbow river in section 11, about one mile upstream from Bragg Creek, near the former site of the Mowberly-Berkley oil well which was drilled during 1913-14. As the shale from this deposit showed unfavourable properties when tested, further comments are unnecessary.

Working and Burned Properties

Sample No. 2970. The pieces of shale are iron-stained on the surface, but when freshly broken are slate grey to nearly black, fissile in structure, quite hard and non-plastic. Even after the sample had been finely ground and had been aged after tempering, it proved to be short and very poor in working properties. Naturally the drying shrinkage was low. The raw strength is also low and the clay is quite unsuitable for industrial processes.

The oxidation was not completed at the end of a 10-hour period consequently even if the other properties of this shale were satisfactory, it would be exceedingly troublesome to oxidize safely. The vitrification changes are very slow and uniform up to cone 3 but the burned colour is quite poor and unattractive. Indications are that the shale is of little ceramic value, especially as it is remote from transportation.

Samples Nos. 2971, 2972, and 2973

Location and Description

Samples Nos. 2971, 2972, and 2973. These samples were all taken from Blairmore beds at the northwest end of the bridge over Elbow river at Bragg Creek. The outcrop at this point discloses at low water the edges of nearly vertical strata in the bed of the stream. The first deposit of the group is a 2-foot band of red shale; adjoining the above deposit is a thin strata of green shale taken as *No. 2972.* Close by, though separated by a hardened sandstone zone, is a 30-foot section of greenish shales sampled for *No. 2973.* Of the three deposits the latter one is the only one which offers commercial possibilities. It would, however, be necessary to trace the beds of this deposit along the strike to higher ground in order to avoid flood waters.

Working and Burned Properties

Sample No. 2971. The bed of shale is quite thin, dark red to chocolate in colour and quite gritty; the pieces are mostly irregular in fracture and shape. Owing to the gritty nature the plasticity was quite weak and the working properties poor, the drying shrinkage is low and safe.

The quantity of shale taken for this sample was insufficient to permit of preparing modulus of rupture trials, though it may safely be stated that the raw strength would prove low. However, the strength of the burned body would most likely prove sufficient for all practical purposes. The changes during the burning stages are very good progressing steadily and uniformly from cone 010 to cone 02; from cone 02 to cone 3 little further vitrification takes place, and higher temperatures would have to be used, especially for those wares where a low absorption is necessary.

The burned colour is of exceptional value. The shale could be used for a wide range of red clay products. However, its distance from rail prevents present development.

Sample No. 2972. This sample was taken from a narrow band of green Blairmore shale at practically the same point as No. 2971 was obtained from. Only a small sample was collected, just sufficient to check its general properties with those of Nos. 2937, 2938, and 2971. Tests have shown it to be quite similar to those samples in that it is short, of low shrinkage, becomes steel hard at cone 010 and burns to a clear deep velvet red of good colour value.

Data from the burned trials show the shale to be less refractory than its close neighbour, No. 2971, its absorption at cone 02 is lower than that of sample No. 2971.

Distance from rail will seriously hamper its development. It may be added that a mixture of this shale with No. 2971 would most likely prove beneficial, especially to the latter sample.

Sample No. 2973. The thickness of the deposit from which the sample was taken is greater than either of the two last samples and is therefore of greater industrial interest. The dry sample is greenish grey in shade though a few pieces show a red and chocolate mixture. Although fine grained it proved to be hard and gritty. It is irregular in fracture and non-laminated. Both plasticity and drying shrinkage are low.

The modulus of rupture of the unburned trials is very low and would not likely prove sufficient for wares other than those of heavy cross-section, like brick.

During burning, expansion takes place up to cone 010, followed by a uniform shrinkage to cone 02. At this point shrinkage apparently ceases until the temperature is raised to cone 3. Overfiring is likely to occur between cones 5 and 6.

The burned colour is light red, clear, and not wholly unattractive, though it could be improved by the introduction or addition of shales Nos. 2971 and 2972. Used alone this material could not be manufactured by other than the dry-press process which would restrict its use very largely to brick.

Sample No. 2974

Location and Description

Sample No. 2974. One mile below the bridge, on section 13, there is a zone, 50 feet wide, of multi-coloured shale mostly green, purple, yellowish, and slate, in the Blairmore. As these beds rise but 3 to 4 feet above low water it would be necessary to trace them to higher ground for development. With both fuel and transportation lacking there is little to attract attention to any of the deposits in this general district.

Working and Burned Properties

Sample No. 2974. The sample is mostly dark grey to slate-coloured. Considerable iron stain is present and, in one part, dark shiny crystal-like faces were noticed. These crystals are quite similar to those seen in sample No. 2939. The fracture is irregular and stony. Notwithstanding the gritty nature of this shale it became quite plastic and of fair working qualities when thoroughly tempered. The drying shrinkage is slightly higher than that of other samples from the same locality.

The raw strength, while low, is very much better than that of No. 2973. On the other hand the oxidation proved more difficult, though kiln losses are not likely to occur from this source, owing to the openness of the body. The burned strength is only medium to cone 02, but the shale is not at its best at that temperature and burning at higher temperatures would increase its strength. The vitrification rate is safe and the body remains quite open and porous even at cone 1, at which cone overfiring begins. (*See* Fig. 29, p. 113.) The burned colour is medium red and is not so good as that of other Blairmore samples tested. A few small black specks not unlike those in No. 2939 were observed.

A more fusible shale or clay added to No. 2974 would no doubt improve its burned properties, otherwise its use will be restricted to wares permitting of medium colour and moderately low absorption, like common brick and hollow tile.

Sample No. 2975

Location and Description

The last deposit in the Bragg Creek area to be sampled was No. 2975 which is a low outcrop of Belly River beds on the west bank of Elbow river, approximately 2½ miles downstream from the bridge at Bragg Creek, on the NE. ¼ of sec. 19, tp. 23, rge. 4, W. 5th mer., about one-quarter mile below the ford on Elbow river, shortly below where it enters the Sarcee Indian reserve. The shale beds at the point of sampling are nearly vertical and rise but 3 or 4 feet above low water. They are varied in shade, the principal ones being brown, slate, blue, green, and yellowish. The overburden is silts, sands, gravel, and waterworn stones, ranging in depth from 4 to 18 feet.

Sampling started at a coal seam and crosscut beds as follows:

	Feet	Inches
Coal	3	6
Shale, dark grey	1	3
Shale, yellowish, sticky	2	6
Sandstone and concretions	0	8
Shale, yellowish to light brown	1	10
Shale, dark brown	2	0
Shale, yellowish, light brown	1	3
Shale, iron-stained, concretions	1	6
Shale, bluish slate colour	5	6
Shale, greenish blue, sandy	2	6
Shale, brownish	0	10
Shale, yellowish, sandy	2	0
Shale, greenish grey, sandy	1	8
Shale, lighter grey, sandy	1	0
Shale, and carbonaceous or coal zone	2	0
Shale, dark bluish grey	1	3
Shale, light bluish grey, sandy	1	4
Shale, greenish yellow, sandy	3	0
Shale and sandy zones	20	0
Coal stringer	0	6
Shale, light grey to bluish	2	3
Shale, light yellowish green	3	0
Iron concretions	10 to 15 inches	
Total shale sampled	54	2

This deposit is of considerable width and quite free of objectionable material, but on the other hand the overburden is excessive and the available material above water is small. Further prospecting may trace these beds to higher ground. Transportation and fuel will be necessary to attract further attention to this deposit.

Working and Burned Properties

Sample No. 2975. The shade of the material when dry is ochreous to buff and light grey; the texture is rather coarse, and the sample has a feel of grittiness. It is of medium hardness and is easily crushed. No carbonates were detected. The tempered mass, although short, possessed sufficient plasticity to permit of readily working into desired shapes. Drying was safe.

Both the raw strength and oxidation period are within practical ranges for clays of this type. Modulus of rupture tests on the burned trials at cone 02 gave low value, but this is not wholly conclusive as higher temperatures would develop greater strength. It is not unlikely that cones 4 to 5 would be necessary to bring this shale to its best condition but with consequent higher burning costs. Its fusion point is cone 6, corresponding to a temperature which is rather high for red-burning materials. (*See* Fig. 20, p. 107.) The body becomes steel hard at cone 010 and from thence vitrification changes take place at a safe, uniform rate, although somewhat slow for the most economical conditions. In addition, the burned colour would not prove suitable for wares other than the cheaper grades like common brick and hollow structural ware.

Therefore, considering the distance of this deposit from transportation and the physical properties of the material there is little likelihood of its being developed.

EAST AREA

Sample No. 2953

Location and Description

Sample No. 2953 was taken from the east bank of Highwood river at the point where it makes a hair pin bend and flows southeastward in the SE. ¼ of sec. 18, tp. 20, rge. 28, W. 4th mer., one mile northeast of Aldersyde. Near the point where the sample was taken a massive bed of sandstone in the form of a cutout occurs, which for a short distance wholly replaces the shale beds. The section where sampled measured as follows:—

	Feet	Inches
Soil	2	0
Alluvial clay and stone	6	0
Silty yellowish clay	5	0
Sandstone, used for cap	1	3
Shale, sandy	1	3
Shale, and sandstone layers	6	0
Sandstone, blocky (discarded)	3	6
Shales, greenish near base, dark and light grey above	4	8
Sandstone and shale seams (discarded)	2	6
Shales, dark and fine grained	3	6
Shales, chocolate and sandy	0	3
Shale, greenish and iron-stained	2	0
Water level		
Total shale sampled	18	2

As the overburden and sandstone layers are excessive in this deposit, it does not appear promising for industrial development. (*See* Plate VIIA.)

Working and Burned Properties

Sample No. 2953. The sample is somewhat gritty, carries carbonates, and is dark grey, somewhat iron-stained, in colour. The pieces are irregular in shape and non-laminated, the fracture being conchoidal. When ground and tempered the mass became highly plastic and of excellent working properties.

Notwithstanding the safe drying of small trial pieces the high drying shrinkage would most likely give trouble in commercial ware, either through twisting or cracking. When safely dried the raw strength is above the average, and the material is well adapted to thin-section ware. On the other hand the oxidation is slow and in large, thick wares might prove troublesome. The general changes taking place during burning proceed at a safe uniform rate, and over a wide range of temperature prior to overfiring, which takes place near cone 4. The burned modulus of rupture is high. The colour is of a shade equal to or better than the average red now on the western market.

Disregarding its drying behaviour this sample of shale appears promising for a full line of red wares, including roofing tile and other thin-section wares.

Additions of a more sandy shale or clay to reduce the high drying shrinkage would open up the pore system for oxidation, thereby improving that property as well. For red wares not now produced in Alberta this sample is worthy of further study, more especially so as it is reasonably near transportation.

Samples Nos. 2954 and 2955

Location and Description

Samples Nos. 2954 and 2955. These were taken at the northeast corner of the last hair pin bend of Highwood river, one mile above its junction with Sheep river, in sec. 32, tp. 20, rge. 28, W. 4th mer. At this point the river has cut a valley or gorge nearly 150 feet deep. The samples were taken near the base of the valley wall where the beds are quite free of stone or concretions. The section for the samples was as follows:—

Sample No. 2954.

	Feet	Inches
Cover, or hill above	100	0
Blocky sandstone at base.		
Shale, dark green, plastic	2	0
Shale, dark green, sandy	0	4
Shale, very dark green, plastic	2	0
Black carbonaceous seam	0	2
Shale, dark green, plastic	2	6
Shale, black	0	6
Shale, green, plastic	2	4
Carbonaceous zone, shells	0	3
Shale, dark green, plastic	3	6
Iron-stained zone, not taken.		
Total shale sampled	13	7

Sample No. 2955.

	Feet	Inches
Shale, black and iron-stained	0	4
Shale, green, rusty and nodular	3	8
Sandstone, shaly	0	10
Shale, green, sandy	0	10
Shale, black	3	6
Shale, grey, hard and sandy	3	0
Shale, dark, rusty	3	0
Sandstone and shale zone	2	4
Shale, black to greyish, blocky	3	0
Shale, very rusty, yellow streaks	2	6
Thin hard flagstone used as base of sample.		
Shale beneath	4	0
Sandstone, ripple-marked, fossils	3	0
Water level.		
Total shale sampled	23	0

Were it not for the excessive overburden these deposits could be worked as a single quarry. Their position at the base of the cliff necessitates their winning by underground mining. However, unless rail transportation reaches the general district, these deposits are not likely to prove of further industrial interest.

Working and Burned Properties

Sample No. 2954. There are three distinct shades to be seen in this sample, dark slate to black, buff, and greenish grey with some iron stain. All portions are medium soft and fine grained, the pieces are small and mostly angular in shape. Carbonates were found present in large amounts.

The tempering developed a high degree of plasticity and excellent working properties. The drying shrinkage is excessive and would very likely prove disastrous to full-sized products. The small trials developed slight cracks in drying but possessed a very high strength, nearly 1,200 pounds per square inch. Oxidation, as in the case of the last sample proved rather slow and difficult. The changes which occur during the burning are moderate and within safe limits; the rate of vitrification, however, is a little rapid between cones 04 and 02, a condition which might cause losses of ware when burned in commercial kilns, where temperatures may fluctuate quite widely. Beyond cone 02 there is a long period where the changes are small and safe, thus once past the critical stage little further trouble would be expected. The burned strength is sufficient for all ordinary requirements.

Should it be found impossible to correct the high shrinkage it would seem that the only possible use for this shale would be that of blending it with other clays or shales to improve their raw strength.

In the event of a method being found to correct the drying shrinkage it could be considered for a general line of red clay products, though corrections would have to be made to overcome scumming on the burned ware.

Sample No. 2955. In the dry state the pieces composing the sample are mostly dark grey with iron stain, irregular to angular in shape, somewhat gritty and carry carbonates. The plastic properties are good with satisfactory working or moulding conditions.

The drying shrinkage is well within safe limits, and the raw strength while much below that of No. 2954 would prove quite sufficient for most red clay wares. From the oxidation trials it is quite evident that the materials composing this sample are high in carbonaceous matter, sulphur, and possibly other unoxidized substances, the quantity being such that care and experience would be necessary to burn safely wares made from this sample unless blended with some well-oxidized or coarse-grained clay or shale.

The porosity-shrinkage curves, other than being slightly higher, are almost the same as those for No. 2954. (*See* Fig. 9, p. 100.) In fact these two materials could very well be blended with benefit to both. The burned colour is better than that of No. 2954 and would be suitable for a wide range of red wares.

Suggested uses are: all classes of building brick, hollow tile, roofing tile, and possibly paving brick. However, great care will be necessary to prevent bloating or oxidation troubles during the burning, especially in heavy cross-section ware, like paving brick. At present transportation is too remote to warrant industrial development of the beds.

Sample No. 2956

Location and Description

Sample No. 2956 was taken in sec. 30, tp. 20, rge. 28, W. 4th mer., and on the east bank of Sheep river, approximately 4½ miles east of Okotoks. At the point of sampling the bank of the stream is 40 feet high and exposes typical Paskapoo beds of shale and sandstone layers. The following section was measured.

	Feet	Inches
Soil and silts	4	0
Stone and gravel	6	0
Clay, bluish, plastic	1	2
Sandstone, blocky, used as cap	1	0
Shale, grey, sandy	3	0
Concretions (discarded)	0	10
Shale, dark grey, plastic	3	6
Carbonaceous seam	0	1
Shale, greenish, plastic and sandy	3	0
Sandstone, nodular (discarded)	1	4
Shale, dark grey, sandy and plastic	3	0
Shale, rusty, blocky, sandy	3	0
Shale, dark slate-coloured to greenish with iron stain	4	0
Clay, black, silty and mica flecks	0	4
Bentonitic seam	0	3
Shale, dark grey to slate-coloured, hard, conchoidal	3	0
Sandstone, massive, used as base	5	0
Water		
Total shale sampled	19	11

The sandstone layers are quite irregular. In places they thin out entirely and give way to shale, in other places they thicken heavily at the expense of the shale. These conditions, as well as the heavy overburden, make this deposit of questionable value, and further careful prospecting is advisable. Furthermore, the distance from rail transportation is a matter for consideration.

Working and Burned Properties

Sample No. 2956. For the most part this sample is composed of soft shales, which are light and dark grey with a small amount nearly black. The fracture is irregular with iron stain on most of the faces, with considerable free carbonates. All portions when dry crushed readily, and when tempered with water softened to a plastic clay mass, smooth and fat in texture, and one which permitted of easy moulding into desired shapes.

The total unburned drying shrinkage is a little above the average. The raw modulus of rupture is fairly high and indicates a clay suitable for thin-section ware such as roofing tile and hollow building tile. Its oxidation requirements are above the average though need not be considered difficult. When burned a slight scum is formed on the surface of the ware, which tends to mar an otherwise deep dark red colour. The modulus of rupture on cone 02 trials is medium high and quite satisfactory. During the burning little change takes place between cones 010 and 04. At the latter cone the vitrification increases rapidly and continues steadily to cone 4 where a body of low porosity and absorption is developed. (*See* Fig. 8, p. 100.)

This clay is somewhat more refractory than the general average of red burning shales and clays. While the vitrification range is equally as wide as that of some of the clays before discussed, it takes place at higher temperatures, therefore burning costs would necessarily prove higher.

The data obtained indicate that the shale could be used for face brick, paving brick, common and stock brick, roofing, building and drain tiles. It is assumed, however, that more extended tests would be undertaken prior to money outlay. Distance from rail is also a matter for serious consideration.

Sample No. 2957

Location and Description

Sample No. 2957 is located in sec. 19, tp. 20, rge. 28, W. 4th mer. and approximately one mile upstream from the deposit just described. The exposure is on the east bank and rises 35 feet above water level. The shales are mostly of dark shades with two thin, nearly black, bands close to the top. The overburden of soil, silts, and river wash is not excessive. The sample was collected from the exposed face where the section was measured as follows:—

	Feet	Inches
Soil, silts, sands, gravel and boulders	5 to 10	0
Shale, yellowish green, sandy	0	8
Shale, dark green, iron-stained	1	2
Black carbonaceous seam	0	2
Shale, dark green, rusty, plastic	1	4
Black carbonaceous seam	0	2
Shale, dark green, rusty	2	10
Shale, hard and sandy	1	0
Shale, dark grey	2	3
Black carbonaceous seam	0	5
Shale, dark greenish grey, plastic	2	1
Shale, greenish, sandy, hard and blocky	1	8
Shale, greenish, plastic	3	0
Shale, green, soft	1	0
Shale, black, plastic	0	2
Shale, green, hard and conchoidal	2	0
Sandstone, hard and nodular (discarded)	1	8
Shale, greenish grey	4	0
Water level.		
Total shale sampled	23	11

As may be noted, the above section shows only one sandstone member, and as it is near the base it could be used for the floor of an open pit providing it is continuous. The remainder of the beds above could be worked by mechanical means, especially as they are practically level. If this deposit were more convenient to the railroad it would be of immediate interest, especially if supplied with gas for the burning of ceramic wares. Further search or prospecting may be the means of tracing the same beds to a point more convenient to the railway.

Working and Burned Properties

Sample No. 2957. The deposit from which this sample was collected is upstream about one-half mile from that of No. 2956. As the unburned properties of the two are nearly alike no separate description will be made of this sample. The drying shrinkage of No. 2957, however, is a little higher and not quite so favourable, though no difficulties were met with in drying small samples. The data obtained from the burned trials show this clay to be less refractory than No. 2956 as considerable vitrification took place prior to cone 010. The rate and range of change during burning can be considered excellent.

Beyond cone 02 shrinkage practically ceases though absorption continues to decrease steadily to a condition of perfect imperviousness at cone 3. Other favourable properties possessed by this sample are its raw and burned strength and its dark red colour. Commercially this material is suitable for a wide variety of red clay products. It is more favourably located to rail than No. 2956.

Sample No. 2958

Location and Description

Sample No. 2958. This deposit is located on the north side of Highwood river, roughly one-quarter mile downstream from the highway bridge near Aldersyde. The exposure is made up of Paskapoo beds which show only a few feet above low water. The shales are variegated in shade, being greenish, chocolate, grey, and nearly black. The overburden of glacial drift or boulder clay is greatly in excess of what could be profitably moved to recover the available shale. Furthermore, the shale beds were found to be high in soluble salts which had leached down from the overburden above. The section measured as follows:—

	Feet	Inches
Yellowish silts and soil	6	0
Dark grey clay and boulders	1	0
Light grey boulder clay carrying soluble salts	6	0
Shale, dark to nearly black	0	6
Shale, greyish, sandy, blocky	1	6
Shale, greyish green, plastic	2	6
Shale, red to chocolate, iron-stained	2	6
Shale, black, carbonaceous	0	6
Shale, greenish mixed with red	3	0
Water		
Total shale sampled	10	6

This deposit is within one mile of the railway and would possess commercial possibilities were it not for the excessive overburden, the soluble salts, and the rather limited amount of shale above water level. The general district is worthy of a more intense study provided gas becomes available at or near Aldersyde.

Working and Burned Properties

There are two definite shades to this sample, grey and chocolate, with some pieces more or less mottled with both. The pieces are small and for the most part are pillow-shaped with conchoidal fracture. The grain is fine and slightly gritty.

Grinding to 20 mesh required no special effort and produced a fairly large percentage of fines; these, with a partial disintegration or softening of the coarser particles when tempered developed a body of excellent plasticity and working properties. All trials dried safely but with a shrinkage dangerously high for wares made by the stiff-mud process. The unburned strength is quite favourable while that of the burned body is exceptionally high. No difficulty was experienced in obtaining proper oxidation of the trials even though the body was quite dense.

The burning properties are very good; vitrification starts early and progresses steadily to cone 02, where the body is at its best, followed by a slow overfiring; indications are that the shale is of a low-burning type and possesses a wide vitrification range decidedly favourable to industrial burning conditions. The burned colour is a good deep red, though slightly specked with minute yellowish particles and somewhat scummed. (*See* Fig. 4, p. 98.)

This shale would prove of interest for the manufacture of all structural red wares, including roofing tile and red floor tile. Special study will be necessary to develop a means of correcting the excessive drying shrinkage and that of the surface scum.

Sample No. 2958A was a small sample collected from the 30-inch red-chocolate seam or layer near the base of the main deposit sampled for No. 2958, near Aldersyde. As the red or chocolate shade closely resembled that of the red seam in the Blairmore (sample No. 2937) beds on Macabee creek, and, on the Elbow river at Bragg Creek, the present sample was collected more for comparative purposes than to test for its commercial value. The results have been recorded in Tables II and III. It will be noted that No. 2958A is very plastic, cracked in the drying, required a high percentage of tempering water, and developed a drying shrinkage which is much too high for plastic clay products, and is nearly 2½ times that of No. 2937. The raw strength could not be measured due to the fact that the trials could not be dried free of checks.

The burned properties are well shown by the absorption-shrinkage curves prepared from the data in Table III. This sample attains almost complete vitrification at the low temperature of cone 07; the absorption drop from cone 010 is too rapid for commercial burning; and in addition the burned shrinkage is too high. The material is of very doubtful value if used by itself, but it might prove useful as a blending material to reduce the burning temperature of a more refractory shale or clay. It is of interest to note that it is in the raw or unburned colour only that this material resembles the red shale in the Blairmore formation.

Sample No. 2959

Location and Description

Sample No. 2959. This sample was taken from an outcrop of Paskapoo shales and sandstones, on the NW. ¼, sec. 22, tp. 20, rge. 29, W. 4th mer., near the railway bridge below Okotoks. The outcrop extends along the east side of the river for some considerable distance, in fact nearly to the ford. A sample of the most favourable part of the outcrop was taken, the section being as below:

	Feet	Inches
Overburden, stone and gravel	12 to 15	0
Sandstone, blocky and irregular (used as cap)		6 to 24
Shale, yellowish, a single dark streak	1	8
Sandstone, blocky and irregular (discarded)	2 to 5	
Shale, yellowish, sandy	4	0
Shale, blue, nodular pieces	1	0
Carbonaceous zone, shells	0	6
Shale, yellowish, sandy	6	0
Shale, dark bluish band, soft	0	6
Shale, greyish to blue, sandy	2	6
Sandstone, massive (for base)		
Water		
Total shale sampled	16	2

Notwithstanding the location of this deposit and the quantity of shale available, the excessive overburden (nearly equal to the shale) and the interstratified layer of stone place a very serious handicap on this deposit for industrial ceramic purposes. It must also be mentioned that the tests did not show the shale to be of very good quality.

Working and Burned Properties

The general colour is that of a pronounced buff, somewhat iron-stained. Carbonates are present in fairly large quantities. The pieces are gritty, non-stratified and with irregular fracture. Owing to the shale being rather soft it was easily ground and developed a good plasticity. Drying shrinkage is quite normal, therefore, no difficulties are likely to be experienced in the drying of full-sized ware.

The modulus of rupture of both the raw and burned trials proved to be fair though rather below the average. The burned colour is of poor tone and low value, and is quite unsuited for exterior structural clay wares. The changes taking place during the burning are quite unsatisfactory as a very sudden or rapid drop takes place between cones 02 and 3, followed by a long period during which porosity remains unreduced while the burning shrinkage continues to increase steadily.

Taking all data into consideration there seems to be few uses for this shale for other than common brick and building tile. However, its location on rail and water is decidedly in its favour.

Samples Nos. 2960 and 2961

Location and Description

Samples Nos. 2960 and 2961. These samples may be grouped as one, as they are closely associated. They were taken from the north bank of the Sheep river in sec. 24, tp. 20, rge. 29, W. 4th mer., approximately $3\frac{1}{2}$ miles southeast of Okotoks. The outcrop is nearly 40 feet high and capped with a light overburden of soil, silts, and stones. The shales which are mostly dark in shade contain some sandstone layers but these could be removed under commercial working conditions. However, they would somewhat hamper mechanical winning of the shale.

As shown by the cross-section below, No. 2960 represents the upper part of the bank, and No. 2961 the lower.

No. 2960

	Feet	Inches
Overburden, soil and stones	4	0
Sandstone (used as cap for 2960)	2 to 3	
Shale, vary dark	0	6
Shale, yellow-green, sandy	1	4
Shale, green to brownish, plastic	2	6
Shale, black, carbonaceous	0	2
Shale, dark green	5	0
Shale, greyish, sandy and in places stone	3	0
Shale, brown, soft	0	2
Shale, black	0	3
Shale, green to brown	2	6
Shale, black	0	3
Shale, green and brown	2	0
Sandstone (marker between 2960 and 2961)	1 to 2	

No. 2961

	Feet	Inches
Shale, dark green, plastic	2	0
Shale, bluish green, iron-stained	1	0
Carbonaceous seam	0	1
Shale, bluish black, plastic	1	0
Shale, black	0	3
Shale, green, sandy	0	8
Shale, black	0	4
Shale, grey, sandy	1	0
Shale, dark, plastic	1	0
Shale, black sandy	1	4
Shale, dark green, grey, sandy and plastic in parts	4	6
Shale, dark green to black, sandy	2	0
Sandstone, grey, irregular	1	3
Shale, dark	0	10
Shale, grey to green, plastic	1	0
Shale, grey to green, sandy	2	0
Shale, grey to green, hard conchoidal; in places changes to sandstone	2	0
Shale, grey-green, soft	0	6
Sandstone, iron-stained and nodular	2	0
Shale, greenish, soft, plastic	1	2
Dark carbonaceous seam	0	2
Shale, green, brown, rusty	1	8
Shale and sandstone zone (used as base)	4	0
Water		
Total shale sampled	38	4

Unfortunately, the deposit is not only some distance from the railway but is on the opposite side of the river. As the material has more than the average industrial importance it would seem advisable to conduct a further search for similar deposits on the same side of the river as the railroad is on.

Working and Burned Properties

Sample No. 2960. For the most part the sample is buff and iron-stained, though close examination showed the presence of light grey, fine-grained pieces and a darker gritty portion. The pieces were small and angular in shape, the light ones carry carbonates while the darker ones do not. All were easily crushed and when tempered the body tends to become smooth or fat rather than highly plastic.

Results of drying were slightly unfavourable though no drying checks were formed. On account of the fine grain, oxidation proceeded rather slowly, although with care losses from this source would be avoided industrially. Vitrification started prior to cone 010 as shown by the steel-hard condition of the body at that temperature. From cone 010 on, the changes taking place proceeded safely over a very wide temperature range, without signs of overfiring. The colour developed was a deep dark red of good value. The modulus of rupture trials showed this shale at cone 02 to have a very high strength, being the highest of all samples tested. (*See* Fig. 5, p. 98.)

The shale appears to be of promise for paving brick manufacture, provided its drying shrinkage can be reduced, and that its resistance to abrasion is found satisfactory. Its high strength also indicates its usefulness for roofing tile, quarry and floor tile, and other wares, including hollow tile and brick. Although its distance from rail is considerable it is not a serious problem from an engineering point of view.

Sample No. 2961. The general colour of the present sample is darker than No. 2960 due in a measure to a lower degree of oxidation and, further, the lower beds are more sandy. The lighter shade beds carry carbonates, the darker strata do not. The plasticity is good but not quite equal to No. 2960; on the other hand, drying shrinkage is slightly less.

The modulus of rupture is practically the same for both samples in their unburned condition, but in their burned strength there is a wide range wholly in favour of No. 2960, a condition due very largely to the lower degree of refractoriness of that sample; at cone 02, for instance, No. 2961 has not reached its best condition while at the same cone No. 2960 is prime. The oxidation period was somewhat longer than the average.

The burned colour is not so good as that of the upper beds. Blending would, no doubt, prove beneficial to its colour and burned properties as well.

It is to be advised that in the event of further attention being given to these deposits that studies be directed to the blending or mixing of the two samples. The uses set forth for No. 2960 could then be applied to the new compounded body.

Samples Nos. 2962 and 2963

Location and Description

Samples Nos. 2962 and 2963. These samples were taken on the east side of Sheep river, about one-quarter of a mile upstream from deposit No. 2956. The beds making up these two deposits are quite limited as to quantity of material above water, though greater depths may be found back from the river. No. 2962 was taken near the base of the outcrop and consisted of a greasy, fine-grained, green shale, lacking in stratification.

The upper sample, No. 2963, is more sandy, and while generally greenish in shade it is dark slate-coloured in places. The fracture is highly conchoidal. The combined thickness of these deposits does not exceed 8 feet, and they are capped by 10 to 12 feet of other beds, stone, gravel, and sand. As stated before these deposits should be traced laterally in an endeavour to locate greater thicknesses.

Working and Burned Properties

Sample No. 2962. This sample is a very fine-grained, green shale having conchoidal fracture and many slickensided surfaces. It is free of both iron stain and carbonates. The hardness is rather high for shales though when tempered with water it became quite plastic and worked nicely and smooth. The fineness of grain is shown in the very high percentage of water required for a proper temper. Drying shrinkage was also very high and resulted in cracked or defective trial pieces; owing to shrinkage it was impossible to obtain reliable modulus of rupture tests, either raw or burned.

The changes which take place during the burning are distinctly unfavourable being very rapid between cones 010 and 07 with little further change beyond that point. (*See* Fig. 7, p. 99.) The burned colour is brownish red, of medium value only.

This shale cannot be worked alone. It would be necessary to blend it with some non-plastic sandy clay or shale in order to improve the drying properties.

Sample No. 2963. In colour and fineness of grain this sample is quite like No. 2962. It is, however, slightly more sandy—a condition in its favour. It tempers freely and develops good plastic working properties. However, during drying it cracked and checked so badly that it was impossible to obtain trials for modulus of rupture studies.

Its vitrification is very much better than No. 2962, the changes being more uniform and extending over a fairly wide range. The burned colour is practically the same. This material has little to recommend it owing to its drying defects, especially for wares manufactured by the stiff-mud process. Any further tests should be directed toward dry pressing, or mixing with other shales.

As better shales are to be found in the district, it would seem inadvisable to investigate this deposit further.

Samples Nos. 2964 and 2965

Location and Description

Samples Nos. 2964 and 2965. These samples were obtained from an outcrop on Sheep river, approximately 2 miles upstream from Okotoks. At the point of sampling on the south side of the stream an outcrop of Paskapoo shales and interstratified sandstones extend along the river for a quarter of a mile. The upper beds are lighter in shade than the lower ones. Sandstone bands are rather numerous, but are not continuous, giving way to shale in places.

In the event of rail and gas reaching these deposits it is advisable that they be examined more fully from a technical and commercial point of view. Their location on a line between Okotoks and Turner Valley may eventually place them in a favourable position. The section given below is in the upper part of the outcrop, and the sample is No. 2964.

	Feet	Inches
Overburden, unknown (tree-covered)		
Sandstone layer (used as cap rock)	2	0
Shale, yellowish and blocky	2	0
Shale, dark green, some ochre-coloured	2	8
Carbonaceous seam, soft	0	2
Shale, dark green, plastic	1	4
Shale, black, plastic	0	3
Shale, greenish, plastic	1	2
Shale, copper to rusty shades	0	10
Shale, dark green, plastic	4	6
Shale, dark, splintery	1	4
Shale, rust-stained and green	3	0
Shale, green, rusty	2	0
Carbonaceous seam	0	2
Sandstone, base of No. 2965	1 to 2	
Talus material to creek	25	0
Total shale sampled	19	5

Owing to the talus material at the foot of the above deposit, sample No. 2965 was taken from a 10-foot section of beds near water level downstream 300 yards. The section is as below.

	Feet	Inches
Overburden, unknown		
Massive sandstone	20	0
Thin layers of shale and stone	8	0
Shales, greenish, rusty, grey and dark, thin seams, sample No. 2965	10	0
Total shale sampled	10	0

On account of the heavy sandstone above this bed of shale it would not prove economical to recover it by open-pit methods, mining would most likely prove best though the cost would be somewhat above that of the former method.

Working and Burned Properties

Sample No. 2964. The dry sample is mostly buff in shade though some portions are darker and iron-stained. The pieces are angular and gritty, some carbonates are present. Fine grinding and tempering resulted in a free plastic mass of good moulding properties. The drying shrinkage is higher than desirable for most red wares but no losses through warping or cracking resulted. The strength is quite satisfactory. Oxidation though a little slow would not likely prove troublesome owing to the open texture of the body up to cone 07.

At cone 010 the body becomes steel hard and at cone 02 attains medium strength; higher temperatures would develop a decided increase in its modulus of rupture. The colour is medium red with a slight scum and a few small yellow specks.

Vitrification is slow until cone 04, the shrinkage then increases steadily to cone 3, followed by overfiring. Porosity and absorption show a decided drop at temperatures above cone 04.

Although this shale is worthy of further interest its distance from rail is a serious disadvantage in its development for commercial wares. No. 2965 lies immediately below the present one and, from a study of the collective data, it is recommended that they be worked as a single deposit.

These shales may possibly prove suitable for the manufacture of face, common, and stock brick, hollow tile and roofing tile, although it should be borne in mind that other deposits nearby develop better shades of red when burned.

Sample No. 2965. As this shale is beneath that of No. 2964, less oxidation has taken place and the beds as a whole are darker in shade. Physically the raw properties of both are quite similar except that No. 2965 is a little finer in grain. This is well shown by its higher degree of plasticity and drying shrinkage. The period necessary for complete oxidation is quite long. (*See* Fig. 6, p. 99.)

The strength, both in the raw and burned states, is sufficiently high for most lines of red ware. The rate of vitrification and the total changes are not quite so favourable as No. 2964. For this reason a blending of the two shales is suggested. The shales are worthy of further study for the production of wares indicated under No. 2964.

Sample No. 2966

Location and Description

Sample No. 2966. This sample was also taken on Sheep river and upstream one-half mile from the highway bridge at Okotoks. The outcrop is a low exposure along the east side of the stream in SW. ¼ of sec. 29. The beds are capped with sandstone, drift, and alluvial clays. The taking of the sample was done at two points about 200 feet apart as it was not possible to obtain the complete section at a single point due to erosion in one case and talus material in another. The complete section is listed below.

	Feet	Inches
Overburden, loam, silts and clays	8	0
Sandstone, grey, shattered	1	0
Sandy shale, yellowish	0	10
Shale, dark grey, ochre	0	11
Shale, black	4	0
Shale, dark green, plastic	1	4
Shale, black, sandy	0	4
Shale, dark green, nodular	1	0
Sandstone, green, hard	1	3
Shale, yellowish green	2	4
Carbonaceous seam	0	2
Shale, yellowish stained	4	0
Sandstone, buff	2	6
Shale, greenish, sandy	2	0
Shale, bluish grey	2	0
Sandstone	0	10
Water		
Total shale sampled	20	4

The above beds are only of medium interest as four sandstone layers are interbedded with the shale, thus the winning of the shale would prove difficult and expensive in that most of the work would have to be by hand. Although fairly close to railway, it is on the opposite side of the river.

Working and Burned Properties

Sample No. 2966. There are three general shades to this sample when dry, viz., buff, dark grey, and slate. The buff and dark grey shales are hard and gritty, the slate-coloured one being finer in grain and more clayey. The fracture of all is irregular to semi-conchoidal with no signs of lamination. Old fracture faces are coated with iron rust and carbonates were found only in the dark pieces. The plasticity and the finish of the moulded ware were both quite satisfactory. The drying shrinkage is rather higher than desired, though the general openness of the body permits of easy evaporation of the water during the drying period.

The raw strength is only medium, it is sufficient, however, for all products except thin-section wares. The oxidation and total fire shrinkage are both safe, although trouble might arise in the burning of wares of thick or heavy cross-section.

Vitrification proceeds slowly up to cone 04, the rate then increases sharply to cone 1, where the sample appears to be at its best.

The changes affecting absorption and fire shrinkage while not of the best, would permit of safe commercial burning if conducted with proper care. The burned colour is medium in quality being such that if placed in competition with a better red the use of this shale would be restricted to the more ordinary lines of ware such as common brick, hollow building tile, and other products in which colour is not an important item. The data on this shale do not appear to indicate much promise for roofing tile or paving brick.

Samples Nos. 2967, 2968, and 2969

Location and Description

The three remaining deposits of the Eastern group are located on the Canadian Pacific railway at Sandstone, Alberta, in Wilson coulée, an ancient valley which was cut down approximately 200 feet below the general level of the uplands. The deposits at Sandstone are in the Paskapoo beds well up the valley-side above the railway. Prior to the war these shales were worked by open-pit method for the manufacture of dry-pressed bricks, but at the time of taking the samples the pits were filled with talus material to such an extent that it was impossible to obtain complete sections of the beds formerly worked. The following cross-section was made in the more easterly pit and represents the material in sample No. 2967. (Plate VIIB).

	Feet	Inches
Sandstone	5	0
Shale, yellowish, dark streaks	4	0
Sandstone	2	6
Shale, yellowish, one dark streak	2	0
Sandstone	2	6
Shale, bluish	1	0
Sandstone, broken (sample starts here)	1	0
Shale, greenish	0	6
Shale, black, fossils	0	8
Shale, light yellow green	3	0

	Feet	Inches
Carbonaceous streak		
Shale, light yellow	0	8
Shale, yellowish green	1	0
Sandstone, nodular	0	10
Shale, greenish, sandy	2	0
Shale, dark green, fine grained	2	0
Shale, yellowish, sandy	1	6
Shale, nearly black	1	0
Shale, yellowish grey	3	0
Shale, nearly black	4	0
Sandstone, massive	10	12
Total shale sampled	19	4

It will be observed from the cross-section of a portion of this pit and Plate VIIB that many heavy bands of sandstone are present which must be discarded should the deposit be worked as an open pit or quarry. The cost of winning the shale would prove high for all ordinary heavy clay products.

The two last samples of the group were taken from the abandoned pit of the Canada Cement Company's brick plant. The pit was formerly worked in two benches and, in sampling, No. 2968 was taken from the lower bench and No. 2969 from the upper one. The overburden is very thick and excessive, and its removal would prove a serious handicap to the developing or working of the deposit for all general lines of structural clay wares. However, should gas become available at the deposit it would seem advisable to investigate the feasibility of either mining the shale from the more favourable beds, or of working the deposit laterally along the face of the valley. Cross-section.

Sample No. 2968.

	Feet	Inches
Overburden, glacial clays	20 to 50	
Shale	3	
Sandstone, blocky	1	
Shale, dark, nearly black	4	0
Nodular ironstone and shale	2	0
Shale, greenish	5	0
Sandstone, variable	½ to 2	
Shales, grey, greenish, dark	15	0
Sandstone	2	0
Shales, grey, greenish, dark	10	0
(Base of No. 2968 here.)		
Sandstone, hard, irregular		6–20
Talus material	25	0

Sample No. 2969.

	Feet	Inches
Sandstone (cap of No. 2969)	2	0
Shales, grey, green and dark	5	0
Carbonaceous streak, fossils	0	4
Shale, greenish	4	0
Shale, greyish	3	6
Nodular sandstone base of No. 2969	0	8
Shales, varied shades, mostly covered with talus	20	0
Total shale sampled	49	10

Owing to the weathered or talus material in the bottom of each pit it was impossible to obtain a complete measure of the shales, thus the above total does not represent the total useful material, but only the part sampled. It is to be noted that sandstone layers are quite numerous and would greatly interfere with economical working of these deposits.

Working and Burned Properties

Sample No. 2967. Material from the pit from which this sample was taken was for a period used in the manufacture of dry-press brick. The plant has not been in operation for several years and the pit has become partly filled with material from strata and overburden above. It was, therefore, impossible to obtain a complete sample of all of the beds formerly worked. The sample taken, however, is a fair representative of the deposit as a whole.

The main shades in the dry sample at the laboratory are similar to those of No. 2966. The buff portion differs in that it shows stratification, higher amounts of carbonates, and is generally more gritty or sandy. Grinding produced a fair amount of fines, and these with a further breaking down of the larger grains during the tempering process resulted in a fairly plastic body. The drying shrinkage was quite normal. The raw strength is only medium and the burned strength is low, at least at cone 02. However, this shale should be burned somewhat higher to produce the best body.

The shale is slow to respond to heat treatment, little change taking place in the condition of the body earlier than cone 04. Vitrification proceeds quite uniformly to approximately cone 1, it then increases sharply to cone 3, absorption remaining high until the latter cone is reached. Therefore, if wares of low absorption are desired from this material, it will be necessary to carry the temperature to a fairly high point which will naturally increase the costs of burning over that of more normal red burning shales. In addition the final drop in porosity between cone 1 and cone 3 is much too rapid; that is the vitrification range is too narrow for safe commercial burning. The burned colour is rather off shade for first class exterior wares, though for common and stock brick, hollow tile and wares not too exacting as to colour and low absorption, this material is quite suitable. It is barely possible that the entire bank or pit face may produce somewhat different properties than those here obtained.

Sample No. 2968. An examination of the sample as taken shows its main shade to be slate grey with a small portion greyish buff. All parts are generally gritty and medium hard, the pieces non-stratified, irregular in shape, and carbonate-bearing.

Notwithstanding the gritty properties this shale proved to be quite plastic and workable when tempered to a stiff-mud condition, in fact more plastic than No. 2967. Its drying shrinkage at the same time is somewhat higher, a condition which may, for certain wares, be considered less favourable. The raw strength is quite satisfactory. Oxidation required 5½ hours, though with proper care and experience in the burning there should be no serious losses commercially. The burned colour is somewhat better than that of No. 2967; on the other hand it shows traces of scum and yellow specks. The former could be removed in industrial practice, but it is doubtful whether much could be done to remove the yellow specks, which are doubtless due to certain bands of a calcareous nature.

A comparison of the data obtained from the burned trials of this sample and those of No. 2967 shows them to react in very much the same manner during burning. However, there is a slight difference in favour of No. 2968, as both porosity and absorption are lower between cones 010 and 04, and although a further drop from cone 04 to cone 1 is quite sharp it results in a low absorption at the latter cone, which is a temperature range of at least two and one-half cones lower than that in No. 2967.

The general uses for this shale are similar to No. 2967.

Sample No. 2969. This deposit is the upper bench or half of the pit mentioned in No. 2968. Excepting that No. 2969 is less sandy the samples resemble one another quite closely in the dry state. That they are physically alike is shown in their similar unburned physical properties, their burned strength, and the time necessary for oxidation. There is, however, a difference in the progress of the vitrification of the two, the progress of No. 2969 being very much more favourable as a more steady and continuous change occurs between cones 010 and 3.

The commercial colour is much better than that of No. 2968, being darker and with fewer yellowish specks. While this shale will require higher temperatures to burn it to the same degree of hardness than would be necessary with No. 2968 it is the more desirable material from a commercial point of view.

Notwithstanding the fact that these shales were for a number of years manufactured into brick by the dry-press process, it would appear from the data here obtained that the stiff-mud process would have been better.

In the event of cheap fuel and a supply of good water becoming available at these deposits there would be justification for a more intensive study of their possibilities especially as they are located near rail transportation.

BOW RIVER AREA

The deposits examined and sampled, were in the following formations: Recent, Paskapoo, Edmonton, Belly River, Benton, and Blairmore. With the exception of the Recent beds near Cochrane and the Paskapoo beds near Calgary all were found to be badly disturbed or dipping at sharp angles, a condition quite unfavourable to economical and practical working conditions.

Samples were taken on Bow river or its tributaries, west of Calgary. Although it was not assumed that it would prove feasible to deliver Turner Valley gas to this district there was the possibility of locating clays or shales of a quality to warrant their shipment to Calgary or other points.

Furthermore, there was the desire to check the lateral extent of certain geological formations and as a result, beds of shale were located along Bow river. However, their values, from a ceramic point of view, have been found to be no greater than deposits in Turner valley and nearby districts, where the gas could be delivered more cheaply. There is, however, the possibility of a supply of gas being tapped by some of the wells now being drilled in the vicinity. A detailed description of the deposits follows:

Sample No. 2976

Location and Description

Sample No. 2976 was taken from steeply pitching beds of Benton shale on Spencer creek, above Cochrane, Alberta. About one-half mile downstream from the highway bridge over the creek a seam of coal, about 3 feet thick was found; below the coal a heavy layer or zone of sandstone was passed, followed by dark Benton shales. A section 30 feet wide was selected for sampling, the general colour of the shale being grey, not unlike coke. The shale proved to be quite gritty and hard, breaking into irregular blocky pieces. A number of concretions were noted, some of which, when broken open, were found to contain fossils. As beds at this point appear to have been badly disturbed, attention should be given to determining the continuity of the deposit prior to development.

Working and Burned Properties

This is a hard, dry, and gritty dark shale, in parts nearly black and not unlike coke in appearance. The fracture is quite irregular with no evidence of stratification or bedding. No carbonates were detected. Grinding was difficult with very few fines produced. Long tempering and ageing failed to produce other than a very small amount of plasticity. Naturally both the drying shrinkage and raw strength are very low; the burned strength is low. Oxidation is such that care would have to be exercised to prevent serious losses.

During burning little vitrification takes place previous to cone 07, and from there on the changes are slow, so that at cone 3 the body is still quite open and weak. Consequently this sample requires high burning temperatures.

The chief value of this shale would be its use as a non-plastic or grog for blending with other clays or shales of high drying shrinkage and short vitrification range. It may also prove of interest as a road-surfacing material when crushed and mixed with gravel.

Sample No. 2977

Location and Description

Sample No. 2977. Grand Valley creek is a small stream entering the Bow from the north in the vicinity of Wildcat hills, west of Cochrane. The present stream is small and follows the bottom of the valley, which is deep from the highway bridge to the mouth of the creek at Bow river. Along the sides of the valley there are exposed beds of Belly River coal, shale, and sandstone. In the past many small mines have been opened on the coal seam and worked quite extensively; none, however, were being worked at the time of the writer's visit.

About one-half mile above the mouth of the creek and on the east side of the valley, diagonally from an abandoned mine, there was located a good exposure of Belly River shales which rests on a seam of coal. The cross-section is approximately as follows and represents the sample collected, No. 2977.

	Feet	Inches
Overburden, soil, shale, and sandstone	8	0
Shale, dark green, iron-stained	5	4
Shale, dark green, soft, fine grained	3	2
Coal, and iron-stained shale	0	11
Shale, dark green, soft	0	10
Shale, dark green, brownish, soft	6	0
Shale, dark green, iron-stained	2	9
Shale, iron-stained shaly pieces	0	11
Shale, yellowish, sandy, soft	1	2
Shale, green, rusty, sandy	2	6
Shale, green, iron-stained, hard	1	4
Shale, yellow-green, sandy	0	3
Shale, buff, bluish, sandy bands	6	6
Sandstone, buff to blue green	1	9
Coal	6	0
Water		
Total shale sampled	31	8

This deposit offers a fairly good depth of stone-free shale and, were it not for the rather steeply tilted position of the beds, and its location on the opposite side of the river from the railroad, it would prove to be of commercial interest in the event of cheap fuel becoming available, though in the latter case it would be advisable to conduct a search on the south side of the river at the railway.

Working and Burned Properties

Sample No. 2977. The shades are grey, buff, rusty, and slate. Some portions carry small amounts of coal or carbonaceous material; other portions are sandy and laminated. The entire sample crushed easily and when tempered developed into a medium sandy body, but of good plasticity. Owing to carbonaceous material present, the material proved to be rather slow in its oxidation, so much so that strict attention would be necessary to avoid losses of full-sized ware burned under commercial conditions.

The raw and burned strengths are both sufficient for practically all lines of red ware. The drying shrinkage is rather higher than is to be desired and this property should receive further study prior to any development work. The vitrification rate is rather slow, but is uniform up to cone 04. It then increases rapidly to cones 02 and 1 where absorption and shrinkage are quite satisfactory. The burned colour is dark red of good value.

Although some of the properties of this shale are not quite normal they could, no doubt, be improved by selective winning or blending with other clay. On the whole providing its drying shrinkage can be controlled the material is worthy of further study for face brick, roofing tile, quarry and floor tile, paving brick, and possibly red terra cotta.

Samples Nos. 2978 and 2979

Location and Description

Samples Nos. 2978 and 2979. These were taken from the same exposure of Edmonton beds which outcrop on the south side of the Bow river, about three-eighths of a mile downstream from the Canadian Pacific railway bridge west of Cochrane. As shown by the section, the samples were taken near the base of the outcrop where the shales are generally dark in shade. The upper strata are somewhat darker in shade and were crosscut for No. 2979. The general dip of the beds is to the northeast at a fairly steep angle. The cross-section is as follows:—

	Feet	Inches
Sandstone cap	40	0
No. 2979.		
Shale, black, slate shades, some stone	4	3
Shale, dark, rusty, greenish and sandy	8	0
Shale, dark, harder, more massive, fossils	2	3
Thin, soft, yellow streak.		
Shales, dark, fine grained, conchoidal	2	0
Covered, probably shales, not sampled	20	0
No. 2978.		
Sandstone, banded with shale, discarded	4	0
Shales, green, black, yellowish	3	0
Shale, greenish, slate shades, soft	4	8
Shales, greenish, top sandy, fine grained	5	0
Shales, chocolate-coloured, flaky	1	0
Shales, green, blocky structure	8	0
Water in creek.		
Total shale sampled	38	2

The general location of this deposit is good, as it is near rail and water. On the other hand, the heavy sandstone member above the shale would prove costly to move. Mining might be used, but the tilt of the beds would prove objectionable. A closer search of the neighbourhood might reveal a more favourable deposit.

Working and Burned Properties

Sample No. 2978. For the most part the pieces of shale in the sample are non-stratified, fine grained, of irregular fracture, somewhat gritty, and entirely free of carbonates. All portions pulverized with little difficulty and tempered into a free working plastic body which dried safely with a medium drying shrinkage. Its raw and burned strengths are rather lower than the average though quite sufficient for the more general wares. Oxidation would not prove troublesome unless through lack of care during the burning process. Very small changes take place during burning in advance of temperatures equal to cone 04, from there on the rate of change increases considerably so that by the time cone 1 is reached the body becomes sufficiently dense to meet the requirements of most red wares other than quarries and pavers. (*See* Fig. 13, p. 103.)

The final colour is a light red of medium value, but under proper firing conditions it could be made suitable for exterior products. As this deposit is near transportation, is on water, and possesses quite favourable properties it is of interest for the following wares: face brick, stock and common brick, roofing tile, and hollow ware. However, as it is directly beneath No. 2979, consideration must be given to the ceramic importance of that deposit as well. It is likely that the two could be developed as one.

Sample No. 2979. As previously mentioned the present one lies directly over No. 2978. The only visible difference in the two deposits is that of colour, the present sample being much darker. It is also harder and carries fairly large amounts of carbonates. Its plasticity and working properties are practically the same as those of No. 2978. The drying shrinkage is medium high, and while the raw strength is a little below the average, losses through handling are not likely to take place. As the time necessary to oxidize thoroughly is longer than the average, it would be necessary to use care in the burning and setting of commercial ware.

A condition of steel hardness is reached at cone 010, from there on little increase in strength or vitrification takes place until cone 04 is reached. Reactions then take place quite rapidly to cone 1 where the body becomes hard and dense. Its colour is not quite equal to that of No. 2978, and, in addition, it is specked with yellow, not unlike many of the Paskapoo samples tested. The burned modulus of rupture at cone 02 is very good and would be materially increased at higher temperatures. The general uses for this shale would be the same as those of No. 2978, except for wares demanding certain colour qualifications. Further tests should include its possible use as paving brick.

Sample No. 2980

Location and Description

Sample No. 2980. This sample was taken from a Recent deposit south of the bridge over Jumpingpound creek, just above its junction with Bow river. The material is chalky white and quite silty, not unlike rock dust. In all there are about 30 feet of horizontal stratified beds, lying unconformably on the northeasterly dipping Paskapoo beds beneath. As tests indicated that the material had little commercial interest, and owing to its distance from rail, further remarks are unnecessary.

Working and Burned Properties

Sample No. 2980. This is a sample of Recent clay collected from the bluffs near the mouth of Jumpingpound creek west of Cochrane. It is light grey to buff in shade but at a distance it appears white or chalky. It is of earthy fracture, exceedingly silty, and high in free carbonates. The degree of hardness is very low, little force being necessary to crush it. When tempered it becomes rather plastic and of poor working properties. Its tempering range is extremely narrow, that is, slight changes of water content produce a dry mealy mixture on the one hand or a soft quivery mass on the other, both conditions being quite outside of practical working conditions.

The drying shrinkage, when the body is properly tempered, is quite normal and safe, and although its raw strength is below the average it would prove ample for heavy cross-section wares. The sample collected was too small to permit of making burned modulus of rupture tests. However, from the openness of the body at all temperatures prior to overfiring, it is safe to predict that its burned strength would prove to be low. Moderate care only would be necessary during the oxidation stage.

The vitrification changes of this clay are quite out of the ordinary, as it expands while under fire instead of shrinking as do all normal clays and shales. (*See* Fig. 3, p. 97.) The expansion continues to cone 3, but beyond this temperature a sudden fusion of the ingredients in the body takes place accompanied by a dangerously high and rapid shrinkage. The absorption and porosity increase steadily to cone 1 followed by a slight drop at cone 3 which only precedes overfiring by a very small margin. The burned colour is an unattractive light cream or chalk shade up to cone 3, at cone 5 it becomes a dirty yellowish green, a colour quite common to highly calcareous clays.

This clay is of doubtful value, the most likely use would be for the making of common brick by the soft-mud process. The product would be of low crushing resistance and extremely absorbent.

Sample No. 2981

Location and Description

Sample No. 2981. This is representative of a shale pit west of Calgary, formerly worked by the Tregillus Clay Products Company, Ltd. The deposit is typical of average Paskapoo beds, sandstone layers and nodules being interbedded with the shale members. At the time the deposit was worked, all but the very hard layers of stone were blended in the general mixture for the manufacture of stiff-mud face brick

Owing to talus material near the base of the working face it was impossible to obtain a complete sample of the material as formerly used. The part sampled is shown below:—

	Feet	Inches
Overburden, soil, silts, and stone	6 to 12	0
Shale, black, soft	1	0
Shale, grey, red near iron concretions		
Shale, sandy, some nodular sandstone	3	0
Shale, light green, soft	0	10
Shale, slate, fine grained, fossils	5	0
Sandstone band, soft	0	10
Shale, black, soft	3	0
Shale, dark green	2	0
Shale, light green	4	0
Sandstone, buff, soft	0	10
Sandstone, nodular, very hard	1	3
Talus material		
Total shale sampled	18	6

The two soft sandstone layers have been included with the shale. The beds are nearly horizontal, thus the winning of the material was by ordinary open-pit procedure, the nodular, hard stone members being discarded by hand.

The chief disadvantage of this pit is its distance from rail and the plant site. In the past the cost of the raw shale delivered to the plant was above normal. With the improved and more modern transportation systems available at the present time the above handicap might not prove so great.

Working and Burned Properties

Sample No. 2981. The beds for the most part are buff to greenish brown and somewhat gritty in parts where seams of sandy shale predominate; other parts are decidedly more plastic. The sandy members carry carbonates in small amounts. The sample proved to be free milling; was readily crushed and when tempered the plasticity and working properties are quite suitable to the stiff-mud process of manufacture. No trouble was experienced in the drying of the trials. The raw strength is average although the oxidation required 5½ hours, little or no trouble would be encountered from that source in that the body is rather open in texture for a considerable time during the burning.

Burning tests indicate an open porous body between cones 010 and 04. Between cone 04 and cone 3 the porosity and absorption drop gradually to cone 1, then more rapidly to cone 3, from thence overfiring or fusion takes place within rather narrow temperature changes. (*See* Fig. 11, p. 102.) The burning shrinkage increases slowly and steadily to cone 3, but is quite safe for most red wares. The burned strength at cone 02 is of medium quality, a condition which could be improved by carrying the temperature one or two cones higher. The burned colour, a medium to dark red, is not of the best quality or value, being slightly greyish in tone. The general uses for this shale as indicated by the data here obtained are for face brick, stock and common brick, building tile, drain tile, and other like wares.

Sample No. 2982

Location and Description

Sample No. 2982. The last deposit examined and sampled was that of the Crandell Pressed Brick Company at Brickburn, a short distance west of Calgary. The pit is located well up on the valley side above the railway and plant, and the shale is moved by gravity into the grinding room of the plant. The beds are in the Paskapoo formation. Sandstone layers are present and must be removed by hand. The sample taken for testing was that of the average ground material in the storage bins at the plant, and are, therefore, representative of the pit as worked. A general cross-section of the pit is given below.

	Feet	Inches
Overburden, along face of outcrop	0 to 10	0
Shale, yellowish, iron-stained	3	0
Sandstone layer	6	18
Shale, nearly black	0	3
Shale, greenish	4	0
Shale, nearly black	0	3
Shale, dark greenish	3	0
Shale, light yellow-green	3	0
Shale, very dark	0	6
Shale, yellowish, blocky	3	0
Shale, green, iron-stained	2	0
Sandstone, soft to hard	2	0
Shale, dark green, grey, rusty	4	6
Shale, blue, plastic, used as floor.		
Total shale sampled	23	6

Other parts of the pit may show a greater depth of shale, though near the top the sandstone layers become more common. This pit has been worked continuously for many years and is sufficient proof that the desired shale can be recovered under existing conditions. As the valley-side rises sharply at the back of the pit, the depth of overburden constantly increases. Because of this, it has been the practice to skirt along the face laterally rather than to drive back at right angles to the face. The fact that this deposit is on rail and water, and near Calgary, makes it one of industrial interest, especially so would this be the case if the site could be supplied with gas at a reasonable price.

Working and Burned Properties

Sample No. 2982. The general appearance of the raw materials of this and the preceding deposit is practically the same.

As the owners, the Crandell Pressed Brick Company, Brickburn, Alberta, were operating their plant at the time of sampling it was possible to obtain a sample from the ground clay bins. In the pit the several strata vary in shade from buff to greenish brown, some members being rather sandy, others being softer and more clay-like.

When tempered and well worked the mass attains a degree of plasticity and working properties highly suitable for the stiff-mud process. All trials dried safely notwithstanding shrinkage slightly above the average. The raw modulus of rupture or strength is also above the average and would prove sufficient for all lines of structural clay wares. The time required for oxidation was 5½ hours and should not prove troublesome with reasonable care during the burning. The vitrification changes of this sample are of the same general nature as those of No. 2981. The total fire shrinkage and absorption at cone 3 are almost identical in the two. The shales show a further similarity in that overfiring occurs rather quickly, following a temperature corresponding to cone 3. In this connexion, careful control of the firing conditions and temperature near cone 3 should be observed to prevent losses from stuck and overfired ware.

The burned strength is not up to its best at cone 02 where measured, material improvement would likely be shown by trials burned at cones 1 and 2. The burned colour is of medium value being a greyish red rather than a clear red, a condition due in part to certain calcareous bands or strata in the pit. This shale has for many years found successful use in the manufacture of face brick (dry pressed). The data collected clearly indicate that it could be used for the manufacture of stiff-mud face brick, stock and common brick, hollow building tile and field tile. Furthermore, tests for paving brick might prove of commercial interest.

TABLE II

Plastic and Dry Properties

Sample No.	General plasticity	Workability	Colour: Wet	Colour: Dry	Drying behaviour	Water of plasticity %	Shrinkage water %	Pore water %	Dry volume shrinkage %	Dry linear shrinkage %
2901	Sticky	Fair to good	Grey	Very light greenish grey.	Checked; warped	27·0	13·7	13·3	27·1	8·3
2902	Sticky	Fair	Grey	Very light greenish grey.	Severely cracked; warped.	30·3	17·6	12·7	34·3	10·3
2903	Sticky	Fair to good	Greyish brown.	Greyish purple	Slightly cracked.	30·1	16·5	13·6	32·8	9·9
2904	Plastic	Fairly good	Dark grey	Greyish purple	Slightly cracked; warped.	28·8	15·5	13·3	30·9	9·4
2905	Very short	Poor	Black	Purplish	Good	16·1	5·5	10·6	11·6	3·7
2906	Plastic	Good	Grey-green	Dark grey	"	20·7	8·8	11·9	18·2	5·7
2907	Rather short	Fairly good	Grey-black	Light greyish purple.	"	20·2	8·8	11·4	18·0	5·7
2908	Fat	Good	Dark olive green.	Light greenish grey.	"	21·7	9·5	12·2	19·1	6·0
2909	Short	Poor	Grey-black	Brownish purple	"	16·2	5·6	10·6	11·6	3·7
2910	Very short	Poor	Black	Purple	"	18·5	6·0	12·5	11·9	3·8
2911	Very fat	Good	Brown	Light grey-brown.	" Slow	27·7	13·8	13·9	26·8	8·2
2912	Plastic, rather fat.	Good	Grey-brown	Light grey-purple.	"	26·8	14·0	12·8	27·3	8·4
2913	Rather short	Poor to fair	Grey-black	Purple	"	17·0	5·8	11·2	11·7	3·8
2914	Short	Poor	Grey-black	Light purple	"	17·4	5·9	11·5	12·0	3·8
2915	Very short	Poor	Olive green	Light green	"	21·8	6·6	15·2	12·6	4·0
2916	Rather short	Fair	Olive green	Light grey-green	"	20·8	7·2	13·6	13·9	4·4
2917	Rather short	Fairly good	Olive green	Light grey-green	"	22·5	8·1	14·4	13·5	4·3
2918	Fairly plastic	Fairly good	Olive green	Very light grey-green.	"	22·8	9·3	13·5	18·1	5·7
2919	Rather short	Poor to fair	Grey-black	Light grey	"	25·8	10·7	15·1	20·5	6·4
2920	Plastic	Good	Grey-green	Light grey	"	23·2	11·0	12·2	22·2	6·9
2921	Rather short	Fair	Dark grey	Light grey	"	22·0	9·8	12·2	19·7	6·2
2922	Plastic	Good	Dark grey	Light grey	"	22·8	10·2	12·6	20·6	6·4
2923	Fairly plastic	Fairly good	Light olive green.	Greenish brown	"	23·0	9·5	13·5	19·0	6·0
2924	Rather short	Poor to fair	Dark grey	Purple-grey	"	20·9	9·0	11·9	18·2	5·7
2925	Rather short	Fair	Grey-black	Dirty grey	"	17·3	6·3	11·0	12·9	4·1
2926	Rather short	Fair	Light olive green.	Yellow-brown	"	20·9	7·8	13·1	15·5	4·9

2927	Rather short....	Fair..........	Black.........	Purple............	"	18·8	7·5	11·3	15·2	4·8
2928	Rather short....	Fair..........	Black.........	Purple-grey.......	"	19·5	7·0	12·5	14·1	4·5
2929	Short...........	Poor to fair...	Grey-black...	Purple............	"	18·6	5·8	12·8	11·4	3·7
2930	Plastic..........	Good.........	Black.........	Purple-grey.......	" Slow	20·7	8·2	12·5	16·3	5·2
2931	Semi-plastic....	Fairly good...	Black.........	Light purple-grey.	" White scum.	18·9	7·2	11·7	14·6	4·6
2932	Short and plastic.	Fair to good..	Black.........	Purple............	"	20·2	8·2	12·0	16·4	5·2
2933	Rather short....	Fair..........	Black.........	Purple............	"	17·1	6·4	10·7	13·3	4·2
2934	Short and fat...	Fair to good..	Black.........	Dirty grey........	"	21·0	8·2	12·8	16·2	5·1
2935	Very short.....	Very poor.....	Black.........	Purple-grey.......	"	17·2	4·5	12·7	8·9	2·9
2936	Short...........	Very poor.....	Black.........	Purple-grey.......	" Calcined material, slakes on exposure; due to hydration of free lime.	15·8	5·1	10·7	10·5	3·4
2937	Fat but granular	Good.........	Intense maroon.	Brownish red.....	Good	17·6	6·6	11·0	14·0	4·5
2938	Short...........	Fair..........	Light greenish brown.	Very light yellow-green.	"	19·0	7·4	11·6	15·1	4·8
2939	Very short......	Fair to good..	Light greenish grey.	Light grey........	"	17·4	6·2	11·2	12·9	4·1
2940	Exceedingly fat, (sticky).	Difficult......	Olive green...	Dirty brownish grey.	"	39·5	25·8	13·7	51·2	14·8
2941	Plastic..........	Very good....	Olive green...	Very light grey-brown.	"	31·6	18·7	12·9	37·5	11·2
2942	Rather short....	Fairly good...	Battleship grey.	Very light grey...	"	21·3	7·8	13·5	15·5	4·9
2943	Plastic..........	Very good....	Olive green...	Very light greenish brown-grey.	"	25·7	10·9	14·8	21·3	6·6
2944	Rather short...	Fairly good...	Green-grey...	Light grey........	"	22·6	8·9	13·7	17·4	5·5
2945	Plastic..........	Good.........	Olive.........	Light brownish	"	26·7	12·8	13·9	25·1	7·7
2946	Plastic..........	Very good....	Light olive...	Brownish grey....	"	32·6	17·2	15·4	33·0	10·0
2947	Slightly short...	Good.........	Olive.........	Light greenish grey.	"	28·3	12·2	16·1	23·0	7·1
2948	Rather short....	Fair..........	Olive.........	Light brown green-grey.	"	25·6	8·6	17·0	16·1	5·1
2949	Plastic..........	Very good....	Dark green...	Lightgreenishgrey	"	25·0	12·6	12·4	25·5	7·9
2950	Fat.............	Very good....	Brown........	Grey.............	"	24·5	11·3	13·2	22·3	6·9
2951	Very plastic.....	Excellent.....	Dull green....	Light dirty grey..	"	25·3	11·7	13·6	23·2	7·2
2952	Plastic..........	Very good....	Olive.........	Light dirty grey..	"	24·4	10·3	14·1	20·2	6·3
2953	Very plastic.....	Excellent.....	Grey.........	Very light dirty grey.	"	29·8	16·1	13·7	32·1	9·7
2954	Very plastic.....	Very good....	Battleship grey.	Light dirty green.	Slightly cracked.	33·2	19·0	14·2	37·4	11·2
2955	Plastic..........	Good.........	Grey-green....	Light dirty green.	Good	23·7	10·7	13·0	21·3	6·6
2956	Fat.............	Very good....	Olive.........	Light grey........	"	28·3	13·8	14·5	27·2	8·4
2957	Plastic..........	Very good....	Grey-green....	Light grey........	"	29·6	15·9	13·7	32·0	9·7

TABLE II—Concluded

Plastic and Dry Properties—Concluded

Sample No.	General plasticity	Workability	Colour		Drying behaviour	Water of plasticity	Shrinkage water	Pore water	Dry volume shrinkage	Dry linear shrinkage
			Wet	Dry						
						%	%	%	%	%
2958	Very plastic.....	Excellent.....	Light cocoa red and light buff spots.	Light pinkish grey with red specks.	Good	29·9	15·6	14·3	31·0	9·4
2958A	Very plastic....	Excellent.....	Intense Indian red.	Rose............	Cracked; much scum	31·0	18·0	13·0	36·2	10·9
2959	Plastic.........	Good.........	Light olive brown.	Very light grey-green.	Good	26·8	12·3	14·5	24·2	7·5
2960	Fat.............	Very good....	Light greenish brown.	Very light grey-green.	"	30·5	15·8	14·7	31·0	9·4
2961	Plastic.........	Good.........	Grey-green, buff specks.	Light grey........	"	28·2	14·7	13·5	29·0	8·9
2962	Plastic.........	Good.........	Green.........	Light greenish grey.	Badly cracked.	35·7	21·4	14·3	42·9	12·6
2963	Plastic.........	Good.........	Light green...	Light green-grey..	Cracks; fast drying; warped.	28·8	15·1	13·7	30·3	9·2
2964	Plastic.........	Very good....	Dark greenish brown.	Light brownish grey.	Good	27·6	13·2	14·4	26·2	8·0
2965	Very plastic.....	Very good....	Dark green...	Light greenish grey.	"	31·0	15·7	15·3	30·6	9·3
2966	Plastic.........	Good.........	Dark green...	Light brownish green.	"	27·5	13·0	14·5	25·5	7·8
2967	Plastic.........	Good.........	Light olive...	Light grey-green..	"	22·6	9·2	13·4	18·3	5·7
2968	Plastic.........	Very good....	Grey-green....	Very light grey...	"	25·7	12·7	13·0	25·7	7·9
2969	Plastic.........	Fairly good...	Grey-green....	Light greenish grey	"	26·1	13·1	13·0	26·2	8·0
2970	Short..........	Very poor.....	Black.........	Purple-grey.......	"	18·1	6·2	11·9	12·5	4·0
2971	Short..........	Poor..........	Indian red....	Brownish red.....	"	17·0	5·7	11·3	11·8	3·8
2972	Short..........	Poor to fair...	Indian red.....	Light maroon.....	"	18·2	6·5	11·7	13·7	4·4
2973	Short..........	Very poor.....	Green.........	Light green.......	"	17·4	5·8	11·6	11·7	3·8
2974	Sandy and plastic.	Fairly good...	Blue-grey.....	Light bluish grey.	"	18·5	7·5	11·0	15·5	4·9
2975	Lean...........	Fairly good...	Brown........	Light brown......	"	27·5	11·0	16·5	20·4	6·4
2976	Very short......	Very poor.....	Black.........	Purple...........	"	16·0	4·4	11·6	9·1	2·9

2977	Sandy and plastic.	Good.........	Grey-brown..	Greenish brown...	"	28·3	12·5	15·8	23·9	7·4
2978	Plastic..........	Good.........	Light olive...	Light greenish grey.	"	23·0	9·2	13·8	18·6	5·8
2979	Plastic..........	Good.........	Olive.........	Light grey........	"	22·9	10·9	12·0	21·9	6·8
2980	Rather plastic..	Fair..........	Brown........	Very light brown.	"	19·5	7·2	12·3	14·8	4·7
2981	Plastic..........	Fairly good...	Light brown..	Light greenish brown.	"	22·2	9·8	12·4	19·6	6·1
2982	Plastic..........	Very good....	Olive brown..	Light greenish brown.	"	24·2	12·8	11·4	26·0	8·0

TABLE III

Fired Properties

No.	Modulus of rupture: Unburned	Modulus of rupture: Cone 02	Time of oxidation 750° C. (Hours)	Firing temp. cone	Volume shrinkage %	Linear shrinkage %	Apparent porosity %	Absorption %	Apparent specific gravity	Hardness	Colour at 02	Colour value	Colour defects, etc.
2901	837	2,847	5¼	010	− 1·3	− 0·4	27·1	14·4	2·57	*S.H.	Light red......	Medium......	Badly scummed
				07	+ 3·9	+ 1·3	23·0	11·6	2·57				
				04	4·6	1·5	22·2	11·2	2·56				
				02	13·3	4·2	13·4	6·1	2·53				
				3	16·5	5·2	2·0	0·9	2·35				
				4	9·2	3·0	0·7	0·3	2·12				
2902	....	Cracked....	4¾	010	− 1·0	− 0·3	27·6	14·8	2·57	S.H.	Medium........	Fair.........	
				07	+ 3·4	+ 1·1	23·5	12·1	2·53				
				04	5·0	1·6	22·5	11·3	2·54				
				02	12·9	4·1	16·2	7·6	2·55				
				3	16·4	5·2	4·9	2·2	2·38				
				4	8·6	2·8	3·6	1·8	2·14				
2903	973	2,340	5	010	1·0	0·3	25·7	13·8	2·52	S.H.	Medium red....	Fair.........	Slight scum.
				07	7·5	2·4	20·7	10·4	2·52				
				04	7·6	2·5	20·4	10·2	2·52				
				02	14·9	4·7	12·2	5·6	2·47				
				3	15·3	4·8	4·8	2·2	2·30				
				4	8·1	2·6	4·4	2·2	2·11				
2904	....	Cracked....	5½	010	1·6	0·5	23·5	12·3	2·48	S.H.	Medium red....	Fair.........	Scum
				07	4·2	1·4	20·4	10·4	2·47				
				04	4·2	1·4	20·8	10·7	2·47				
				02	10·1	3·2	12·8	6·1	2·40				
				3	11·4	3·6	5·5	2·6	2·22				
				4	0·6	0·2	3·3	1·7	1·95				
2905	264	1,520	6	010	− 2·5	− 0·8	26·7	14·1	2·58	S.H.	Light pink......	Poor.........	Heavy scum
				07	− 2·0	− 0·7	26·7	14·1	2·58				
				04	− 1·9	− 0·6	26·0	13·7	2·57				
				02	− 0·8	− 0·3	26·0	13·7	2·55				
				1	+ 1·4	+ 0·5	22·4	11·6	2·48				
				3	5·2	1·7	17·0	8·6	2·49				
2906	421	3,230	4½	010	− 0·6	− 0·2	28·8	15·3	2·66	S.H.	Dark red.......	Good........	Slight scum
				07	+ 1·2	+ 0·4	28·2	14·6	2·68				
				04	0·6	0·2	23·8	11·7	2·66				
				02	9·2	3·0	21·0	10·0	2·65				
				1	11·1	3·6	11·8	5·6	2·41				
				3	11·5	3·7	10·2	4·7	2·39				

				010	− 0·9	− 0·3	25·8	13·4	2·59	S.H.			
				07	+ 4·2	+ 1·4	21·9	10·9	2·58				
				04	3·9	1·3	21·9	10·9	2·58				
2907	320	3,030	6	02	10·3	3·3	15·7	7·4	2·54	....	Medium red....	Good	Scum
				3	11·5	3·7	10·5	4·8	2·30				
				4	7·0	2·3	10·1	4·9	2·33				
				010	0·0	0·0	27·7	14·4	2·65	S.H.			
				07	2·3	0·7	26·0	13·2	2·66				
				04	8·0	2·6	21·1	10·1	2·65				
2908	447	3,477	5½	02	12·3	4·0	18·2	8·3	2·66	....	Dark red.......	Good.........	
				1	17·3	5·5	7·5	3·2	2·52				
				3	16·9	5·3	5·7	2·5	2·43				
				010	− 1·2	− 0·4	27·1	14·0	2·64				
				07	+ 0·8	+ 0·3	26·4	13·3	2·69	S.H.			
				04	3·6	1·2	23·3	11·4	2·65				
2909	160	2,007	4½	02	4·7	1·5	21·4	10·4	2·62	....	Light red.......	Medium......	Scum (yellow)
				1	7·6	2·5	18·1	8·6	2·57				
				3	8·6	2·8	16·7	7·8	2·57				
				010	− 2·0	− 0·7	28·6	15·4	2·60				
				07	+ 0·3	+ 0·1	28·1	14·9	2·62	S.H.			
				04	3·6	1·2	25·0	12·8	2·60				
2910	188	2,503	3½	02	5·1	1·7	23·2	11·7	2·58	....	Dirty red.......	Poor..........	Yellow specks
				1	5·6	1·8	20·0	10·0	2·50				
				3	6·0	2·0	19·1	9·6	2·47				
				010	1·0	0·3	30·3	16·5	2·64	S.H.			
				07	2·3	0·8	28·2	15·2	2·58				
				04	8·7	2·8	22·3	11·2	2·57				
2911	1,035	4,370	4	02	12·6	4·0	18·1	8·7	2·54	....	Medium red....	Medium......	Slight scum
				1	17·3	5·5	4·3	1·9	2·28				
				3	17·2	5·4	1·5	0·7	2·20				
				010	0·6	0·2	28·8	15·6	2·59	S.H.			
				07	2·9	0·9	27·0	14·2	2·55				
				04	10·9	3·5	19·6	9·5	2·56				
2912	927	3,793	9	02	14·4	4·6	15·7	7·3	2·55	....	Light red.......	Medium......	
				1	18·0	5·6	7·4	3·3	2·42				
				3	18·0	5·6	6·0	2·7	2·36				
				010	− 1·4	− 0·5	33·4	18·8	2·67				
				07	− 1·4	− 0·5	32·8	18·6	2·62				
				04	− 2·0	− 0·7	34·0	19·4	2·64	S.H.	Undesirable		
2913	275	2,780	4	02	− 1·7	− 0·6	34·7	19·9	2·66	....	green-grey.....	Poor..........	Red specks
				1	+ 6·6	+ 2·2	27·2	14·4	2·58				
				3	12·9	4·2	14·8	7·3	2·39				
				010	− 2·7	− 0·9	26·6	14·0	2·58	S.H.			
				07	− 2·0	− 0·7	27·3	14·3	2·62				
				04	+ 0·9	+ 0·3	25·1	12·9	2·60				
2914	305	2,243	4	02	1·4	0·5	24·4	12·5	2·58	....	Medium bright	Medium......	Good
				1	2·9	0·9	21·2	10·7	2·51		red.		
				3	4·0	1·3	20·3	10·1	2·52				

* S.H.=Steel hard.

TABLE III—Continued

Fired Properties—Continued

No.	Modulus of rupture		Time of oxidation 750° C.	Firing temp. cone	Volume shrinkage	Linear shrinkage	Apparent porosity	Absorption	Apparent specific gravity	Hardness	Colour at 02	Colour value	Colour defects, etc.
	Unburned	Cone 02											
			Hours		%	%	%	%					
2915	259	3,085	4¾	010	0·0	0·0	31·4	17·3	2·64	S.H.	Dark red.......	Good.........	Good
				07	0·0	0·0	32·0	17·7	2·64				
				04	1·2	0·4	28·2	14·9	2·63				
				02	7·9	2·7	25·1	12·8	2·62				
				1	17·4	5·5	12·7	5·9	2·47				
				3	18·2	5·7	5·5	2·5	2·35				
2916	517	2,683	4¾	010	− 1·2	− 0·4	30·6	16·7	2·64	S.H.	Dark red.......	Good.........	Good
				07	− 0·9	− 0·3	29·0	15·7	2·61				
				04	− 0·3	− 0·1	29·2	15·8	2·61				
				02	+ 3·6	+ 1·2	24·5	12·7	2·55				
				3	11·6	3·7	15·5	7·4	2·47				
				4	17·0	5·4	6·9	3·1	2·41				
2917	601	3,960	4¾	010	0·0	0·0	29·7	16·0	2·64	S.H.	Dark red.......	Good.........	Good
				07	1·8	0·6	27·7	14·6	2·62				
				04	2·0	0·7	25·7	13·4	2·57				
				02	10·0	3·2	19·0	9·1	2·57				
				3	17·2	5·4	10·0	4·4	2·49				
				4	17·2	5·4	6·1	2·7	2·39				
2918	490	3,000	5¼	010	0·0	0·0	29·0	15·5	2·63	S.H.	Dard red.......	Good.........	Slight scum
				07	2·1	0·7	27·2	14·2	2·63				
				04	3·2	1·0	26·6	13·8	2·63				
				02	11·3	3·6	19·1	9·1	2·58				
				3	18·9	5·9	8·0	3·5	2·50				
				4	17·6	5·5	4·6	2·0	2·39				
2919	871	3,107	5½	010	− 0·6	− 0·2	30·7	17·2	2·58	S.H.	Purple red......	Medium......	Heavy scum (yellow)
				07	+ 0·3	+ 0·1	30·2	16·6	2·60				
				04	1·0	0·3	30·0	16·5	2·60				
				02	4·6	1·5	26·8	14·3	2·57				
				3	11·5	3·7	19·7	9·7	2·54				
				4	16·6	5·2	12·0	5·5	2·48				
2920	676	4,170	4½	010	0·3	0·1	25·1	12·8	2·60	S.H.	Dark red.......	Good.........	Good
				07	5·2	1·7	19·8	9·6	2·54				
				04	5·9	1·9	20·6	10·0	2·59				
				02	14·9	4·7	10·6	4·7	2·53				
				1	16·9	5·3	5·5	2·4	2·44				
				3	16·7	5·3	0·0	0·0	2·31				

2921	472	3,510	4½	010	0·0	0·0	27·8	14·7	2·63				
				07	1·5	0·5	27·0	14·0	2·64				
				04	7·3	2·4	22·3	10·9	2·62	S.H.			
				02	11·5	3·7	18·1	8·5	2·60	....	Medium dark red.	Good.........	Good
				1	16·3	5·2	9·3	4·1	2·50				
				3	16·5	5·2	7·7	3·4	2·45				
2922	443	3,842	4½	010	0·0	0·0	28·7	15·2	2·65				
				07	1·2	0·4	28·4	14·8	2·68	S.H.			
				04	8·2	2·7	22·5	10·9	2·67				
				02	11·3	3·6	16·3	7·7	2·54	....	Medium dark red.	Good.........	Slight scum
				1	15·7	5·0	9·9	4·4	2·49				
				3	15·3	4·8	8·3	3·7	2·45				
2923	460	4,370	4½	010	0·0	0·0	28·8	15·2	2·65	S.H.			
				07	2·1	0·7	28·4	14·6	2·69				
				04	7·8	2·8	23·1	11·4	2·64				
				02	11·5	3·7	18·2	8·5	2·60	....	Medium dark red.	Good.........	Good
				1	13·7	4·4	10·3	4·7	2·42				
				3	15·1	4·8	8·0	3·6	2·41				
2924	321	3,180	4½	010	− 1·0	− 0·3	28·2	15·0	2·64	S.H.			
				07	+ 5·1	1·7	25·1	12·6	2·66				
				04	5·3	1·7	25·0	12·5	2·66				
				02	10·2	3·3	19·8	9·4	2·62	....	Medium light red.	Good.........	Good
				3	12·7	4·1	14·9	6·9	2·54				
				4	12·4	4·0	12·5	5·8	2·46				
2925	234	3,197	4½	010	− 1·7	− 0·6	22·0	14·2	2·60	S.H.			
				07	− 0·6	− 0·2	25·8	13·4	2·60				
				04	1·4	+ 0·5	25·0	12·8	2·60				
				02	2·2	0·7	25·0	12·9	2·60	....	Greyish red.....	Poor.........	Slight scum
				1	6·4	2·1	18·2	9·0	2·49				
				3	8·4	2·7	15·2	7·3	2·45				
2926	460	3,573	5½	010	− 1·0	− 0·3	30·5	16·2	2·70	S.H.			
				07	+ 2·0	+ 0·7	29·0	15·0	2·71				
				04	2·9	0·9	27·9	14·4	2·69				
				02	8·2	2·7	20·9	10·1	2·62	....	Medium red....	Good.........	Good
				03	13·2	4·2	15·6	7·2	2·57				
				4	14·2	4·5	11·8	5·3	2·51				
2927	315	3,883	4	010	− 2·6	− 0·9	27·2	14·4	2·60	S.H.			
				07	+ 2·0	+ 0·7	26·2	13·3	2·64				
				04	3·2	1·0	22·0	11·1	2·55				
				02	7·0	2·3	19·0	9·2	2·55	....	Greyish red....	Poor.........	Scum
				3	9·6	3·1	14·4	6·7	2·49				
				4	12·4	4·0	10·3	4·7	2·44				
2928	291	3,477	Less than 3	010	− 2·6	− 0·9	28·5	15·5	2·58	S.H.			
				07	+ 3·9	+ 1·3	24·7	12·6	2·59				
				04	4·7	1·5	24·4	12·4	2·59				
				02	8·1	2·6	20·4	10·0	2·54	....	Light greyish red.	Poor.........	Good
				3	12·5	4·0	13·1	7·1	2·48				
				4	13·7	4·4	12·3	5·7	2·45				

TABLE III—Continued

Fired Properties—Continued

No.	Modulus of rupture: Unburned	Modulus of rupture: Cone 02	Time of oxidation 750° C.	Firing temp. cone	Volume shrinkage	Linear shrinkage	Apparent porosity	Absorption	Apparent specific gravity	Hardness	Colour at 02	Colour value	Colour defects, etc.
			Hours		%	%	%	%					
2929	246	1,765	4½	010	− 2·2	− 0·7	31·0	17·2	2·61	S.H.	Light greyish red.	Poor	Slight scum, yellow specks.
				07	− 1·9	− 0·6	31·3	17·2	2·64				
				04	− 2·0	− 0·7	31·4	17·5	2·61				
				02	− 1·4	− 0·5	31·2	17·3	2·61				
				1	+ 2·1	+ 0·7	26·8	14·4	2·54				
				3	5·1	1·7	25·4	13·4	2·54				
2930	332	4,022	11	010	− 2·3	− 0·7	29·1	16·0	2·57	S.H.	Medium red	Good	Heavy scum (yellow)
				07	+ 8·0	+ 2·6	21·2	10·5	2·57				
				04	11·4	3·7	19·6	9·3	2·59				
				02	17·9	5·6	9·8	4·4	2·48				
				3	17·7	5·6	6·7	3·0	2·39				
				4	16·7	5·3	5·8	2·6	2·34				
2931	373	3,862	4	07	3·4	1·1	25·0	12·4	2·68	S.H.	Medium red	Good	Scum
				04	9·6	3·1	19·1	9·0	2·63				
				02	12·2	3·9	15·6	7·1	2·60				
				1	14·4	4·6	10·4	4·6	2·50				
				3	14·9	4·7	9·1	4·0	2·47				
				5	0·3	0·1	6·0	3·1	2·04				
2932	257	2,582	4	010	1·0	0·3	28·2	15·1	2·60	S.H.	Medium red	Good	Yellow specks. Overfired at 02.
				07	4·9	1·6	25·0	12·9	2·59				
				04	12·2	3·9	17·0	8·1	2·53				
				02	16·0	5·1	14·4	6·5	2·57				
				1	15·0	4·8	11·2	5·2	2·44				
				3	14·5	4·6	9·1	4·2	2·38				
2933	286	2,310	5	010	− 1·4	− 0·5	25·4	12·9	2·62	S.H.	Light greyish red.	Fair	Specks
				07	+ 0·3	+ 0·1	24·1	12·2	2·61				
				04	3·5	1·1	21·3	10·4	2·61				
				02	5·0	1·6	20·2	9·8	2·58				
				1	6·2	2·0	17·9	8·6	2·53				
				3	6·4	2·1	16·4	7·8	2·50				
2934	272	2,923	4	010	1·1	0·4	28·5	15·1	2·64	S.H.	Medium red	Medium	Good
				07	2·0	0·7	26·8	14·0	2·62				
				04	9·1	2·9	20·2	9·8	2·57				
				02	12·1	3·9	17·7	8·4	2·58				
				1	13·6	4·3	14·1	6·6	2·51				
				3	15·1	4·8	13·3	6·1	2·52				

2935	95	1,545	4	010	− 2·0	− 0·7	30·6	16·8	2·63	S.H.	Dirty red	Poor	Green specks
				07	− 1·0	− 0·3	29·6	15·8	2·66				
				04	0·0	0·0	28·5	15·1	2·65				
				02	− 2·0	− 0·7	26·4	13·6	2·59				
				3	2·2	0·7	22·7	12·4	2·53				
				4	3·1	1·0	23·8	11·7	2·52				
2936	139	2,088	4	010	− 2·5	− 0·8	35·4	20·2	2·71	S.H.	Grey buff	Poor	Poor
				07	− 3·9	− 1·3	36·2	21·1	2·69				
				04	− 3·4	− 1·1	35·0	20·3	2·66				
				02	− 3·0	− 1·0	33·7	19·6	2·60				
				1	+ 2·2	+ 0·7	28·8	15·9	2·54				
				3	3·9	1·3	27·6	15·1	2·53				
2937	403	4,113	3	010	1·0	0·3	26·6	13·1	2·78	S.H.	Bright red	Very good	Good
				07	3·8	1·2	24·4	11·6	2·78				
				04	10·7	3·4	18·0	8·0	2·75				
				02	14·0	4·5	13·5	5·8	2·71				
				1	15·4	4·9	11·2	4·7	2·69				
				3	16·2	5·1	10·8	4·5	2·68				
2938	365	2,355	4¼	07	0·0	0·0	26·2	13·5	2·63	S.H.	Bright red	Very good	Good
				04	3·8	1·2	23·7	11·8	2·65				
				02	6·0	1·9	21·3	10·3	2·61				
				1	8·0	2·6	19·3	9·3	2·59				
				3	8·6	2·8	18·5	8·8	2·58				
				5	10·8	3·5	15·3	7·1	2·55				
2939	258	3,267	5¼	010	− 1·7	− 0·6	24·9	12·6	2·62	S.H.	Bright red	Good	Good
				07	− 0·3	− 0·1	23·7	11·8	2·62				
				04	+ 3·7	+ 1·2	20·2	9·7	2·60				
				02	6·8	2·2	15·6	7·3	2·54				
				1	9·0	2·9	12·7	5·8	2·50				
				3	9·8	3·2	10·5	4·8	2·47				
2940	1,770	Cracked during firing	10	010	4·1	1·4	22·1	12·2	2·33	S.H.	Medium bright red.	Good	Slight scum. A few very small black specks.
				07	5·6	1·8	22·9	12·5	2·37				
				04	6·8	2·2	23·2	12·6	2·40				
				02	16·7	5·3	4·0	1·9	2·17				
				1	4·3	1·4	10·6	5·8	2·02				
2941	1,115	4,383	4½	010	3·3	1·1	26·1	14·0	2·52	S.H.	Medium	Poor	Heavy scum. Yellow specks.
				07	3·1	1·0	27·5	14·7	2·57				
				04	4·0	1·3	24·8	13·2	2·50				
				02	11·8	3·8	15·8	7·7	2·43				
				3	21·0	6·6	0·4	0·2	2·29				
				4	17·0	5·4	1·2	0·6	2·19				
2942	423	1,845	4¼	07	− 2·5	− 0·8	35·8	20·9	2·66	S.H.	Pinkish buff	Poor	Specks
				04	− 2·5	− 0·8	35·0	20·4	2·64				
				02	− 0·9	− 0·3	32·9	18·7	2·61				
				1	7·2	2·3	27·2	14·4	2·60				
				3	13·6	4·3	21·5	10·6	2·58				
				5	2·0	0·7	2·3	1·3	1·84				

TABLE III—Continued

Fired Properties—Continued

No.	Modulus of rupture		Time of oxidation 750° C.	Firing temp. cone	Volume shrinkage	Linear shrinkage	Apparent porosity	Absorption	Apparent specific gravity	Hardness	Colour at 02	Colour value	Colour defects, etc.
	Unburned	Cone 02											
			Hours		%	%	%	%					
				07	0·6	0·2	32·5	18·3	2·64	S.H.			
				04	2·1	0·7	32·3	18·1	2·64				
				02	5·9	1·9	26·2	14·0	2·64	....	Greyish red.....	Fair..........	Specks
2943	448	2,922	4¾	1	17·0	5·4	11·4	5·4	2·40				
				3	23·2	7·2	1·5	0·7	2·32				
				5	4·0	1·3	0·1	0·1	1·90				
				07	− 0·9	− 0·3	30·0	16·6	2·57	S.H.			
				04	+ 0·3	+ 0·1	29·3	16·0	2·58				
				02	2·9	1·0	27·0	14·4	2·56	....	Greyish red.....	Fair..........	Slight scum. Specks
2944	465	2,483	4¾	1	8·8	2·8	21·8	10·8	2·56				
				3	14·1	4·5	15·8	7·5	2·51				
				5	−11·0	− 3·5	9·6	5·8	1·83				
				010	0·3	0·1	30·5	17·0	2·58	S.H.			
				07	1·5	0·5	29·6	16·3	2·58				
				04	2·8	0·9	29·7	16·2	2·61				
2945	563	3,243	5¼	02	10·0	3·2	21·2	10·7	2·51	....	Dark greyish red.	Fair..........	Slight scum. Specks.
				1	15·8	5·0	11·5	5·4	2·39				
				3	21·3	6·6	3·2	1·4	2·33				
				010	3·2	1·0	29·2	15·6	2·65	S.H.			
				07	6·3	2·0	26·9	13·8	2·67				
				04	16·3	5·2	16·4	7·5	2·61				
2946	793	2,380	5¼	02	21·6	6·7	6·9	2·9	2·49	....	Dark red.......	Good.........	Good
				1	14·8	4·7	6·6	3·1	2·29				
				3	18·3	5·7	3·2	1·4	2·31				
				010	− 0·6	− 0·2	31·3	17·2	2·64	S.H.			
				07	− 4·9	+ 1·6	27·5	14·4	2·64				
				04	7·2	2·3	25·4	13·0	2·63				
2947	531	3,033	5¼	02	16·3	5·2	14·7	6·8	2·55	....	Light red.......	Good.........	Good
				3	20·5	6·4	8·7	3·8	2·52				
				4	19·8	6·2	6·3	2·8	2·41				
				010	− 0·6	− 0·2	33·8	19·1	2·67	S.H.			
				07	+ 2·0	+ 0·7	32·2	17·7	2·69				
				04	3·4	1·1	31·0	16·8	2·68				
2948	501	2,024	4¼	02	12·1	3·9	22·7	11·2	2·62	....	Medium red....	Good.........	Good
				3	18·2	5·7	16·1	7·4	2·58				
				4	21·0	6·6	11·4	5·1	2·55				

2949	731	4,678	7	010	0·0	0·0	26·3	13·5	2·64	S.H.	Medium red....	Good.........	Kiln-marked
				07	6·2	2·0	20·8	10·0	2·63				
				04	13·2	4·2	12·2	5·4	2·58				
				02	16·1	5·1	2·8	1·2	2·39	....			
				3	7·8	2·5	0·3	0·1	2·11				
				4	4·9	1·6	1·6	0·8	2·06				
2950	455	4,362	9	010	0·0	0·0	28·8	15·5	2·61	S.H.	Brownish red...	Good.........	Good
				07	2·4	0·8	30·2	16·1	2·70				
				04	12·8	4·1	16·7	7·8	2·68				
				02	18·1	5·7	10·3	4·5	2·53	....			
				1	18·5	5·8	7·4	3·2	2·47				
				3	9·9	− 3·2	4·8	2·8	1·78				
2951	551	3,572	Less than 3	07	5·5	1·8	23·6	11·8	2·60	S.H.	Medium clear red.	Good.........	Slight scum
				04	9·6	3·1	18·8	9·0	2·57				
				02	17·1	5·4	9·6	4·2	2·52	....			
				1	19·0	6·0	5·6	2·4	2·46				
				3	17·0	5·4	2·2	0·9	2·32				
				5	3·9	1·3	11·9	6·2	2·21				
2952	495	2,230	Less than 3	07	0·0	0·0	30·5	16·9	2·59	S.H.	Light greyish red.	Poor..........	Specks
				04	0·9	0·3	29·7	16·3	2·58				
				02	6·3	2·0	23·7	12·4	2·51	....			
				1	11·6	3·7	19·4	9·6	2·51				
				3	19·6	6·1	4·0	1·8	2·32				
				5	− 3·3	− 1·1	0·6	0·3	1·77				
2953	972	3,747	9	010	2·6	0·9	25·2	13·2	2·53	S.H.	Dark red.......	Fair to good..	
				07	7·3	2·4	22·0	11·1	2·55				
				04	8·0	2·6	20·2	10·1	2·52				
				02	16·9	5·3	11·7	5·4	2·47	....			
				3	21·5	6·7	0·4	0·2	2·34				
				4	21·2	6·6	0·4	0·2	2·34				
2954	1,180	3,035	9	010	4·8	1·6	26·1	13·8	2·44	S.H.	Dark brown....	Medium.......	Heavy scum (yellow)
				07	8·7	2·8	19·8	10·1	2·45				
				04	9·1	2·9	16·3	8·2	2·38				
				02	17·6	5·6	3·6	1·6	2·28	....			
				3	18·2	5·7	0·0	0·0	2·20				
				4	17·7	5·6	1·2	0·6	2·30				
2955	688	4,287	10	010	1·5	0·5	28·8	15·0	2·69	S.H.	Medium red....	Good.........	Heavy scum (yellow)
				07	5·7	1·9	25·3	12·7	2·66				
				04	7·8	2·5	24·1	11·8	2·68				
				02	17·5	5·5	11·0	4·8	2·55	....			
				3	21·6	6·7	1·1	0·5	2·41				
				4	21·4	6·7	1·1	0·5	2·43				
2956	861	3,165	5½	010	1·8	0·6	28·0	14·9	2·60	S.H.	Dark red.......	Good.........	Slight scum Readily reduced.
				07	5·1	1·7	26·5	13·8	2·61				
				04	6·0	2·0	26·8	13·8	2·65				
				02	11·3	3·6	18·5	8·9	2·55	....			
				3	19·5	6·1	7·4	3·2	2·49				
				4	19·6	6·1	5·0	2·2	2·41				

TABLE III—Continued

Fired Properties—Continued

No.	Modulus of rupture		Time of oxidation 750° C.	Firing temp. cone	Volume shrinkage	Linear shrinkage	Apparent porosity	Absorption	Apparent specific gravity	Hardness	Colour at 02	Colour value	Colour defects, etc.
	Unburned	Cone 02											
			Hours		%	%	%	%					
				010	2·9	1·0	26·3	13·5	2·65	S.H.			
				07	12·0	3·8	16·2	7·5	2·56				
				04	14·0	4·5	14·0	6·3	2·57				
2957	911	3,647	5	02	19·5	6·1	6·6	2·8	2·52	....	Dark red.......	Good.........	A very few yellowish specks. Slight scum.
				3	20·2	6·3	0·8	0·4	2·40				
				4	16·8	5·3	0·8	0·4	2·29				
				010	2·6	0·8	25·2	12·9	2·61	S.H.			
				07	14·2	4·5	14·2	6·4	2·58				
				04	18·1	5·7	9·1	3·9	2·56				
2958	656	5,297	3	02	21·4	6·7	4·3	1·7	2·52	....	Dark red.......	Good.........	A very few yellowish specks. Heavy scum.
				3	15·6	4·9	1·1	0·5	2·28				
				4	16·6	5·2	1·5	0·7	2·31				
				010	2·7	0·9	25·8	13·1	2·65	S.H.			
				07	20·8	6·5	3·9	1·6	2·50				
				04	22·1	6·9	2·6	1·1	2·51				
2958A	....	....	....	02	18·2	5·7	1·2	0·5	2·37	....	Medium red....	Good.........	Heavy scum.
				3	4·4	1·5	1·4	0·7	2·04				
				4	− 2·7	− 0·9	4·9	2·7	1·92				
				010	1·9	0·6	31·3	17·2	2·64	S.H.			
				07	1·9	0·6	31·3	17·3	2·64				
				04	3·1	1·0	31·0	17·0	2·64				
2959	693	2,595	5½	02	7·5	2·4	25·8	13·5	2·58	....	Dark greyish red	Poor..........	Slight scum. Specks.
				3	22·7	6·6	0·5	2·2	2·42				
				4	21·0	7·0	0·8	3·6	2·44				
				010	4·2	1·4	27·3	14·2	2·64	S.H.			
				07	11·1	3·6	19·8	9·6	2·58				
				04	12·8	4·1	18·0	8·6	2·57				
2960	976	5,680	5½	02	20·4	6·4	9·8	4·2	2·56	....	Dark red.......	Good.........	A few yellowish specks.
				3	20·4	6·4	0·1	0·0	2·34				
				4	21·8	6·8	1·6	0·7	2·39				
				07	2·9	0·9	25·7	13·5	2·55	S.H.			
				04	4·4	1·4	23·2	12·0	2·52				
				02	11·1	3·5	14·7	7·0	2·43	....	Orange red......	Medium......	Slight scum.
2961	960	3,180	7	1	15·8	5·0	7·8	3·6	2·40				
				3	16·6	5·2	1·5	0·7	2·24				
				5	37·1	11·1	7·4	5·5	1·45				

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2962			Less than 3	010	4·3	1·4	24·0	11·9	2·65	S.H.	Brownish red	Medium	Trials badly cracked.
				07	24·3	7·5	2·8	1·1	2·54				
				04	24·5	7·6	1·9	0·7	2·58				
				02	16·7	5·3	2·1	0·9	2·32				
				3	—32·7	— 9·9	16·3	11·2	1·73				
				4	—31·4	— 9·5	19·4	13·5	1·78				
2963	303		5½	010	1·6	0·5	25·2	12·9	2·61	S.H.	Brownish red	Good	Trials badly cracked.
				07	12·0	3·8	15·1	6·9	2·57				
				04	16·4	5·2	9·3	4·1	2·52				
				02	18·4	5·8	1·9	0·8	2·40				
				3	12·2	3·9	1·4	0·6	2·20				
				4	13·8	4·4	1·1	0·5	2·24				
2964	712	2,923	5½	010	2·2	0·7	29·6	15·9	2·65	S.H.	Medium red	Medium	A very few yellowish specks. Slight scum.
				07	6·4	2·1	24·5	12·5	2·59				
				04	7·9	2·6	23·0	11·7	2·57				
				02	15·2	4·8	13·1	6·1	2·48				
				3	22·6	7·0	3·7	1·6	2·42				
				4	21·3	6·6	4·7	2·0	2·45				
2965	767	3,320	7	010	4·3	1·4	27·8	15·0	2·57	S.H.	Medium red	Medium	A very few yellowish specks. Slight scum.
				07	8·0	2·6	23·5	12·2	2·51				
				04	9·3	3·0	22·9	11·7	2·53				
				02	16·3	5·2	12·8	6·1	2·43				
				1	25·0	7·7	1·5	0·6	2·39				
				3	25·0	7·7	0·8	0·3	2·38				
2966	569	2,850	5½	010	1·6	0·5	29·1	16·0	2·56	S.H.	Orange red	Poor	Slight scum. Yellow specks.
				07	4·5	1·5	25·5	13·4	2·54				
				04	5·4	1·7	25·3	13·3	2·54				
				02	10·3	3·3	19·6	9·8	2·49				
				1	21·5	6·7	4·7	2·4	2·41				
				3	21·2	6·6	5·6	2·5	2·42				
2967	545	1,578	5½	010	0·3	0·1	31·6	17·4	2·65	S.H.	Medium greyish red.	Poor	Yellow specks.
				07	0·6	0·2	30·8	17·0	2·63				
				04	1·5	0·5	30·5	16·6	2·63				
				02	6·3	2·0	25·0	13·0	2·56				
				1	9·6	3·1	21·5	10·7	2·55				
				3	19·6	6·1	4·8	2·1	2·36				
2968	762	3,723	5½	010	0·0	0·0	26·9	14·8	2·50	S.H.	Dark red	Medium	Few yellowish specks. Scum.
				07	1·9	0·6	26·2	14·0	2·53				
				04	2·5	0·8	25·3	13·4	2·52				
				02	8·1	2·6	17·7	8·9	2·41				
				1	20·1	6·3	1·2	0·5	2·32				
2969	717	3,317	5½	010	0·6	0·2	27·3	14·7	2·54	S.H.	Dark red	Medium	A few yellow specks. Slight scum.
				07	4·7	1·5	23·3	12·0	2·53				
				04	4·9	1·6	22·6	11·6	2·52				
				02	11·7	3·7	15·0	7·2	2·46				
				1	18·4	5·8	7·9	3·5	2·46				
				3	19·4	6·1	1·1	0·5	2·31				

TABLE III—Concluded

Fired Properties—Concluded

No.	Modulus of rupture: Un-burned	Modulus of rupture: Cone 02	Time of oxidation 750° C.	Firing temp. cone	Volume shrinkage	Linear shrinkage	Apparent porosity	Absorption	Apparent specific gravity	Hardness	Colour at 02	Colour value	Colour defects, etc.
			Hours		%	%	%	%					
				010	0·0	0·0	28·7	15·3	2·63	S.H.			
				07	2·8	0·9	25·8	13·3	2·61				
				04	7·7	2·5	21·2	10·4	2·58				
2970	104	2,336	10	02	10·1	3·3	19·2	9·3	2·56	....	Very light orange.	Poor..........	Heavy scum. Yellow specks.
				1	9·5	3·1	17·2	8·2	2·53				
				3	10·8	3·5	15·4	7·4	2·48				
				010	0·0	0·0	29·5	15·2	2·76	S.H.			
				07	2·5	0·8	26·6	13·2	2·76				
				04	7·0	2·3	20·4	9·6	2·67				
2971	....	....	....	02	11·8	3·8	16·6	7·6	2·63	....	Dark velvet red.	Good..........	Good
				1	12·2	3·9	15·8	7·1	2·63				
				3	12·5	4·0	16·4	7·4	2·65				
				07	5·4	1·7	19·7	9·3	2·64	S.H.			
				04	10·5	3·4	16·3	7·3	2·67				
				02	11·5	3·7	14·0	6·3	2·60	....	Dark velvet red	Good..........	Good
2972	....	....	....	1	10·2	3·3	12·0	5·5	2·52				
				3	10·1	3·2	12·0	5·5	2·50				
				5	7·7	2·5	8·0	3·7	2·32				
				010	− 1·4	− 0·5	28·6	14·8	2·70	S.H.			
				07	+ 1·7	+ 0·6	27·4	13·8	2·73				
				04	6·3	2·0	22·2	10·7	2·67				
2973	149	2,736	Less than 4	02	12·0	3·8	17·5	7·9	2·70	....	Light red.......	Good..........	Slight scum
				1	10·9	3·5	17·7	8·1	2·65				
				3	11·0	3·5	14·0	6·4	2·54				
				010	− 1·8	− 0·6	27·0	13·9	2·66	S.H.			
				07	+ 0·3	+ 0·1	24·1	12·2	2·61				
				04	4·3	1·4	21·4	10·3	2·62				
2974	336	2,130	5½	02	7·0	2·3	17·9	8·4	2·59	....	Medium red....	Medium......	Slight scum.
				1	6·6	2·2	17·3	8·1	2·56				
				3	6·1	2·0	15·2	7·2	2·58				
				010	− 0·9	− 0·3	33·8	19·5	2·62	S.H.			
				07	− 0·3	− 0·1	32·1	18·2	2·60				
				04	3·8	1·2	29·5	16·2	2·57				
2975	499	1,453	5½	02	8·2	2·7	25·3	13·2	2·56	....	Light red.......	Medium......	Slight scum.
				1	11·4	3·7	22·0	11·1	2·54				
				3	13·0	4·2	17·7	8·8	2·46				

2976	136	1,220	7	010	− 0·8	− 0·3	28·3	14·7	2·68	S.H.	Medium red....	Poor..........	Many yellow specks.
				07	0·0	0·0	28·0	14·6	2·69				
				04	1·9	0·6	24·2	12·3	2·59				
				02	2·7	0·9	21·8	10·8	2·59	....			
				1	3·5	1·2	22·1	11·0	2·58				
				3	6·8	2·2	17·0	8·3	2·47				
2977	671	3,383	7	010	0·6	0·2	32·3	17·9	2·66	S.H.	Dark red.......	Good.........	Good.
				07	5·3	1·7	28·8	15·2	2·65				
				04	8·5	2·7	25·7	13·1	2·64				
				02	19·1	6·0	11·8	5·3	2·51	....			
				1	20·9	6·5	5·8	2·6	2·43				
				3	21·2	6·6	6·0	2·6	2·41				
2978	417	2,620	Less than 5	010	− 1·2	− 0·4	27·2	14·5	2·59	S.H.	Medium red....	Good.........	Good.
				07	2·3	+ 0·7	24·3	12·4	2·59				
				04	3·9	1·3	23·1	11·6	2·59				
				02	10·2	3·3	16·1	7·5	2·56	....			
				1	14·1	4·5	8·7	4·0	2·42				
				3	15·4	4·9	10·2	4·5	2·48				
2979	475	3,353	7	010	1·6	0·5	29·0	15·6	2·61	S.H.	Medium red....	Medium......	Yellowish specks.
				07	2·1	0·7	26·8	14·2	2·56				
				04	3·7	1·2	26·1	13·8	2·56				
				02	10·4	3·3	17·3	8·4	2·47	....			
				1	20·2	6·3	0·0	0·0	2·26				
2980	404	....	5½	07	− 5·0	− 1·6	43·5	29·4	2·63	S.H.	Cream..........	Low..........	Highly absorbent.
				04	− 8·2	− 2·7	44·6	30·9	2·60				
				02	−10·0	− 3·2	47·0	33·2	2·67	....			
				1	− 8·4	− 2·7	47·4	33·0	2·72				
				3	− 5·2	− 1·7	46·7	31·6	2·76				
				5	+29·4	+ 9·0	20·2	9·2	2·77				
2981	522	2,453	5½	07	0·3	0·1	30·0	16·2	2·64	S.H.	Medium light red.	Medium......	Yellow specks.
				04	0·9	0·3	29·1	15·6	2·62				
				02	3·9	1·3	25·6	13·2	2·60	....			
				1	7·1	2·3	23·0	11·7	2·55				
				3	16·4	5·2	3·5	1·6	2·27				
				5	− 7·8	− 2·5	1·6	0·9	1·73				
2982	882	2,356	5½	07	0·0	0·0	28·1	15·1	2·59	S.H.	Medium light red.	Medium......	Yellow specks.
				04	1·6	0·5	27·5	14·5	2·62				
				02	2·2	0·7	26·3	13·7	2·59	....			
				1	12·7	4·0	11·4	5·3	2·42				
				3	16·2	5·1	3·0	1·3	2·30				
				5	−18·5	− 5·8	0·8	0·5	1·59				

CHAPTER IV

FUSION TESTS AND ABSORPTION AND SHRINKAGE

FUSION TESTS

Fusion tests were made on a number of the samples having high porosity in order that their degree of refractoriness might be determined. This work was not undertaken because particular clays offered promise of proving refractory, but rather to determine whether any were sufficiently heat resistant to prove of interest in the manufacture of sewer pipe, conduits, and other like wares where higher temperatures than those used in the burning of building brick and other red wares are necessary. The chief difference between clay suitable for sewer pipe and that used for ordinary structural wares is that the former must be capable of withstanding the sufficiently high temperature required to develop the glaze or glossy impervious coating on the surface of the ware.

Without going into detail, it may be briefly stated that sewer pipe and electric conduits are glazed by introducing ordinary salt into the kiln at a period near the end of the burn when the temperatures are highest. The salt is decomposed by the heat, forming soda (Na_2O) and hydrochloric acid (HCl). The former in passing through the kiln comes in contact with the ware and reacts with silica, alumina, and other substances in the clay to form a natural glaze. It is, therefore, necessary that the clay used in making the ware be sufficiently refractory to withstand the temperature necessary to volatilize the salt.

The samples selected for fusion tests and the results are shown in Table IV.

TABLE IV

Sample	Fused at cone	Geological formation	Sample	Fused at cone	Geological formation
2905	4+	Benton	2935	6	Benton
2909	9	"	2936	4+	"
2910	8	"	2939	7+	Blairmore
2913	4+	"	2970	9	Benton
2914	8	"	2971	7	Blairmore
2925	7	Belly River	2973	9+	"
2929	6	Benton	2974	9+	"
2933	9	"	2975	6	Belly River
2934	10	"	2976	7	Benton

In most cases a kiln temperature equal to cones 4 to 8 is desirable for salt glazes, therefore clays of very much higher fusion points than those represented by the above cones are necessary, otherwise the ware will become overfired and ruined during the glazing period of the burn.

It is of interest to note that the above fusion points, even in the more refractory samples, do not greatly exceed the average salt glaze temperatures. While some of the Benton samples fuse at cones 8 and 9, and in one case, at cone 10, temperatures which might prove sufficient under certain conditions, they would not answer for the manufacture of sewer pipe on account of their extremely low degree of plasticity and weak unburned strength. The Blairmore and Belly River beds, especially the former, are of more general interest for further study for the manufacture of sewer pipe than are the Bentons.

Notwithstanding the somewhat unfavourable prospects of the samples tested for use alone in the making of salt-glazed wares, further work may prove a number of them suitable for that purpose if blended with plastic semi-refractory clays similar to those of the Whitemud and Willowbunch beds in Saskatchewan.

ABSORPTION AND SHRINKAGE

In order to present clearly a study of the data collected from the burned trials of this report, a number of graphs or curves have been prepared covering the absorption and linear shrinkage in per cent, plotted against temperature, or rather heat-work as measured by cones. While in most cases it is more desirable to plot the porosity and volume shrinkage rather than that of absorption and linear shrinkage, it has, in the present case, been considered more advisable to use the latter as they are measures which have long been used by the industry and, therefore, carry a more definite meaning to the practical mind than does porosity and volume shrinkage. Moreover, it will not prove to be a difficult task to any one having need for the porosity graphs, to plot them from the data given in Table III.

Relation Ceramically

An attempt has been made to classify or group the several types of clay or shale of each formation, irrespective of location, according to the similarity of their pyro-physical changes, as illustrated by their curves. As a result it has been found that rather wide variations occur within the clays from a single formation. For instance, eight distinct groups or classes can be made from the Paskapoo samples and six are necessary to properly place the Bentons.

The curve sheets shown in this report have been prepared to represent typical examples of each group or class; slight variations from the type occur in each case. They will be discussed in geological sequence without reference to the importance of the formations from an industrial point of view.

Recent

While only a small number of samples were collected from the Recent beds the graphs depict them to be of three general groups.

First: That represented by sample No. 2940, which is a material little affected by heat until cone 04 is reached, from there on to cone 02 very rapid changes take place, the absorption drops quickly and overfiring occurs at cone 1. (Paskapoo sample No. 2959 is of this same type). Clays of this group if used at all should be manufactured into wares which need not be carried to a degree of low absorption.

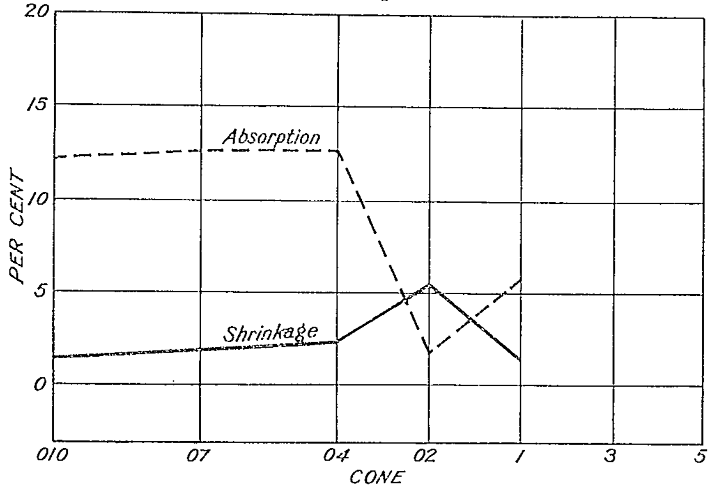


Figure 1. Absorption and shrinkage curves of sample No. 2940, Recent formation (first type), Millar ranch, Quirk creek.

Second: The second graph is that of clay No. 2941, which, like its companion above, shows but little sign of vitrification prior to cone 04, from there on the curve is more gradual and uniform, extending over a spread of 6 cones; in other words, a fairly wide heat range; a condition very much in its favour over sample No. 2940. Unfortunately, overfiring takes place very shortly after low absorption has been reached.

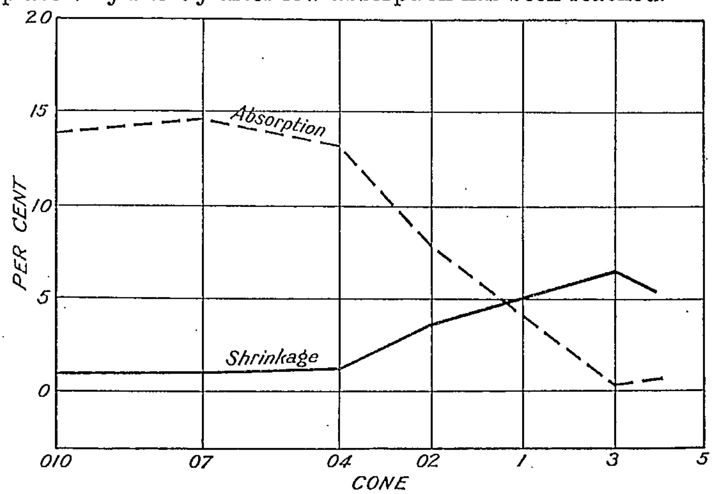


Figure 2. Absorption and shrinkage curves of sample No. 2941, Recent formation (second type), Millar ranch, Quirk creek.

Third: The graphs presented for the absorption and shrinkage of sample No. 2980 reveal clearly the unusual properties of this clay, and the manner in which it differs sharply from all other samples studied. The absorption increases materially between cones 07 and 02 rather than decreasing as is the case with normal clays. In addition there is a small drop in the absorption at cones 1 and 3 followed by a sudden and rapid fusion. It is of further interest that just prior to fusion the absorption at cone 3 is more than two per cent above that at cone 07.

Accompanying the unusual increase in absorption during the greater part of the firing period there are marked increased volume changes taking place as shown by the shrinkage curve between cones 07 and 02. While the body starts to shrink at the latter cone it does not return to its original dry volume until overfiring or fusion has taken place shortly above cone 3.

Clays or shales of the properties indicated in the present case should be avoided if possible.

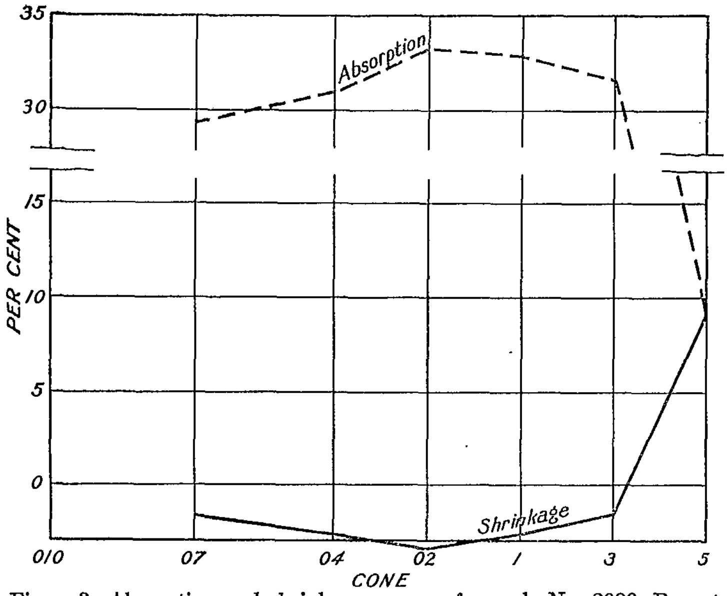


Figure 3. Absorption and shrinkage curves of sample No. 2980, Recent formation (third type), near mouth of Jumpingpound creek.

Paskapoo

The curves of the Paskapoo samples show them to be more variable in their reactions to heat than that of any other single formation. As before stated, eight distinct groups have been noted.

First: This group is represented by sample No. 2958; the curve for same indicates a clay which starts to vitrify at cone 010 and continues steadily to a degree of low absorption at cone 02 with overfiring shortly thereafter. The shrinkage increases rather rapidly between cone 010 and 07; from the latter cone to 02 the rate is slower and more favourable.

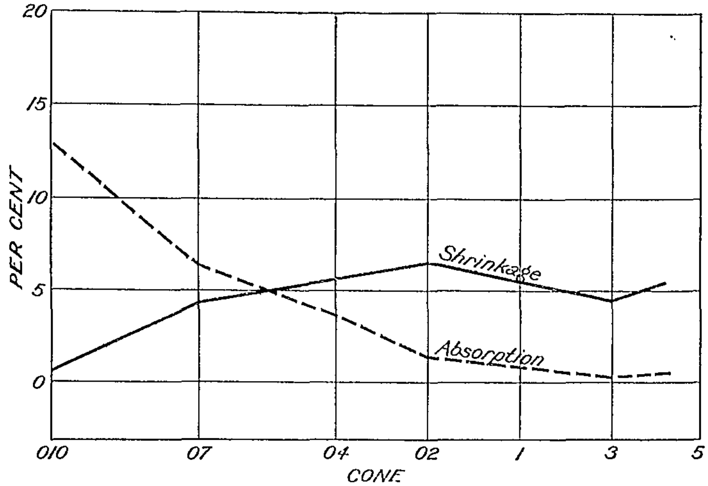


Figure 4. Absorption and shrinkage curves of sample No. 2958, Paskapoo formation (first type), Highwood river, near Aldersyde.

Second: The vitrification change in this group is rapid from cone 010 to 07 then slows up to cone 04, it then increases to cone 02, followed by a reduction in rate to cone 3, where a very low absorption occurs. The shrinkage rate reacts in much the same manner except that it remains stationary between cones 02 and 3. On the whole this general group may be considered favourable in its reaction to heat. The samples typical of this group are Nos. 2951, 2954, 2957 and 2960. Figure 5 shows sample No. 2960.

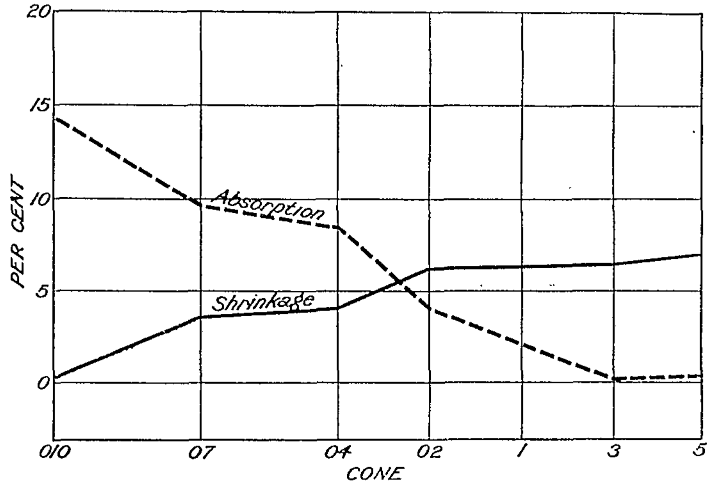


Figure 5. Absorption and shrinkage curves of sample No. 2960, Paskapoo formation (second type), Sheep river, southeast of Okotoks.

Third: The absorption drop in this group is steady or uniform from cone 010 to 07, it then remains practically stationary to cone 04. The rate then increases rapidly to cone 1 and then remains nearly constant to cone 3. While the total drop in percentage of absorption from cone 010 to cone 3 is rather high the general rate is within practical limits. The shrinkage rates correspond to those of the absorption, the total amount though is rather higher than desirable. The samples are Nos. 2965, 2966, and 2968.

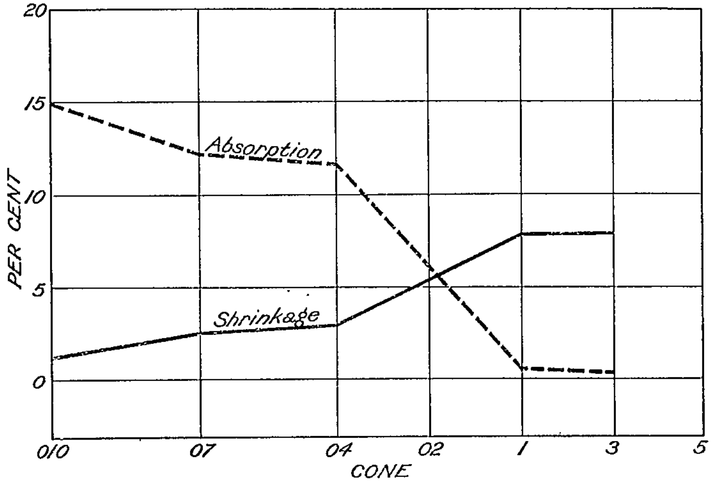


Figure 6. Absorption and shrinkage curves of sample No. 2965, Paskapoo formation (third type), Sheep river, upstream from Okotoks.

Fourth: The two samples of this group, Nos. 2958A and 2962, present rather unusual curves in that the absorption drops rapidly from cone 010 to 07 where a low per cent of same is obtained; from the latter cone little change takes place until overfiring occurs near cone 04. The chief advantage shown by these curves is that of a low burning type of material, the rate of change though is somewhat great, or faster than would be desired. Figure 7 shows sample No. 2962.

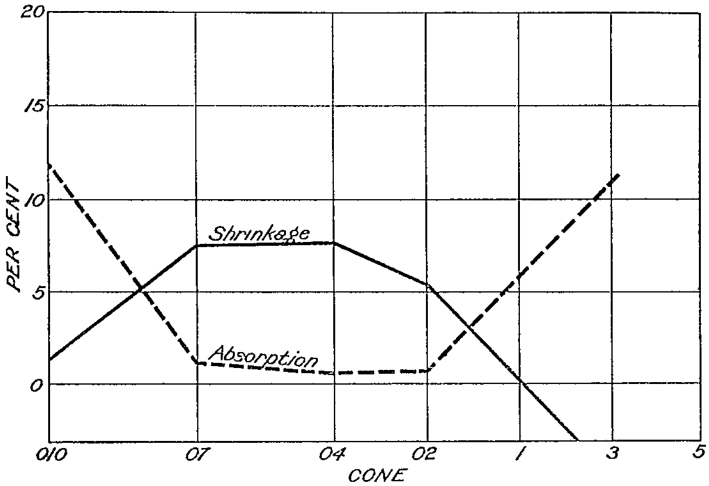


Figure 7. Absorption and shrinkage curves of sample No. 2962, Paskapoo formation (fourth type), Sheep river, east of Okotoks.

Fifth: The outstanding feature of this group of shales is that of very small absorption-shrinkage changes prior to cone 04; from there on the changes are gradual and uniform to cones 3-4. Somewhat higher temperatures are necessary in this group to produce low absorption than is necessary with the group one type. Shales Nos. 2947 and 2956 are of type five. Figure 8 shows sample No. 2956.

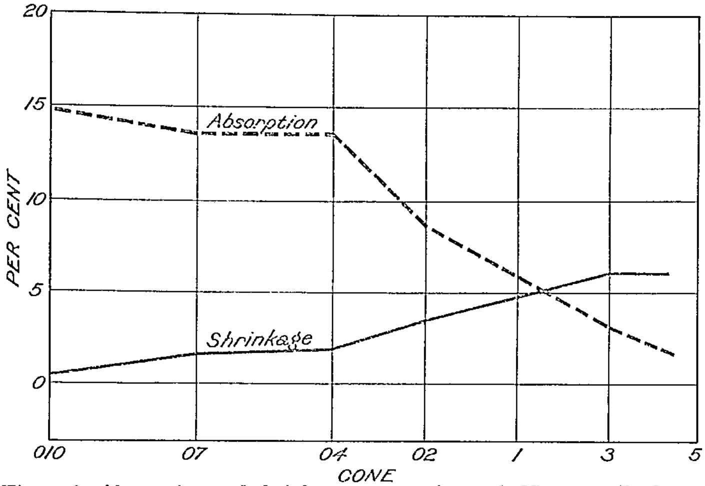


Figure 8. Absorption and shrinkage curves of sample No. 2956, Paskapoo formation (fifth type), Sheep river, east of Okotoks.

Sixth: The graph for sample No. 2955 is typical of this group or class. It will be observed that vitrification proceeds steadily from cone 010 to 07, then the rate is slow to 04, followed by a sharp reaction or drop to cone 02, where the rate then decreases a second time, finally resulting in a low absorption at cone 3; during the same period the shrinkage remains nearly constant and may be considered favourable. The danger period in the firing of this group lies between cones 04 and 02. Other samples are Nos. 2953, 2961, 2964, and 2969.

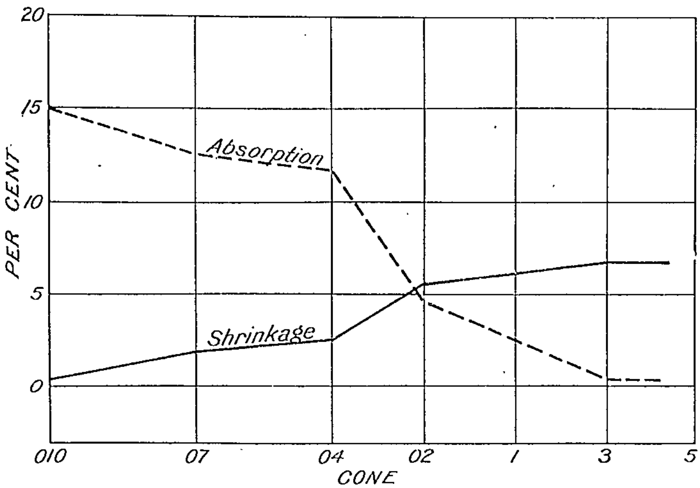


Figure 9. Absorption and shrinkage curves of sample No. 2955, Paskapoo formation (sixth type), Highwood river, near mouth of Sheep river.

Seventh: In this group the absorption is quite high at cone 010, the per cent of same drops gradually to cone 04, then the rate increases to cone 3 and follows shortly with overfiring. Typical samples are Nos. 2942 and 2944 and 2948. Figure 10 shows sample No. 2942.

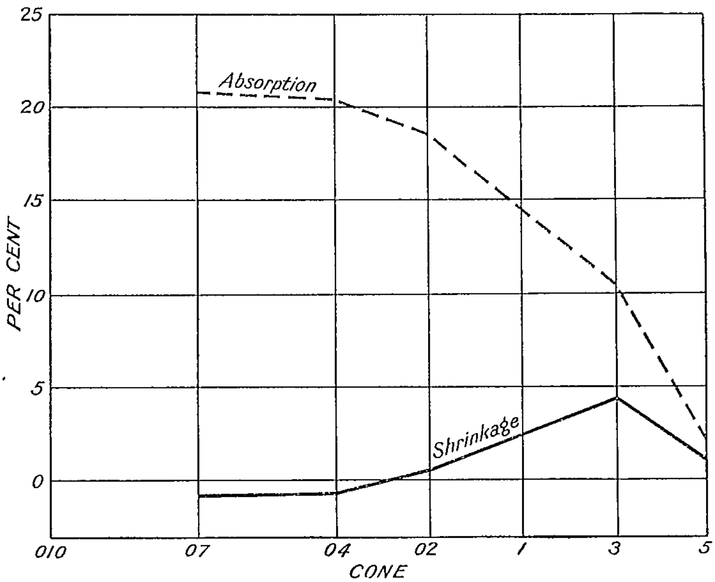


Figure 10. Absorption and shrinkage curves of sample No. 2942, Paskapoo formation (seventh type), Freeman ranch, Quirk creek.

Eighth: There are several samples in this group as follows: Nos. 2943, 2945, 2952, 2967, and 2981. A typical graph or curve has been taken from sample No. 2981. It will be noted that there has been little change or vitrification prior to cone 04 followed by a steady reduction in absorption to cone 1 and a more rapid drop to cone 3. The shrinkage proceeds more gradual and uniform than does that of the absorption. This group, like the seventh, requires considerable heat to start vitrification.

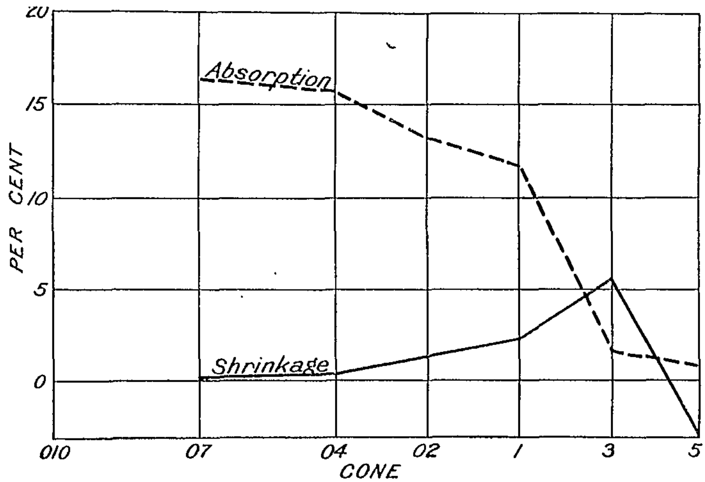


Figure 11. Absorption and shrinkage curves of sample No. 2981, Paskapoo formation (eighth type), Bow river, pit of dismantled plant of Tregillus Clay Products Co., Ltd. (1914).

Edmonton

The Edmonton samples have been divided into five groups which have been represented by the curve sheets prepared for their illustration.

First: In this group the vitrification starts quite early, at or before cone 010, it then proceeds slowly to cone 04, where the rate increases somewhat to cone 3 followed by overfiring near cone 4. In this group a fairly wide cone spread or heat range is available within which to lower the absorption to medium or low. Further, the shrinkage rate is quite gradual and safe, thus the general changes taking place during the burning are all quite favourable. The numbers are 2916, 2917, 2918, and 2919. Figure 12 shows sample No. 2917.

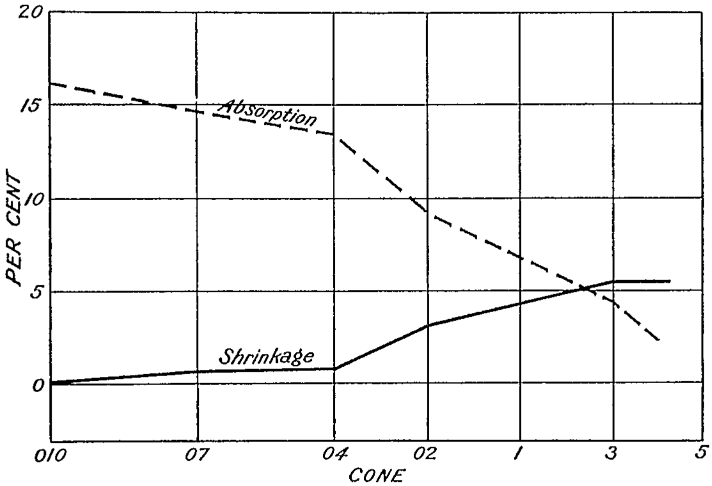


Figure 12. Absorption and shrinkage curves of sample No. 2917, Edmonton formation (first type), Sheep river, near Black Diamond.

Second: This group differs from the last in that there is a sharper drop in absorption from cone 07 to 04 and, further, the final per cent of absorption at cone 3 is generally lower as well. Typical examples are Nos. 2901, 2903, 2904, 2978, and 2979.

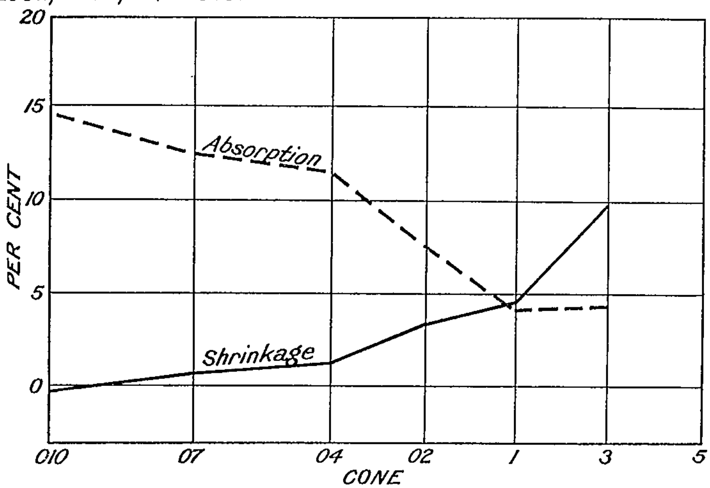


Figure 13. Absorption and shrinkage curves of sample No. 2978, Edmonton formation (second type), Bow river, near C.P.R. bridge west of Cochrane.

Third: There are but two samples in this group, Nos. 2946 and 2949. Their curves are interesting in that the absorption-shrinkage data show a continuous and regular rate of vitrification from cone 010 to 02 where a low per cent of absorption is developed. The graphs for these samples indicate them to be safe burning, and at comparatively low temperatures as well. Figure 14 shows sample No. 2949.

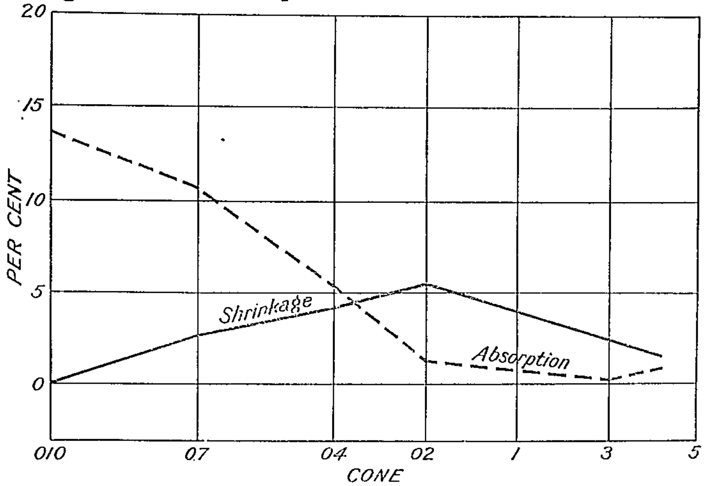


Figure 14. Absorption and shrinkage curves of sample No. 2949, Edmonton formation (third type), Fish creek, above Priddis.

Fourth: A single sample, No. 2902, is outstanding in that it differs from all other Edmonton samples in the matter of its action while under fire. The absorption curve drops steadily and uniformly between cone 010 and 3, where a low per cent of absorption is developed. None of the other samples shows such a degree of regularity in vitrification progress as the present sample. The shrinkage curve is more variable; an increased rate occurs between cones 04 and 02.

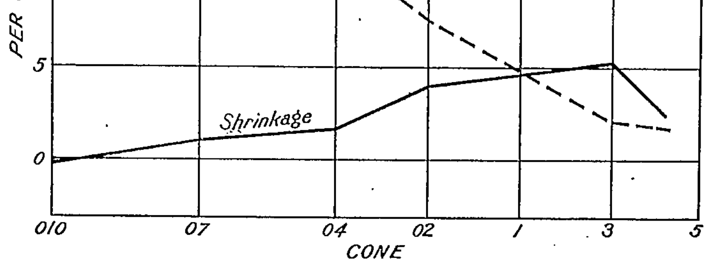


Figure 15. Absorption and shrinkage curves of sample No. 2902, Edmonton formation (fourth type), Highwood river, below Bull creek.

Fifth.—This group differs from the last in that little vitrification occurs in advance of cone 07, from there on it proceeds steadily to cone 02 and then more sharply at cones 1 to 3, as shown by curve sheet from sample No. 2915 and the data for No. 2950.

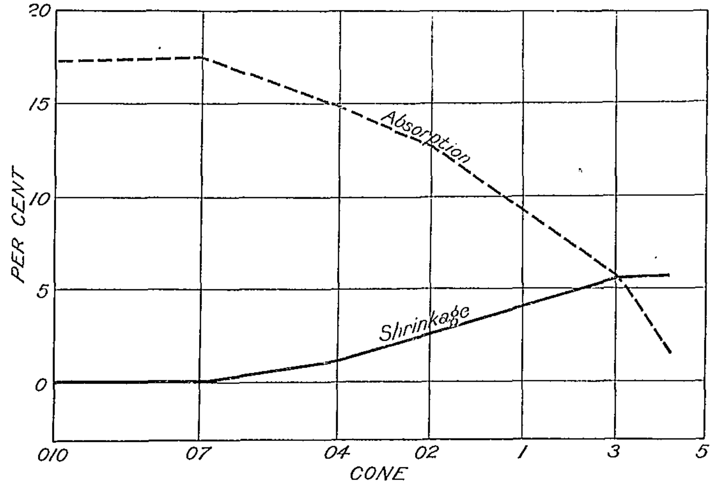


Figure 16. Absorption and shrinkage curves of sample No. 2915, Edmonton formation (fifth type), Sheep river, near Black Diamond.

Belly River

The Belly River samples are quite clearly divided into five groups, all of which, from an industrial point of view, are quite favourable, in that the rate of vitrification is generally gradual and conducive to safe burning of commercial wares. The groups are:—

First: These samples, like Nos. 2908, 2912, 2921, 2922, and 2923, show a steady gradual decrease in absorption from cone 010 to cones 1 to 3 where the per cent of same becomes low. The shrinkage curve is also uniform and is made in easy stages. On the whole this group represents one of the most favourable when compared with all groups from the several formations. Figure 17 shows sample No. 2921.

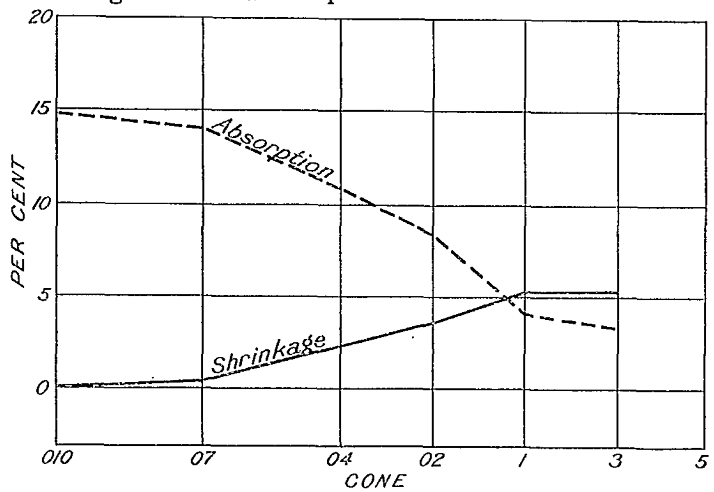


Figure 17. Absorption and shrinkage curves of sample No. 2921, Belly River formation (first type), Sheep river, near Lineham.

Second: The chief difference between this group and the first one is that of the small drop in absorption which takes place prior to cone 04; in other words, a somewhat higher temperature is necessary to start actual vitrification, when once started it continues rapidly to cones 1 to 3 where a low absorption is obtained, the same as in group one. On account of the delayed vitrification the general conditions are not quite so favourable in the present case. Samples Nos. 2920 and 2977 are of this type. Figure 18 shows sample No. 2920.

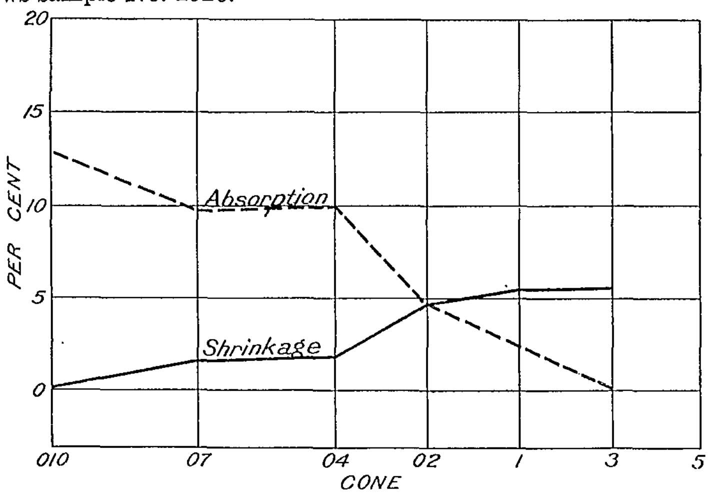


Figure 18. Absorption and shrinkage curves of sample No. 2920, Belly River formation (second type), Sheep river, near Lineham.

Third: There are but small differences in this group and the second, the main one is that of the necessity of higher temperatures to produce equally low absorptions; in other words, cones 3 to 4 are required rather than cones 1 to 3; this condition would naturally increase burning costs. Shales Nos. 2924 and 2926 are representative of this type.

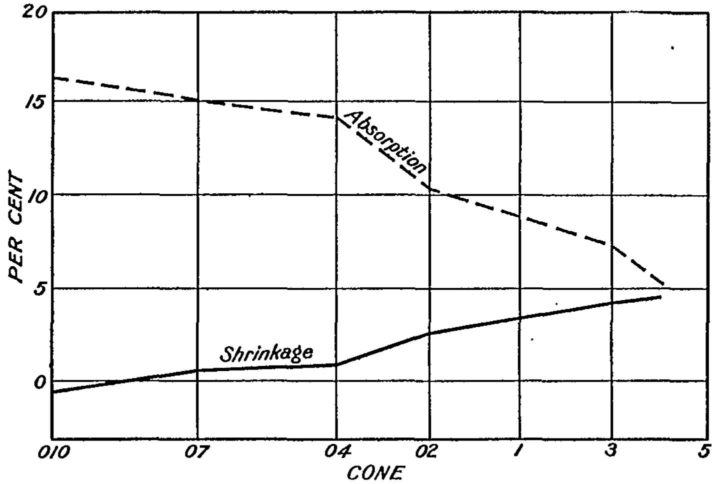


Figure 19. Absorption and shrinkage curves of sample No. 2926, Belly River formation (third type), Quirk creek, west of Millarville.

Fourth: Sample No. 2975 alone stands for this group. In general it might have been placed in group one in so far as the slow steady drop in absorption from cone 010 to cone 3 is concerned. The difference is that of the absorption being higher at all stages of the burn than is the case with shales of the first type; cones 4 to 5 are necessary to reduce the absorption per cent to reasonably low figures, therefore increased burning costs. The total shrinkage and its rate are both distinctly favourable.

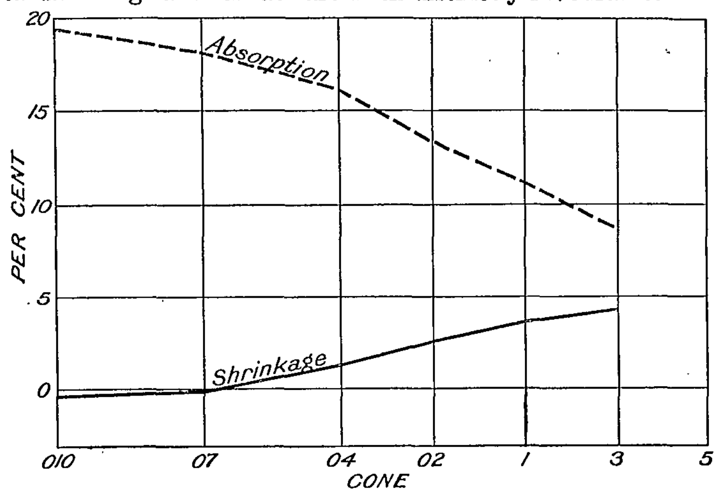


Figure 20. Absorption and shrinkage curves of sample No. 2975, Belly River formation (fourth type), Elbow river, Sarcee Indian reserve.

Fifth: This sample, No. 2925, or group, varies from the fourth in that the per cent of absorption and shrinkage are both generally lower and, further, there is little evidence of vitrification in advance of cone 02, from there on it progresses steadily with cones 4 to 5 necessary to reduce the per cent of absorption to a low figure. On the whole it is not so favourable as shale No. 2975 of the fourth class.

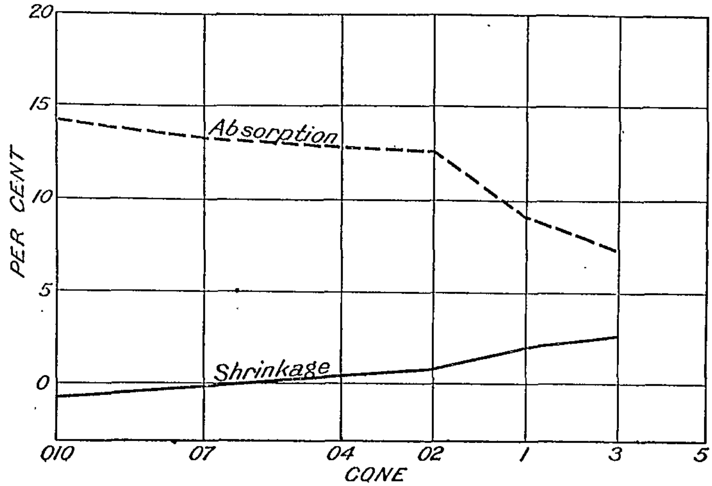


Figure 21. Absorption and shrinkage curves of sample No. 2925, Belly River formation (fifth type), Quirk creek, west of Millarville.

Benton

It has been found possible to group the Benton samples into six divisions or groups according to their rate and degree of vitrification as shown by the graphs which have been prepared; typical ones of each are shown.

First: These shales show a somewhat gradual drop in absorption from cone 010 to cone 02 and 1, with little change taking place until just past cone 3, where overfiring takes place. The shrinkage curves are generally in accord with that of the absorption changes. Samples Nos. 2930 and 2931 are of this type. Figure 22 shows sample No. 2930.

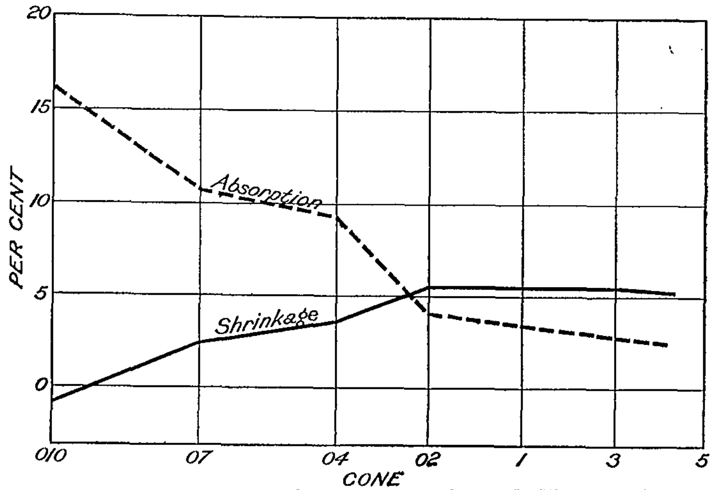


Figure 22. Absorption and shrinkage curves of sample No. 2930, Benton formation (first type), Turner valley, near small bridge, main trail.

Second: In this group the absorption drop, while irregular, is of medium rate to cone 04, it then proceeds steadily to approximately 5 per cent at cone 3. Samples of the group are Nos. 2907, 2906, and 2932. Figure 23 shows sample No. 2932.

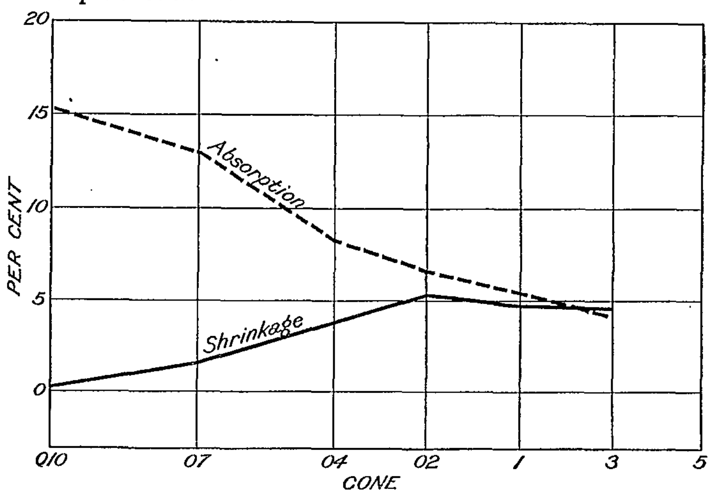


Figure 23. Absorption and shrinkage curves of sample No. 2932, Benton formation (second type), Turner valley, east of Imperial Oil refinery.

Third: The general type of curve or graph shown for this group resembles that of number one in that it is fairly continuous from cone 010 to cone 3, the main difference being that of a higher total per cent of absorption at all cones. The final per cent at cone 3 is in the neighbourhood of 7, thus for low per cents higher burning temperatures would be necessary. The samples of this group are Nos. 2909, 2927, 2928, 2933, 2934, 2970, and 2976. Figure 24 shows sample No. 2933.

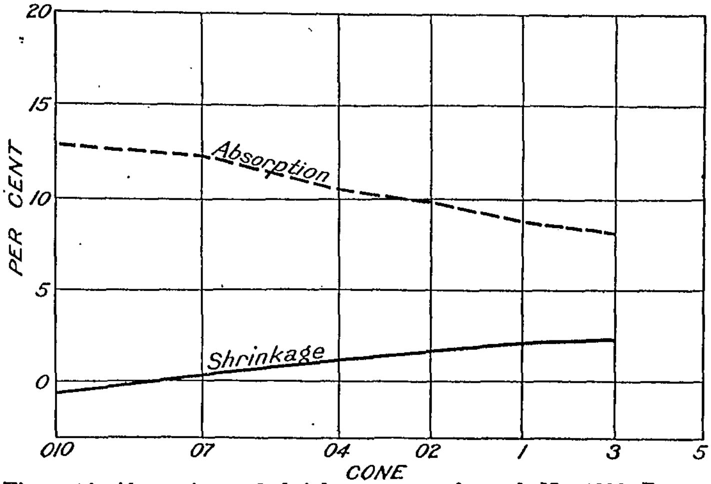


Figure 24. Absorption and shrinkage curves of sample No. 2933, Benton formation (third type), Turner valley, east of Imperial Oil refinery.

Fourth: The same general rate of vitrification is shown in this group as that of the preceding one, the chief difference being that of slightly higher per cents of absorption and a final one of 10 per cent at cone 3. The general samples are Nos. 2905, 2910, 2914, and 2935. Figure 25 shows sample No. 2914.

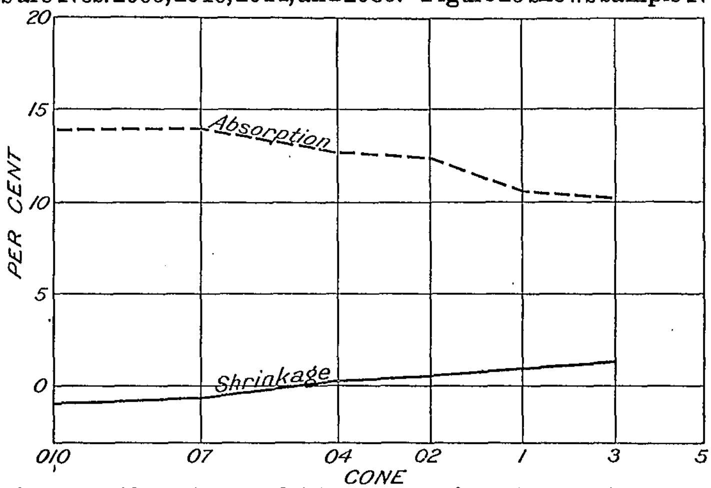


Figure 25. Absorption and shrinkage curves of sample No. 2914, Benton formation (fourth type), Highwood river, below Ings creek.

Fifth: This group or type is quite different to the others in that the absorption curve shows an upward curve from cone 010 to cone 07; in other words, the per cent actually increases through the action of heat. At cone 04 the per cent has dropped back to that of cone 010, it then slowly decreases to cone 3, where the per cent is still very high, which, under ordinary conditions would indicate a degree of heat resistance above that of the average red or dark burning clay or shale. However, a fusion test has shown this shale to deform or soften quite early, in fact at cone 4+.

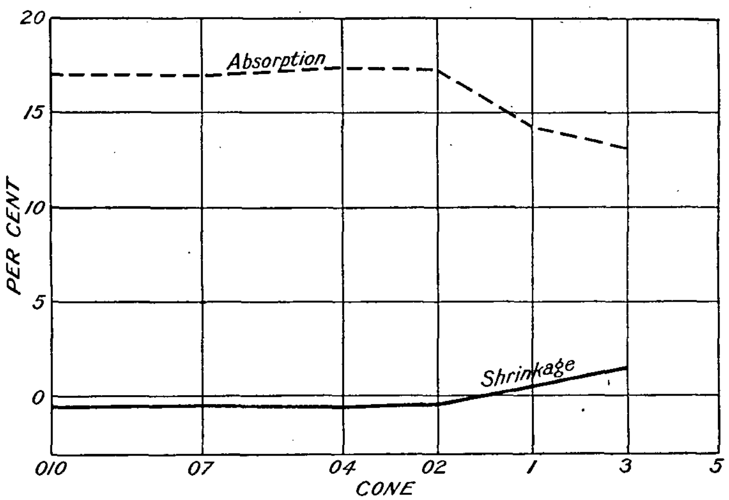


Figure 26. Absorption and shrinkage curves of sample No. 2929, Benton formation (fifth type), Turner valley, near small bridge, main trail.

It is of further interest to note that the two shales in this group, Nos. 2929 and 2936, expand while under heat treatment between cones 010 and 02 and it is not until cone 1 has been reached that shrinkage actually takes place. On the whole the curves developed from the data on the above shales indicate them to be of doubtful values. Figure 26 shows sample No. 2929.

Sixth: A single shale, No. 2913, has developed absorption-shrinkage curves not unlike those of the last group with the exception that a very rapid rate of vitrification takes place between cones 02 and 3, followed quickly by overfiring-conditions which are quite unfavourable.

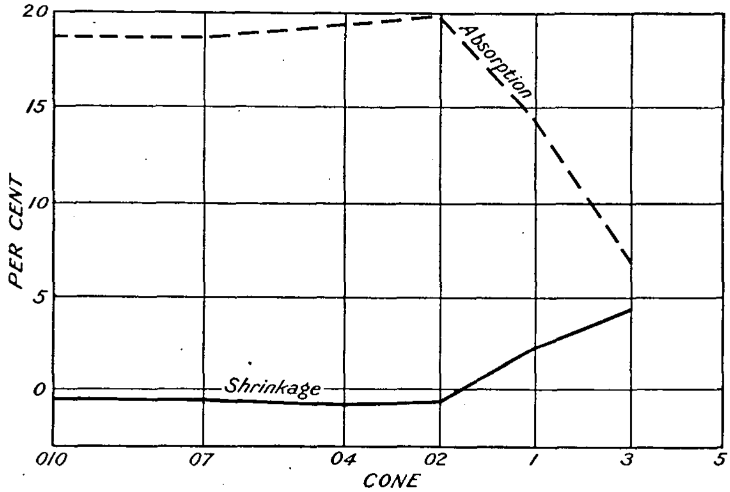


Figure 27. Absorption and shrinkage curves of sample No. 2913, Benton formation (sixth type), Highwood river, below Ings creek.

Blairmore

A study of the absorption-shrinkage curves developed from the tests on the Blairmore shales prove them to have, on the average, the most uniform and gradual vitrification changes of all samples tested. While the rate of change as shown by the drop in absorption is safe in all cases, the chief detraction is that of the necessity of fairly high temperature, cones 4 to 6, to produce or develop a low per cent of absorption. The shrinkage in all cases is uniform and safe in its rate of progress, such that kiln losses should prove very low under ordinary practice. Figures 28 and 29 show samples Nos. 2939 and 2974.

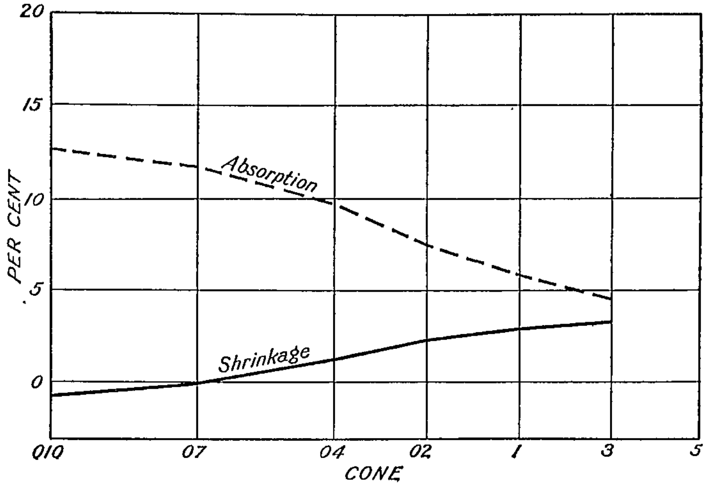


Figure 28. Absorption and shrinkage curves of sample No. 2939, Blairmore formation (typical type), Macabee creek, near mouth.

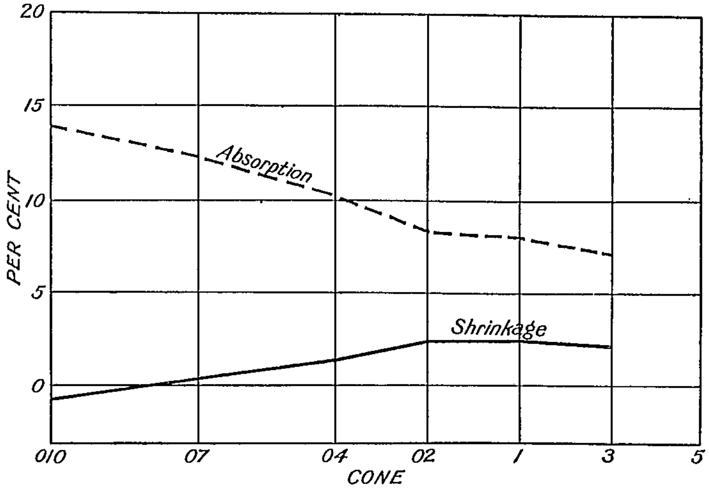


Figure 29. Absorption and shrinkage curves of sample No. 2974, Blairmore formation (typical type), Elbow river, near Bragg Creek.

GENERAL NOTES CONCERNING TEST DATA

From a general review of the data supplied by the tests on the samples from all districts covered it may be stated that certain facts and conditions have been brought to light.

First: All of the samples, with the single exception of No. 2980, are dark burning and may be classed as heavy clay product materials. The single exception proved to be light burning; notwithstanding this, it belongs to the same class as the other samples.

Second: The beds of each formation are quite consistent in their ceramic values from point to point laterally, except the Edmonton beds in the Upper Highwood River area, on the Highwood river and Bull creek, where they were found to be somewhat different to those near Black Diamond and farther north, in that they are generally darker in shade, less hardened, carry more soluble salts and colloidal matter and in fact are of lower value and interest than where examined elsewhere.

Third: A large percentage of the samples collected represent materials which may be used in the production of commercial clay wares.

Fourth: None of the samples proved to be refractory (fire clays) nor did any of them prove to be suitable for pottery wares other than red ware.

Fifth: Among the samples from the Turner Valley area are shales suitable for the manufacture of a wide variety of clay wares, the more important being paving brick, face brick, roofing tile and red terra cotta, quarry and floor tile, common brick, building tile, drain tile and red-ware pottery.

Sixth: Shales from other districts now supplied with transportation were found to offer the same possibilities.

Among the samples tested there were several, including Nos. 2903, 2930, 2940, and 2967, which would prove suitable for the production of Haydite or similar bloated, light-weight products.

At present, and for some years past, there has been an increasing demand for flashed or multi-coloured face brick, these are usually produced from red burning clays through a proper manipulation of the kiln fires during vitrification. While no attempt was made in the present work to test the samples for flashing it is safe to state that many of them can be readily flashed, and more especially the shales from the Edmonton and Belly River formations.

Seventh: In a general way the geological formations sampled are of future ceramic interest in the following order:—

Belly River	First
Blairmore, Edmonton	Second
Paskapoo	Third
Benton	Fourth
Recent	Fifth

As the ceramic value of a deposit, bed or formation depends largely upon its location and the ultimate objective or class of ware desired, it becomes impossible to construct a classification or division to meet all cases. For instance, if a material suitable for common brick is sought, then a Recent or soft clay may prove of greater interest and value than would a shale; on the other hand, shales are more important and necessary for the production of paving brick, face brick, and other wares where colour and hardness are important properties.

Thus in the present case the above list or order has been derived from a study of the physical properties of the samples, irrespective of their location.

GENERAL CONCLUSIONS

Notwithstanding the many deposits of excellent red burning shales in the Turner Valley district their commercial development at this time is not to be recommended. Two conditions warrant the above statement. First: lack of rail transportation at the source of the raw material; and, second, the general class of ware which can be produced from the present known shales of Turner valley will not, for economic reasons, permit of long distance haulage to markets or to points for rail shipment.

Further, any thought or consideration given to the use of the Turner Valley shales and gas must take into account the present clay-working plants in Alberta, and the lines of ware produced by them, otherwise an overproduction of certain wares might easily occur, and especially so is this true in that the raw materials used in most of the present plants correspond quite closely to those tested.

In the event of rail transportation entering Turner valley conditions would become distinctly favourable for the building up of a varied clay products industry, provided of course markets were available or could be created.

Lines which may be suggested, and which would make use of large quantities of gas, would be the manufacture of paving brick, the burning or calcining of clay or shale for use as railroad track ballast, for highways, and concrete, also the production of Haydite or similar bloated lightweight burned clays or shales for use in concrete where reduced weights are desirable, or in vicinities where good gravel is lacking.

In view of the handicap due to lack of railway transportation in the Turner Valley district the following suggestions are offered as a possible means to assist in the utilization of at least a portion of the present waste gas.

Unless there is concrete evidence of a proposal to provide Turner Valley with a rail outlet in the near future, it would seem advisable to consider the extension or construction of a gas main from Turner Valley to nearby clay and shale deposits on rail, for instance in the vicinities of Okotoks, Aldersyde and Calgary, locations where important beds occur in the Paskapoo formation. There is, however, to be taken into account the fact that in those districts clays or shales are available from a single formation only, while in the Turner Valley area raw material may be drawn from at least five, therefore the industrial scope or possibilities of the first-mentioned districts may not prove so broad or attractive as in the latter, in that the same possibilities are not present for the blending of two or more raw materials that wares of definite physical properties may be produced.

However, as revealed by the tests, the lines or variety of ware which may be produced from the Paskapoo shales is broad and quite complete, therefore, in the absence of more favourable conditions, their development should be given careful and serious consideration as a means to the utilization of a portion of the gas from Turner Valley.

Among the wares which could very well receive favourable attention are paving brick, roofing tile, red terra cotta, Haydite, and calcined shale—lines not now produced in Alberta.

Further, in the event of gas becoming available at rail for use in the ceramic industry there would be open for consideration the establishing of clay product plants for the production of wares other than those possible from the Paskapoo shales. In this connexion there may be mentioned the shipping in of clay for terra cotta, stoneware and yellow-ware pottery, whiteware including pottery, electrical porcelain, floor and wall tiles, sanitary wares and other high-grade wares in which clays, possibly from other points in Alberta, other provinces, or imported from outside sources would be drawn upon as sources of raw material.

PLATE II

A. View of Paskapoo-Edmonton beds on Highwood river, below mouth of Bull creek, where samples Nos. 2901 and 2902 were taken.

B. Exposed Edmonton shales on the Highwood river at the mouth of Bull creek. White patches are incrustations of soluble salts.

PLATE III

A. Low exposure of Edmonton shales on Sheep river, below bridge at Black Diamond. Sample No. 2918 was collected at this point.

B. Belly River beds on the west flank of the Turner Valley anticline near Lineham ford. Sample No. 2922 was taken from these beds.

PLATE IV

A. Belly River shales exposed on Quirk creek, above Millarville. These beds were sampled for No. 2923.

B. Low exposure of Benton shale below main Black Diamond-Turner Valley highway. Samples Nos. 2927 to 2931 were taken from these outcrops.

PLATE V

A. Vertical Blairmore beds on Sheep river, opposite mouth of Macabee creek. Samples Nos. 2937 and 2938 were taken from similar beds on opposite side of river.

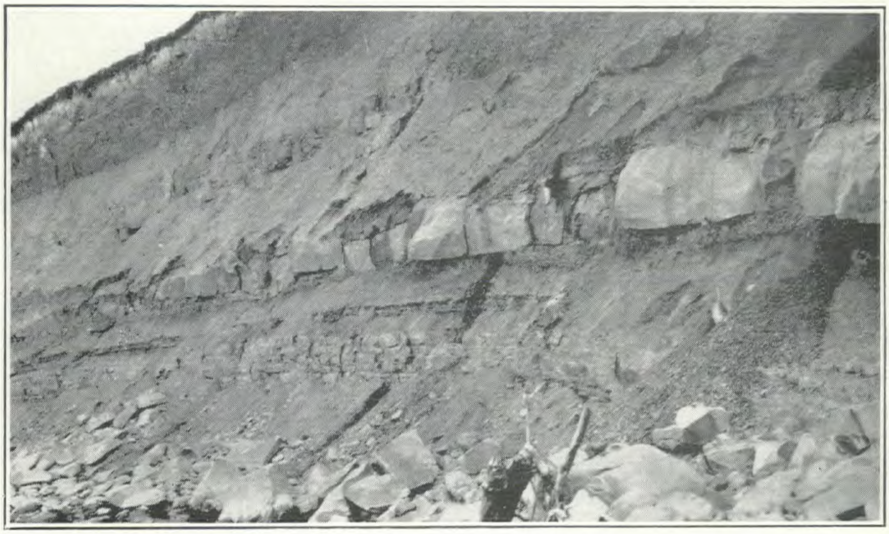
B. Outcrop of Paskapoo shales and sandstone on Sheep river, below Black Diamond, where sample No. 2945 was taken.

PLATE VI

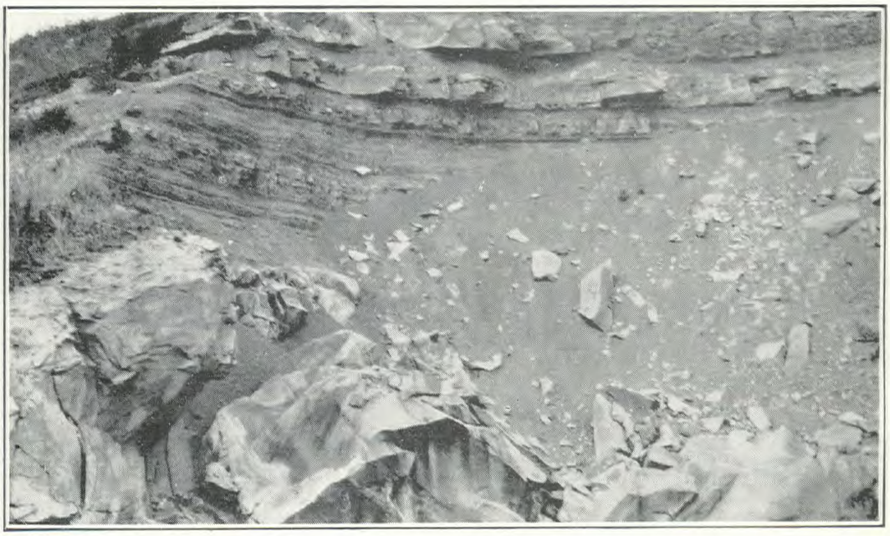
A. Paskapoo sandstone and shale on Fish creek, opposite the post office at Priddis. Sample No. 2947 was collected at this point.

B. Exposure of Paskapoo shales below the forks of Quirk creek and Sheep river. Sample No. 2951 was taken at this point.

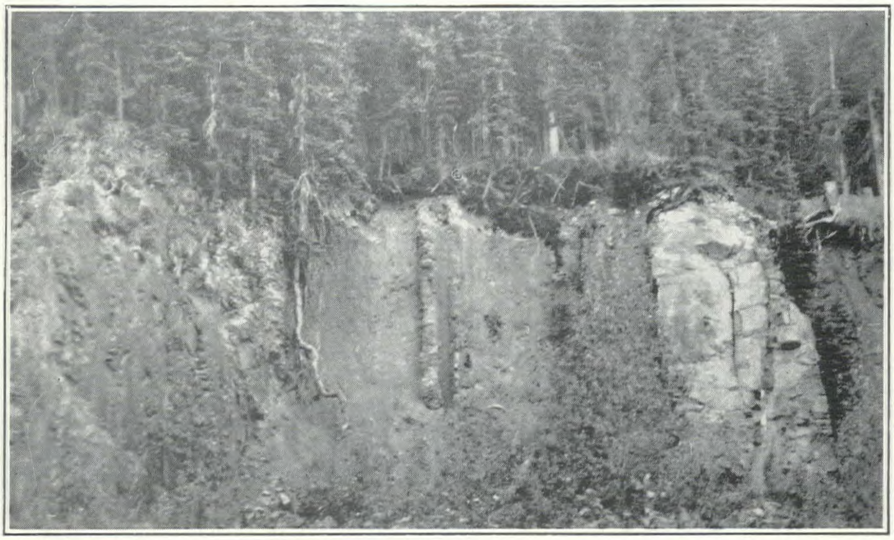
PLATE VII



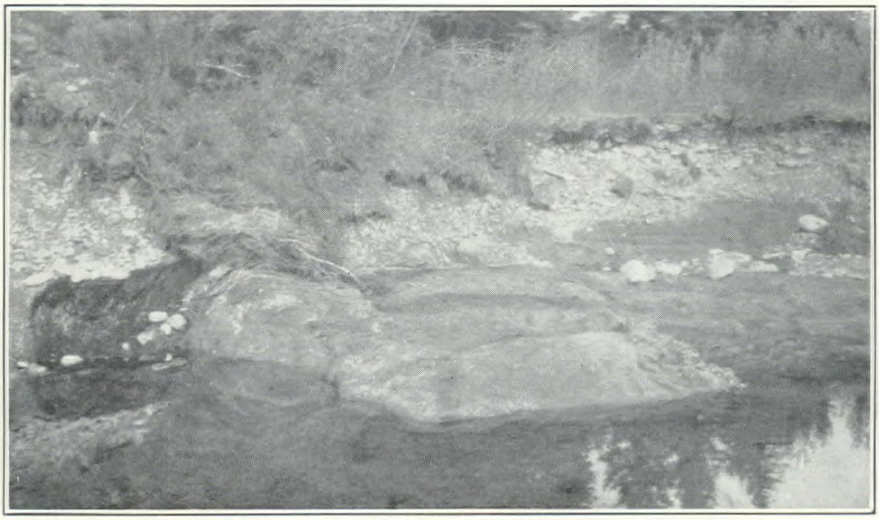
A. View of Paskapoo beds on Highwood river, near Aldersyde. Sample No. 2953 was taken at this point.



B. Pit in Paskapoo shales and sandstone at Sandstone. Sample No. 2967 was taken from beds shown in upper left-hand corner.



A. Blairmore beds on the Elbow river, near Bragg Creek. Samples Nos. 2971, 2972, and 2973 were taken near this outcrop.



B. Thin coal seam and Belly River shales in bed of Elbow river, on the Sarcee Indian reserve near Bragg Creek. Sample No. 2975 was taken at this point.

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