CANADA
DEPARTMENT OF MINES
GEOLOGICAL SURVEY BRANCH

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

MEMOIR No. 24-E

PRELIMINARY REPORT

ON

THE CLAY AND SHALE DEPOSITS

OF THE

WESTERN PROVINCES

BY

HEINRICH RIES

AND

JOSEPH KEELE

OTTAWA
GOVERNMENT PRINTING BUREAU
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LETTER OF TRANSMITTAL.

To R. W. Brock, Esq.,
Director Geological Survey,
Department of Mines,
Ottawa.

Sir,—We beg to submit, herewith, a preliminary report on the Clay and Shale Deposits of the Western Provinces.

We have the honour to be,

Sir,

Your obedient servants,

(Signed) **Heinrich Ries.**
Joseph Keele.

June, 1911.

CONTENTS.

CHAPTER X—*Continued.*

ILLUSTRATIONS.

Photographs.

Drawings.

Maps.

PRELIMINARY REPORT

ON

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WESTERN PROVINCES

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Heinrich Ries and Joseph Keele

INTRODUCTORY

The following report on the clay deposits of the western provinces is to be regarded, partly, as a preliminary report. The field work was done during the summer of 1910, and the laboratory tests during the following winter. Owing to the large size of the area to be covered, it was naturally impossible to cover the region in detail, but most of the important occurrences were visited.

During the time spent in the field we were able to visit a number of the shale areas, these being considered the most important; but in addition, a large number of surface clay deposits were also investigated.

The results of our work, even though not detailed, have shown that the western provinces contain a wide variety of clays and shales adapted to the manufacture of firebrick, coke-oven brick, sewer-pipe, fireproofing, paving brick, pressed and common brick, and drain tile. Many of these deposits still remain undeveloped; but it is hoped that this report will be the means of calling attention to them, and leading to their utilization.

As the results given in the body of the report show, samples were examined from a number of localities, and subjected to tests that will be of value to the manufacturer of clay products. The samples collected were usually of 50 to 75 pounds weight, and were taken by trenching, so as to represent the average of the deposit. The numbers given in parenthesis in the descriptions of the tests refer in all cases to the laboratory numbers.

In addition, samples of burned brick were also selected at a number of yards, and these have been tested by Prof. Macphail, of the Kingston School of Mines. The results of these tests are incorporated in the report. These will show the character of the product made from the different formations, and bring out the fact that the bricks made from the surface silts and sandy clays are often of inferior character. The use of them, however, is frequently a matter of necessity, since better materials are not available, and transportation rates prohibit bringing common brick from other points.

Inasmuch as many persons having occasion to refer to this report may not have a detailed knowledge of the properties of clays, there has been appended to the report a brief discussion of these phases of the subject.

CHAPTER I.

Great Plains Region

SURFACE CLAYS.

By far the greater number of clay deposits worked in the Great Plains region are surface clays of unconsolidated character, and recent geological age.

They consist of a heterogeneous mantle of silts and clays, mixed with gravel and sand deposits, which usually conceal and level up the inequalities of the bed-rock. So thick are they in some cases, that the bed-rock lies several hundred feet below the surface.

Whatever their character, these materials were in most cases deposited by water; the latter having often been derived from the melting ice of the continental or mountain glaciers.

MODE OF OCCURRENCE.

The surface clays of the Great Plains region used for brick-making purposes may belong to any of the following groups: (1) lake clays; (2) river-terrace or flood-plain deposits; (3) delta deposits.

Lake Clays.—As the front of the great continental glacier receded towards the north, lakes of various dimensions filled the depressions in the uneven surface of the country; and into these lakes the drainage of the surrounding land was carried, the sediment thus transported settling to the bottom, and forming beds of fine stratified clay silt and sand. Some of the clay in these lakes was contributed by streams flowing from glaciers at or near their margins. The dark grey clay underlying the brick clay in the Red River valley is probably derived from this source. It is a massive clay, containing vertical joints, faintly stratified in the upper part and carrying scattered boulders and streaks of gravel below (Fig. 1). In time the supply of water from the melting ice diminished and the lakes became partially, or totally, drained by the cutting down of their outlets.

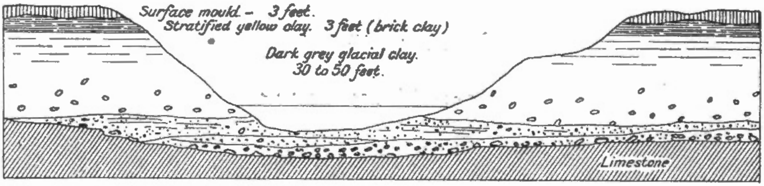


FIG. 1.—Section across the Red River valley at Winnipeg.

One of the most extensive clay deposits as yet known occurs in the former bed of glacial "Lake Agassiz,"[1] the sediments of which constitute the best brick clays of Manitoba. Raised beaches at various levels are still preserved for long distances on the eastern slopes of Pembina, Riding, and Duck mountains, and these mark what were once the western shores of this great body of water.

Large areas of surface clays occur in the Saskatchewan valley from Prince Albert to Edmonton, and on the South Saskatchewan as far as Saskatoon. These clays often occur in thick beds, showing a vertical jointing which is sometimes more pronounced than the lines of stratification. Their plasticity is generally good and the beds are free from layers of sand or gravel. These clays were probably deposited in bodies of water lying in the wide basin like depressions of the river valleys and impounded behind temporary dams formed by terminal moraines.

Evidences of similar conditions are found in clays which occur near the Red Deer river at Red Deer, in the expansion of the valley of the Bow river at Cochrane, and in the valley of the Oldman river in the vicinity of Pincher. The lake clays that occur in the latter localities, however, are more distinctly stratified, and are often interlaminated with sandy layers, a feature due, probably, to the greater velocity of the entering streams.

The overburden of these clays usually consists of loam of

[1] Upham, W. Glacial Lake Agassiz in Manitoba, Part E, Ann. Rep., Vol. IV, Geol. Sur., Canada.

no great thickness, but for some distance below the loam the clay is liable to be silty. This silty portion, however, is mixed in with the underclay when mining.

River-Terrace or Flood-Plain Deposits.—Rivers which cut through drift deposits carry a certain amount of sand, clay, and gravel, according to their velocity and volume. Whenever the slope of the stream bed is lessened, the water loses velocity, and consequently carrying power, and is then compelled to deposit the larger particles in its load, and these accumulate to form beds of gravel or sand; but the finer particles are carried on until a further reduction of the velocity compels the stream to drop them also. If the clays are deposited where the current is very slow, and remains fairly constant, a thick bed may be built up; but owing to fluctuations due to changing seasons, the kind of deposit usually accumulated consists of alternating layers of sand, silt, and gravel.

The greater portion of these deposits is eventually removed by the stream as it cuts down its bed, but often wide areas bordering the stream remain as terraces at one or more levels above the water. The clay on the surface of the flood-plain terrace may be added to by the deposition of sediment during periods of high water.

Some extensive terraces containing brick-clays exist along the valley bottom of the North and South Saskatchewan river, and to a lesser extent in many of the smaller stream valleys throughout the region.

Clay beds in river terraces are usually irregular in extent, and can rarely be mined alone, as the interbedded sand and silt must be taken out with the clay; consequently, the bricks made from many deposits of this class are porous, and low in crushing strength.

Delta Deposits.—These occur at points where streams discharge into lakes, and vary in extent with the volume of material carried in by the river. One of the most extensive deposits of this class occurs in Manitoba, and, known as the Assiniboine delta,[1] was formed during the maximum development of glacial

[1] Upham, W.: Glacial Lake Agassiz in Manitoba, Part E, Ann. Rep., Vol. IV, Geol. Sur., Canada.

"Lake Agassiz". The remains of this delta show a roughly triangular area of about 800 square miles lying between Neepawa, Brandon, and Cypress River. The materials composing the deltas are more or less stratified beds of gravel, sand, and clay, which slope towards the lake bottom. There is generally, however, an absence of definite arrangement of material. The clays occur in lenses or pockets, and often contain streaks of pebbles and sand which cannot be separated from the clay in mining.

PROPERTIES AND USES.

Nearly every part of the western provinces has beds of brick-clay which are utilized in proportion to the demands of settlement. The bricks, however, that are made from them vary considerably in quality, according to the kind of clay used, or the care and skill exercised by the brick-maker.

In some cases the quality of the bricks could be improved by better methods of handling the clay, and harder burning; but, sometimes, the only remedy is to move the brick plant to a better clay deposit.

As the amount paid for bricks is not a large item in the cost of a structure, it is better to pay transportation charges on good brick, than to use a poor quality material, because it happens to be close at hand.

During late years increase in population and consequent demand for building material has been so great, that builders were compelled to use a quantity of inferior brick which would otherwise be rejected.

Generally speaking, the surface clays of the region possess certain characteristics in common, being all more or less calcareous,often silty, and showing a tendency to check in air drying.

Their calcareous content is due to the erosion of extensive areas of limestones, which lay directly in the path of the general movement of the ice sheet, while their silty character was contributed largely by the amount of rock flour in the boulder clay or till, from which many of the beds were derived.

These clays for the most part are easily fusible: melting at the fusing point of cone 1 (1150° C.); but in certain localities they are more refractory, due no doubt to the large percentage of magnesia present, and these do not melt until cone 3 or even cone.6 is reached.

The following chemical analyses of some Manitoba clays, made by Mr. M. F. Connor, of the Mines Branch, show the large amount of lime and magnesia in their composition. These samples were collected in 1904 by J. Walter Wells.[1]

	1	2	3
Silica (SiO_2)	54·00	50·66	45·15
Alumina (Al_2O_3)	9·25	10·00	9·05
Iron oxide (Fe_2O_3)	2·77	3·43	3·75
Lime (CaO)	9·77	10·00	14·00
Magnesia (MgO)	3·51	3·10	7·11
Alkalies (Na_2O,K_2O)	2·34	2·31	2·52
Sulphur trioxide (SO_3)	0·05	1·80	0·10
Moisture	8·66	4·00	1·50
By difference	9·95	15·04	16·82

(1) Yellowish-grey unstratified clay free from sand. Stephens Brick Company, Portage la Prairie.

(2) Yellowish clay free from sand. Virden Brick Company, Virden.

(3) Yellowish clay. Eastman's Brickyard, Gilbert Plains.

The melting of calcareous clays occurs rather suddenly after the point of incipient fusion is reached in the kiln, so that it is unsafe to attempt the manufacture of vitrified wares from them (See Fig. 9).

These clays burn to a buff colour when the percentage of lime is high; but the majority of them burn red, owing to the iron content being proportionately high. When underburned the strongly calcareous clays are red or salmon coloured.

The greater part of the bricks produced in the country are common bricks made by the soft-mud or sand-moulded method; a small quantity of these are re-pressed for facing bricks. Only a few works make stiff-mud bricks. There is an ever-increasing demand for dry-press bricks, and some firms produce no other kind; but these are mostly made from shales; the silty surface clays or those containing an excess of sand not being suitable for this process. Some of the more plastic surface clays, however, when burned to cone 03 will produce a good hard dry-press brick.

The silty and sandy clays, when tempered with water, work up into a body which is "short", or lacking in cohesion when wet, and if used in a stiff-mud machine is liable to tear at the corners when coming from the die.

The plastic clays will generally come through the die intact, but the chief objection to working them by this method is, that the green bricks are too difficult to dry.

[1] Wells, J. Walter.: Industrial value of the clays and shales of Manitoba, Mines Branch. Dept. of the Interior, Ottawa, 1905.

2

There is no doubt that taking these clays from the bank in the autumn, and weathering in stock piles over winter, improves their working qualities. This precaution is especially desirable if the bank contains some highly plastic beds or layers, as the frost seems to open the body and reduce the stickiness and lessen the tendency to checking in the green bricks when air drying. A few of the brickmakers have adopted this method with good results, as it does not cost much more for labour, and the clay is available for use earlier in the spring; because the frost goes out of the piles quicker than it does from the bank. Pebbles of limestone are a source of weakness if allowed to pass into the bricks without being crushed. These pebbles burn to lime oxide in the kiln, and afterwards absorb moisture from the air which causes them to swell and burst the bricks.

Clays containing pebbles should be passed through rolls before entering the pug-mill; the rolls will throw out the larger pebbles and crush the small ones. The finer the pebbles are crushed and the better the particles are distributed through the clay, the greater the improvement in the brick (Plate LXI).

The bricks made from these surface clays are usually burned in scove kilns, the fuel used being wood, lignite, or natural gas, according to the locality.

DESCRIPTION OF LOCALITIES.

Winnipeg, Man.—This town is surrounded by the greatest cluster of brickyards in the western provinces.

The clays found here (Plate I) are of two types, viz.: (1) a silty calcareous surface clay, immediately underlying the surface, and extending to a depth of from 4 to 5 feet; (2) a tough, sticky clay, which the local brickmakers pronounce unfit for use. The former is cream-burning, the latter red-burning.

The top clay is evidently a surface or flood-plain silt deposited by the Red and Assiniboine rivers, while the bottom clay may be a lake deposit, laid down in the waters of Lake Agassiz which formerly covered this region.

The upper clay (1637) worked up with 28 per cent of water into a mass of good plasticity. The air shrinkage was 4·5 per cent and the tensile strength 240 pounds per square inch.

Pit in surface clay at Alsip's brick plant, Winnipeg, Man. The pit has been excavated in the calcareous surface clay and the bottom of the excavation represents the top of the underclay.

The burning tests were as follows:—

Cone.	Fire.	Absorption.	Colour.
	%	%	
010	-2·5	31·44	Salmon
03	-2·4	31·42	Buff
1	-2·4	28·27	"
3	-1·7	27·13	
6	Fused		

This is one of the most refractory of the surface clays found in the west. The temperature reached in the scove kilns is not less than cone 1, and in some cases may even reach cone 3.

Samples of the bottom clay were tested from two different localities. The first of these (1638) was collected at Alsip's brickyard at Winnipeg. It is a tough, sticky clay, which is hard to work up, but forms a very plastic mass when mixed with 39 per cent of water. The average air shrinkage of the hand-moulded bricklets was 10·3 per cent, and the tensile strength was about 250 pounds per square inch. It was difficult, however, to get flawless briquettes.

The following results were obtained in firing:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	3·7	13·31	Red
03	3·4	0·50	Red brown

This clay, as seen from the above tests, has a higher fire shrinkage at cone 010 than most common-brick clays; it, however, burns steel hard at this cone and gives a good colour, with not excessive absorption. The clay is slightly beyond vitrification at cone 03.

The brickmakers at Winnipeg claim that this is of no value, as when burned in their kilns it warps, cracks, and gets porous.

This is no doubt due in part to the fact that the surface clay used at this locality stands a higher heat. The extreme toughness and stickiness also interfere with the moulding, and furthermore, difficulty was encountered at the yard in drying this clay on the pallet racks, as it cracks badly.

A sample of this clay preheated to 300° C. was still very plastic, but much easier to work up than the raw clay, but even after preheating to this temperature it would not stand rapid drying, although this treatment improved its drying qualities.

Its air shrinkage after preheating was 8 per cent and fire shrinkage at cone 010, 3·1 per cent; at cone 05 it was 9·6 per cent.

The absorption at cone 010 was 17 per cent and at cone 05, 1·56 per cent. It was nearly steel hard at cone 010, and preheating diminished the total shrinkage by 3 per cent.

Morris, Man.—This town lies south of Winnipeg at the junction of the Canadian Pacific railway and Canadian Northern railway, and in the Red River valley. One may, therefore, expect to find clays similar to those occurring around Winnipeg. The sections in fact are just alike. Mr. McCutcheon, who formerly operated a brickyard at Winnipeg, has moved to Morris as his clay supply at the former locality gave out. The yard lies about half a mile southwest of the town, along the Canadian Northern railway.

The section shows:—

Top black loam	1 to 2 feet.
Yellow clay	3 to 5 feet
Under joint clay	

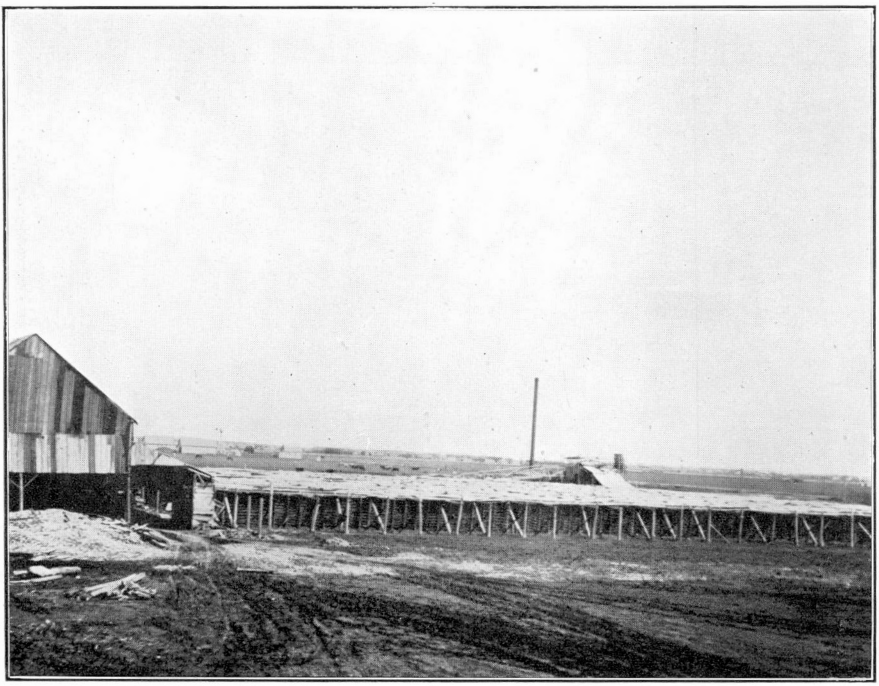
The yellow clay alone is used, being dumped into a Martin machine, dried on racks, and burned in scove kilns. As the yard had only been recently started there were no burned bricks around. It is presumably buff burning.

The bottom clay (1639) is somewhat different from that at Alsip's yard, as it contains fewer pebbles and also appears to behave somewhat differently in burning.

Its air shrinkage is 11·1 per cent, and water required for moulding 37·5 per cent. In these respects it, therefore, resembles the preceding.

The behaviour in burning was as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	3	10·42	Red
03	4·7	2·74	Red



Drying racks for soft mud bricks, Gate City Brick Co., Winnipeg, Man.

Conveyer and drying racks for soft mud bricks at Alsip's brickyard, Winnipeg, Man.

Comparing these tests with those of the preceding it is seen that the McCutcheon clay has a slightly lower fire shrinkage and absorption at cone 010, and stands a somewhat higher temperature, as it is not as well vitrified at cone 03, but the bricklets cracked some at this cone.

The high air shrinkage is a serious objection to both clays.

Clay Industry Around Winnipeg.—A number of brick plants are in operation around the city of Winnipeg. All of them use the calcareous surface clay, and as the deposit is rather shallow, and the output of brick large, a very extensive area has been worked over. Two yards have already been moved to other localities, Morris and Somerset, and it is highly probable that at no distant date others will have to follow suit, and transfer their plants to new deposits farther from the city.

All of the yards are engaged in the manufacture of common bricks by either the soft-mud or stiff-mud process. At one yard at least, hollow brick are also produced. The drying is done on open yards or on pallet racks, and burning in scove kilns.

Carman, Man.—There is an abandoned brickyard on the bank of the Boyne river, in the town of Carman, fifty-two miles southwest of Winnipeg, on the Canadian Northern railway. The clay deposit here is of the flood-plain type, consisting of thinly bedded, interstratified sand, silt, and clay. The greater part of a scove kiln of bricks still remains on the ground. The bricks are light red and soft, but those near the fire arches were partly vitrified and of a dirty-buff colour. Any further attempt to make brick at this point would probably also be a failure, as the proportion of sand and silt to clay is altogether too large to produce a good product. There is no brick clay near the river in this vicinity, but towards the southeast, and at some distance from the valley of the river, brick clay may be found, if the covering of soil is not too great for economic working.

Portage la Prairie, Man.—The brick plant owned and operated by the Stephens Brick Company is situated north of the main line of the Canadian Pacific railway, about a fourth of a mile east of the station.

The clay used by this Company is taken from an excavation in the flat land adjoining the works. The face of the excavation is about 10½ feet high, and shows 9 feet of brick clay capped with a foot or so of black soil. Underlying the clay bed is sand and gravel of unknown depth, through which a small quantity of ground water circulates. The upper portion of the deposit is a light-yellowish silty clay, while the lower part is of a mottled yellow and grey colour and is more dense and plastic. There is very little evidence of stratification.

The clay occurs in a band of about 600 feet in width, and considerable length in an east-west direction, but is replaced by sand to the north and south. The clay deposit appears to occupy an abandoned channel of the Assiniboine river, which is now about half a mile to the south and has cut down to a much lower level.

The only product made is soft-mud brick, of light buff colour, hard, and with a good ring when fully burned, but light red and rather porous if underburned. The laboratory examination of the clay (1621) collected at the yard of the Stephens Brick Company gave the following results.

It is a very plastic, calcareous clay which worked up with 24·8 per cent of water, and had an average air shrinkage of 6·2 per cent. Rapid drying has to be guarded against, as the clay shows a tendency to crack. The average tensile strength was 269 pounds per square inch.

The following results were obtained with the wet-moulded bricks on firing:—

Cone.	Fire shrinkage.	Absorption.	Colour
	%	%	
010	Slightly swelled	20·56	Light red
03	0	20·15	Pink buff
02	3·0	9·00	Buff
1	Fused		

The clay burned to a good body at cone 010, but is not steel hard until burned to cone 02. It shows the high absorption, low fire shrinkage, and even swelling at the low cones, characteristic of calcareous clay. It does not seem to work dry-press.

Stephens Brick Company.—The plant operated by the Stephens Brick Company is one of the largest and best managed in Manitoba. Two soft-mud brick machines are in operation, and have a combined capacity of 40,000 bricks a day of 10 hours.

The clay is hauled in carts from the excavation up an incline and dumped at the pug-mill. The whole depth of the deposit is used and there is no admixture of sand. The green bricks on coming from the machines are brought to the drying racks on a double wire rope conveyer. The bricks are dried on enclosed covered racks, so as to prevent too quick drying and consequent checking.

The bricks are burned in 10 down-draft kilns of 20,000 capacity each, and in continuous kilns having a capacity of 25,000 per chamber. The fuel used is anthracite screenings, burned under a forced draft in the down-draft kilns. The forced draft is driven by a six horse-power gas engine, the gas being supplied from a producer and made from anthracite screenings. A fairly uniform temperature is maintained throughout the kilns, and there is very little waste in burning. Water smoking and burning is accomplished in seven and a half to eight days. The season for brickmaking lasts from some time in May until about October 1, the production for the season of 1909 being 8,500,000. The greater part of this output is shipped to the westward of Portage la Prairie and is sent as far as Saskatoon and Moosejaw, the price obtained being $11 to $12 a thousand.

Virden, Man.—The plant of the Virden Brick and Tile Company, Ltd., is situated a short distance east of the town of Virden, and near the main line of the Canadian Pacific railway.

The clay deposit at this locality is apparently an extensive one and is said to be at least 20 feet in depth. It is overlain by about 2 feet of black soil and yellow sandy loam, which is stripped before working the bank, and the clay for a depth of 9 feet below this is used for brickmaking. The clay, originally of a bluish colour, is now weathered to a yellow, or mottled blue and yellow colour; it is well stratified and interlaminated with sandy partings and films of iron oxide.

The sample tested (1633) is a smooth, highly plastic, calcareous clay, which worked up with 29 per cent of water to a mass whose air shrinkage was 6·5 per cent and average tensile strength 210 pounds per square inch.

On burning it yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	26·47	Light red
03	0	26·56	Buff red
02	2·0	11·65	Buff
1	8·3	0	Green
3	Fused		

The clay shows the usual characteristics of calcareous clays and makes a good brick, but it would be unsafe to burn it to vitrification.

Virden Brick and Tile Company.—Only soft-mud bricks are made by this Company. The run of the bank is taken and the clay is passed through a pair of rolls before entering the pug-mill. No sand is used, but about a peck of ground anthracite to 1,000 pounds of clay is added to assist in burning the bricks. The green bricks are air dried on covered racks, and are protected against fast drying to prevent checking. The burning is done in scove kilns, the fuel used being dry poplar, which is procured from Riding mountain.

Hartney, Man.—The brickyard owned and operated by Mr. William Kirkland is situated about half a mile north of the town of Hartney, near the line of the Estevan section of the Canadian Pacific railway. The clay here is probably a lake deposit; it is said to underlie an extensive area and to reach a depth of 60 feet. It is overlain by 1½ feet of soil, and below this the clay is worked for brickmaking to a depth of 10 feet. The upper portion of the clay is silty, of a yellow colour, and faintly stratified, the underclay is stiffer and of a blue colour. No pebbles were observed in the deposit.

A small sample of clay (1631) was collected from the stock-pile and tested in the laboratory. It is a very plastic, gritty, calcareous clay, which works up with 22 per cent water, whose average air shrinkage was 5·2 per cent.

In burning it behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	19·94	Light red
03	1·30	16·38	" "
1	2·30	7·66	Dirty buff

The clay burns to a good body, and is steel hard at cone 03. The curious drop in absorption is not accompanied by a correspondingly high increase in fire shrinkage. The clay can be dry-pressed, but should be burned to cone 03 to yield a sufficiently hard product.

Only soft-mud bricks are produced, but the owner intends to put in the machinery and kilns for making drain tile and hollow blocks by next season. The clay is weathered over winter in a stockpile placed close to the machine. The moulding and handling of the green bricks is more carefully done than usual, and there is very little loss from checking while air drying.

The burning is done in scove kilns, and the fuel used is dry poplar from the Pembina hills. For several years the bricks produced at this yard were of poor quality, being soft and very porous, due to using the silty surface clay and underburning. Taking out some of the stiffer underclay with the more silty portion to weather over winter, and burning to a higher temperature has greatly improved the quality of the brick. About 1,000,000 bricks were produced last season, the greater part of which were shipped to Regina for use in the construction of the Parliament buildings.

Brandon, Man.—The brickyard owned by Mr. Robinson Bell is situated on the south escarpment of the valley of the Assiniboine river about one and a half miles from the city of Brandon.

The material used is a shallow deposit of silty surface clay about 3 feet in thickness, overlain by a foot or more of black sandy loam, and underlain by sand and silt beds. The soft-mud process is used, and burning done in scove kilns with dry poplar.

There is also a small circular down-draft kiln on the ground, used for burning face bricks. The bricks produced are mostly of red colour, but the best burned ones are said to be buff. The arch bricks are a greenish-buff colour, cracked, and hard baked, having the open granular structure, without vitrification, which is common to bricks made from very sandy clays.

The surface deposits in the escarpment bordering both sides of the valley at Brandon are of great thickness, and sections of them show the confused arrangement of sands, silts, clays, and gravel so often seen in delta deposits. These are underlain by very stiff, plastic, boulder clay of blue colour, which in some places is fairly free from boulders and pebbles, but it is generally too deeply buried to be accessible for brickmaking, even if suitable for that purpose.

The plant of the Silicate Brick Company of Brandon is located a short distance west of the city. The sand is obtained from a ridge in the rear of the plant, the pit showing a section of about 15 feet of cross bedded sands with some layers of fine gravel. Machinery for the manufacture of sand-lime brick, by the usual process, is installed, and the plant was running full time.

Somerset, Man.—The brickyard here is operated by Messrs. Coture and Marion, who have recently removed their plant from St. Boniface to this point. It is located a short distance east of the village of Somerset, on the line of the Canadian Northern railway, which here crosses the flat topped summit of Pembina mountain.

The clay deposit used for brickmaking is of the delta type, consisting of irregular layers of silty clay and sand, with some thin beds of "fat" clay, the proportion of sand to clay being large. About a foot or so of black soil is removed in working the bank, and about 8 feet below the surface there is a 2 inch bed of pebbles, while numerous small limonite concretions are scattered through the deposit.

Soft-mud bricks are the only product, and these are burned in scove kilns with dry poplar for fuel, using half a cord to 1,000 bricks. This clay evidently contains more iron than most of the calcareous clays in the Province, so that only the very hardest burned bricks are buff, the greater part of the kiln being red.

The capacity of the plant is 2,000,000 bricks annually, and these are shipped westward of Somerset.

Souris, Man.—The banks of the Souris river near Souris are partly composed of drift deposits, and partly of Pierre shale. Although the unconsolidated deposits are often of considerable depth only a comparatively small amount of clay was seen in any of the exposed sections. The clay occurs in the upper portion of the drift, however, and is easily accessible after the removal of about a foot of black loam. Beneath the clays are bedded silts and river gravels or boulder clay. The clay bed although generally rather silty or sandy is, in some localities, plastic enough to make fairly good common brick, and has a depth of 5 feet.

There is an abundance of Pierre shale at hand easy to mine, and which if mixed with the surface clay in the proportion of one part to three would produce good hollow brick or drain tile. The clay for this purpose should be ground with the shale in a dry pan, and only the most plastic clay should be used. In some places the Pierre shale is found decomposed and soft, but is hard to work, being rather stiff. If half surface clay and half soft shale be used an easily worked mixture is obtained, and one that will stand up well in firing. For this mixture the surface clay would not require to be so plastic as when hard shale is used. The tests referred to under Laboratory No. 1633 A and B are made with somewhat similar materials.

Neepawa, Man.—The brickyard of the Neepawa Brick Company is situated south of the town on the line of the Rossburn-Neepawa section of the Canadian Northern railway. The region in this vicinity is a high delta plateau formed of drift deposits, which are deeply dissected by streams. The streams, however, do not appear to have cut down to the underlying shales, the upper beds of which can be seen in the escarpment of Riding mountain about twenty miles or so to the northward.

The section in the pit at the brickworks shows stratified yellow, calcareous clay, lying between beds of a stratified sand. There are a few layers of white-coated pebbles, with scattered larger pebbles of gneiss and limestone. Several vertical crevices lined with iron oxide traverse the clay bed. Both sand and clay beds are irregular in thickness and clay is liable to be replaced laterally by sand beds and vice-versa. There is, however, an abundance of clay or "near" clay at hand.

A small sample of the clay (1622) was collected and submitted to a test in the laboratory. There was no admixture of sand in this sample. The clay works up with 23 per cent of water to a mass of good plasticity, whose average air shrinkage is 6·8 per cent. Rapid drying has to be guarded against. The tensile strength was not tested, but it is probably good.

Wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	21·36	Light red
03	0	20·19	Red
1	Fused		

The clay is a good common-brick clay, but the lime pebbles should either be screened out or crushed.

Soft-mud bricks are made, and about one-third sand is added to the clay to prevent checking during air drying. The burning is done in two down-draft kilns with capacity of 100,000 bricks each, and it requires 40 cords of dry poplar to burn a kiln of bricks. The body of the burned bricks has a fairly good red colour, but the surfaces are disfigured with a lighter colour due to the moulding sand. The upper ten courses of the bricks which get flashed and over burned have a greenish colour and many of them are slagged. Owing to the lime pebbles, some of the burned bricks crack on absorbing moisture.

The clay for this season's (1910) use was taken out and weathered in piles over winter, and better results are expected. The weathering will undoubtedly improve the working and drying qualities of the clay, but in addition to this it should be passed through rolls before going to the machine so as to get rid of the large pebbles and to break up and distribute the fragments of the smaller ones.

Birnie, Man.—Some of the smaller streams issuing from the escarpment of Riding mountain have built up alluvial fans along its base. A considerable quantity of clay is often included in these deposits, the clay being derived from shale beds and boulder clay, both of which are cut down and transported by the stream as it traverses the upland. A sample of clay was obtained from a deposit of this character lying near the Canadian Northern Railway line a short distance north of Birnie station and two miles east of the shale escarpment. Although there is a considerable quantity of shale mixed in with this clay, it is plastic enough to carry a large proportion of ground hard shale in addition. It is not known to what depth the clay extends and only about 3 feet of the deposit was seen. The shales and plastic clay occur close together at this point, and could be used in a mixture for the manufacture of hollow block or fireproofing. It is conveniently situated for transportation, and there is an abundance of dry poplar fuel close at hand.

A small sample (1624) tested gave the following results:—

The material worked up with 35 per cent of water into a mass of good plasticity, and had an average air shrinkage of 6·6 per cent.

The burning tests were as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·9	28·36	Light red
05	2·4	28·14	" "
03	3·6	22·54	Dirty buff
1	8·6	6·30	" "

This clay burns to a good brick body at cone 010, but does not get steel hard until cone 03, although it is nearly so at the first cone. The high porosity is somewhat unfavourable, but the low fire shrinkage is an advantage. At the lower cones the shale particles influence its behaviour, but the sudden increase in shrinkage and density shows the limy ingredients beginning to act, although the total shrinkage even at cone 1 is not excessive.

Gilbert Plains, Man.—The brick plant of Messrs. A. Snyder & Company is situated one and one-half miles east of the village of Gilbert Plains, and on the line of the Canadian Northern railway. This is the only brickworks now in operation at this point.

The region in this vicinity is a portion of the undulating lowland area lying between Riding mountain and Lake Dauphin. The surface clays in this area are lake deposits, and overlie an uneven sheet of boulder clay. The lake clay is often silty or sandy in the upper portion, and more plastic and stiffer lower down. It is free from pebbles, except at the ancient shore lines or raised beaches, which occur at intervals in this area.

The clay at Snyder's brickyard comes to within a foot of the surface. It is worked to a depth of 10 feet, and below this boulder clay is encountered. The clay is yellow in the upper portion, turning to bluish below the zone of weathering, and appears to be quite free from pebbles. It is highly calcareous, and also contains quite a large percentage of magnesia, which causes this clay to be somewhat refactory.

A large sample of the more plastic underclay was collected for testing purposes. The laboratory tests probably give higher shrinkages than would be obtained by taking the run of the bank. The very plastic clay was taken with the object of trying various quantities in mixtures with the Pierre shales from Riding mountain. This deposit, however, was considered to be too far from the nearest shale beds for a mixture to be worked economically in practice.

The clay (1626) worked up with 27·2 per cent water to a mass whose average air shrinkage was 8·2 per cent, and average tensile strength 252 pounds per square inch. Rapid drying caused cracking.

In burning the clay behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·9	23·97	Light red
05	0·4	22·68	" "
03	0·3	23·51	Cream
1	6·7	5·36	Buff

The clay gives a good brick even at cone 010, but is not steel hard until about cone 1. The fire shrinkage is low, but the absorption is high. Vitrification seems to begin suddenly about cone 1, but the clay stands cone 3 without fusing. The clay is mixed with about 10 per cent of sawdust and made into soft-mud bricks. These are dried on covered racks, with doors to the passages for protection against the dry winds which otherwise would cause checking of the green bricks.

The burning is done in scove kilns, with dry poplar, of which there is an abundance in the neighbourhood. About 250,000 bricks are burned in a kiln, the burning lasting from six to nine days, and the settle is 3 inches. The upper courses of bricks turn out rather soft and of a reddish colour, due to underburning, but the most of the kiln consists of good, hard, buff-coloured bricks.

The only moulding sand that can be obtained in the vicinity is rather coarse and dirty, so that it is hard to clear the moulds after coming from the machine unless the pressure is light. Consequently some of the bricks are not as shapely as they might be.

Prince Albert, Sask.—This town is situated on the Saskatchewan river in northern Saskatchewan province. To the north of the river the country is practically uninhabited and wooded, while to the south lies the rolling country of the plains with a scattering of small towns. The town of Prince Albert lies on a flood-plain terrace, a few feet above the river (Plate IV), with low hills rising behind it. Surface clays of several kinds are found in the vicinity.

One of these is a tough, plastic clay which underlies the town, and is exposed in digging trenches for sewers or other purposes, but is not utilized. It may be flood-plain clay, and if so should be looked for at other points along the river where the low terrace exists.

A second type is a sandy clay, forming basin-shaped deposits (Plate V) between low hills around Prince Albert. It may be a flood-plain clay deposited during higher stages of the river, or possibly a pond deposit. The material is worked by the Celtic Brick Company two miles south of Prince Albert.

A third type is a very silty surface clay lying on the ridge east of the town, and worked at Ittner's brickyard. It lies too high above the Saskatchewan river to be a flood-plain deposit, but may be a glacial silt deposited in a lake formed by a glacier damming the Saskatchewan valley.

The clay at the yard of the Celtic Brick Company referred to above is worked as a shallow excavation (Plate V) and its depth is not known. It is surrounded by sand. This clay (1652) is a tough, silty material, of calcareous character, which worked up with 29 per cent of water to a mass of good plasticity. The average air shrinkage was 9 per cent and the clay cracked slightly on slow drying, while full-sized bricks cracked badly on fast drying. The average tensile strength was 380 pounds per square inch.

The following results were obtained on firing the wet-moulded bricklets:—

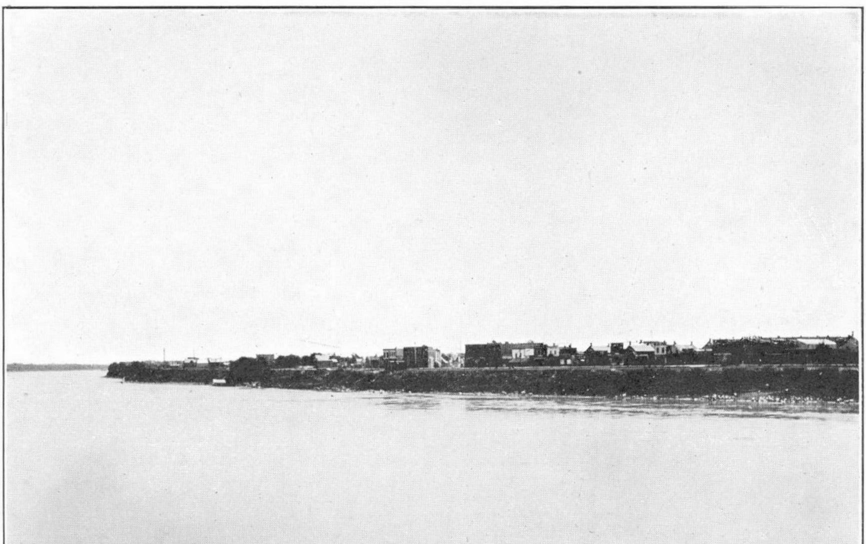
Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	15·16	Light red
03	1	14·26	Red
1	Fused		

The clay burned to a body with good ring at cone 010, which was nearly steel hard. It should make a good common brick if carefully dried, and the absorption is not excessive.

At the works of the Celtic Brick Company (Plate VI) the clay is being worked by the dry-press process, but the product was quite porous and not burned hard enough. A dry-press bricklet burned to cone 03 in the laboratory was steel hard, of dark red colour, and 10 per cent absorption. It was somewhat cracked.

The material is loosened with plows, gathered with scrapers, and piled under sheds to dry. The plant is equipped with a dry pan, screen, four-mould dry press, and three Dutch kilns, but it was not in operation at the time of our visit.

Little difficulty is experienced in getting a brick of bright-red colour, but the product does not seem to be fired hard enough to make a good hard brick.

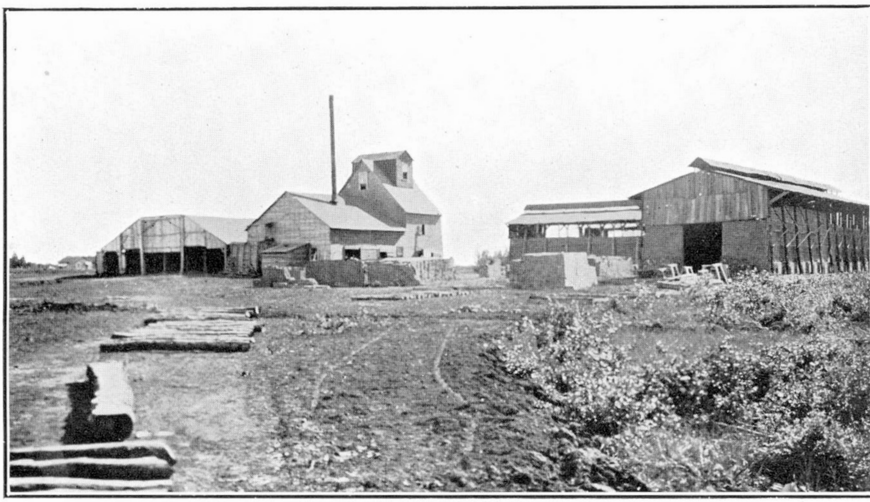


Prince Albert, Sask. Shows flood-plain terrace bordering Saskatchewan river.

PLATE V.

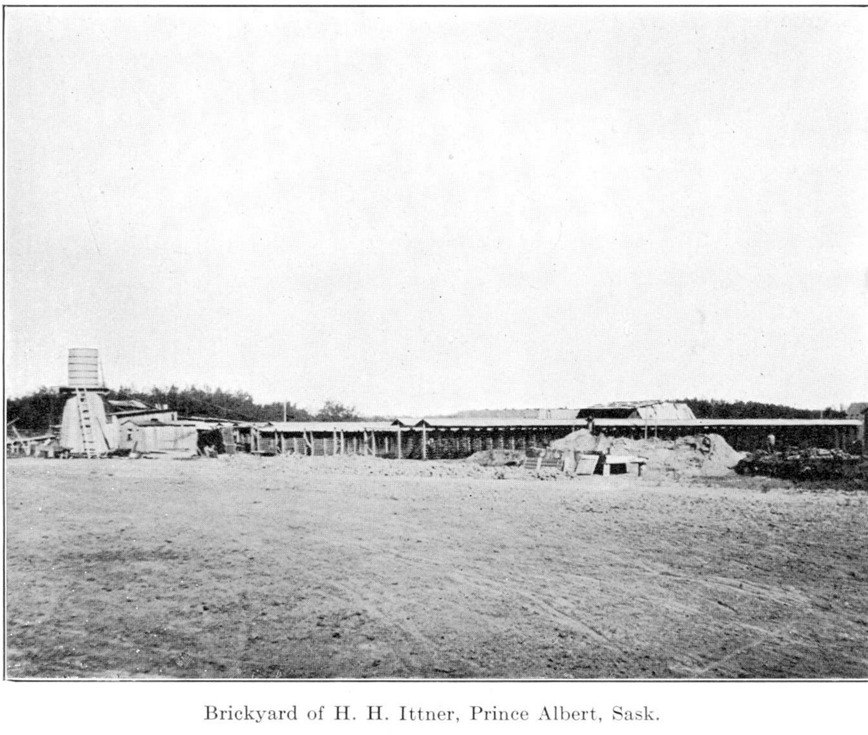
Surface clay pit at Celtic Brick Co.'s works, Prince Albert, Sask.

p. 32



Dry press brick plant, using surface clay, Celtic Brick Co., Prince Albert, Sask.

p. 32



Brickyard of H. H. Ittner, Prince Albert, Sask.

At H. H. Ittner's yard (Plate VII) on the ridge about one-fourth mile south of town, the clay is moulded in a soft-mud machine operated by gasoline engine, dried on pallet racks, and burned in scove kilns. The clay burns to a good red colour, but owing to the high percentage of sand the body is very porous.

Geographic conditions are not favourable for an immediate expansion of the brick industry here, for local demand is limited, and the few towns to the south can hardly call for many bricks. Moreover there are several yards at Saskatoon, which are also looking for a market in the surrounding country.

Saskatoon, Sask.—There are several common brickyards at this town, and at all of them silty surface clays are used.

Rosthern, Sask.—A small hand yard is in operation here. Surface clays are used.

Moosejaw, Sask.—There is little good clay in this vicinity, the surface being mostly a pebbly silt.

About one mile southeast of town, a very gritty, glacial clay, containing scattered pebbles, is being dug for common-brick manufacture.

The yard is operated by Wellington White. Soft-mud machines are used for moulding, drying is done on pallet racks and burning in scove kilns. The bricks are very porous and have but little ring.

Medicine Hat, Alta.—The surface formation is typical of many other localities of the central plains. It shows a heavy bed of silty or sandy clay, with occasional pebbly streaks, and forms a deposit of varying thickness, resting usually on the uneven surface of the Belly River shales, but sometimes separated from them by a layer of Pliocene gravels. Scattered through these very silty clays are irregular patches of a tough dark clay, known as "gumbo", and sometimes so hard and tough as to appear like clay shale.

At the several common yards in operation around Medicine Hat, only the silty clay is used, the gumbo being avoided for the reason that it is hard to dig, hard to mould, and does not burn well alone. On the other hand one cannot regard the silty clay as a satisfactory brick material, since it burns to a very porous brick, is very tender, and cracks if exposed to the wind during drying. Moreover some portions of the deposit are full of lime pebbles.

The following tests will serve to show the character of the gumbo clay, the sample selected (1690) being from one of the lenses in silty clay at Hoffman's brickyard, two miles east of Medicine Hat.

This is a very smooth, calcareous clay, but stiff and hard to work, on which account it is difficult to pug in a machine, and hence is avoided in brick manufacture. Large bricks will not dry without cracking, but the small ones do. Its air shrinkage, when mixed up with 33 per cent of water, was high, viz., 11·9 per cent. The tensile strength was also high, viz., about 300 pounds per square inch, but it was difficult to get briquettes free from flaws.

The wet-moulded bricklets burned to a good red colour, and were steel hard at cone 010.

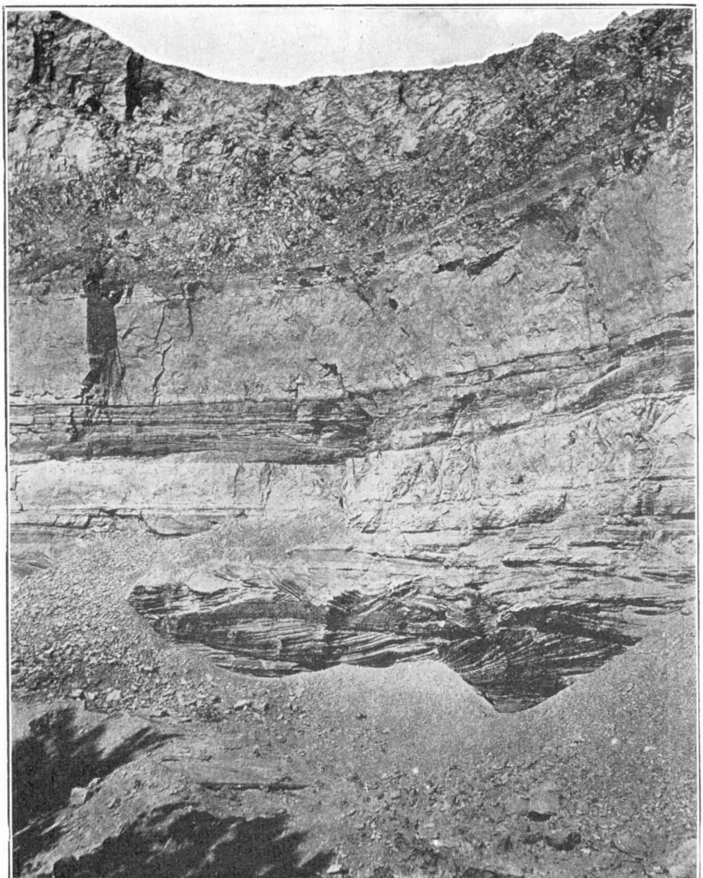
They gave the following additional data:—

Cone.	Fire shrinkage.	Absorption.	
	%	%	
010	1	10·65	
03	0·7	9·31	
1	Fused		

The main objections to this clay have been mentioned above, and while preheating might improve the clay, the brickmakers dislike to use it for the further reason that it is pockety in its occurrence, and moreover there is in the same locality an abundance of very silty clay, which can be moulded and burned with less trouble, but makes a very porous and somewhat inferior brick.

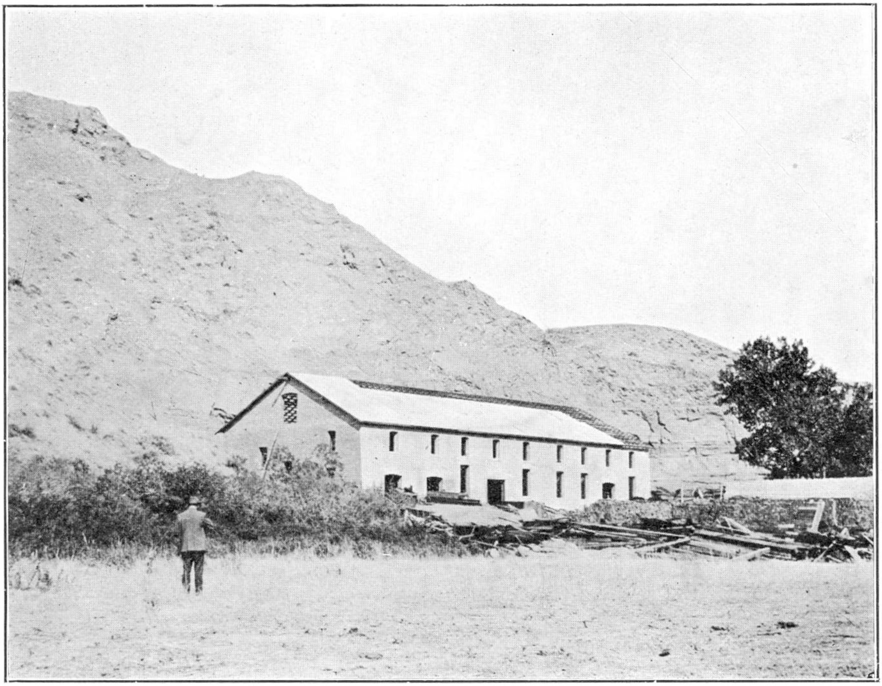
A dry-press bricklet burned to good colour, but was too soft and porous at cone 05.

Occasionally deposits of clay are found in the Pleistocene surface formations, which are less silty than those commonly used. One of these is a bed of stiff blue clay (1700), from the north bank of the Saskatchewan river, near the bridge at Medicine Hat, Alta. This is a material of good plasticity, but much grit, which worked up with 18 per cent of water to a mass



Section of drift deposits at Medicine Hat, Alta., showing silts, clays, and cross-bedded sands, probably pleistocene.

p. 34



Brick plant of Pruitt and Purmal, Medicine Hat, with thick deposit of drift containing the brick clay.

p. 34

whose air shrinkage was 5·2 per cent. It burned to a good red colour, and hard body even at cone 010.

At cone 010 the fire shrinkage was minus and absorption 12·52 per cent.

At cone 03 the fire shrinkage was 0·7 per cent and absorption 9·81 per cent.

This clay could be used for making a good red brick. The main objection to its use is the heavy overburden. A more accessible deposit is exposed in a test shaft, one and a half miles northwest of Medicine Hat. This clay (1701)is plastic, fairly smooth, and of calcareous character. It has a high air shrinkage, viz., 10·7 per cent; but in actual working this would be less, partly for the reason that the sample does not include the surface clay, which is more sandy. It burns to a good red colour and hard body, and could probably be used for dry-pressed brick.

The fire shrinkage and absorption at cone 010 were 0·4 and 13·05 per cent respectively, while at cone 03, they were 3·4 and 6·81 per cent.

There were two common brickyards at Medicine Hat in the summer of 1910, but only one was in operation. The active one was operated by the Canadian Brick Company. The plant is equipped with a soft-mud machine, pallet racks, and scove kilns. The other yard, operated by Pruitt and Purmal, (Plate IX) was being rebuilt following a fire. It is the larger plant of the two.

Red Deer, Alta.—The town of Red Deer lies in a fertile hilly country, cut by the valley of the Red Deer river. In the area surrounding the town, there is a heavy deposit of drift material, which at and near the brick pits shows the following section:—

Soil—
- Laminated sandy clays, with clay streaks..... 6 inches to 6 feet.
- Fine grained, silty, joint clay............... 2 to 3 feet.
- Boulder drift.

The material used at the brickyards is the laminated clay. The upper part of this, which is sometimes 2 feet thick, is much lighter and often lacks the laminated structure. This alone does not make good brick, and at both yards the run of the bank is used as far down as the tough joint clay, it being claimed that the latter is hard to work.

It is suggested that the joint clay may be used for dry pressed brick. That there is a noticeable difference between the brick mixture used and the lower clay is brought out by the following tests.

The upper clay (1664 *a*) is calcareous, but of good plasticity when worked up with 22 per cent of water. Its air shrinkage was 4·8 per cent and the average tensile strength 273 pounds per square inch.

The burning tests gave:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	24·36	Light red
03	"	23·72	Buff
1	Vitrified		

These tests are characteristic of a calcareous clay, in that the clay shows a high absorption until cone 03 and then vitrifies suddenly. It is not steel hard at cone 010. The clay is used for common brick at Red Deer but is not burned hard enough to develop the buff colour.

The yellowish joint clay (1664) is much denser, but developed good plasticity when worked up with 25 per cent water. The mixture thus made had an air shrinkage of 7·6 per cent and an average tensile strength of 268 pounds per square inch.

It behaved as follows in burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·55	18·21	Light red
03	3·4	13·22	"

The clay burns to a good body, but is not liked as well as the overlying bed because of its higher shrinkage. It made a nice dry press bricklet at cone 05, but should be burned to cone 03, at which temperature it is almost steel hard, and has an absorption of 18·21 per cent.

At both yards they are making common soft-mud bricks, which are dried in part on pallet racks, and in part in steam heated dryers. The burning is done in scove kilns, and there is practically no shrinkage. The layers of tough clay are not always thoroughly broken up in the pug-mill and may cause cracking in drying.

Edmonton, Alta.—Two types of Pleistocene clay occur at this locality, viz.: (1) flood-plain clays underlying the flat terrace bordering the Saskatchewan river (Plate X); and, (2) glacial clays, underlying the upper level terrace (Fig. 4.) on which Stratchcona and Edmonton stand. The former are mostly used.

Flood-plain Clays.—This material, which is used by all four of the brickyards in operation at Edmonton, consists of alternating layers of sandy, silty clay, and occasional pockets of gravel, in other words, a typical flood-plain deposit (Plate XI). So sandy is the material that one is surprised to see it being used for brick manufacture. Nevertheless it is employed for both common soft-mud, and dry-press face brick, the latter made from the less sandy portions of the deposit.

The thickness of these flood-plain clays cannot be exactly stated, but excavations at the brickyards show a maximum of not less than 9 or 10 feet, although in one pit bottom was struck at about 7 feet. The supply unfortunately is sufficient to last for some time. We say this because the clay does not make a very good brick, and a city the size of Edmonton should be constructed of better material.

The tests given below bring out well the character of the run of bank, and less sandy layers. The samples tested were taken from the pit of the Edmonton Brick Company.

Run of Bank (1653) Edmonton Brick Co., Edmonton, Alta.—This is a plastic, very gritty, calcareous clay, which worked up with 20 per cent water, and had an average air shrinkage of 5·6 per cent. Its average tensile strength was 212 pounds per square inch.

The clay burned to a light red at cone 03, and brownish at cone 1. The other fire tests were as follows:—

Cone.	Fire shrinkage.	Absorption.	
	%	%	
010	Slightly swelled	21·75	
03	"	17·84	
1	4·0	1·75	
2	Fused		

The clay did not burn to a very hard dense brick, owing to its highly silty character, and is not steel hard at cone 03.

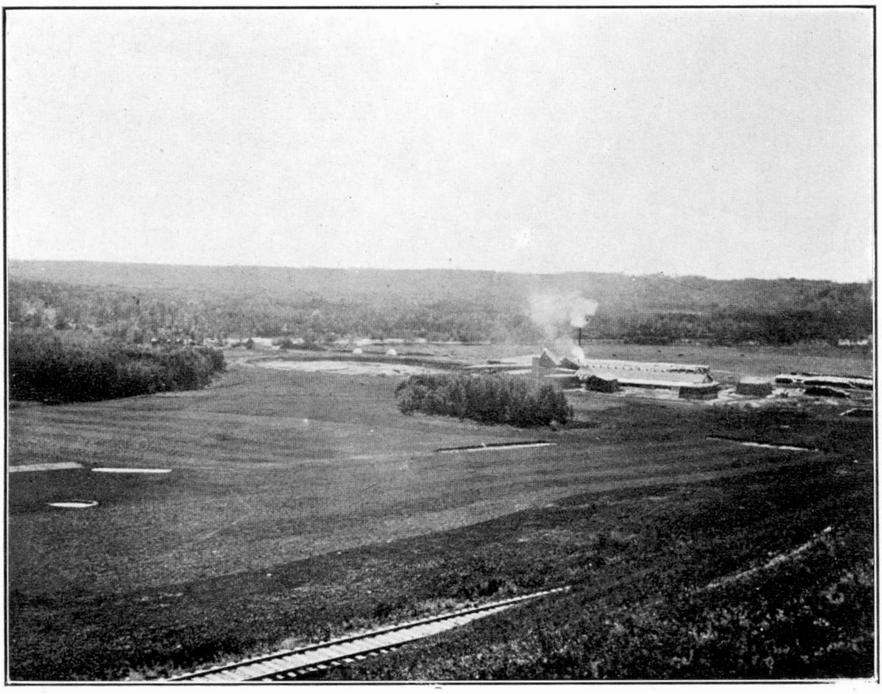
The more clayey portions of the bank (1654) are used for dry-press brick, and when wet-moulded behaved somewhat differently.

Water required for mixing 25 per cent; average tensile strength over 200 pounds per square inch; air shrinkage, 8 per cent.

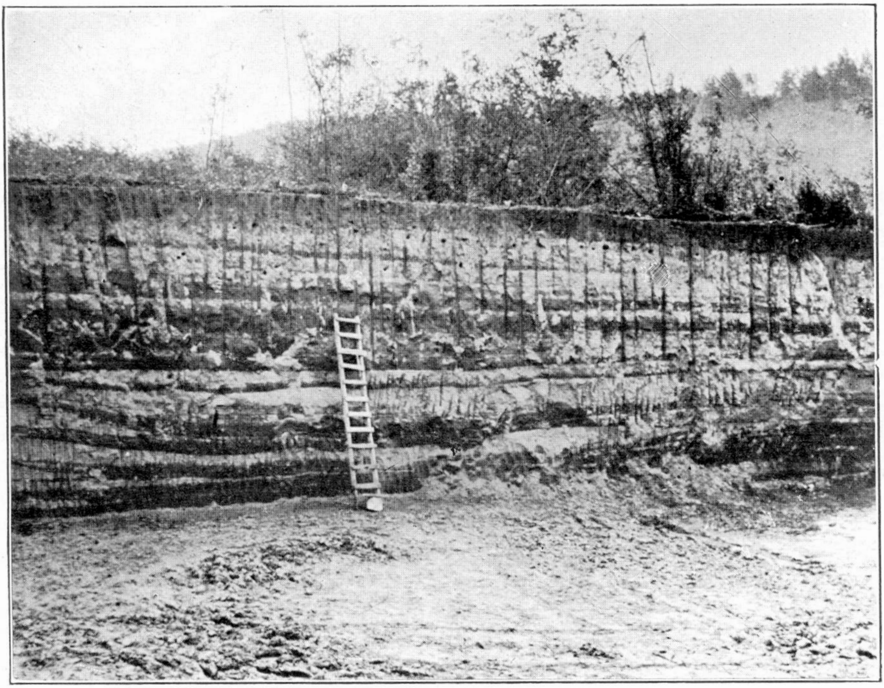
Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	18·96	Red
03	5·3	5·94	Dark red
1	Beyond vitrification		

This clay, it will be seen, showed higher air shrinkage than the run of bank, is slightly denser at cone 010, and much more so at cone 03, but it does not stand as much heat as the former. It burned to a good hard body at cone 010, but unfortunately there is not enough of this clay to permit its exclusive use for common brick. It is also claimed that it is impossible to run it through a stiff-mud machine, and produce a ware that does not air or fire crack. Its exclusive use is for dry-press brick.

A dry-press bricklet at cone 03 had 7·76 per cent absorption.



Brick plant of the Edmonton Brick Co., on flood-plain of Saskatchewan river.



Section of flood-plain deposits, consisting of sand, silt, and clay, in pit worked by the Anderson Brick Co., Edmonton, Alta.

Glacial Clays.—Underlying the surface of the upper terrace there is a deposit of plastic clay, evidently of considerable extent and far better quality than the flood-plain material. The main objection that a practical man would probably urge against it would be its high air shrinkage and toughness, but these could probably be overcome by the incorporation of some more sandy clay.

At the time of our visit a good section of this clay was exposed in a deep trench on the University grounds near Strathcona. Only a small sample was collected, and this did not include about 2 feet of somewhat sandy clay immediately under the surface. The sample collected (1659) was a very plastic, sticky, but smooth clay which worked up with 34 per cent of water, and had an average air shrinkage of 8·9 per cent. The latter is high and in practice some sand would have to be added to the clay.

In burning the results given below were obtained:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·45	13·84	Light red
03	4·3	4·60	Red
5	Fused		

The clay burned to a good body of excellent colour, and was steel hard at cone 010. Its fire shrinkage was not excessive, but it is not vitrified at cone 03.

A dry-press bricklet made of this clay had an absorption of 13·3 per cent at cone 05.

Another deposit (1655), of the same type of clay, was obtained from N. E. corner, section 15, township 53, range 25 W. This is about three miles north of Edmonton. This clay belongs to the same formation as 1659. It worked up with 25 per cent of water to a very smooth, plastic mass, whose average air shrinkage was 8·2 per cent and average tensile strength 335 pounds per square inch. The air shrinkage is somewhat high, but the addition of 25 per cent sand causes a considerable reduction in it.

For purposes of comparison we give below the fire tests made on: (A) wet-moulded bricklets of the clay alone, and (B), a wet-moulded bricklet of the clay with 25 per cent sand added.

	A	B
Air shrinkage	8·2	6·5
CONE 010—		
Fire shrinkage	0·15	0
Absorption	16·63	14·68
Colour	Light red	Light red
CONE 03—		
Fire shrinkage	2·4	2·3
Absorption	11·02	8·85
Colour	Red	Red
CONE 1—		
Fire shrinkage	Beyond vitrification	3·3
Absorption	......	1·5
Colour	......	Brown
CONE 5	Fused	......

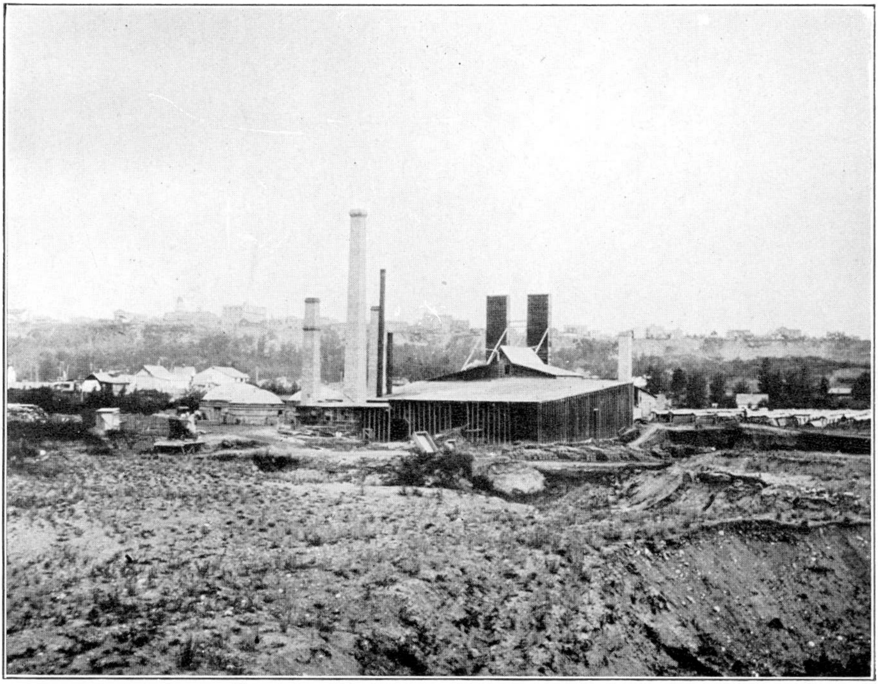
They were both steel hard, and of good red colour at cone 010. The addition of the sand gave lower air and fire shrinkage and also reduced the absorption.

A dry-press bricklet made from the clay alone burned to a nice colour and body at cone 05, but should preferably be burned to cone 03. At the former cone its absorption was 17·42 per cent and at the latter 10·36 per cent as well as being steel hard.

This clay, also, is better than that used for common brick by the yards at Edmonton. It might be used for lining sewers if burned hard enough.

The clay used by the Acme brick works, situated about half a mile north of the last named locality, is probably of the same quality. Owing to the limited time at our disposal this yard was not visited.

Edmonton Brick Industry.—The firms engaged in the manufacture of brick here are Edmonton Brick Company, Ltd. (Plate X), J. B. Little, Peter Anderson (Plate XII), and Pollard Brothers. All these yards make a common brick either by the stiff-mud or soft-mud process. At the yard of the Edmonton Brick Company the stiff-mud brick are made from a mixture of tough silty clay and sand, a mixture which naturally tends to make the product very porous. They claim, however, that the clay alone will not flow through the die. Anderson uses a very



Brickworks of the Anderson Brick Co., Edmonton, Alta.

sandy clay for his stiff-mud brick. For dry-press brick he selects the more clayey portion of his deposit, runs it through a stiff-mud machine, sets the brick aside to dry, grinds them up with some moist clay and presses this mixture in a dry press.

Much trouble is experienced with the brick cracking in air drying, and this has to be carried on very slowly. Scove kilns are commonly used for burning, but at Anderson's yard some down-draft kilns are also employed. The local lignites are utilized for fuel.

The product made from the flood-plain clays occurring here is naturally very porous, from the nature of the material used. The market is chiefly a local one.

Riverside, Calgary, Alta.—The sample (1744) from this locality was sent in for testing and appears to be a boulder clay. It worked up with 19·4 per cent water to a gritty mass of good plasticity. The air shrinkage was 6·9 per cent.

In burning it gave:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·2	11·65	Red
03	4·4	3·12	"
1	2·4	1·45	Brown
5	Fused		

This makes a good hard brick, but the numerous pebbles are somewhat troublesome, and the clay should be well crushed before moulding.

Lethbridge, Alta.—In discussing the Belly River shales at Lethbridge, reference was made to the heavy mantle of silty clays (Plate XX) which cover them. This material, so widespread in this region, can hardly be regarded as an ideal brick material because of its sandy nature, but since there is nothing better in the immediate vicinity, it is employed for brick making. That worked by the Brick and Terra Cotta Company (Plate XIII) at Lethbridge is a very gritty, calcareous clay (1667), with numerous lime pebbles.

It worked up with 19 per cent of water, to a mass of sufficient plasticity to mould, the average air shrinkage of which was 4 per cent.

Wet-moulded bricklets gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	.....	Light red
03	0	13·58	" "

No absorption test was made at cone 010 as the clay was very porous and cracked by the air slaking of the lime pebbles. It was not steel hard at cone 03. This is not a very desirable clay to use and makes a rather porous soft brick.

Pincher, Alta.—Here, too, a surface clay (Plate XIV) is employed for common brick, but it is less silty, and more plastic than the Lethbridge material. Like the latter, however, it is very calcareous, and contains scattered lime pebbles. The clay also has a considerable amount of soluble salts which form a scum on the surface in drying.

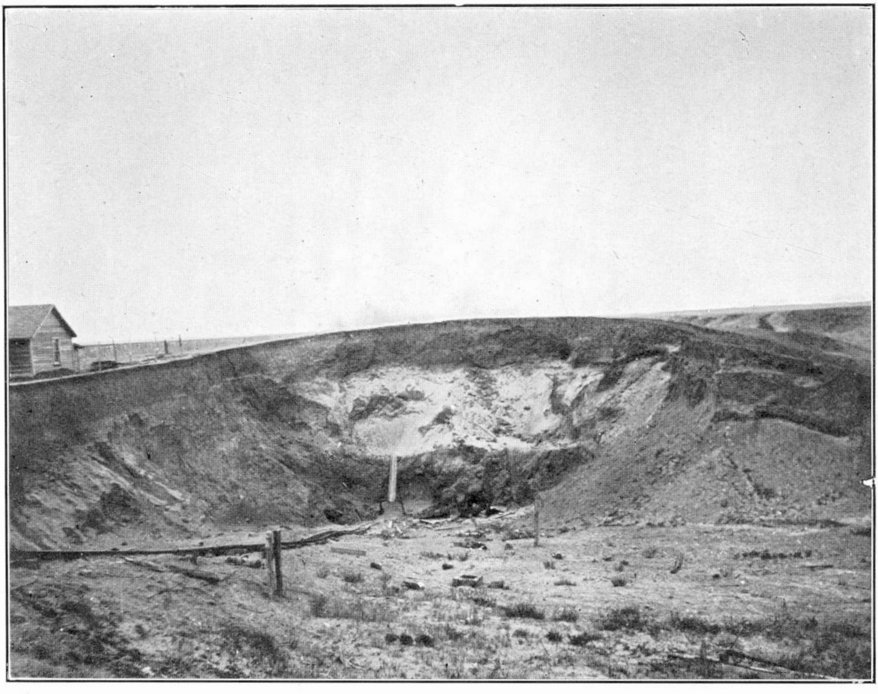
The clay (1673) worked up with 29 per cent of water to a very plastic but tough mass with much fine grit.

Its air shrinkage was 8·8 per cent, and the average tensile strength above 250 pounds per square inch, but it was hard to get briquettes free from flaws.

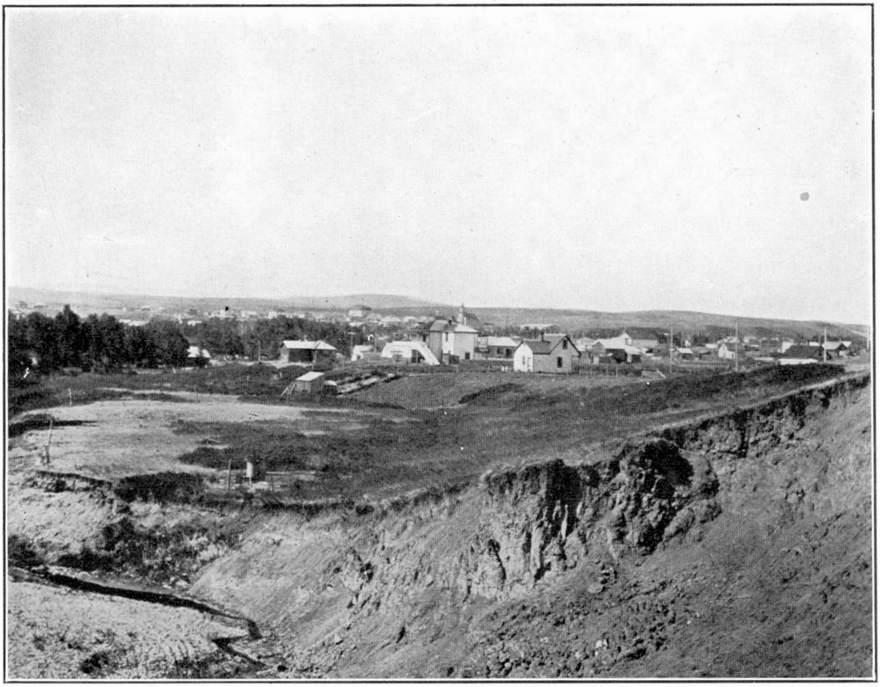
Burning tests yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·3	11·68	Light red
03	3·7	1·54	Red
1	Fused		

This is not a very desirable clay for several reasons. The scum of soluble salts is objectionable, the clay cracks at cone 03,



Clay deposit of Lethbridge Brick and Terra Cotta Co., Lethbridge, Alta.



Pincher, Alta.: surface clay pit in foreground.

Surface clay pit at Cochrane, Alta.

and the lime pebbles also cause cracking after burning. Moreover, the material is so very tough and sticky, that when worked on an auger machine it develops serious laminations. Owing to its toughness and stickiness, it would be difficult to mix sand with it.

A dry-press bricklet burned at cone 05 gave a good red colour, but it was cracked and porous.

It is noticeable, however, that there is some variation in the surface clays of the Plains region, and thus about seven miles west of Pincher there is surface clay (1674) which is considerably better than the brick clay worked at Pincher. It is also calcareous, but works much better, and with 25 per cent of water makes a very plastic mass, whose air shrinkage was 6·5 per cent. There was much less white wash on this clay than on 1673.

At cone 010, its fire shrinkage was 0·65 per cent and absorption 18·02 per cent. At cone 03 it showed 0 per cent fire shrinkage, and absorbed 16·90 per cent water. It burned red.

Cochrane, Alta.—The Bow River valley at Cochrane is bordered by a flat terrace on which the town lies. Underlying this terrace is a silty, laminated, hard clay (Plate XV), of strongly calcareous character, and not requiring the addition of any sand for brick making.

As this was evidently about the only use to which it could be put, no attempt was made to test it in detail, but a few physical tests of the clay (1710) may be of interest.

It worked up with 26 per cent of water to a very plastic, smooth mass, whose air shrinkage was 7·9 per cent. The latter was evidently somewhat higher than that obtained in actual practice.

In burning at cone 010 the fire shrinkage and absorption were respectively 0·5 per cent and 21·98 per cent; while at cone 03 they were 0·3 per cent and 20·96 per cent. It fused at cone 1. Like all strongly calcareous clays it burns buff.

Three common brickyards are in operation, and most of the product is shipped to Calgary.

CHAPTER II.

Shale Formations

Cretaceous Shales

Shales of Cretaceous age and lower than the Laramie, which cannot be classed as wholly Cretaceous, are worked only in Manitoba. In that Province they extend from the Pembina river at the International Boundary northwestward along the base of the Pembina, Riding, Duck, and Porcupine mountains. In Manitoba this system contains the following members in ascending order: Dakota, Benton, Niobrara, Pierre.

The Dakota or lowest member of the Cretaceous, resting uncomformably on Devonian limestone, is composed of soft white or reddish sandstones, which are commonly interbanded with thin beds of shale. It occurs along the foot of the northern portion of the Manitoba escarpment, and appears to be exposed chiefly on the cut banks of streams, one of the best outcrops being on the Swan river some miles below the Canadian Northern Railway crossing.

At this point Mr. Tyrrell[1] reports a 12 foot bed of hard grey shale in which some lignite was embedded; the overburden however, is excessive. The Dakota sandstones are known to contain highly refractory interbedded shales in some localities, such as Colorado.

The Benton which overlies the Dakota is made up of very dark-grey carbonaceous shales. This shale is evenly bedded and breaks down readily into small flakes. It is said to be 178 feet thick, and occurs along the foot of Duck and Riding mountains. The Benton and Dakota shales were not examined, partly for the reason that they are at present more or less inaccessible, and no test of their qualities is on record.

The Niobrara formation conformably overlies, and is an upward extension of the Benton. It is composed mostly of grey calcareous shale, but towards the top of the formation a band of greyish chalky limestone is generally met with, this band being often highly charged with pyrite. Very characteristic exposures of these shales may be seen in the valleys of all the streams on

[1]Tyrrell, J. B., Northwestern Manitoba, Geological Survey, Canada, 1892.

the north side of Riding mountain, from the Ochre to the Valley rivers. In the southern part of the Province they may be seen on the Carman-Hartney section of the Canadian Northern railway between Leary and Cardinal, and on the Pembina river near the International Boundary. The shales of the Niobrara formation are used for brickmaking only at one locality, viz., Leary, Man.

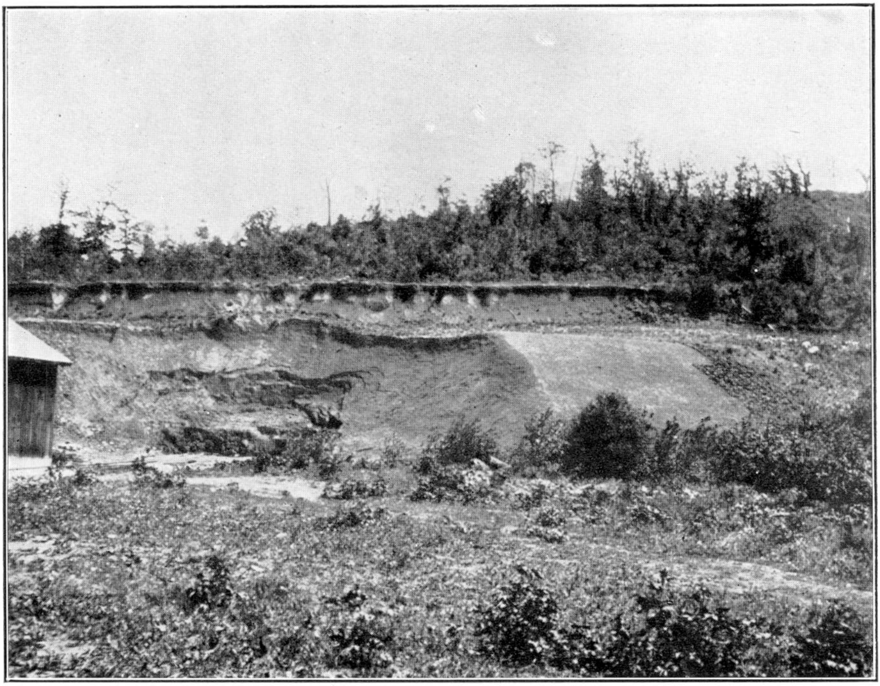
The following table taken from Dowling's report gives the subdivisions of the Cretaceous and also Tertiary formations in the Great Plains region.

	Groups	Alberta	Saskatchewan	Manitoba	Kind of Rocks.
Tertiary...	Miocene... Eocene	Miocene..... Paskapoo	Miocene.......	....	Conglomerates and sandy clays.
		Edmonton.	Laramie.	Laramie.	Sandstones and clays.
	Montana.	Bearpaw. Belly River Claggett. Eagle.	Pierre-Foxhill. Belly River	Pierre	Sandstones and clays. Shales. Sandstones. Shales. Sandstones.
Cretaceous	Colorado.	Niobrara. Cardium. Benton.		Niobrara. Benton.	Calcareous shales. Shales.
	Dakota.	Dakota.		Dakota.	Sandstones.
	Kootanie.	Kootanie.			Sandstones and shales.

NIOBRARA SHALE.

Leary, Man.—The general relations of the Niobrara shales have been referred to on page 46. The only locality from which a sample was collected was Leary.

This station lies on the Canadian Northern railway south-east of Winnipeg, and represents the only locality at which the Niobrara shales are utilized. They are well seen here as a bank has been opened at the base of a wooded hill (Plate XVI) exposing about 30 feet of shale, capped with 6 feet of calcareous loam. This forms the first bench of the hill, to whose top the shale continues.



Bank of decomposed Niobrara shale, used for dry-press bricks, Leary, Man.

Scattered through the shale are flakes of gypsum and concretions, some of the latter 2 to 3 feet in diameter and 1 foot thick.

A sample (1636) representing the run of the bank gave the following results on testing:—

It mixed up with 32 per cent of water to a very plastic, sticky mass, that was hard to work, whose average air shrinkage was 9·2 per cent, and average tensile strength 349 pounds per square inch. Both these figures are high. It is doubtful whether this would stand rapid drying.

Wet-moulded bricklets gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·65	15·21	Light red
03	9·6	0·21	Reddish brown
1	Beyond vitrification.		

The clay was almost steel hard at 010, but cracked slightly at cone 03. Its high shrinkage would, however, prevent its being moulded either soft-mud or stiff-mud.

The shale can be ground and dry-pressed with good results, and yields a very fair brick even at cone 05. It should be burned to cone 03, if only to get a stronger red.

In burning the large dry-pressed brick, the firing was carried on slowly to prevent cracking and black coring.

The clay contains both gypsum and pebbles, and the latter if not ground fine enough cause trouble.

The following chemical analysis of a sample of shale from the Leary pit, collected in 1904, by J. Walter Wells, was made by Mr. M. F. Connor, of the Mines Branch, Department of Mines:—

Silica (SiO_2)	20·67
Alumina (Al_2O_3)	8·70
Ferric oxide (Fe_2O_3)	3·14
Lime (CaO)	33·23
Magnesia (MgO)	0·50
Alkalies (Na_2O, K_2O)	1·20
Sulphur trioxide (SO_3)	0·49
Organic matter	0·63
Carbon dioxide (CO_2) Combined water (H_2O)	28·77
Moisture	2·30

This analysis can hardly represent the composition of the clay now being worked, unless the lime indicated was present in a concretion, for any clay containing so much lime could not, if the latter was evenly distributed, fail to burn buff.

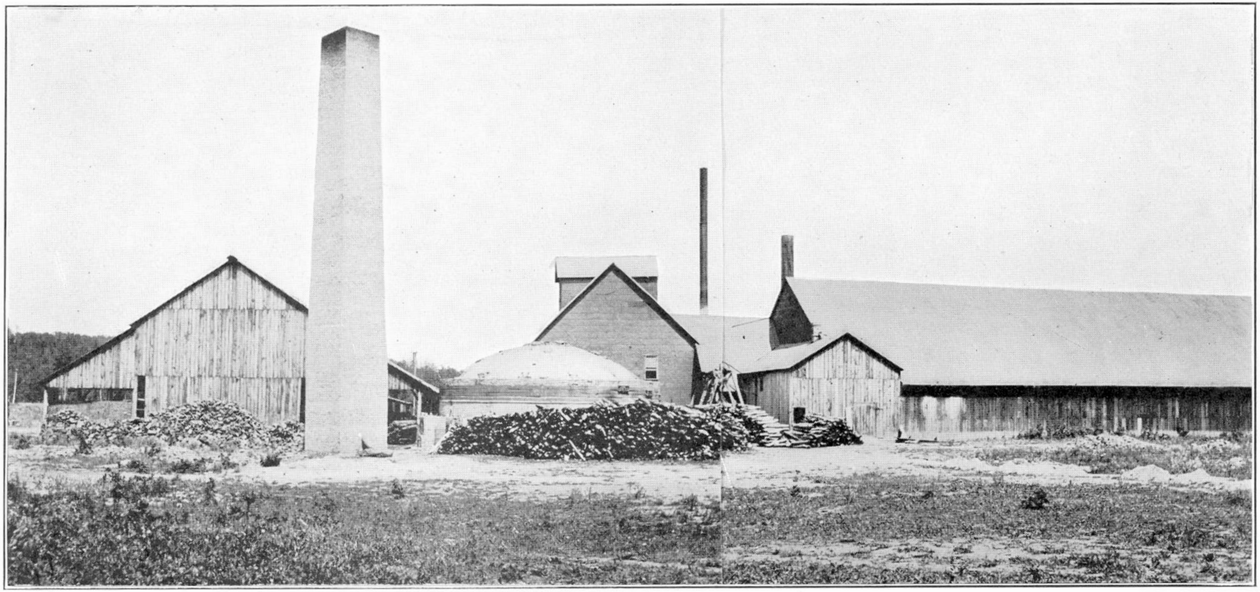
Leary Brick Company.—The Niobrara shale is here used for the manufacture of dry-pressed brick (Plate XVII). The shale is quarried from the bank, loaded on to a tram car and run into a storage shed. When needed for use, it is put through a short cylindrical dryer heated by wood, in order to dry out some of the moisture, but the treatment here is overdone and so some water is sprinkled on the shale before it is shovelled into the dry pan. The clay, which is moulded in a dry-press, and burned in a down-draft kiln, is quite carbonaceous and has to be water-smoked and burned very slowly. Moreover, if the oxidation period is not continued sufficiently long after the carbon is burned off, the colour of the brick is not a good bright red.

PIERRE SHALES.

The Pierre formation, which is composed almost wholly of shales, occupies the summits of all the higher land in the western portion of the Province of Manitoba. It has a total thickness of about 800 feet.

The upper portion of the Pierre contains a considerable thickness of hard, light grey, fine-grained shale, the lower portion being made up of softer dark grey shale, which contains crystals of selenite, or crystalline gypsum, and nodules of clay-ironstone. These shales were originally sediments, fine-grained enough to permit being carried by water, and deposited in marine basins, and no doubt they were buried beneath still later sediments. Subsequent uplift of the land has brought them to the surface and overlying deposits have been removed by erosion. The original soft sediments became transformed into hard shale, having a slaty appearance, and have for the greater part lost their original plasticity during the process of hardening, so that if they are finely ground and mixed with water, they cannot be moulded into shapes. All hard shales, however, do not behave so, for those found in many localities become quite plastic when ground and wetted.

p. 48



Pressed brick plant at Leary, Man.

There are some instances, however, where considerable portions of shale beds have become weathered into residual clay, and these portions while preserving their originally shaly structure are quite soft and plastic, so that they can be moulded into any of the forms that structural clay wares generally take.

This weathering appears to go on if the shale bed becomes permanently saturated with water. If the shales be overlain by a porous mantle of soil, sand, and gravel, the surface water will percolate through to the underlying shale. There it may accumulate in the shale, and perhaps disintegrate it to a certain depth. Wells which are sunk in lands of this character receive no water supply until the shales are reached.

Where streams have cut through shales, the lower part of the deposit, near the stream bed, is often found to be disintegrated, due to the presence of permanent ground water, but the soft shale regains a certain amount of hardness on drying.

The Pierre shales are found outcropping at numerous points in the Province, and samples for testing were collected at a few localities where they could be easily mined, and were convenient to transportation. The samples were taken sufficiently far apart to give general information about the character of the formation as a whole.

No chemical analyses were made for this report, but the following from a published source [1] may be given.

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[1]Industrial value of the clays and shales of Manitoba. J. Walter Wells, Ottawa, Canada, 1905.

CHEMICAL ANALYSES OF PIERRE SHALES FROM MANITOBA.

	1	2	3
Moisture / Combined water } above 100° C.	6·06	6·78	8·25
Silica (SiO_2)	79·55	81·94	78·32
Alumina (Al_2O_3)	8·35	6·52	7·11
Ferric oxide (Fe_2O_3)	1·90	2·40	2·59
Lime (CaO)	1·50	0·80	0·91
Magnesia (MgO)	1·02	0·93	1·28
Alkalies (Na_2O, K_2O)	1·17	1·30	1·11
Sulphur trioxide (SO_3)	....	0·16	0·05
Carbon dioxide (CO_2)	....	Traces	Traces
Organic matter, etc	....	Traces	0·29

(1) Compact, light, bluish-grey, tough, smooth shale from Souris river, near Souris. Analyst, F. G. Wait, Department of Mines.

(2) Compact, light grey, fissile shale, from south bank of Big creek, northwest corner of section 8, township 17, range 15, west. Analyst, M. F. Connor, Department of Mines.

(3) From bank of Assiniboine river, four miles east of Virden. Similar to No. 2. Analyst, M. F. Connor.

4

Birnie, Man.—Streams issuing from the eastward facing escarpment of Riding mountain have cut down through a considerable thickness of Pierre shale. The Canadian Northern railway between Neepawa and Dauphin is located on the terrace bordering the escarpment and approaches it closely at Birnie station. A sample was collected on the north bank of Big creek at a point two miles west of Birnie station.

The shale here is exposed in banks over 100 feet in height. It is generally uniform in character, light grey in colour, and contains bands of ironstone. The beds are much fissured, the fissures being coated with films of iron rust.

The upper 30 feet of the deposit was sampled, but none of the ironstone nodules were included, as these could be thrown aside in mining. The deposit is easily accessible for working and there is no overburden. The shale could be broken down into cars and run down grade on a tramway to the railway line. The tests on this sample of unweathered shale (1623) are as follows:—

It worked up with 37 per cent of water to a feebly plastic mass, whose average air shrinkage was 4·9 per cent. The average tensile strength was 113 pounds per square inch. No test was made to determine the rapid drying qualities.

Wet-moulded bricklets behaved as below in the kiln tests:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	2·45	28·73	Light red
03	4·00	24·45	" "
1	5·00	19·50	Red
3	6·40	16·00	Brown

The clay does not show excessive fire shrinkage, but burns to a very porous body, and yet the bricklets have a good ring even at cone 010. It is not steel hard at cone 1, and, judging from tests made on a similar material from another locality, it may stand cone 5. To yield the best results this shale should be weathered before using, but this would be a rather long operation, as the shale seems to slake down very slowly under the weather.

About two miles north of the last locality, on section 28, township 17, range XV, on the property of Ernest Ames, the Pierre shales are exposed along a small creek in banks about 40 feet high. The lower portion of the shale here is quite decomposed and soft, but the greater part of the bank above this is composed of hard material. The sample was collected principally from the decomposed portion of the deposit. There is a rather heavy overburden of sand and gravel at this point.

The laboratory tests are as follows:—

The sample (1625) represents a mixture of fresh and partly weathered shale. It worked up with 40 per cent of water to a mass of good plasticity, but was rather stiff and hard to work. Its average air shrinkage was 5·6 per cent.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·65	23·16	Light red
03	3·70	17·26	Dark red
1	5·7	10·40	"
5	10·4	4·42	Brown

The clay burned to a good body, of excellent colour, and was nearly steel hard at cone 03. Its absorption at this cone is a little high, but not excessive.

At cone 5 it has a vitreous, slightly rough surface, and bluish sheen, which produces a rather artistic effect.

The fracture of the brick at this cone shows a number of buff specks, which indicates that certain portions of the deposit burn to a different colour, but whether these represent a separate bed or not, is unknown. If they do, this portion of the deposit might be worked separately if it is thick enough.

Comparison of this sample with the one from Big creek shows that the latter, which is unweathered, has a lower fire shrinkage and higher absorption.

Souris, Man.—There is an abundance of Pierre shales in the neighbourhood of the town of Souris, and they are exposed in great thickness on the banks of the Souris river. A sample was obtained on the south bank of the river at a point about one and a half miles southeast of the town. The shale is here covered with about 4 feet of boulder clay and black soil, and is decomposed and soft for a depth of about 10 feet below the boulder clay, but the lower portion is hard, and the whole mass is fairly free from ironstone nodules.

The banks on the opposite side of the river at this point are much lower and formed of hard shales in which ironstone is rather frequent.

The sample collected (1632) gave the following results, the tests being made on a mixture of equal parts of fresh and weathered shale, as the former is only feebly, the latter strongly plastic. The mixture worked up with 42·2 per cent of water to excellent plasticity, but was rather hard to work. The average air shrinkage was 6 per cent, and the average tensile strength 120 pounds per square inch. This is not high, but entirely sufficient.

Burning tests yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·85	32·81	Light red
03	3·0	27·45	Red
1	7·3	15·32	Brown
5	7·7	12·30	"
9	Vitrified		

This gave a very porous body up to cone 03, but above that the absorption was not high. The bricklet, in spite of its high absorption, has a good ring at cone 010, but did not become steel hard until cone 1. It was vitrified at cone 9, and represents one of the most refractory Pierre shales tested. The material could be used for common brick, but the good plasticity and porous character of the burned clay suggests the possibility of using it for fireproofing.

The shale gave good results on dry pressing, burning to a red and buff speckled product. The bricklet had a fair ring at cone 03, but should be burned to cone 1. At the latter cone it was not quite steel hard, and still had an absorption of 20 per cent.

Virden, Man.—The escarpment along the north side of the valley of the Assiniboine river between Virden and Oak Lake is formed of Pierre shale. A section of over 100 feet is exposed in places, showing a uniform light-grey hard shale, which breaks up into slaty fragments, but there are a few thin seams of soft decomposed shale.

A sample was collected on the roadside near the bridge, about four miles east of Virden, which represents the upper 25 feet of the section. There is little or no overburden in the vicinity. The lower slopes of the escarpments and the river flats contain beds of plastic surface clay, much of which has been derived from the weathering of the shales.

Continuous heavy deposits of drift occur between the river and the Canadian Pacific railway at Virden, and no shale exposures are found in that area.

The results of tests made on the Assiniboine shale (1634) are as follows:—

Like the fresh Pierre shale from other localities, this is only slightly plastic. It worked up with 37 per cent of water, but its air shrinkage was only 2·8 per cent. It was not sufficiently plastic to make good briquettes.

Burning tests yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·5	35·59	Light red
03	1·3	33·33	" "
1	3·4	29·61	Red
5	5·7	23·37	Red brown

Although this clay burned to a good colour, it is not very promising material, on account of its low plasticity and high absorption after burning. If some plastic clay could be found near at hand to mix with it, better results might be obtained. It gives a nice coloured dry-press brick, but for this purpose should be burned to cone 1.

Acting on the above idea, a mixture (1633 A) was made of 50 per cent of 1634 and 50 per cent Virden surface clay.

This mixture worked up with 36 per cent water to a mass of medium plasticity, with 4·2 per cent air shrinkage, but a full sized brick would not stand rapid drying.

The burning tests show the effect of the surface clay in a reducing of the absorption.

Cone.	Fire shrinkage.	Absorption.	Colour.
		%	
010	0·7	27·45	Light red
03	0·7	27·45	Red
1	7·0	7·17	Dark red
3	8·6	4·82	" "

The bricklets at cone 03 had a good ring, and were very hard at cone 1. The mixture at cone 1 had a lower fire shrinkage than 1633, and a higher one than 1644. The other properties were intermediate between 1633 and 1634. It makes a good dry-press bricklet at cone 03. It might also do for partition tile.

A mixture of three parts surface clay to one part shale (1633B) was also prepared. This mixture worked well when wet, and had an air shrinkage of 4·3 per cent when dried.

In burning it behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·7	26·00	Light red
03	0·7	25·00	" "
1	10·3	0·32	Light brown

In general the addition of Pierre shale to surface clay causes it to dry quicker and overcomes the tendency towards checking in drying and reduces the air shrinkage. When clay is used alone the bricks soften and become deformed at a temperature slightly above that of cone 1, but the addition of shale helps to prolong the vitrification stage and prevent the sudden melting peculiar to calcareous clays, making it possible to produce a ware having a dense body, which is difficult to obtain if clay alone is used. In other words, the shale acts as a "stiffener" to the clay.

The effect of heat on the surface clay (1633) is shown graphically in Fig. 9. The sudden drop in the absorption curve beyond cone 03 and a corresponding increase in fire shrinkage indicates that vitrification proceeds very fast, and is completed at cone 1. It is generally unsafe to heat such a clay to a point of vitrification, as rapid softening is liable to occur also.

In Fig. 10, the curves for Pierre shale (1632) from Souris show a high fire shrinkage at cone 1, but the value for absorption is still great at that cone, showing that vitrification has not been reached.

Pembina Mountains, Man.—There are many artificial and natural sections of the Pierre shales along the line of the Canadian Northern railway as it crosses the Pembina mountains, between Leary Siding and Greenway, but a portion of the shales on the eastern escarpment may belong to the underlying Niobrara member.

Somerset, Man.—In the vicinity of the village of Somerset, the shales occur at varying depths below the surface, and are generally reached when sinking wells. A small sample of shale collected at this point had a total shrinkage of 10·0 per cent at cone 1, and absorption of 19 per cent. It burned to a light-red colour and was steel hard. It was the characteristic light weight, porous brick usually produced from these shales. A mixture of equal parts of shale and local surface clay was tried, but as the latter contained too great a proportion of lime pebbles, the test was discarded.

Ninette, Man.—In the valley of Pelican lake, near Ninette, twenty-eight miles west of Greenway, the escarpments on each side of the valley are formed of typical Pierre shales. No weathered shale was found at this point, the beds being of the usual hard variety, and traversed by many iron-stained fissures. When finely ground and mixed with water, these shales had no plasticity whatever and could not be moulded into shapes for testing. A mixture (1635) of Pierre shale with a very plastic, easily fusible clay, from the Red River valley, was tried with the following results.

This mixture consisted of 75 per cent Winnipeg underclay and 25 per cent Pierre shale from the escarpment east of Ninette, Man.

It worked up with 37 per cent water to a plastic, though sticky mass, whose average air shrinkage was 5·8 per cent.

Burning tests gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	2	23·18	Light red
03	3	16·73	Red
1	5·4	13·75	Brown

The addition of even so much surface clay, did not materially increase the fire shrinkage, or decrease the absorption. At cone 010 the brick was hard with a good ring, and steel hard at cone 03. The colour at the latter cone was deeper, but not too dark for marketable purposes. At cone 1 the clay bond had fused, but the shale still held up the absorption. This mixture is good for brick and might do for fireproofing.

Irvine, Alta.—In the hills (Plate XVIII) forming the south side of the valley at Irvine, a number of natural cuts and gullies expose a series of beds of clays, sands, and shales of Cretaceous (probably Pierre) age. They consist of alternating beds of gypsiferous clays, sands, and thinly laminated paper shales, the gypsiferous shales predominating in the upper half of the section and the sands in the lower, the whole series dipping southeast at a low angle.

Red gypsiferous shales form one bed at least 50 feet thick at the top of the section, and could be worked if necessary, and these are underlain by a bed of grey clay not less than 20 feet thick.

The grey clay (1697) is a very smooth, plastic, sticky clay, which cracked badly during air drying. It also cracks badly in burning, and although tending to burn to a red colour, is somewhat stained by soluble salts. The clay worked up with 36 per

Clay and shale deposits at Irvine, Alta.

cent of water, and gave an air shrinkage of 9·4 per cent. At cone 010 the fire shrinkage was 0·2 per cent and absorption 16·40 per cent; and at cone 03, fire shrinkage 2·3 per cent and absorption 6·85 per cent. This clay is hardly to be recommended for use by itself.

The red shale (1698) overlying the preceding is somewhat better, in that it did not crack as badly in drying and burning. It is very plastic and smooth; worked up with 36·6 per cent of water, and had an air shrinkage of 9·7 per cent, which is high.

In burning at cone 010, the fire shrinkage was 1·9 per cent, and absorption 18·30 per cent; at cone 03 it showed 6 per cent, fire shrinkage and 10·26 per cent absorption. The high shrinkage renders the clay undesirable.

If it became necessary to work these shales, the best results would be obtained by mixing in some of the sandy beds outcropping at the base of the hill. These, however, contain scattered thin layers or lenses of sandstone or cemented sand, which would have to be thrown out in the mining.

The basal beds of the section exposed at Irvine consist of a hard grey shale (1699), which outcrops on the flat between the base of the hill and the wagon road leading into town. It is also gypsiferous. This worked up with 33 per cent of water to a very plastic, sticky mass which checked badly in air drying, but one per cent of salt reduced this. The air shrinkage was very high, viz., 11·6 per cent. At cone 010 the fire shrinkage was 0·35 per cent and absorption 15·57 per cent; at cone 03, fire shrinkage 2 per cent, and absorption 10·48 per cent. A mixture of the three shales was tried for dry-press bricks, but owing to the poor results obtained these shales are not recommended for that purpose.

BELLY RIVER FORMATION.

Distribution.—The general distribution of the rocks of this formation is shown on the geological map, and while it will be seen to underlie a very large area, there is usually such a heavy mantle of Pleistocene material that outcrops are scarce. They are consequently to be sought for only in the deeper valleys although even there they may be discontinuous, partly because the surface of the bed-rock is very uneven (Plate XX), and the covering of later silts and clays may extend below the river level in places.

Where outcrops are lacking the character of the shales can, in some instances, be ascertained from coal mine workings or deep wells. Dowling,[1] in his report on the coal-fields of Manitoba, etc., refers, of course, only to exposures of coal, but since these have shales associated with them, it may be well to refer to the areas of outcrop noted by him. These coal beds are best exposed along the Belly river near Lethbridge. South of Lethbridge there are a few on the Milk Creek ridge, and on St. Mary river, about six miles above its mouth; and again along the Bow river, below the mouth of the Little Bow river.

At Stair, and for twenty-four miles below Medicine Hat, outcrops permit the tracing of a coal seam. He further mentions outcrops at the mouth of the Red Deer river.

The formation is also found on the north side of the valley near Irvine station, but to the eastward it either dips under the rocks of the plains or thins out.

To the westward of the area outlined on the map, the formation disappears beneath the trough which runs through McLeod northward past Calgary, but is said to reappear in several narrow bands in the foothills to the west of Calgary and in the Peace River country.

Dowling says, "In the strip which runs through the foothills large portions are not prospected, but for one area at least we have more details".

"This comprises the foothills south of the main line of the Canadian Pacific railway, as far as Highwood river. On the Stoney reserve, south of Morley station, there is a 6 foot seam in this formation."

Exposures of the formation are also referred to on Jumpingpound and Elbow rivers, and on the south branch of Sheep creek. Near Kananaskis station the Rocky Mountain outer range overrides these beds.

In the Peace River country[2] two areas of the Belly

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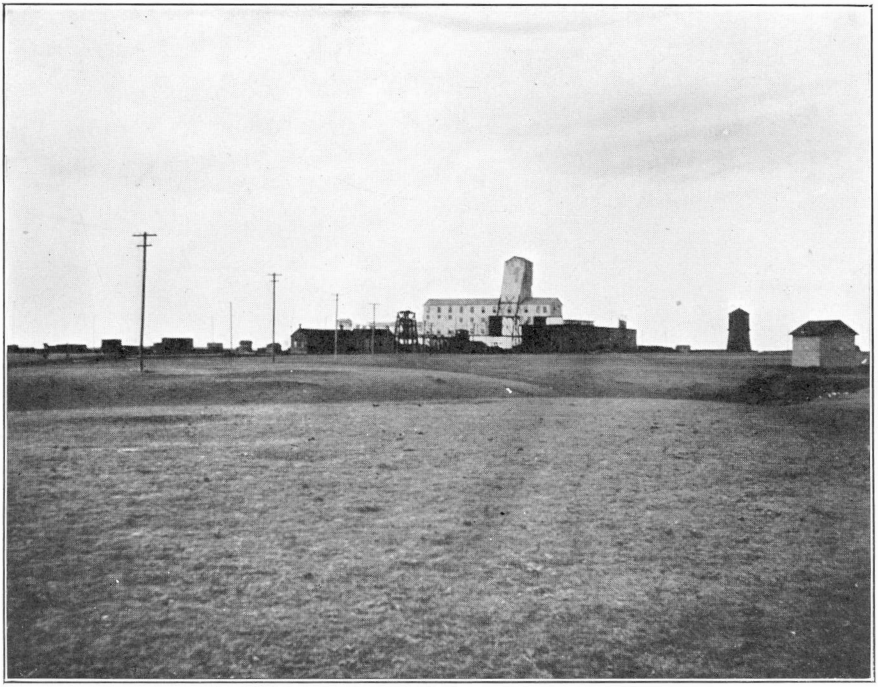
[1]Geol. Surv., Can., Paper No. 1035.

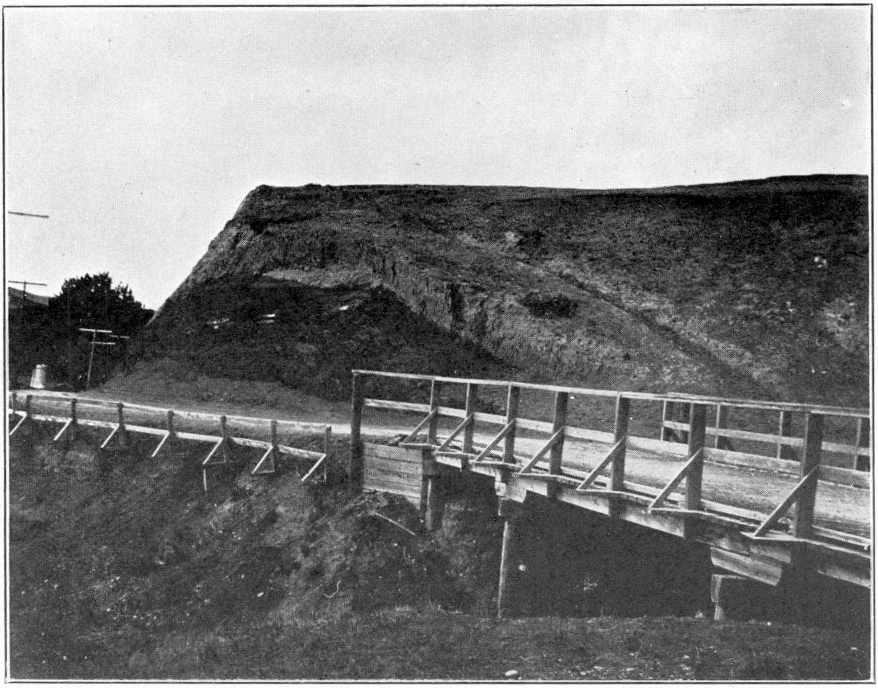
[2]Dowling, loc. cit. quotes from Report of Progress 1875-6, pp. 6, 53; Ibid, 1879-80,pp. 117, 119, 134-136 B; Report of Progress, 1882, 1884, pp. 25-39 M.

PLATE XIX.



The Lethbridge Coal Co., No. 6, Lethbridge, Alta.

p. 58



Bed of dark grey shale, overlain by drift, on roadside near highway bridge, Lethbridge, Alta.

River formation are known. One of these is in Alberta reaching up the Smoky river to the valley of Peace river, and one in British Columbia, near the Peace River cañon. The area over which the Belly River formation occurs is about 25,000 square miles.

In describing the different localities visited, we proceed from south to north.

Lethbridge, Alta.—A number of shale beds were penetrated in sinking the shafts of the Lethbridge Coal Company (Plate XIX) north of the town, but the materials passed through were all either very carbonaceous or gritty, and no samples were tested.

Along the Belly river at Lethbridge there are some outcrops of shale, but they are near the river level, and lie under a heavy overburden of Pleistocene silts and gravelly sands or till. One of these is a few feet south of the eastern end of the wagon bridge across the Belly river, and shows a shale (Plate XX) of most deceptive character. This material (1666), in its raw condition, appears to be carbonaceous and gritty, but mixes up to a very plastic mass with 25 per cent of water. The air shrinkage was 6·3 per cent.

Wet-moulded bricklets behaved as follows in burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·7	15·42	Light red
03	8·0	3·22	Dark red
1	Not vitrified	.....	Deep red
3	6·3	1·90	
5	Beyond vitrification		

These tests show low fire shrinkage to cone 05, but a noticeable increase at cone 03, at which point the absorption is quite low. It makes a good, nearly steel hard body at cone 010, and is not vitrified at cone 1.

A dry-press bricklet at cone 05 showed a good red colour, and was steel hard, with a very few surface cracks. At cone 03, it had 5·1 per cent absorption. This shale is well worth using, is easily accessible, and far superior to the surface clay used for making common brick at Lethbridge. The only objection to its use is a somewhat heavy overburden, but this could be easily removed.

Milk Creek.—Milk creek, a tributary of the Oldman river, lies southwest of Pincher. The road to the Beaver Creek valley crosses it about ten miles from Pincher, and at this point there are a number of exposures of shales and sandstones, some of the beds indicating very strong folding, and many showing a nearly vertical dip (Plates XXII and XXIII).

Just before reaching the bridge across Milk creek the thinly laminated shales outcropping on both sides of the stream contain considerable carbonaceous matter and sandstone layers. A somewhat plastic shale, however, outcrops under or close to the bridge over Milk creek, and is typical of several shale outcrops near there (Plate XXI).

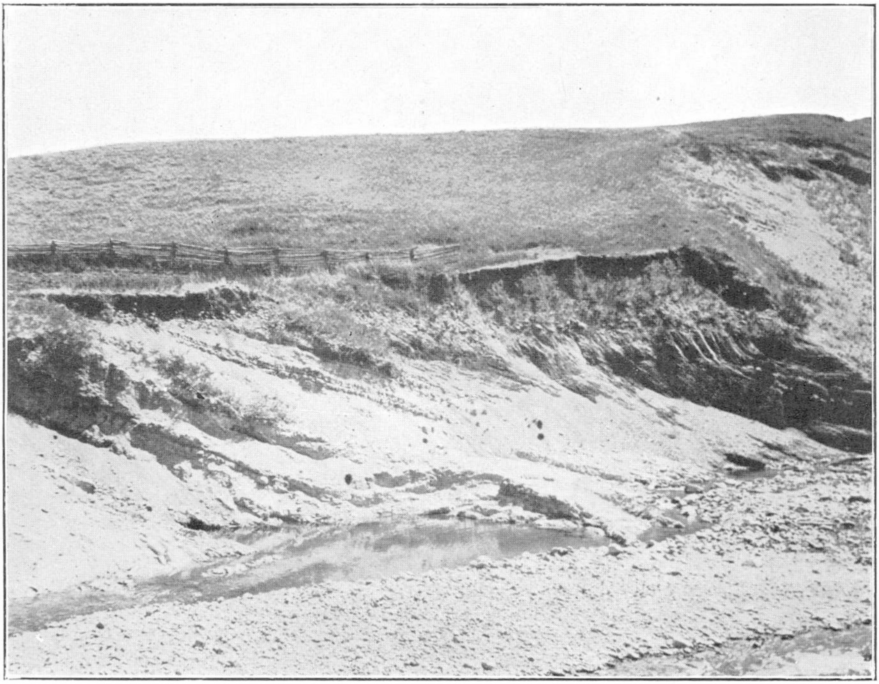
It (1668) worked up to a plastic but somewhat gritty mass, whose air shrinkage was 6·4 per cent.

The wet-moulded bricklets gave rather good results as follows:—

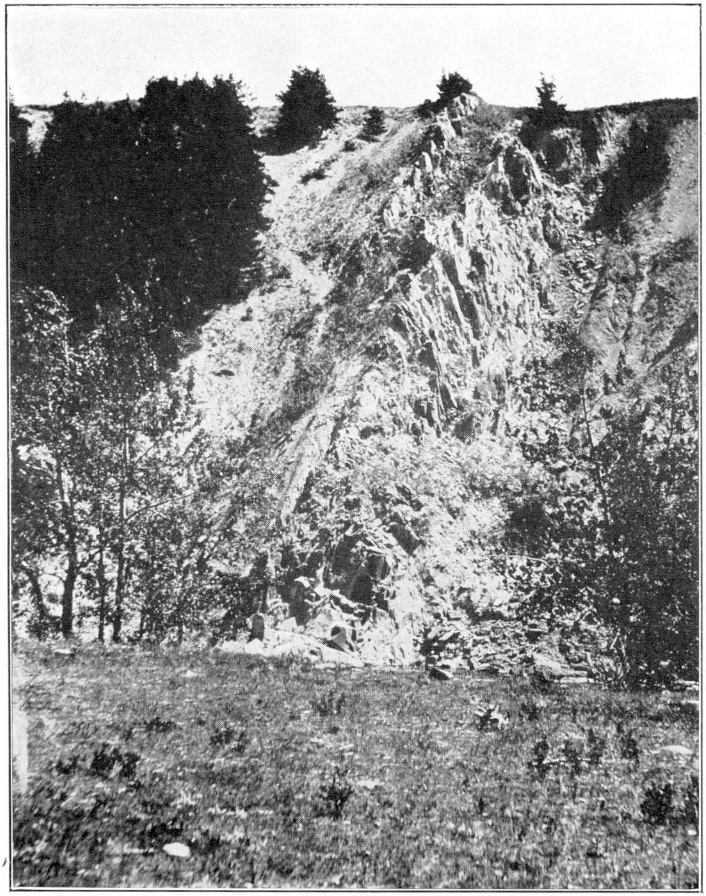
Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·7	11·47	Light red
03	6·6	0·9	Deep red
1	5·7	0·4	" "

This is a good shale. It burns to a good and steel hard body at cone 010, and a vitrified body at cone 03. There is not a very large deposit of this particular type, but similar shales occur in the immediate vicinity.

About 500 feet up stream from the bridge, there is a long steep bank (Plates XXII and XXIII), exposing shales and sandstones of vertical dip and striking across the stream. The shales are decomposed to a depth of a few feet from the surface. One bed of shale (1669) is about 100 feet thick. It is slightly calcareous, very plastic and gritty. Even the small bricklets checked in air drying, but the addition of 1 per cent of salt stopped this.

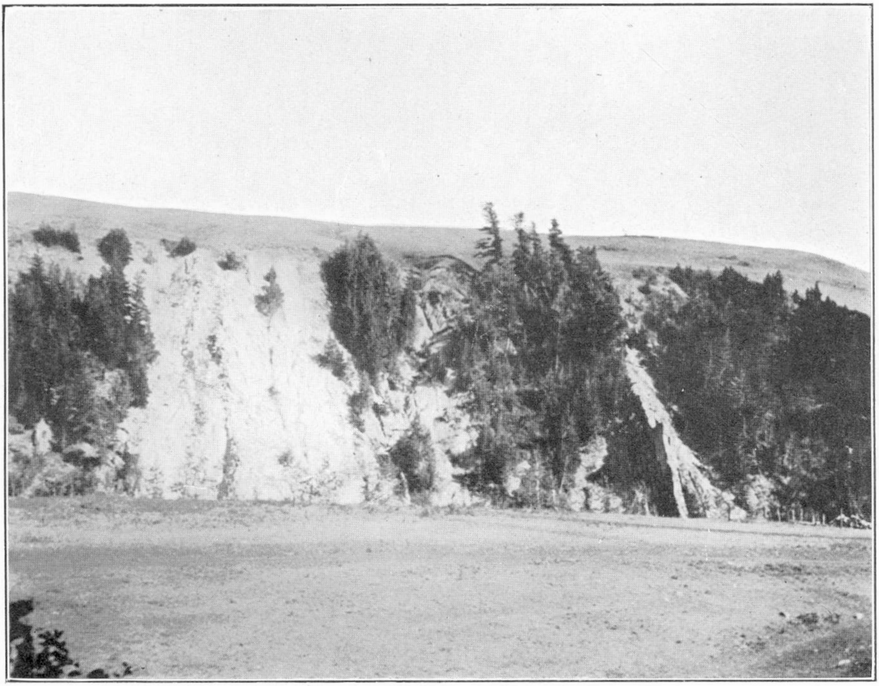


Shale exposures near bridge, on bank of Milk creek, Alta.



Vertical beds of partly decomposed shale, near bridge, on eastern bank of Milk creek, Alta.

p. 60



Vertical beds of shale and sandstone, near bridge, on east bank of Milk creek, Alta.

When mixed up with 24 per cent of water, the mass had an average air shrinkage of 6·5 per cent. The average tensile strength was about 150 pounds per square inch.

Wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	14·14	Red
03	1·6	7·64	Dark red
1	2·0	6·11	" "
5	Fusing.	.....	" "

The clay was nearly steel hard and burned to a good red at cone 010, but above this cone the colour is undesirable for building brick. The shale, however, shows a low fire shrinkage and fairly low absorption, and does not begin to fuse until cone 5.

The possible use which suggests itself is for hollow blocks, fireproofing, or perhaps even sewer-pipe, although there is some doubt whether it is sufficiently plastic for this purpose. It makes a good dry-press, nearly steel hard at cone 05. The surface showed small cracks, and if used for this purpose the clay might require preheating.

Another bed, of decomposed clay shale (1670), is seen at the southwestern end of the exposed cliffs along Milk creek, and next to 1669. This is also a moderately plastic, gritty shale, of non-calcareous character. It worked up with 21 per cent of water, and had an average air shrinkage of 6·3 per cent.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	12·17	Light red
03	2·0	7·64	Red
1	2·7	3·30	Brown

The small bricklets dried without cracking, and while the body was good and hard at cone 010, it was not steel hard until cone 03, at which point the colour was excellent.

This clay could be mixed with 1669.

Lying between 1669 and 1670 is a greenish-grey shale (1671). It is of good plasticity, somewhat gritty, and cracks in air drying unless 1 per cent of salt is added. It worked up with 21 per cent of water and had an average air shrinkage of 4·5 per cent.

The following burning tests of the wet-moulded bricklets gave good results:—

Cone	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	12·38	Light red
03	2·0	5·41	Red
1	3·0	2·58	Brown

This shows a good red steel-hard body at cone 010, but a brighter red was obtained by burning to cone 03. Even at cone 1 it is barely vitrified. In many respects it resembles the preceding. There seemed no reason why a mixture of the last three should not be used, and with this in view one was made up consisting of 50 per cent 1669, 25 per cent 1670, and 25 per cent 1671.

The air shrinkage of this mixture was 5 per cent, and the fire shrinkage at cone 1 was 2 per cent, with an absorption of 4·2 per cent.

It will not air dry without cracking unless preheated or salt treated. The main advantage of making such a mixture is that it permits the run of the bank being used.

There are also some gritty shales in the neighbourhood which are not plastic. These, if worked in with the plastic shales, would help to overcome the trouble in air drying, and probably yield as good a body in burning.

Medicine Hat District.— Some of the best exposures of the Belly River formation are found along the Saskatchewan and tributary valleys in the vicinity of Medicine Hat.

McConnell[1] in speaking of the district says:—

"The Saskatchewan at Medicine Hat enters and traverses

[1]Geol. Surv., Can., Rept. 1885, p. 57 C.

for some distance one of those drift filled depressions which so constantly interrupt the sections on all the principal streams."

"West of Medicine Hat the Saskatchewan is somewhat closely confined to a narrow valley by rocky banks, but east of that point it becomes much more tortuous and continues so until it crosses the pre-glacial hollow."

"The deposits in this basin are partly glacial and partly pre-glacial. The latter are pebble conglomerates, coarse ferruginous sands with small pebbles, silts, and sands. They are probably of Pliocene (Tertiary) age."

"The glacial deposits consist of light-yellowish boulder-clay overlaid in some places by thick sandy beds."

"The rocks of the Belly River series disappear below the Pliocene at Medicine Hat, and reappear about seven miles farther down. The exposure consists of dark arenaceous shales overlying greyish sands and sandstones, and underlying unconformably the sands and gravels of the Pliocene. A few miles farther down, the same beds enclose a small coal seam, which occurs at the same horizon and is probably a continuation of the seam mined above Medicine Hat. It is seen at several places between Medicine Hat and Drowning Man ford."

"A promising exposure occurs about one mile north of the southern boundary of township 16, range 5, W. of 3rd Principal Meridan. Between here and Drowning Man ford the Belly River rocks are often well exposed along the river."

"The river bends east from Drowning Man ford, and passes through a deep cañon, containing fine exposures of the upper part of the Belly River series, and exhibiting pure clays and sands with all gradations between the two."

"They are extremely irregular and no section measured at one place would be applicable anywhere else."

"The Belly River series[1], which underlies the Pierre, is represented by its light coloured upper division which is distributed over a large area in the northwestern and south-western part of the district. It is well shown in the cañon-like part of the Saskatchewan between Medicine Hat and the mouth of the Red Deer, where almost complete sections can be obtained, and also in the valleys of Milk river and Many Berries creek, at

[1]l. c. p. 63 C.

Bull Head plateau, Ross creek, and numerous other places along its eastern boundary."

McConnell quotes the following from G. M. Dawson[1] which refers to Bow and Belly Rivers district, but says it is equally applicable there:—

"It is composed for the most part of sandy clays, with shales and sandstone, the latter often of considerable thickness and usually rather soft or irregularly hardened. Layers of ironstone nodules, which are at times very large, are of frequent occurrence and the beds generally have a characteristic bluish or greenish-grey tint, and are, on the whole, rather massive and weather easily into "bad lands". In these features with the occurrence of rolled clay pellets, and the rounded character of many of the included bones, there is evidence of a considerable amount of current or wave action."

"In addition to the varieties mentioned above, beds of yellowish nodular sandstone attain considerable importance in some of the sections, and are frequently found capping the formation. The distinctive pale colour which is so characteristic of the series as a whole from Medicine Hat west, is replaced towards the northeast to some extent at least by more yellowish tints."

In the time at our disposal it was possible to examine only some of the sections in the vicinity of Medicine Hat.

Redcliff.—About six miles up the Saskatchewan river from Medicine Hat, a fine section is obtained in a narrow coulee (Plate XXIV) leading from the top of the escarpment at the works of the Red Cliff Brick Company down to the river.

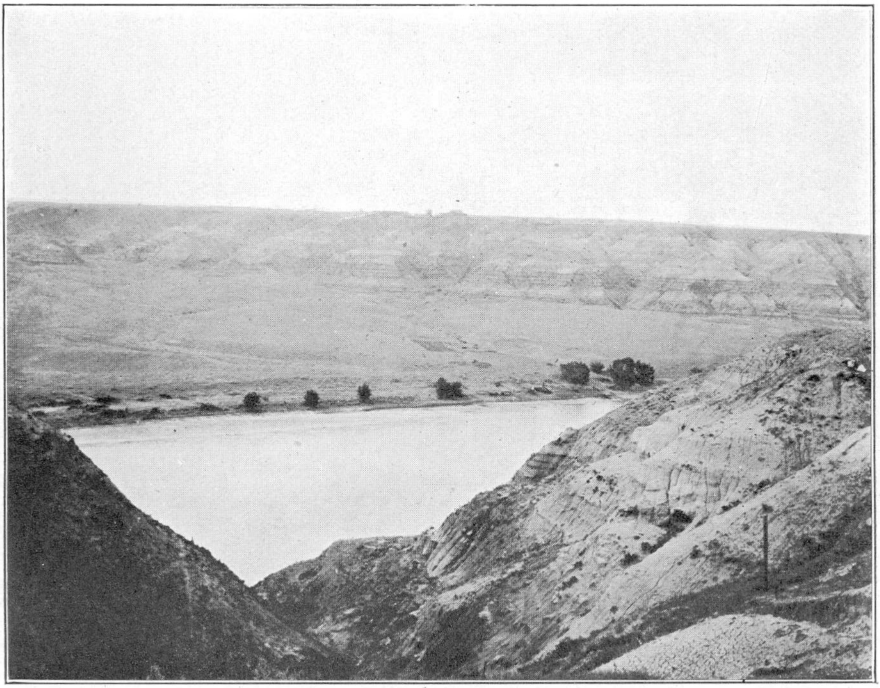
The Company has opened up a large pit about 100 feet below the top, and the general section from the top of this excavation (Plate XXVI) down to the river level is as follows:—

Shales with some sandstones	50 feet.
Dark chocolate clay, cracks in drying	3 "
Alternating shales, silts, and some lignite seams	30 "
Lignite	5 "
Sandy shales	15 "
Lignite	4-5 "
Carbonaceous shale	2 "
To river level (concealed)	50 "

[1]Rept. Prog. 1882-84, p. 116 C.

Shale and clay deposits on the banks of Saskatchewan river, Alta.: clay pit of the Red Cliff Brick Co. in foreground.

p. 64



Stratified clay and shale deposits of the Belly River series, on Saskatchewan river, west of Medicine Hat; looking from Anslee's coal mine towards Redcliff.

p. 64

It is not known how far each of the shale and sandstone beds mentioned in this section extends horizontally, but they are all of undoubted lens-like character, and on the opposite side of the river at Anslee's mine the section is distinctly different, but this will be referred to later.

Returning to the clay pit of the Red Cliff Brick Company, the section there is made up of grey, green, brown, and blackish shales of varying texture, interbedded with sandy streaks or sandstone layers of varying thickness (Plate XXVI B). Some of the shales are very smooth, others contain sandy streaks and even thin laminæ of coal.

The run of the bank, excluding the sandstone beds, is used for making common wire-cut brick, and a layer about two-thirds up the face is used for dry-press.

At the bottom of the bank is a dark-coloured clay shale, which checks in drying if used alone.

In order to determine the qualities of these, three samples were tested, as described below:—

Tests of Redcliff Shales.—Run of bank used for wire-cut brick (1688). This shale shows good plasticity, but a full sized brick would not stand rapid drying, and considerable trouble has been experienced at the works on this account. It would, therefore, be well to try adding 1 per cent of salt to the shale. It worked up with 19 per cent of water to a mass whose air shrinkage was 7·2 per cent and average tensile strength 378 pounds per square inch.

The wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	11·59	Red
03	0·4	8·87	"
1	3·0	3·44	"
3	Vitrified		
5	Fused		

The shale burned to a good red colour, and became steel hard at cone 010. It is not adapted to paving brick or sewer-pipe because of the tendency to crack, and also because it does not make a good vitrified body. We were shown some samples of drain tile and fireproofing said to have been made from this shale, but the Company at Redcliff has not yet attempted the production of this.

A test was also run of the shale bed (1686) occurring near top of bank, and used alone for making dry-press brick. In the laboratory both wet-moulded and dry-press tests were made. It was found to be a very plastic sticky material, which worked up with 30 per cent of water. Its average air shrinkage was 11 per cent, and the average tensile strength 305 pounds per square inch.

The shale alone cracked badly in air drying, but the addition of salt prevented this. The use of the latter also reduced the air shrinkage to 7·3 per cent.

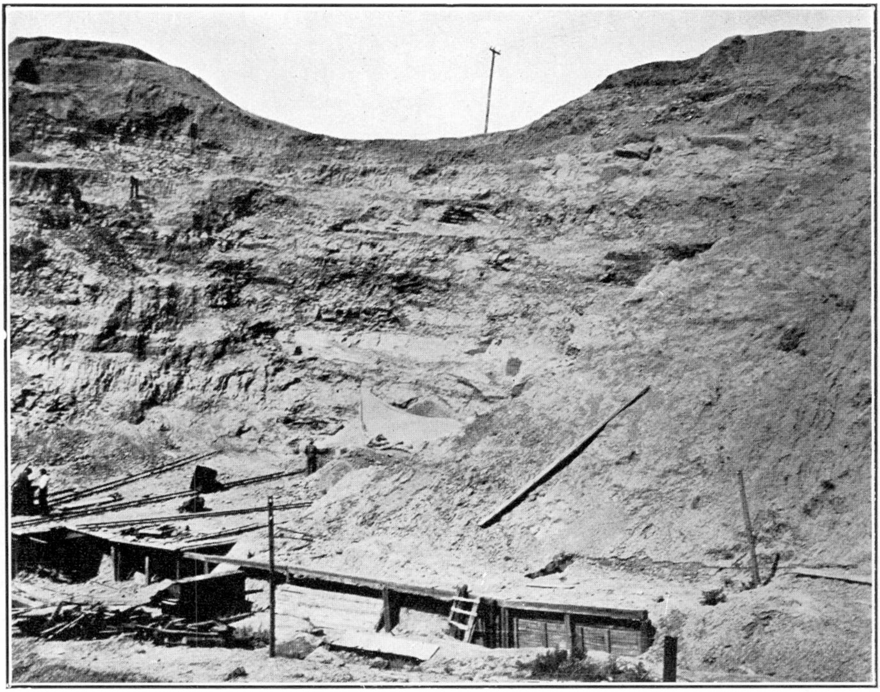
The following tests represent the results obtained with wet-moulded bricklets made of the shale without salt, and dried very slowly:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	10·77	Light red
03	2·3	4·18	Dark red
1	5·0	1·34	" "
3	4·6	0	" "
5	Nearly fused		

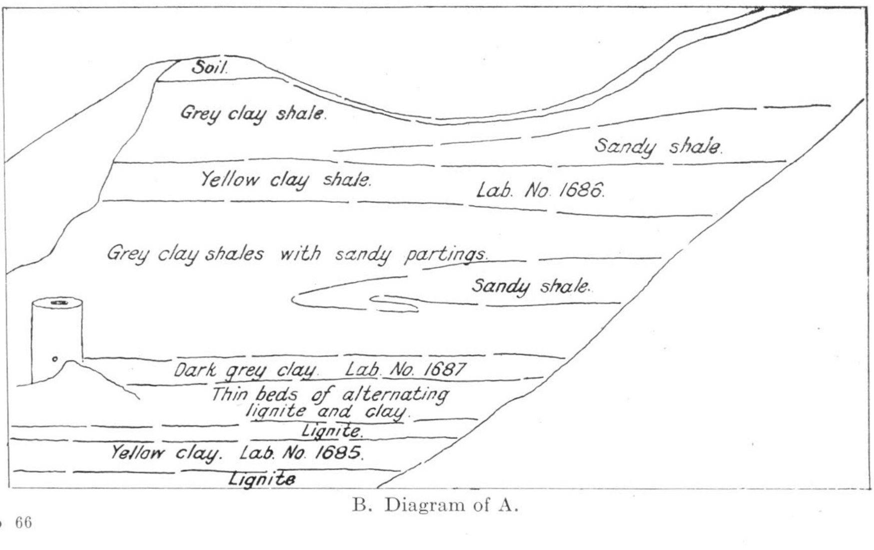
The shale burned to a good red colour, and hard body at cone 010, but was not steel hard until cone 03. Its colour deepened very considerably at this cone. Were it not for the trouble caused in drying, it might be useful for sewer-pipe.

A dry press bricklet at cone 05 had a good body, was steel hard, of dark red colour, and had an absorption of only 6·2 per cent.

The best results obtained in the laboratory in treating this clay were obtained by calcining a portion of it, and using the calcined part as "grog" in the raw clay, taking equal parts of each. This mixture worked well when wet. It could be dried moderately fast with safety and when burned to cone appeared to give a good sewer-pipe body.



A. Clay and shale beds in deposit worked by the Red Cliff Brick Company, Alta.



B. Diagram of A.

This clay could probably be calcined at the works by the method in use now for burning lime. This is done by building up limestone blocks in hollow, beehive shaped heaps, and burning with natural gas. The calcined clay "grog" would have to be charged in a dry pan with the raw clay.

The dark shale (1687) from the base of pit is exceedingly sticky and plastic, and worked up with difficulty. It took 43 per cent of water for mixing, and the shale also checked badly in air drying.

This mass was thoroughly dried, re-ground, and mixed with water, and 2 per cent its weight of hydrochloric acid added. It then took only 33 per cent of water. This acidified clay had a high air shrinkage of 11·6 per cent, and dried in the warm room without cracking. Salt could be used instead of the acid.

The tensile strength is probably high, but the briquettes shrunk so much that they would not hold in the clips of the testing machine.

Wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·65	10·82	Light red
03	2·00	6·07	Red
1	0	3·41	Brown
5	Fused		(Cracked)

The clay burned steel hard at cone 010. The most serious objections to this clay are its high air shrinkage, and cracking in drying. On account of the latter, it is not mixed in with the other layers of the bank.

Underlying the upper 5 foot lignite seam in the coulee below shale bank, is a 4 foot bed of light-buff sandy shale (1685), which was tested because it was claimed to be of buff-burning character.

When mixed with 28 per cent of water this formed a plastic springy mass, which seemed rather short in the working. The average air shrinkage was 4·4 per cent, and the average tensile strength 297 pounds per square inch. The clay did not stand fast drying.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	22·36	Salmon
03	0	22·27	Pale red
1	1·3	14·00	
2	Vitrified		
3	Well fused		

This clay behaved similar to a silty surface clay. Its high porosity up to cone 03, and sudden softening below cone 1, would lead one to believe that it is calcareous, but this is not the case. It is called a buff-burning clay, but the fire tests show that it is not. The clay did not make a good dry-press.

The material can hardly be used for anything but common brick, and is not sufficiently plastic for fireproofing. Moreover, it would have to be worked by underground methods and in connexion with the overlying lignite.

Red Cliff Brick Company.—This Company has erected a somewhat extensive plant, which is located about one-half mile southwest of the main line of the Canadian Pacific railway. The equipment consists of a dry-press, an auger machine, two dry-pans, drying tunnels, down-draft and scove kilns. A continuous kiln was also under construction.

The common wire-cut brick are made from the run of the bank, and it is found best to include some of the sandy layers to reduce cracking.

The dry-pressed brick are made from an 8 foot layer in the upper part of the bank (Plate XXVI), tests of which are given above. This shale is sufficiently moist as it comes from the bank to be fed into the machines.

An inclined hoisting plane has been built in the coulee and is used to hoist the clay and also lignite to the top.

Natural gas obtained from a nearby well is used for fuel.

The Company was also attempting the manufacture of simple forms of red architectural terra-cotta.

Coleridge, Alta.—This station, formerly called Dunmore, is located on the main line of the Canadian Pacific railway about six miles northeast of Medicine Hat.

The clay pits of the Alberta Clay Products Company are located on the west side of a ridge (PlateXXVII), overlooking the valley of Bullshead creek, and about one and a half miles southwest of Coleridge.

This ridge rises rather steeply from the bottom land, and shows few natural outcrops until near the top, where sandstone ledges appear. The shales are more or less covered by wash, and latter silts and gravels.

A bank was being opened on a spur of the ridge (Plate XXVIII) in the summer of 1910. At this point there was in places not less than 15 feet of stripping. The bank had not been opened very much, but from what excavation had been done, together with limited exposures in a shallow coulee cutting through the deposit, we were able to form some idea of the mode of occurrence.

From the data thus obtained one finds that the general arrangement of the beds is lenticular and consists of clay shales of varying degrees of siliceousness, smoothness, and colour, interbedded with some soft sandstones.

This means then, that care must be exercised in working the deposits, to prevent the mixing of shales of widely different character.

It is somewhat difficult to describe the arrangement of the clays in the bank, but the following may serve:—

On the south side of the coulee, near the base of the bank (Plate XXVIII) is a tough, brownish clay, known as sewer-pipe clay. The greatest thickness of this is about 10 feet, and it can be traced for about 30 feet to the left side of the entrance to a short drift (Plate XXVIII). Overlying the sewer-pipe clay is a stiff blue clay, and on top of this is sand. The higher portion of the section was not uncovered. The blue clay is said to crack in air drying. Both the blue clay and the sand appear at a somewhat lower level in a trench on the north side of the coulee.

Another lens of clay, called pressed-brick clay, outcrops on the south side of the coulee, between the loading platform and the railway track, and it is possible that the sewer-pipe clay grades into it, since they adjoin each other at the same level, but a short drift had been dug out on the line of contact.

At the east end of the bank, by the powder house, a buff clay (1693) outcrops, but its horizontal extent is not known, although it may pass under the fireclay outcropping nearer the coulee. The latter (1692) is a black, coarse-textured clay with numerous fragments of plant remains, and having a thickness of about 6 feet. It extends across the face of the hill from near the powder house to the coulee, and there seem to be traces of it on the other side, above where the pipeclay is being dug.

Overlying the fireclay is a lighter coloured sandy clay which in turn is capped by a thin bed of soft sandstones. It is said that borings which have been made on the property have disclosed the presence of much clay, and this is no doubt true, but the lenticular character of the beds, and consequent necessary sorting will preclude the possibility of mining by any such cheap method as steam shovelling.

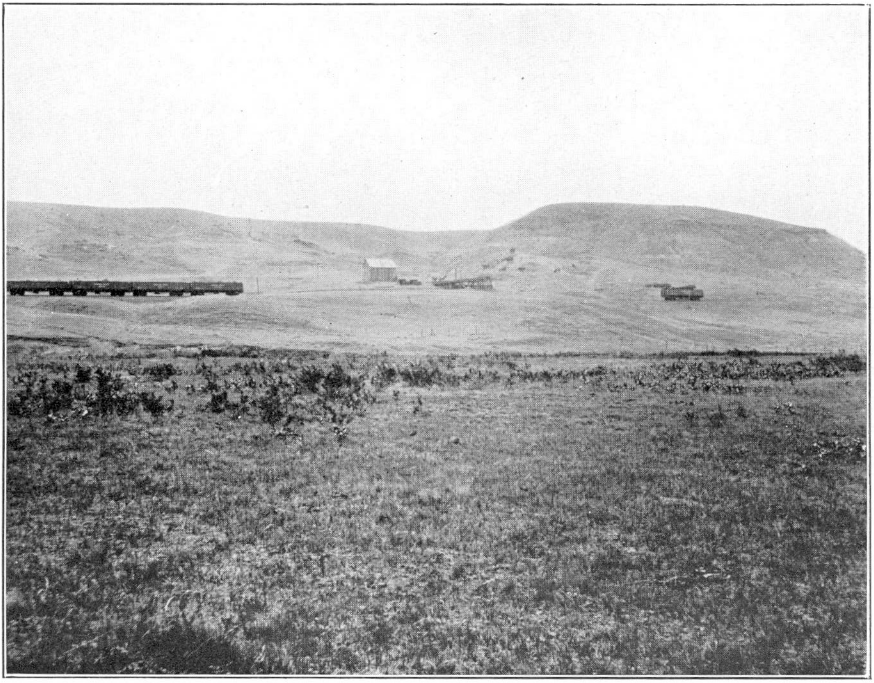
The overburden will also increase as the workings extend into the hill. Several samples were collected at the bank and their properties are shown by the following laboratory tests.

So-called Sewer-pipe Clay (1694)—This is a very plastic, sticky clay, of highly gritty character. It worked up with 21 per cent of water, to a mass whose air shrinkage was 5·2 per cent. Even the small bricklets cracked in air drying, and a full-sized brick with 1 per cent salt cracked in fast drying. A full sized brick with salt can be dried in three days without cracking, at a temperature of 73° F. to 90° F. The average tensile strength was 270 pounds per square inch.

Wet-moulded bricklets gave the following results in burning:—

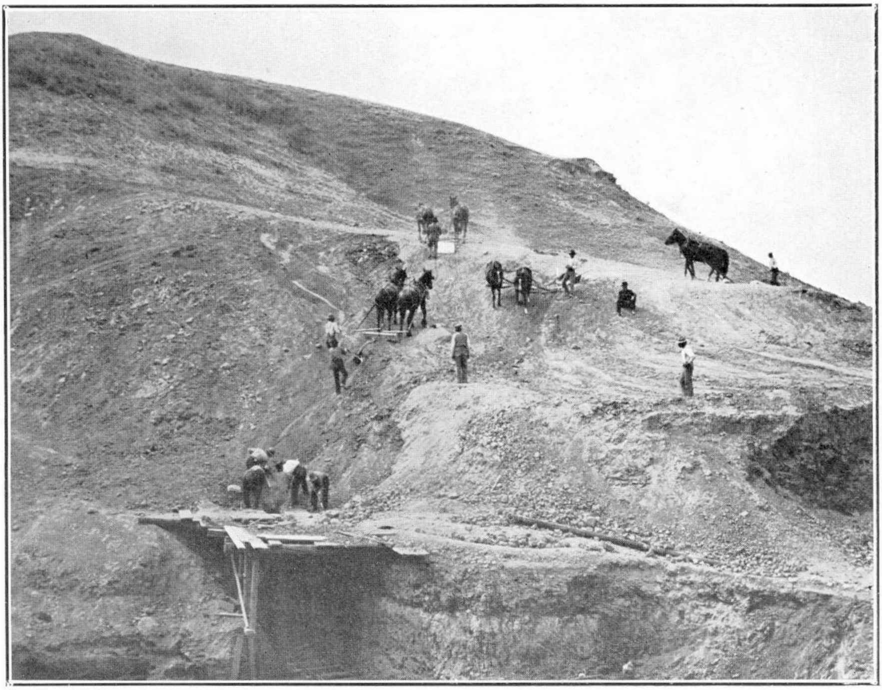
Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	12·00	Pale red
03	3·4	4·76	Red
1	4	3·97	Brown
1[1]	3	3·26	"
3	3	4·00	

[1]With salt.



Escarpment of clays and shales on property of Alberta Clay Products Co., Coleridge, Alta.

p. 70



Clay and shale deposit of the Alberta Clay Products Co., Coleridge, Alta.

The clay burned steel hard at cone 010, and formed a good hard dense body at a low cone, viz., 1. Its fusion point lies above cone 3. The fire shrinkage is somewhat diminished by the addition of salt, but the latter at cone 1 or higher gives a slight glaze on the surface. For sewer-pipe this will make no difference, as they would be salt glazed anyhow. If the drying trouble can be prevented, this clay will probably work for sewer-pipe.

The clay gave a nice looking dry-press at 05, but should be burned to 03. The absorption at 05 was 10·71 per cent.[1]

Grey sandy clay, near the top of section, and overlying "fireclay" (1691). Although this is very gritty, and on the dry outcrop appears quite sandy, still it worked up with 24 per cent of water to a highly plastic, sticky mass, whose air shrinkage was 8 per cent, and average tensile strength 387 pounds per square inch. A full-sized brick cracked in fast drying.

The following show the fire tests on wet-moulded bricklets:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled.	10·67	Light red
03	0·6	7·27	" "
1	4·3	3·78	Dark red
3	4·6	2·00	" "
5	Beyond vitrification nearly fused.		

The clay burned nearly steel hard at cone 010, and had a good colour. It is a good brick clay, but is probably too gritty to make a dry-press brick.

So-called Fireclay (1692).—This clay, which underlies 1691, is also very plastic and sticky, but it can be moulded with slightly less water, viz., 21 per cent. The air shrinkage was 8·5 per cent, and the average tensile strength 334 pounds per square inch.

[1]In a communication since received from the superintendent of the Company, it is said that this clay is no longer used for sewer-pipe, but that they are using a mixture of clays occurring higher up in the section and experience no trouble.

Wet-moulded bricklets behaved as follows on firing:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	10·50	Pale red
03	"	6·56	" "
1	2·4	3·89	Umber
5	3·6	2·34	Grey
9	Beyond vitrification		
13	Fused		

It is quite evident that this is not a fireclay, but it is sufficiently refractory to be used for boiler-setting brick. It burned to a very dense body at cone 5, somewhat denser in fact than is desirable. At cone 9 the clay had begun to swell and even developed a black core, which was not the case with the others. It is somewhat carbonaceous and should not be fired too rapidly.

Buff Shale from Near Powder House (1693).—This is a very plastic, smooth, non-calcareous clay shale, the small bricklets of which dried rapidly without cracking. This is more than some of the other clays from this bank would do. When worked up with 22 per cent of water, the bricklets had an air shrinkage of 7 per cent. The tensile strength was not tested.

Wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·2	12·94	Light red
03	4·6	2·60	Red
1	Fused		

The clay burned steel hard, and of good red colour at cone 010. The colour was also good at cone 03. It is of low refractoriness.

As trouble was experienced in using the sewer-pipe clay alone, a mixture (1694A) consisting of equal parts of 1691, 1693, and 1694, was made up. This mixture had an air shrinkage of 7·0 per cent and the test pieces showed no sign of checking in drying, which 1694 when used alone did. The fire shrinkage at cone 1 was 2·3 per cent, and the absorption 1·9 per cent.

It will be seen from these tests that the fire shrinkage and absorption are lower than those of 1694, better vitrification being secured by the use of 1693 in the mixture. Furthermore, the drying qualities are much improved by the incorporation of 1691 in the body.

Alberta Clay Products Company.—The works of this Company are located at Medicine Hat. The clay is loaded on to cars at the bank and these are run down a spur to the main line and then hauled to the factory where the shales and clays are dumped into separate bins.

The factory, which is one of the largest in the western provinces, has been equipped with dry-press brick and sewer-pipe machinery. Natural gas is used for fuel.

At the time of our visit, the factory was turning out dry-press bricks for constructional work at the plant. These were being burned in scove kilns, and were used for the entire construction of circular down-draft kilns, with the exception of the flues and bag walls.

The sample dry-press bricks that were shown us were hard, of good red colour, but somewhat coarse grained. Finer grinding of the shale would improve the appearance of the product.

South Bank of Saskatchewan, West of Medicine Hat.—An examination was made of the shale deposits outcropping between Medicine Hat and Anslee's mine opposite Redcliff. About one and a half miles west of town, a deep coulee shows an outcrop of lignite, a few feet above the river level.

Shales occur above and below the coal, but they are mostly sandy and it is doubtful if they extend very far above the lignite, as the float on the sides of the coulee indicates an abundance of sandstone.

Immediately above the lignites is a 2 foot layer of clay shale, which could be easily mined with the coal. Although it had a greasy look, so frequently seen in many clays running high in colloidal matter, still a small sample (1695) was taken for testing. Its properties are as follows:—

This is a plastic shale with 6·7 per cent air shrinkage. The bricklets did not crack in the warm temperature of the laboratory.

The shale burned to a good red colour, but had a rather high fire shrinkage. At the same time it burned to a fairly dense body at cone 03, and a very dense one at cone 1, as shown by the tests below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	20·62	Light red
03	7·3	6·92	Red
1	7·4	0·73	Deep red

The clay was vitrified at cone 1. Its fusion point was not determined, but it probably does not exceed cone 3.

This is a good brick shale, if the large bricks will dry without cracking, but it is of no value unless mined in connexion with the lignite.

Anslee's Mine.—At William Anslee's mine (Plate XXV) there is an incline running from the top of the cliff down to the river level, a difference in elevation of about 250 feet. A fine section is exposed along this, and although it is directly opposite the Redcliff one, already referred to, differs from it to a marked degree.

Indeed careful search failed to reveal any series of beds like those at Redcliff, the only similar deposit being one about 20 feet below the top of incline. This is a yellow and grey mottled clay similar to the deposit used for dry-press brick at Redcliff. The lens is of limited size and grades into a brownish shale clay resembling the "sewer-pipe" clay mined near Coleridge.

The remainder of the section down the incline to the first lignite seam consists chiefly of sandy shales and sands, but just above the lignite is a 2 foot layer of light clay, and under this same (upper) lignite seam is a reddish clay shale. The latter could only be worked by underground methods, and is probably not of sufficiently high quality to warrant the expense.

The only sample tested from the entire section was the mottled clay from near the top of the incline. This material (1696) was found to be a very plastic, smooth, non-calcareous shale, which worked up with 31 per cent of water, and in the test bricklets showed a rather high air shrinkage, viz., 10·8 per cent. In practice this would undoubtedly be somewhat less.

Firing tests on wet-moulded bricklets gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·65	12·04	Light red
03	5·3	2·10	Red
3	Beyond vitrification		

This shale is very similar to 1695 and somewhat resembles the dry-press clay at Redcliff, but cracked less in drying and burning than the latter.

CHAPTER III.

Laramie Formation

The Laramie formation proper underlies a small triangular area in southern Manitoba, in the Turtle Mountain region.

Farther west a second but much larger triangular area is found in southern Saskatchewan. The base of this triangle forms the southern boundary of this Province, as far west as the Wood Mountain district, which is included in it. From the apex of the triangle a narrow belt extends northwestward to a little beyond the main line of the Canadian Pacific railway west of Moosejaw. This area it will be seen includes the Souris coal-field and the Dirt hills.

Detached areas are found west of this, where the Laramie formation occupies the summits of some of the plateaus, and portions of elevations such as the Cypress hills.

SHALES OF SOURIS COAL-FIELD.

The Souris field lies in southern Saskatchewan, just north of the International Boundary, and east and west of the Canadian Pacific Railway line from Moosejaw to Portal.

The exact areal extent of the field is not known, because there are so few exposures and a heavy surface covering of boulder clay which extends northward through the Moose mountains and beyond the Assiniboine river.

The eastern outcrop of the coal rocks is concealed by it, but they are known to extend at least as far as the mouth of Moose Mountain creek.

Associated with the coal seams are beds of clay shale, sandy clay, and sandstone, but since they are not always persistent, there may be some question as to the value of considering the stratigraphic details of the field.

It may be briefly stated nevertheless, that the coals which are of Laramie age are divided by Dowling into an upper, middle, and lower horizon.

The upper horizon generally carries a 4 foot seam that is fairly continuous, but in places thins out or is joined by seams of the middle horizon to form a 7 foot seam. The coal seams are separated by deposits of sandstone, clay, and shale of varying thickness and areal distribution.

The upper horizon has been prospected at several points in the vicinity of Estevan.

The middle horizon is found exposed along the north side of the Souris valley.

The lower horizon is the most important in the district.

Dowling in his report gives a number of sections, some of which indicate a sufficient thickness of clay to be worth noting. These are as follows:—

(1) Section in Souris valley, west of Estevan, and south of Dominion mine:—

	Feet.	In.	Approx. elevation	
Clay	6	0	Top of hill	1847
Lignite, thin streaks	..	..	" "	1841
Clay	16	0	" coal	1825
Lignite	1	6		
Clay	2	6		
Lignite	1	0		
Clay	2	0		
Lignite	3	6		

Bottom of section 1814.

(2) Section on southwest corner, section 3, township 2, range 7:—

	Feet.	In.	Approx. elevation.
Prairie level	..	..	1850
Clay and small fragments ironstone	5	0	
Grey clay	6	0	
Black shale	0	8	
Brown lignite shale	1	0	
Light yellow sandy clay	6	0	

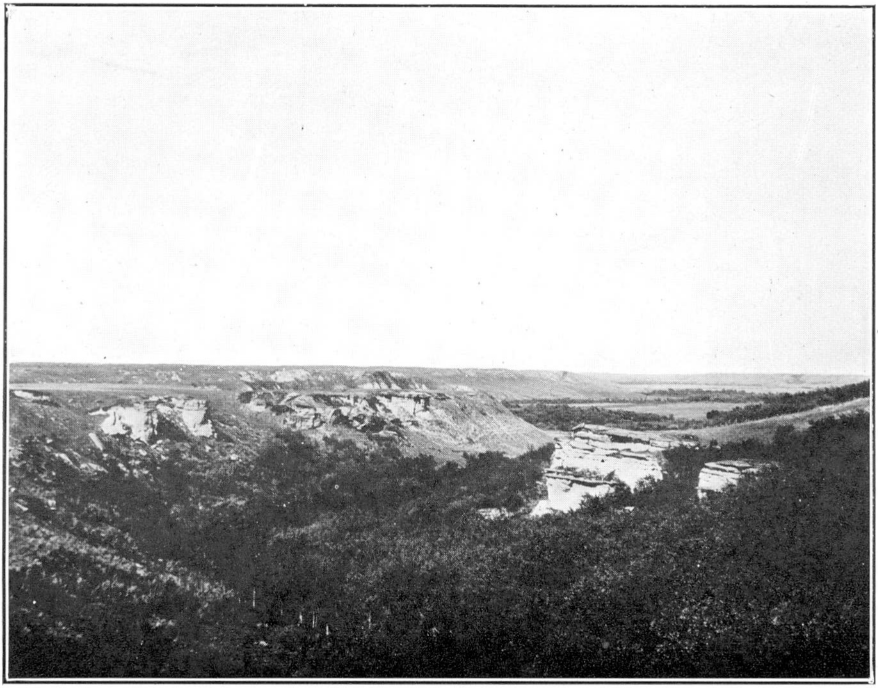
Etc.

(3) Exposure on southeast part of section 35, township 1, range 7:—

Boulder clay and surface deposit	2 feet	0 inches
Brown sandstone	2 "	0 inches
Grey clay	8 "	0 inches
Sandstones	6 "	
Clay with shells	12 "	
Red burnt shales	4 "	
Lignite (?)	"	
Yellow and blue clay	6 "	

(4) Section in side valley near Roche Percee station, section 31, township 1, range 6:—

Surface deposit	4 feet.	
Yellow sandstone	2 "	
Yellow clay	4 "	6 inches.
Lignite	4 "	
Whitish clay, some sandstone	8 "	
Light yellow clays and sands	12 "	
Bluish clay with carbonaceous layers	6 "	



Outcrops of sandstone in Souris valley near Pinto, Sask.

p. 78

(5) Section in section 36, township 1, range 6:—

Concealed by grassy slope	20 feet.
Sandstones partly hardened	56 "
Lignite	4 "
Light grey clay and some sand	36 "
Darker grey clay	24 "
Concealed to river	6 "

The shales were examined and samples collected at several points in the Souris field as follows:—

Estevan.—About one and a half miles east of the town excavations have been made in the east slope of a broad coulee, by the Estevan Coal and Brick Company.

The section there shows:—

Boulder clay, with shale fragments in lower portion	10 to 20 feet.
Lignite	8 feet.
Parting clay	2 feet to 2 feet 6 inches.
Lignite	8 inches to 2 feet.
Blue clay shale	30 to 40 feet.
Upper 15 feet smooth, but lower portion quite sandy.	

The top clay (Plate XXX), which is a calcareous glacial clay with scattered stones, pebbles, and boulders, is worked as an open pit. The large stones are thrown out in the pit, but the smaller ones are crushed in a rolls. A sample of the material thus crushed was taken for laboratory test.

This (1645) is a very calcareous and rather gritty clay, which worked up with 21 per cent of water to a mass of good plasticity, but one which will not stand rapid drying.

The average air shrinkage was 5 per cent, and the average tensile strength 334 pounds per square inch.

In burning it behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	24·48	Light red
03	"	23·94	Cream
1	0·4	19·76	Buff
3	Fused		

The clay shows the characteristic behaviour of a very calcareous one, and the numerous limestone fragments scattered through it caused some splitting of the brick. It is doubtful whether this top clay could be used for anything but common brick.

Of the clay shale underlying the lower lignite (Plate XXXI) seam only the upper 9 feet were being worked at the time of our visit, but the Company proposes to strip off first the top clay and lignite, and then use the parting clay, lower thin lignite, and lower blue clay shale altogether. The 9 feet referred to above were being removed by drift and chamber mining in the summer of 1910. A sample of this was also taken for testing.

The material (1644) which worked up with 33 per cent of water to a very plastic, sticky, tough mass, was rather hard to knead, and checked even with very slow air drying. Preheating seemed to reduce the cracking, and the addition of salt would probably correct it also. An attempt was made to test the tensile strength, but the briquettes were so full of flaws, that no good results could be obtained. Some, however, ran over 300 pounds per square inch. The average air shrinkage was high, viz., 9·6 per cent.

The wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·45	14·00	Light red
03	6·3	0	Dark red
3	Fused		

The clay showed a low fire shrinkage, and was almost steel hard at cone 010, but the bricklets cracked some. It was so thoroughly vitrified at cone 03, that the burning was not carried beyond that point.

The clay makes a red dry-press brick at cone 05, which is steel hard, but tends to crack in burning. Since the clay is too moist for moulding dry-press as it comes from the bank, the material is put through a cylindrical dryer. It has been found that this preliminary treatment also reduces the cracking, due evidently to the fact that the temperature of the drying is sufficiently high to preheat the clay enough to destroy some of the colloids. The product is not vitrified.

Surface deposit of glacial clay, used for stiff-mud bricks, Estevan Brick and Coal Co.

Clay and lignite beds at Estevan, Sask., pit of the Estevan Brick and Coal Co.

No attempt is made at the yard to make stiff-mud brick from this particular shale.

Plant of Estevan Coal and Brick Company.—The top clay is utilized for making common brick. After crushing the raw material in rolls as previously mentioned, it is tempered in a horizontal pug-mill, and then moulded in a side-cut machine. The green bricks are run through a dryer, and burned in Dutch kilns.

The blue clay from the mine is first put through a drying cylinder, then ground in a dry pan, and moulded in a four-mould Berg dry-press. Burning is done chiefly in Dutch kilns, but some in a rectangular down-draft kiln.

Some trouble is experienced with checking of the green dry-press brick, but the use of the dryer has reduced this. It is impossible to mould the clay by the stiff-mud process on account of the very serious cracking.

The stiff-mud bricks made at this works are cream colour, and the dry-press ones are red. The lignite obtained at the plant is used for fuel.

Pinto.—At Pinto station, the Pinto Coal and Brick Company has driven a short slope about 300 feet long, which at its lower end meets a bed of lignite belonging presumably to the upper horizon.

Overlying this is a buff-clay shale (1641) about 5 feet thick, which we sampled in the mine, and higher up, but not immediately overlying it, is a softer, reddish shale (1642). Another shale (1643) underlies the lignite.

The measures here lie horizontally or nearly so, and these beds should outcrop in the Souris valley a few hundred feet to the north, but since the clay shale and sandstone beds are not apparently as continuous as the coal beds, there may be some doubt whether they extend that far.

The Souris river has here cut a fine trench in the plain, (Plate XXXII) but while the sandstone ledges stand out here and there on the valley sides in some prominence, the softer layers such as clay and shale have mellowed down and are more or less completely concealed.

Tests were made of the several beds of clay shale associated with the lignite at Pinto, and the results of these are described in the following lines: —

Shale Over Coal, Pinto Coal and Brick Co. (1641).—This is a very smooth, calcareous shale, which worked up with 30·8 per cent of water to a very plastic mass, and in the small bricklets dried without cracking, but in full-sized bricks would not stand fast drying. The average air shrinkage was 7·5 per cent and the average tensile strength 293 pounds per square inch.

The following results were obtained on firing:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1	22·28	Red
03	1·0	21·70	Buff
1	Well vitrified		
3	Fused		

Like all calcareous clays it burns to a very porous body, as shown by the absorption tests given above, and is not thoroughly steel hard even at cone 03. At cone 1 it is thoroughly vitrified, and if heated slightly beyond this begins to fuse.

The clay makes a nice dry-press brick at cone 05, with 25 per cent absorption.

Weathered Shale Near Surface, Pinto Coal and Brick Company (1642).—This represents a small sample, collected from the railway cut, just west of the mine. It is a very smooth, plastic material, which works up with 34 per cent of water, and forms a rather sticky mass, but does not crack in air drying. There is not enough calcium carbonate in the clay to cause effervescence, but the clay appears to contain enough soluble salts to form a slight scum on the green brick. This showed on the burned ware at cone 010, but did not at cone 03. The average air shrinkage was 9·2 per cent.

Souris valley, looking northwest from Pinto, Sask.

Firing tests of the wet-moulded bricklets yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·5	14·36	Light red
03	8·6	0	Red

The clay has a rather high air shrinkage, but the fire shrinkage and absorption at cone 010 are satisfactory. While it burns to a good vitrified body at cone 03, the total shrinkage at this point is too high for practical purposes, but the colour of the body is good.

Shale Under Coal, Pinto Coal and Brick Co. (1643).—This is a non-calcareous clay, of which even the small bricklets cracked in air drying, but the addition of 1 per cent of salt prevented this. It worked up with 30 per cent of water to a stiff, very plastic mass, whose average air shrinkage was 8 per cent.

The burning tests gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·7	13·60	Red
03	7·4	0·15	Dark red

The clay burned nearly steel hard at cone 010, and makes a good brick. It is well vitrified at cone 03.

It can be classed as a good brick clay, but if used for fireproofing, might cause difficulty in moulding.

It was thought that if the drying difficulty could be overcome, a mixture of the three Pinto clays might be used for paving brick. Such a mixture (1643A), consisting of equal parts of 1641, 1642, and 1643, to which 1 per cent of salt was added, was tried. The average air shrinkage was 8 per cent. The fire shrinkage at cone 010 was 0 per cent, and the absorption 17·33 per cent. Above this the clay worked badly unless burned very slowly, and the results could hardly be considered satisfactory.

A dry-press bricklet at cone 05 gave a mottled red brick, which was nearly steel hard, and had an absorption of 15·74 per cent.

The close association of the clay and fuel are factors of decided advantage.

Bienfait.—We are informed that in the shaft of the Manitoba and Saskatchewan Coal Company, there was found a bed of buff shale, under the lignite, 10 to 15 feet thick, but that tests had shown it to be of no value. Below this, however, it is claimed that there is a red-burning clay shale 20 to 30 feet thick, resting on a ferruginous sand.

No general statement can be made regarding the shales found in the Souris field, but the results obtained in our laboratory tests warrant the hope that other good shales may be found.

The field should be carefully prospected, for the shales or clay if suitable can, in most instances, be cheaply mined or excavated, and moreover they are well located with reference to lines of transportation. Fuel, also, is plentiful and cheap. The growing cities of Moosejaw and Regina form a nearby market.

Dirt Hills.—The Dirt hills form an isolated elevation rising from the plains (Plate XXXIII) about twenty-three miles south of Drinkwater, and about thirty miles south of Moosejaw. They have received some notice because of the coal seams which were known to occur in them, and were made the subject of a report by Dr. Bell[1] at an earlier date.

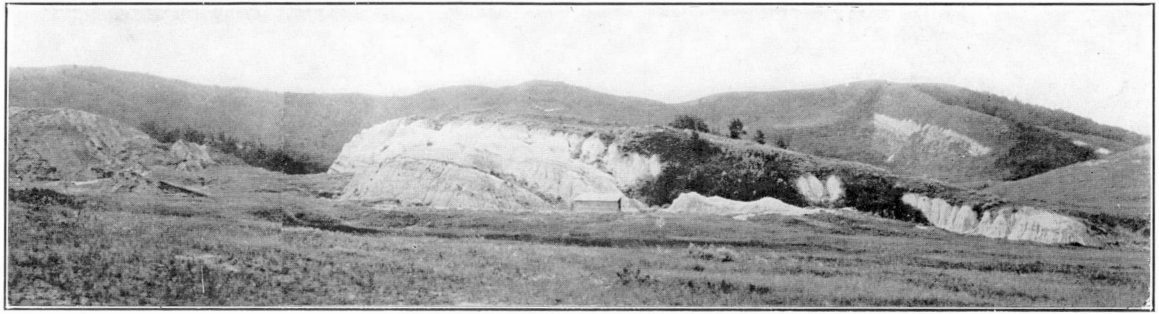
He writes as follows:—

"Several extensive landslides on the northern front of the Dirt hills afforded us sections of 200 or 300 feet of the rocks which underlie gravelly peaks and slopes. These consist of grey sandy clays or marls in thick bands of slightly different shades interstratified with bands of lignite, and holding nodules of sandstone and clay ironstone. At the base of the hills a section of between

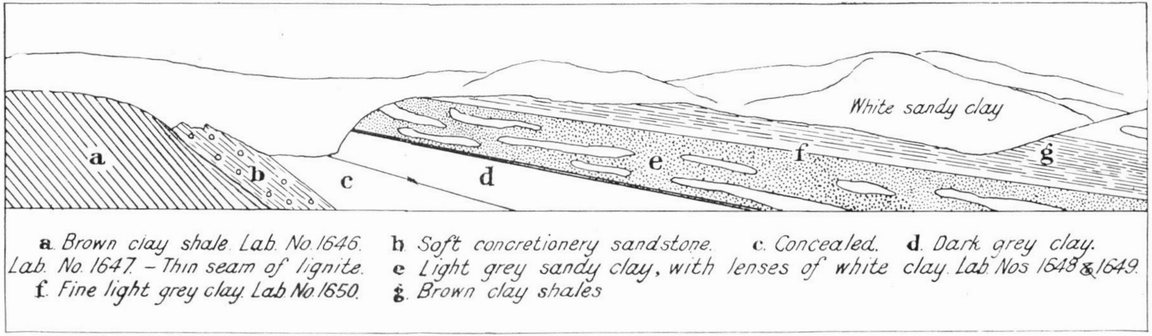
[1]Report of Progress, Geol. Surv., Can., 1873-74, p. 76.

General view of escarpment of Dirt hills, from the east.

p. 84



A. Clay and shale outcrops, Dirt hills, Sask. View looking south from margin of hills.



B. Diagram of A.

20 and 30 feet of soft grey sandstone was found in one of the ravines which cut for a short distance into the plains. The strata in this locality appear to be about horizontal, but in the great masses detached by the landslides[1] they are tilted up to various angles as high as 45°, the slope being to the south-westward, while the undermining force has evidently acted from the northeastward. The large surfaces of bare and often muddy clay, which are here exposed, contrasting with the grassy or gravelly prairies, have probably given rise to the name which these hills bear. Those of the bluffs formed by the landslides are conspicuous at the northeastern extremity of the Dirt hills."

This description gives one a pretty clear account of the structural conditions, and it is in these Laramie beds exposed in the landslide masses on the north side of the hills, that one finds some of the most refractory clays thus far discovered in western Canada.

The clays which were examined occur in section 28, township 12, range 24, west of the 2nd Meridian, and form a series of knolls at the base of the hills. All the beds appear to dip westward, the knolls having a steep eastern face and a gentle western slope.

The general topography of those hills in which the clay occurs is well shown in Plates XXXIV to XXXVI, while a generalized section is given in Plate XXXIV A.

The photographs might lead one to believe that the clays are all white, but while these predominate other types are not wanting.

They can be described as a series of white and greyish-white sandy clays, bluish and purplish clays, brownish siliceous clay shale, and gypsiferous shales (shown in part in Plate XXXIV A.)

Tests and other descriptions are given below.

At the west side of the ridge is a spur or knoll (No. 5, Plate XXXVI), containing a series of alternating red and brown siliceous shales, which have been referred to by some as sewer-pipe clays. The individual beds of this series differ somewhat in their sandiness, and if used the entire series should be mixed

[1]See our Plates XXXIV and XXXV.

together. A few scattered sandstone layers are present, but these are soft and could be easily crushed up.

Overlying these siliceous clays and separating them from knoll No. 2 (Plate XXXVI) is a series of soft sandstone beds, containing large scattered concretions (Plate XXXVII). These beds should not be mixed in with the shales underlying them.

The following tests represent the character of the "sewer-pipe clays" (1646), the sample being taken by making a trench across the complete section of the beds shown in Plate XXXIV B, layer A.

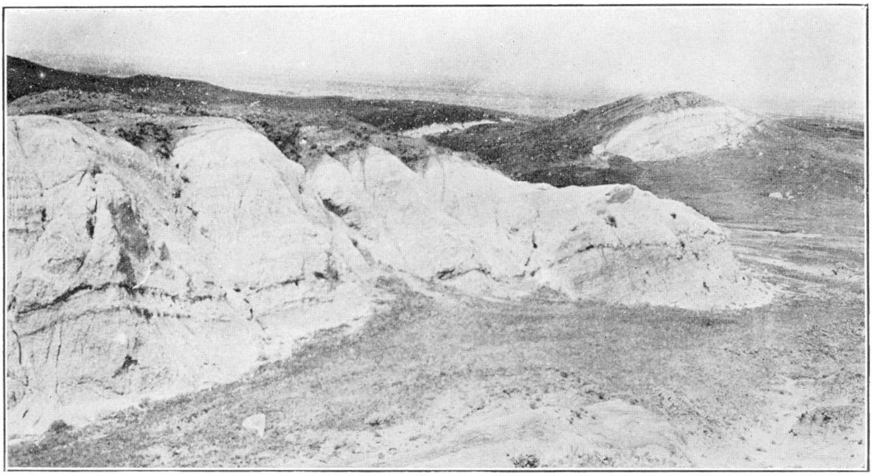
The sample thus obtained, when ground and tempered with water, formed a stiff, plastic mass which was hard to work, and checked badly in air drying. As the clay was useless in the natural state a portion of the sample was preheated to a temperature of 500°C. Under this treatment the clay changed to a red colour and became granular in texture, but retained sufficient plasticity to be wet-moulded. It also stood fast drying, and the air shrinkage was 3·3 per cent.

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·7	9·7	Light red
03	9·3	5·5	Red
1	13·3	Vitrified	Brown

This clay has too high a fire shrinkage, but it might be useful to mix with some of the more refractory clays of the locality in order to produce vitrified ware at lower temperatures.

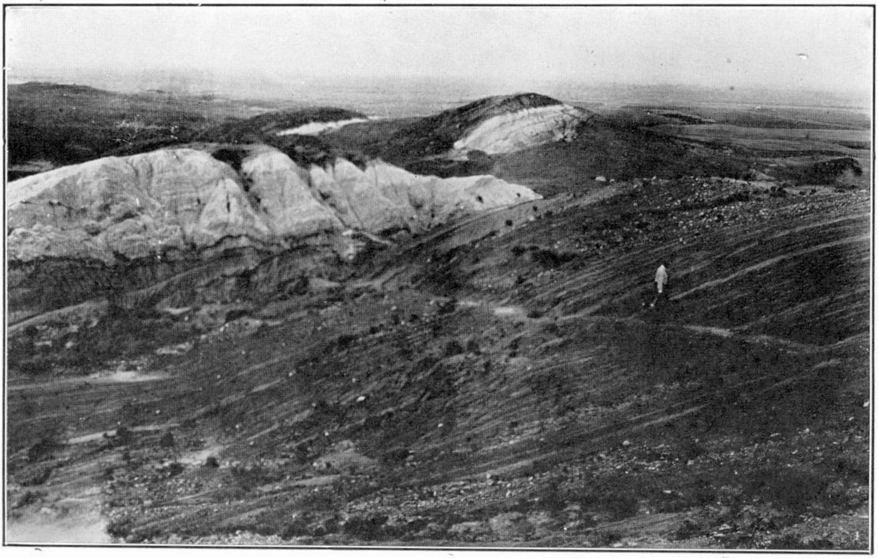
Hill No. 2 (Plate XXXVI) shows heavy beds of grey and greyish-white sandy clay and brownish-grey clay, the two sets being separated by a thin layer of lignite (Plate XXXIV B). The brownish-grey clay (1647) forms a bed about 20 feet thick in the lower half of the section.

It is a plastic clay, containing much fine grit, and worked up with 30 per cent of water. Small pieces dried slowly without cracking, but large ones cracked badly in rapid drying. The average air shrinkage was 8·5 per cent, and the average tensile strength 334 pounds per square inch.

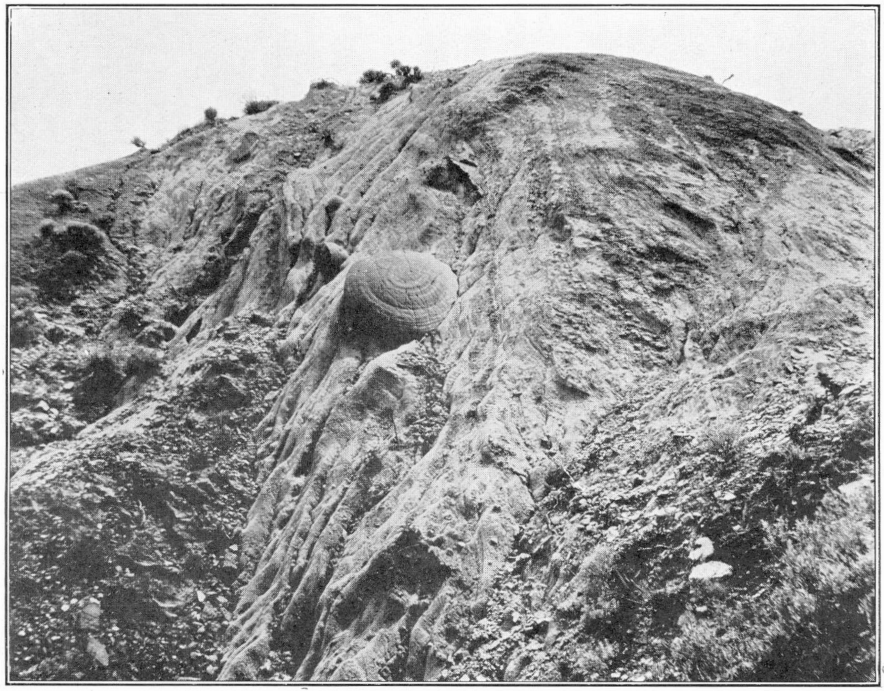


White and grey clay outcrops, Dirt hills, Sask.

PLATE XXXVI.



Clay and shale outcrops at Dirt hills, Sask.; brown shales in foreground.



Outcrop of sandy shale and soft sandstone with concretions, Dirt hills, Sask.

The wet-moulded bricks yielded the following results on burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·2	16·38	Pale red
03	4·4	7·52	Light red
1	5·4	4·78	Brown
3	5·3	4·39	"

The air shrinkage is somewhat high, but in actual working it would be lower. The fire shrinkage at cone 1 is not excessive. The absorption at this cone is also low. The clay burned steel hard at cone 03, but if fired too rapidly may develop a black core at cone 1. It burned to a good hard body, and stands cone 3. The clay gave a dry-press bricklet of fair colour and ring at cone 05, but if moulded by this method should probably be burned to cone 03.

The absorption at cone 05 was 18·62, and at cone 03 it was 10·93, with the bricklet steel hard.

Overlying the preceding is a grey and white sandy clay (1648), containing lenses of white clay (1649). Where the clay is exposed it would hardly pay to separate these lenses, but if they occur in greater quantity in other parts of the deposit, it would be worth doing so. On this account we not only made a test of the run of the deposit, including the white clay, but also of the latter alone.

The run of the bank (1648), although containing considerable sand, worked up with 27 per cent of water to a mass of good plasticity, and one which caused no difficulty in moulding.

The average air shrinkage was 6·1 per cent, and a full-sized brick stood fast drying. The average tensile strength was 123 pounds per square inch.

The clay appears to contain a noticeable amount of soluble salts, which collected on the corners and edges of the brick in drying, and caused a slight enamel on those parts even at cone 03.

Wet-moulded bricklets yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	18·58	Whitish
03	2·7	15·41	"
5	2·7	10·70	"
9	3·3	9·81	"
32	Fused		

Small black iron specks began to appear at cone 1.

The clay has a low fire shrinkage, and the absorption above cone 010 is not excessive. It burned steel hard at cone 1.

This clay can be classed as a fireclay, and represents the most refractory one found by us in western Canada.

A dry-press bricklet burned to cone 1, was not steel hard with an absorption of 17·50 per cent.

Since the clay is rather loose in texture, it was put through a washing test and 45 per cent of washed product (1648W) obtained. The latter showed an average air shrinkage of 8·5 per cent. Burned to cone 5, its fire shrinkage was 9·7 per cent, absorption 7·11 per cent, and colour light creamy white. It was also steel hard, but showed some small cracks. At cone 9, the fire shrinkage was 11·3 per cent, absorption 3·7 per cent, and colour greyish white.

Since there is a large quantity of this material it might pay to wash it and use it in pottery bodies. Some difficulty would be encountered in getting sufficient water, but the springs on the neighbouring slopes could be drawn upon for this purpose.

In figures 2 and 3, we have shown graphically the absorption and fire-shrinkage curves of the crude (1648) and washed samples of this clay.

The white clay (1649) forming lenses in 1648, although appearing smooth, nevertheless contains considerable fine grit, and an appreciable quantity of soluble salts, which came out on the edges as needle-shaped crystals in drying. It worked up with 30 per cent of water to a mass of good plasticity, whose average air shrinkage was 7·7 per cent.

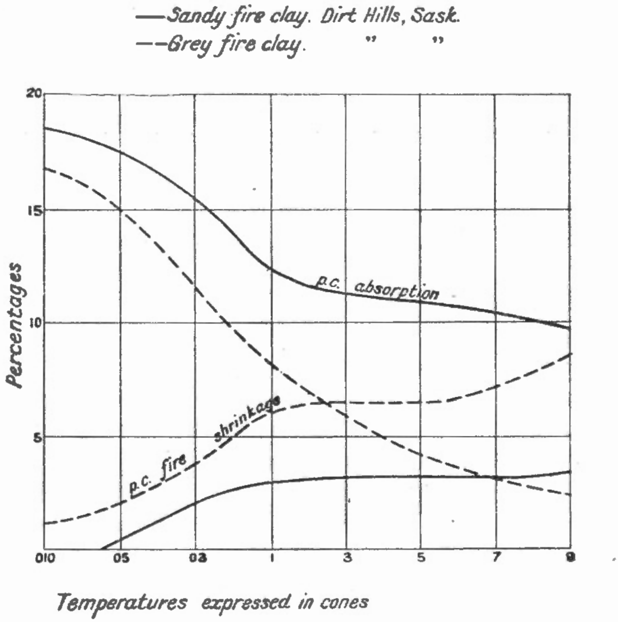


FIG. 2.—Fire shrinkage and absorption curves of Dirt Hills fireclays.

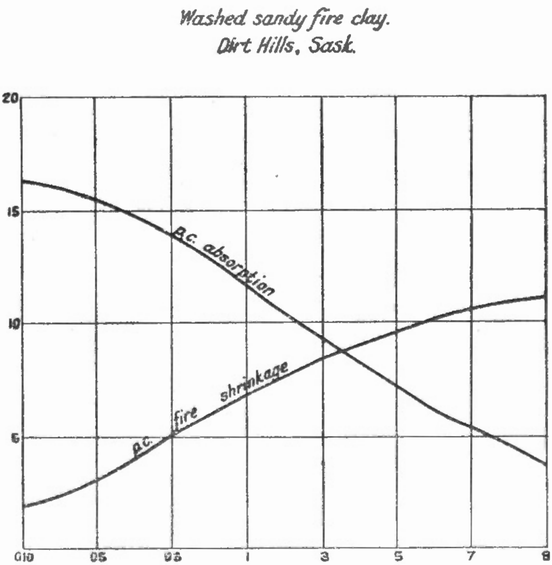


FIG 3.—Fire shrinkage and absorption curves of washed fireclay from Dirt hills.

On burning the wet-moulded bricklets behaved as below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	16·74	Creamy white
03	3·7	10·34	" "
1	5·3	7·67	" "
5	6·6	4·67	" "
9	6·6	2·60	" "
31	Fused		

The clay burned nearly steel hard at cone 010, and gave a pretty dense body at cone 5. Small black iron specks appeared at cone 1. This is a dense-burning fireclay, and it is unfortunate that it does not occur in larger quantities.

The grey clay (1650) described here, overlies 1648. It does not appear in the steep southern escarpment of the hills, but shows on the gentle north slope. Like 1648 it mixed up to a mass of good plasticity, whose average air shrinkage was 7·8 per cent.

Wet-moulded bricklets were tested as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1	16·76	Cream white
03	3·6	11·60	" "
1	6·0	8·23	" "
5	6·6	4·37	" "
9	8·4	2·25	" "
32	Fused		

The clay burned nearly steel hard at cone 010, and thoroughly so at cone 03. Small black specks appeared at cone 010.

This clay closely resembles 1649, but has a slightly higher fire shrinkage. It is a good dense-burning fireclay and well worth working. Figure 2 shows the absorption and fire shrinkage curves of the grey fireclay. It is placed in the same figure with 1648, and comparison of the two shows the effect of the sand in reducing both the fire shrinkage and absorption.

Owing to the fact that 1646 cracked badly in drying it was decided to try a mixture of equal parts of 1646, 1647, and 1648. This (1651) when tempered with 32 per cent of water was very plastic and small test pieces dried without checking. The air shrinkage was 8 per cent.

The wet-moulded bricklets fired as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·0	14·16	Light red
03	3·3	8·00	Red
1	4·3	5·33	Brown

This mixture burned to a steel hard body at cone 010, at which temperature it would probably make good common brick either by the soft-mud or stiff-mud process. At cone 1 the fire shrinkage is rather high, and the body not burned quite dense enough for sewer-pipe, but would probably become more vitrified at cone 2.

The mixture makes an excellent dry-press brick of good colour and steel hardness at cone 05, with an absorption of 13·75 per cent.

Clays and shales similar to those seen at the Dirt hills occur rather widespread in the western part of the State of North Dakota, and are worked at two points, Hebron and Dickinson, on the Northern Pacific railway.

The section at Dickinson shows 8 feet of almost white fire-clay, and about 2 feet of fine plastic pottery clay, underlying which is 6 feet of a semi-refractory grey clay. These beds rest partially on a thick lens of greyish white sandy clay almost identical in composition with No. 1648.

There is a layer of hardened yellowish clay found generally overlying the white clays in the vicinity of Dickinson, which is absent in the area examined at the Dirt hills. This hard clay is useful in the manufacture of firebricks, as when coarsely ground it serves as "grog" for the plastic clays.

A grey and yellow ferruginous shale or clay, similar to 1646, underlies the fireclays and sands and is here used for red dry-press bricks or for mixing with the semi-refractory grey clay to produce a spotted facing brick.

The dry-press process only is used at these works, firebricks and facing brick alike being made by this method. The firebricks which are made in 8 and 9 inch sizes are often shipped in large quantities to the neighbouring parts of Canada, the price obtained being $25 to $28 per thousand f.o.b., and both the Hebron and Dickinson plants send buff and spotted face bricks into Canada.

CHAPTER IV.

Edmonton Formation

This formation underlies a belt of varying width extending from the International Boundary, northward through the centre of the Province of Alberta.

In Alberta it is divided by Dowling into two parts: (1) A coal-bearing member known as the Edmonton and likely to be the more productive of shales, and (2) a heavy sandstone formation known as the Paskapoo.

The first forms a trough, which is filled along its centre by the latter. This trough widens towards the north, and also flattens, exposing a larger area of the Edmonton series than in the southern part.

Considerable attention has been given to the coal seams in the reports of Tyrrell[1] and Dowling[2], but practically nothing is said regarding the character of the associated shales. This is not unnatural since their economic value had not been considered. However, it is reasonable to suppose that at many points where the coal outcrops, mentioned by these authors, occur, there the shales may be exposed also. This would be mainly in the Edmonton series whose distribution is shown on the geological map.

The shales are found with the coal seams around Edmonton, and also up the Saskatchewan river south of there, as well as westward in the vicinity of Pembina.

Shale exposures should also be looked for on the Red Deer river within the limits of the area underlain by the formation on the Bow river near Crowfoot Crossing. A narrow belt of the Edmonton formation occurs along the foothills, and passes west of Cowley on the Crows Nest branch, and west of Cochrane on the main line of the Canadian Pacific railway.

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[1]Annual Report Geol. Surv., Can., 1886, Vol. II.
[2]Geol. Surv., Can., No. 1035.

Cowley.—The most southern deposit of Edmonton shales visited was at Jameson's mine, south of Cowley and six miles northwest of Pincher. The mine is located on the south fork of the Oldman river, in section 27, township 6, range 1.

Along the bank of the river the visible exposures (Plate XXXVIII) consist of alternating beds of sandstones and sandy shales, dipping northeast about 20 degrees. At the coal mine, the beds turn up suddenly along a fault line, and coal is badly crushed. Overlying the coal, which is bituminous, there is a 15 foot bed of clay which has also been disturbed somewhat by the faulting, for coal fragments are mixed up with it near the contact of the two.

It has been commonly supposed that this material was a fireclay, but the tests given below disprove this.

The shaly clay (1675) is a light grey material, containing enough lime carbonate to make it effervesce with hydrochloric acid, but not sufficient to cause it to burn buff.

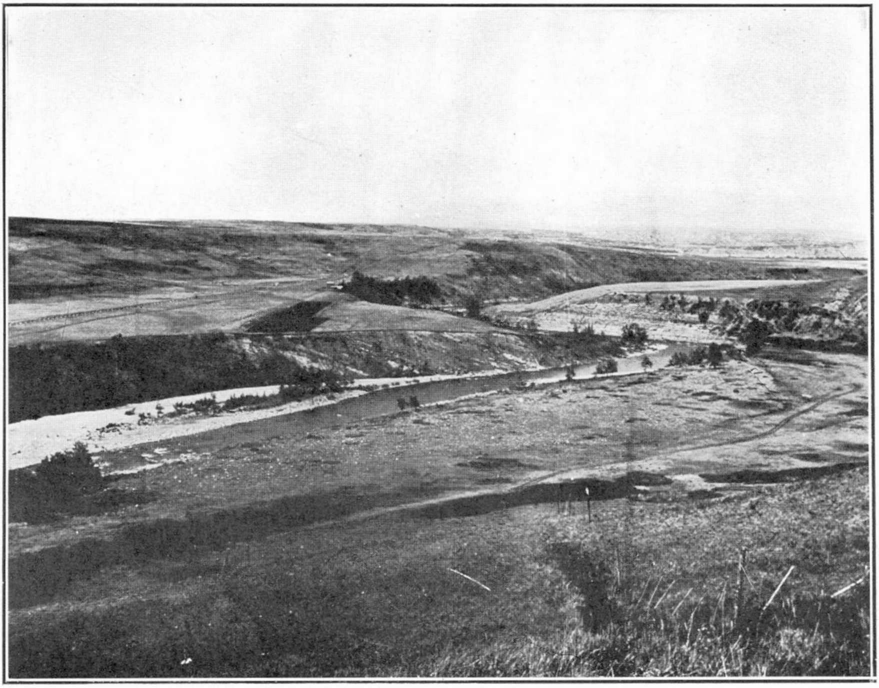
About 28 per cent of water was used to mix the clay, and the average air shrinkage was 8·9 per cent. The average tensile strength was 205 pounds per square inch. Even the small bricklets checked in air drying, but salt will prevent this.

Burning tests yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	15·36	Light red
03	0	13·83	Red
1	3·7	5·95	Greyish
3	3·8	4·80	Grey
5	Vitrified		
9	Fused		

The clay burned to a good colour at the lower cones and steel hard at cone 03. Above this cone the colour becomes poor.

The position of the clay would make it rather expensive to mine, and it would have to be done in connexion with the coal. It might work for sewer-pipe, but for this purpose is not as desirable as the material located on Mill creek. It is not a fireclay. Pressed brick could probably also be made from it.



Valley of the Oldman river, north of Pincher, Alta.

Lundbreck to Bermis.—East of the front range of the Rockies, the country is broken by a series of hills and ridges, whose axes lie more or less parallel with the mountains. These ridges contain a series of folded shale and sandstone beds, which dip at a varying angle, and in the case of those between Lundbreck and Bermis, usually to the eastward.

These beds are well exposed in a series of cuts along the Crows Nest Pass branch of the Canadian Pacific railway, beginning about two miles west of Lundbreck, and the last one being about one-half mile east of Bermis.

In most of these cuts the shale beds are lenticular and rarely over a few feet in thickness, but if they were refractory it would be possible to work them as narrow cuts. With this idea in mind, samples were taken from the most promising looking ones, but none turned out to be fireclays. The first exposure met with was a dark shale on the bank of the Oldman river, one mile west of Lundbreck. The width of the outcrop is over 50 feet and there is no overburden.

This was a fairly plastic shale (1679) with much grit, whose air shrinkage was 4·6 per cent.

The following results were obtained on burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	14·17	Light red
03	3·3	7·75	Red
1	5·5	1·85	Brown

This shale burned to a good red colour and good hard body. It is not only a good brick material, but may perhaps do for making paving brick.

Along the railway track two beds of shale lying between heavy sandstone were noted in the first cut, 27 posts east of 77th mile post. The material (1680) of the lower bed is somewhat hard when fresh, but gives a plastic mass if finely ground. Its air shrinkage was 4·7 per cent.

At cone 010 the absorption was 12·75 per cent, and the bricklet was slightly swelled. At cone 03, the fire shrinkage was

2·7 per cent, and absorption 5·84 per cent. The clay burned red, but was well past vitrification at cone 1. It was tested with the hope that it might prove to be a fireclay, but as can be seen from the tests this is not the case. If there was enough of it and the material could be easily quarried, it might pay to work it.

The first cut west of that from which sample 1680 was obtained contains a light grey shale (1692), which was also tested with the hope that it might be a fireclay, but tests disprove this; moreover the shale is calcareous. When ground and mixed with water, it is very plastic, and has an air shrinkage of 5·4 per cent.

It behaved as follows in burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·55	13·96	Light red
03	0·70	12·80	Red
1	Fused		

The clay burned to an excellent colour and good hard body, but there is not enough of it to permit cheap working.

Near the western end of the line of cuts, between Lundbreck and Bermis, is a green plastic shale (1683) of slightly gritty character, whose air shrinkage was 5·5 per cent.

Burning tests gave the following data:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·3	10·40	Light red
03	5·7	1·40	Dark red
1	2·3	0	" "
5	Beyond vitrification		

This clay burned dense at a low cone, but softens a little too rapidly for paving brick. It could, however, be used for red building brick.

In the first cut east of Bermis, there is a good sized deposit of a dark slaty shale (1684), but unfortunately it is but feebly plastic, and somewhat gritty. Its air shrinkage was 4·0 per cent.

Burning tests resulted as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	13·71	Light red
03	"	11·37	" "
1	2·3	4·28	Red
3	0·4	7·58	
6	Fused		

The clay burned to an excellent hard body when wet-moulded, and became quite dense at cone 1. It makes a good dry-press at cone 03, but needs to be fired slowly, and be well oxidized to give a good colour. At this last cone the absorption was 9·82 per cent.

Edmonton.—At this locality the Saskatchewan river has cut a trench about 160 feet deep through the strata of the Edmonton formation. This would afford an excellent section were it not for the numerous landslides which conceal the beds on the valley sides (Fig. 4.)

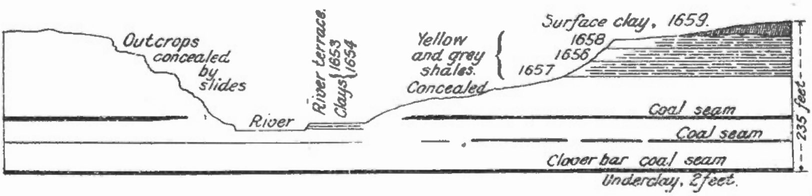


FIG. 4.—Generalized section of Saskatchewan valley at Edmonton, Alta.

The shales and sandstones are found above and below the coal seams, and at a higher horizon than the coal there may also occur beds of massive shale. Those shales associated with the coal are often carbonaceous in their character, and few of them were tested.

One of these, representing a 2 foot seam under the coal at the Ritchie mine, stood cone 13 without fusing, but the bed is too thin to work, and moreover the shale would need to be preheated as it cracks so badly in drying.

One of the heaviest series of shale beds is that located on the property of the Western Clays Company, Ltd. This Company owns eighteen acres near Strathcona, lying between the wagon road from Edmonton to Strathcona, and the Edmonton, Yukon, and Pacific railway.

The natural outcrops occur along the line of this road below the Twin City mines, at the latter, and between them and the Western Clay Company's property.

These several outcrops show a variety of shales. In most of the outcrops passed along the track up to the Twin City coal mines, there is little room for development, as the highway is close to the railway. Shortly before reaching the Twin City mine the two diverge, and chances for development are better.

The shales on the property of the Western Clays Company, Ltd., are mostly grey with brownish or yellowish streaks and occasional small iron crusts. All the beds weather down to a plastic clay. There is no doubt that these shale beds are higher up than the coal in the Twin City mine, but their exact thickness is not known as none of the borings made went deeper than 23 feet.

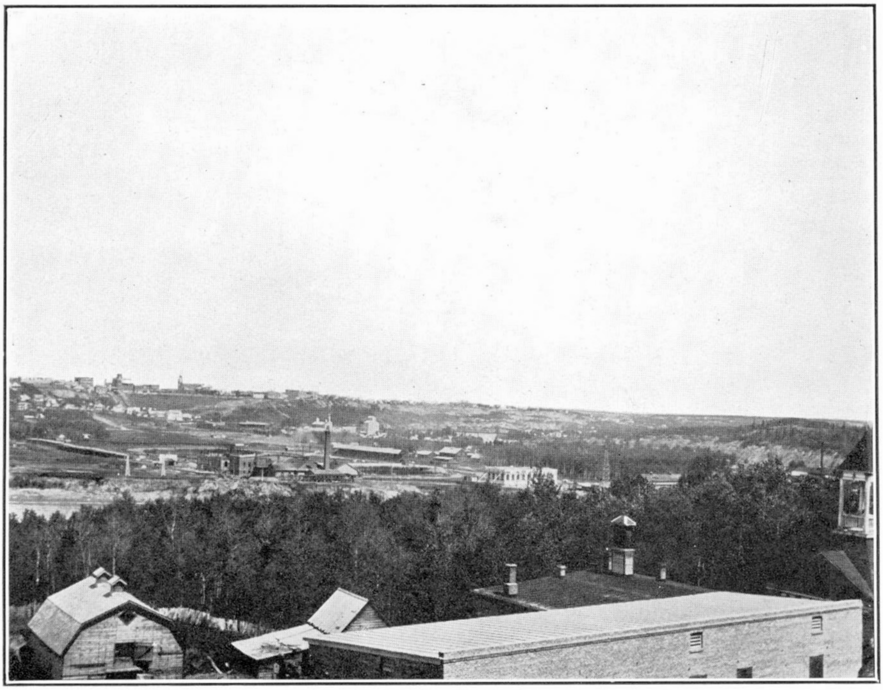
On the opposite side of the small valley in which these shales outcrop, there appears to be a heavy drift mantle, and it is said that the Company prospected over there without result. If the beds continue on the other side of the valley, they must lie at a slightly higher level, as the formation rises in that direction, but they are covered by glacial drift.

It is claimed that tests made of these shales in England have proven their value for paving brick and sewer-pipe.

The following data were obtained by us in the laboratory:—

Lower Shale (1657).—This shale worked up with 33 per cent of water to a very plastic, sticky mass, with much fine grit, and which showed air cracks in drying. Its average air shrinkage was 8·1 per cent.

PLATE XXXIX.



General view of the Saskatchewan valley at Edmonton, looking northeast from Strathcona.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	2·2	17·30	Light red
03	2·4	14·09	Red

The bricklets showed a tendency to crack in burning, and we should not regard this as a desirable material to be used alone.

Middle Shale (1656).—This worked up with 28·6 per cent of water to a very plastic mass, whose average air shrinkage was 10·4 per cent, and tensile strength 279 pounds per square inch.

It would not stand rapid drying without cracking. In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·2	14·24	Light red
03	3·7	9·23	Red
1	4·3	.....	Dark red
3	6·7	1·50	" "
5	Nearly fused		

A dry-press bricklet burned steel hard at cone 05, red in colour, and had 14·80 per cent absorption. This shale burned to a good colour, but the main objection to it was the high air shrinkage. If the clay were used for dry-pressed brick this difficulty could be overcome.

Upper Shale (1658).—The upper shale is very plastic, smooth, and sticky when wet, as well as being difficult to mould. It is also calcareous in its character, but not sufficiently so to cause it to burn buff. Thirty-five per cent of water was required to work it up, and the average air shrinkage was very high viz., 13·1 per cent. The average tensile strength was not less than 150 pounds per square inch, but owing to the small size of the briquettes, due to high shrinkage, it was difficult to hold them in the clips of the machine.

Wet-moulded bricklets gave the following tests:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	2·15	12·08	Light red
3	6·0	1·20	Dark red
5	Nearly fused		

A dry-press bricklet burned to cone 05, had a red colour and absorption of 17·24 per cent, but the body was not hard.

Clover Bar, Alberta.—This locality is situated along the Saskatchewan river, six miles from Edmonton, and near the bridge of the Grand Trunk Pacific railway.

There are lignite mines on both sides of the river, and some outcropping seams are seen in the river banks. The shales associated with these are all very sandy, but even if suitable for making clay products there is too much overburden to permit economical working.

The Humberstone mine was visited, but the underclay there is too thin.

Entwhistle, Alta.—A heavy series of shale beds occur on the property of the Pembina Coal Company, Ltd., at Entwhistle, Alta. We did not have time to visit this locality, but the section (Fig. 5) supplied by Mr. C. C. Richards, Superintendent, shows the position and thickness of the beds, and also the location of those from which samples were tested.

These samples were taken by Mr. Richards in accordance with our instructions.

The tests are given below:—

Shale No. 1662 is a smooth, plastic, slightly calcareous one, which worked up with 22 per cent of water. Its average air shrinkage was 4·8 per cent, and average tensile strength 381 pounds per square inch. A full-sized brick would not stand fast drying.

In burning it behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	14·62	Pale red
03	3	6·02	Red
1	5	0	Brown
3	6	0	"
5	Fused.		

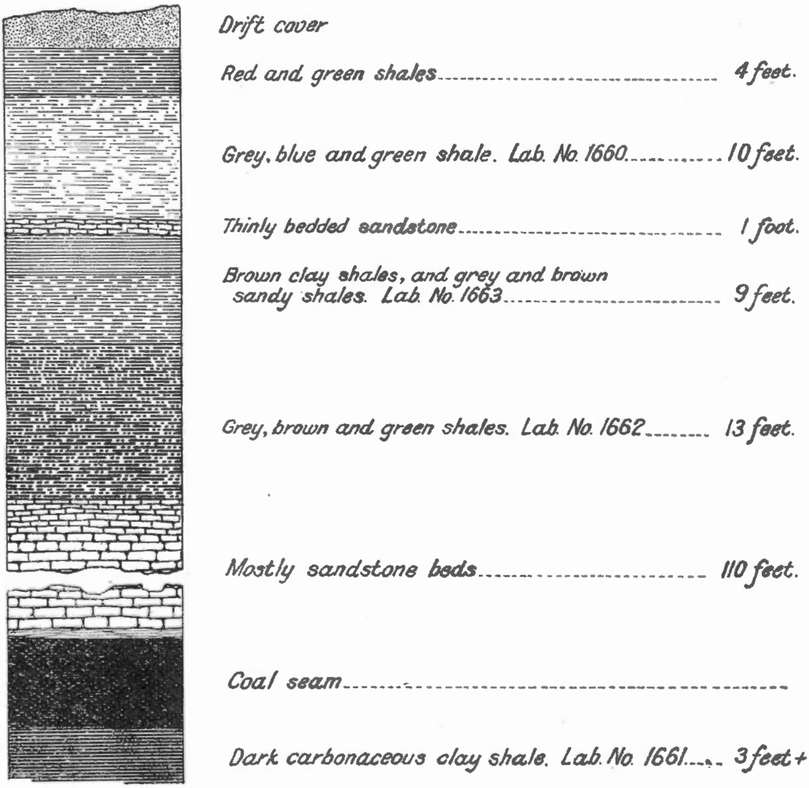


FIG. 5—Section of shale beds at Pembina Coal Company mine, Entwhistle, Alta. *After C. C. Richards.*

The shale burned to a good hard body at cone 010, and became steel hard at cone 03. This shale seems adapted not only to the manufacture of common brick, but is well worth trying for paving brick and even sewer-pipe or hollow brick. The last would, of course, have to be burned at a lower heat than the other two.

Shale No. 1663 overlies No. 1662. It is a calcareous, plastic, somewhat gritty material which worked up with 22 per cent of water. The average air shrinkage was 4·7 per cent, and average tensile strength 198 pounds per square inch. A full-sized brick checked slightly in fast drying.

Burning tests yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	17·96	Pale red
03	3·6	8·72	Red
1	9·0	·75	Red brown
3	Fused		

This makes a good brick material, but fuses at a lower temperature than the preceding, and does not vitrify as slowly; consequently it seems less well adapted to the manufacture of vitrified wares. It might work dry-press. Although calcareous in its character, it does not contain enough lime to make it burn buff.

A dry-press brick was made consisting of equal parts of 1660, 1662, and 1663. This at cone 05 gave a body, of good red colour, sound ring, and 12·38 per cent absorption.

Shale 1660 (see section Fig. 5) overlies No. 1663. It is slightly calcareous, worked up with 24 per cent of water to a mass of good plasticity, and showed some grit. The average air shrinkage was 6·7 per cent, and the clay would not stand rapid drying.

Its behaviour in burning was as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	14·58	Light red
03	4·4	6·05	" "
1	Slightly swelled	0	Brown
3	Fused		

It became steel hard at cone 010, and makes a good hard brick, but at cone 1 seemed to be slightly beyond vitrification as evidenced by the swelling. It would probably work dry-press. It is doubtful if the clay would stand more than cone 3 without fusing.

Clay under coal seam (1661), Pembina Coal Company, Entwhistle: This is a very plastic, sticky clay, which cracks badly in air drying even small bricklets, but it is one of the most refractory clays tested from the Edmonton region. In order to improve the working of this clay it was tested under three different conditions as follows:—

1661. Untreated clay. Very plastic, sticky, hard to work, could be dried without cracking only in moist atmosphere.

1661A. Clay, with 1 per cent common salt added, worked up much better, and did not crack in air drying.

1661B. Preheated to 350° C. still cracked on air drying. Preheated to 500° C. plasticity still good, clay granular, but dried without cracking, even moderately fast.

The tests of these three are given below:—

	1661	1661A	1661B
Water required	35	26	......
Air shrinkage	10·2	7·6	4·7
Cone 010—			
Fire shrinkage	0·6	1·5	0·7
Absorption	14·54	14·28	20·19
Colour	Light red	Light red	Red
Cone 03—			
Fire shrinkage	7·3	6·7	......
Absorption	1·04	4·2	....
Colour	Red brown	Red	......

Cone 1—			
Fire shrinkage..........	......	7·3	7·0
Absorption............	......	1·0	2·8
Colour...............	......	Red brown	......
Cone 3—			
Fire shrinkage..........	......	......	8·6
Absorption............	......	......	3·76
Cone 5—			
Fire shrinkage..........	5·0	......	......
Absorption............	1·0	......	......
Colour...............	Brown	......	......
Cone 13..................	Vitrified.		

Kananaskis, to Cochrane, Alta.—The Rocky mountains end in a pronounced escarpment at Kananaskis (Plate XL). From there eastward the country consists of low foothills which merge into the plains.

Underlying this region are beds of shales and sandstones chiefly Cretaceous, the whole series being highly folded. At Seebe Siding east of Kananaskis the flat-lying Cretaceous shales have been opened up in a pit (Plate XLI) along the Bow river, in order to obtain material for the cement works at Exshaw. They are siliceous, hard, and not adapted to the manufacture of clay products.

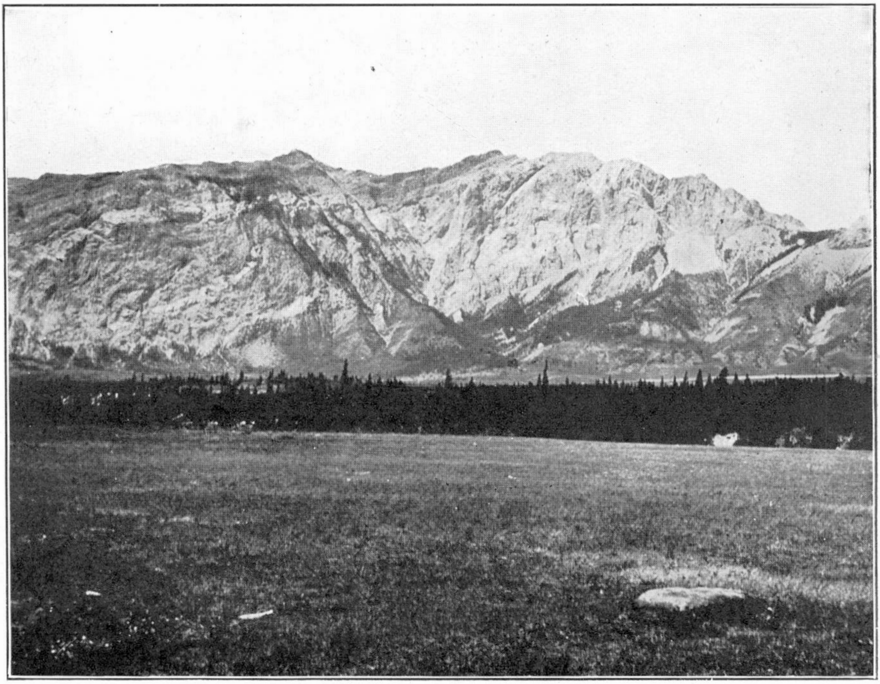
Eastward from here sandstones are the predominating rock, and shales appear to be rather scarce, except between Radford and Mitford, where they are worth investigating.

Tertiary Formation.

This overlies the Edmonton series, and forms a broad belt (Geological map) extending from somewhat north of the Grand Trunk Pacific railway west of Edmonton, southward almost to the International Boundary.

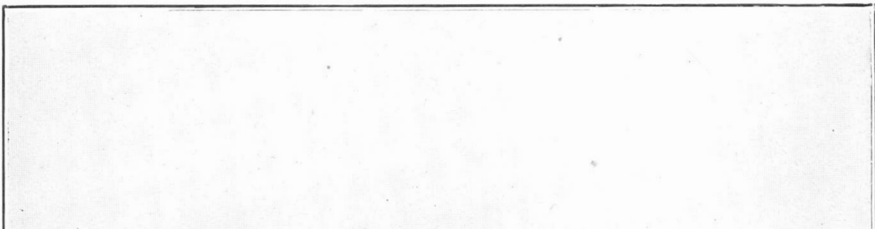
The formation consists of shales and sandstones, often alternating in rapid succession, but the minute stratigraphic details have not been worked out in any of the areas. Outcrops are also scarce, as the formation is heavily and extensively covered by Pleistocene materials. It includes the shale areas examined at Red Deer, Calgary, Sandstone, and Pincher Creek, by Pincher.

Pincher, Alta.—Shale outcrops on Pincher Creek (Plate XLII), just east of Plunketts ranch. It is a very plastic calcar-



Folded limestone beds in eastern front of the Rocky mountains, Kananaskis, Alta. The flat tract in the foreground is underlain by dark, gritty, Cretaceous shales.

p. 104



Beds of gritty Cretaceous shales at Seebe siding, Alta., formerly used by cement plant at Exshaw.

Shale beds exposed on bank of creek at Pincher, Alta.

eous shale (1672), but does not contain enough lime to make it burn buff.

It worked up with 24 per cent of water, and had an air shrinkage of 7·7 per cent. The average tensile strength was 79 pounds per square inch.

Burning tests of wet-moulded bricklets yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·8	14·63	Light red
03	6·0	4·65	Deep red
1	Past vitrification		

This shale is all right as to colour and hardness, but there is some doubt as to the amount and economy of working. It made a good, nearly steel hard dry-press brick at cone 03, with an absorption of 8·4 per cent.

Calgary Region.—The region around Calgary is underlaid by Tertiary shales, but unfortunately there are few outcrops owing to the extensive and usually thick deposits of Pleistocene gravel and silts. They are to be looked for especially in the valleys, but at present, the wash from the upper slopes though thin may be sufficient to conceal them.

At present these shales are worked at two localities, viz., Sandstone south of Calgary, and Brickburn west of Calgary. At both these localities considerable trouble is caused by the numerous sandstone layers in the shale,which have to be thrown out in mining. It would be well worth careful prospecting to find some localities at which the sandstone layers are absent or less abundant. Such a one was found by us east of Cochrane.

The several localities in the Calgary region may be referred to separately.

Brickburn.—This place is located about five miles west of Calgary on the south side of the Bow River valley. The valley (Plate XLIII) here is quite broad, and the Bow meanders in it, but here and there has cut a cliff in the sides, exposing beds of shale.

The Calgary Pressed Brick and Sandstone Company has opened up a bank in a bluff about 100 feet above the river level, at a point where the shale outcrop is hidden under a thin sheet of wash and talus. The excavation, about 30 feet in height (Plate XLIV), exposes a series of beds of hard, sandy, brown shale, soft brown shale, thin layers of blue shale, and beds of sandstone.

The sandstone and shale beds alternate and there are no beds of the latter which are over 3 feet in thickness. In blasting down the material the shale becomes pretty thoroughly shattered, but the sandstone is left in large blocks. This facilitates its removal, which is fortunate, as it forms about 30 per cent of the material in the bank.

Little prospecting appears to have been done to ascertain whether a better deposit of the material could be found in the immediate vicinity. This cannot be accomplished without testpitting and trenching as most of the surface, including the steep slope leading down to the river, is covered by a silty clay containing lime pebbles. That other material may be present is indicated by the fact that along the railway track there is a mass of solid shale which has slid down from a higher level.

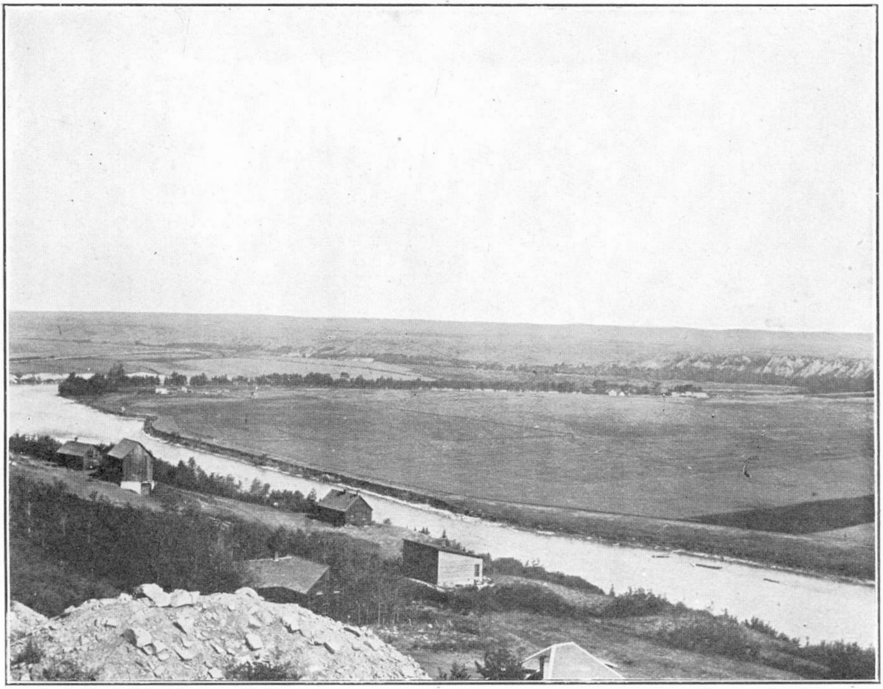
At present the bricks are made from the shale obtained from the quarry near the top of the bluff, and this material has the following qualities:—

This shale (1703) slakes down slowly, but when ground and mixed with 17 per cent of water gave a plastic but gritty mass, whose air shrinkage was 5 per cent and average tensile strength 154 pounds per square inch.

The wet-moulded bricklets behaved as follows in burning:—

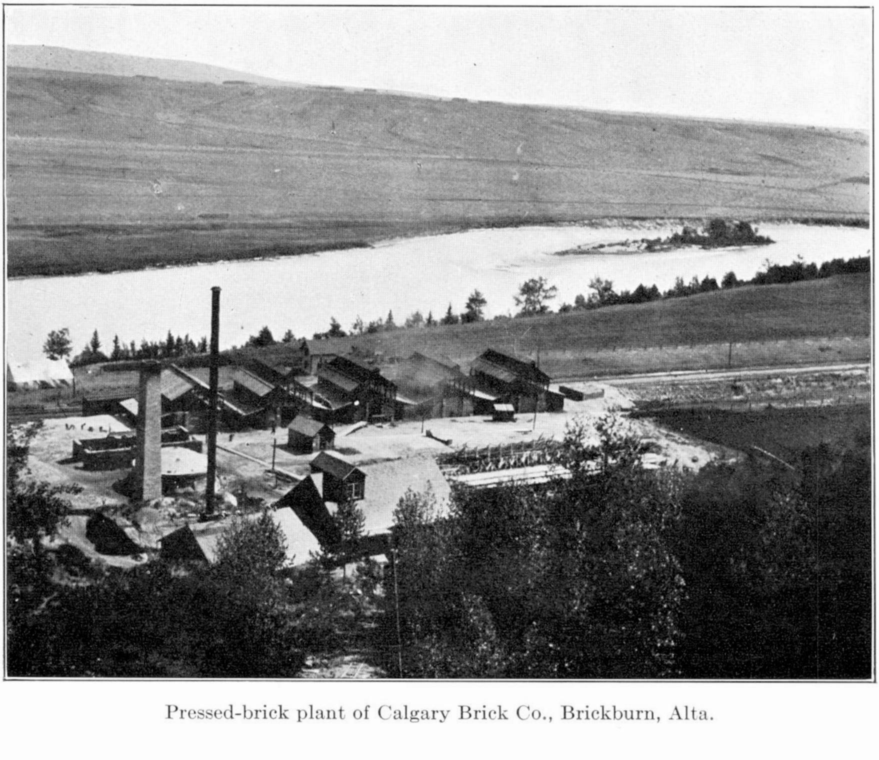
Cone.	Fire shrinkage	Absorption.	Colour.
	%	%	
010	0·6	13·43	Red
03	2·3	8·73	"
1	Fused		

This clay burned to an excellent hard body when wet-



Valley of the Bow river, looking northwest from shale pit at Brickburn, Alta.

Beds of alternating shale and sandstone on property of Calgary Pressed Brick and Sandstone Company, Brickburn, Alta.



Pressed-brick plant of Calgary Brick Co., Brickburn, Alta.

p. 106

Sand-lime Brick Co., Calgary, Alta.

moulded, and it should be tried in a stiff-mud machine. At the present time it is employed for dry-press brick, but our tests of the clay moulded in this manner showed that firing to cone 05 in the coke-fired kiln was not high enough. Its absorption at 05 was 13·00 per cent and at cone 03, 11·65 per cent.

Calgary Pressed-Brick Company.—The shale after quarrying is loaded on to cars and run down a gravity plane to the works (Plate XLV). There it is ground in a dry pan, and put through a Boyd dry-press. Burning is done in part in a circular down-draft kiln, and in part in a Dutch kiln. The superintendent stated that the bricks settled 3 inches in thirty-three courses. After burning they are graded according to colour.

The burned bricks show numerous grains and small fragments of sandstone on the fracture. If the mixture contained less sandstone it would burn to a much denser body. It is claimed that no trouble is experienced in checking unless the bricks are exposed to the wind when green, or burned too fast.

Calgary, Alta.—The Golden West Realty Company has established a small dry-press plant located on a hill about one mile west of the city. The shale is exposed in a coulee just west of the yard, and is possibly not of great extent as there is a sandstone quarry at nearly the same level not more than 200 feet from it. It is probable that the shale overlies the sandstone, as the latter in the quarry is covered by a brown and buff shale with sandy streaks. The Brick Company's opening is small and shallow and no test was made of the material, but it is known to be red burning.

Sandstone, Alberta.—The branch of the Canadian Pacific railway from Calgary to McLeod passes few outcrops until it reaches Sandstone, where the railway is located in a somewhat narrow valley whose sides are rather steep, and afford some exposures of the Tertiary shales and sandstone.

The best section, however, is that shown in the quarry of the Canadian Cement Company, where a face about 50 feet high has been opened up, showing a series of alternating layers of sandstone with blue and grey shales (Plates XLVII and XLVIII). The shale layers are from 8 inches to 2 feet and vary in thickness from point to point in the quarry, the same being true of the sandstone. There may thus be an excess of sandstone in one part of the quarry, or of shale in another.

The shale is hard, fine-grained, with a splintery break and conchoidal fracture. The blue, if used alone, is said to crack in water smoking, but the grey does not, nor does a mixture of the two. The blue seems to disintegrate less readily, and the grains of it in the brick are often coarser than the grey.

In testing the quality of the material from this bank, a full test was made of the ground mixture as prepared for dry-press, and a partial test of each of the shales alone.

These tests follow:—

The ground shale mixture (1704) is calcareous, but not sufficiently so to burn to a buff product. It does not crush down very easily, and unless finely screened yields a coarse-textured brick, which should be burned to cone 03 to give proper hardness.

When wet-moulded with 19 per cent of water, it yielded a plastic but sticky mass, whose air shrinkage was 6 per cent, and average tensile strength 165 pounds per square inch. A full-sized brick would not stand very rapid drying without cracking.

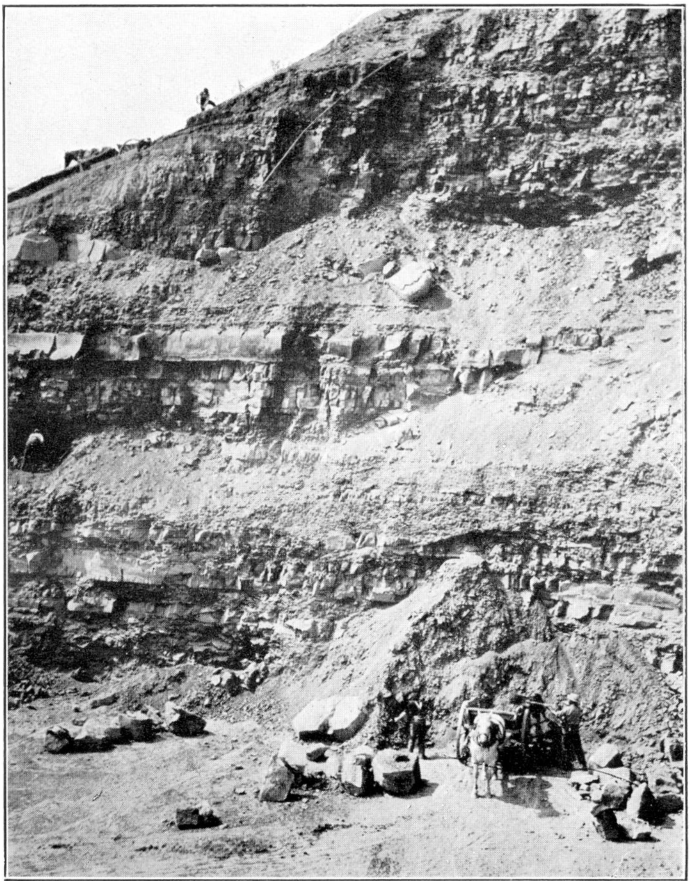
The following results were obtained in firing the wet-moulded bricklets:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	14·90	Red
03	2·3	9·46	"
1	Fused.		

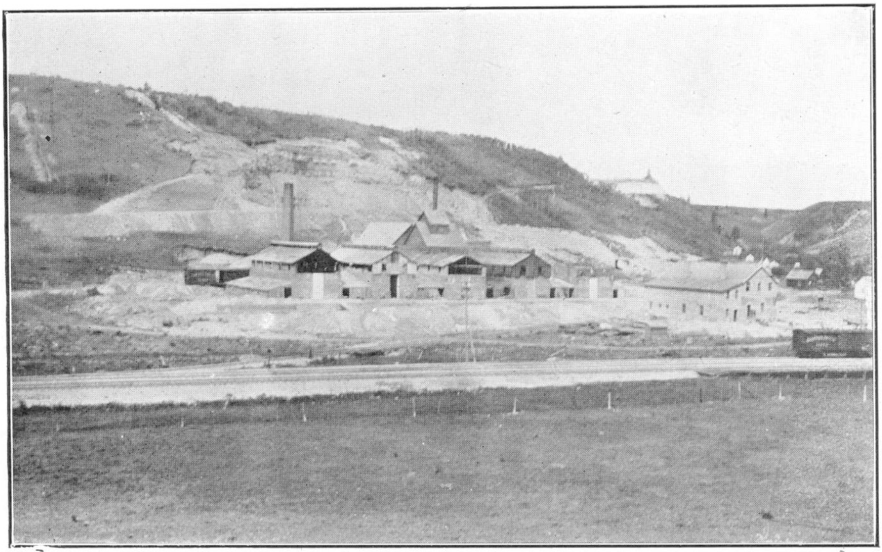
A dry-press bricklet at cone 05 showed 14·28 per cent absorption, and 12·00 per cent at cone 03. It was steel hard at the latter cone.

The grey shale (1705) is calcareous and worked up with 21 per cent of water to a plastic mass with some grit. Its

Alternating beds of shale and sandstone: lower portion of pit worked by Canada Cement Company, Sandstone, Alta.



Alternating beds of shale and sandstone in deposit worked by Canada Cement Company, Sandstone, Alta.



Pressed-brick plant of the Canada Cement Company at Sandstone, Alta.

p. 108

air shrinkage was 5 per cent, and it burned to a good red colour, becoming steel hard at cone 03. At cone 010 the fire shrinkage was 0·2 per cent and absorption 15·56 per cent. At cone 03 the fire shrinkage was 2·3 per cent and absorption 13·67 per cent. The clay fused at cone 1.

The blue shale (1706) from the same quarry required the same amount of water for mixing, but was more plastic than the preceding. Its air shrinkage was also higher, being 6·8 per cent. Like the former, it burned red and fused at cone 1, but was considerably denser after firing. Thus at cone 010 the fire shrinkage was 1·4 per cent and the absorption 12·82 per cent. At cone 03 the fire shrinkage was 4·3 per cent and absorption 5·5 per cent.

Brick Plant of Canadian Cement Company (Plate XLIX)—The Company operates what might be called a double quarry, one-half being at a higher level. The material from the latter is shipped to Calgary for use in Portland cement manufacture while that from the former is used at Sandstone for brick making.

In either case the quarrying involves the disposal of a great deal of waste sandstone, which must add appreciably to the cost of extraction.

For making bricks, the shale is ground in drypans, of which there are two, moulded in a dry-press, and burned in circular down-draft, or Dutch kilns. The bricks are red, have a fair ring, and are somewhat porous. This last is due in part to the sandy character of the material as more or less sandstone from the quarry gets in with the shale. Variations in the material due to this cause some variations in the size of the bricks.

South of Sandstone.—Following down the valley towards Okotoks, there are several places along Sheep creek, containing shale beds similar to those at Sandstone, but in no case was the bank more than 15 feet high. The region should be carefully prospected. From Okotoks back to Calgary by wagon road, no shale outcrops whatever were seen.

Cochrane, Alta.—This locality lies along the Canadian Pacific railway about thirty miles west of Calgary.

The town itself lies on a terrace that is underlain by calcareous clay, and extends to the foot of the ridge forming the north wall of the Bow River valley. Outcrops in the ridge at Cochrane are few, and seem to be chiefly sandstone. Interbedded shales may be present, but if so the wash covers them.

One mile east of the town there is a railway cut in the steep slope bordering the river (Plate L) which exposes a fine section of bluish shales and interbedded sandstone. The former in their general appearance much resemble those found east of Bermis. As this section is in a bluff overhanging the railway, there is no chance of working it without causing slides on to the track, and so only a small sample was taken to get some idea of the character of the material in this vicinity

A test of this shale (1708) showed it to be somewhat calcareous, and that with 20 per cent of water it worked up to a mass of good plasticity but showing some grit. The average air shrinkage was 5 per cent and colour after burning a good red. It was nearly steel hard at cone 010.

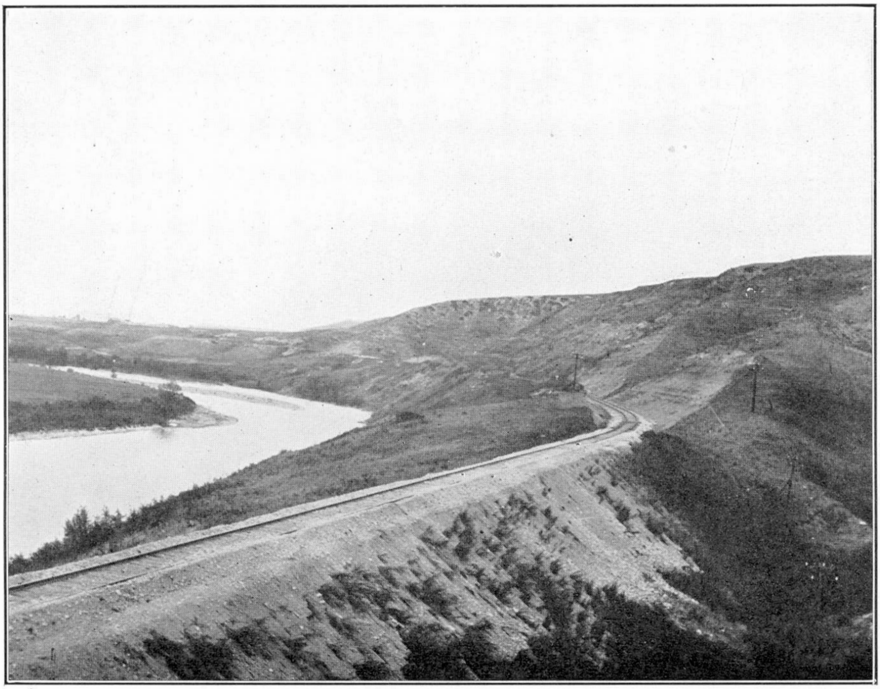
The fire shrinkage and absorption were respectively 0·3 per cent and 17·68 per cent at cone 010, and 0·6 per cent and 17·38 per cent at cone 03. The shale fused at cone 1.

Eastward from this cut, there are a number of small spurs, extending out from the main ridge, and in the coulees between these spurs shale outcrops are sometimes found.

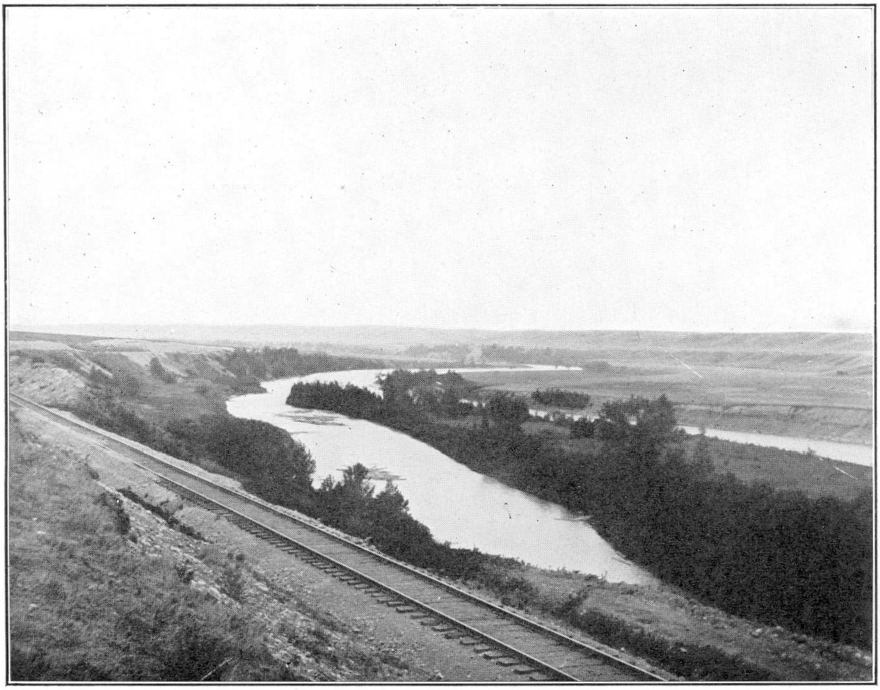
In the first of these, east of the cut from which sample 1708 was taken, there is a deposit of shale at least 40 feet thick, which is free from sandstone, but grades upward into shaly sand.

The deposit of shale must be of some extent, as evidence of it is seen in coulees to the eastward, where it is covered by a thin wash of gravel. This section stands in rather strong contrast to those noted from Brickburn and Sandstone, and shows the possibility of finding shales free from interbedded sandstones in this region.

The tests of this shale (1707) which is slightly calcareous were also encouraging. It worked up with 21 per cent of water to a mass of good plasticity, but showing some grit. A full-sized brick had an air shrinkage of 5·1 per cent and cracked a little in rapid drying. The average tensile strength was 128 pounds per square inch.



The Bow river east of Cochrane, Alta.; shale beds on right of picture.



Valley of the Bow river, looking east from railway track near Cochrane.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·7	18·73	Red
03	2·0	15·57	"
1	Fused		

This makes a good red brick, of sound body, and while it did not burn as dense as the shale from Brickburn or Sandstone, it gave as good a colour, and the deposit was free from the numerous interbedded sandstone layers found at the other localities. It also gave a good dry-press even at 05, but had better be burned at cone 03. At the latter cone it had an absorption of 12·09 and was steel hard.

Didsbury, Alta.—This town is situated near Rosebud Creek, about fifty miles north of Calgary. A brickyard was started here three years ago, on the property of William Hunsperger, but it was only in operation for a short time; the plant being afterwards moved to Camrose.

Wire-cut bricks were made from the decomposed portion of a bed of shale which outcrops in the bottom of a small coulee near the Canadian Pacific Railway line. The plant was badly located as the shale is not very accessible at this point, it being overlain by 20 feet or so of sandstone and glacial drift, and the amount of weathered material exposed in the bottom of the coulee is small.

The shale in the neighbourhood of Didsbury occurs in a horizontal bed and includes a thin seam of lignite. It is thick enough to be worked for brick-making purposes, but to do this economically would have to be found at a place where the sandstone capping was worn off, so as to allow the material being worked in open pits. Such a favourable place could no doubt be found by a little prospecting.

The shale (1702) is of yellowish colour, calcareous, very plastic and smooth, easy to work, and gives no trouble in air drying. The air shrinkage is 5·6 per cent.

Wet-moulded bricklets gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·7	24·03	Pale red
03	0·4	24·80	Buff
1	5·7	13·18	"

This clay burned to a good body, but showed the usual characteristics of a calcareous clay as to colour and absorption. It makes a nice looking dry-press bricklet even at cone 05, but should be burned to cone 03. The absorption at 03 is 27·00 per cent.

Red Deer, Alta.—The only clays in use at this locality are Pleistocene ones, occurring in the heavy deposits of this formation.

Neocene (Tertiary) shales are known, however, to underlie this region and are exposed on the right bank of the Red Deer river, above the railway bridge. For a short distance above the bridge, there is a 15 foot terrace underlain in its upper portion by gravel, but below this and outcropping in the face of the bank are grey shales, which rarely extend more than 10 feet above the river level. These are not very persistent, for up-stream the shale passes into sandstone. About three-fourths of a mile farther up-stream, the high bluffs on the same bank of the stream show about 25 feet of shale, overlain by about 50 feet of till with lenses of silty clay in it.

Below the wagon bridge close to town, the shale outcrops, but is very sandy. About eighteen miles down the river there are said to be heavy bodies of shale over the coal seam. We expect to visit these later.

At the 15 foot terrace previously referred to, the following section was noted:—

Soil	1 foot	
Gravel	2 feet	
Shaly sandstone	2 "	6 inches.
Shale	3 "	
Rock		6 "
Lignite, thin layer		2 "
Shale (1665)	10 "	

The tests of this 10 foot bed of shale, whose exact location is S.E. corner, section 17, township 38, range 27 W., are given below.

It is very calcareous, and worked up with 25 per cent of water to a mass of good plasticity, whose average air shrinkage was 6·9[1] per cent, and the average tensile strength 176 pounds per square inch.

The firing tests of the wet-moulded bricklets yielded the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·8	19·34	Light red
03	1·0	18·47	Pinkish
1	Fused.		

This shows a shale of low fire shrinkage, and rather strong absorption. It makes a common brick and also a nice d y-press brick, but one which should be burned to cone 03. The absorption of this at cone 03 was 20·30 per cent. The fact that it shows a strong absorption at cone 03, but fuses at cone 1 indicates a somewhat rapid softening, due evidently to the lime content.

A full-sized brick did not stand rapid drying.

[1]The air shrinkage of a full-sized, hand-moulded brick was 5·5 per cent.

CHAPTER V.

Mountain Region.

This includes the region bordered on the east by the Great Plains, and on the west by the Coast range, and so far as known does not contain extensive clay resources. Moreover, even those which do occur in this region cannot be of much commercial value unless situated close to lines of transportation.

Shales are rare because in most instances deposits of argillaceous material have been altered to slaty rock or schists. Extensive deposits of surface clays are also rare, and those which are present are mostly of small size and of silty character.

The few localities which were examined are described below:—

SHALE FORMATION.

Blairmore, Alta.—The Kootanie shale outcrops at the base of the hill on the southwest side of the valley (Plate LII). The material is a siliceous, ferruginous, fissile shale, containing occasional sandstone streaks and scattered concretions of iron carbonate. It appears hard when fresh, but nevertheless grinds up rather easily. We have no tests of it as the samples collected were lost in transit, and we can only say that it is red-burning and non-refractory.

The material is used by J. W. Budd for the manufacture of dry-press brick (Plate LIII).

Coleman, Alta.—The same shale is exposed in the hillside near the entrance to the main slope of the International Coal and Coke Company, and probably would give similar results to that used at Blairmore. Our sample of this was also lost in transit.

Cranbrook, B.C.—A sample of a hard grey shale, said to come from a point fifteen miles west of Blairmore, was sent in by J. D. Elmer, of Cranbrook. Nothing further is known about it.

The material (1676) is non-calcareous, and worked up with 20 per cent of water to a mass of medium plasticity. Its average air shrinkage was 6 per cent.

Burning tests of the wet-moulded bricklets are given below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·15	8·10	Buff
03	3·7	2·70	
1	0·6	2·00	"
3	Past vitrification		

Steel hard at cone 010.

A dry-press bricklet at cone 03 had 2·82 per cent absorption.

Elko, B.C.—A talcose schist which occurs in the vicinity of Elko has been regarded by some as a fireclay, and several samples of this material were shown us during the summer. We did not get to see the deposit, but a piece of it was tested and found not to be of refractory character, as it fused completely below cone 27.

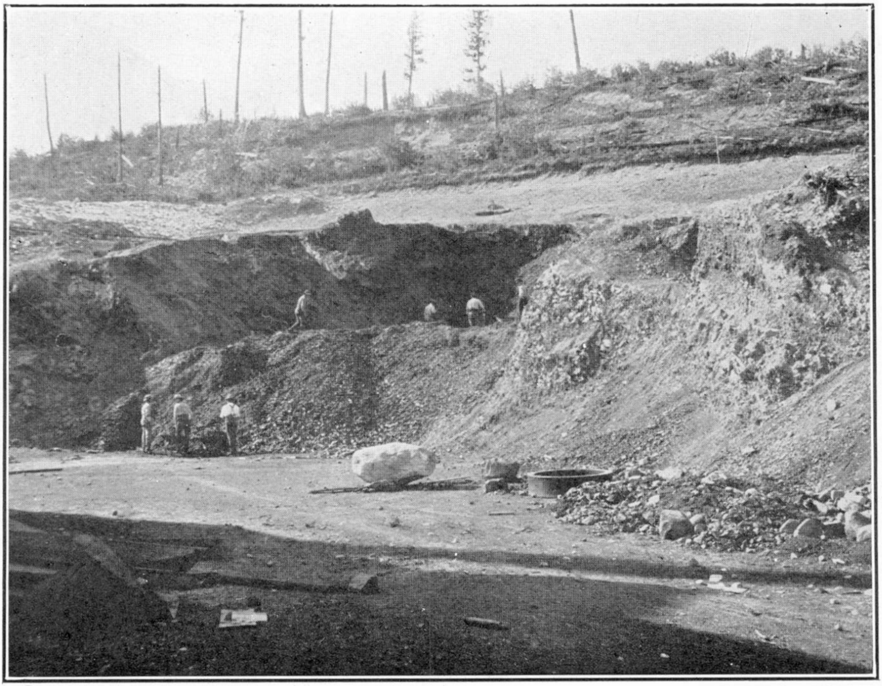
Collins Gulch, B.C.—Nothing definite is known regarding the occurrence of this shale, except that it was obtained from the tunnel of the coal mine by Mr. Chas. Camsell of the Canadian Geological Survey, and sent to us for testing.

The material (1742) is quite plastic, but checks rapidly in air drying. Preheating to 550° C. did not destroy the plasticity, but permitted slow drying without cracking. The air shrinkage was 5·3 per cent, and the fire shrinkage at cone 5 was 8 per cent. At this cone the absorption is 6·8 per cent. The clay is not fused even at cone 13, but is not a fireclay.

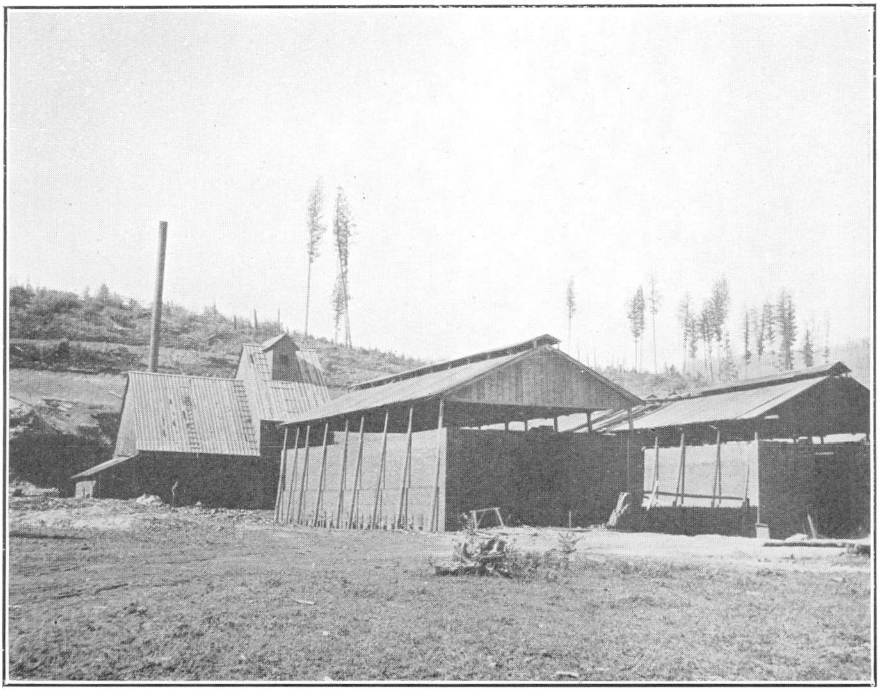
This would seem to be an excellent pressed-brick clay if the cracking is overcome.

Canmore, Alta.—Along the railway spur leading to the coal mines at Canmore, small pockets of clay are found underlying the boulder till of the embankment at the foot of the hill.

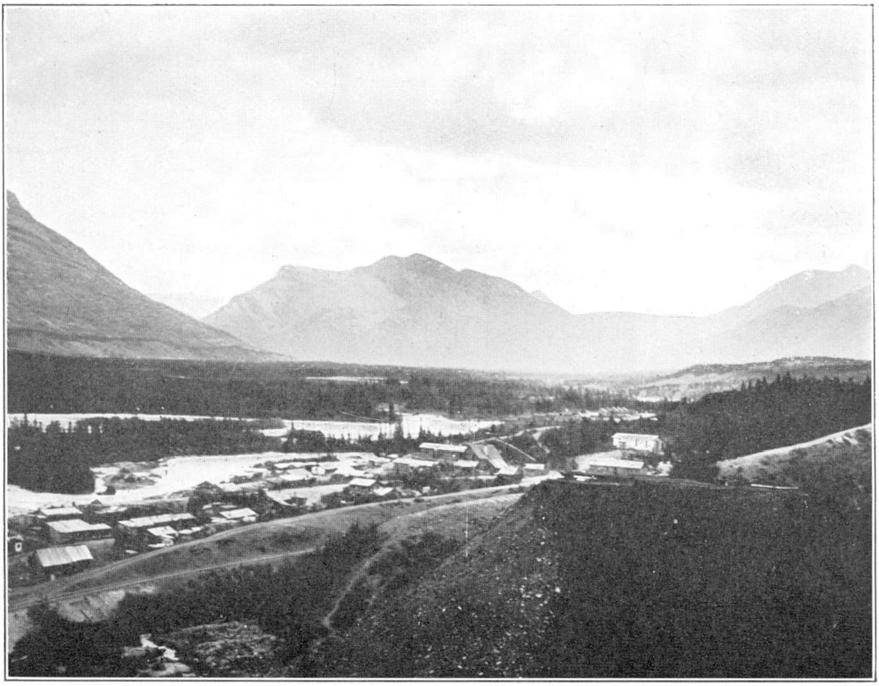
Their location is such that very little of the clay can be removed without stripping off the till, and no attention would have been paid to the material had it not been claimed to be a fireclay. For this reason, therefore, a sample was tested.



Bank of Cretaceous shale, mined for dry-press brick, at Blairmore, Alta.



Dry-press brick plant at Blairmore, Alta., with bank of Cretaceous shale in rear.



View looking down the valley of the Bow river towards the Gap, from coal mine at Canmore, Alta.

It turned out to be silty, highly calcareous clay (1711) which burned to a light-cream colour. Moreover, there is not enough of it to work for brickmaking. Since the tests were made, they might as well be recorded.

Water required, 22 per cent; air shrinkage, 4·2 per cent; brick slightly swelled at cone 010 and cone 03; absorption, 35·41 per cent at cone 010.

SURFACE CLAYS.

Field, B.C.—At the base of Mount Stephen (Plate LV), and close to the railway yards of the Canadian Pacific railway, there is a heavy deposit of tough, strong clay (Plate LVI) which belongs to the colluvial type.

The clay (1713) is derived from an easily decomposed schist on the slopes of Mount Stephen, and has slid to the bottom of the slope. The stones are mostly partly decomposed schist fragments.

Tests made on an average sample showed it to be a somewhat plastic clay that worked up with 20 per cent of water to a mass whose air shrinkage was only 2·7 per cent, due to the large amount of very fine grit.

The shrinkage was zero at all cones up to 1, indeed there was in fact a slight swelling. The clay also burned to a very porous body, the absorption being 21·95 per cent at cone 010; 20·00 per cent at cone 03; and 16·65 per cent at cone 1. It is vitrified and softened at cone 5. The colour after burning is red brown. This is not a highly satisfactory clay, but it could easily be utilized to supply a local demand for brick.

Yoho Valley, B.C.—Along the new wagon road up the valley, about one mile before reaching the "Lower Camp," the road cuts through a deposit of yellowish-brown laminated, and highly calcareous clay.

The clay (1712) is not strongly plastic, and has, moreover, a toughness and springiness which interferes somewhat with easy moulding. Its average air shrinkage was 5·0 per cent, and average tensile strength 111 pounds per square inch. It swelled slightly in burning and at cone 010 had an absorption of 37·92 per cent, while at cone 03 it was equally high. The clay fuses at cone 1.

The clay is not plastic enough to be thrown on a wheel, but could probably be pressed or cast in plastic moulds, and no difficulty was experienced in casting some pieces of pottery in the laboratory.

There is no object in using this clay for brickmaking, but it could be easily employed and at very little cost, for making cheap art pottery souvenirs for the many tourists passing through Field.

Nelson, B.C.—No extensive deposits of clay are known along the Arrow or Kootenay lakes. At one or two points on the Arrow lakes a bluish-grey, laminated clay crops out at water level, but it carries a rather heavy overburden and is not used.

Elsewhere at several points there are found limited deposits of silty clay, usually close to the lake level, and which may have been deposited from it at some earlier date when the lake level stood higher, or they may be of glacial origin. Such a one (1714) is worked at Nelson for common brick manufacture, and another is used near Castlegar Junction, west of Nelson.

That from Nelson forms a mass of good plasticity with 28 per cent of water, and an air shrinkage of 5 per cent.

The clay when wet-moulded burned to a hard but not very dense brick, of red colour. It showed a slight swelling at cone 010, and 2 per cent fire shr nkage at cone 03. The absorption at cone 010 is 23·94 per cent, and at cone 03, 18·33 per cent.

It is past vitrification at cone 1 and fuses at cone 3. It can be classed as a good common brick-clay, but can hardly be considered as useful for much else.

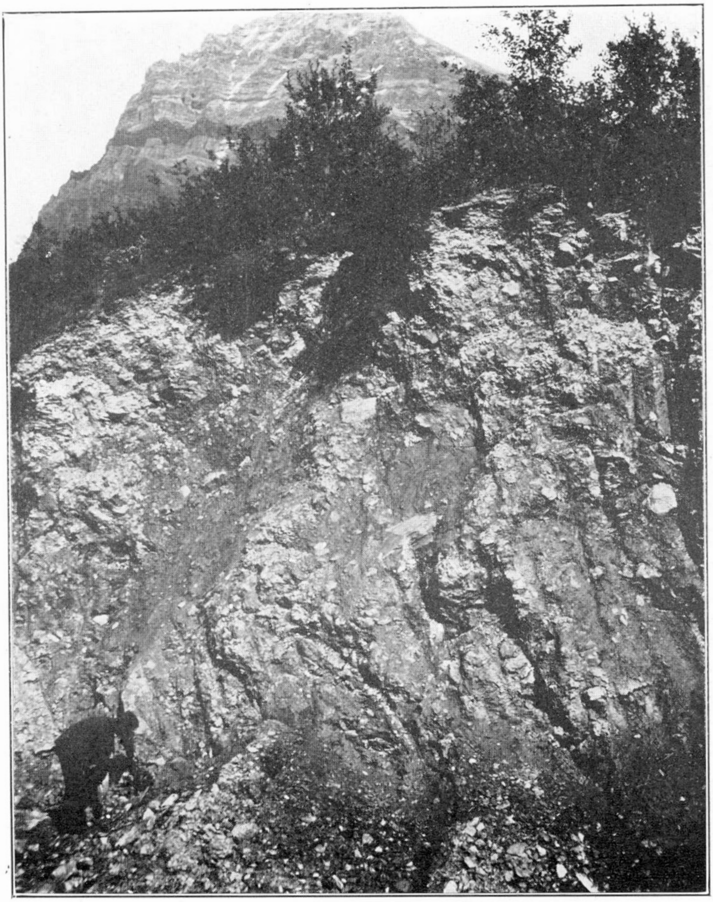
Enderby, B.C.—This town is situated in the Okanagan valley about twenty-five miles south of Sicamous Junction, on a branch line of the Canadian Pacific railway.

The Enderby Brick and Tile Company's works are located on the bank of the Shuswap river near the railway station.

A stratified clay, calcareous, of yellow colour, strongly impregnated with iron oxide, is obtained from the river terrace. The clay bed is not continuous, but is replaced laterally by sand. It appears to be free from pebbles. It is mined to

Field, B.C.

p. 118



Deposit of colluvial clay along line of Canadian Pacific railway at Field, B.C.

about 4 feet in depth for brickmaking, and there is very little overburden. The clay (1715) is somewhat silty and contains an abundance of mica scales, and is only moderately plastic. A full-sized brick stood rapid drying.

It worked up with 28 per cent of water to a mass whose air shrinkage was 6·3 per cent, and average tensile strength 290 pounds per square inch.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	20·76	Red
03	3	14·77	"
1	7·3	0·23	Dark red
5	Fused		

It is steel hard at cone 03 and makes a good common brick. It burns to a vitrified body at cone 1, but the fire shrinkage is rather high at this temperature. It is more refractory than most of the surface clays tested, and the bricks could be burned hard enough to use for lining sewers, or for underground work where a non-absorbent brick was required. The clay as dug is too silty to use in a stiff-mud brick machine, but the lower portion of the bank which is more plastic would probably serve for this process.

A soft-mud brick machine made by J. Bain & Co., Hamilton, is used, and a small quantity of facing bricks are repressed by a hand machine. The clay is brought to the machine by scrapers, and no sand is added; the green bricks are air dried in covered racks, and show no sign of checking.

The burning is done in scove kilns, with dry wood for fuel. The bricks are set thirty-eight courses high and the settle is 8 or 9 inches. The bricks have a good hard red body when burned, but the colour of the faces is somewhat obscured by the impure sand used in moulding.

The product of this yard is shipped south in the Okanagan valley as far as Kelowna, and east along the main line of the

Canadian Pacific railway as far as Revelstoke, the price obtained being $14 per thousand, f.o.b. on cars.

Kamloops, B.C.—The town of Kamloops lies at the junction of the North and South Thompson rivers, in the Interior Plateaus region, and near the main line of the Canadian Pacific railway.

The brick plant of Messrs. Johnston & Company is situated on the river terrace, two and a half miles west of the town.

The clay for brickmaking is obtained from the high terrace, about 100 feet above the level of the works, and is the weathered portion of a hard laminated silty clay (Fig. 6).

The hard clay is called shale by the brickmakers. It breaks out in plate-like fragments and will ring when struck with a hammer. The weathered clay is quite soft and incoherent when dry. It lies in a layer a few feet thick on the slopes of the terrace. It is shovelled into carts, hauled to the edge of the rock bench and dumped on a chute which lands it at the machine.

When the soft clay is stripped from the slopes, the indurated clay is exposed and bears a strong resemblance to an outcrop of shale or thinly bedded sandstone.

The weathered clay (1717) is calcareous and rather silty in character, containing much fine grit and mica. It also contains a high percentage of soluble salts, which come to the surface in drying. It stands rapid drying.

It worked up with 23 per cent of water to a mass of moderate plasticity, whose average air shrinkage was 4·6 per cent and tensile strength 156 pounds per square inch.

In burning it behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	19·12	Red
03	2·0	11·74	"

A re-pressed wet-moulded bricklet gave a good colour and body at 03, with 0 per cent fire shrinkage. The clay is too silty to work stiff-mud. It made a fair dry-press at cone 03, with 13·6 per cent absorption.

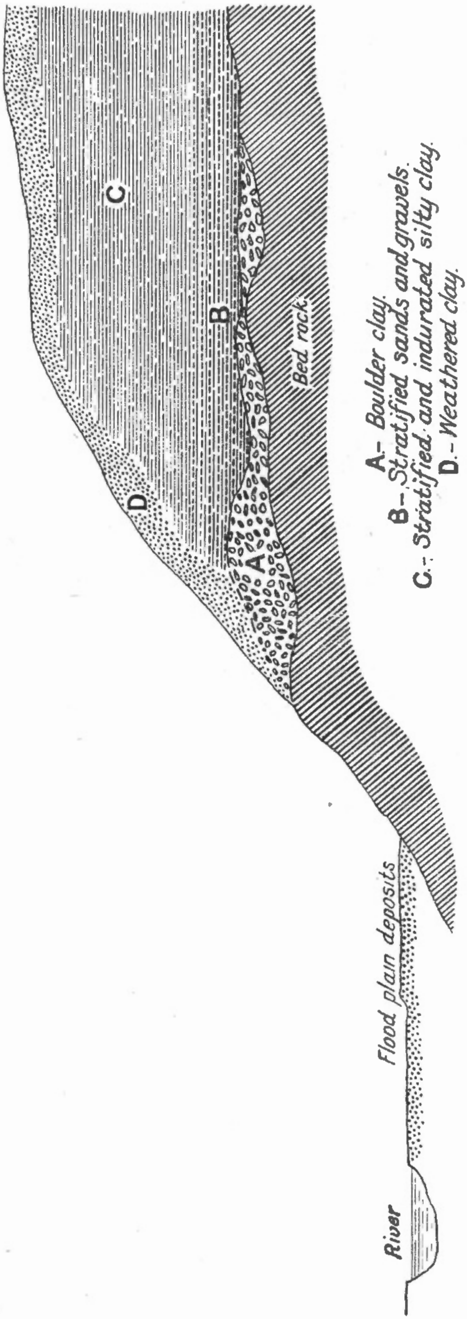


FIG. 6.—Section of clay deposits at brickworks west of Kamloops, B.C.

A sample of the indurated clay (1718) was also collected for testing. This seems superior to the weathered material, being more plastic, works more easily, and has less soluble salts. Indeed, the material is so much more plastic than the weathered clay, that it seems possible to work it on the stiff-mud machine.

This clay worked up with 27 per cent of water, and had an air shrinkage of 8·4 per cent. In burning it behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	2·2	18·38	Red
03	13·0	0·15	"
1	Fused		

The clay is of poor colour, and has altogether too high a shrinkage at cone 03, but gives a satisfactory product at cone 010. If burned to the latter cone it could perhaps be used for drain tile.

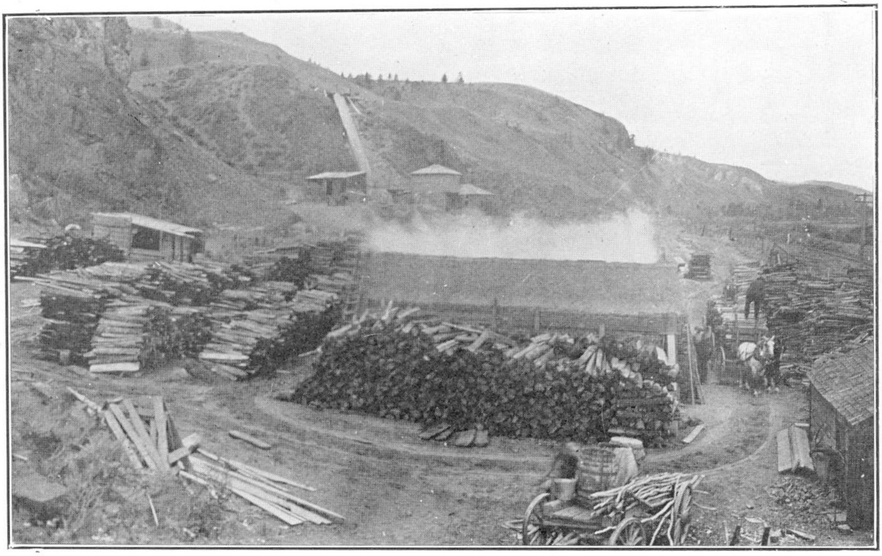
The contrast beween the weathered and unweathered clay is curious. One naturally expects a higher percentage of soluble salts in the weathered clay, but the higher plasticity and shrinkage would be looked for in the weathered and not the unweathered, as found here.

The unweathered clay makes a nice dry-press at cone 05, with an absorption of 14 per cent. It would require the use of a dry-pan grinder to prepare it for manufacture.

A mixture of the two varieties of clay would probably give good results in the stiff-mud process, the hard clay supplying the plasticity and the weathered clay in the mixture would reduce the shrinkages. Only the weathered portion of the clay is used at this yard for brickmaking. It works up well for soft-mud bricks, the only product of the plant.

Scove kilns are used, the time occupied in water smoking and burning is twelve days. Dry wood is used for fuel, at a cost of $3.50 per cord, and a half cord of wood is consumed in burning 1,000 bricks.

The bricks are burned hard and to a deep-red colour;



Brick-yard at Kamloops, B.C.

the price obtained is $14 per thousand at the yard, or $16 delivered at Kamloops, where the output is mostly used.

Gullifords, Otter Creek, Tulameen District, B.C.—A sample (1743) collected by Mr. Chas. Camsell, and sent in from this district, appears to be a flood-plain silt of fair plasticity and non-calcareous character. Its air shrinkage is 5·6 per cent, and at cone 010 it swells slightly, has an absorption of 17·24 per cent, and burns to a good red common brick. At cone 03 it was dark red, had an absorption of 4·5 per cent and fire shrinkage of 5·8 per cent. It fused at cone 1.

CHAPTER VI.

Pacific Coast Region.

This includes the territory lying west of the Coast range, and while limited in the extent of its clay resources, contains a considerable variety, so far as our investigations have gone.

The most important shale deposits are those of Sumas mountain east of Vancouver, which, as shown by the tests given on other pages, represent one of the most important series found in Canada. No other shale deposits of economic value and favourably located have thus far been discovered on the mainland elsewhere in this region.

On Vancouver island, shales are found associated with the Tertiary coals at Nanaimo and Comox, but most of those thus far discovered appear to be too sandy or too carbonaceous for use. Some have been obtained from Nanaimo and more recently from Comox, for use in the sewer-pipe mixture at the pipe works near Victoria. It serves well for this purpose, but is of little value if used alone.

Much is heard locally regarding the value of the shale deposits said to exist on Mayne and Pender islands. It is true that there are shaly deposits on these islands, but the shale deposits so far as our experience goes consist of thin layers, interstratified by the thin beds of sandstone, and Mr. C.H. Clapp, who has carefully examined both of these islands, corroborates our view.

The surface clays are more extensive than the shale deposits in the Pacific Coast region.

Around Vancouver there are a number of deposits of grey stratified surface clay suitable for common brick. Similar clays occur in the immediate vicinity of Victoria, and also on several of the islands between Vancouver island and the mainland. They probably represent reworked glacial clays.

One of the most interesting deposits, however, is the residual clay from Kyuquot on Vancouver island, which is of refractory character.

TERTIARY SHALES.

Clayburn, B.C.—One of the most interesting series of clay deposits found in the western provinces is that lying in Sumas mountain, east of Clayburn, on the Seattle branch of the Canadian Pacific railway.

The works of the Clayburn Company, Ltd., are located one mile east of Clayburn station, at the base of the mountain. Sumas mountain is a heavily wooded hill rising above the surrounding prairie to an elevation of several hundred feet. It consists of a series of shales, sandstones, and a few conglomerates and coal beds, the whole series having a gentle southwest dip.

Owing to the somewhat heavily wooded character of the surface, outcrops are scarce, except in the steeper ravines, while the lower slopes are mantled by a covering of clay and sands of Pleistocene age, and landslides.

The shales were visited at two places. The first of these was along the line of the Clayburn Brick Company's narrow gauge railway, running three and a half miles east from the factory. The other was at Kilgard on the south side of Sumas mountain.

Deposits of the Clayburn Company, Ltd.—About 1,000 feet from the brickworks along the narrow-gauge railway is a bank of blue-grey surface clay, which is dug with a steam shovel. This is used for common brick, and is the same kind of clay that is found and worked at New Westminster. No tests were made of it, and it may be simply added that this type of material is found in the ravines for some distance up the track, as well as up to an elevation of about 150 feet above the valley.

The first shale outcrops are reached about two miles up the railway, in S.E. $\frac{1}{4}$, section 31, township 19, Sumas municipality. At this point the shale outcrops on both sides of the track (Plate LVIII), and is overlain by a coarse conglomerate composed of fragments of shale, granite, feldspar, etc. The outcrop is not of great length, but from what scant evidence there is we are inclined to believe that the shale deposit may be of lenticular character.

The shale is separable into two beds, viz.: a lower grey shale of smooth, plastic character, and an upper purplish one,

p. 126

Shale beds at Clayburn, B.C.

which is harder and grittier. The former is buff-burning, and on the south side of the track is at least 6 feet thick, while the upper or grey-burning shale is 4 to 6 feet thick.

The workings have not been run in more than 100 feet, and for part of this distance both beds are worked out, leaving a chamber about 10 feet high. If this practice is continued, care should be taken to properly timber the workings.

A test made of the buff-burning or lower shale (1724) which is the one most used, showed it to be of good plasticity, and, with the exception of 1728, the most plastic of the Clayburn series tested. It worked up with 17 per cent of water to a mass whose air shrinkage was 6·1 per cent, and average tensile strength 100 pounds per square inch. A full-sized brick cracked slightly in rapid drying.

The wet-moulded bricklets behaved as follows in burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·85	14·32	Pale salmon
03	2·7	9·20	Buff
1	5·0	7·00	
5	6·0	1·43	Brownish
9	7·0	0	Grey
12	Thoroughly vitrified		

A dry-press bricklet was good and hard at cone 05, and pink buff colour, but in practice it is burned somewhat higher.

The upper bed of grey-burning shale (1730) worked up with 15 per cent of water to a moderately plastic mass, with much grit, whose air shrinkage was 3·6 per cent.

Following are the fire tests:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	15·82	Pink grey
03	0·4	14·28	Grey
1	1·7	11·00	"
5	3·7	3·06	"

This is an interesting shale. It burned to a grey brick, of low fire shrinkage, and low absorption, and could be used for pressed brick.

Two and a half miles up the railway in N. E. ¼, section 30, township 19, there is a shale bank on the right side of the track which shows the following section:—

Red-burning shale	40 feet+
Coal	6 to 8 inches
Buff-burning shale of ferruginous appearance	12 feet +

The section extends down to the floor of the pit, which is about 15 feet above the track level.

The hill slope extends upward beyond the top of the excavation, and more shale beds occur higher up, but these are not at present worked.

Several years ago the Company worked a shale about 100 feet above the track, which was said to be adapted to the manufacture of sewer-pipe.

A sample of the 40 foot bed of shale (1723), from the pit described above, was tested with the following results:—

It worked up with 19 per cent of water to a mass of low plasticity and much fine grit, so that the body is somewhat short. Its air shrinkage was 5·0 per cent, and average tensile strength 196 pounds per square inch. A full-sized brick stood fast drying without cracking.

In burning wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·3	16·16	Red
03	4·0	8·28	"
1	6·0	3·34	"
3	7·0	2·90	"

The shale burned steel hard at cone 03.

This seems to be a shale of slow vitrifying qualities, and is worth trying for a paving brick, or even sewer-pipe. It would be better to weather it, or mix it with a more plastic material.

A test was also made of a sample of shale (1728), underlying the above. It took 22 per cent of water to work up, and gave a mass of good plasticity, whose air shrinkage was 4·8 per cent.

The fire tests of wet-moulded bricklets are given below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	2·2	15·54	Red
03	4·0	11·93	"
1	7·0	7·57	"

At the end of the narrow gauge road, three and a half miles from the works, in N.W. $\frac{1}{4}$, section 29, township 19, Sumas municipality, the Company obtains its fireclays from a small mine. The section, as near as can be made out, shows:—

Sandstone—	
Upper fireclay	8+ feet.
Coal, with flint-clay partings	6 inches to 1 foot.
Lower fireclay	7+ feet.
Ferruginous clay	4 feet.
China-clay	10 to 15 feet.

In mining the material, no attempt has been made in the past to keep the two fireclay beds separate, but this should be done, unless it is known that they are alike. The need of care in mining is well shown by our own tests.

The first of these was made on an average sample of seventy-five pounds collected from the stockpile at the brickworks, and said to represent the run of the mine. This sample (1722) worked up with 16 per cent of water to a very gritty mass of moderate plasticity, whose air shrinkage was 3 per cent and average tensile strength 75 pounds per square inch.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·45	15·89	Light pink
03	2·3	13·63	Buff
1	3·1	12·30	"
5	3·6	10·96	"
9	4·0	9·75	"

The clay was unaffected at cone 13, but thoroughly fused at cone 17. At cone 1 numerous small iron specks developed, and it became steel hard at cone 5.

At the time this sample was collected, it seemed to us that the stockpile contained a great deal of inferior material, which had been included because of carelessness in mining. In order to corroborate our results, we tested a sample of best-grade fireclay, taken from a bin at the mine, and found this to have a fusion point at cone 32. We then tested a sample of firebrick made at these works, for delivery at one of the British Columbia smelters, and also a sample of Glenboig brick collected at the same plant. Both of these stood cone 31.

Our conclusions are that the mine on Sumas mountain contains some good fireclay, but that in mining the several beds in the deposit should be kept separate, until their qualities are thoroughly known.

The china-clay (1721) is a fine-grained, whitish shale, sometimes soft and smooth, at other times hard and porcelain like, with a conchoidal fracture. It grades upwards into an iron-stained whitish shale. There are numerous small limonite spots scattered through it. When ground to pass through a 20 mesh sieve, it worked up with 16 per cent of water to a feebly plastic mass, whose air shrinkage was 3·2 per cent.

The wet-moulded bricklets gave the following results in burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	14·57	Pinkish white
03	"	13·53	" "
1	0·3	12·76	" "
5	0·6	11·21	" "
9	1·2	9·72	" "

At cone 20, the cone of china-clay was erect, but was glassy, and contained many fused iron spots. It probably will not stand much above cone 22. Even at cone 03 the bricklets show many small iron spots, which are fused at cone 9. It is barely steel hard at cone 9.

It is doubtful if this clay would be suitable for anything better than boiler brick. The iron could not be washed out of it. The clay seems to dry-press if ground fine.

No analyses of the Clayburn materials were made for this report, but the following two may be quoted from a report on the clay industry of the coast published by the Provincial Mineralogist of British Columbia, in the Annual Report of the Minister of Mines for 1908.

No. 1 corresponds to the bed underlying the coal parting in the fireclay mine at the end of the narrow-gauge road, while No. 2 lies above the coal:—

	1	2
Silica (SiO_2)	60·85	58·80
Alumina (Al_2O_3)	35·27	30·55
Ferric oxide (Fe_2O_3)	2·75	0·65
Lime (CaO)	0·25	None
Magnesia (MgO)	Trace	0·50
Alkalies (Na_2O, K_2O)	1·88	.....
Water and loss	.....	9·50

Kilgard.—A series of shales similar to those seen east of Clayburn are exposed on the southeast side of Sumas mountain, on the property of Messrs. McClure. On this side of the mountain the land rises steeply from the prairie to its summit, being interrupted by two benches (Fig. 7).

The best series of exposures is in the S.W. ¼, section 29, township 19, in a steep ravine which is crossed by the wagon-road bridge. A section up the south face of the mountain, along the line of this stream, is given in Fig. 7, and is compiled from data supplied by Mr. J. C. McClure, who made the survey.

This section shows a series of shales and sandstones similar to those found to the north on the property of the Clayburn Brick Company, and from what can be inferred from the limited exposures along the creek, the dip may be southwest.

Unfortunately our time was too limited to permit us to make a detailed study of the structure of Sumas mountain. Outcrops were scarce along the wagon road from Abbotsford to the locality at which the section is given. It may be noted, however, that outcrops of quartz porphyry were found at the base of the mountain about one and a half miles west of the line of the section.

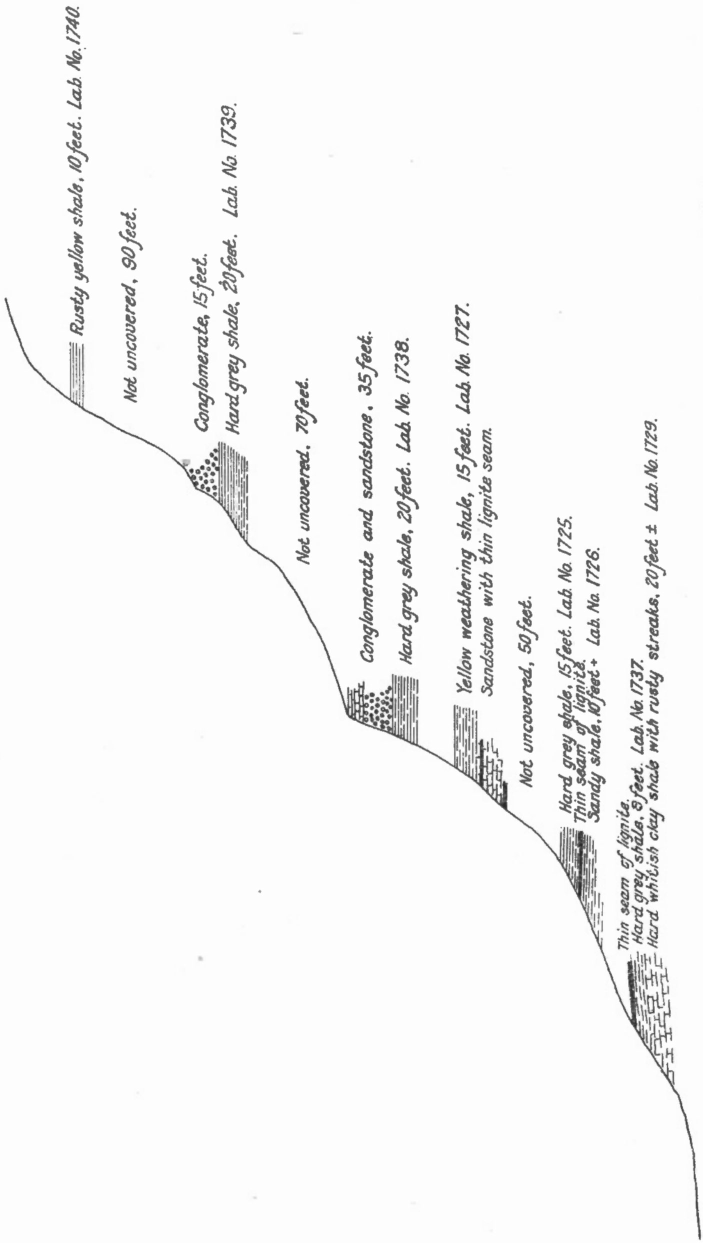


FIG. 7.—Section showing outcrops of shale beds on slope of Sumas mountain, at Kilgard, B.C.

After J. C. Maclure.

Details of Section on Section 29.—Starting at the lower end of the ravine about 75 feet lower than the wagon bridge, there was here a small outcrop of the so-called china-clay in which a test pit had been sunk. About 20 feet down the stream from this is a bluish shale capped by a very thin coal seam. The dip here appears to be southwest, and if so the shale (called No. 1 fireclay) probably overlies the so-called china-clay.

About 50 feet up (vertically) the stream from this point, a ferruginous shale outcrops. Under the bridge is another shale (not shown in section Fig. 7), which is very hard, and underlain by sandstone. Still higher up, and a short distance above the bridge, is a good exposure showing:—

Sandstone	....
Soft fireclay (No. 4)	9 feet+
Coal	4 inches
Hard clay shale (No. 3)	4 feet
Sandstone	2 feet
Shale	....

The thickness of the upper fireclay is more than 9 feet, but owing to slide material its upper limit could not be seen. Mr. McClure claims that it is 15 feet thick.

No more exposures were seen until a point about 100 feet above the bridge, on the west side of the creek. This ledge showed:—

Buff-burning shale	15 feet
Sandstone	5 "
Coal	3 "
Clay	......

The following samples, listed in the order of their occurrence, from the lowest to the highest, were tested. Of these Nos. 1729, 1726, 1725, and 1727, were collected by us. The others were sent in by Mr. McClure. The bed from which each sample was taken can be seen by reference to the section Fig. 7.

China-clay from lower end of section (1729). This has very little plasticity, and was moulded with difficulty. Its air shrinkage was 2 per cent.

The fire tests of wet-moulded bricklets were as below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	14·00	Pink
03	1·0	12·95	"
5	1·0	11·00	Grey speckled
9	1·0	9·34	" "

The low shrinkage is due to the sandy granular character. At cone 22 the clay was glassy on the surface, and it is doubtful whether it will stand more than cone 25. A sample of this clay ground in a ball mill, and then run through a 100 mesh sieve was quite plastic. A 4 inch square dry-press tile, made from the clay thus prepared, was burned at cone 5. At this cone it was not steel hard, very porous, and not white. It cannot, therefore, be classed as a china-clay.

Fireclay from bed above china-clay (1737). This shale is only feebly plastic, and when mixed up with 14 per cent of water, moulded with difficulty. Its air shrinkage was low, being only 2·4 per cent.

Fire tests were as below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	Slightly swelled	11·73	Dirty white
03	"	9·91	" "
1	0·4	9·00	Grey, black specks
5	1·6	9·37	" " "
9	4·7	8·68	" " "
31	Fused.		

This clay is of good refractoriness, and becomes steel hard at cone 9. It is nearly so at cone 5. The clay, however, is too feebly plastic to be used alone, but there is a fireclay overlying the coal seam, higher up in the section, that could be mixed with it to produce a plastic mixture.

Grey shale (1726) below coal seam, from bed just above bridge. This is a moderately plastic, gritty clay, which worked up with 16·8 per cent of water and had an air shrinkage of 3 per cent.

Wet-moulded bricklets gave the following results in burning:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0	18·58	Pinkish
03	0·6	17·20	"
1	2·3	12·50	"
5	5·3	9·50	Brown
9	4·6	2·26	"

This clay is distinctly inferior to the one above the coal, and we do not class it as a fireclay. The slight swelling at cone 9 was due to the fusion of the numerous iron spots scattered all through the mass. With the abundance of other good shales in the section it hardly seems worth working, although it might be added to a sewer-pipe shale.

Upper fireclay (1725), above coal, from ledge just above bridge. This shale when ground up in its fresh condition is moderately plastic, but the plasticity would no doubt be improved by weathering and thorough pugging.

The sample collected by us worked up with 15 per cent of water, and had an air shrinkage of 3 per cent, together with a tensile strength of 103 pounds per square inch.

The burning tests resulted as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·65	14·42	Pink
03	1	14·21	Whitish
5	3·3	10·95	Buff
9	3·6	8·67	Buff
27+	Fused		

The colour deepens considerably on flashing. It is nearly steel hard at cone 03, and the bricklets were thoroughly so at cone 5. This is to be regarded as a fair grade of fireclay, with low shrinkage and of fairly dense-burning character.

Buff-burning shale (1727), overlying sandstone, 100 feet above bridge. This is a material which worked-up with 20 per cent of water to a mass of fairly good plasticity. Its air shrinkage was 4 per cent, average tensile strength 114 pounds per square inch, and a full-sized brick stood rapid drying.

Burning tests of wet-moulded bricklets showed the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·6	17·73	Pink
03	1·0	15·21	"
1	3·3	13·54	"
5	4·7	10·42	Buff
9	5·0	10·29	"
13	Not vitrified, except in spots.		

This is a good shale, which burns to a good colour wet-moulded, and makes a nice buff dry-press brick. The latter is steel hard at cone 03, with an absorption of 12·6 per cent at cone 1.

Pressed-brick shale (1738). This is of good plasticity, and the most plastic of all the Kilgard samples tested. It required 18 per cent of water for mixing, and had an air shrinkage of 4·0 per cent. A full-sized brick did not crack in fast drying.

The burning tests are given below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·2	17·74	Pinkish
03	0·3	15·78	Pink
1	3	10·30	Grey
5	5	3·26	Dark grey
9	2·6	5·45	Brown
13	Fused		

The shale burned steel hard at cone 03, and is an excellent material for pressed brick, but it is of doubtful value for sewer-pipe alone, although it would probably be useful for this if mixed with a better vitrifying clay. The swelling at cone 9 is due to the numerous iron specks becoming viscous.

Dry-pressed, it makes a nice greyish-buff brick, at cone 05, with an absorption of 17·3 per cent. At cone 1 it is grey with 11·78 per cent absorption.

Shale No. 1739. This material worked up with 15 per cent of water to a mass of only moderate plasticity, and was rather gritty. Its air shrinkage was 3 per cent.

Burning tests of wet-moulded bricklets resulted as below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·15	14·41	Light salmon
03	1·0	13·02	" "
5	2·7	9·55	Buff
9	1·7	9·48	"

This might also be classed as a pressed-brick clay. Its colour after burning is similar to that of 1727, and while its absorption is somewhat the same at cones 5 and 9, its fire shrinkage is lower.

Shale No. 1740. A yellowish, gritty shale, with rusty streaks, and working up with 22 per cent of water to a mass of fair plasticity, the air shrinkage of which was 4·4 per cent. A full-sized brick cracked slightly in rapid drying.

On firing the shale developed the properties of a paving-brick clay, as the tests given herewith show:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	1·0	16·75	Red
03	9·0	2·12	"
1	9·3	1·00	"
3	9·4	1·00	"
5	Vitrified		

These tests show that the shale burned dense at a low cone, but is not beyond vitrification even at cone 5. It is steel hard at cone 010.

A mixture of 1740 and 1738 might do for sewer-pipe, but the clay alone while burning to a dense body at a low cone shows a somewhat high fire shrinkage.

Plans are being made to work these clays and shales at a factory, to be located at the base of the hill, near the projected line of the Great Northern railway. The Company has been incorporated under the name of the Vancouver Sewer-pipe and Refractories Company, Ltd.

Owing to the steepness of the mountain face, the different beds will all have to be worked by drift mining, and the clay can be easily transported down to the works by means of a wire-rope t amway.

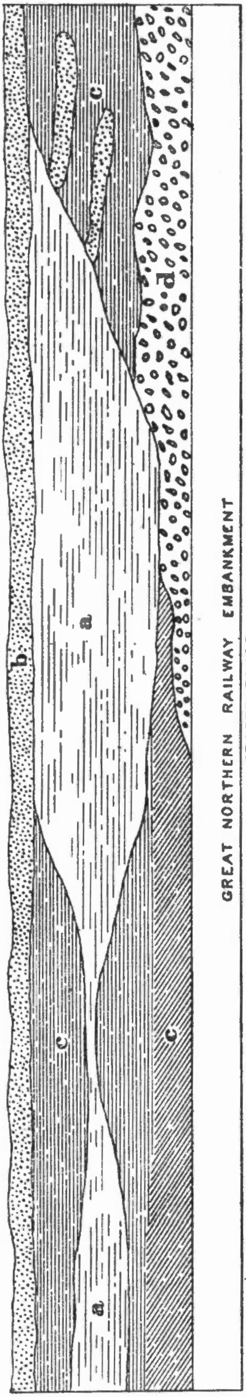
Clayburn Company, Limited.—The works of this Company lie one mile east of Clayburn, and are connected with the Seattle branch of the Canadian Pacific railway by a spur. The clay is brought down from the mines on a narrow-gauge road, three miles long and with a 3 per cent grade. The plant is equipped with dry pans, dry-press, and stiff-mud machines, steam dryers, and down-draft kilns. The product consists of common, paving, pressed, and firebrick.

SURFACE CLAYS.

Vancouver and Vicinity.—Surface clays only are available in the region around Vancouver. Shales underlie the surface formations and are sometimes exposed in excavations for foundations or sewers, but they usually lie under too deep cover to be worth working.

The common type of clay used for brickmaking around Vancouver is a bluish-grey laminated clay, containing very thin sand layers. The clay appears to lie in beds, but these if traced for any distance often thin out, while the sand which overlies and underlies them appears to thicken up. The formation then consists of a series of clay lenses surrounded by ferruginous sands.

There seems to be rather strong evidence that the formation is of interglacial character, for glacial drift is found both above and below it. Fig. 8 shows the structural relations of the deposit.



a.-Stratified clay (brick clay) b.-Soil, sand, gravel (overburden) c.-Stratified sand, containing gravel lenses d.-Boulder clay.

Fig. 8.—Section of clay deposit on bank of Fraser river, near works of Fraser River Brick Co., B.C.

A good example of the mode of occurrence of this clay deposit can be seen near the yard of the Fraser River Brick Company, on the south side of the Fraser river, about two miles southwest of New Westminster About 500 feet west of the yard, the clay is 15 feet thick (Fig. 8) but thins out completely to the eastward, its place being taken by sand. Nearer to the yard another clay lens begins, thickens to about 2½ feet and then thins out again. East of the yard is still a third lens with a maximum thickness of perhaps 15 feet.

Again, at the yard of Coughlan and Sons, just east of New Westminster, the clay shows the same lens-shaped character, and in the bank being worked in September, 1910, the section showed:—

Boulder clay	0 – 6 feet.
Laminated blue clay	20+ "
Gravel	

This blue-grey clay appears to show such uniformity in its character and working properties that a test of an average sample obtained from the yard of Coughlan at New Westminster will serve to show its quality.

The sample from there is a moderately plastic clay (1720), containing much fine grit. When worked up with 19 per cent of water, it developed a somewhat flabby mass, whose air shrinkage was 4·1 per cent, and average tensile strength 256 pounds per square inch. A full-sized brick stood rapid drying without cracking.

In burning the wet-moulded bricklets behaved as follows:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	15·35	Red
03	1·7	10·44	"
1	Fused		

This is a good common brick-clay, and can also be used for drain tile. It could be re-pressed, although practically none of this is done. When worked in a stiff-mud machine the clay swells somewhat as it comes from the die.

Brick Industry Around Vancouver.—Common brick are manufactured at a number of points east of Vancouver. One of the largest plants is that of Coughlan and Sons, located just east of the city of New Westminster, and on the hillside above the Fraser river.

The run of the bank is used for making brick, although the laminated clay alone is said to burn to a better red. The yard is equipped with a rolls, pug-mill, and soft-mud machine. Drying is done on pallet racks, but a hot-air dryer was being constructed at the time of our visit. The burning is accomplished in part in scove kilns, and partly in a Hoffman continuous one. The clay burns to a good hard brick, and there seems no good reason why re-pressed ones should not be made. This yard has been in operation for about twelve years, but bricks have been manufactured on this site for about thirty. Common bricks are also made at the penitentiary.

The works of the Fraser River Brick Company lie in a small valley on the south side of the Fraser river, about two miles east of New Westminster. The product consists entirely of common brick. As the plant was originally constructed, clay had to be put through a pug-mill, rolls, and auger machine. It is claimed, however, that long pugging softens the clay too much, and since the elimination of the pug-mill better results have been obtained. The Company contemplated changing to the soft-mud system. The green bricks are sent to a tunnel dryer and burned in a scove kiln.

The plant of the Port Haney Brick Company, Limited, is located at Port Haney, on the Fraser river, east of Vancouver. The surface clay with one-fifth sand added is used chiefly for stiff-mud common brick, but some pressed brick and drain tile are also produced. The product is dried in tunnels and burned in scove kilns.

Clayburn, B.C.—The bluish-grey surface clays at the base of Sumas mountain have been referred to in connexion with the shales, but on the property of Mr. L. Russell, near Clayburn station, there is a deposit of hard stratified clay which at first sight appeared to be shale.

The clay (1741), which resembles the surface clays of the region in its behaviour, worked up with 30 per cent of water to a very plastic mass, having an air shrinkage of 6·3 per cent.

Wet-moulded bricklets showed the following shrinkages and absorption at different cones:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·3	18·63	Red
03	2·6	13·14	"
1	Past vitrification		
3	Fused.		

This is a good brick-clay, with a low fire shrinkage and becoming steel hard at cone 03.

Anvil Island.—This is an island of metamorphic rock, lying in Howe sound, about twenty-three miles from Vancouver. The slopes descend rather steeply towards the water, with some bench like interruptions, but here and there are depressions in which pockets of drift and clay have been deposited.

Two deposits of the latter are being worked on the south side of the island, one of them by the Columbia Clay Company, and the other by the Anvil Island Brick Company, Ltd.

At the former the deposit consists of a stratified clay with scattered boulders, and is thought by C. H. Clapp to be a reworked glacial deposit. The clay, which is hard, tough, and silty, is yellow above and bluish-grey below. Both varieties appear hard and dry in the bank, but when worked for a few minutes between the fingers become soft and moist and little water has to be added to them.

A sample of the buff or upper clay (1733) was put through a few tests. This clay has good plasticity, much fine grit, and some pebbles. It worked up with 26 per cent of water, had an air shrinkage of 6 per cent, and average tensile strength of 283 pounds per square inch.

Burning tests are as below:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·35	16·74	Red
03	3·00	7·76	"
1	Fused		

This gives a good body for common brick, and could probably be used for drain tile.

A good dry-press was obtained at cone 03, with an absorption of 10·27 per cent.

If the blue clay alone is used it seems to ball up in the soft-mud machine, and clings to the blades on the shaft. The clays alone show a tendency to crack, and so about 10 per cent of sand is added as the former is shovelled into a double rolls. From these the mixture passes to a pug-mill and then to a soft-mud machine. The bricks are put through dryers, heated by waste heat from the kilns, and burned in a Haigh continuous kiln. A stiff-mud machine was tried but did not work well with this clay.

The clay at the yard of the Anvil Island Brick Company, Ltd., is similar, consisting of an upper buff and lower blue, except that the latter is more massive and resembles a boulder clay.

At the time of our visit the brick plant was not yet completed. The process which it is proposed to use, however, consisted in first feeding the clay into dry-pans, then screening, and after this moulding in a Whittaker dry-press. The Company had one rectangular down-draft kiln under construction and proposed to build a continuous one.

Sidney Island.—The clay deposit here is similar to that on Anvil island. It is utilized for making stiff-mud common brick.

Vancouver Island.—The following notes on Vancouver island have been collected by C. H. Clapp. They are followed by the tests of samples collected by us from several localities:—

There are four types of clay deposits which have been recognized on Vancouver island:—

Shales of the Nanaimo series (upper Cretaceous).

Shales of the Tertiary west coast deposits.

Clays of the Pleistocene and Recent unconsolidated superficial deposits.

Residual clays derived by the decomposition of igneous rocks. (Of this type there is only one deposit known, viz., that at Kyuquot, which I have not seen).

Nanaimo Series.—The greater part of the shales of the Nanaimo series are sandy and interbedded with thin layers of sandstone which average less than a foot apart. In the northern basins in the vicinity of Nanaimo and Comox, there are, however, near the base, relatively thin lens-like beds of shale (such as is used at the Victoria Pottery Company's plant, of which a sample was taken), up to 3 to 5 feet in thickness. They are usually more or less closely associated with the coal.

The Tertiary sediments are chiefly very coarse, thick-bedded conglomerates and sandstone. The shale beds are thin and very sandy and unlikely sources of clay.

With the exception of the shale used at the British Columbia Pottery Company's plant all the clays at present utilized are derived from the superficial deposits.

The greater part of Vancouver island is mantled with unconsolidated deposits of various kinds; largely referable to the Glacial period. Underlying the low flat areas of the east and west coast, and the vicinity of Victoria, the Saanich peninsula, and the neighbouring islands in Haro straits, the superficial deposits, although composed of glacial detritus, are largely stratified. Stratified deposits also occur in the large inland valleys such as the Cowichan and Alberni. For the greater part the stratified deposits occur at elevations less than 250 feet above sea-level, although in the large valleys they occur much higher. The higher slopes are covered chiefly with Glacial till, modified slightly by sliding. It is in the stratified deposits that clays occur. The clays have the usual characteristics of Glacial clays, those used for brick being high in sand, as the more plastic clays have a very high air-shrinkage.

In the neighbourhood of Victoria and the Saanich peninsula, which is the only portion of the area where the Pleistocene deposits have been studied in detail, several types have been recognized. These may be classified roughly as follows:—

Glacial till
Estuarine and lake deposits
"River" and delta deposits.

Glacial till is for the greater part confined to the slopes of the higher elevations and usually occurs above the 250 foot level. In the eastern part of the area, notably on James and Sydney islands, the stratified deposits are covered with Glacial till, which doubtless represents a second period of glaciation that was insignificant as compared with the principal period.

The estuarine deposits consist largely of stratified clays and sand, and occasional layers of gravel. Irregularly distributed through the deposits are glacial boulders of varying size, from small pebbles to boulders 2 and 3 feet in diameter. Deposits of this type underlie relatively low, flat areas and valleys, and often rest directly upon the glaciated surface of the underlying crystalline rocks. Many of the deposits contain marine organisms, showing that they were deposited in salt water. Their occurrence in the lower parts of the area and in valleys between the ridges of crystalline rocks and of stratified sands and gravel shows their estuarine origin. It is probable that some of the higher deposits of this type were formed in lakes.

The clays are usually near the base of the formation and occur in beds up to 10 or 15 feet thick. The clays are chiefly sandy, but are fairly plastic. Fat blue clays also occur, especially underlying the sandy clays.

The "river" and delta deposits consist chiefly of stratified sands and gravels, showing cross bedding, contemporaneous erosion and deposition, and other features characteristic of river and delta deposits. They occasionally have interbedded clay. These deposits occur principally as ridges 100 to 200 feet high, one-fourth of a mile wide, and one to two miles long. They are esker-like in form but differ from typical eskers in their large size and straight axes. The clays and fine-grained beds contain, in one or two instances, marine fossils. The origin of these deposits is at present obscure. The clay beds are similar to those described above but are apt to be more sandy, and more free from glacial pebbles.

Near Boulder point, on the north shore of Union bay, North Saanich district, there is exposed 20 feet of stratified clay with gravel and sand, and occasional boulders of crystalline rocks. Clay occurs in a bed up to 10 feet in thickness. It is greyish-blue in colour, somewhat sandy, but plastic. Clay underlies the greater part of the flat country at the northern end of the Saanich peninsula, but is only exposed at elevations below 150 feet.

In the pits of the Sydney Brick and Tile Co. located 20 feet above sea-level the section shows:—

Loamy sandy soil, not stripped	6 inches
Clay and sand, yellow to grey, unoxidized, with frequent pebbles and boulders of glacial origin. Clay is fragile and not plastic	16 inches
Yellowish-grey sandy clay, plasticity good	2 feet 6 inches
Blue clay, plastic, with high air shrinkage. (Clay flat and undisturbed. It was derived from glacial till, but has been deposited in marine basins.)	

On James island, which is composed of a ridge of stratified sand and gravel of river origin, 15 to 25 feet of yellow-sandy clay occurs near the top of the 200 foot section, and 20 feet of similar clay also occurs near the base.

Loam and sandy soil, with vegetable growth (stripped)	12 to 18 inches
Yellow sand. Increases in thickness to south, so that 30 yards from clay pits there is 3½ feet of sand.	
Used for mixing with clay, about 5 to 1	12 inches
Yellow-grey sandy clay, unoxidized, soft, good plasticity, contains numerous pebbles of crystalline rocks	13 feet
Blue plastic clay	

The clay is flat and undisturbed, and occurs near the base of the river deposits.

At Tod inlet, South Saanich district, in the pits of the Vancouver Portland Cement Co., clay occurs in marine deposits of sand and clay, about 60 feet above sea-level. The pits show 15 feet of fairly uniform sandy clay, with a few glacial boulders and pebbles. Analysis of clay, which is said to be uniform, is given by Adolph Neu, the chemist of the cement company.

	Per Cent
Silica (SiO_2)	65·00
Ferric oxide (Fe_2O_3)	14·00
Alumina (Al_2O_3)	10·00
Lime (CaO)	5·00
Magnesia (MgO)	1·10
Alkalies (Na_2O, K_2O)	tr

At Cadboro bay there is exposed at the base of a 100 foot section of stratified sand and gravel, with a few arge boulders, about 15 feet of fine-grained somewhat sandy clay. The contact with the overlying sand and gravel is marked by numerous springs. Along the shore to the south of Victoria, and to the east of Clover point, the following section of the marine Pleistocene deposits is exposed:—

Sand, gravel, and clay, with many glacial boulders	4 feet
Yellowish sand and gravel	2 "
Buff sandy clay, good for brick	9 "
Light to yellowish-grey sand and gravel, with a few large boulders	2 "

Near the mouth of the Sombrio river, Renfrew district, the underlying crystalline rocks and Tertiary sandstone are covered by sandy clay of indefinite thickness, probably not more than 10 or 15 feet, since it is only exposed a few feet above sea-level. Similar, although more compact, fatter clay is exposed in the cut bank of the Sombrio river, 200 yards from the shore, and contains Pleistocene marine fossils.

The clays are overlain by stratified gravel, 300 to 500 feet thick. Clays of this character have a wide distribution along the west coast from Sooke to San Juan.

The following section of the Pleistocene deposits is exposed at Pasons point, at the entrance of Sooke harbour.

Drift, red to grey colour, stratified, ferruginous gravels and sand, with a little clay	30 feet
Sandy clay with carbonaceous particles	30 "
Clayey sand	20 "
Yellow ferruginous sand	10 "
Gravel	10 "

VANCOUVER ISLAND CLAYS AND SHALES.

Comox.—Shale beds are found associated with the Cretaceous coals at Comox, but most of those thus far opened up are too gritty, or contain too much carbonaceous matter.

By themselves they seem to be of little value, but have been found useful for mixing with the surface clays at Victoria, for making sewer-pipe and hollow brick. One sample of the Comox shale was taken from the stockpile at the works of the British Columbia Pottery Company. This was a very dark grey shale (1734) which worked up with 15 per cent of water to a feebly plastic mass, and was moulded with difficulty. It is not plastic enough to be used alone. The average air shrinkage was 2·6 per cent.

In burning the wet-moulded bricklets gave the following results:—

Cone.	Fire shrinkage.	Absorption.	Colour.
	%	%	
010	0·55	16·00	Dirty pink
03	1·4	13·47	Drab
1	2·3	13·72	"
5	5·00	6·31	"

The clay did not burn steel hard even at cone 5, and as can be seen from the above tests does not burn to a very dense body.

Its chief use is as a stiffener with some more plastic clay, in which mixture it would also reduce the shrinkage.

In spite of its sandiness it made a fair dry-press brick, which had a good ring even at cone 05, and a buff colour. The absorption was 14 per cent.

British Columbia Pottery Company, Ltd.—The factory of this Company is located at Victoria West on the line of the Esquimalt and Nanaimo railway. The product consisted originally of pottery, but now the chief output is sewer-pipe and fireproofing. The raw material used is a mixture of local surface clay, shale from Comox, and a residual clay from Kyuquot. The factory is equipped with rolls, wet pan, sewer-pipe press, pot machines, and circular down-draft kilns. The ware is burned at cone 6 for the sewer-pipe. More recently sewer-pipe have been made from the shale and Kyuquot clay alone.

Victoria.—There is considerable similarity in the clays found around Victoria, all being red-burning, rather tough, and gritty Occasionally a deposit of material is encountered which is smoother than the average, and can be utilized for drain tile. Some is also employed in the sewer-pipe mixture, at the works of the British Columbia Pottery Company, and the following tests show its character (1736). Like the other surface clays of this vicinity, the material is very plastic and somewhat sticky, but even so contains much grit and scattered pebbles. It is much more plastic, however, than the surface clays on the adjoining mainland.

Twenty-eight per cent of water was required to work it up, and the resulting mass had an air shrinkage of 7·9 per cent, with an average tensile strength of 364 pounds per square inch. The clay burns to a red colour, which changes to brown at cone 03. The firing tests developed:—

Cone 010, 0·45 per cent fire shrinkage, and 15·61 per cent absorption; cone 03, 8 per cent fire shrinkage, and 0 per cent absorption; cone 1, fused.

The total shrinkage at cone 03 is rather high for practical purposes, but at cone 010 it forms an excellent material for brick or tile, and when smooth enough, flower pots.

Kyuquot, Vancouver Island.—The British Columbia Pottery Company has recently been obtaining some clay from this locality, which is located on the western side of Vancouver island, near its northern end. We were not able to visit this locality, but the material appears to be a residual clay derived from a partly metamorphosed volcanic rock, presumably a rhyolite. The stuff consists of a mixture of clay and lumps of the partially decomposed rock, and turns out to be one of the most refractory clays found in western Canada.

A sample lot (1735) taken from the stock pile at the factory showed the clay to be of rather low plasticity, for the reason that much of it represents but partly kaolinized rock.

It was worked up with 20 per cent of water, and had an air shrinkage of 3 per cent, with a tensile strength of 84 pounds per square inch.

The burning tests were carried out in some detail because of the refractory character of the material.

Cone.	Fire shrinkage.	Absorption.	Colour.
010	Slightly swelled	15·50	Salmon
03	"	14·22	Pink
1	"	11·7	"
5	0·6	9·23	Drab
9	−1·7	7·92	Grey
13	Not vitrified		
30	Fused		

It burns steel hard at cone 1, and shows good refractoriness, in fact there are few more refractory clays thus far known in the western provinces. Its occurrence should encourage further search.

The following analysis was supplied us by A. T. Monteith, of Victoria:—

Silica (SiO_2)	71·10
Alumina (Al_2O_3)	23·40
Ferric oxide (Fe_2O_3)	3·8
Lime (CaO)	None
Magnesia (MgO)	0·3
Loss on ignition	1·0
Total	99·60

This analysis indicates that much of the rock is but little altered to clay, otherwise there would be a higher percentage of chemically combined water, as represented by the loss on ignition. It is probable that the material analysed does not represent a fair sample.

Analyses of British Columbia Clays.—The following analyses are given by the Provincial Mineralogist in the 1908 report of the Minister of Mines for British Columbia.

	1	2	3	4	5	6	7	8	9	10
Silica (SiO_2)	60·00	60·2	63·6	67·6	56·8	57·5	57·5	58·5	58·6	60·6
Alumina (Al_2O_3)	20·8	15·5	19·0	13·6	17·5	22·8	20·2	21·1	26·7	24·0
Ferric oxide (Fe_2O_3)	7·6	9·4	7·6	8·8	10·8	9·2	9·2	8·6	7·5	7·6
Lime (CaO)	4·6	5·3	3·6	3·6	3·1	4·0	7·0	6·5	4·0	1·0
Magnesia (MgO)	0·7	1·5	0·2	0·2	0·3	0·5	3·2	0·5	tr	0·3
Water and loss	5·1	6·8	6·0	5·6	6·8	6·0	2·9	4·8	3·0	7·0

1. Clay, Brethour's road, Sidney.
2. Chinese yard, Sidney.
3. Atkins' lot, Esquimalt.
4. Duncan.
5. Roger Cook, Alberni dist.
6. Lot 7.
7. Smith Landing.
8. Port Haney.
9. Anvil island.
10. Howe sound.

CHAPTER VII.

The Clayworking Industry.

The chief clay products now made in the western provinces are common brick. These are produced at a number of localities, and usually from sandy surface clay, so that the ware is very porous. Winnipeg, Vancouver, and Victoria contain the largest groups of yards, but there are many single plants too numerous to mention.

The press-brick industry is but slightly developed. A shale brick of good colour is made at Leary, Man., and a few dry-press bricks are also produced from surface clays at two other localities in Manitoba. At Medicine Hat, and Redcliff, Alta., red dry-pressed bricks are made from the shales. A few are also made at Edmonton, Alta., from the surface clays, and red ones are manufactured from the Tertiary shales at Sandstone and Brickburn near Calgary, Alta.

The Dirt hills south of Moosejaw yield clays which could be employed for white, cream, and spotted effects, while those of the Souris valley will make buff, red, or mottled brick.

The only buff-pressed brick made in the western provinces are those at Clayburn, where grey and red ones are also produced. It seems very doubtful, however, if these could be marketed far to the eastward owing to the expensive haul across the mountains.

Sewer-pipe are manufactured only at Victoria, but their production at Medicine Hat will begin this season. We have pointed out in our report, however, that the shales at Clayburn, B.C., and on Milk creek, near Pincher, or at Entwhistle, Alta., could be used for this purpose.

The only locality at which firebrick are produced is Clayburn, B.C., and the output from these works is far below the domestic consumption.

These few paragraphs will, therefore, show the restricted development of the clayworking industry in the western provinces at the present time.

In the report of the Mines Branch, Department of Mines, for 1909, Mr. J. McLeish gives the following statistics of production of clay products for the years 1907, 1908, and 1909:—

Production of Brick in the Western Provinces.

	1907		1908		1909	
Manitoba........	45,094,180	$465,282	26,818,000	$254,591	59,110,100	$544,548
Saskatchewan....	12,024,070	125,459	8,262,906	87,566	14,416,770	144,316
Alberta..........	31,384,740	353,672	25,521,911	240,336	45,479,855	441,606
British Columbia..	12,522,045	131,137	18,152,362	169,546	28,445,758	305,520

A comparison of these figures, with those representing the total value of all clay products produced in these Provinces, shows that in every case, bricks form nearly the entire production; except in the case of British Columbia.

Total Value of All Clay Products Produced in the Western Provinces.

	1907	1908	1909
Manitoba..................	$466,432	$265,091	$559,008
Saskatchewan..............	125,459	187,566	145,516
Alberta....................	353,672	240,384	442,486
British Columbia...........	306,137	344,446	470,442

From the figures given above it can be seen that the production is not large, although it has been slowly increasing. With the rapid development that is going on in the western provinces, however, and the rapid growth of large cities like

Winnipeg, Calgary, Edmonton, Vancouver, etc., there is bound to be a demand that should stimulate the growth of the clay-working industry, provided that suitable raw materials exist, and we believe they do.

Certain factors, however, must be taken into account, which may temporarily at least retard its development. The cost of labour is high and often an uncertain quantity to the western manufacturer. The region is a large one, local freight rates are high, and, therefore, long hauls add appreciably to the market value of the product. Certain well-known firms in the United States send annually large quantities of clay products into Canada. Although their products pay duty, these people, by reason of the facility of handling material in long established plants, and having more stable labour conditions, can compete successfully with Canadian goods. As an example, fireproofing and pressed brick from St. Paul and Minneapolis, Minn., and Menomonie, Wis., have been shipped to Edmonton. Brandon imports sewer-pipe from St. Louis, Mo. Pressed bricks from Hebron, N. Dak. are sent to Winnipeg and into Saskatchewan, etc.

Existing conditions also permit the shipment of common brick and fireproofing from factories in Washington to the Vancouver market. But if clay products, which can be sold as cheaply and are as good as those brought in from the United States, can be made in Alberta, Saskatchewan, or British Columbia, then the ability of the manufacturers to supply the home market should only be limited by the capacity of their plants.

Many of the Canadian manufacturers complain that the tariff is not sufficiently high to keep out the products from the States, and that with existing tariff conditions they cannot meet the prices of the imported goods, and earn a profit at the same time.

The authors have not sufficient data at hand to go into a detailed and critical analysis of this situation, but one point seems clear, viz., that while a raise in the tariff may benefit the manufacturer, it may not help the consumer, as the price of the domestic product may be increased with higher protection.

In this connexion it may be of interest to give the rates of duty on different kinds of clay products, as below:—

Canadian Customs Duties on Clay Products.

(From the Customs Tariff, 1907, revised 1910).

Item.	——	British Preferential Tariff.	Intermediate Tariff.	General Tariff.
281	Firebrick of a class or kind not made in Canada.	Free.	Free.	Free.
282	Building brick, paving brick, and mfgs. of clay or cement (N.O.P.)	12½ %	20 %	22½ %
283	Drain tiles not glazed	15 "	17½ "	20 "
284	Drain pipes, sewer-pipes, and earthenware fittings therefor, chimney linings or vents, chimney tops and inverted blocks, glazed or unglazed, earthenware tiles (N.O.P.)	25 "	32½ "	35 "
285	Tiles or blocks of earthenware or of stone prepared for mosaic flooring	20 "	27½ "	30 "
286	Earthenware and stoneware, viz., demijohns, churns or crocks	20 "	27½ "	30 "
287	Tableware of china, porcelain, white granite or ironstone	15 "	27½ "	27½ "
288	Earthenware and stoneware, brown or coloured, and Rockingham ware "C.C." or cream coloured ware, decorated, printed, or sponged, and all earthenware, (N.O.P.)	20 "	27½ "	30 "
289	Closets, urinals, basins, lavatories, baths, bath tubs, sinks, and laundry tubs of earthenware, stone, cement, or clay or of other material	20 "	30 "	35 "
295	Clays, including china-clays, fireclay, and pipe-clay, not further manufactured than ground; ganister and sand; gravels; earths, crude only	Free.	Free.	Free.

There are some lines of ware for which there is a strong demand in the western provinces, and of which there is at present practically no domestic supply. We refer especially to firebrick of different kinds.

The increasing number of coke ovens in operation in British Columbia, and the smelters of the same region, call for a large number of bricks, nearly all of which they are obliged to import.

These come in part from Scotland, but also to a large extent from Pennsylvania, and St. Louis, Mo., and are consequently high priced.

There seems no valid reason why the deposits at Clayburn, B.C., and the Dirt hills, Sask., should not supply this demand.

With terra-cotta it is perhaps somewhat different. There is not a strong demand for this, except in the larger cities, where expensive buildings are erected, and since the manufacture of terra-cotta involves the employment of skilled workmen, a factory producing this class of ware must be kept busy. Practically all the terra-cotta now used in the western provinces comes from the United States, but one of the largest contracts in Vancouver was supplied by an English firm.

CHAPTER VIII.

Methods of Testing Clays.

There are two methods of testing clays, the chemical and the physical.

CHEMICAL METHOD.

This consists usually in making a chemical analysis, which shows us the percentage of the different ingredients present in the clay, but gives us few or no clues regarding the physical properties of the material. In the ordinary chemical analysis the substances usually determined are silica, alumina, ferric oxide, lime, magnesia, and alkalies. Carbon, and sulphur trioxide, both deleterious substances, are rarely determined. A special application of chemical examination would be a determination of the amount and kind of soluble salts present.

The chemical analysis is, however, of such small practical value that no analyses were made for this report.

PHYSICAL METHOD.

This is the much more important method of testing, for it gives us valuable information regarding the possible uses of the clay or shale, and consists in a determination of their plasticity; water required for mixing; tensile strength; air shrinkage; fire shrinkage; colour and absorption at different temperatures; and fusing point.

The method of making each of these determinations is given below.

Tensile Strength.—The determination of the tensile strength of the raw material is made because it gives a clue to the clay's ability to stand strains in handling before burning, and possibly also of its bonding power or its ability to stand the addition of non-plastic materials like sand or "grog."

The clays and shales submitted to the physical tests were first thoroughly dried, then ground in a jaw crusher and afterwards sifted through a 20 mesh sieve.

A weighed quantity of the sifted material, sufficient to make the necessary number of test pieces, was mixed with just enough water to give it the greatest plasticity, and thoroughly kneaded and wedged so as to render it perfectly homogeneous and free from cavities. The consistency generally arrived at was about midway in stiffness between a soft-mud and stiff-mud brick in practice.

In making briquettes for the tensile test a small piece of the kneaded clay was clamped into the briquette mould, and struck by the hand until it filled the mould completely, the excess of clay being struck off by a fine wire.

The clay was removed from the mould on a dry clay briquette—a set of them being kept for the purpose—and the wet clay briquette was not handled until it had hardened on its support, so that they were not distorted while soft.

The briquettes when hard were dried to 100° C., the cross section at the waist carefully measured, and then broken in an ordinary tensile strength machine.

The results for the various tensile strengths given in this report are the average of 10 to 12 briquettes.

Shrinkage.—All clays shrink more or less in drying and burning. The shrinkage that occurs while the clay is drying is termed air shrinkage, while that which occurs during the burning is known as fire shrinkage.

Air Shrinkage.—A portion of the kneaded clay was made into bricklets in a mould $4'' \times 1\frac{1}{2}'' \times \frac{3}{4}''$ in size. Two fine lines, exactly 3 inches apart, were impressed with a steel stencil on the wet clay bricklet immediately after leaving the mould. When the bricklets were thoroughly dry the distance between these lines was measured, and the percentage of air shrinkage calculated. The average of 6 to 8 bricklets is given in the results for air shrinkage.

Fire Shrinkage.—The burning of the bricklets at the lower cones was done in a down-draft muffle kiln, the fuel used being coke, and the time of burning from 12 to 18 hours. For the higher temperatures a gas-fired muffle kiln was used.

The lines on the burned bricklets were again measured after each successive firing, and the total amounts of shrinkage calculated. The difference between the total shrinkage and the air shrinkage represents the fire shrinkage.

The air and fire shrinkage are given separately in the results, but their sum would represent the total shrinkage of any clay from the time it was taken from the mould.

Fusibility.—Small pyramids or cones of the ground clays or shales were burned in the gas fired furnace until they were deformed or melted (Plates LX and LXI). The temperatures at which the test cones melted are expressed in terms of the standard Seger cones.

A Deville furnace, fired with coke, under air blast was used for determining the fusing points of the more refractory clays, including those which did not fuse until a temperature ranging from cone 18 to cone 32 was reached.

Absorption.—The bricklets were carefully weighed after each burning, and immersed in water to about three-fourths of their thickness. This permits the air from the burned clay body to escape freely, allowing the water to better and more quickly fill the pores. After standing at least 24 hours in water, the saturated bricklets are weighed, the increase in weight recorded, and the percentage of absorption calculated as follows:—

$$\frac{\text{Saturated weight—dry weight}}{\text{Dry weight}} \times 100.$$

Dry-Press Tests.—The clay or shale used for the dry-press test was ground to pass a 20 mesh sieve, and moistened with 5 to 10 per cent of water. A mould was filled with the damp clay, and pressed in a hand screw press, the size of the bricklet produced being $4'' \times 1\frac{1}{2}'' \times 1''$.

Rapid Drying.—For this test the clay or shale was ground to pass a 12 mesh sieve, and kneaded up with sufficient water to a fairly stiff mass, from which a full-sized building brick was made by hand in a wooden mould.

Immediately after coming from the mould the moist brick was placed on a rack in a box open at the bottom and with a perforated top, which stood on a steam heated radiator. The temperature in this box ranged from 120° to 150° F. which is the heat usually attained in artificial dryers. If the brick cracked under this treatment it was stated that it would not stand rapid drying.

Drying Defects in Certain Clays.—Various Tertiary clays, and some Cretaceous shales found in Alberta and Saskatchewan have the serious defect of checking while drying.

Clays of this character are usually very fine grained and highly colloidal, absorbing a large percentage of water when tempered for wet moulding. They are exceedingly plastic and sticky when wet, becoming a stiff, soap-like, and sticky mass, which is hard to work.

Generally, within half an hour after leaving the moulds fine cracks appear at the edges of the brick, which quickly spread over the surfaces, and as drying progresses these cracks widen and deepen. In time the outside of the brick becomes bone dry, but the inside may remain quite moist for several days.

In some clays the cracks which developed in drying closed up completely when the drying was ended, but reappeared again in the burned product.

Several of the clays that displayed this drying defect gave fairly low air and fire shrinkages, were somewhat refractory, and burned to a good hard body at cone 1.

In several districts they were the only materials available, and as they might turn out to be sewer-pipe or paving brick clays, it was very desirable to devise some practical method of treatment to make them workable.

Hitherto, whenever brickmakers had to deal with clays which were too "fat" or "strong", as they termed those clays which were highly plastic, they usually added from 10 to 25 per cent of sand. The sanded clays were found to dry quicker, and work easier; the air and fire shrinkages were reduced, and generally a good burned product is obtained from the mixture.

Apparently, then, the proper remedy to cure the objectionable behaviour of the clays we were dealing with was the addition of sand. But when 25 per cent of sand is added to these clays they crack quite as badly as before. They can be dried with the addition of 40 to 50 per cent of sand, but this amount is evidently in excess of the bonding power of the clay, because the burned brick made from such a mixture is altogether too porous and weak for any purpose whatever.

It was then found by experiment that if any of these clays be ground and calcined or burned to a red heat, that the calcined clay, which has lost its plasticity, can be added to the raw clay in quantities as large as desired to secure the best working quality; that drying at a moderately fast rate can be accomplished with safety, and the properties of the burned clay body are not affected.

The calcined clay, then, acts as sand during the early stages of manufacture, but when burned it proceeds towards vitrification with the raw clay, and does not remain inert at ordinary burning temperatures as sand will.

Further experiments on preheating clays show that if the ground clay be heated from 300° to 500° C. that they lose a great deal of their plasticity, and the quality of the clay is changed from a tough sticky mass when melted to a granular and easily worked body which can be moulded by the stiff-mud process, and will stand fast or moderately fast drying.

How extremely finely divided some of these clays are in the raw state and the change in texture they undergo in preheating is shown in the following mechanical analyses, made by the centrifugal method.

MATERIAL	Percentage retained on 200 mesh sieve	Percentage of silt.	Percentage of clay
1. Normal clay	trace	57·40	38·40
Preheated to 500° C	36·20	46·20	15·00
2. Normal clay	6·4	45·6	46·0
Preheated to 450° C	14·6	62·0	14·4
3. Normal clay	1·5	49·6	46·8
Preheated to 500° C	22·1	52·0	24·5

1. Brown clay shale—Dirt hills, Alta. Lab. No. 1646.
2. Yellowish clay shale—Redcliff, Alta. Lab. No. 1686.
3. Dark grey underclay—Entwhistle, Alta. Lab. No. 1661.

The grains included under the heading of silt have a diameter from $\frac{1}{200}$ to $\frac{1}{5000}$ of an inch, and those under clay from $\frac{1}{5000}$ to $\frac{1}{25000}$ of an inch.

Inasmuch as calcining and preheating clays involves the expense of extra machinery, fuel, and labour, it follows that only clays used for the higher grade products can be treated economically by this method.

Further experiments were undertaken with certain substances which when added to the clay would reduce the amount of water used in mixing, and also assist in conveying the moisture from the body of the clay to the surface during drying.

Of the various materials tried for this purpose during the experiments, those that gave the best results were hydrochloric acid and salt. Most cases of cracking could be cured by the addition of 1 to 2 per cent of hydrochloric acid to the mixing water, or 1 to 2 per cent by weight of common salt added to the dry clay. The salt seemed to be the most practical and was used in the greater number of tests.

The amount of water required for tempering the clay was reduced by about 10 per cent by the addition of salt. The water appeared to convey the salt from the body and deposit it at the surface in a slight scum, but this generally disappeared in burning.

The bricks so treated dried perfectly in about 4 days at a temperature of 70° to 80° F. but would not stand fast drying.

The object of preheating any clay is to overcome drying difficulties, and the temperature required to accomplish this object varies with different kinds of clay. The amount of heat necessary for some clays would destroy the plasticity of another clay and render it useless for moulding.

In some cases while drying can be carried on safely after preheating, the burned wares may show a tendency to crack, but such clays generally work perfectly when dry pressed.

The temperature used in calcining clay must be sufficiently high to deprive the clay of all plasticity and reduce it to a condition resembling sand. Although this operation requires a higher temperature than preheating with the object of destroying only a portion of the plasticity, the operation is a simpler one because critical temperatures are not observed.

Clays to which salt is added frequently show a slight glaze when burned to cone 1, but the quality of the body does not seem to be affected, especially if the clay is somewhat refractory.

The use of salt appears to be detrimental to some of the more easily fusible clays.

No difference was detected in the burned wares made from clay treated with hydrochloric acid.

It is hoped that a more complete investigation will follow the preliminary work already done, but the manufacturer having drying trouble with his clay will probably overcome it by adopting after trial the method which is best suited to his particular case.

CHAPTER IX.

Tests of Brick by Prof. A. Macphail, Kingston.

Samples of normally burned brick, collected at various yards visited, were sent to Prof. A. Macphail of the School of Mining, Kingston, to be tested in the laboratories there, and his report on these tests is given in the succeeding portion of this chapter.

Sixteen lots of bricks were received, each lot containing about 12 bricks. Each lot was designated by a series letter (A to P) and each brick of each lot was indicated by a number (1 to 12). The following list gives the series letter, the locality from which the bricks were obtained, and the kind of brick.

LIST OF BRICKS COLLECTED FOR TESTING—RIES AND KEELE, 1910.

(About 12 of each kind.)

Series.		
	Manitoba.	
E.	Alsip Brick & Tile Co., Winnipeg	soft-mud.
B.	The Stephens Brick Co., Portage la Prairie	" "
C.	A. Snyder & Co., Gilbert Plains	" "
D.	Leary's Pressed brick works, Leary Siding	dry-press.
	Saskatchewan.	
A.	Eureka Coal & Brick Co., Estevan	dry-press.
F.	" " " "	stiff-mud.
	Alberta.	
G.	P. Anderson & Co., Edmonton	dry-press.
H.	Edmonton Brick Co., Edmonton	stiff-mud.
I.	" " "	soft-mud.
J.	Red Deer Brick Co., Red Deer	" "
K.	Canadian Brick Co., Medicine Hat	" "
L.	Red Cliff Brick Co., Redcliff	stiff-mud.
M.	Alberta Portland Cement Co., Sandstone	dry-press.
N.	Calgary Pressed Brick & Sandstone Co., Calgary	dry-press.
	British Columbia.	
O.	Enderby Brick & Tile Co., Enderby	soft-mud.
P.	John Coughlan & Sons, New Westminster	" "

TESTS.

Eight separate tests were conducted on the bricks of each series, and these tests are indicated by the lower case letters (a to h). Here follow the specifications under which the tests were made.

a. Place six thoroughly dried bricks in water to the depth of one inch, and leave them covered over for 48 hours. Weigh before and after this partial immersion, to calculate the percentage of absorption in terms of the original dry weight.

b. Test six *dry* bricks flatwise on supports 7 inches apart, to determine their transverse strength.

c. Take the six bricks from the absorption test, soaking them some more if they have dried out, and determine the transverse strength of these wet ones.

d. Take one-half of each brick from series b and determine its crushing strength set flatwise.

e. Take the other half of each of the bricks from b, and determine their crushing strength when set on edge.

f. Take one-half of each of the bricks from series c, and determine their crushing strength when set on edge.

g. Take the other half of each brick from c, soak it for one hour in ice water, and then subject to a temperature of not less than 15° F. for five hours, all faces of the samples being exposed. The bricks are then thawed in water of not less than 150° F. for one hour. This is to be repeated twenty times.

h. Determine the crushing strength on edge of the bricks after they have been through the frost test.

With regard to the crushing test the sides or edges of the brick in contact with the machine are to be made flat and parallel with plaster of paris. The opposite sides should be exactly parallel. The testing machine should be equipped with spherical bearing blocks.

The results of the various tests are given in Table I and are the averages of the observations on six bricks in all cases, except those in test "h," where the bricks which were destroyed in the freezing test were, of course, not given.

The modulus of rupture was calculated from the transverse test by the usual formula:—

$$S = \frac{3}{2} \quad \frac{W\ l}{b\ d^2}$$

Where W is breaking load at centre in pounds, l is the span, b is the breadth of the brick, and d the depth.

In the case of bricks which had a frog, the area of the frog was deducted from the gross area when the bricks were tested for compression strength on edge.

Table II. Bricks were frozen and thawed twenty times as specified. In the column "Remarks," the numerals denote the number of times the brick was frozen before disintegration began to set in.

TABLE I.

Series No.	Test a. Per cent absorption.	Test b. Transverse (dry)		Test c. Transverse (wet)		Test d. Crushing flat (dry)	Test e. Crushing on edge (dry)	Test f. Crushing on edge (wet)	Test h. Crushing on edge (dry) after freezing.
		Breaking load.	Modulus of rupture.	Breaking load.	Modulus of rupture.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
A	13·5	1533	805	1490	773	6975	5960	5132	4700
B	23·2	887	472	843	472	2208	2358	1547	2196
C	22·1	1150	647	1073	594	2435	2567	1983	3260
D	10·5	1295	622	1273	610	2807	2652	2833	3378
E	23·1	983	473	1432	716	1830	2468	2310	2846
F	25·8	1286	746	977	568	2932	2050	2065	1730
G	25·5	704	337	720	345	2612	1744	1562	1250
H	19·2	825	384	920	428	1692	1868	1628	2027
I	22·2	702	365	617	320	1298	1512	1282	1400
J	24·1	774	337	797	343	1220	1492	1502	1989
K	15·8	640	298	506	237	1320	1494	1310	1732
L	14·4	672	313	598	278	2242	1660	1948	1950
M	15·3	657	267	612	249	2343	1364	1513	1503
N	15·8	808	329	662	270	2420	1640	1296	1190
O	20·8	972	467	983	471	1869	1950	2658	1990
P	14·4	2008	972	1618	776	5242	5735	4028	5115

TABLE II.

Freezing Tests.

No.	Series A. Remarks.	No.	Series B. Remarks.	No.	Series C. Remarks.	No.	Series D. Remarks.
1	8 cracked, 15 broken.	1	5 cracked, 14 broken.	1	20 cracked.	1	16 broken.
2	11 " 15 "	2		2		2	16 "
3	8 " 15 "	3	5 slight crack.	3		3	
4		4		4		4	16 slight crack.
5		5		5		5	
		6	5 slight scaling.	6		6	
	Series E.		**Series F.**		**Series G.**		**Series H.**
1	8 scaling, 20 broken.	1	20 scaling.	1	2 cracked, 8 broken.	1	
2		2	16 broken.	2	2 " 8 "	2	
3		3	3 scaling, 16 broken.	3	2 " 16 "	3	Unaffected
4		4		4	2 " 16 "	4	
5	5 crack.	5		5	2 "	5	
6		6	5 scaling, 8 cracked.	6	2 "	6	
	Series I.		**Series J.**		**Series K.**		**Series L.**
1	8 scaling.	1	3 scaling.	1	8 scaling.	1	2 cracked.
2		2		2		2	8 "
3		3		3	2 scaling.	3	8 "
4		4		4	8 scaling.	4	8 "
5		5		5		5	2 "
6		6	5 scaling.	6		6	
	Series M.		**Series N.**		**Series O.**		**Series P.**
1	2 cracked, 8 large cracks.	1	7 crumbled.	1	20 broken.	1	16 broken.
2	2 " 8 crumbled.	2	16 "	2		2	8 corner cracked.
3	2 " 8 "	3	7 "	3		3	8 cracks and blisters.
4	2 " 16 "	4	11 cracks.	4	16 crumbled.	4	16 cracked, 20 broken.
5	8 " 11 large cracks.	5	8 crumbled.	5	20 broken.	5	8 " 15 "
6	8 " 16 " "			6	12 corner crumbling.	6	

The accompanying diagrams exhibit the relative qualities of the different series as follows:—

a—Absorption.
b—Transverse strength—dry.
c—Transverse strength—wet.
d—Compressive strength—dry—flatwise.
e—Compressive strength—dry—edgewise.
f—Compressive strength—wet—edgewise.
g—Resistance to frost under repeated freezing and thawing.
h—Compressive strength of repeatedly frozen bricks.

In these diagrams the series giving the highest results is taken as 100, and the others are exhibited in percentages of this.

In computing test g, the average number of freezings which the bricks underwent without deterioration was taken as the measure of their quality.

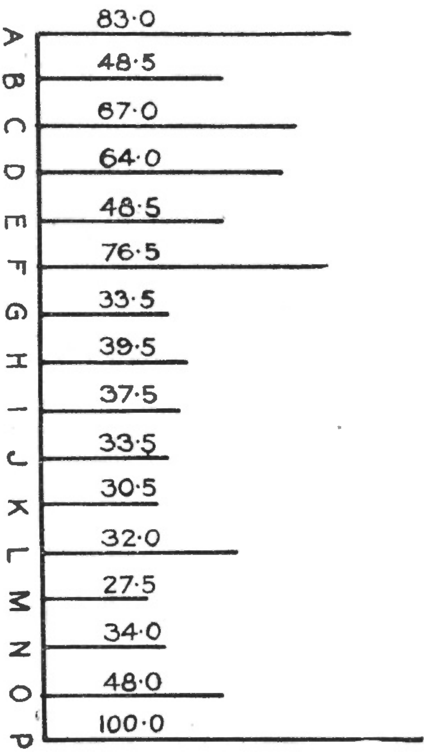
The last diagram (i) gives the averages of the percentages of the different series, and indicates in so far as the tests apply, the resistant quality of the bricks.

(Signed) **Alexander Macphail.**

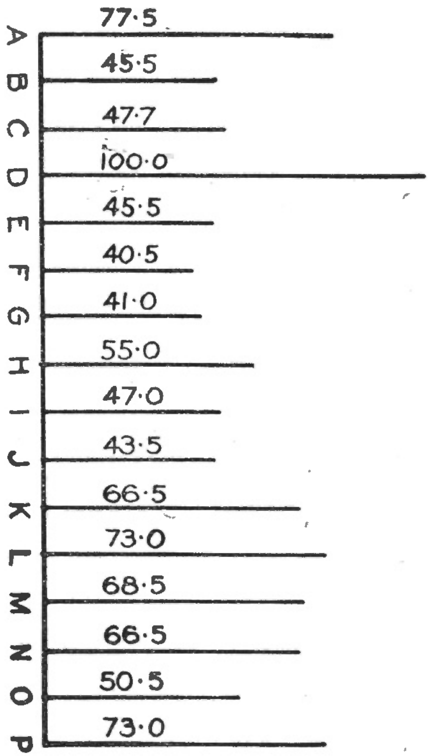
School of Mining, Kingston,
May, 1911.

Modulus of Rupture.

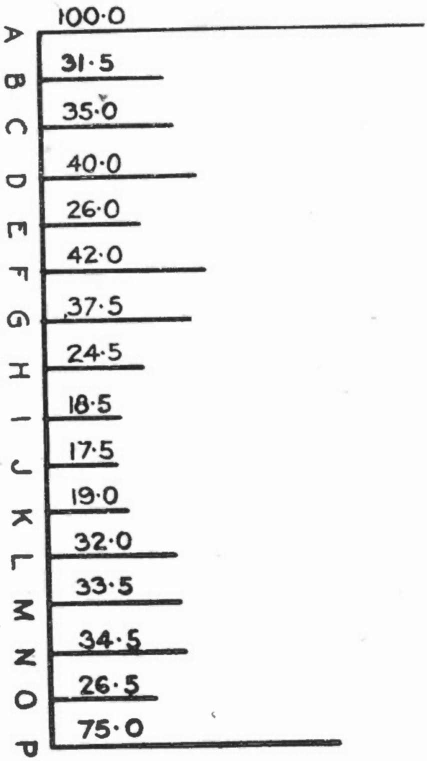
Dry



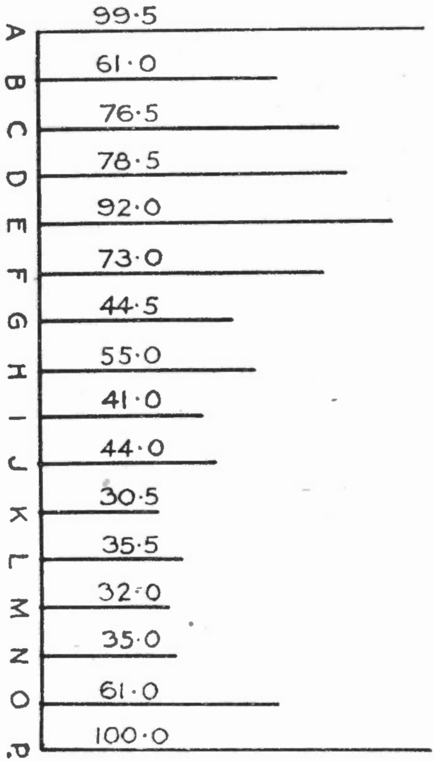
Absorption.



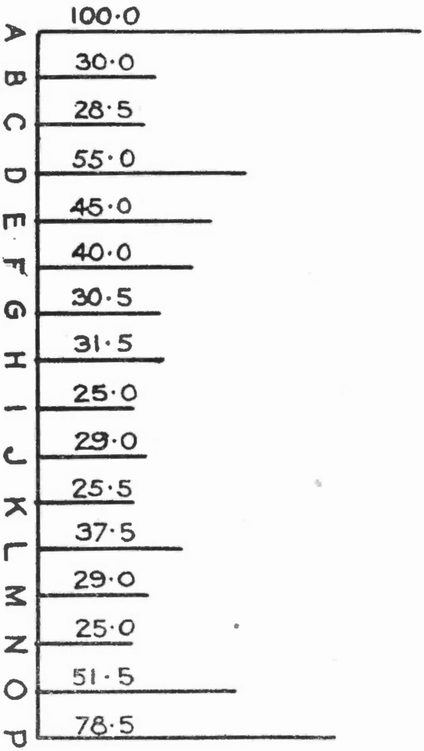
Crushing Strength—flat.
Dry.



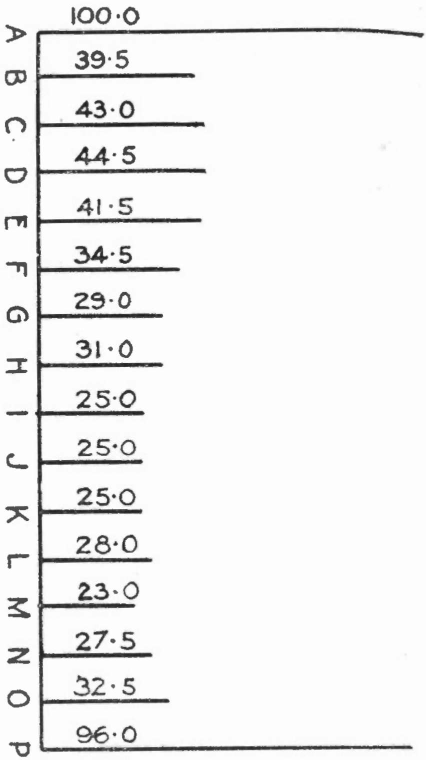
Modulus of Rupture.
Wet.



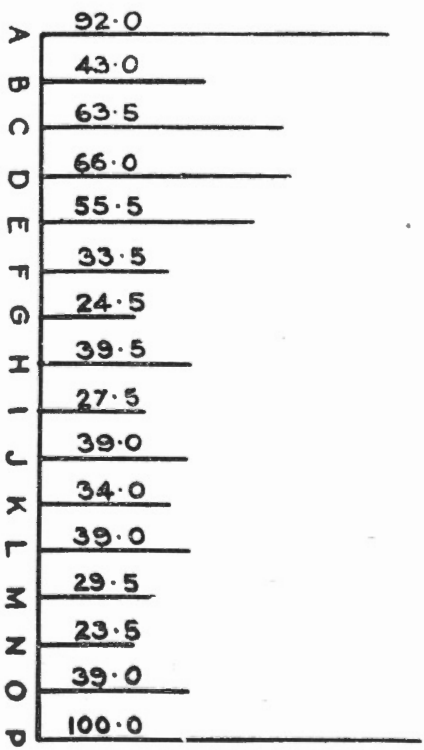
Crushing Strength—on edge.
Wet.



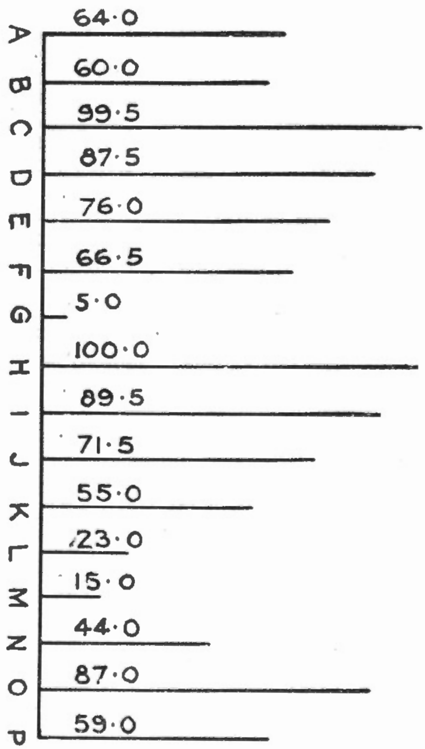
Crushing Strength—on edge.
Dry.



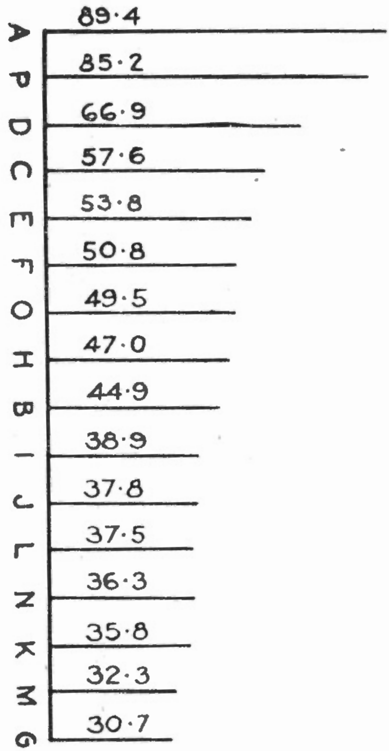
Crushing Strength—on edge.
Dry, after freezing.



Frost resistance.



Average of all Tests.



DISCUSSION ON BRICK TESTS.

The results of the tests made on the bricks are of great interest and bear careful study. Considering the entire series of tests without regard to the method of manufacture, the following facts are observable:—

(1) The absorption ranges from 10·5 per cent to 25·8 per cent, and half of those tested shows over 20 per cent, which is rather high.

(2) The transverse strength is usually good, and in eleven of the sixteen sets tested the transverse strength of the wet bricks was lower than that of the dry ones. The exact cause of this is not quite clear.

(3) Comparing the crushing test flat (dry) with the crushing test on edge (dry) there seems to be no constant increase or decrease, for in seven cases the crushing strength on edge is less and in the other eleven cases it is greater.

(4) Comparing the strength on edge dry with the strength on edge wet, it was found that in ten of the sixteen series the soaked ones were weaker.

(5) In only seven cases was the crushing test of the bricks which had been through the frost test less than that of the bricks not so treated.

(6) The tests bring out well the inferiority of the bricks made from too sandy surface clays.

(7) A grouping of the tests according to kinds shows that in the series tested: (a) the dry press bricks average lower in absorption, probably because they are made of denser burning materials; (b) many of the soft-mud brick show a high percentage of absorption, largely because they are made of very sandy surface clays; (c) all three groups show a considerable range in their modulus of rupture; (d) the soft-mud and dry-press bricks show a higher maximum crushing strength than the stiff-mud, but this is due certainly to the raw materials and not to the process.

(8) If some of these clays were burned a little harder the product would be stronger.

(9) In Table III Prof. McPhail has assigned a value to the different series to indicate their rank, the best one being rated as 100 and the others proportionately less.

Referring especially to the freezing test it will be seen that there is no relation between the absorption and frost resistance as some persons commonly suppose. The following figures make this clear.

Series number.	Rating in per cent.	Per cent absorption.
H	100	19·2
C	99·5	22·1
I	89·5	22·2
D	87·5	10·5
O	87	20·8
E	76	23·1
J	71·5	24·1
F	66·5	25·8
A	64	13·5
B	60	23·2
P	59	14·4
K	55	15·8
N	44	15·3
L	23	14·4
M	15	15·3
G	5	25·5

CHAPTER X.

The Origin and Nature of Clay.

In the following pages there is given a brief discussion of the origin and nature of clays (including shales). This is not intended to be exhaustive and is simply added to serve as a guide for those persons having no technical knowledge of the subject but who may have occasion to use this report.

In all cases where it is necessary to render statements clear by citing examples or illustrations of facts, these are taken as far as possible from the western provinces.

ORIGIN OF CLAY.

Definition.—Clay is the term applied to those earthy materials occurring in nature, the most prominent property of which is that of plasticity when wet. On this account they can be moulded into almost any desired shape, which is retained when dry. Furthermore, if heated to redness, or higher, the material becomes hard and rock like. Physically, clay is made up of a number of small particles, mostly of mineral character, ranging from grains of coarse sand to those which are of microscopic size, or under $\frac{1}{1000}$ of a millimetre in diameter. Mineralogically, it consists of many mineral fragments of varying degrees of freshness, and representing chemically many different compounds, such as oxides, carbonates, silicates, hydroxides, etc. Most of these mineral grains are not visible to the naked eye. Some of the constituents are of colloidal character.

Weathering Processes Involved.—Clays are always of secondary origin, and result primarily from the decomposition of rocks, very frequently from rocks containing feldspar; but in some cases rocks containing little or no feldspar, such as gabbro or serpentine, may, on weathering, produce some of the most plastic clays known.

In order to trace the changes occurring in the formation of clay we may take the case of a rock like granite.

When such a mass of rock is exposed to the weather, minute cracks are formed in it, due to the rock expanding when heated by the sun and contracting when cooled at night, or they may be joint-planes formed by the contraction of the rock as it is cooled from a molten condition. Into these cracks the rain water percolates, and when it freezes in cold weather it expands, thereby exerting a prying action, which further opens the fissures, or may even wedge off fragments of the rock. Plant roots force their way into these cracks, and, as they expand, supplement the action of the frost, thus further aiding in the breaking up of the mass. This process alone, if kept up, may reduce the rock to a mass of small angular fragments, or even a mass of sand.

The rock having been opened up by disintegrative forces, the silicates are next attacked by the surface waters, although those exposed on the surface of the stone may already have begun to change.

The most prominent chemical change is the alteration of the feldspar grains to a white, powdery substance, known as kaolinite, a hydrous silicate of alumina. The alteration of the feldspar is termed kaolinization. Other silicates, such as hornblende, probably undergo similar changes.

As a result of these changes the entire rock may slowly but surely break down to a clayey mass.

Residual Clay.—Where the clay is thus found overlying the rock from which it was formed, it is termed a residual clay, because it represents the residue of rock decay, and its grains are more or less insoluble.

If a granite which is composed chiefly of feldspar decays under weathering action, the rock will be converted into a clayey mass, with quartz and mica scattered through it. Remembering that the weathering began at the surface and has been going on there for a longer period than in deeper portions of the rock, we should expect to find, on digging downward from the surface: (A) a layer of fully formed clay, (B) below this a poorly defined zone containing clay and some partially decomposed rock fragments, (C) a third zone, with some clay and many rock fragments, grading downward into the solid bed-rock. In other words, there is usually a gradual transition from the fully formed clay at the surface into the parent rock beneath. The only exception to this is found in clays derived from limestone, where the passage from clay to rock is sudden. The reason for this is that the change from limestone into clay does not take place in the same manner as granite. Limestone consists of carbonate of lime, or carbonate of lime and magnesia, with a variable quantity of clayey impurities, so that when the weathering agents attack the rock, the carbonates are dissolved by the surface waters, and the insoluble clay impurities are left behind as a mantle on the undissolved rock, the change from rock to clay being, therefore, a sudden one, and not due to a gradual breaking down of the minerals in the rock, as in the case of granite.

Kaolin.—A residual clay derived from a rock composed entirely of feldspar, or one containing little or no iron oxide, is usually white, and, therefore, termed a kaolin. Deposits of this type may contain a high percentage of the mineral kaolinite,[1] this being assumed, because, after washing the sand out of such materials, the silica, alumina, and water in the remaining portion are in much the same ratios as in kaolinite, although, as previously mentioned, other aluminous silicates may at times be present.

A clay made up entirely of kaolinite is sometimes termed a pure clay, but since the term clay refers to a physical condition, and not a definite chemical composition, it would perhaps be more correct to term kaolin the simplest form of clay.

Form of Residual Deposits.—The form of a residual clay deposit, which is also variable, depends on the shape of the parent rock. Where the residual clay has been derived from a great mass of granite or other clay-yielding rock, the deposit may form a mantle covering a considerable area. On the other hand, some rocks, such as pegmatites (feldspar and quartz), occur in veins, that is, in masses having but small width as compared with their length, and in this case the outcrop of residual clay along the surface will form a narrow belt.

Clay derived from a rock containing much iron oxide will be yellow, red, or brown, depending on the iron compounds present.

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[1] The terms *kaolinite*, referring to the mineral, and *kaolin*, referring to the clay-mass, are often carelessly confused even by scientific writers, although there seems to be little excuse for so doing.

Between the white clays and the brilliantly coloured ones others are found representing all intermediate stages, so that residual clays vary widely in their colour.

The depth of a deposit of residual clay will depend on climatic conditions, character of the parent rock, topography, and location. Rock decay proceeds very slowly, and in the case of most rocks the rate of decay is not to be measured in months or years, but rather in centuries. Only a few rocks, such as some shales or other soft rocks, change to clay in an easily measurable time. With other things equal, rock decay proceeds more rapidly in a moist climate, and consequently it is in such regions that the greatest thickness of residual material is to be looked for. The thickness might also be affected by the character of the parent rock, whether composed of easily weathering minerals or not. Where the slope is gentle, or the surface flat, much of the residual clay will remain after being formed, but on steep slopes it will soon wash away.

In some cases the residual materials are washed but a short distance, and accumulate on a flat or very gentle slope at the foot of the steeper one, forming a deposit not greatly different from the original ones, although they are not, strictly speaking, residual clays.[1]

Deposits of residual clay are exceedingly rare in all parts of the Dominion of Canada, for the reason that nearly all of those formed have been swept away by glacial action. The only one referred to in this report is the fireclay from Kyuquot, Vancouver island.[2]

Transported Clays.

SEDIMENTARY CLAYS.

Origin.—As mentioned above, residual clays rarely remain on steep slopes, but are washed away by rainstorms into streams, and carried off by these to lower and sometimes distant areas. By this means residual clays, possibly of different character, may be washed down into the same stream and become mixed together. This process of wash and transportation can be seen

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[1] These are termed *colluvial clays* by G. P. Merrill. The only deposit of this character described in this report is one from Field, B.C.

[2] An interesting one in quartzite occurs near St. Remi d'Amherst, and will be described in a forthcoming report.

in any abandoned clay bank, where the clay of the slopes is washed down and spread out over the bottom of the pit.

As long as the stream maintains its velocity it will carry the clay in suspension, but if its velocity be checked, so that the water becomes quiet and free from currents, the particles begin to settle on the bottom, forming a clay layer of variable extent and thickness. This may be added to from time to time, and to such a deposit the name of sedimentary clay is applied. All sedimentary clays are stratified or made up of layers, this being due to the fact that one layer of sediment is laid down on top of another. These layers may also vary in thickness, and since there is less cohesion between unlike particles, the two layers will tend to separate along their line of contact.

As the finer material can only be deposited in quiet water, and coarse material in disturbed waters, so from the character of the deposit we can read much regarding the conditions under which it was formed. If, therefore, in the same bank, alternating layers of sand, clay, and gravel are found, it indicates a change from disturbed to quiet water, and still later rapid currents over the spot in which these materials were deposited. The commonest evidence of current deposition is seen in the cross-bedded structure of some sand beds where the layers dip in many different directions, due to shifting currents which have deposited the sand in inclined layers.

Sedimentary clays can be distinguished from residual clays chiefly by their stratification, and also by the fact that they commonly bear no direct relation to the underlying rock on which they may rest.

Structural Irregularities in Sedimentary Clays.—All sedimentary clays resemble each other in being stratified, but aside from this, they may show marked irregularities in structure.

Thus, any one bed, if followed from point to point, may show variations in thickness, pinching, or narrowing in one place and thickening or swelling in others.

Occasionally a bed of clay may be extensively worn away or eroded by currents subsequent to its deposition, leaving its upper surface very uneven, and on this an entirely different kind of material may be deposited, covering the earlier bed, and filling the depressions in its surface.

The general character of sedimentary clays is more or less influenced by the locality and conditions of deposition, which enables us, therefore, to divide them into the following classes:—

Marine Clays.—This class includes those sedimentary clays deposited on the ocean bottom, where the water is quiet. They have, therefore, been laid down at some distance from the shore, since nearer the land, where the water is shallower and disturbed, only coarser materials can be deposited. Beds of clay of this type may be of vast extent and great thickness, but will naturally show some variation, horizontally at least, because the different rivers flowing into the sea usually bring down different classes of material. Since most marine clays have become deeply buried under other sedimentary rocks subsequent to their deposition, they are often changed to shale: these shale beds, moreover, are sometimes interstratified with sandstones. The shale is now found exposed, because the ocean bottom has been uplifted, and the overlying rocks worn away.

The Cretaceous shales of the Great Plains are in part of this type.

Estuarine Clays.—These form a second type of some importance in certain areas. They represent bodies of clay laid down in shallow arms of the sea, and are consequently found in areas that are comparatively long and narrow, with the deposits showing a tendency towards basin shapes. If strong currents enter the estuary from its upper end, the settling of the clay mud may be prevented, except in areas of quiet water in recesses of the bay shore. Or, if the estuary is supplied by one stream at its head, and this of low velocity, the finer clays will be found at a point more distant from the mouth of the river. In such cases we should anticipate an increase in coarseness of the clay beds, or series of beds, as they are followed from what was formerly the old shore line up to the mouth of the former river that brought down the sediment.

Estuarine clays often show sandy laminations, and are not infrequently associated with shore marshes, due to the gradual filling up of the estuary, and the growth of plants on the mud flats thus formed. The clays of the Annapolis and Shubenacadie valleys in Nova Scotia are of estuarine type.

Swamp and Lake Clays.—Swamp and lake clays constitute a third class of deposits, which have been formed in basin-shaped depressions occupied by lakes or swamps. They represent a common type, of variable extent and thickness, but all agree in being more or less basin-shaped. They not infrequently show alternating beds of clay and sand, the latter in such thin laminæ as to be readily overlooked, but causing the clay layers to split apart easily. Many of the lake clays are directly or indirectly of glacial origin, having been laid down in basins or hollows along the margin of the continental ice sheet, or else in valleys that have been dammed up by the accumulation of a mass of drift across them. This wall of drift serves to obstruct the drainage in the valley, thus giving rise to a lake, in which the clay has been deposited. Clay beds of this type are extremely abundant in all glaciated regions. They are usually surface deposits, of varying thickness, often highly plastic, and more or less impure. Their chief use is for common brick and earthenware, and they are rarely of refractory character.

The under-clay of Winnipeg has been shown to be of this character, as are some of the other surface clays of the Plains region, the brick-clay at Cochrane, Alta., etc.

Flood-Plain and Terrace Clays.—Many rivers, especially in broad valleys, are bordered by a terrace or plain, there being sometimes two or more, extending like a series of shelves, or steps, up the valley side. The lowest of these is often covered by the river during periods of high water, and is consequently termed the flood-plain. In such times much clayey sediment is added to the surface of this flood terrace, and thus a flood-plain clay deposit may be built up.

Owing to the fact that there is usually some current setting along over the plain when it is overflowed, the finest sediments cannot settle down, except in protected spots, and consequently most terrace clays are rather sandy, with here and there pockets of fine, plastic clay. They also frequently contain more or less organic matter. Along its inner edge the terrace may be covered by a mixture of clay, sand, and stones, washed down from neighbouring slopes.

Flood-plain clays are not an uncommon type in the western provinces. Those worked for common brick at Edmonton and Winnipeg are of this class.

Drift or Boulder Clays.—In that portion of the United States formerly covered by the continental ice sheet there are occasional deposits of clay formed directly by the glacier. These are usually tough, dense, gritty clays, often containing many stones. The material deposited by the ice (till) is usually too stony and sandy to serve for brickmaking, although often known as boulder clay. Locally, however, although the ice-transported material has been largely ground to a fine rock flour, the boulder clay is plastic enough, and not too full of stones for use. Such deposits are mostly of limited extent, impure, and of little value.

In addition to this type of clay, formed directly by the ice, there were clays deposited in lakes or along flood-plains by the streams issuing from the glacier. These were composed of material derived from the ice, but since they were deposited by water they were stratified, and may properly be classed as lacustrine, estuarine, or flood-plain clays of glacial age. Boulder clays, although abundantly distributed, are often too stony to be of much value for the manufacture of clay products.

Æolian Clays.—In many parts of the west there is found a silty, often calcareous clay, termed the loess. This, although commonly a water deposit, may at times have been formed by wind action. It can, therefore, properly be classed as transported clay, and also shows a stratified structure.

Classification of Clays.

Considering the different ways in which clays have been formed, it is possible to formulate the following classification, based primarily on their origin, and also bringing out, somewhat, their commercial characters. Examples are given where known in the western provinces.

A. *Residual clays.* (By decomposition of rocks in place).

I. Kaolins or china-clays. (White burning, and derived from igneous or metamorphic rocks low in iron oxide).

(*a*) Vein-like deposits derived from pegmatite veins, or dykes of igneous rock, such as rhyolite.

(*b*) Blanket deposits, derived from extensive areas of igneous rock. (Kyuquot, Vancouver island).

(*c*) Pockets in limestone, as the indianaite of Indiana, U.S.A.

II. Red-burning residuals, derived from different kinds of rocks. These may be formed by the decomposition of such rocks as granite, by a process of solution as in limestone, or by simple disintegration as in many shales.

B. *Colluvial clays*, representing deposits formed by wash from the foregoing, and of either refractory or non-refractory character. (Field, B.C.)

C. *Transported clays.*

I. Deposited in water.

(*a*) Marine clays or shales. Deposits of ten of great extent. (Pierre shales.)

White burning clays. Ball clays and plastic kaolins.

Fireclays or shales. Buff burning. (Dirt hills, Sask., and Clayburn, B.C.)

Impure clays or shales (Calcareous, Niobrara shales, Non-calcareous, Coleridge, Sask., shale.)

(*b*) Lacustrine clays (deposited in lakes or swamps).

Fireclays and some shales.

Impure clays or shales, red-burning. (Edmonton shales).

Calcareous clays, usually of surface character. (Cochrane, Alta., clay).

(*c*) Flood-plain clays. Usually impure and sandy. (Edmonton, Alta.)

(*d*) Estuarine clays (deposited in estuaries). Mostly impure and finely laminated. (New Westminster, B.C.)

II. Deposited by glaciers.
Boulder clay. (Estevan, Sask.)

Secondary Changes in Clay Deposits.

Changes often take place in clays subsequent to their deposition. These may be local or widespread, and in many cases either greatly improve the deposit or render it worthless. The marked effect of some of these changes is often well seen in clay beds of which only a portion has been altered. These secondary changes are of two kinds, viz., mechanical and chemical.

MECHANICAL CHANGES.

Formation of Shale.—Clay deposits laid down on the ocean floor often become covered by many hundreds of feet of other sediments, whose weight alone is often sufficient to cause a consolidation and hardening of the clay mass. Deposition of mineral matter around the grains may cement them together and aid in the hardening process. Such a consolidated clay is termed a shale. When ground and mixed with water, it may develop high plasticity. Shale deposits have thus received their properties by deep burial, but are now often exposed at the surface because the overlying strata have been worn away.

Shale beds were originally formed in a more or less horizontal position, but since then have often become more or less tilted by uneven movements of the earth's crust. As evidence of this the shale beds around Medicine Hat and Edmonton are nearly flat; those at Blairmore are slightly tilted; while those on Milk creek, southwest of Pincher, show dips ranging from 0° to 90° (See Plates XLVII, XLII, XXIII).

CHEMICAL CHANGES.

Nearly all clay deposits are frequently changed superficially, at least, by the weather, or by surface waters. The changes are chiefly chemical, and can be grouped under the following heads: (1) change of colour; (2) leaching; (3) softening; (4) consolidation.

Change of Colour.—Many clay deposits which are yellow, red, or brown, near the surface, are grey or greyish-black below. This is due primarily to the iron in the clay being oxidized, that is changed from ferrous to ferric oxide (See under iron oxide.) This change in colour will extend to a variable depth below the surface, depending on the distance to which the weathering agents have penetrated the clay.

Leaching.—Clays usually contain at least some soluble materials, the commonest of which is lime carbonate. Surface waters seeping into the clay may take this lime carbonate into solution, and thus the upper layers or portion of the deposit may be freed from it. The lime carbonate so removed may be carried off by the infiltrating waters, or deposited in the lower layers. In a deposit of calcareous clay, therefore, the upper layers may be red burning, while the lower beds are buff-burning. This change is more common in moist than in arid climates, and at any rate, is characteristic only of highly calcareous clays. The idea held by some that lime, or even other impurities, will decrease with the distance from the surface, is erroneous.

Some clays contain considerable gypsum, often in a finely divided condition. Such clays sometimes show coarse crystalline masses of gypsum on the outcrop, due to the fact that water entering the deposit has dissolved the gypsum, and brought it to the surface in solution, where, on the evaporation of the water, it has crystallized out in large crystals. This process takes place chiefly in arid regions.

The Niobrara shales contain numerous clusters and bunches of transparent crystalline gypsum. Rosettes and irregular lumps are very abundant on the clay outcrops at Irvine. Gypsum is also found in the sandy surface clay at the Acme Brick Company north of Edmonton.

In moist climates this segregation of the gypsum usually occurs within the clay mass, and transparent plate-like masses of selenite of varying size may be formed.

The formation of concretions may be regarded as the result of leaching action.

By concretions are meant the hard, often rounded masses found in many clay or shale deposits. They are most commonly formed of iron carbonate, or hydrous iron oxide (limonite), but lime carbonate concretions are likewise not uncommon. They have probably been formed by the dissolving of iron or lime compounds in the clay by infiltrating waters, and their redeposition around some nucleus.

Concretions of iron carbonate are not uncommon in the Niobrara shales of Manitoba, and in the Kootanie shales at Blairmore. They are usually altered superficially to limonite.

The sands of the Dirt hills also show large rounded sandstone concretions.

Softening.—Many shales become softened on exposure to the weather. This is largely a simple process of disintegration, and usually involves little change in composition, except in the case of calcareous shales, which may show but little lime at the surface.

Consolidation.—Clays, especially those of a sandy and porous character, sometimes become hardened along certain layers, or along joint planes, due to the deposition of iron oxide. This may result in the formation of a number of crusts, or hard layers in the deposit, which have to be crushed or thrown out if the clay is to be used. In some localities these are so numerous as to render an otherwise good clay worthless.

MINERALS IN CLAY.

Owing to the fine-grained character of most clays, it is usually impossible to recognize the mineral grains in them with the naked eye, but microscopic study of clays has revealed the presence of a number of different mineral species. A few of these, such as quartz, mica, gypsum, calcite, and pyrite, are sometimes of sufficient size to be recognized at sight.

It is not necessary here to enumerate all the mineral species that have been found in clays, and only those which are of probable common occurrence need be referred to.

Kaolinite.—This mineral, which is a hydrous aluminium silicate, having the formula, $Al_2O_3,2SiO_2,2H_2O$, is thought by many to be present in all clays, but its existence has not in all cases been definitely proven; moreover, it is somewhat difficult to recognize even under the microscope. If the kaolinite itself is not present, it is possible that other hydrous aluminium silicates, such as pholerite, halloysite, etc., exist in the clays.

Clays of high purity no doubt contain a considerable percentage of kaolinite, the best grades of china-clay running as high as 95 per cent, or even more.

Kaolinite is exceedingly refractory, and is to be regarded as a heat-resisting element, but at high temperatures it fluxes actively with silica, if the latter is present. This fact is contrary to the view formerly held by many firebrick manufacturers. It will be seen from what has been said above, that a good fireclay should be low in silica and high in kaolinite.

Quartz.—This mineral, whose formula is SiO_2, is found in at least small quantities in nearly every clay, whether residual or sedimentary, but the grains are rarely large enough to be seen with the naked eye. They are translucent or transparent, usually of angular form in residual clays, and rounded in sedimentary ones on account of the rolling they have received while being washed along the river channel to the sea, or dashed about by the waves on the beach previous to their deposition in deeper, quiet water. The quartz grains may be colourless, but are more often coloured superficially red or yellow by iron oxide. Nodular masses of amorphous silica, termed chert or flint, are found in some clays.

Both quartz and flint are highly refractory, being fusible only at cone 35 of the Seger series, but the presence of other minerals in the clay may exert a fluxing action and cause the quartz to soften at a much lower temperature.

The amount of quartz in clays varies from under 1 per cent in some kaolins or fireclays to over 50 or 60 per cent in some very sandy brick-clays.

Feldspar.—This mineral is nearly as abundant in some clays as quartz, but, owing to the ease with which it decomposes, the grains are rarely as large. When fresh and undecomposed, the grains have a bright lustre, and split off with flat surfaces or cleavages. Feldspar is slightly softer than quartz, and while the latter, as already mentioned, scratches glass, the former will not.

The fusing point of feldspar is about cone 9 (see Seger cones, under Fusibility), but the different species vary somewhat in their melting points. The feldspar grains may, however, begin to flux with other ingredients of the clay at a much lower temperature (See under Alkalies.)

Mica.—This is one of the few minerals in clay that can be easily detected with the naked eye, for it occurs commonly in the form of thin, scaly particles, whose bright, shining surface renders them very conspicuous, even when small. Very few clays are entirely free from mica, even in their washed condition, for, on account of the light scaly character of the mineral, it floats off with the clay particles. Some clays are highly micaceous, but such are rarely of much commercial value.

Iron Ores.—This title includes a series of iron compounds, which are sometimes grouped under the above heading, because they are precisely similar to those that serve as ores of iron when found in sufficiently concentrated form. The mineral species included under this head are: limonite ($2Fe_2O_3$, $3H_2O$); hematite (Fe_2O_3); magnetite (Fe_3O_4); siderite ($FeCO_3$).

Limonite.—This mineral occurs in clays in a variety of forms, and is often widely distributed in them, its presence when in a finely divided condition being shown by the yellow or brown colour of the material. When the clay is uniformly coloured the limonite is evenly distributed through it, sometimes forming a mere film on the surface of the grains; at other times it is collected into small rusty grains, or again forms concretionary masses of spherical or irregular shape; in still other clays it is found in the form of stringers and crusts, extending through the clay in many directions. The concretions are often especially abundant in some weathered clays. At times they take the shape of thick-walled cylindrical bodies which have apparently formed around plant roots. The beds of sandstone found in many of the sand and gravel deposits associated with some clays are caused by limonite cementing the sand grains together.

Limonite concretions can often be removed by handpicking. If left in the clay, they cause fused blotches, which are unsightly and sometimes even cause splitting of the ware.

Limonite is most abundant in surface clays, especially those which are of sandy character or sufficiently porous to admit the oxidizing waters from the surface. It is also found quite frequently in the weathered outcrops of many shales.

Siderite, the carbonate of iron, may occur in clay in the following forms. (1) As concretionary masses known as clayironstones, ranging in size from a fraction of an inch to several feet in diameter. They are very abundant in some Carboniferous shales, as those at New Glasgow, Nova Scotia, and are often strung out in lines parallel with the stratification of the clay. If near the surface, the siderite concretions often change to limonite. (2) In the form of crystalline grains, scattered through the clay and rarely visible to the naked eye. (3) As a film, coating other minerals in the clay. This mineral will also change to limonite if exposed to the weather.

When iron carbonate is in a finely divided condition and evenly distributed through the clay it may give it a blue or slate-grey colour.

Siderite may be present in some surface clays, but it is probably of greatest importance in shales, notably those associated with coal seams, and may occur in either finely divided (disseminated) or concretionary form.

Pyrite [1] (FeS_2 = Fe 46·6 per cent, S 53·4 per cent).—This mineral, which is not uncommon in some clays, can be often seen by the naked eye, and is known to the miners in some districts as sulphur. It has a yellow colour, metallic lustre, and occurs in large lumps, small grains, or cubes, or again in flat rosette-like forms. Not infrequently it is formed on or around lumps of lignite, showing quite clearly that the carbonaceous matter has reduced some iron sulphate present to sulphide. The only Nova Scotia clays in which it was found were those at Shubenacadie, and in the Musquodoboit valley.

When exposed to the weather, pyrite alters rather easily, first to the sulphate of iron, and then to limonite. Clays containing pyrite are not, as a rule, desired by the clay worker, and in mining the pyritic material is rejected.

Pyrite may be found in almost any clay or shale, but owing to the ease with which it is converted into limonite its formation or permanence in surface clays is rare.

Calcite ($CaCO_3$ = CaO 56·00 per cent, CO_2 44·0 per cent).—This mineral, when abundant, is found chiefly in clays of recent geological age, but some shales also contain considerable quantities of it. It can be easily detected, for it dissolves rapidly in

[1] In some clays this may be marcasite, the orthorhombic form of FeS_2.

weak acids, and effervesces violently upon the application of a drop of muriatic acid or even vinegar. It is rarely present in grains large enough to be seen with the naked eye, but has been detected with the microscope.

In some clays, calcite, as well as some other minerals, may form concretions. The brick-clay found on the Mira river, Nova Scotia, contains lime carbonate in a finely divided form, but not in sufficient quantities to make the clay burn buff coloured. The brick-clay at Winnipeg, Estevan, and other places, is also very calcareous.

Gypsum ($CaSO_4$, $2H_2O = CaO$ 32·6 per cent, SO_3 46·5 per cent, H_2O 20·9 per cent).—It is doubtful whether this mineral is widely distributed in clays, but is true that some deposits contain large quantities of it. It may occur in a finely divided condition, or in the form of crystals, plates, or fibrous masses of selenite. Its softness, pearly lustre, and transparency render its identification easy when the pieces are of sufficient size to be seen with the naked eye. When heated to a temperature of 250° F. (121° C.) the gypsum loses its water of combination, and when burned to a still higher temperature the sulphuric acid passes off.

Gypsum is a common constituent of the Pierre and Niobrara shales.

CHEMICAL ANALYSIS OF CLAYS

There are two methods of quantitatively analysing clays. One of these is termed the ultimate analysis, the other is known as the rational analysis.

The Ultimate Analysis.—In this method of analysis, which is the one usually employed, the various ingredients of clay are considered to exist as oxides, although they may really be present in much more complex forms. Thus, for example, calcium carbonate ($CaCO_3$), if it were present, is not expressed as such, but instead it is considered as broken up into carbon dioxide (CO_2) and lime (CaO), with the percentage of each given separately. The sum of these two percentages would, however, be equal to the amount of lime carbonate present.

Altogether too much weight is attached to the chemical analysis by those unfamiliar with the properties and behaviour of clay, and many wholly unwarranted deductions are made from it. It is true that the chemical analysis indicates the percentage of different substances present in the clay, and that the effect or action of these substances is understood in a fairly definite way, but their effectiveness depends to a large degree on their uniformity of distribution, and this is not indicated by the analysis.

Moreover, the ultimate analysis gives us little or no information regarding certain physical properties, such as the plasticity, degree of shrinkage in drying and burning, density after burning, etc.

It is, therefore, more or less absurd to conclude from a chemical analysis alone that a clay could be used for certain classes of ware.

But regarding the matter from a fair and conservative standpoint, it would seem that the following inferences may be made from an ultimate chemical analysis, provided the clay is of fine-grained uniform texture, and the elements in it evenly distributed, and not forgetting that there may be numerous exceptions to every case:—

(1) The purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities present. High grade clays often show a percentage of silica, alumina, and chemically combined water, approaching quite closely to kaolinite.

(2) The approximate refractoriness of a clay; for other things being equal, a clay with high total fluxes is commonly less refractory than one with low total fluxes. Several factors, it must be remembered, such as texture, irregularity of distribution of the constituents, and condition of kiln atmosphere may affect the result.

(3) The colour to which the clay burns. This must be judged with extreme caution. Assuming the constituents to be evenly distributed, then a clay with 1 per cent or less of ferric oxide is likely to burn pure white, but at high temperatures titanium, if present, appears to produce discoloration.

One with 2 to 3 per cent ferric oxide is likely to burn buff, and one with more than this will probably burn red, if there is not an excess of lime or alumina present.

(4) Excess of silica. A high percentage of silica (80 to 90 per cent) may indicate a sandy clay, and possibly one of low shrinkage, but it does not necessarily indicate low plasticity. High silica in a fireclay usually shows moderate refractoriness, provided it is evenly distributed.

(5) Carbon. This should be determined, as it causes trouble in burning if present to the extent of several per cent, requiring thorough oxidation in firing before the clay is allowed to pass to the vitrification stage.

(6) Sulphur trioxide. Since this may be the cause of swelling in improperly burned wares, and also indicate the presence of soluble sulphates, it should also be determined.

(7) The presence of a high percentage of lime carbonate shows the clay to be of calcareous character, and if this is evenly distributed it is likely to be of buff-burning character, with low refractoriness, and a narrow margin between vitrification and viscosity.

(8) Titanium dioxide should be determined in fireclays, as 2 or 3 per cent may reduce the refractoriness to an appreciable degree.

Yet, though the above deductions appear to yield much information, the conclusions are not definite, and, as mentioned above, we are still left in the dark regarding many important physical properties. The physical tests of a clay are, therefore, of vastly more importance and practical value, and it is for this reason that so few chemical analyses appear in this report.

The Rational Analysis.—In this method of analysis an attempt is made to determine the compounds actually present in a clay, such as kaolinite, quartz, feldspar, etc. The methods thus far developed are unsatisfactory.

SUBSTANCES PRESENT IN CLAY AND THEIR EFFECT

Silica.[1]—This is present in clay in two different forms, namely, uncombined as silica or quartz, and in silicates, of

[1] See also description of the minerals quartz, feldspar, kaolinite, and mica, above.

which there are several. Of these, one of the most important is the mineral kaolinite, which probably occurs in all clays, and is termed the clay base, or clay substance. The other silicates include feldspar, mica, glauconite, hornblende, garnet, etc. These two modes of occurrence of silica, however, are not always distinguished in the ultimate analysis of a clay, but when this is done they are commonly designated as 'free' and 'combined' silica, the former referring to all silica except that contained in the kaolinite, which is indicated by the latter term. This is an unfortunate custom, for the silica in silicates is, properly speaking, combined silica, just as much as that contained in kaolinite. A better practice is to use the term sand, to include quartz and silicate minerals other than kaolinite, which are supposedly not decomposable by sulphuric acid. In most analyses, however, the silica from both groups of minerals is expressed collectively as total silica.

The percentage of both quartz and total silica found in clays varies between wide limits.

The free silica or quartz is one of the commonest constituents of clay, and ranges in size from particles sufficiently large to be visible to the eye down to the smallest grains of silt.

Sand (quartz and silicates) is an important anti-shrinkage agent, which greatly diminishes the air shrinkage, plasticity, and tensile strength of clay, its effect in this respect increasing with the coarseness of the material; clays containing a high percentage of very finely divided sand (silt) may absorb considerable water in mixing, but show a low air shrinkage. The brickmaker recognizes the value of the effects mentioned above, and adds sand or loam to his clay, and the potter brings about similar results in his mixture by the use of ground flint. If too much sand is added to the brick mixture it makes the product too porous, and soft.

It is thought by some that because of the refractoriness of quartz its addition to any clay will raise its fusion point, but this is true only of those clays containing a high percentage of common fluxes and silica, and which are burned at low temperatures. Its effect on highly aluminous low flux clays reduces their refractoriness.

In considering the effects of sand in the burning of clays, it must first be stated that the quartz and silicates fuse at different temperatures. A very sandy clay will, therefore, have a low fire shrinkage, as long as none of the sand-grains fuse, but when fusion begins a shrinkage of the mass occurs. We should, therefore, expect a low fire shrinkage to continue to a higher temperature in a clay whose sand-grains are refractory.

Iron Oxide: Sources of Iron Oxide in Clays.—Iron oxide is one of the commonest ingredients of clay, and a number of different mineral species may serve as sources of it, the most important of which are grouped below:—

Hydrous oxide, limonite; oxides, hematite, magnetite; silicates, biotite, glauconite (greensand), hornblende, garnet, etc.; sulphides, pyrite; carbonates, siderite; sulphate, melanterite.

In some, such as the oxides, the iron is combined only with oxygen, and is better prepared to enter into chemical combination with other elements in the clay when fusion begins. In the case of the sulphides and carbonate, on the contrary, the volatile elements, namely, the sulphuric-acid gas of the pyrite, and the carbonic-acid gas of the siderite, have to be driven off before the iron contained in them is ready to enter into similar union. In the silicates the iron is chemically combined with silica and several bases, forming mixtures of rather complex composition, and all of them of low fusibility, particularly the glauconite. Several of these silicates are easily decomposed by the action of the weather, and the iron oxide which they contain combines with water to form limonite. This is usually in a finely divided condition, so that its colouring action is quite effective.

Effects of Iron Compounds.—Iron is the great colouring agent of both burned and unburned clays. It may also serve as a flux, and even affect the absorption and shrinkage of the material.

Colouring Action of Iron in Unburned Clay.—Many clays show a yellow or brown coloration due to the presence of limonite, and a red coloration due to hematite.

Colouring Action of Iron Oxide on Burned Clay.—All of the iron ores will, in burning, change to the red or ferric oxide, provided a sufficient supply of oxygen is able to enter the pores of the clay before it is vitrified; if vitrification occurs the iron oxide enters into the formation of silicates of complex composition. The colour and depth of shade produced by the iron will, however, depend on: (1) the amount of iron in the clay; (2) the temperature of burning; (3) condition of the iron oxide; and (4) the condition of the kiln atmosphere.

Clay free from iron oxide burns white. If a small quantity, say 1 per cent, is present, a slightly yellowish tinge may be imparted to the burned material, but an increase in the iron content to 2 or 3 per cent often produces a buff product; while 4 or 5 per cent of iron oxide in many cases makes the clay burn red. There seem, however, to be not a few exceptions to the above statements. Thus, we find that the white-burning clays carry from a few hundredths per cent to over 1 per cent of iron oxide, the more ferruginous containing more iron than the purer grades of buff-burning clays. Again, among the buff-burning clays we find some with an iron oxide content of 4 or 5 per cent, an amount equal to that contained in some red-burning ones.

The facts would, therefore, seem to indicate that the colour of the burned clay is not influenced solely by the quantity of iron present.

The brilliancy of the colour appears to be influenced by the texture, as the more sandy clays can be heated to a higher temperature, without destruction of the red colour, than the more aluminous ones. Alkalies also appear to diminish the brightness of the iron coloration.

Among the oxides of iron two kinds are recognized, known respectively as the ferrous oxide (FeO), and ferric oxide (Fe_2O_3). In the former we see one part of iron united with oxygen, while in the latter one part of iron is combined with one and one-half parts of oxygen. The ferric oxide, therefore, contains more oxygen per unit of iron than the ferrous salt, and represents a higher stage of oxidation. In the limonite and hematite the iron is in the ferric form, representing a higher stage of oxidation. In magnetite both ferrous and ferric iron are present, but in siderite the ferrous iron alone occurs. In the ultimate analysis the iron is usually determined as ferric oxide, no effort being made to find out the quantity present in the ferrous form, although if there is any reason to suspect that much of the latter exists it should be determined. Iron passes rather readily from the ferric to the ferrous form. It also oxidizes easily unless carbon and sulphur are present, in which case its oxidation is not possible until these two substances have been oxidized. Indeed they are sometimes supplied with oxygen at the expense of the iron, which may be left in a ferrous, magnetic, or even spongy, metallic condition; so if there is a deficit of oxygen in the inside of the kiln the iron does not get enough oxygen, and the ferrous compound results, but the latter changes rapidly to the ferric condition if sufficient air carrying oxygen is admitted. If, however, the oxidation of the iron does not begin until the clay has become so dense as to prevent free circulation of the air through it, then it may form ferrous silicates, which impart black or dark colours to the clay.

Moreover, in the burning of ferruginous clays it is usually desirable to get the iron thoroughly oxidized to prevent trouble in the later stages of burning. To accomplish this the iron must be freed of any sulphur or carbon dioxide which may be combined with it, and other volatile or combustible elements in the clay must be driven off, so as to allow the oxidizing gases to enter the clay and unite with any ferrous iron that may be present.

Sulphide of iron (pyrite) loses half its sulphur at a red heat, and the balance will, under oxidizing conditions, pass off probably by 900° C.; while siderite or ferrous carbonate loses its carbon dioxide between 400° and 500° C.; magnesium carbonate and calcium carbonate lose their CO_2 at about 500° C., and 800° to 900° C. respectively. Carbonaceous matter or sulphur, if present, must also be carefully burned off. If the clay contains much volatile or combustible matter the burning must proceed slowly below 1000° C., in order to remove it and allow the iron to get oxidized while the clay is still porous.

After oxidation the clays will show a more brilliant iron colour than they do at the end of the dehydration period. They are also harder, and show a slight decrease in volume.

If the clay has been improperly oxidized it shows later when vitrification is reached, by the dark ferrous silicate cores in the centre of the brick. This may form, however, without the development of any swelling. When swelling does accompany the formation of this black core it is to be traced to sulphur.

Fine-grained clays are more difficult to oxidize than coarse-grained, because of the small size of their pores, and grog is, therefore, added at times to open the grain of the material.

Since the stage of oxidization of the iron is dependent on the quantity of air it receives during burning, the condition of the kiln atmosphere is of great importance. If there is a deficiency of oxygen in the kiln, so that the iron oxide, if present, is reduced to the ferrous condition, the fire is said to be reducing. If, on the contrary, there is an excess of oxygen, so that ferric oxides are formed, the fire is said to be oxidizing. These various conditions are often used by the manufacturer to produce certain shades of colour effects in his ware. Thus, for example, the manufacturer of flashed brick produces the beautiful shading on the surface of his product by having a reducing atmosphere in his kiln, followed by an oxidizing one. The potter aims to reduce the yellow tint in his white ware by cooling the kiln as quickly as possible to prevent the iron from oxidizing.

In those clays which are of grey or black colour the iron may be present in both the ferrous and ferric form; the quantity present in that from several localities is shown below:—

—	Field Number.				
	41.	42.	47.	91.	94.
Fe_2O_3	1·56	1·96	1·34	2·46	1·91
FeO	4·97	3·19	6·12	2·29	3·61

41. Shale from Standard Drain Pipe Works, New Glasgow.
42. Lower shale, Brooks' brickyard, New Glasgow.
47. Shale, Intercolonial Coal Company, Westville.
91. Shale under coal seam, King mine, Minto, N.B.
94. Shale under coal, Canadian Coal Company, Salmon bay, N.B.

All analysed by H. A. Leverin, analyst, Mines Branch.

As these clays and shales all contain small amounts of sulphur and carbon, it is highly important to fire the material slowly, in order to burn off the carbon, and as much sulphur as possible, as well as to cause the large amount of ferrous iron to become oxidized.

Fluxing Action of Iron Oxide.—Iron oxide is a fluxing impurity, lowering the fusing point of the clay, and this effect will, in general, be more pronounced if the iron is in a ferrous condition, or if silica is present.

Effect of Lime Carbonate on Clay.—Lime is probably most effective in the form of the carbonate, and if finely divided is an active flux. When clays containing it are burned, they not only lose their chemically combined water but also their carbon dioxide, but while the water of hydration passes off between 450° C. (842° F.) and 600° C. (1112° F.) the carbon dioxide (CO_2) does not seem to go off until between 600° C. (1112° F.) and 725° C. (1562° F.). In fact, it more probably passes off between 850° C. (1562° F.), and 900° C. (1652° F.). The result of driving off this gas, in addition to the chemically combined water, is to leave calcareous clays more porous than other clays up to the beginning of fusion.

If the burning is carried only far enough to drive off the carbonic acid gas, the result will be that the quicklime thus formed will absorb moisture from the air and slake. No injury may result from this if the lime is in a finely divided condition and uniformly distributed through the brick, but if, on the contrary, it is present in the form of lumps the slaking and accompanying swelling of these may split the brick.

The effect of lime carbonate grains of different size is well shown in Plate LXI.

Limestone pebbles, if present in the clay, should be either removed, if this can be done cheaply, or crushed before the clay is moulded.

Effect of Gypsum.—Gypsum in the clay has probably often been formed by sulphuric acid, liberated by the decomposition of iron pyrite, acting on lime carbonate. Lime, if present in the form of gypsum, seems to behave differently from lime in the form of carbonate, although few clays contain large percentages of it.

If present in grains or lumps these burn to a white powder, but unlike lime do not slake and swell.

Magnesia.—Magnesia (MgO) rarely occurs in clay in larger quantities than 1 per cent. When present, its source may be any one of several classes of compounds, that is, silicates, carbonates, and sulphates.

It is to be regarded as a flux, but perhaps not as active a one as lime. It is always present in a finely divided form.

Alkalies.—The alkalies commonly present in clays include potash (K_2O), soda (Na_2O), and ammonia (NH_3). There are other alkalies, but they are probably of rare occurrence.

Several common minerals may serve as sources of the alkalies. Feldspar may supply either potash or soda. Muscovite, the white mica, contains potash. Greensand, or glauconite, contains potash. Other minerals, such as hornblende or garnet, might serve as sources of the alkalies, but are unimportant, as they are rarely present in clays in large quantities.

The alkalies are strong fluxes, but they are rarely present in large amounts.

Titanium.—Titanium is an element which is found in several minerals, some of which are more common in clays than is usually imagined, although they appear rare because they are seldom found in large quantities. The two commonest of these are rutile and ilmenite. So far as known, neither of these is ever found in clays in sufficiently large grains to be visible to the naked eye, so that a microscopic examination would be necessary to identify them. Although titanium is such a common constituent of clay, it is rarely shown in an analysis, because its determination by chemical methods is attended with more or less difficulty and is rarely carried out. In the ordinary process of chemical analysis it is usually included with the alumina.

Titanium may be regarded as a flux, but since the quantity present in most clays is usually small, it seems to operate mainly at high temperatures. Thus, a clay whose fusion point lay between cones 34 (1810° C.) and 35 (1830° C.), fused at cone 32 (1770° C.), when 5 per cent of titanium oxide was mixed with it.

WATER IN CLAY.

Under this head are included two kinds of water: (1) mechanically combined water or moisture; (2) chemically combined water.

Mechanically Combined Water.—The mechanically combined water is that which is held in the pores of the clay by capillary action, and fills all the spaces between the clay grains. When these are all small, the clay may absorb and retain a large quantity, because each interspace acts like a capillary tube. If the spaces exceed a certain size, they will no longer hold the moisture by capillary action, and the water, if poured on the clay, would fast drain away. The fine-grained clays, for these reasons, show high powers of absorption and retention, while coarse, sandy clays or sands represent a condition of minimum absorption. This same phenomenon shows itself in the amount of water required for tempering a clay. Thus, a very coarse sandy mixture from one deposit may require only 15 per cent of water, while a very fat one from another deposit may take 45 per cent of water. It is not the highly aluminous ones, however, that always absorb the most water.

The total quantity of water found in different clays varies exceedingly. In some air dried clays it may be as low as 0·5 per cent, while in those freshly taken from the bank it may reach 30 to 40 per cent without the clay being very soft.

Clay is very hygroscopic, and when thoroughly dry greedily absorbs moisture from the atmosphere; indeed it may absorb as much as 10 per cent of its weight.

Water held mechanically in a clay will pass off partly by evaporation in air, but can all be driven off by heating the clay to 100° C. (212° F.). The evaporation of the mechanical water is accompanied by a shrinkage of the mass, which ceases, however, when the particles have all come in contact, and before all the moisture is driven off, because some remains in the pores of the clay. This last portion is driven off during the early stages of burning. The shrinkage that takes place when the mechanical water is driven off varies, ranging from 1 per cent, or less, in very sandy clays, up to 10 or 12 per cent in very plastic ones.

Since most clays having a high absorption shrink a large amount in drying, there is often danger of their cracking, especially if rapidly dried, owing to the rapid escape of the water vapour. Mechanical water may hurt the clay in other ways. Thus, if the material contains any mineral compounds which are soluble in water, the latter, when added to the clay, will dissolve a portion of them at least. During the drying of the brick the water rises to the surface to evaporate, and brings out the compounds in solution, leaving them behind when it vaporizes. It may also help the fire gases to act on certain elements of the clay, a point explained under "Burning."

Chemically Combined Water.—Chemically combined water, as its name indicates, is that which exists in the clay in chemical combination with other elements, and which, in most cases, can be driven out only at a temperature ranging from 400° C., (752° F.), to 600° C. (1112° F.). This combined water may be derived from several minerals, such as kaolinite, which contains nearly 14 per cent white mica, or muscovite with 4 to 5½ per cent, and limonite with 14·5 per cent. Unless a clay contains considerable limonite or hydrous silica, the percentage of combined water is commonly about one-third the percentage of alumina found in the clay. In pure, or nearly pure kaolin, there is nearly 14 per cent, and other clays contain varying amounts, ranging from this down to 3 or 4 per cent, the latter being the quantity found in some very sandy clays. The loss of its combined water is accompanied by a slight but variable shrinkage in the clay, which reaches its maximum some time after all the volatile matters have been driven off.

In many clay analyses the chemically combined water is determined as loss on ignition, which is incorrect if the clay contains carbon dioxide, sulphur trioxide, or organic matter, all of which are driven off, in part at least, at a dull red heat.

EFFECTS OF CARBON IN CLAY.

Carbon may be present in clay in the form of: (1) vegetable matter; (2) asphaltic carbon, and (3) fixed carbon. Only the second and third of the groups mentioned need be considered. The first alone causes trouble when it occurs in the form of sticks or thick roots, and has to be screened out. It is, therefore, not included in what follows.

Carbonaceous matter often serves as a strong colouring agent of raw clays, tinging them grey, bluish-grey, or black. Indeed, so strong may this be that it masks the effect of other colouring agents, such as iron. In fact, two clays coloured black might burn red and white respectively, because one had much iron and the other none, and yet, owing to their black colour, this could not be foretold with definiteness.

Some of the shales of the Edmonton formation at Edmonton, and those associated with the coal beds at Canmore and Banff, are coloured by carbonaceous matter.

Asphaltic carbon, aside from its colouring action, often causes much trouble in burning, causing black cores, or even swelling and fusing of the brick. More than this, it may keep the iron in a ferrous condition and prevent the development of the best colour effects in the ware.

The reason for this is due to several causes.

Carbon has a strong affinity for oxygen, much stronger than that of iron, therefore as long as it remains in the clay it will monopolize the supply of oxygen and keep the iron in a ferrous condition, the form in which much of it is, in grey or black clays and shales. Now, in burning a clay, one of the aims of the clay worker is to get the iron into a ferric condition, so as to fully develop its colouring properties and prevent other troubles. As long as any carbonaceous matter remains the oxidation of the iron is prevented or retarded, and consequently the carbon must be burned out.

The experiments of Orton and Griffin have shown that between 800° and 900° C. is the best temperature interval for burning off the carbon, as below this its oxidation does not proceed as rapidly, and above this there is danger of vitrification beginning, and the oxidation being stopped.

The method of procedure would, therefore, be to drive all moisture out of the clay first, then raise the heat as rapidly as possible to a temperature between 800° and 900° C., and hold it there until the ware no longer shows a black core denoting ferrous iron.

In order to burn off the carbon and oxidize the iron, air supplying oxygen must be drawn into the kiln during burning, for the gases of combustion from the fuel will supply none. Oxidation may be accelerated by increasing the amount of air entering the kiln, and by reducing the density of the clay as much as possible. In case this is not done, and the pores of the clay close up before all the carbon is burned off, it also interferes with the expulsion of sulphur present which may result in a swelling of the clay. This may be even followed by complete fusion of the interior of the mass, caused by the formation of an easily fusible ferrous silicate. When the carbon is all burned off the iron has a chance to oxidize. If the clay contains much asphaltic carbon the oxidation must be carried on with as little air as possible, otherwise the heat generated by the burning hydrocarbons may be so intense as to vitrify the ware before the oxidation is completed.

Since dense clays are more difficult to oxidize than those which are porous, the process of manufacture may also influence the results, and in this connexion it has been found that bricks made by the soft-mud process are most rapidly oxidized, followed by either the stiff-mud or dry-press (there being no difference between the two), and lastly by the semi-dry-press.

Effect of Water on Black Coring.—It is often stated by brick makers that black cores are caused by the brick being set too wet. This is not strictly true, and the relation is a very indirect one. While carbon burns off most rapidly between the temperatures of 800° and 900° C., it also passes off somewhat at much lower temperatures. If the brick is set wet it requires so much more heat in the early stages of firing to drive out or evaporate the water that other changes, such as the oxidation of the carbon, will be retarded, and brick begins to vitrify before the process is completed.

SULPHUR.

Many clays contain at least a trace of sulphur, and some show appreciable quantities, but determinations of it are rarely made, unless the clay is to be employed for Portland cement manufacture. As can be seen from the experiments of Seger, and more especially Orton and Staley, it may cause serious trouble, and should always be determined in the analysis of a clay.

Sulphur might be present in a clay, as:—

(1) Sulphate, such as gypsum (CSO_4, $2H_2O$), epsomite ($MgSO_4$, $7H_2O$), or melanterite ($FeSO_4$, $7H_2O$).

(2) Sulphide, as pyrite (FeS_2), or marcasite (FeS_2).

Few investigators have, however, given much attention to the matter.

From experiments on a Columbus black shale, running high in carbon, ferrous iron, and sulphur, Orton and Staley adopted the series of conclusions given below:—

The shale contained an average of 2·997 per cent of total sulphur, expressed as the element, of which 0·76 per cent was contained in soluble sulphates, and 2·235 in sulphides.

They conclude:—

(1) Both sulphates and sulphides experience rapid diminution by dissociation, in that portion of the burn up to 800° C., in those portions of the ware which get air freely. This loss of sulphur may amount to two-thirds or three-fourths of the amount originally present.

(2) Both sulphates and sulphides experience a further slow diminution by dissociation or oxidation, beginning at 800° C., and continuing as long as the clay structure remains porous and permeable to air. The loss of sulphur may amount to 90 per cent or more of the initial sulphur content at the end of the period, but it proceeds increasingly slowly, and would probably never become complete.

(3) In the interior portions of the clay, to which air cannot readily penetrate, the loss of sulphur may be less, and if there are any bases, such as FeO, CaO, or MgO present, with which the sulphur may combine, the sulphur is not likely to be expelled.

(4) Carbon, even in small quantities, interferes strongly with the expulsion of sulphur, which does not pass off to any extent until after the carbon goes. The clay may, therefore, have become too dense by that time for the oxidation of the sulphur to proceed, so that the carbon has virtually prevented its escape.

(5) Sulphur retained in the clay in any form, and from any cause, is not likely to cause physical disturbances in the clay until a fairly complete degree of vitrification is reached.

(6) When a clay reaches a dense vitrified condition it proceeds normally, after a longer or shorter interval, to become less dense, by reason of the development of multitudes of minute vesicles in the viscous body; this process is progressive and in the end the body becomes spongy and worthless.

(7) The length of this period of dense vitrification is much shortened, and in some cases practically abolished, by the presence of sulphur compounds, which break down and evolve gases copiously, producing a prematurely spongy body.

(8) The cause of this gas evolution is chiefly the dissociation of sulphides and sulphates by silicic acid, which becomes increasingly active as the temperature rises, and appropriates the bases formerly combined with the sulphur.

(9) In clays of low sulphur content, and of favourable structure for oxidation, the amount of sulphur left in the clay at vitrification is very small. Hence the period of good structure is long, the vesicular structure develops slowly, and the clay is said to stand over-firing well.

(10) In clays of high sulphur content, or of dense structure unfavourable for oxidation, or of high content of iron and carbon, the escape of the sulphur is prevented, the clay has a very narrow period of usefulness, or none at all, and the vesicular structure becomes enormously exaggerated.

(11) While this premature and exaggerated swelling from sulphur may in aggravated cases occur in well oxidized clays, it is practically certain to occur where clays containing a partly oxidized core are allowed to reach the vitrification period.

(12) This breaking down of sulphur compounds by silicic acid is the chief or common cause of the premature swelling of black coloured clays, and the occasional cause of sudden and severe swelling of properly oxidized clay wares.

(13) The proper way to avoid the effects of sulphur in vitrifying clay bodies is to apply a deliberate and complete oxidation treatment while the clay remains porous. This will rid the clay of the greater part of the sulphur, and will prevent sudden or premature slagging of the clay by ferrous oxide, if it is true that ferrous oxide has such a tendency, and will thus avoid, so far as possible, the conditions which favour swelling.

Clays which still give trouble from swelling after this treatment must be regarded as bad clays.

REACTIONS INVOLVED IN EXPULSION OF SULPHUR.

These may be expressed briefly as follows, the simpler and most probable ones only being given:—

Pyrite heated to 400° C. gives $FeS_2 + heat = FeS + S$.

The S in the air catches fire and burns to SO_2 or SO_3, but if liberated in a clay soft and spongy by heat it may attack FeO, CaO, or MgO. However, most of it probably escapes.

FeS exposed to oxidizing conditions might oxidize to ferrous sulphate, but further heating to 550-650° C. breaks it up, leaving FeO, the latter in an oxidizing atmosphere changing to Fe_2O_3.

Calcium sulphate also breaks down, but at higher temperatures than ferrous sulphate and less completely. The action of carbon in restraining the liberation of sulphur is explained as follows:—

$$FeCO_3 + 425° C. = FeO + CO_2.$$

If, now, free sulphur is liberated in the immediate vicinity,

$$FeO + C + S = FeS + CO.$$

This ferrous sulphide cannot be broken up by heat alone, but only by roasting in air, or interaction with silicic acid, for as pointed out by Seger, silicic acid at high temperatures has the power of displacing all other common acids, and combining with their bases to form silicates. It thus has the power to replace sulphuric acid, and sulphur of sulphides. He found that a bisilicate glass mixture, saturated with sulphates, showed 4 per cent sulphuric acid; while the same glass, with one more molecule of silica added and melted at the same temperature and under the same conditions, contained only 2 per cent sulphuric acid. Now, in raising the temperature of burning, the fusing matrix of a clay becomes more siliceous, resulting in the expulsion of sulphur.

SOLUBLE SALTS.

Origin.—It has been pointed out, in explaining the origin of clay, that in the decomposition of mineral grains in clay soluble compounds are often formed. During the drying of the clay the moisture brings these to the surface, and leaves them there when it evaporates, thus forming a scum on the air-dried ware, and sometimes a white coating on the clay after it is burned. Those found in the clay are commonly sulphates of lime, iron, or alkalies, and their formation is generally due to the decomposition of the iron pyrite frequently contained in the clay. A much greater quantity of soluble sulphates will be formed if the pyrite is in a finely divided condition and evenly distributed through the clay, but soluble compounds may also be formed without the aid of pyrite, as when carbonates are set free by the decomposition of silicates, such as feldspar. When the soluble compounds have formed in the green clay their presence can often be detected by spreading the dug clay out to weather, which will result in their forming a crust on the surface of the mass.

Their formation does not cease, however, when they are removed from the ground, for in some cases, fresh pyrite grains remain in the clay after mixing, and if the clay is stored in a moist place these may decompose, yielding an additional amount of soluble material. One means of preventing this would seem to be the use of the clay as soon as possible after mixing.

In some cases soluble sulphates may be even introduced into the clay by the water used for mixing, for distilled water is the only kind that is free from soluble salts. All well and spring waters contain some at least, and if these flow or drain from clays or rocks containing any pyrite they are almost sure to contain soluble salts. Those flowing from lime rocks are usually hard, on account of the lime carbonate which they contain. Still another source of soluble salts in raw clay lies in some of the artifical colouring materials which are sometimes used.

Soluble salts brought out in the drying of the clay are termed dryer-white, but do not differ in composition from those formed during burning and known as kiln-white.

Soluble sulphates are sometimes formed in burning, through the use of sulphurous fuel, that is, coal containing more or less iron pyrite. When the coal is burned part of the sulphur in the pyrite is expelled, and, uniting with the oxygen, forms sulphuric-acid gas (SO_3). This passes through the kiln, and, if it comes in contact with carbonates in the clay, converts them into sulphates, because some substances, such as lime (CaO), have a stronger affinity for sulphur trioxide (SO_3) than for carbon dioxide (CO_2).

It frequently happens that clay products come from the kiln apparently free from any superficial discoloration or coating, but develop one later on if subjected to moisture. This type of coating is known as wall-white. It may be derived from salts formed within the body of the ware during burning, and subsequently brought to the surface by the evaporation of moisture absorbed during rainy weather, or it may come from the mortar, either by the direct introduction of soluble salts from it, or by reaction between carbonates of magnesium, potassium, and sodium of the mortar, with calcium sulphate in the brick. This gives calcium carbonate.

Mäckler found that, in a series of fifty bricks examined, the sum of the sulphates of lime, magnesium, and alkalies varied from 0·0134 per cent to 0·7668 per cent.

The coatings thus far mentioned are all white in colour. In some instances, however, the product becomes covered with a yellow or green stain, which is caused either by the growth of vegetable matter on the surface of the bricks, or by soluble compounds of the rare element vanadium.

Quantity of Soluble Salts in Clays.—The amount of soluble salts present in a clay is never very great, but less than 0·1 per cent is often sufficient to produce a white incrustation.

The accurate determination of soluble salts in a clay is somewhat difficult, and no such determinations were made for the present report. Several clays were found, however, which contained an appreciable quantity of them as shown by the formation of a scum or crystals on the surface during drying. The worst case was that of the unweathered clay from Kamloops, B.C. Some of the Dirt Hills clays also contained a noticeable amount of soluble salts.

Prevention of Soluble Salts.—The methods of prevention that have been suggested for dryer-white and kiln-white are:—

(1) Use of the clay in its unweathered condition, or before the soluble salts have time to form.

(2) Use of the clay in a thoroughly weathered condition, thus permitting removal of soluble salts by leaching.

(3) Change of the soluble salts to a harmless form by precipitation with barium compounds.

(4) Prevention of concentration of salts on surface of brick by rapid firing.

(5) Removal of whitewash in the kiln by using a reducing flame.

(6) Coating the brick with some combustible substance, as wheat flour, or coal tar, which burns away with a strong reducing action and removes the whitewash.

Referring in more detail to (3), it may be explained that the substance commonly added is either barium chloride or barium carbonate. When barium salts come in contact with soluble sulphates, barium sulphate is formed, a combination which is insoluble in water. This is expressed by the first of the following chemical reactions, if barium is used, and by the second, if barium chloride is employed:—

(1) $CaSO_4 + BaCO_3 = CaCO_3 + BaSO_4$.

(2) $CaSO_4 + BaCl_2 = CaCl_2 + BaSO_4$.

We thus see that in both cases we get compounds which are insoluble, or nearly so. If soluble sodium compounds are present the addition of barium carbonate, or barium chloride, will form either sodium carbonate or sodium chloride (common salt), but since both of these are easily soluble in water they can be washed off without much trouble.

Method of Use.—As carbonate of barium is insoluble in water, in order to make it thoroughly and uniformly effective it should be used in a finely powdered condition, and distributed through the clay as thoroughly as possible, because it will only act where it comes into immediate contact with the soluble sulphates. While only a small quantity of barium is necessary, it is desirable to use somewhat more than is actually required.

According to Gerlach, a clay containing 0·1 per cent sulphate of lime, which is the same as 0·4 grams per pound, would need 0·6 of a gram of barium carbonate per pound of clay. For safety, however, 6 or 7 grams should be added to every pound of clay. This would be about 100 pounds for every thousand bricks, based on the supposition that a green brick weighs 7 pounds. As a pound of barium carbonate costs about 2½ cents, the amount required for 1,000 bricks would be $2.50. It is cheaper to use barium chloride, for the reason that the salt is soluble in water, and hence can be distributed more evenly with the use of a smaller quantity; the chemical reaction also takes place much more rapidly when it is used. There is this objection to it, however, that as near the theoretic amount as possible must be used; for if any remains in the clay unchanged, that is, without having reacted with the soluble salts, it may of itself form an incrustation.

In the case of a clay containing 0·1 per cent calicum sulphate it would require 26 pounds of barium chloride per thousand bricks and this, at 2½ cents a pound, would mean an outlay of 65 cents. With the barium-chloride treatment, chloride of lime is formed, but this is decomposed in burning.

Since, in drying moulded clay objects, the evaporation is greatest from the edges and corners of the ware, the incrustations may be heaviest at these points, but the more rapidly the water is evaporated the less will be the quantity of soluble salts deposited on the surface. Incrustations which appear during drying are found more commonly on bricks made from very plastic clays, which, owing to their density, do not allow the water to evaporate quickly.

Remedy for Wall-White.—This is more difficult, but consists primarily in preventing entrance of moisture to the walls. It is suggested to make the walls as inpervious as possible by the use of well-burned brick, and proper drainage and waterproofing of the foundations. If the efflorescence appears, the walls may be painted so as to cover the efflorescence, but it may then peel off in damp spots. A coat of paraffin or linseed oil will conceal the white coating somewhat, but also darken the brick. They should also be made waterproof if possible.

Soluble Salts in Canadian Clays.—No determination was made of the amount of soluble salts present in the clays tested for this report, but some of them show scumming in drying. The worst case was that of the clay from Kamloops. Some of the Dirt Hills clays also showed it.

PLASTICITY.

Definition.—Plasticity is probably by far the most important property of clay, lacking which it would be of comparatively little value for the manufacturer of clay products. Seger has defined it as the property which solid bodies show of absorbing and holding a liquid in their pores, and forming a mass which can be pressed or kneaded into any desired shape, which it retains when the pressure ceases, and on the withdrawal of the water, changes to a hard mass. The term hard, of course, refers to its hardness as compared with its wet condition, for some air-dried clays are rather soft.

TENSILE STRENGTH.

Definition.—The tensile strength of a clay is the resistance which it offers to rupture or being pulled apart when air-dried.

Practical Bearing.—The tensile strength is an important property, and has a practical bearing on problems connected with the handling, moulding, and drying of the ware, since a high strength enables the clay to withstand the shocks and strains of handling. Through it, also, the clay is able to carry a large quantity of non-plastic material, such as flint or feldspar, ground bricks, etc.

Relation to Plasticity.—Although it was formerly believed by many that tensile strength and plasticity were closely related, this view is no longer generally accepted. High tensile strength and high plasticity often go together, but a clay low in tensile strength may have high plasticity, and vice versa.

Measurement of Tensile Strength.—The tensile strength is measured by moulding the thoroughly kneaded clay into briquettes, of the same shape and size as those made in cement testing, and, when thoroughly air-dried, pulling them apart in a suitable testing machine.

SHRINKAGE.

All clays shrink in drying and burning, the former loss being termed the air shrinkage, and the latter the fire shrinkage.

Air Shrinkage.—In a clay which is perfectly dry all the grains are in contact, but between them there will be a variable amount of pore space, depending on the texture of the clay. The volume of this pore space is indicated somewhat by the quantity of water that will be absorbed without the clay changing its volume, this water filling in the space between the grains. It may be termed pore water.

The presence of more water than is required to fill the spaces between the grains produces a swelling of the mass, and in this condition each grain is regarded as being surrounded by a film of water; but while the grains still mutually attract each other the attraction is less than in the dry clay, and the mass yields readily to pressure. An excess, however, separates the clay particles to such an extent that the clay softens and runs. A clay will, therefore, continue to swell as water is added to it, until the amount becomes too great to permit it to retain its shape.

The amount of air shrinkage is usually low in sandy clays, at times being under 1 per cent in coarsely sandy ones, while it is high in very plastic clays, or in some of very fine grain, reaching at times as much as 12 or 15 per cent. Five or six per cent is about the average seen in the manufacture of clay products.

All clays requiring a high percentage of water in mixing do not show a high air shrinkage. The air shrinkage of a clay will not only vary with the amount of water added, but also with the texture of the materials.

Some clays and shales show a strong tendency to crack badly in air drying, no matter how slowly this is done, but this trouble can often be remedied by preheating the clay to a temperature varying from 250° to 500° C., depending on the clay. The addition of a very small percentage of salt will also prevent the cracking. The effects of this treatment are referred to in some detail in Chapter VIII. Many of the Belly River and Edmonton shales require preheating.

Sand or materials of a sandy nature counteract the shrinkage, and are frequently added for this purpose, but, since they also render the mixture more porous, they facilitate the drying as well, permitting the water to escape more readily, and often reducing the danger from cracking. If the sand added to dilute the shrinkage is refractory it also aids the clay in retaining its shape during burning.

Fire Shrinkage.—All clays shrink during some stage of the burning operation, even though they may expand slightly at certain temperatures. The fire shrinkage, like the air shrinkage, varies within wide limits, the amount depending partly on the quantity of volatile elements, such as combined water, organic matter, and carbon dioxide, and partly on the texture and fusibility.

Fire shrinkage may begin at a dull red heat, or about the point at which chemically combined water begins to pass off, and reaches its maximum when the clay vitrifies, but does not increase uniformly up to that point. The clay worker, however, always tries to get a low fire shrinkage, using a mixture of clays if necessary in order to prevent cracking and warping. After the expulsion of the volatile elements the clay is left in a porous condition, until the fire shrinkage recommences.

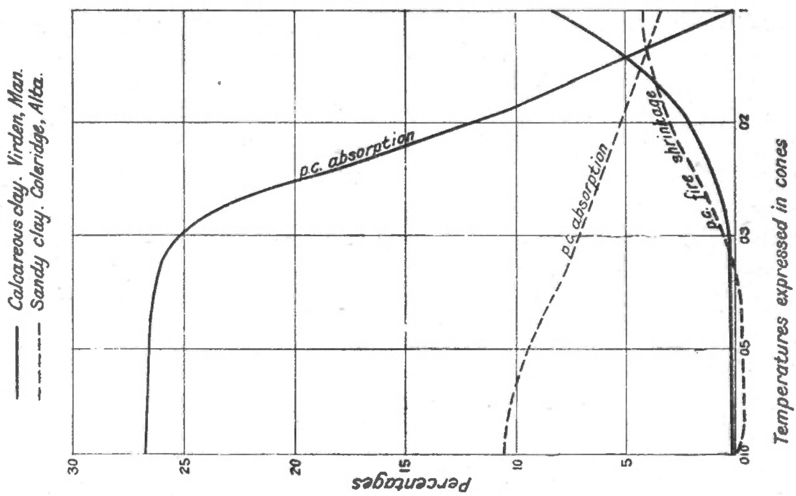


FIG. 9.—Curves of absorption and fire shrinkage of calcareous and sandy clays.

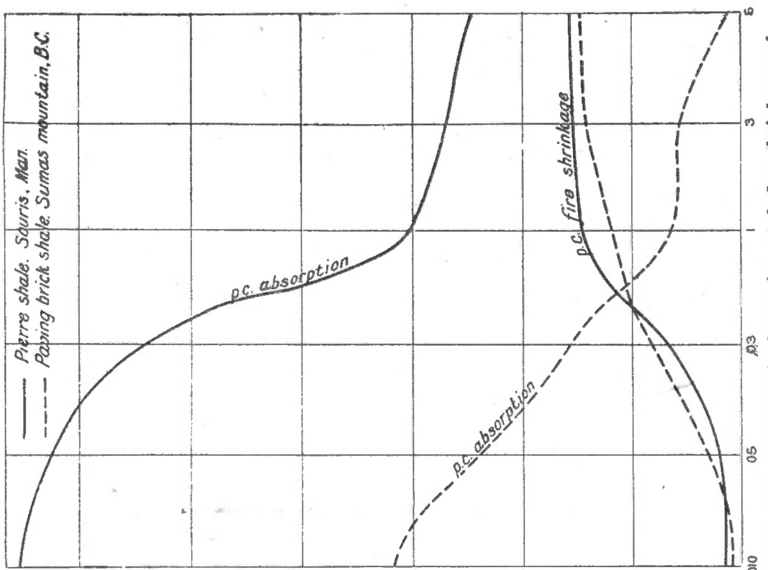


FIG. 10.—Curves of absorption and fire shrinkage of Pierre shale from Souris, Man., and paving brick shale from Sumas mountain, B.C.

Figures 2, 3, 9, and 10, give some curves showing the fire shrinkage and absorption of different clays and shales.

Figures 9 and 10 show how two clays may agree quite closely in their fire shrinkage at different temperatures, but differ greatly in their density as shown by the absorption curves.

The solid line of Fig. 9 is characteristic of a calcareous clay, and it will be noticed that both the fire shrinkage and absorption are respectively low and high up to a certain temperature and then change suddenly.

Figure 3 shows how washing a sandy clay increases its fire shrinkage and decreases its absorption. The corresponding curves for the unwashed clay are shown in Fig. 2. Referring again to Fig. 2 attention should be called to the difference between the sandy fireclay and the grey fireclay from the Dirt hills. The former being more sandy has a higher absorption and lower fire shrinkage.

FUSIBILITY.

All clays fuse at one temperature or another, the temperature of fusion depending on: (1) the amount of fluxes; (2) the size of grain of the refractory and non-refractory particles; (3) the homogeneity of the mass; (4) the condition of the fire, whether oxidizing or reducing; and (5) the form of chemical combination of the elements contained in the clay.

When clays undergo a fusion process they do not soften at once, but melt with comparative slowness. This is not surprising when we consider their heterogeneous composition, and may account for their slow softening, as one kind of mineral after another fuses. As soon as a softening of one or more of the mineral grains occurs, interreactions between the different ones begin, the number involved increasing until all constituents of the mass are involved. In most cases no reaction occurs between any of the grains until one melts, but it is not necessary to reach the fusion point of each before it can react with the others.

Incipient Vitrification.—In this stage the clay has softened sufficiently to make the grains stick together, and enough to prevent the recognition of any, except the larger ones. The particles have not, however, softened sufficiently to close up all the pores of the mass.

Complete Vitrification.—A further heating of the clay, through a variable temperature interval ranging from about 27·7° C. (500° F.) to 111·1° C. (200° F.), or sometimes even more, produces an additional softening of the grains sufficient to close up all the pores and render the mass impervious. Clays burned to this condition of complete vitrification show a smooth fracture, with a slight lustre. The attainment of this condition also represents the point of maximum shrinkage.

Viscosity.—A still further variable rise in the temperature is accompanied by both swelling and softening of the clay, until it flows or gets viscous.

It is sometimes difficult to recognize precisely the exact attainment of these three conditions, for the clay may soften so slowly that the change from one to the other is gradual.

SEGER CONES.

These test pieces consist of a series of mixtures of clays with fluxes, so graded that they represent a series of fusion-points, each being a few degrees higher than the one next to it. They are so called because originally introduced by H. Seger, a German ceramist. The materials which he used in making them were such as would have a constant composition, and consisted of washed Zettlitz kaolin, Rörstrand feldspar, Norwegian quartz, Carrara marble, and pure ferric oxide. Cone 1 melts at the same temperature as an alloy composed of one part of platinum and nine parts of gold, or at 1150° C. (2102° F.). Cone 20 melts at the highest temperature obtained in a porcelain furnace, or at 1530° C. (2786° F.). The difference between any two successive numbers is 20° C. (36° F.), and the upper member of the series is cone 39. Cone 36 is composed of a very refractory clay slate, while cone 35 is composed of kaolin from Zettlitz, Bohemia. A lower series of numbers was produced by Cramer, of Berlin, who mixed boracic acid with the materials already mentioned. Hecht obtained still more fusible mixtures by adding both boracic acid and lead in proper proportions to the cones. The result is that there is now a series of 61 numbers, the fusion-point of the lowest being 590° C. (1094° F.) and that of the highest 1940° C. (3470° F.). As the temperature rises the cone begins to soften, and when its fusion-point is reached it begins to bend over until its tip touches the base. For practical purposes these cones are very successful, though their use has been somewhat unreasonably discouraged by some. They have been much used by foreign manufacturers of clay products, and their use in the United States and Canada is increasing.

The composition and fusing points of the different members of the series are given below:—

Composition and Fusing Points of Seger Cones.

No. of Cone.	Composition.			Fusing-point.	
				Degrees F.	Degrees C.
0·022	$0.5\ Na_2O$, $0.5\ PbO$		$2.0\ SiO_2$, $1.0\ B_2O_3$	1,094	590
0·021	$0.5\ Na_2O$, $0.5\ PbO$	$0.1\ Al_2O_3$	$2.2\ SiO_2$, $1.0\ B_2O_3$	1,148	620
0·020	$0.5\ Na_2O$, $0.5\ PbO$	$0.2\ Al_2O_3$	$2.4\ SiO_2$, $1.0\ B_2O_3$	1,202	650
0·019	$0.5\ Na_2O$, $0.5\ PbO$	$0.3\ Al_2O_3$	$2.6\ SiO_2$, $1.0\ B_2O_3$	1,256	680
0·018	$0.5\ Na_2O$, $0.5\ PbO$	$0.4\ Al_2O_3$	$2.8\ SiO_2$, $1.0\ B_2O_3$	1,310	710
0·017	$0.5\ Na_2O$, $0.5\ PbO$	$0.5\ Al_2O_3$	$3.0\ SiO_2$, $1.0\ B_2O_3$	1,364	740
0·016	$0.5\ Na_2O$, $0.5\ PbO$	$0.55\ Al_2O_3$	$3.1\ SiO_2$, $1.0\ B_2O_3$	1,418	770
0·015	$0.5\ Na_2O$, $0.5\ PbO$	$0.6\ Al_2O_3$	$3.2\ SiO_2$, $1.0\ B_2O_3$	1,472	800
0·014	$0.5\ Na_2O$, $0.5\ PbO$	$0.65\ Al_2O_3$	$3.3\ SiO_2$, $1.0\ B_2O_3$	1,526	830
0·013	$0.5\ Na_2O$, $0.5\ PbO$	$0.7\ Al_2O_3$	$3.4\ SiO_2$, $1.0\ B_2O_3$	1,580	860
0·012	$0.5\ Na_2O$, $0.5\ PbO$	$0.75\ Al_2O_3$	$3.5\ SiO_2$, $1.0\ B_2O_3$	1,634	890
0·011	$0.5\ Na_2O$, $0.5\ PbO$	$0.8\ Al_2O_3$	$3.6\ SiO_2$, $1.0\ B_2O_3$	1,688	920
0·010	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.50\ SiO_2$, $0.50\ B_2O_3$	1,742	950
0·09	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.55\ SiO_2$, $0.45\ B_2O_3$	1,778	970
0·08	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.60\ SiO_2$, $0.40\ B_2O_3$	1,814	990
0·07	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.65\ SiO_2$, $0.35\ B_2O_3$	1,850	1,010
0·06	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.70\ SiO_2$, $0.30\ B_2O_3$	1,886	1,030
0·05	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.75\ SiO_2$, $0.25\ B_2O_3$	1,922	1,050
0·04	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.80\ SiO_2$, $0.20\ B_2O_3$	1,958	1,070
0·03	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.85\ SiO_2$, $0.15\ B_2O_3$	1,994	1,090
0·02	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.90\ SiO_2$, $0.10\ B_2O_3$	2,030	1,110
0·01	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$3.95\ SiO_2$, $0.05\ B_2O_3$	2,066	1,130
1	$0.3\ K_2O$, $0.7\ CaO$	$0.2\ Fe_2O_3$, $0.3\ Al_2O_3$	$4\ SiO_2$	2,102	1,150
2	$0.3\ K_2O$, $0.7\ CaO$	$0.1\ Fe_2O_3$, $0.4\ Al_2O_3$	$4\ SiO_2$	2,138	1,170
3	$0.3\ K_2O$, $0.7\ CaO$	$0.05\ Fe_2O_3$, $0.45\ Al_2O_3$	$4\ SiO_2$	2,174	1,190
4	$0.3\ K_2O$, $0.7\ CaO$	$0.5\ Al_2O_3$	$4\ SiO_2$	2,210	1,210

Composition and Fusing-Points of Seger Cones—Continued.

No. of Cone.	Composition.	Fusing-point.	
		Degrees F.	Degrees C.
5	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $0\cdot5\ Al_2O_3$ $5\ SiO_2$	2,246	1,230
6	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $0\cdot6\ Al_2O_3$ $6\ SiO_2$	2,282	1,250
7	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $0\cdot7\ Al_2O_3$ $7\ SiO_2$	2,318	1,270
8	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $0\cdot8\ Al_2O_3$ $8\ SiO_2$	2,354	1,290
9	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $0\cdot9\ Al_2O_3$ $9\ SiO_2$	2,390	1,310
10	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $1\cdot0\ Al_2O_3$ $10\ SiO_2$	2,426	1,330
11	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $1\cdot2\ Al_2O_3$ $12\ SiO_2$	2,462	1,350
12	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $1\cdot4\ Al_2O_3$ $14\ SiO_2$	2,498	1,370
13	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $1\cdot6\ Al_2O_3$ $16\ SiO_2$	2,534	1,390
14	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $1\cdot8\ Al_2O_3$ $18\ SiO_2$	2,570	1,410
15	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $2\cdot1\ Al_2O_3$ $21\ SiO_2$	2,606	1,430
16	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $2\cdot4\ Al_2O_2$ $24\ SiO_2$	2,642	1,450
17	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $2\cdot7\ Al_2O_3$ $27\ SiO_2$	2,678	1,470
18	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $3\cdot1\ Al_2O_3$ $31\ SiO_2$	2,714	1,490
19	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $3\cdot5\ Al_2O_3$ $35\ SiO_2$	2,750	1,510
20	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $3\cdot9\ Al_2O_3$ $39\ SiO_2$	2,786	1,530
21	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $4\cdot4\ Al_2O_3$ $44\ SiO_2$	2,822	1,550
22	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $4\cdot9\ Al_2O_3$ $49\ SiO_2$	2,858	1,570
23	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $5\cdot4\ Al_2O_3$ $54\ SiO_2$	2,894	1,590
24	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $6\cdot0\ Al_2O_3$ $60\ SiO_2$	2,930	1,610
25	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $6\cdot6\ Al_2O_3$ 66 SiO2	2,966	1,630
26	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $7\cdot2\ Al_2O_3$ $72\ SiO_2$	3,002	1,650
27	{$0\cdot3\ K_2O$ / $0\cdot7\ CaO$} $20\ Al_2O_3$ $200 SiO_2$	3,038	1,670
28	Al_2O_3 10 SiO_2	3,074	1,690
29	Al_2O_3 8 SiO_2	3,110	1,710
30	Al_2O_3 6 SiO_2	3,146	1,730
31	Al_2O_3 5 SiO_2	3,182	1,750
32	Al_2O_3 4 SiO_2	3,218	1,770
33	Al_2O_3 3 SiO_2	3,254	1,790
34	Al_2O_3 $2\cdot5$ SiO_2	3,290	1,810
35	Al_2O_3 2 SiO_2	3,326	1,830
36	Al_2O_3 $1\cdot5$ SiO_2	3,362	1,850
37	....	3,398	1,880
38	....	3,434	1,910
39	....	3,470	1,940

In actual use they are placed in the kiln at a point where they can be watched through a peep-hole, but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones of different numbers in the kiln, so that warning can be had, not only of the end point of firing, but also of the rapidity with which the temperature is rising.

In determining the proper cone to use in burning any kind of ware, several cones are put in the kiln, as, for example, numbers ·08, 1, and 5. If ·08 and 1 are bent over in burning, and 5 is not affected, the temperature of the kiln is between 1 and 5. The next time numbers 2, 3, and 4 are put in, and 2 and 3 may be fused, but 4 remains unaffected, indicating that the temperature reached the fusing-point of 3.

While the temperature of fusion of each cone is given in the preceding table, it must not be understood that these cones are for measuring temperature, but rather for measuring pyro-chemical effects.

The cones used in the different branches of the clay-working industry in the United States and Canada are approximately as follows:—

Common brick	012–01
Hard burned, common brick	1–2
Buff face brick	5–9 or even higher.
Hollow blocks and fireproofing	03–1
Terra-cotta	02–7 or 8
Conduits	7–8
White earthenware	8–9
Firebricks	5–14
Porcelain	11–13
Red earthenware	010–05
Stoneware	6–8
Electrical porcelain	10–12
Sewer-pipe	3–7

In Plates LX and LXI there are shown a series of cones of Canadian clays, heated to the fusing point of Seger cones 1 and 3.

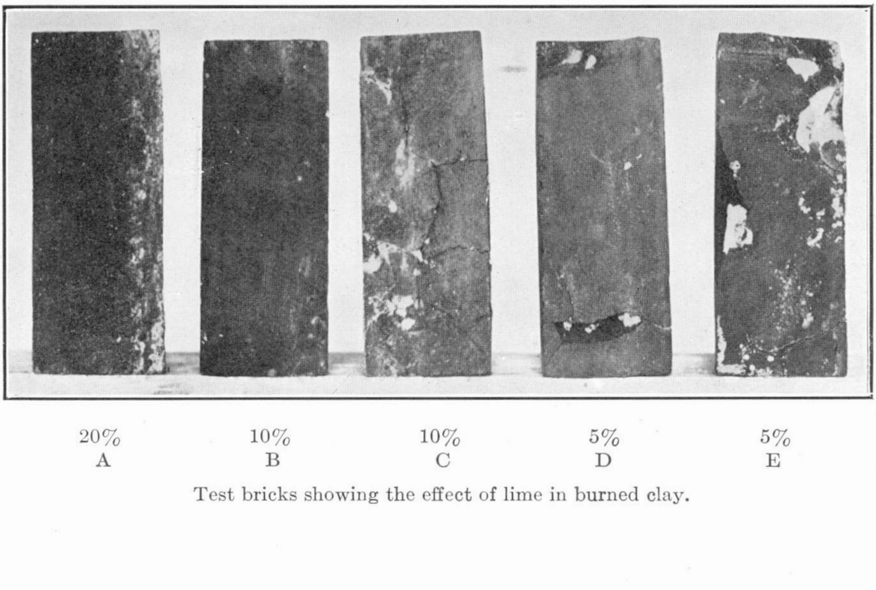
Summary Table of Physical Tests.

In the accompanying table we have given in summarized form the physical tests made on the different samples, and described in detail in the body of the report. These can be identified both by the description of locality and also the laboratory number which precedes each set of tests.

SUMMARY TABLE OF PHYSICAL TESTS.

Locality	Laboratory No.	Water %	Air Shrinkage.	Tensile Strength.	Cone 010		Cone 03		Cone 1		Cone 3		Cone 5		Cone 9		Fusing Point.	Colour.	REMARKS.
					Fire Shrinkage.	Absorption.	Fire Shrinkage	Absorption.	Fire Shrinkage.	Absorption.	Fire Shrinkage.	Absorption.	Fire Shrinkage.	Absorption.	Fire Shrinkage.	Absorption.	Cone,		
Surface clay, Portage la Prairie, Man.	1621	24·8	6·2	269	s.s.	20·56	0·0	20·15	3·00	9·00							1	Buff	The cone 1 is cone 02 in this case.
Surface clay, Neepawa, Man.	1622	23	6·8		0	21·36	0·0	20·19									1	Light red	
Pierre shale, Riding Mountain, Man.	1623	37·8	4·9	113	2·4	28·73	4	24·45	5	19·54	6·4	16·07						Brown	
Surface clay, Birnie, Man.	1624	35	6·6		2	28·36	3·6	22·54	8·6	6·30								Buff	
Pierre shale, Riding Mountain, Man.	1625	40·4	5·6		1·6	23·16	3·7	17·26	5·7	10·4			10·4	4·62				Red	
Surface clay, Gilbert Plains, Man.	1626	27·2	8·2	252	1·6	23·97	3	23·51	6·7	5·36							4	Buff	
Surface clay, Hartney, Man.	1631	22	5·2		s.s.	19·94	2·0	16·38	2·3	7·66							5	Buff	
Pierre shale, Souris, Man.	1632	42	6	120	0·9	32·81	3	27·45	7·3	15·32			7·7	12·3	Vit.		12	Red brown	
Surface clay, Virden, Man.	1633	29	6·5	210	0·4	26·47	0·0	26·56	11·6	Vit.							3	Buff	
Pierre shale and surface clay, Virden, Man.	1633 A	36	4·2		2·3	27·45	0·7	27·45	7	7·17	8·6	4·82					5	Red	
" "	1633 B		4·3		0·7	26·10	0·7	25·80	10·3	0·32									
Pierre shale, Assiniboine river, Man.	1634	37·8	2·8		1·5	35·59	1·3	33·33	3·4	33·0			5·7	23·35				Red	
Pierre shale and surface clay, Ninette, Man.	1635 A	37	5·8		2	23·18	3·0	16·73	5·4	13·75								Red	
Niobrara shale, Leary, Man.	1636	32	9·2	349	0·6	15·21	9·6	0·21	3·0	0·65							5	Red	
Surface clay, Winnipeg, Man.	1637	28·2	4·5	240	−2·5	31·44	−2·4	31·42	−2·4	28·37	−1·7	27·13					5	Buff	
Underclay, Winnipeg, Man.	1638	39	10·3	248	3·7	13·31	3·4	Vit.										Red	
Underclay, Morris, Man.	1640	37·5	11·1		3·0	10·42	4·7	2·74									1	Red	
Shale over coal, Pinto, Sask.	1641	30·8	7·5	293	1·0	22·23	1·0	21·7	8·7	0·0							3	Pink buff	
Shale at surface, Pinto, Sask.	1642	34	9·2		1·5	14·36	8·6	Vit.									5	Red	
Shale under coal, Pinto, Sask.	1643	30	8·0		1·7	13·6	7·4	Vit.										Red	
Shale under coal, Estevan, Sask.	1644	33·4	9·6	325	0·5	14·0	6·3	Vit.									3	Red	
Surface clay, Estevan, Sask.	1645	21	5	334	s.s.	24·48	s.s.	23·94	0·4	19·76							3	Buff	
Brown shale, Dirt hills, Sask.	1646				1·7	14·7	2·3	8·31	13·3	0·0							2	Brown	
Dark grey clay, Dirt hills, Sask.	1647	30	8·5	334	0·2	16·38	4·4	7·52	5·4	3·92	5·3	4·39						Red	
Light grey sandy clay, Dirt hills, Sask.	1648	27	6·1	123	0	18·58	2·7	15·41					2·7	10·3	3·3	9·81	32	Grey white	
White clay, Dirt hills, Sask.	1649	30	7·7		0·4	16·74	3·7	10·34	5·3	7·67			6·6	4·67	6·6	2·60	31	White	
Grey fireclay, Dirt hills, Sask.	1650		7·8		1	16·76	3·6	11·60	6	8·23			6·6	4·37	8·4	2·25	32	White	
Mixture of clays, Dirt hills, Sask.	1651	32	8·1		1	14·16	3·3	8	4·3	5·3									
Surface clay, Prince Albert, Sask.	1652	29	9·0	380	0·0	15·16	1	14·26									2	Red	
Surface clay, Edmonton, Alta.	1653	20	5·6	212	s.s.	21·75	s.s.	17·84	4	1·75							2	Red	
" " "	1654	25	8	275	s.s.	18·16	5·3	5·94		Vit.								Red	
" " "	1655	25	8·2	335	0·2	16·63	2	11·02	4·6	0·0	4·7	Vit.					5	Red	
Surface clay with sand, Edmonton, Alta.	1655 A	23·5	6·5		0·0	14·68	2·3	8·85	3·3	1·52							5	Red	
Shale, Edmonton, Alta.	1656	28	10·4	270	0·2	14·24	3·7	9·23	4·3	0·8	6·7	1·5					6	Red	
" "	1657	33	8·1		2·2	17·30	2·4	14·09										Red	
" "	1658	35	13·1	150	2·1	12·08					6	1·2					5	Red	
Surface clay, Edmonton, Alta.	1659	34	8·9		1·4	13·84	4·3	4·6									5	Red	
Shale, Entwhistle, Alta.	1660	24	6·7		0	14·58	4·4	6·05			6·7	Vit.						Red	
Underclay, Entwhistle, Alta.	1661	35	10·2		0·5	14·54	7·3	1·04					5	1			15	Brown	
" " "	1661 A	26·3	7·6		0·5	14·28	6·7	4·62	7·3	1·4							15	Dark red	
" " "	1661 B		4·7		0·7	20·19			7·3	1·06	8·6	3·76						Brown	
Shale, Entwhistle, Alta.	1662	22	4·8	381	s.s.	14·62	3	6·02	5	0·0	6	0·0					5+	Red	
" "	1663	22·5	4·7	198	s.s.	17·96	3·6	8·72	9	0·75							3	Red	
Surface clay, Red Deer, Alta.	1664	25	7·6	268	1·6	18·21	3·4	13·22									1	Red	
" " "	1664 A	22	4·8	273	s.s.	24·36	s.s.	23·72									2	Red	
Shale, Red Deer, Alta.	1665	25	6·9	176	0·8	19·34	1	18·47									1	Red	
Shale, Lethbridge, Alta.	1666	25	6·3		0·7	15·42	8·0	3·22			6·3	1·93					5	Dark red	
Surface clay, Lethbridge, Alta.	1667	19	4				0·0	13·58										Red	
Shale, Milk creek, Alta.	1668		6·4			11·47	4·3	Vit.										Red	
" "	1669	25	6·5	150	s.s.	14·14	1·6	7·64	2	6·11							7	Red	
" "	1670	21	6·3		s.s.	12·17	2	7·64	2·7	3·3								Red	
" "	1671	21	4·5		s.s.	12·38	2	5·41	3·0	2·58								Red	
Shale, Pincher, Alta.	1672	24	7·7		0·8	14·63	6	4·65	Vit.								3	Red	
Surface clay, 7 miles west of Pincher, Alta.	1673	29	8·8	300	1·3	11·68	3·7	1·54									1	Red	
Surface clay, Pincher, Alta.	1674	25	6·5		0·6	18·02	0	16·9										Red	
Shale over coal, Oldman river, Alta.	1675	28·6	8·9	205	s.s.	15·36	0	13·83	3·7	5·95	3·8	4·8	Vit.				9	Grey	
Shale, 15 miles west of Blairmore, Alta.	1676	20	6		1	8	3·7	3	0·6	2									
Shale, 1 mile west of Lundbreck, Alta.	1679		4·6		0·4	14·17	3·3	7·75	s.s.	1·6								Red	
Shale, between Bermis and Lundbreck, Alta.	1680		4·7		s.s.	12·75	2·7	5·84									1	Red	
" " " "	1682		5·4		0·5	13·96	0·7	12·80									1	Red	
" " " "	1683		5·5		1	10·4	5·7	1·4	2·3	0·0							7	Red	
" " " "	1684		4·0		s.s.	13·71	s.s.	11·37	2·3	4·28	0·4	7·58					6	Red	
Clay under lignite, Redcliff, Alta.	1685	28	4·4	297	s.s.	22·36	0·0	22·27	1·3	14·0							3	Red	
Yellow clay shale, Redcliff, Alta.	1686	30	11·0	305	s.s.	10·77	2·3	4·18	5·0	1·34	4·6	0·5					5	Dark red	
Shale over lignite, Redcliff, Alta.	1687		11·6	High	0·7	10·82	2	6·07	0·0	3·4							5	Red	
Green wire cut brick, Redcliff, Alta.	1688	19	7·2	378	0	11·59	0·4	8·87	3·0	3·44	Vit.						5	Red	
Stiff clay in lenses, Medicine Hat, Alta.	1690	33·8	11·9	300	1·0	10·55	0·7	9·31									1	Red	
Grey sandy clay, Coleridge, Alta.	1691	24·5	8·0	387	s.s.	10·67	0·6	7·27	4·3	3·78	4·6	2·0					5	Red	
Black carbonaceous clay, Coleridge, Alta.	1692	21	8·5	334	s.s.	10·50	s.s.	6·56	2·4	3·89			3·0	2·34	Vit.		15	Grey	
Buff shale, Coleridge, Alta.	1693	22	7·0		0·2	12·92	4·6	2·60									1	Red	
Brown sandy shale, Coleridge, Alta.	1694	21	7·2	270	0·0	12·0	3·4	4·76	4·4	3·26								Red	
Shale over coal seam, near Medicine Hat, Alta.	1695		6·7		0·4	20·62	7·3	6·92	7·4	0·73								Red	
Shale, Anslee coal mine, Alta.	1696	31	10·8		0·6	12·04	5·3	2·10										Red	
Grey clay, Irvine, Alta.	1697	36	9·4		0·2	16·40	2·3	6·85										Red	
Red shale, Irvine, Alta.	1698	36	9·7		2·0	18·30	6·0	10·26										Red	
Hard grey shale, Irvine, Alta.	1699	33·3	11·6		0·4	15·57	2·0	10·48										Red	
Surface clay, Medicine Hat, Alta.	1700	18	5·2		s.s.	12·52	0·7	9·81										Red	
Surface clay, north of Medicine Hat, Alta.	1701		10·7		0·4	13·05	3·4	6·81										Red	
Shale, Didsbury, Alta.	1702		5·6		0·7	24·03	0·4	24·80	5·7	13·18								Buff	
Shale, Brickburn, Alta.	1703	17	5	154	0·6	13·43	2·3	8·73									1	Red	
Green shale brick, Sandstone, Alta.	1704	19	6	165	0·4	14·90	2·3	9·46									1	Red	
Grey shale, Sandstone, Alta.	1705	21	5		0·2	15·56	2·3	13·67									1	Red	
Blue shale, Sandstone, Alta.	1706	21	6·8		1·4	12·82	5·45	5·58									1	Red	
Buff shale east of Cochrane, Alta.	1707	21	5·5	128	0·7	18·73	2·00	15·57									1	Red	
Blue shale east of Cochrane, Alta.	1708	20	5·0		0·3	17·68	6	17·38									1	Red	
Surface clay, Cochrane, Alta.	1710	26	7·9		0·5	21·98	0·3	20·96									1	Buff	
Surface clay, Canmore, Alta.	1711	22	4·2		s.s.	35·41	s.s.	0·0										Buff	
Surface clay, Yoho valley, B.C.	1712	28	5·0	111	s.s.	37·92	s.s.	40									1	Buff	
Colluvial clay, Field, B.C.	1713	20	2·7		s.s.	21·95	s.s.	20	s.s.	16·65							5	Red	
Surface clay, Nelson, B.C.	1714	28	5		0	23·94	2·0	18·33									2	Red	
Surface clay, Enderby, B.C.	1715	28	6·3	290	0	20·76	3·0	14·77	7·3	0·2							5	Red	
Weathered surface clay, Kamloops, B.C.	1717	23	4·6	156	s.s.	19·12	2·0	11·74									1	Red	
Hard surface clay, Kamloops, B.C.	1718	27	8·4		2·2	18·36	3·3	0·15									1	Red	
Surface clay, New Westminster, B.C.	1720	19	4·3	256	0·4	15·35	1·7	10·44									1	Red	
Hard white clay shale, Clayburn, B.C.	1721	16	3·2		s.s.	14·57	s.s.	13·53	0·3	12·76			0·6	11·21	1·2	9·72	22	Whitish	
Fireclay, Clayburn, B.C.	1722	16	3	78	1·5	15·89	2·3	13·63	3·1	12·3			3·6	10·96	4·0	9·75	17		Selected sample fused cone 32
Yellow shale, Clayburn, B.C.	1723	19	5	196	0·3	16·16	4	8·28	6	3·34	7	2·90						Red	
Purple shale, Clayburn, B.C.	1724	17·6	6·1	108	0·8	14·32	2·7	9·20	5	7			6	1·43	7	0·2			Vit. at 12.
Fireclay, Kilgard, B.C.	1725	15	3	103	0·6	14·42	1	14·21					3·3	10·95	3·6	8·67	27+	Pink buff	
Hard grey sandy shale, Kilgard, B.C.	1726	16·8	3		0	18·58	0·6	17·20	2·3	12·50			5·3	9·50	0·6	2·26		Light brown	
Yellow shale, Kilgard, B.C.	1727	20	4	114	0·6	17·73	2	15·21	3·3	13·54			4·7	10·42	5	11·29		Buff	
Rusty shale, Clayburn, B.C.	1728	22	4·8		2·2	15·54	4	11·93	7	7·57			not	vit.				Red	
Hard clay and white clay shale, Kilgard, B.C.	1729		2		s.s.	14·00	1	12·95					1	11·00	1	9·34	22+	Grey white	
Grey burning shale, Clayburn, B.C.	1730	15	3·6		0	15·82	0·4	14·28	1·7	11·0			3·7	3·06				Drab	
Lower fireclay, Clayburn, B.C.	1731																31		
Surface clay, Anvil Island, B.C.	1733	26	6	283	0·3	16·74	3	7·76									1	Red	
Dark grey shale, Comox, B.C.	1734	15	2·6		0·6	16·0	1·4	13·47	2·3	13·72			5	6·31				Drab	
Residual clay, Kyuquot, B.C.	1735	20	3	84	s.s.	15·50	s.s.	14·22	s.s.	11·70			0·6	9·23	1·7	7·92	30	Pink grey	
Surface clay, Victoria, B.C.	1736	28	7·9	364	0·5	15·61	8	0·0									1	Red	
Hard grey shale (fireclay), Kilgard, B.C.	1737	14	2·4		0	11·73	s.s.	9·91	4	9			1·6	9·37	4·7	8·68	31	Grey	
Shale, Kilgard, B.C.	1738	18	4		0	17·74	0·3	15·78	3	10·30			5	3·26	2·6	5·45	13	Grey	
" "	1739	15	3		0·2	14·41	1·0	13·02					2·7	9·55	1·7	9·45		Buff	
Rusty shale, Kilgard, B.C.	1740	22	4·4		1	16·75	9	2·12	9·3	1	9·4	1						Red	
Surface clay, Hazel Brae, B.C.	1741	30	6·3		0·3	18·63	2·6	13·14									2	Red	
Clay under coal, Collins gulch, B.C.	1742		5·3										8	7				Grey	
Surface clay, Tulameen, B.C.	1743	25	5·6		s.s.	17·24	5·8	4·57										Red	
Boulder clay, Riverside, Alta.	1744	19	6·9		0·2	11·65	4·4	3·12	2·4	1·5							5	Red	

Abbreviation: s.s. =slightly swelled; vit. =vitrified



20% A

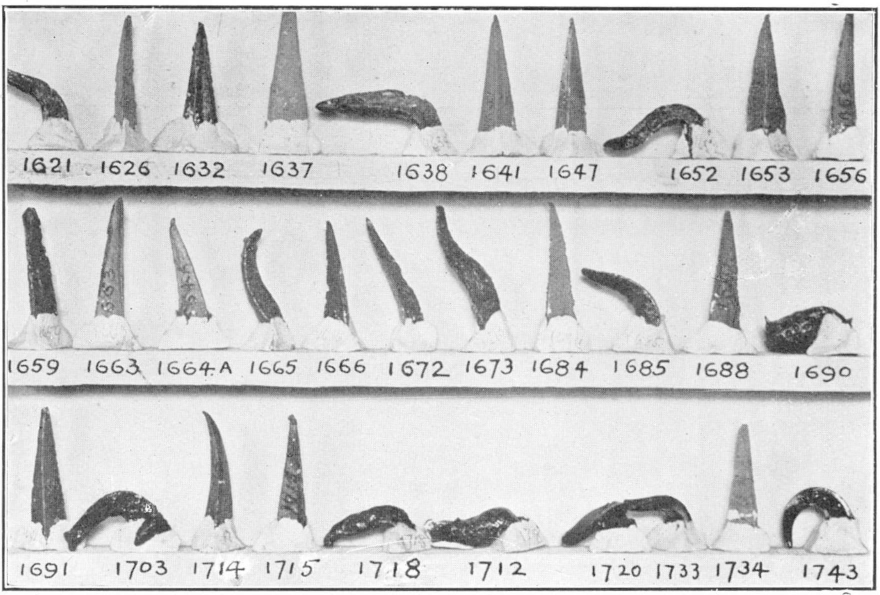
10% B

10% C

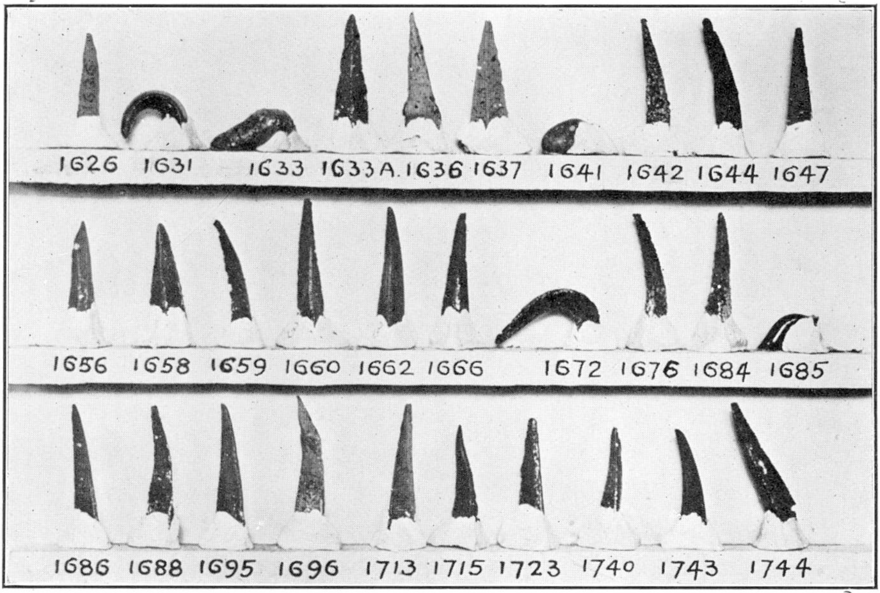
5% D

5% E

Test bricks showing the effect of lime in burned clay.



Pyramids of clay showing the results of heating to cone 1. The figures given under each are the laboratory numbers.



Pyramids of clay showing the results of heating to cone 3. The figures gives under each are the laboratory numbers.

INDEX.

A

B

C

G

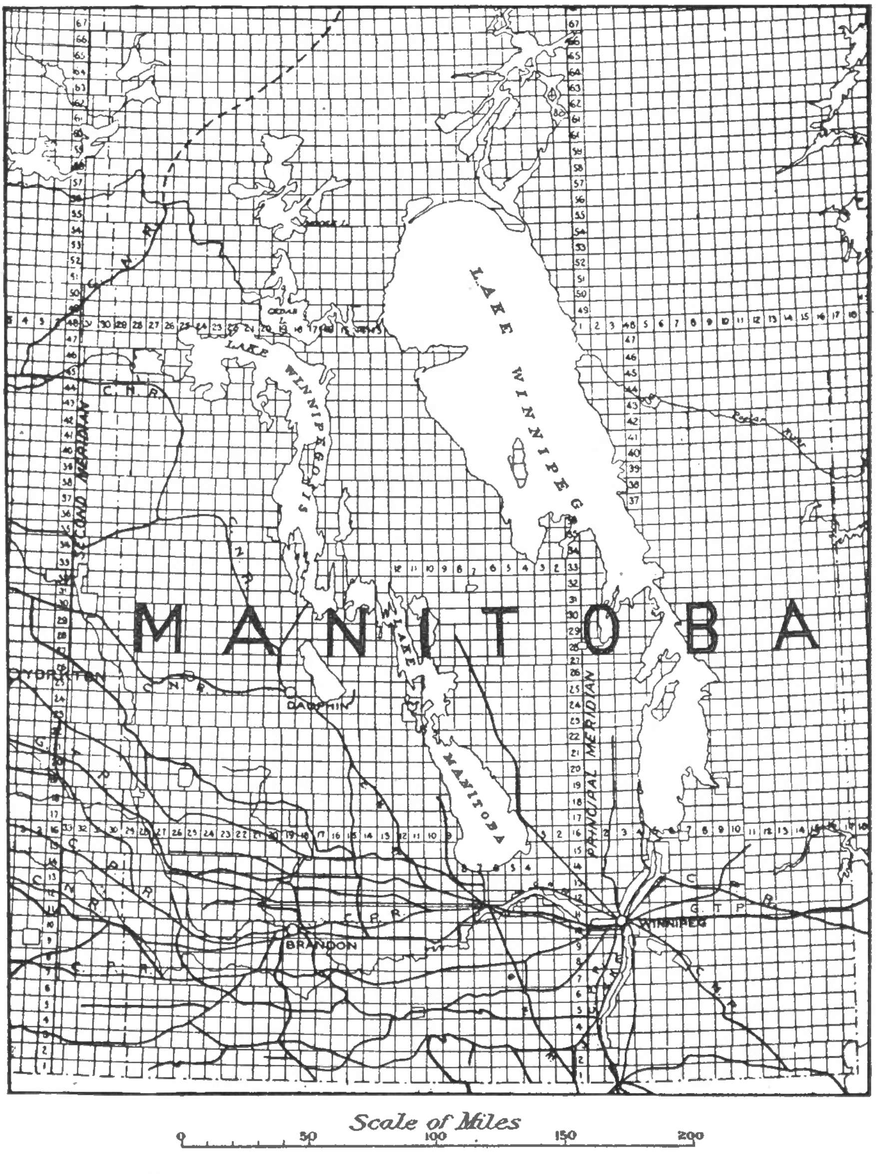
T

U

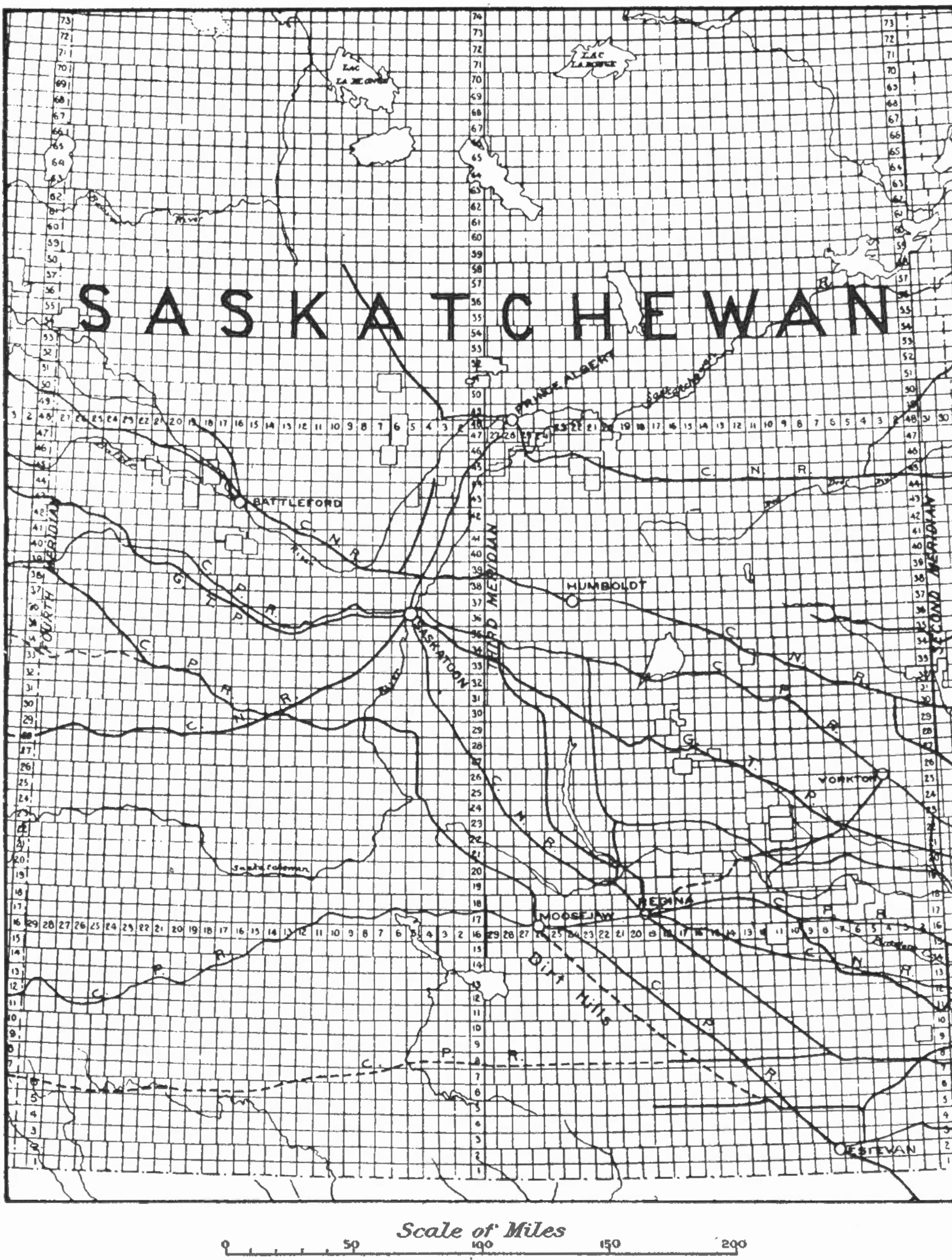
V

W

Y



PART OF THE PROVINCE OF MANITOBA



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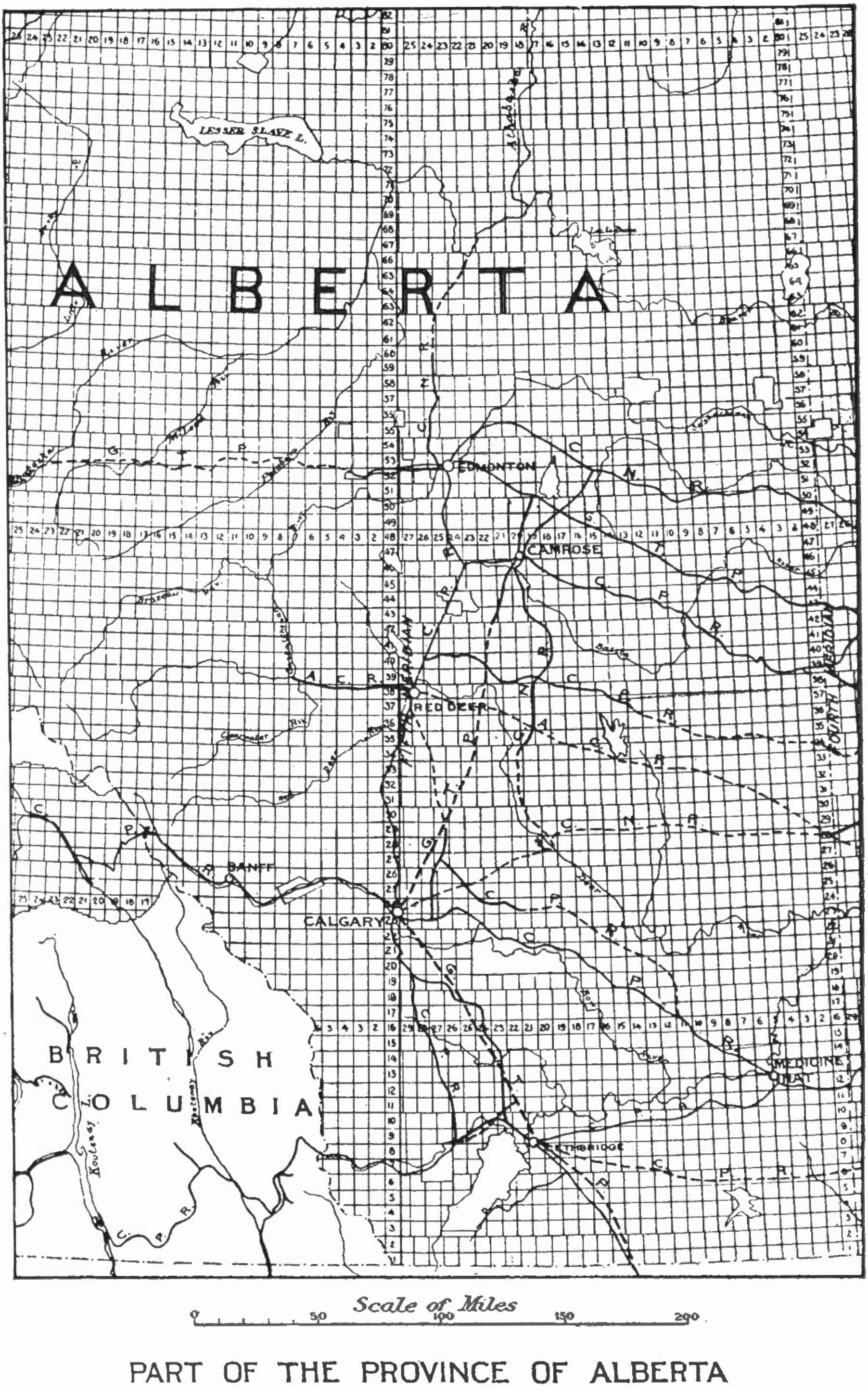

PART OF THE PROVINCE OF ALBERTA

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

SELECTED LIST OF REPORTS AND MAPS

(SINCE 1885)

OF SPECIAL ECONOMIC INTEREST

PUBLISHED BY

THE GEOLOGICAL SURVEY

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No. 245.	Report of Mines Section,		1886.	No. 662.	Report of Mines Section,		1897.
272	"	"	1887.	698	"	"	1898.
*300	"	"	1888.	718.	"	"	1899.
301	"	"	1889.	744	"	"	1900.
334	"	"	1890.	800	"	"	1901.
335	"	"	1891.	835	"	"	1902.
360	"	"	1892.	893	"	"	1903.
572	"	"	1893-4	*928	"	"	1904.
602	"	"	1895.	971	"	"	1905.
625	"	"	1896.				

Mineral Production of Canada:—

No. *414.	Year 1886.	No. *422.	Year 1893.	No. 719.	Year 1900.
*415	" 1887.	*555	" 1894.	719a	" 1901.
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*417	" 1889.	*612	" 1896.	861	" 1903.
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*421	" 1892.	*686	" 1899.		

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No. *818.	Platinum.	No. 860.	Zinc.	No. 881.	Phosphate.
851.	Coal.	869.	Mica.	882.	Copper.
*854.	Asbestos.	872.	Molybdenum and Tungsten.	913.	Mineral Pigments.
857.	Infusorial Earth.	*877.	Graphite.	953.	Barytes.
858.	Manganese.	880.	Peat.	984.	Mineral Pigments (French).
859.	Salt.				

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No. *102.	Year 1874-5.	No. *169.	Year 1882-3-4.	No. 580.	Year 1894.
*110	" 1875-6.	222	" 1885.	616	" 1895.
*119	" 1876-7.	246	" 1886.	651	" 1896.
*126	" 1877-8.	273	" 1887-8.	695	" 1898.
*138	" 1878-9.	299	" 1888-9.	724	" 1899.
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GENERAL

745. Altitudes of Canada, by J. White. 1899.
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SASKATCHEWAN.

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ONTARIO

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