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GEOLOGICAL SURVEY

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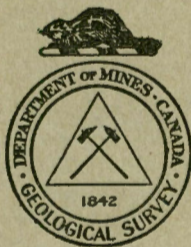
MEMOIR 142

No. 123, GEOLOGICAL SERIES

Preliminary Report on the Clay and Shale Deposits of Ontario

BY

J. Keele



OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1924

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Deposit of Iroquois clay, silt, and sand in pits of National Fireproofing Company, Waterdown. (Page 96.)

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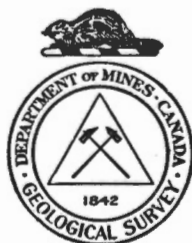
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Preliminary Report on the Clay and Shale Deposits of Ontario¹

CHAPTER I

INTRODUCTION

Ontario is an extensive province, covering an area of 407,262 square miles. The clay and shale deposits in the eastern and southern parts of the province, which are thickly settled, are fairly well known. A certain amount of information is also available regarding the northern and western parts, which are thinly settled, but there is a large part of the province about which little is known. There is, however, fairly full knowledge of the general geology of the more inaccessible parts, and this information, together with what is known of the clay and shale deposits in the settled parts of the province, justifies the following generalizations:

The greater part of the province is underlain by ancient crystalline rocks, principally granite gneisses and various schists. These rocks yield no clay, nor are any shales known to be embedded in them, except at one locality. Furthermore, the cover of glacial drift over these rocks contains very little clay.

The shales used in the clay industry are almost entirely confined to two formations, the Lorraine and the Queenston, of Upper Ordovician age, and these useful shales occur at points where there is the largest demand for clay products.

The greater part of the clays used in the clay industry in Ontario are of glacial origin and, owing to their heterogeneous composition, are subject to certain limitations as regards the classes of ware that may be made from them.

Workable deposits of clay are more abundant on the shores of the great lakes than inland.

¹ This report is one of a series dealing with the clay and shale deposits of Canada, of which the following have been published:

"Clay and Shale Deposits of Nova Scotia and New Brunswick," by H. Ries (Geol. Surv., Can., Mem. 16).

"Clay and Shale Deposits of the Western Provinces," by H. Ries and J. Keele (in five volumes, Geol. Surv., Can., Mems. 24, 25, 47, 65, and 66).

"Clay and Shale Deposits of New Brunswick," by J. Keele (Geol. Surv., Can., Mem. 44).

"Clay and Shale Deposits of the Province of Quebec," by J. Keele (Geol. Surv., Can., Mem. 64).

"Clay Resources of Southern Saskatchewan," by N. B. Davis (Mines Branch publication 465).

Clays or shales that will make vitrified wares, or fire-clays or china-clays, have not been found, so far, at accessible localities in Ontario. They appear to be entirely absent in the southern part, where they are most needed, and are known to occur only at remote points on the Hudson Bay slope.

Clayworking is a very important industry in Ontario which has a greater production of burned clay products than any other province in the Dominion. The total value of domestic clay products sold in Canada in 1920 was \$10,664,929, of which Ontario contributed \$5,613,488.¹

No systematic survey has been made covering the clay and shale resources of the whole province. The following report is only a summary of our knowledge to date. It contains descriptions of only a few localities, but the raw materials used by the clayworkers are so much alike over large areas that an unnecessary amount of repetition would be introduced if every deposit in every county were described. An effort is made to describe the different kinds of clay found and their occurrence, properties, and uses.

Particular attention was given to the materials available in the vicinity of large towns and industrial centres. The position of deposits of brick-clay is important; if they are situated far from a market the cost of transportation precludes their use.

The manufacture of drain-tile for agricultural lands occupies a prominent place in the clay industry in southern Ontario, but land drainage has to a great extent been neglected in eastern Ontario, and there is little or no demand there for drain-tile. Clay deposits which may be suitable for making drain-tile in that region are described rather fully, however, as the time is coming when they will be needed.

An outline of the pottery and other special clay wares as articles of utility or ornament is included, as technical schools and even public schools are now teaching modelling and designing in clay.

Samples of all the clays and shales described in the report have been tested in the Mines Branch laboratory; and a great many of the clay-working plants were visited, so that the results of actual working conditions and laboratory tests could be correlated.

The Ontario Bureau of Mines, in 1906, published a report on the clay and shale industry of Ontario, by Professor M. B. Baker, which contains considerable information on the equipment and kind of raw material used in various clayworking plants throughout the province, and has furnished most of the chemical analyses for the present report.

In order to simplify the descriptions, the large and irregular region included in the province of Ontario has been arbitrarily divided into five districts, viz., eastern, central, Interlake peninsula, northern, and north-western. The boundaries of these regions are defined under the headings of the corresponding chapters.

¹ Report on the Mineral Production of Canada, 1920, Mines Branch, Ottawa.

CHAPTER II

KINDS OF CLAYS

Clays have a wide variety of colours in the raw state, varying from white to almost black. The glacial clays in Ontario are prevailingly light and dark grey, yellowish grey, and brownish red. Some of them turn to various shades of red when burned in kilns, owing to the oxidation of the iron contained in the clay, iron being an active colouring agent.

Some of the clays which contain a high percentage of lime that prevents the formation of red colours in the firing burn to buff or cream colours. Most fire-clays burn to buff colours, not because of the presence of lime, but on account of their low iron content. Some ball-clays which are nearly black in the raw state become white on burning, owing to the absence of iron or other minerals which cause discoloration.

Shales are merely hardened clays. The terms clay and shale are used interchangeably by clayworkers when speaking of shale. Some shales when ground fine enough to pass through a screen of 16-mesh to an inch and worked up with water, develop a plasticity equal to that of some clays which occur in a soft, or unconsolidated state.

It will thus be seen that the colour and texture of clay in the raw state has often very little bearing on the character of the finished product.

The following classification is based on the industrial uses of clays and shales.

KAOLIN AND CHINA-CLAY

The process by which kaolin is formed in a rock is termed kaolinization. The rocks yielding most of the kaolin of commerce are: granite, gneiss, pegmatite, porphyry, and sandstone, but kaolinization affects basic rocks as well, and there is an example of kaolin in Ontario which has resulted from diabase.

Although kaolinized rocks are distributed all over the world, commercially valuable kaolin is comparatively rare, owing to the rocks being stained and discoloured, or insufficiently pure, or too remote from markets. In the kaolin deposit at St. Remi-d'Amherst, Quebec, one of the few of these deposits known in Canada and the only one worked at present, discoloured clay forms quite a large proportion of the mass.

The most valuable kaolin is white in the raw state and remains white in burning, and is the most refractory of all clays.

Crude kaolin as it comes from the mine is unsuitable for most industrial processes, and must be prepared by a washing process which separates the coarse material—generally quartz and mica grains—from the fine clay. The fine white clay thus obtained is known as china-clay.

China-clays are used in the manufacture of white tableware, electrical and sanitary goods, and floor and wall-tile. A great deal of china-clay is used by paper mills as a filler for the best grades of white paper and for wallpaper. It is also one of the ingredients used in the manufacture of rubber tires.

The essential chemical components of china-clay are silica, alumina, and water. The washed product of the Canadian China Clay Company has the following composition which shows it to be a china-clay 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
	<hr/> 100.40

Although discoloured kaolin cannot be used for making products in which whiteness is essential, it is of some value as a fire-clay, and is made into fire-brick. The discoloured kaolin at St. Rémi has been found particularly suitable in a mixture for making saggers used by the potteries.

BALL-CLAY

Almost all white pottery is made from a mixture of china-clay, ball-clay, flint, and feldspar, in varying proportions. China-clay has not much plasticity, and flint and feldspar have none; a white burning, highly plastic clay called ball-clay is, therefore, added to the mixture, to make it workable in the shaping processes. No true ball-clay occurs in Canada so far as known, but certain of the white, highly plastic, clays in southern Saskatchewan approach it in character.

FIRE-CLAY

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 fire-clay to all clays and shales found underlying coal beds; but, although underclays in many parts of the world are fire-clays, some are not. Of the great number of clays and shales underlying coal seams in the Maritime Provinces, that have been tested, only one proved to be fire-clay; and the same is true in British Columbia and Alberta, although certain clays not directly connected with coal seams in these provinces were found to be refractory enough to be classed as fire-clays.

The definitions proposed by the American Society for Testing Materials for clay fire-brick are as follows:

High heat duty, softening point not lower than cone.....	No. 31	(1685°C.-3065°F.)
Intermediate heat duty, softening point not lower than cone.....	No. 28	(1635°C.-2975°F.)
Moderate heat duty, softening point not lower than cone.....	No. 26	(1600°C.-2912°F.)
Low heat duty, softening point not lower than cone.....	No. 19	(1510°C.-2750°F.)

Fire-clays are used most generally and extensively in industrial furnaces, blast furnaces, crucible melting furnaces, the layers and bottoms of Bessemer converters, the furnaces used in lime, glass, clay, and cement works, in lead-refining furnaces, in basic open-hearth furnaces above the slag line, and for flues, boiler settings, linings of stacks, household stoves, etc.

No fire-clays are known in the more settled parts of Ontario, and requirements for the various industries are all imported, either from the United States or Great Britain.

The two following chemical analyses are given to illustrate the composition of fire-clays. No. 1 is from Shubenacadie, N.S., and No. 2 is from Willows, Sask.

	No. 1	No. 2
Silica.....	74.03	58.28
Alumina.....	17.30	26.07
Ferric oxide.....	1.15	1.79
Titanic oxide.....	1.04	.....
Lime.....	0.38	0.68
Magnesia.....	0.16	0.34
Potash.....	0.88	1.46
Soda.....	0.53	
Water.....	4.78	12.02
Refractory value.....	Cone 27	Cone 30

STONEWARE CLAY

Though much of this material is as refractory as the clay used for fire-brick, it differs from fire-clay in burning to a very dense body at temperatures at which fire-clays remain open and porous. Stoneware clay is very plastic and smooth, and should have good tensile strength, or toughness, in the raw state, to permit of its being turned on the potters' wheel. Its fire shrinkage should be low, its vitrifying qualities good, and it should be so refractory that the wares made from it will hold their shapes in burning. Most stoneware is made from a mixture of clays that will produce a body having the proper qualities both in the raw and burned state.

Stoneware clay is principally used in the manufacture of heavy household ware such as crocks, pans, and churns, or for acid-proof chemical appliances, but it is also used for art pottery, earthenware, and architectural terra-cotta. Stoneware clay is in some cases used in Great Britain for the manufacture of sewer-pipe. Owing to its smooth finish, its hardness and strength, and the fine salt glaze which it takes, this class of ware ranks high for sanitary drain-pipe. Modelling clay used by sculptors, and in art schools, is a smooth plastic clay of the stoneware type not known to occur in southern Ontario. It has been found so far at only two localities in northern Ontario, one on Missinaibi river and another on the Mattagami, but at points far beyond present transportation facilities. Details concerning it are given in another part of this report.

SEWER-PIPE CLAY

Clays or shales that burn to a vitrified body having low shrinkage, that hold their shapes in burning, and also take a salt glaze, are essential to this class of ware. Fire-clay is in some cases added to lower grade clay or shale, or a mixture of two or more clays or shales may be used. Some of the material used for making sewer-pipe, if it is a shale, can be used for paving brick also, so that the two products can be made in the same factory. Materials suitable for the manufacture of sewer-pipe are of rare occurrence in Ontario.

PAVING-BRICK CLAYS

Paving brick are mostly made from red-burning shales which have a long range of vitrification. The essential quality of paving brick is toughness, and this quality can be imparted only by slow burning at the vitrification stage; hence, a shale that softens or bloats at a temperature a little above the vitrification stage is useless for paving brick.

BRICK-CLAYS

Clays and shales suitable for making common brick are widely distributed in Ontario. The main requisites are that they mould and dry easily, and burn hard at as low a temperature as possible, with only a small loss from cracking, or warping. Because many common clays, when used alone, show a higher air or fire shrinkage than is desirable, it is customary to correct this fault by mixing sand with the clay, or by mixing a more sandy clay with a plastic one. Brickmakers call a clay strong, or fat, when it is highly plastic, some what stiff and sticky; and lean, when it is gritty or sandy.

Brick used for facing buildings are moulded and burned with special care, and some are re-pressed if made by the plastic process. When dry-pressed facing brick are required, either shale or a mixture of shale and clay must be used. None of the Ontario surface or glacial clays is suitable for making dry-pressed brick. The rough-surface brick, used so much for facing purposes, are made from shales, or mixtures of shale and clay, by the plastic process. It is difficult to obtain the proper rough face from clay alone.

Deposits of brick-clay should be situated as close as possible to places where brick are used, as the cost of freight soon becomes too burdensome.

Any clay containing stones, pebbles, or concretions should be avoided by intending brickmakers.

CLAY FOR CEMENT

Clays or shales are used in great quantities in the manufacture of Portland cement, an artificial material which consists essentially of lime, silica, and alumina. The first ingredient is commonly supplied by some form of calcareous material, such as limestone, marl, or chalk; the other two are furnished by clay, the mixture of raw materials containing approximately 75 per cent of limestone and 25 per cent of clay. Clays or shales to be used for Portland cement should be as free as possible from coarse rock particles, gravel, or concretions. These conditions are best met by stratified, or transported clays; for residual clays are mostly sandy or stony, and nearly all boulder clays are notably so. Suitable limestone is the principal thing sought for by prospective cement manufacturers. The clay is a secondary consideration, but it is desirable to have both close together.

PIPE-CLAY

Pipe-clays are clays suitable for making tobacco pipes, but the term is also used for any white clay. Clay suitable for making sewer-pipe is in some cases called pipe-clay.

PAPER-CLAY

Clays of various kinds are used as a filler for paper, the finer china-clays being chiefly used for this purpose. Whiteness, freedom from grit, covering power, and retentivity are the qualities requisite for the best grades. The greater part of the white clay produced by the Canadian China Clay Company at St. Rémi-d'Amherst is sold as a paper-clay.

POTTERY CLAYS

Potters' clays are any clayey material suitable for the manufacture of pottery, though the term is as a rule understood to exclude materials which can be used only for the lowest grades of ware. Good plasticity and tensile strength in the raw state are essential for making pottery on the potters' wheel, but clays that are short in texture and weak, if otherwise suitable, can be cast in plaster of Paris pottery moulds when they cannot be worked by the plastic process. High-grade pottery clays are known in Ontario only in the northern part. Some of the brick-clay can be used for making flower-pots, and in many cases, by washing and screening to remove the coarse particles, may be used for making ornamental glazed wares.

MARL

The term marl, or malm, is used in England, locally, to denote brick-clays containing much carbonate of lime. Sagger marls are a variety of fire-clay used for making the cases (saggers) in which pottery is placed for firing. In Canada the term marl is applied only to chalky, friable deposits of lime carbonate, in many cases found underlying peat beds, or in the bottoms of small lakes. On account of its softness, whiteness, and slight plasticity much of it has been mistaken for white clay, or kaolin.

CHAPTER III

RESIDUAL CLAYS

Residual clays are the result of certain processes which break down rocks and soften them in situ. Weathering and leaching by surface and ground-waters appear to be the most active agencies in the formation of residual clays, the acidulated waters from lignite beds or swamps being particularly effective. Certain deposits of residual clay have no doubt been the result of the action of heated, chemically active vapours ascending from below. The formation of a large body of residual clay requires a considerable length of time under favourable conditions. The amount of weathering and decay on the surface of the Precambrian rocks in Ontario since the close of the last Glacial period is negligible, and this time has been variously estimated to be from 10,000 to 20,000 years.

The principal rocks yielding residual clay are granites, felsites, porphyrites, basalts, tuffs, slates, argillaceous quartzites, and impure limestones. Clays derived from rocks containing much iron-bearing minerals are mostly yellow, red, or brown, according to the iron compounds present. The residual clay most highly valued is kaolin from granites and pegmatites. The action of weathering or other processes which change rock to clay is known as kaolinization, and feldspar is the mineral which furnishes most of the kaolin, whereas quartz, mica, and other associated minerals may remain unaltered.

Although the greater part of Ontario is underlain by igneous and metamorphic rocks, some of which might be expected to yield residual clays, there is little or no clay present. On the contrary, the rock surfaces are everywhere fresh and solid. This condition is probably due to glaciation which scoured off the soft, weathered products and laid bare the fresh, firm rock. The absence of kaolin and residual clays in general on the Precambrian upland seems to favour the theory that residual clays originate by weathering, because if kaolin deposits were the result of deep-seated pneumatolytic action, glaciation would not be able to remove them completely.

Notwithstanding the large amount of rock surface visible naturally, and the amounts exposed by mining, farming, and lumbering, there is always the possibility that deposits of residual clay, perhaps of valuable kaolin, are concealed beneath the widespread mantle of glacial drift. The following are the only known localities in Ontario where residual clays occur or at which the probable source of residual clays may be found.

HELEN MINE, MICHIPICOTEN, ALGOMA WEST

Many mining engineers and geologists have observed the kaolinized diabase dyke, and the yellow residual clay from Keewatin schist, in the Helen iron mine. A. L. Parsons¹ has described it as follows:

¹24th Rept. Ont. Bureau of Mines, pt. I, p. 192.

"The most striking example of rock decomposition which has been exposed at this region is in the Helen mine, where there are two notable deposits of kaolin, in addition to others of secondary importance, which have resulted from the decomposition of rocks of very different ages. The largest deposit of kaolin is due to the alteration of a diabase dyke to a depth of several hundred feet. The dyke is well exposed on the 300-foot level, and the decomposition is so perfect that the material can be taken out with a shovel. Although so entirely changed from its original condition, the original texture is preserved and there is a distinct contrast between the products of decomposition of the light and dark minerals of the original rock. In colour the kaolin is nearly white and would appear to contain very little iron. On the sixth level the decomposition has not gone so far, but the dyke is decidedly soft.

"The kaolin from the 300-foot level has been analysed by Mr. W. K. McNeill with the following results:

	Per cent		Per cent
SiO ₂	49.43	H ₂ O.....	11.85
Fe ₂ O ₃	4.83	CO ₂	0.52
Al ₂ O ₃	30.49	TiO ₂	1.33
CaO.....	0.30	S.....	0.24
MgO.....	Trace	SO ₃	0.46
K ₂ O.....	0.48		
Na ₂ O.....	0.30	Total.....	100.23

"The remarkable feature of this analysis is the almost total removal of the alkalis and alkali earths. The presence of almost 5 per cent of ferric oxide in a nearly pure white clay indicates that it must be in some unusual combination.

"On the wall of the ore-body below the eighth level the Keewatin rock is much decomposed, the result being a decidedly plastic kaolin of a banded and mottled character. This is at a depth of 540 feet. In colour the material is decidedly yellow and there are nodules of goethite scattered through the mass."

Samples of both clays were submitted to the writer for physical tests. The sample from the kaolinized dyke is light grey, but contains numerous small particles of dark-coloured mineral. About 90 per cent of the clay can be washed through a 200-mesh sieve, the coarse residue apparently consisting mainly of particles of feldspar, not completely kaolinized. The clay requires 40 per cent water to bring it to the best working consistency. It is very plastic, being more so than most residual clays, and its shrinkage in drying is 7 per cent. It burns to a light grey porous body at low temperatures, the test pieces being badly cracked in the fire, and the body weak. When burned to cone 9 (1,310 degrees centigrade) the body is hard and dense, and light grey in colour, with dark fused specks on the surface. Vitrification is not quite complete at this temperature as the absorption of the burned body is 3 per cent. The shrinkage is very high, the total shrinkage at cone 9 being 20 per cent.

The clay was tested for refractoriness in a Hoskins electric resistance furnace and found to remain intact at the softening point of cone 30 (1,730 degrees centigrade) so that it is a No. 1 fire-clay, and one of the most refractory clays found in Canada.

The material exhibits all the physical properties of kaolin or china-clay with the exception of colour. It is not white either in the raw or burned state. Washing does not improve the colour of the burned body, for most of the dark iron-bearing material is so finely divided that in the washing process it passes over with the minute clay particles.

The yellow residual clay from Keewatin schist carries over 6 per cent of iron oxide; its plasticity is low, and it is difficult to mould into shape. It burns to a red porous body at low temperatures, but becomes vitrified at cone 9, and is less refractory than the diabase clay.

These clays were never used and the mine workings where they were found are now filled in.

MATTAGAMI RIVER

"About 1½ miles below the head of Long portage on the Mattagami river, on the left bank, a highly kaolinized syenite gneiss occupies the bottom of a ravine which enters the river valley from the east. The material is exposed for a distance of about 400 feet. The height is about 20 feet at the highest point.

"The material is kaolinized to a remarkable degree if the kaolinization be of post-Glacial age. If, on the other hand, the bottom of this valley escaped the erosion of the last Glacial period, then the kaolinized material would be pre-Glacial in age, which would account for its extreme alteration. The material is probably too impure for the manufacture of china-ware, but it might be suitable for making fire-brick and refractory ware. The heavy overburden of glacial drift would probably prevent its commercial development even if railway facilities were available and the kaolinization were proved to continue to a considerable depth."¹

Mr. Cross is correct in assuming that the kaolinization of the gneiss happened in pre-Glacial time. Post-Glacial time is too short for kaolinization and the conditions at the locality since the last glaciation are unfavourable. It is probable that this body of material is the semi-kaolinized part below the roots of a kaolin deposit which was removed either by stream erosion in pre-Glacial time, or by glaciation. A few miles farther downstream deposits of white clays and quartz sands which were undoubtedly derived from the erosion of the kaolin body are found below glacial drift.

MISSINAIBI RIVER

The canyon walls at Long portage on Missinaibi river are partly composed of a large mass of binary granite. The feldspar in the granite is softened by incipient kaolinization, so that the quartz grains are loose and the rock is friable. This rock is probably the lower and less altered part of a mass of almost completely kaolinized rock. A few miles downstream beds of white and mottled clay and quartz sand, which are evidently derived from the erosion of kaolinized granites, are found below glacial drift. The fire-clay deposits on Missinaibi and Mattagami rivers are described in another part of the report.

¹ Cross, J. G., 29th Ann. Rept., Ont. Bureau of Mines, pt. II, p. 17.

CHAPTER IV

SHALE FORMATIONS AND PRODUCTS

FORMATIONS

Shales of varying degrees of hardness form a considerable part of the bedrock in some parts of Ontario. Nearly all of them require to be prepared by grinding with machinery of special form. Some of them become quite plastic when ground and mixed with water; others are low in plasticity.

Slates are shales that have been very much hardened, and have lost their water of plasticity; when finely ground and mixed with water, no plasticity is developed, the ground slate acting like sand in this respect.

Shales are used in preference to clays as they mostly give a denser, harder, and stronger product. Furthermore, their drying properties are better than those of clay, their shrinkage is less, and they are not so easily over-fired. Shales cannot be worked by the simple methods and equipment commonly used for clays, and a heavy initial expense is entailed in building a plant suitable for working them.

The crystalline rocks of the Precambrian contain little or no plastic material, and shales suitable for brickmaking have been found only at one point. The Ordovician system, which overlies the Precambrian, contains an abundance of shales and furnishes all the raw material of this kind at present used in the clay industry of Ontario. The Silurian system has possibly one formation that may be used in clayworking, but it is doubtful if any of the shale beds in the overlying Devonian can be used.

Shales of the Precambrian

Rocks of Precambrian age underlie the greater part of the province. They consist of igneous rocks either massive or schistose and a great series of metamorphic rocks of both igneous and sedimentary origin. These rocks are non-plastic and consequently of no use to the clayworker, who deals only with plastic materials. The Precambrian, however, furnishes materials of great value to some branches of ceramics. These include feldspar, quartzite, and magnesite.

ANIMIKIE SHALE

The shale in this formation is greyish in colour and occurs in very thin layers. It is friable at the outcrops, some of the layers being weathered into clay, and varies in hardness from a slate which lacks plasticity when ground and wetted, to a shale which has some plasticity. None of it, however, except on the surface, could be called plastic shale. It is found at the base of the cliffs on the east side of Thunder bay, from the main shore to Thunder cape. Some shale was mined at Sawyer bay and brought to the Alsip brick plant at Fort William, where it was made into dry-pressed face-brick, but it has not yet been used extensively.

The Animikie shale at Caribou island in Thunder bay would be a good source of supply for brickmaking material, as there is good anchorage on the north side of the island. The shale bed is about 30 feet thick, and is overlain by a great thickness of other rocks, but a sufficient amount could be procured from the talus and outcrops without resorting to drift mining.

The results of tests of the Animikie shale are given in the chapter on northwestern Ontario.

Shales of the Ordovician

Rocks of Cambrian age are not known in Ontario, and the rocks which overlie the Archæan or Precambrian are known as Ordovician. They are sedimentary rocks, principally limestones and dolomites with a little sandstone in the lower part, and great thicknesses of shales in the upper part. The lowest beds are known as Potsdam sandstone, and the highest shale member as the Queenston. In some places the Potsdam sandstone is absent, and later limestone beds rest directly on the Precambrian.

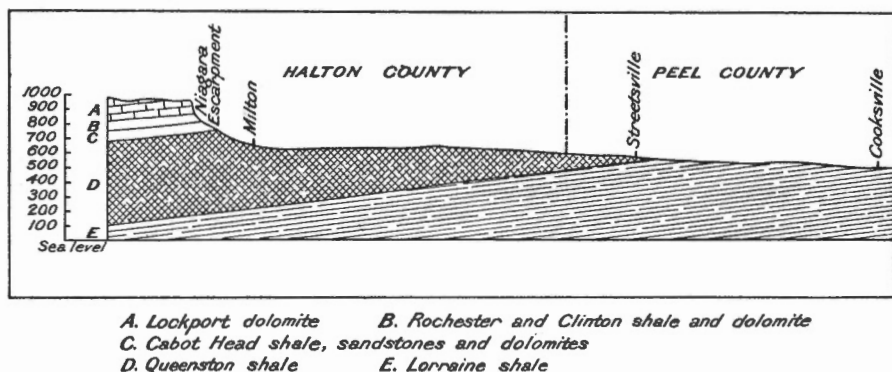


Figure 1. Section northeast-southwest through parts of Halton and Peel counties, showing succession of shale formations.

The Ordovician rocks are thin near the margin of the Precambrian upland, but increase in thickness with distance from the upland. In other words, the Ordovician sediments were deposited in seawater and on a southward-sloping floor. The Ordovician rocks are in turn covered by later sedimentary rocks in the Interlake peninsula (Figure 1); but there are large areas in southern Ontario in which the Ordovician forms the bedrock. By far the larger part of these areas has limestone or dolomite for the bedrock, but shale forms the bedrock over a considerable part.

The most useful raw materials for the clayworker are found in two formations, the Lorraine and Queenston, in the upper part of the Ordovician, formerly known as Hudson River and Medina. The face-brick industry, which has been developed to a high degree of efficiency by Ontario brickmakers, is based on these two formations.

The Utica shale, which underlies the Lorraine, is used to a small extent in eastern Ontario, but has not the same range of usefulness as the Lorraine and Queenston.

The Chazy shale, a minor formation that, with limestone and sandstone beds, occurs in the lower part of the Ordovician, is not regarded as of importance at present, but it may come into use in the future, especially in mixtures with plastic clay.

CHAZY SHALES

The Chazy is the lowest shale-bearing formation in the Ordovician. It lies below the Black River limestone and contains beds of limestone in the upper part, and in places the shales are interbanded with thin limestone beds.

The shales are mostly confined to a comparatively small area along Ottawa river, near Ottawa. The best outcrops are at Rockcliffe, and for several hundred yards east and west of the Gatineau ferry landing, where they form a cliff that extends to the old wharf at the clay flat at the rifle range. The shales outcrop also on the Montreal road east of Greens creek in Gloucester township, Carleton county. At Cumberland, Russell county, they may be seen at intervals and are well exposed in the escarpment south of the village.¹

The shales as a rule are grey with tints of red and green. They have a sandy texture, and occasional beds of sandstone occur with them. Their thickness is about 110 feet.

Ottawa. A sample was taken for testing from the beds of Chazy shale exposed in Rockcliffe park where they were free from limestone bands. The shale when ground to pass a 16-mesh screen was only feebly plastic. It dried readily and the drying shrinkage was only 3 per cent. It burned to a very porous rather pinkish body, and swelled rather than shrank in the burning. A test brick fired to cone 03 was slightly larger than the mould in which the brick was made when in the plastic state. This is the most extreme case of swelling in firing that the writer encountered in testing. Clays or shales with a very high lime content swell in burning, but not to such an extent.

The shale is of no value for burned clay products when used alone, but some of it might be used with the Champlain clay, to counteract its high plasticity and excessive shrinkage.

It is not clear whether the shales described below belong to the Chazy formation or not, but they occur below the Black River limestone, and, therefore, may be provisionally included with the Chazy.

Tamworth. Greenish grey shales about 6 feet in thickness are exposed in a cutting on the Canadian National railway just east of Tamworth station, Lennox and Addington county. A sample of the shale was ground to pass a 16-mesh screen, but was too low in plasticity for moulding in the wet state, so test brick were made by the semi-dry-pressed process and burned. The shale burned to a light red at low temperatures, but changed to a good buff colour at cone 03. The pressed brick are very porous and would be improved by the addition of some dense-burning plastic clay.

Similar shale is found east of Tamworth; and near Harrowsmith, interstratified with limestone beds, but these shales cannot be worked on account of their thinness and the overburden of limestone.

¹ Ellis, R. W., "Geology and Natural Resources of the Area Included in the Map of the City of Ottawa and Vicinity," Geol. Surv., Can., Ann. Rept., vol. XII, pt. G., 1899, p. 31.

Longford Mills, Rama Township, Ontario County. A bed of shale about 10 feet thick is exposed at the northwest end of lake St. John near Longford Mills. The shale is greenish grey, weathered, and disintegrated, and contains an occasional thin layer of sandstone.

The shale when ground and mixed with water has fair plasticity. The working and drying qualities are good, but the shrinkage on drying is rather high. It burns to a red colour and porous body at cone 010. When burned at higher temperatures the red colour disappears, the body then being light brown, or buff. The body is still porous, however, and even when burned at cone 01 the water absorption is over 20 per cent. Although this material stands up at a higher temperature than any other shale found in Ontario it does not seem to produce a vitrified product, for the body remains open and granular almost to the softening point.

The shale makes a very fair dry-pressed brick when burned to cone 03. The colour, brownish buff, is very pleasing for face-brick. If this shale occurred nearer to a good market for clay products it could doubtless be used.

UTICA SHALE

The Utica shale overlies the Trenton limestone and is the lowest member of the Ordovician that is worked for brickmaking. It is a thin-bedded, almost black shale, quite gritty or slaty in texture, and is as a rule bituminous.

The amount of bituminous, or carbonaceous matter is quite small in some places. An analysis made at the Mines Branch of Utica shale from Rideau river at Billings Bridge, Ottawa, showed 2.1 per cent of organic carbon. At other places the bituminous content is higher, and certain beds at the base of the formation in Collingwood township, Grey county, were actually worked in 1860 for oil.

Distribution. Natural exposures of Utica shale are mostly confined to eastern Ontario, but a few outcrops are found on the shores of Georgian bay. The shale is seen at only one or two points in the southern part of eastern Ontario and nowhere in northern Ontario.

The Utica shale is found in many places in the eastern part of Ottawa, where excavations for foundations have been made. It extends from New Edinburgh nearly to Hogsback, a distance of about 7 miles, on the east side of Rideau river. It underlies a part of the township of Gloucester, but the drift cover is so thick that it is seldom seen near the surface except close to Rideau river. The shales spread over a wide area in the township of Cumberland and are exposed at intervals in the broad and mostly level district between the villages of Russell and Sarsfield.¹

A small basin of Utica shale occurs about Maxville, Glengarry county. It is found in many well borings at 8 to 16 feet below the surface and is exposed on lot 16, range X, Caledonia township. The Utica shale has not been recognized east of Ottawa district, except on the slope of the mountain south of lake Clear, Sebastopol township, Renfrew county.

¹ Ellis, R. W., "Geology and Natural Resources of the Area Included in the Map of the City of Ottawa and Vicinity," Geol. Surv., Can., Ann. Rept., vol. XII, pt. G, 1899, pp. 21-24.

The Utica shale has been mostly removed by erosion in central Ontario, and Trenton or Black River limestone, which lie below the Utica, form the bedrock over the greater part of the areas of Palæozoic rocks. The black shales of the Utica are exposed at two places, however, below thick covers of glacial drift, one being at the mouth of the creek in Whitby and the other in the bank of a creek about one mile north of Pickering, both in Ontario county. The outcrop at Whitby is small and is covered by a great thickness of glacial drift. The shale is exposed for a few hundred feet on the bank of the stream near Pickering. It forms the creek bed and rises to about 35 feet above the level of the stream and is overlain by about 20 feet of glacial drift. The shale at this point is brownish black, rather hard and brittle, and splits into thin laminæ. When ground and mixed with water, it develops a low plasticity, and can be run through the die of a stiff-mud brick machine. It burns to a red colour.

The Utica shale exposed near the shore of Georgian bay, at Craigleith, Collingwood township, Grey county, is highly calcareous and contains a high percentage of bituminous matter. It burns to a cream-coloured, chalky body of no value for structural purposes.

Utica shales are found at the surface on the high ground in Little Current, Manitoulin island, and they cover the whole of Strawberry island, except the northern extremity. Small patches occur in Sheguiandah village and on Heywood island. They cross the peninsula between Manitowaning and Smith bay and form a small area at the extremity of cape Smith.

The thickness of the Utica shale varies from 50 to 55 feet at Georgian bay to probably 400 feet in the Ottawa district.

Character and Uses. The Utica shale when ground to pass a 10-mesh screen, and mixed with water, has little or no plasticity. When ground to pass a 16-mesh screen, and wetted, it is slightly more plastic. It is doubtful if this shale can be worked by the stiff-mud process of brickmaking on account of its lack of coherence. It can, however, be used by the semi-dry-press process, or, if mixed with clay, by the plastic process.

Owing to the percentage of carbonaceous matter, some difficulty would be experienced in burning, for the brick would be liable to bloat or form black cores. This difficulty can be overcome by allowing the carbon to burn off before raising the temperature in the kiln too high. The shale has a rather short vitrification range, and consequently would be an unsafe material for making vitrified wares. It is used for brickmaking at only one plant, that of the Peerless Brick Company, situated just outside Ottawa, near Rideau river. No wares are made from the shale alone, but it is used in a mixture with Champlain clay, which is abundant at this locality. A mixture of equal parts of ground shale and clay is used for making rough-face plastic brick, and a mixture with less shale is used for making hollow building blocks.

Iron pyrite, in some cases disseminated in yellow crystals through the shale, creates trouble in the burned product as it causes the formation of a white or yellow scum which in many cases obscures the colour of the face of the brick. This trouble can be overcome by using a small quantity of barium carbonate, which is added to the shale and clay mixture as it passes through the pug-mill.

Physical tests were made of samples of Utica shale from two localities, with the following results:

Sample No.	%	%	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption
239.....	14	3	0	10	1	7	.....	.....
768.....	15	3	0	12	2	11	3	5

239. Billings Bridge, Ottawa—used in brick mixture by Merkley's Ltd.

768. Pickering, Ontario county, on stream bank 1 mile north of village.

The small amount of water required to develop the best working qualities of the ground shale denotes a low plasticity. The drying shrinkage is correspondingly low, and drying can be accomplished quickly. The body is strong and the colour is red at all temperatures. It was difficult to fire the bricklets to the softening point of pyrometric cone 03 as they showed a tendency to bloat and become cindery in the quick firing of the test kilns. The difficulty was apparently caused by the carbonaceous matter.

LORRAINE SHALE

The Lorraine (Hudson River) shale overlies the Utica shale and is more widespread and nearer to the surface. It has been worked for many years and was probably the first shale to be used for brickmaking in Ontario. It is lighter in colour than the Utica and develops more plasticity when ground and wetted. It is not a homogeneous clay shale formation, as it contains numerous hard sandy layers, and a few thin limestone beds, which must be eliminated.

Distribution. Lorraine shale is the bedrock of a considerable area on the lake shore of York, Peel, and Halton counties. Outcrops are numerous, particularly in stream banks; but it is mostly covered with glacial drift. Near Toronto the shale forms cliffs that reach 30 or 40 feet within the first 3 or 4 miles up Humber river, and 10 to 16 feet on the Don about 2 miles from its mouth. The Don Valley brick-yard near Rosedale, Toronto, offers the best artificial exposure, where a face of over 60 feet of the unweathered shale is worked for brickmaking (Plate II). The Sun Brick Company, about half a mile farther up the Don valley, works the same shale beds.

The Lorraine shale is exposed on the banks of the Humber for about a mile south of Weston, 3 miles northwest of Toronto. One of the bluffs on the west side of the river has a vertical exposure of about 20 feet, and another bluff on the east side exposes about 40 feet of shale and rock. The drift cover is thin on the flat area near Mimico, and the Lorraine shale is near the surface. Two brick plants operate at this locality, using the shale exclusively for their raw material.

The shale is also accessible a short distance below the surface in Peel county, and two brick-yards, one near the lake shore at Port Credit, and another at Cooksville, have made large excavations in it. The western

limit of the shale in Peel county is at Streetsville, where it passes under the red Queenston shale (Figure 1), but near the lake shore it continues below a thin drift cover into Halton county nearly as far west as Oakville. The shale is exposed in the beds of most of the streams west of Toronto as far as Rouge river, near Dunbarton, but is not workable owing to the cover of glacial drift.

"Escaping from beneath the great mass of drift which conceals the formation between lake Ontario and lake Huron, the whole thickness of the deposit can be determined on the east side of the township of Collingwood, where it rises in nearly horizontal strata to the height of 770 feet, in the flank of a hill overlooking the Utica shales which have been mentioned as exposed at the level of the lake. Farther on, the deposit shows itself near cape Boucher in Nottawasaga bay, where cliffs, rising abruptly to the height of 150 feet, present sections of buff or drab-coloured argillaceous shale, interstratified with thin beds of grey, yellow-weathering sandstone. The formation is exposed near Meaford and, appearing again at point Rich, continues in a high and nearly vertical cliff to point William, where we find bluish and drab argillaceous shale, with thin beds of limestone and calcareous sandstone. The strata are piled on one another to the height of 335 feet above the lake, and they are capped by 20 feet of red and bluish-green shales of the Queenston (Richmond) formation. Exposures of Lorraine strata occur on the road between concessions B and C of Sydenham, from lots 16 to 23."¹

"In Manitoulin island the Lorraine strata are largely developed in the township of Sheguiandah and also in the area lying between Manitowaning bay, Smith bay, James bay, and the head of South bay. In this region they consist mostly of bluish grey and drab shales, interstratified with thin layers of limestone, and fine-grained sandstones, with a 30 or 40-foot band of rather thinly bedded grey limestone at the top. The whole thickness of the formation at cape Smith is 300 feet, but it diminishes to the westward and may not exceed 250 feet to the south of Little Current. Lonely, Club, and Rabbit islands, also consist of Lorraine strata."²

There is no known occurrence of Lorraine shale in central Ontario, but it is abundant in Carleton and Russell counties and outcrops are found not far from Ottawa, and farther east near Vars, Russell township.

The upper part of the Utica shale and the lower part of the Lorraine are similar in many respects and there is a gradual transition from the black, thinly-bedded, brittle shale at Hurdman, to a brownish and thicker-bedded shale near Willowdale, up to grey shales interbedded with thin limestone and sandstone, near Hawthorne. The shales also become slightly more plastic as they become lighter in colour.

The Lorraine shale is not worked in the Ottawa district, so that there are no pits where it is exposed, and there are no natural exposures of any thickness, a few feet being the most seen. Consequently, it is not known whether the hard bands seen in the formation elsewhere are prevalent or not. There is a thin bed of limestone with the shale in the 2-foot section on the bank of a small stream near the road between Hawthorne and Ramsayville, but the 2-foot section on the roadside at lot 25, concession II, Gloucester township, does not contain any hard rock layers.

¹ "Geology of Canada, 1863," pp. 213-214.

² Geol. Surv., Can., Ann. Rept., vol. IX, p. 23 I.

It is estimated, from a boring made for gas and oil near Ramsayville, that the thickness of the shale at that point is 440 to 450 feet.

Properties and Uses. The Lorraine shale in the Ottawa district is rather gritty and does not develop much plasticity when ground and mixed with water. It is plastic enough for use in making wire-cut brick, but for hollow ware it should be mixed with some of the plastic surface clay abundant in that area. The shales are fairly plastic in Toronto district, and are used freely for the manufacture of hollow ware, without any admixture of clay.

The Lorraine shale on Georgian bay, at Craigeleith and Meaford, becomes very plastic when ground and wet, so that it comes smoothly through a die of almost any form. The shale at Gore Bay, Manitoulin

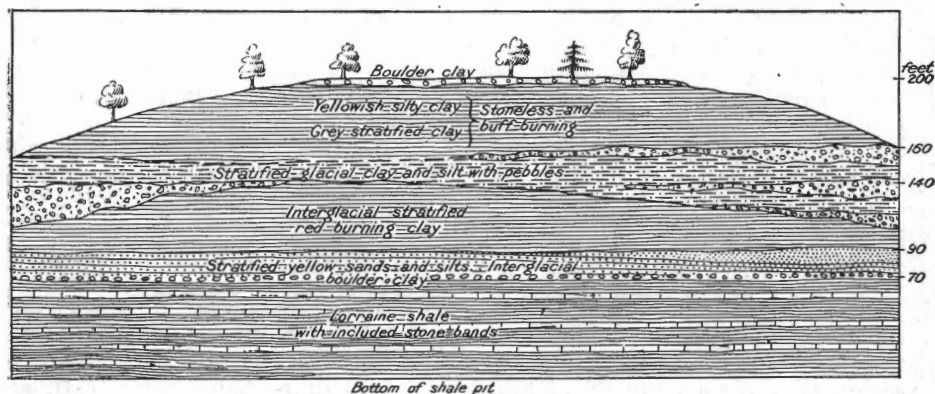


Figure 2. Working face, about 1,500 feet long, in clay and shale, Don Valley Brick Company, Toronto, 1914.

island, is even more clay-like and plastic. There are extensive masses of clay on the slopes at Georgian bay, which are weathered and softened parts of the underlying shale.

The use of Lorraine shale is handicapped by the hard, sandy, and limestone layers. This waste product can seldom be disposed of except for making roads in the vicinity of the workings, though a few of the hard bands can be sold for building stone (Figure 2).

The shale is mostly worked by the plastic, or stiff-mud process, but it is also used for dry-pressed brick. The principal wares made from it are common wire-cut brick, rough, or rustic face-brick, hollow building blocks, fireproofing, and drain-tile.

The Ontario Government plant at Mimico is the only plant that makes roofing tile and floor tile from Lorraine shale. For this purpose the shale requires to be ground much finer than when used for rough clay products.

The shale burns to a good hard, light red body at comparatively low temperatures, but the best results are obtained both in body and colour when the firing is carried up to about 1,850 degrees F. in ordinary down-draft kilns.

Hollow ware can be burned hard at a lower temperature than brick on account of the thinness of the walls in that ware. When the shale is over-fired it deforms and becomes dark brown, and when greatly overfired it bloats and has a spongy structure. Its range of vitrification is short,

so that it cannot be used safely for the manufacture of paving blocks. The table of physical tests shows that the shale in some cases becomes very dense at cone 03.

The following analyses show the chemical composition of Lorraine shale from various localities.

—	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Lime CaO	Magnesia MgO	Alkalis K ₂ O-Na ₂ O	Loss on ignition
1	57.86	20.00	6.83	2.92	3.25	not det.	5.74
2	57.60	16.30	8.00	3.47	3.97	3.40	.....
3	60.01	18.62	10.15	0.10	0.20	6.70	11.45
4	59.21	18.42	5.37	3.32	3.30	1.60	9.16
5	58.42	16.18	7.41	3.53	3.18	not det.	8.88
6	56.46	18.19	7.43	2.56	2.93	4.17	8.52
7	61.60	17.62	7.32	0.68	3.07	4.27	5.81

1. Don Valley Brick Co., Toronto. Ont. Bureau of Mines, vol. XV, pt. II, p. 8.
2. Ontario Government plant, Mimico, Ont. L. J. Rogers, analyst.
3. Upper weathered shale, Ontario Paving Brick Co., Islington, Ont., Ont. Bureau of Mines, vol. XV, pt. II, p. 114.
4. Made shale, Ontario Paving Brick Co., Islington, Ont.
5. Average shale, Meaford Brick Company, Canadian Clayworker, Jan., 1914.
6. Port Credit Brick Co., Ont. Bureau of Mines, vol. XV, pt. II, p. 90.
7. Lot 25, con. 2, Gloucester tp., Carleton co. No. 381.

The above analyses show that the Lorraine shales contain a high percentage of fluxing impurities, running as high as 19 per cent in No. 2. This explains why these shales fail in the fire test when they are heated up to, or a little beyond, their vitrification point. On the other hand, incipient vitrification takes place early in the burning, so that strong structural wares can be made with a comparatively small expenditure of fuel. The low lime content of No. 3 is explained by the weathering and leaching of the upper exposed part of the shale. No. 7 has a lower lime, and slightly higher silica content than any of the unweathered shales, and is the most promising one for paving brick.

Physical Tests of Lorraine Shale, Wet Moulded

Lab. No.	Water of plasticity	Drying shrinkage	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorpt- ion	% Fire shrinkage	% Absorpt- ion	% Fire shrinkage	% Absorpt- ion
—	.....	3	0	12	2	8	2	1
228	19	3	0	12	1	8	5	2
217	22	4	2	10	3	5	.....	.....
243b	25	6	0	17	5	7	8	0
243	25	7	0	12	4	10	10	0
220	24	5	4	6	6	2	8	0
369	24	6	1	13	2	11	3	11
381	14	3	0	11	1	9	2	7
233	15	3	0	11	1	8	3	2

- , Ontario Government clayworking plant, Mimico.
228. Shale one mile west of Dunbarton station, Grand Trunk railway.
 217. Shale partly weathered at Craighleith, Collingwood tp., Grey county.
 - 243b. Shale partly weathered at Thornbury, Collingwood tp., Grey county.
 243. Clay on top of shale, at Thornbury, Collingwood tp., Grey county.
 220. Shale, Meaford Brick Co., Ltd., near Meaford, Grey county.
 369. Shale, partly weathered, east side of Gore bay, Manitoulin island.
 381. Shale, lot 25, con. II, Gloucester tp., Carleton county.
 233. Shale, Hawthorne, Gloucester tp., Carleton county.

QUEENSTON SHALE

The Interlake peninsula contains a red shale long known as Medina, but lately called Queenston, the name Medina being reserved for an overlying grey sandstone formation. The Queenston shale rests directly on the Lorraine and outcrops more frequently because it occupies the base of the Niagara escarpment for a long distance between lake Ontario and lake Huron, whereas the Lorraine shale forms part of the escarpment only near the shore of Georgian bay.

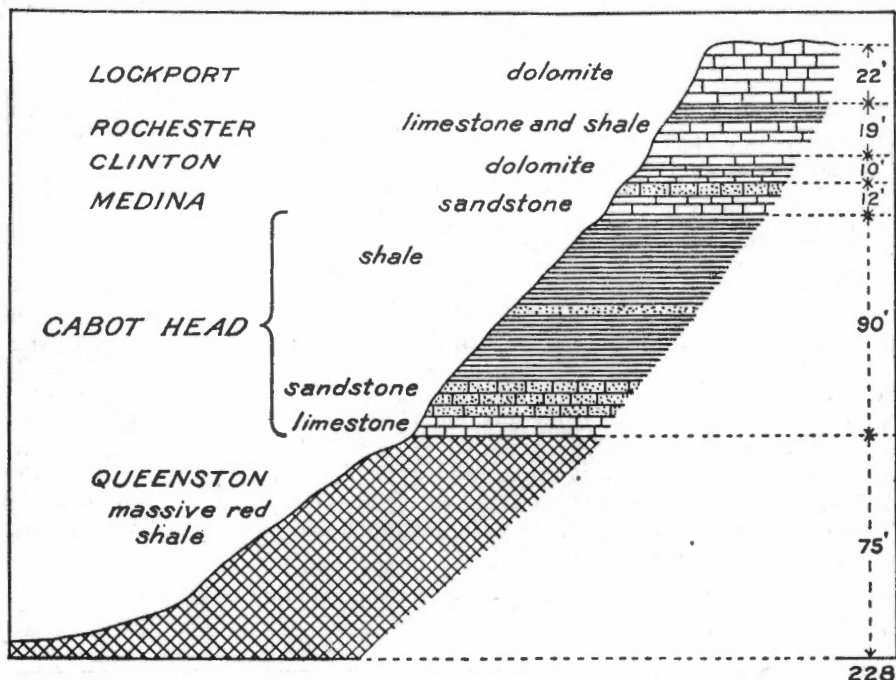


Figure 3. Section of the Niagara escarpment at Hamilton, Ont., showing succession of shale formations.

The Queenston is a more homogeneous formation than the Lorraine, as it contains few hard bands. Furthermore, it contains more clay substance and, consequently, is more plastic and easily weathered, so that many of the outcrops carry a mantle of soft clay. The shale is massive as a rule and seldom or never shows the thinly-laminated structure so common in this kind of rocks (Plate III A). The prevailing colour is reddish brown, but in some cases it contains greenish grey bands of sandy texture, and patches of the lighter colour occur irregularly in the red shale. Owing to its position on the sloping ground at the foot of the Niagara escarpment, this shale can as a rule be worked with a face above the level of the lower ground, so that there is natural drainage from the floors of the pits (Figure 3).

The Queenston shale between Beamsville and Milton burns to a red colour at all temperatures. Buff-burning shale is interbedded with red-burning at Milton, and brick of each colour can be produced from the same

pit. The shale in the upper part of Credit valley burns red or salmon colour at low temperatures, and buff or greenish at the higher temperatures. The lime content increases to the north, and the shale at Meaford and Owen Sound burns to buff colours at all temperatures.

Distribution. The top of the Queenston shales is about at the level of the entrance to Welland canal, at Port Weller, but at that point it is covered by about 50 feet of glacial drift. It comes to the surface at Beamsville, 12 miles west of Port Weller, and from there it can be traced by the red soil to Hamilton. A thickness of about 100 feet is exposed at the base of the Niagara escarpment at Grimsby, and about 245 feet is exposed in the same position at Hamilton (Figure 3).

From Hamilton the outcrops are easily traceable northward through Halton, Peel, and Dufferin counties, the exposures being especially numerous where Credit and Nottawasaga rivers indent the escarpment. The level at which Queenston shale occurs in the escarpment rises in the vicinity of Georgian bay. Beaver river, which cuts through the limestone overlying the shale, has a deep valley extending southward, so that outcrops of the red shales can be seen as far as Eugenia, Artemesia township, Grey county. The shale declines in height at Owen Sound, where there are several outcrops close to the shore, and disappears below the lake level a short distance to the north. The shale is found near Little Current, Gore Bay, and other localities on the north shore of Manitoulin island, but it does not extend any farther west in Ontario. Red clay shale, which is supposed to correspond to the Queenston formation, outcrops below Coral portage on Abitibi river in northern Ontario.¹

Queenston shale is not known to occur in central Ontario. A small, isolated area occurs at the surface or beneath a thin cover of drift in eastern Ontario, in the township of Cumberland, Carleton county, south of the Grand Trunk railway, and covers about 6 square miles.

Properties and Uses. The Queenston is the most abundant and widely used shale in Ontario. It is homogeneous in physical character and is easily mined and crushed. There is a variation in its composition, principally in the lime content. When ground to pass a 10-mesh screen, and mixed with water, it develops a good plasticity so that it can be used for the manufacture of wire-cut brick and hollow building blocks, and field drain-tile. Hitherto, the greater part of the products made from this shale have been brick made by the semi-dry-pressed process, but these are gradually being replaced by brick made by the plastic or stiff-mud process, the shale being well adapted for these kinds of brick.

Brick made from the shale stand fast drying without cracking, and the drying shrinkage is low, as shown by the table of physical tests. The brick burned at the lower temperatures are very porous; but the body is strong and becomes denser and stronger at the higher temperatures. The porosity does not diminish much in the shales with a high lime content, such as No. 221, although the body is stronger and the colour better at the higher temperatures.

There is a very short interval in firing between the temperature at which the shale becomes dense, and the temperature at which the brick made from it begin to soften and stick together; so that it is impossible to

¹ Ont. Bureau of Mines, 1920, vol. XXIX, pt. II, p. 21.

use it for vitrified wares. The chemical analyses verify the fire tests, as it can be seen from the analyses given below that the amount of fluxing impurities is high.

Chemical Analysis of Queenston Shales¹

—	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Lime CaO	Magnesia MgO	Potash K ₂ O	Soda Na ₂ O	Loss on ignition
1.....	55.90	18.46	6.60	3.82	2.65	3.55	0.53	8.74
2.....	56.90	17.40	6.64	3.84	2.65	3.51	0.53	8.78
3.....	53.20	17.73	6.91	6.00	3.24	3.40	0.46	9.58
4.....	47.98	13.10	4.42	12.53	3.25	3.39	0.78	14.50
5.....	56.52	15.21	5.82	6.86	2.82	3.59	0.56	8.79
6.....	62.28	17.22	8.82	1.56	2.64	.....	.....	5.24

1. Beamsville, Lincoln county.
2. Fruitland Brick Co., Wentworth county.
3. Milton Brick Co., Halton county, red-burning shale.
4. Milton Brick Co., Halton county, buff-burning shale.
5. Brampton Brick Co., Peel county.
6. Russell Shale Bricks, Ltd., Russell county. Analyst, M. B. Baker.

Table of Physical Tests of Queenston Shale, Wet Moulded

Lab. No.	Water of plasti- city	% Drying shrink- age	Cone 010		Cone 06		Cone 03		Colour
			% Fire shrink- age	% Ab- sorption	% Fire shrink- age	% Ab- sorption	% Fire shrink- age	% Ab- sorption	
201.....	17	4	1	11	.....	.....	4	1	Red
325.....	17	4	0	10	0	8	0	6	Red
326.....	18	4	S	15	S	.....	S	15	Buff
275.....	20	5	0	10	1	8	4	0	Red
267.....	18	4	0	15	0	12	0	6	Salmon to buff
268.....	18	4	0	16	0	14	0	13	Salmon to buff
269.....	17	3	S	18	S	17	S	15	Buff
221.....	21	5	0	20	0	18	0	17	Salmon to buff
222.....	20	4	0	18	0	17	0	16	Buff
238.....	14	2	0	11	0	9	2	6	Red

S = Slight swelling in burning.

201. Canadian Pressed Brick Co., Bartonville, Hamilton.
325. Milton Pressed Brick Co., Ltd., red-burning shale.
326. Milton Pressed Brick Co., Ltd., buff-burning shale.
275. Streetsville Brick Co., Ltd., Streetsville, Peel county.
267. Halton Brick Co., Terra Cotta, upper shale.
268. Halton Brick Co., Terra Cotta, middle shale.
269. Halton Brick Co., Terra Cotta, lower shale.
221. Meaford Brick Co., Ltd.
222. Imperial Cement Co., Owen Sound, Grey county.
238. Russell Shale Bricks, Ltd., Russell, Russell county.

¹ Ont. Bureau of Mines.

Shales of the Silurian

CABOT HEAD SHALE

Above the Queenston shale, and separated from it by beds of sandstone and dolomite, there is an important formation known as the Cabot Head shale, the type locality for the shale being the cliffs at Cabot head, Bruce county.¹ The shales are mostly greenish grey, but at some localities there are beds of reddish shale in the same formation. Part of the formation is, as a rule, made up of alternating thin beds of limestone and shale, but at most places where it is exposed there is also a considerable thickness of shale with a few included limestone bands (Plate III B).

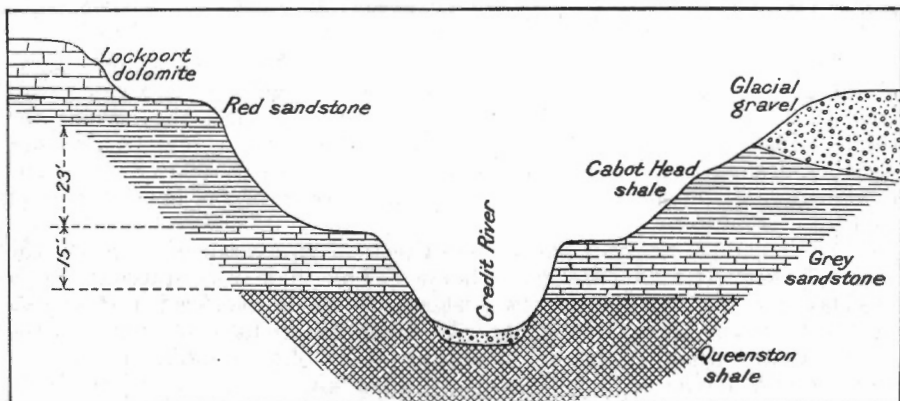


Figure 4. Section of shales and sandstones between Cataract junction and Credit Forks, Peel county.

The Cabot Head is more plastic than any other shale in Ontario. It weathers readily into a plastic, sticky clay at the outcrops, and even the fresh shale, when ground and mixed with water, slakes readily into a smooth, plastic clay.

Most of the outcrops of Cabot Head shale occur in the Niagara escarpment and are overlain by hard beds of Lockport dolomite, but in this position the formation is difficult to work without mining, which would be unprofitable with such low-grade material. Furthermore, the occasional limestone bands in the shale are a detriment, although by careful mining they might be eliminated.

Distribution. The valley of Fortymile creek at Grimsby, Lincoln county, presents one of the best sections to be seen along the face of the escarpment. The Cabot Head shale and included limestone is 74 feet thick at this point, and the base of the formation is 234 feet above lake Ontario.

A good section is also presented at Stony Creek, Wentworth county, where the shale is exposed in a gorge just above the line of the Toronto, Hamilton, and Buffalo railway (Plate III B). The shale is exposed at various points on the face of the escarpment at Hamilton, one of the best sections being in the "Jolly Cut"² (Figure 3). The shale can be traced along the

¹ "The Silurian Geology of Ontario Peninsula," Geol. Surv., Can., Mem. 3, p. 32.

² Southwestern Ontario, Geol. Surv., Can., 1913, Guide Book No. 4, p. 136.

escarpment through Ancaster and Waterdown into Halton county, where it is seen in the cuttings on the Grand Trunk railway at Limehouse, but at this point it is much thinner than at Hamilton. At Inglewood, in Credit River valley, it is exposed in a bed 6 feet thick, overlying Medina sandstone, which is quarried for building purposes, and at Cataract, several miles farther up Credit valley, a section of over 20 feet of shale is exposed (Figure 4). It is as a rule covered with drift north of this point, although the hard formations above and below it are visible at many places on the escarpment. It can be seen in the deep valley of Beaver river at Eugenia falls and at other points on the escarpment in Grey county as far north as Wiarton. The section at the Imperial Cement Company's works at Owen Sound shows sandy Queenston shale.

Character and Uses. The section in the gorge at Stony Creek shows about 25 feet of grey Cabot Head shale which includes five calcareous sandstone bands about 6 inches thick, spaced irregularly throughout the shale. The fresh shale is hard and would require to be blasted, but the weathered shale is smooth and soapy to the feel when wet. Sample 205 in the table of physical tests represents an average of the lower 8 feet of shale.

The chemical analysis and physical tests of an average sample of the upper 7 feet, No. 206, are given below. The shale was stated to be a fire-clay, but it is nothing of the sort, as it is easily overfired and is more fusible than the Queenston shale. It would be useful, however, for the manufacture of field drain-tile, or perhaps for hollow-building blocks, its working and drying qualities being very good, and it burns to a hard body at a low temperature. The colour of the burned ware is bad, as it is a pale red at cone 010, and at higher temperatures is indefinite, being neither red nor buff.

There are two shale beds in the railway cutting at Limehouse, an upper grey bed 7 feet thick and a lower 4-foot red bed, separated by calcareous sandstone. The upper grey bed is useless as it contains thin limestone layers, but the lower red shale is free from this impurity. It is more sandy than is usual in this shale, so that its shrinkage is less and it is more open burning. The red colour is only fairly good at cone 010, and bad at the higher temperatures.

The Cabot Head shale at Inglewood is good at cone 010, but the shrinkage is too great, and the colour is poor at the higher temperature. It is not as good a material as the Queenston shale nearby, which is worked for brickmaking.

The shale at Cataract is probably the best of the group, and on account of its good plasticity and working qualities it would be useful for making drain-tile, or hollow blocks.

The Cabot Head shale at Owen Sound, although quite distinct in the raw state from the red Queenston shale that lies below, makes a burned product very similar to it. The burned shale is slightly denser, but the buff colour does not develop as well as in the Queenston.

The shale at Manitoulin island is too far away to be of much value, besides, its shrinkage is too high, and it is liable to check in firing.

The Cabot Head shale has not hitherto been used in any branch of clayworking. As already stated it is not well situated for mining, and furthermore, the Queenston red shale, which is a more reliable brick material, is as a rule available in abundance at a slightly lower level. The Cabot Head would be a good material for roofing tile, owing to its smoothness and plasticity and to the fact that it burns to a steel hard surface at low temperatures, but the burned colour is not good enough for this purpose. None of the Cabot Head shales was found to stand quite as much fire as the Queenston and Lorraine shales, except the red bed at Limehouse which was slightly more refractory than the others.

Physical Tests of Cabot Head Shale

Lab. No.	% Water of plasticity	% Drying shrinkage	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorp- tion	% Fire shrinkage	% Absorp- tion	% Fire shrinkage	% Absorp- tion
205.....	20	5	2	10	3	5	1	0
206.....	23	5	1	12	7	2	0	0
327.....	25	4	0	20	0	19	0	17
227.....	25	5	0	16	5	2	7	0
266.....	24	5	1	20	3	13	5	8
223.....	21	5	0	17	0	14	2	10
264.....	25	5	2	15	3	4	.....	.....

205. Stony Creek, Wentworth co., lower hard grey shale.

206. Stony Creek, Wentworth co., upper hard grey shale.

327. Limehouse, Halton co., hard red shale.

227. Inglewood, Peel co., hard grey shale.

266. Cataract, Peel co., soft greyish green shale.

223. Owen Sound, Grey co., soft greyish green shale.

264. Lake Manitou, Manitoulin island, soft red shale.

The following analysis made by Mr. A. Sadler, Mines Branch, shows the composition of Cabot Head shale from Stony Creek.

	Per cent
Silica, SiO_2	54.28
Alumina, Al_2O_3	22.12
Iron, Fe_2O_3	5.94
Lime, CaO	1.34
Magnesia, MgO	3.58
Potash, K_2O	5.71
Soda, Na_2O	0.49
Loss on ignition.....	7.07

100.53

These results show that the alumina content is slightly higher than in most of the clays and shales in Ontario. The potash is also unusually high and the soda correspondingly low. It is also uncommon for a clay to show so much more magnesia than lime. The fluxing action of the potash probably accounts for the density and hardness of bricklets burned at a comparatively low temperature.

SALINA FORMATION

The Salina is the highest shale-bearing formation in the Silurian, and is the salt and gypsum-bearing formation of New York state and Ontario. Its lowest member in Ontario is a green or grey shale, that contains beds of argillaceous dolomite, and in places, deposits of gypsum and salt.

Distribution. Although the Salina formation is frequently pierced by borings in the western part of the Interlake peninsula, outcrops of it are rarely seen, the strip of country where it forms the bedrock being covered by a thick mantle of glacial drift.

The upper shales are represented by pea-green to grey, hackly shale, in outcrops along Niagara river 100 yards north of the International bridge at Bridgeburg, Ontario. The best of the northern sections is on the south Saugeen river between Ayton and Neustadt in Normandy township, Grey county, where a section on lot 19, concession VI, is as follows: 3 feet shale; 10 feet hard, grey dolomite; 12 feet soft shale; 15 feet nodular, green shale; 2 feet mottled green and red shale; 4 feet dolomite.¹

About one mile above the bridge at Neustadt, about 10 feet of grey, gritty shale is exposed on the north bank of the Saugeen. It is overlain by 8 feet of thin-bedded argillaceous limestone capped with boulder clay. A little farther upstream the limestone above the shale is missing.

Salina shales are exposed on the banks of the Saugeen, above Walkerton. They are green and reddish, hard, sandy shales, interbedded with grey limestone and overlain by gravels.

Properties and Uses. Two samples of Salina shale, from Walkerton and Neustadt, were tested. When ground and mixed with water their plasticity was so low that they were difficult to mould. They dry rapidly and their drying shrinkage was only 2 per cent. They burned to cream-coloured, chalky bodies and swelled in the firing. The shale evidently contains thin layers of limestone, as some of the bricklets spalled, and showed lime specks after burning. The Salina shale, therefore, is not recommended for the manufacture of clay products.

Shales of the Devonian

The upper part of the Devonian in Ontario contains two shale-bearing formations, the Hamilton and the Huron. These shales underlie Lambton, Middlesex, and Kent counties, and shales, supposed to be of Huron age, outcrop on Abitibi river in northern Ontario.

HAMILTON SHALE

The most extensive outcrops of the shale member of the Hamilton are in the vicinity of Arkona and Marsh's mill, along Ausable river and its tributaries, in Lambton and Middlesex counties. The total outcrop of the shale at the mill measures 27 feet. The outcrop best known to clayworkers is at Thedford, where it was formerly used for making brick and field drain-tile. The amount of shale available at this point is not

¹ "The Silurian Geology of Ontario Peninsula," Geol. Surv., Can., Mem. 111, p. 83.

large, as most of it is covered by a thick deposit of glacial drift. In the railway cutting one mile east of Thedford station there is about 50 feet of shale with some limestone bands, capped by 3 feet of limestone. Samples collected at the old brick-yard and in the railway-cut show that the shale is exceedingly plastic and smooth when wet; in fact, it behaves more like a plastic clay than a shale.

The behaviour in burning is indicated below.

Lab. No.	% Drying shrinkage	Cone 010		Cone 06		Cone 03		Colour
		% Fire shrinkage	% Absorpt- ion	% Fire shrinkage	% Absorpt- ion	% Fire shrinkage	% Absorpt- ion	
247.....	4	0	28	0	26	0	26	Buff
248.....	6	0	17	1	8	4	7	Red

No. 247 is an average sample of the upper 25 feet of shale in the railway cut. It burns to a hard but very porous buff body, very much like that obtained from many of the surface clays in the region, over which it has no advantage.

No. 248 is an average of 9 feet in thickness at the old brick-yard. This material burns to a steel-hard red body at cone 010, but a better red colour and denser body are obtained by burning to cone 06. It bloats and becomes spongy if fired to higher temperatures than cone 03. Owing to its smoothness, high plasticity, and tensile strength in the raw state, and its density in the burned state, it is one of the best drain-tile clays in the province. This clay was formerly used at exhibitions for illustrating the manufacture of tile by Baird and Company, of Parkhill, and perfect tile 20 feet long were run out to exhibit its good working properties. The drawback to working the deposit is the thick cover of glacial drift.

*Analyses of Devonian Shales*¹

	I	II
Silica, SiO ₂	54.96	66.82
Alumina, Al ₂ O ₃	19.15	11.68
Iron, Fe ₂ O ₃	6.68	6.58
Lime, CaO.....	4.02	0.62
Magnesia, MgO.....	2.71	0.90
Potash, K ₂ O.....	3.47	2.58
Soda, Na ₂ O.....	0.30	0.38
Sulphur, SO ₃	0.63	0.59
Loss on ignition.....	8.48	8.85

I. Hamilton shale, Thedford.

II. Huron shale, Alvinston.

¹ Ont. Bureau of Mines, vol. XV, pt. II, p. 8.

HURON SHALE

Owing to the flat topography and the prevailing cover of glacial drift over the region underlain by Devonian shales, outcrops of bedrock are rare. The best known exposure is at Kettle point, Lambton county.

The Huron shale is dark grey, black, or brown, and weathers rusty red. It outcrops for about $1\frac{1}{2}$ miles along the shore of lake Huron, and excites interest because of its oil content and possible fuel value.¹

The shale cannot be regarded as a promising material for clayworking as it has little or no plasticity when finely ground and mixed with water. Furthermore, its high content of carbonaceous matter—6 per cent in some cases—would cause bloating during burning. It is possible that the shale could be advantageously mixed with plastic clay for making burned-clay products, just as the Utica shale is used at Ottawa. The large spherical concretions of calcite, popularly known as "kettles," which are characteristic of the shale at Kettle point, are another deterrent to its use.

"The Upper Devonian or Huron shale outcrops at other places in Lambton county. Among these may be mentioned that along the upper part of the north branch of Sydenham river (Bear creek), north of Kingscourt, in Warwick township. Along Sydenham river at Alvinston, Brooke township, there is a very good outcrop, although only a few feet of the shale shows at any one place. At Shetland, Euphemia township, 10 feet of Huron shale outcrops in a bank near the iron bridge above town. Then, about 8 miles southwest of Shetland, along the same river (Sydenham) there is another outcrop of the Huron shale just below Croton, in Camden township, Kent county."²

PRODUCTS

The use of brick made from shale or mixtures of shale and clay is increasing yearly, especially for city and large industrial buildings, where heavy floor loads have to be 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. Although the buildings, kilns, and machinery of a plant designed for the manufacture of shale-brick entail a large initial expense, these plants are able to compete with the comparatively cheap and simple soft-mud plants. Their large and constant output and their ability to work throughout the winter give them an appreciable advantage over the soft-mud plants. Shale has another advantage over clay, inasmuch as bricks made from it can be dried more rapidly with safety from cracking—an important consideration when a large output is desired.

Twenty-two plants in Ontario make brick from shale or mixtures of shale and clay. With one exception these plants are situated either on outcrops of Queenston shale in Wentworth, Halton, and Peel counties, or on Lorraine shale in Peel and York counties. Abundant supplies of suitable shale conveniently near Toronto and Hamilton give impetus to the industry. In addition to supplying these and neighbouring towns, some of the larger plants ship face-brick for long distances, even into the province of Quebec.

¹ For analyses and distillation tests, see Geol. Surv., Can., Sum. Rept., 1917, pt. E, p. 26.

² "The Devonian of Southwestern Ontario," Geol. Surv., Can., Mem. 34, p. 185.

DRY-PRESSED BRICK

Some years ago whenever face-brick were required for city buildings and dwellings the demand was almost always for dry-pressed brick, but, recently, brick with a roughened face made by the plastic process have been favoured.

The chief advantage of dry-pressed brick, from the manufacturers' point of view, was the simplicity of the process, the brick as they came from the machine being set directly in the kilns without preliminary drying. The perfect edges, smooth faces, and uniformity in colour and size of dry-pressed brick were supposed to be advantages.

It is never possible to obtain a whole kiln of brick of uniform colour, so that the sorting of brick for colour as they are drawn from the kiln is an important part of the work in every plant-producing face-brick. The principal defects in some of the dry-pressed brick made in Ontario result either from too coarse grinding of the shale or from underburning. The strength of dry-press brick depends largely on the degree of firing to which they are subjected, and this must always be done to a higher temperature than that used for brick made by the plastic process from the same material. Dry-pressed brick made from coarsely ground shale, and insufficiently burned, are not any better than, and in many cases not so good as, common soft-mud brick. The majority of dry-pressed brick in Ontario, however, are carefully made and fully burned, and are produced in a large range of colours from dark red to cream.

Objection has been made to the use of dry-pressed brick made in Ontario on the ground that they are too porous. It is almost impossible to produce a non-absorbent brick from any of the Ontario shales, but, such as they are, they have stood the weathering test successfully. Porosity in brick, however, means eventual discoloration from dust collecting in the pores; but, owing to the smoothness of the faces of dry-pressed brick, this defect affects them less than rough-texture face-brick. Architects who object to the porosity of Ontario brick do not hesitate to import non-absorbent, rough-texture brick—the worst dust catchers of any structural material in use.

The chief objection to dry-pressed brick from an architectural standpoint is the lack of expression in walls built of them. The smoothness of surface, the uniformity of colour, and the thinness of the mortar joints, almost totally destroy the structural value and texture associated with the older brick work. The monotony of pressed-brick walls and their lack of variety of colour and texture finally led architects almost to abandon their use in city work. They are still freely used, however, for buildings other than city dwellings. By increasing the thickness of the mortar joint and mixing various shades, very pleasing effects can be obtained from pressed brick. The desire for uniformity of colour in brick work still prevails in the country districts, and there the dry-pressed brick sorted for colour find a ready market when they are cheap.

The makers of dry-press brick machines, however, are meeting the demand for rough texture by producing dies that put a rough face on dry-pressed brick.

ROUGH-FACED BRICK

When smooth-faced, dry-pressed brick passed out of favour, architects went to the other extreme and demanded brick with very rough surfaces. The clayworkers make these in their ordinary stiff-mud or wire-cut machines. The rough face is obtained by placing a tight wire in front of the die or mouth of the machine in such manner that a thin veneer is removed from one or two faces of the clay bar as it issues from the dies. If an extra rough face be desired the clay bar is scored with rakes. Rough-faced brick can be made from mixtures of clay and shales as well as from all shale, but they cannot be produced from clay alone unless a certain amount of coarse sand be added.

Rough-faced brick are more easily attacked by the weather than smooth-faced; consequently, to make them durable they must be burned to as high a temperature as the material will stand. They are as a rule set in the upper part of the kilns where they receive the most fire, and variety of colour, or flashing, is obtained by setting some of the brick so that the faces are exposed to the flames and hot gases, whereas the faces of others are protected. Some plants in Ontario produce parti-coloured, rough-texture brick exclusively and other plants which formerly produced all dry-press are now making rough-texture plastic bricks as well as dry-pressed. Lorraine and Queenston shales are equally good for making rough-texture face-brick, but the latter gives a varied range of colour in some localities, whereas the Lorraine shale is all red burning. By mixing Lorraine shale and buff-burning clay, one plant at Toronto obtains a range of colours from dark red to light buff.

PLASTIC BRICK

These are the ordinary stiff-mud, or wire-cut brick made on the auger machine from ground shale mixed with sufficient water to make a stiff, plastic mass. The clay issues from the die of the machine in a smooth bar which is cut by wires into brick sizes. The brick are loaded on cars and wheeled into dryers; when drying is complete they are set in down-draft kilns for burning. Much of the shale brick made by this process is just common brick used for backing or filling, or for piers and foundations. It is as a rule harder and stronger than clay brick and is made in great quantity, some machines having a capacity of 100,000 a day. These brick have rough edges and are apt to be coated with white scum, which obscures the red colour, but as they do not appear in the finished structure the colour does not matter so long as they are hard and strong. Many of the ordinary wire-cut brick, however, are used for facing purposes. If the shale be finely ground and the brick carefully made, the wire-cut face-brick will be first grade. The smooth skin imparted to the moist bar of clay by the friction of the die is harder and denser than the body of the brick, and gives a good, even, smooth, wearing surface.

The principal defect to which wire-cut brick are subject is lamination, or a spiral structure in the body of the brick, due to the turning motion of the auger that expels the clay through the mouth of the machine. This defect can as a rule be overcome by making changes in the part of the machine in front of the auger.

FIREPROOFING AND HOLLOW BUILDING BLOCKS

The business of making burned-clay wares in hollow shapes has increased greatly in recent years with the growth of steel-frame structures. The reason for covering the steel members of buildings with hollow clay blocks is two-fold. The burned-clay block is the best material for protecting the steel from the effects of fire, and it gives structural value to the steel member, as the uprights can be made to look like square piers or round columns by means of the covering blocks. Almost any shape of hollow block can be made on the stiff-mud brick machine by changing the dies, and die-making is now an important part of clay machinery manufacture.

Hollow clay blocks are also now adapted for walls of dwellings, warehouses, stores, and silos, or almost any structure. Although hollow ware is made extensively from clay, by far the greater part of it is made from shale or a mixture of shale and clay. Shale blocks are easier to handle in the raw state, they crack less in drying and firing, shrink less, and are stronger than clay. The Queenston shale, on account of its good working qualities and plasticity, seems to be the best material available in Ontario for fireproofing.

FIELD DRAIN-TILE

A limited number of tile for underdrainage in farms is made in Ontario from Queenston shale, but most of them are made from glacial clays. There is a limited demand for strong, dense tile in preference to the porous tile commonly used, and these can be made from the Queenston shales.

ROOFING TILE

The only plant making roofing tile in Ontario is at Mimico, Peel county, and is owned and operated by the Ontario Government. Lorraine shale is ground very fine, to make it more plastic and smooth, and is run out of a stiff-mud brick machine through a curved die. Ridge pieces, finials, and other special shapes are pressed in plaster moulds. An excellent, hard, red tile is made.

FLOOR TILE

These are also made at Mimico from finely-ground Lorraine shale, run-out plastic, and wire-cut. The tile are used chiefly for the floors of corridors, kitchens, etc., of hospitals, asylums, and other buildings, and a considerable number of them are sold to dealers in building supplies. The tile made from the Lorraine shale is best adapted to inside work, as it does not weather satisfactorily when used in the open.

Queenston shale would be suitable for making either roofing or floor tile, but is not used for this purpose at present. The demand for vitrified red floor tile makes it difficult for the Ontario tile to compete with imported tile, which comes mostly from Wales, although the somewhat porous Ontario tile is quite satisfactory for indoor use.

ARCHITECTURAL TERRA-COTTA

About 1897 a considerable quantity of architectural terra-cotta was made from finely-ground Lorraine shale at the Don Valley Brick Company's plant, Rosedale. None of the buildings was faced entirely with this

material, but cornices, mouldings, string courses, and door and window heads, some being quite large pieces, were produced. The Toronto Pressed Brick Company, at Milton, also made similar wares from the Queenston shale. The Rathbun Company, at Deseronto, had a plant for the making of architectural terra-cotta only. They imported stoneware clay from the United States and used it in a mixture with local clays. This plant was burned while in operation and was not rebuilt. The terra-cotta made at Toronto and Milton was quite satisfactory so far as appearance and weathering qualities were concerned, but the use of the red unglazed terra-cotta was not continued very long by architects, and its manufacture in Ontario ceased, the demand for glazed terra-cotta made in England and the United States becoming general.

PAVING BRICK

The chemical composition and mineralogical constitution of a shale or clay do not give a reliable clue to their vitrification behaviour, rate of fusion, or development of toughness. Neither does the toughness of the finished brick bear consistent relation to the degree or range of vitrification, for each clay has its own range and degree of vitrification at which its maximum toughness is developed. In some clays this is attained when the brick still shows an absorption of 8 or 12 per cent, and in others not until the absorption has been decreased to 2 or 4 per cent.

It is clear from past experience that the shales at present used for making building brick in the Interlake peninsula are not suited for paving brick, if used alone. Nevertheless, a passable paving brick has been made from a mixture of the materials at hand in that region. These are made at only one plant in Ontario, which is situated on Weston road, West Toronto. Although paving brick are the principal production of this plant, a number of sidewalk brick and building brick are also made. The raw materials consist of a mixture of plastic surface clay, the weathered and leached top of the Lorraine shales, and the lower unaltered Lorraine shale. The first two ingredients contain little or no lime, are very plastic, and have large shrinkages, whereas the lower shale contains an appreciable amount of lime and magnesia, is low in plasticity, and has a small shrinkage. By the proper proportioning and thorough mixing in the dry pans, by skilful burning and slow cooling, it is possible to make pavers with the above ingredients. The burning is carried to the softening point of cone 02 in the top of the kiln.

The weathered top of the Queenston shale, which is used for making sewer-pipe, would be the best surface clay to use in the mixture, and a shale bed with the upper part weathered to a brown colour and leached of its lime content is also essential for the purpose. Attention has been already directed to the Lorraine shale No. 381 in which the lime content is low. This shale is vitrified, but not overfired, at cone 1, and seems to stand up better than any of the other shales in southern Ontario. Its plasticity is low, and the addition of a plastic clay would probably be necessary.

CHAPTER V

CRETACEOUS CLAYS

The presence of high-grade clays along the streams flowing into James bay has been known for a long time, but until recent years there was no definite information regarding their quality or extent. These clays are far from a railway, and present difficulties in mining owing to the presence of underground water and the thick overburden of glacial drift. The proposed extension of the Temiskaming and Northern Ontario railway to points on Mattagami river will bring transportation facilities nearer and an economic method of mining may be found. In any event the arrival of the railway will ensure a closer scrutiny of the field, and deposits may be found more favourably situated than those known at present. For these reasons and because similar high-grade clays are unknown in any other part of Ontario, the following detailed description is given.

These deposits were first mentioned by Dr. Robert Bell as occurring in the bank of Coal brook, a small tributary of Missinaibi river. A 3-foot bed of lignite in the bank is underlain by sticky blue clay, and overlain by late glacial drift.¹ In 1880 Mr. E. B. Borron discovered an extensive deposit of white sand and clay on the east side of Missinaibi river, about 5 miles below the mouth of Coal brook.² In 1882 Mr. Borron found an outcrop of what he called yellow ochre with some fine white clay on the eastern bank of Mattagami river, about a quarter of a mile below the north end of Long portage. During the same journey, he saw a thin seam of lignite on Mattagami river, about 5 miles below Long portage.

In 1890 he examined the lignite on Missinaibi river, devoting most of his attention to boring the outcrop on Coal brook.³ He recognized that the clays at this point were quite distinct from the widespread glacial clays of the region, and reported that they might be used for fire-brick if metallurgical operations were undertaken in the region. Other lignite seams farther north on the Missinaibi were examined during the same season, but these appear to be merely beds of indurated peat in interglacial materials.

In 1904, Mr. J. M. Bell discovered a bed of white clay on Wabiskagami river, about 2 miles west of the deposit discovered by Mr. Borron in 1880. In 1908 attention was attracted to the possibility of using the coal of this region, and most of the outcrops of lignite described by Bell and Borron were staked by prospectors.

In 1910, Professor M. B. Baker investigated the lignite and iron ore deposits on Mattagami river,⁴ and made borings on the lignite seam discovered by Mr. Borron in 1882.

In 1913 Messrs. Tees Curran and H. A. Calkins staked claims and did assessment work on the deposits on Missinaibi and Wabiskagami rivers. Their work showed that the clays and sands were over 70 feet thick. In 1918, Mr. C. M. McCarthy, of Elk Lake, Ontario, took samples from the clay exposures near the foot of Long portage, and sent them to the Mines Branch for testing.

¹ Geol. Surv., Can., 1877-1878, p. 4 C.

² Borron, E. B., "Part of the Basin of Hudson Bay," Toronto.

³ Borron, E. B., "Report on the Basin of Moose River," Toronto, 1890, pp. 65-69.

⁴ Ont. Bureau of Mines, vol. XX, pt. I, p. 236.

The following report on the Cretaceous clays and sand is based on the results obtained by the writer during two short visits to the region in 1919 and 1920.¹

The Cretaceous deposits in northern Ontario occur in isolated outcrops on Missinaibi and Mattagami rivers in the Precambrian area. The deposits consist of white sands, pink, white, yellow, black, and grey to almost black clays, and lignite. Few of the outcrops seen along the river banks afford complete information as to the character of the deposits, and information has been got mainly from borings.

MISSINAIBI RIVER

The first borings were made in 1890 by Mr. Borron at Coal brook and the following record is selected from his list of borings to illustrate the character of the materials.

	Feet
Drab and variegated clays.....	5
Black carbonaceous clays and lignite.....	7
Drab clay.....	2
Black clay and lignite.....	1
Variegated clays.....	3
Sandy clay.....	3
Lignite.....	2
Coarse white sand.....	2
Variegated clay.....	1
White clay.....	9

35

The clays and sands are apparently identical in character with those found by the writer in a bore-hole on the Mattagami deposit near Long portage, except that no lignite seams were found at the latter locality.

The most extensive remnant of Cretaceous deposits known in northern Ontario occurs on the east bank of Missinaibi river, about 45 miles north of the Canadian National railway and about 4 miles above the mouth of Wabiskagami river. The Precambrian area is about 6 miles to the south of these deposits. The Cretaceous beds are exposed for half a mile along the lower part of the river bank, and in places they rise to a height of 30 feet above low-water level. The greater part of the deposit is made up of quartz sand, the particles of which are coated with white clay, but, in places, the sand is stained pink or yellow. The clay is of various colours, white, pink, grey, and yellow, but most of that exposed is mottled pink and white.

The whole deposit is overlain by the late glacial stony clay, some of which is pressed into and intermixed with the Cretaceous clay to a depth of several feet. Two small streams have cut down through the overlying glacial drift, exposing the lower clay and providing convenient points for the examination of the deposit. In one of these sections the glacial drift rests directly on the white sand. The glacial clay has a high content of lime, and some of the lime leached from it has been re-deposited in the white sands cementing the upper 3 or 4 feet, so that it forms a protective capping.

The arrangement of the Cretaceous material is irregular. Although the sands are stratified in places, they mostly form lens-like masses. The clay also occurs in lenses, in places banded in different colours. This

¹ Ont. Bureau of Mines, 29th Ann. Rept., pt. II.

banding does not appear to be related to bedding, except that it is due to the varying quantity of iron oxide that was deposited with the sediments and in that sense may be bedding. In the great masses of mottled clay, however, the discoloured part and the white clay are mixed without any banding.

On Wabiskagami river, about 8 miles above its mouth, Mr. J. M. Bell found material which he describes as follows: "The deposit lies on the right or southern bank of the stream, along which it is traceable for about 400 feet, rising above the summer level to a height of at least about 10 feet. It is overlain by a talus of soft boulder clay which in places entirely obscures the underlying material. The kaolinic clay is soft, plastic, and unctuous, generally almost white in colour, but sometimes stained deep hematite red or yellow ochre by impregnation of iron oxide. Much of it is remarkably free from sand, but other parts contain lenses and small pocket-like areas, composed of grains of clear, glassy quartz sand mixed with pure white kaolin."

This deposit lies about 2 miles west of the large body of similar material on the east bank of the Missinaibi. No other deposits of similar character are known on this river or its tributaries. No lignite was seen with the clays and sands at either of the above localities.

MATTAGAMI RIVER

The most extensive outcrop of Cretaceous beds known on Mattagami river occurs on the eastern bank about a quarter of a mile below the north end of Long portage. At this point the bright-coloured clays outcrop at intervals from beneath the river wash along the strip of sloping bank between high- and low-water levels. The greatest vertical height to which the clays rise is about 8 feet, and, above this level, banks of glacial clay rise to a height of 75 feet.

The writer bored a number of holes at various places along the strip of clay outcrops in order to ascertain the thickness of the clays and the variation of the beds. None of the holes was very deep, because in every case a bed of white or pale yellowish sand was encountered which let water into the hole and put an end to boring operations.

In the summer of 1922, Mr. C. M. McCarthy bored through 20 feet of white quartz sand and 5 feet of white silty clay which underlaid the white sand. The boring was accomplished by casing the hole with iron pipe which prevented the wet sand from caving.

The following three examples summarize the results of the borings:

	Ft.	In.
(1) Bright red and grey, mottled clay.....	2	0
Yellow and grey, mottled clay.....	2	0
Black clay.....	3	0
White clay.....	1	0
Sand.....	1	0
Water.....	1	0
(2) Dark grey, highly plastic clay.....	3	0
White clay.....	3	0
White sand with clay bond.....	10	0
Water		
(3) White clay.....	3	0
Mottled pink and yellow clay.....	2	0
Reddish pink clay.....	2	0
Silty, grey clay.....	3	6
White sand.....	1	0
Water		

An effort was made to find the clay at higher levels by boring through the glacial drift in the high banks. Five holes were started on terraces at different levels on the boulder clay, but none of them succeeded in getting down very far owing to the stones scattered through the clay. There are no surface indications of the fire-clays in the slopes of the higher part of the bank, but the constant slumping of the glacial clay, and the thick forest and plant growth, are sufficient to conceal any outcrops. The bottom of a small creek not far from the fire-clay outcrop was followed up, but although the little stream had cut deeply into the glacial clays, it did not reveal any fire-clays beneath them.

In 1922, Mr. McCarthy found brownish fire-clay in the bottom of a narrow stream valley about half a mile east of the Mattagami.

About 6 miles below Long portage another outcrop of fire-clays occurs in the lower part of the river bank. The following beds were seen between the overburden of glacial clay and the river level.

	Feet
Stiff, plastic, bluish clay.....	4
Well-indurated, yellowish sandstone, with abundant fossil plant remains....	2
Light blue-grey clay.....	2
Laminated, bluish grey, silty clay.....	2
Massive bed of dark grey, micaceous, plastic clay.....	3

A little farther downstream a bed of hard, black lignite with a woody structure, accompanied by white and black plastic clays, outcrops at intervals near the river level for a distance of 100 yards. Only about 2 or 3 feet of these beds are exposed below the glacial drift, and from the upturned attitude of the lignite seam they seem to have slumped from a higher level. It is possible that the lignite and the white and black clays really overlies the section given above. The 3-foot bed of micaceous clay at the bottom of the section was the only one sampled for testing, as it looked the least promising from a refractory point of view, but it proved to be a fire-clay. It was assumed that all the upper beds were fire-clays as well as those accompanying the lignite, which are similar to those occurring just below Long portage.

Borings made in this locality in 1910 by Professor M. B. Baker, show that the fire-clays reach a depth below the river of 16 feet, but no lignite was found below the seam which outcrops on the river bank.¹ The bottom of the clay was not reached in the borings, and the material underlying them is unknown.

The greatest thickness of Cretaceous found was on the large deposit on Missinaibi river. This deposit was examined by Mr. H. A. Calkins, C.E., in 1913, for a Montreal syndicate. He made a series of borings, and in a hole farthest from the river bank found red and white clay below the glacial drift at a height of 74 feet above the river level. As a white and red clay can be seen in the bed of the river at this point, a considerable amount would have to be added in order to obtain the complete thickness, and it is probable that there is in the neighbourhood of 100 feet of Cretaceous measures in this region.

¹ Ont. Bureau of Mines, vol. XX, pt. 1, p. 236.

PHYSICAL PROPERTIES AND CHEMICAL COMPOSITION OF CLAYS
AND SANDS

The clays in the Cretaceous in northern Ontario are high grade and of a kind that is rare in Canada. Close to transportation and easily mined they would have a great value, owing to their good working qualities and refractoriness. Samples from the borings on Mattagami river were tested by the writer in the laboratories of the Mines Branch, with the following results.

The clays are smooth and free from coarse grit, with good plasticity and working qualities. Only sample No. 10 contained coarse quartz grains which had to be separated by washing. The contrast in colour and texture of these materials with the ordinary glacial clays of the region is very striking.

The following table shows the character of the various clays when burned in a commercial stoneware kiln to cone 7. Part of each sample was dipped in Albany slip glaze before firing. The glaze was found to be fully matured when the samples were drawn from the kiln.

No. of sample	Raw colour	Burned colour	Cone 7—1270°C.— 2318°F.	
			Percentage of total shrinkage	Percentage absorption
1.....	Pink.....	Buff.....	16	2
2.....	Pink.....	Cream.....	15	2
4.....	Buff.....	Pink.....	16	3
5.....	Orange.....	Red.....	13	13
6.....	Orange.....	Red.....	12	12
7.....	Black.....	White.....	9	15
8.....	Drab.....	Cream.....	12	8
10.....	White.....	White.....	12	12
11.....	Light grey..	Cream.....	13	6
12.....	White.....	Cream.....	.....	10

These clays fall into two groups: those that are high in iron, and those that are low. The iron has an effect on the colour, particularly in the burned state, and on the refractoriness. The first group, however, are fire-clays, with the exception of No. 5, which begins to soften at cone 20—1530°C.—and is the least refractory of the group. The others do not soften until the deformation points of cones 26 and 27—1650°C. to 1670°C.—are reached. Samples 7 to 12 are highly refractory, 10 and 12 being No. 1 fire-clays, as they do not deform at cone 33—1790°C. This is the first record of No. 1 fire-clays in Canada.

Owing to their variety these clays are suitable for the manufacture of quite a wide range of clay products. Numbers 1, 2, and 4 are vitrified at the temperature indicated, but have a very high shrinkage, which would require to be corrected by mixtures. These are suitable for the manufacture of stoneware goods and sewer-pipe or other vitrified products, as well as fire-brick. Clays 7 to 11 are high-grade materials which would be suitable for retorts, crucibles, or fire-brick in the crude state and, if washed, for the manufacture of electric or sanitary porcelain as well as floor and wall tiles.

Only one bed of clay was sampled from the Cretaceous outcrops, 6 miles below Long portage. This was the massive bed of dark grey micaceous clay at the bottom of the section, and although it looked the least promising from a refractory point of view it turned out to be a No. 3 fire-clay that would make a good commercial fire-brick.

Glass Sand

The white sands beneath the clay beds are composed almost entirely of subangular and rounded quartz grains with which is intermingled a small quantity of white clay.

A washing test made of an average sample of 10 feet of this sand showed that it contained 12 per cent of white clay.

The sand, when freed from the clay and screened to the proper texture for glassmaking, was analysed by Prof. L. J. Rogers of the University of Toronto, with the following results:

	Per cent
Silica.....	99.1
Alumina.....	0.324
Iron.....	0.176
Lime.....	trace
Magnesia.....	trace

The white clay washed from the sand is very plastic and highly refractory, and burns to a whiter colour than any clay in the overlying beds. The analysis by Professor Rogers was as follows:

	Per cent
Silica.....	49.40
Alumina.....	35.79
Iron.....	0.13
Lime.....	trace
Magnesia.....	trace
Loss on ignition.....	13.85

This analysis shows that the material is like china-clay in composition, but it is far more plastic than most commercial china-clays.

The sand contains enough plastic fire-clay to act as a bond when it is moistened and pressed into brick shapes. Brick of this description is known as "gannister", its use being mostly confined to lining steel furnaces. The test brick were subjected to frequent burnings up to a temperature of 3,000 degrees F., but they remained soft and friable, the materials being apparently too refractory to produce a fused bond. The addition of a little iron and lime oxide would produce the necessary bond in firing.

Sands

The sand on Missinaibi river is made up almost wholly of quartz particles of rather coarse texture with angular outlines, and coated with white clay. A sample representing about 15 feet in thickness was sub-

mitted to a washing test, and yielded 5 per cent of fine white clay. The analysis of grain size of the washed sand is as follows:

	Per cent
Retained on 10-mesh screen.....	8.27
Retained on 20-mesh screen.....	19.47
Retained on 35-mesh screen.....	38.04
Retained on 100-mesh screen.....	32.44
Retained on 200-mesh screen.....	1.33
Through 200-mesh screen.....	0.10

The chemical analysis of the washed sand made by Mr. A. Sadler of the Mines Branch is as follows:

	Per cent
Silica.....	97.72
Alumina.....	0.42
Iron oxide.....	0.32
Lime.....	0.28
Magnesia.....	0.21
Loss on ignition.....	0.12
	<hr/> 99.07

The iron content of the washed sand is rather too high for white glass, but it would be suitable for green bottle glass. The alumina content is also higher than desirable, alumina having the effect of making the glass batch more difficult to melt. The grain size or texture of the sand is right for glassmaking as most of it is included between the 20 and 100-mesh screens. The unwashed sand should be suitable for steel moulding foundry use, the clay present being sufficient to act as a binder. The clay content is greater than 5 per cent in some parts of the sand deposit, and a considerable amount of fine white clay could be obtained by washing the sand. There are also lenses of pink and yellowish sand as well as white sand, but the colour in this case appears to be easily washed out in water, and a white sand is obtained. There are no sands of this description either in the Glacial or inter-Glacial deposits of the region.

Clays

It would be difficult to mine any of the special parts of the deposit separately, for the white clay—the most valuable part—merges into pink, yellow, or grey clay, and no great quantity of it can be extracted alone.

The mottled pink and white clay, which is the greater part of the clay, is fairly plastic, but gritty, and has good working and drying qualities. It burns to a pink, dense body at 1,100°C. When burned to 1,300°C.—the temperature at which fire-brick are commonly burned—the body is steel hard and of a greyish pink colour. The total shrinkage at this temperature is 10 per cent, and the absorption 13 per cent. This material is a fire-clay, softening commencing only at 1,670°C., and it would make a good fire-brick or other refractory ware. If used for stoneware pottery, it should be washed and screened, to free it from coarse grit.

The white is somewhat more refractory than the mottled clay, and when washed would probably be suitable for white floor and wall tile, or for sanitary ware.

Chemical Analyses of the Various Clays

—	I	II	III	IV
Silica.....	58.90	55.17	53.78	53.10
Alumina.....	26.63	28.06	29.58	31.92
Ferric oxide.....	1.40	5.36	5.09	1.52
Titanic oxide.....	1.25	not determined	not determined	not determined
Lime.....	0.56	0.25	0.44	0.51
Magnesia.....	0.16	0.16	trace	trace
Manganese.....	0.01	not determined	not determined	not determined
Potash.....	0.31	0.26	trace	0.28
Soda.....	0.42	0.03	trace	0.54
Water.....	10.30	9.13	11.0	12.35

- I. White clay, Missinaibi river. Analyst, M. F. Connor.
 II. Mottled clay, Missinaibi river. Analyst, A. Sadler.
 III. Mottled clay, Wabiskagami river. Ontario Bureau of Mines.
 IV. White clay, Mattagami river. Ontario Bureau of Mines.

The almost complete absence of lime, magnesia, and alkalis in these clays renders them very different from the Glacial or inter-Glacial clays, in which the sum of these impurities ranges from 15 to 30 per cent. These impurities are all active fluxes and make the glacial clays easily fusible.

No. IV is an exceptionally high-grade clay as regards refractoriness. It stands as high a temperature as English china-clay before deforming, and is the only example of a No. 1 fire-clay yet found in Canada.

DISTRIBUTION OF CRETACEOUS DEPOSITS

It is quite probable that Mesozoic clays, sands, and lignites were formerly widespread in northern Ontario, but a long period of pre-Glacial erosion, inter-Glacial erosion, and two distinct periods of glaciation in Pleistocene time have well-nigh obliterated them. Now, only small detached patches are found at points where the rivers have cut down through the overlying glacial debris deeply enough to expose them. Only five outcrops of these rocks are known and, with one exception, are all situated from 1 to 8 miles north of the northern border of the Precambrian upland. The outcrops on the Mattagami are 40 miles from those on Missinaibi river. It is quite possible that Cretaceous deposits were once continuous over the intervening area. The beds on Wabiskagami river are about 2 miles west of the Missinaibi outcrops. The materials in both localities are alike, and the deposits are very probably continuous, but the stony character of the glacial overburden makes it difficult to prove this by boring.

Sink-holes and solution channels in limestone on Mattagami river at Grand rapids contain partial fillings of iron ore, clay, and a small quantity of lignite. Some of the clay beds in the limestone cavities are refractory enough to be classed as fire-clays, and may belong to the same period of deposition as the clays and lignite farther south. These clays are 20 miles north of the Precambrian rock boundary. The known scattered remnants of Cretaceous clays indicate that these clays were once spread

over an area at least 40 miles long and 20 miles wide, but it is certain that originally they were much more extensive. The Cretaceous clays have been found only on the Palæozoic plain, and no remnants have been found on the Precambrian upland to the south. The clays were not laid down at so high a level, or the Precambrian surface was swept bare of them before Pleistocene time.

OTHER OCCURRENCES OF CRETACEOUS CLAYS

As these clays occur in such a remote region, isolated from all other deposits of a similar character, it is interesting to compare them with clays of similar age elsewhere. The most extensive areas of Lower Cretaceous clays on the Atlantic coast occur in southern New Jersey, where there are several grades of fire-clay and stoneware clay. Large shipments of the raw clays are made from this field, and the clays are used on the spot in the manufacture of sanitary ware, architectural terra-cotta, fireproofing, stoneware pottery, and fire-brick. Small areas of Lower Cretaceous clays occur at Middle Musquodoboit and Shubenacadie, in Nova Scotia, and are worked for stoneware pottery and fire-brick.

The large areas of white stoneware clays and fire-clays in southern Saskatchewan are of Upper Cretaceous age, but in northern Saskatchewan and Manitoba there are certain beds of sandstone and clays which are Lower Cretaceous and were probably laid down nearly at the same period as those in northern Ontario. The most extensive deposits of fire-clays of Lower Cretaceous age occur in northern Alberta, north of McMurray, on Athabaska river and its tributaries.

So far as known, no other rocks of Lower Cretaceous age in Canada contain the fine-grained, high-grade clays that are so useful in the clay industry.

CHAPTER VI

QUATERNARY CLAYS AND SANDS

The greater part of the clays worked in Ontario belong to the latest of the geological periods, the Quaternary, which is subdivided into Pleistocene and Recent.

During Pleistocene, or Glacial time, great ice-sheets, or continental glaciers, spread outward from gathering grounds in northern Canada, and the entire province of Ontario was for a considerable period covered by ice. This resulted in the deposition of an almost continuous sheet of boulder clay, a deposit made up of clay, silt, sand, and boulders, and in many cases these materials were transported for long distances. The great amount of water from the melting ice formed large lakes in which streams cutting through the boulder clay deposited clay, silt, and sand. After the glacial lakes had shrunk, or disappeared, the bottoms on which the sediments were deposited became dry land. The following pages deal principally with the post-Glacial clays found in these abandoned lake basins.

CLASSIFICATION AND NOMENCLATURE OF GLACIAL AND POST-GLACIAL CLAYS

In a report on "Clay and the Clay Industry of Ontario," Baker attempts to classify the Glacial and post-Glacial clays of Ontario under different local names which, with one exception, were used much earlier, when the geology of Canada was summarized by Logan in 1863.

The names, Erie, Saugeen, and Leda clays are used in the 1863 report. Erie clay was defined as a clay of blue colour, when moist, with thin grey bands, commonly calcareous, and always holding boulders and pebbles in varying abundance. Clays of this description are plentiful along the north shore of lake Erie from Long point westward to Detroit river, and underlie the whole country between this part of the lake and the main body of lake Huron. The Saugeen clay was named from Saugeen river, in Bruce county, where thinly-bedded, brown, calcareous clay, as a rule containing only a few boulders, or pebbles, was found overlying Erie clay. Clays belonging to the Erie division are widespread throughout the Inter-lake peninsula and at differences in level amounting to 500 feet; and the upper, or Saugeen division, or clays having similar character, are similarly distributed.¹

The deposits described in the above report as Erie clay, as well as those at a number of other localities, included clays that are massive and not banded. Massive clays are more common than banded, and the quantity of stones embedded in all of them varies greatly. Baker found the Erie clay to be much more extensively distributed than was formerly believed, extending as far east as Ottawa. Far more extensive deposits than any in southern Ontario, and answering the description of Erie clay fully as well, were found by the writer on the rivers flowing into James bay in northern Ontario.²

¹ "Geology of Canada, 1863," p. 897.

² Ont. Bureau of Mines, vol. XXIX, pt. II, p. 38.

Baker observes that the Erie clay appears to be cleaner, localized accumulations of the boulder clay, that were probably formed in much deeper water than the typical boulder clay; but as he elsewhere refers to deposits of typical boulder clay as stony Erie clay, it is not easy to decide how much stone a boulder clay may carry and still be Erie clay.

The Saugeen clay, as originally defined, was a later deposit than the Erie which it overlaid unconformably, but Baker observed that in most cases the so-called Saugeen clay was only the leached and weathered upper part of the Erie. He gave the name Red-top to that part of the Erie, as it became red when burned. The so-called Red-top clay is everywhere a surface clay, overlying boulder clay and stratified clay alike.

He retained the name Saugeen clay for all stratified and laminated clays, irrespective of colour in the raw state, which on burning produced red-coloured brick, and extended the name to stratified clays in northern Ontario and also to some of the marine clays in eastern Ontario.¹ It is obvious, however, that the Saugeen clay in Bruce county is not contemporaneous with the clays of northern Ontario, and, furthermore, some of the deposits of so-called Saugeen clay in northern Ontario burn to buff colours instead of red, and on that account should be classed as Erie clay.

The classification proposed by Coleman² is the best, but the writer takes exception to the Clarke being called an inter-Glacial formation. If the Clarke sediments be regarded as having been laid down in a glacial lake between two advances of the same ice-sheet, and not as an inter-Glacial deposit, Coleman's classification becomes as follows:

	In Interlake Peninsula	In eastern Ontario
	Recent deposits	Recent deposits
Lacustrine.....	{ Nipissing clay, sand, and gravel..... Algonquin clay, sand, and gravel..... Iroquois clay, sand, and gravel..... Warren gravels.....	Marine { Saxicava sand and gravel Champlain clay
Glacial.....	Wisconsin moraines.....	Wisconsin moraines
Lacustrine.....	Wisconsin till.....	Wisconsin till
Glacial.....	Clarke sands and clays.....	
Inter-Glacial.....	Wisconsin till.....	
	Toronto formation { Scarborough beds.... Don beds	
Glacial.....	Illinoian till.....	

The deposits of marine clay which extend up the St. Lawrence valley into eastern Ontario were called Leda clay in former reports and in this report are called Champlain clays, a still older name.³

Owing to the difficulty of applying local names to widely separated and varying deposits the clays in this report will be described according to their economic value. The clays are of two main types, those that burn to a red colour and those that burn to cream, or buff. Included in both types are clays that are very plastic, stiff in working, and sticky, and those that have low plasticity and are easily worked.

All the clays contain a large amount of fluxing impurities (lime, iron, magnesia, and alkalis); consequently, they need be burned at only a comparatively low temperature in making structural materials, but none of them is suitable for making vitrified clay products.

¹ Ont. Bureau of Mines, vol. XV, pt. II, 1906, pp. 10-15, 18, 25.

² Ont. Bureau of Mines, 18th Report, 1909, p. 297.

³ Johnston, W. A., "Pleistocene and Recent Deposits in the Vicinity of Ottawa," Geol. Surv., Can., Mem. 101.

GLACIATION AND SUPERFICIAL DEPOSITS

Glaciation had such a profound influence in determining the distribution and arrangement of the superficial deposits of Ontario that it inevitably enters into any discussion of the surface clays used for clay products.

The bare facts regarding Pleistocene glaciation are that glacial conditions gradually extended southward until the entire province was involved, and that the ice thickened and moved until, at its maximum extension, it filled the basins of the Great Lakes and covered the highland between lakes Huron and Ontario. The total relief from the bottom of lake Ontario to the highest point in the Ontario highland is 2,450 feet. The ice-sheet that covered Ontario persisted for a long period, and gradually disappeared on the return of a milder climate. Its melting released the great quantities of debris which it carried, as well as a vast volume of water. The land that was laid bare on the retreat of the ice was mostly covered with a heterogeneous deposit of boulders, gravel, sand, and clay, but in places these materials were sorted and re-arranged by water that issued from the edges of the waning ice-sheet.

The chief result of glaciation was the removal and transportation of loose material. Some of this material was carried for long distances, as shown by certain boulders of crystalline rocks found in the extreme southern parts of Ontario, at least 200 miles from their place of origin. There does not appear to have been a great deal of clay material moved from the resistant Archæan rocks, for these rocks had not accumulated any important amount of residual clays on their surfaces in pre-Glacial time. The limestones, sandstones, and shales of the Palæozoic areas in southern Ontario were deeply softened by pre-Glacial weathering, and large amounts of this weathered rock were moved by the ice and re-deposited.

There appear to have been two distinct periods of glaciation in Ontario in Pleistocene time, in which the events just outlined were repeated. Certain stratified clays associated with yellow sands found in and near Toronto are the results of the first glaciation. These are desirable clays from a clayworker's point of view, and they were sought at other points in southern Ontario, but so far have not been found. Clays similar to the Toronto beds¹ are exposed on rivers flowing into James bay.² Apparently the clays laid down at the close of the previous glacial period were mostly destroyed by a later advance of the ice.

One of the peculiarities which characterized the retreat of the last ice-sheet was the oscillation of its front, or edge. During the time of general retreat the front did not retreat evenly nor at a uniform rate, but by alternating steps of advance and retreat, in which the backward steps were always longer than the forward steps. These movements are recorded in many of the sections of drift materials exposed in the Interlake peninsula, where stratified clays and sands are overlain by unsorted glacial debris. These movements of the ice did not occur in other parts of the province, where the stratified clays are not buried beneath glacial drift.

The effect of glaciation, on the whole, has been favourable to agriculture, for it has replaced old soils by new ones stocked with available or potential, plant food, but its effects on clays for industrial purposes were

¹ Twelfth Inter. Geol. Cong., Guide Book No. 6, p. 13.

² Ont. Bureau of Mines, vol. XIII, 1904, p. 161.

not beneficial. The high-grade pre-Glacial clays were removed and so intimately mixed with glacial dirt that their identity was totally lost. All endeavours to find white-burning clays of any kind in the areas in Ontario draining into the St. Lawrence basin have so far failed. There are some remnants of high-grade clays beneath the glacial drift on the rivers draining into Hudson bay, and high-grade clays of pre-Glacial origin may possibly be buried beneath the glacial drift.

Boulder Clays

Boulder clay or till is the most widespread product of glaciation. It represents the various materials from the wastage of a land surface, gathered up by the moving ice. When the ice melted, the rock fragments and dirt were left behind in a nearly continuous sheet of varying thickness, known as boulder clay, till, or drift (Plate IV A).

The average boulder clay is a mixture of clay, silt, sand, gravel, and boulders, as a rule without arrangement, and in many places resembling a mass of concrete in appearance. Boulder clays vary from material consisting almost wholly of plastic clay with only a few scattered pebbles, to material made up mostly of boulders, gravel, and sand, with very little clay. The former predominates in the Interlake peninsula, particularly in the counties bordering lakes Erie and Huron, and in the part of northern Ontario known as the clay belt. The stony and sandy till is characteristic of the Precambrian highland, which is underlain by granites, gneisses, and schists, and in many places contains so little clay that boulder drift is a better name for it than boulder clay. In places the boulder clay is very hard and tough, and resists wave erosion as successfully as some of the solid rock formations. When encountered in digging it is extremely difficult to remove with pick and shovel, hence the name "hard pan."

Large areas of the boulder clay still remain almost intact since deposition, except that the surfaces have been eroded and modified to some extent by rainfall and leaching. Some of the best agricultural lands in the province are found in these areas, whose weathered surface produces a wide textural variety of soils.

The greater part of the boulder clay is quite useless from the clayworkers' standpoint, but some of it is free enough from stones and coarse rock particles to be used for the manufacture of brick and tile, in Wentworth, Norfolk, Middlesex, and other counties in southern Ontario. If boulder clay be subjected to a washing process it will yield clay and silt as well as sand, gravel, and boulders. The separation and deposition of these materials as classified or sized deposits after washing depends on the amount of running water available, the grade of the surface over which they are moved, and the distance they travel before finally coming to rest in the bottom of some lake basin.

Stoneless clays and silts are the most important products of the washed boulder clay to the clayworker and they will be considered separately.

SILT

The fine-grained material resulting from the wet grinding of rocks under glacial conditions in many cases forms a considerable percentage in the drift deposits. The wet grinding of such rocks as quartzite, granite, and sand-

stone produces a gritty variety of silts; and shales, slates, schists, diabase, and limestone produce silts with more plasticity. This by-product, which is carried and deposited by glacial rivers along with whatever clay happens to be present, is called silt.

If sufficiently weathered, silts may be converted into clays, but most of the glacial silts were rapidly deposited below the zone of weathering before chemical or solvent action took place, and have remained almost unchanged since deposition. Silt may be very finely divided—almost as finely as clay—but does not, in the raw state, possess the qualities of plasticity and tensile strength of clay. Furthermore, silts take up water readily and part with it easily in drying, whereas clays do so far more slowly. From an engineering point of view any fine earthy sediment carried and deposited by water is silt; mud and alluvium are other names used in the same sense. Silt beds encountered in excavation give considerable trouble by their tendency to slump or run, especially when saturated with water, as in many cases they are, whereas stiff clay will retain a perpendicular face for a long time, provided the underlying material holds firm. From a clayworker's point of view a silt deposit is unworkable and a clay containing a large amount of silt or fine sand is termed a lean clay.

POST-GLACIAL LAKE AND ESTUARINE CLAYS

The features of the Glacial period of most interest to clayworkers were the great water bodies formed at the margin of the ice during its retreat. A considerable amount of clay sediments was laid down in these glacial lakes during their prolonged existence. The melting of ice barriers and the changes of level in the land surfaces have greatly diminished the extent of these water areas, and some of the sediments laid down in them now form dry land.

Lakes Superior, Michigan, Huron, Nipigon, Nipissing, and Simcoe were in post-Glacial time all included in one great water body, known as lake Algonquin. It is to the Algonquin stage that certain deposits of stratified stoneless clays are attributed—notably those on the banks of Muskoka and Spanish rivers, the extensive clay terraces at Sault Ste. Marie and Steelton, and on Kaministiquia river at Fort William, and deposits near lake Simcoe, at Beaverton and Orillia.

Lake Iroquois was the name given to the glacial waters that occupied the basin of the present lake Ontario, and clays laid down in it are worked at Hamilton, Toronto, Bowmanville, Whitby, and elsewhere. Lake Erie likewise formerly stood at a higher level, and a small amount of stratified clay was laid down which is now available, but most of the material worked there is water-laid boulder clay.

Other glacial lakes in northern Ontario, whose boundaries have not been defined, were catch basins for a large amount of clay and silt. These lakes were extensive and numerous, for large areas of stratified materials are found at intervals from the head of lake Timiskaming northward almost to the line of the Canadian National railway, and also in smaller isolated patches extending westward along that line for 200 miles.

In later Pleistocene time the land in eastern Canada was depressed to such an extent that marine waters advanced up the St. Lawrence and Ottawa valleys and a large amount of sediments, of which much still

remains, were deposited in these basins. Nearly all the brick-clays in eastern Ontario, from the Quebec boundary to Brockville and Pembroke, are of marine origin.

Clays are commonly laid down in layers in fresh water and in many places layers of clay and silt alternate regularly in the deposit (Plate IV B), but the clays laid down in salt water are mostly massive, and the deposits seldom show distinct layers or stratification (Plate V). Clay sediments carried into salt water fall to the bottom more quickly than in fresh water. The coarser silt grains are the first to settle, the fine clay particles sinking more leisurely. The sorting of grains from suspension seems to be the origin of stratification in freshwater deposits; the rapid deposition of sediments in salt water tends to form more homogeneous and massive beds.

COMPOSITION OF GLACIAL CLAYS

Glacial clays and silts are composed of materials derived from the disintegration of rocks. The igneous rocks which form the greater part of the bedrock in Ontario are made up largely of quartz, feldspar, hornblende, pyroxene, mica, and other accessory minerals. These minerals are found in clay in an extremely fine state of division, some of them fresh and others in all stages of decay, and representing, chemically, many different compounds, such as oxides, carbonates, silicates, hydroxides, etc. Slates, shales, sandstone, limestone, and other sedimentary rocks, although not underlying quite as large an area as the igneous rocks, have yielded a far greater amount of glacial clay, because they were more easily reduced by attrition and weathering. The slates and shales are merely hardened clays and can be returned to the condition of soft clays by wet grinding.

As sedimentary rocks are derived from igneous rocks, and the stoneless glacial clays from both these sources, it is evident that the chemical composition of the latter will be similar to the parent rocks. On account of the changes occurring in the mineral constituents of the fresh rock in the various phases during its passage into clay, certain compounds are formed which were not apparent in the original rock. Quartz, feldspar, and mica may undergo little or no change, but the other minerals decompose quickly, so that the chief constituents of the clay become quartz, feldspar, mica, hydrous silicates, iron compounds, lime compounds, and compounds of the alkalis, sulphur, carbon, and water. These constituents influence the working and burning qualities of clay, according to their amount and the size of grain to which they have been reduced.

Surface clays of glacial origin vary widely in texture, and most of them carry rock particles, or quartz grains of appreciable size, but the coarseness of texture does not in many cases interfere with their use for the manufacture of rough clay products, unless the rock particles are limestone.

WEATHERING OF CLAYS

All the superficial deposits, including boulder clay, stratified clay, silts, and sands, are weathered to depths that vary with the resistance of the material to water and air, with climatic and topographic conditions, and with modifications in the level of the groundwater, and plant growth.

The reactions which accompany weathering are essentially those of hydration and oxidation; the removal of the more soluble material is effected by leaching. Oxidation affects, chiefly, the iron in the clay. Ferrous compounds become ferric, with an accompanying change in colour from grey to yellowish. Hydration accompanies the decomposition of more complex minerals such as feldspar and hornblende, increasing the clay content and making the weathered material more plastic. The soluble products of mineral decay are chiefly salts of lime, magnesia, and the alkalis; analyses and physical tests show that these constituents decrease in proportion to the weathering.

It is not uncommon to find the yellow colour due to weathering extending to a depth of 12 feet in the sandy varieties of boulder clay in southern Ontario, whereas the more compact varieties containing more clay are not weathered for more than 6 feet. Owing to the difference in climate and the protective covering of moss, similar material in northern Ontario may not be weathered more than 1 or 2 feet in depth. Below these depths the clays are as a rule bluish-grey and very much as originally laid down.

The boulder clays in the Interlake peninsula contain a high percentage of finely divided lime, as well as limestone pebbles, but at some places they are fairly free from pebbles. In some districts underlain by boulder clay the upper part has been so thoroughly leached as to reduce the lime content considerably; even small limestone pebbles have been dissolved by weathering, and oxidation of the iron has changed the clay from lead grey to yellow. This clay extends downwards from 1 to 4 feet and is used for making red brick and tile, but the grey clay containing limestone pebbles is unworkable below the limit of leaching.

The importance of using only the leached surface of the clays near Hamilton and Waterdown has long been recognized by the manufacturers of sewer-pipe.

The effect of weathering on clays is illustrated by the investigations of Mr. A. R. Duff of the University of Toronto, on the deposits of sewer-pipe clay east of Hamilton. He took samples of clay at three localities at intervals of 6 inches to 1 foot from the surface downward and determined their lime content as follows:

No. 1		Per cent lime as CaO	No. 2		Per cent lime as CaO	No. 3		Per cent lime as CaO			
Top 6 ins.		None	Top 6 ins.		1.05	Top 12 ins.		Trace			
Ft.	Ins.		Ft.	Ins.		Ft.	Ins.				
6	to 1	0	6	to 1	2	1	0	to 2	0.5		
1	0	to 2	0	2	to 2	0	2	0	to 3	1.1	
2	0	to 2	6	2	0	to 3	0	3	0	to 4	0.9
2	6	to 3	6	3	0	to 3	6	4	0	to 5	3.5
3	6	to 4	0	3	6	to 4	0	5	0	to 6	2.5
4	0	to 5	0								

The above results show that the upper 2 feet of the deposits contain little or no lime, and that the lime content as a rule increases gradually with depth. The irregularity with which leaching takes place is also shown by the depth at which an excess of lime is encountered. Up to 3 feet of clay can be taken in No. 1, less than 2 feet in No. 2, and 4 feet in No. 3.

The leaching of clay by atmospheric weathering requires a considerable length of time, but comparatively short-time exposures to weathering render some clays more easily worked than when used as they come from the bank. Weathering of clay in many cases increases its plasticity, but this may be due to several causes—such as mechanical disintegration by frost, water soaking, oxidation, or the production of colloids by hydrolysis—or to bacterial action.¹ Some of the brick and tile makers dig their clay in the autumn and pile it near the brick machines. Exposure during winter disintegrates it and improves its working qualities. For the manufacture of pottery the clay is in many cases left to weather for a year before using.

RECENT DEPOSITS

Recent deposits in Ontario consist of silt, fine sand, clay, peat, and marl. These materials were laid down in small lakes or ponds or on low river banks and islands in rivers.

Alluvium deposited on river banks in time of flood mostly consists of materials brought from higher levels by tributary streams. Most of the sediment laid down consists of fine sand and silt, with some organic matter, whereas the clay is commonly carried along by the river currents to the lakes. Where the floor of the valley widens, the current is temporarily checked, and some of the clay may be laid down with the silt and sand. Deposits of this kind are in some cases worked for brickmaking, but they are not of frequent occurrence in Ontario.

Alluvial, or flood-plain deposits of workable clays are mostly open or sandy in texture, but free from pebbly or coarse grit. They are easy to work and dry, as a rule, but in many the burned colour is poor, owing to the fact that these deposits may consist of a mixture of calcareous buff-burning clays, and red-burning surface clay. The alluvial clays are as a rule underlain by sand or gravel, and beds of clay and sand are in many cases found alternating, but the clay deposits of this kind are mostly thin. Pits in flood-plain clay are easily drained, but it is in many cases unwise to place a brick plant on them because of the danger from flooding in seasons of abnormally high water.

DISTRIBUTION OF ALLUVIAL CLAY

The flood-plains along Sydenham river and its tributaries furnish alluvial clay which is worked for brick and tile at several points in Lambton county. Alluvial clay on the bank of the Thames is extensively worked at Chatham, Kent county, and similar clay occurs near Conestogo, Waterloo county, where it is manufactured into red building brick. A thin deposit of sandy flood-plain clay occurs on the flats along the Don near Toronto. The islands on Ottawa river below the Gattineau are composed largely of alluvium, consisting principally of fine sand containing considerable organic material.

¹ Ries, H., "Clays, Their Occurrence, Properties, and Uses."

CHAPTER VII

CLAYS OF EASTERN ONTARIO

Eastern Ontario, as employed in this report, includes the region between St. Lawrence and Ottawa rivers as far west as Hastings county. The greater part of this area is lowland underlain by nearly flat-lying limestone, dolomite, sandstone, and a little shale, all of Ordovician age. Crystalline rocks of Precambrian age rise from beneath the Ordovician rocks in the western part of the region.

The bedrock of the region is almost wholly covered by glacial drift, and the material exposed at the surface is mostly clay, especially in areas where Ordovician rocks form the bedrock. A great part of eastern Ontario was covered by the sea in late Pleistocene time and the clay laid down then is widespread and occurs up to 500 feet above sea-level, but no clays of importance are found above this elevation. These marine sediments are known as "Champlain clays", large areas of which are found laid bare, or covered with a veneer of sand laid down in the Champlain sea as it receded.

The Champlain clay occurs in greatest abundance in the eastern part of the region. In the western part the occurrences are fewer and more scattered and merge into clays of freshwater origin. The areas of Champlain clay are surrounded by unsorted glacial drift, boulder clays, gravel and sand, and the boundaries between the Champlain and stony clay are in many places indefinite. Any clay in the region containing stone is quite unsuited to the manufacture of brick and tile, for most of the pebbles are limestone and would be extremely detrimental in burned clay products. The marine clay areas are as a rule flat, but the surface of the stony clay is rolling and hummocky.

The largest areas of Champlain clay in the region occur in the counties of Russell and Prescott, but several small areas are found in Carleton county. The counties along the St. Lawrence—Glengarry, Stormont, Dundas, and Grenville—also contain large, isolated patches, but none of them is so extensive as the areas on the Ottawa. The Champlain clay extends only a short distance into Leeds and Lanark counties, but it is fairly well developed in Renfrew as far as Pembroke. Some silt beds, perhaps of marine origin, are found underlying the great sand areas occupied by the military camp at Petawawa, but beyond this the Ottawa valley seems to be devoid of clays as far as the head of lake Timiskaming. The crystalline rocks of the Precambrian plateau occupy the greater part of Leeds, Lanark, and Frontenac counties and within these areas surface clay is either absent or confined to small, isolated patches in hollows.

The crystalline rocks, particularly the pegmatites and binary granites, in some places alter and break down into residual clays of value, but the glaciation of the region was so thorough that only fresh rock surfaces are seen and if there be any residual clays, or kaolins, remaining, they are buried beneath the glacial drift.

Frontenac County

Frontenac county contains a great number of lakes lying between ridges of Precambrian crystalline rocks. The hollows between the ridges, not occupied by lakes or ponds, are mostly floored with stony glacial drift, or sand, with little or no clay. The southern part of the county is underlain by flat-lying Ordovician limestone with some sandstone, and occasional patches of clay are found in that area.

Kingston. Stoneless clay is found near Kingston, especially deposits in the valley of Little Cataraqui creek west of the city; smaller deposits occur in the valley of Cataraqui river, east of the city. North of Kingston a shallow deposit of red-burning clay overlies glaciated limestone. It contains numerous lime concretions, and a few pebbles, and is surrounded by limestone outcrops and very stony boulder clay. It is worked by the Kingston Brick and Tile Company.

Clay is also exposed on Little Cataraqui creek near the crossing of the Kingston and Pembroke railway, and on the shore of lake Ontario. These are laminated silty clays, containing many lime concretions, especially in the thicker clay layers. One of the sections on the shore west of the creek shows stratified clay with the beds crumpled in places and containing an occasional boulder or a small mass of glacial till, which was, apparently, dropped from floating ice while the clay was being laid down.

Clay was seen on Little Cataraqui creek as far as Division street, and two brick-yards were formerly operated in that neighbourhood, but only the top red-burning material was used. Lime concretions were the chief trouble encountered. Clay is found overlying sand south of the sand ridge at Cataraqui cemetery. The sand is probably of fluvioglacial origin and was deposited in shallow water.

Storrington Township. Clay, apparently stoneless, occurs in a small area on the road between Collins and Mud lakes, and farther east, between Sunberry and Dog lakes. About 10 feet in thickness is exposed at the head of Collins lake. It is stratified clay, interlaminated with silt films, brownish in the upper part and grey below, and appears to have been laid down in depressions in the boulder clay surface.

Loughborough Township. The wide valley about half a mile west of Sydenham is floored with a thin deposit of highly plastic greenish grey clay, of little value. Stoneless clay from 3 to 4 feet thick occurs on the bank of a small stream at the village. It is stiff brown clay on top, with yellowish sandy and silty layers below, like most of the small deposits in this region. The remains of a brick-yard show that a very fair, red, building brick was made.

Kingston Township. Six samples of clays, sand, and sandy loam from the eastern half of lot 23, concession IV, were tested for brick and tile. Some of the clays were very stiff when wet and difficult to mould. Brick made from the stiff clays are hard to dry and the shrinkage is excessive. The loamy or sandy clays are easily dried and have low shrinkages; but, being of low plasticity, they are not suitable for making drain-tile, or wire-cut brick, but would probably do for the soft-mud process. A mixture of equal parts of stiff and sandy clays makes a very good, common, red building brick.

The sand at this locality is very fine grained and burns to a strong red colour; it could be used as a moulding sand for brick made by the soft-mud process.

The clay suitable for brickmaking is only about 3 feet thick, as the material below contains particles of limestone that unfit it for use.

Leeds County

Ridges and domes of Precambrian granites, gneisses, and quartzites occupy the greater part of Leeds county. The Precambrian rocks extend nearly the whole width of the county on the St. Lawrence river. Patches of clay are found at many places near the river in depressions among the rock ridges. The clay areas are fewer north of the St. Lawrence and are not found in the more rugged parts of the county. A few clay areas occur in the flat land underlain by Palæozoic rocks in the northeastern part of the county.

The transition between the Champlain or marine clays and the freshwater clays is well displayed in the deposits along the St. Lawrence, and good exposures of marine clay are seen a short distance east of the eastern border of the county.

It is difficult to get a good section of the clay deposits near Brockville as they are not thick, and weathering has obscured the stratification. Near Lyn station, on the Canadian National railway 4 miles west of Brockville, a section in the bank of the creek shows stratified clay interlaminated with films of silt, which appear to have been laid down in a body of fresh water. The nearest deposit of undoubted marine clay is 10 miles east of this occurrence. Throughout the southern part of Leeds county, from Lyn westward, the clay deposits indicate a freshwater origin, and these clays nearly always have lime concretions scattered through them, but concretions are rarely seen in the massive clays.

Elizabethtown Township. A brick-yard was in operation for many years on the northern outskirts of Brockville, where a deposit from 3 to 5 feet thick of red-burning clay was used for making common building brick.

About 2 miles west of Brockville in lot 24, concession I, deposits of red-burning clay underlie a layer of yellow sand which is used as a moulding sand in iron foundries. Samples of clay taken to a depth of 6 feet in this deposit were tested. They are brownish, non-calcareous clays free from pebbles and have good working qualities, but as the shrinkage is high and the drying qualities not very good, at least 25 per cent of sand must be added to correct these defects. The mixture will make good building brick, or field drain-tile.

Yonge Township. The old maps show two long, narrow lakes in concession II, between lots 14 and 26, but the lakes were drained and the bottoms used as meadows. A shallow deposit of Recent clay underlies the meadows.

Escott Township. In concession II, a narrow strip of stoneless clay lies between the highway and the Canadian National railway, and extends from Mallorytown to Waterton. It is stiff, plastic, brownish clay, appar-

ently free from pebbles and lime concretions, and burns red. It would require the addition of sand if used for making brick or tile.

Vanston pond, north of the railway at Waterton, has been drained and there are deposits of Recent clay in the dry basin.

Lansdowne Township. The most extensive area of stoneless clay in Leeds county is in concessions III and IV, Lansdowne. There are also smaller areas on the old Grand Trunk railway in the western part of the township.

Leeds Township. Many of the flat areas between the rock ridges in the southern part of Leeds township are underlain by stratified clay. One of the small deposits on the northern outskirts of Gananoque was used for making brick and tile, but is now abandoned. Good sections of clay were exposed during road construction from 1 to 4 miles west of Gananoque. The deposit consists of alternating thin layers of silt and clay. The upper part is very plastic and has a smooth, waxy feel when wet. It has a high shrinkage and is liable to crack in drying, and burns to a dense red body (Sample No. 724). A great part of the clay is spoiled by lime concretions which are difficult to avoid in excavating. The clay in this part of the county appears to contain more lime concretions than that in the eastern part, and in selecting a suitable site for a brick and tile plant the first consideration should be given to obtaining a deposit as free from them as possible. A convenient supply of sand is also necessary, for the clay requires the addition of about 35 per cent of sand to reduce the excessive shrinkage.

Bastard Township. A thin deposit of clay in a narrow stream valley about half a mile west of Phillippsville was worked for common red building brick and field drain-tile, but is now abandoned. It consists of 3 feet of yellowish, stratified, silty clay underlain by a stiffer grey clay carrying scattered pebbles in the lower part.

A flat valley bottom near Forfar is underlain by stoneless clay. East of Crosby another similar patch of clay was observed.

These clays appear to be small local deposits in valleys, or stream courses, and were probably laid down in small lakes, or ponds, which have been drained. They are more silty and have less shrinkage and produce as good brick as the clays near the St. Lawrence, but drain-tile made from them are not so smooth and dense.

Grenville County

Edwardsburg Township. Much of the northeastern part of this township is underlain by sand and stoneless clay, but the sand covering is as a rule too thick, except in the vicinity of stream banks. Furthermore, the area underlain by clay is flat, and drainage is sluggish, so that it would be difficult to control the water in the pits. In the southern and western parts of the township brick-clay occurs only in small patches surrounded by stony or sandy ground.

Four samples from different localities were tested, with the following results.

Sample No. 703 represents a deposit about a quarter of a mile wide, situated about half a mile east of Prescott and extending along the St. Lawrence nearly to Windmill point. It has a steep bank, facing the river, from which it was possible to secure an average sample to a depth of 12 feet, beginning at the surface, but the total depth of the deposit is 16 feet. It is the ordinary, grey, massive Champlain clay, working up very plastic and smooth when wet. Brick made from it will dry in air, but they crack in an artificial drier even at 125 degrees F. The addition of sand helps in drying the brick, but does not make it able to stand high temperature drying. The shrinkage in drying can be reduced by adding sand. The burned colour is a good red and the body is hard and strong. This clay would be suitable for making drain-tile and common building brick.

Brickmaking was carried on for over fifty years at Prescott, but operations ceased about 1913. The material used consisted of about 8 feet of red-burning upper Champlain clay, underlain by highly calcareous clay from which buff brick and field drain-tile were made. The chemical analysis of the lower clay is given in the table of analyses of the deposits in eastern Ontario. Buff-burning clay possibly underlies the deposit east of Prescott from which sample No. 703 was taken, but the upper 12 feet at least is buff-burning clay.

Sample No. 704 was taken from a 4-foot section on Drummond island, the surface of which is all composed of this clay. It works up into a very stiff mass when ground and wet and burns to a dense red body, but has abnormally high shrinkage and is liable to check in firing. The addition of sand overcomes this to some extent, but the material is not recommended.

Sample No. 721 was taken from the road ditch about 2 miles west of Spencerville, where the stoneless clay covers an area of about one square mile. There is another smaller patch of clay about $1\frac{1}{2}$ miles south of this one, not far south of Roebuck. The sample represents only about 3 feet in depth from the surface, as it was impossible to secure one from a greater depth without boring or digging. This clay works well, not being too stiff when wet. It burns to a deep red colour and hard body, and will make a good, strong, field drain-tile, as well as building brick. It requires the addition of about 25 per cent of sand to reduce the shrinkage and help in drying.

Sample No. 706 was taken from a cut bank on the St. Lawrence, in a bay just west of the canal entrance at Cardinal. The deposit is a small one and has a thickness of 15 feet above the river level. This clay works well in the raw state, and has a fairly low drying shrinkage. It burns to a good, red, sound body, and will make field drain-tile as well as brick. It is not necessary to add sand to this clay for making field tile. This is the best of the clays examined in Edwardshurg township.

Dundas County

Matilda Township. The surface of this township is as a rule flat, the western part being mostly underlain by marine, stoneless clay and sand, whereas stony clay covers most of the eastern and southern parts. Marine clay was found outcropping only at two places along the St. Lawrence, at points from 1 to 2 miles east of Iroquois.

Sample No. 705 was taken from a clay deposit $1\frac{1}{2}$ miles east of Hainsville, on lot 24, concession IV. The deposit consists of $7\frac{1}{2}$ feet of stiff, marine, stoneless clay, underlain by 1 foot of silty clay, and then by fine gravel. The clay has good working qualities but sand must be added for brickmaking, owing to the high shrinkage and defective drying. It will make a good, strong, red, farm tile. There is an extensive area underlain by this kind of clay, and sand can be procured in the vicinity.

Williamsburgh Township. The surface of this township is covered mostly with stony clay, but there is a considerable area of swamp land, some of which may be underlain by marine clay. A few outcrops of stoneless clay are found along the St. Lawrence, beginning about 2 miles east of Morrisburg. There is also a small area of stoneless clay in concessions V and VI, along the banks of a small stream flowing into South Nation river.

Sample No. 707 was taken from a bed about 4 feet thick on the bank of this stream, on lot 32, concession VI. This clay is a rather indifferent material. Its shrinkage is too high, and it is liable to crack in burning. It would require to be mixed with one-third its bulk of sand to become workable, and there is no convenient supply of sand. The clay deposits along the St. Lawrence in this township are in places sandy and silty in the upper part, particularly near the old brick-yard, a short distance east of the Chrysler monument, and along the shore on lot 10, where sample No. 687 was collected. The upper part of the deposit at this point is flood-plain material, deposited by the river before it had cut down to its present level. This material contains silt and fine sand as well as clay, hence it is more easily worked and dried than the ordinary stiff marine clay, and it has less shrinkage. Sample No. 687b represents the lower part of the bank at this point, and is the typical unmodified marine clay of the region. The material worked for brickmaking by Mr. Casselman, who formerly operated a plant slightly north of this point, is similar to the upper part of the deposit exposed on the river bank. A section on the creek bank, just south of the old brick-yard, shows about 6 feet of yellowish silty clay in the upper part, and stiff, plastic, blue-grey clay in the lower. Sand, varying from a few inches to 5 feet in thickness, covers most of the clay in the vicinity. This was a favourable point to carry on brickmaking, as a good working mixture of the stiff bottom plastic clay, the upper silt, and the sand could be obtained. The clay pits were easily drained into the small creek, and a supply of water could be obtained all through the summer. The great advantage of the silty clay in this locality lies in its having lower shrinkage, easier working, and better drying qualities than the ordinary stiff grey clay.

Stormont County

Osnabruck Township. The area underlain by stoneless clay in this township is confined to patches, mostly in the southern part.

Sample No. 690 was procured from a clay area just north of Farran Point, where a section of about 9 feet is exposed in the bank of a small creek. The sample represents an average of the deposit from top to bottom. It is a good brick material, less stiff to work than most of the marine

clays, and has a reasonable shrinkage. It appears to contain a rather high percentage of lime which exercises a bleaching action on the iron during firing and renders the burned red colour too pale. This clay is scarcely strong enough to make round tile, except the smaller sizes; the larger are apt to become deformed as they issue from the die of the machine.

Two patches of stoneless clay north of Dickinson Landing, on Doherty brook, contain brick and tile clays of a strong plastic character, but the deposits are shallow. The clay is 15 feet thick in a narrow band at the railway bridge, and this narrow band continues south along Hoople creek, but does not reach the St. Lawrence.

The steep bank along the St. Lawrence between Woodlands and Dickinson Landing consists of dark grey, silty clay, overlain by yellow sand. Sample No. 691 is an average of about 10 feet of the silty clay. The deposit is stratified, very greasy to the feel when wet, and represents a phase of sediment found in many places in the lower part of the Champlain clays. It requires less water for mixing, has a far lower drying shrinkage than the upper clay, and contains such a high percentage of lime that it burns to a cream colour—in contrast with the prevailing red-burning upper clay. A small brick plant was operated in this locality about 70 years ago, but only the upper red-burning clay appears to have been used. The bottom silt deposit would make a very fine, cream-coloured, soft-mud brick, but it is doubtful if sufficient space could be found for a brick plant.

There is a small area of clay and swamp land along Raisin river, east of Lunenburg. A boring made in this deposit on lot 2, concession IV, showed the following:

	Ft.	Ins.
Drab, non-calcareous plastic clay, No. 695.....	4	0
Peat.....	1	6
Grey sand.....	2	0
Highly calcareous, grey, silty clay, No. 696.....	8	6

The bottom of the silt deposit was not reached; water was struck at the peat level and the silt became too liquid to be lifted by the auger.

Sample No. 695 is a good brick material. It works more easily, dries more readily, and shrinks less than the ordinary marine clay of the region. It burns to a good, sound, red body, and will make both drain-tile and brick.

Sample No. 696 is a typical silt, containing very little real clay substance, and difficult to mould into shape for testing purposes because of its low plasticity. This material will stand fast drying without cracking, and has a very small drying shrinkage. It burns to a light red colour at low temperatures, and to buff or cream colour at a higher heat. It could hardly be used alone for brickmaking, but would be useful to mix with the upper clay. It resembles No. 691, but is not so plastic. These are the only two cases where buff-burning material was encountered.

A test was made of clay from one of the small clay areas near Aultsville, where brick was formerly made. The sample (689) appears to be the regular Champlain clay of the region.

Cornwall Township. Several irregular patches of stoneless clay occupy depressions between the morainal ridges of glacial drift in this township. Many of these depressions still contain swamps, and some that

contain stoneless clays may have been swampy before being drained and cultivated. Some of the clays in this area are more recent than the marine clays. They appear to have been washed down from higher ground and carried into temporary ponds or swampy basins as the marine waters receded. In this manner some of the clay sediment became mixed with peaty matter, and when this finely divided and carbonaceous matter is intimately mixed with a stiff plastic clay it causes trouble in burning in many cases. Such a clay is liable to bloat and become cindery, especially if the temperature in the kiln be raised too rapidly. The carbonaceous clays in many cases prove to have defective properties in the raw state, such as excessive stickiness, bad drying qualities, and abnormally high shrinkages. Samples Nos. 693, 697, and 699 are examples of this kind, but such clays can be improved by the addition of a liberal quantity of sand, as indicated in the table, where the results of two clays thus treated are given below the corresponding number without the sand addition. These clays, however, are not recommended for burned clay products.

Sample No. 693 was taken from the small clay area adjacent to the quarries one mile north of Moulinette. The deposit includes 6 feet of brownish grey upper stiff clay overlying 9 feet of silty grey clay resting on limestone bedrock.

Sample No. 694 was taken from a field on the west side of the road, in lot 25, concession VI. This clay deposit, which lies in the valley of Raisin river, is 15 feet thick at the point tested, and is underlain by boulder clay. There is stiff grey clay in the upper part, but it is more silty below, the sample being an average of the whole depth. This clay would be suitable for field drain-tile and brick, but for brick it needs an addition of sand. Black River station, on the New York and Ottawa railway, is about one mile west of the deposit.

The best exposure of stoneless clay known in the township is in the artificial cutting below the sluiceway at the eastern end of Sheek island. The upper and lower parts of the bank, about 14 feet in all, were sampled, but there is very little difference in their qualities, either in the raw or burned state. Neither did the chemical analyses show much difference, so that the deposit can be regarded as homogeneous (Nos. 693, 693a). This deposit, although probably useless, on account of its position, was selected as a typical outcrop of the Champlain clay.

At the northwestern end of Sheek island, opposite the last house on the road, there is a section of dark grey, stratified silt, sand, and clay in alternate layers, rising to a height of 12 feet above the river-level, and overlain by 10 feet of sand. This is a very different material from the massive clay at the eastern end of the island, but it lies almost on the same level. They are both marine sediments.

Glengarry County

Charlottenburg Township. The topography of this township is similar to that of Cornwall and is characterized by the same kind of isolated stoneless clay deposits lying between ridges of glacial moraines. One of the largest of these clay patches, nearly a mile in width, occurs along the valley

of Raisin river, southeast of Martintown. Sample No. 708 taken from a ditch one mile north of MacGillivray bridge represents the clay in this locality, and identifies it as the ordinary marine clay of the region.

Sample No. 700 was taken from the bank of a small creek flowing into Raisin river on lot 3, concession IV, one mile south of Williamstown, where 5 feet of clay is exposed above water-level, overlain by 3 feet of sandy loam. This clay, mixed with an equal proportion of the sandy loam, works well for brick and tile.

There is quite a large area between Williamstown and Lancaster in which clay occurs beneath a variable thickness of fine sand or sandy loam, but the land is flat, and drainage of clay pits would be difficult except close to Raisin river.

Sample No. 697 was taken by an auger boring from the bank of Crays creek in concession I. This clay is deficient in working and drying qualities, and the shrinkage is excessive. It is not recommended for the manufacture of clay products.

Lancaster Township. Most of the southern part of this township is flat land with sand, sandy loam, and some clay as the surface material, and a large part of it has stoneless clay as the subsoil. North of the flat, sandy area, the topography is the same as that of Charlottenburg.

Sample No. 709 was an average sample of the material thrown out while digging a well in a field near the road one-fourth of a mile north of North Lancaster station, on the Canadian Pacific railway, in lot 24, concession IV. The well was probably dug to a depth of 6 feet or more, and among the ordinary grey clay thrown out of the excavation some reddish clay was noticed. A layer or band of red clay is occasionally seen in the Champlain clay at other places, but it rarely occurs in the region examined. This is a good brick and tile clay. It works easily, and its shrinkage is not too great. It burns to a good red colour, with a hard, sound body, and is recommended for the manufacture of field drain-tile. The only drawback is the lack of adequate drainage necessary to keep a clay excavation from being flooded.

Sample No. 698 was taken from the bank of a small creek in lot 30, concession V. Sand overlies the clay a short distance from the banks of the creek. This is one of the good brick and tile clays.

Sample No. 713 was taken from the bank of a creek in lot 10, concession VI, three-fourths of a mile south of Dalhousie station. This clay works easily, has good drying qualities, and the shrinkages are not unduly large. It is recommended for the manufacture of red building brick or field drain-tile. The clay is only 3 feet thick at this point and is underlain by sand, but there may be more clay below the sand.

Sample No. 714 was collected on the bank of a creek at the railway bridge, half a mile east of Bridge End station, on the Canadian Pacific. A thickness of 7 feet of stratified grey clay is exposed, but one of the layers about 2 inches thick is a fine-grained, reddish, highly plastic clay. An average sample of this deposit, with the addition of the proper amount of sand, would be suitable for brick, and drain-tile. The drainage is good, and supplies of wood for fuel can be procured in the district.

Prescott County

The extensive flat areas in Prescott county are mostly underlain by Champlain clay. Two brick-yards, one at Plantagenet Springs and one at Vankleek Hill, are in operation, but no field drain-tile are produced, although several sections of the county would be much improved by underdrainage.

The clay deposits near Alfred have a special interest in view of their proximity to the peat bog there. The bog itself is underlain by clay, as well as much of the surrounding land. The Canadian Pacific railway runs through the bog, but on the road between Alfred station and the village of Alfred there is a deposit of mixed sand and clay about one-eighth of a mile wide. This deposit lies on sloping ground at the base of an escarpment of Champlain clay with a thick capping of sand, and the erosion of the escarpment supplied the material of the deposit.

The section, 3 or 4 feet thick, in the ditches at the roadside, shows that there is rather more sand than clay. Sample No. 767, collected for testing, was rather flabby when wet, but was firm enough to be moulded into shape. It dries quickly without cracking and the shrinkage in drying is only 4 per cent. It burns to a good red colour and strong body at ordinary temperatures. Like most very sandy clays it swells a little in firing at the lower temperatures, but begins to shrink at cone 03, as can be seen from the table of physical tests. A little more clay added to this deposit would make it one of the best brick materials in the county. No boring was done at this point, but it is almost certain that clay will be found below the sandy beds. The results obtained by adding sand to the ordinary fat Champlain clay are far inferior to a natural mixture like the above.

Sample No. 765, from the bottom of the bog, was like the ordinary surface clay in many respects, but it worked better and was not quite so stiff, nor was the shrinkage in drying quite so high. Another sample, No. 766, was an average of about 5 feet on the bank of a creek near the edge of the bog, on lot 13, concession VII, Alfred township. This is the typical grey Champlain clay of the region, with the usual drying defects and high shrinkage, which require to be corrected by the addition of sand.

Two samples of clay were collected from near Treadwell station and L'Orignal. Clay is exposed on the bank of Mill creek near L'Orignal station, but the sample collected was from the bank of the Ottawa about a mile west of the station, where a section of 25 feet is exposed. The clay at this point is stratified in red and grey layers and contains no pebbles or concretions. The deposit is fairly uniform throughout, except that the clay from the lower 10 feet was easier to work and not so stiff as the upper part. A mixture of two parts of this clay with one of sand was found much better for brickmaking than the clay alone, but only about 20 per cent of sand should be added for making drain-tile.

The clay at Treadwell was also mixed with sand for testing purposes and the test bricks obtained were similar to those from L'Orignal. None of the above artificial mixtures made nearly as good test bricks as those made from the natural sandy clay at Alfred Station.

Russell County

The greater part of Russell county is a plain underlain by stoneless marine clay. In some places the clay is covered by a layer of fine, grey sand, but it also forms the surface soil in large areas. The clay for the most part is the grey, sticky Champlain clay, and a typical sample, No. 579, collected at Navan, Cumberland township, shows it to have the average physical characters of this kind of clay.

In the southern part of the county the clay has a brownish red colour. The clay in the pits of the brick-yards on the bank of South Nation river, at Casselman, is banded reddish brown and grey, with interstratified thin layers of sand and silt, overlain by about 3 feet of fine sand. It would appear from the unusual character of this section that the clay at Casselman is the lower part of the marine sediments, for there is no interbedded sand or silt in the upper clay. The clay at Russell is plastic and reddish brown, with high shrinkage. It resembles the upper part of the Champlain clay in every way except colour. A small area of Queenston red shales and boulder clay lies on a slightly elevated area north of Russell, and the local reddish colour of the marine clay is probably derived from that source.

The cuttings along the Montreal road in the northern part of the county, east of Rockland, show numerous patches and bands of red clay irregularly distributed through the grey clay, the reason for the variation in colour not being apparent. A sample of red clay, No. 778, collected near Clarence, was tested. Its shrinkage in drying is excessive, being 12 per cent, the highest drying shrinkage recorded for Champlain clay. The red clay, however, has excellent plasticity and was one of the few Champlain clays that could be thrown on the potters' wheel. It acted like a high-grade modelling clay, but all the pottery forms made from it cracked in the firing. The addition of about 25 per cent of potters' flint might bring this clay safely through the burning. It is the only clay so far found south of the river near the capital that could be used for coloured earthenware, but similar red clay can be obtained nearer the city on the banks of the Gatineau.

Carleton County

Every township in Carleton county has areas of marine clay, some of them quite large. They were not all visited, but they are as a rule uniform in character and descriptions of a few will suffice. The distribution of the marine clay near Ottawa is shown in detail on the map which accompanies W. A. Johnston's report.¹ The report states that the central part of the city of Ottawa is underlain by marine clay that has a maximum thickness of nearly 100 feet.

Good sections of the clay are seen on the banks of the Ottawa in Gloucester, Nepean, and Torbolton townships, and in the cut banks of Greens creek, on Rideau river, between Ottawa and Kars; and on the Mississippi, above Galetta.

Ottawa. The marine clays are well exposed in the pits at the brick plants on Rideau canal near Hogsback lock, and on the south side of Rideau river, near Billings Bridge. Their general character is similar in most of the sections exposed in the pits and stream banks. The upper

¹ Dept. of Mines, Geol. Surv., Can., Mem. 101, p. 19.

part, as a rule, to a depth of 5 to 10 feet, consists of a uniformly fine-grained, grey, plastic clay, the top 1 to 3 feet being somewhat brownish. In places the upper clay is overlain by a varying thickness of sand. The upper clay is underlain by grey, silty clay which passes down into blue silt greasy to the feel, and some sand is found in the lower part interbedded with the silt. The upper stiff or "strong" clay is mixed with sand for brickmaking and in some places the three kinds of clay are mixed and used without the addition of sand, the high shrinkage of the upper clay being counteracted by the smaller shrinkage of the lower clays. Here as elsewhere the Champlain clays are impure and easily softened by overfiring, so that no higher grade of structural material than common brick or tile can be made from them.

Rideau Junction to Black Rapids. On the east side of Rideau river below Black rapids the bank is composed of: at the bottom, bluish, silty clay; overlain by alternate layers of clay and yellow sand, with yellowish stratified sand on top. A sample taken from the average of the bank below the top sand was found to have poor working qualities and the brick made from it were too weak for structural purposes. About one-fourth of a mile below Rideau Junction, west of the highway, grey marine clay was found interstratified with sand layers. A sample of this material, No. 331, was found to be the best brick material known in the county. The deposit contains enough sand to counteract the defects in the clay, and this natural mixture appeared to give better results than when the sand is added to the clay artificially.

Carp. Marine clay forms a fairly extensive surface sheet in the upper part of the valley of Carp river between Carp and Kinburn. Ridges of boulder clay and rock in places rise above the clay plain, but there is a considerable thickness of stoneless clay in some places. Two samples were collected for testing on a stream bank about 20 feet high in lot 21, concession VI, Huntley township, 4 miles west of Carp. The upper part of the clay, No. 589, is coarser than the average marine clay and, therefore, it is not so difficult to work and dry; and its shrinkage is lower than ordinary. The bottom clay is similar to the top clay in the raw state, and its drying qualities are somewhat better. It also contains a greater percentage of lime than the top clay, which causes it to burn to a buff colour, and to stand higher firing without softening. These clays are better than the average marine clay for the manufacture of brick and drain-tile, and clays of similar quality can no doubt be found nearer the railway.

Fitzroy Harbour. Stoneless marine clay about 35 feet thick is exposed on the bank of the Ottawa near Fitzroy Harbour, and 10 to 15 feet on the banks of the Carp nearby. The upper part of the clay is dark grey, fine grained, and massive, and the lower part is in places stratified and in places contains sandy layers. Sample No. 598 is the average of 12 feet from the bank of the Carp on lot 23, concession X, Fitzroy township. Sample No. 598a was taken at a depth of 30 feet from the top of the bank of the Ottawa near the wharf. The shrinkages are not quite as high as usual, but sand should be added for making brick and tile, and drying should be done slowly to avoid cracking. The bottom clay burns red, as it does not contain enough lime to produce buff colours.

Renfrew County

A large part of Renfrew county is rugged, with numerous ridges of crystalline rocks, mostly bare, but in some places covered with a thin layer of stony glacial drift. The Champlain clay occupies the lowland and is not found more than 500 feet above sea-level, but the rock ridges rise in places to 1,600 feet.

The largest continuous area of this clay in the county extends up the valley of Bonnechère river from its mouth to Caldwell. It attains a width of 5 miles in an area lying on both sides of the river in Admaston and Bromley townships. Stoneless clay is absent in Bonnechère valley west of Caldwell, but extends northerly in a wide area between concessions III and VIII, Bromley township, as far as lot 24. Separated from this area by rocky ridges of gneiss is another clay plain about 2 miles wide, west of Muskrat lake and extending along the Canadian Pacific railway from Cobden to Snake River.

A large area of Champlain clay extends along the Ottawa, west to concession VI, Ross township, and to the Canadian National railway in Westmeath township, and a clay plain in McNab township extends between Arnprior and White Lake. Clay is also found in detached patches among rock ridges between Arnprior and Renfrew. Small areas occur in the eastern part of Alice and Wilberforce townships between Rankin and Pembroke, and a narrow strip extends along the bank of the Ottawa 3 miles north of Pembroke.

The Champlain clay in Renfrew county does not differ materially from the clay in the St. Lawrence valley. It exhibits the same physical properties in the raw and burned states, and its uses are limited to the same kind of wares, viz., common red building brick and field drain-tile.

Horton Township. Sections on the bank of Ottawa river in Horton township show a thickness of about 50 feet of stoneless clay in places, the bottom being concealed by slides and talus. Sample 646 was taken from the upper part of the bank, on the road leading to the bridge at Portage-du-Fort.

Terraces of marine clay occur along the road near Ottawa for 2 miles below the Bonnechère, in Horton township. A section exposed below the first dam on Bonnechère river shows 25 feet of stoneless, massive clay, faintly banded at the bottom and mostly lying on crystalline limestone, but partly underlain by sand and boulder clay. Sample No. 591, from the lower 10 feet of the deposit, was tested for lime and was expected to give a buff colour, but was found to be red-burning.

Renfrew. Part of Renfrew is built on marine clay which extends in a narrow strip along Bonnechère river. A brick plant was operated for many years in the valley of Hurd creek, near its entrance into the Bonnechère. About 25 feet of banded brownish and grey clay with interlaminated silt films is exposed. The lower part contains a high percentage of lime, and made drain-tile of a buff colour, but the lime is mostly leached from the upper part, which was used for making common, red, building brick. The clay is rather stiff and plastic throughout and has good working qualities when properly prepared for moulding. This site is now abandoned and the plant has been moved to the eastern outskirts of the town alongside the Canadian Pacific railway. The plant is equipped with round, down-draft kilns and a track and pallet outdoor

drying yard of good capacity. The upper part of the clay deposit is stiff and of a brownish colour, but the lower part contains more silt and burns red. Below the worked part there is a buff-burning silt. Lime concretions are scattered through the clay, and, as they are difficult to avoid, occasionally spoil some brick and tile (Plate V). Common red brick and field drain-tile are made, but the buff-burning lower silt is not used, as it is inferior to the buff-burning clay at the old plant, at Hurd creek.

Arnprior. A brick and tile plant has been in operation near Arnprior for a number of years, on the banks of Dochert brook, about half a mile north of the town. A great deal of material has been taken out for brick-making, and good sections are exposed showing stratified silts overlain by about 25 feet of stiff, brown, marine clay. Toward the Ottawa the upper clay is overlain by 10 feet of yellow sand. Buff-coloured brick can be made from the lower silty clay, but none has been made in recent years. The upper clay, mixed with sand, is used for making common, red, building brick and field drain-tile. This plant is equipped with round down-draft kilns and covered dryers and has a large output of drain-tile.

Pembroke. The marine clay so widespread in the southern part of Renfrew county is a comparatively narrow strip and nearly reaches its northern limit at Pembroke. Two plants making common red building brick are using only the lower part of the clay, as the upper part is said to be too stiff and difficult to work. One of the sections exposed in the clay pit near Indian river shows 3 feet of brown, rather stiff clay overlying a foot of grey stratified clay which is underlain by 9 inches of coarse brown sand. Silty and sandy clay, too lean for brickmaking, lies below the sand layer. The clay at a higher elevation west of the town is typical Champlain clay. It is very stiff in working, hard to dry, and has a very high shrinkage (Sample No. 647). With better means than the brick-yard possesses for preparing the clay, it would be possible to use some of it in a mixture with the lean lower clay.

Cobden. Sample No. 645 was collected at an abandoned brick plant at Cobden. It is ordinary marine clay, but seemed smooth, and had a higher tensile strength in the raw state than most of the Champlain clay. With a little sand added to reduce the shrinkage and make it dry more readily this clay would make good field drain-tile. The abundant stoneless clay in this vicinity is of uneven thickness, knobs of granite gneiss in some places rising above the level of the clay plain.

Douglas. This village is situated on a rock ridge at the western edge of the large clay plain in the Bonnechère valley. A branch of the Canadian National railways runs through the plain. Sample No. 593, taken from the upper 3 feet of the plain near Douglas station, is the usual brown oxidized part of the clay. The small ridges or hogbacks that rise from the plain seem to be due to the hummocky floor of boulder clay on which the marine clay was laid down.

Forester Falls. One of the best sections of the drift seen in the county is found in a cut bank below the bridge over a small creek at Forester Falls in Ross township, and is as follows:

	Feet
Brownish, stiff, unstratified marine clay, with fossils.....	30
Silt and sand, interstratified.....	3
Massive and stratified, greasy, grey silt, to water-level.....	10

The bottom stratified silt is crumpled in places, but the overlying silt and sand are horizontal. Above the top of the cut bank there is a sloping terrace of marine clay, capped by sand, which would add about 25 feet to the thickness of the marine clay exposed in the bank.

A small plant near the village is engaged in the manufacture of common brick and drain-tile from the stiff, brown, upper clay with a sandy top. There is a seam of hard lime concretions about 5 feet below the surface, some of which have been allowed to go into the tile to their detriment.

Ridges of granite gneiss project above the clay plain in the vicinity of the tile-plant, and in the creek nearby the clay was seen to be 70 feet thick, so that this locality displays very well the uneven character of the floor on which the sediments were laid down.

Waba. Sample No. 575 was collected from the bank of White river in lot 1, concession VI, McNab township, where there is an average of about 6 feet of grey, pasty, stiff, marine clay. It would require the addition of about 35 per cent of sand to make it workable. A large swamp in this neighbourhood is underlain by marl, a white or light grey, fine-grained deposit, consisting mostly of lime carbonate. A little marl added to the clay would improve its working and drying qualities, and buff colours in the burned state would be produced if the amount were large. The results of experiments made with this mixture are given in another section of this report.

Lanark County

There are no clay deposits known in the rugged Precambrian upland that forms the greater part of Lanark county, and the lowland along its eastern and southern margin is mostly covered with stony and sandy drift. A small area of massive clay occurs east of the old Grand Trunk railway to Carleton Place.

A narrow strip of marine clay lies in the valley of Mississippi river between Almonte and Pakenham, and the clay continues along the edge of the granitic rocks into Renfrew county.

Sections exposed in the steep banks of the river near Pakenham show about 40 feet of massive, grey, stoneless clay, containing a few fossil marine shells. In some places, alternating layers of sand and clay occur in the upper part of the bank, which would make a good natural mixture for brick or tile.

A small deposit of marine clay on the north bank of Rideau river, above Smiths Falls, was formerly used for brickmaking. There appears to be no clay between Smiths Falls and Perth, but, in a valley at the eastern edge of Perth, a thin deposit of clay occurs which is entirely different from the marine clay. Perth is 12 miles west of Smiths Falls, and the intervening country is fairly level, the difference in elevation between the two towns being only 10 feet. The deposit near Perth consists of about 3 feet of dark brown clay underlain by white marl, or clay and marl interstratified, but only the top clay is used. It carries a high percentage of lime and the brick are cream-coloured when burned. There are a great many limestone particles in the clay which cause the burned brick to spall shortly after exposure. Formerly the clay was washed to eliminate the limestone grit and pebbles and excellent brick were made from the washed clay.

On the Scotch line road a few miles west of Perth is a small area of stoneless brown clay, which does not look like marine clay, but has similar working and burning qualities. For brickmaking it would require the addition of sand; it burns to a good red colour.

A small deposit of stoneless clay was seen in the valley of the Clyde near Lanark.

Analysis of Champlain Clays in Eastern Ontario

Red-burning Clays

Sample No.	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Lime CaO	Magnesia MgO	Potash K ₂ O	Soda Na ₂ O	Loss on ignition
692.....	54.90	18.20	6.64	4.68	3.62	3.78	1.36	3.22
692a.....	53.48	18.06	7.36	4.62	4.62	3.33	1.75	2.76
34.....	59.34	17.68	6.74	2.94	3.36	3.07	2.13	4.60
29.....	61.08	17.28	6.20	2.54	2.35	3.50	1.80	5.19
32.....	58.54	17.02	5.48	6.36	2.22	2.95	2.18	3.42
33.....	56.00	17.07	8.27	4.17	4.55	2.57	1.81	4.89
60.....	57.98	19.00	6.18	3.78	3.82	3.81	1.87	3.18
48.....	54.38	19.18	7.30	4.60	3.70	3.62	1.42	5.60
49.....	55.34	19.80	7.62	2.18	2.39	3.74	1.93	7.12
35.....	62.30	16.51	5.65	3.16	2.68	2.61	2.25	3.60

Buff-burning Clays

30.....	51.92	13.74	5.03	10.03	3.78	3.06	1.67	11.34
31.....	51.30	9.80	3.70	13.63	3.82	2.27	1.64	13.88
38.....	51.06	15.58	4.78	10.00	4.47	2.68	2.42	9.76
42.....	49.85	15.10	6.18	11.32	4.13	2.79	1.35	10.28

Analysis by Ontario Bureau of Mines, except 692 by Mines Branch, Ottawa.

692. East end of Sheek island, Stormont co. Average of upper 8 feet of bank.
 692a. East end of Sheek island, Stormont co. Average of lower 12 feet of bank.
 34. Casselman, Russell co. Average of 10 feet from pit at Merkley Bro's brick-yard.
 29. Prescott, Grenville co. Upper clay, overlying Nos. 30 and 31.
 32. Ottawa. Average of 14 feet deep, worked by Cain Brick Co.
 33. Ottawa. Average of similar bank worked by Morris and Ballantyne.
 60. Arnprior, Renfrew co. Upper clay at brick-yard.
 48. Renfrew, Renfrew co. Upper clay in Thomas Henderson brick-yard.
 49. Renfrew, Renfrew co. Upper clay in Thomas Henderson brick-yard.
 35. Pembroke, Renfrew co. Average of 10 feet, worked for brickmaking.
 30. Prescott, Grenville co. Underclay at Wiser and Son brick plant.
 31. Prescott, Grenville co. Underclay at Wiser and Son brick plant.
 38. Renfrew, Renfrew co. Clay underlying Nos. 48 and 49.
 42. Renfrew, Renfrew co. Clay underlying Nos. 48 and 49.

Remarks on Chemical Analyses

The above table shows that the composition of the red-burning clays in eastern Ontario is very uniform, as the samples were taken at intervals over a distance of 130 miles. They are all Champlain clays and have a common origin.

The sum of the iron, lime, magnesia, potash, and soda is high, and, as these are fluxes, the clays will admit burning to only low temperatures. Furthermore, the clays are fine grained, and fusion takes place more readily than in the case of coarse-grained clays or shales of the same composition.

The titanium oxide in the clays was determined in only two of the samples, Nos. 692 and 692a, the amount being 0.83 and 0.84 respectively; but all of them probably contain similar percentages.

The analyses of buff-burning clays show higher lime content and greater loss on ignition, but less silica and alumina than red-burning clays. None of the calcareous clays found in eastern Ontario contain as much lime as those in southern Ontario. All the clays listed in the above table contain lime and most of them effervesce if acid be dropped on them. In this report clays that contain enough lime and magnesia to burn to buff colours are called calcareous clays, and the clays containing a larger amount, highly calcareous.

Table of Physical Tests of Champlain and Lacustrine Clays in the Counties Along St. Lawrence River and Lake Ontario

Sample No.	% Water of plasticity	% Drying shrinkage	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption
714.....	27	9	1	18	1	12	6	
713.....	23	9	0	11	1	10	5	2
709.....	25	8	0	15	0	13	5	4
698.....	27	8	1	12	1	13	2	2
700.....	37	10	0	18	3	14		9
708.....	30	11	1	11	1	10		*
697.....	38	13	1	13	6	1		*
697a.....	30	8	1	15	1	14	5	7
693.....	37	10	1	14	3	2		*
693a.....	40	10	1	17	5	7		*
692.....	37	10	1	15	1	14		*
692a.....	38	10	1	18	1	14		*
694.....	32	9	0	16	1	14	8	0
696.....	20	5	0	14	0	14	1	12
695.....	27	8	0	15	1	14	4	6
691.....	22	5	0	17	0	17	1	16
690.....	25	7	0	16	0	16	1	16
689.....	32	9	0	16	1	14	8	0
687.....	26	6	0	14	1	14	5	5
687a.....	22	6	0	14	1	13	4	5
687b.....	30	8	0	15	1	15	6	1
707.....	31	12	2	11	2	10	9	0
705.....	29	10	1	15	1	15	7	0
706.....	30	8	1		1	17	7	1
704.....	31	11	5	18	5	6		*
703.....	30	9	1	15	1	14	5	2
721.....	30	11	2	9	2	10		*
731.....	27	7	0	20	1	18	5	9
725.....	27	7	0	16	2	11	5	3
724.....	29	9	0	20	5	0		*
602.....	31	7	0	22	1	22	4	0
241.....	30	7	0	20	2	17	4	9
263.....	35	7	1	23	2	19	5	6
396.....	30	9	0	15	2	12	6	0
230.....	30	7	1	17	3	13	8	0

*Softens and deforms.

714. Lancaster tp., Glengarry co., lot 9, con. V, $\frac{1}{2}$ mile east of Bridge End station, C.P.R.

713. Lancaster tp., Glengarry co., lot 10, con. VI, $\frac{1}{2}$ mile south of Dalhousie station, G.T.R.

709. Lancaster tp., Glengarry co., lot 25, con. IV, $\frac{1}{2}$ mile north of North Lancaster station.

698. Lancaster tp., Glengarry co., lot 30, con. V.

700. Charlottenburg tp., Glengarry co., lot 3, con. IV.

708. Charlottenburg tp., Glengarry co., lot 22, con. VI, 1 mile north of MacGillivray bridge.

697. Charlottenburg tp., Glengarry co., con. I, bank of Crays creek.
 697a. Charlottenburg tp., Glengarry co., con. I, bank of Crays creek, one part sand to two parts clay.
 699. Cornwall tp., Stormont co., lot 2, con. V.
 693. Near quarries 1 mile north of Moulinette—average of upper 6 feet of bore-hole.
 693a. Near quarries 1 mile north of Moulinette—average of lower 8 feet of bore-hole.
 692. East end of Sheek island, Stormont co.—average of upper 8 feet of bank.
 692a. East end of Sheek island, Stormont co.—average of lower 12 feet of bank.
 694. Cornwall tp., lot 25, con. VI.
 696. Osnabruck tp., lot 3, con. IV, bottom clay, burns to buff colour.
 695. Osnabruck tp., lot 3, con. IV, upper clay.
 691. Bank of St. Lawrence river, $1\frac{1}{2}$ miles west of Dickinson landing.
 690. Bank of stream at Farran Point, Stormont co.
 689. Bank of stream 1 mile northwest of Aultsville, Stormont co.
 687. Williamsburg tp., east of Chrysler monument.
 687a. Williamsburg tp., east of Chrysler monument.
 687b. Williamsburg tp., east of Chrysler monument.
 707. Williamsburg tp., lot 32, con. VI.
 705. Matilda tp., lot 24, con. IV, $1\frac{1}{2}$ miles east of Hainsville.
 706. Edwardsburg tp., lot 11, con. I, at west end of canal at Cardinal.
 704. Edwardsburg tp., on Drummond island.
 703. Bank of St. Lawrence river, 2 miles east of Prescott.
 721. Edwardsburg tp., lot 33, con. VII, 2 miles west of Spencerville.
 231. Brockville, Leeds co.
 725. Mallorytown, Leeds co.
 724. Gananoque, Leeds co.
 602. Phillipsville, Leeds co.
 241. Kingston, Frontenac co., Kingston Brick and Tile Co.
 263. Kingston, Frontenac co., Little Cataraqui creek.
 396. Kingston, Frontenac co., Brookside farm.
 230. Napanee, Addington co., clay from pit at brick plant.

Remarks on Physical Tests

Most of these clays were laid down in marine waters and are known as Champlain clays. Attention has been directed to their remarkable similarity in composition as shown by the chemical analyses, but not less striking is the similarity of their physical properties over large areas. The clays are characterized by an almost uniformly lead grey to brownish grey colour, fineness of grain, high plasticity, and sticky feel when wet. The shrinkage on drying is large, and full-sized brick made from them have to be dried very slowly to avoid cracking.

The clay when dry requires on an average about 34 per cent of water to bring it to the best working consistency. This is known as the water of plasticity. The average drying shrinkage is 9 to 5 per cent, but there is very little fire shrinkage in burning to cone 010, and the average shrinkage when burned to cone 06 is 2 per cent. When burned to cone 03 the average shrinkage is excessively high. The test brick were quite porous at the lower temperature, the average water absorption being about 18 per cent, and at cone 06 the average absorption is 15 per cent. The body becomes so dense when burned to cone 03 that the capacity for absorbing water vanishes; and in some cases vitrification is completed at this temperature. The burned colour is as a rule light to dark red, and only in a few places does the bottom bed, under the red-burning clay, burn to a buff colour.

If a deposit is made up of mixed clay and sand or very silty clay, the amount of water required for working and the drying shrinkage are much lower than in the ordinary marine clay. The water of plasticity is as low as 17 and 18 per cent for some of the sandy clays, and the drying shrinkage only 4 to 5 per cent. The shrinkage of calcareous clays in drying and burning is also less than the red-burning, upper, marine clay.

Most of the building brick made in the region are burned only to about the softening point of cone 010, but when the upper marine clay is used sand is invariably added to assist the drying and reduce the shrinkage. Nos. 697 and 762b are examples of the effect of using a mixture two parts clay to one part sand. The difference in shrinkage between them and the unsanded clays recorded above them is quite marked.

Most of the clays melt to a slag in the test kilns when heated up to the softening point of cone 1. A few of them will stand up to cone 2 without slagging, and the silty and calcareous ones to cone 3, but not higher. All the clays have a short vitrification range, so that it is not safe to use them for the manufacture of vitrified ware.

The temperatures in the test kilns do not quite correspond to the equivalent temperatures given for the softening points of pyrometric cones by the manufacturers, but they give closer agreement in the longer period of firing in the large commercial kilns. During the burning tests the following average temperatures were recorded by the pyrometer when the cones went down:

Cone 010—1,680 deg. F. 920 deg. C.

Cone 06—1800 deg. F. 980 deg. C.

Cone 03—1900 deg. F. 1040 deg. C.

Cone 1—1976 deg. F. 1080 deg. C.

Table of Physical Tests of Champlain Clays in the Counties Along Ottawa River

Sample No.	% Water of plasticity	% Drying shrinkage	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption
762.....	38	9	0	17	4	10	8	0
762a.....	40	10	0	20	1	19	10	0
762b.....	30	7	1	16	1	15	4	7
765.....	35	9	1	19	3	15	.....	*
766.....	42	10	0	20	3	14	9	0
767.....	17	4	0	15	0	12	4	5
333.....	30	10	1	13	3	8	.....	*
778.....	40	12	0	21	2	17	8	0
597.....	31	9	0	15	1	15	.....	*
330.....	27	9	1	12	2	9	6	0
331.....	18	5	0	11	0	11	0	9
237.....	32	9	0	17	2	16	9	0
235.....	27	6	0	17	1	15	3	3
387.....	30	10	0	15	2	12	.....	*
598.....	32	8	0	16	0	15	.....	*
598a.....	30	8	0	17	0	17	8	0
589.....	23	7	0	15	0	14	4	1
589a.....	23	7	0	17	0	16	5	0
357.....	30	9	0	15	2	13	.....	*
590a.....	30	10	1	16	2	15	.....	*
590.....	28	5	0	20	0	20	10	0
591.....	35	9	0	11	1	10	9	0
592a.....	30	10	0	17	0	16	7	0
592.....	28	8	0	22	0	21	1	14
593.....	35	8	0	18	1	18	5	0
595.....	35	8	1	20	2	18	.....	*
646.....	30	8	1	15	1	13	7	0
645.....	30	8	1	14	2	13	7	0
647.....	24	10	2	12	2	10	7	0
599.....	31	8	1	16	2	16	8	0
601.....	31	8	0	17	0	16	7	0

*Softened and deformed.

762. L'Original, Prescott co., from bank of Ottawa river, one mile west of village, upper clay. 7
 762a. L'Original, Prescott co., from bank of Ottawa river, lower clay. 80. 80
 762b. L'Original, Prescott co., from bank of Ottawa river, average of bank with 33 per cent sand.
 765. Alfred, Prescott co., clay from bottom of bog.
 766. Alfred tp., Prescott co., lot 13, con. VII.
 767. Alfred, Prescott co., sandy clay near Alfred station.
 333. Lemieux, Prescott co., red clay from bank of Nation river.
 778. Russell co., red clay on Montreal road, 2 miles east of Clarence station.
 597. Navan, Russell co.
 330. Black rapids, Rideau river, Carleton co., upper marine clay above lock.
 331. Rideau Junction, Carleton co. Very sandy clay.
 237. Ottawa, upper clay, Merkley's Ltd.
 235. Ottawa, bottom clay, Merkley's Ltd.
 387. Graham bay, lake Deschêne, Carleton co.
 598. Fitzroy Harbour, Carleton co., upper clay on bank of Ottawa river.
 598a. Fitzroy Harbour, Carleton co., lower clay on bank of Ottawa river.
 589. Carp, Carleton co., upper clay, lot 21, concession VI, Huntley tp.
 589a. Carp, Carleton co., lower clay, lot 21, concession VI, Huntley tp.
 357. Pakenham, Lanark co.
 590a. Arnprior, Renfrew co., upper clay at brick-yard.
 590. Arnprior, Renfrew co., lower clay at brick-yard.
 591. Castleford station, C.P.R., Renfrew co.
 592. Renfrew, Renfrew co., bottom clay at old brick-yard, burns to buff colour.
 592a. Renfrew, Renfrew co., upper clay at old brick-yard.
 593. Douglas, Renfrew co.
 595. White Lake, Renfrew co.
 646. Horton tp., Renfrew co., lot 27, con. VII, upper clay from bank of Ottawa.
 645. Cobden, Renfrew co.
 647. Pembroke, Renfrew co., upper clay near station on Canadian National railway.
 599. Smiths Falls, Lanark co., clay at old brick-yard.
 601. Scotch line, Lanark co.

Uses of Champlain Clays

There were formerly more brick plants in operation in eastern Ontario than there are today. Most of them were small summer plants making just enough brick to supply local demands. Some of these smaller plants still remain. The principal product is red, soft-mud brick, which are as a rule dried outdoors on racks and pallets and then burned in scove or clamp kilns. These plants remain idle in winter, but as the amount invested in them is small there is little or no overhead.

Some attempts have been made to substitute stiff-mud brick machines and to build artificial dryers, in order to give an increased output, but most of them were failures. The greater part of the Champlain clay is not adapted to the stiff-mud process, and furthermore it will not stand fast drying, even with a liberal addition of sand. The losses from the stiff-mud process occur not only from cracked brick in the dryer, but also from fire checking in the kilns. Silty or sandy clay in the lower part of a deposit can be mixed with the fat, top clay for brickmaking. In any case the upper, highly plastic clay cannot be used alone, and if a milder or sandy clay is not available for mixing, sand must be added. Rough-surface face-brick are made by the stiff-mud process by Merkley's, Limited, at Ottawa, from a mixture of upper fat clay, lower mild clay, and ground shale.

With the introduction of intensive farming, and improved farming methods, there is likely to be an increased use of tile for underdrainage. The clays best suited for making tile, so far as they have been examined, are indicated on a previous page. It is better to have several small brick and tile plants distributed through the region than a few, large, central plants, for farmers prefer to haul the tile from the plant.

Hollow blocks made by burned clay have increased in favour in recent years more than any other kind of structural material. They have many advantages, among them being cheapness of construction and better resistance to extremes of heat and cold than the ordinary solid walls. Hard-burned hollow-ware cannot be made from the Champlain clay, but it is possible to make the soft, porous kind known as terra-cotta lumber, which is made from a mixture of clay, sand, and sawdust. The sawdust burns out and leaves cavities in the burned block, so that nails can be driven into it when placing furring on the walls.

The Champlain clays soften and deform at a comparatively low temperature, so that the products that can be made from them are practically limited to common brick, drain-tile, and terra-cotta lumber, all porous wares. Many attempts have been made to extend the usefulness of this clay by the addition of some cheap material. The experiments made at the Mines Branch laboratories include adding mine wastes, such as tailings, from the graphite mines at Buckingham and the asbestos mines at Thetford, Que., also quicklime, marl, finely ground limestone and dolomite, ground talc schist, and coal ashes. All these materials were found to improve the working and drying qualities of the clay, and to enable it to stand a little higher temperature. Except in the case of quicklime not less than 15 per cent was found to be effective. Sand to the amount of 25 per cent or more is in some cases effective in overcoming the stiffness in working and the cracking in drying and also enables the clay to stand a little higher temperature without softening; but an excessive amount of sand weakens the burned brick.

Fire-clay or discarded fire-brick, crushed to pass a quarter-inch screen, would probably give the best results for increasing the range of usefulness of the Champlain clays, and about 35 per cent would have to be added. The writer knows of no deposits of fire-clay in the region, the nearest deposit being in Nova Scotia, if Canadian materials only are considered. Fire-clay costs \$4 a ton loaded on cars in Nova Scotia and the freight in 1920 to points in eastern Ontario was \$8 to \$10 a ton.

In many places it is possible to accumulate a large supply of coal ash convenient to a brick plant. If the ash be ground it forms a useful ingredient to add to the Champlain clay. It helps in the working and drying, reduces the shrinkage, and increases the vitrification range. It has, too, some fuel value on account of the unburned and partly consumed coal. The ashes, however, spoil the red colour of the burned wares; but this is of no consequence for hollow block or drain-tile, where the ware is not exposed to view.

CHAPTER VIII

CLAYS OF SOUTH-CENTRAL ONTARIO

South-central Ontario, as the term is employed here, extends from the eastern border of Hastings county, west to Georgian bay, and from lake Nipissing and French river, south to lake Ontario. It is mostly an upland region of lakes, rivers, and forest, underlain by Precambrian crystalline rocks. A smaller area underlain by Palæozoic limestones and shales extends from the Precambrian upland to lake Ontario, and similar rocks underlie Lake Simcoe basin, and the region near the southern part of Georgian bay.

Shales do not occur among the rocks of the Precambrian upland in south-central Ontario, but kaolin occurs in a similar region in Quebec, and this is the only form in which clay is likely to be found.

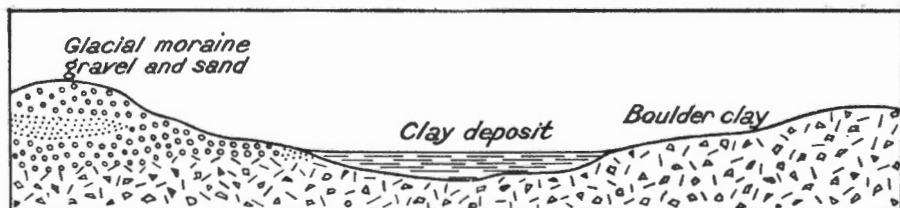


Figure 5. Type of small, stoneless clay deposit in southern part of central Ontario.

The drift materials spread over the Precambrian upland consist of boulders, gravel, sand, and silt, with very little clay. Stratified, stoneless clay occurs only in one part of the region, in the valleys of Muskoka and South rivers. Either the upland stood too high to receive general sedimentation during the maximum stages of the great glacial lakes, or the land ice still covered most of it during that period. Clay in the southern part of the region is mostly underlain by Palæozoic rocks and patches of stratified clay laid down in glacial lake Iroquois border lake Ontario all the way from Napanee to Whitby. These clays are limited in a northerly direction by the shore-line of the ancient lake, but certain deep indentations and small lakes tributary to lake Iroquois contained clay sediments. Small, detached clay areas, like those at Peterborough and Lindsay, were probably laid down in small lakes connected by short rivers with lake Iroquois.

These detached areas are in many places surrounded by ridges of glacial drift (Figure 5). Similar, small, isolated clay areas are found near the Precambrian upland at Tweed and Madoc, Hastings county, and at Fells, Victoria county.

The stratified stoneless clays in Lake Simcoe basin, in Muskoka and Parry Sound, and those near Georgian bay were laid down in glacial lake Algonquin.

At no place in the region are there such large expanses of stoneless clay lands as those underlain by marine clay in eastern Ontario. The Iroquois clay areas near lake Ontario are in many places interrupted by larger areas of glacial drift, so that there is far more stony clay, sand, and gravel exposed at the surface than stoneless clay. The stratified deposits of Algonquin clay are thinner and even more scattered in Lake Simcoe basin. Some of the deposits near Georgian bay are much thicker than those in Lake Simcoe area, but their superficial extent is limited.

Hastings County

The lowland area lying between the irregular southern border of the Precambrian plateau and lake Ontario is largely occupied by a series of glacial moraines, composed mostly of boulders and gravel or with undulating areas of stony clay. Deposits of stoneless clay are rarely seen. In the northern part of the county there are no known deposits of clay overlying crystalline rocks.

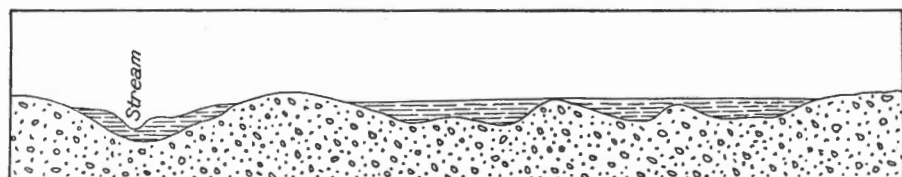


Figure 6. Diagram of deposits of stratified Iroquois clay in central Ontario, near lake Ontario, laid down on an uneven floor of boulder clay.

Thurlow Township. The most extensive deposit of stoneless clay occurs about $3\frac{1}{2}$ miles east of Belleville. The clay and the limestone nearby are used in the manufacture of Portland cement in one of the large plants of the Canada Cement Company. A steam shovel is used to excavate the clay and load it on cars, and several acres have already been stripped to a depth of 7 to 10 feet. The bottom of the pits is composed of very stony, light grey boulder clay. In some places the stony clay rises to the surface and at other places it comes to within a foot or two of the surface, but it is not used in the cement mixture. This locality shows better than anywhere else the uneven character of the floor upon which the Iroquois Lake clays were laid down (Figure 6).

A section of the upper clay exposed by the steam shovel is as follows:

	Feet
Stratified clay with many lime concretions.....	4
Yellow sand.....	1
Grey, laminated clay with scattered limestone particles.....	5
Stratified, highly calcareous grey silt.....	1

The top part is highly plastic, weathered, and leached. It burns to a good red colour, but is spoiled for brickmaking by concretions. The 5-foot bed of grey clay burns to a hard, buff-coloured brick, but is spoiled by limestone particles. The bottom silt contains so much lime that it cannot be used even in the cement mixture.

Another section, close to and south of the Kingston highway, consists of about 7 feet of brownish, stratified, stoneless clay. It is a very stiff plastic clay when wet, has a high shrinkage, and an average sample of the face burned to a good red colour. This part of the deposit is, apparently, free from concretions and limestone.

Bedrock outcrops a short distance east of the clay pits and continues at or near the surface for several miles along the Kingston highway.

A small brick plant has been in operation for many years at the eastern outskirts of Belleville. All the clay near the plant has been worked out, and clay is now hauled from another deposit nearby. A good, hard, red, soft-mud brick, almost free from the defect of lime pebbles, is produced, but constant care has to be exercised in the clay pit to avoid taking up the stony underclay by digging too deeply.

Foxboro. A shallow deposit of clay for brick and drain-tile occurs on the banks of Moira river, at Foxboro, about 6 miles north of Belleville. The deposit consists of 4 feet of brown, loamy clay, partly stratified, which is said to be underlain by about 12 feet of grey clay. A bed of sand about one foot thick lies between the upper and lower clay. Only a few feet of the lower clay is exposed in the pits, so that about 6 feet of the deposit is used. This deposit contains numerous lime concretions scattered through it, and as it is difficult or impossible to separate them from the clay by the method of preparation used, a loss in tile results.

Tweed. A small plant for common red building brick is situated south of Tweed, on lot 10, concession IX, Hungerford township. The clay lies in a small, flat area between glacial moraines and was evidently laid down in a lake which has been drained (Figure 5). The clay is stiff and plastic near the surface and silty to sandy below, the whole deposit being about 3 feet thick. Although large boulders occur at intervals near the bottom of the deposit the clay above appears to be free from pebbles or stones.

A more extensive flat area at the south end of Stoco lake is underlain by clay, and other smaller areas of clay are to be found in this township west of the brick-yard.

Madoc. A small area of clay in a depression west of Madoc is used for common red building brick and drain-tile. It consists of about 3 feet of mottled grey and brown, loamy clay underlain by stiff, plastic clay carrying numerous lime concretions. Only the top loamy clay is used.

Stirling. A small clay area covers about three lots a short distance east of Stirling. Sample No. 604 was taken from lot 8, concession II, Rawdon township. The upper part of the clay is brownish and very stiff, but lower down it is lighter in colour and texture.

The clay appears to be free from pebbles, or concretions, and would be suitable for common red brick or field drain-tile. The deposit is surrounded by sand and gravel and was probably laid down in a small lake which has since been drained.

Durham County

The thickest deposits of glacial drift exposed in the Interlake peninsula are found on the shore of lake Ontario, in Clarke and Hope townships. Although not so imposing as those at Scarborough, the cliffs formed of the drift in Clarke reach a height of 135 feet in places. The section from Darlington to Port Hope was examined in detail, but no clays of value were found. The principal part of the drift is composed of an upper thick sheet and two thinner sheets of boulder clay. Between the boulder clays there are stratified sands, silt, and clay in irregular or lens-like deposits. The following section measured near Wesleyville is typical of the exposures in that vicinity:

	Feet
Boulder clay, yellowed by weathering.....	25
Stratified sand, silt, and gravel.....	50
Interlaminated silt and clay with scattered pebbles.....	20
Very stony boulder clay.....	10
Stratified sand and gravel.....	6
Very compact blue boulder clay to lake level.....	6

Most of the fine-grained stratified deposits which look like clays are really silts, but at Darlington, and near Newcastle wharf, beds from 10 to 25 feet thick contain more clay substance than usual. The clays are very calcareous and burn to buff colours, but are spoiled in places by limestone pebbles. Furthermore, these clays are out of reach as they occur below great thicknesses of a stony and sandy overburden. The drift sections in Clarke have been described and illustrated by A. W. G. Wilson.¹

Bowmanville. The small stream at the eastern outskirts of Bowmanville cuts through a thick deposit of stratified Iroquois clay. The upper part is weathered and leached to a depth of 3 feet and is used for common brick by the soft-mud process. Below the red-burning top clay is a highly calcareous, rather silty, cream-burning clay, formerly used for hollow blocks and drain-tile. It is an uncertain material to use as it carries a layer of lime concretions. The clay, however, becomes more plastic and carries less impurities at greater depth.

Sample No. 771 is an average of 5 feet in thickness, taken just below the bottom of the red-burning clay at the brick-yard, and No. 256 is from a 6-foot section exposed on the stream bank about 10 feet below No. 771. The tests show the difference between the two clays, the porosity of No. 771 being the greater, so that the lower clay will make the better and stronger drain-tile or hollow block.

The lower clay would be suitable for making coloured earthenware or majolica pottery as it is strong enough to be thrown on the potters' wheel, but as it contains coarse grit particles it should be washed and screened. Because the clay softens and deforms at a comparatively low temperature, any glaze with which the ware was covered should mature at cone 06. The same directions apply to the tile clay, No. 272, at Whitby, which is similar in all respects to the lowest clay at Bowmanville.

¹ "A Forty Mile Section of Pleistocene Deposits North of Lake Ontario." Canadian Institute, Toronto, 1905.

Many small deposits of stratified silt and clay occur in depressions in various parts of Durham county. It is usual for streams on their way to lake Ontario to flow through these comparatively soft materials in preference to the widespread, harder, stony clays. There is a deposit of this kind just east of Newcastle, near the railway bridge over the highway. It is mostly composed of stratified and crumpled silts, without much clay, and resembles some of the deposits between the boulder clay sheets in the clay cliffs in the vicinity, on the shore of lake Ontario. About 2 miles west of Welcome another deposit of this kind, cut by a small stream, carries more clay substance. Sample No. 774 of this deposit showed it to be a highly calcareous clay that burns to a rather chalky cream colour and very porous body and is not nearly so good as that at Whitby and Bowmanville.

Peterborough County

Most of the immediate vicinity of Peterborough is underlain by boulder clay, sand, and gravel, but there are a few small areas of stoneless clay from which brick and drain-tile are made.

The deposits are not very thick, and consist of an upper part of weathered clay burning to a red colour and a lower part from which porous, cream-coloured drain-tile are produced. The clay deposits, which are of the kind shown in Figure 6, are conveniently situated near Trent Valley canal, but they have been worked for many years and are nearly exhausted. The products were among the best in the province.

Drummond. The Canada Cement Company obtain the clay for their Lakefield plant in an elongated depression between low, rounded hills and ridges of glacial drift. The clay pits are on lots 17 and 18, concession X, Otonabee township, and the clay flat in which they are dug is said to extend to Otonabee river and to have a width of from 300 yards to half a mile. The clay-filled depression also extends northeasterly beyond the railway track to lot 19, concession XI; but no excavations have been made in that part of it, the clay there being reported unsuitable for cement. The clay pit has been excavated for a length of half a mile and is about 60 feet wide and from 6 to 25 feet deep.

The cement clay is bottomed on stony clay throughout, and at two places the stony clay comes so near the surface as to interrupt the continuity of the excavation. The clay was shipped to the cement plant over the old Grand Trunk railway from Drummond station, but no clay has been excavated there for some years and the pits are now full of water. Suitable clay was found nearer to the Lakefield plant, and is represented by sample No. 776. It burns to a buff colour and gives results very similar to No. 270, which is the tile clay at Peterborough, but the latter is more sandy. No. 777 is surface clay from midway between the pit and the railway. It is an entirely different material from the clay in the pit, being rather gritty, with low shrinkage, and burning to a fine red colour and hard body. This clay is recommended for red building brick, but the deposit is not more than a few feet thick.

Ontario County

The southern part of Ontario county is heavily covered with glacial drift, and outcrops of granite gneiss and Ordovician limestone are numerous in the northern part. Glacial lake Algonquin formerly extended over the part of the county near lake Simcoe and some of the clay laid down in it is still found in detached patches. In some places the clay appears at the surface and in others it is covered with sand. Small deposits of stratified clay near lake Ontario were laid down in glacial lake Iroquois.

Mara Township. Sample No. 386 was collected by W. A. Johnston, of the Geological Survey, on lot 24, concession VIII, from the upper part of a stratified deposit consisting of alternating layers of clay and silt. It was very plastic and smooth when wet. Its drying properties are not good, and it has a drying shrinkage of 10 per cent, which is excessive. It produces a very porous, but hard, light-red body at low temperatures. Sand should be added to assist the drying and lessen the shrinkage, and render the mixture suitable for common building brick or perhaps for field drain-tile. There are small particles of limestone in the sample and if these should prove to be prevalent through the deposit they would greatly lessen its usefulness. Several deposits of clay along the railway between Schepeler and Atherley are apparently of a similar character.

Beaverton. One of the largest deposits of stoneless clay in the country occurs in Thorah township, extending from lake Simcoe for about 4 miles up Beaverton river. A brick and tile plant is operated by Mr. A. Snelgrove, near the river, about a mile east of the village. About 15 feet of bluish grey, rather massive, stoneless clay is exposed in the pit. It is underlain by boulder clay and overlain by yellow sand. The stoneless clay is very smooth and plastic and works well through a tile die. It burns to a very porous, light pink body at the lower temperatures, but when fully burned the body is light buff and although still very porous is sound and durable. The clay appears to be free from limestone particles and, if no lamination occur in the moulding, produces an excellent field drain-tile or building brick.

A thin layer of the surface clay is leached and the lime content so much reduced that it burns red, therefore a small amount of common red building brick are made, in addition to the buff brick.

Whitby. The clay worked for brick and tile is situated on the banks of Lyon brook, near the railway bridge, a short distance west of Whitby. The upper part is weathered and leached for a depth of 3 or 4 feet and is used for making red brick. The underclay is stratified grey to brownish and highly calcareous, burning to buff or cream colour.

Brick has been made for the past sixty years at this place and the red-burning clay near the plant is almost exhausted, but a similar clay is abundant in the adjoining property south of the railway. The brick plant was remodelled recently and a round down-draft kiln is used for burning drain-tile.

The underclay is a good tile material and provides sound ware of cream colour, very similar to that made at Beaverton. The tile-clay is underlain by boulder clay, and unless care be taken in excavating, some of the stony bottom clay is likely to be included with it, to the detriment of

the finished product. Trouble is caused by the irregularity of depth of the Iroquois tile-clay, as the men digging in the pits in many cases continue working down to the same level without regard to the rise and fall of the bottom stony clay (Figure 6).

There is an exposure of dark grey, stratified, stoneless clay (No. 775) on the east bank of Lyon brook about 200 yards below the railway bridge. The clay is underlain by yellow sand and overlain by stony clay similar to that found under the cream-burning tile-clay. The clay differs from any other in the district, burning to a dense red body at low temperatures, but becoming paler when burned higher; it does not turn to a buff colour. In quality and in its position at the bottom of the other glacial clays it resembles the interglacial clay worked for red brick on Greenwood avenue, Toronto.

Simcoe County, Eastern Part

Most of the eastern part of Simcoe county is underlain by limestone, but a fringe of granite gneiss borders on Muskoka. Some deposits of silt and fine sand along Trent Valley canal, about a mile north of Washago, have been derived wholly from the gneiss, and are free from lime particles. The silty clay burns to a good red colour and would be suitable for common building-brick made by the soft-mud process, but it is not plastic enough for drain-tile. Most of the stoneless clay in Simcoe is calcareous and burns to buff or cream colours, but carries a thin layer of red-burning clay on top. Some deposits near Georgian bay are red-burning clays throughout their entire thickness.

Penetanguishene. A deposit of stratified clay lies in a depression between two ridges of glacial drift, at a considerable height above the level of Georgian bay, near Penetanguishene. A good deal of this clay has been worked out, but a supply for a considerable number of years still remains. The stratified clay is 6 to 12 feet thick and overlies an uneven floor of gravel and boulder clay and is overlain by 2 to 3 feet of sand. Soft-mud, red building brick are made from a mixture of three parts clay to one part sand, and are among the best common red brick made in the province. With down-draft kilns, hard, dark red and purple, flashed brick similar to those made on Greenwood avenue, Toronto, could be produced, but the local business seems to demand only intermediate to light-red, uniform colours.

A clay deposit formerly worked at Midland for making brick is now abandoned. The clay is said to have contained scattered limestone pebbles, which spalled the brick. The clay deposit at Penetanguishene is free from that defect.

Wyebridge. Grey to reddish stratified clay is exposed along the Penetang road for about 3 miles near Wyebridge, but in some places is covered thickly with rusty sand. The clay occupies a depression through which Wye river flows, and probably extends south as far as Birch Junction, but the sand cover may be of considerable thickness there.

The clay is exposed in many places on the banks of Wye river and in gullies leading to the river, one of the best exposures being close to the old Grand Trunk railway, a mile south of Wyebridge station, where there is a nearly vertical section about 30 feet thick. The deposit is made up

of stratified layers of clay and silt of varying thickness. The silt and clay do not alternate as they do in so many deposits of this character, but certain parts of the deposit contain more silt than clay, and other layers, particularly the reddish or brownish ones, are highly plastic clay. The clay comes to the surface; but in many places is capped by a layer of sand of varying thickness.

Sample No. 770, of the upper 12 feet of this deposit, burned to a buff colour, contrary to expectations, although it is probable that the upper 2 or 3 feet will burn to red colours if used separately. The test brick and tile produced from this deposit were excellent, and the clay can be recommended as a convenient source of drain-tile for the surrounding farm lands.

Orillia North. There are two areas of stoneless clay in the southern part of this township, one extending along the shore of lake Couchiching for about 4 miles between concessions VIII and XI in a belt about half a mile wide; the other extending from the Canadian Pacific railway on concession V, to concession VII, and passing north of Hampshire mills. Sample No. 216, from the latter deposit (lot 13, concession VI), was found to be a dense-burning clay which would make excellent red-coloured drain-tile or, with a little sand, would make good brick.

Parry Sound District

No body of stoneless clay was found in the immediate vicinity of Parry Sound, but about 4 miles north deposits of reddish clay occur in depressions between rock ridges.

Thicker deposits near Nobel seem to have been deeply eroded and in some places are covered by sands. There is a patch of about 5 acres near the Canadian Pacific Railway station, underlain by this clay. Sample No. 246 was taken from a 4-foot section exposed farther south. This is a good dense-burning clay and is suitable for making red building brick or field drain-tile. Its working qualities are good and the shrinkage not unduly high, but the addition of a small quantity of sand would improve its drying qualities when made into brick.

The principal clay deposits in the district—in the valleys of Maganatawan and South rivers—were formerly worked for brickmaking at Burks Falls and Powassan. The clays there are characterized by inter-banded sand, so that the deposit yields a natural mixture of sandy clay, easily worked and dried, and suitable for common red building brick.

Muskoka District

The clays which occur as terraces in the valley of the Muskoka are worked for the manufacture of brick and tile at Huntsville and Bracebridge. The deposits consist of layers of reddish brown clay and rusty sands, with interlaminated ash-coloured silts, varying in depth from 12 to 20 feet.

These and the Parry Sound deposits are Algonquin clays; and due to the absence of limestone in the bedrock in this region, they are free from the limestone pebbles which are such a nuisance in other parts of the province. The burned colour is always red, and very good common building-brick are produced.

Chemical Analysis of Post-Glacial Clays in South-central Ontario

Red-burning Clays

Sample No.	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Lime CaO	Magnesia MgO	Potash K ₂ O	Soda Na ₂ O	Loss on ignition
43.....	59.48	17.48	7.38	2.60	3.32	2.96	1.74	3.82
44.....	66.14	14.80	5.50	1.76	1.50	2.19	1.33	6.56
47.....	57.88	18.46	7.20	2.86	1.95	3.22	1.46	6.64
51.....	61.78	16.03	6.16	3.37	2.28	2.38	1.95	5.50
45.....	63.28	17.20	6.26	2.82	1.60	3.14	1.85	4.30
46.....	58.97	18.10	7.30	2.84	2.50	2.40	2.12	5.90
57.....	64.44	15.26	5.96	3.65	1.78	3.20	2.52	2.92
26.....	63.00	15.15	6.28	3.48	2.67	3.11	2.64	3.63
67.....	65.42	16.06	5.44	3.20	2.31	3.06	1.90	2.87

Buff-burning Clays

41.....	53.22	14.03	5.21	11.08	0.61	3.44	1.01	11.87
27.....	34.48	9.11	3.71	23.33	4.83	1.76	0.90	22.30
270.....	47.50	13.66	4.44	15.58	0.80	1.60	2.82	12.94
256.....								
215.....	37.50	10.31	3.59	22.56	2.61	2.34	1.11	19.60
256.....	49.46	14.64	5.14	10.82	2.75	2.84	1.12	13.21

Analyses by Ontario Bureau of Mines, except No. 256 by Mines Branch, Ottawa.

43. Kingston, Frontenac co. Mouldy Bros.' brick-yard.

44. Kingston, Frontenac co. Mouldy Bros.' brick-yard.

47. Tweed, Hastings co.

51. Tweed, Hastings co., loamy clay.

45. Belleville, Hastings co., F. Lingham brick-yard, loamy clay.

46. Belleville, Hastings co. F. Lingham brick-yard.

57. Peterborough. Surface clay overlying 270, at Curtis brick-yard.

26. Bracebridge, Muskoka. Watson and Hutchinson brick-yard.

67. Powassan, Parry Sound. D. Clarke.

41. Picton, Prince Edward county, upper clay.

27. Picton, Prince Edward county, lower clay.

270. Peterborough, lower clay used for tile at Curtis brick-yard.

256. Bowmanville, Durham co., lower buff-burning clay.

215. Beaverton, Ontario co., used for tile by Beaverton Brick and Tile Company.

Table of Physical Tests of Post-Glacial Clays in South-central Ontario

Red-burning Clays

Sample No.	% Water of plasticity	% Drying shrinkage	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption
603.....	22	7	0	14	0	13	3	6
648.....	36	8	0	18	0	16	8	3
773.....	27	9	1	22	2	21	9	4
649.....	31	7	0	16	0	16	4	7
604.....	23	6	0	21	0	20	4	0
777.....	20	7	0	12	0	12	3	4
775.....	26	9	0	16	1	15	1	10
329.....	23	4	0	17	0	17	2	10
216.....	25	8	1	13	4	5	8	0
769.....	28	10	0	15	1	13	7	0
246.....	25	7	0	13	3	8	5	2
162.....	28	5	0	17	1	15	4	8

Buff-burning Clays

774.....	18	5	0	22	S.S.	25	0	22
270.....	20	4	S.S.	19	0	18	1	10
776.....	26	7	0	26	0	25	1	18
771.....	21	6	0	24	S.S.	29	S.S.	28
256.....	27	7	0	23	0	21	2	14
272.....	28	7	0	22	0	22	1	18
386.....	40	10	0	20	1	20	.....	.....
770.....	24	6	0	21	0	20	2	13
215.....	25	7	0	25	0	25	1	23

S.S. denotes slight swelling in firing.

603. Tweed, Hastings co., clay from brick-yard.

648. Madoc, Hastings co., clay from brick-yard.

773. Belleville, Hastings co., from cement works clay pit.

649. Foxboro, Hastings co., clay from brick-yard.

604. Lot 8, con. II, Rawdon tp., Hastings co., east of Stirling.

777. Drummonds, Peterborough co., surface clay.

775. Whitby, Ontario co., lower clay on Lyon brook.

329. Fells, Victoria co.

216. Lot 13, con. VI, Orillia North tp., Ontario co.

769. Penetanguishene, Simcoe co., clay from brick-yard.

246. Nobel, Parry Sound.

162. Huntsville, Parry Sound.

774. Welcome, Hope tp., Durham co.

270. Peterborough. Underclay from Curtis brick-yard.

776. Drummonds, Peterborough co., from cement clay pit.

771. Bowmanville, Durham co., underclay from brick-yard.

256. Bowmanville, Durham co., clay below 771.

272. Whitby, Ontario co., underclay from brick-yard.

386. Lot 24, con. VIII, Mara tp., Ontario co.

770. Wyebridge, Simcoe co. Average of 12 feet of stratified clay.

215. Beaverton, Ontario co.

CHAPTER IX

CLAYS OF THE INTERLAKE PENINSULA

The Interlake or Ontario peninsula lies between lake Erie and lake Huron, and lake Ontario forms its eastern border. This region is entirely underlain by Palæozoic rocks, comprising limestones, dolomites, shales, and sandstone. These rocks range in age from Devonian to Ordovician. No fire-clays, or vitrifying clays or shales have been found in them.

Two shale formations in the Ordovician, the Lorraine and Queenston—Hudson River and Medina—are thick and widespread, and are used at various points for the manufacture of structural clay wares. The Cabot Head shale, which overlies the Queenston shale, is suitable for the manufacture of clay products, but it has not been used up to the present.

Unlike the hard, crystalline rocks of the Precambrian plateau, the comparatively soft rocks in the peninsula break down readily into clay by weathering, or were ground by the glacier to a clay-like consistency. Hence, clay deposits of Glacial and post-Glacial age are more abundant here than elsewhere in the province. The heaviest deposits of stoneless clay, and the most accessible, are near the shores of the Great Lakes, and although clay deposits occur inland at the higher levels they are never so thick nor so extensive as those near the lakes.

Owing to the prevalence of limestone in the bedrock, the surface clays, which are mostly Glacial, or post-Glacial, deposits contain a high percentage of carbonate of lime. The lime content is as a rule large enough to produce a buff colour in the burned ware. When the lime is present in a finely divided state it is harmless, but limestone in lumps, or even small particles, is seriously detrimental to burned wares. The methods commonly used to overcome the difficulty of limestone pebbles have been described in previous pages.

In many places, the lime is leached by weathering from the upper part of the clay deposits, and the leached zone, where it is free from pebbles, burns to a strong red and is worked for brick and tile; but as a rule the amount of red-burning clay is small compared with the mass of buff-burning clay.

Silt is the only material available in some localities, and as this has a very low plasticity it can only be used for soft-mud brick. The best way to work the silt is in a mixture with plastic clay.

Parts of the area underlain by the Lorraine and Queenston shales have only a very thin cover of drift, or none at all. In these places the shales, for a depth of a few feet, are weathered and softened into clay. These weathered shales, or residual clays, are the source of the sewer-pipe clay, and, being very plastic, are mixed with the underlying shale to improve its working qualities.

The examination of this area is incomplete, but enough examples are given in the following pages to cover all the kinds of clay likely to be found. The Glacial and post-Glacial clays are grouped according to their proximity to one of the great lakes, and the inland and higher level clays follow. The shale deposits are described in a separate section.

CLAYS NEAR LAKE ERIE

The greatest thickness of clay exposed is in the high banks on the shore of lake Erie between Port Dover and Port Talbot. The banks, which rise 150 feet above the level of the lake in places, are composed almost entirely of glacial clay. The lower part of the clay carries stones and pebbles, but is not so stony as boulder clay elsewhere. The upper part carries less stones and in some places is fairly free from them, and is used for making brick and tile. The clay, in some places, is banded in the upper layers with silt and clay, or shows lenses of silt, and some gravel embedded in massive clay. The deposit as a whole is highly calcareous and many of

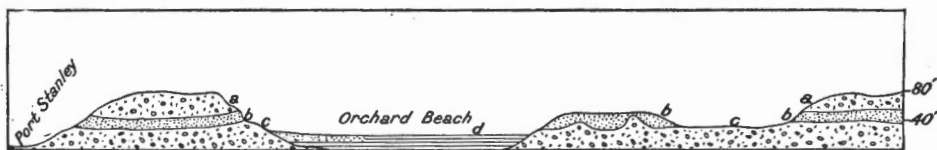


Figure 7. Section on shore of lake Erie, east of Port Stanley. a, upper boulder clay; b, sand; c, lower boulder clay; d, stratified clay, peat, and marl.

the pebbles are limestone, so that the clay has to be excavated cautiously. In some places there is a bed of sand between the upper and lower clay (Figure 7), and sand mostly overlies the upper clay.

Norfolk County

Port Dover. The Erie Clay Products company manufactures red and buff brick, hollow building blocks, and field drain-tile at Port Dover. A section just east of the wharf shows about 40 feet of stratified clays and silts, the upper 8 feet being weathered yellowish, whereas the lower part is grey. A remarkable feature of the deposit is the crumpling of a part of the clay and silt layers for a width of a few feet, with horizontal layers above and below. There are very few stones in this part of the deposit and only a few small pebbles are found on the sand beach at the base of the clay cliff. A short distance east of the wharf a stony, blue, massive boulder clay is exposed for a foot or two at the base of the cliff. The clay worked at the brick plant has a weathered upper part, which is more plastic than the lower part, and is red burning. It is used for hollow blocks and large drain-tile, because it is stiffer and after coming through the die holds its shape better than the lower clay. The red clay requires to be wetted before manufacture so as to slake it thoroughly, otherwise it will laminate and tear in the die.

Simcoe. The cuttings on the Lake Erie and Northern railway near Simcoe reveal materials entirely different from those exposed on the shore of lake Erie. A confused arrangement of sand, gravel, and boulder clay constitutes the greater part of the sections, and very little stoneless clay is present. In some places a deposit of stratified sand and silt reaches a thickness of 12 feet. It contains layers of reddish clay from $\frac{1}{2}$ -inch to 2 inches in thickness at intervals of 6 inches, but the proportion of sand to clay is too large to allow of its use.

A small brick and tile plant at Simcoe uses rather sandy clay which contains concretions and limestone pebbles, and is not a very desirable material for the manufacture of clay products.

Port Rowan. The following is a generalized section of the clay cliffs on the shore of lake Erie between Port Rowan and St. Williams.

	Variable thickness
	Feet
Yellow sand	
Grey, laminated and contorted clay and silt, becoming more massive on top, the whole containing very few pebbles.....	30
Sand with streaks of gravel.....	3
Massive boulder clay, quite stony.....	20
Stratified sand (not always present).....	2
Massive, compact, gritty, boulder clay, to level of lake Erie.....	30

The clay in the pit at the brick plant at Port Rowan consists of 4 feet of stratified clay and silt underlain by 6 feet of compact, massive, stoneless clay, which breaks down into fragments of road-metal size. This is the clay used for drain-tile and hollow blocks, as the upper stratified beds are in many places too sandy. A sample of the massive clay, No. 262, was tested in the laboratory. The clay is prepared at the plant by passing through a pair of rolls and a long pug-mill before entering the tile machine, and a smooth, hard, buff-coloured tile is produced from it.

Elgin County

Port Stanley. The sections exposed in the clay cliffs facing lake Erie to the east and west of Port Stanley differ from those farther east, as the clays are all massive and contain little or no stratified material. Furthermore, the upper and lower boulder clay sheets are separated by a considerable thickness of sand (Figure 7). The cliffs reach a height of about 80 feet just east of the wharf at Port Stanley. The lower boulder clay has the prevailing grey colour, with a purple tone in places. It is very hard, tough, and gritty and carries fragments of brown shale as well as a few large, glaciated boulders. There is 20 feet of sand in places between the boulder clays. The sand is fine-grained, grey, and has an occasional clay layer an inch or two in thickness. The upper boulder clay is oxidized to a yellow colour to a depth from 6 to 12 feet, and shows pressure stratification in places, but is mostly massive and carries scattered pebbles and shale fragments.

There is a series of recent deposits in a depression about 1,000 feet wide between two boulder clay bluffs at Orchard Beach, a short distance east of Port Stanley. The deposits are from 10 to 15 feet thick and consist of beds of sand, yellowish sandy clay, grey clay with layers of peat, and marl. There is a layer of peat about 2 feet thick, containing sticks and branches of trees, at the bottom of the deposits, and there are numerous freshwater fossils in the marly and peaty beds.

Similar deposits occur about a mile west of Port Stanley, but at an elevation of 35 feet above lake Erie. The section at that point consists of 2½ feet of yellow, massive, sandy clay underlain by 2 feet of grey, peaty clay containing driftwood, below which is a layer of stream gravels about 1 foot thick. These deposits rest on the eroded surface of the lower boulder clay.

Brick and tile were formerly made at Port Stanley, but none has been produced in recent years. The upper boulder clay, where it contains few or no pebbles, is used for brick and drain-tile. The clays in the recent deposits described above are quite free from pebbles and could be used for brickmaking, but the quantity is too small.

St. Thomas. The material worked for brickmaking at St. Thomas is mostly a massive clay, with irregular inclusions of sand and silt, but fairly free from pebbles. It has a reddish tone in the upper part and is bluish below. Balls of sand, some a foot in diameter, are embedded in the clay. The clay is worked to a depth of 12 feet in places, which includes about a foot of red-burning clay on top, below the thin cover of sand. Wire-cut brick, hollow building block, and field drain-tile of buff colour are made.

Clay similar to that worked at the brick-yards is abundant in the neighbourhood, but is not all so free from pebbles and lime concretions. It is worked at Southwold and Orwell, at which places there is some stratified clay, but it is mostly massive, brown clay, with sand and silt inclusions, and fairly free from pebbles and concretions.

The clay, in general, has good working and drying qualities, so that it does well for making hollow ware. The underburned wares in the bottom of the kiln are pink, but the best fully-burned ware has a light sulphur colour and a clear sounding ring when struck. The principal defects are auger lamination, which especially affects the end-cut brick, whereas the drain-tile do not appear to suffer. The main trouble is occasional limestone fragments which spall the surface. This trouble appears to be worst in the lower part of the deposits.

Clay of similar character is worked at a brick and tile plant at Middlemiss in Middlesex county, and makes the same kind of wares.

These clays occur in a narrow band about 25 miles long, from 8 to 10 miles north of lake Erie, but they appear to be quite different from the clay on the high banks along the shore. The numerous brick-yards in Kent, the adjoining county on the east, have never encountered buff-burning clays similar to those in Elgin county.

Kent and Essex Counties

The clay banks decline in height and become more complex in character toward the western end of lake Erie. A short distance west of Kingsville the following section was observed on the lake shore.

	Feet
Yellow sand.....	4.6
Grey sand.....	5.0
Massive, grey clay with gritty particles.....	6.0
Stratified clay fairly free from pebbles.....	0.6
Massive clay fairly free from pebbles.....	2.6
Grey, laminated, silty clay with small pebbles.....	3.0
Reddish, massive clay with sand lenses and pebbles.....	6.0
Massive, grey clay with numerous pebbles and cobblestones.....	8.0

The upper clay, beneath the grey sand, appears to be like the brick-clay used elsewhere in the district. It is difficult, however, to compare the clay beds in this section with clays found inland on account of the level character of the land, and the lack of deep cuttings on stream banks or railways. At Hill Bros.' brick and tile plant at Essex, about 4 feet of

stiff, red-burning clay is used. It has no overburden except the sod, which is stripped. This clay contains streaks of sand and an occasional thin layer of pebbles. Pebbles are also scattered through the mass of clay, which is workable only when they are eliminated. Below the red-burning clay is a deposit of very stony, highly calcareous clay which cannot be used. The sand overlying the clays appears to be mostly confined to a narrow strip along the lake shore.

There are several brick and tile plants in Essex and Kent counties, but in most cases only the top clay is used. The clay is dug to a depth of only 12 to 18 inches after stripping the sod. It is very thoroughly leached from lime to this depth; even the small limestone pebbles have been dissolved, so that clayworkers by confining their operations to this depth have no trouble from the popping of lime in the burned wares. The disadvantage of using such a thin layer of clay is, of course, the quickly increasing hauling distance. On the other hand, the land can be returned to cultivation after the brick-clay is stripped off.

Flood-plain, or Recent clay is found along the banks in the lower part of Thames river, and is worked at Chatham for brick and tile.

	Feet
Loamy clay with sand layers (red burning).....	3 to 4
Blue-grey, stratified, rather stiff clay (buff burning).....	3
Sand and fine gravel.....	2

The clay does not extend very far from the banks of the river, as the flood-plain on which it was laid down was narrow.

The bottom blue clay contains peat layers and driftwood; fossil freshwater shells are found in both the upper and lower clay. The sand beds overlie boulder clay, which continues to bedrock, a distance of 70 feet. The red colour obtained in burning the upper clay is poor compared with the strong red colour of the thin layer of leached clay on top of the boulder clay at Kingsville, Essex, and other points. A moulding sand which burns to a good red colour is used for facing the brick at Chatham to improve the defective colour.

The drain-tile are made from a mixture of the top and bottom clays and some, in consequence, are mottled in colour. The tile are sound and free from defects and, being used underground, the colour is immaterial.

CLAYS NEAR LAKE HURON

The land bordering lake Huron is composed for the most part of a thick sheet of boulder clay, and bedrock is rarely seen. The clay is similar to that on the shores of lake Erie, but most of the sections show massive, stony clay up to 100 feet, without the sand partings, seen in so many places along the lake. The boulder clay on the shore extends inland for some distance. Its surface is, as a rule, flat, and it forms the soil over large areas. In some places the top is a brown, or reddish, plastic clay, containing few stones, which forms the best soil. In other places, it is tough and gritty and does not disintegrate so readily under cultivation and consequently forms a poorer soil.

The boulder clay near lake Huron is apparently in no place quite free from limestone pebbles and would not be a safe material for brick and tile. The only materials suitable for brickmaking are the comparatively small areas of stoneless, stratified clay, which were laid down after the boulder clay. A few examples of this clay will now be described.

Huron County

Benmiller. A small plant making brick and tile obtains clay from a little depression in Colborne township. The clay deposit is about 3 feet thick and contains some layers of sand. A swamp evidently covered the clay at one time, for the upper part has the stiff, waxy feel characteristic of swamp clays. The clay was evidently derived in the first place from the boulder clay in the surrounding hills and collected in a pond which became a swamp and later was drained. A good, hard, smooth, light buff-coloured tile is produced, but a few small lime pebbles disfigure some of the tile. Similar deposits are found at various places in the peninsula, but are never extensive nor thick.

The character of the boulder clay below the stratified clay can be seen to advantage in the banks of Maitland river, and on the lake shore at Goderich. It is a solid, massive, stony clay about 100 feet thick, none of which appears to be clean enough for brickmaking.

Crediton. Clays suitable for brick and tile are found in an area less than $\frac{1}{4}$ mile wide and 1 to 2 miles long, on the banks of Ausable river, near Crediton. Outside this small area, the clays are too stony for use.

The clay exposed in the pits of the three plants operating in this area shows some variation, being stratified in some places and massive in others. Some of the sections show a confused arrangement of sand lenses embedded in a massive, stiff, reddish clay, containing scattered pebbles. The pits are worked to a depth of 7 to 9 feet, but there is 3 feet of clay still lower which cannot be excavated on account of lack of drainage. Most of the upper part of the clay (Sample No. 250), consists of 2 to 3 feet of waxy, grey clay, stiff and hard to work; it does not mix well with the lower clay, as many of the lumps remain unslaked.

Massive, reddish clay, containing streaks and pockets of sand and a few small pebbles, occurs in the middle part of the bank (Plate VI A). This clay breaks down more easily when wet, and is a far better material to work than the upper part. It burns to a porous, cream-coloured body, and requires firing to a high temperature to produce strong wares. It is one of the most refractory surface clays in Ontario, not being affected when raised to the softening point of cone 5 (2246 degrees F.). This property, however, is of no value because the clay has a high lime content and will fuse suddenly into a slag soon after vitrification. The chemical composition of the clay (No. 251), is given in the table of analyses.

The lower part of the bank is grey, silty clay containing an excessive amount of lime. It also contains sand layers and a few pebbles. It is greasy to the feel when wet, but lacks plasticity and tensile strength and consequently does not hold its shape after coming from the tile die. It burns to a cream-coloured, very porous body, that is soft enough to be cut with a knife. Some of it is used in the tile mixture because it helps the other clays to slip smoothly through the die.

The northern part of the deposit, as shown at Kerr's plant, is well stratified, with alternate layers of sand and clay, and contains less pebbles than are in the southern part. Many of these pebbles are not limestone and do not injure the burned tile by popping, but occasional defects in the tile are traceable to limestone particles.

The brick and tile are dried under covered sheds, and are burned in round, down-draft kilns, cordwood being used for fuel. The burned products are a good grade of buff drain-tile. The mixture of clays produces a buff colour, and the upper clay, if used alone, burns red, but the high content of lime in the lower clay overpowers the red-burning quality of the top clay. If the top clay be not thoroughly broken down and well mixed it is liable to appear as red lumps or streaks in a buff brick.

Bruce County

The western part of Bruce county is quite flat and the streams have shallow trenches except near the lake, where they are deeply incised. The surface is dissected by Saugeen river and its tributaries, so that it has a rolling aspect. The county is wholly underlain by glacial drift,

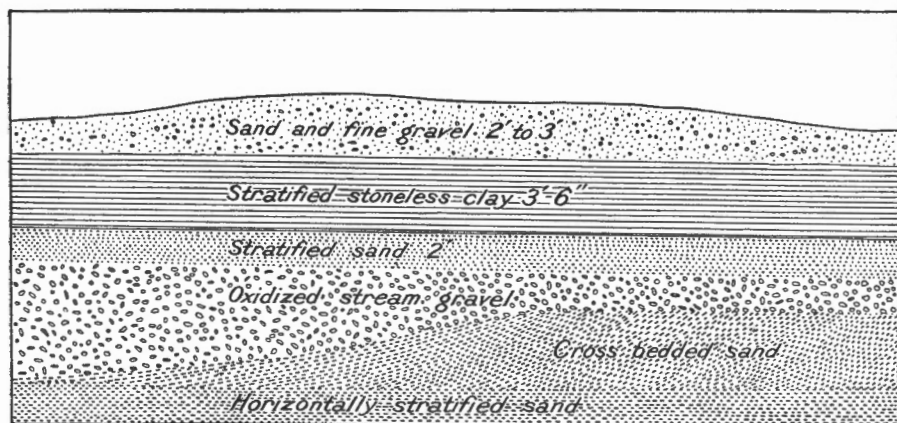


Figure 8. Section of sands, gravels, and brick-clay at old pit in brick-yard, Kincardine, Bruce county.

which varies in thickness from a few feet in the northern part to over 200 feet in the south. The principal member of the drift is a sheet of tough, brownish, boulder clay which covers about three-fourths of the total area of cultivated land. In some places, the till sheet is replaced by stratified stoneless clay, suitable for brick and tile, but this clay occurs only in small patches, that were laid down in depressions in the boulder clay in Algonquin time.

Kincardine. Stratified, stoneless clay suitable for brick and tile occurs sparingly near Kincardine, and is associated with, and in some places overlain by, deposits of fluviatile sand and gravel (Figure 8). The other superficial deposits lying over and under the clay are used for building sand, concrete gravel, and road materials. This occurrence shows that brick-clay is in some places overlain and concealed by sand, or gravel.

Near the bridge over Pine river, 7 miles south of Kincardine, 8 feet of yellowish grey, stratified, silty clay, is underlain by 2 feet of sand and gravel, which rests on boulder clay. Several small deposits of stratified clay of this character near lake Huron were laid down in depressions and

ancient stream valleys when the level of the Great Lakes was more than 100 feet higher than at present. These clays also show the fluctuations to which the water-level was subject in Glacial and post-Glacial times. The valley was first carved in the boulder clay by a stream, then the lake water rose, and flooded the valley, and clays and silts were laid down. Finally, the lake-level fell and the stream, becoming active again, cut out much of the clay and silt and sunk its bed 30 feet in the underlying boulder clay.

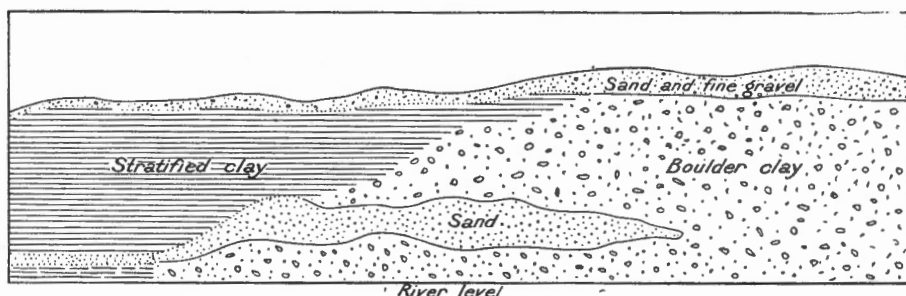


Figure 9. Sketch showing arrangement of clays and sands in 50-foot bank on Saugeen river, between Port Elgin and Paisley, Bruce county.

Port Elgin. The clay used at Port Elgin for making brick occurs on the bank of Mill creek. The deposit consists of about 40 feet of yellowish, silty clay interlaminated with silt and sand layers. It contains a few fossil freshwater shells, but no pebbles or concretions were observed. On the west side of the creek, the clay is overlain by gravels of the Algonquin beach, but on the east side where the brick plant is situated (Figure 9), there is no overburden.

The clay is not suitable for drain-tile, being too silty and not strong enough to hold its shape after coming from the die. Strong clay from about a mile south of the town is mixed with the silty clay for tile, but the chief product is soft-mud brick made from the silty clay alone. The clay burns to a light buff or cream colour and the burned brick are very porous and light in weight. Although the brick have the highest water absorption of any made in Ontario they have (No. 259), when well burned, sufficient strength and freedom from defects, as is testified by their appearance in buildings that have stood for many years in a trying climate.

Saugeen river near Port Elgin has cut a deep trench in the glacial drift and exposes sections of clays and sands. There are two principal members of the clay series, a brownish, massive boulder clay carrying pebbles and boulders; and stratified, mostly stoneless, clay more plastic than the clay used for brickmaking at Mill creek.

These clays are not arranged in stratigraphical sequence, but are in irregular or lens-shaped masses. In places the boulder clay forms the entire bank of the river, or is overlain by a layer of yellow sand. In other places there is an upward transition from massive, stony clay to stoneless, stratified clay. About 3 miles above the mouth of Mill creek a lens of sand about 10 feet thick and 1,000 feet long is included in the clays on the east bank (Figure 9).

The stratified clay is suitable for buff building brick and field drain-tile. In some places it is abundant, at others it comes in contact with the stony clay, which is unworkable.

Paisley. The high bank on the east side of Saugeen river at Paisley contains about 50 feet of stratified, brownish clay underlain by massive clay containing pebbles. The upper clay, worked for brick and tile, consists of alternating layers of brown clay and thinner layers of yellowish silt, but the peculiarity of this deposit is the lens-shaped layers of sand, half an inch thick and 3 or 4 inches long, scattered through it.

The drain-tile made at Paisley are of a light buff colour, smooth and hard, with a good ring when struck. The lime specks in the brick and tile are not due to the clay, but to the added sand. The top of the clay is weathered, and the lime leached, so that it can be used for red building brick, but buff brick are also made from the lower clay. The brick are made by the stiff-mud process, with end cut.

Another good section of the clays is seen on the banks of the Saugeen near the Fair grounds. A lens-shaped mass of stony clay rises 20 feet above the river, and above this is 75 feet of reddish brown, stratified clay, stoneless except for a few scattered pebbles in the lower 5 feet. On the opposite side of the river the whole bank is composed of boulder clay, so that although there is a great thickness of tile clay its horizontal extension is not great.

The sections obtained here and at Port Elgin show the same irregularity, viz., alternation of stony massive clay and stoneless stratified clay on the surface. The stratified clay does not always rest on boulder clay, but overlies sand as shown in Figure 9. On the bank of Willow creek, near Paisley, the stratified clay was observed overlying a great thickness of fluvioglacial gravels and sand.

Walkerton. The best section of the glacial drift near Walkerton occurs in a high bank at the bend of Saugeen river. There is more complexity in the arrangement of the materials of the drift at this point than in any of the sections seen downstream and described above, as the following section from top to bottom shows:

	Feet
1. Sands and gravels—morainic.....	18
2. Yellow, stoneless, stratified, silty clay.....	10
3. Massive, brownish, compact, gritty clay with pebbles.....	16
4. Fine-grained, grey, stratified, brown and grey clay and silt.....	10
5. Stratified sand and silt.....	2
6. Massive, brownish, compact, gritty clay.....	5
7. Stratified sand.....	3
8. Massive boulder clay, grey below and yellow above.....	35

99

No. 2 is worked for brick and tile in a small plant on the bank. This clay has fairly good working and drying properties, and when fully burned is hard and of a light buff colour, but the underburned ware is pink. The brick, which are pink, are not too soft, as is the case in so many underburned limy clays, but are hard and have a good ring. The brick have clean faces with sharp edges and look like dry-pressed brick when laid in a building. The principal defects in the brick are a few limestone pebbles which fall from the overlying gravels and become mixed with the clay.

The lower stratified clay, No. 4, in the section, and No. 225 in the table of physical tests, is also exposed on the Canadian Pacific railway about half a mile east of Walkerton. The overlying deposits are eroded at this point and very little overburden remains, so that the clay is accessible. It consists of thinly-bedded, brown, calcareous clay in layers seldom exceeding an inch in thickness, separated by partings of drab silt, and is free from stones or coarse grit. This clay has good plasticity and working qualities and dries readily. It burns to a rather soft, very porous, buff-coloured body, and the sample tile made from it were not nearly so good as those made at Paisley. This clay has no fire shrinkage; but, on the contrary, shows a slight increase in volume after burning. Other highly calcareous clays, like that at Port Elgin, do this. The upper foot or so of the clays in this district is leached, as usual, and burns to a red colour.

Red brick and hollow building blocks were formerly made at a plant near the Grand Trunk Railway station, but the clay within reach is exhausted.

CLAYS IN GREY COUNTY NEAR GEORGIAN BAY

Brick plants have been operated at Owen Sound, Meaford, Thornbury, and Oxmead, in former years, but at present only one plant, the Owen Sound Brick Company, is manufacturing. The clay at Owen Sound is situated on a broad terrace about 100 feet above the lake-level. It is rather sandy in texture and vertically jointed, with a rusty grey colour. The deposit consists of 2 to 3 feet of red-burning clay underlain by 2 feet of buff-burning material, but both kinds are mixed for brickmaking. The bricks are light red when underburned, but turn to a peculiar yellowish brown when hard burned. The moulding sand which sticks to the face of the brick burns to a fine deep red. The faces of the brick that are flashed have a deep red centre and a brown rim, which gives one of the best colour effects seen on any brick in the province.

According to Mr. M. B. Baker the old brick-yards at Owen Sound got their clay from a pre-Glacial gorge in the Medina and Clinton formations, but the clays in the gorge are more sandy than those on the terraces.¹

In general, the clays around this part of Georgian bay are not found in very extensive or very thick deposits. Most of them burn to red colours and make good, hard building brick. Buff-burning clay was used at Thornbury for making drain-tile, and the overlying clay was made up into red brick.

Most of the clay on the terraces and slopes of the escarpment between Thornbury and Meaford is quite different from that used in brickmaking, as the latter was probably laid down in glacial lake Algonquin, whereas the clay on the slopes is the weathered phase of the shales of the escarpment. The clay that overlies the Queenston red shale burns to a buff colour, but the clay on the lower slopes overlying dark grey Lorraine or Eden shales is red burning. These clays are more plastic and have a higher shrinkage than the underlying shales, but a mixture of the clays and shales would be suitable for hollow building blocks or fireproofing.

¹ Ont. Bureau of Mines, vol. XV, pt. II, p. 66.

The large brick plant at Meaford used only Lorraine shale for brick-making, but a larger range and colour of products were made by using the weathered Queenston shale which lies above the Lorraine shale, within easy reach.

CLAYS NEAR LAKE ONTARIO

Lincoln County

Port Weller. The trench excavated in 1913-14 for the new Welland canal between Port Weller and Thorold was mostly in Pleistocene deposits and shows the character of the glacial drift in that part of the county.

A vertical section of about 50 feet, near Port Weller, shows a lower, massive, reddish clay containing many pebbles and fragments of red shale; alternating stratified beds and massive stony beds; and an upper part of yellowish, massive, partly stratified, sandy clay, less strong than the lower clays. The upper 4 feet of the bank is composed of later, stratified, sandy and silty clay, and in some places contains a layer of peat at the base. The upper clay seemed to carry too much sand to be used as a brick-clay, and the lower part is too stony. Queenston red shale is exposed at the bottom of the canal trench, and the overlying boulder clay is mostly derived from it.

Homer. A large patch of fine and coarse gravels and sands overlies clay at Homer. Large quantities of these gravels are shipped to St. Catharines for use in construction work, and as the gravels are stripped the clay is exposed. The clay is blue-grey, comparatively free from stone, and extremely tough and compact, but plastic. Where the gravels are absent the overlying material consists of 3 to 4 feet of yellowish, loamy sand roughly stratified and in some cases containing enough clay to be used for brickmaking. A layer of branches of wood, leaves, and beech mast occurs between the stiff, blue bottom clay and the overlying sandy clay. A mixture of the upper and lower clay would be suitable for brick-making. In places, the covering material is thin and in some places the stiff blue clay outcrops at the surface.

Similar clay was seen in the bank of the ship canal about 2 miles south of Homer, and a small sample, No. 261, was collected for testing, as it was free from pebbles. The clay is stiff and rather hard to work by hand, but would work well in a machine. The shrinkage in drying is low for such a stiff, plastic variety of clay. It burns to a hard red body, but the colour is obscured by yellow scum. The clay is similar in many respects to that worked at St. Catharines for brick and tile.

Thorold. The drift deposits near Thorold are very irregular and complex, and sections vary considerably within short distances.

Near the crossing of the electric railway the following materials are exposed:

	Feet
Brown, sandy clay.....	2
Massive, blue-grey clay.....	3
Stratified silts and clays, grey and a few brownish.....	10
Massive, compact boulder clay.....	6

The banding in the stratified clays is irregular but pronounced, and they also contain blebs of clay or shale scattered through them. It is a red-burning brick-clay. About 800 feet from the above section, the entire bank consists of massive clay. About 200 feet farther north, a 50-foot section near Peter Street bridge shows a ledge of limestone at the bottom of the cutting, overlain by a mass of gravels and sand in one place and by roughly stratified till carrying angular blocks of limestone nearby. The till or boulder clay sheet comes almost to the surface, and is less stony toward the top. The top of the stony clay is oxidized and leached for a depth of about 2 feet.

St. Catharines. The clay used for brick and tile at St. Catharines is similar to that found under the gravels near Homer. The section exposed in the pit at Paxton and Bray's brick-yard shows blue-grey, stiff, massive clay with vertical joints. It contains some small and a few large pebbles. The clay is very hard in dry weather, but when passed through rolls and pug-mill, with water added, it breaks down quickly into a fairly smooth paste. The rolls are conical, and expel most of the pebbles. A good, hard, red building brick is produced by the soft-mud process, the burning being done in coal-fired case kilns. The principal defect is a yellow scum that obscures the colour of the faces. The same defect is present in the clay near Homer, which was tested in the laboratory, but can be cured by the addition of a small amount of barium carbonate.

The clay pit in an abandoned plant in a ravine about half a mile south of Paxton and Bray's brick-yard shows similar material, but containing far more pebbles.

Jordan. About 7 miles west of St. Catharines, in the village of Jordan, a small stream coming down from the Niagara escarpment has cut a deep trench in the glacial drift deposits bordering lake Ontario. The section exposed consists of 15 feet of stratified clay, underlain by 3 feet of fine gravel and sand, below which is 3 feet of stratified clay underlain by 5 feet of sand, gravel, and boulders, resting on boulder clay. The boulder clay is excavated by the stream to a depth of 30 feet and a layer of sand lies on top of the stratified clay. The upper stratified clay, although free from stone, contains numerous concretions and is weathered so much that it probably burns to a red colour. Sample No. 254, from a lower part of the bank, was tested and found to be an excellent buff-burning brick and tile clay. It is very similar to the bottom part of the clay in the brick-yard on Ancaster road near Hamilton, which is used for making buff brick.

CLAYS NEAR LONDON

The superficial deposits in the London district are composed mostly of sand, gravel, and boulder clay. Borings made for water encounter bedrock at a depth of about 100 feet, but no rock outcrops. Stoneless clay suitable for the manufacture of brick and tile is sparingly distributed and appears to occur only near the banks of Thames river, or on its tributaries.

The deposits are not very uniform. They mostly consist of alternating beds of stiff clay, and silty clay and sand beds. There is a prevalent bed of stiff-joint clay, 3 to 5 feet thick, in the upper part of the stratified

deposits, and this, taken with the sand and silt and lean clay in the lower parts, forms a suitable mixture for brickmaking, or the stiff clay can be worked alone for the manufacture of field drain-tile. Deposits that lack the band of stiff, highly plastic clay are only suitable for making soft-mud brick, as they lack the plasticity and tensile strength in the raw state which is necessary for making hollow ware. In some places several feet of gravel overlie the brick-clay, but this can be stripped and sold for road material.

All the clays of the district are light buff or sulphur coloured when fully burned, but in some cases there is a foot or two of red-burning clay at the surface. Small, thin patches of red-burning clay occur at some places, and one of them, on lot 22, concession I, Westminster township, was used on a small scale for the manufacture of flower-pots, but none of them can be relied upon for a large production.

The principal product is soft-mud, building brick, but wire-cut brick and field drain-tile are also made. Most of the plants use circular, down-draft kilns for burning both brick and tile. London is built principally of buff brick made in the local plants, and any red-coloured face-brick used in buildings is as a rule imported. The local buff brick are mostly well made and burned, and provide an excellent and durable building material, but the desire for variety of colour has led to a large increase in the use of imported brick in recent years.

Waide's Brick-yard. The following section in Waide's brick-yard at the north end of Adelaide street, illustrates the uneven character of the material used in the London district:

	Feet
Gravel.....	3 to 6
Roughly stratified and jointed, stiff, reddish clay.....	2 to 3
Fine, yellow sand, silt, and silty clay, in bands.....	3
Stratified, yellow clay interlaminated with silt.....	3
Grey sand.....	1 to 2
Stratified, grey clay in thick layers.....	8 to 10

The amount of sand and silt in this face is not excessive, for making brick, but some of the sand is discarded for tile making.

McLoughlin's Brick-yard. Adjoining Waide's yard to the northwest and at a lower level, clay beds are worked, which represent the lower part of the London clay. It is a bluish grey, stratified clay, interbedded with a few layers of sand, 6 to 9 inches thick. A clay face of about 10 feet is worked, and the beds exposed show an unusual arrangement, being inclined at a considerable angle from the horizontal.

Cawse Brick-yard. This plant is situated on the Pipe Line road on lot 33, broken front concession, Westminster township, Middlesex county. The clay on the west side of the road is exposed in the pits for a depth of 8 or 10 feet, and includes stratified clay and fine sand. The clay in the upper 5 feet is weathered brownish and the sands are yellow, but the lower part is blue-grey. The clay layers vary from less than an inch to 6 inches in thickness, but the sand layers are mostly thinner. Some of the clay layers contain pellets of sand up to several inches in diameter.

McGrenere Brick-yard. The pit at this plant is situated on a river terrace, and shows a face of about 12 feet of bluish grey, stratified silt and clay, overlain by 2 or 3 feet of sandy gravel. This clay, owing to its silty character, works easily and dries quickly without cracking. The brick are burned in round, down-draft kilns and many of those from the upper part of the kiln, which get the most heat, are crazed and brittle on account of the high content of sand and silt.

CLAYS NEAR BRANTFORD

The greater part of Brant county is underlain by sand, gravel, and boulder clay, and stoneless clay suitable for the manufacture of brick and tile is of rare occurrence. The only place where brick and tile are made is at Brantford. Red, soft-mud brick made from the surface clay are the principal product, and were extensively used in the city buildings. An old brick-yard at Mohawk park near the east end of Colborne street produced only cream or buff-coloured brick, and the site was abandoned more than 12 years ago.

The Ideal Brick and Tile Company's plant on Stanley street, near the old Grand Trunk railway, is a modern plant with three multiple-stack circular kilns and steam-drying sheds. The clay deposit consists of from 2 to 3 feet of loamy, red-burning clay, overlying brownish, laminated, and massive clay which burns to a buff colour and is used for making drain-tile.

The clay deposits near Brantford are very irregular, and the older yards which used only the surface clay had considerable difficulty in obtaining a proper brick mixture, as the surface material varied from sandy loam to strong clay. There is a layer of lime concretions just below the thin layer of upper clay, but the clay gatherers are careful not to take any of them as they are detrimental to the finished brick. In some places there is a sufficient quantity of stoneless, buff-burning clay below the concretions to be used for tile or brick, but the older plants, devoted to making red stock brick, did not use it. The practice in using the surface clay was to spread each kind in alternate layers close to the brick machine until a pile sufficient for the season's work was accumulated. The clay was sliced vertically and put through the machine without preliminary grinding, for the weathering has rendered the stiff clay as easily worked as the loam. The buff-burning underclay at Brantford burns to a good, dense body and produces an excellent drain-tile, but unfortunately it is not uniform in character and at some places it carries scattered concretions, or pebbles, and at others is too much charged with silt, entailing careful selection to ensure good results.

One of the thickest deposits of stratified clay inland from the Great Lakes occurs at Cainsville, on Grand river. It is about 75 feet thick and consists in the lower part of grey clay layers alternating with lighter-coloured silt. This passes upward into grey, massive, plastic, stoneless clay, but higher up is stratified and overlain by 1 to 3 feet of yellow sand. The clay is apparently stoneless throughout, and no concretions were observed. The clay worked for so many years in the old brick-yard at Mohawk park in Brantford was evidently an extension of this deposit, for the material at both places seems to be the same. This clay was laid down in a lake which occupied a part of the old valley of Grand river. The deposit was mainly confined to the river valley.

CLAYS AND SHALES NEAR HAMILTON

STRATIFIED CLAYS

The surface clays used for brickmaking near Hamilton are confined to the lower Dundas valley, and lie behind the high gravel bar that extends north through Dundurn park and the cemetery. These clays were laid down in glacial lake Iroquois, and their upper surface now stands about 80 feet above lake Ontario.

A good deal of the clay has been cut away by the streams flowing down the valley, but there are still considerable areas along the Ancaster road. The older brick plants are situated a short distance west of Sydney street, but some newer plants are farther west, along the Ancaster road. The clay varies from 6 to 18 feet in thickness. It is mostly underlain by sands and gravels, is free from pebbles, and carries no overburden.

The upper 4 feet of the deposit is red, but on close inspection is seen to consist of thin layers of alternating red and yellowish grey layers. This part is rather stiff in working and has high plasticity; it burns to a good, strong, red colour but is hard to handle during the drying stage, as it is liable to check if the drying be hurried. The bottom 9 feet of the deposit is a more silty clay of yellowish grey colour, that is easily worked, stands fast drying at 150 to 200 degrees F. without checking, and burns to a buff colour. Between the top and bottom clay there is about 2 feet that burns to a porous, salmon-coloured body, and is as a rule included with the upper 4 feet for making red brick.

The following tests of two samples taken from a pit on the Ancaster road show the character of these clays. Sample 203 represents an average of the upper 6 feet of the face of the pit, excluding the surface loam. This clay is very plastic and smooth when tempered with water. It has good working qualities and can be moulded into hollow block or drain-tile. It stands drying without checking, in a drier working to about 120 degrees F., but would probably check at a higher temperature. The shrinkage on drying is a little higher than that of the underclay, as it is a stronger clay and does not contain so much sandy material. It burns to a good red colour and hard body, without much fire shrinkage at the lower temperatures. If burned to 1950 or 2000 degrees F. the colour becomes dark red, the body is vitrified, and the shrinkage rather high. Brick made from this clay should be burned to about 1850 degrees F.; but this temperature is not always reached in the scove kilns now in use. Although the top clay stands more fire without softening than the underclay, the table of tests shows that it can be burned to a denser body at lower temperatures. The bottom clay contains a considerable quantity of lime carbonate, which causes the burned body to be more open or porous than the one containing less lime.

The bottom clay sample (No. 204) has not the smooth plasticity of the upper kind, but is rather sticky when wet. Its drying qualities are good and the shrinkage when thoroughly dry is low. It burns to a porous, salmon-coloured body at the lower temperatures, but turns buff when fired higher, and for hard brick requires about 100 degrees of heat more than the top clay.

Only soft-mud brick are made at these plants. The greatest demand is for red brick, made from the upper clay; buff brick from the lower clay is only made to order, although it is an excellent building material. The fuel used is coal and natural gas, carried in pipes from Dunnville. The deepest red colour is obtained with coal fires. Most of the plants are provided with steam dryers, but the rack-and-pallet system of outdoor drying is used extensively. Up-draft or scove-kilns are used exclusively, some being provided with permanent side walls.

Many of the red brick are too pale in colour and rather punky in body, from mixing in too much of the bottom clay with the top, or by underburning. A really good, dark, red face-brick is turned out from a part of the up-draft kilns, but a much larger percentage of these could be obtained by means of down-draft kilns and by using only the upper 5 feet of clay.

CLAY FOR FLOWER-POTS

Owing to its good plasticity and smooth-working qualities, the upper clay is adapted for the manufacture of some of the finer grades of clay wares. The Foster Pottery Company turn out a large quantity of flower-pots from the upper 4 feet of the deposit. The pots, which are very smooth and bright red, are pressed in steel moulds by machinery, a process which has almost entirely superseded the old method of throwing by hand on the wheel.

FIREPROOFING AND SEWER-PIPE CLAYS

Another area of surface clay, somewhat similar to that in the Dundas valley, lies a few miles north of Hamilton, between the old Grand Trunk railway and the Plains road. The plant of the National Fireproofing Company, the only concern in Ontario manufacturing hollow ware exclusively, is in this area, about half a mile west of Waterdown.

The following section is exposed in the face of the pit worked by this company:

	Feet
1. Stiff, plastic, stratified red clay.....	3 to 4
2. Reddish sand.....	1 to 2
3. Alternating layers of red clay, sand, and silt.....	4
4. Grey sand, below bottom of pit.....	1
5. Gravels, thickness unknown	

The first and third members of the series are mixed for making fireproofing. The intervening sand is discarded, so that it is impossible to work the bank with a steam shovel (Plate I).

The underclay has poor working qualities, being silty and short in texture, but when used with a stiff upper clay the mixture forms a workable wet body capable of making the largest size hollow block without sagging or deforming when handled. The upper part of the clay is known as the sewer-pipe clay, as it can be burned to a vitrified body and salt glazed. Most of the fields have been stripped of their top clay for use in the sewer-pipe factories, and have been returned again to cultivation. The whole deposit does not exceed 4 miles in length, and is a little more than half a mile wide. The sediments that compose it were laid down behind

a low gravel bar in Lake Iroquois time. Figure 10 is a sketch section showing the relations of this deposit to the surrounding materials. The upper stiff clay seems to be derived mostly from weathering of the red shales which here formed the shore-line of the ancient lake.

In the Iroquois deposits, both at Waterdown and in Dundas valley, the upper clay is so distinct from the lower clay as to suggest different origins for them. The lower clay is undoubtedly derived from the washings of the glacial stony calcareous clay, but the upper clay appears to contain a large amount of sediment derived from the red shale. Weathering and leaching have had an important effect on the character of the top clay by increasing its plasticity and reducing the lime content.

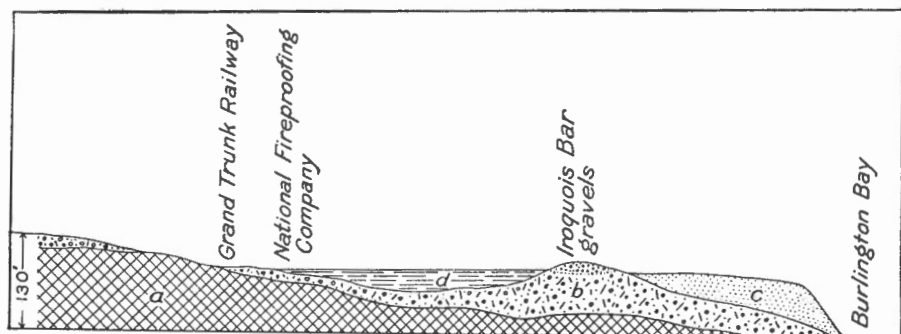


Figure 10. Section of shale, clays, and sand at Waterdown, Ont. a, Queenston shale; b, boulder clay; c, sands; d, stratified clays.

The Iroquois clays near Hamilton seem to be confined to the two areas described above. In the wide valley extending southward between Bartonville and Stony Creek none was found, although careful search was made for them. There is no apparent reason why the Iroquois sediments should not occur, for the bottom of this valley was submerged during that period.

There is, apparently, no stratified, stoneless brick-clay between Hamilton and Grimsby, although it might be expected to occur within the limits of the Iroquois submergence on the lowland between the escarpment and the lake shore. The same is true of the lake-shore area in a northerly direction, beyond the Waterdown area, toward Oakville.

MASSIVE STONY CLAYS

Clay deposits of glacial origin are abundant in the outskirts of Hamilton, particularly along the railway to Guelph Junction. The material, which is 30 to 40 feet thick, is a bluish to grey, or yellowish, massive clay, some parts quite stony, but other parts so free from pebbles that it might be mistaken for a brick-clay. Very little is quite free from pebbles, and as these are mostly limestone and dolomite they render the material practically unfit for clay products, unless it be finely ground or washed. The same material is found underlying the valley between Bartonville and Stony Creek.

A small sample of clay from the Canadian Pressed Brick Company plant at Bartonville was ground to pass a 10-mesh sieve and tempered with water to a proper consistency. The clay had very high plasticity

with good working qualities, and dried easily, with a low shrinkage. It burned to a pink colour at low temperatures, but turned buff when fired higher, the best results in colour and body being obtained about cone 05. The clay shrinks greatly if burned as high as cone 03, and melts at cone 2 or 3. About two months after burning, the test pieces made from this clay showed white lime specks, but some of them that were immersed in water after burning did not show the effect of the lime particles. A mixture of this clay with the red shale at Bartonville will produce various shades of salmon to buff-faced brick. If the clay and shale are ground together in dry pans and the ground product screened sufficiently fine, it could be manufactured by the stiff-mud process into face-brick ranging from salmon to buff or brown. The dry-press process would not be so satisfactory, as the air slaking of the burned limestone grains would probably destroy the dry-press brick in time.

The glacial moraines, mounds, and low ridges south of Hamilton, that lie 500 feet above lake Ontario, are composed mostly of clay similar to that described above. The stones and pebbles are more plentiful in some parts of these deposits, but samples of the clay can be selected that show no pebbles.

A plant was built in 1914 near Rymal to work one of the morainal ridges for brick. The material is a light grey, massive clay containing small pebbles and coarse grit particles, with a few rounded stones up to 6 inches in diameter. Most of the pebbles are small, and of the same colour as the clay. Evidences of stratification or banding in these deposits accentuate their resemblance to a real lake-laid, brick-clay.

The plant at Rymal, worked by the Buff Pressed Brick Company, of Hamilton, was designed for wire-cut building brick, but it soon became evident that this clay could not be put through the simple preparation of pug-mill and rolls and a 9-foot dry pan was installed to grind and screen it to a size small enough to render the limestone and dolomite harmless. This operation, although reducing the output, improves the quality, all the brick being suitable for facing.

The ground-clay is very plastic and flows through the die of the auger machine in a smooth bar without lubrication. It may give a little trouble in drying, especially if much of the top clay be used. The clay burns to a very dense body of fine, rich, buff or straw colour at about 1900 degrees F. The upper foot or so of the deposit burns to a red colour, and a pink tone can be given to the brick by adding a part of the top of the underclay. Considerable trouble was encountered through lamination on first working this clay, but this defect has been largely overcome by altering the shape of the mouth of the machine.

POTTERY CLAY

The upper part of the stratified brick-clay is used for flower-pots and could be used also for glazed pottery or tile. Its working qualities and tensile strength in the raw state make it a good clay for throwing on the potters' wheel, but it carries some fine sand which interferes with a smooth finish.

The glacial clay just described, when washed and screened, is an excellent pottery and modelling clay. It has the plasticity, smoothness, and tensile strength of a stoneware clay, but will not stand as high a fire as the latter. It would probably be just as cheap to prepare this clay for use in public buildings—especially schools—as to import stoneware clay from the United States for the purpose. The red clay could be used without any preparation, for making ornamental tiles, and some of the yellow clay may be free enough from stones for the same purpose. The yellow clay has the advantage of cleanliness over red clay for schools.

The Queenstown shale when ground to pass an 80-mesh screen and made into a slip, can be cast in plaster moulds, or used in the plaster state for ornamental tiles. A mixture of clay and shale ground to pass a 20-mesh screen keeps its shape better, shrinks less than clay alone, and is suitable for tiles.

SHALE DEPOSITS

The escarpment at Hamilton is made up as shown in Figure 3. The beds included under the name Cabot Head contain red and grey shales which weather to a very plastic clay at the outcrops. The best section of this material occurs on Stony creek above the Toronto, Hamilton, and Buffalo Railway bridge (Plate III B), where fewer sandstone bands are included in the shale than in the Hamilton sections.

The hard, fresh shale of the Cabot Head series works up into a very smooth, plastic mass when finely ground and tempered with water, although it is rather stiff in working. It is a far more plastic shale than the red Queenston shale at the base of the section. It flows through either a solid or hollow die in a uniform bar, and will produce wire-cut brick looking almost as well as those made by the dry-pressed process. This shale burns to a good, hard, dense body at low temperatures, but the colour, a pale red, is not good. When overfired it bloats and softens if an attempt be made to vitrify it. It was recently exploited as a fire-clay, but has no claim whatever to refractoriness, being more easily fusible than the sewer-pipe clay at Waterdown.

The Cabot Head shale in Hamilton district underlies a great thickness of other rocks, and underground mining would be necessary to get it out. This method is too expensive for clays and shales intended for structural products. A considerable quantity of the shale could be gathered on the surface at Stony Creek and other places where the overlying formations have been eroded.

The Queenston red shale at the base of the escarpment at Hamilton supplies the face-brick industry in that city. Three plants in Bartonville are built close to the shale bank so that the material can be conveniently broken down and sent to the dry-pan grinders. The dry-press process is used exclusively, no attempt being made to produce a wire-cut, rough-faced brick. The burning is done in round, down-draft kilns fired direct with coal, but during the watersmoking stage wood is used to avoid the deposit of scum which coal makes on the surface of the brick.

Queenston red shale is exposed between the escarpment and the shore of Burlington bay (Plate III A). The hard shale in this area is used at Waterdown for common wire-cut brick and field drain-tile, and the weathered top of the shale is stripped for making sewer-pipe. The weathering

action on the shale, softening and leaching, penetrate to a depth of 1 to 4 feet. The softening increases the plasticity of the shale very considerably, and leaching decreases the lime content. Both processes are essential in producing a clay for sewer-pipe in which smoothness of surface, and salt-glazing qualities are required. These qualities cannot be obtained by using the hard, unweathered shale, nor can any of this material be used in a mixture with the soft clay, for the lime content is too high for salt-glazing. The lime varies from none to 2 per cent in the upper 3 feet of clay, whereas the hard shale at a depth of 5 feet below the surface carries 7 to 12 per cent.

The prevailing colour of the Queenston shale is brownish red, but there are bands or irregular streaks that are greenish. Most of the green bands contain a higher percentage of lime than the red and will produce a buff-coloured product when burned, whereas the bulk of the shale in the Hamilton area burns red.

The Queenston shale is easily ground, has good plasticity and working qualities, and will stand fast drying without checking. It burns to a good, hard, red body at the softening temperature of cone 010, the absorption being 10 per cent and the total shrinkage 5 per cent. A very dense body almost vitrified, of dark red or brown colour, is produced at the softening temperature of cone 03, but it is unsafe to carry the material to a higher temperature as the brick or tile will begin to deform and stick together. For this reason it is impossible to produce paving brick from this shale. Some of the brick in the top of the down-draft kilns near the bag-walls become vitrified in the ordinary course of burning common brick, but the quality of the vitrification is not good, being too brittle, a characteristic common to clays containing too much lime.

The Queenston shale is well suited for wire-cut brick and hollow ware or fireproofing, as well as for dry-pressed brick. Its plasticity and good working qualities recommend it for stiff-mud floor-tile and roofing-tile. The grinding should be much finer than for dry-pressed or common brick. Screening through 30 meshes to an inch would probably be required.

CLAYS AT TORONTO

No other area in Ontario supplies such a variety of brick-clays as the Toronto district. The abundance and variety of raw materials have made Toronto the chief clayworking centre in Ontario. The clays and associated deposits have received more attention from students of glacial geology¹ than those in any other part of the Dominion. This is owing not only to the ease with which the thick sections on the lake shore and river valleys may be examined, but to the presence of one clay formation, the equivalent of which is not known elsewhere in the province.

In the present report the descriptions, which are confined to materials used for brick and tile, follow the classification adopted by Coleman: (1) Iroquois clay, (2) Upper Interglacial clay, (3) Lower Interglacial clay, otherwise known as the "peaty" clay and the Toronto formation.

¹A detailed description of these deposits is given by Professor A. P. Coleman in the Guide Book of the Twelfth International Geological Congress to the vicinity of Toronto, published by the Ontario Bureau of Mines.

IROQUOIS CLAY

The clays and sands deposited in lake Iroquois are the latest of the Pleistocene materials. The terrace formed by this ancient lake slopes gently upward from lake Ontario to a height of 200 feet, where it ends in an abrupt escarpment cut by wave-action during the Iroquois period. This escarpment is a prominent feature in the north of Toronto, the change in elevation being particularly noticeable between Bloor street and St. Clair avenue.

The bulk of the Iroquois deposits are sands, strewn in a thin layer nearly everywhere over the sloping terrace occupied by the city. The clays are restricted to a few, small, isolated areas, which were formerly bays in the ancient lake or depressions behind sand-pits or gravel bars extending from the old shore-line, where the sediments were protected from wave-action. One of the best examples of these old gravel bars occurs in the eastern part of the city. The Canadian National railway crosses it, and numerous gravel pits have been opened up along the line, particularly near York station.

Much of the clay deposited behind this bar has been cut away by surface drainage, but a small area remains on a flat terrace north of Danforth avenue, between Dawes road and Kelvin avenue. It has been worked for a considerable period to supply building brick for the surrounding neighbourhood. The sections exposed at the brick-yards on Dawes road show 2 to 3 feet of browned silt, which forms the terrace top and burns to a red colour. The silt is underlain by 6 to 8 feet of yellowish grey, silty clay, in layers, which burns to a buff colour.

These clays are free from stones, with the exception of one narrow band which carries small pebbles. The underlying materials are stratified sands and gravels, used to a limited extent for building. The clay industry here produces only a red and buff sand-moulded brick. These are burned principally in scove kilns, but a few down-draft kilns are used for burning a better grade of buff brick for facing buildings.

The underclay must be burned to a temperature of at least 2,000 degrees F. to produce a hard building brick with a good ring. The brick in the fire-arches of the scove-kiln turn out cracked and shattered, but the surfaces are not fused. This is characteristic of many calcareous, silty, and gritty clays, in which the amount of true clay substance is low.

The clay terrace ends at the Iroquois beach, which rises a short distance north of the brick-yards, and the same feature limits the deposit in an easterly direction. In a northerly direction from the Dawes Road brick-yards, extensive deposits of Iroquois clay are again found capping the terraces of the interstream areas of Don river and its tributaries. These areas constitute the only unworked deposits of the kind now available for brickmaking, convenient to the city, but parts are too sandy for use in this connexion. The area west of the Don is entirely composed of sand. The Iroquois clays do not occur above the 450-foot level, so that it is useless to look for them in the upland region north of the city, that lies above this elevation.

One of the earliest worked deposits of Iroquois clay in the city was found on Greenwood avenue between Queen and Gerrard streets. It consisted of 8 to 15 feet of stratified, silty clay, almost stoneless and without

overburden. One of the best sections shows these loosely deposited sediments that have never been compacted by an overburden of later materials. The deposit consists of an alternation of yellowish to grey clay and silt layers, interbanded with fairly coarse-grained, whitish sand layers, up to an inch or more thick. Where the upper part is leached it has a brownish colour that extends to various depths according to the density of the deposit, but rarely exceeds 4 feet. The brown tint guides the workmen when separating the red-burning top clay from the buff-burning part below.

The industry on this deposit was confined to the manufacture of red and buff, soft-mud, building brick, of which large quantities have been used during the last sixty years. The deposit is now nearly worked out, and what were once brick-yards are now streets and dwelling sites.

Iroquois clay, covering a terrace several square miles in extent, occurs at West Toronto between St. Clair avenue and Mount Dennis. Black creek, a tributary of Humber river, flows across the terrace and cuts through the clay into the underlying sands and gravels to a depth of 50 feet. The brick-clay as usual occupies the top of the terrace and varies in thickness from 2 to 9 feet or more, being made of alternate layers of clay and silt, with sand layers as a rule toward the bottom. The whole deposit was originally highly calcareous, but the upper 2 or 3 feet are now so leached that the lime content is reduced sufficiently to produce a red-burning product. This part of the deposit is irregular in quality. Some parts of it are too weak and sandy in texture for brickmaking, although they are used for that purpose. They are, also, likely to contain limestone pebbles, which appear as soft, white spots in the burned product.

The underclay contains about 17 per cent of lime, so that it burns to a buff colour, but it contains more clay substance than the upper clay, and consequently burns as a rule to a harder and denser body.

Brick plants scattered over this area, particularly along the Weston road, have an annual output of 1,000,000 to 3,000,000 brick each. The simplest methods are employed, and the capital invested in any one plant is small. The out-door rack-and-pallet system is used for drying, and the clamp kiln for burning, the fuel used being wood. Some of the older plants on this area, producing upwards of 3,000,000 brick a year, have steam dryers and permanent, walled, up-draft kilns burning coal.

With the exception of one plant, which makes a limited amount of field drain-tile, the industry of this area is confined to the manufacture of soft-mud, red and buff building brick. The deposit is best suited for this class of product, and is not suited for higher grade wares.

The clay in the eastern part of this area is becoming worked out, and the abandoned brick-yard sites are being turned into building lots. The western limit of the deposit occurs a short distance beyond the Kodak Company buildings at Mount Dennis, where it merges into the upper boulder clay and becomes on account of its very stony character unfit for brickmaking.

Nearly all these plants are summer yards only.

UPPER INTERGLACIAL CLAY

The greater part of the Upper Interglacial clay appears to have been deposited in water near the margin of the continental ice-sheet. The effect of the proximity of the ice on these sediments has already been discussed. It seems evident that the stoneless areas of this clay were laid down in quiet water, undisturbed by ice advances or by floating ice.

~~For~~ This material, though abundant near Toronto, has not been worked so extensively as the Iroquois clay on account of the overburden of stony clay. The following section measured by Coleman at Scarborough a mile or so east of the city limits shows the relation of the interglacial, stoneless, stratified clays to the boulder clays and sands:

	Feet
Boulder clay.....	48
Stratified sand and clay.....	36
Boulder clay.....	32
Silty sand.....	25
Boulder clay.....	9
Cross-bedded sand.....	29
Boulder clay.....	24
Sand.....	59
Peaty clay to lake level.....	92
Total thickness above lake Ontario.....	354

It can be readily seen that working the stratified, stoneless clays is impracticable, as they are buried under a thickness of stony clay. In a few localities, however, almost all the overlying stony material has been eroded away, or is so thin that it can be removed economically. Such an area occurs north of Bloor street, from Yonge street to Spadina road. One of the earliest brick plants in the city was located on this area at Yorkville, just west of Yonge street. It was known as the Steam Brick plant, and the first dry-pressed brick made in the province were manufactured from this stratified clay. The Prince George Hotel (Rossin House) on King street, was faced with buff, dry-pressed brick made at this plant. This area of clay is now almost entirely built upon, and some of the old brick-yard sites at Yorkville are occupied by a park. A section of the clay was exposed in 1913 while grading the ground for the park. It was a fine-grained, bluish grey clay, very plastic and smooth, regularly stratified in thin layers, interlaminated with films of silt, and free from pebbles or coarse grit. It was a much better material than the Iroquois clay, containing more clay substance and less silt and sand.

The Upper Interglacial clay is used more extensively by the Don Valley Brick Company for the manufacture of clay products than at any other locality, and the excavation at their works shows the best sections (Figure 2). The overburden is light, consisting of only a foot or so of sand and boulders, the remnant of a much thicker sheet of glacial till.

The brick-clays at this point, belonging to the Upper Interglacial series, fall into three divisions. The uppermost consists of 9 or 10 feet of yellow, rusty, stratified silt, which is never used alone. Its working qualities in the raw state are poor, and it burns to a whitish, chalky body, very porous at ordinary temperatures, and shrunken and warped if overburned.

Beneath this, about 30 feet of grey, stratified, plastic clay, has excellent working properties in the raw state, and burns to a hard, buff-coloured body, resembling the clay at Yorkville. The upper silt added to this clay gives a mixture easy to dry, and the silt does not appear to injure the quality of the burned body. It is used for buff, soft-mud brick and for fireproofing blocks. The grey clay is also used in a mixture with the Lorraine shale for various shades of buff, dry-pressed brick, and a similar mixture is used for rough-faced brick in the stiff-mud or wire-cut process.

The buff stock or soft-mud brick are burned in down-draft kilns, or in a continuous kiln fired with producer gas. The best quality of body is produced at 1900 degrees F. as registered by the pyrometer in the crown of the kiln. The brick have a clear ring, and a sulphur or straw-coloured body, but if they are underburned the colour is pale, and the body not so hard.

The special feature about the upper part of this clay is its freedom from pebbles.

The third or lowest division of the series contains massive, stony bands of clay included in stratified materials, which also contain scattered pebbles or layers of them.

The massive clay contains numerous pebbles and coarse grit particles with a few large stones. It is very compact and breaks out from the bank in large blocks, being apparently a regular boulder clay or glacial till. The stratified parts consist of alternate layers of silt and clay, varying from $\frac{1}{4}$ to 2 inches in thickness. The light-grey, dust-like layers of silt are readily distinguished from the darker, putty-like clay layers. Occasional layers of the stratified clay are made up largely of small, angular particles of rock and some pebbles.

This clay is used principally for cheap end-cut wire-cut brick. It is carefully watched as it passes through the preparatory machinery, and as many stones as possible are removed or crushed before it passes into the auger machine. The clay is very plastic, works easily through the die or the auger machine, without lubrication, and dries rapidly without checking. These brick are burned as hard as possible in an overhead, coal-fired continuous kiln, in which reducing conditions prevail, so that most of the limestone particles that still remain in the clay are rendered harmless by partial fusion.

These brick, although rough in appearance, and of all shades of buff, have a ready sale for backing and filling walls or piers.

At Pears brick-yard, on Eglinton avenue, a short distance west of Yonge street, the Upper Interglacial is worked in a small depression running north and south. The stream which flows here has worn away the overlying glacial till so that it was possible to get at the brick-clay, but the overburden of stony clay increases in thickness as the deposit is worked back toward the side of the depression.

The section in the west face of the pit is as follows:

	Feet
Very stony boulder clay or till.....	4 to 6
Brownish, stratified clay.....	3
Grey sand.....	1 to 2
Grey, stratified clay, to bottom of pit.....	8
Brown, silty sand.....	2
Coarse, grey, compact sand.....	3
Boulder clay of unknown thickness	

After the stony clay has been removed, the brown and grey clay with the intervening sand are mixed together and used for making buff brick by the soft-mud process. A few hard pebbles and particles of grey shale from the Utica formation are embedded in the stratified clay. The brick are burned at a temperature high enough to fuse the shale particles so that they form curious warty protuberances on the surface of the burned brick, only a small percentage of which are affected by the particles.

About a foot of the upper boulder clay is used for making red brick, but it is never quite free from pebbles, some of which are limestone. None of the Upper Interglacial clays examined has an upper part which burns red, because the covering of till has prevented leaching. The brown colour is caused by weathering, which penetrated through the overburden.

No other areas of brick-clay were observed in this region, the surface deposits for many miles being the stony glacial tills.

A small area of almost stoneless clay occurs on both sides of Humber river from Swansea to Mimico creek. This may be an Iroquois deposit, but certain evidence points to its belonging to the Upper Interglacial series. The deposit, unlike any other in the district, is for the most part a massive, yellow, silty material with vertical cleavage planes, resembling a wind-blown accumulation, but some parts of the deposit are thinly laminated and curiously contorted.

A section on the lake shore just west of the mouth of Humber river shows this material overlying a thin boulder clay that rests on Lorraine shale which outcrops at water-level.

This clay is used at Butwell's brick-yard on the Lake Shore road, and at the Price, Cummings plant alongside the Grand Trunk railway a little distance to the north. It extends as far north as Queen street on the west side of the Humber, but beyond this is overlain by sand which rapidly increases in thickness to the north.

The clay has no overburden to the south of Queen street and is deeply leached in places, so that as much as 9 feet of red-burning clay has been obtained, but as a rule the red-burning material outcrops only about 3 feet. The bottom clay is calcareous and buff burning. The material has been worked to a greater depth at the Price, Cumming's plant than elsewhere. An underlying, bluish grey clay, probably the unweathered part, contains fragments of Utica shale and a few, hard, rounded pebbles.

The Lorraine shale at this point was found 32 feet below the surface when boring for water. A sheet of stony glacial till occurs between the brick-clay and the shale. The lower blue clay, though rather tough and compact, is more plastic and has better working qualities than the upper yellow clay, which is very silty and short in texture. Both kinds are mixed and used for the manufacture of buff, soft-mud building brick. These and a similar brick made from the red-burning surface clays are the only wares produced. Porous fireproofing blocks might, perhaps, be made from the bottom clay. The underclay requires burning to about 100 degrees higher than any of the other clays around the city, and the buff brick produced are above the average in quality. Owing to the variable character of the surface stripping the red brick range from good hard ones of deep colour, to weak, porous, light-red ware.

LOWER INTERGLACIAL CLAY

The Lower Interglacial clay appears to be peculiar to Toronto, and is the oldest known deposit of brick-clay in Ontario. Although it was laid down during a climate much like the present one, the period of its formation was preceded and followed by glacial conditions in this locality. It is composed of an accumulation of sediments washed down from a land surface which must have been fairly well leached of its lime content, for it carries about the same percentage of lime as the leached top of the Iroquois clay, and like it, burns to a red colour. A vast amount of this material was accumulated in a huge delta at least 15 miles wide. It is considerably over 100 feet thick and much of it remains intact, but buried under later sediments and glacial drift. This deposit is confined principally to the eastern part of Toronto, along the banks of the Don and its tributaries, and in the high lake shore at Scarborough as far east as the mouth of Highland creek. On account of the heavy overburden it is worked only in exceptional cases, one being at the Don Valley brickworks, where it is manufactured into clay products, the other being at Greenwood avenue, where it can be removed economically, and where six plants are in operation (Plate VI B). The sides of a ravine about 100 feet in depth are worked at this point. The section shows about 30 to 80 feet of stratified clay, overlain by 10 to 20 feet of sand and boulders. The clay, which is uniform in character and free from pebbles, occurs in alternate layers with silty clay, up to 3 inches thick, but there are a few beds, 3 or 4 feet thick, in which the silty clay is absent. Much of the silty part is replaced by peat, so that this deposit is sometimes referred to as the peaty clay. Thin sheets of impure siderite occur at intervals of a few feet in many of the sections. The clay is prevailing grey when freshly dug, but quickly weathers to yellowish rusty tints. It is broken down into the bed of the ravine and hauled by cable cars to the top, where the plants are located. It is rather stiff and very plastic, with good working qualities, but does not stand such fast drying as the Iroquois clay. The industry is confined to the manufacture of a high-grade, red, soft-mud brick for facing purposes. They are burned in down-draft kilns at a maximum of about 1850 degrees F. This material will make excellent field drain-tile or hollow building blocks, but cannot be used for vitrified products.

The Lower Interglacial, or peaty, clay is the most important clay worked by the Don Valley Brick Company (Figure 2). It varies from 10 to 40 feet in thickness, the upper part having been eroded unevenly previous to the deposition of the overlying sediments and drift. The clay is mined separately and utilized for the same purpose as that of Greenwood avenue. Most of the better residences in the city are faced with the dark, reddish brown brick made at these two localities.

As already stated, the points at which this clay can be profitably worked are very few, but the material is very desirable and a brief reference is, therefore, made to its distribution. It is found underlying the district from Yonge street to the mouth of Highland creek. It extends up the valley of the Don to within a mile of York Mills, and on the Little Don to about a mile above the high-level bridge on the Canadian Pacific railway. The clay is exposed at intervals in the bottom of the high banks along these streams. In most cases the overburden is too heavy for removal

and the land too costly for the site of a clay working plant. At a few points above and below the railway bridge, low terraces of this clay, with little or no overburden, stand out in the valley bottom. These terraces could be easily worked, but the amount of clay available is not very great, nor is there sufficient room for a plant in the narrow valley.

It is not known whether this clay extends farther north, as the stream bottoms rise until they are above the level of the surface of the peaty clay. The ground rises inland from the lake shore at Scarborough heights, so that the overburden on the peaty clay increases to over 200 feet in thickness. There are no streams that have cut down far enough to reveal the underlying clay.

HIGH-LEVEL CLAYS

Small, scattered areas of stoneless clay, suitable for brick and tile, are found on the elevated plateau between lakes Ontario and Huron. These clays were not laid down in any of the large glacial lakes or their extensions, for they occur far above the extinct shore-lines of the lakes.

Some of the clays, such as those in Perth county, about 1,200 feet above sea-level, are merely a thin veneer of leached boulder clay, which might occur at any level, but the clays at Proton, in Grey county, 1,586 feet above sea-level, were laid down in small lake basins formed between moraines or ridges of glacial drift. The glacial ice, as well as the drift ridges, may have formed the border of the small lakes. These lakes existed only for a short time, as the cutting down of their outlets soon drained them. They contributed no large deposits of clay. The scarcity of clays in the counties of Dufferin, Wellington, Perth, Waterloo, and the southern part of Grey is due to the fact that they stand above the level which received sedimentation during the existence of the great post-Glacial lakes.

Perth County

Stratford. Small ponds about 3 miles east of Stratford, that drain into Avon river, are evidently remnants of a large lake in which clay sediments were laid down. The clay, to a depth of 15 feet, was formerly worked for soft-mud building brick by Mr. F. Entricken. It is overlain by about 2 feet of peat. It is thinly laminated, grey, silty clay, very uniform in character, free from pebbles and concretions, and burned to a cream or buff colour. The brick compared favourably with any of a similar kind made in the province.

The clay worked by the Stratford Brick, Tile, and Lumber Company and the Red Star Brick and Tile yard is the leached top of the boulder clay, which burns to a strong red. The clay areas appear to occupy slight depressions in the plain surrounding the city of Stratford, but the thinness of the deposits and the numerous large boulders show that they are not lake sediments. From $1\frac{1}{2}$ to 3 feet of clay is obtained between the sod and the stony underclay (Plate VIIA). Most of the lime content of the upper clay and some of the limestone pebbles have been dissolved by weathering and leaching, but several large boulders and some pebbles of granitic rock remain and are easily discarded. The red colour in the burned ware is about the brightest of any seen in the province, but the products are otherwise the same as those made in Essex county, where

similar clay occurs. Below the red top clay is grey, stony clay which, on account of limestone pebbles, is unworkable. Some years ago the Stratford Brick and Tile Company tried to work this clay by the dry-press process of brickmaking, but none of the glacial clays is suitable for this process. Only shale or a mixture of shale and glacial clay can be used successfully for dry-press brick.

The industry at Stratford is confined to stiff-mud brick and field drain-tile. The clay is rather tender, and has to be dried outdoors on racks and pallets. The burning is done principally in round, down-draft kilns.

Baker mentions two plants making brick and tile from red top clay at Monkton in 1906, and a similar plant at Mitchell. Since that time brick plants have been operated at St. Marys, Listowel, Topping, Dublin, and Lisbon. Only the last two were producing in 1921.

Southern Part of Grey County

Proton. The highest elevation in Ontario where clay is suitable for brick and tile is at Proton, in a small, flat area surrounded by gravel ridges.

The section exposed in the excavation at the brick plant consists of rather irregular beds of clay, silt, and sand, the typical arrangement being as follows:

	Feet	Inches
Stiff, brownish clay—red burning.....	2	0
Stratified, peaty clay and sand.....	0	6
Blue, stratified, silty clay—buff burning.....	5	0
Grey sand.....	2	0

The upper bed is used for making red building brick by the soft-mud process. It is not so plastic as the upper clay in other localities, but if well burned makes a very good brick. The bottom clay is low in plasticity and short in texture when wet. It dries readily and has a low shrinkage. It burns to a rather chalky porous body and swells in burning, so that the burned brick is a little larger than the green brick. The clay does not give very good results when used alone. Equal parts of the top and bottom clay are used for making drain-tile, and this mixture produces a fairly good product. The clay deposit appears to be free from pebbles or concretions.

Chemical Analysis of Post-Glacial Clays in Southwestern Ontario¹

Buff-burning Clays

Sample No.	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Lime CaO	Magnesia MgO	Potash K ₂ O	Soda Na ₂ O	Loss on ignition
2.....	46.16	13.76	5.58	15.74	3.78	2.00	0.70	17.48
8.....	37.72	10.72	3.51	16.90	7.05	2.19	0.87	21.76
349.....	49.46	14.64	5.14	10.82	2.75	2.84	1.12	13.21
11.....	38.94	12.10	4.83	17.58	4.17	2.38	0.90	18.62
12.....	50.20	12.66	5.14	11.46	2.93	2.12	1.35	13.88
13.....	41.40	12.54	4.88	15.98	4.20	2.33	1.00	17.65
14.....	39.92	12.69	4.67	16.56	3.72	2.43	0.76	18.82
17.....	40.14	15.04	4.56	14.60	4.97	1.86	0.81	18.51

Red-burning Clays

1.....	69.12	14.03	4.81	1.94	1.10	2.05	1.53	4.80
7.....	63.56	16.91	6.24	1.91	2.42	3.15	0.70	5.64
10.....	65.06	14.15	4.67	2.36	2.18	2.66	1.48	6.76

¹Analysis by Ontario Bureau of Mines, except No. 349 by Mines Branch, Ottawa.

2. Stratford, Perth co., lower clay worked for brick and tile by the Stratford Brick, Tile, and Lumber Company. Underlies No. 1.
8. Crediton, Huron co., lower clay worked for brick and tile.
349. Port Dover, Norfolk co., upper part of clay bank used for drain tile by Erie Clay Products, Ltd.
11. Norwich, Oxford co., used for drain-tile by James Irwin.
12. Orwell, Elgin co., used for drain-tile.
13. Delaware, Middlesex co., used for brick and tile by H. James.
14. Alvinston, Lambton co., used for tile and hollow blocks by Alvinston Brick and Tile Co., Ltd.
17. Paisley, Bruce co., used for brick and tile.
1. Stratford, Perth co., red brick-clay overlying No. 2.
7. Crediton, Huron co., red brick-clay overlying No. 8.
10. Conestogo, Waterloo co., flood-plain clay used for red brick.

Remarks on Chemical Analysis

The buff-burning clays are characterized by a high percentage of lime and, compared with the red-burning clays, are all rather low in silica and alumina. The high loss on ignition is due to loss of carbon dioxide from the carbonate of lime, as many of these clays are largely made up of finely-ground limestone or dolomite. Most clays that contain about three times more lime than iron burn to buff colours. Clays with high percentages of lime produce very porous, cream-coloured bricks. Those with a lower lime content produce red or salmon colours at low temperatures and fairly dense, buff-coloured bodies at high temperatures. Magnesia has the same colouring action as lime, for in some of the samples, as No. 349 and No. 12, the excess of lime over iron does not counteract the red colour of the iron without the aid of the magnesia.

A high percentage of magnesia appears to make the clay more refractory and No. 8 or No. 251 in the table of physical tests, containing 7 per cent of magnesia, remains intact when heated to the softening point of pyrometric cone 5 (about 1230 degrees C., 2246 degrees F.). The refractoriness is of no advantage in this clay as it cannot be used for vitrified ware on account of its sudden fusion when heated slightly above cone 5, and the open and porous character of the body below this point. The sudden fusion of calcareous clays appears to be caused by the large percentage of lime and alkalis.

The red-burning clays contain comparatively low percentages of lime and magnesia; the alkalis (potash and soda), remain about the same as the buff-burning clays, but the percentage of silica is higher. The red-burning clays burn to denser bodies at lower temperatures than those with a high lime content.

Clays that contain a large amount of fluxes, such as iron, lime, magnesia, and the alkalis (soda and potash), are easily fusible. All the clays in the above table contain these fluxing impurities which cause incipient vitrification at a low temperature, and hence common brick and tile can be produced with less fuel.

*Table of Physical Tests of Glacial and Post-Glacial Clays in
Southwestern Ontario*

Buff-burning Clays

Sample No.	Water of plasticity	% Drying shrinkage	Cone 010		Cone 06		Cone 03	
			% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption	% Fire shrinkage	% Absorption
208.....	28	7	1	22	1	24	2	20
209.....	22	5	S.S.	29	S.S.	30	S.S.	28
392.....	30	8	1	22	2	20	3	16
391.....	32	7	0	20	1	20	3	13
393.....	28	7	0	22	1	20	2	17
394.....	32	7	0	23	2	20	5	15
395.....	28	8	0	22	2	20	2	18
251.....	20	5	S.S.	28	S.S.	25	S.S.	25
249.....	25	6	0	22	0	20	0	20
349.....	25	7	1	18	1	16	3	9
262.....	25	7	0	21	1	20	3	15
254.....	24	5	1	20	1	20	1	17
199.....	22	6	0	18	1	19	5	6
200.....	23	6	0	19	1	17	4	8
203.....	25	7	0	16	1	14	6	4
204.....	26	6	0	22	0	21	4	17
214.....	17	4	S.	26	S.	26	S.	23
212.....	20	5	0	17	0	18	1	7
772.....	28	7	0	30	0	34	1	21
225.....	25	5	S.S.	28	S.S.	27	S.S.	26
259.....	20	4	S.	36	S.	36	S.	37
258.....	20	4	S.	34	S.	32	S.	35

Red-burning Clays

252.....	25	7	0	15	3	13	6	0
250.....	21	5	0	15	0	13	0	11
271.....	25	7	1	12	2	11	3	4
211.....	17	4	0	11	0	11	1	8
231.....	22	6	0	15	0	13	2	9
323.....	16	6	0	13	0	12	1	8
261.....	27	6	0	20	1	20	5	11
203.....	25	6	0	16	1	14	6	4
328.....	25	7	2	11	4	4	7	3
255.....	21	6	0	15	0	14	3	6

S.S. = Slight swelling in firing. S. = Appreciable swelling.

Buff-burning Clays

208. London, Middlesex co. Waide's brick-yard. Upper calcareous clay, below surface gravels.
 209. London, Middlesex co. Waide's brick-yard. Highly calcareous clay below upper sand bed.
 392. St. Thomas, Elgin co. Thos. Hitch brick-yard.
 391. Lot 1, con. VII, Malahide tp., Elgin co., tile clay.
 393. Lot 20, Caradoc tp., Middlesex co., brick and tile yard on Longwood road, burns light red at low temperature.
 394. Middlemiss, Middlesex co., McArthur Bros'. brick and tile yard.
 395. Lot 5, con. I, Southwold tp., Elgin co. Bogart Bros'. brick and tile yard, burns light red at low temperature.
 251. Crediton, Huron co., highly calcareous clay from middle of bank at clay pit, underlies No. 250.
 249. Thedford, Lambton co., massive, yellowish, calcareous clay, overlying Hamilton shale. In stream bank near old brick-yard.

349. Port Dover, Norfolk co., brownish calcareous clay from upper part of bank at brick and tile plant, burns light red at low temperature.
 262. Port Rowan, Norfolk co., grey, calcareous clay used for making field drain-tile.
 254. Jordan, Lincoln co., stratified, yellowish grey, calcareous clay.
 199. Bartonville, Hamilton co., yellowish, massive, calcareous glacial clay.
 200. Rymal, Wentworth co., yellowish, massive, calcareous glacial clay, used for making stiff-mud brick.
 203. Hamilton. Upper clay. W. H. Cooper's brick-yard.
 204. Hamilton. Lower clay. W. H. Cooper's brick-yard.
 214. Brantford. Stratified, grey, silty, calcareous clay in Grand Trunk Railway cutting.
 212. Brantford. Lower clay at Ideal Brick and Tile Co.'s pit.
 772. Unionville, York co., highly calcareous, stratified clay on bank of Rouge creek.
 225. Walkerton, Bruce co., grey, stratified, highly calcareous clay in cutting on Canadian Pacific railway.
 259. Port Elgin, Bruce co., yellowish, stratified, highly calcareous silt used for brickmaking.
 258. Proton Station, Grey co., yellowish, calcareous clay, underlying No. 257.

Red-burning Clays

252. Essex Centre, Essex co., surface clay used for brick and tile at Hill Bros'. brick plant.
 250. Crediton, Huron co., surface clay, overlying No. 251.
 271. Stratford, surface clay used for brick and tile by Star Brick Company.
 211. Brantford, reddish, sandy, surface clay used in brick mixture.
 213. Brantford, mixture of surface clays, overlying No. 212, used for brickmaking.
 323. Attercliffe Station, Haldimand co., surface clay.
 261. Homer, Lincoln co., grey, calcareous, glacial clay, from cutting on ship canal.
 203. Hamilton, upper clay. W. H. Cooper's brick-yard, overlying 204.
 328. Waterdown, Wentworth co., surface clay used for sewer-pipe.
 255. Toronto, interglacial clay used for brickmaking on Greenwood avenue.

Remarks on Physical Tests

Buff-burning Clays. The above table includes all the varieties of buff to cream-burning clays in the Interlake peninsula. The quantity of water required to bring the clay to the best working condition, called the water of plasticity, varies according to the texture of the clay. The gritty, or silty, clays require less than the finer-grained, plastic clays. Drying of brick is more easily accomplished and the drying shrinkage is less when only a little water is required. The table shows this correspondence between water of plasticity and shrinkage. Plastic, fine-grained clays produce denser and stronger wares than the silty clays. Shrinkage that takes place in burning calcareous clays is as a rule very small, but when there is a high percentage of lime present in the clay it does not shrink, but actually swells. Several cases in the above table show that swelling occurred in burning. Very few of the test bricks, when burned only to cone 010, were of much value as structural materials, and any particles of limestone in the clay showed their presence by spalling the brick more quickly than those burned to the higher temperatures. The best brick were those burned up to cone 03, but even at this temperature they remained porous, most of the high lime brick, showing 28 to 37 per cent of absorption, are good structural material, notwithstanding their porous structure, and if free from coarse limestone particles are extremely durable even in the most rigorous climate.

Some of the above clays, particularly the more plastic, shrink greatly and become softened at temperatures slightly above cone 03, so that it is not safe to carry the burning higher. Some fuse to a slag at cone 1, others at cone 3, and a few will stand as high as cone 5 without softening. A certain quantity of very dense, dark buff, or greenish brick can be obtained

at the top of down-draft kilns or in the fire arches of up-draft kilns, but it is not possible to produce a full kiln of this kind of ware as those that receive the hottest fire would melt.

Red-burning Clays. These are as a rule the weathered and leached surface layers of the calcareous or buff-burning clays. A considerable part of the lime has been removed, so that red colours are developed in burning. Brick made from this kind of clay are more in demand than the buff or cream colours, but they are not always the better brick. The principal advantage to the makers is in fuel consumption, which is less for fuel to burn red than for buff or cream-coloured brick. The table shows clearly the marked difference in the density of the two kinds of clay when burned, the fire shrinkage being always greater and the absorption less in the red-burning clays. Unlike the buff-burning clays it is possible to produce good wares from red-burning clays fired only to cone 010. It is as a rule better, however, to burn them to a rather higher temperature, but it is seldom necessary to fire them as high as cone 03, unless dark-red, hard brick be required. It is not quite safe to burn most of the red clay-brick to cone 03, as they are liable to soften and stick together.

CHAPTER X

CLAYS OF NORTHERN ONTARIO

The region lying between lake Nipissing and Georgian bay on the south, and James bay on the north, with Quebec as the eastern, and the district of Thunder Bay as the western, boundary is called northern Ontario for the purpose of this report. The greater part of the region is rugged, heavily forested, and contains numerous lakes and streams. It is underlain chiefly by crystalline schists and igneous rocks of Precambrian age. The strip of limestone and shale of Palæozoic age which encircles James bay is comparatively small.

A great deal of the region is thinly settled and without means of transportation, consequently clay deposits in remote parts have little or no immediate value. Clay sediments were laid down in post-Glacial time when lake Huron, Georgian bay, and lake Nipissing were merged in one extensive body of water known as lake Algonquin. Some of these clays are found at intervals up to 150 feet above the present lakes, and furnish material for brickmaking. Small areas of clay in Dill and McKim townships, Sudbury district, differ in texture from, and occur much higher than, those near the Great Lakes.

The northern part of the region is covered with a great mass of stony, glacial clay which extends from south of the National Transcontinental railway to the shores of James bay. That part of the region through which the railway runs is popularly known as the clay belt. The surface of the clay area is an undulating plain, the shallow depressions mostly occupied by a swamp or peat bog. In places rock ridges rise above the plain, but for the most part the clay is thick enough to conceal the bedrock. The greater part of the clay area consists of highly calcareous, plastic boulder clay carrying a great deal of fine rock particles as well as pebbles and boulders, but there are a few patches of stratified clay in depressions on the boulder clay surface.

The glacial drift in the region between these two clay areas consists mostly of sand, gravel, and boulders, with little or no clay, and is so thin that it does not conceal the rugged character of the Precambrian rock surface.

During the retreat of the ice-sheet the northern part of the region remained covered with ice, after the land surface to the south was laid bare, consequently there was no northward drainage into James bay. A considerable body of water appears to have extended from lake Timiskaming north to the margin of the ice-sheet. It included Abitibi, Nighthawk, and Frederick House lakes, and submerged the present watershed. The name Ojibway lake is proposed by Coleman¹ for this post-Glacial body of water. The clays are found from Mattagami river to east of lake Abitibi, Quebec, so that lake Ojibway had probably a maximum width of 100 miles in an east and west direction, and its length was about 150 miles.

¹ Ont. Bureau of Mines, 1909, vol. XVIII, pp. 284-292.

It appears to have stood about 300 feet lower than at present, and sea-water replaced the ice on the northward slope of the region. Marine sedimentation was active at that time, and a considerable amount of massive, calcareous, mostly stoneless, clay was laid down. When the land was re-elevated these clays formed the surface of a great part of the coastal plain of James bay for nearly 100 miles inland, but a good deal of the marine clay has been carried away by stream erosion.

The series of events which accompany the advance and retreat of an ice-sheet was repeated twice during Pleistocene times in the northern part of the region. Stratified clays, sands, and peat beds laid down after the retreat of the first ice-sheet were not entirely removed by the second ice advance, and remnants of interglacial beds are found at intervals beneath later boulder clay on the banks of rivers flowing into James bay.

Clays of, probably, Lower Cretaceous age, associated with pure quartz sands and lignite, are found overlying Palæozoic rocks on the banks of some of the streams flowing into James bay. These deposits include the only high-grade clays found in the region, but they are too deeply buried beneath glacial drift, and too far from transportation, to be of use.

Black and greenish, soft, plastic shales of Upper Devonian age occur at several points on Abitibi and Mattagami rivers north of the Precambrian rocks.

Exposed in cliffs on the north shore of Manitoulin island are soft, plastic Silurian shales suitable for clay products, but too far from a market at present.

Small outcrops of red shales, possibly Precambrian, occur near New Liskeard. When mixed with water they can be moulded and could probably be used for vitrified wares.

Residual clays are almost unknown in the Precambrian rocks in northern Ontario. The crystalline rock surfaces are mostly fresh, and so little decay has occurred since glaciation that glacial scratches and grooves are still intact.

A diabase dyke in the Helen mine near Michipicoten is completely kaolinized, but is the only example known in the region.

CLAYS OF GLACIAL LAKE OJIBWAY

The stoneless clays found at or near the surface in northern Ontario are nearly all composed of sediments deposited in glacial lakes that were formerly of large dimensions. Lake Abitibi may be taken as an example of the shrunken remnant of a once extensive body of water from glacial sources. The distribution of the clays is governed by the extent of land covered by the lakes, the amount of sediment carried into them, and the subsequent drainage which either reduced the water area or destroyed the lakes, and made their sediments available land surface. The largest area in the region underlain by stratified, stoneless clay extends, with a few interruptions, from lake Timiskaming to lake Abitibi. These clays, laid down in glacial lake Ojibway, are characterized by alternate layers of grey clay and fine-grained, ash-coloured, calcareous silts. A deposit in which the silt layers are thick is not good for brickmaking, as the burned product is rather punky. When the deposit consists mostly of clay layers

with thin films of silt, a better quality brick is produced, but it has a high shrinkage and requires the addition of sand. The Ojibway clays are slow drying, and brick shapes made from them are liable to crack if the drying be hastened by artificial heat. Their uses are limited to the manufacture of common building brick and field drain-tile, but vitrified wares cannot be made from them.

CLAYS ON THE TEMISKAMING AND NORTHERN ONTARIO RAILWAY

The rugged region traversed by the railway between North Bay and Cobalt appears to be devoid of clay of any description, even boulder clay. The unconsolidated materials overlying the bedrock are sand, gravel, and drift boulders. Stratified glacial lake clays begin at North Cobalt and continue in an almost unbroken stretch to Mindoka, a distance of 50 miles. Between Mindoka and Bourkes the railway traverses the upland containing the watershed between Hudson bay and Ottawa river, in which clays are absent or confined to the bottom of narrow valleys between steep-sided rock ridges. There are extensive patches of lake clays between Bourkes and Porquis, a distance of 40 miles. The superficial deposits between Porquis and Cochrane are sand and gravel, and some extensive areas of bog land, but some of the bogs may be underlain by stoneless clay. Samples collected at the following points illustrate the character of these clays.

Haileybury. The brick plant at this point was in full operation in the summer of 1915. The clay bank, which is about 30 feet high, consists of alternating clay and silt layers. The clay layers are brown and $\frac{1}{2}$ inch to 1 inch thick. The silt layers vary from half an inch to mere films, are ash-coloured, and are thickest toward the top of the bank. Numerous concretions of hard, limy clay occur only in the upper 6 feet. The lime content of this deposit is rather large, especially in the silt layers. The bank is weathered brownish to a depth of 10 to 12 feet below the surface, but beneath the weathered zone the colour is dark grey. The sample taken for testing included an average of 20 feet from the surface. The results of the test are given in the table.

In working the clay for brickmaking about 25 per cent of rock tailings from the mines at Cobalt are added instead of sand. This mixture is passed through two pug-mills, with a pair of rolls set between, and sent to a soft-mud machine for moulding. A stiff-mud machine was formerly used, but too many cracked brick resulted. The best results are obtained by moulding the clay as wet as possible in the soft-mud machine; but even then a considerable number of checked brick occur in every burning. The loss from checking could probably be still further reduced by the addition of a small amount of common salt to the wet clay. The brick after moulding are sent to a dryer heated with steam pipes, and some of the checking appears to occur here, especially in the lower part of the dryer cars nearest the steam pipes.

The burning is done in up-draft scove-kilns, two of which are supplied with permanent side-walls, the fuel used being wood. There is some loss in the fire-arches from cracked and slagged brick, and others above the

arches show fire checks. The best brick are hard, and ring when struck together. The colour is a good red, which is mostly imparted by the coating of moulding sand, as the body is somewhat pale or salmon colour. The Court House, Armouries, and Central Methodist church, in Haileybury, are built of these brick, the church being a specially good example of brick-work.

The use of Cobalt tailings for mixing with the clay should be noted. The material—crushed diabase and slate conglomerate—stands a little more heat without fusing than does the clay, but it undergoes incipient vitrification along with the clay at the temperature of burning the brick; consequently it is sintered in the body and becomes part of it. An ordinary sand, which is mostly composed of quartz grains, is inert at this temperature and consequently if much is used becomes a source of weakness and makes the burned brick punky. It is useless to add it even in small quantities to a silty clay such as the above. Rock tailings of different grades of fineness can be obtained from the mine dumps. The finest of all remains suspended in the waste water for some time without settling. Experiments proved that it could be used as a dark brown glaze such as that produced by the Albany slip clay which is used so much for glazing stoneware goods. It matures between cone 7 and 9, and is a richer colour than the Albany slip.

Heaslip. Borings for water at Heaslip show the depth of clay to be 110 feet. In some places, however, low ridges of rock or boulder clay protrude through the clay plain, so that the depth of the stoneless clay is variable. There is apparently an abundance of stratified, stoneless clay available at many points. The sample for testing was taken on the bank of a creek alongside the wagon road opposite 133 mile-post on the railway, about $1\frac{1}{2}$ miles south of Heaslip. The clay is brownish on top, grading to yellow to blue-grey below. It is well stratified and contains films of silt between the clay layers. An average sample of 15 feet in thickness from the surface downward, a separate sample including only the bottom blue clay, and a small sample of the top brown clay, were taken at this point.

The clay at Heaslip contains less silt than that at Haileybury, and is consequently rather more plastic. It has the same drying shrinkage, but it must be dried slowly to avoid cracking. The working qualities of the average sample (No. 345) are fair, and it can probably be used for the smaller sizes of field drain-tile. It burns to a light red, porous, strong body at the lower temperatures, but turns lighter if burned higher; it would be suitable for common brick, preferably by the soft-mud process. A moulding sand which burns to a good red colour should be selected, as the body colour is not good. About 25 per cent of sand should be added to this clay to improve the drying qualities and lower the shrinkages.

The bottom clay, No. 346a, is more silty than the average sample, consequently its working qualities are not so good. It carries a higher percentage of lime, which causes it to burn to a buff colour and a more porous body. This material would make good buff building-brick if used alone. It would not need the addition of sand as the shrinkages are low.

The top clay to a depth of about 2 feet below the surface is the most plastic and best part of the deposit. It has good working qualities, burns to a strong red colour, and good dense hard body.

A layer of ash-coloured silt overlies the surface clay near Heaslip. It varies in thickness from a veneer to nearly 3 feet, and grades into a fine-grained sand or sandy loam in places. It has a low plasticity, can be moulded by hand, burns to a pale red, very porous body at low temperature, and in this form can be used for scouring purposes, like bathbrick. It gives better results as a polisher than most of the commercial bathbrick on the market.

Matheson. Matheson and the immediate vicinity are underlain by stratified stoneless clay. Records of two wells showed 60 feet of clay, of a third well 46 feet, and of a fourth only 16 feet. Bedrock crops out under the clay in the bank of Black river, in the village, but south of the village the clay rises in terraces to a height of 60 feet above the railway. This clay is as a rule brownish in the upper part, but bluish grey below the weathered zone, and appears to be absolutely free from pebbles, concretions, or coarse grit. There is a layer of light grey silt barely a foot thick on the surface.

The sample (No. 344) was taken about a quarter of a mile east of the station, near the track, in a depression, where about 8 or 9 feet in depth were exposed. This clay, when mixed with water to the proper consistency, has good working qualities, being very smooth and plastic. It must, however, be dried slowly after moulding to avoid cracking, and there is also too much shrinkage in drying. The clay burns to a salmon-coloured, porous body at the lower temperatures, but owing to its high lime content turns to buff when fully fired.

The addition of 25 per cent of sand improves the drying qualities and reduces the drying shrinkage by 2 per cent. With this amount of sand a very fair, buff building brick and field drain-tile can be produced. Sand is available in the high ridge near the village, but is mixed with gravel and requires screening. Tailings from the mines at Porcupine would be better than this sand, but distance makes them economically impossible.

Porquis Junction. About half a mile south of the station at Porquis Junction the railway cutting exposes a section consisting of 5 feet of brownish weathered and crumbling clay, underlain by 6 feet of banded brown and grey clay with silt films, below which is 2 feet of dark grey, stratified clay, the whole being free from stones or concretions. This clay is similar in its qualities to the deposit at Matheson, having the defective drying and high shrinkages characteristic of most of this area. A fairly good common brick, however, could be made from it by the soft-mud process, using about one part sand to three parts clay. The colours obtained are salmon to buff, depending on the heat of burning. Sand for mixing can be obtained about a mile or so to the north.

Timmins. A sample of clay from this vicinity was found to be similar to that described from Porquis Junction, except that the Timmins sample appeared to be taken only from the upper weathered part and consequently was rather more plastic and sticky when wet than if some of the bottom silty clay had been included. A sample of sand accompanied the clay sample.

Mixtures were made of three parts clay to one of sand, and two parts clay to one of sand. Both mixtures worked fairly well in the machine, the hollow tile coming perfect through a die without lubrication. The brick tore a little at the corners when passing out of the die.

In the drying tests the brick made of three to one mixture cracked in the dryers at 120 degrees F. Brick kept at room temperature indoors for two days, and then exposed to wind and sun, checked shortly after exposing. The samples of 4-inch drain-tile and brick made by hand from the same mixture did not crack under the above conditions of drying. Brick made by hand from a mixture of two parts clay to one part sand, exposed to sun and wind immediately after moulding, cracked within an hour. When protected from the sun, but exposed to the wind, cracking ensued within two hours. Samples of soft-mud, hand-made brick, of the three to one mixture, kept continually indoors at room temperature, dried in seven days, and stiff-mud brick made on the machine required nine days to dry. The drying qualities of this clay are decidedly poor, and much care and patience would have to be exercised to avoid excessive loss. A clay of this type is known as "tender" by brickmakers, and the deposits at South Porcupine, Porquis, and Matheson may be so called.

The sand, of which 85 per cent passed through the 100-mesh screen, is suitable for a moulding sand for making soft-mud brick, but a coarser grade of sand would be more suitable for mixing. The coarse rock tailings from the dump would give better results than sand, especially in the quality of the burned ware.

CLAYS ON THE NATIONAL TRANSCONTINENTAL RAILWAY

Between Cochrane and Hearst the railway crosses an undulating boulder-clay plain, largely covered with much forest and swamp growth, but several patches of land are cultivated and drained. The commonly stony character of the clay is revealed in occasional shallow cuttings on the railway, but at a few points stratified and stoneless clay occurs in small areas, as a rule on the banks of streams.

The boulder clay is useless for brick and tile manufactures as it contains numerous limestone and other pebbles. In some places the clay at the surface contains very few pebbles and might be used for making clay products, but not much of the stoneless part is thick, and pebbles are invariably encountered at depth. All the boulder clays contain a high percentage of lime and are buff burning, but there is as a rule a leached layer at the top of the stratified clay which burns to a red colour.

Mattice. The railway station at the crossing of Missinaibi river is named Mattice. About half a mile east of the station, a small stream has cut down 8 feet through a deposit of stratified clay, as far as the underlying stony clay. This deposit consists of alternating layers of ash-coloured silt and brown, plastic clay. In the middle and lower parts of the section there are some small pockets of coarse, gritty rock particles, and individual pebbles are sparingly scattered through the deposit. An average sample of this deposit was found to have good plasticity and working qualities, so that it could be used for drain-tile as well as brick. The drying qualities

were not tested, but similar clays in this region were found to crack if subjected to fast drying. This clay burns to a buff or light-cream colour, with a total shrinkage of 6 per cent, and forms a hard brick when fired to about 1900 degrees F.

There are a few particles of limestone in this clay, and these are detrimental to the burned brick, owing to their tendency to swell on taking up moisture from the air and spall off parts of the brick or tile. A good deal of the trouble from limestone could be avoided by working only the upper 4 feet, where the pebbles are less numerous than below.

The surface of the deposit is weathered, and the lime has been leached out for a depth of about 18 inches below the surface. This part is very stiff and plastic, burning to a dense, hard, red brick.

A more extensive deposit of a similar clay occurs on Mr. John Christianson's ranch, on the west bank of Missinaibi river.

Kapuskasing. The plant of the Spruce Falls Pulp and Paper Company is situated near the bridge of the National Transcontinental railway. Two samples from the excavation made for building were received from this company. One sample, from the upper part, was yellowish and the lower one was grey. The materials are highly calcareous silts containing very little clay. The silts are low in plasticity and difficult to mould. They burn to a light buff-coloured, very porous, and weak body with little structural value, and are not recommended for brickmaking.

Calder Township. Dark grey clay occurs in the bank of Driftwood creek a short distance north of the railway. This is a smooth-working clay with good plasticity and working qualities. The shrinkages are low, so that it does not seem to need the addition of sand. It burns to a hard, red body at low temperature and would make a very good common red building brick. This sample and the following ones were collected by Mr. F. Olsen during road construction. Only the upper part of the clay deposits was sampled.

Clute Township. Yellow calcareous clay, with thin, dark bands of stiffer clay, from road between Clute and Fournier townships. This clay has good plasticity and working qualities, and brick shapes made from it dry without cracking. It burns to a pink colour at low temperatures, but turns buff at about 1850 degrees F. There appears to be some grains of limestone scattered through the clay which may cause trouble in the burned wares by air slaking and spalling, otherwise it would be suitable for brick and drain-tile.

Lamarche Township. Yellowish clay with layers of brown clay from line between concessions I and II, lot 6. This clay is highly plastic and smooth and would work through a die for making hollow brick or field drain-tile. It would require the addition of a small quantity of sand to reduce the shrinkage and assist the drying. It burns to a hard, dense, straw-coloured body and would make a good face-brick for buildings if burned to about 1850 or 1900 degrees F. Similar clay occurs on the line between concessions II and III.

Grey clay from road between Lamarche and Brower townships near National Transcontinental railway. This clay works very smoothly and has good plasticity. It is salmon-coloured when burned at a low tempera-

ture, but is a hard, buff-coloured body at 1850 degrees F., and would be good for common building brick, or field drain-tile.

Brower Township. Yellowish, calcareous clay on road between concessions II and III, lot 7. This clay is fairly smooth and plastic and is easily worked and dried. It burns to a very porous but strong buff-coloured body and can be used for common building brick or porous drain-tile.

The last four samples turned out products very much like those made in the Interlake peninsula from similar clays containing a high percentage of lime.

ALGONQUIN CLAYS

Clays laid down in glacial lake Algonquin are found near the shores of lake Nipissing, Georgian bay, and lake Huron. The clay areas are not very extensive, and occur in isolated patches, as a rule in low land with a margin of rock ridges. The Algonquin clays are stratified, and mostly of a reddish colour in the raw state. They contain less silt and a smaller percentage of lime than the Ojibway Lake clays, and as a rule burn to red. The clays are used only for common building brick and for field drain-tile. They are not suitable for vitrified wares.

CLAYS NEAR LAKE NIPISSING

North Bay. Small areas of stoneless clay near North Bay have been used for brickmaking. The clay occurs in depressions between rock ridges and is mostly covered by a varying thickness of sand. Clay has been worked to a depth of 12 feet and in places it is said to be 18 feet deep. It is mostly underlain by gravel or boulder clay, but in the abandoned pit at the western end of the town it was laid down on bedrock.

The clay section exposed in the pit at the plant of R. Wallace and Son is about 7 feet thick. The upper part of the deposit consists of alternate horizontal layers of reddish and olive-green clay with thin layers of silt and a few layers and lenses of sand. The layers are contorted and folded in the bottom part of this deposit as well as in others seen in the neighbourhood.

Sand-moulded building brick are the only product made. These are of fair quality, the best-burned brick being hard and of a good red colour, but the lightly-burned brick are rather soft and pale in colour. The brick from the fire-arches of the scove-kilns are all shattered from contact with the flames and are a loss. Clays with a high silt content do not seem to stand direct contact with flame without checking badly.

Sturgeon Falls. A considerable area of flat land underlain by stratified clay and sand lies between a high rock ridge and lake Nipissing at this point on the Canadian Pacific railway, and extends west to Cache Bay. A few small ridges of rock protrude above the clay plain. A brick-plant, formerly operated at Sturgeon Falls, was abandoned some years ago.

Baker,¹ who examined this deposit in 1905 when the brick-yard was in operation, states that the upper 3 feet of the deposit consisted of stiff, blue, massive, stoneless, sandy clay which burns to a buff colour, and is

¹ Ont. Bureau of Mines, vol. XV, pt. II, 1906, p. 84.

underlain by brown and grey clay in alternating layers, which burns red. This is an uncommon occurrence as the buff-burning clay is mostly found at the lower levels, whereas the top part burns red.

A small sample of clay was obtained from the bank of Sturgeon river, south of the falls, where 7 feet of finely laminated, brown clay interbanded with fine sand or silt is exposed, but the upper, massive, buff-burning clay was missing. The clay at this point is more plastic than that at North Bay, but it is difficult to dry after moulding, and the colours produced on burning are not good. The addition of about 25 per cent of sand would improve the drying qualities.

CLAYS NEAR LAKE HURON

The region north of lake Huron was examined in 1917 by W. H. Collins,¹ who made the following notes regarding clay and sand.

"For distances up to 20 miles north of lake Huron, the Precambrian rocks are covered up to a height of 150 feet above lake Huron, by sand, silt, and clay deposited there at a time in the glacial history of the region when lake Huron stood far higher than it does now.

"The clay is usually finely laminated, grey or reddish in colour, free from boulders or pebbles, and where it is not mixed with too much sand, appears to be suitable for brickmaking. Clay of this sort is common from Dean lake westward to Bruce Mines and from Massey east to Espanola. In order to test the value of this clay for brick or tile manufacture, two samples were taken from the farm of Mr. R. J. Hoath, just south of Rydal Bank, concession I, Plummer township. A small creek has cut banks 10 to 30 feet high at this place, affording a good section of the clay deposit.

"One sample, of reddish colour, was taken from the bank 8 feet above water; another, of bluish colour, from the water's edge. The two samples were submitted to the laboratories in the Mines Branch for examination, and the result of the tests is given below.

No. 587. From upper part of stream bank. Reddish brown, laminated, non-calcareous clay, free from pebbles or coarse grit.

"It is very plastic and rather sticky when wetted; its working qualities are good. It dries slowly after moulding, with a high shrinkage. It burns to a compact, red body at cone 010 (1742 degrees F.), becomes vitrified and shrunken at cone 03 (about 2000 degrees F.), and fuses at cone 1 (2100 degrees F.).

No. 587a. From lower part of stream bank. Grey clay with an occasional brown layer, non-calcareous, and free from pebbles.

"This sample contains a considerable amount of silt and consequently is not so plastic as the upper clay. It dries readily after moulding into shape, and the shrinkage on drying is much less than the upper clay. It burns to a light red, porous body at cone 010 and does not become dense and hard until burned as high as cone 03. It stands a little more heat than the upper clay before softening, but the colour at any temperature is not so good.

¹ Geol. Surv., Can., Sum. Rept., 1917, pt. E, p. 15.

The following results were obtained in burning the samples at various temperatures:

Laboratory No.	Per cent total shrinkage			Per cent absorption		
	Cone 010	Cone 05	Cone 03	Cone 010	Cone 05	Cone 03
587.....	9	9	17	17	17	0
587a.....	4	4	11	15	14	7

These clays are useful for the manufacture of common brick and field drain-tile. The upper clay when used alone is difficult to dry and has too much shrinkage. It is, also, liable to check in the firing, which results in too many broken brick. The lower clay stands drying and firing well and has low shrinkages, but its working qualities, especially for the manufacture of tile, are not good.

A mixture of equal parts of the two clays gives good results, the defects of one offsetting the good qualities of the other.

"If for any reason the lower clay can not be worked to advantage, either on account of drainage or other causes, then about 25 per cent of sand should be added to the upper clay in order to assist in the drying and reduce the shrinkage.

"From what the writer has seen of the Pleistocene deposits along the north shore of lake Huron, clays equally suitable for brick or tilemaking can be obtained in many places between Echo Bay and Blind River, and between Massey and Espanola. Maple, birch, and other woods for fuel are abundant within easy reach of the clay areas and can be obtained for little more than the cost of cutting and hauling. The Canadian Pacific and the Lake Huron and Northern Ontario railways furnish convenient means of transportation."

Espanola District. Quirke¹ states that there is a thick band of stratified clay exposed on the north side of Spanish river between the two bridges west of Espanola Mills, and that it carries many strange inclusions resembling concretions. A discussion on the nature and origin of the inclusions is given in his report.

Baker described the deposits on Spanish river between Webbwood and Massey. The section in this locality consists of 2 to 20 feet of sand underlain by 8 to 12 feet of alternating layers of clay and sand, and beneath this is very strong clay almost free from sand.

The buildings of the Spanish River Pulp and Paper Company and the employees' houses at Espanola were built of red brick made from the clay nearby. The section at this point consists of 5 feet of sand at the bottom of the bank, overlain by 10 feet of strong clay interlaminated with thin layers of sand. This is overlain by 10 or 12 feet of alternating clay and sand layers of equal thickness, but above this there is 6 to 10 feet in which the sand layers are much thicker than the clay layers.²

¹ Geol. Surv., Can., 1917, Mem. 102, p. 56.

² Ont. Bureau of Mines, 1906, vol. XV, pt. II, p. 23.

Desbarats. A small sample from Desbarats lake is a red, calcareous clay containing films of white silt. It is very plastic and smooth and somewhat stiff in working when wet. It burns to a light red, hard body at low temperatures, but it has too much shrinkage. A mixture of two parts of this clay with one part sand would be required for brickmaking, or for drain-tile. The clay is more smooth and plastic and less silty than any of the clays to the eastward. It might be used for making flower-pots if its shrinkage were lower, as it contains very little grit and has enough tensile strength in the raw state to be worked on the potters' wheel.

Sault Ste. Marie. Near Sault Ste. Marie and Steelton an extensive deposit of Algonquin clay is exposed in places in a terrace about 30 feet high at an elevation of about 100 feet above lake Huron. It is a reddish, stratified clay interlaminated with films of silt, but in some places the silt and clay layers are of equal thickness. Numerous hard concretions of lime carbonate scattered through the deposit spoil it for brickmaking. A large brick plant was built near a cutting on the Algoma Central railway, the clay for brickmaking being excavated from the front of the terrace. The clay was placed on hot floors to dry, then ground in dry pans, shaped in a dry-press brick machine, and then burned in rectangular down-draft kilns. The brick soon crumbled when exposed to the air, owing to the numerous lime concretions. Overburning the brick so as to seal up the limestone particles and prevent them from air slaking, was unsuccessful, as the brick softened and stuck together. This plant soon ceased work, the lime concretions in the clay being the prime cause of failure. The dry-press process is also unsuited to this clay, for such brick from glacial clays are too porous and weak.

Two brick-yards near Steelton have been operating successfully for several years, making brick by the soft-mud process. The clay is taken from the flood-plain at a lower level than the top of the clay terrace. The deposit is recent, and consists mostly of clay washed down from higher levels along with silt and sand, but without coarse particles or lime concretions. The mixture makes good, sound building brick, and is a better material than the clay in the terrace.

Sudbury. The deposit worked for brickmaking by the Sudbury Brick Company is situated near the Copper Cliff road about $1\frac{1}{2}$ miles west of Sudbury. The clay lies in a valley surrounded by bare, rocky ridges and a few mounds of sand and gravel. The upper part of the deposit exposed in the pit consists of 7 or 8 feet of alternate layers of yellowish clay and silt with a few layers of fine sand overlying 3 feet of blue, silty clay. The best material lies in the middle part of the deposit; the upper and lower parts carry an excess of silt and sand which have a tendency to make the burned brick, especially those in and near the fire arches, rather brittle.

The brick are made by the soft-mud process, dried outdoors on racks and pallets, and burned in scove-kilns. A fairly large proportion of each kiln is good, common, red building brick. Another deposit of similar clay nearer town was also worked for brickmaking a few years ago.

Clay deposits are not plentiful in the district, and what there are do not contain enough true clay substance to give the best results, but suffer from an excess of silt and sand.

Analysis of Post-glacial Clays in Northern Ontario¹

Sample No.	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Lime CaO	Magnesia MgO	Potash K ₂ O	Soda Na ₂ O	Loss on ignition
64.....	64.08	17.21	5.40	2.34	2.75	2.97	1.94	3.90
59.....	51.00	16.11	4.69	8.26	4.10	2.76	1.74	9.64
65.....	59.30	15.70	5.41	5.10	3.27	2.73	2.04	7.30
344.....	48.58	14.10	4.94	9.38	4.82	2.78	1.67	13.57
56.....	65.08	14.83	3.17	4.18	2.57	2.24	2.76	5.10
68.....	63.20	15.75	4.67	4.32	2.73	2.80	1.91	4.35
2.....	59.50	15.30	5.26	6.15	3.14	2.50	2.82	6.16
69.....	64.30	15.45	5.22	3.42	2.02	2.72	2.51	3.89

¹Analysis by Ontario Bureau of Mines, except 344 by Mines Branch.

64. North Bay, Wallace and Sons' brick-yard.

59. Haileybury, clay from cutting on T. and N.O. railway between Haileybury and New Liskeard.

65. New Liskeard, R. Scott's brick-yard.

344. Matheson, clay near railway east of station.

56. Sturgeon Falls, Imperial Land Company's brick-yard.

68. Sudbury, A. W. Evans' brick-yard.

2. Webbwood. Workable clay from middle part of bank on Spanish river.

69. Sault Ste. Marie. Algoma Commercial Company's brick-yard.

Remarks on Analysis

The clays in the above table are mostly characterized by their silty texture. They are derived largely from the wet grinding of Precambrian rocks by glacial action, hence their silica content is as a rule higher than that of the clays in southern Ontario, which were derived largely from softer rocks. The clays, with the exception of No. 344, burn to red colours, but some of them contain enough lime and magnesia, compared with iron, to give only a poor, pale red. The lime content increases in the clays in a northerly direction, and along the National Transcontinental railway they are all buff burning on account of the high lime content, but there may be a thin, leached layer on the surface which burns red.

The sum of the fluxing impurities is high compared with the silica and alumina, in all the clays, and, therefore, they soften readily at comparatively low temperatures.

CHAPTER XI

CLAYS OF WESTERN ONTARIO

Western Ontario includes the districts of Thunder Bay, Rainy River, Kenora, and Patricia. Railways run through the southern part of the region; travelling in the other parts is by canoes in summer and by dog teams in winter.

Except for a narrow band of flat-lying Silurian limestone bordering Hudson bay, the whole region is underlain by Precambrian crystalline rocks, consisting of various gneisses, schists, and slates, with granite, diabase, and other igneous intrusions. All rock outcrops are fresh, and many still bear the grooves and scratches of glacial action. Shales suitable for use by the clayworker are found only on the shores of Thunder bay near Port Arthur, and fire-clay, kaolin, or other high-grade clay have not been discovered so far in the region.

Clay of any kind is exceedingly scarce over large parts of the region. The hollows between the rocky knolls are partly filled with glacial drift consisting mainly of sand and boulders. Where sand and boulders are absent, the hollows are filled with water, thus forming innumerable lakes, ponds, and swamps.

Stoneless, stratified, glacial lake clays suitable for brickmaking are found at a few localities. Wherever these clays occur the land is mostly cleared and cultivated, forming a striking contrast with the rugged, forest-covered country adjoining them.

One of the largest post-Glacial lakes, known as lake Agassiz, at one time covered a great part of the province of Manitoba, the state of Minnesota, and a small part of northwestern Ontario, where it occupied the basin of lake of the Woods and the valleys of Rainy river and Seine river.

One of the principal clay areas resulting from sedimentation in this extinct lake is found around Wabigoon lake and river. It extends as far north as English river, but at this locality sand predominates over clay, as shown in the sections on the shores of lac Seul, but sections showing more silt and clay than sand are exposed on the banks of Mattawa river,¹ which enters English river a few miles west of lac Seul.

There appear to be no clay deposits of any account for a long distance north of English river, but close to the shore of Hudson bay stoneless calcareous clay of marine origin, similar to that in northern Ontario, is found overlying boulder clay.²

Another extensive area overlain by stratified clay occurs along Rainy river, between Rainy lake and lake of the Woods. Small detached patches of clay occur north of lake of the Woods near Kenora and near Mine Centre, on Shoal and Bad Vermilion lakes. These clays are grouped around the southwestern part of the region and were evidently all laid down during a general submergence.

¹ Geol. Surv., Can., Ann. Rept., vol. VII, p. 52 F.

² McInnes, W., "Report on a Part of the North West Territories of Canada Drained by the Winisk and Upper Attawapiskat Rivers," Geol. Surv., Can., 1902.

None of the areas has the plain-like appearance which is such a characteristic surface indication of stratified clay in other places. The clay fills hollows between domes and ridges of rock, but even where a considerable extent of clay is unbroken by protruding rock, its surface is carved so much by subaerial erosion that very few level patches are seen.

Stoneless clay somewhat different in character from the Agassiz lake clays is found near lake Superior at elevations from 1,150 to 1,400 feet above sea-level. Only the lower part of the clay is stratified, the greater part of it is massive, and shows no banding. It is very fine grained, free from stones and pebbles, and of a bright red colour. It is exposed for about 12 miles in cuttings on the three railway lines running westerly from Fort

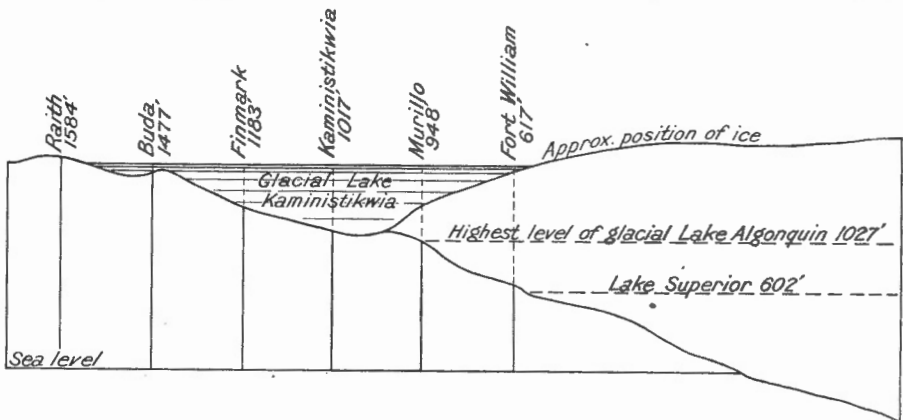


Figure 11. Diagram showing conditions under which temporary glacial lake existed when the Finmark clay was laid down.

William, the greatest thickness on the Canadian Pacific railway being in the vicinity of Finmark and on the Canadian National railway between Matawin and Shabakwa.

The red clay lies at too great an elevation to belong to any of the large post-Glacial lakes. The peculiar conditions under which it was deposited are shown in Figure 11. The ice had melted and disappeared from the highlands, but a great mass still occupied the basin of lake Superior. The ice standing like a wall across the valley containing the outlet of Kaministikwia river and its tributaries held up the water between it and the height of land, and a lake was formed having shores partly of ice and partly of land. The name Kaministikwia lake has been suggested by Mr. F. B. Taylor¹ for this body of water. This lake persisted long enough to lay down a thickness of at least 20 feet of fine, red clay over an area of about 200 square miles. The red clays are evidently derived from the red rocks of the Keweenaw series.

When the ice mass in Lake Superior basin melted, lake Kaministikwia disappeared and glacial lake Algonquin came into existence, its level being maintained by the ice barrier which still prevailed to the eastward and prevented the water from discharging through the present St. Lawrence

¹ Am. Geol., vol. XX, p. 119.

River outlet. Kaministiquia river and its tributaries became active and carried a great body of fine sediment, including some of the Finmark clay, into lake Algonquin, and built up the delta through which the lower part of the river is now cutting, and from which the supplies of brick-clay are obtained.

Several sand-plains and terraces rising to 100 feet above the level of lake Nipigon are attributed to deposition in glacial lake Algonquin, as the Nipigon basin was a bay of this lake. Stratified clays and silts occur below the sands at places in Nipigon area, but as a rule the overburden of sand is very thick.¹

The valley of Pic river, which enters lake Superior at Heron bay, is about a mile wide and is partly filled with stratified clays, silts, and sands which were laid down in glacial lake Algonquin. The stratified materials are found for 50 miles along the lower part of the river and reach a height of 200 feet above the level of lake Superior.² No samples of clay from Pic valley were treated in the physical laboratory, but samples collected by Robert Bell in 1870 were found to be highly calcareous, as the average content of lime carbonate was 30 per cent.³

An isolated area of sedimentation not apparently connected with any of the great glacial lake basins, or with marine submergence, occurs in the district of Patricia, about 200 miles north of lake Superior, and lies between the watershed of Albany and Severn rivers. One of the branches of Attawapiskat river is now cutting through the deposits which are exposed at intervals for 50 miles along its course. The section described by McInnes⁴ consists of very fine, white quartz sand and siliceous clay, underlain by tough, blue clay, in fine laminæ, and overlain by irregularly distributed deposits of coarse sand and gravel, the whole being from 50 to 60 feet in thickness. The lake in which this material was laid was probably formed in a land depression with an ice barrier blocking the drainage outlet, or the barrier may have been a terminal moraine of glacial drift which formed a natural dam. The cutting down of the drift barrier by the outlet stream finally drained the lake and exposed the lake sediments.

Fort William. There is an abundance of stoneless clay along the lower reaches of Kaministiquia river suitable for the manufacture of brick and tile, in fact there is no other point in Ontario, except Toronto, so well supplied with a convenient brick material.

A good opportunity for examining the clay deposit is afforded by the excavation made for brickmaking at the three brick plants situated close to the river at the outskirts of Fort William. The best section is at Gownlock's plant, where 76 feet in thickness of stratified clay is exposed (Plate VII B). The upper part of the clay is composed of smooth, olive, clay layers, interlaminated with reddish bands of silty clay. The middle part of the bank is of greyish, stratified clay rather more silty and shorter in texture than the top clay. The lowest part is brownish to grey, silty clay, more compact and massive than the upper clay, but showing rude

¹ Wilson, A. W. G., "Geology of the Nipigon Basin, Ontario," Geol. Surv., Can., Mem. 1, 1910.

² Ont. Bureau of Mines, vol. XVIII, 1909, p. 153.

³ Geol. Surv., Can., 1870-71, pp. 237-238.

⁴ Ibid., p. 37.

lamination. It is sandy in places, but the clay as a whole is plastic enough, though not nearly so smooth and plastic as the upper part. No stones, pebbles, or concretions could be detected in any part of the deposit.

About 4 or 5 feet of yellow sand overlies the clay. The stratified brick-clay deposit is underlain by coarse river gravels, but these are at such a depth that they are not exposed on the lower reaches of the river. On going up stream, however, the clay thins out and the gravels rise toward the surface.

Rosslyn. At Rosslyn, about 6 miles north of Fort William, the gravels come to within about 6 feet of the surface. The clay deposit at the pits of the Superior Brick and Tile Company's plant consists of about 5 feet of smooth, plastic, red clay interlaminated with red, sandy clay. The coarse river gravels lie immediately under the clay and it is overlain by 2 to 3 feet of reddish sand. The clay disappears a short distance beyond Rosslyn and the gravels rise to the surface.

Finmark. No clay appears beyond the point near the Canadian Pacific railway until about 5 miles west of Kaministiquia station or half a mile beyond Matawin River bridge, where thin deposits of stoneless red clay thickens considerably toward Finmark, 4 miles farther on, and extends as far west as Buda, 8 miles west of Finmark.

A sample of the red clay, No. 341, was collected near Sunrise section house. The clay at this point appears to lie in a broad depression in the Precambrian upland through which Matawin river flows. The base of the clay is near the level of the railway track and consists of layers of coarse grey sand interstratified with thin clay layers, whereas the upper part of the deposit is all red clay rather massive in structure. The whole section is about 25 feet thick.

The red clay is exceedingly smooth, plastic, and rather sticky when freshly dug from the bank. It appears to be quite stoneless, but contains a few scattered concretions. It is very stiff and difficult to work and its shrinkage on drying is too great. It burns to a porous but hard red body at low temperatures and is liable to become fire checked. It would make common building brick, however, if mixed with 50 per cent of sand, but the clay could not be worked without the sand addition. This clay is not as good a brick material as the clay at Rosslyn.

Another sample, from Finmark, was tested as a pottery clay. It, also, is fine grained, highly plastic, and red and as it has good tensile strength in the raw state is well adapted for the potters' wheel. It contains a few, coarse, gritty particles which came to the surface when the pieces were being turned on the wheel and made it difficult to secure a smooth finish. Washed and screened, it gave excellent results. The shrinkage on drying and burning is too great, otherwise the clay would be suitable for flower-pots or cheap, coloured earthenware. The high shrinkage can be overcome by the addition of about 35 per cent of finely ground quartz or potters' flint. The mixture of washed clay and flint is an excellent pottery body, and makes very good glazed wares when fired at temperatures ranging from cone 08 to cone 03. When coated with a white slip inside, and the whole piece covered with a clear glaze, very good, red earthenware for cooking purposes can be produced from this clay.

The chemical analyses is as follows:

	Per cent
Silica SiO_2	52.10
Alumina Al_2O_3	14.77
Iron Fe_2O_3	7.79
Lime CaO	5.62
Magnesia MgO	5.34
Potash K_2O	2.45
Soda Na_2O	1.88
Loss on ignition.....	9.49

Port Arthur. There is a large deposit of clay on the bank of McIntyre river, in Port Arthur, on the property owned by the Canadian Resources Development Company. Borings made by the company are said to have proved the thickness of the clay to be 24 to 32 feet. Only about 6 feet of the upper part of the deposit was available for sampling when the writer visited the locality. It is a rather stiff, red to yellowish, sandy clay in the upper part, and bluish, stratified clay below, which contains a 2-inch streak of fine gravel.

About a foot or two of brownish red, sandy loam overlies the clay, and about 10 per cent of this was included in the sample No. 339 with the average of the top and bottom clays.

This clay is not so plastic as the clay at Fort William, being short in texture when wet, but it has the advantage of low shrinkage and will stand fast drying without checking, which the Fort William clay does not. It burns to a pale red and very porous body, apparently because it contains a rather high percentage of carbonate of lime. This clay would probably make common building brick by the soft-mud process. Its poor colour and high porosity exclude it from face-brick, but it might be used for backing and partition brick.

Dorion Township. A few small, clay areas occur in this township near the shore of lake Superior. Brick were made near Dorion station. The clay is rather highly calcareous, but yields a good, strong, buff-coloured common building brick. It is short in texture and rather stiff, so that it is suitable only for use by the soft-mud or sand-moulded process of brick-making.

WABIGOON CLAY AREA

Stratified clay extends along the line of the Canadian Pacific railway, though not continuously, for about 45 miles. Westward from near Dinorwic it is almost continuous to Eagle River. A small patch of clay occurs at Vermilion Bay, but between this point and Eagle River a vast sheet of glacial outwash gravel is exposed along the railway line. It extends from the railway northward to the lower ends of Gull and Pelican lakes, roughly paralleling Wabigoon river at a distance of about 3 miles. Crossing the National Transcontinental railway it passes east of Clay lake and reaches the south end of Mountain lake. The clay extends south of the railway line on each side of Wabigoon lake, but its southern limit is unknown.

Dryden. Apart from its use as agricultural land the clay has been used only for brickmaking at Dryden. The first buildings of the Dryden Paper Company were built of brick from clay in the vicinity, but much of the brick was defective, and has been replaced by brick from other localities.

A good section of clay is exposed in the cutting through which a flume is carried from the dam to the power house. It consists of about 10 feet of alternating layers of red clay and ash-coloured silt, each about half an inch thick, passing down into fine, stratified, light grey sand and silt which carries numerous large concretions. The sides of the excavation at the site of the abandoned brick plant nearby were covered with talus, but the upper part which was cleaned off for sampling showed about 8 feet of alternating grey clay and silt, with only a few red layers, and a small number of concretions.

About $3\frac{1}{2}$ miles east of Dryden on the property of Mr. M. Zentil, an auger hole was put down 12 feet through clay close to the railway. The first 7 feet pierced alternating thin layers of grey clay and silt, with about a foot of red clay below. At a depth of 11 feet there is a layer of sand and silt about a foot thick, with clay below. Several outcrops of clay were seen between Dryden and Thunder lake, all similar in character, showing the red band from 3 to 10 feet below the surface. Very little sand was seen on top of the clay, but in some places grey silt and fine sand outcrop at the surface.

The chemical analysis of an average sample of 11 feet in depth of clay No. 757 is as follows:

	Per cent
Silica SiO_2	54.48
Alumina Al_2O_3	16.09
Iron Fe_2O_3	5.99
Lime CaO	5.50
Magnesia MgO	3.86
Potash K_2O	2.59
Soda Na_2O	2.58
Loss on ignition.....	9.34
	<hr/> 100.43

Kenora. The clay deposits near Kenora are confined to small patches in hollows between rocky knolls. The largest area occurs along the bank of Laurenson creek as far as Laurenson lake. It is impossible without boring to tell its thickness, as the floor on which it was laid down is very irregular, and rock knolls rise in many places above the surface, or are seen in stream cuttings a few feet below it. Nevertheless, there is enough clay at some places to supply a small brick plant for several years. The upper part of the clay consists of a stiff, brownish, highly plastic, and rather sticky variety which might be termed gumbo, and much of this is underlain by grey, silty clay with streaks of sand. There is another small area of similar clay south of the railway, one mile east of Kenora station. The clay deposits so far examined in this neighbourhood were free from pebbles, or the injurious lime concretions.

The brown clay in this area burns to a dense, hard, red body, but it is difficult to work and dry, and the shrinkage in drying and burning is too great. The grey clay works and dries easier than the brown, but has a rather high drying shrinkage. The clays easily hold 35 per cent of their weight in sand without seriously diminishing the strength of the burned brick. In fact it would not be practicable to make building brick from the clays without the addition of at least 25 per cent of sand.

A brick plant was operated for some years in the valley of Laurenson creek near the railway round-house. The red brick used in the older buildings in Kenora were made at this plant, and they appear to be still intact and show little or no sign of spalling, or disintegration.

In the excavations made near Ridout bay by the Backus-Brooks Construction Company, for a pulp and paper mill, the following section was seen:

	Feet
Yellow sand.....	2
Laminated, grey clay.....	2 to 3
Grey silt.....	1
White sand.....	6

There is an unconformity between the white sand and the overlying silt and clay, which marks a change from current to still-water deposits. The white sand is composed almost wholly of quartz grains and looks like a glass sand, but carries numerous grains of hornblende, which would spoil it for glassmaking purposes by introducing too high a content of iron.

Several pits were dug by the Backus-Brooks Company in low ground north of Boundary street and east of the cemetery. Below the surface soil in this ground there is 1 to 3 feet of brown clay underlain by 2 to 4 feet of black, sandy clay, and fine sand saturated with water was found below the clay in most of the pits. The extent proved to be underlain by clay was about $3\frac{1}{2}$ acres, but unless adequate drainage was provided this deposit would be too wet to work.

The brown clay burns to a dense, hard, red body but is very difficult to dry, and the shrinkage is excessive. The dark-coloured underclay is sandy and easier to work and dry than the brown clay and has a lower shrinkage. Very good, red building brick can be made from a mixture of the clays, but the addition of some sand is desirable.

CLAYS ON RAINY RIVER

W. A. Johnston examined the superficial deposits and prepared a map and report of Rainy River district,¹ which includes part of the following description of the clay deposits.

"Stratified clays, silts, and sands occupy a surface area of about 120 square miles, and they probably underlie much of the muck and peat deposits which make up nearly one-third of the total surface."

Numerous sections exposing the clay occur along Rainy river and its tributaries. The clays differ somewhat in general character in different sections and some in different parts of the same section, owing to diverse modes of formation. The greater part of the clay is, however, fluvio-lacustrine in origin, that is, the material was derived from land erosion, and transported by streams of low gradient which could only carry fine sediment. These clays are mostly free from pebbles and are smooth to the feel when wet.

"*Fort Frances.* The deposit that occurs at the brick-yard $1\frac{1}{2}$ miles below Fort Frances is of this character. It is fairly uniform to a depth of 14 feet and is underlain by sand."

¹ Geol. Surv., Can., 1915, Mem. 82.

"A sample of this clay, No. 759, sent to the laboratory, was very plastic and had good working qualities. It dries slowly after moulding and the shrinkage was 10 per cent, which is too high. It burns to a hard, red body at 1,750 degrees F., and does not suffer from overfiring as much as the other red-burning clays. As far as the results from laboratory tests show, this is probably the best red-burning brick and tile clay of the district. The addition of a small quantity of sand for the purpose of reducing the shrinkage would be desirable."

Just below the dam at Fort Frances a section shows 12 feet of the yellowish grey, silty, and gravelly clay. The total thickness of the clays here is at least 25 feet, but a short distance back from the river calcareous boulder clay comes to the surface.

Rainy River. Clay deposits occur along the bank of the river both above and below the town of Rainy River. The deposits vary in thickness from 2 to 10 feet or more, and extend back from the river for some distance. They are thickest near the river, and gradually thin out away from it. Sand, to a thickness of 1 to 3 feet, overlies the clays, and they are underlain by stony till or boulder clay. Sample No. 276 was collected from 1 to 4 feet below the surface about half a mile below the railway bridge. The sample was free from pebbles, but contained a small amount of coarse grit. It required 23 per cent of water to bring it to the best working consistency. The clay was rather sticky when wet, but had fairly good working properties and flowed smoothly through a die for making drain-pipe. It required a considerable time to become air-dried at ordinary temperatures, and the shrinkage in drying was 7 per cent. The following results were obtained in burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	18	Pale red
06	0	15	Pale red
03	0	14	Mottled
1	2	15	Buff

This clay is suitable for common brick, or field drain-tile, a good hard product of reddish colour being obtained even at as low a temperature as cone 010 (1742 degrees F.). On burning to higher temperatures the red colour almost disappears, and a harder, denser product of buff colour results at cone 03 to cone 1 (2,000 to 2,100 degrees F.). There is no fire shrinkage until the latter temperature is reached. This clay resembles the brick-clays of the Red River valley in Manitoba, and, like them, appears to be derived largely from magnesian limestones, but the percentage of lime is much lower in the Rainy River clay, as the latter does not effervesce with dilute acid. The Red River brick-clays stand up without softening at a much higher temperature than most surface clays, and sample No. 276 from Rainy river likewise stood a higher fire than any other clay collected in northwestern Ontario.

A sample from the lower part of the deposit from which sample No. 276 was taken, shows a yellow, gritty clay containing numerous rock fragments and some pebbles. Limestone pebbles spoil this clay for burned-clay products.

CLAYS NEAR SHOAL LAKE

It is probable that Shoal lake and Seine River valley once formed a bay of glacial lake Agassiz, and that the clay now found in them was laid down at the same time as that along Rainy river and near lake of the Woods. The difference in level between Shoal lake and lake of the Woods is only 46 feet. Clay also occurs near Bad Vermilion and Little Turtle lakes, which lie to the north of Shoal lake, at a slightly higher elevation. It is probable that similar clay partly underlies the valley of Seine and Little Turtle rivers, but as rock ridges are frequent the clay occurs only in small, detached patches.

Mine Centre. Several patches of stoneless, stratified clay occur on the road between Mine Centre, on the Canadian National railway, and old Mine Centre on Shoal lake, and on the side road to Island bay on Bad Vermilion lake. The upper part of the deposit is stratified, grey clay and silt, and below this is stiff red clay. In some places the grey clay is worn away and the red clay appears at the surface. Part of the land is cultivated, and whenever the red clay outcrops at the surface it is exceedingly stiff, and difficult to plough.

Several samples of clay were collected by Mr. A. H. A. Robinson of the Mines Branch, and tested in the laboratory, but the samples were taken from only the top 2 or 3 feet and are not sufficiently representative of the deposits. The stratified grey clay, No. 611, behaves like an ordinary common brick-clay in working and burning, but the red clay is hard to work on account of its extreme stiffness in the wet state. Furthermore, the red clay shrinks excessively in drying, and cracks in firing. If the grey and red clay are mixed, sand must be added to counteract the defects in the red clay.

SHALE DEPOSITS

Shale suitable for clay products occurs on the east shore of Thunder bay. The shale outcrops at the water's edge and is exposed for several miles along the shore. It is overlain by a great thickness of conglomerate, sandstone, and red shale, but the upper material contains no beds suitable for the manufacture of brick or tile. The shale exposed along the shore reaches a thickness of 40 feet in places, and an abundant supply could be mined for many years and brought across the bay in barges. It is greenish grey in colour and weathers into thin, flaky layers with films of yellowish clay between.

A large sample of this shale was tested at the Mines Branch laboratories and found to be satisfactory for working up into brick and hollowware shapes. When ground and mixed with water the material develops fairly good plasticity and working qualities. Its drying qualities are good and the shrinkage low. It burns to a good strong body with a fine red colour. The burned ware is liable to show a white scum, but this can be eliminated by adding a small amount of barium carbonate. This shale has not a very long range of vitrification, consequently it would not be safe to attempt the manufacture of vitrified products. It is possible that the shale could also be used for the manufacture of heavy, red floor or roofing tile, but for this purpose it would have to be ground much finer than if used for brick.

It would be advisable to mix some of the plastic surface clay at Fort William with the shale, as this mixture would flow more easily through the dies of the machine and would require less power than if shale alone were used. A mixture of half shale and half clay would be found suitable for making large hollow blocks and this method would reduce the amount of shale that would otherwise have to be ground.

SLATE

Mount McKay, near Fort William, is composed largely of dark Animikie slate beds. These beds are not true slates, but are really hard, gritty shales which do not show plasticity when finely ground and mixed with water. An attempt was made to utilize these slates by working them up into brick by the dry-pressed process. A plant was actually built for this purpose at the base of mount McKay and operated for a short period.

Unless the brick made from this slate are burned to nearly the point of vitrification they will be too soft and weak for structural purposes, but as the softening point of the slate is low the brick will become overfired and deformed, especially in the upper part of the down-draft kiln, on approaching the temperature necessary for vitrification. Furthermore, owing to the short vitrification range of the slate, the brick in the lower part of the kiln may be far too soft, whereas the upper ones are overfired.

The important difference between shale and slate is that shale is plastic when ground and moistened, whereas slate is not. Consequently some bonding material, such as plastic clay, must be added to the ground slate for the purpose of brickmaking. The obvious remedy in the case of the Mount McKay brick plant would be to add some plastic surface clay to the slate while it was being ground in the dry pans. This mixture could be relied upon to make a much better brick than if slate alone were used.

BRICK PLANTS

There were formerly five plants making burned-clay products and one sand-lime brick plant in the vicinity of Fort William and Port Arthur. During 1922 three brick plants were in operation, and none of them ran at full capacity, but an increased production was expected.

The large deposits of stratified clay on the banks of Kaministiquia river at West Fort William constitute a good raw material for the manufacture of common red building brick. This clay slakes readily when wet and is not inclined to be lumpy. It runs easily in the machine and slips well from the mould. These properties facilitate production and it is said that as many as 50,000 brick have been made in a day in a Martin machine at the old Alsip plant. This is probably the highest record in Canada from a soft-mud brick machine. A very good red stock brick is produced at the various plants at West Fort William. The hard-burned ones, of course, are the best. They have a good ring when struck together. The moulding sand is obtained from the top of the clay deposits and as it burns to a rich red it imparts this colour to the surfaces of the brick, and in those parts of the kiln where the air supply is limited the reducing action

turns the colour into fine, dark, and flashed shades. These variegated shades, which range from almost black to red in the burned brick, are greatly in demand, especially for the best class of dwellings. Brick made from this clay, that are underburned, are weak and of poor colour, which even the moulding sand does not always conceal.

The plants in West Fort William make only soft-mud or sand-moulded brick. The brick are mostly air-dried on racks and pallets. The burning is done in scove-kilns fired with wood. This method of burning is simple and involves no outlay of capital for kilns or overhead expenses during the winter months when the plants are closed. There is a great deal of waste, however, in the scove-kilns due to broken, overburned brick in the fire-arches as well as an undue quantity of soft brick. Better results are obtained in permanent round or rectangular down-draft kilns, fired with wood and coal, where a saving of fuel is effected and a larger percentage of hard brick produced. These kilns can also be constructed, without much extra expense, so that the waste heat from cooling kilns can be drawn off by means of underground flues and sent into the brick driers, or the waste heat can be used to preheat another kiln.

The plant of the Superior Brick and Tile Company is situated at Rosslyn about 6 miles north of Fort William. This is a well-equipped plant with six down-draft kilns of a capacity of 80,000 to 90,000 brick each. Provision is made to take the waste heat from the cooling kilns to the brick-drying tunnels by means of a suction fan. A good quality of wire-cut, rough-faced, red building brick is made at this plant. Some fine effects of colour are produced on the faces of the brick in the upper part of the kiln where some of the brick are of a gunmetal shade. Unfortunately the clay will not stand overfiring, consequently the brick at the top of the kiln are liable to be partly melted or stuck together if the finishing temperature is carried too high. The clay at this plant burns to a hard, strong body at low temperatures and is very smooth and plastic, so that it would make a good field drain-tile or hollow building brick for interior construction. This clay also appears to be smooth enough to be used for the manufacture of flower-pots.

The utilization of the plastic Animikie shale from Sawyer bay should provide a means for increasing the range of clay products made in this district. This shale, or a mixture of clay and shale, should give satisfactory hollow building block or fireproofing together with rough-faced and dry-press building brick. It is also possible that when finely ground, this shale could be used in the manufacture of floor tile or roof tile.

CHAPTER XII

CLAYWORKING INDUSTRY OF ONTARIO

The clayworking industry in Ontario is confined principally to the manufacture of building brick, hollow building-block or fireproofing, and field drain-tile.

COMMON BRICK

These are made principally from the red and buff-burning post-Glacial clays, but a considerable quantity is now made from both the Lorraine and Queenston shales. The principal use for common brick is in backing or filling walls, but they are also used, particularly in the towns and villages, for facing brick, the best-burned brick being selected from the kilns for that purpose. The brick made from the clays vary widely in quality, in accordance with the character of the material used and in the care taken in preparation of the clay, the moulding, and the burning.

The soft-mud process of moulding is principally employed and several of the smaller brick-yards confine themselves wholly to the manufacture of soft-mud brick. Many plants combine the production of wire-cut brick and field drain-tile, using the same machine for moulding by merely changing the die. The clay is mostly dug by hand, loaded into trucks or horse carts, and hauled to the machines. Drying is mostly done outdoors on racks and pallets, but some of the smaller plants use artificially heated dryers. The brick are burned chiefly in the scove or clamp-kiln, but drain-tile are burned in round, down-draft or beehive kilns. The principal fuel is wood and coal, but natural gas is used in some plants near lake Erie.

Some of the common brick suffer from defects due to limestone pebbles or lime concretions in the clay. These when near the surface show as soft white spots in the brick and they often disrupt the brick or tile when they occur in the centre. A chapter on the working of stony clay is included later on.

Another defect found only in stiff-mud brick is lamination, which is a spiral structure given to the brick as the clay is expelled through the die of the machine by the rotary motion of the auger. Lamination seems to be more pronounced when brick are made from plastic clays by the end-cut process, but it also occurs in side-cut brick. Brick made from shale or mixtures of clay and shale are not so liable to lamination. End-cut brick with serious lamination are especially liable to rapid disintegration by weathering, as frost enters through the layers. The crowns of some of the round kilns built of end-cut brick, with the ends exposed, suffer rapid deterioration on account of the lamination of the brick. When a clay is found to laminate badly some adjustment of the machine must be made to overcome it, as it is difficult to design a standard machine in which all clays work equally well.

DRAIN-TILE

The principal defects found in drain-tile are bridge checks, lamination, and spalling due to lime pebbles (Plate VIII). The longitudinal cracks seen in so many places in drain-tile are probably caused by the clay not welding properly after it crosses the bridge of the die, but the checks or cracks can in some cases be avoided by roughening the bridges. The cause of lamination in tile is similar to that in brick. If a plunger type of machine such as is used for making sewer-pipe were used for tile the lamination would cease, but no machine of this kind giving a sufficient output has yet been invented.

Most of the drain-tile produced is made from the calcareous or buff-burning clays, and some of these tile are very porous, with a high water absorption. A series of tests made by Mr. F. L. Ferguson at the Ontario Agricultural College, Guelph, shows that the drain-tile which come through best in the freezing and thawing tests are those with the lowest water absorption.

It is manifestly impossible to make drain-tile with a low absorption from calcareous clays. Some of the tilemakers, however, are trying to make tile from highly calcareous, silty clays which burn to a very porous chalky body and are quite unfitted for the purpose. Other makers send out tile that are insufficiently burned, and hence open to the objection of softness and high porosity.

Several of the buff-burning clays in use in southern Ontario are capable of making good drain-tile. The best clays of this class have good plasticity and show a drying shrinkage of about 6 per cent. They burn to pink colours at low temperatures, but to buff and sulphur colours at the higher temperatures, with a fire shrinkage of 1 to 2 per cent. The sulphur colour denotes a hard, well-burned tile, which has a clear ring when struck. Such a tile is practically indestructible by the ordinary weather conditions either above or below ground.

The makers of tile who use red-burning clays have the advantage of being able to produce a fairly dense tile at the lower temperatures, but pale red tile are often sent out which are underburned and hence too soft. The deep red colour is a good guide for hardness. When a maker uses a mixture of red and buff-burning clays the colour guide does not hold, so that the clear ring and low absorption are the best guides for tile made from a mixture of clays.

FACE-BRICK

Face-brick of both red and buff colours made by the soft-mud process from post-Glacial clays are used extensively in dwellings in Toronto. The red brick are made from the great interglacial clay deposit which underlies the eastern part of the city and the buff brick are made from Iroquois clay at points both east and west of the city. The Toronto market demands a well-shaped and well-burned brick and the makers take care to supply these. The brick are burned in down-draft kilns and 90 per cent or more of face-brick are turned out. Some of the plants near the city of Hamilton also make soft-mud facing brick from clay.

The soft-mud process is better adapted to most of the Ontario clays than the stiff-mud, but some of the buff-burning clays seem to work well

by the latter process. Some plants changed over from soft-mud to the stiff-mud process, but were not a success. The stiff-mud brick were found difficult to dry and a good deal of checking took place in firing, so that heavy losses resulted from cracked brick.

There is no better structural material made than a well-moulded, well-burned, soft-mud brick, and architects prefer them for domestic work to any other. Some architects would like to obtain the hand-moulded, water-struck brick, but as this process is slow, it has passed out of the clayworking industry in Canada.

None of the post-Glacial clays in Ontario are suited for the semi-dry-pressed process of making face-brick, but mixtures of clay and shale are successfully employed, as noted under the head of shale products.

HOLLOW BLOCK

A considerable amount of hollow building blocks are made from clay alone. Some of the buff-burning clays in the Interlake peninsula produce a very fair brick which are sold largely for barn construction. The National Fireproofing Company at Watertown use Iroquois clay for their products. The upper part of the clay bed on their property is the sewer-pipe clay and this, mixed with the underclay, makes a very strong block.

SEWER-PIPE

All the sewer-pipe made in Ontario is produced from a special kind of clay which occurs in the fields east of Hamilton. It is underlain by Queenston shale in some places and in others by an inferior stratified clay. It seems quite clear that this clay is derived from the weathering and leaching of the Queenston shale nearby, which results in a material with a very low percentage of lime and with good plastic properties. Only a few feet in depth is suitable for making sewer-pipe, but up to the present enough clay is obtained to keep three plants running. Sewer-pipe clay of this kind has not been found so far at any other locality in Ontario. It is probable that the weathered top of the Lorraine shale which is rather thoroughly leached of its lime content and is quite plastic would also be suitable for sewer-pipe, but the weathered top only occurs sparingly as most of it seems to have been removed by glaciation. The essential qualities for a sewer-pipe clay are that it can be salt glazed and that it has good working and drying properties. If a clay contain enough lime to show effervescence with dilute acid it apparently cannot be salt glazed, but the fact that a clay does not contain lime does not necessarily qualify it for a sewer-pipe clay, for it may not stand a high enough temperature to allow salt glazing, or it may not have the plastic properties necessary for moulding.

WORKING STONY CLAYS FOR BRICK AND TILE

Clays containing pebbles or stones are usually avoided by brick and tilemakers when choosing a suitable location for the erection of a plant. Mistakes have frequently been made in Canada by erecting plants on sites where stony clay occurred, when a thorough preliminary examination of the ground would have proved the futility of such an enterprise. In some cases, however, plants which have been working for years perfectly

stoneless clay, and making good burned products, find on extending their clay pits that they are gradually running into a stony variety of clay. In many parts of southern Ontario only a foot or two of the surface clay is stoneless. A thin sheet of stoneless clay is so quickly worked out that the distance from the clay pit to the machine rapidly increases, hence tilemakers would if they dared dip deeper in the vicinity of their plants.

Over the recently opened agricultural region along the National Transcontinental railway between Cochrane and Hearst is a great sheet of plastic, stony, glacial clay. It would be difficult to select a patch sufficiently free from pebbles for brick and tilemaking, but enough clean clay could be obtained for a small output. The clay burns to a buff colour, and will make brick or tile of very similar quality to buff or so-called white products in southern Ontario.

There are large areas of plastic, yellowish grey, glacial clay near Hamilton, and along the Welland canal, as well as in several parts of Niagara peninsula. Much of this clay appears on a casual inspection to be stoneless, but close scrutiny as a rule reveals the presence of small rock particles and pebbles.

A clay that contained only a few scattered pebbles of rock other than limestone or dolomite may be worked, if its other properties be good. Broken wires may frequently occur in the cutter if stiff-mud brick is being made, or an occasional brick will firecheck if it contain too large a pebble, but if suitable crushing rolls be provided for the clay to pass through, or if a dry pan be used for grinding, the loss of time due to broken wires can be stopped.

It is the limestone pebbles and concretions that cause the real difficulty in working stony clays. Limestone concretions (Plate IX A), though not so abundant as pebbles, in clay deposits, are more active agents in spalling burned brick. Palissy, the celebrated French potter, experimenting with various clays in the sixteenth century and recording his impressions of them, says: "because among them there are little stones, which when the vessels are baked, the little stones which are in the said vessels are reduced to lime, and suddenly when they come to feel the humidity of the air they swell and cause the said vessel to split in the place where they are enclosed, and this is because the said stones were calcined in the baking; and by this means many vessels are lost, however great the labour one may have employed upon them." This quotation expresses the experience of all clayworkers from Palissy's time to the present day, when they had to deal with clay containing limestone pebbles.

Crushing and Grinding

Many methods have been tried to eliminate the troubles due to limestone in clay. The simplest, probably, is the use of a pair of rolls set above the machine. Rolls designed for crushing stony plastic clays reject the rocks or hard parts which are too large to fall within the angle of nip, and grind or pulverize the smaller stones which pass through with the clay.

Another device is to use a dry pan with the mullers set an inch or so above the surface of the pan. This process is supposed to break down the clay and force it through the perforated bottom of the pan while the pebbles stay behind. The pan is stopped occasionally and the stones are thrown

out. In using this method the clay must be dry, which involves storage room for drying clays, or use of a rotary dryer. Where shale is used, it is easier to grind a mixture of shale and clay in a dry pan than to grind clay alone, as the shale helps to keep the screen plates of the pan from becoming clogged.

Another plan is to grind the clay, pebbles and all, in the ordinary way in a dry pan, working continuously, and run the clay over screens so as to reduce the limestone pebbles to a small enough size to be harmless.

It has been proved that unless limestone in clay is ground finely enough to pass through a 30-mesh screen it will cause trouble by developing soft, white specks in the burned bricks, which will cause flaking of the surfaces. These grains of lime, unless very plentiful, would not materially weaken a well-burned brick, but would disfigure brick for facing purposes.

As it is not practicable in any of the crushing or grinding processes outlined above to reduce the pebbles to this small size, the trouble caused by lime grains is not entirely eliminated by the fire screens. Furthermore, any rough-grinding process, such as passing the clay through rolls, merely accentuates the trouble, since in many cases it converts one pebble into several smaller ones each of which then becomes active after burning.

Washing

One effective way to treat clays containing limestone pebbles is by washing, which leaves the stone behind as a heavy residue, the overflow taking the fine clay down to settling basins.

Washing of high-grade clays, such as china-clay and paper clays, is a common practice, but the cost of washing poorer grades is seldom warranted. A plant at Hutcheson, Minn., successfully eliminates limestone pebbles by washing.¹

"The washing machinery occupies a space not over 20 feet square and 15 feet high, and washes 130 yards of clay in a day. The clay from the bank is hauled by cable car to the washer, where it is mixed with an excess of water and agitated by a series of vertical rods fastened to a rotating cross-beam. The harrow-like motion of these rods tends to throw the larger pebbles towards the centre and leaves the fine clay and sand suspended and distributed throughout the washer pit. A bucket elevator of continuous operation dips into the pit near the centre and removes the gravel. The gravel, if cleansed, forms a by-product of considerable value. At the sides of the pit a screen of proper mesh allows the escape of the fine sand and clay to one of a series of open ponds in which they are allowed to settle. After a time some of the water is pumped off and the rest is left to sink into the ground. The sand naturally settles close to the intake of the pond, and the clay is carried to the farther side. After partial drying the material is taken to the stiff-mud machine, where the clay and sand are mixed in approximately the same proportions in which they existed in the drift before the washing. Experiments are now in progress to determine whether the clay is improved by standing in the settling ponds all winter. The gravel is sold for concrete. Both the clay and the sand contain a considerable amount of calcium carbonate, but if care is taken to remove the coarser sand the lime does no harm, and it is certainly less

¹ U.S. Geol. Surv., Bull. 678.

abundant than in the unwashed drift. The plant at Hutcheson uses three, round, down-draft kilns, and plans are made to double the capacity. It has been found possible with this clay to produce a very good drain-tile and hollow building block, so that the production of common brick has become secondary."

Some of the glacial stony clays in southern Ontario would yield good tile-clays when washed, and a small plant located where there are no tile plants and no stoneless clays available should have a chance of success.

A brick and tile plant at Perth made a practice of washing stony clay, which enabled them to produce durable wares which brought a higher price than the ordinary brick-yard obtained.¹ The washing was done in the autumn when brickmaking has ceased and a deposit of washed clay is ready for the following season's work.

In some cases the stones are loosely held in the clay and separation by washing is comparatively easy, but some boulder clays are so tough and the stones so firmly embedded that it is almost impossible to break up the clay and separate the stones by washing. Such a plant, however, could not ship its products over any considerable territory as it would then compete with plants using clay free from pebbles and, therefore, more cheaply worked.

Burning

Certain aspects of the burning of clays and of methods of dealing with the burned product must be considered. In some parts of England where clays containing limestone pebbles are worked, it is customary to grind the clay as fine as practicable, and after the bricks are burned the cars on which they are loaded are drawn through a pool of water so that they are completely immersed and saturated. This treatment slakes the lime particles quickly and appears to do less damage than if they are allowed to slake and expand slowly from the moisture absorbed in the atmosphere.

At the Don Valley Brick Works, in Toronto, stony clay is interbedded with stoneless clay and both are worked together. As the clay drops down through the rolls from the pug-mills the larger stones are expelled by the rolls and the small ones go through to the machine and are crushed. This clay is used for the end wire-cut brick and burned in an overhead, fired, continuous kiln. The limestone particles give surprisingly little trouble in the burned product. Perhaps the smoky atmosphere and reducing conditions present in the chambers of the continuous kiln check the subsequent activity of the lime pebbles. The reducing condition at high temperatures may cause fusion between the surface of the lime particles and the surrounding clay, and this fused skin may prevent access of moisture to the lime; but whatever the reason is, the lime is more effectually killed than it would be after coming through a well-oxidized firing.

A plant producing face-brick from glacial clays containing a few scattered pebbles of limestone is situated at Rymal, about 4 miles southwest of Hamilton. The clay is ground in dry pans, screened, and made up into stiff-mud brick. The burning is done in round, down-draft kilns up to as high a temperature as the brick will stand without sticking

¹ Baker, M. B., Ont. Bureau of Mines, vol. XV, pt. 2, "Clay and the Clay Industry of Ontario," p. 76.

together. The product is hard, sulphur-coloured brick which shows no bad effects from the lime-grains. In this case the lime-grains probably form a fused bond with the clay so that there are no after effects.

Pulverizing

The most satisfactory way to deal with stony clay containing limestone is by pulverizing it to pass a 30-mesh screen. The process necessitates drying the clay before pulverizing, and this is done by passing the clay through a rotary dryer, or by storing it until it becomes dried out.

Some of the brick and tile plants in Indiana and Illinois, where there is a large demand for these products and where nothing but stony clays are available, use the pulverizing process successfully. At Decatur,¹ Indiana, the stony clay is excavated with a ditching machine, or clay digger, so as to take up the clay in thin layers and not in large lumps, that it may dry faster. It is then passed through a rotary dryer 7 feet in diameter and 70 feet in length, that has a capacity of 30 tons per hour. The clay from the rotary dryer is fed into a ring hammer pulverizer, and then elevated to screens.

Two gravity screens are used. The top screen has eight meshes to an inch and removes all the coarsely ground clay and gives greater capacity to the finer bottom screen which allows only the dust and particles finer than 30-mesh to pass through. The pulverized clay is run into storage bins and is elevated from these to bins set above the pug-mills, and the ordinary processes of brickmaking follow.

Another operator in the same region stores the clay for about six weeks before using. It is then run through a disintegrator and over an 8-mesh screen. The tailings from the screen are put through a Williams pulverizer.

POTTERY AND POTTERY CLAYS AND GLAZES

The characteristic quality of clay plasticity enables wet clay to be moulded into any desired form and to retain this form when dried and during burning. It is necessary to use a highly plastic clay and also one which is smooth in texture for most of the methods used in making art pottery.

Almost all the clays used by sculptors and art students in Canada are imported either from the United States or England. They are of the stoneware type, being highly plastic and smooth, and much cleaner to work with than the common brick or tile-clays. Similar clays are available in Nova Scotia and Saskatchewan, but none are known to occur in the other provinces within the present range of transportation facilities. All clays require a certain amount of preparation before they can be used in the arts. There are no firms engaged in mining, preparing, and selling clays for these purposes in Canada, but many of the clays tested at the Mines Branch laboratory show sufficient plasticity and smoothness to indicate that they might be used for modelling. Especially is this true of the clays from Saskatchewan and Nova Scotia.

A clay to be tested as a pottery clay first undergoes the regular tests as to shrinkage, drying, range of fire, and burned colour. Its behaviour

¹ Krick, G. M., "Clay-Worker," Feb., 1922.

on the wheel, for casting, and building, remains then to be determined. For making pottery by the casting process the clay is mixed with an excess of water and run through a 60-mesh screen. It is then known as a slip. This slip is allowed to stand for a day, after which the excess water is siphoned off. Part of the slip is set aside to be used for casting; the remainder is left in plaster dishes until enough water has been absorbed by the plaster to bring the clay to the proper consistency for wheel work and building.

The casting slip is brought to the consistency of cream, and is then allowed to stand in a plaster pottery mould a few minutes, after which all that will run is poured out. The remainder, which adheres to the mould in an even layer, will shrink away from the mould surface on drying and can be easily removed. The cast piece is then smoothed and finished by hand. The casting process is largely used in commercial work, especially for shapes that cannot be made on the potters' wheel.

The clay may then be tried out on the wheel and for built ware. Pieces made by these methods are allowed to dry, and together with the cast ware are fired to a temperature ranging from 1800 to 1900 degrees F. (cone 06 to cone 03). The fired pieces of pottery before being glazed are known as biscuit ware. The biscuit pieces that are cracked or warped are rejected and perfect pieces are glazed and refired. The glaze is, as a rule, crazed or cracked on many of the pieces. Tiles may be made either by pressing ground, semi-dry clay in steel moulds by machinery or by pressing the clay into plaster moulds. Tiles made from clay alone nearly always show a tendency to warp in drying, and to obviate this, ground calcined clay or sand is added to the clay.

Most clays require the addition of a non-plastic material such as finely ground feldspar or quartz before they can be made up into a satisfactory earthenware body that can be properly glazed. Therefore, a clay which promises to prove suitable for pottery work is further tested by adding to it various proportions of feldspar or flint, until the most desirable mixture or body is obtained. Flint is the name that potters give to finely pulverized quartz, no matter whether it be produced from true flint or from white sand. Most of the feldspar used in the potteries in America is produced in Ontario and Quebec.

The test pieces made from mixtures of clay and flint, or feldspar, are fired and afterwards glazed with a raw transparent glaze. As a rule it will be found that many of the glazed pieces containing all clay, those containing clay and feldspar alone, and those containing a large amount of feldspar, will be crazed. From such tests, it is possible to determine the proper proportions of feldspar and flint to add to the clay.

Glazes and Enamels

The terms glaze and enamel are in many cases used to signify the same thing. Strictly speaking, a glaze is transparent and shows the colour of the body beneath it. Enamels, called majolica glaze, are opaque, and conceal the character of the body to which they are applied.

As pointed out above, the character of the body materially affects the behaviour of the glaze. Besides crazing or cracking, the glaze may develop

bubbles or blisters or may shiver or crawl during firing. The crawling is due to excessively fine grinding of the glaze, or to an excess of clay, but the other troubles are seldom due to the glaze itself and can, as a rule, be remedied by modifications of the body and proper attention to the firing.

Transparent Glazes. The clear, transparent glaze used in the laboratory of the Mines Branch on trial pieces made of brick and tile clays from Ontario has the following composition:

Whitelead.....	168 parts
Whiting.....	25
Feldspar.....	56
Kaolin.....	13
Flint.....	36

These ingredients are weighed out and ground wet in a ball-mill for 2 hours, sieved through 100 mesh, and brought to the consistency of thick cream. The piece to be glazed is soaked in water, then partly dried, and afterwards dipped in the glaze. When it is difficult to obtain an even coat of glaze by dipping, the glaze is sprayed on. The glazed piece is then fired in an oil kiln to the softening point of cone 06 to 04.

For coloured transparent glazes, blue tones are secured by the addition before grinding of a small quantity of cobalt oxide to the above ingredients. For greens, copper oxide is used, and iron oxide for browns. Combinations of two or more of these metallic oxides added to the clear glaze will give a further range of colours, and many beautiful effects can be obtained by such mixtures.

Opaque Glazes or Enamels. Tin oxide added to a transparent glaze gives an opaque glaze of corresponding colour. These glazes are called tin enamels. A very pleasing shade of blue, to be fired at 1900 degrees F., has the following composition:

Whitelead.....	155 parts
Whiting.....	15
Feldspar.....	97
China-clay.....	2
Flint.....	30
Tin oxide.....	74
Cobalt oxide.....	4

A glaze of this type was used for pottery made of the buff-burning tile-clays found in Ontario.

Matt Glazes. The matt or dull glazes are produced by an excess of alumina or silica in the glaze. The alumina matt is the more easily handled and is produced by increasing the clay content and decreasing the flint in a clear glaze formula. Matt glazes require less grinding than the transparent glazes, and a thicker coat of glaze must be applied to the biscuit ware. Many of the small laboratory kilns will not produce silica matt glazes as they cool down too quickly after firing is finished.¹

Colour Decoration. Two methods of decorating pottery with coloured patterns are underglaze and overglaze.

The underglaze colours are applied to either the unburned or biscuit ware, and the colour is burned on. A coat of clear glaze is then applied and the final fire is given. Underglaze decoration is a true ceramic method

¹ Binns, C. F., "The Potters Craft," p. 123. D. Van Nostrand Co., New York.

of decoration, as after the final firing the body, colour, and glaze are fused together. In underglazing, firing takes place at high temperatures, ranging from 1,800 to 2,500 degrees F., and takes anywhere from 6 hours to 6 days to accomplish.

In overglaze work the decoration is applied to a piece already glazed. The colour in this case requires to be fixed by firing, but the temperature used in overglaze firing is much lower than for underglaze. In ordinary china painting the colours are applied to a piece that has been commercially glazed, and they only require to be fixed at a low, red heat, attained by a couple of hours' firing.

Types of Pottery

Art pottery includes such divergent types as the low-fired, buff, or red-burning ware with a soft porous body, and the high-fired, white, vitreous, and translucent porcelains.

Porcelain is made from a combination of china-clay, feldspar, and flint. It is biscuited at a low fire, then glazed and refired at a high temperature. The only two deposits of china-clay known in Canada are at St. Rémi, Quebec, and Williams Lake, B.C. The Quebec china-clay is of high grade and compares favourably in colour and texture with the standard brands on the market.

Much art pottery, however, is made of stoneware clay. This burns to a very hard, dense body, which may be white, buff, or grey. Both body and glaze are fired to a temperature of approximately 2,400 degrees F. The Rookwood, Fulpar, and Roseville potteries in the United States make art pottery with a stoneware clay body.

Earthenware and majolica wares have a soft, porous, opaque body, and the colour varies from deep cream to buff and red. From an art standpoint, this ware may be quite as attractive as the most expensive porcelain. The ware is glazed with a coloured transparent glaze or an enamel. Some of the clays tested in the Mines Branch could be used for wares of this type. The defect in this kind of pottery is that if the glaze crazes the vessel will not hold water.

All the art pottery sold in Canada is imported, principally from England, Japan, and the United States. Small industries of this kind should prove profitable at points where suitable clays occur, and where there is a considerable tourist trade.

POTTERY CLAYS IN ONTARIO

The domestic clays available for making pottery in Ontario are the post-Glacial clays described in this report, which are used at present for building brick and drain-tile. Mention has already been made of the former use of these clays in heavy earthenware articles, but this industry has disappeared.

There is a growing demand for coloured earthenware pottery of domestic manufacture, and this class of ware can be made very well from some of the clays in the province. Only those clays which have good plasticity and working properties in the raw state can be used for pottery. There are, however, some clays which work well, but contain too much lime. These highly calcareous clays burn to a very chalky porous body

which is difficult to cover with a glaze. Probably the best results are obtained by a mixture of the most suitable red-burning and buff-burning clays and these mostly occur in the same localities.

Nearly all the clays contain grit, and are not smooth enough to be shaped on the potters' wheel; consequently they must undergo preparation which will eliminate the coarse material. This is accomplished either by slaking the clay in water and passing it through a screen, the method commonly employed, or by drying the clay and pulverizing it. Heavy household pottery, such as butter crocks, mixing bowls, and jardinières, can be made from the washed glacial clays. The only objection to their use is that the body is porous, and when the glaze becomes accidentally chipped off, a spot which gathers dirt results. The stoneware articles are not open to this objection, for even when the glaze chips the vitrified body beneath will not absorb water.

Although household pottery made from surface clays may not be able to compete with those made from stoneware clay, except in a limited way, there is a large demand for glazed ornamental ware which has a distinctive treatment both in form, colour, and texture, and this demand can be supplied in part by wares made from the common clays.

The following notes refer to clays tested at a few localities, but there are many others equally good.

Toronto. The interglacial clay used by the Don Valley Brick Company for making red stock-brick was tried out on the wheel and its working qualities were fairly good. The pieces had good drying qualities and low shrinkage. Burned to cone 05 the body was porous and of light red colour. Very good results were obtained from this clay with the use of coloured tin enamels. The clay also made a good casting body.

A large deposit of similar clay occurs at Greenwood avenue, north of Gerrard street, where several brick-yards are in operation. The clay was used just as it came from the bank for the wheel, but it was washed for the casting slip.

Plastic buff-burning clays can be obtained from the brick-yards at West Toronto, or from those at the eastern end of the city. A mixture of the interglacial red-burning clay and the buff-burning clay gives good results. A large deposit of buff-burning clay overlies the red-burning clay at the Don Valley brick-yard, but is too silty and short in texture for throwing on the potters' wheel, though it would do very well for ornamental tile.

Hamilton. A very plastic, but coarse-grained clay, east of Hamilton and near Waterdown, is used for sewer-pipe. This clay requires to be washed and screened through a 60-mesh screen before a fine finish can be secured on the potters' wheel. The working and drying qualities of the washed clay are good and it burns a dense, dark red body, easy to glaze.

An abundance of yellowish glacial clay near the brick-yards at Bartonville is highly plastic and has good working qualities; but owing to coarse grit and pebbles must be washed and screened. The washed clay is excellent for throwing on the wheel and for modelling, in fact it is as good as many of the high-priced clays. It burns to a buff colour and fairly hard body at cone 06. Coloured tin enamels applied rather thickly will cover well on biscuit-ware made of this clay. Mixtures of the sewer-pipe clay

and the buff-burning clay will make a better pottery body than either of them used alone. Similar buff and red-burning clays can be obtained at Frid's, or Cooper's brick-yards.

The finely-ground Queenston shales at Hamilton, or mixtures of ground shale and clay are excellent for ornamental tile.

The physical properties of the clays in and near Hamilton are given in the tables in this report.

Brantford. Glacial clay is fairly abundant near Brantford. Probably the thickest and most extensive, stratified, stoneless clay deposit in southern Ontario, except on the shores of the Great Lakes, occurs along the bank of Grand river, near Cainsville, about 3 miles from Brantford. The old brick-yard at Mohawk park, at the east end of Colborne street, worked a bank of stratified clay and silt, but this material would not be suitable for pottery, as it is not plastic enough. The old brick-yard, worked by Mr. W. H. Freeborn, had a red-burning clay on the surface to a depth of 2 or 3 feet, and below this is a stiff, brownish, laminated clay which has good plasticity and burns to a hard buff body. A similar clay is found in the pits of the Ideal Brick and Tile Company, on Stanley street, and a sample of the clay was procured for testing purposes. This clay contains so many gritty particles that it must be prepared by washing and screening. It is less coarse than the Port Dover clay, and passing through a 40-mesh screen will eliminate enough of the grit to make a very smooth and highly plastic modelling clay. The washed clay has enough tensile strength and toughness and can be thrown on the wheel to make any desired shape. It would also serve as a modelling clay for school use, as built pottery forms either square or round, and tiles can be made from it. The opaque enamels, which have thin oxide in their composition, seem to work well on this clay, but the clear glazes have a tendency to craze. The burned colour of the body before glazing varies from a pink to a light buff according to the heats used.

Red-burning surface clay near Brantford is plastic enough for pottery, after being freed from grit. It can be used alone, or in a mixture with the buff-burning clay. It can also be made into a slip, and used for coating the buff clay.

The results of physical tests of Brantford clays are given elsewhere in this report.

Port Dover. The high banks facing lake Erie at Port Dover, Port Rowan, Port Stanley, and other places, are composed largely of yellowish calcareous clay. Building brick and field drain-tile are made from it at certain points, but not all the clay in these banks is suitable for brick or tile, because certain portions of it contain too many pebbles, stones, or concretions which would be too expensive to remove in making rough clay products; but a great deal of it is practically free from this defect. This clay burns to a buff colour because it contains a large amount of lime. As long as the lime is finely divided, no trouble is experienced after the ware is burned, but if particles and pebbles of limestone are present, they are turned into quicklime on burning, and eventually destroy the brick or tile containing them.

A sample of the upper part of the bank at Port Dover was secured from the Erie Clay Products Company, which manufactures tile and building brick at this point. This clay is yellowish, effervesces freely when dilute acid is dropped on it, and appears to be fairly free from coarse grit. It has good plasticity when wet, and flows smoothly through the die of a tile machine, but when used on the potters' wheel the grit comes to the surface and spoils the shape of the piece of ware. Furthermore, some of the grit consists of particles of limestone, hence for two reasons it is important to screen this clay for use in pottery.

When washed and screened through a 40-mesh screen, this clay still contains a good deal of fine grit, but it can be used on the wheel if a very fine finish is not required; the trouble from limestone particles is also removed. The washed clay has very good plasticity, and would make a good clay for modelling as well as for throwing on the wheel, but should be screened through a 60-mesh screen for the finest work. The washed clay will stand tolerably fast drying without cracking. Thin wares like pottery dry out more quickly than brick or tile, but are just as liable to crack as is brick if dried too fast.

The Port Dover clay burns to a buff colour with a trace of pink when fired to the softening point of pyrometric cone 06, the pink colour being more pronounced if the firing is finished at a lower temperature. The fired body is very strong and tough, but quite porous at this temperature. If fired to a higher temperature, say cone 03, this clay is liable to soften slightly and deform. It also shrinks greatly at the higher heats, and the body becomes quite hard and of a sulphur colour.

When a clear colourless glaze is applied over the burned ware, and the pieces re-fired, they come out of the kiln a rich dark buff tone. The clear glazes, however, have a tendency to craze some time after the pieces are fired, but the crazing can be stopped by altering the composition of the glaze to suit the clay. By adding iron oxide to the clear glaze, a brown colour can be obtained, which does not craze so readily.

Tin enamels gave the best results on this clay, blues and greens being especially good.

The clay might be used for the manufacture of heavy household ware, such as mixing bowls, bean pots, and jardinières, but the expense of preparing it by washing and screening may be prohibitive. Several pieces of pottery made on the wheel and glazed in different colours at the laboratory of the Mines Branch were very attractive as flower vases or ornamental pottery.

The chemical analysis and physical tests of the clay are given elsewhere in this report.

Essex County. The clay used for the manufacture of brick and tile in Essex county occurs as a thin sheet on the surface of certain areas. It is seldom more than about 2 feet thick. The top clay is brownish and free from lime. The clay below this is a grey stony material quite useless for clay products. The top clay burns to a good strong body and a fine red colour, in fact, the burned ware has the best red colour among all the red clay products in Canada.

The clay as it comes from the pits contains a good deal of coarse and fine gritty particles, which must be removed by washing and screening before it can be used for modelling or for wheel work; furthermore, it is

necessary to use a screen of 60-mesh to an inch in order to make it give a smooth finish. This screened clay is very plastic, and has sufficient tensile strength that it can be turned into any shape on the wheel, or used for modelling. Ornamental pottery made from it need only be glazed on the inside; the outside can rely on the fine burned red colour without the addition of glazes or enamels, but the whole body can be glazed if desired.

Whitby. Both red and buff-burning clays are available in the vicinity of Whitby. The clay used for making cream-coloured tile at the brick-yard is very plastic and rather smooth, but contains occasional particles of coarse grit which can be removed by washing through a 40-mesh screen. Washed clay works well on the potters' wheel or for casting in plaster moulds. The fired ware has a good strong body, but is very porous and requires a thick coating of coloured tin enamel before the second firing, in order to cover the pieces.

A pottery body was made up using 75 per cent clay, 15 per cent flint, and 10 per cent feldspar. This mixture gave better results in firing and glazing than clay alone. The buff-burning clay could also be improved by using it as a mixture with the red-burning clay, about half of each. This would give a denser fired body than the buff-burning clay alone and would also be suitable for coloured transparent glazes as well as tin enamels.

Bowmanville. A rather sandy, red-burning surface clay is used for making building brick at Whitby. There is about 6 feet of silty buff-burning clay below the surface clay, but there is a more plastic and denser-burning, buff clay still lower. The lower clay has good plasticity and working qualities, and is similar to the underclay at Whitby. When washed, it works well on the potters' wheel or for casting in plaster moulds. It can be glazed at cone 06 with coloured tin enamels, but like the Whitby clay, it would be improved by the addition of some flint and feldspar.

The chemical analysis and physical tests are given elsewhere.

Renfrew. There is a great quantity of stoneless, plastic clay of marine origin along Ottawa and St. Lawrence rivers. It is a dark grey, sticky clay, hard to dry, and has a high shrinkage. It is unsatisfactory to use for pottery. A quantity of flower-pots were made from it in a small plant, but as a general rule this clay is a failure as far as pottery is concerned. It burns to a red colour, but at a few points there is a bed of buff-burning clay below the red. Most of the buff-burning underclays are very silty and only feebly plastic, but at Renfrew the underclay has very good plasticity, and better working qualities than any of the red upper clays—which is a very unusual occurrence.

A sample of the underclay was collected from the old brick-yard site in the valley of Smith creek. This clay was formerly used in the manufacture of field drain-tile; it is fairly smooth and appears to be free from coarse grit. It cannot be used, however, direct from the bank as a wheel clay, because it contains certain layers which do not slake in water, but remain in small lumps. It is necessary to either pulverize the dry clay very finely, or else wash and screen it. The washed clay is very smooth and makes an excellent clay for modelling, hence is recommended for use in schools.

The chemical analysis and physical tests of this clay are given elsewhere in this report.

SPECIAL CLAY WARES

Some of the plants engaged in the manufacture of brick and drain-tile might take up with advantage the making of a more specialized and profitable line of wares wherever they have a suitable clay or shale. There is a large and growing demand for the ordinary red floor-tile, used in corridors, kitchens, hospitals, and other places, which may easily be made from some of the red brick shales by simply grinding them finely.

Though these shales may not be suitable for tiles for outdoor use, on account of their porosity, they will give good wear indoors. Roofing tile and tile for lining digesters in the pulp-mills are other profitable lines for the manufacturers, but the latter would have to be salt glazed.

Porous clay wares, such as iceless refrigerators and water coolers, would have a large sale if any one undertook their manufacture. Vessels of this kind owe their cooling properties to their ability to soak up a large quantity of water, and the evaporation of this water as it comes to the outer surface keeps the contents cool. The Medalta Pottery Company at Medicine Hat, Alberta, is the only firm in Canada which makes this class of ware. This firm makes a porous water jug, especially designed for keeping water cool, and similar to the jugs and bowls in use in tropical countries.

FLOWER-POTS

Clay suitable for making flower-pots should be fairly smooth and plastic, with low shrinkages, and burn to a porous but hard red body at low temperatures. Most of the clays used in Ontario for making field drain-tile of red colours would also be suitable for flower-pots. Some of the cream-burning tile clays would answer just as well or better than the red-burning clays, but the red colour is preferred.

Flower-pots can be made by hand on the potter's wheel, but the output by this method is small, and owing to irregularities in size will not nest so well as machine-made pots, when stacked for firing and shipping. They may also be jigged in plaster moulds on a power-driven wheel. This method gives a larger output with more uniform sizes than the potters' wheel, and does not require an experienced potter, but it necessitates a large number of moulds if any capacity is to be obtained. For production on a quantity basis the vertical flower-pot press is by far the best method in use. It is not necessary to have experienced and long-trained men to operate them. The capacity of these machines is considerable. An hourly output of 300 to 400 medium-sized flower-pots is not unusual.

The clay requires slightly more preparation and ageing than is considered necessary for drain-tile. It is usual to have a storage place protected from the weather where the clay can be placed after it is dug from the pit. The clay is wetted and allowed to stand until it thoroughly absorbs the water. It is then run through a stiff-mud brick machine and as the bar issues from the die it is cut into sections by stiff wires attached to the face of the die. The clay bar is also cut longitudinally into pieces depending on the size of flower-pot required, then the pieces are made into balls and delivered at the flower-pot press.

The pots are formed between steel shapes. The lower shape, the inside of which corresponds to the outside of the pot, is fixed, and the upper one, or plunger, which shapes the inside, rotates rapidly. Flower-pots can be dried outdoors on wooden racks, but it is better to place them in an artificial dryer.

Either round or rectangular down-draft kilns can be used for burning. The usual form of setting is to place one pot on top of another, each pot resting on the shoulder of the one below. It is not safe to make the stacks more than 4 feet high, otherwise the weight will break the lowest pots. In order to fill the kiln it is necessary to have fire-clay shelves and supports so that a second pile can be placed above the ones resting on the floor of the kiln and still not carry the weight of the upper ones. If brick are being made in the same plant, the bottom part of the kiln can be set with brick and the top with flower-pots.

On account of the thinness of the walls of flower-pots they are easily burned, but the cooling off should be done as slowly as possible to avoid cracking. The pots must be burned so thoroughly that even a hard frost will not harm them. The constant moisture to which a flower-pot is subjected will have a disintegrating effect on soft-burned ware even without the aid of frost.

HEAVY EARTHENWARE

"The pottery industry a few years ago was of great importance in Ontario, and almost every town had its local pottery. The manufacture of the better classes of pottery, stoneware, etc., in the southern parts of United States, where there is a better class of clays, much purer than the glacial clays found in Ontario, has seriously interfered with the use of the Ontario clays, which are suitable only for the manufacture of common pottery. Consequently, nine-tenths of the potteries of Ontario have been forced to close, and those which remain are running on a very small scale. Pottery is made, however, from both the Red-top clay and the Erie blue clay; the first turning out red pottery suitable for flower-pots, etc., the second a better pottery suitable for domestic purposes, such as churns, milk-pans, crocks, jugs of all sorts, and other common earthenware. The clay in all cases is well washed, and then worked by hand into the desired articles. Most of the ware is glazed, the glaze being varied to suit the requirement.

As stated above, very few of the potteries formerly in operation now exist. A few, however, are still engaged in the manufacture of flower-pots, butter crocks, churns, and jugs of various kinds, including vinegar and syrup jugs. The flower-pots, both red and white, are unglazed, while the other classes of pottery are glazed in various ways from clear transparent glazes through mixed glazes to deep brown and almost black. Among the potteries operating in Ontario in 1906, the following may be mentioned: J. Taylor, Port Hope, Durham county; Horning and Brownscombe, Owen Sound, Grey county; F. Burgarde and Son, Egmondville, Huron county; S. R. Burns, Bolton, Peel county; J. and G. Cranston, Hamilton, Wentworth county; S. P. Foster, Hamilton, Wentworth county; Wm. Stonehouse, Carleton Place, York county; Joseph Davis, Davisville, York county.

The method of manufacture, the output, and the varieties of goods made in all these works are about the same, so that only a general description need be given of them. Both the Erie and Red-top clay are used in the manufacture of pottery. The Erie burns to a white colour, and the Red-top burns to red. These clays are usually dug and re-washed so as to remove all sand, gravel, or other impurities. The washed clay is run into settling tanks and allowed to dry, or it is taken wet and is thoroughly beaten to remove all air from the interspaces, or, as the potters say, to beat the wind out of it. After this, the clay is either moulded by hand for certain of the forms, or is pressed into moulds for other forms. The articles are then slowly dried to prevent cracking, and when thoroughly dry are ready for the kilns if they are to be unglazed.

If glazed ware is required, the thoroughly dried articles are dipped into the required glaze several times until a sufficient coat has adhered. They are then placed in the kiln where they are slowly heated for three or four hours, after which they are fired up to a high temperature, about the same as for brick, that is, from 1,700 to 1,900 degrees Fahrenheit. The kilns are fired with wood or coal or coke, but the ware is not exposed to direct heat, that is, the fires do not lead through the ware. The inner lining of the kilns is built of fire-brick. The output varies with the demand, so that no definite list can be given. Some of the potteries have now gone into the manufacture of drain-tile, since the demand for pottery is not brisk.¹

From the above extract it will be seen that the small potteries scattered over many parts of southern Ontario began to disappear in 1906, and soon ceased to exist. It is now difficult even to find the former site of a pottery. It is unfortunate that this picturesque and interesting industry died out. It formed a convenient source for the heavy earthenware articles in daily household use and gave local employment in many places, but more important than that, the craftsmanship of pottery was preserved, and a means was always at hand for any of the workers to give expression to their talents in artistic clayworking. There is no reason why decorated tiles like the old English and Moorish could not be made from the glacial clays in Ontario as well as milk pans and butter crocks.

The industry succumbed, as Mr. Baker points out, to the competition of the mass production of stoneware articles from the large factories in the United States, and the improved transportation facilities for distribution. It is true that the articles made of stoneware clay are better than the home made earthenware, because the stoneware body is vitrified and the other is not. Consequently, when a piece becomes clipped so that the glaze is removed, the body under the glaze of the stoneware is still impervious to water whereas the earthenware is not.

POTTERY INDUSTRY IN ONTARIO

The following industries operate independently of domestic clays, as none of these clays are suitable. Whiteness and hardness are essential to the wares made. The body of the ware is composed of about 50 per cent or a little more of clay, the rest being non-plastic material.

¹ Baker, M. B., Rept. Ont. Bureau of Mines, 1906, pt. II, p. 118.

The ingredients used are china-clay, ball-clay, flint, and feldspar, and all the materials are imported, except that Canadian feldspar is now largely used. Most of these industries are situated near a market for their wares, and at points where transportation facilities are convenient for assembling raw materials and fuel, and distributing the finished products.

Table Ware

White table ware will be made for the first time in Ontario in large quantities when the factory which the Ontario Pottery Company is now building on King street, Oshawa, is completed. The firm is at present operating in temporary quarters in the same town, turning out white granite ware and ornamental white earthenware with coloured glazes. The company very wisely intend to confine their efforts to the production in quantity of the heavy white ware used so much in restaurants, lunch counters, and elsewhere. The market for this kind of ware is large and the amount that has to be replaced daily by breakage is very considerable. Later on it is purposed to supplement the plain white by gilt and printed wares. Two pottery kilns are being built, but room is provided for four more, and there is sufficient ground adjacent to the factory for further buildings as required.

It is also proposed to utilize the buff-burning brick and tile clay which occurs at Bowmanville and Whitby for the manufacture of majolica pottery and wall-tile. The brick-clay with about 25 per cent of flint added to give it stiffness in the firing will be a very suitable body for the purpose. Raw materials from England are being used at present for making white ware articles, but Canadian china-clay will also be used if available, as well as Canadian spar.

Port Hope. A company was incorporated in August, 1922, with a capital of \$1,000,000, for the purpose of manufacturing ceramic and porcelain products and enamelled ware. The head office is at Port Hope and the company is known as the Bush English China Company, Limited.

Electrical Porcelain

Hamilton. The Canadian Porcelain Company, Ltd., have been manufacturing insulators for high tension transmission lines for some years at their plant in Hamilton. The raw materials used are china-clay, ball-clay, flint, and feldspar. Canadian feldspar is used, but the rest of the materials are imported.

Peterborough. The Canadian General Electric Company, Ltd., have an electrical porcelain works in Peterborough in connexion with their plant for the manufacture of electrical apparatus. This plant had three pottery kilns in full time operation in 1922.

Georgetown. A plant for the manufacture of porcelain fittings for electrical apparatus and specialties is being started at Georgetown by Smith and Stone, Ltd.

Floor and Wall Tile

There is one plant in Ontario engaged solely in the manufacture of white and coloured vitrified floor tile and wall tile. This is the Frontenac Floor and Wall Tile Company, Ltd., Kingston. The plant is compara-

tively new and furnished with all the modern apparatus and kilns necessary for turning out a large supply of standard floor and wall tile. The raw materials used are china-clay, ball-clay, flint, feldspar, and fire-clay, as well as various mineral oxides for colouring. The ball-clay and flint are imported, but the rest of the material is obtained in Canada.

The different ingredients of the tile body, which are the same as those used in table ware, are thoroughly mixed together in water, and then screened and dried. The dried clay is ground to a powder and fed into the various machines which press it into the required shapes and sizes. The tiles are packed in saggars between layers of quartz sand as soon as they come from the presses. The loaded saggars are placed directly in the kiln and as soon as it is full the door is closed and firing begins. The firing is continued until the tile are vitrified, which occurs at the softening point of standard cone 10 (about 1,330°C. or 2,426°F.).

The wall tile are made in the same manner, but the body is not fired to vitrification. Two firings are necessary for wall tile, the first being the biscuit stage, and the second for firing the glaze which is applied to the biscuit.

The making of saggars for holding the tile while burning is an important part of any pottery, as the loss from breakage is large and cannot be avoided. Some sagger mixtures, however, have a longer life than others, depending on the clay, or mixture of clay used. The sagger mixture used at Kingston consists of a mixture of crude discoloured kaolin from St. Rémi, Que., and stoneware clay from Musquodoboit, N.S., with a certain proportion of grog made by grinding broken saggars. It is said to give entire satisfaction.

This plant has recently added machinery for grinding feldspar, so that in buying crude spar from the mines north of Kingston and grinding it themselves a considerable saving is effected.

CHAPTER XIII

METHOD OF TESTING CLAYS AND SHALES

The ordinary physical tests made on clays in the laboratory are used to determine their plasticity or working qualities, drying qualities and shrinkage in drying, their behaviour in burning, and the character and colour of the burned body.

Preparation. Samples of shale are usually ground to pass a screen of 12 meshes to the inch or in some cases finer according to the kind of product required. The coarser grained material is used for brick and the finer for tile. Clays are ground fine enough to allow them to slake readily in water, and except in the case of high-grade clays are not screened or washed.

Plasticity and Working Qualities. Water is added to the ground clay or shale and mixed until the best working consistency is attained. The amount required to bring the clay to this condition is called the water of plasticity and varies according to the texture and slaking qualities. Hard, gritty shales and sandy clays require less and fine-grained, fat clays require a great deal. The clays that require a large amount of water to make a plastic mass shrink more in drying and take longer to dry than those requiring a small amount of water. There is no standard measure of plasticity, but clays are rated as highly plastic, plastic, or low in plasticity in a comparative way, and the experience of the worker in clay is the most reliable guide so far.

Moulding. When the clay is thoroughly kneaded and wedged so as to render it perfectly homogeneous and free from cavities, it is stored in a damp chamber for at least twenty-four hours. The consistency of the moist clay is generally not so stiff as a stiff-mud brick-clay in practice or as soft as a soft-mud brick preparation. The kneaded clay is then made into several bricklets in a mould 4 inches by $1\frac{1}{2}$ inches by 1 inch in size. Two fine lines, exactly 3 inches apart, are impressed with a steel stencil on the wet bricklet immediately after leaving the mould.

Test pieces for tile are made by expressing the clay from a hand plunger press through a round die with an inside diameter of 2 inches.

Dry-pressed test pieces were made by making the ground shale damp, and pressing into a dense bricklet in a powerful hand press. All test pieces are thoroughly dried at room temperature.

Drying Qualities. For this test the kneaded clay is pressed into a 3-inch cube in a mould. The cube is placed in an electrically heated drying oven which can be heated to various temperatures between 120 and 180 degrees F. If the cube of clay cracked under this treatment it was stated that it would not stand quick drying. A drying test is one of the most important of the series, especially if it is proposed to build a dryer for surface clays. Shale in Ontario and eastern Canada generally, stand quick drying successfully, but a great many shales in western Canada, particularly those of the Great Plains region, will crack badly if dried too fast.

Drying Shrinkage. All clays shrink more or less in the change from the wet to the dry condition. When the bricklets were thoroughly air-dried the distance between the lines impressed on them, which was originally 3 inches, was measured and the percentage of linear air shrinkage calculated.

Linear Fire Shrinkage. The air-dried bricklets were placed in either a gas-fired or oil-fired laboratory kiln, and the time occupied in burning was 8 to 10 hours. A bricklet of each clay was burned at three different temperatures, or sometimes more if the material stood up under the higher heats. The distance between the lines on the burned bricklets was measured after each successive firing, and the total amount of shrinkage calculated. The difference between the total shrinkage and the air shrinkage represents the linear fire shrinkage.

Volume Shrinkage. The plastic volume, dry volume, and fired volume of clay test pieces are determined in a volumeter of the Seger type. Distilled water is used for the burned pieces and kerosene for the others.

Absorption. The bricklets are carefully weighed after each burning and immersed in water to about three-fourths of their thickness. This permits the air to escape freely from the burned clay so that the water quickly fills the pores. After standing 24 hours in water, the saturated bricklets are weighed, and the percentage of absorption calculated as follows:

$$\frac{\text{Saturated weight} - \text{dry weight}}{\text{Dry weight}} \times 100$$

The saturation of the burned clay is more thorough if the weighed test pieces are placed in water in a suitable vessel and boiled for 2 hours, then allowed to cool to room temperature, while still immersed in water.

Control of Temperature in Firing. Pyrometric cones of the Seger formula as made by Professor Edward Orton, jun., afford an inexpensive means of fixing the finishing points of kilns, even though they do not measure temperature. Since they are composed of silicate mixtures their softening point expresses the effect of both time and temperature.

The cones are mounted on a base and placed in the kiln with the test pieces. The cones placed for the firing of most of the clays and shales of Ontario are 010, 06, and 03. These are placed opposite a peephole where the observer can see them as the firing progresses. When the cone softens and bends to form a semicircle with its point touching the base, the firing is stopped (Plate IXA).

The temperature of the kiln is also recorded by a pyrometer with a platinum-rhodium thermocouple. The average temperature recorded on the pyrometer when the cones are down is as follows:

- Cone 010, 1,680 deg. F., 920 deg. C.
- Cone 06, 1,800 deg. F., 980 deg. C.
- Cone 03, 1,900 deg. F., 1,040 deg. C.
- Cone 1, 1,976 deg. F., 1,080 deg. C.

Softening Point. For the determination of the softening point of a clay, test pieces were made in a steel mould the size and shape of the standard pyrometric cones. The test pieces are mounted and placed with standard cones in the kiln. The standard cone that goes down the same time as the clay is the record of its softening point. Many of the red-burning brick and tile in Ontario soften about cone 1, and the shales about cone 3. The buff-burning clays soften about cone 3, but some require higher heat before softening.

FIELD EXAMINATION AND TESTING OF CLAYS

"It is really surprising to note the immense waste of money due directly to the erection of plants without first making the proper tests of the raw material it was proposed to use."¹

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, be in a body large enough to keep a plant going for a considerable time, be free from harmful impurities, and be easily worked. There are many important questions to be considered, however, in a preliminary inquiry, for example:

Can drainage be provided as excavation or mining proceeds, since it is necessary to keep the workings dry?

Is the water supply for all purposes adequate and of good quality?

If sand is required for mixing or moulding can it be obtained cheaply?

Consideration of the fuel supply.

Are conditions in the locality favourable for labour?

Can breakages of machinery be repaired quickly?

Can the kiln foundations be kept dry?

Would further prospecting probably 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 ploughed fields or hillsides or ridges and along the banks of streams or dry gullies. Springs issuing from hillsides sometimes furnish a clue to 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 they are freshly made. As soft clays in a steep bank are liable to be concealed by slide material which has washed down over them, it is in many cases necessary to cut a deep trench up 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 fire-clays, 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

¹ Graves, A. F., Walker, C. E., "Clay Plant Construction and Operation," Brick and Clay Record, Chicago, U.S.A.

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 hydraulicking, if a sufficient head of water is available. An overburden which contains pebbles, especially pebbles of limestones, 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 the material to be removed.

Shale deposits are often exposed in fairly steep banks, either in an escarpment or on stream banks, 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 of western Canada can be tested with an auger as easily as surface clays from boring, but the shales in the east are too hard for this method.

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 Deposits

Some impurities in clay or shale are visible to the naked eye, and others are not. 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 be 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 contain even a few scattered pebbles. Beds of calcareous clay contain in many instances layers of concretions, but are otherwise free from pebbles. Concretions are hard, rounded, elongated, or fantastically-shaped nodules, known as "clay dogs" by men working at the clay banks (Plate IX A). They will destroy burned brick more effectively than any other form of lime, and should be rigorously excluded from the brick mixture. This may be done easily if the concretions occur in layers, but if they are scattered through the mass there is no hope for the deposit. Layers or pockets of sand, if not too large, are sometimes beneficial in a surface clay, especially if it be highly plastic. Brickmakers prefer a clay bank to work itself, meaning that it carries the right proportion of sand to clay, but a clay deposit that is too sandy is undesirable because the product made from it is liable to be weak and porous. Although a shale deposit may consist largely of beds of true shale, it may also contain so many layers of sandstone or limestone as to be of doubtful economic value. If the stone bands or layers are thick enough they may be sold for building stone, if a convenient market exist. Ironstone concretions and lumps of iron pyrites are among the serious impurities in shales and clays. They are sometimes so large that they may be discarded in mining. Gypsum or lime sulphate is a frequent impurity in the soft shales of western Canada. It mostly occurs in

small, glistening particles disseminated through the shale; or it may be in large crystals or rosettes. As a rule it follows in the west that clays carrying gypsum are hard to dry without cracking.

It is as a rule impossible to foretell much about the value of a clay or shale by simply inspecting the deposit. An experienced clayworker, 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 may be distinguished from a slate by grinding a little with a hammer and moistening it. The shale dust will have 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 strong effervescence in a clay it may be discarded as unsuited for this purpose.

Clays that will crack in drying can be easily detected by kneading up a sample with water to the proper consistency, shaping it into a rough brick or cube, and setting it to dry. 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 give a large output of finished products.

Practical Instructions as to Sampling

Many people send a few ounces of clay to a testing laboratory and expect to be told all about its properties and uses. At least two pounds of clay should be submitted, and even then the testing is only preliminary to testing a larger sample.

Few clay or shale deposits are uniform in character throughout their entire thickness, and the selection of samples for testing is, therefore, a matter of some importance. If the deposit appears to be uniform, 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 in many cases misleading in clay investigation. Many persons pick a small sample of clay from the surface of a deposit and send it to be tested. Tests on such samples are mostly useless. The body of material, when opened up for working, may give results entirely different from the thin veneer of weathered clay overlying it. In a locality where industries have been for a long time working satisfactorily on a widespread material 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 the manufacture of common brick only is concerned. Where any of the highest class of clay products are to be made, the cheapest method is to take every possible precaution at the outset of the enterprise.

The following method of sampling shale and clay deposits is approved by the Committee on Standards, American Ceramic Society.

Preliminary Sampling. A face of the body of clay to be sampled shall be carefully stripped of loose or foreign materials, and a series of parallel trenches cut, each a straight line, so as to make as nearly as may be a vertical section entirely across the outcrop. In the case of stratified or bedded deposits which are inclined, the direction of these trenches shall be, preferably, across the dip, so that a proportionate amount of clay will be obtained from each individual layer. Each trench shall be about 12 inches wide and deep enough to produce at least 100 pounds of material. Where natural outcrops are not available for a sampling, preliminary trials may be made with a hand auger, and test pits dug to the necessary depth to expose a section (or face) of the clay.

As this may yield more material than is necessary for even a complete series of tests, the clay from the different trenches shall be reduced to lumps not exceeding 2 inches in diameter, mixed together and reduced by quartering to about 100 pounds which is to be sent to the testing laboratory. The quartering shall be done on a heavy sail cloth at least 8 feet square.

If the deposit shows distinct difference as regards structure, colour, or texture, each bed showing these individual differences shall be sampled separately, provided these beds are sufficiently thick to be mined by themselves or can be thrown out if undesirable.

Where the clay is stored in stock piles the sample may be taken from these, *provided they are representative.* At least one-half of the sample shall be taken from the lower third of the pile.

In the case of those clays which are being purified a sample of both the crude material and the clay as prepared for the market shall be taken.

The samples collected as outlined above shall be placed in clean, tight-weave, strong sacks and carefully labelled by means of two tags, each bearing the proper identification marks. One folded tag shall be placed within the sack and the other securely attached to the outside.

Extended Sampling. After a clay proves satisfactory in the preliminary testing, the surrounding tract must be surveyed and systematically sampled. A topographical survey of the tract shall be made. Holes shall be drilled or dug through the deposit not more than 100 feet apart. A record shall be kept of the thickness of each stratum encountered. By plotting these results to scale, the shape, size, and dip of the strata can be estimated.

A few larger holes shall be dug at the extremities of the properties or at any points of doubtful value in order to get samples large enough for a complete series of tests. These shall be taken under the direction of "Preliminary sampling."

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.

A good deal of time and money have 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, based upon the results of their chemical analysis 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 of little use for the general group of clays or shales used in the manufacture of structural ware.

What the clayworker desires to know about a clay or shale is:

- Its plasticity and working qualities
- The rate of drying
- The exact drying and burning shrinkages
- The commercial limit of burning
- The porosity and absorption of the burned wares
- The actual difficulties encountered in burning, such as cracking, warping, or swelling and scumming or whitewash.

Many of the important clayworking plants in the United States and England, especially those making a variety of wares, have an experimental laboratory, with small kilns for burning trials, in charge of a competent ceramist. These firms test a large number of clays from outside sources. Two of the universities in Canada and four of the United States Universities give courses in ceramic engineering and have fully equipped clay-testing laboratories. A certain amount of commercial work is done, for which fixed charges are made, according to the scope of the investigation. The tests are conducted by experienced men, whose reports are reliable and extremely valuable to the person or company about to start a clayworking industry.

Most of the manufacturers of clayworking machinery have a clay-testing department on their premises. These people invite prospective customers for machinery to send samples of their clay and have them worked up into specimens of ware. They generally make the tests free of charge. The specimens of burned wares sent back by the machinery companies to their prospective customers are as a rule perfect in every respect. These samples should be regarded as a standard to be ultimately attained, however seldom reached in the everyday world of clayworking, but it must always be remembered that the principal object of a manufacturer is to sell machinery.

Testing Under Working Conditions

If a company or individual wishes to establish an important clay-working industry at a certain place to make a certain class of wares, a reasonable way to proceed in the test of their clay—provided the field examination be 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. An experienced man must do the sampling and 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. The plan of the buildings, the design of the kilns or driers, and the selection of the best types of clayworking machinery, should be supervised by a competent ceramic engineer.

It is impossible to provide against all the troubles which may arise in new localities when dealing with a new material; but the risk of trouble can be materially lessened by proper precaution.

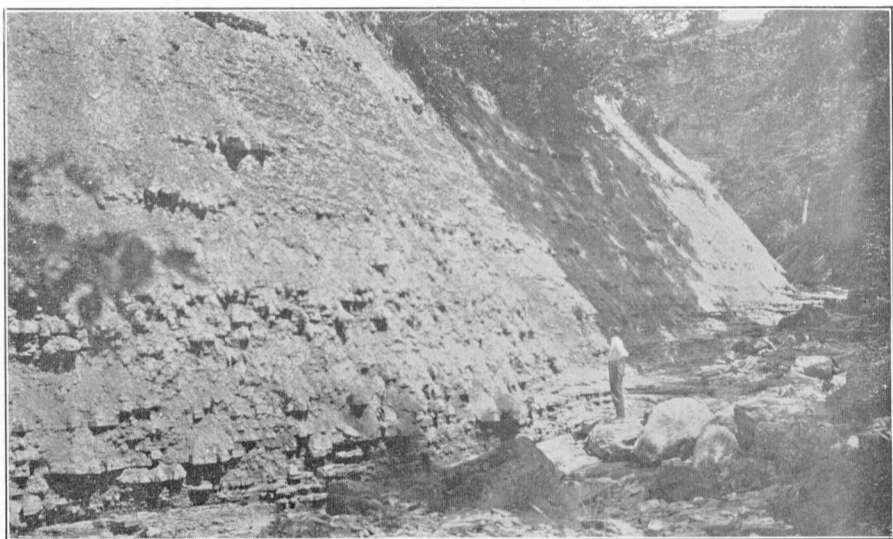
The manufacture of clay products is a desirable one in many respects. It gives healthy employment and produces articles of great use to a community. It is a fairly profitable business when backed by brains, technical skill, and capital, but it is just as easy for the unwary novice to lose his money in a homely-looking, clayworking plant as in the more spectacular operations of metal mining.



Lorraine shale, in excavation at the Don Valley Company's brickworks—used in the manufacture of face-brick. (Page 16.)



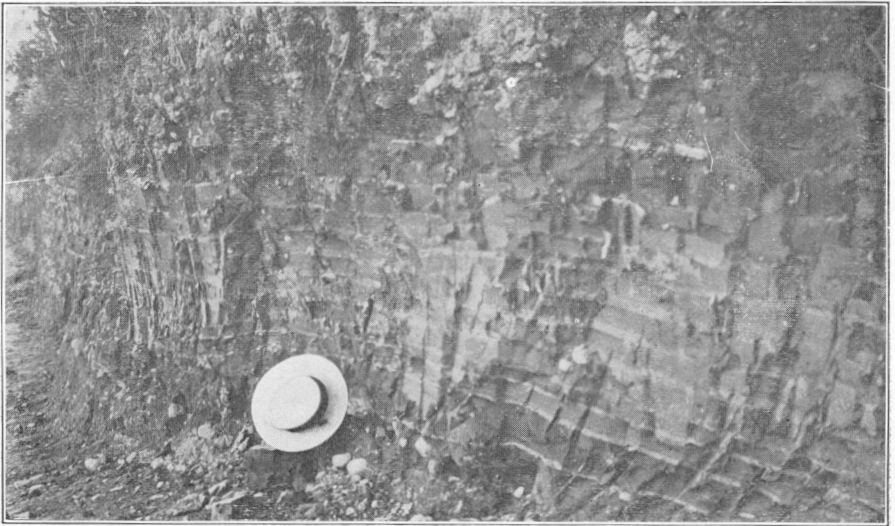
A. Typical exposure of Queenston shale, Waterdown. (Pages 20, 99.)



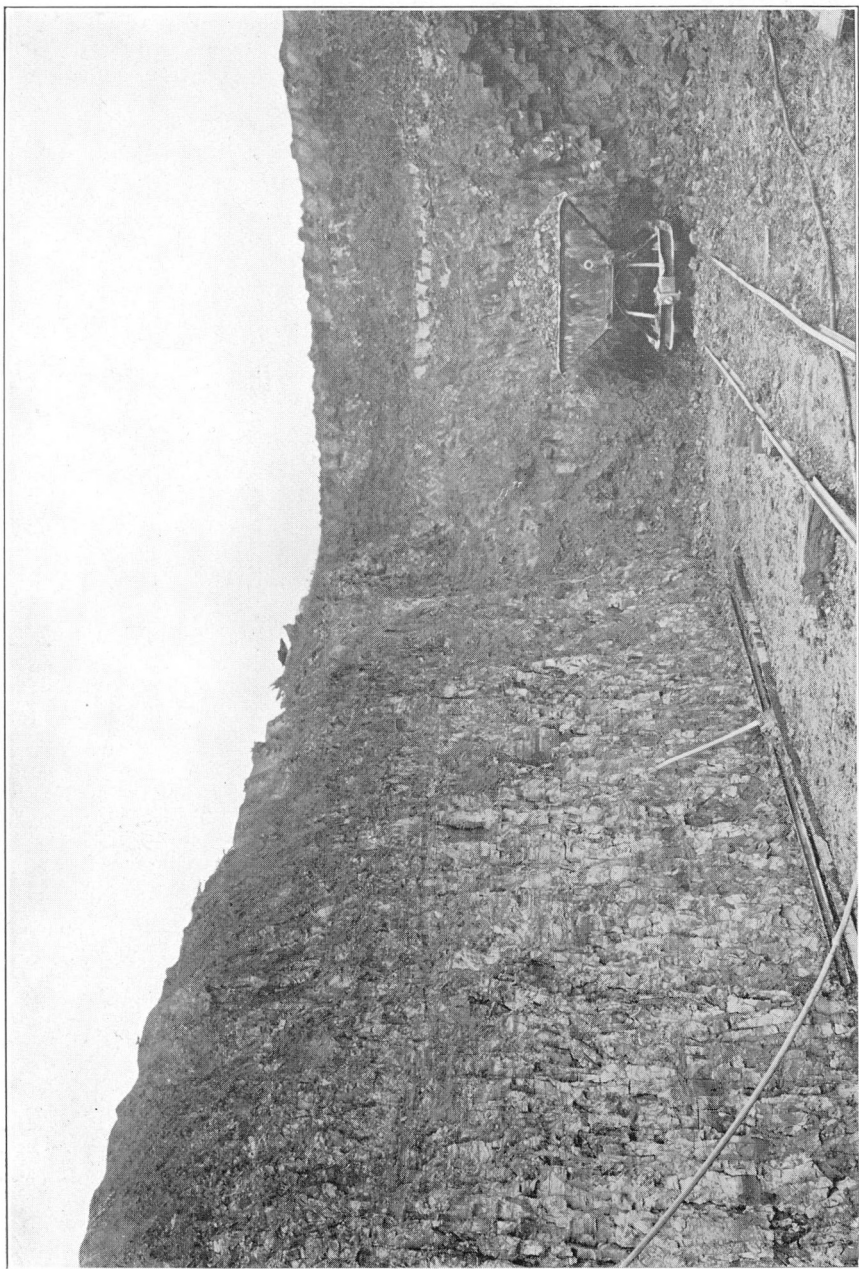
B. Section of Cabot Head shale in gorge on Stony creek, Wentworth county. (Pages 23, 99.)



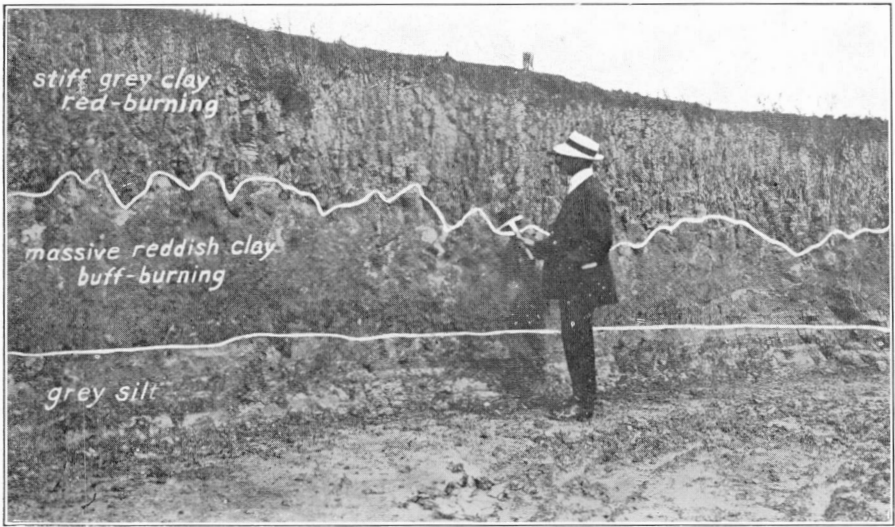
A. Typical example of boulder clay in central Ontario, near lake Ontario. (Page 45.)



B. Stratified postglacial lake clay overlying stony clay, showing alternating layers of clay and silt. The lighter-coloured, thin layers are silt. (Page 47.)



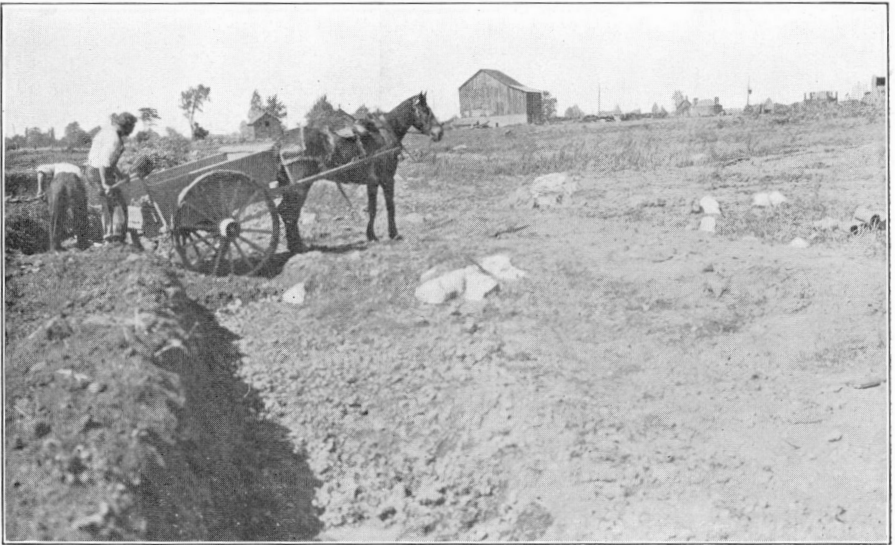
Excavation in upper Champlain clay, Renfrew. (Page 47.)



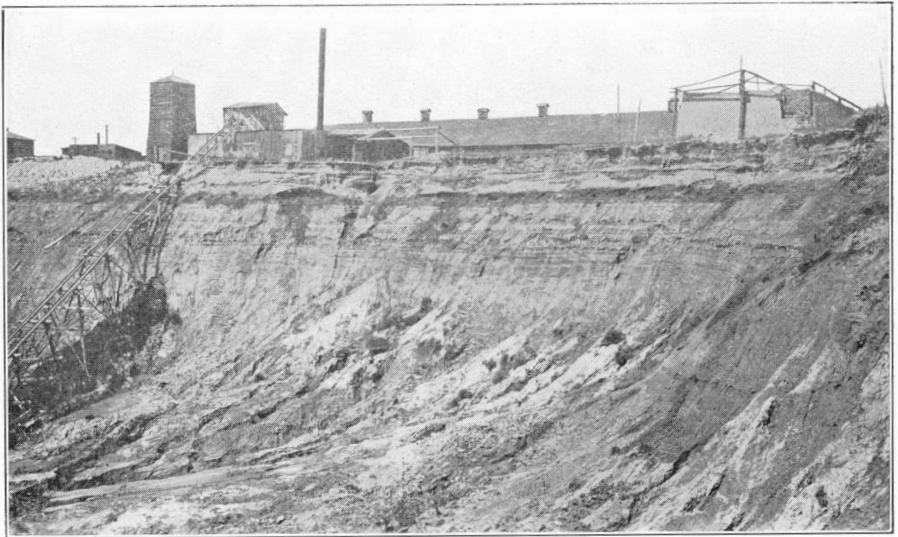
A. Clay pit at tile works, Crediton, Huron county. Showing irregular depth of weathering and leaching, and unweathered clay and silt below. (Page 86.)



B. Stratified interglacial clay at Greenwood avenue, north of Gerrard street, Toronto. (Page 106.)



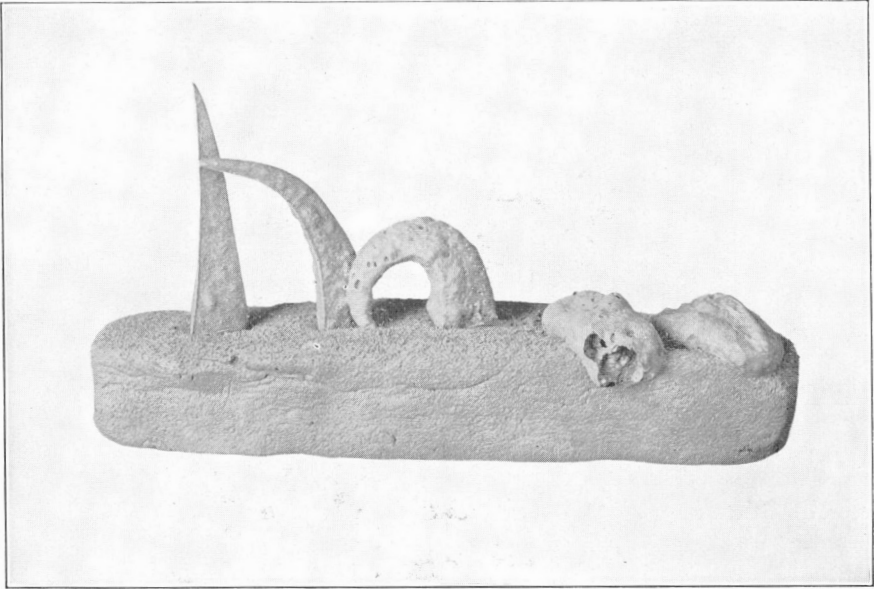
A. Thin layer of leached surface clay, overlying stony clay at Stratford. Used for red brick and drain-tile. (Page 107.)



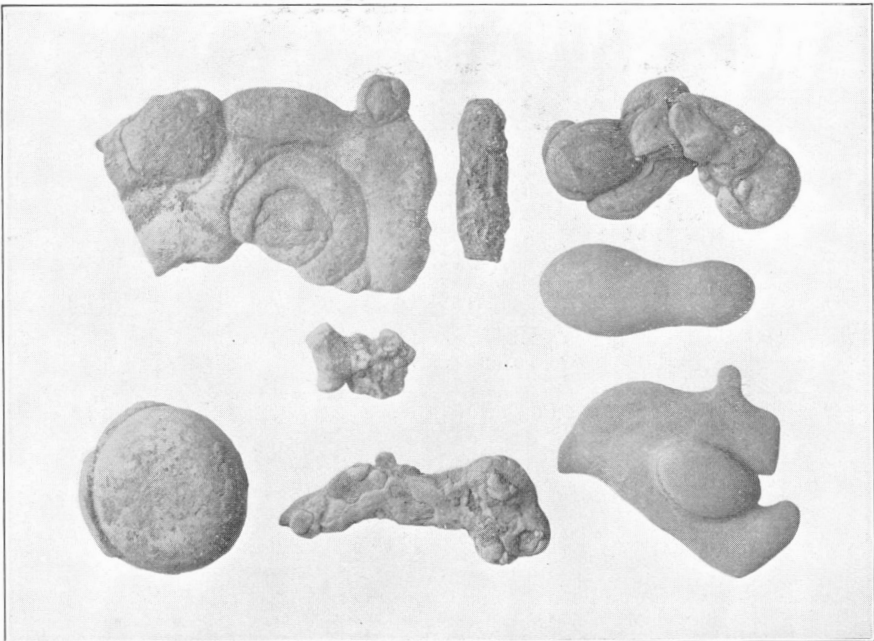
B. Stratified Algonquin clay on bank of Kaministiquia river at Fort William. (Page 127.)



Field drain-tile showing the effect of limestone pebbles. (Page 137.)



A. Pyrometric cones for measuring the effect of heat on clays. (Page 156.)



B. Various forms of calcareous concretions found in stratified post-Glacial clays in Ontario. (Page 158.)

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