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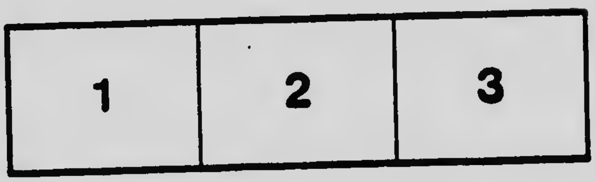

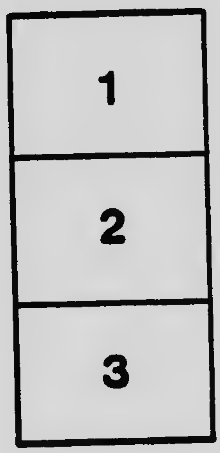

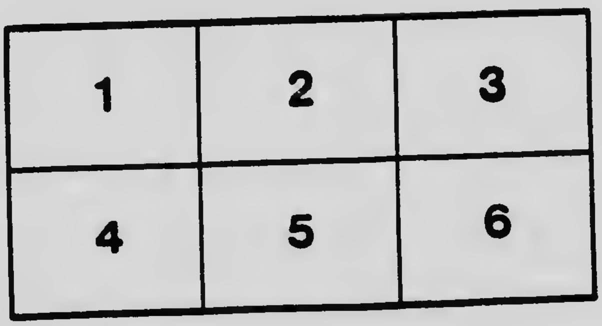

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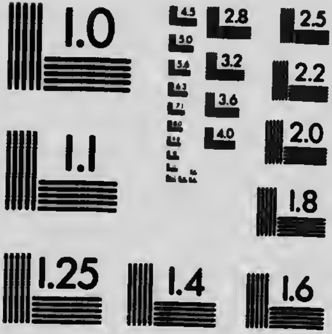

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GEOLOGICAL SURVEY

MEMOIR 64

No. 52, GEOLOGICAL SERIES

Preliminary Report on the Clay and Shale Deposits of the Province of Quebec

BY
J. Keele

OTTAWA
GOVERNMENT PRINTING BUREAU
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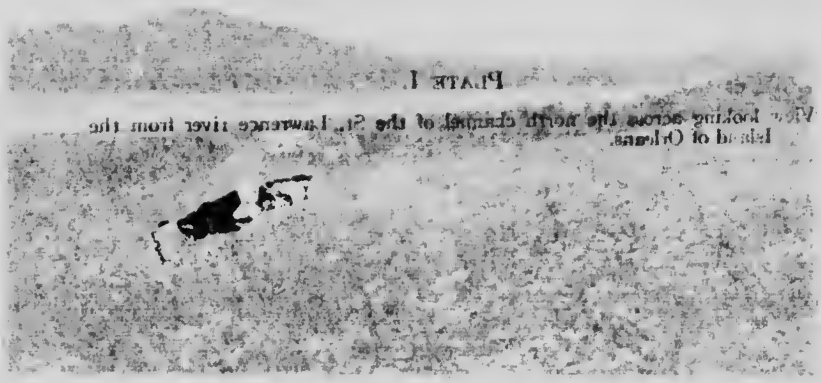
PLATE I.

Plate I.

View looking across the north channel of the St. Lawrence river from the Island of Orleans.



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PREFACE.

The following report is based on the results of field and laboratory work done during portions of two seasons, 1912 and 1913. The investigation was confined principally to the thickly settled portions of the province, as clay and shale deposits, in order to be of economic value, must be situated at localities convenient as to transportation, and reasonably close to markets for the products made from them.

Clay and shale deposits are generally so widespread that they cannot be monopolized and cannot be exhausted. They have little or no value in the raw state; it is the labour expended on these deposits that transforms them into articles of value so important in the growth of communities. Hence the clay working industry is one well suited to our social and economic needs.

The investigation has shown that there is a lack of high grade clays, like fireclays or pottery clays, in the province; but that there is an abundance of raw material suitable for the manufacture of rough clay products, and well situated with regard to transportation. We can only surmise at present what the probabilities are for finding high grade clays in the vast undeveloped portions of this province, but wherever they may be found in the future their value will depend primarily upon their nearness to railways, or their branches, or to water transport.

All the experimental work for this report was done by the writer in the laboratories of the Department of Metallurgy at the University of Toronto. The samples collected at the various localities were submitted to tests for working qualities, drying, shrinkage, and burning, as this is the information a clay worker requires concerning his raw material. Chemical analyses are of little value to him, as practically no information regarding the behaviour of clays can be derived from such analyses.

A number of chemical analyses, however, are added to the physical tests on various clay and shale samples to illustrate their composition. These analyses may be usefu' to those who require information regarding material for the manufacture of Portland cement.

This report is written with the view of supplying more or less definite information to those who have little or no knowledge of clays and their uses, as well as to manufacturers in search of raw materials. Therefore, the report contains chapters which explain briefly the origin and properties of clays, and methods of manufacture of the common clay wares. It is written in a simple manner, and without the use of technical terms, wherever they can be avoided. A chapter on the manufacture of sand-lime brick is also included.

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HON L CODERRE MINISTER. R.W.BR

GEOLOGICAL SU

C.O.Senécal, *Geographer and Chief Draughtsman*

MAP 134 A

(Issued 1914)

PART OF THE PROVIN

Scale of Mile

To accompany Memoir by J. Keele

Canada
ment of Mines
STER. R W BROCK, DEPUTY MINISTER

OGICAL SURVEY

OUTLINE MAP

From map of the Dominion of Canada, by Department of the Interior

1390

AP 134 A
sued 1914)

PROVINCE OF QUEBEC

e of Miles

Preliminary Report on the Clay and Shale Deposits of the Province of Quebec.

CHAPTER I.

SHALE-BEARING FORMATIONS.

INTRODUCTION.

The principal bedrock formations in which shales are found in the province of Quebec are the Silurian and the Ordovician. The Devonian formation furnishes a limited amount of shale of value to the clay worker. The extensive Pre-Cambrian area, which comprises the greater part of the province, is made up of hard crystalline rocks, which with only one known exception are entirely devoid of plastic material.

Lower Carboniferous rocks occur in a narrow strip along Chaleur bay in Bonaventure and Gaspe counties. These consist mostly of sandstones and conglomerates, and no workable beds of shale were observed among them. The Middle and Upper Carboniferous rocks which often contain very valuable beds of clays and shales, as well as coal seams, do not occur in Quebec.

The Mesozoic formations, notably the Cretaceous, are the chief sources of clays and coal over large areas of western Canada; but no trace of them has been found in this province.

A vestige of what is supposed to be the Tertiary was found in the Chaudiere valley during gold mining operations. It contained some thin beds of yellow clay and sands, of no economic value.

The entire province has been subjected to severe glaciation by land ice. The unconsolidated Pleistocene deposits, which form such a widespread covering on the bedrock, are directly or indirectly the result of glacial conditions. The Pleistocene deposits are the ones most worked at present in the clay working industry. These are described in a separate chapter.

PRE-CAMBRIAN.

KAOLIN AT ST. REMI D'AMHERST.

A deposit of kaolin, or white residual clay, occurs near St. Remi d'Amherst, Labelle county, about 7 miles from Huberdeau, the terminus of the Montfort branch of the Canadian Northern railway. The kaolin is found in dykes or veins of varying width in a ridge of quartzite lying on the east side of the wagon road 2 miles south of the village of St. Remi. The slopes of the ridge are covered with glacial drift varying in thickness from 2 to 15 feet as seen in the various cuttings and pits which have been made to reach the kaolin.

Mining operations have been in progress on this deposit since 1910, and a very complete plant is installed for washing the kaolin (Plate II, A).

The prospecting so far done has shown that there are several veins of kaolin in the ridge, but some of them are too narrow to work. The main deposit is a vertical vein between quartzite walls in which kaolin reaches a depth of at least 150 feet as ascertained by boring. This vein has been revealed by stripping the drift, or by test pitting for a distance of about 500 feet, and was found to vary from 15 to 30 feet in width. Two smaller veins about 4 feet wide have been uncovered in the vicinity of the main vein. Kaolin was also found in the bottom of a well at a point about 1,000 feet south of this property.

The rock that contains the kaolin veins varies from a massive, brownish, coarse-grained quartzite to a fine-grained white variety. It has a gneissic structure for a distance of several feet from the walls of the veins, where it is penetrated by stringers and films of kaolin. This contact zone is very friable and easily shattered.

The main kaolin vein seems to follow the direction of one of the principal joint planes in the quartzite, N. 53° W., for about

100 feet, and then bends to almost due north and south, as shown in the accompanying plan (Figure 1). The vein was

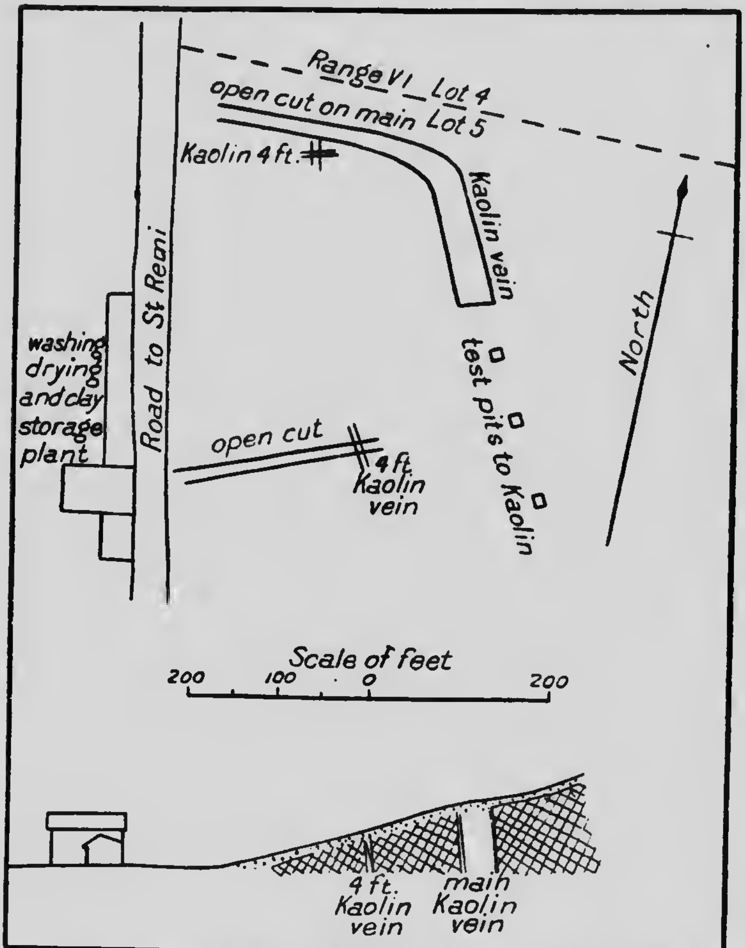


Figure 1. Plan and section of kaolin mine at St. Rémi d'Amherst.

originally composed of feldspar and quartz irregularly distributed. The feldspar became decomposed, and the soluble products of decomposition were carried away.

The crude material, therefore, is a mixture of fine-grained white clay and angular fragments of quartz, mostly under one-fourth of an inch in size. A small quantity of tourmaline is also present. In some parts of the vein the material is almost free from quartz, but for the most part quartz forms over 50 per cent of the deposit.

The lumps of crude kaolin coming from the mine are broken up in a blunger, an iron tank filled with water, in which a vertical shaft, furnished with horizontal arms, revolves. The quartz settles to the bottom of the tank, while the clay is carried off through an overflow pipe and led into a series of troughs, where the finest particles of sand are deposited. After flowing slowly through the troughs, the clay-water finally falls into settling tanks. The clay gradually sinks to the bottom of the tanks and the clear liquid is pumped out. By means of this washing process the deposits yield from 30 to 40 per cent of fine-grained clay. A chemical analysis made from a sample of the washed clay by G. E. F. Lundell, gave the following results:

Silica	46·13
Alumina	39·45
Iron oxide	0·72
Lime	none
Magnesia	none
Potash	0·20
Soda	0·09
Loss on ignition	13·81
	100·40

The analysis shows the material to be of high purity. The physical tests are as follows. The washed kaolin requires 45 per cent of water for tempering. It has a fair amount of plasticity, but like all kaolin, it works rather short and crumbly. The shrinkage on drying is 7 per cent.

Cone	Fire shrinkage %	Absorption %
010	3·0	34·3
06	3·6	34·3
1	4·5	32·0
5	9·3	20·0
9	11·3	17·0
34	Softens	

This material has greater plasticity and higher shrinkages than most of the standard brands of washed kaolin or china-clay. The samples for testing were taken from near the surface, but at deeper levels, it is possible that the kaolin will not be so plastic and not shrink so much on drying and burning.

The Canadian China Clay company which operates this mine is disposing of the washed product in Montreal, where it is used as a paper filler. On account of its fineness of grain and pure white colour, it is very suitable for this purpose.

Washed kaolin is one of the ingredients used in all whiteware pottery bodies, such as table ware, china, porcelain, wall tile, sanitary pottery, electrical porcelain, etc. Potters generally call it china-clay. It is the most valuable of all the clays.

PROSPECTING FOR KAOLIN.

Considerable prospecting has been done for kaolin in the vicinity of St. Remi, but so far no other workable deposit has been uncovered. Two test pits were sunk on the property of the Canadian China Clay company, 600 feet east of the main vein, and near the top of the ridge of quartzite. Some lumps of discoloured kaolin were found in the glacial drift at a depth of 5 to 8 feet below the surface, but no vein was reached.

About a mile north of the village of St. Remi, on lot 9, range IV, some shallow pits dug on the bank of Pike creek revealed the presence of residual clay. This material was quite plastic, but very gritty, owing to the amount of quartz grains it contained. It is striped in yellow, white, and pink bands. It appears to have resulted from the weathering of a quartzose gneiss. On account of its discoloration, and its remoteness from transportation, this deposit appears to have no commercial value.

The rocks associated with the quartzite which contains the kaolin veins, are rusty gneisses, sillimanite gneiss, and minor bands of crystalline limestone. These appear to belong to the Grenville series, and occupy only a comparatively small area in this locality. They are completely surrounded by granite gneisses, probably Laurentian.

The whole country has been heavily glaciated, and much of the residual clays which may have existed in pre-glacial time have been removed by erosion. A sheet of glacial drift materials, principally boulder clay, covers the slopes of the hills and the valley bottoms. The kaolin was first discovered by a farmer when sinking a well. He went through 15 feet of boulder clay, and found the white clay deposit beneath. There are probably other deposits in the region, as the Grenville rocks occur at intervals as far west as the Ottawa river and beyond. The general prevalence of the drift covering renders prospecting a tedious and difficult operation, and kaolin being a soft deposit, is never exposed at the surface, unless a stream has cut down to it through the overburden.

PRE-CAMBRIAN SCHIST AT SHERBROOKE.

A few relatively small areas of Pre-Cambrian rocks occur in the hilly region south of the St. Lawrence. Included in these rocks are some beds of talcose schist, which are quarried for building stone in the vicinity of the city of Sherbrooke.

This material when ground to pass a 20 mesh sieve and tempered with water, is not plastic. The ground schist, however, when slightly moistened, makes a dry-press brick which can easily be handled in the green state, and could probably be set in kilns without crumbling. It burns to a pleasing greyish buff colour at cone 3. The body is hard, and the surfaces have a slightly vitreous appearance, the absorption is 6·8 per cent. The schist is not refractory as it fuses at cone 12 (1370° C.), but it is the most refractory brick material found so far in Quebec.

This rock has a silver grey colour when fresh, but other beds of similar schists contain a higher percentage of iron and are dark grey or rusty coloured. These can also be ground easily and made up into dry-pressed face brick. They burn to a deeper buff colour than the light grey schist, and would give a better effect in face bricks.

SILLERY FORMATION.

The Sillery formation is made up principally of great masses of purple, red, green, or black shales, interstratified with sandstones. It is mostly confined to that portion of the province lying south of the St. Lawrence, between Sherbrooke and Rivière-du-Loup. It forms the bedrock of the principal portion of the Island of Orleans, and a small area occurs on the north side of the St. Lawrence river, south of the city of Quebec.

Although the shales of this group were originally clay sediments, they have become so hardened that they have more the qualities of slate than of shale. In some localities they are true slates. There are occasional beds which have remained comparatively unchanged, and these when finely ground and mixed with water, develop some degree of plasticity. These are the only ones of interest to the clay worker.

QUEBEC CITY AND VICINITY.

The Sillery shales form an escarpment on both sides of the St. Lawrence for some distance south of the cities of Quebec and Lévis. The red shales that outcrop at Cap Rouge are hard and splintery, being too gritty for use in clay working. A short distance north of Cap Rouge, near the eastern end of the National Transcontinental Railway viaduct, the red beds are replaced by dark grey and black shales. The dark shales are quite plastic, and as far as their working qualities are concerned, would be suitable for the manufacture of clay products, but they are interbedded with hard sandstone bands, which would interfere with their economic working. Furthermore the land on which they occur is laid out for sale as suburban lots, and consequently would be too expensive for industrial purposes.

About a quarter of a mile south of Sillery church there is a bed of red shale which weathers into a soft plastic clay at the outcrop, and even the harder portion under the weathered outcrop becomes quite plastic when ground and tempered with water. This shale burns to a hard red body at low temperatures, vitrified at about cone 1, and is not fused at cone 5. It would probably be suitable for making sewer-pipe or paving brick, but the material is inaccessible at this locality as the line of the National Transcontinental railway is built across it.

The Sillery shales are exposed in cliffs in the southern part of the town of Lévis. These shales are mostly hard and gritty; they break down into splintery fragments which do not readily soften into clay. A sample of the red shale which was collected for testing, did not have the necessary plasticity for wet-moulding when finely ground and mixed with water. It worked fairly well in the dry-press process, and made a coherent brick which could be handled safely in the green state. It burns to a reddish brown colour, with buff specks. The body is strong and dense, the absorption being only 4 per cent. As the burned colour is not very good and the shale hard to grind, it is doubtful if the deposit is of much value for the manufacture of face brick.

ST. CHARLES-DE-BELLECHASSE.

The unaltered red shales of the Sillery formation outcrop at two points on the south side of the Boyer river near St. Charles. It forms the red soil on the Illustration farm of the Commission of Conservation, owned by Mr. John Chabot, and the adjoining farm to the east. The red soil is seen again about half a mile farther on in the fields of Mr. M. Fournier. The shale is exposed in a low ridge at this point. It is quite soft and crumbles down very easily, and the red weathered clay at the base of the ridge is quite plastic.

A sample of the fresh red shale from this locality was collected for testing. This shale was easy to grind, the ground material requiring 19 per cent of water for tempering. It worked up into a rather gritty mass of low plasticity, but was easily moulded into shape. Its drying qualities are good, the shrinkage on drying being 4 per cent. It gave the following results on burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	13·0	light red
06	1·3	10·6	light red
03	4·5	2·7	red
1	6·3	2·2	brown
3	6·3	2·2	brown
5	6·3	2·2	brown

This is a good vitrifying shale, it has an ample margin of safety in firing, and the shrinkages are within working limits. As its plasticity is not very good the working qualities are consequently deficient. Some short lengths of 3-inch pipe were made from it in a handpress. These were burned in a commercial sewer-pipe kiln, and salt glazed at cone 3, with good results, the glaze being uniform and bright. This material is well suited for dry-pressing, and makes an excellent face brick by this process. It has a solid bright red colour, and dense, hard body, when burned to cone 03.

If this shale is mixed with about 15 per cent of the very plastic surface clay which occurs in the vicinity its working qualities are much improved, and it can be moulded for sewer-pipe, or for paving brick. It could also be used for rough-faced building brick by the wire-cut process. It can be burned to a very dense, steel hard body of rich, dark red colour at cone 03, or flashed to a steel blue at this temperature.

ST. APOLLINAIRE.

A short distance east of St. Apollinaire station on the Intercolonial railway, the red colour of the soil seems to indicate that the soft red Sillery shale underlies this locality. No samples were collected at this point, but it would probably repay investigation as the material is well situated with regard to transportation. These unaltered beds in the Sillery are apparently the best structural materials so far discovered in the province.

LÉVIS FORMATION.

LÉVIS.

In the vicinity of Lévis the rocks comprising the Lévis formation cover a small extent of territory, being confined to a few square miles in the northern part of the town. They are mostly slates, sandstones, conglomerates, and slightly altered shales. The latter outcrop along the Intercolonial railway for about 500 feet or more to the west of Ruel siding, near St. Joseph. These are rather gritty, thin-bedded, grey and rusty shales, dipping southeast at an angle of about 30 degrees. The soil in the fields and gardens on each side of the railway line is composed of the weathered portion of these shales, which in some places are quite plastic. The shales appear to be more altered and harder at some places than at others, and the harder kinds break down into splintery fragments which do not readily weather into clay.

A sample of these shales was collected from two points, one from near Ruel siding, and another from the roadside north of St. Joseph. Both samples gave practically the same results when tested. Although not a true shale, this material grinds fairly easily, and when tempered with 17 per cent of water has some plasticity, being quite as plastic as the Utica-Lorraine shale at Laprairie which is used for brickmaking.

The Lévis shale has good drying qualities, and a shrinkage on drying of 4 per cent. It gave the following results on burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	1·3	10·6	light red
06	1·3	9·0	light red
03	4·0	4·5	red
1	4·3	3·4	dark red
3	4·3	2·9	dark red
5	5·0	0·0	brown
9	Not softened		

This is a vitrifying shale, and could probably be used for paving brick. It is rather gritty and lacks sufficient plasticity for moulding in a sewer-pipe press, otherwise it could be used for this purpose as the material takes a good salt glaze. With the addition of a little plastic surface clay its working qualities could be improved so much that it could be used for the manufacture of vitrified wares such as those mentioned.

It makes a fine dry-pressed face brick, with a good red colour, but not so bright as the Sillery shale from St. Charles which it resembles.

The Lévis shale is the most refractory material so far found among the structural materials available in the province.

UTICA-LORRAINE.

INTRODUCTION.

This compound group is the most widespread of all the rock formations which contain plastic materials of value to the clay worker. The areas in the St. Lawrence valley, supposed to be underlain by them, are mapped on the general geological sheets of the region. On these maps they are seen to form a strip of varying width on both sides of the St. Lawrence river between Montreal and the city of Quebec. These rocks appear to form the greater part of the floor of the valley, and do not extend into the upland or hilly country on both sides of the valley.

The Utica shale formations are not found for some distance below Quebec and Lévis, being replaced by slates and schists on the south side of the river and by granite gneisses on the north. They appear again on the south side of the Gulf of St. Lawrence where they occur in a narrow strip along the coast, reaching almost to the extremity of the Gaspe peninsula. A small patch of these rocks occurs as an outlier among Pre-Cambrian rocks in the Lake St. John basin.

The separation of these two formations in the field was largely based on their fossil contents; they are very similar in composition, appearance, and economic value. The Lorraine portion of the group, however, seems to contain a greater quantity of workable material than the other.

The shales of the Lorraine formation are more sandy texture than the Utica, and consequently are not so plasti They are generally of greyish colour, frequently sandy, ai sometimes pass into sandstone layers. The underlying Uti shales are generally darker in colour, sometimes nearly blac due to the presence of carbonaceous matter. Occasional these shales contain bands of hard dolomitic limest ..., but a rule they are more uniform in texture and freer from sandstoi bands than the Lorraine.

These shales vary considerably in their lime content different localities. In the vicinity of Quebec and Lévis, sever deposits contain enough lime to develop a buff colour whe burned to 2000 degrees F., but nearly all these shales farth west are red-burning, which indicates that the amount of lin they contain in these localities is comparatively small.

Some of the Utica shales contain small percentages carbon. This causes a variety of troubles in the burning clay wares made from them.

Owing to their grittiness, these shales at many localitie when finely ground and mixed with water, do not develop ver good plasticity, so that it is frequently necessary to add a certai proportion of the highly plastic Pleistocene clay, which generall occurs convenient to them, in order to improve their workin qualities.

The Utica-Lorraine shales contain a large percentage c fluxing impurities, so that they are rather easily fusible, an have a short vitrification range. On this account their use i restricted to the manufacture of building brick and fireproofing while vitrified wares such as paving brick and sewer-pipe canno be made from them.

As the greater part of the areas over which these shale are distributed has a covering, of varying thickness, of sand gravel, or clay, the character of the underlying bedrock is inferred from occasional outcrops of the rock in the banks o streams, or in hillsides, or from evidence found in excavations Where the overburden of loose material is thick, the shale underlying them are not available to the clayworker, as th expense of stripping the overburden in order to work the shale would be too great. They must be looked for in those localities where they occur at the surface or only a few feet beneath it. The following descriptions of deposits and results of tests on samples collected from them, although few in number, are probably representative of the material as a whole. As the investigation proceeds other localities will be examined.

LAPRAIRIE COUNTY.

Laprairie.

The Utica-Lorraine shales come to the surface over a large portion of Laprairie county, or can easily be reached by the removal of a light overburden, hence they are readily available for use.

The manufacture of shale building brick has developed into a very important industry at Laprairie station on the Grand Trunk railway, and also at Delson junction, a point 5 miles farther east. The shales have been worked for several years at Laprairie and a large area in the vicinity of the work has been excavated in the process of mining the raw material. The shales lie horizontally in alternate thin layers of sandy and finer grained materials. The fine-grained beds crumble rapidly into fragments upon exposure, but these do not readily soften even after prolonged weathering, as most shales do. The harder sandy bands remain [illegible]s, and do not crumble on weathering; many of these have been discarded as too hard for grinding.

A sample of the shale, selected at this point from the pit of the National Brick company, was tested after being ground to pass a 20 mesh sieve.

The ground shale required 17 per cent of water for tempering. The plasticity was low, as the material is very gritty, so that the test pieces were difficult to mould. The drying shrinkage was only 3 per cent and the drying can be accomplished safely in 12 hours if necessary. The burning tests were as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	Swells	13·5	pale red
06	Swells	12·3	
03	1·0	8·8	red
1	Overfired		
3	Fused		

This material must be finely ground and burned to cor 03 in order to produce hard bricks, which will stand transpo tation without crumbling at the edges and corners.

A dry-pressed brick had good red colour, no fire-shrinkag and 9 per cent absorption when burned to cone 03. The bod was steel hard. If burned only to cone 06 the dry-pressed piec were too soft. The shale alone is used in practice for makin dry-press face brick, but as it is not quite plastic enough fo making stiff-mud brick it receives an addition of 25 per cer of plastic surface clay.

A mixture of two parts shale, ground to pass a 20 mes screen, and one part of surface clay was tested in the laborator The working qualities of this mixture were good; it was prob ably plastic enough to use in making fireproofing or hollo building blocks. The drying shrinkage was 5 per cent. I gave the following results in burning:

Cone	Fire shrinkage %	Absorption %
010	0·0	10·0
06	0·3	8·3
03	2·0	3·4

The addition of surface clay has the effect of improvin the working qualities; it increases the drying period, and th dying shrinkage, but the body burns dense at lower temper atures. In practice the shale is coarsely ground, probabl passing an 8 mesh screen, which gives the brick a very roug appearance. The surface clay used in the mixture is obtaine about 2 miles south of Laprairie, and brought to the works in cars over a light railway. It resembles very closely that found at St. Johns, and is probably a marine clay.

The plant of the National Brick company at Laprairie (Plate XX) is the largest in the province, and one of the largest in Canada. This company claims a production of 400,000 brick per day when operating to full capacity. The greater part of the product is wire-cut brick, but a quantity of red dry pressed brick is also made. A small quantity of buff face brick is produced by artificial means, which simply consists in adding about 10 per cent of lime to the shale.

This shale cannot be used for the manufacture of vitrified products as it softens readily with a slight rise of temperature above that necessary to produce vitrification.

The plant of the St. Lawrence Brick and Terra-cotta company (Plate II, B) is also situated at Laprairie. The product manufactured by this plant consists entirely of wire-cut brick, made from precisely the same shale as that just described. They obtain a workable mixture by using the weathered top of the shale which is of sufficient thickness at this plant for the purpose.

The plastic top was all removed from the National Brick company's property during the early years of operation. This soft weathered top is only a foot or two in thickness, but when mixed with about 6 feet, in depth, of the underlying hard shale, a good workable mixture was obtained.

Delson Junction.

A branch plant of the National Brick company (Plate III,A) began operations at Delson Junction in the summer of 1912, manufacturing wire-cut bricks similar to those produced in Laprairie. The raw material used at this point consists of boulder clay, marine clay, and Utica-Lorraine shale. The relation of these deposits to each other at this locality is shown in Figure 2.

The boulder clay is oxidized to a brownish colour above, while the lower part of the deposit is bluish grey. The clay which encloses the pebbles is mostly derived from the under-

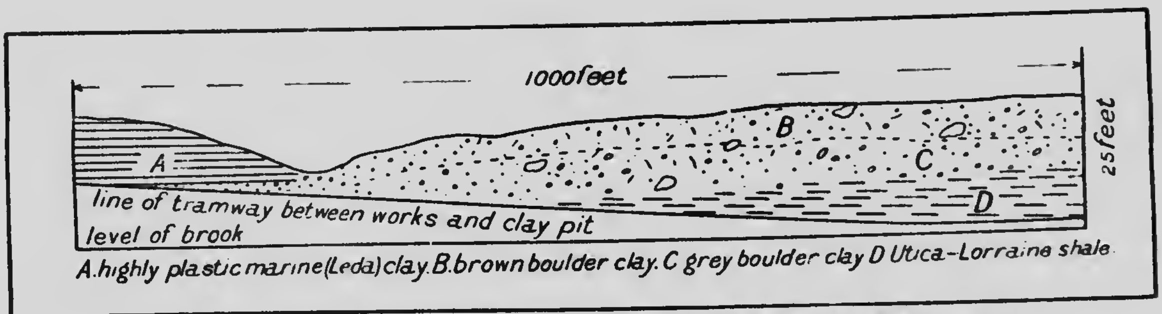


Figure 2. Section of materials used for brickmaking at Delson junction, Laprairie county.

lying shale. The stones in this deposit are of all sizes from 3 feet or more in diameter, down to fine gravel. It is a typical land-ice deposit, and is the lower boulder clay of the region, which is so widespread.

This is the only locality in the province of Quebec at which this class of material is used. The shale in the bottom of the pit and the overlying boulder clay are mined together with the steam shovel (Plate XXV, B). The larger boulders are left behind in the clay pit, and many of the smaller ones are picked out by hand before the material goes into the grinding pans. A deposit of highly plastic stoneless clay in the vicinity is mined separately, and added to the ground boulder clay as it passes through the pug-mills before entering the machine.

The boulder clay contains specimens of many varieties of rocks, from the hardest of granites and quartzites to comparatively soft limestone and schist, but all kinds go through the dry pans and are ground into brick material. The grinding is done rather coarsely, but the boulder clay formation itself carries a good deal of plastic clay, which with the highly plastic surface clay added to the mass, suffices to stick the roughly ground rock particles together. The surface of the burned bricks is crazed, the crazing being due to the high shrinkage of the plastic clay, while the coarse particles of ground rock in the brick have no shrinkage.

In all these plants, producing shale brick, the burning is done in overhead-fired, continuous kiln, using coal or coke for fuel. Not much attention is bestowed on producing a smooth or finished product, the object being as large an output as possible of cheap, common brick. Provided they are hard-burned, they fulfill the purpose for which they are required; and as these bricks are mostly concealed in the structures in which they are used, appearances do not seem to matter so much as strength and durability. These brick, however, are of little practical value if they are underburned. It is disastrous to underburn the Delson Junction product, as it contains limestone particles which cause the brick to crumble by air slaking when exposed to weathering. A further discussion of these plants is given in the chapter on the clayworking industry.

CHAMBLY COUNTY.

The Utica-Lorraine shale forms the bedrock underlying this county. These shales occur quite close to the surface along the St. Lawrence river, between St. Lambert, Longueuil, and Boucherville. Going inland, east from the river, the clay covering is seen to thicken gradually and the shale is not so accessible.

St. Lambert.

Trenches dug for water mains and sewers along the streets in St. Lambert during the summer of 1913, gave a good opportunity for observing the character of the Utica-Lorraine shales. They appeared quite similar to those worked by the brick plants at Laprairie, being alternate thin beds of hard and softer grey shale with some sandstone bands. A plant for the manufacture of sewer-pipe was erected here several years ago. It consisted of a large three-story wooden building with extensive drying floor capacity, together with the requisite machinery for grinding the shale and pressing pipe. Five 40-foot circular kilns, built of firebrick, were also provided. This plant was never operated for the reason that the shale in this vicinty, which it was proposed to use, was quite unsuitable for the purpose, being too easily fusible to be salt glazed, and not possessing the necessary plasticity to allow its being moulded into shape. The enterprise might have succeeded as a brick plant if enough plastic clay was brought in to mix with the shale. Another alternative would have been to import plastic fireclay, and mix about 25 per cent of it with the shale. The fireclay would impart the necessary plasticity for moulding, and also furnish the fire resisting qualities necessary for salt glazing the sewer-pipe. This plant remained idie for many years, and was pulled down and sold in 1914.

Chambly.

Utica-Lorraine shales are exposed on both banks of the Richelieu river, above and below the dam of the Montreal Light and Power company near the village of Chambly. The shales at this locality are very gritty, approaching the character of slates in hardness, and also contain several limestone bands (Plate III, B). A small sample of shale collected on the west side of the river at this locality was tested. When ground to pass a 20 mesh sieve, and tempered with 17 per cent of water, this shale was only feebly plastic, and was difficult to mould. The drying shrinkage was only 2·5 per cent. On burning it behaved as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	13·3	pale red
06	0·0	10·0	pale red
03	0·0	11·0	buff
1	0·5	5·0	brown
3	Fused		

This material appears to contain considerable lime in fairly coarse particles. Underburned brick made from it disintegrate when exposed to the weather. Brick made by the dry-pressed process had a poor colour when burned to cone 03. This shale could doubtless be improved by the addition of some of the plastic surface clay which occurs in the vicinity.

MISSISQUOI COUNTY.

Farnham.

The shales underlying the town of Farnham and vicinity, belong to the Trenton division of the Ordovician. These differ somewhat from the Utica-Lorraine shales, being darker in colour and more calcareous. They are also disturbed and altered locally into slate, by intrusive basic dykes, while secondary, small, white, calcite veins and stringers are common. A small sample was taken from an outcrop on the road north of the Yamaska river about half a mile east of the town. The shales in this area appeared to be free from intrusive materials. This was the only sample examined from this formation, as the greater part of it does not appear suitable for the manufacture of clay products.

The shale was very gritty being only feebly plastic when finely ground and mixed with water, but it was quite as plastic as any of the samples so far examined from the Utica-Lorraine formation. The drying shrinkage was only 2·5 per cent. The burning tests were as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	Swells	18·0	pale red
06	Swells	16·0	pale red
03	0·0	15·8	buff
1	5·0	2·7	brown
3	Softened		

The shale needs the addition of some plastic clay in order to make it workable for wire-cut brick. The slight swelling at the lower cones is due to a rather high lime content, and not to carbon. A dry-pressed brick with steel hard body, and 12 per cent absorption was made from this shale. It has a speckled red and buff colour, which would give a pleasing effect for face bricks.

The material is not suitable for the manufacture of vitrified wares.

YAMASKA COUNTY.

The Utica-Lorraine shales are exposed for several miles along the banks of the St. Francis river in the eastern part of this county. The shales are mostly overlain by a thick covering of drift materials, which unfits them for economic working.

St. Joachim-de-Courval.

Dark grey shales outcrop near St. Joachim-de-Courval on the north bank of the St. Francis river, about 8 miles below Drummondville. They are overlain by highly plastic surface clay of no great thickness.

This shale when finely ground and tempered with water has very fair plasticity, and good working qualities. The drying shrinkage was 3 per cent. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	1·0	10·0	light red
06	1·0	7·5	red
03	5·0	3·2	dark red
1	overfired		

This shale has a low percentage of lime. It burns to a steel hard red body at cone 010, and to a very dense almost impervious body at cone 03.

It is suitable for the manufacture of wire-cut brick, sewer brick, and fireproofing. When dry-pressed and burned to cone 03 it makes a fine hard face brick with a solid red colour, which is free from light coloured specks. The absorption of the dry-press brick was only 7 per cent.

This is the best sample of shale from this formation so far obtained in the province. Unfortunately this deposit is not well situated for transportation purposes, being about 8 miles from the nearest railway.

LOTBINIERE COUNTY.

The Utica-Lorraine is exposed in high cliffs bordering the St. Lawrence river from the Richelieu light to the eastern border of this county. These shales are found inland from the river for a distance of 3 or 4 miles with only a thin covering of soil, but farther south near the line of the Intercolonial railway they are, apparently, concealed by a thick covering of drift.

The shales soften readily into a plastic yellowish clay on exposure to weathering, and this weathered shale forms the soil in the fields over a considerable area near the river.

St. Antoine-de-Tilly.

The shales form the high bank of the St. Lawrence at St. Antoine-de-Tilly. They are not flat lying, like those seen farther west, but are tilted at a high angle, the beds dipping east at an angle of about 60 degrees from the horizontal. Thes shales are dark grey in colour, very free from sandstone bands and uniform in texture. An average sample collected ove about 40 feet in thickness, at right angles to the bedding, con tained only one sandstone layer about 3 inches thick. Thi sample when ground to pass a 20 mesh sieve, and tempered wit 17 per cent of water, had fairly good plasticity, but was rathe "short" in working quality, as the shale is somewhat gritty.

The drying qualities are good, and the drying shrinkage i 3·5 per cent. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·3	14·0	light red
06	0·4	12·5	light red
03	0·5	13·3	light red
1	3·0	6·4	brown
3	softened		

This shale appears to be plastic enough for use in the manu facture of wire-cut brick, but it is doubtful if it is sufficientl so for fireproofing. It makes a satisfactory body and surfac for dry-press face brick, but the colour is not very good. Th shale appears to contain enough lime to prevent the developmen of a good red colour, and not enough to produce a buff colou It is very similar to the shale occurring at St. Augustin on th opposite side of the St. Lawrence river, which is describe further on.

L'ASSOMPTION COUNTY.

Although the Utica-Lorraine shale underlies a considerabl portion of this county, it is not found exposed at many point as it is concealed by a very general covering of clay and san

Charlemagne.

These shales are exposed in a low ridge about half a mi west of Charlemagne station on the Canadian Northern railwa No tests were made of these shales by the writer, but they a said by those who have made tests, to give results similar to the Laprairie shale. There is also an abundance of plastic surface clay at this locality for mixing with the shale, if it should prove too gritty for working alone.

The site is a good one from which to supply building material for the city of Montreal, but the activity of real estate dealers, who have subdivided the property of this section into suburban lots, places the land at too high a value for brickmaking purposes.

L'Epiphanie.

An outcrop of thinly bedded, black shale, apparently typical Utica, occurs on the bank of the L'Achigan river about half a mile above the highway bridge between the Canadian Pacific Railway station and the village of L'Epiphanie.

The shale is about 10 feet in thickness, and occupies the lower part of the bank. It is overlain by boulder clay and stoneless, highly plastic, stratified clay. When finely ground and tempered with water, the sample from this locality did not become plastic but formed a gritty non-coherent mass which was difficult to mould. It appears to contain some carbonaceous matter which gives trouble in burning, the brick being liable to develop black cores and swell unless the burning is done very slowly during the oxidation stage.

As the working and burning qualities of this shale are bad, and the colour of the burned samples is poor, the material is not recommended for the manufacture of clay products.

A mixture of equal parts of ground shale and the overlying plastic clay was also tested, but the results obtained in drying and burning were not good.

PORTNEUF COUNTY.

There is an area of Utica-Lorraine shales intervening between the granitic rocks of the Laurentian upland, and the St. Lawrence river, in which are some of the most accessible and easily worked deposits in the province. These deposits are situated along the high banks of the river, and along the line of the Canadian Northern railway.

The shales of this region are generally more plastic tha those worked at Laprairie, and many of the deposits could b manufactured into wire-cut brick without the addition of plast clay. Their lime content runs rather high, but not high enoug in all cases to produce buff-coloured wares; it merely interfer with the development of good red colours.

Portneuf.

There is a cutting about 12 to 15 feet deep in Utica shale near Portneuf station on the National Transcontinental railwa The shale occurs in very thin layers. It is nearly black in colou when fresh, but bleaches to grey on exposure to weatherin so that it probably contains some carbonaceous matter. Th shale is not plastic when finely ground and mixed with wate therefore it cannot be worked by the wet-moulded process f brick manufacture. When made up dry-pressed and burne to cone 03, a strong, steel-hard body is produced, with a absorption of 9 per cent. The colour is dark buff, with ligl buff specks, giving a rather pleasing effect for face brick.

Cap Santé.

For a great part of the distance, between this point ar Donnacona, the railway line lies along the base of shale clif (Plate IV). These shales are not very plastic; some of tl layers resemble slates, being particularly hard and gritt With the addition of some plastic material they could be us for making wire-cut brick. A small sample of shale from th locality gave the following results in burning tests:

Cone	Fire shrinkage %	Absorption %	Colour
010	swelling	15·0	light red
06	swelling	15·0	light red
03	swelling	8·0	buff
1	softened		

This shale swells slightly in burning, probably owing to a rather high percentage of lime in its composition.

The pulp mills of the Donnacona Paper company are situated at the mouth of the Jacques Cartier river. There are some shales along the river bank at this locality, but a thick covering of sand and gravel renders them inaccessible.

The shales are particularly well exposed along the railway line between Les Escuriels and Neuville. These appear to weather easily into a soft mass, and are fairly free from hard or stony bands. No sample was collected at this point, but they are probably similar to the one next described which occurs a short distance to the east.

St. Augustin.

Between St. Augustin and Cap Santé, the railway line occupies nearly all the available space between the shale cliffs and the river, so that there is very little room for the erection of a plant. At St. Augustin station the shale escarpment recedes from the river, leaving a level terrace of considerable width, which would provide a good building site.

A sample of shale was collected from the banks of a small brook which cuts through the shale escarpment a short distance north of the railway station. This shale when finely ground and mixed with 19 per cent of water had medium plasticity, and would probably work in an auger machine for making wire-cut brick, but it is doubtful if it would pass through a fireproofing die without tearing. The tensile strength of the raw clay is 50 pounds per square inch.

The shale will stand fast drying at 150 degrees F. Its drying shrinkage is 3·5 per cent. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	14·7	light red
06	0	14·0	light red
03	0	13·8	light red
1	3	9·0	red

The body is hard and has a good ring at cone 010, and i steel hard when burned to cone 06. It should make good wire cut or stiff-mud brick, but it cannot be used for vitrified product as it melts rather suddenly when the temperature is raised t cone 2 or 3.

This shale makes a hard, dry-press brick with 12 per cen absorption at cone 06, but the light red or salmon colour that i yields might not be generally acceptable for face brick. It i probable, however, that better colour would be produced whe burned in commercial kilns, under alternate oxidizing and redu cing conditions, this process being termed "flashing" by brick makers.

This shale has the following composition according to chemical analysis, made by W. S. Bishop, of the sample collected

Silica	56·30
Alumina	18·12
Iron oxide	3·68
Lime	6·62
Magnesia	3·30
Potash, Soda	1·20
Sulphur trioxide	1·80
Loss on ignition	8·26
Moisture	1·54

About a mile east of St. Augustin the shale cliffs rise abruptl from the river's edge, a cutting being necessary to accommodat the railway line. The shale has weathered considerably sinc the railway cutting was made, and the surface of the cliff crumbling into clay (Plate V, A). The small sample collecte at this point was more plastic, and consequently had bette working qualities than the sample last described.

The lime content is smaller, so that a good red colour developed in burning, the shrinkage is higher, and a dens body is obtained at the lower temperatures, as the results of th burning tests indicate:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	11·8	red
06	0·0	10·4	red
03	6·0	2·3	dark red
1	overfired		

The colour is good and the body steel hard at cone 010. The shale is suitable for wire-cut or dry-pressed building brick. There is an abundance of the material, easily obtained at this locality.

Cap Rouge.

The Uti[illegible] shale forms the escarpment on the west side of the valley of Cap Rouge river. The soil of the Experimental farm which is situated on this escarpment, is composed of the weathered shale, but fresh hard shale is found at a depth of a few feet below the surface.

A small sample of shale was collected from the side of the road leading from the village of Cap Rouge to the Experimental farm, near the top of the hill.

This shale when ground and tempered with 17 per cent of water, had good plasticity and working qualities Its drying shrinkage was 4 per cent. It gave the following results in burning:

Cone	Fire shrinkage	Absorption	Colour
010	0·0	12·0	light red
06	2·0	8·0	red
03	4·3	2·0	red
1	Vitrified and slightly softened		

This material will make good wire-cut building brick even at the temperature of cone 010. If burned to cone 06, it is steel hard and dense, and would produce brick suitable for sewer linings or underground work where strength and density are requisite. It also makes a fine red, dry-pressed brick at this temperature; the body is hard and the absorption is 9 per cent.

If this shale deposit is as plastic throughout as it is at tl outcrop, it should be suitable for the manufacture of fireproofin Owing to its comparative freedom from lime, this shale bur to a good red colour. It was the only sample from this formatic in Portneuf or Quebec county that did so.

QUEBEC COUNTY.

Beauport.

The Utica-Lorraine shale outcrops in a terrace whi continues from Beauport to Ste. Anne-de-Beaupré, fronting the north channel of the St. Lawrence river. The terrace about 35 feet high at Beauport. It consists of thinly bedde dark, hard, calcareous shale. The beds are not horizontal, b have a southerly dip at an angle of about 30 degrees (Plate V, E

A sample of this shale was collected from a cutting on tl branch line of the Quebec railway which leads to the top Montmorency falls.

The pulverized shale was tempered with 16 per cent of wate its plasticity was low, and the test pieces were moulded wi difficulty. Its drying shrinkage was 3·5 per cent. The burni tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	swells	17·3	light red
06	swells	17·3	light red
03	0·0	17·0	buff
1	2·7	8·9	dark buff
3	softens		

This shale would require the addition of some plastic cl to make it workable in wet-moulded processes. It may used in the dry-press process where plasticity is not so essenti

Dry-pressed brick burned to cone 06 are pink in colo and rather too soft. It develops a good buff colour at co 03, the body is hard and the absorption 17 per cent.

The dry-pressed body is hard and dense when burned cone 1, being probably at its best, the colour is also good this temperature. The burning would have to be done slowly or trouble with black cores and swelling is likely to ensue, as the shale evidently contains a small percentage of carbon.

A mixture made up of half this shale and half surface clay from the abandoned brick-yard at Beauport was tested. This mixture with 21 per cent of water had good plasticity and very fair working qualities. Its drying shrinkage was 5·6 per cent. It gave the following results in burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	swells	16·2	light red
06	swells	14·8	light red
03	1·0	12·5	mottled
1	4·6	4·4	brown

This mixture makes a good strong brick at cone 010, it could probably be used in the stiff-mud process, for brick or fireproofing.

Montmorency

The shales in the escarpment which extends from Beauport to Ste. Anne and beyond, are generally soft, weathering easily into clay. The front of the escarpment, therefore, is generally a gradual slope, often concealed by trees or shrubbery. An excellent cross section, however, is obtained where the falls of the Montmorency river have cut back a steep walled gorge entirely through the shales to the hard crystalline rocks of the Pre-Cambrian (Figure 3). The shales seen in this section are fairly uniform in texture and colour throughout, having few stony bands (Plate VI, A).

The Citadel Brick company has established a plant for working these shales (Plate XXI, B) at Boischatel, a short distance beyond Montmorency falls, on the line of the Quebec railway.

A sample of shale collected at these works was tested with the following results. The pulverized shale makes a fairly plastic body when tempered with 16 per cent of water. The green brick can be dried rapidly without checking. The shrink-

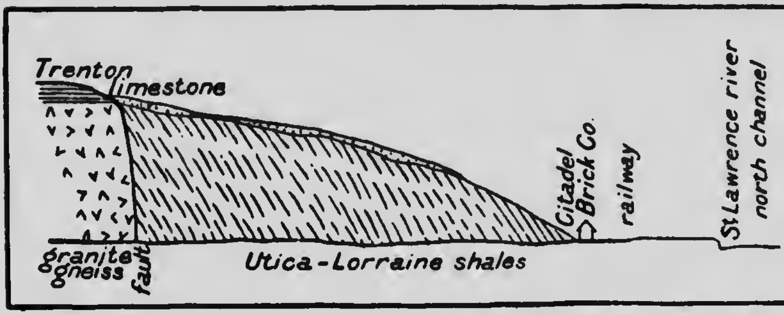


Figure 3. Section of escarpment at Citadel Brick Company's plant, near Montmorency falls.

age on drying is only 3 per cent. It behaves as follows in burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	swells	19·0	pink
06	swells	17·0	pink
03	0·6	17·0	buff
1	4·6	3·0	dark buff

This material makes good, hard, wire-cut brick, those burned to cone 03 being suitable for sewer linings or other underground work where strength and density of body are required.

If worked by the dry-pressed process it makes a fine, buff face brick at cone 03, the absorption being 18 per cent, but the body is hard. It forms a denser body and darker buff colour at cone 1, but is not quite safe to fire as high as this, as the material is liable to soften.

This shale does not seem quite plastic enough for the manufacture of fireproofing, and would probably require the addition of some plastic clay. It would also be unsafe to attempt to produce vitrified ware from it as the margin between vitrification and softening is too small.

Charlebourg West.

Shale outcrops in a terrace for several miles along the line of the Canadian Northern railway in this vicinity. These shales are thinly bedded and rather hard; they break down into splintery fragments which do not readily weather into clay. A small sample of this shale, collected at a point about half a mile west of the above station, was not plastic when finely ground and mixed with water. Some bricklets made by the dry-pressed process burned to a cream coloured chalky body, with considerable swelling at cone 1.

This shale appears to contain far more lime than any sample from the Utica-Lorraine formation previously tested. It is useless for the manufacture of clay products.

SILURIAN.

NICOLET COUNTY.

The Medina formation is the lowest member of the Silurian. It overlies the Lorraine shale and appears to be unconformable with it. During the last few years stratigraphical geologists are inclined to think that this formation in the province of Quebec is of Ordovician age. As the name Medina appears on the only geological maps so far published of this region, it will be retained for the purposes of this report.

The lower portion of the Medina formation consists of thin layers of sandstone, interbedded with sandy shales, but the upper part consists of thick beds of fairly plastic shale, containing few sandstone bands. The shales are of a uniformly dark red or reddish brown colour; there are some greenish or grey sandstone bands as well as red.

The formation as a whole is very friable, and offers little resistance to erosion by glacial or stream action. Its distribution in Quebec is limited to three or four small patches on the south side of the St. Lawrence, situated about midway between Montreal and Lévis. These patches are evidently remnants of a much larger area.

Workable deposits of the Medina shale occur at three localities in Nicolet county, which are described in these pages. A small remnant, principally sandstones, occurs in the same county, near Houdes mill, about 3 miles south of the town of Nicolet. It is overlain by a thick deposit of boulder clay.

The Medina shale was uncovered during the construction of the Lotbiniere and Megantic railway, between Villeroy and St. Philomène in Lotbinière county.

A small remnant also occurs on the St. Francis river about 3 miles south of Pierreville in Yamaska county. This deposit is not of economic value, being covered with a great thickness of drift materials.

A boring was made for natural gas at the southeast end of the concession of Bonsejour, near St. Grégoire, Nicolet county, in 1885.[1] This boring was 1,115 feet deep, it passed through 68 feet of clay and sand, 565 feet of Medina shale and sandstone, and 540 feet of Lorraine shale.

It would appear that the Utica shale was not penetrated nor was the underlying Trenton reached, which was supposed to be the true source of the gas. A flow of gas sufficient to hurl mud and stone to a height of 60 feet in the air, was encountered at 640 feet. This bore-hole discharged gas for a considerable time after boring operations ceased.

Samples were collected from three different workable deposits; the results show that the shales differ very little in character over this area.

Ste. Monique.

Extensive outcrops of Medina shale occur on both sides of the Nicolet river just above the highway bridge at this point.

The section exposed on the east bank of the river is as follows, from top to bottom:

	Feet
Stratified, stoneless, bluish grey clay (*overburden*)	25
Gritty red shales	6
Sandstone layer	1
Gritty red shale	8
Thinly bedded sandstone, to river level	4

[1] Annual Report, Geol. Surv., Vol. III, Part I, p. 33 A.

The sample taken for testing represents an average of the 14 feet of shale below the grey, surface clay.

This shale when ground to pass a 20 mesh sieve, works up into a fairly plastic wet body when tempered with 17 per cent of water. It is very gritty and rather short in texture, but it appears to be sufficiently plastic to work in a stiff-mud machine for wire-cut brick manufacture. The shale can be dried rapidly, with safety from checking, showing a drying shrinkage of only 3 per cent. The following table gives its behaviour in burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	11·4	red
06	0·0	8·5	red
03	2·0	5·7	brown
1	2·0	1·0	brown
3	softened and deformed		

A mixture of equal parts of this shale and the overlying clay was taken and tested for drain tile or fireproofing. Samples of 3 inch round tile were made in a hand screw-press. These tile when burned showed bridge checks, which are due to the inability of the clay to weld together after passing over the bridges of the die. The body of the tile was otherwise perfectly good, but a smaller amount of clay in the mixture would give better results. This deposit is situated about 2 miles from a branch of the Intercolonial railway between Nicolet and St. Leonards junction.

The Medina shales are seen to best advantage at Ste. Monique on the west bank of the river where they occur without any clay or drift overburden. The beds of shale and sandstone have slight undulations, but they are generally nearly horizontal.

St. Gregoire.

The red shales outcrop in a low terrace, south of Lake St. Paul, about one mile east of the village of St. Gregoire. The weathered clay from these shales forms the soil of the farm lands for a considerable distance; its red colour is in stron contrast with the generally grey aspect of the soils in the regio

The shale on the slope of the terrace is soft where expose to the weather, but it is hard beneath the weathered cove It did not appear to be so gritty as the shale at St. Monique.

The sample collected for testing was from the propert of M. Octave Lablanc. There was no overburden of dri materials on the part of the terrace from which the samp was taken, but the clay and gravel seem to thicken and com pletely conceal the shale farther south.

This shale is easily pulverized and when mixed with per cent of water, works up into a fairly plastic body. It stan fast drying without checking, the shrinkage in drying being per cent.

The tensile strength of the air dried raw clay was 60 poun per square inch.

The results obtained in burning are:

Cone	Fire shrinkage %	Absorption %	Colour
010	1·0	10·0	red
06	1·3	7·6	red
03	4·8	0·0	brown
1	3·3	0·0	brown
3	fused		

Some samples of 3 inch round pipe made on a hand pre from this shale were smooth, dense, and of considerable strengt It is recommended for the manufacture of a superior field dra tile.

Dry-pressed test pieces made from this shale and burn to cone 06, were steel hard and dense; the fire shrinkage was per cent and the absorption 7 per cent. When burned to co 03, the total fire shrinkage was 4·5 per cent and the absorpti only 3 per cent. The colour was deep red, with some b specks.

The following chemical analysis gives the composition this shale:

Silica	63·0
Alumina	18·58
Iron oxide	5·57
Lime	1·61
Magnesia	2·46
Potash, Soda	2·60
Sulphur trioxide	0·10
Loss on ignition	4·84
Moisture	1·78

This deposit is situated conveniently to the intersection of the Quebec, Montreal, and Southern, and the Grand Trunk Railway branch line to Doucet Landing on the St. Lawrence river.

Becancour.

The thickest exposures of Medina shales in this district occur on the banks of the Becancour river, a short distance south of the railway bridge near the village. The shale is 40 feet thick in places, it contains a few greenish, gritty bands, but is free from hard sandstone layers except at the base of the bank along the water edge. The sample collected for testing was an average of the upper 10 feet of the bank. There is a foot of soil on top of the shale.

The ground material is very gritty, but works up with 17 per cent of water into a body of medium plasticity, rather short in texture, but easy to work. The drying qualities are good; the air shrinkage is 4 per cent. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	11·3	red
06	1·0	8·8	
03	3·0	5·5	
1	2·6	0·0	
3	fused		

When made up by the dry-pressed process, and burned t
cone 06, the test pieces had a fire shrinkage of 1·5 per cen
and an absorption of 7 per cent. When burned to cone 03 th
fire-shrinkage is 5 per cent and the absorption 4 per cent. Th
body is steel hard and of fine, uniform, deep red colour at bot
temperatures.

Summary of Tests of Medina Shale.

These shales are probably the most useful in the provinc
for the manufacture of structural materials. They are easil
ground, will stand fast drying without checking, and burn t
a dense body with good colour and little shrinkage at low temper
atures, a steel hard body with low absorption being obtaine
at as low a temperature as cone 010 (1742 degrees F.). Thes
shales are not likely to cause lamination, when made up by th
stiff-mud auger machine into wire-cut brick, as many of th
more plastic clays do, but this point could not be determine
unless by actual test in a machine of this type.

Weathering the shale in stock piles for some time befor
using, should improve its working qualities, and give a produc
with smoother surface, especially if it was intended for the manu
facture of fireproofing or hollow building blocks.

These shales appear to be suitable for dry-pressed face-brick
Their good qualities are: clean colours, density of body, an
hardness of edges and corners, so that they are not liable to suffe
much from breakages in transportation, which is an essentia
quality for face brick.

The Medina shales do not seem to be suitable for the manu
facture of vitrified brick or sewer-pipe, as their softening poin
is too low to perform the operation of vitrification or salt glazin
with safety.

Their commercial limit of burning is about cone 03 (200
degrees F.), but at this temperature a hard brick, with lo
absorption, approaching vitrification and suitable for sewe
linings or underground work is produced. If fired to cone
(2102 degrees F.) swelling begins, the body passes beyond it
point of usefulness, and softening and deformation of the ware
become evident.

The chief circumstance against the material is its location, as the deposits are not situated conveniently to any large market for clay products. St. Gregoire is over 80 miles east of Montreal, and Becancour about 7 miles farther.

BONAVENTURE COUNTY.

The principal areas of Silurian rocks occur in the far eastern portion of the province, but in this region they consist generally of slates and sandstones, which on account of their hardness and lack of plasticity are of little or no value to the clayworker For the most part these rocks are compact and massive in appearance, but in some localities their cleavage is so well developed and they crumble down so easily in consequence, that they resemble shales.

The soft shaly appearance of the Silurian rocks exposed in the Matapedia River valley, along the line of the Intercolonial railway, has led to the belief that these are brick shales. A small sample was collected from an outcrop of these slates at Matapedia Junction for the purpose of testing. This material when finely ground and mixed with water did not possess enough plasticity to enable it to be properly moulded into shape. When burned to cone 03, it produced a soft chalky body having a very high absorption. The softness and porosity of the burned body was due to an excessive percentage of lime. Them aterial is useless for the manufacture of clay products.

GASPE COUNTY.

The Silurian slates or schists in the vicinity of Newport and Grand Pabos, are weathered in places, to a depth of 1 to 3 feet, into residual clay. Pockets or seams of residual clay are also found in the body of the rocks, generally in the shattered zones along thrust fault planes.

This clay is generally of a bright, yellow colour, but patches of pink, grey, or white clay are often seen. This clay has fairly good plasticity, but is rather "short" in its working properties, like most residual clays. It burns to a bright red, hard body at cone 03 with a rather high shrinkage. It vitrified at cone and fuses at cone 5. The yellow clay contains a quantity hard schist fragments and some sand and gravel from the ove lying drift. The quantity that occurs at any place is sma and the deposits are consequently of no economic value.

The Silurian slates and schists of this region are hard ar non-plastic, being too highly altered to be of any value to tl clayworking industry.

DEVONIAN.

Certain shale beds of various colours generally greeni or dark grey are found underlying the red sandstones and co glomerates along the shore of Chaleur bay in Bonaventu and Gaspe counties.

Some of these shales have the requisite properties for i dustrial purposes, and occur in deposits large enough to be economic importance, but their remoteness from any mark for wares made from them, places these deposits at a disa vantage.

BONAVENTURE COUNTY.

Fleurant Point.

Greenish shales, interstratified with hard bands, having total thickness of about 30 feet, without overburden, occur on t shore of Chaleur bay at Fleurant point (Plate VI, B). Th underlie red sandstones and conglomerates. The shale beds a from 2 to 8 feet thick, and very plastic; the hard bands a gritty, but the whole section would probably work up togeth A small sample of the shale collected at this point was grou and tempered with 19 per cent of water. It formed a ve smooth plastic mass, with good working and drying qualiti Its drying shrinkage was 4 per cent. The burning tests w as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	13·2	red
06	1·0	10·6	red
03	5·0	5·3	dark red
1	7·0	vitrified	dark red
3	5·6	vitrified	chocolate
5	softens		

The body is steel hard at cone 010, and vitrified at cone 1, and the material does not appear to be injured by firing slightly higher than this; but swelling and vesicular structure shows at cone 3. It would be an excellent material for the manufacture of fireproofing, and owing to its good working qualities and fine red colour when burned, would probably be suitable for the manufacture of roofing tile. It produces a fine red dry-press face brick of good body and solid colour, when burned to cone 03, the absorption being only 4·5 per cent.

GASPE COUNTY.

Percé.

A considerable quantity of bright yellow clay, formed from weathered Devonian shale, occurs at the village of Percé. It appears to be thickest between the Roman Catholic church, and the slopes of Mount Ste. Anne. The clay is fairly plastic but contains a large amount of hard shale fragments. It burns to a red porous body at cone 06, without much shrinkage. It is vitrified at cone 1, and softens at cone 3. The test pieces burned to the higher temperatures were dark red, but the colour was obscured to some extent by white scum. This clay is not of much value, but it might be washed, and used for the manufacture of cheap pottery.

Several beds of dark grey, calcareous shale occur in the seashore cliffs a short distance east of Le Grand Coup. These shales are weathered into a soft but rather gritty clay at the outcrops. This clay burns to a good hard red body at cone 06. When burned to a higher temperature the test pieces develop

black vesicular cores which caused them to swell and cracl
This shale evidently contains carbonaceous matter. It is nc
of much value for the manufacture of clay products.

A bed of soft olive shale outcrops on the road to the Corne
of-the-Beach, a few miles from Percé. It is highly plastic an
smooth when tempered with water. It burns to a dense, harc
red body at cone 06, and softens at cone 3. This shale underlie
the red sandstones of Mount Ste. Anne, and appears to be th
same shale as at Cape Fleurant already described.

SUMMARY TABLE OF PHYSICAL TESTS ON SHALES.

LOCALITY	Labty. No.	Water %	Drying shr.	CONE 010		CONE 06		CONE 03		CONE 1		CONE 3		CONE 5		Fusing point
				Fire shr.	Absorp.	Fire shr.	Absorp.	Fire shr.	Absorp.	Fire shr.	Absorp.	Fire shr.	Absorp.	Fire shr.	Absorp.	
St. Charles	127	19	4	0	13	1·3	10·6	4·5	2·7	6·3	2·2	6·3	2·2	6·3	2·2	9
Levis	83	17	4	1·3	10·6	1·3	9	4	4·5	4·3	3·4	4·3	2·9	5·0	0	10
Laprairie	36	17	3	..	13·5	..	12·3	1	8·8	..	..	..	..	..	..	3
Chambly	53	17	2·5	0	13·3	0	10·0	0	11·0	0.5	5·0	..	..	..	..	3
Farnham	54	17	2·5	..	18·0	..	16·0	0	15·8	5	2·7	..	..	..	..	4
St. Joachim	63	18	3	1	10	1	7·5	5	3·2	..	..	..	..	..	..	3
St. Antoine du Thilly	77	17	3·5	0·3	14	0·4	12·5	0·5	13·3	3	6·4	..	..	..	..	4
Cap Santé	76	15	3	..	15	..	15	..	8	..	..	..	..	..	..	2
St. Augustin	80	17	3·5	0	14·7	0	14	0	13·8	3	9	..	..	..	..	3
St. Augustin	81	..	..	0	11·8	0	10·4	6	2·3	..	..	..	..	..	..	3
Cap Rouge	123	17	4·0	0	12	2	8	4·3	2	..	..	..	..	..	..	3
Beauport	87	16	3·5	..	17·3	..	17·3	0	17	2·7	8·9	..	..	..	..	4
Montmorency	89	16	3	..	19	..	17	0·6	..	4·6	3	..	..	..	..	4
Ste. Monique	60	17	3	0	11·4	0	8·5	2	5·7	2	1	..	..	..	..	3
St. Gregoire	61	16	4	1	10	1·3	7·6	4·8	0	3·3	0	..	..	..	..	3
Becancour	62	17	4	0	11·3	1	8·8	3	5·5	2·6	0	..	..	..	..	3
Fleurant point	..	19	4	0	13·2	1	10·6	5	5·3	7	0	5·6	0	..	..	5

CHAPTER II.

PLEISTOCENE DEPOSITS.

SUPERFICIAL DEPOSITS IN GENERAL.

Unconsolidated deposits are more frequently encount than bedrock on the surface over the greater part of the prov of Quebec (Figure 4). These surface deposits consist of sa gravels, boulders, and clays which vary in thickness from or several hundred feet. The materials of which these dep are composed have been mostly transported for long dista before coming to rest in their present position; hence they frequently referred to as the "drift."

Extensive ice sheets moving acrossing the land during Glacial period, gathered and moved most of the loose mat in their paths. When the ice melted, the debris accumul by them remained behind in irregular patches and heaps. M of this drift material has since been worked over by st action and assorted into deposits of coarse gravel, sand, or which were deposited at various localities, depending on ditions of grade and outfall of drainage.

Each period of glaciation, and the marine submerge contributed drift materials, such as sands, gravels, bo clays, and stratified clays, which have been more or less distu confused, or modified by each succeeding event. It is ra then, that an orderly record of the materials contributed b of these events is found in any one locality.

The series of surface deposits, that occurs most comm consists of boulder clay, stratified clay and sand arrange indicated in Figure 5.

A more complex series of surface deposits was note Dr. Chalmers on Rivière-du-Loup, near the Chaudiere riv Beauce county. This section shows two boulder clay separated by 15 feet of stratified clay, with pre-Glacial dep beneath the lowest (Figure 6).

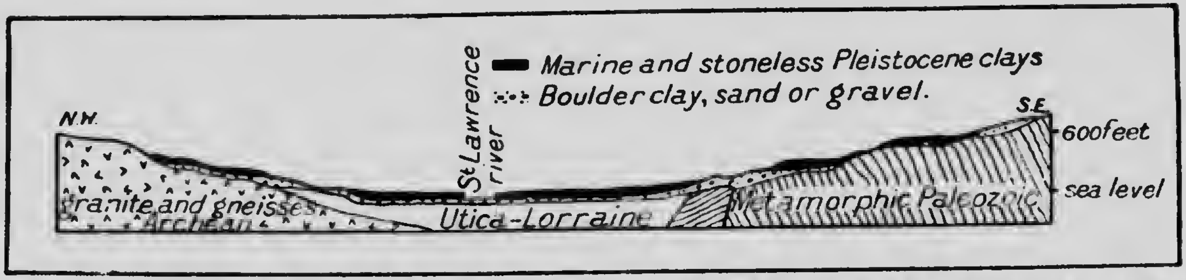


Figure 4. Diagrammatic section of St. Lawrence valley in the vicinity of Lake St. Peter, showing relation of surface deposits to underlying bedrock.

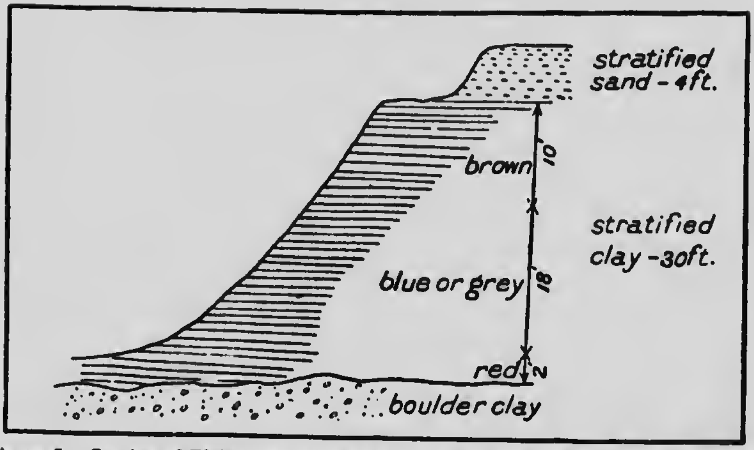


Figure 5. Section of Pleistocene deposits at terrace on Davidson street, Montreal.

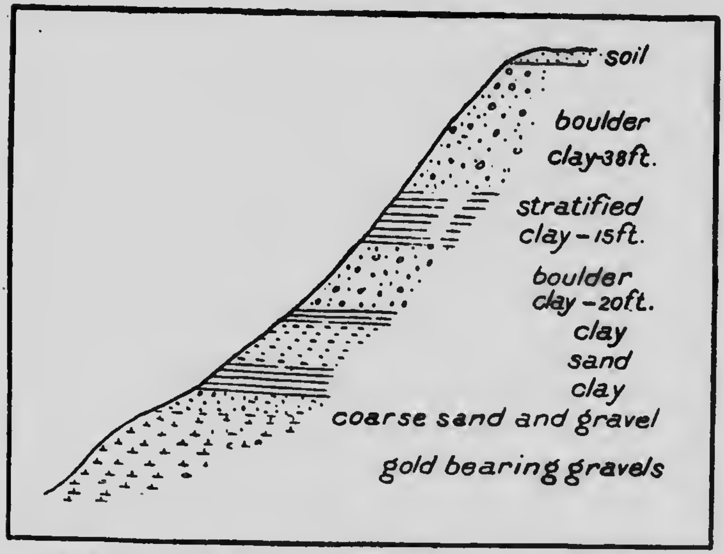


Figure 6. Section near mouth of Rivière-du-Loup, after Chalmers.

A still more complex arrangement of surface deposits was noted by the writer at several points in the banks of the St. Francis river in Yamaska county, the details being given on a later page (see Figure 8).

Although the stratified, stoneless clays generally overlie the boulder clay deposits, they occasionally rest directly on bedrock as observed at St. Joseph, Beauce county, Richmond, and Chicoutimi. Stratified clay overlies stratified sand which occurs at the base of the section at Deschaillons (Plate VII, A).

Near Elmwood cemetery at Sherbrooke, a small area of stratified clay overlies cross bedded sands and river gravels arranged as indicated in Figure 7.

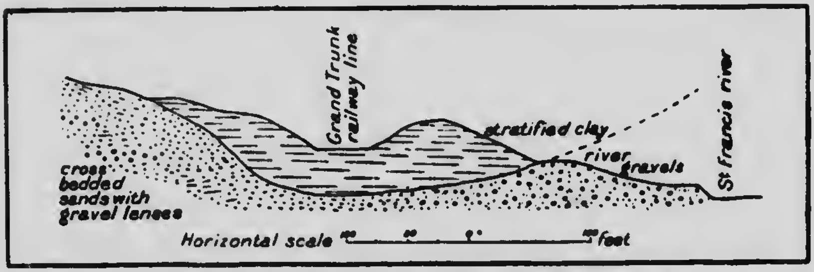


Figure 7. Small deposit of high level clay, overlying river gravels, near Elmwood cemetery, Sherbrooke.

The boulder clay seems to be the most widely distributed member of the Pleistocene. It occurs at all levels everywhere in the province, and consists generally of hard, grey, gritty clay packed with boulders and pebbles. In some places the boulder clay matrix partakes of the colour of the bedrock in its vicinity, being red when overlying the Medina shale, and black over some of the Utica shale areas.

Owing to their stony character the boulder clays are not a source of material for the clayworker, and will not be considered further in this report. The following details refer only to those deposits of clay which are free from pebbles or boulders, or almost so.

DISTRIBUTION OF PLEISTOCENE CLAYS.

The greater part of the stoneless surface clays in southern Quebec was apparently deposited in a sea basin. The surface of the land between the Great Lakes and the present seaboard was depressed at one time to a depth of about 625 feet at Montreal, and 630 feet at Quebec city. This downward movement of the land allowed the sea to enter all the lowland districts of the province. The valley of the St. Lawrence river was then occupied by a great inland sea, which was about 70 miles wide in the vicinity of the present city of Montreal. The tops of Mount Royal, Rougemont, Beloeil, and other isolated hills were islands in this sea. The valleys of all the principal rivers tributary to the St. Lawrence were bays extending inland from the main body of water. Remains of the shore-lines or beaches of this ancient sea are still preserved at various levels on some of the Laurentian highlands to the north, and on the Notre Dame mountains to the south of the St. Lawrence.

A great volume of coarse and fine-grained sediments was washed into this sea. The finest kinds were carried far out from land by tides and currents, and finally deposited in the deepest parts of the basin. The coarser sediments were deposited near the shore-lines.

This inland sea must have existed for a long period because clay forming sediments accumulated to a thickness of 150 feet or more in some parts of the basin and filled up all the hollows and formed a fairly level sea floor.

Various beaches found at successive lower levels indicate that the land rose by stages until finally the bottom of the St. Lawrence valley became above sea-level. Extensive areas of the old sea floor are still preserved on the south side of the St. Lawrence between the Ontario boundary line and Lévis, and smaller areas exist on the north side between Ottawa and Three Rivers. The general elevation of this plain, which is mostly covered with clay, does not exceed a height of 150 feet above sea-level. If it were bare of trees, this plain would look exactly the same as prairie lands in the western provinces. The rivers and streams have cut trenches in it, but not very deeply. To a spectator standing in L'Assomption county, looking southward across the level land toward Vercheres county, there is not the slightest evidence that one of the largest rivers in the world intervenes between these two counties.

The clay appears at the surface over large areas of this plain, but at other places it is covered by more or less extensive layers of sand of varying thickness. Occasionally isolated patches or ridges of gravels and boulders which appear to be slightly above the general level, are seen on the clay plain.

One of the largest areas of clay lands occurs between the Richelieu river and the St. Lawrence, and extends south to the International Boundary. This is one of the best farming tracts in the province; some of it requires draining, and at other places the sand covering is rather thick, but for the most part it is an area of excellent land, well adapted for agricultural and horticultural purposes. Areas of similar clay lands alternating with sandy patches are seen in the counties bordering the St. Lawrence between the Richelieu river and Lotbinière county.

About 60 per cent of the plain north of the St. Lawrence is covered with sand which sometimes attains a great thickness. The contrast between the attractive appearance of the clay lands, and the desolate aspect of the sand areas is very marked. The land occupied by these sands is almost useless for agricultural purposes, and large tracts of it are covered with a stunted growth of scrub pine, poplar, and black spruce with a few white maples in the hollows; at other places they are barren and wind blown. The rocky highlands on the north and south sides of the valley, approach the St. Lawrence river at Quebec and Lévis, and beyond this there are no extensive tracts of clay lands in the valley. From these points eastward the clays are restricted to comparatively narrow strips along the river banks. It is missing altogether, for long distances on the lower St. Lawrence.

Although the clay areas on the lower St. Lawrence are not so extensive as those in the western portion of the province, yet they are better adapted in many respects for the manufacture of clay wares, being free from the working and drying defects which are so prevalent in the clays at the same level above the city of Quebec.

The clay areas so far mentioned were formed by sediments deposited in the deepest part of the basin, i.e., the valley floor; but in addition to this main body of clays there are several detached areas of lesser extent at various high levels. On the north side of the St. Lawrence, clay terraces are found along the edge of the Laurentian escarpment up to 400 and 500 feet or more above sea-level. These are seen along the line of the Canadian Northern railway, in Maskinonge, St. Maurice, and Champlain counties. Similar areas of high level clays occur on the south side of the St. Lawrence valley in Sherbrooke, Richmond, and Wolfe counties. One of these deposits, worked for brickmaking at Ascot, is 630 feet above sea-level.

Below the city of Quebec, the elevation at which stoneless clays are found steadily declines until it is less than 200 feet on the northern shore of the peninsula of Gaspe, and less than 70 feet on the Chaleur Bay shore.

No stoneless clays of any extent appear to occur higher in the St. Lawrence valley than the levels given above. Whether all the clays found below these levels, which appear to mark the limit of marine submergence, are of marine origin or not, is a subject beyond the scope of this report; but it is probable that the greater portion of them are of this origin.

Sir William Dawson[1] in his studies of the clays of the St. Lawrence valley applied the name Leda clay to them, from the fact that fossil shells of *Leda truncata* were abundant in the formation at some localities. The name Saxicava was given to the overlying sands (Plate VII, B) owing to the frequent occurrence of the shells *Saxicava rugosa*. The localities at which marine fossils are found are few; the greater bulk of the clays and sands contains none.

There is evidently more than one kind of clay present, as will be seen later on when the differences in the physical character of these are explained. Furthermore, clays older than those due to marine submergence appear to be preserved beneath boulder clay sheets in certain localities.

[1] Dawson, Sir J. William, "The Canadian Ice Age": Chap. II.

For these reasons the name Leda is not used in this report in the general sense that Dawson and, later, Chalmers used it for all surface clays other than boulder clays.

The Lake St. John region at the head of the Saguenay river, contains the largest area of Pleistocene clay of any of the valleys tributary to the St. Lawrence. This extensive basin stands at an elevation of about 500 feet above sea-level, and is separated by a barrier of rocky ridges from the clay terraces on the Saguenay river in the vicinity of Chicoutimi. As no fossils have been found in the Lake St. John clay it is difficult to determine whether it is a product of the marine submergence or not.

The clay is grey in colour, well stratified, and free from pebbles. It resembles the high level clays of the St. Lawrence valley more closely than the low level variety.

A large area of Pleistocene clay known as the "clay belt" occurs in northern Quebec, beyond the limits of the drainage basin of the St. Lawrence. The principal rivers which drain this area, the Bell, and Hurricanaw rivers, flow northward into Hudson bay. The headwaters of the Ottawa lie below its southern fringe. The clays of this area appear to have been deposited in water ponded between a land margin to the south, and the front of a retreating ice sheet, which blocked the drainage toward the north. The clays and silts deposited in this glacial lake are of much practical value to the farmer, and the region is becoming settled for cultivation since the building of the National Transcontinental railway rendered it accessible.

GENERAL CHARACTER OF THE PLEISTOCENE CLAYS.

The greater part of the material used for the manufacture of common brick in the province of Quebec is taken from the soft, stoneless clays of Pleistocene age, that occur either immediately on the surface or at little depth below it. This material is distributed unequally. It occurs abundantly in the St. Lawrence and St. John valleys and in the clay belt of northern Quebec, but it is absent over the greater part of the province.

The Pleistocene clay is remarkably uniform in its composition over all the region. The following is an average of five chemical analyses of samples taken from widely separated localities:

Loss on ignition	4·6
Silica (SiO_2)	60·28
Alumina (Al_2O_3)	20·15
Iron (Fe_2O_3)	5·30
Lime (CaO)	3·55
Magnesia (MgO)	2·87
Sulphur trioxide (SO_3)	0·17
Potash (K_2O) / Soda (Na_2O)	2·11

Most of the deposits are stratified, and show the manner of their formation in layers, very distinctly. These layers probably represent yearly additions; therefore, if the entire thickness of the deposit was exposed, the time taken to accumulate it could be determined. Good examples of pronounced stratification in these clays are found at the brick plants at St. Lin junction, Deschaillons, St. Joseph (Plate VIII), Beauce, St. Raymond, Bell river, etc.

These stratified clays may contain layers of sand or silt alternating with clay layers. These materials probably indicate periods of flood, when coarser materials would be carried farther out into the still water basins and deposited with the clay. When the sand and silt layers occur plentifully through the deposit, brickmakers call it a "lean" clay. Clays of this description work easily, dry quickly, and have small shrinkages, but they do not burn to a very dense body if the sandy content is too great.

The deposits which are made up of alternate layers of clay, silt, and sand, if the latter is not too abundant, are the ones sought for by brickmakers, and as a rule give a good, natural, even mixture, and produce a brick of uniform strength. Attempts to obtain an even mixture by adding sand to a stiff, fat clay are not very successful, especially with the simple machinery used in most common brick plants.

At some localities the deposits show no layers or bands but on the contrary any lines seen are vertical. These vertical lines are the marks of joint planes, which are caused by shrinkage. In some places these kinds of clay are called "joint" clays, and at other places by the expressive name "gumbo." The term gumbo is descriptive of the sticky, adhesive qualities of the stiff and highly plastic, massive or joint clays. Examples of massive, highly plastic clays occur at St. John, Varennes, Nicolet, L'Epiphanie, etc. (Plate IX). These are known to brickmakers as "fat" or "strong" clays; they are generally hard to work, difficult to dry, with drying shrinkages sometimes abnormally high, and are avoided as much as possible in the industry.

The colour of most of the deposits varies from a lead grey in the lower portion to a brownish colour at the top. The brownish colour is secondary, being due to the weathering and consequent oxidation of the iron content in the clay, so that the originally grey clay takes on a slightly rusty appearance.

The depth to which the weathering penetrates varies with the thickness of the overburden, the texture of the clay, and the age of the deposit.

The top brown clay is the most desirable, it has better working qualities, dries easier, and shrinks less than the bottom blue clay. It is preferred by all the makers of clay wares, especially those making field drain-tile or porous fireproofing blocks.

The low level clays or those at and below about 200 feet above sea-level, are mostly massive, highly plastic, sticky clays, difficult to work and dry, and with abnormal drying shrinkages. The high level clays are generally interstratified with silt and sand layers, they are easily worked and dry rapidly with normal shrinkages. There are some instances, however, where the low level clays are of the silty type, like the deposits at Deschaillons, 150 feet above sea-level, and where the high level clays are of the "fat" or gumbo type like the clay at Huberdeau 584 feet above sea-level. The generalization, therefore, of clays with two widely different working qualities, one at high levels and the other at low levels, does not hold good for all cases, but it does for most of the deposits.

The low level, highly plastic clays make a smooth paste when mixed with water. They are generally so fine grained that they will pass through a 200 mesh sieve without leaving any residue, and most of the grains are infinitely small. The high level clays may contain from 5 to 20 per cent of grains which will not pass a 200 mesh sieve. The tensile strength of the air dried raw clay varies from 100 to 150 pounds per square inch,

With one exception, all of the Pleistocene clays so far examined in Quebec burn to a red colour. The commercial limit of burning seems to be about 1850 degrees F. or cone 07, but fairly good hard brick are produced in the scove kilns at cone 010 (1742 degrees F.). They are underburned and soft if burned at a lower temperature than this. All these clays show overfiring and excessive shrinkages when burned to cone 03 (about 2000 degrees F.). Most of them soften and begin to form slags at a temperature of cone 1 (2100 degrees F.).

They are not suitable for the manufacture of vitrified wares, any attempt to burn them to this state would result in loss, as the vitrification point and the softening point are too close. The Pleistocene clays are also unsuited to the manufacture of dry-pressed brick.

LOCALITIES NORTH OF THE ST. LAWRENCE RIVER.

LABELLE COUNTY.

The clays of Labelle county are confined to one general type and occur in strips of no great width along the principal valley bottoms, to an elevation of 630 feet above sea-level. The extensive terrace in the Gatineau River valley, between Kazabazua and Gracefield about 60 miles north of Hull, stands at this level. The terrace is composed mostly of clay, but like all deposits of this class in Quebec, parts of it are covered with patches of sand, gravel, and boulders. At those localities where the valley of the Gatineau is narrow, as at Cascades, the rocky walls come close to the waters edge, and the clay is missing, Where the valley is wide and basin shaped, the clay may occur in correspondingly wide deposits, covering the bottom of the basin. This rule applies also to the Lièvre river, and in fact, to all river valleys of any extent within the Laurentian upland north of the St. Lawrence and Ottawa rivers, below the limit of marine submergence or an elevation of 600 to 700 feet (Plate X).

The wide depression at the junction of the Ottawa and Gatineau rivers is floored principally with clay, in terraces of considerable width, at several levels and from the banks of the Ottawa river at Hull to the edge of the Laurentian escarpment at Chelsea. Good sections of clay are to be seen in the railway cuttings between Ironsides and Chelsea, and in the banks of streams which in places have cut trenches to a depth of 50 feet or more in the terraces. A fringe of very perfect clay terraces extends all along the northern side of the Ottawa river, from the mouth of the Gatineau river to Calumet.

Hull.

A large quantity of clay is used annually in the manufacture of portland cement at the works of the Canada Cement company. The clay is gathered by horse-scrapers and dumped into a car, which is sent to the works by an overhead conveyor. The raw materials used for cement at this point are approximately 25 per cent of clay and 75 per cent of limestone.

Brick are manufactured on the Chelsea road, a short distance north of Hull, by Alex. Richard and Son (Plate XI, A). A sample of the clay from this work was collected for testing. It is typical of most of the material of the district, and is identical with that used at the cement works. It is bluish-grey in colour, but becomes browner or rust coloured toward the surface owing to the oxidation of the iron content. The clay bank shows only faint lines of stratification, the vertical joints being the more pronounced feature in the structure. When exposed in a steep face it breaks down into pieces about the size of road metal, and in dry weather these fragments crumble into small particles.

The dry clay when finely ground requires 35 per cent of water to bring it to a working consistency. It then forms a highly plastic, sticky mass, rather smooth to the feel, but stiff and hard to work.

Owing to the large quantity of water required for tempering, the shrinkage on drying is excessive, being about 11 per cent. The clay burns to a light red, almost steel hard body at cone 010 (1742 degrees F.), with a fire shrinkage of 1 per cent, and an absorption of 13·8 per cent. When burned to cone 06 (1886 degrees F.) the colour is deeper, and the body harde and denser, the absorption being 11·3 per cent. If burned t cone 03 (1994 degrees C.) the body becomes vitrified, th shrinkage is high, and over-firing with softening begins. I the temperature is carried up to cone 1 (2102 degrees F.) th clay melts. When mixed with about 30 per cent sand, an burned to a temperature of 1800 degrees to 1850 degrees F., good common red building brick is produced.

The brick are made by the soft-mud process, and these ar the only wares produced by this plant, but the material wi make a very good field drain-tile, as tests made for this purpose o a 3-inch hand press turned out well. The brick are dried out doors, on racks and pallets, as the clay will not stand fast dryin without cracking. The brick are burned in scove kilns wit wood for fuel, but one down-draft kiln fired with coal ha recently been built. Many of the brick are underburned these are soft and light in colour.

One machine making about 20,000 brick per day is i operation for about 5 months in the year. The brick are sol in the city of Hull.

Kirk Ferry.

A narrow fringe of clay extends along the river for a sho distance in this locality. A sample was taken for testing fro the high bank at Patterson's farm on the east side of the riv opposite Tanaga station. Marine fossils occur plentiful about 10 feet below the surface of the bank. Lower down the bank there is quite a thickness of cemented river gravel

This clay required 32 per cent of water for temperin it was highly plastic, stiff, and sticky, although it contains considerable amount of fine grit or silt. The drying shrinka was 8·5 per cent.

It burns to a light red, hard body at cone 010, with ve little fire shrinkage, and an absorption of 16 per cent. The is not much change in the character of the body when burn to cone 06, but the colour is deeper. The clay vitrifies at co

03, and melts at cone 1. This is a good common brick clay and is probably suitable for the manufacture of field drain tile, but would require the addition of about 25 per cent of sand.

It contains considerably more grit than the clay at Hull, which accounts for the lower drying shrinkage, and higher absorption of the burned body. Both of these clays are unsuited for vitrified wares, as they begin to soften almost as soon as the point of vitrification is reached, and it is unsafe to carry the burning so far.

ARGENTEUIL COUNTY.

The principal deposits of clay in this county are confined to strips along the Ottawa river, but stratified surface deposits, including clays, extend for a considerable distance into the hilly and rocky region to the north. Terraces of these materials are found from 12 to 15 miles north of Lachute up to an elevation of 720 feet above sea-level.

The clays along the Ottawa river in this county resemble those from Labelle already described. The following description is given of a sample taken much farther north.

Huberdeau.

This village is situated on the Rouge river, about 25 miles north of the Ottawa, and at the terminus of the Montfort branch of the Canadian Northern railway. It lies well within the rocky Laurentian upland, its elevation being about 584 feet above sea-level. Stratified clay and sand in terraces extending about a mile or more on each side of the river, occupy a depression or basin among the rocky hills at this locality. The clay is underlain by boulder clay, and overlain by a layer of yellow stratified sands and gravels of varying thickness, but the sand covering is absent in places. The entire thickness of these deposits is about 100 feet.

This small irregularly shaped area of clay lands is cultivated right up to the enclosing rocky border.

A sample of the clay for testing purposes was taken from a cutting on the wagon road, on the west side of the Rouge river. This clay bank was dark grey in colour beneath and brownish toward the top. It had very pronounced stratification, with thick layers toward the bottom but thinner in the upper part. The deposit had no sandy or silty layers or pebbles, but appeared to be of uniform character throughout the 20 feet of material exposed at this place.

The clay when dried and ground required 35 per cent of water to bring it to a workable condition. It was exceedingly plastic, fairly smooth, rather stiff and sticky, being hard to work.

The moulded shapes do not dry readily and will crack badly if the drying is forced by artificial means. The drying shrinkage is 9 per cent.

The clay burns to a light red, hard, but rather porous body at cone 010. When burned to cone 06 the body is steel hard, the fire shrinkage 4 per cent, and the absorption 12 per cent. The clay vitrifies at cone 03 and melts at cone 1.

A mixture of two parts of this clay with 1 part sand could probably be used for making brick, but even this mixture would have to be dried very slowly to prevent cracking.

It is interesting to note that this clay resembles in many respects those found at Nicolet and L'Epiphanie, which are described later, in the middle of the great clay belt of the St. Lawrence.

It was expected that the clay at Huberdeau, occurring as it does at a high level, and near the land margin of the ancient inland sea, would be more sandy or silty in texture than those laid down in the deepest water and farthest from land. On the contrary it turns out to be an extremely plastic and pasty clay having the character and defects of a gumbo.

TERREBONNE COUNTY.

The surface clays underlie that portion of this county situated between the Canadian Northern Railway line and the Rivière-des-Mille Iles. A rocky upland country lies north of the railway, where clays only exist in the principal river valleys. The farm of the boys home at Shawbridge on Rivière-du-Nord as well as most of the farms in this picturesque valley as far as St. Sauveur are situated on the narrow strip of clay banks along the river.

A layer of sand, sometimes of great thickness, overlies the clay on considerable portions of the level land in the southern part of the county, but on certain areas between Montfort Junction and St. Jerome, and between Ste. Thérèse and St. Lin Junction the clay is free from sand or carries only a light overburden, which could be easily removed.

St. Lin.

There are three small plants making common brick at this locality. The clay appears to be of marine origin as it contains numerous fossil shells characteristic of the Leda clay, but it differs from most of the clay of this kind which occurs at the lower levels in the St. Lawrence valley. The section in Gauthier's pit shows a light grey, well stratified clay in the upper part, but more massive below. It contains layers and pockets of silt, with shells and small rounded pebbles scattered sparingly through the deposit. The clay is overlain by 3 to 5 feet of grey and yellow stratified sand, and is exposed for a depth of about 15 feet in the excavation. The defect of this deposit is that some of the pebbles it contains are limestone. These burn to white, soft, quicklime lumps, which swell on absorbing moisture from the air and generally burst the brick that they happen to occur in.

The clay at the pit of the Dominion Brick company's plant, about one-eighth of a mile distant from the one just described, does not seem to contain any pebbles or shells, as far as the excavation has gone. A sample taken from this deposit required only 17 per cent of water for tempering. The wet body is rather short in working and somewhat open in texture, so that it can be dried safely at a temperature of 120 degrees F. Its drying shrinkage is about 7 per cent.

This clay burns to a light red, hard body at cone 010, without any fire shrinkage, and an absorption of 13 per cent. There is not much change in the character of the body burned to cone 06, but the colour is better. If fired to cone 03 a deep red almost vitrified body is formed; the fire shrinkage is rather high at this temperature. The clay melts at cone 1.

Owing to its silty character, this clay takes less water for mixing, and works and dries better than the fat clays from Lakeside and Montreal. It requires little or no addition of sand, and burns to a better body than the fatter clays do when sanded.

The Dominion Brick company has a new plant, better equipped than most of the common brick plants in Quebec. The clay is well prepared before moulding, passing through two pug-mills and a pair of rolls on its way to the machine. The moulding is carefully done, and the brick are dried on cars in steam driers. The burning is done in scove kilns, having temporary grates fitted into the fire arches for burning coal. The watersmoking is done with wood fires, and the finishing with coal.

This company aims to make a better common brick than those usually supplied to the Montreal builders.

Ste. Thérèse.

An unusual and interesting deposit of surface materials occurs about half a mile north of Ste. Thérèse station. These the Canadian Pacific Railway company uses for ballast. The deposit consists mostly of well rounded gravels, but it is replaced by marine clay at the same level. The gravel underlies the clay, and tongues of clay protrude into the gravel. Marine fossil shells are found in both materials. The contact is sharp, there being no grading from one extreme to the other.

Island of Montreal.

The greater part of the surface of the Island of Montreal is composed of boulder clay, but there are fairly extensive patches of stoneless stratified marine clay, either capped by layers of sand or without any sand cover. At other places ridges of rock with little or no covering of loose materials come to the surface.

A strip of marine clay, varying to about a mile at its greatest width, extends from Beaconsfield to Montreal junction, but is interrupted by a patch of stony boulder clay which lies between Dorval and Blue Bonnets racing tracks. This strip of clay continues, fronting on the St. Lawrence river, through the City of Montreal eastward to Bout-De-l'Isle. The clay is found up to a height of 160 feet above sea-level, which is slightly higher than the terrace on which Sherbrooke street is situated.

Abundant marine fossil remains, principally shells, have been found in the stratified clays and overlying sands and gravels in these localities.

Montreal.

The clay used in the brick plant of C. Bourdon, 605 Davidson street, is taken from a bank which appears to be on the same level, and is probably a continuation of the Sherbrooke Street terrace. About 25 feet, in thickness, of clay is exposed in the bank. It is mostly blue grey in colour turning brownish toward the top, but about a foot or so of red clay occurs near the bottom of the bank. No pebbles were seen in the clay, nor is there any evidence of pebbles in the burned brick. Stratified sands, 3 to 5 feet in thickness, form the level top of the terrace. An average sample of the clay taken from this bank was tested. It required 35 per cent of water for tempering, and worked up into a very plastic, stiff, and rather sticky mass. It has an excessive drying shrinkage, and poor drying qualities, but these defects are corrected in practice by the addition of sand. It burns to a fairly hard red body at cone 010, but it is very porous, the absorption being 18 per cent. This clay has the excessive fire shrinkage of 10·7 per cent, making the total shrinkage 20 per cent, when fired to cone 03. The high shrinkage is also accompanied by overfiring and partial softening at this temperature. For brickmaking purposes a mixture of two parts clay, and one of sand is required. If all blue clay is used less sand is required.

The best results in burning are obtained at a temperature of about 1850 degrees F. (cone 07), but most of the brick are burned at a much lower temperature than this; and many of them are underburned.

This plant operates about 6 months in the year, making common sand moulded brick, which are sold to the builders in Montreal. The brick are dried by the rack and pallet method, and the burning is done in scove kilns, the fuel used being wood. The output cannot be increased by fast drying, as even with the addition of 30 per cent of sand the drying of the green brick cannot be hurried.

The following tests made on samples of the Montreal clay, show very clearly the effect of varying quantities of sand on the strength of the burned clay body:

	Crushing load in pounds per square inch	Absorption %
Clay, without sand	7025	21
4 parts clay to 1 part sand	3765	18·5
3 " " " " "	3667	17·0
2 " " " " "	2765	15·2
1 " " " " "	1895	13·2

The crushing tests were made on 2-inch cubes, burned to cone 010. The sand was thoroughly mixed with the clay, a better mixture being obtained than is usually the case in practice. The tests were made in duplicate, the average result being given.

The addition of 25 per cent of sand reduces the strength of the body nearly one-half, while with 50 per cent of sand there is only about one-quarter the strength of the all clay cube.

Lakeside.

The plant of the Montreal Terra Cotta company at Lakeside is situated on the level ground between the tracks of the Grand Trunk railway, and a clay terrace which rises to a height of about 40 feet above the railway. The plant is well situated for working the deposit, and shipping the finished products (Plate XI, B). The clay is excavated from the upper part of the terrace, and sent by a belt conveyor (Plate XXV, A) to the machine, where it is mixed with sawdust, and worked up into the various shapes used in fireproofing and for hollow building blocks.

The blocks are dried on cars in driers supplied with waste heat from the cooling kilns. When dried they are placed and burned in down-draft kilns fired with coal. The sawdust burns out, and leaves the block porous and light, and supposedly tougher. The product is used in Montreal for protecting structural steelwork in various buildings, and for partitions and floors, in fireproofing construction. The drying properties of the clay are poor, and there is considerable loss from checking.

The excavation in the terrace shows 8 to 12 feet of brownish clay overlying blue grey clay. The blue clay carries a red bed similar to that at Bourdons pit in Montreal. The deposit is underlain by boulder clay, which is exposed a few feet below the surface of the flat at the railway siding. There is no sand overburden on the terrace in this vicinity.

The upper brown clay is considered better for the manufacture of fireproofing, as it is more plastic and holds its shape better in the large hollow pieces. The brown clay is merely the weathered and oxidized portion of the deposit nearest the surface. About 25 per cent of sand would improve the drying qualities of this clay, but there is none available in the vicinity.

The clay when dry takes 30 per cent of water to bring it to a working consistency. It is very plastic, and stiff in the wet body. The clay is smooth to the feel, owing to its fineness of grain. It is so finely divided that all the clay grains will pass through a 200 mesh screen. Brick moulded from it will crack if dried fast, so that they must be sanded and dried very slowly. On account of the comparatively thin walls of the fireproofing, this ware can be dried more successfully than standard size brick, but the drying qualities of the clay are not good in any kind of ware.

The following table gives the physical tests for the clay alone, and mixed with varying amounts of sand:

	1 %	2 %	3 %	4 %
Water required	30	27	26	20
Drying shrinkage	8·5	7·0	7·0	4·9
Cone 010				
Fire shrinkage	1·3	0·4	0·7	0·4
Absorption	15·7	15·0	14·6	12·5
Cone 06				
Fire shrinkage	2·2	0·4	0·3	0·0
Absorption	15·5	15·0	14·3	12·2
Cone 03				
Fire shrinkage	10·0	7·0	6·4	3·0
Absorption	0·0	2·0	4·2	7·6

No. 1, clay alone.
No. 2, 3 parts clay to 1 of sand
No. 3, 2 parts clay to 1 of sand
No. 4, 1 part clay to 1 of sand.

The addition of sand has the effect of reducing the quantit of water required for tempering, and reducing the shrinkage especially the fire shrinkage. It makes the clay easier to work easier to dry, and easier to burn. If too much sand is added i weakens the brick; the mixture of half clay and half sand ha an excess of sand; consequently the test piece burned at con 010 is very weak, and a strong body is not formed until cone 0 is reached. The mixture of two parts clay and one part san gives good results for working qualities and shrinkages but i requires burning to cone 06 to make a good sound body fo common brick.

From the results of further experiments made with thi clay it appears that the material could be considerably improve by the addition of 10 per cent of lime, or better still by addin 10 per cent of finely ground magnesian limestone or dolomit These materials even in small amounts improve the drying an burning qualities of the clay. This clay is easily overfire so that the blocks nearest the fire holes in the down-draft kiln become partly fused and deformed, while the blocks at the bot tom of the kiln and farthest from the heat may be underburne The addition of the lime or dolomite would prevent the ove firing, so that the temperature of the whole kiln could be raise to a higher degree, and a more uniform burn produced than is done at present. These special tests are given in detail in a subsequent chapter.

L'ASSOMPTION COUNTY.

The greater part of this county is underlain by stoneless Pleistocene clay, which is probably of marine origin, but no fossil shells have been recorded from any part of the area. As is usually the case a sand covering of variable thickness overlies the clay; but there are some fairly extensive patches between Charlemagne and St. Paul-l'Ermite, and in the vicinity of L'Epiphanie on the Canadian Pacific Railway line, where the clay comes to the surface. Large boulders of granitic rocks from the Laurentian upland are scattered over the level surface of the clay or sand.

A small plant manufacturing common red brick is located at Lachenaie. The brick are brought in carts to Charlemagne station on the Canadian Northern railway, a haul of about 2 miles, and shipped to Montreal. The clay in this locality is rather silty in character, and can be dried outdoors without checking when some sand is added. It makes a rather soft building brick. Most of the clay in the county is of a stiff bluish to brown massive variety, very plastic and sticky when wet and hard to dry after moulding.

L'Epiphanie.

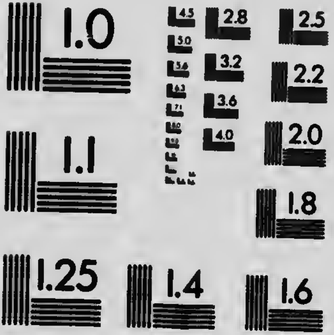
A sample collected just outside this village is a typical example of the greater part of the clay deposits of the county. This clay when tempered with water, forms a highly plastic but stiff sticky body which is hard to work.

Its drying shrinkage is excessive, being 10·5 per cent. The defective drying qualities of this clay are very pronounced, as it cracks in slow drying at 70 degrees F., even with the addition of 33 per cent of sand.

It might be possible to dry this clay safely by using a mixture of half clay and half sand. Brick made from this

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

mixture would have to be dried very slowly to prevent cracking; furthermore the burned body that would result from such a highly sanded clay would be too weak, and of no practical value.

A mixture of this clay with the Utica shale which occurs at L'Epiphanie, was experimented with. Equal parts of clay and shale were used, but the results given by this mixture were not satisfactory.

This clay is not suitable for the manufacture of brick or tile in the raw state. It might be utilized if the clay was preheated up to a temperature of about 300 degrees C. before moulding. The experiments on preheating this clay are referred to in a separate chapter.

PORTNEUF COUNTY.

The rugged Laurentian highlands approach the St. Lawrence in this county, consequently the low-lying border of clays and sands, which is fairly wide in St. Maurice and Champlain counties, is here confined to a rather narrow strip.

The clay deposits in the vicinity of Portneuf village are covered with a great thickness of sands and boulder clays, so that they are unworkable. The following section was observed on the bank of Portneuf river near the village:

	Feet
Sand, clay, and large boulders	10
Stratified sands and silts	30
Stoneless stratified clay	20
Cross-bedded sand and gravel (marine shells)	10

The clay occurs nearer the surface west of this locality. A small brick plant is in operation at St. Marc, a station on the Canadian Northern railway.

St. Raymond.

Two small brick plants are in operation at this locality. They are situated close together on the west bank of the Ste. Anne river, about 1½ miles north of the village. They are owned respectively by Messrs. Nap. Genois and E. Paradis. Both produce red, soft-mud building brick by the ordinary simple method used in all the small plants in the province. A mixture of three parts clay to one of sand is used in brick-making. The green brick are hacked out on the ground to dry, after being moulded. The burning is done in scove kilns with wood for fuel.

The clay deposit occurs in a small basin formed by a widening of the valley of the Ste. Anne river at this point during pre-Glacial times. It is entirely surrounded by a rim of the low Laurentian hills (Plate XII, A). Most of the deposit has been cut out by the river, but quite extensive terraces still remain on both banks. The clay is overlain by quite a thickness of sand and gravel The upper terrace, at an elevation of about 600 feet above sea-level, is composed entirely of sand, and rests against the rocky rim of the enclosing hills. The lower terrace fronting the river at the brick-yards is about 40 feet high, consisting of 25 feet of clay, overlain by 15 feet of sand and gravel. The clay is bluish grey in colour, well stratified in half inch layers, which are interlaminated with silt. It is free from pebbles, and contains numerous visible scales of mica. The layers of the upper 5 feet or so of clay are folded and crumpled (Plate XII, B) probably the result of pushing by either floating ice or a tongue of land ice. The overlying sands and gravels are very irregularly bedded, and contain many well rounded small sized rocks as well as large subangular boulders.

The overburden of sand is excessive and costly to remove. There is a temptation to mix too much of it with the clay when using it for brick, which weakens the product.

A small sample of the clay was tested, with the following results. It required 22 per cent of water for tempering and formed a body of medium plasticity which was easy to work, but was rather short and inclined to be flabby owing to its siltiness.

The clay appears to have good drying properties, with a drying shrinkage of only 4·5 per cent. The burning data are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	15·5	light red
06	0·5	14·2	red
03	5·3	4·0	dark red
1	softened		

This is a good common brick clay, the shrinkages are lo the working qualities favourable, and the burned body is sou and strong. The red colour is rather light at the lower te peratures, but a fine deep red colour is produced at cone 03; t body is then also steel hard and almost impermeable to moistu If burned to about 1900 degrees F. brick made from this cl would probably be suitable for sewer linings or any undergrou work. The clay does not require the addition of sand. Too mu sand weakens the body, and increases the porosity, so that t clay does not have its full strength developed.

Clays occur in terraces along a considerable portion the valley of the Ste. Anne river and its tributaries which rea far back into the hilly country to the north of the county.

A remarkable landslip happened in the Rivière Blanc valley, near St. Thuribe, on May 7, 1898.[1]

This landslip destroyed a large portion of three farr and the quantity of material which was discharged into the riv valley was so great as to fill it to a depth of 25 feet or more, a distance of nearly 2 miles.

Landslips are of frequent occurrence in the clay terrac of these river valleys, especially during seasons of excessi rainfall. The silty underclay becomes saturated with wat and flows under the pressure of the stiff top clay and sand, t latter breaking away as it becomes undermined. Plate XI shows a view of a portion of the effect of the landslip at S Thuribe, shortly after it occurred. The large pyramidal ma seen near the right of the picture, is principally composed upper stiff clay; it has been carried several hundred feet on t semi-liquid underclay.

[1] For full description of this landslip see Annual Report, Geologi Survey, Vol. XI, pp. 65 to 70 J.

QUEBEC COUNTY.

The surface clays in Quebec county are confined to comparatively small areas which occur in the lower parts of the valleys of the St. Charles, and Cap Rouge rivers, or in some of the terraces along the bank of the north channel of the St. Lawrence.

Quebec City.

There are several plants manufacturing common brick by the soft mud process at Stadacona, and St. Malo within the city limits at Quebec. St. Malo is on the south bank of the St. Charles river at the west end of the city. Brick are said to have been made here during the last 200 years, so that the site of the oldest brick plant in the province is in this vicinity. The clay in this immediate neighbourhood is exhausted; and, although the brick plants still continue to manufacture at St. Malo, the clay has to be carted for some distance from the north side of the river. This deposit consists of 4 or 5 feet of grey silty clay with rusty streaks, overlying blue sand and silt. A face of about 6 feet is worked; therefore about 2 feet of sand is worked in with the overlying clay. A porous light red brick is produced, which may be used for the backing and filling of walls but is not suitable for facing brick. There appear to be pebbles scattered through the clay, some of which are limestone. These cause trouble by air slaking, after burning, which results in cracked brick.

The largest brick plant under single ownership, is that of M. Paradis, at Stadacona, a short distance east of the St. Malo clay pits. Four brick machines are in operation, producing 3,000,000 to 4,000,000 brick annually. The deposit which is worked for brick-making occurs in the vicinity of the plant. It consists of about 4 feet of silty and sandy clay, overlying pure sand.

All these plants adopt the same simple method of working. The brick are hacked out in open spaces to dry; when dry they are built up in clamp kilns and burned with cordwood.

A small quantity of field drain tile is made by Messrs. W. and D. Bell on Little River road, a few miles west of the city.

These are burned in small round down-draft kilns. The tile are rather soft and porous, as the clay is of the lean variety and too sandy for this purpose. No tests were made of the clays from St. Malo or Stadacona, as they do not appear to be suitable for anything but soft common brick. These plants will shortly be forced to move farther out as the ground they occupy is required for building purposes.

Beauport.

A brick plant was in operation until a few years ago at Beauport, about 4 miles north of the city of Quebec. The original plant produced soft-mud brick, but a stiff-mud machine for making wire-cut brick was substituted later, as well as steam dryers. The causes of failure which led to the abandonment of this plant were: (1) too many limestone pebbles in the deposit, (2) auger laminations produced in the brick by the stiff-mud machine. The deposit worked by this plant shows the following section:

	Feet
Stratified bluish grey clay................	3 to 4
" gravels, with many limestone pebbles....................	2
" shale fragments................	1
" sand........................	2

The gravel surface underlying the clay is very uneven, the gravel rising in hummocks; as the clay was worked with scrapers too many pebbles were included; and since many of these were limestone, serious losses resulted.

A sample of clay without pebbles was tested with the following results. It required 27 per cent of water for tempering, and formed a wet body of good plasticity and fair working quality. The drying shrinkage was 6·5 per cent. The clay burns to a good red colour, and nearly steel hard body at cone 010, the fire shrinkage being zero, and the absorption 13·6 per cent. If burned to cone 03, the colour is deep red, the body steel hard, the fire shrinkage 4·8 per cent, and the absorption 6·7 per cent. The clay melts at about cone 2.

This is the best material in the way of surface clay in the vicinity of Quebec for the manufacture of common brick or drain tile; but, like almost all the surface clays, it is not suitable for the manufacture of vitrified wares. The deposit is too shallow, and not very extensive at the point sampled, as shale bedrock outcrops at a short distance behind the old plant. The clay is much thicker on some of the terraces in this vicinity as seen in the rear of the Beauport asylum.

Cap Rouge.

The village of Cap Rouge is situated in the valley of a small stream, between two high shale escarpments, about 8 miles west of the city of Quebec. There is quite an extensive deposit of surface clay in the valley, as indicated by the exposures in the banks of the stream. A sample of the clay was collected for testing purposes at a point a short distance north of the Canadian Northern Railway station. The bank of the stream is here about 20 feet high; the upper 10 feet consists of stiff grey clay with reddish patches and is free from pebbles, while the bottom of the bank is concealed by slide material.

This clay requires 20 per cent of water for tempering. It has good plasticity and working qualities. The drying shrinkage is 6 per cent. Its drying qualities are not good, as it cannot be dried fast, even with the addition of 33 per cent of sand.

It burns to a good hard red body, with 13 per cent absorption at cone 010. It has a bright red colour and steel hard body at cone 06. When burned to cone 03, the body is vitrified, and the colour dark red, but the shrinkage at this temperature is rather too high. It is unfortunate that the drying qualities of this clay are so poor, as otherwise it is an excellent brick material. It may be dried slowly outdoors on racks and pallets with the addition of 25 per cent of sand. A full sized brick made in the laboratory of 3 parts clay to one of sand, was dried in 4 days at a temperature of 60 degrees to 70 degrees F., without checking. Another brick of the same mixture cracked at 90 degrees F. If the drying difficulties can be overcome, this clay will make excellent field drain tile.

CHICOUTIMI COUNTY.

This county lies almost wholly within the elevated rocky Laurentian region. The clay deposits seen were confined to small patches or strips of marine clay which occur in terraces at various elevations along the sides of the deep valley of the Saguenay river between Ha Ha bay and Jonquieres. No clays occur beyond Jonquieres within the limits of Chicoutimi county.

Chicoutimi.

This town is situated at the head of navigation on the Saguenay river 75 miles from the St. Lawrence. It is one of the most important centres for the manufacture of wood pulp and paper in the province. The town is built on ground rising from the water's edge, partly on rock and partly on clay terraces. The clay in the terraces sometimes rests on smooth glaciated surfaces of the granite gneiss bedrock. The clay slips occasionally, but so far little damage has been done by any slips that have occurred.

A small brick plant owned by Messrs. Jalbert and Thibeault is located at Chicoutimi. The clay occurs in a terrace (Plate XIV, A), which rises to a height of 20 or 30 feet, behind the plant. It is thinly laminated, blue below and brownish toward the top. Occasional small, well rounded pebbles and several shells, indicating the marine origin of the deposit, are scattered through the clay. In some places pockets or streaks of gravel occur, possibly dropped from pieces of floating ice. A mixture of two parts clay and one part sand is used for brickmaking. The drying qualities of the clay are not good; it must be dried slowly outdoors, and even then the green brick are cracked by warm dry winds. The brick are burned with wood in scove kilns. They have a good red colour when burned, but are rather too porous and soft, owing to the large quantity of sand used in the mixture.

A sample of clay taken from the bank at this plant was tested with the following results. It required 23 per cent of water to bring it to a working consistency. It dries slowly with a drying shrinkage of 5 per cent. When burned to cone 010, the body is hard but porous, the absorption being 20 per cent. The body is steel hard when burned to cone 06 but is still rather porous. This clay contains slightly more lime than most of the clays west of this point. It melts to a slag at cone 1. This clay will make a far better brick when used alone than it does with the sand added. The drying problem, however, has to be overcome, and the addition of sand is necessary to accomplish this safely.

An attempt to make some 3-inch round tile from this clay failed. The clay appears to be lacking in good plastic qualities, being granular to the feel and short or flabby in the wet state. It differs in this respect from most of the other low level clays in the province. The clay does not appear to be adapted to the manufacture of any other product than the one it is now used for.

Lake St. John.

The terraced clay plain which surrounds Lake St. John is, on the south side, 1 to 2 miles in width; its general elevation above sea-level is about 515 feet. The Canadian Northern railway traverses this plain between Chambord junction and Roberval, a distance of 12 miles.

It is sometimes overlain by sand, particularly toward the high rocky rim of the basin; but over large areas the clay forms the surface of the farming land in this region.

The clay is well stratified horizontally in thin layers, apparently free from pebbles and grit, and is of a light grey colour when dry. No fossils have yet been found in the area, so that it is not known whether the deposit is of marine origin, and connected with similar deposits in the St. Lawrence valley, or whether it is a fresh-water deposit formed in the detached basin in which it occurs. Its elevation does not preclude it from the possibility of being a marine deposit.

As far as its economic value is concerned it does not differ very much from the high level clays in the St. Lawrence valley. In appearance it probably resembles more closely the fresh-water clay deposits of the Ontario basin of the St. Lawrence.

Roberval.

A sample of clay collected from the slope of the first terrac above the lake level at the village of Roberval gave the followin results when tested.

This clay requires 28 per cent of water to bring it to a goo working consistency. It is fairly plastic, and works easil but becomes rather flabby with a slight excess of water. It smooth in texture, and fine grained, 99 per cent of the cla passing through a 200 mesh sieve, but much of this is fine-graine silt. This clay can be dried moderately fast without checkin and has a drying shrinkage of 6·5 per cent. It burns to a ligh red colour and fairly hard body at cone 010, with an absorptio of 15 per cent. When burned to cone 06 the red colour is bett and the body slightly denser and almost steel hard. There is n shrinkage in firing at either temperature, and the bricklet have a good ring when struck together. The clay is overfire and shrunken at cone 03, and melted at cone 1.

This clay is suitable for the manufacture of common bric preferably by the soft-mud process. A little sand might b added but it does not require much, as the shrinkages are no high and the working qualities good. It will also make fiel drain tile if necessary. The samples of tile made in the labora tory from this material were satisfactory in average.

PLEISTOCENE CLAYS SOUTH OF THE ST. LAWRENCE

CHATEAUGUAY COUNTY.

A large portion of the level land in this county is underlai by clay. The Grand Trunk railway between St. Martin Junction and Ormstown appears to be located on the clay land which border the Chateauguay river. The clay is worked fo brickmaking at only one point in the county.

Ormstown.

The clays of this locality can be readily examined in th pits of two brick plants which are in active operation. Th plant owned by Mr. Alex. Mills is situated alongside the Grand Trunk railway about half a mile east of the station. The section in the pit at this plant shows 2 to 3 feet of yellowish loamy clay, overlying 4 to 6 feet of grey clay with rusty streaks, which is underlain by massive blue grey clay (Plate XIV, B). The blue underclay is said to be 40 feet in thickness.

The rusty grey clay does not appear to be stratified, but it contains a stratified sandy clay layer, 6 inches to a foot in width. The bank is worked for brickmaking down to the top of the blue clay, but as the upper surface of the underclay is uneven and hummocky a certain amount of it is included when levelling off the bottom of the pit. This bottom blue clay has a high shrinkage, and would require careful mixing with sand to make it workable, but sand appears to be scarce in this vicinity.

The clay is rather tender; it has to be dried slowly on outdoor racks and pallets; and any attempt to hasten the drying by artificial means results in serious losses. It might be possible to dry this clay in a drier working at about 100 degrees to 120 degrees F. if 20 per cent of sand were added, but the sand would have to be brought from some distance for this purpose. The following table gives the results of tests made on samples of these clays. No sand was added.

	32 %	33 %	34 %
Water required for mixing	25·0	25·0	30·0
Drying shrinkage	6·0	7·0	8·5
Cone 010			
Fire shrinkage	0·0	0·0	0·7
Absorption	14·2	14·8	17·0
Cone 06			
Fire shrinkage	0·4	0·0	0·7
Absorption	13·3	14·0	17·0
Cone 03			
Fire shrinkage	3·4	3·0	7·0
Absorption	4·8	7·7	3·0
Cone 1	vitrified	softened	softened

No. 32 is an average of the 9-foot bank used in brickmaking. It contains a small percentage of the blue bottom clay.

No 33 is selected from the bed of strong brownish clay which lies between the upper loamy clay and the blue clay.

No. 34 is the bottom blue clay.

Nos. 32 and 33 have good plasticity and working qualities; but No. 34 is rather silty and works up into a sticky and rather flabby body, which is hard to mould, especially for hollow tile.

The brick mixture burns to a fine red, nearly steel hard body with a good ring at cone 010. Better results in colour and density of body are obtained by burning to cone 06. The colour becomes a fine dark red, and the body nearly impervious when burned up to the temperature of cone 03.

Some samples of 3-inch field drain tile were made from 32 and 33 in a hand screw press. The good working qualities of the clays were apparent in this process, the pipe issuing smooth and straight through the die. These tile were strong and structurally sound when burned to cone 07. These tests show that if the clay is well prepared, carefully handled, and hard burned, an exceptionally good field drain tile could be produced here.

The clays are not suitable for the manufacture of dry-pressed brick or vitrified wares.

An extensive plant owned by a company known as the Crown Pressed Brick company, was erected at this locality some years ago, but has since been abandoned. It was equipped with machinery for making soft-mud and dry-pressed brick, steam drying tunnels, 4 multiple stack down-draft kilns, and 5 permanent wall up-draft kilns.

The expensive steam drier was a failure as this clay cannot be forced in drying without serious loss. It requires the addition of 15 to 20 per cent of sand before even moderately fast drying could be accomplished with safety. The brick in the fine group of buildings of Macdonald College at Ste. Anne were made at Ormstown.

The following chemical analysis of the brick clay at Ormstown was made from an average sample taken at Mr. Alex. Mills' clay pit:

Silica	62·17
Alumina	19·34
Iron oxide	4·0
Lime	4·14
Magnesia	2·90
Alkalis	not determined
Sulphur trioxide	0·18
Loss on ignition	4·35

ST. JOHN COUNTY.

The greater part of this county is an almost absolutely level plain underlain by marine clay. This clay is in evidence at the surface over large areas; but in a few places slight rolls on the surface indicate the presence of sand and gravel. The clay is 41 feet in thickness at L'Acadie station on the Canadian Pacific railway and about 30 feet at the Standard Clay Products company's plant. Fossil marine shells are abundant from 6 to 10 feet below the surface at L'Acadie, where the clay is reddish instead of the usual grey colour.

St. John.

The surface clay is extensively used at the works of the Standard Clay Products company, situated on the Canadian Pacific railway about one mile west of the town of St. John (Plate XXII, A).

The surface clay is mixed with a certain percentage of fireclay imported from the State of New Jersey, and manufactured into sewer-pipe. Some ground waste pipe is added to the mixture to reduce the shrinkage. The clay is loosened on the surface with disc harrows, then gathered into piles with scrapers (Plate XV, A). It is then shovelled into carts, hauled to storage sheds, and allowed to dry. The surface clay is mixed with fireclay and tempered in wet pans. The tempered mixture of clays is hoisted to the sewer-pipe presses and made into the various sizes of pipe. Special shapes like elbows and branch joints are made by hand in plaster moulds. The pipe, when taken from the press, are placed to dry on the floors of the factory. They are burned in round down-draft kilns, and salt glazed in the usual manner at a temperature of about cone 2 (2138 degrees F.).

The products of this factory are widely distributed, shipments being made even west of Winnipeg. A large number of pipe are sold in Toronto, but the principal part of the output goes to Montreal and Ottawa.

A sample of clay was collected at this work for the purpose of testing. It is the ordinary grey or drab, highly plastic variety which occurs so widespread in this region. It is exceedingly fine grained and smooth when wet, all passing through a sieve of 200 meshes to the inch.

The chemical analysis (by W. S. Bishop) is as follows:

Silica	60·20
Alumina	21·68
Iron oxide	4·05
Magnesia	2·80
Lime	2·00
Potash, Soda	3·32
Loss on ignition	3·97

In the physical tests it requires 27 per cent of water in order to bring it to a working consistency. It is stiff, highly plastic, and pasty in the wet condition. Its drying qualities are poor, and although it may be dried very slowly, it will crack badly if the drying is hastened. The drying shrinkage is 8 per cent. This clay burns to a light red, steel hard body at cone 010, with a fire shrinkage of 1·5 per cent, and an absorption of 12·4 per cent. When burned to cone 03 the fire shrinkage is 6·6 per cent, the colour dark red or brown, and the body is vitrified. It softens at cone 1 and fuses at cone 2.

Owing to its fineness of grain and the amount of fluxing impurities it contains, this clay does not stand a high degree of heat, and is not suitable for the manufacture of vitrified wares. When mixed with about one-third its weight of fireclay, it is used for sewer-pipe. The fireclay assists in the drying, and during the burning it acts the part of an infusible skeleton or stiffener in the body of the pipes, so that they hold their shape and do not deform or soften under the temperature necessary to produce salt glazed wares. The sewer-pipe made at this plant have a reddish vitrified body, generally sound and free from cavities, covered with a uniform dark brown glaze.

An abandoned brick plant is situated at the intersection of the two railway lines, a short distance west of the town. This plant was built for the manufacture of common building brick, but, owing to the defective drying qualities of the clay, operations did not continue very long.

If a mixture of two parts clay and one part sand is used, this clay may be used for brick, as the sand will prevent cracking and reduce the shrinkage to working limits. There is no sand available in the vicinity of this plant.

A series of tests showing the effects of additions of small quantities of lime, dolomite, and talc schist to this clay are given in a separate chapter. These tests are of importance to manufacturers of fireproofing or hollow building blocks, brick, or tile.

MISSISQUOI COUNTY.

Most of the western part of this county consists of hills, higher in elevation than the levels at which the stratified stoneless clays are generally found. The deeper valleys among the hills contain terraced remnants of stratified deposits, but these are generally of sand and gravel. The eastern portion of the county, which is comparatively low in elevation, is generally underlain by boulder clay with sand or gravel patches, the stoneless stratified clay being rarely met. The adjoining counties to the east, Iberville and Rouville, contain larger areas of clay lands; but these are low lying counties and part of the plain of the St. Lawrence valley.

Farnham.

The materials found along the west bank of the Yamaska river below this town consist of stony glacial clays, a thin layer of stoneless stratified clay and sandy loam, making a total thickness exposed of 10 to 12 feet. There appear to be two different glacial clays, one at the bottom of the section containing large stones, and an upper one, which is tough, compact, dark grey clay containing small pebbles and much coarse grit but no boulders.

A small sample of this clay was tested with the following results: the clay was very gritty and contained some small pebbles but, when tempered with 18 per cent of water, gave a fairly plastic body with good drying and working qualities. The drying shrinkage was 3·6 per cent.

The clay burned to a light red colour and good hard body at cone 010, the absorption being 14·5 per cent. The clay contains many particles of lime, and the test pieces after burning to this temperature, crumbled on exposure to air. If burned to cone 03, a steel hard body is produced, and the higher temperature of burning renders the lime particles harmless because they are partly fused into the surrounding clay. Brick burned to this temperature are perfectly safe to use. The clay softens at cone 1 and melts at cone 2.

The material will make good building brick without the addition of sand. Some machinery for crushing the pebbles must be used, and down-draft or continuous kilns provided in order to get hard brick.

There was a small brick plant in operation some years ago, about 1½ miles northwest of the town, between the line of the Central Vermont railway and the Yamaska river, but no brick have been made recently.

The material used was a highly plastic brown or grey surface clay, similar to that at St. John already described. This clay overlies stony glacial clay and does not appear to be of any great thickness.

VERCHÈRES COUNTY.

The surface of this county is an almost perfectly level, clay plain, bordered by the St. Lawrence river on the east and the Richelieu river on the west. Occasional slight swells on the surface indicate the presence of strips or patches of gravel and boulders; but for the most part a stiff, brownish clay without pebbles lies immediately under the layer of soil.

Varennes.

A very extensive brick plant was erected at Varennes during the summer of 1913 by the Mount Royal Brick company. This plant is equipped with the most recent improvements for handling clays and clay wares. It is designed for a large output of wire-cut brick to supply the demand of the builders in Montreal.

Two stiff-mud machines with double stream, end cut dies, waste heat dryers to accommodate 1,250,000 brick, and Haigh kilns with removable tops constitute the principal equipment. The capacity of the plant is supposed to be from 300,000 to 500,000 brick per day.

The buildings are situated on the line of the Quebec, Montreal, and Southern railway, near Varennes station, about 20 miles east of Montreal. Borings were made by the company in the vicinity of the plant to a depth of 24 feet, all in clay, without reaching the bottom of the deposit.

The upper 3 or 4 feet of clay is brownish in colour due to surface weathering; underneath it is bluish grey. The deposit is massive in structure, there being scarcely any indication of stratification, but vertical jointing is pronounced in the upper part. It contains no pebbles, nor fossil shells, although it is probably a marine deposit.

A sample of this clay was taken for testing purposes. When dried and ground it requires 32 per cent of water for tempering. It then forms an exceedingly plastic, soapy, stiff mass which is hard to work. It shrinks greatly in drying, and cracks badly even in room temperature of 65 degrees F.

A mixture, of 2 parts clay and one part sand, was made up into standard brick size. The sand reduced the shrinkage, but the brick cracked in slow drying at 65 degrees F.

As it seems impossible to work this clay even with the addition of 33 per cent of sand, some experiments were made in order to determine if the clay could be made workable by the pre-heating treatment. The results of these tests are given in a later chapter.

RICHELIEU COUNTY.

This county, like Verchères, is an absolutely featureless plain for the most part, the surface being underlain by clays and sands. There are some large areas of sand along the line of the Quebec, Montreal, and Southern railway, and along the banks of the Richelieu river near Sorel. The dredges working on the St. Lawrence river opposite the mouth of the Richelieu have worked in a sand bottom to a depth of 30 feet. The clay deposits are worked at various points along the banks of the Richelieu river, small plants for the manufacture of common red brick being located at St. Roch, St. Ours, and Sorel. No tests were made of these clays, but they are similar to those in the adjoining counties already described.

YAMASKA COUNTY.

The sands and clays are about equally distributed over the level surface of Yamaska county. There are large areas of sand between the Yamaska and St. Francis rivers, while clay lands are more widespread between the St. Francis and Nicolet rivers.

The most complex series of Pleistocene deposits observed in the province are exposed on the banks of the St. Francis river for several miles above Pierreville. The river and its small tributary stream have cut deep, steep-sided trenches through these deposits, to a depth of 60 feet in places (Plate XV, B). There are several deposits of stoneless clays included in these sections (Figure 8) which vary from massive highly plastic kinds to lean, or sandy, stratified varieties. These clays vary considerably in regard to their working and drying qualities; but they are alike in so far that they are only suitable for the manufacture of common red building brick or field drain tile. Some of these clays are covered with a great thickness of drift and are out of reach for working, while others are exposed on the surface. The presence of an upper and lower boulder clay, separated by stratified clays, seems to indicate that there were two periods of glaciation in this region. Whether these two deposits were formed

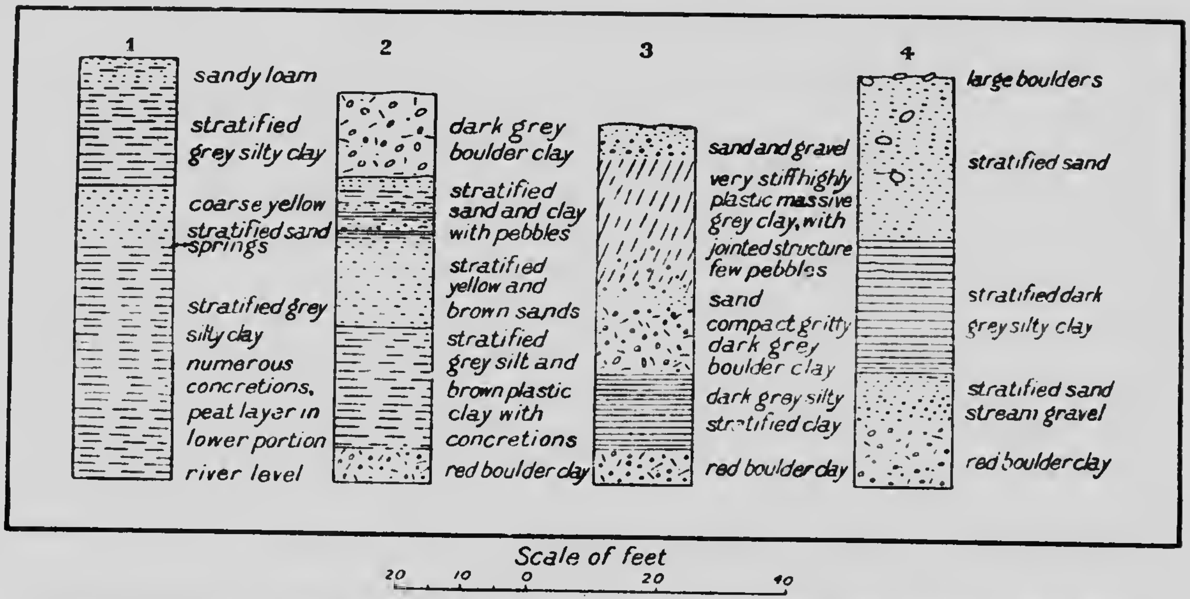

Figure 8. Sections of Pleistocene deposits on St. Francis river, Yamaska county, from river level to top of bank.

1. About 1 mile south of Pierreville.
2. Near mouth of Rivière-aux-Vaches.
3. About 4 miles south of Pierreville.
4. About 5 miles south of Pierreville.

by two advances of the same ice sheet, or by two ice sheets
different origin, was not determined. The lower boulder c
partakes of the character of the bedrock on which it rests, be
red in colour over the red Medina shale, while the upper st
clay is usually dark grey in colour.

St. François-du-Lac.

There are two small brick-yards in operation on the w
side of the St. Francis river about a mile south of St. Franç
du-Lac station on the Quebec, Montreal, and Southern railw
These are owned respectively by E. Mondon and Louis Cote.

The clay used by M. Mondon is excavated from the side
a small stream and elevated to the plant on top of the ba
The section exposed on the bank shows 15 to 20 feet of stratif
bluish grey clay, overlain by an oxidized or rusty portion abou
feet thick, which contains thin streaks and layers of limon
The clay is mixed with some sand for brickmaking, but it s
gives trouble in drying, being liable to crack in warm dry win
Only soft-mud brick are made at this plant. These are bur
in a scove kiln with wood obtained in the neighbourhood.

The brick-yard owned by Mr. Cote is placed at the b
of a bank of grey stratified rather silty clay (Plate XVI,
The material is broken down convenient to the machine, a
easily handled as required. The machine is operated by ho
power, the brick are hacked out on the ground to dry, and burn
in a scove kiln. Most of the output of these two plants, wh
is about 1,000,000 to 2,000,000, annually, is shipped to Montre

Pierreville.

A sample of clay was collected from an unworked depo
about 1 mile south of the village of Pierreville. The clay
exposed in a gully near the roadside; it has no overburden a
its colour is light grey when dry. There are no stratified lay
in the deposit, but vertical jointing is pronounced (Plate IX) a
it appears to be free from pebbles.

This clay requires 32 per cent of water for tempering; it was very plastic, hard to work, and rather sticky, although it contains a large amount of fine grit particles. It cracks slightly in slow drying, with an air shrinkage of 8·5 per cent. It burns to a hard red body at cone 010, with a fire shrinkage of 1 per cent and an absorption of 16·5 per cent. If burned to cone 03 the shrinkage is excessive, and the body vitrified. It softens and deforms at cone 1.

The addition of 25 per cent of sand makes this clay easier to work and to dry. The sand also reduced the air shrinkage to 6·5 per cent, and the fire shrinkage at cone 010 to zero. Samples of 3-inch drain tile were made from this mixture in a handscrew press. This clay, being sticky, did not work smoothly through the die, so that it was rather rough in appearance. Owing to the stiff qualities of this clay it would be difficult to mix in the sand uniformly, unless the clay was thoroughly mixed in a long pug-mill before passing into the machine.

Yamaska East.

A small brick plant at this locality is making common red brick from a stratified bluish clay which occurs on the east bank of the Yamaska river. About 15 feet of clay in the upper part of the bank is used. The clay is interlaminated with sandy layers, and overlain by 2 or 3 feet of sand. On account of the frequent heavy rains during the season of 1912, the clay in this bank was too wet for proper moulding, so that the brick had a tendency to deform when dumped from the moulds to the drying floor. Silty clays of this kind do not hold their shape or stand handling so well as the more plastic, stiff varieties, especially when they contain an excess of water.

NICOLET COUNTY.

A considerable area of the southwestern portion of this county is underlain by clay. The banks of the river near the town of Nicolet, which are about 50 feet high, are composed almost entirely of clay, only the upper 2 or 3 feet being sand or loam. The various sections of clay, seen on the banks of the Nicolet and Becancour rivers and in the smaller streams, all show a similar grey to brownish, massive, stiff, and sticky clay without stratification in the upper part, but strongly marked by vertical jointing. It is of uniform character throughout, and as far as could be seen appears to be entirely free from even the smallest pebbles. No fossils were seen in this clay, but it is probably of marine origin.

A sample was taken for testing from the banks of the Nicolet river, north of the railway bridge. A small brick plant was operated here some years ago, but no brick have been made recently in this vicinity.

This clay requires 32 per cent of water to bring it to a working consistency. It is very plastic, somewhat sticky, and hard to work on account of its stiffness. Its drying shrinkage is 9 per cent, which is too high, and its worst defect is cracking in drying.

The clay burns to a light red steel hard body at cone 010 with a fire shrinkage of 1·5 per cent and an absorption of 14·8 per cent. If burned to cone 03, the colour is brown, the body vitrified, but the fire shrinkage is 10 per cent, which is excessive.

This clay would require the addition of an equal weight of sand before it could be worked for brickmaking, but this amount of sand would weaken the body too much, unless the brick were hard burned. The underburned brick would be useless.

This clay may be used for the manufacture of field drain tile, in a mixture of two parts clay to one of sand, as on account of the comparatively thin walls of this class of ware they could be dried more safely than brick.

Samples of 3-inch round tile made from this mixture were smooth and sound in structure, being hard when burned to cone 010, and better when burned to cone 06.

A sample of clay which overlies the Medina shale on the bank of the Nicolet river at Ste. Monique, gave practically the same results as the one from Nicolet.

LOTBINIÈRE COUNTY.

The greater part of this county lying between the Intercolonial railway and the St. Lawrence river, is a featureless plain, with sand, gravel, clay, or peat underlying the surface.

There is an extensive body of stratified clay exposed in high banks along the St. Lawrence river between Point Platon and the eastern border of Nicolet county, a distance of about 16 miles. It could not be ascertained how far this deposit extends inland, as an overburden of sand or gravel becomes very great at a short distance from the river.

Deschaillons.

A large part of the common brick industry of Quebec is centralized at this point, about 15 individual plants being located along a narrow strip between a high clay bank and the St. Lawrence river (Plate XVI, B). The total height of the bank varies from 75 to over 100 feet, being made up of stratified clay and sand, carrying boulders in the upper part. A generalized section showing the arrangement of these deposits is given in Figure 9.

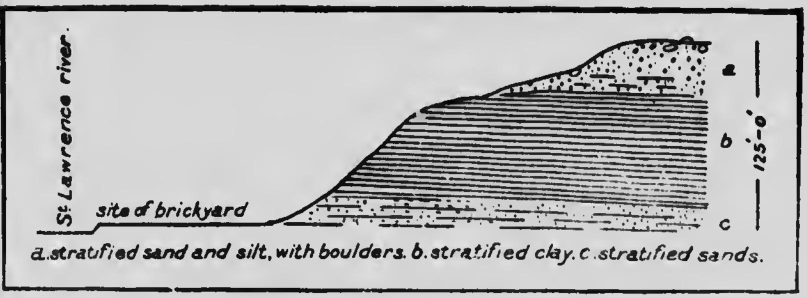

Figure 9. Section of Pleistocene deposits at Deschaillons, Lotbiniere county.

The clay is well stratified in layers about one-half inch in thickness, with thin films of sand or silt between. The colour is bluish grey in the lower part, while the layers in the upper part are brownish red, with ash coloured films of silt between them. The clay part of the deposit appears to be entirely free from pebbles. The sand which underlies the clay (Plate VII, A) is oxidized, rather coarse in grain, well stratified in definite layers, and sometimes cross-bedded.

The clay is entirely different in character, and appears to have a different origin from any of the low level clays so far described on the south side of the St. Lawrence. The following tests were made on samples collected from this locality; no sand was added to the clays in making these tests.

The lower blue clay (Lab. No. 74) required 30 per cent of water for tempering. It worked into a rather flabby body of low plasticity. The drying shrinkage was 7 per cent.

The upper brownish or red clay (Lab. No. 75) required 25 per cent . water. Its plasticity is better, and it forms a rather stiffer wet body, easier to handle, than the blue clay. Its drying shrinkage is 6 per cent. Both clays will stand fast drying in a temperature of 150 degrees F., and the brick can be dried in 24 hours. This is an advantage which few of the Pleistocene clays in Quebec possess.

The results in burning are as follows:

No.	Cone	Fire shrinkage %	Absorption %
74	010	1·7	18·2
	06	2·0	16·6
	03		0·0
	1	softened	
75	010	1·0	16·6
	06	1·5	13·2
	03	9·7	0·0
	1		

These clays are among the best common brick materials in the province; they burn to a hard red body, with a good ring, at cone 010, becoming denser and deeper in colour if burned to cone 06.

The upper clay will make good field drain tile if burned hard, the samples of tile made in the laboratory being satisfactory in every respect. The bottom blue clay is not recommended for this purpose.

The chemical analysis made from equal parts of the upper and lower clay is given below:

Silica	61·9
Alumina	21·08
Iron oxide	5·72
Lime	3·62
Magnesia	2·44
Potash, Soda	0·32
Sulphur trioxide	0·12
Loss on ignition	3·39
Moisture	1·00

For use in brickmaking, the upper and lower clays are broken down by hand from the bank, and dumped into soak pits; a small quantity of sand, and sufficient water for tempering, are added. The clay is left overnight in the soak pits, and then wheeled direct to the brick machines in hand barrows. No rolls nor pug-mills are used for further mixing and tempering the clay. As the green brick come from the machine they are hacked out on the open level spaces provided for drying (Plate XVI, B). During good weather in summer the drying is completed in 5 days. The bottom blue clay shrinks more in drying, if used alone, than the upper brown clay, so that a larger sized mould is required when a mixture with an excess of blue clay is being used. The burning is done in scove kilns, the fuel used being the soft woods, hemlock, spruce, and tamarack, obtained from Gentilly. The soft wood is preferred to the hardwood as it gives a longer flame, and the heat reaches to the top of the kiln more readily.

About 15 individual plants make from 15,000 to 20,000 brick per day, each, during the working season, which lasts from the end of April to about October 1. After this date weather for drying cannot be depended on.

The entire output of this locality goes up the river to Montreal and Three Rivers in schooners, the cost of carriage being $1.75 per thousand.

A good quality of common red brick made by the soft-mud process is produced, but the product could be improved by working up the clay in pug-mills and passing it through rolls. This would give a stronger brick, and one of better appearance.

RICHMOND COUNTY.

This county lies wholly within a hilly upland region, with surface deposits consisting principally of boulder clays, sands, and gravels. Small areas of clay comparatively free from pebbles occur in places on the higher terraces along the St. Francis river (Figure 10).

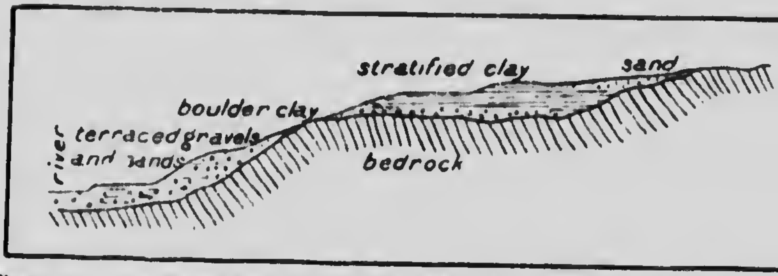

Figure 10. Type of high level clay deposit at Ascot and Lennoxville, Sherbrooke co

Richmond.

A clay deposit of this kind, worked for brickmaking by M. Proulx, is situated on a terrace at an elevation of a few hundred feet above the town of Richmond. This deposit differs from any surface clay so far examined in the province. It appears to be mostly of glacial origin, and the materials which go to make it up are of varying thickness and irregularly distributed. The following is a generalized section:

	Feet	Inches
Top soil	0	6
Brownish glacial gritty clay	2	6
Sand	0	6
Greenish grey silty clay	1	0
Reddish brown glacial clay	3	0
Stratified bluish grey clay with concretions	20	0 (?)

The brownish glacial clays contain angular particles of schist from the surrounding country rock as well as some small rounded pebbles.

The clay deposit is worked down to the top of the blue clay, but the latter is not used as it contains numerous rounded concretions which are very hard and resemble pebbles.

The material used makes a very fair red building brick. The harder ones give a good ring when struck together. Most of the brick manufactured here are shipped to Montreal. The product of this plant could be improved by passing the clay through rolls, so as to break up the clay lumps, and pulverize the pebbles. A portion of the bottom blue clay could also be used if it were passed through rolls, to expel or crush the concretions.

SHERBROOKE COUNTY.

The superficial deposits which occur in the hilly upland region included in this county are mostly composed of boulder clay, sands, and gravels, the stoneless clay deposits being generally of small extent. An examination of the materials in the vicinity of the city of Sherbrooke failed to reveal any large workable deposits of clay, although a few small patches were seen of a character similar to those indicated in Figure 10. Between the Canadian Pacific Railway station and the railway bridge over the Magog river, a bed of dark grey, gritty stratified clay about 3 or 4 feet thick, overlying boulder clay, occurs on the south side of the track. The clay contains several fragments of schist derived from the neighbouring rocks, and a few scattered small rounded pebbles. When ground and tempered with 19 per cent of water, this material makes a good working body of fair plasticity. It dries rapidly, with a shrinkage of 5 per cent, and behaves in burning as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	12·5	red
06	1·0	9·0	deep red
03	4·7	4·0	brown
1	softened		

This material makes an excellent brick, with good red colour and steel hard body at cone 010. When burned to cone

06, a hard dense brick suitable for sewer linings or any underground work could be produced. The clay would require to be passed through rolls to pulverize the pebbles; but the deposit appears to be of small extent and not of economic value.

Lennoxville.

The brick plant of the Eastern Townships company (Plate XVII, A) is situated at Webster siding on the Canadian Pacific railway about 1½ miles from Lennoxville. It is one of the more important plants manufacturing common brick in the province. The clay deposit worked at this point is situated in a hilly upland district, at an elevation which is near the highest limit of brick clays in the region.

The clay deposit consists of two divisions, an upper part which is weathered to a brownish or rusty colour, about 9 to 12 feet in thickness, and a lower dark grey portion. This clay is stratified throughout, in layers from one-half to one inch in thickness, with films or thin layers of sand between. The upper part appears to be free from pebbles, but the lower part carries numerous stony concretions.

The entire deposit is about 35 feet thick. It is overlain by a few feet of sand and gravel, and underlain by boulder clay or bedrock. The sketch section shown in Figure 10 shows the relations of these materials.

All the upper portion and about 2 feet of the lower are used for brickmaking. The bank is excavated with a steam shovel an dumped into cars running on rails to the machine house. The brick are dried, in 48 hours, in a radiation drier, the temperature of which varies from 120 degrees F. at the cool end to 190 degrees F. at the hotter end.

The burning is done in a continuous kiln using producer gas as fuel. This was the first kiln of the kind erected in Canada, and up to the present is the only one in use in the province of Quebec. Provision is made at this plant for storing clay for use when the bank is frozen or when in too wet a condition for moulding.

The following tests were made of a sample of the clay. It was an average sample of the portion of the bank used for brickmaking. It required 24 per cent of water to bring it to a working consistency. Its plasticity is only medium, and, owing to its sandy or silty character, the wet body is rather flabby, especially if a slight excess of water is added. The clay stands fast drying without checking, the shrinkage in drying being 5 per cent. It burns to a light red porous but hard body, with a good ring, at cone 010, without any fire shrinkage, and an absorption of 16·4 per cent. When burned to cone 06 the fire shrinkage is 1·4 and the absorption 13·6 per cent. A good red building brick is produced at this temperature, which is about the commercial limit of burning for this clay.

The only product made by this plant is soft-mud brick; these are lighter in colour than usual. It is probable that the gas firing does not produce as dark colours in some clays, as the direct coal firing. The brick from the upper part of the chambers in the continuous kiln are the best, the ones in the lower portion are often underburned.

Some experiments made with this clay show that it will make a sound, hard field drain tile. The quantity of water in the clay must be carefully adjusted, and only the upper portion of the bank used for this purpose. The tile should be burned to cone 06 or about 1850 degrees F.

Ascot.

The brick plant of Mr. M. E. Loomis is situated at this point. The clay deposit, worked for brickmaking (Plate XVII, B), is situated on a high terrace overlooking the St. Francis river. The clay occurs in stratified layers which are frequently interlaminated with layers of sand or silt. It appears to be free from pebbles. The upper part of the deposit is of a yellowish and brown colour, which is mostly due to weathering, the lower part is prevailingly grey. The thickness of the clay varies from 10 to 35 feet; it is underlain by gravels and bouldery clay, and carries an overburden of 1 to 3 feet of yellow sand.

The occurrence is of the general type of high level deposits, a sketch of which is shown in section under Figure 10.

A sample of the upper clay collected at this locality was tested with the following results. It requires 26 per cent of water to bring it to a working consistency, and works up easily into a fairly plastic wet body, but becomes flabby with a slight excess of water.

The clay will stand fast drying. The drying shrinkage of small pieces was 6 per cent, but a full sized brick showed a shrinkage of only 4 per cent. This clay burns to a good red, almost steel hard body at cone 010 without any fire shrinkage, and an absorption of 16 per cent. If burned to cone 06 the fire shrinkage is 3 per cent and the absorption 10 per cent. This clay becomes overfired, with an excessive shrinkage at cone 03, and begins to soften below cone 1. The best commercial results seem to be obtained at about cone 08, a little higher than 1800 degrees F.

This deposit is of a character similar to that near Lennoxville but is not quite so silty; consequently it burns to a denser body at lower temperatures. The clay in the upper part of the deposit is suitable for the manufacture of field drain tile.

The plant at this locality manufactures common red brick by the soft-mud process, the output being 40,000 per day. The clay is more carefully prepared for moulding than usual, being passed through a pug-mill and a pair of rolls before entering the machine. The brick are dried in 3 days in an artificial drier, working from 100 degrees to 140 degrees F. The burning is done in a continuous kiln of 16 chambers with a capacity of 30,000 each (Plate XVII, A), and is the only coal fired, continuous kiln used for burning soft-mud brick in the province at present. The results obtained are good both in colour and hardness, the product being one of the best of its class in this market. The brick are shipped to the cities of Montreal, Quebec, and Sherbrooke. This plant operates for about 8 months of the year; a large quantity of surplus green brick are piled in storage during the summer operations, and burned in the late autumn when the clay bank is too wet for proper working.

COMPTON COUNTY.

Angus.

Dr. Chalmers gives an account of an interesting section of Pleistocene deposits which occurs in a cutting on the Quebec Central railway about 3 miles east of Angus station.[1]
The series in descending order is as follows:

	Feet
Gravelly boulder clay containing glaciated boulders...	3 to 5
Fine, highly plastic, stratified grey clay............	12 to 15
Boulder clay, thickness unknown.	

The facts given in this section seem to favour the view of an interglacial period between two glaciations.

Deposits of boulder clay overlying stoneless brick clays are unusual in the province, but they do occur at a few localities, already noted in this report. As the investigation proceeds, it is probable that more examples will be found.

BEAUCE COUNTY.

The clay deposits of this county are generally found in detached areas or patches, in the river terraces along the wide valley of the Chaudiere, and on a few of its principal tributaries. The greater portion of the terraces, however, are formed of sand, gravel, or boulder clay. A section of a terrace near the mouth of Rivière-du-Loup shows boulder clay in two divisions with stratified stoneless clay between (See Figure 6).

The clays which occur along the Chaudiere valley are very similar to those already described as worked for brickmaking at Ascot and Lennoxville. Small quantities of common brick are made from them at Scott Junction on the Quebec Central railway, and at St. Victor-de-Tring, farther south on the same line.

St. Joseph-de-Beauce.

An examination was made of an unworked deposit situated about 2 miles south of the village of St. Joseph or about 7½ miles

[1] Chalmers, R., "Surface geology and auriferous deposits of southeastern Quebec": Part J, Ann. Rept., Vol. X, p. 44.

south of Beauce Junction, and on the property of Mr. T. J. Doyen. A terrace to the east of Mr. Doyen's house is cut by a small stream which exposed a face about 40 feet in height (Plate XVIII, A) consisting of 1 to 3 feet of yellow sand and gravel overlying stratified clay, the latter apparently resting on the slate bedrock exposed in the stream bottom.

The clay is weathered to a brownish colour in the upper part, but is of the usual blue colour below. It is horizontally stratified (Plate VIII) with thin films or layers of sand and silt alternating with the clay layers. Some of the clay layers are of original reddish brown colours, which are not due to oxidation or weathering. No pebbles were observed in the deposit, but numerous, perfectly shaped, rounded, stony concretions are scattered through it.

Two samples of clay were selected for testing, one representing the upper 15 feet, the other being an average of the lower 20 feet. No concretions were included in the samples. The upper clay requires 29 per cent of water to bring it to a working consistency. It is fairly plastic and smooth, but is easily made flabby by a slight excess of water. The clay will stand fast drying, with a shrinkage of 6 per cent. It burns to a light red colour and fairly hard body at cone 010, the fire shrinkage being about 2 per cent, and the absorption 15 per cent. If heated up to cone 06, the body is denser, but the shrinkage becomes too great. The clay is overfired at cone 03, and softens at cone 1. It would be suitable for common brick made by the soft-mud process, and possibly for field drain tile. Owing to its very silty or sandy character the lower clay does not work up as well as the upper. It is low in plasticity, the wet body being flabby and hard to mould. It burns to a pale red, rather soft body at cone 010, with the high absorption of 20 per cent.

The numerous stony concretions render this clay almost useless; and, even if these were crushed, the lower clay which carries the more concretions is not of much value for brickmaking purposes.

BELLECHASSE COUNTY.

Marine clay occurs in terraces along the valley of the Boyer river in the vicinity of St. Charles. This clay appears to be confined to the lower levels of the river valley, and is not seen on the ridge to the north along which the Intercolonial railway runs, nor on the ridge south of the river.

The terraces along the Rivière du Sud valley, both in Bellechasse and Montmagny counties, appear to contain clays, but no examination of them was made.

St. Charles-de-Bellechasse.

A sample of clay was collected from a cutting on the south side of the highway bridge over the Boyer river about a mile east of St. Charles station. It is a massive blue clay, with a brownish weathered upper part, free from pebbles, and contains a layer with fossil shells, about 12 feet below the surface. This clay requires 27 per cent of water for tempering; it is exceedingly plastic, very stiff, and rather sticky and smooth. It has a high drying shrinkage, 8 per cent, and cracks in drying even when this operation is done slowly. Even with the addition of 33 per cent of sand, this clay will not stand fast drying without cracking.

The following table gives the results obtained in burning. No. 128 is the clay alone, No. 128 A is a mixture of two parts clay to one part sand:

	128 %	128 A %
Water required	27·0	19·0
Drying shrinkage	8·0	5·5
Cone 010		
Fire shrinkage	0·0	0·0
Absorption	15·0	11·0
Cone 06		
Fire shrinkage	0·7	0·0
Absorption	14·0	10·0
Cone 03		
Fire shrinkage	7·6	4·6
Absorption	0·0	3·4
Cone 1	Softened	

The addition of 33 per cent sand makes the clay much easier to work and dry, and also reduces the shrinkages. It is unfortunate that this material has defective drying qualities, otherwise it would make a very good common brick. It is possible to use it with the above quantity of sand, so that it could be dried carefully outdoors on racks and pallets. The red colour is good and the body hard when burned to cone 010.

This clay would be useful for adding to the red shale in this vicinity, to supply the plasticity for working which alone the shale lacks. This use is referred to later.

Field drain tile can also be made from this clay with the addition of sand. The samples made in the laboratory, using 20 per cent of sand, were satisfactory, but the shrinkage was rather high.

The following chemical analysis was made from the sample of clay collected at St. Charles:

Silica	60·70
Alumina	18·10
Iron oxide	6·61
Lime	3·06
Magnesia	2·72
Potash / Soda	1·90
Sulphur trioxide	0·10
Loss on ignition	4·71
Moisture	1·92

L'ISLET COUNTY.

The clay deposits of this county were only examined at L'Islet station on the Intercolonial railway, where common red brick are made at three plants.

The clay of this locality as seen in the pit worked by La Compagnie de Brique de L'Islet, differs from any deposit so far examined in the province. The following sketch shows a section at their pit (Figure 11).

The bottom clay is a highly plastic, tough, fine-grained reddish clay, without jointing or bedding. The stones embedded in it are small round boulders, probably dropped from floating ice, but there do not appear to be any gravel pockets or layers, such as generally occur in clays under such circumstances. The upper surface of this deposit is uneven; it appears to have been eroded before the deposition of the upper stratified clay.

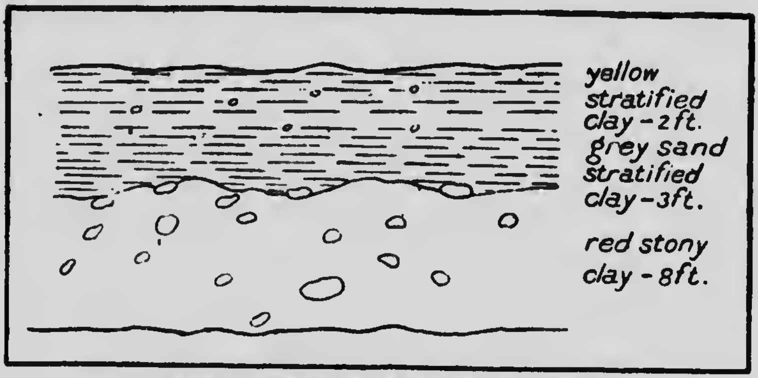

Figure 11. Section of clay deposits at L'Islet.

The upper deposit contains sandy and silty layers interstratified with clay, and a few small scattered pebbles. It resembles a flood-plain deposit. The upper 2 or 3 feet is weathered to a brownish colour while the lower part is bluish grey.

The whole of the bank is used in brickmaking, the different clays being mixed in the proportions in which they occur. The larger stones are separated out by hand picking and no sand is added.

A sample of the mixture of clays was taken for testing. It requires 21 per cent of water to bring it to a working consistency; its plasticity and working qualities are good. The sample was ground to pass a 12 mesh sieve, and any pebbles that were present were also pulverized to this degree of fineness; consequently this test represents a clay which is far better prepared than it would be in practice. The clay appears to have good drying qualities, with a drying shrinkage of 5 per cent. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	13·0	light red
06	0·6	12·0	red
03	6·7	0·0	dark red
2	fused		

If it were free from pebbles, this would be one of the bes brick-clay deposits in the province. It burns to a hard red body with good ring when struck, at cone 010, the shrinkage and al sorption being low. If burned to cone 06 or higher, in down-dra kilns, the brick could be used for sewer linings or undergroun work.

The clay when ground works smoothly through a die an makes an almost perfect round tile, which is sound and stron when hard burned.

The plant of La Compagnie de Brique de L'Islet is bett equipped with machinery than most of the smaller plants in th province. The clay is prepared for moulding by passing through a pair of rolls which break up the pebbles, and the through a long pug-mill which disintegrates the clay lump The brick are dried on racks and pallets, this operation requi ing 6 days under favourable conditions. The clay appears have good drying properties, but the manager states that th green brick are sometimes cracked if a hot dry wind comes contact with them. Pebbles are often the cause of cracking drying, and the finer these are ground the easier the brick a to dry safely.

The clay is a difficult one to deal with owing to pebbles an the tough character of the lower red clay; and, unless great ca is taken in its preparation, too many pebbles and clay lumps a allowed to pass into the finished brick. These are a source weakness in drying and burning, reducing the quality of th finished brick very seriously. This company, however, succeed in producing a fairly good sound building brick, which will com pare favourably with any other make of soft-mud brick in th province. The difference due to the preparation of the clay apparent by an inspection of the brick produced at other plants in this vicinity where no rolls or disintegrators are used.

About 8,000,000 brick are produced annually by the three plants at this locality. These go principally to the cities of Quebec and Montreal. The working season lasts from May 20 to October 20.

TEMISCOUATA COUNTY.

Rivière-du-Loup.

A small plant making soft mud-brick was in operation at this locality until a few years ago. It was situated near the Temiscouata railway bridge, which spans the river about a mile southeast of the station. The material worked consists of a thin deposit of red and grey silty clay, overlain by sand or gravel, and underlain by boulder clay. Owing to the sandy character of the clay the brick made from it are rather soft and porous. Many pebbles were also allowed to pass into the finished brick, which caused cracking in drying and burning.

The abandoned plant stands on the flood-plain of the river, which is not a favourable site, as the drainage is bad and the clay pits become flooded.

Trois Pistoles.

Sir William J. Dawson states in his book on the Canadian Ice Age: "At this place one of the most complete and instructive sections of the Pleistocene in Canada has been exposed by the deep ravine of the river, and by the cuttings for the Intercolonial railway. In the deep railway cutting a bed of homogeneous clay is exposed, of a purplish grey colour, containing a few fossils of *Leda glacialis*. Its thickness in the lower terrace can scarcely be less than 120 feet. Under the Leda clay a typical boulder-clay has been exposed at one place in digging a mill sluice. It seemed to be about 20 feet thick, and rests on the smoothed edges of the shales of the Quebec group.

"Though the Leda clay at the Trois Pistoles seems perfectly homogeneous, it shows indications of stratification, and holds a few large Laurentian boulders, which become more numerous in tracing it to the westward. A short distance west of Trois Pistoles, it is seen to be overlaid by a boulder deposit, in some places consisting of large loose boulders, in others approaching the character of a true boulder clay or associated with sand and gravel."

RIMOUSKI COUNTY.

The clay deposits in this county appear to be confined to the river valleys. Very perfect examples of terraces were seen on the Southwest river at St. Fabien, and on the Rimouski river near its mouth.

A landslip which occurred recently about a mile from the town of Rimouski, has revealed a good section of the clay deposit in the terraces.

The upper part is washed gravels and coarse sand, in layers about 2 feet thick at the front of the terrace and 15 feet thick some distance back. The greater part of the terrace is a massive blue grey clay with purple patches. A few small pebbles are sparingly scattered through the clay, with an occasional marine fossil shell.

A sample of this clay required 28 per cent of water to bring it to a working consistency; its plasticity was medium, and its working qualities fairly good. The clay can be dried without checking if not hurried too fast in the drier. The air shrinkage is about 6 per cent. The test pieces burned to a light red porous body, with a good ring, at cone 010, the absorption being 18 per cent. When burned to cone 06 the body was slightly denser and of a deeper colour. The shrinkage at cone 03 was excessive, and the body was vitrified. The clay softened at cone 1 and melted at cone 2.

This clay is suitable for the manufacture of soft-mud building brick, or it might be used for field drain tile. The tests made for the latter purpose showed that the clay flows smoothly through a die. The burned tile were sound.

The test pieces were covered with an unsightly whitish scum which conceals the red colour of the body. This is due to soluble salts of lime or magnesia, which appear to be brought to the surface of the ware during drying. The addition of a small percentage of barium carbonate will get rid of the scumming. The chemical analysis of this clay is as follows:

Silica	56·42
Alumina	20·56
Iron oxide	6·03
Lime	3·95
Magnesia	3·52
Potash, Soda	2·90
Sulphur trioxide	0·27
Loss on ignition	6·55
Moisture	0·60

BONAVENTURE COUNTY.

The principal area of stoneless Pleistocene clay available for brickmaking in this county is found in the wide lowlands which border the sea coast between the mouths of the Cascapedia and Little Cascapedia rivers. Small areas of similar clay also occur in remnants of terraces along East river at Port Daniel. The surface deposits in general appear to be sands, gravels, or boulder clay, and small patches of residual soils due to the weathering of the underlying bedrock.

New Richmond.

An examination of the sea coast in the neighbourhood of the village of New Richmond shows a series of Pleistocene deposits of similar character and arrangement to those in the St. Lawrence valley (Plate XVIII, B).

The sections shown in Figure 12 were observed along the shore just west of the mouth of Little Cascapedia river. These show the uneven upper surface of the boulder clay, and the thinning out of the overlying marine clay and sands to the east.

A sample of the clay collected at this locality showed rather poor working qualities when tempered with water, the wet body being rather short in texture and flabby. It did not come very smoothly through a die, being liable to tear unless good lubrication was provided. The clay dries readily, with a drying shrinkage of 6 per cen'. It burns to a light red, soft, and very

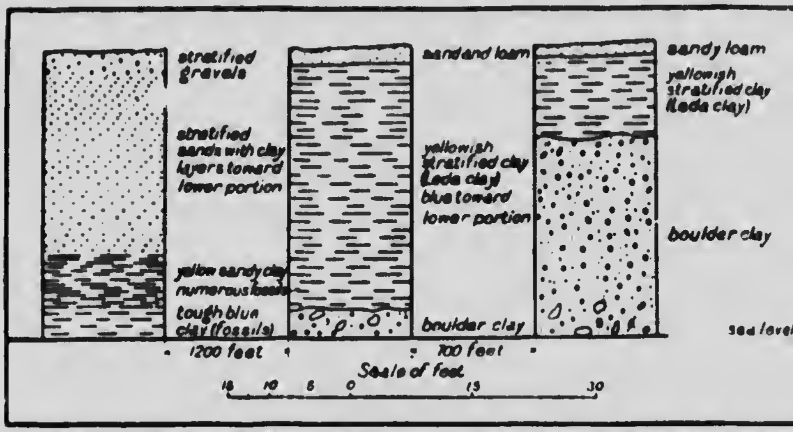

Figure 12. Sections of Pleistocene deposits on sea coast at west side of mouth of Little Cascapedia river, near New Richmond.

porous body at cone 010, the absorption being 22 per cent, which is high. There is a slight swelling in firing, which is probably due to the rather high percentage of lime in this clay. It burns to a very dense body at cone 03, but the shrinkage is excessive at this temperature. Softening begins below cone 1 and fusion at cone 2.

This clay is suitable for common brick made by the soft-mud process, but it must be burned to a temperature of about 1900 degrees F. to produce a sufficiently hard body. It might also be used for field drain tile for the vicinity in which it occurs, but it would be far inferior to the tile which could be produced at Bathurst or Campbellton on the south shore of Chaleur bay.

GASPE COUNTY.

The portion of this county which borders Chaleur bay appears to contain very few deposits of Pleistocene clays, either of the bouldery or stoneless marine varieties. There are several patches of residual clay which have resulted from the decay of slaty rocks on which they rest. They are bright yellow, pink, and grey in colour, as seen in the vicinity of Newport and Percé. Being not more than a foot or two in thickness they have little or no economic value.

The terraces which extend for a few miles upstream from the mouth of the Grand Pabos river on the east side were found to be mostly composed of stoneless Pleistocene clay. This clay resembles that at New Richmond and is probably of marine origin. The deposit is of considerable thickness and extent, free from pebbles, and without a heavy overburden of sand.

This clay burns to a salmon coloured, porous, rather soft body at cone 010; the absorption, 24 per cent, is very high. When burned to cone 03, the colour is buff, and the body although hard and strong, is still porous. It softens at cone 1 and fuses at cone 2. This is the only Pleistocene clay so far found in the province that burns to a buff colour. The lime content is high enough to overpower the red coloration of the iron, and give a buff instead of a red colour. The buff colour, however, is not developed until the higher temperatures are reached, the lower temperatures of burning giving a light red or salmon colour.

The clay will make common brick by the soft-mud process, but in order to produce a hard brick it should be burned to a temperature high enough to produce a buff colour.

The Laurentide Sulphide Pulp and Lumber company began building operations at the mouth of the Grand Pabos river in 1912. The construction of a railway for 50 miles up this river is part of the work planned. The townsite of the company, Chandler, promises to become the most important industrial centre in Gaspe.

CLAY BELT, NORTHERN QUEBEC.

The clays which occur in this region were probably deposited in a large body of still water, which appears to have been brought into existence at a certain stage in glacial conditions.

This lake was temporary, but was maintained long enough to accumulate a considerable thickness of sediment over quite a large area. A. P. Coleman has proposed the name Ojibway lake for this extinct body of water, therefore the name "Ojibway clay," might be applied to its sediments. Samples of clay were tested from two localities in this area.

Amos.

This is a village at the crossing of the Hurricanaw river by the National Transcontinental railway. Mr. J. H. Valliquette of the Quebec Mines Branch collected samples in 1912 at this point. His notes on the deposits are as follows:

"No. 1 is a greyish stratified clay, taken in a well, to a depth of 10 feet below the surface, on town lot No. 2, block 2. The clay layers are about one-half inch in thickness, separated by a film of lighter coloured silt. The total thickness of the deposit is 14 feet. Some small boulders about as big as the fist, are occasionally found in the upper part, also some concretions. The clay is overlain by a thin layer of moss and decayed wood.

"Sample No. 2 is a bluish stratified clay taken from the same well as No. 1, but about 18 feet below the surface. The layers of this clay are about 2 inches in thickness. The line of division between the upper and lower clay is very sharply marked.

"We struck a little bed of sand in this well at a depth of 21 feet. It gave a flow of about 150 gallons of water a day. The same bluish clay was found below the sand."

Sample No. 1 requires 28 per cent of water to bring it to a working consistency; it is fairly plastic, and works easily, but makes a rather flabby wet body if a slight excess of water is used in tempering. It will stand fast drying, without checking. The drying shrinkage is 5 per cent and the tensile strength of the dried raw clay was 84 pounds per square inch. Over 80 per cent of the clay passes through a 200 mesh sieve, and no pebbles of coarse grit particles were observed in the sample submitted. The burning tests were as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·0	19·3	light red
06	0·0	16·6	red
03	2·0	12·3	red
02	5·6	5·2	dark red
3	fused		

This clay burns to a fairly hard body with good colour at cone 06. The colour is deep red, and the body steel hard at cone 03.

Some short lengths of 3-inch pipe were made from this clay in a hand screw press and burned to cone 05. The results of this test are good, and show that the clay will make an excellent field drain tile. In fact, it was one of the smoothest and soundest drain tile produced from any of the surface clays in Quebec, so far tested.

The clay will make good building brick by the sand-moulded process, and will probably also make wire-cut brick, if the auger of the machine does not cause laminated structure in the finished brick.

The addition of sand is not necessary as the clay works easily and the shrinkages are low.

The clay compares favourably both in working and burning properties with any of the surface clays used in the older settled portions of the province; but in order to obtain the best results it must be burned to a higher temperature than the clays of the St. Lawrence valley. Sample No. 2 does not possess as good plasticity nor working properties as No. 1. It is very silty or "lean" in character. The drying shrinkage is 4 per cent, and the tensile strength of the air dried raw clay was 60 pounds per square inch.

This clay burns to a porous body, rather soft and of poor colour, at the ordinary temperatures employed in common brickmaking. It contains quite a percentage of lime, which accounts for the porous soft body at the lower temperatures. As there is an abundance of the upper clay in this region, the use of the lower clay is not recommended.

Bell River.

A sample of clay was collected by Mr. Morley Wilson of the Geological Survey, near the crossing of the Bell river by the National Transcontinental railway. This locality is about 45 miles east of Amos, where the last sample described was collected.

This clay is stratified horizontally in layers of bluish grey colour with thin layers of ash coloured silt alternating (Plate XIX). It is non-calcareous, fairly plastic, smooth, and fine grained. The drying shrinkage is about 6 per cent. It behaved in burning as follows:

Cone	Fire shrinkage %	Absorption %	Colour
010	0·5	17·0	light red
06	0·5	16·0	red
03	4·0	7·5	dark red
01	7·0	1·5	dark red
3	fused		

This clay is very similar to that from Amos. It is rather more plastic, and burns to a slightly denser body at lower temperatures. It is suitable for common building brick or field drain tile. These clays stand much higher firing than most of the Pleistocene clays from the St. Lawrence valley.

SUMMARY TABLE OF PHYSICAL TESTS ON PLEISTOCENE CLAYS.

Locality	Labty. No.	Water %	Drying shrink.	Cone 010		Cone 06		Cone 03		Cone of fusion
				Fire shrink.	Absorp.	Fire shrink.	Absorp.	Fire shrink.	Absorp.	
Hull	30	35	11·0	1·0	13·8	1·6	11·3	8	0	1
Kirk Ferry	31	32	8·5	0·7	16	1·7	15	4	0	1
Ormstown	32	25	6	0	14·2	0·4	13·3	3·4	4·8	2
Lakeside	35	30	8·5	1·3	15·7	2·2	15·5	10	0	1
St. Thérèse	41	17	7	0	13	0	13	6	1·8	1
Huberdeau	42	35	9	0·7	18	4	12	7·6	0	1
Montreal	43	35	9	0·7	18	4	16·6	10·7	0	1
Varennes	44	32	8·5	1	18	1	11·5	10·4	0	1
St. John	45	27	8	1·5	12·4	2	9·4	6·6	0	2
L'Epiphanie	50	32	10·5	0	15·5	2	11	5·7	0	1
Farnham	55	18	3·6	0	14·5	0	13·6	0·7	12·3	2
Pierreville	57	32	8·5	1	16·5	1·7	15·5	9·7	0	2
Nicolet	58	32	9	1·5	14·8	2·9	13	10	0	1
Ascot	70	26	6	0	16	3	10	9·3	0	1
Lennoxville	71	24	5	0	16·4	1·4	13·6	8	0	1
St. Joseph-de-Beauce	....	29	6	2	15	....	....	....	....	1
Deschaillons	75	25	6	1	16·6	1·5	13·2	9·7	0	2
St. Raymond	79	[illegible]2	4·5	0	15·5	0·5	14·2	5·3	4	2
Beauport	8[illegible]		6·5	0	13·6	0·6	12	4·8	6·7	2
Amos	90		5	0	19·3	0	16·6	2	12·3	3
Bell Riv[illegible]	93	[illegible]	6	0·5	17	0·5	16	4	7·5	3
Cap Ro[illegible]	122	20	6	0	13	0·6	12	6·7	0	2
L'Islet	124	21	5	0	13	0·6	12	6·7	0	2
Baie St. Paul	125	30	10	1	20	2·3	14	10	0	1
St. Charles-de-Bellechasse	128	27	8	0	15	0·7	14	7·6	0	1
Chicoutimi	129	23	5	0	20	0·6	19	5·7	8	1
Roberval	130	29	6·5	0	15	0·6	14	....	....	1
Rimouski	131	28	6	0·7	18	1	17	9	0	2
New Richmond	132	....	6	0	22	0·0	22	9	1·3	2
Chandler, Gaspe	134	....	5	0·4	24	....	....	1	20	2

CHAPTER III.

DRAIN TILE.

MANUFACTURE.

For the making of drain tile the clay should be thoroughly tempered to a stiff mud, before moulding, this operation being done commonly in a pug-mill (Plate XXVII).

The moulding is usually done in an auger machine having a circular die, although different styles of plunger machines and also hand presses are used in their manufacture. Drain tile are made in sizes varying from 2 inches in diameter to 3 feet. Drying is done frequently on pallet racks (Plate XXXI, B) such as are used for common brick, or it may also be done in tunnels.

Any means of drying and burning may be used with the smaller sizes, but the larger sizes require considerable care to prevent cracking. The burning is usually done at a low temperature but they should be burned sufficiently hard to resist breaking when handled, and to support the required weight when stacked in piles, or buried in trenches. Besides sufficient hardness the important requirements for drain tile are straightness, uniformity of diameter, and smoothness of ends.

The best practice demands a vitrified tile for underdrainage, as it is not necessary for a field tile to be porous. None of the Quebec clays can be burned to vitrification safely. On this account manufacturers will have to content themselves with burning a porous tile, but these can be made strong and durable if properly burned, and the material properly prepared before burning.

ESTIMATED COST OF DRAIN TILE PLANT.

The following is an approximate estimate of the cost of a small, but complete plant, to produce about 10,000 medium sized field drain tile per day:

Combined brick and tile stiff-mud machine, with crusher and pug-mill attached	$1,000
Engine and boiler	1,000
Installing	400
Building	500
Three dryer sheds	750
Barrows, tools, bitting, etc	200
Two 22 foot circular down-draft kilns	2,000
Clay car, steel rails, and winding drum	150
Total	$6,000

This plant would require the labour of 10 men. The cost for fuel would be about $2 per thousand.

ADVANTAGES OF UNDERDRAINAGE FOR SOILS.

Drainage does four things: first, it removes the surplus water and makes it possible to cultivate and seed about three weeks earlier in the spring than on the same land when undrained. Secondly, it makes the land from 10 to 15 degrees warmer than if not drained, and this warmth germinates the seed properly and gives a good stand of grain. Thirdly, it lets plenty of air down to the roots of the plant, which is necessary for satisfactory growth. Fourthly, it makes the soil more porous, and this in turn causes the soil to store up more water for the use of the crops in the time of drought.

Frequently the increase of crop in one year pays for the drainage, and seldom or never does it take longer than three years, so that drainage pays from 33 per cent to 100 per cent per annum on the money invested.

DRAIN TILE TESTS ON QUEBEC CLAYS.

Drain tile may be made from almost any clay which does not crack too badly in drying, and which is free from pebbles, especially limestone pebbles. Limestone particles are reduced to the lime oxide in burning, these afterwards absorb moisture, swell, and crumble the tile. The samples of clay to be tested were ground, mixed with a certain proportion of sand when necessary, and after tempering with water, stored in damp cloths for 2 or 3 days.

A small hand screw press was used for moulding the test pieces. There was no means of lubricating the die of this press, consequently some of the tile were rougher in appearance than they would be if made through a properly lubricated die. The diameter of the pipe was 2 inches inside, and 3 inches outside measure. The test pieces when dried were burned at two temperatures, cone 010 (1742 degrees F.) and cone 06 (1886 degrees F.).

These tests are incomplete as a plunger type of machine was used for moulding. The important fact, whether a clay laminates in an auger machine, was not ascertained. Lamination given to a bar of clay by the spiral motion of the propelling auger of a machine is a serious defect in clay wares, especially if underburned. The layers in the clay, caused in this manner, peel if under the action of frost and destroy the tile. The strong or highly plastic clays are the ones most liable to show auger laminations. Tests of clays for field drain tile were made from the following localities. These include all the types of Pleistocene clays likely to be met with in the province. Descriptions of these clays are given in the preceding chapter, as well as of several others which are also suitable for the manufacture of drain tile.

Hull.

The clay from Richards' brick plant on the Chelsea road appears to work well through a die. The burned pipe made from it is smooth, strong, dense, and sound in structure. The shrinkage is rather high, but the addition of about 25 per cent of sand would correct this. The clay would also be improved by weathering over winter in stock piles if it were to be used for making drain tile. The absorption of the test pieces of tile is 12 per cent at cone 010, and the body is sufficiently hard when burned to this temperature.

Ormstown.

Tests for drain tile were made on the clay used for brick-making, which measures about 9 feet from the surface down. It included top loamy clay, lower strong yellowish clay, and a very little bottom blue clay. This clay seems remarkably well adapted to the making of drain tile; it flows smoothly through the die of the machine even without lubrication, and burns to a dense strong body. The absorption of test pieces at cone 010 was 15 per cent and at cone 05 was 14 per cent. This clay does not require the addition of sand when used for tile, but a small quantity, say 10 per cent, might improve the drying qualities. The strong yellow clay if used alone would probably give the best results, if no trouble were experienced in the drying.

Laprairie.

A mixture of 2 parts finely ground Utica-Lorraine shale to one part of plastic surface clay was tested for drain tile. This mixture needs lubrication in the die, otherwise it is liable to produce pipe with a rough surface. The burned pipe are sound and strong, but the shale in the mixture makes a heavier pipe than that made from all surface clay. The absorption of test pipe when burned to cone 010 was only 8·7 per cent. The expense of grinding shale would probably be too great in the manufacture of tile, but there is no doubt that a superior article could be produced. The mixture is well suited to the manufacture of hollow building blocks or fireproofing, being hard and tough.

The highly plastic surface clays of Laprairie county are not recommended for use alone, as their shrinkage is too high, and the drying qualities poor. They would require to be weathered in stock piles, and to receive an addition of at least 33 per cent of sand to make them workable.

Varennes.

The clay at Varennes is highly plastic, stiff, and sticky. It gives trouble in drying, as it cracks badly during this operation, when made into bricks. A mixture of 3 parts clay to one part sand was tested for drain tile. It flowed smoothly through the die, and the green pipe could be handled easily without damage. The pipe dried without cracking, as the walls were thin when compared with brick. The shrinkage was rather high, but the body was dense enough and apparently sound in structure. The absorption, when burned to cone 010, was 14·7 per cent.

The clay at this locality is not recommended, owing to its stickiness, stiffness in working, and its poor drying qualities. If it should become necessary to use this clay, however, it must be dug from the bank and thoroughly weathered over winter, and used with a mixture of 2 parts clay to one of sand.

The pipe should also be protected while drying on the racks.

Pierreville.

The clay tested for drain tile was obtained from the bank of a gully about one mile south of the village of Pierreville. It was mixed with 25 per cent of sand for the test. The pipe made on the hand press was rather rough, on account of there being no lubrication in the die. It stood handling in the green state without damage, and burned to a good sound body at cone 010, with an absorption of 15 per cent. The principal objection to this clay is its stiffness in working, and poor drying qualities. It is possible, however, with weathering the clay and thorough mixing of sand to produce a fairly good pipe from it. There are other clays in the vicinity, which are more silty, and consequently more open in body and easier to work, that might give better results for tile making.

Nicolet.

The clay at Nicolet is open to objection, on account of its poor drying qualities; but when a mixture of 2 parts clay and one of sand is thoroughly prepared it seems very suitable for the manufacture of tile. The test pieces made from this mixture were smooth and sound in structure with a dense body. The absorption of tile burned to cone 010 was 13 per cent, and of those burned to cone 06 was 11 per cent.

For use in tile making the clay should be weathered and thoroughly worked up with the sand. The green tile would probably have to be protected from dry warm wind while drying.

Ste. Monique.

The clay at this locality is practically the same as that at Nicolet, and the above results apply equally well to it. A further test was made of the materials at this locality on a mixture of ground Medina shale and the plastic surface clay overlying it, using equal parts of each. The results obtained with this mixture are exceptionally good, the tile having a dense, sound, tough body, with an absorption when burned to cone 010 of only 10 per cent. A tile of this kind would stand transportation well, and be very durable.

The drying can be effected safely by the addition of the shale, and the body produced is far superior to a sand mixture. The cost of grinding shale is the only objection to its use for this product.

St. Gregoire.

The tile from this locality were made from the Medina shale which occurs about one mile east of the village on the road to Becancour. This material when finely ground and mixed with water is sufficiently plastic to pass through a die, and worked fairly well in the hand press. The test pipe were smooth, but did not bear handling in the green state as well as the pipe made from the plastic clays. The pipe burned to a strong, structurally sound, dense body, the absorption at cone 010 being only 7·4 per cent, and 6·3 per cent when burned to cone 06.

This shale will produce a pipe which is much superior in every respect to those made from the surface clays, and there is no difficulty in drying as fast as desired. The shale grinds easily, and the additional price which could be obtained for the tile would offset the cost of grinding. If it were required to add some plastic surface clay, it could be obtained in the neighbourhood. Although the shale is plastic enough, its working qualities would be improved and the cost of grinding reduced by the addition of about 33 per cent of plastic clay.

Ascot.

The upper brownish clay at this locality is one of the best surface clays so far examined for the purpose of tile making. It can be used directly as it comes from the bank, without weathering and will stand fast drying. On account of its silty character it works easily, and it comes smoothly through the die; but the pipe does not bear handling in the green state as well as some of the fat clays from the low level deposits. The pipe burns to a dense strong body at cone 010, the absorption being 9·6 per cent. The bottom blue clay from this locality does not seem to give such good results, but some of it could probably be worked in with the brown top clay.

Lennoxville.

The clay tested for tile making at this locality was collected at the Eastern Townships Brick plant at Webster siding. This clay is similar to that at Ascot, but is more silty, and does not burn to quite as dense a body, the absorption of the test pipe at cone 010 being 15·5 per cent. It makes a good strong pipe, but the burning should be carried higher. The advantages of the clay are its good drying and easy working qualities; but, on account of its silty character, the pipes do not keep their shape so well in the green state when handled between the machine and the dry rack. It requires no sand.

Deschaillons.

The clay at Deschaillons belongs to the easily worked type, which requires no sand, and has good drying qualities. The upper part of the bank, which consists of a brownish fairly plastic clay, is recommended for tile making. The bottom grey clay is not, as it is rather too silty, and forms a flabby body when a slight excess of water is added to it. The upper clay makes a fairly smooth pipe, which burns to a strong though rather porous body at cone 010, the absorption at this temperature being 15 per cent, and 12 per cent if burned to cone 06. The pipe from this locality should be burned to the higher temperature in order to get the best results for hardness and density of body.

Cap Rouge.

The clay at this locality has good working qualities and formed a smooth pipe, which was easy to handle in the green state. The tile burned to a fine, dense, strong body at cone 010, with an absorption of 13·6 per cent, and not much shrinkage. This clay will make a strong, durable, drain tile, but it has one disadvantage—poor drying qualities. If the drying part of the process can be carried on safely a very desirable tile could be produced here.

L'Islet.

If the clay at L'Islet did not contain so many pebbles, it would be one of the best tile clays in the province. Its working qualities are unsurpassed, as it flows in a smooth straight column from the die of the press. It burns to a sound, dense body at cone 010, with an absorption of 13 per cent, or 12 per cent if burned to cone 06. The clay used in testing was ground finely and the pebbles pulverized. The pebbles in this clay would interfere seriously with the manufacture of tile.

St. Charles.

The clay that occurs in the valley of the Boyer river in this vicinity is highly plastic, stiff, and rather sticky. Its drying qualities are poor and its shrinkage high. In making the tile tests, 20 per cent of sand was added to the clay. A fairly smooth strong pipe was obtained, having an absorption of 13 per cent when burned to cone 010, or 8 per cent at the temperature of cone 06. A better working body could be obtained and one with less shrinkage by using a mixture of 2 parts clay to one of sand. The clay should be dug and weathered in stock piles, and the sand thoroughly worked in for use in tile making.

Rimouski.

The clay at Rimouski is fairly well adapted for the making of drain tile. It works easily and has good drying qualities with low shrinkage. The quantity of tempering water must be carefully adjusted, as a slight excess causes the wet body to become flabby. It flows smoothly through the die of the press, and burns to a strong but rather porous body at cone 010, the absorption being 20 per cent. The body is harder and denser, and a better pipe is produced at cone 06.

There are lime pebbles and particles in this clay which cause spalling of the surface of the pipe after burning. It would be necessary to pulverize the clay and carry the burning as far as possible to overcome this defect.

CHAPTER IV.

DRYING DEFECTS IN PLEISTOCENE CLAYS.

Many clays have a tendency to crack or check while drying, after being moulded into shape. Brickmakers call them "tender" clays. It is troublesome to use these clays, as they not only require attention and protection while drying, but the time taken for drying them safely is often prolonged unduly. There are some clays that crack so badly in drying that no amount of care or protection will bring them safely through this stage in the process of manufacture.

The drying defects found in many of the clays in the western provinces are a serious obstacle to the development of the clay industry in that region. The present investigation brought out the fact that some of the Pleistocene clays in the St. Lawrence valley had similar defects While these are not so deficient in this respect as some of the western examples, their poor drying qualities are troublesome enough to interfere with their use in the manufacture of wet-moulded clay products.

The clays that crack in drying are confined to the low level deposits, such as occur in St. John, Verchères, L'Assomption, Nicolet, and other adjoining counties.

The tendency to crack in drying is almost always accompanied by a sticky and pasty type of plasticity which causes these clays to adhere strongly to metals in clay working machinery, making them very hard to work or mould into wares. The excessive shrinkage in drying, accompanied by warping, is also a further objection against these clays.

The shrinkage on burning is moderate, and within working limits, and the colour, strength, hardness, etc., of the burned body compares favourably with any of the other Pleistocene clays which are free from the drying defect.

The successful use, therefore, of these materials depends on the application of some practical method to overcome the sticky qualities, and the excessive drying shrinkage.

The causes of cracking and shrinkage are, briefly, the extreme fineness of grain, and a large percentage of colloidal matter in the sediments which compose these deposits. Such clays absorb a large quantity of water in tempering and part with it very slowly in drying. The surface of brick made from these clays begins to show cracks very shortly after moulding. These cracks deepen and widen until they reach almost to the centre of the brick. The labour used in making this brick is lost. The addition of large percentages of sand does not seem to help much in overcoming the drying defect except in mild cases; furthermore the sticky qualities of the clay remain. If sand is added in amounts large enough to stop the cracking and shrinkage the burned product is too weak and crumbly to be of any value. It is also very difficult to add sand to these stiff clays so as to obtain a uniform mixture, unless special machinery is provided for the purpose.

The probable causes of cracking and the various methods used in overcoming it, were fully described in a report[1] dealing with certain clays in the western provinces.

PREHEATING CLAYS.

As the best results were obtained by a preliminary heat treatment of the raw clay, a few of the Quebec examples were put through this process on a limited scale in the laboratory. The ground dry clay was merely heated slowly in a thick cast iron pan over a gas flame. The clay was stirred up to ensure even heating, and its temperature was obtained by placing the bulb of a thermometer in the heated mass.

Three samples of clay from the following localities were experimented with: Varennes (No. 44), L'Epiphanie (No. 50), Nicolet (No. 58).

When heated up to 200 degrees C. and over, these clays give off a strong sour odour while hot, and change from a light to a dark grey colour. They become granular in texture and lose their stickiness. If heated up to 350 degrees C. they will lose their plasticity. The change that takes place in the character of these clays with a small rise in temperature is remarkable; a

[1] Clay and Shale Deposits of the Western Provinces, Part II, Chap. VI

200 degrees the properties of the clays are not materially altered; but at 300 degrees an entire change is effected; while at 350 degrees C. the material produced is not a clay at all as far as its working properties are concerned.

The clay at Varennes is a stiff, sticky, highly plastic clay which is hard to work and cracks while drying in a room with a temperature of 65 degrees F. The same thing happens even when 33 per cent of sand is added. When heated up to 200 degrees C. it is not quite so sticky as in the raw state and is somewhat easier to work. A 3 inch cube made from it dried intact at 65 degrees F., but cracked if dried at 120 degrees F. When heated up to 250 degrees C. most of the stickiness had gone, and the body was more open in texture; it had retained good plasticity, being easily moulded into shape. The 3-inch cubes moulded from the clay preheated to this temperature, cracked in the drier at 120 degrees F.

When heated to 300 degrees C., a very pronounced change is observed; the stickiness is gone, the plasticity is low, the granular character is particularly noticeable as the particles do not slake readily in the mixing water but remain rough to the feel. The clay can still be moulded, however, and a 3-inch cube made from it dried intact at 150 degrees F.

When this clay is heated up to 350 degrees C., it is entirely changed in character, and loses its plasticity. The mass of clay grains when tempered with water simply falls into an incoherent mass which cannot be moulded into shape. If the clay which has been heated up to 350 degrees C., be allowed to stand in water for 3 or 4 days it will regain enough plasticity to allow it to be moulded.

The clays from Nicolet and L'Epiphanie are very similar in the raw state to that at Varennes, having practically the same defects in working and drying. Their behaviour in the preliminary heating trials was also practically the same as that just described, except that the clay from L'Epiphanie does not require quite such a high heat treatment to bring it to a rwokable condition, a temperature of 250 degrees C. being sufficient. The following table shows the effect of the preliminary heating on the air shrinkage of these clays:

No.	Average per cent air shrinkage	
	Raw clay	Preheated clay
44	8·5	4·0
50	10·0	3·3
58	9·0	4·5

The air shrinkages are reduced one-half or more, thus bringing these clays within working limits. The preheating seems to impart the character of a coarse-grained shale to a very fine-grained clay.

The effect of preliminary heating on the burned ware is also very marked, as it produces a body which is far more porous and slightly softer than that given by the raw clay.

The following table of absorptions shows the increased porosity caused by preheating:

No.	Cone	Percentage of absorption	
		Raw clay	Preheated clay
44	010	18·0	25·0
	06	11·5	20·0
50	010	15·5	25·7
	06	13·2	21·3
58	010	14·8	23·4
	06	13·0	23·0

There is little or no difference in the burned bodies at cone 03, both being very much shrunken, vitrified, and overfired.

It is apparent that these clays can be made workable by the preheating process if commercial conditions allow of its use. The process involves the extra expense of a suitable type of rotary drier or kiln, with cost of fuel and labour over and above the ordinary brick plant's equipment. The best results would be obtained by storing the clay until dry, grinding in rolls or disintegrators, and heating the ground clay. As these clays can only be used for making a cheap class of product it is doubtful if they could be treated thus profitably, as they would have to compete with clay deposits in the same region which require no preheating.

ANTE-FIRED PROCESS.

This process has been suggested for the working of those clays that are defective in working and drying qualities and cannot be treated by the ordinary methods of brick manufacture. The ante-fired process consists in burning the clay in heaps as it comes from the bank, or in special types of kilns, using either wood, coal, or natural gas for fuel. The burned clay lumps are ground in dry pans fine enough to pass a 12 mesh sieve. The ground clay is moistened and mixed with about 5 or 6 per cent of hydrated lime. This mixture is pressed into brick shapes, by the usual dry-press machines.

The pressed brick are h[illegible]linders under a steam pressure of 100 to 140 pou[illegible]quare inch for 8 hours. The brick are ready for use shortly after coming from the hardening cylinder, the whole process being exactly the same as that used in the manufacture of sand-lime brick (Chapter VII) excepting that ground burned clay is substituted for sand.

As this process is new, and has not been demonstrated on a commercial scale, the following series of experiments were conducted for the purpose of determining the strength and durability of brick made in this manner.

A quantity of clay from Varennes (No. 44) was burned at four different temperatures, that would probably be obtained in practice while calcining roast heaps of clay. The temperatures of burning ranged from 1600 degrees F. to 2000 degrees F.

The lumps of clay burned at these different temperatures were ground together until the grains were all small enough to pass through a screen of 10 meshes to an inch. The ground calcined clay was mixed with 6 per cent of hydrated lime, and 11 per cent of water. This mixture was pressed by machinery into standard size brick and 3-inch cubes. These test pieces were placed in a cylinder for 8 hours under a steam pressure of 120 pounds per square inch. They were allowed to stand for a week after steaming before the tests were begun. The absorption of water by the brick was 20 per cent.

Cross bedding test of whole brick:

Dimensions 4·05 inches × 2·34 inches × 8·26 inches.

Distance between supports 7 inches.

Breaking load in lbs. applied at centre.................. 1230

Fibre stress in lbs. per square inch..................... 580

Crushing strength of half brick:

Area of surface carrying load........ 13·57 sq. in.

Crushing load..................... 43,970 lbs.

Stress............................ 3,240 lbs. per sq. in.

FREEZING TEST.

The half brick from the absorption test was placed while wet in a freezing temperature for 12 hours. It was taken inside and thawed out in water heated to about 150 degrees F. This process was repeated 20 times, and the brick was finally dried, and crushed with the following results:

Area of surface carrying loads.......17·5 sq. in.

Crushing load.....................53,870 lbs.

Stress............................ 3,070 lbs. per sq. in.

The brick showed no apparent defects due to the repeated freezing and thawing conditions.

As far as the laboratory tests go the "ante-fired" brick made from the Varennes clay appears to be as strong and to withstand the freezing test as well as a medium grade of soft-mud brick. The ante-fired brick, however, does not appear to possess the quality of toughness possessed by the soft-mud brick as the edges and corners are rather crumbly. This is a defect which would show up plainly in handling and transportation, so that the product would probably arrive on the job looking rather the worse for wear.

The ante-fired brick have the advantage over the soft-mud brick as regards uniformity of size. They can all be made absolutely the same size.

The only advantage they have over sand-lime brick is in regard to colour, although the colour of the burned clay in the ante-fired brick is subdued to some extent by the addition of lime which gives a salmon colour instead of red.

The producing of brick by the ante-fired process is patented.

CHAPTER V.

EFFECTS OF LIME, DOLOMITE, AND TALC SCHIST ON LEDA CLAY.

The working and burning of the highly plastic low level and Leda clays of the St. Lawrence valley in Quebec are attended by certain difficulties due to defects peculiar to these materials. The difficulties encountered in working and drying, and the methods adopted for overcoming them, were explained in the last chapter.

It is no trouble to make ordinary porous common brick, as the temperature at which they are burned is low, but if it is required to burn wares to a hard body in down-draft kilns trouble is likely to ensue from the low fusing point, short range of vitrification, and excessive fire shrinkage of these clays. This behaviour under firing is owing to the large amount of fluxing impurities present, and the extreme fineness of grain. The particles are in such close contact in fine-grained clays, that fluxing action, contraction, and softening take place much quicker and at a much lower temperature than in a coarse-grained clay of the same kind. On account of this difference in their physical condition, it is possible to produce a dense brick from the coarsely ground Utica shale in Laprairie county, but not from the Leda clay from the same locality, although their chemical compositions are very similar.

It is only possible to produce an impervious body from these clays by adding a large proportion of refractory material such as fireclay. The fireclay acts as an infusible skeleton, and holds the easily fusible clay in shape during the burning. A considerable quantity of local clay is used at St. John in the manufacture of sewer-pipe by the simple, but costly, process of adding 35 per cent of imported fireclay.

The cost of importing fireclay to mix with the local clays would be too great in the case of the cheaper clay products suhc as fireproofing or hollow building blocks. Certain experiments were undertaken to find out what effect small percentages of lime, dolomite, or talcose schist, had on the Leda clay at the higher temperatures of burning. The source of the lime used in the experiments was marble, ground to pass a 40 mesh screen. The dolomite was magnesian limestone ground to the same degree of fineness. The talcose schist was from Sherbrooke, where it is quarried for building stone, and is the most refractory material in the region.

The clay used in the experiments was taken from the pit used by the Standard Clay Products company at St. John. It is a typical low level marine clay, which occurs so widespread in this region. It is exactly the same as the clay that occurs at Delson Junction, L'Acadie, Lakeside, and Montreal. The above ground materials were added to the clay in the proportions of 5, 10, and 15 per cent of each. These mixtures were made up into bricklets 4 inches long and 1 inch thick, and burned at various temperatures indicated by cones.

The following table gives the percentages of absorption and total shrinkages. The 5 per cent mixtures are omitted, as these small amounts of material did not affect the quality of the burned body to any marked degree.

Mixtures	Total shrinkage				Absorption			
	Cone 05	Cone 03	Cone 02	Cone 1	Cone 05	Cone 03	Cone 02	Cone 1
Clay	14·0	17·0	17·0		7·0	0·0	0·0	
90% clay, 10% talc schist	12·6	16·0	17·0	14·3	7·4	2·0	2·0	0·0
85% clay, 15% talc schist	11·6	15·6	15·6	13·6	9·5	2·5	1·7	0·0
90% clay, 10% lime	11·0	12·6	14·0	14·3	13·0	8·8	6·6	0·7
85% clay, 15% lime	10·6	12·0	13·0	13·8	15·3	10·3	9·0	3·0
90% clay, 10% dolomite	10·6	13·6	15·0	13·6	13·0	9·0	6·7	0·0
85% clay, 15% dolomite	10·6	11·6	12·6	14	14·6	11·0	9·6	3·0

EFFECTS ON SHRINKAGE AND ABSORPTION.

The effect of all these materials is to lessen the shrinkage and increase the absorption. The decrease in shrinkage is obviously caused by the introduction of coarse-grained non-plastic materials, which act like sand.

The larger grains of dolomite and limestone did not enter into fusion, but remained porous, hence the higher absorption in the mixtures than in the bricklets where clay alone is used.

The grains of talc schist appear to enter into fluxing action with the surrounding clay and had less effect in keeping the clay body open, and in reducing the shrinkage in firing than the other two materials.

The clay test pieces were vitrified[1] at cone 03, but none of the mixtures had this density, except the mixture containing 10 per cent talc schist. The only bricklets not vitrified at cone 1 were those containing 15 per cent of lime or dolomite. The addition, therefore, of this small amount of finely ground lime or dolomite has the effect of raising the vitrification point of this clay from cone 03 to cone 1, being equivalent to a difference in temperature of 60 degrees C. or 108 degrees F., which is a considerable gain.

EFFECT ON DEFORMATION IN BURNING.

The temperature which a clay will stand without deforming is one of the most important points in burning clay wares. The aim of the person in charge of the burning operations is usually to produce as large a percentage as possible of hard burned wares in his kiln, and at the same time to prevent losses from overfiring and softening.

What influence the above materials have in preventing deformation in burning could only be determined by special tests. For this purpose strips 4 inches long by half an inch wide and one-quarter inch thick were prepared from the same clay with percentages of the different ingredients similar to those used in

[1] The term vitrification in these experiments means that degree of density in the burned body when the absorption test shows less than 3 per cent, whether the test pieces have a glassy fracture or not, when broken.

the vitrification tests. These were supported on fireclay blocks, specially made for this test, so that about 3 inches of the clay bars projected horizontally, and this portion was free to droop if it became softened in the fire. The diagram Figure 13 shows

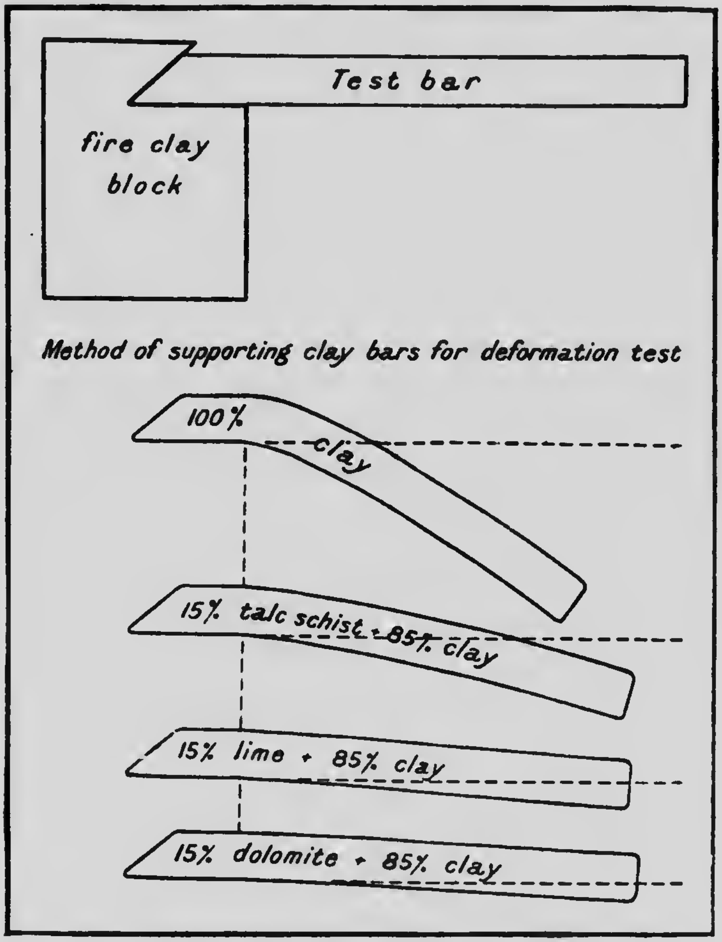

Figure 13. Diagram showing amount of deformation in test bars burned to cone 03.

the method of supporting the bars during the firing, and also the amount of deformation the different pieces undergo when burned to cone 03. There appears to be a relation between the density of body and the softening point, as the neat clay bars and the one containing 15 per cent of talc schist, which are vitrified at cone 03, are also much deformed at this temperature. All the 10 per cent mixtures had a greater droop in the same order as the 15 per cent mixtures shown in the diagram.

PRACTICAL APPLICATION OF TESTS.

The working and burning properties of this clay are much improved by the addition of 10 to 15 per cent of lime or dolomite, the most marked advantage being the prevention of deformation at temperatures up to 04. Makers of thin walled wares, such as porous terra-cotta, or fireproofing, roofing tile, and drain tile, using the fine-grained plastic clays in the St. Lawrence valley, could increase the stiffness of their products under fire, and consequently ensure a greater percentage of hard burned ware in a down-draft kiln. The commercial limit of burning these clays when used alone, or with the addition of sand, is about cone 07.

The common magnesian limestone seems to be the most effective cheap ingredient to use in preventing premature softening, but ground limestone, marl, whiting, or quicklime will answer almost equally well. If quicklime is used, less than 10 per cent will be sufficient.

It is absolutely essential that these materials should be ground fine enough to pass a 40 mesh sieve. If introduced in larger sized grains they are a positive detriment to the clay and would ruin the burned product. Hence whiting, or marl, are the safest forms of lime to use, on account of their fineness of grain.

Unless the mixing is thoroughly done, the small amount of lime added will be ineffective. Enough sand to keep the shrinkage within working limits is also essential.

The only form of lime in small percentages that affects the working qualities of the clay is caustic or quicklime. Five per cent of this ingredient would probably make the clay unworkable in the wet state, and weaken the burned body, instead of helping it. One per cent of quicklime added to a stiff clay will improve its working qualities, and assist in drying, without any bad effects on the burned body, provided the lime is added in a powdered form with thorough mixing. Further details regarding effects of lime on the working of stiff clay are given in Chapter XII.

CHAPTER VI.

CLAYWORKING INDUSTRY.

Although brickmaking is an ancient industry in the province of Quebec, its scope has hitherto been limited. Owing to the growing expense and insecurity of wooden construction, the absence of building stone over large areas, and the abundance of clays and shales, the clay products industry has of late years assumed more important dimensions.

The evolution of domestic architecture on the great clay plain of the St. Lawrence valley is an interesting illustration. The first dwellings were naturally built of logs, as the area was then well forested. Later on, those who wanted better houses, built them of field stone, using the boulders which they found scattered on the plain. To a later generation the frame house covered with planed boards and painted seemed more desirable. To-day the red brick house is the token of prosperity, and these are being erected more than ever in every town and village. The prodigious growth of the city of Montreal during the last few years was attended by an almost equal development of the brick industry, as brick was the material almost exclusively used in the newer portions of the city. The largest single clay working plant in Canada, as well as several small ones, were built to supply [illegible]'s demand.

COMMON BRICK.

The common building brick used in the province are of two varieties, a soft-mud, red brick made from the surface clay, and stiff-mud or wire-cut brick made from shale, or a mixture of shale with surface clay, the colour being red in most cases.

SOFT-MUD BRICK.

Small plants producing 500,000 to 1,000,000 or 2,000,000 soft mud brick annually are common over the more settled portions of the province. These generally consist of one machine operated either by horse-power or a small engine. The brick are hacked out to dry on open floors, or set on racks and pallets. They are burned in scove kilns, set 35 courses high and burned with wood. These plants operate only during the summer months, or shut down altogether if there is not enough demand for their product. As the outlay of capital to equip a plant of this kind is small they can afford to be left idle during the winter or in dull season.

The scove kiln costs nothing but the labour of setting the brick to be burned, and has the further advantage that the kiln can always be shifted as the clay bank moves farther away from the old ground. Their disadvantage is that no matter how tightly the outside layers of brick may be walled in and daubed over there is always a considerable loss of heat, and a large proportion of brick are underburned and soft. Probably not more than 60 per cent of good hard brick come from the majority of scove kilns in the province. Other things being equal it is possible to get 95 per cent hard brick in a good down-draft or continuous kiln; but in some localities as high as 90 per cent of hard brick have been obtained from scove kilns.

The tendency among brickmakers is to use a sandy clay or to add sand to a clay if it is too "fat." The latter is done for three reasons: (1) for ease of working, a sandy clay works easier in the machine than a stiff clay; (2) to help in the drying; (3) to reduce the shrinkage. But sand is often added in excess of these requirements, hence a weaker burned body[1] is produced and one which deforms more easily while handling in the wet state. A brick sanded to excess and underburned is worse than useless.

The drying defects in the low level Pleistocene clays at many localities in the province of Quebec, are a serious obstacle to their utilization. Several failures are due to a lack of preliminary inquiry as to whether this defect existed in certain deposits or not previous to erecting a plant on them. The tests made for this report include the drying qualities of the clays.

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[1] See tests on Montreal clay in this report.

SHALE BRICK.

The use of shale for building brick is growing in favour, especially in cities, to meet the requirements of large structures where heavy loads are carried on walls and piers. The advantages of shale are that it gives a dense, strong product if burned sufficiently hard, and the brick are uniform in size on account of the low shrinkage of this material. Most of the shales can also be dried quickly by artificial means, which is an important consideration where a large output is desired.

Although the building and equipping of a large plant for the manufacture of shale brick is an expensive undertaking, these plants are able to compete with the producers of soft-mud brick, because they can cut down the cost of production by labour saving devices (Plate XXI, A), and by their large and constant output during the greater part of the year, as they can work all through the winter when the soft-mud yards are forced to shut down.

The largest plant in Canada for the production of shale brick alone is situated at Laprairie (Plate XX) on the Grand Trunk railway, 14 miles southwest of Montreal. This plant and a similar one at Delson Junction, about 4 miles farther west, are owned by the National Brick company. An output of 250,000 brick per day is claimed for this plant, and 400,000 per day for the one at Laprairie; but these amounts are not always to be reckoned on in practice.

The plant of the St. Lawrence Brick and Terra Cotta company is situated a short distance west of the National Brick company at Laprairie. An output of 100,000 wire-cut shale brick per day is claimed by this company. The materials used and the products of the two plants are similar. The raw materials used by these plants are described in a previous page. The product made from them is chiefly a rough common brick. Quantity being the principal object not much attention is given to appearance. The shale is ground rather too coarse, and unless the bricks are hard burned they have a tendency, on this account, to crumble at the edges and corners. Finer grinding means less ground shale coming from the dry pans, but it also means a brick of better finish. Many of the brick are also covered with an unsightly white scum. This scumming appears to occur in the driers, and becomes enhanced in the coal fired continuous kilns.

As most of the brick from these plants is used for piers, foundations, and backing, the colour and finish are not so important. The outside finish or facing, whatever it may be, conceals their defects.

The city of Quebec has not yet developed the activity in building, and the increase in area, that so many of the cities in the Dominion have shown in recent years. There has, however, been a considerable increase of construction recently, and consequently a demand has arisen for a better class of brick than the soft-mud clays the St. Charles River valley can furnish. The escarpment of Utica-Lorraine shale which borders the north channel of the St. Lawrence river and approaches within a few miles of the city, contains an abundance of raw materials for a good class of brick.

The Citadel Brick company erected a plant for the manufacture of shale brick in 1912, at Boischatel, a short distance beyond Montmorency falls (Plate XXI, B). This plant started in a small way, and produced an excellent building brick. The results were so good and the demand so great, that the plant is now being enlarged to four times its original capacity. The shale at this point is easier to grind, and is more plastic than that at Laprairie. It burns to a very pleasing shade of dark buff, or a flashed effect of pink and buff can be produced, when burned to a high temperature, while those burned at lower temperatures are salmon coloured.

FACE BRICK.

The face brick industry is not very well developed in Quebec, and a large quantity of brick are imported annually into the province for this purpose.

Buff and red pressed brick from Milton, Ontario, from the Don Valley company of Toronto, and from various makers in the United States are used in Montreal and many of the smaller cities and towns. Scotch firebrick are used to quite an extent for facing buildings in the city of Quebec. These are unloaded from steamers at the wharves in that city and sold for $24 per thousand. The Chateau Frontenac, one of the most important hotels of the Canadian Pacific group, is a good example of the use of this material for external work. The practice in architecture at present is in favour of a rough texture face brick in preference to the old smooth surface dry-pressed brick. Manufacturers of face brick meet this demand by making their brick by the stiff-mud process, having a special device for roughening the face to be exposed in the walls.

The Fiske company of New York were probably the first makers to use this device, adopting the trade name "tapestry" brick for their product. A similar rough faced brick sold under various names is now made at many works in the United States, and by a few in Canada. They are gradually replacing the smooth faced dry-press brick, and in fact these are a thing of the past in many localities; but it is probable that they will remain in favour at other places.

There are several fine examples of buildings faced with rough textured brick in Montreal, where their use is increasing even for the best class of structures where it was formerly considered essential to use stone.

The National Brick company at Laprairie have been making red dry-pressed brick successfully for many years, and have recently made a very creditable showing with rough textured stiff-mud brick. By the use of a certain percentage of lime added to the red burning shale and clay, and by "flashing" the latter during the burning process, they are able to produce tones ranging through buffs, reds, purples, to blue black in the finished bricks. Montreal architects are now able to procure a local material which will produce almost any colour effect peculiar to burned clay wares that they desire to give to their buildings.

Quite a large proportion of the brick from the kilns of the Citadel Brick company at Quebec, are sorted for colour and sold for facing buildings. The prevailing colours obtained are salmon to dark buff or greenish, with gradations of these tones on the same brick. As these brick are carefully made and hard burned, and have pleasing and effective colours, they are very suitable for facing purposes.

The makers of soft-mud brick have made no special attempt to produce an article for facing the better class of buildings. The red colours are generally too pale, and the brick are not very carefully moulded and handled. There is no better structural material made than a good soft-mud brick. Architects like them, on account of their colour and texture, especially for dwellings, for which they are eminently suitable when laid up with the proper width and colour of mortar joint.

Some of the brick that come from the continuous coal fired kiln at Ascot, near Sherbrooke, may be sorted for facing purposes, and give good results.

The scove kiln generally gives too light a red colour in the Quebec clays, on account of the good oxidizing conditions inherent in this type of kiln.

The reducing conditions that can be obtained in the down-draft or continuous kilns seem to produce the richest dark red colour.

The items to be considered in an enterprise of this kind are: the cost of building down-draft kilns, the selection of a suitable clay and moulding sand, and extra machinery for preparing the clay, so as to produce a body of uniform structure. The extra price obtained for this class of brick, over the ordinary soft-mud brick, should meet the added cost of production.

The surface clays do not give good results when used in the manufacture of dry-pressed face brick. Brick made by this method must be burned to a higher temperature than those made by the wet-moulded processes in order to produce sufficient density of body.

The silty and sandy high level clays of the Pleistocene produce a weak, punky, burned body when dry-pressed. The highly plastic fine-grained clays found at low levels shrink too much, and are also subject to checking in the firing.

In burning dry-pressed brick of either kind, the losses due to overfiring at the upper part of a down-draft kiln would be large, and at the same time a considerable number of brick in the lower part of the kiln would be too soft and porous to be of any value.

Most of the shales are suitable for use by the dry-pressed process, as they can be burned hard without much risk of over-firing on account of their coarseness of grain, and generally higher range of fusibility than the clays. Attention has been directed in this report to the suitability of the Medina shales in Nicolet county for this purpose. These shales will produce a fine red, smooth, dry-pressed brick with dense, strong body at comparatively low temperatures.

A still higher grade of dry-pressed face brick would be possible from the Lévis or Sillery shales at the localities given in this report. The uniform rich red colour and the density of body produced by these shales appear equal to the famous Accrington reds made in Lancashire.

PAVING BRICK.

Vitrified paving brick or blocks are not manufactured in this province, and very few are produced in Canada, for the reason that good vitrifying shales which are necessary for this purpose are comparatively rare. They are used, however, to some extent in many of the cities in Canada, and would be utilized more if they could be obtained conveniently. When laid on streets they afford the nearest possible approach to a dustless town and hence to a sanitary condition.

Makers of paving brick, more than any other class of clay products manufacturers, have been forced to produce a good article on account of the exacting tests this material must stand before it is accepted for use. Many of the failures charged against paving brick are really due to bad foundations, as the best brick in the world will fail if badly laid.

The essential qualities of a paving brick are soundness of structure, impermeability to moisture, and toughness. The latter quality is imperative as the material must withstand the impact of heavy traffic for a reasonable number of years without failure. Shales that burn to a dense body, and have a long vitrification range, are required for the manufacture of paving brick. The Medina or Utica-Lorraine shales will not meet these requirements as their vitrification points and softening points are too close together, or in other words their vitrification range is too short. As far as the present investigation has been carried only two shale deposits were found whose behaviour in burning indicated that they would be suitable for the manufacture of vitrified wares. These were a shale from the Sillery formation at St. Charles-de-Bellechasse, and one from the Lévis formation at Lévis. A complete series of tests made on them is given in this report.

It should also be possible to utilize the Utica-Lorraine shales for this purpose by adding about 25 per cent of plastic fireclay to them. The addition of this amount of refractory material would certainly tend to lengthen their vitrification range and prevent their softening under the heat necessary to produce vitrification throughout a kiln of brick.

FIREPROOFING.

Fireproofing is at present made by only one plant in Quebec, the Montreal Terra Cotta company at Lakeside. The material used here is a highly plastic Pleistocene clay to which is added 30 per cent by bulk of sawdust. The sawdust burns out in the kilns, and leaves cavities in the ware, which render it soft and porous so that nails may be driven into it, hence the name "terra cotta lumber." The products of this company are used in Montreal for protecting steel work in high buildings, or for floors, furring, and partitions.

Another class of this ware known as hard burned fireproofing is generally made from shale or a mixture of shale and plastic clay. It has slightly thinner walls than terra-cotta lumber, but is generally stronger and tougher, being capable of carrying loads and entering into the actual structural parts of a building.

This class of ware is not manufactured in Quebec, but the National Fireproofing company are investigating the possibilities of the raw materials in the vicinity of Montreal for this purpose. It is probable that clay products of this kind can be made from a mixture of the Utica-Lorraine shale with plastic surface clay, both of which occur in Laprairie and Chambly counties, convenient to Montreal.

The Medina shales in Nicolet county also appear very suitable for this class of product as already pointed out in the pages of this report. Unfortunately these deposits are situated too far from Montreal to obtain the cheap transportation rates, but it might be possible to send them up by water carriage.

Hollow blocks are becoming very popular for various structures, being used largely in the outside walls of dwellings in some localities. The air spaces are said to give protection against dampness and cold, and to provide a cooler house in summer than the solid wall. The blocks are finished on the outside with a coating of stucco, which may be tinted to any colour desired. Some very attractive and comfortable residences are built in this manner at a comparatively low cost.

SEWER-PIPE.

The only sewer-pipe plant in the province at present is the works of the Standard Clay Products company at St. Johns (Plate XXII, A). This company uses the plastic surface clay which occurs so abundantly in that vicinity, adding about 30 per cent of imported fireclay to stiffen it up to the required temperature for salt glazing.

This plant has a large storage capacity to house clay for winter use, which enables it to operate all the year round. The output of this plant is large, as 12 circular down-draft kilns are kept constantly operating, and the product is widely distributed. The results of tests on the local clay used in this locality have already been given.

Attention has been directed in the pages of this report to the presence of vitrifying shales at St. Joseph-de-Lévis and at St. Charles-de-Bellechasse. These shales stand up in the fire without softening, and with a good margin of safety above the temperature required for salt glazing. Their weak point is lack of sufficient plasticity for making into pipe, but their working qualities could be improved by the addition of some plastic surface clay which occurs conveniently in both localities.

REFRACTORY WARES.

An important part of the works of the Standard Clay Products company at St. Johns is devoted to the manufacture of refractory goods made from fireclay. These include stove linings, boiler setting blocks, arch brick, or any special shapes for furnace work. Four round down-draft kilns are used for burning. The clay is all imported.

The Montreal Fire Brick works on Ambroise street, owned by Clayton Bros., carries on a business exclusively in refractories. Their principal output is cupola blocks, locomotive boiler settings, muffles, and laboratory goods made to order. Two small rectangular kilns are used for burning.

The clay is brought from New Jersey, and crushed Potsdam sandstone from Beauharnois, which yields a fairly pure quartz grain, is used for "grog" to reduce the shrinkage.

SANITARY POTTERY.

Sanitary pottery is produced at St. Johns by two firms, the Canadian Trenton Potteries company, Ltd., and the Dominion Sanitary Pottery company. Both firms make the same class of ware in two articles, closet bowls and wash basins.

The raw materials used in this important branch of the clay industry, are all imported, there being no duty to pay on these.

The materials which enter into the composition of sanitary pottery bodies are china-clay, ball-clay, quartz, and feldspar, the same ingredients being used for all classes of whiteware.

The china-clay is imported from either England, Georgia, or Maryland, the ball-clay from England, Florida, or Tennessee, and the flint and feldspar from Maine. The fireclay for making the saggars or vessels in which the ware is burned, is brought from New Jersey.

Some of these ingredients are found in Quebec. There is a limited quantity of kaolin or china-clay at St. Remi d'Amherst, and other deposits of a similar kind may be found. The quartz or flint as the potters call it, and feldspar also occur in the province, but as the demand is only limited, no mills for grinding flint or spar have ever been established here. As far as we know at present no ball-clay nor fireclay occur in this province.

POTTERY.

The manufacture of stoneware pottery was carried on extensively at Cap Rouge almost 40 years ago. The articles made consisted of plates, and platters, jugs, teapots, dairy utensils, etc. The clay was brought from New Jersey in schooners to this works, and about 60 men were employed.

A high grade of glazed ware with special designs in overglaze colours was produced as well as the rougher stoneware articles. Examples of Cap Rouge pottery are rare; most of it that has survived is in the hands of collectors.

A limited amount of stoneware pottery is made at present at Iberville, on the Richelieu river, from stoneware clay brought from the Woodbridge district in New Jersey.

A small quantity of flower pots are made at St. Eustache in Two Mountains county from the red burning Pleistocene clay of that vicinity.

PUBLICATIONS ON THE CLAY INDUSTRIES.

A complete list of the clayworking plants of the province, with the localities and names of owners, together with a description of equipment and quantity of output, were included in the following publication:

Report on the Mining and Metallurgical Industries of Canada, Mines Branch, Department of Mines, 1907-8.

A bulletin on statistics of production of the clayworking industries is published annually by Mr. John McLeish of the Mines Branch under the following title:

"The Production of Cement, Lime, Clay Products, Stone, and Other Structural Materials."

An annual list of the names of manufacturers of clay products, with locations of plants, is also published by the Division of Mineral Resources and Statistics. These bulletins or lists may be obtained on application to The Director, Mines Branch, Department of Mines, Ottawa.

CHAPTER VII.

SAND-LIME BRICK.

These are building brick made from sand and lime as the name implies. Their manufacture began over 50 years ago, when attempts were made to mould common lime mortar into brick, and harden them by exposure to the atmosphere. The hardening of these brick was due to the formation of calcium carbonate by the absorption of carbon dioxide from the air. The same thing takes place in any lime mortar in the joints of a wall.

The large percentage of lime required in their manufacture, and the length of time necessary to harden them, made these too costly to compete with common brick. In order to hasten the hardening of the mortar brick it became the practice to store them in enclosed sheds, and to enrich the atmosphere with carbonic acid gas or carbon dioxide. Afterwards steam and carbon dioxide were introduced into the curing sheds in order to shorten the time required for hardening.

The first patent for hardening mixtures of sand and lime by high pressure steam was taken out in Germany in 1881, but it was not until the year 1898 that sand-lime brick were produced on a large scale in that country, and very few were made in the United States previous to 1904.

Sand-lime brick of poor quality were produced in many instances during the early stages of the industry. Their defects were chiefly owing to the use of inferior sand or lime or incomplete mixing of these ingredients.

Of late years, improved methods of manufacture, and more careful selection of sand and lime have raised the quality of this product so much, that it is possible to obtain sand-like brick which will compare favourably in testing with a good make of burned clay brick. A good deal of prejudice also exists against the use of this material on account of its cold grey colour, which is quite unsuitable for a northern climate. While this objection holds good for exterior work, there is an extensive demand for sand-lime brick for use in basements or rear walls, particularly where the wall is required to reflect some light. Attempts to produce a reddish colour by the use of iron oxides, are expensive and not very successful.

RAW MATERIALS.

The raw materials used in the manufacture of sand-lime brick are sand and limestone. The sands generally used are those which occur in the Pleistocene deposits, and may be sea or lake shore, river, or wind blown sands. These sands are widespread in the province of Quebec; particularly extensive deposits occur at such convenient localities as Three Rivers and Sorel. In general a sand bank in Quebec probably marks an ancient seashore deposit. These sands are particularly well adapted for the manufacture of brick, as they are free from limestone grains, silt, and loam, the greater part of them being made up of quartz grains of varying size.

The lime intended for this use should be burned in a proper manner from good raw materials, these being limestone of a fair degree of purity or marble.

The product obtained after burning is quicklime or caustic lime. When water is added to caustic lime the latter becomes hydrated or slaked, and it is essential that the lime used in the sand-lime brick industry should hydrate readily.

METHODS OF MANUFACTURE.

The first step in the manufacture of sand-lime brick is the mixing of the sand and lime, and it is in this that the various processes differ. One of the three following methods are generally adopted.

(1). Lime is slaked before being mixed with any part of the sand.

(2). Caustic lime is finely pulverized and mixed with all the sand and sufficient water to ensure complete hydration. It is then stored in a silo for a time before pressing.

(3). The caustic lime and a part of the dried sand are ground together. This mixture is then added to the remainder of the sand along with sufficient water to ensure complete hydration of the lime. The complete mixture is then stored in a silo for 24 hours, and then pressed into brick shapes.

The mixture is pressed into shape in a powerful machine of two general types (Plate XXIII), the pressure exerted being about 10,000 pounds to the square inch.

After removal from the press the bricks are immediately placed in huge steel cylinders, usually 60 to 80 feet long, and about 7 feet in diameter, and are subjected to the action of high pressure steam from 8 to 10 hours.

Under the action of high pressure steam the lime attacks the particles of sand, and a chemical composition of water, lime, and silica is produced, which forms a strong bond between the larger particles of sand. This is the reaction on which the sand-lime brick industry is based.

The proportion of lime generally used is 5 or 6 per cent. It must be thoroughly mixed with the sand, to ensure that each grain is coated with a film of lime. Any of the lime remaining in lumps or large particles is detrimental to the finished brick.

Only two factories are operating in the province of Quebec at present, as the industry is new to this region. These two plants have taken care to install the best apparatus that could be obtained and to select the best raw materials on the market. The product turned out is highly satisfactory, and will no doubt help to remove the prejudice against sand-lime brick.

POINTE-AUX-TREMBLES.

The Canadian Brick and Tile company began operations at this point, 8 miles north of Montreal, during the summer of 1913 (Plate XXII, B). The German method of manufacture is used and the machinery was imported from Hamburg. The preparation and mixing of the material is more carefully done in this plant than in any other in Canada. It illustrates the thoroughness of the European methods in all branches of the clay and silicate industries. The lime and sand are brought by rail from Joliette. The lumps of caustic lime are ground in jaw crushers, then pulverized in a ball mill, and taken to the top of the building in a belt elevator. The pulverized lime with a small percentage of the sand and a little water is dumped into a rotary drum mixer. The rotary drum is opened when the mixing is complete, to allow the steam generated in slaking the lime to escape. The remainder of the sand is added and the drum again rotated until the whole charge is thoroughly mixed. The mixture is dumped into a storage bin set directly beneath the mixing drum. The storage bin has a hopper bottom through which the sand-lime mixture is fed to a belt conveyor which brings it to a bucket elevator. The elevator brings it to . dry pan grinder where a further mixing and grinding operation takes place, and any lumps of lime or coarse particles of sand are broken up. The mixture is then ready for pressing, and passes by gravity from the grinding pan to the brick press. The brick are loaded on cars and wheeled into the hardening cylinders, where they are subjected to an atmosphere of steam at a pressure of 120 pounds per square inch for 8 hours. The capacity of this plant is 25,000 brick per day.

ST. LAMBERT.

The plant of the Silicate Engineering company for the manufacture of sand-lime brick is located at this point.

The lime used here is made from marble at Missisquoi and the sand is brought from South Durham by rail. The lime is added to about 30 per cent of the sand, and they are ground together in a tube mill until fine enough to pass a 100 mesh screen. The ground product is added to the balance of the sand with some water and mixed in a pug-mill. The mixture is then elevated to a silo and left for 24 hours. As it comes from the silo it is passed through another pug-mill before going to the press, which is of the rotary type, with a capacity of 22,000 brick per day. The brick remain in the hardening cylinders for 10 hours, under a steam pressure of 120 to 140 pounds per square inch.

The following tests made by Mr. A. G. Spencer of the Canadian Inspection and Testing Laboratories, Limited, show the strength of sand-lime brick made at this plant. The results are an average of the tests on 7 brick.

Transverse breaking load, 6 inches between supports.....	1490
Modulus of rupture in pounds per sq. in................	633

Crushing load in pounds per sq. in.................... 2932
Percentage of absorption.............................. 7·4

These results may be compared with the following tests made at the Engineering Laboratory of McGill University, on a hard burned shale brick from Laprairie, made by the stiff-mud process:

Crushing load in pounds per sq. in.................... 4640
Percentage of absorption.............................. 7·7

As might be expected the shale brick is much the stronger article, but the sand-lime brick are as strong as the average soft-mud brick made from the surface clays in Quebec.

MATERIALS OTHER THAN SAND.

Various rock materials can be ground, mixed with hydrated lime, and pressed into bricks, which are apparently quite as good as those made with sand. The slag from blast furnaces, waste rock tailings from the silver mines in Cobalt, and ground burned clay, have been used successfully for brick.

The ante-fired process described in Chapter IV was designed to utilize those clay deposits which have such defective qualities that they cannot be used in the ordinary methods of brickmaking.

Some tests made in the laboratory on rock tailings from the silver mines at Cobalt and Gowganda in Ontario, show that this waste product when made up with hydrated lime into bricks, gives as good if not better results than the sand-lime brick.

It is evident from these tests that the various silicates will also combine with lime in the presence of heat and moisture to produce calcium-hydro-silicate, as well as silica. If, however, the chemical reaction is not quite the same between silica and lime as between lime and the silicate minerals, the bond produced, whatever it may be, is quite as good for the purpose.

The brick made from the ground diabase rock from the silver mines gave good results in the crushing and freezing tests. The strength was not impaired at the end of 20 repeated freezings and thawings. The colour of the brick made from the diabase rock is dark greenish grey, and is no improvement on sand-lime brick in colour.

The brick made from the burned clay and lime is only a makeshift to produce a building material in a region where there is no sand, and where the clay is too defective for use in the ordinary methods of making and burning.

SILICA BRICK.

Sand-lime brick are sometimes erronously called silica brick. It is true that there is a good deal of resemblance between the materials that enter into the composition of each kind, but the ordinary sand-lime brick would be useless for the purposes to which silica brick are applied.

Silica brick are generally made from pure crushed quartzite to which is added about 3 per cent of lime. These brick are moulded by hand and burned in kilns, for a period of 7 to 10 days, the temperature of burning rising as high as 1600 degrees C. (2900 degrees F.). The bond produced between the silica grains and the lime in the fire is a true calcium silicate.

There is an extensive demand for silica brick in the various metallurgical industries as they are more suitable for special parts of furnaces than clay firebrick. They are used in the roofs of open-hearth furnaces in steel and iron works, and for the roofs and floors of reverberatory furnaces in copper smelters.

No silica brick are at present produced in Canada. It is possible that in Quebec, the Grenville series of the Pre-Cambrian or the Potsdam of the Cambrian, may furnish quartzites pure enough for the manufacture of silica brick.

PUBLICATIONS ON SAND-LIME BRICK.

Peppel. The Manufacture of Sand-Lime Brick: Bulletin No. 5, Geological Survey of Ohio, Columbus, O.

Parr and Ernest. A study of Sand-Lime Brick: Bulletin No. 18, Illinois State Geological Survey, Urbana. University of Illinois.

PUBLICATIONS ON SILICA BRICK.

Havard. Refractories and Furnaces: McGraw-Hill Book Company, New York.

CHAPTER VIII.

ORIGIN AND PROPERTIES OF CLAY.

DEFINITION.

Clay is the term applied to those earthy materials occurring in nature, whose most prominent property 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. Clay is made up of a number of small grains, which are mostly particles of mineral matter. Some of the grains are so small that they cannot be seen without the aid of a microscope. The particles of clay represent many different chemical compounds such as oxides, carbonates, silicates, hydroxides, etc.

ORIGIN OF CLAY.

Clays are always of secondary origin, and result from the breaking down of rocks by weathering. All the rocks of the earth's surface may be divided into two great classes, igneous and sedimentary. Igneous rocks are those which have been forced up from the interior of the earth in a molten condition, and have cooled and crystallized into their present form, either on or below the surface. Rocks of this character are granites, diorites, diabases, and basalts. Sedimentary rocks such as sandstones, shales, clays, sands, and gravels are derived from the wearing down of these igneous rocks, or of older sediments whose ultimate origin must be sought for in the igneous rocks. If borings were made deep enough the igneous rocks would be found underlying all the portions of the earth's surface occupied by sedimentary rocks.

WEATHERING PROCESSES.

Rain, frost, wind, and running water are agents which may reduce even the hardest of the igneous rocks to the condition of clay.

Expansion due to the sun's heat during the day, and contraction from cooling at night, form minute cracks in rocks, or there may be joint planes formed by the contraction of the rock. Rain water creeping down these crevices, expands on freezing, and helps to wedge adjacent blocks apart. Plant roots force their way into the cracks, and grow there, so that a prying action occurs which supplements the action of frost in breaking up the rock. These and allied processes will reduce the rock, a portion at a time, to a mass of small angular fragments.

When the rock is in this condition, the rain water or organic acids, the oxygen of the atmosphere, and other agencies bring about chemical changes of a rather complicated character, which hasten its decay and waste.

Surface water, supplied by rain or melting snow, washes the finer rock waste down the slopes to the valley bottoms or to the streams, and the streams bear the waste along their channels, thus sweeping it from one place, and spreading it over another or carrying it to the sea.

The finest grained materials of the rock waste are carried for long distances by running water, but on entering quiet waters like seas and lakes, this finely divided material settles down on the bottom of these bodies of water and forms beds of clay.

RESIDUAL CLAY.

Most rocks suffer chemical changes under the action of water and air, and as a rule these changes aid decay and crumbling. The change may go as deep beneath the surface as water and air can penetrate, and is aided when the ground water carries down with it the products of decomposing vegetation from the surface. Some rocks such as limestone may be slowly dissolved by water; as the limestone weathers the soluble parts are slowly carried away while most of the insoluble parts of the rock remain:

thus it may happen that a blue limestone is covered with rusty clay waste.

Granite, consisting of crystalline grains of quartz, feldspar, and mica closely bound together, is one of the most resistant rocks, but the weathering of one of its minerals (feldspar) unbinds its parts, and it slowly crumbles to a clayey mass with quartz and mica scattered through it. The alteration of the feldspar grains to a white, powdery substance known as kaolinite, is one of the most important chemical changes that occur in rock decay. 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.

Clay derived from a rock containing much iron oxide will be yellow, red, or brown, depending on the iron compounds present.

FORMS OF RESIDUAL DEPOSITS.

The form of a residual clay deposit is variable and 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. Some rocks such as pegmatites (feldspar and quartz), occur in veins or dykes, 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. The kaolin deposit at St. Remi d'Amherst, Labelle county, is of this type (See Figure 1).

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; 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 shales or other soft rocks, change to clay in measurable time. With other things equal, rock decay proceeds more rapidly in a moist climate. The thickness of a residual deposit may 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 in place after being formed, but on steep slopes it will soon wash away.

Deposits of residual clay are very rare in the province of Quebec, for the reason that nearly all of those formed have been swept away by glacial action.

TRANSPORTED CLAYS.

Nearly all the clays in the province of Quebec are transported clays, that is they were brought to their present position from distant sources. The process of clay formation by the washing down of rock waste from highlands into valleys is constantly going on. Some of these clays are very old, and have become rock like, while some of the later ones are so soft that they may be dug out by the hand. These clay beds have been deposited at various times in bodies of still water, and the materials of which they are formed have been supplied by streams flowing into these bodies of water. When water is in motion it will carry clay grains in suspension, but as soon as its motion or current is checked, the particles begin to settle on the bottom forming a clay layer of variable extent and thickness. The fine-grained material carried out into lakes or seas by running water is called sediment. The sediment is often carried for some distance from the shore by currents, but it finally settles as a fine soft mud.

During certain portions of the year, especially in the spring time, when the melting snow supplies a large volume of water to the streams, the amount of sediment carried and deposited, will be large, while at other seasons of the year it will be small. During flood time, the streams will carry coarser materials than when the water is low, so that sandy layers may be deposited on top of fine-grained materials. If this process is kept up and these layers are added to every year a considerable thickness may be laid down, forming a deposit of sedimentary clay.

Most of the sedimentary clays are stratified or made up of layers. For some reason a larger amount of sediments may be deposited in one year than in others, and then the layers will vary in thickness.

CLASSIFICATION OF SEDIMENTARY CLAYS.

The great bulk of the clays used in the various clay working industries is derived from sedimentary deposits laid down in still water.

The nature and extent of these deposits depends on the size of the body of water, the number of streams discharging material into it, the kind of rocks on the land surface through which the streams flow, and climatic conditions.

MARINE CLAYS.

This class includes those sedimentary clays deposited on the ocean bottom where 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 material 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. The shale is now found exposed, because the ocean bottom has been uplifted, and the overlying rocks worn away.

SHALES.

Shales are beds of hardened clay, and generally show the stratified structure which they had when originally laid down as soft muds or sediments. Owing to this structure these rocks break down most easily along the lines of the layers into plate like fragments.

The shale clays are not commonly plastic, but when finely ground, or subjected to weathering processes, they frequently become very plastic, so that they can be easily moulded into shape.

Although sometimes of great thickness and uniform composition, shales are frequently found as thin bands between beds of sandstone. Shales are among the most valuable clay deposits and they occur widespread along the St. Lawrence river, between Montreal and Quebec, and to a lesser extent on the shores of Gaspe, and Bonaventure counties.

SLATES.

These rocks are also derived from clay sediments, but have been hardened to such a degree by pressure and other agents that the plasticity of the clay has been destroyed. Beds of slates may resemble shales in colour and structure, but usually they are not of much value to the clayworker, because when finely ground and mixed with water they do not develop plasticity like the shales, but on the contrary, behave like a mass of sand.

All degrees of transition exist, however, between the shales which are readily made plastic by grinding and tempering with water, and those slates which no amount of grinding and working up will render even feebly plastic. Some of the slates or shales of low plasticity can be worked if a plastic clay is added to them, and such a mixture will often give better results for certain purposes than if the plastic clay were used alone.

The slates have a wide distribution in the southern portion of the province of Quebec.

ESTUARINE CLAYS.

These represent bodies of clay laid down in shallow arms of the sea, and consequently are found in areas that are comparatively long and narrow, with the deposits tending to occur in basin-like 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 at a long distance from the point of entry of the river. If tides having great changes of level enter the estuary, such as those which occur at the present time in the Bay of Fundy, coarse sediment would be carried out far into the basin by the scouring action of the tides. Estuarine clays frequently show sandy laminations as a result of these disturbances to the sedimentation.

The soft clays that occur in the valleys of the Ottawa and St. Lawrence rivers, are of both estaurine and marine type.

LAKE AND SWAMP CLAYS.

There is another class of deposit which has been formed in basin-shaped depressions, occupied by lakes or swamps. This type is variable in extent and thickness, but frequently shows alternating beds of clay and sand. 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 is deposited. Clay beds of this type are extremely abundant in all glaciated regions.

GLACIAL CLAYS.

The greater part of Canada was covered with a thick ice sheet for a long period during recent geological time.

On its advance over the land, the ice sheet gathered up loose materials of all kinds, so that any accumulations of residual clays which existed on the rock surfaces throughout the region were destroyed. The planing action of the ice went so deep in many places, that it not only removed the weathered portions, but scraped into the fresh rock beneath. The scratches and grooves made by the passage of the ice sheet are still very well preserved on many rock outcrops throughout the province.

The ice sheet gradually melted and finally disappeared, but all the material it had gathered from the surface of the land remained behind. The mixture of sand, gravel, boulders, and clay accumulated and deposited by the ice sheet is called boulder clay.

Although much of the boulder clay has been removed and its materials assorted by the large quantities of running water set free by the melting ice, there are still extensive sheets of it found in the province. It is of no value to the clayworker, on account of the large number of stones and pebbles embedded in the clay.

In some cases the streams issuing from the ice sheet deposited fairly extensive bodies of clay in lakes which formed at the edges of the ice. This variety of glacial clay is often fairly free from pebbles and highly plastic, but sometimes it is very gritty and carries numerous small pebbles or grit particles. Both kinds have been used in various localities for brickmaking purposes. These deposits, although they are of sedimentary type, do not as a rule show the layers or stratification that clays washed into lakes from land surfaces do, but are massive in structure, and often show crevices running in a vertical direction similar to joint planes in rocks. In some localities they are called joint clays.

MINERALS IN CLAY.

The process by which clays are formed from the breaking down of older rocks have been described briefly. Many different kinds of rocks, composed of various minerals, may have contributed the materials of which clay deposits are composed; therefore in examining a clay we might expect to find most of the minerals which were contained in the parent rocks present in it.

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 minerals. The following are those most commonly found and which affect the working and burning properties of a clay.

KAOLINITE.

Kaolinite is a hydrous aluminium silicate, and is thought by many to be present in all clays, but its existence has only been proven in the case of the purest white burning clays. It cannot be regarded as the source of plasticity in clay, as some authorities think, because many impure clays containing little or no kaolinite are highly plastic.

There is some property which gives all clay its plasticity, causes shrinkage in drying and burning, and sometimes gives trouble in drying. It is likely that this property is due to the presence of various minerals containing chemically combined water, which is not driven off until a temperature of 600 degrees C. is reached. Some writers refer to this as *clay substance*, and state that all clays contain it in various stages of purity.

QUARTZ.

Quartz consists entirely of silica. It is found in almost all clays in the form of sand grains which are rarely large enough to be seen by the naked eye. It constitutes a large part of the sandy and silty clays; but only a very small amount may be present in the more highly plastic clays.

Quartz is quite hard and will scratch glass, while feldspar will not.

Besides being in the form of sand or quartz grains, silica may be present in combination with other minerals, such as alumina, lime, magnesia, and iron. These compounds are known as silicates; they include feldspars, hornblendes, micas, etc., which with quartz are the chief constituents of granitic rocks.

Quartz is not plastic, no matter how finely it may be ground. Sand made up mostly of quartz grains is added to fat clays to make them easier to work and dry, and also to lessen shrinkages. It requires an extremely high degree of heat to soften pure quartz, so that for some purposes a firebrick is made of pure silica sand or crushed quartz rock.

Quartz sand added to impure clays enables them to stand more heat, but as the quartz grains do not enter into bond with the clay in firing at low temperatures, too much sand or too coarse sand will be a source of weakness to common brick or tile.

FELDSPAR.

Grains of feldspar although present in most clays are rarely visible. When feldspar decomposes it furnishes the alkalis—potash and soda. It melts at a much lower temperature than quartz, and burns to a white colour, so that it is used as a flux, and added to pottery mixtures to produce vitrified wares. Feldspar does not act rapidly like some other fluxes, but softens quite slowly, hence it is a safe material to use for this purpose.

MICA.

Mica is one of the few minerals in clay that can easily be seen with the naked eye. It is found in many of the Pleistocene clays in Quebec, in the form of thin scaly particles, with shining yellow or white surfaces plainly visible even when very small, in both the raw and burned clays.

The white mica is a silicate of potash and alumina, and the dark kind is a silicate of iron, magnesia, and alumina. When very finely divided mica acts as a flux like feldspar; but the larger grains of mica are rather infusible, and will resist a high degree of heat before fusing. Mica does not burn to a white colour, especially the dark kind, but to a dark or reddish colour.

IRON COMPOUNDS.

Iron compounds occur in nearly all clays, and in a variety of forms. Pure white burning clays contain little or no iron, buff burning clays contain more, and as the iron content increases the redder the burned clay becomes.

Iron in clay occurs compounded with oxygen, sulphur, or carbon, usually with oxygen. The iron-bearing material may be so finely divided and disseminated throughout the deposit as not to be apparent except that it may stain the clay a red, yellow, or brown colour, or it may occur as grains or in lumps large enough to be separated from the clay if necessary. The prominent compounds of iron are its two oxides, ferric and ferrous. These are very active fluxes, but the ferrous form is the more active and often causes trouble in burning.

Hematite, an iron ore of reddish colour, is an example of ferric oxide, but it readily changes to yellowish coloured limonite on exposure to air and moisture. The yellowish colours or rusty streaks in the upper part of the Pleistocene clays in Quebec are due to the presence of limonite. Red brick contains the iron in the form of ferric oxide.

Ferrous oxide is an active flux, combining rapidly with the silica of clay to form ferrous silicate which is dark in colour.

A red brick with a black core is an example of the occurrence of iron oxide in both the ferric and ferrous condition. In one case the iron is said to be completely oxidized, in the other case it is unoxidized, or reduced. Reducing action is the reverse of oxidation, as this process robs the iron or other oxide of part of their oxygen.

Pyrite or iron sulphide occurs in many clays. It is composed of iron and sulphur. It occurs in large lumps, small grains, or cubes, with a metallic lustre and yellowish colour. When exposed to weathering, pyrite alters in time to limonite or ferric oxide. When pyrite is exposed to heat in a kiln, the sulphur burns out and is expelled as a gas called sulphur dioxide. The iron which is left behind, after the passing away of the sulphur, takes up oxygen from the air entering the kiln and becomes ferric oxide. Clays containing pyrite are not desirable to clay workers as the sulphur gases nearly always cause trouble in burning.

LIME COMPOUNDS.

There are two principal compounds of lime, lime carbonate, and sulphate of lime. The lime carbonate is frequently derived from limestone or marble. Its presence in a clay may be detected by dropping a little muriatic acid or even strong vinegar upon it. If the lime is present, bubbling or effervescense will ensue. Lime carbonate is composed of oxide of lime, and carbonic acid. The latter in passing off is the cause of the effervescense when the acid is dropped on lime carbonate.

When limestone is burned in a kiln, the carbonic acid is driven off as a gas as soon as the heat becomes great enough, and caustic lime or quicklime is left behind. The same thing happens to lime carbonate in clay when the latter is burned in a brick kiln. This quicklime is a very active flux, and unites readily with the clay to produce vitrification. If the heat is raised high enough it will melt the clay into a slag very quickly after vitrification begins.

A large quantity of lime in a clay will exert a bleaching action on the iron in burning, so that a buff or light yellow colour results instead of red, which would be the case if an excess of lime was not present. This is the reason that so many clay deposits in Ontario and Manitoba are buff burning clays.

Most of the Pleistocene clays in Quebec will effervesce if a few drops of acid are poured on them, showing that some lime is present, but the quantity of lime is never large enough to produce a buff colour. Some of the Utica shales in Quebec contain quite large amounts of lime, and will burn to a buff colour.

So long as the lime is in a finely divided condition it causes no trouble, except that a clay high in lime makes a more porous brick than a red burning clay will at the same temperature.

If the lime is in lumps or large particles in a clay, they will cause brick made from it to burst on exposure to air after burning. The limestone lumps or pebbles are burned to quicklime, these swell on absorbing moisture from the air, and the force exerted by the swelling invariably breaks the brick.

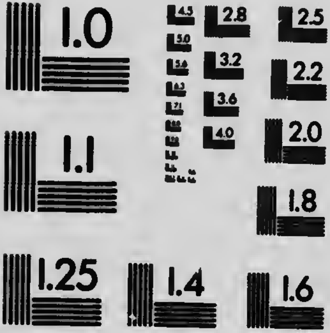
Lime sulphate or gypsum is another lime compound found in some clays. It is of rare occurrence in the clays of Quebec, but is found rather abundantly in many clay deposits in western Canada. It is a combination of quicklime and sulphuric acid. Muriatic acid does not cause effervescence when dropped on lime sulphate because the chemical bond between the quicklime and sulphuric acid is much stronger than that between it and carbonic acid gas in lime carbonate. The sulphuric acid gas is not driven off from gypsum, at the temperature at which common brick is generally burned, consequently it exercises no influence on the colour of a red burning clay, except to appear as white specks.

ALKALIS.

The alkalis, soda and potash, are derived principally from the decomposition of feldspars amd mica. They are regarded as the most powerful fluxing materials that the clays contain; but the amounts present are generally small.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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SULPHUR.

Sulphur may be present in clay as an element of gypsum, the lime sulphate, or as an element of pyrite, the sulphide of iron. Sulphur is driven off from its compounds as sulphurous acid gas, during the burning of clay wares, when air is admitted freely to the kiln. All of the sulphur may not be burned out of the ware, because air cannot readily penetrate the interior. If carbon is also present, even in small quantities, it interferes with the expulsion of sulphur. Sulphur retained in a clay produces a spongy body with swelling soon after vitrification begins. Pyrite in the coal used for burning clay wares is a frequent source of sulphurous gases in kilns.

CARBONS.

Most clays contain some carbon either in the form of decayed organic matter which occurs in soft clays close to the surface, or as bituminous and asphaltic matter found in some shales. In various localities in Quebec, the Utica shale is very dark in colour from the bituminous matter it contains, while the oil-shales in New Brunswick will burn almost like coal, and give off great volumes of combustible gas. The organic matter in soft clays burns out readily and rarely gives any trouble; but shales containing asphaltic carbon are very difficult to burn, and, if the quantity is large, they cannot be used at all for making clay wares.

It is extremely hard to burn carbonaceous matter out of fine-grained, dense shales or clays as air cannot penetrate them quickly enough; consequently wares made from these clays are liable to become vitrified on the surfaces before the carbon is all burned out of the interior. If carbon is left in the body of the clay, it interferes with the expulsion of sulphur and the change from ferrous to ferric iron. This may result in complete fusion of the interior of the mass during the vitrification stage.

Clays containing carbon require a prolonged period of burning during the oxidation stage before the temperature is raised to a vitrifying heat, otherwise trouble from black cores and swelling is almost sure to occur.

On account of their open texture, brick made by the soft-mud process are more easily oxidized than stiff-mud or dry-press brick. The Utica shale in some parts of Quebec contain enough bituminous matter to give trouble in burning.

WATER.

There is always some water held in the pores of clay after it is thoroughly air dried. This is called mechanically combined water or pore water, and is not driven off until the clay is subjected to a temperature of 210 degrees F., or the boiling point of water, when it passes off in the form of steam. This process, called watersmoking in burning brick or other clay wares, is the passing-off of mechanically combined water in the form of steam. If, after all the pore water has been driven off, the clay is exposed to the air again, it takes up the same amount of water that it gave off.

Fine-grained plastic clays absorb a great deal of water in tempering, and are hard to dry; sandy clays require much less, and part with their water readily. Most of the mineral grains in clay contain water in their composition, which is called chemically combined water. This water is not driven off at 212 degrees F., but at temperatures ranging from 750 degrees F. to 1100 degrees F. When this is accomplished, the clay is said to be dehydrated. It has also lost its plasticity.

PHYSICAL PROPERTIES OF RAW CLAYS.

PLASTICITY.

The characteristic quality of clay is its plasticity. On account of this property the clay can be moulded into shape while wet and it retains this shape in the dry condition with sufficient strength to permit its being handled without breaking. It is this property that gives clay its value in the various industries, and without which it would be worthless for most purposes to which it is put. The plasticity varies with several factors, but seems to be absolutely controlled by none of them.

Among these factors are fineness of grain, amount of colloidal matter, amount of sand or silt, and the shape of the clay particles. The amount of working or kneading which the clay has undergone in a wet condition also affects the plasticity.

TENSILE STRENGTH.

The tensile strength of a clay is the resistance which it offers to rupture, or being pulled apart, when air dried. Upon this property depends the resistance of the dry clay to crumbling, to breaking when handled, and to pressure when set in kilns. High tensile strength and high plasticity sometimes go together; but this relation does not always hold.

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.

FINENESS OF GRAIN.

The fineness of grain of a clay is closely related to many of its working and burning qualities, such as plasticity, porosity, rate of drying, tensile strength, shrinkage, warping or cracking, temperature of fusion, and vitrification range. Other things being equal, the finer grained the clay the more water is required to make it plastic, and the smaller the pore space. This causes a greater shrinkage in the fine-grained clays and a slower rate of drying, as the water can only move out through the small pores very slowly.

The finer grained clays heat up more rapidly in the kiln and also melt more rapidly, since the different minerals in the finely divided condition can exert a greater fluxing action upon each other than when they occur in larger pieces.

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 very fine-grained ones, 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.

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 lessen 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 it 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.

CHAPTER IX.

THE EFFECTS OF HEAT UPON CLAYS.

Any clay, on firing, goes through a series of changes or stages from the weak, raw condition to the strong and permanently burned condition. The changes are usually increasing density, increasing strength, increasing shrinkage, decreasing porosity, and decreasing specific gravity. But in any clay, a point is attained when these changes reach a condition of balance—when the clay is at its best—and further increase of heat leads to a reversal of all these properties.

In surface clays, the burning is customarily stopped considerably short of vitrification and while the ware is yet porous. Owing to the fineness of grain of these clays and the large amount of fluxing impurities present in them, they shrink very rapidly when approaching vitrification, while softening and swelling follow closely on a slight rise in temperature above that necessary to produce vitrification. The shales are generally burned to a higher degree of maturity, as their comparatively coarse-grained structure requires more heat to bring them to the proper degree of density and strength of body, while the risks of unduly high fire-shrinkage and danger of overfiring are not so great as in the case of the fine-grained close textured surface clays.

The process of burning clay wares may be divided into four periods: (1) watersmoking; (2) dehydration; (3) oxidation; (4) vitrification. Each of these stages is characterized by certain reactions, but there is no sharp dividing line between them, the changes of one stage beginning before those of the preceding one are completed.

WATERSMOKING.

Watersmoking begins after the fires are lighted in a kiln of clay wares. Although brick may come from the drier in a bone-dry condition they still retain considerable moisture in the pores of the clay. The object of watersmoking is to expel this moisture. It comes off in the form of steam; but the heat has to be raised to a temperature above the boiling point of water before all this pore water is driven off from the inside of the brick. The watersmoking is done slowly, and ample time allowed for the heating up of the clay, so that steam is not formed too fast for escape through the pores of the clay. If the heat is raised too fast the steam pressure in the centre of the brick, especially if they are made from fat or fine-grained clay, is often sufficient to spall or burst the brick. This is called "popping" by brickmakers. There is practically no change in the properties of the clay after watersmoking, but the operation must be thoroughly performed to prepare it for the second stage.

DEHYDRATION.

Dehydration is the term used to express the process of depriving the clay of its chemically combined water. It occurs at temperatures which make the clay glow with a dull red colour, and is practically complete at 700 degrees C. (1292 degrees F.). If the operation of burning were stopped at this point and the clay cooled down it would be found to have lost all its plasticity.

Before the dehydration of the clay is complete other gases also begin to pass off, including carbon dioxide from lime and iron carbonate, sulphur from pyrite, and gases produced from the combustion of carbonaceous matter in the clay. All of these may not have passed off when the dehydration of the clay is ended, but some may be carried over to the next period.

OXIDATION.

The process of oxidation begins in the later stage of dehydration or at as low a temperature as 500 degrees C., and is probably completed at 900 degrees C. (1652 degrees F.). During this period the oxidation or burning-off of the combustible matter must be accomplished; the remaining sulphur is set free from the pyrite, the carbon dioxide is all driven off from the lime or iron carbonate, and the iron is changed from the ferrous to the ferric condition. Loose open textured clays or shales allow these changes to take place more readily than dense fine-grained clays, as the latter retard the entrance of oxidizing gases into the mass. Much air must be admitted with the fuel gases to facilitate the removal of the combustible or volatile elements in the clay, especially the carbonaceous matter, since air carries the oxygen which helps to remove them.

The formation of the red colour in most clays is due to the absorption of oxygen by ferrous oxide, causing the change to ferric oxide during this and the succeeding stage. If the temperature is raised to a vitrification heat before oxidation is complete, the iron in the central part of the mass remains in a ferrous condition and forms a black core which may fuse rapidly and swell.

The length of time during which oxidation must be allowed to proceed varies according to the character and composition of the clay, and is easily determined by experiment. In general the clays that are not oxidized during this period will never become so, as fluxing action begins at the opening of the next period, and the pores of the clay begin to close up.

VITRIFICATION.

During the vitrifying stage the greatest change takes place in clay under the influence of heat. This process begins during, or shortly after oxidation, by a slight fusion of the particles, sufficient to cause the mass to become cemented and hardened; but as the [illegible] material in clay which is fusible at such a low temp[illegible] small, there is no appearance of vitrification, and the b[illegible] porous. The clay, however, may have softened su[illegible]y to cause the smaller particles to stick together and to prevent the recognition of any except the larger mineral grains. As the temperature in the kiln is raised more particles enter into fusion, and the clay becomes more compact. A still further rise in temperature produces an additional quantity of fusible material, until finally the whole mass of the clay is involved, the pores close up, and an impervious body is produced.

Clays burned to this condition are said to be completely vitrified and they have a smooth fracture and a glassy lustre, as the name vitrification implies. The heat necessary to actually produce a glass is never allowed, intentionally, in the burning of clay wares, because then they would soften too much and lose their shape or become viscous and flow. There must be a firm skeleton or framework of unfused material left to hold up the piece.

Fine-grained clays will fuse easier than coarse-grained ones, other things being equal, as the grains, being closer in contact, fuse more readily, and the pores close up quicker, being smaller. Sand or coarse grog is added to fine-grained clay for the reason that it assists the pieces to retain their shape, by preventing undue shrinkage and warping through softening.

Many of the common red brick burned in Quebec will, when broken, show an earthy or rough sandy fracture. The earthy fracture generally indicates an underburned brick, which is weak and friable, because the temperature of burning has not been carried high enough. The sandy fracture indicates that a clay has been used which is of a sandy composition or that an excess of sand has been added. The sand being mostly composed of quartz grains, takes no part in the vitrification at the low temperature that common brick are generally burned at; hence the quartz grains remain unaltered by the fire with little or no bond between them and the clay particles. An excess of sand is, therefore, a source of weakness, and underburned brick made from sandy clay are useless.

CONTROL OF TEMPERATURE.

In most of the brick plants in Canada the temperature to which the product is burned is judged by the eye, the wares being burned to a dull red, cherry red, or white heat. This method results in much variation in the burned products, and depends on the experience of the man in charge of the burning. There may also be a wide difference in temperature in different parts of the kiln which will not be apparent to the eye.

The matter of controlling the temperature and of obtaining a uniformly burned product is comparatively simple. One of the methods best adapted to commercial plants is the use of the Seger pyrometric cones.

SEGER CONES.

These cones are small triangular pyramids about one-half inch dimension at the base, and tapering to a point at the top. They are about 3 inches long.

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 degrees C. (2102 degrees F.). Cone 20 melts at the highest temperature obtained in a porcelain furnace, or at 1530 degrees C. (2786 degrees F). The difference between any two successive members is 20 degrees C. (36 degrees 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 be[illegible] [illegible]90 degrees C. (1094 degrees F.) and that of the highes[illegible] [illegible]40 degrees C. (3470 degrees 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.

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 (Plate XXIV).

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 following table, it must not be understood that these cones are for measuring temperature, but rather for measuring pyrochemical effects.

The following list gives the approximate fusing-points of some of the members of the series of cones used for this report:

No. of cone.	Fusing point.	
	Degrees F.	Degrees C.
010	1742°	950°
07	1850°	1010°
06	1886°	1030°
05	1922°	1050°
03	1944°	1090°
01	2066°	1130°
1	2102°	1150°
2	2138°	1170°
3	2174°	1190°
5	2246°	1230°
9	2390°	1310°

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
Paving brick	01–5
Sewer-pipe	3–7
Buff face brick	3–9
Hollow blocks and fireproofing	07–1
Terra-cotta	02–7
Conduits	5–8
Firebricks	5–14
White earthenware	8–9
Red earthenware	010–05
Stoneware	6–8
Porcelain	11–13
Electrical porcelain	10–12

CHAPTER X.

KINDS OF CLAYS.

As shale is merely a hardened clay, the terms clay and shale are regarded as one and the same thing by the clayworker. Most shales, when pulverized finely enough to pass through a screen of 20 meshes to an inch, can be tempered with water, and worked up until they have a plasticity equal to that of some clays which occur in a soft or unconsolidated state.

Slates are also hardened clays, but the process of hardening has proceeded to such a degree that they no longer possess the property of plasticity, which is so important in the clay-working industry. Slates may resemble shales in colour and structure, but the fact that they cannot be moulded into shape renders them useless for the purposes of the clay industry.

Clays have a wide variety of colour in the raw state, varying from white to almost black. The prevailing colours of the clays or shales in Quebec are light and dark grey, brown, and red. Most of them turn to various shades of red, when burned in kilns, the red colour developed in burning being due to the oxidation of the iron contained in the clay, the iron being an active colouring agent. Clays in which there is a very low percentage of iron will burn to white, grey, or buff tones, Clays which have a very high percentage of lime, like the Erie clay in Ontario, will burn to a buff colour, the lime exercising a bleaching action on the iron.

KAOLINS AND CHINA-CLAYS.

The name kaolin is commonly applied to natural deposits of white burning residual clays, which are composed mostly of silica, alumina, and chemically combined water, but having a very low percentage of fluxing impurities, especially iron. Deposits of kaolin generally contain quartz fragments, and mica grains as impurities. When these are separated from the mass by washing, the fine-grained washed product is called "china-clay." China-clays are used in the manufacture of white table ware, electrical porcelain, wall tile, as a paper filler, and as an ingredient of slips and glazes in ceramics. The white ware and porcelain bodies are made up of: china-clay, which gives whiteness and refractoriness, ball-clay to give plasticity and bond, ground quartz (called flint) to reduce the shrinkage and give stiffness to the body, and feldspar to serve as a flux.

The only workable deposit of kaolin, so far known in Canada, occurs at St. Remi d'Amherst, about 70 miles northwest of Montreal. As shown by the following chemical analysis, it is a kaolin of high purity:

Silica (SiO_2)	46·13
Alumina (Al_2O_3)	39·45
Ferric oxide (Fe_2O_3)	0·72
Lime (CaO)	none
Magnesia (MgO)	none
Potash (K_2O)	0·20
Soda (Na_2O)	0·09
Loss on ignition	13·81
	100·40

BALL-CLAY.

This is the plastic ingredient in white ware bodies. The raw clays of this class should combine plasticity with good tensile strength, and burn white or nearly so. No true ball-clay has been found in Canada, but the white beds among certain sedimentary clays in the Musquodoboit valley, Nova Scotia, approach it in character.

FIRECLAYS.

The most important property of this class of clays is refractoriness or ability to withstand a high degree of heat without softening. They may vary widely in other respects, showing great differences in plasticity, density, shrinkage, and colour.

It is customary for miners to apply the term fireclay to all clays and shales found underlying coal beds. While it is true that in Great Britain, and in several of the states, valuable fireclays underlie coal seams, still there are many of the clays under the coal in these countries, that are not refractory.

None of the clays and shales underlying the coal seams in the Maritime Provinces, as far as they have been tested, proved to be fireclays.

The standard adopted in these reports is, that the material shall stand up, without softening under fire at the fusing point of cone 27 (3038°F.) before it can be termed a fireclay.

Some authorities in the United States refer to clays which will stand cone 30 or better as a No. 1 fireclay, from cone 20 to cone 30 as No. 2, and from cone 10 to 20 as No. 3 fireclays. While some of the lower grade clays may be worked up into shapes for various industrial uses, such as stove linings, sewer-pipes, electrical conduits, etc., they would not be suitable at all for metallurgical work, where slags are formed, or where intense heat is used.

Fireclays are used most generally and extensively in the industrial furnaces, in blast furnaces, crucible melting furnaces, the layers and bottoms of Bessemer converters, the furnaces used in the lime, glass, clay, and cement industries, in lead refining furnaces, in basic open-hearth furnaces above the slag line, for flues, boiler settings, linings of stacks, household grates, etc.

The fireclays used in the various industries in Quebec are all imported from the United States, as none has so far been discovered in this province.

The two following chemical analyses are given to illustrate the composition of fireclays. No. 1 is from Shubenacadie, N.S., No. 2 is from Murphy brook, Middle Musquodoboit, N.S.

	No. 1	No. 2
Silica	74·03	55·14
Alumina	17·30	28·84
Ferric oxide	1·15	1·91
Titanic oxide	1·04	2·37
Magnesia	0·16	0·25

Lime	0·38	0·33
Soda	0·53	0·48
Potash	0·88	1·88
Water	4·78	9·24
	100·25	100·49

STONEWARE CLAY.

While this material is often as refractory as the clay used for firebrick, it differs from it in burning to a very dense body at comparatively low temperatures. It should have sufficient plasticity and toughness to permit its being turned on a potter's wheel. Its fire-shrinkage should be low, its vitrifying qualities good, and it should be sufficiently refractory so that the wares made from it will hold their shape in burning. Most stoneware is now made from a mixture of clays, so as to produce a body of the proper qualities, both before and after burning.

Stoneware clays are used not only for the manufacture of all grades of stoneware, but also for yellow ware, art pottery, earthenware, and architectural terra-cotta.

Stoneware clay is used largely in Great Britain for the manufacture of sewer-pipe. Owing to its smoothness, and the fine salt glaze which it takes, added to the hardness and strength of the body, this class of ware is the very highest grade of sanitary drain pipe.

SLIP-CLAYS.

These clays contain such a high percentage of fluxing impurities, and are of such texture, that at a low temperature they melt to a greenish or brown glass, thus forming a natural glaze. While easily fusible clays are common, few of them produce a good glaze on melting.

A good slip-clay makes a glaze which is free from defects common to artificial glazes. It will fit a wide range of clays, and since it is a natural clay, it will undergo the same changes in burning, as the body on which it is placed. Artificial mixtures of exactly similar composition to the natural slip clays have failed to give the excellent results as to gloss or colour that are attained by the natural clay.

In applying the glaze to the ware the clay is mixed with water to a creamy consistency, and applied to the ware either by dipping or spraying. The most satisfactory slip-clay is obtained from Albany, N.Y.; it is shipped to all parts of the United States and Canada for potters' use in glazing stoneware.

PAPER-CLAY.

In paper making, a clay may be used as a filler or as a coating material. Since clay enters into the composition of all the ordinary printing and bond papers, as well as many wrapping papers, its most important use in this industry is as a filler. Whiteness and freedom from grit are essential, in the best grades of paper-clay.

FULLERS EARTH.

The name fullers earth is made to include a variety of clay-like materials of a prevailing greenish-white or grey, olive green or brownish colour, soft and with a greasy feel. This type of clay has a high absorbent power for many substances. It was originally used for fulling cloth, that is, cleansing it of grease. Its most important use, at the present time, is for bleaching cotton oil and lard oil. Mineral oils are also filtered through it. There is no record of fullers earth occurring in Canada.

PIPE-CLAY.

So-called because tobacco pipes are made from it, is an impure kaolin containing free silica. This term is also used in referring to clays or shales suitable for making sewer-pipe.

SEWER-PIPE CLAY.

Clays or shales that burn to a vitrified body, have low absorption, that hold their shape in burning, and also take a satl glaze, are essential in the manufacture of this class of ware. Fireclay is often added to a vitrifiable shale, or a mixture of two or more shales may be used.

The clays used for this purpose are similar to those used for paving brick, so that the two products are sometimes made in the same factory from the same clay.

Materials suitable for the manufacture of sewer-pipe are of rare occurrence in Quebec.

BRICK-CLAYS.

The clays or shales used for common brick are generally of a low grade, and in most cases red burning. The main requisites are that they will mould easily, and burn hard at as low a temperature as possible, with a minimum loss from cracking and warping. Since many common clays or shales when used alone show a higher air or fire-shrinkage than is desirable, it is customary to decrease this by mixing some sand with the clay, or by mixing a loamy or sandy clay with a more plastic one. Brickmakers call a clay "strong" or "fat," when it is highly plastic, somewhat stiff and sticky, and "lean" when a clay is gritty or sandy and works easily.

Brick used for facing buildings are moulded with special care, or re-pressed, if made by the wet-moulded processes. When dry-pressed brick are required, the best results are obtained by using shale. Smoothness of surface and uniformity of colour are no longer required, as formerly, for this purpose, so that special methods are resorted to by face-brick manufacturers to produce roughness in surface, and variety in colour.

PORTLAND CEMENT CLAY.

Shales or clays are largely used in the manufacture of Portland cement. This material is essentially an artificial mixture of lime, silica, and alumina. The first ingredient is usually supplied by some form of calcareous material, such as limestone, marl, or chalk, while the other two are obtained by the selection of a clay or shale, the mixture consisting approximately of 75 per cent of lime carbonate to 25 per cent clay or shale.

Clays or shales to be used for Portland cement manufacture, should be as free as possible from coarse particles or lump sand, gravel, or concretions. These conditions are best met by the transported clays, since residual clays are frequently sandy or stony, and many glacial clays notably so.

Several of the surface clays and shales in Quebec will probably be found suitable for this purpose. For economic reasons they should be located in the vicinity of marl, or limestone deposits, and convenient for transportation.

MARL.

Shale or clay that contained a large percentage of lime were formerly referred to as "marly," hence certain soft red shale beds occurring in the Lower Carboniferous formation in New Brunswick and Nova Scotia are often called "marls" in the Geological Survey reports. These shales, however, do not contain an excessive quantity of lime, and burn to a red colour.

The term marl is now restricted to those soft, chalky deposits containing shells, which occur sometimes in the bottom of fresh-water lakes.

Marl is found at several localities in Quebec, either underlying peat deposits, or occupying the bottoms of small lakes. It is often used as a fertilizer, and when burned produces a very white and very pure lime. On account of its softness, white colour, and slight plasticity, it has frequently been mistaken for a white clay, but it is lime carbonate.

CHAPTER XI.

FIELD EXAMINATION AND TESTING OF CLAYS.

FIELD EXAMINATION.

The testing of any clay or shale for commercial purposes begins with an examination of the deposit in the field. A clay deposit should be conveniently situated with regard to transportation; in a body large enough to keep a plant going for a considerable time; free from harmful impurities; and easily worked. There are many important questions to be considered, however, in the preliminary inquiry, for example:

(1) Can drainage be provided as excavation or mining proceeds, as it is necessary to keep the workings dry?

(2) Is the water supply for all purposes adequate and of good quality?

(3) If sand is required for mixing, or moulding, can it be obtained cheaply?

(4) Consideration of the fuel supply.

(5) Are conditions in the locality favourable for labour?

(6) Can breakages of machinery be repaired quickly?

(7) Can the kiln foundations be kept dry?

(8) Would further prospecting reveal a more desirable deposit?

Some idea of the extent of a clay deposit may be gathered in a preliminary way from outcroppings either in plowed fields, hillsides, or ridges, and along the banks of streams or dry gullies. Springs issuing from hillsides sometimes furnish a clue to the character of the upper level of a bed of clay, as the surface water cannot seep down through it. Wells and foundations excavated for buildings are useful guides; but railway cuttings often furnish the best information, especially when lately made. As soft clays in a steep bank are liable to be concealed by slide material which has washed down over them, it is often necessary to cut a deep trench down the slope from top to bottom of the deposit before the true character of the beds is seen. Some banks contain several different grades of clay, some of which may be worthless, and so situated as to render the good clay unworkable.

In addition to the information gained from outcrops, it will be necessary to make several borings in order to get at the extent of the deposit and its variations. Borings can be made quickly and cheaply in surface clay deposits with a 2 inch auger, coupled to short lengths of pipe and fitted to a cross head. The auger is screwed into the clay for about 6 inches, then withdrawn with a straight pull, and the clay which clings to the auger removed. As the boring proceeds, extra lengths of pipe are added. The clay stripped from the auger is laid out in the proper order on boards or on the grass, from which small samples can be selected at any depth up to 30 feet or more if desired.

The clay deposit may be covered with a varying thickness of either gravel or stony clay which cannot be used for any purpose. In most cases it will not pay to strip this overburden if it is very thick; but the higher grades of clay like stoneware and fireclays can have an overburden of one foot removed for every foot of clay obtained. If the overburden is composed of sand, much of it may be used for mixing with the clay, especially if it should be a fat clay with high shrinkage. An otherwise useless overburden may sometimes be used for filling or levelling up ground on which it is proposed to erect the plant, or it may be removed cheaply by hydraulicing, if a sufficient head of water is available. An overburden which contains pebbles, especially pebbles of limestone, should be removed completely and kept well back from the face of the bank which is being worked, so that there will be no danger of the pebbles rolling into material that is being worked for the manufacture of clay products.

Shale deposits are often exposed in fairly steep banks, either in an escarpment, or in a stream bank, or in a railway cutting. From exposures of this kind a good idea of their probable value may often be formed. If the outcrops on the property to be examined are not exposed to any appreciable depth, it will be necessary to sink some shafts before any sampling can be done or any decision formed regarding its economic value.

Several of the soft shale deposits in the plains region of western Canada can be examined as easily as surface clays by boring with an auger; but the shales in the east are all too hard for this method of sampling.

The shale formations in eastern Canada are generally uniform in character over very large areas; but those in the west are often extremely variable, so that they require great care in sampling and examination.

Impurities in clay or shale are of two kinds, those which are visible to the naked eye, and those which are not. The field examination detects the first kind, and the laboratory tests should reveal the second kind. Pebbles are probably the most serious visible impurities in surface clays. They may occur sparsely scattered throughout the clay or they may be in the form of gravel streaks, pockets, or regular layers. If the pebbles are mostly of limestone, the deposit is practically hopeless. Some manufacturers in search of material will not consider a deposit, if they find it contains even a few scattered pebbles. Layers or pockets of sand, if not in too large a quantity, are sometimes beneficial in a surface clay, especially if it is of a highly plastic nature. Brickmakers like a clay bank to work itself, meaning one that carries the right proportion of sand for a proper mixture. An excess of sand layers is undesirable in a clay deposit, because the product made from it is liable to be weak and porous, or lacking in clay bond. Although a shale deposit may consist largely of beds of true shale, it is possible that it may also contain so many layers of sandstone or limestone as to be of doubtful economic value. If the sandstone or limestone bands are thick enough they may be sold for building stone if a convenient market exists for them. Ironstone concretions and lumps of iron pyrite are among the serious impurities in shales and clays. They sometimes are of such large size that they may be discarded in mining. Gypsum or lime sulphate is a frequent impurity in the soft shales of western Canada. It generally occurs in small glistening particles disseminated through the shale; or it may be in large crystals or rosettes. In most cases it follows in the west that clays carrying gypsum are hard to dry without cracking.

As a rule it is impossible to foretell much about the value of a clay or shale by simply inspecting the deposit in the field. An experienced clay worker, however, can gather some information for his guidance in the selection of material. The feel of the moistened clay when kneaded in the hands indicates its degree of plasticity and its probable working qualities. A shale can be distinguished from a slate by grinding a little with hammer and moistening it. The moistened shale dust will have more or less plasticity, but a slate will have none. Any clay or shale that carries more than about 7 per cent of lime will probably be useless for the manufacture of vitrified wares, such as paving brick or sewer-pipe. If a few drops of diluted hydrochloric acid will produce a strong effervescence in a clay it may be discarded as unsuited for this purpose.

Many clays will crack in drying. These can be easily detected by kneading up some of the clay with water to the proper consistency, shaping it into a rough brick or cube, and setting it to dry exposed to the sun and wind. Some clays thus exposed will crack in less than an hour after being set to dry. Others will not show cracking for several hours. If the clay dries intact, then make another brick by hand and set it over a boiler, or in an oven at a temperature of about 150 degrees F., and observe the results. A clay must be able to stand a certain amount of abuse in drying in order to allow a large output of finished products.

SAMPLING CLAY DEPOSITS.

Since few clay or shale deposits are uniform in character throughout their entire thickness, the selection of samples for testing purposes is a matter of some importance.

If the deposit appears to be uniform, then the sample should represent an average of the depth of the face it is proposed to work. The average sample should be supplemented by two or three other samples taken from different depths, as appearances are frequently misleading in clay investigations. Many persons pick a small sample of clay from the surface of a deposit and send it to be tested. The results of tests from this kind of sampling are generally useless. The body of material when opened up for working may give entirely different results from the thin veneer of weathered clay overlying it. In a locality where industries have been located for a long time, working satisfactorily on a material which occurs widespread and uniform in character, the necessary information may be obtained merely by inspection of a suitable site in the vicinity of the older plants. This proceeding is often, but not always, safe where manufacture of common brick only is concerned. Where any of the higher class of clay products are to be made, the cheapest method is to take every possible precaution at the outset of the enterprise.

LABORATORY TESTS.

The invisible impurities in a clay, which may produce defects in the process of manufacture or in the appearance of the finished ware, can be detected only by working up and burning test pieces made from the clay. These are known as physical tests.

A great deal of time and money has been expended on the chemical analysis of clay, and many chemists have been rash enough to state in reports, the kind of wares a clay will make, from the results of their chemical analyses alone. There may be special instances, as in the case of some high grade clays, where the chemical analysis is of value; but it is worthless for the general group of clays or shales used in the manufacture of structural ware.

What the clay workers desire to know about a clay or shale is:

(1) Its plasticity and working properties.
(2) The drying qualities, and rate of drying.
(3) The exact drying and burning shrinkages.
(4) The commercial limit of burning.
(5) The porosity and absorption of the burned ware.
(6) The actual difficulties encountered in burning, such as cracking, warping, or swelling and scumming or whitewash.

The clays and shales submitted to the physical tests were first thoroughly dried, then ground in a jaw crusher and sifted through an 18 mesh sieve for shales, and 12 mesh sieve for soft clays.

A weighed quantity of the ground material, sufficient to make the necessary number of test pieces, was mixed with just enough water to give it its greatest plasticity, and thoroughly kneaded and wedged so as to render it perfectly homogeneous and free from cavities. The consistency of wet body generally used was about midway in stiffness between a soft-mud and stiff-mud mixture in practice.

The mass of kneaded clay was stored in a damp place for at least 24 hours before moulding into shape. Judging the plasticity of the clay is largely a matter of experience in testing. Clays or shales are classified as having low, medium, good, or high plasticity.

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" × 1½" × ¾" in size. Two fine lines, exactly 3 inches apart, were impressed with a steel stencil on the wet clay bricklets 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 an up-draft muffle kiln, the fuel used being oil, and the time of burning 12 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-shrinkages 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. The temperatures at which the test cones melted are expressed in terms of the standard Seger cones.

A Hoskins electric furnace is used for determining the fusing points of the more refractory clays, which require a temperature range from cone 18 to cone 34. None of the Quebec clays, except the one sample of kaolin, required the use of the electric furnace, as they are all fusible at low temperatures.

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" × 1½" × 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 give 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 degrees to 150 degrees F., which is the heat usually attained in commercial dryers. If the brick cracked in this treatment it was stated that it would not stand rapid drying.

TESTS UNDER WORKING CONDITIONS.

If a company or an individual wishes to establish an important clayworking industry at a certain place or make a certain class of wares, a reasonable way to proceed in the tests of their clay, provided the field examination was satisfactory, is as follows: take an average sample of say 50 pounds from top to bottom of the workable depth of the deposit, if it is uniform in appearance, or as many samples as there are different beds. Have a complete set of laboratory tests made from the samples. If the laboratory tests prove satisfactory, then make arrangements with some firm, outside the zone of competition, who are making wares similar to those required, to put a large quantity of clay through their process and to burn it in their kilns. It is important to have an experienced man do the sampling and accompany the clay to its destination, so that he may observe the behaviour of the material in the various stages of manufacture.

The proper location of the deposit and the assurance of the suitability of the clay for the purpose for which it is to be used, are absolutely essential to begin with.

The plan of the buildings, the design of the kilns and dryers, and the selection of the best types of clay working machinery, should be done by a competent ceramic engineer.

It is impossible to provide against all the troubles which may arise in new localities when dealing with a raw material; but the chances for the occurrence of trouble can be materially lessened by proper precautions.

CHAPTER XII.

METHODS OF MINING AND MANUFACTURE.

METHODS OF WINNING THE CLAY.

The first operation in manufacture is called winning the clay, which consists of loosening the material from its natural position in the ground and loading it for removal to the next stage in the process. Clay and shale deposits are commonly worked either as open pits or quarry workings, or by underground methods. Almost all the winning of clay in Canada is done by open pits, but if the clay is soft it is almost impossible to work by this method between November and April. Enough clay may be gathered and placed in storage during the summer months for winter operations, but this is seldom done.

The actual operations of clay digging or excavation are accomplished by pick and shovel work, by plow and scraper work (Plate XV, A), by clay gathering machines, and by steam shovels (Plate XXV, B). In some of the small brickyards in Quebec the clay is excavated by pick and shovel, and loaded into barrows which are wheeled by hand to the machine. This is the simplest method in use, it is the least expensive of all in equipment, and the most expensive of any method in labour.

Most of the clay plants use the pick and shovel method for breaking out the clay, but the clay is usually loaded into side or end dump cars and hauled either by horses or by a wire rope attached to a hoisting drum.

A more economical method is to plow the clay loose, and haul it to the plant in wheeled scrapers. If the distance from the clay bed to the plant is short, this method is an excellent one. The unloading can be done on an elevated platform from which the clay can be shovelled into the disintegrators.

Shale deposits are usually worked by quarrying in long banks or benches. The overburden or stripping is removed, and then the material is loosened either by blasting or by a steam shovel. If there is little or no variation in the shale in the depth of the deposit, a face of 40 or 50 feet may be worked, but it is usually more advantageous to work in benches of 10 to 20 feet.

The loosened shale is loaded by hand labour or by a steam shovel on to dump cars and hauled to the plant (Plate XXI, A). If the plant is situated below the level of the floor of the shale pit, the hauling may be done by gravity. Double tracks are often used so that the weight of the loaded cars may be utilized to pull the empty ones back to the pit.

Underground mining is much more expensive than open pit or quarry work and is practised only when dealing with the more valuable clays.

The methods of mining clay do not differ from those employed in mining coal. If the clay outcrops on the side of a hill, drift mines may be opened from the outcrop; but if there is no outcrop available, the shaft and tunnel method must be used. The roof of the tunnel must be supported by timbering or by leaving pillars of the clay at intervals as is done in coal mining.

MANUFACTURE OF BRICK.

The methods everywhere employed in the manufacture of common and pressed brick are usually very similar, the difference lying chiefly in the care taken in the preparation of the clay, and the skill shown in burning.

The manufacture of brick may be separated into the following steps: preparation, moulding, drying, and burning.

PREPARATION.

The preparation of ordinary soft plastic clay consists in breaking it down from its lumpy state as it comes from the bank, and mixing it with water so that it can be moulded into the desired shape. If the addition of sand is necessary, it is added to the clay in the machine which breaks it down. The hard clays and shales require to be crushed and pulverized so as to develop their plasticity.

Many clays are prepared by weathering, before they are worked up by machinery, especially if they are to be used in the manufacture of pressed brick, drain tile, or sewer-pipe. The weathering is done by distributing the clay or shale in a layer of about 3 or 4 feet in thickness on the ground, so as to expose it to the action of frost, rain, and sunshine. The result of this is a slow but thorough disintegration or slaking.

Some clay workers state that the working qualities of all clays and shales are improved by the weathering process.

The breaking down and grinding of most shales or clays is done by artificial means, and the machine employed varies with the character of the material.

Rolls. The roll is one of the simplest and oldest forms of grinding machines. It consists of two cylinders or cones whose surfaces are in close contact, or held closely parallel to each other. Rolls are sometimes used for the wet grinding of stony clays, the small pebbles being crushed between the surface of the rolls, while the larger stones are rejected and can be removed. Rolls which are set too far apart, or those whose surfaces have become grooved or worn irregularly are worthless, as they allow pebbles large enough to destroy the brick to pass through with the clay. Rolls are largely used for the dry grinding of soft alluvial clays; but if damp clays are put through them the lumps will be only flattened out.

Dry Pans. The dry pan (Plate XXVI) is the best apparatus so far devised for the grinding of shales or tough hard clays. It consists of a heavy, revolving circular pan supported on a vertical shaft, and driven by a heavy gear at the top of the frame. The pan supports two large wheels or mullers which are mounted on a horizontal shaft. The ends of the shaft work in grooves in the end of the frame of the machine to permit the mullers riding over pebbles or hard lumps of shale. The pan is rotated by steam or electrical power; the friction of the mullers against the bottom of the pan causes them to turn, and in turning they grind by reason of their weight, which ranges from 2,000 to 5,000 pounds. The bottom of the pan is solid under the mullers, but perforated near the circumference. Two scrapers are placed in the bottom of the pan, in front of the mullers, to throw the material in their path. As the shale becomes ground finely enough, it falls through the perforated plates in the outer part of the pan, into a collector which leads to an elevator.

TEMPERING.

By tempering is meant the thorough mixing of the clay with water until a uniformly plastic mass results. Tempering is accomplished by one of four methods, the soak pit, the ring pit, pug-mill, or wet pan.

The soak pit consists simply of a rectangular or circular pit dug in the ground. The clay and sand are thrown into the pit, mixed with water, and allowed to stand until the clay is softened. This method does not give a thorough mixture, and is applicable only to the soft-mud process of making brick.

The ring pit is like the soak pit except that it is always circular and has walls of board or brick. A post is set in the centre to which a long rod or sweep is attached by a pivot. The sweep carries a wheel which is so geared that as the sweep travels around the circle the wheel travels back and forth between the centre and the circumference. This motion thoroughly kneads and mixes the clay. The capacity of ring pits varies from 3,000 to 8,000 brick. The wheel is usually of iron and 6 feet in diameter. The sweep is driven by steam power, or by horses attached to its outer end. Like the soak pit, the ring pit is used only in the preparation of soft mud for common brick.

The pug-mill (Plate XXVII) consists of a semi-cylindrical trough, within which revolves a shaft, bearing knives that are set at an angle so that the clay while being cut and kneaded is forced from one end of the trough to the other. Some form of pug-mill is used with almost all clay moulding machines. Pug mills are thorough and continuous in their action, take up less space than ring pits, and do not require much power to operate. They are used in connexion with both soft-mud and stiff-mud machines.

Wet Pans. These are similar to dry pans, the only difference being that the bottom of the wet pan is solid, instead of being perforated. The clay to be prepared is thrown into the pan and ground to the required fineness, with the addition of water, the action of the mullers and scrapers thoroughly mixing and kneading the clay. The wet pan is not continuous in its action for it must be stopped and emptied when the charge of clay is tempered.

MOULDING.

Clays are moulded into brick shapes in three different conditions: (1) soft-mud, (2) stiff-mud, (3) dry-pressed.

Soft-mud Process. In this method the clay, or clay and sand, are mixed with water to the consistency of a soft-mud or paste and pressed into wooden moulds. The moulds are sanded to prevent the soft clay from sticking, hence soft-mud brick show five sanded surfaces, with the sixth surface rather rough, where the excess clay is scraped off even with the top of the mould.

Soft-mud brick may be made by hand; a good moulder can make 5,000 to 8,000 per day.

The machine for making soft-mud brick consists usually of an upright box of wood or iron, in which there revolves a vertical shaft bearing several blades or arms. Attached to the bottom of the shaft is a curved arm which forces the clay into the press box. The moulds after being sanded, are shoved underneath the press box from the side of the machine. Each mould has six divisions, and as it comes under the press box, the plunger descends and forces the soft clay into it. The filled mould is then pushed forward automatically upon the delivery table, while an empty one moves into its place. As soon as the filled mould is delivered, its upper surface is struck off with an iron scraper. The brick are turned out of the mould, on a board or "pallet". They are not handled until dry, as they deform easily when wet.

The machines are driven by either horse or steam power, which performs the operation more rapidly than hand moulding. The horse-power machines (Plate XVI, A) have a capacity of from 8,000 to 15,000 and the steam power 20,000 to 35,000 brick per day (Plate XXVIII). The soft-mud process is suited to a wide range of clays, especially those of low plasticity. Highly plastic clays stick to the moulds and cannot be removed easily.

This process was the first method of moulding employed, and is still used more than any other in Canada. It possesses the advantage of producing not only a brick of very uniform structure, but one which stands the action of frost extremely well.

Stiff-mud Process. With this method the clay is tempered with less water, and consequently is much stiffer, so that the wet brick can be handled without being deformed. The principle of the process consists in taking the clay thus prepared, and forcing it through a die in the form of a rectangular bar, which is then cut up into brick.

Stiff-mud machines are of two types, the plunger and the auger machine, the latter being most generally used in brick-making.

The auger machine (Plate XXX) consists of a closed cylinder pug-mill, with an auger at the end of the shaft. The clay is worked up by the blades of the shaft and pushed forward to the auger which forces it out of a die as a column of the desired shape. By changing the die, brick, drain tile, roofing tile, or fireproofing can be made on the same machine. The die may be shaped so that its length is either the width or the length of a brick. In the former the product is end cut brick, and in the latter, side cut brick. When the bar of clay issues from the machine it is carried on a belt to the cutter in which wires are fitted for cutting the bar into the proper size.

Dry-press Process. In this process the clay is not mixed with water, but is used when damp enough to retain its shape when pressed firmly in the hand. It usually contains about 5 to 10 per cent of water. The material used is prepared by grinding in the dry pan, and screened to about one-sixteenth inch. The dry-press machine (Plate XXIX) consists of a very heavy iron frame containing a press box and delivery table and two sets of plungers working vertically in opposite directions. The clay is fed from the bin into the charger, which when filled is pushed forward over the moulds filling them with clay, and is then withdrawn. The upper plungers then move down against the clay and the lower ones, which form the bottom of the moulds; these are then forced upward, which subject the clay to pressure from both sides. When the upper plungers withdraw, the lower ones follow them up, pushing the brick to the level of the delivery table. The charger in its next move forward over the moulds pushes the brick out on the delivery table. The brick are taken from the delivery table and stacked on wheelbarrows which are wheeled directly to the kiln.

The advantages claimed for the dry-press process are that in one operation it produces a brick with sharp edges and smooth faces. The operation of drying, which is necessary in the soft and stiff-mud processes, is done away with, as the bricks made by the dry process go directly from the machine to the kiln. Many shales which are too gritty and not plastic enough to be used in the wet-moulded processes, may be dry-pressed.

The dry-press process has an important application in western Canada owing to the fact that many of the clays and shales of that region show drying defects, which prohibit their being used in the wet-moulded processes.

Dry-press machines are generally constructed to mould four bricks at one pressure; two and six mould machines are also made.

DRYING.

Brick made by either the soft or stiff-mud process must be thoroughly dried before they are placed in the kiln for burning. Many clays give no trouble at all in drying, but some clays are tender and will crack if exposed to warm winds, or direct sunshine, so that they have to be protected and dried slowly.

Open Air Drying. In many of the smaller brick-yards the brick are simply turned out of the moulds on level ground and dried in the open air. After standing until they are hard enough to be handled, the brick are turned on their sides. When nearly dry they are stacked in rows eight brick high and covered with an inverted trough made with boards to protect them from rain (Plate XXXI).

Rack and Pallet Driers. In this method the freshly moulded brick are turned out on a board or pallet. The pallets are placed on a covered rack or frame (Plate XXXI, B). The drying capacity may be as large as desired if there is sufficient room at the plant for building a number of racks. This method has the advantage over the open system because the brick are protected from rain at all stages of the drying.

The disadvantage of both these methods is that they can only be used for a portion of the year in Canada. They are suitable, however, to plants having a small output, which are idle during the winter months, as only a very moderate amount of capital is involved.

Artificial Drying. A closed building of some kind must be provided for artificial drying, and heat from the consumption of fuel is utilized. The main underlying principle of the best systems of drying by artificial heat is the use of a small volume of air at a high temperature in place of a large volume of cooler air.

Brick driers are usually in the form of a tunnel built of brick or concrete (Plate XXXII, A). Tracks are laid through the tunnel, so that the cars loaded with brick may be pushed into it. The cars enter at the cooler end, are pushed slowly forward and removed at the warmer end of the tunnel; the time required for drying is from 24 to 72 hours. The tunnel driers used at different localities differ chiefly in the manner in which they are heated. Steam heat, hot air, or waste heat from cooling kilns may be employed, while fans are generally used to draw the warm air through the tunnel.

Effects of Caustic Lime on Drying.

It has been observed by the writer during the testing of a large number of western clays that the more calcareous ones generally gave less trouble in drying than the non-calcareous clays.

A series of tests was consequently begun to determine the effects of various percentages of lime added to those clays that cracked in drying. The only form of lime found to be effective was caustic lime, generally known as quicklime.

Only one sample of the Quebec clays was tested, that from L'Epiphanie; but this is representative of the troublesome clays of that region. Attention has already been directed to the defects in this clay. It is highly plastic, adhesive and stiff in working, then cracks badly in drying.

The addition of 2 per cent of quicklime to this clay gives immediate relief, by destroying the stickiness, and causing an extraordinary difference in the ease with which it can be worked. An excess of quicklime will actually make the wet body short and crumbly, so that it will be liable to tear in moulding.

The effect of quicklime in drying is even more pronounced than on the working qualities of the clay. A 3-inch cube moulded from this clay with an addition of 2 per cent of quicklime was dried intact in warm sunshine and wind in 12 hours. The clay alone cracks on a shelf at ordinary room temperature.

A white scum is caused on the surface of the burned ware by the action of the quicklime, and the body is rather more porous.

It is probable that 1 per cent of quicklime will cure most of the causes of cracking in drying of Quebec clays, and this small amount will not have much effect on the burned body.

The quicklime should be finely ground and sprinkled over the clay, the mixing being done at least 24 hours before moulding. Another method of mixing is to dissolve the right proportion of lime in water, and add it to the clay as milk of lime.

Clayworkers as a rule avoid lime if possible, as it is a detriment when present in coarse particles. Its use in connexion with these troublesome clays is only advocated when all other remedies have failed. One per cent of powdered quicklime thoroughly mixed with the clay, will have no bad effect on the burned body, other than making a white scum, but this is better than not being able to work the clay at all.

BURNING.

The different stages of the burning of clay wares and the changes that take place in the clay during the burning have been stated in another chapter. The different types of kilns and the fuels used in them are briefly mentioned in the following pages.

Kilns used for burning brick may be divided into two main groups: (a) single or intermittent kilns, (b) continuous kilns.

The first group may be subdivided into two classes according to the direction in which the air products of combustion and flue gases travel viz., (1) up-draft, (2) down-draft kilns. The single or intermittent kilns are filled with brick, burned, cooled down, and unloaded. The operations of burning, cooling, and unloading may be going on at the same time in the continuous likn.

Up-draft kilns. The simplest kiln of any description is the scove kiln (Plate XXXII, B). This is a temporary arrangement consisting merely of a rectangular pile of the dried brick which are to be burned. The lower courses of brick are set to form a series of parallel arches extending for the entire width across the bottom of the kiln. The outside of the kiln is daubed over with a thick paste of clay, to prevent the escape of heat, and the entrance of cold air. The fuel for burning is thrown into the arches, and the fires rise through the mass of brickworks. The results of the burning are very irregular; the upper and outside brick are underburned, while the brick in the arches are overburned. The loss of heat is so great that this method can only be applied to the burning of common brick or other ware that does not require exposure to high temperatures. Seventy per cent of saleable brick is considered a good yield for a scove kiln.

Cased kilns or Dutch kilns are permanent rectangular up-draft kilns. The side walls being built of brickwork masonry are an improvement on the scove kiln as they retain the heat better, and admit less cold air. The end walls of the cased kilns are left partly open so as to admit a wagon for unloading the burned brick, and they are generally protected by a wooden roof.

Down-draft Kilns. The walls and roof of the down-draft kilns are built of brickwork masonry. The style most generally used for burning brick is rectangular in shape, with an arched roof on the interior, and a door at each end for loading and removing the brick. Down-draft kilns that are circular in plan, with a dome shaped roof (Plate XXXIII) are used to some extent for burning brick, but are more frequently used for the burning of drain tile and sewer-pipe. Fire boxes are constructed in the outside walls of the kiln which connect with flues on the inside wall. The fire gases pass to the top of the kiln chamber through these flues, and then down through the ware finding an outlet through openings in the floor of the kiln which lead to the chimney stack. There are a number of different types of down-draft kilns according to the arrangement of fireplaces, flues, etc.

The heat is more uniformly distributed in down-draft kilns, far higher temperatures can be obtained, and there is less waste than in the up-draft type of kiln. They are used for burning face brick, dry-pressed brick, paving and fire-brick.

Continuous Kilns. The continuous kiln consists of a number of chambers arranged in an oval or rectangle. These chambers are connected with each other, and with a control stack by flues, so that the fire gases may be led from any chamber into any of the others or to the stack. They were originally designed to utilize the waste heat from burning. For many years after their introduction they were not very well understood, but in recent years they have been growing steadily in favour, especially with manufacturers who wish to produce a large output.

The main principle of the continuous kiln is that the heat from a chamber that is under fire is not allowed to escape into the chimney stack, but is conducted into another chamber which has been newly filled, to perform the operation called watersmoking. By the time the first chamber is burned, it requires only a short period of active firing to finish the second chamber, and the waste heat from it is utilized in warming up a third chamber. In other words the chambers ahead of the finished one are heating up, while the chambers behind it are cooling down. It is thus possible to be burning brick in certain chambers, filling others, and emptying still others, all at the same time, making the process a continuous one. Continuous kilns are employed for burning common brick in Quebec and Ontario with considerable success. With the use of producer gas for firing a great saving in fuel is said to be possible (Plate XXXIV).

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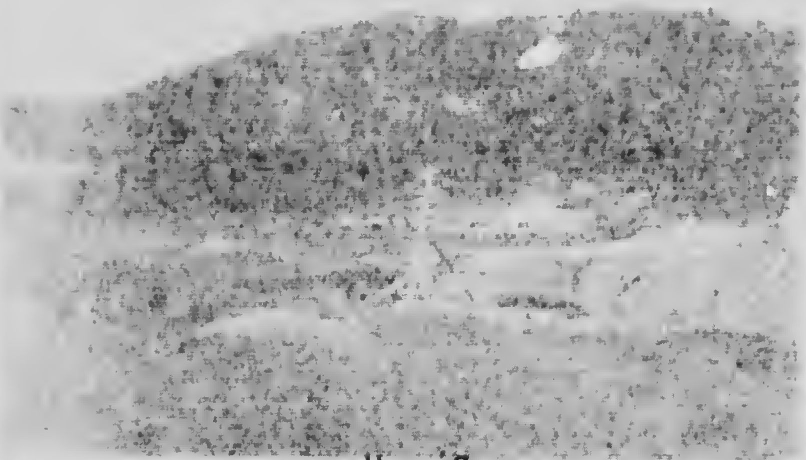

PLATE II.

A. Kaolin mine and washing plant at St. Remi d'Amherst.

B. The plant of the St. Lawrence Brick and Terra Cotta Co., Laprairie.

PLATE II.

A.

B.

PLATE III.

A. Plant of the National Brick Co. at Delson Junction.

B. Utica-Lorraine shale with interbedded sandstone, Chambly.

PLATE III.

A.

B.

PLATE IV

Utica-Lorraine shale at Cap Santé.

Plate IV.

PLATE V.

A. Utica-Lorraine shale on Canadian Northern railway between Cap Rouge and St. Augustin.

B. Utica-Lorraine shale at Beauport.

PLATE V.

A.

Cap Rouge

B.

PLATE VI.

A. The escarpment of Utica-Lorraine shale at Montmorency falls.

B. Devonian shale at Cap Fleurant, Bonaventure county.

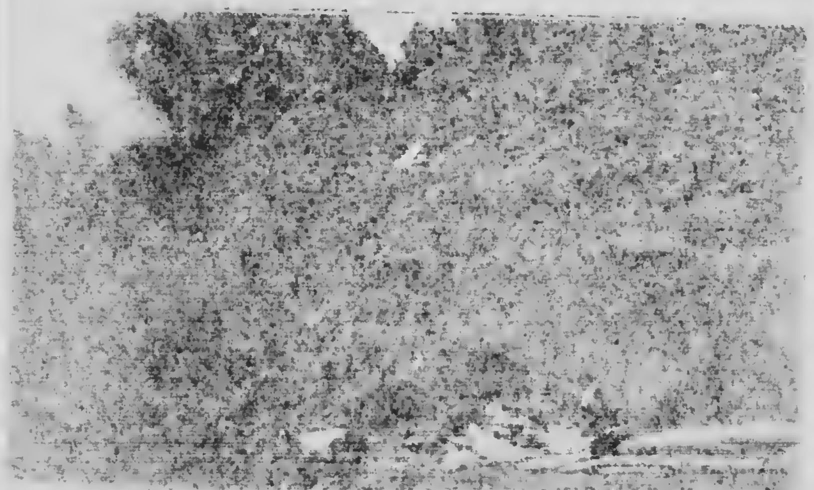

PLATE VI.

A. The escarpment of Utica-Lorraine shale at Montmorency falls.

B. Devonian shale at Cap Fleurant, Bonaventure county.

PLATE VI.

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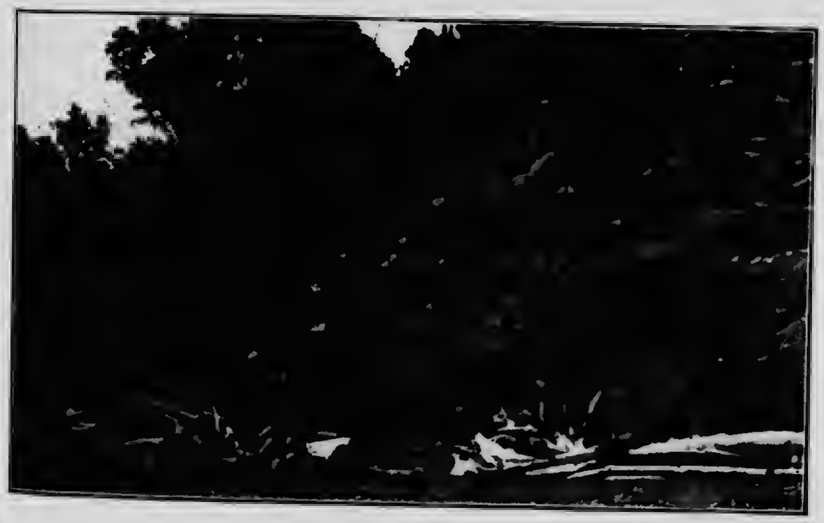

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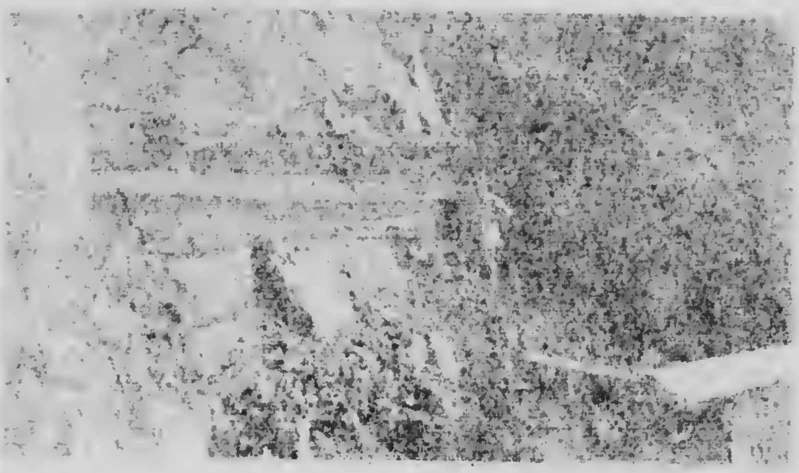


PLATE VII.

A. Stratified sands at base of clay bank at Deschaillons.

B. Leda clay overlain by Saxicava sand at high school building, Montreal.

PLATE VII.

A. Stratified sands at base of clay bank at Deschaillons.

B. Leda clay overlain by Saxicava sand at high school building, Montr

PLATE VII.

A.

ng, Montreal.

B.

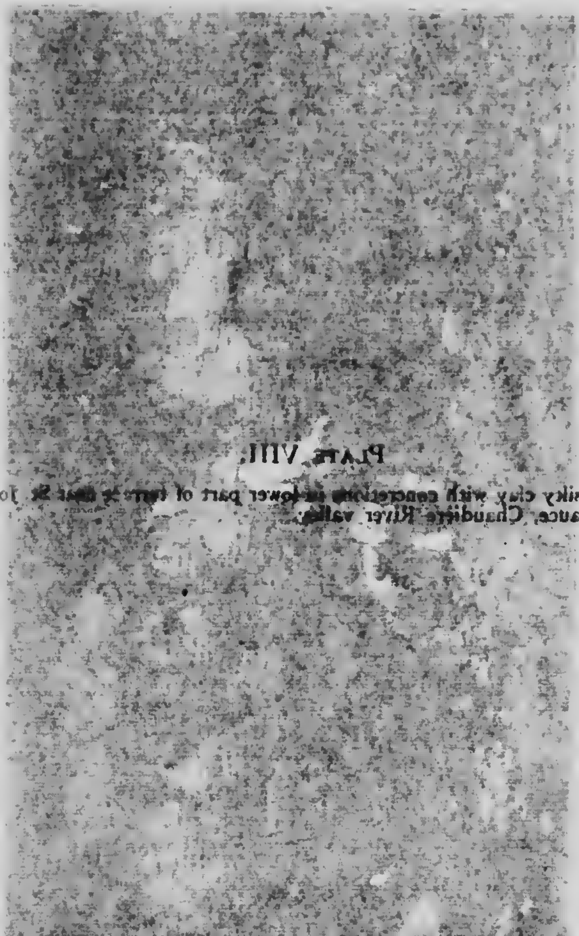


PLATE VIII.

Stratified silty clay with concretions in lower part of terrace near St. Joseph-de-Beauce, Chaudière River valley.

PLATE VIII.

Stratified silty clay with concretions in lower part of terrace near St. Josep[h]-de-Beauce, Chaudière River valley.

Plate VIII.

PLATE IX.

Natural exposure of typical low-level stoneless Pleistocene clay, Pierreville

Plate IX.

, Pierreville.

PLATE X.

The Lièvre River valley from Valier hill, Portland township. The valley is floored with Pleistocene clay and the deposit is typical of the clay deposits of the Laurentian upland.

PLATE X.

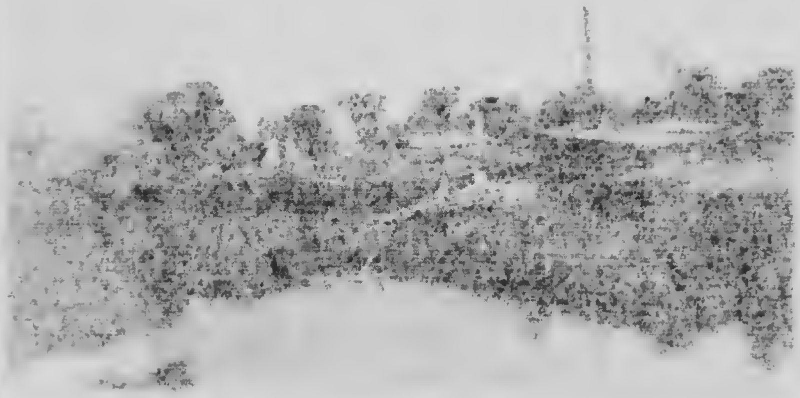
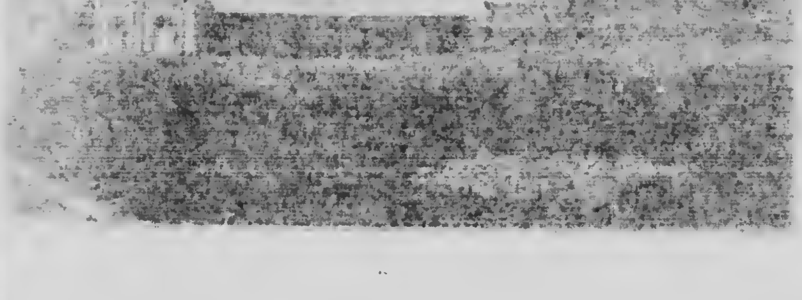


PLATE XI.

A. Richard's brick-yard near Hull.

B. Plant of the Montreal Terra Cotta Co., Lakeside.



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B. Plant of the Montreal Terra Cotta Co., Lakeside.

PLATE XI.

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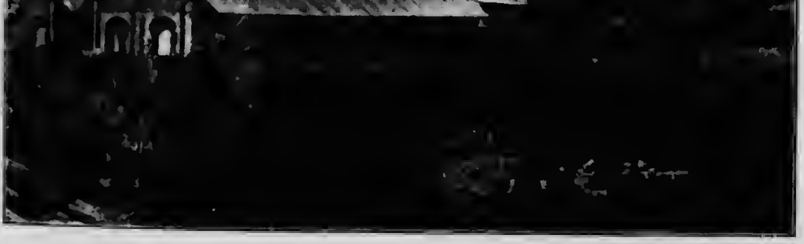

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PLATE XII

A. Brick plant at St. Raymond, Portneuf county, valley of Ste. Anne river.

B. Clay with crumpled strata, St. Raymond, Portneuf county.

PLATE XII.

A. Brick plant at St. Raymond, Portneuf county; valley of Ste. Anne river.

B. Clay with crumpled strata, St. Raymond, Portneuf county.

PLATE XII.

A.

B.

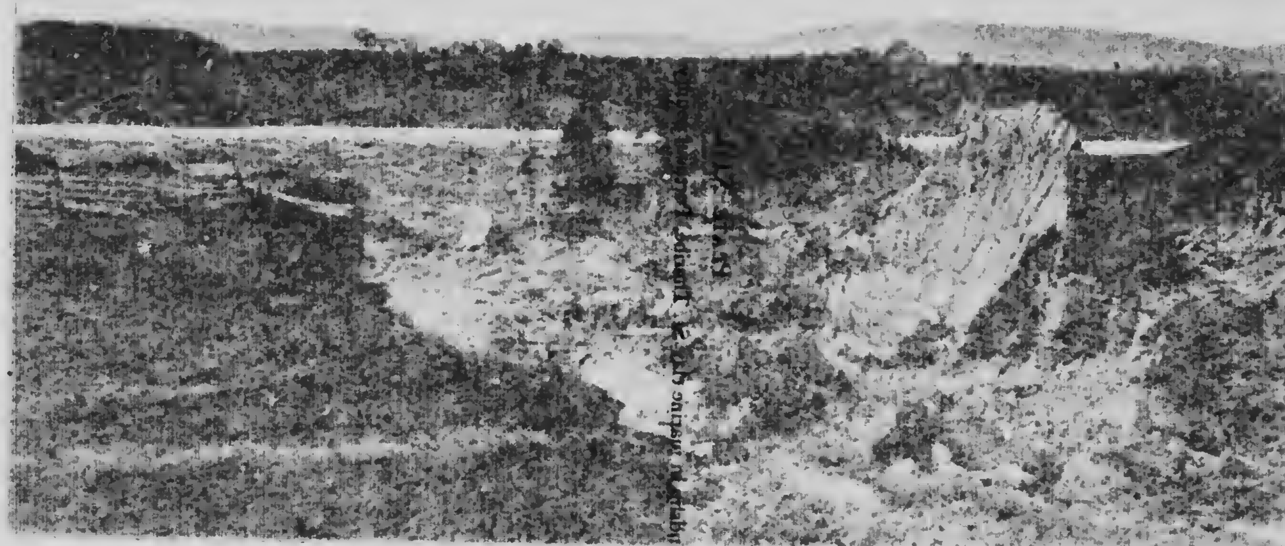

PLATE XL

Landslip in marine clay, St. Thuribe, Portneuf

PLATE XIII.

Landslip in marine clay St. Thuribe, Portneuf county.

PLATE XIII.

PLATE XIV.

A. Terrace of marine clay at Chicoutimi.

B. Massive Pleistocene clay deposit at Ormstown.

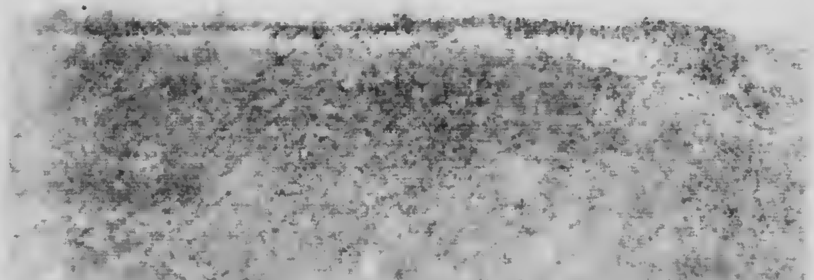

PLATE XIV.

A. Terrace of marine clay at Chicoutimi.

B. Massive Pleistocene clay deposit at Ormstown.

Plate XIV.

A.

B.

PLATE XV.

A. Gathering surface clay at the pit of the Standard Clay Products Co. Clay-storage sheds in the distance.

B. Banks of Pleistocene clay and sand on St. Francis river near Pierreville.

PLATE XV.

A.

B.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

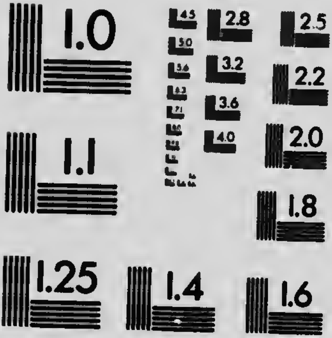

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PLATE XVI.

A. Small, common brick plant near St. François-du-Lac, Yamaska county.

B. General view of brick plants along the St. Lawrence river at Deschaillons.

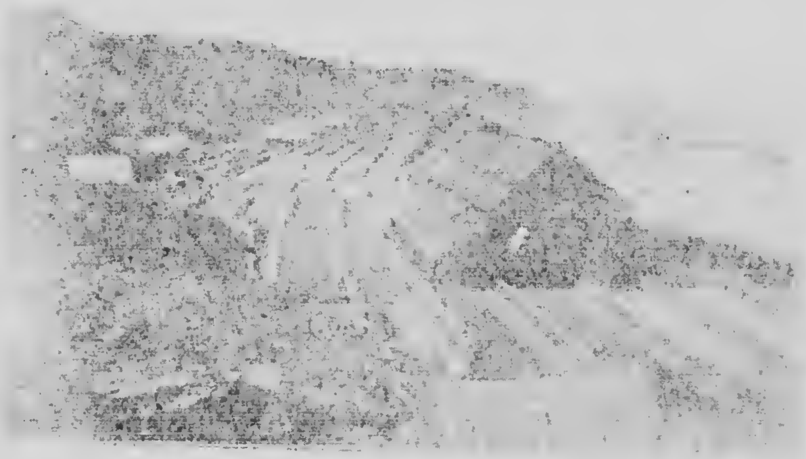

Plate XVI.

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B. General view of brick plants along the St. Lawrence river at Deschaillons.

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PLATE XVI.

A.

B.

PLATE XVII.

A. Continuous kiln, fired with producer gas, at Lennoxville, Eastern Townships Brick Co.

B. High level Pleistocene clay, at brick plant, Ascot.

PLATE XVII.

A.

B.

PLATE XVIII.

A. Terrace of Pleistocene clay near St. Joseph de Beauce, Chaudière River valley.

B. Clay terrace along the shore of Chaleur bay at New Richmond, Bonaventure county.

Plate XVIII.

A. Terrace of Pleistocene clay near St. Joseph-de-Beauce, Chaudière River valley.

B. Clay terrace along the shore of Chaleur bay at New Richmond, Bonaventure county.

PLATE XVIII.

A.

B.

PLATE XIX.

Exposure of typical stratified Ojibway clay on the National Transcontinental railway in Lasarre township, northern Quebec. A bed of peat overlies the clay.

Plate XIX.

PLATE XX.

Plant of the National Brick Co. at Laprairie.

PLATE XX.

PLATE XXI.

A. Steam shovel excavating Utica-Lorraine shale at Laprairie.

B. Plant of Citadel Brick Co., Boischatel.

PLATE XXI.

A. Steam shovel excavating Utica-Lorraine shale at Laprairie.

B. Plant of Citadel Brick Co., Boischatel.

Plate XXI.

A.

B.

PLATE XXII.

A. Plant of the Standard Clay Products Co. at St. Johns.

B. Sand-lime brick plant at Pointe aux Trembles.

PLATE XXII.

A. Plant of the Standard Clay Products Co. at St. Johns.

B. Sand-lime brick plant at Pointe aux Trembles.

PLATE XXII.

A.

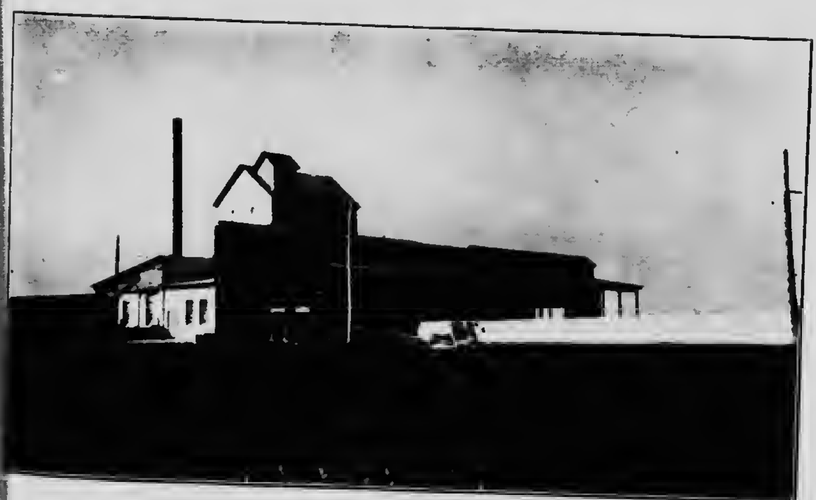

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PLATE X[illegible]I.

Rotary press for making sand-li[illegible] brick.

Plate XXIII.

PLATE XXIV.

Seger cones, showing effects of high temperatures.

Plate XXIV.

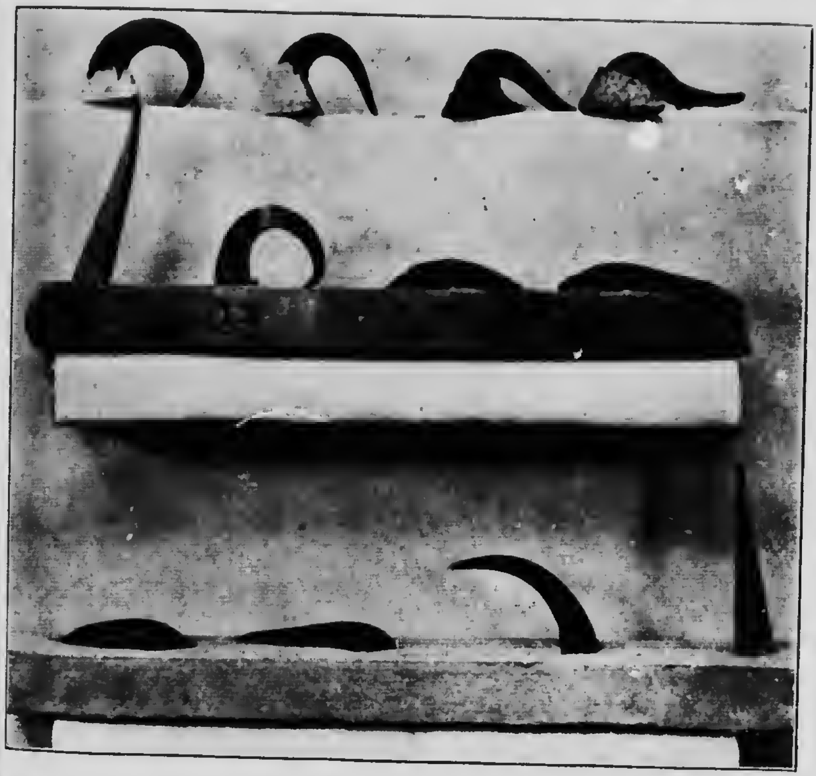

PLATE XXV.

A. Belt clay conveyor extending from clay bank to machine house Montreal Terra Cotta Co., Lakeside.

B Mining shale and boulder clay with a steam shovel at Delson Junction

PLATE XXV.

A.

B.

PLATE XXVI.

Dry pan for grinding shale.

PLATE XXVI.

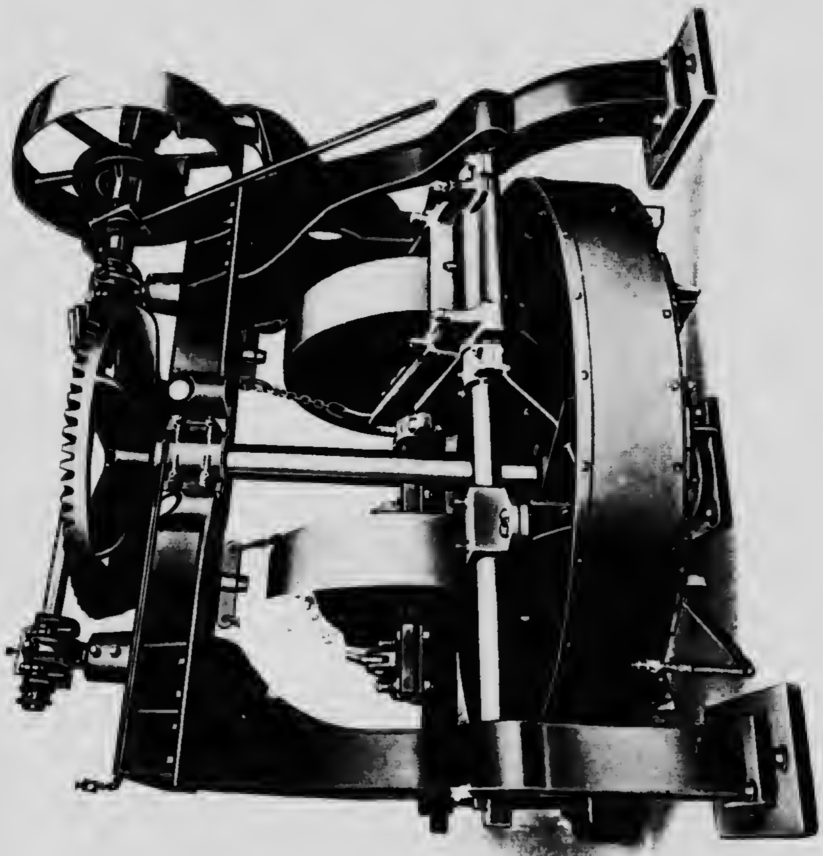

PLATE XXVII.

Pug-mill.

Plate XXVII.

PLATE XXVIII.

Soft-mud brick machine.

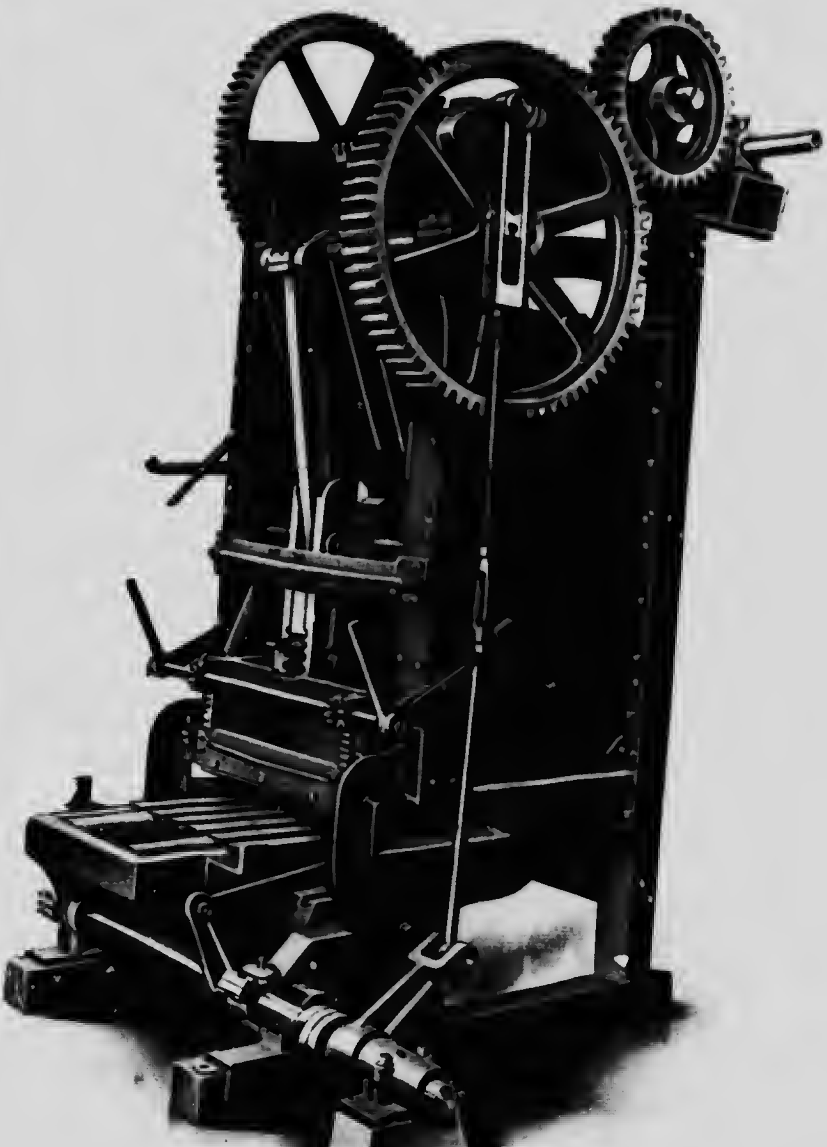

PLATE XXIX.

Dry-press brick machine.

PLATE XXIX.

Dry-press brick machine.

PLATE XXIX.

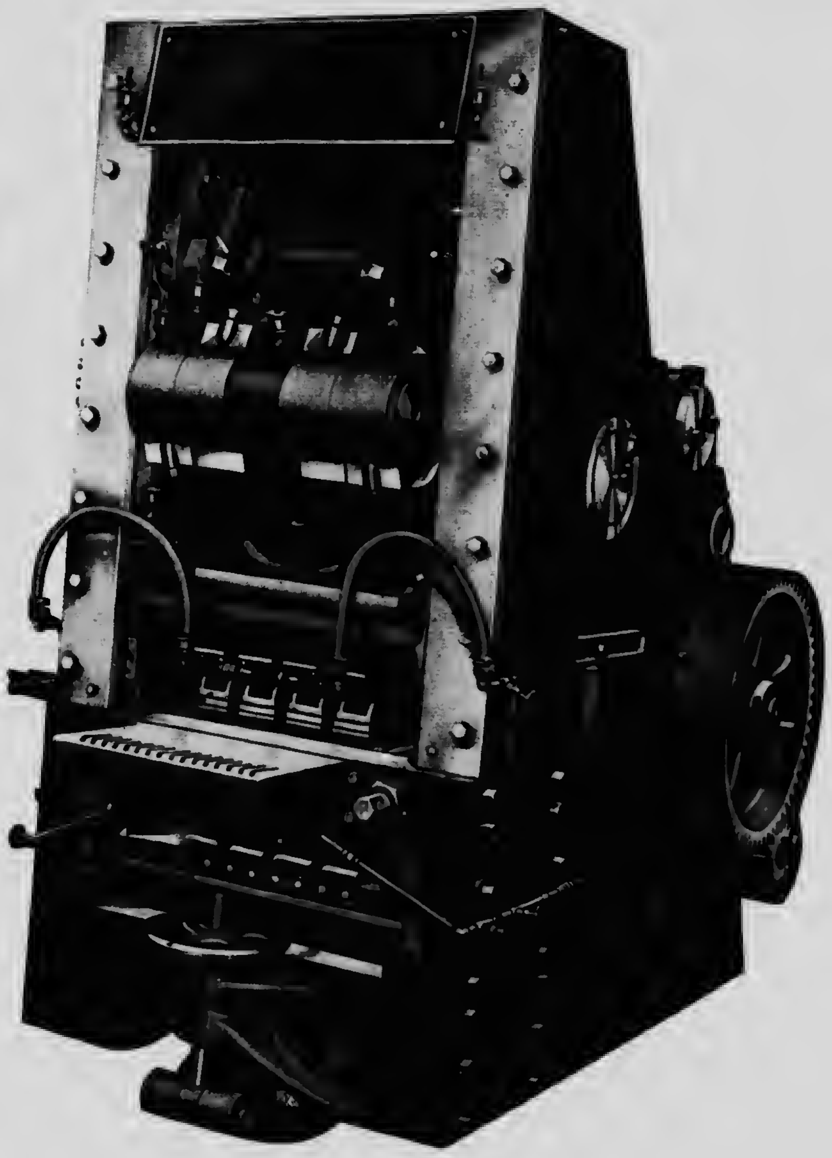

PLATE XXX.

Auger machine for brick and hollow ware.

PLATE XXX.

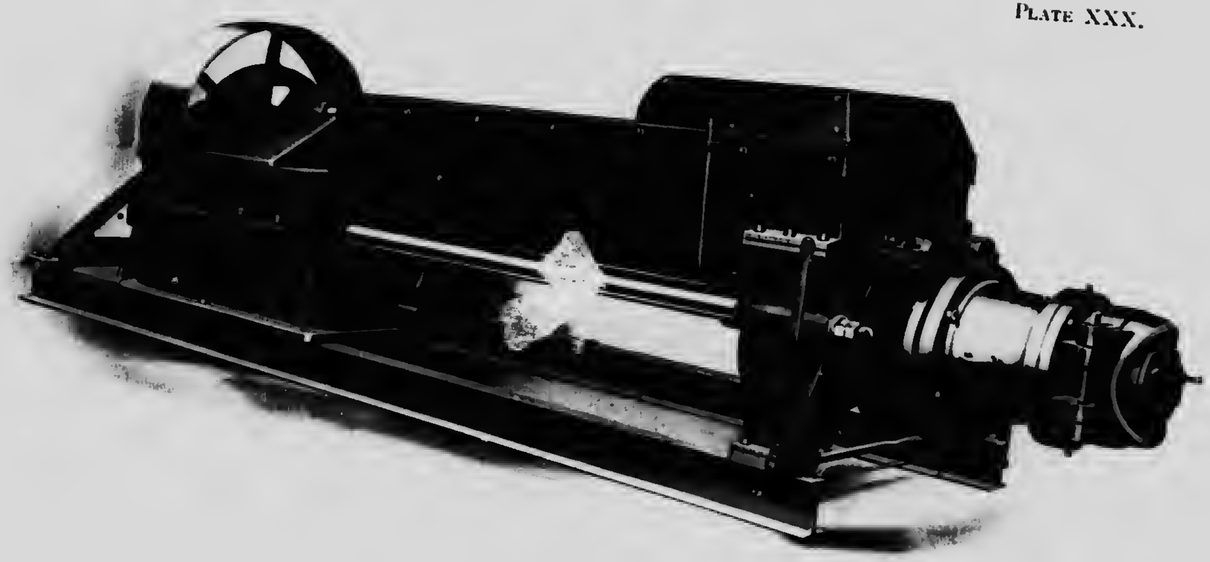

PLATE XXXI.

Drying brick on an open floor, L'Islet.

Drying brick on pallets in covered racks.

PLATE XXXI.

Drying brick on an open floor, L'Islet.

Drying brick on pallets in covered racks.

PLATE XXXI.

A.

B.

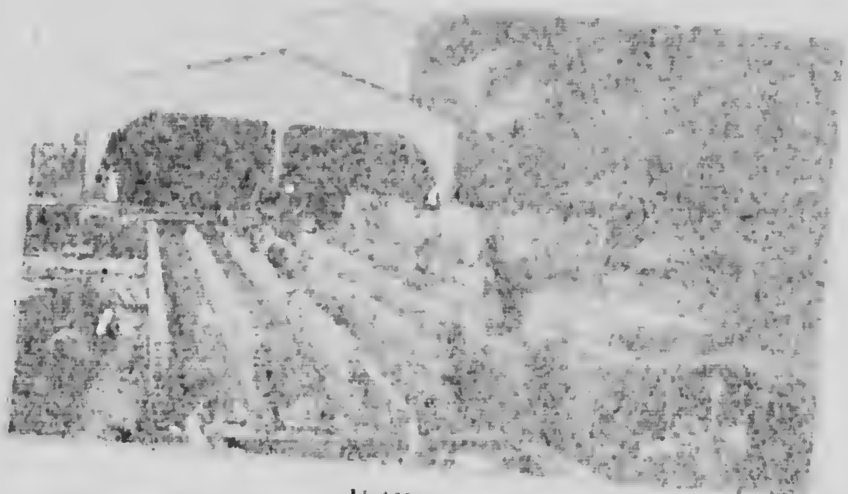

PLATE XXXII.

A. Drying tunnels under construction at the plant of the Citadel Brick Co., Montmorency.

B. Setting brick in a scove kiln.

PLATE XXXII.

A. Drying tunnels under construction at the plant of the Citadel Brick Co., Montmorency.

B. Setting brick in a scove kiln.

PLATE XXXII.

A.

B.

PLATE XXXIII.

Multiple stack, down-draft circular kiln, Ontario government brick plant at Mimico.

PLATE XXXIII.

Multiple stack, down-draft circular kiln, Ontario government brick plant at Mimico.

PLATE XXXIII.

PLATE XXXIV.

A. Continuous tunnel kiln fired with producer gas.

B. Continuous kiln for burning common brick, Toronto.

PLATE XXXIV.

A. Continuous brick kiln fired with producer gas.

B. Continuous kiln for burning common brick, Ascot

PLATE XXXIV.

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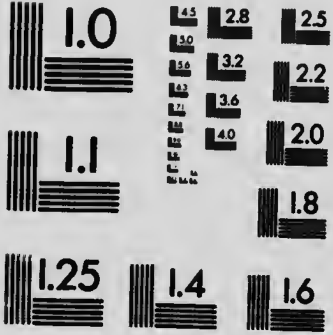

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MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

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Guide Book No. 4. Excursions in southwestern Ontario.

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Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

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Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

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