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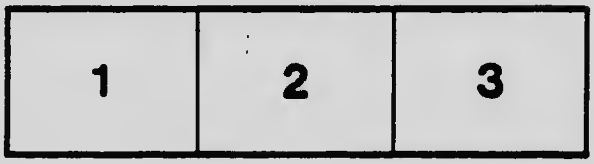
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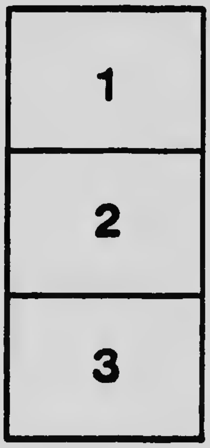
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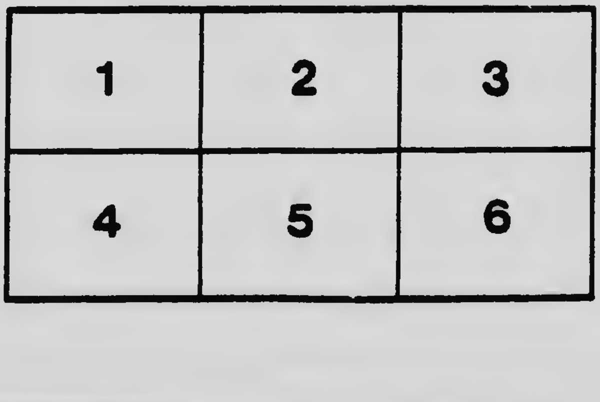
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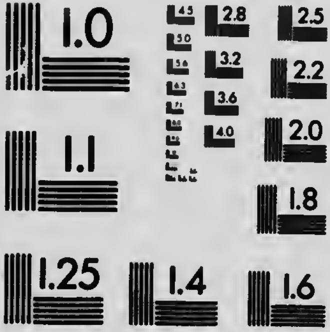

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GEOLOGICAL SURVEY
R. W. BROCK, DIRECTOR.

MEMOIR 44

No. 37, GEOLOGICAL SERIES

Clay and Shale Deposits of New Brunswick.

BY

J. Keele

OTTAWA
GOVERNMENT PRINTING BUREAU
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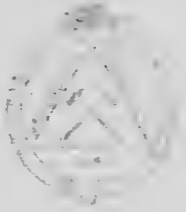

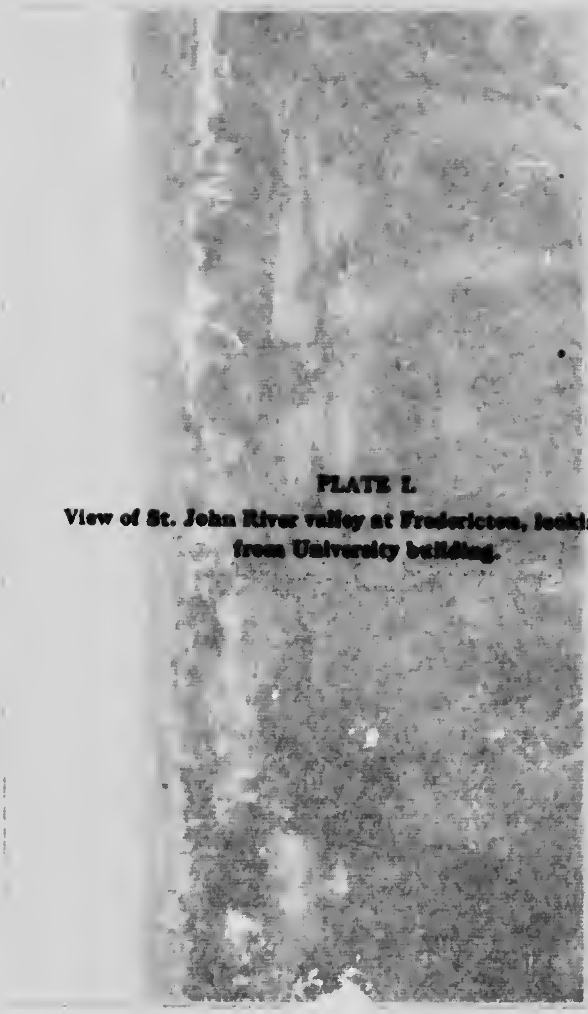

PLATE I.

View of St. John River valley at Fredericton, looking east from University building.

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Introductory.

The following report on the clay and shale deposits of New Brunswick was begun in the autumn of 1909. The laboratory work on the material collected was done during the following winter. The results were published in 1911 as Memoir 16, under the title "The Clay and Shale deposits of Nova Scotia and Portions of New Brunswick," by Heinrich Ries and Joseph Keele. The work in New Brunswick was resumed during the latter portion of the season of 1911, and again in the summer of 1912, in connection with work of a similar kind in the Province of Quebec.

The work of 1909 is republished in this report, but the results of the work done in 1911 and 1912 are published here in detail for the first time. The greater part of the laboratory work, and all the field examinations, with the exception of two or three localities examined by Professor Ries, were done by the writer.

The object of the work was the investigation of the clay or shale deposits of sufficient extent to be of economic value, and which would be useful to the manufacturer of burned clay wares, for structural or other purposes.

Oil-bearing shales are not included in this report, as it is impossible to mould such material into shape, and afterwards burn it so that it will retain its shape intact.

If the extraction of oil from shale is ever undertaken in this Province, there will result large quantities of "spent" shale. The question as to whether this material, which is a waste product as far as the oil industry is concerned, can be used for the manufacture of brick or tile, is one for future experiment. The oil bearing shales of this Province have been examined and very fully reported on.[1]

The work on clays and shales involves:—

(1) The description of their mode of occurrence, and of the areas underlain by them. (2) The sampling of the deposits in the field. (3) The laboratory work to determine their industrial value. The field work, or prospecting, was guided to a large extent by the geological maps already published by the Geological Survey.

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[1] Ells, R. W., Bituminous or oil-shales of New Brunswick and Nova Scotia, Canada, Department of Mines, 1910.

Some of the rock formations are usually barren of materials used by clayworkers, while others, like the coal measures in the Carboniferous, often abound in them, and consequently more time was devoted to the latter formation, than to any other.

As it is difficult to tell much about the qualities of a clay from its appearance in the field, samples for laboratory tests were taken from a number of localities. These samples were generally of about 40 pounds weight, taken, after scraping off the weathered surface and slide material, by trenching the bed from top to bottom and throwing out only those impurities or layers that it would be practicable to remove in working.

The laboratory work includes those physical tests which give the clay worker the most information regarding the quality of the clay. These include tensile, working, shrinkage, burning, and porosity tests.

Chemical analyses are generally regarded by ceramists as useless for foretelling the working and burning properties of a clay, none were made for this report.

CLAY AND SHALE DEPOSITS OF NEW BRUNSWICK.

CHAPTER I.

THE ORIGIN AND NATURE OF CLAY.

In the following pages there is given a brief discussion of the origin and nature of clays (including shales). This is not intended to be exhaustive and is simply added to serve as a guide for those persons having no technical knowledge of the subject but who may have occasion to use this report.

In all cases where it is necessary to render statements clear by citing examples or illustrations of facts, these are taken as far as possible from the Maritime Provinces.

ORIGIN OF CLAY.

DEFINITION.

Clay is the term applied to those earthy materials occurring in nature, the most prominent property of which is that of plasticity when wet. On this account they can be moulded into almost any desired shape, which is retained when dry. Furthermore, if heated to redness, or higher, the material becomes hard and rock like. Physically, clay is made up of a number of small particles, mostly of mineral character, ranging from grains of coarse sand to those which are of microscopic size, or under $\frac{1}{1000}$ of a millimetre in diameter. Mineralogically, it consists of many mineral fragments of varying degrees of freshness, and representing chemically many different compounds, such as oxides, carbonates, silicates, hydroxides, etc. Most of these mineral grains are not visible to the naked eye. Some of the constituents are of colloidal character.

WEATHERING PROCESSES INVOLVED.

Clays are always of secondary origin, and result primarily from the decomposition of rocks, very frequently from rocks containing feldspar; but in some cases rocks containing comparatively little or no feldspar, such as gabbro or serpentine, may, on weathering, produce some of the most plastic clays known.

In order to trace the changes occurring in the formation of clay we may take the case of a rock like granite.

When such a mass of rock is exposed to the weather, minute cracks are formed in it, due to the rock expanding when heated by the sun and contracting when cooled at night, or they may be joint-planes formed by the contraction of the rock as it is cooled from a molten condition. Into these cracks the rain water percolates, and when it freezes in cold weather it expands, thereby exerting a prying action, which further opens the fissures or may even wedge off fragments of the rock. Plant roots force their way into these cracks, and, as they expand, supplement the action of the frost, thus further aiding in the breaking up of the mass. This process alone, if kept up, may reduce the rock to a mass of small angular fragments, or even a mass of sand.

The rock having been opened up by disintegrative forces, the silicates are next attacked by the surface waters, although those exposed on the surface of the stone may already have begun to change.

The most prominent chemical change is the alteration of the feldspar grains to a white, powdery substance, known as kaolinite, a hydrous silicate of alumina. The alteration of the feldspar is termed kaolinization. Other silicates, such as hornblende, probably undergo similar changes.

As a result of these changes the entire rock may slowly but surely break down to a clayey mass.

RESIDUAL CLAY.

Where the clay is thus found overlying the rock from which it was formed, it is termed a residual clay, because it represents the residue of rock decay, and its grains are more or less insoluble.

If a granite which is composed chiefly of feldspar decays under weathering action, the rock will be converted into a clayey mass, with quartz and mica scattered through it. Remembering that the weathering began at the surface and has been going on there for a longer period than in deeper portions of the rock, we should expect to find, on digging downward from the surface: (A) a layer of fully formed clay (B) below this a poorly defined zone containing clay and some partially decomposed rock fragments, (C) a third zone, with some clay and many rock fragments, grading downward into the solid bed-rock. In other words, there is usually a gradual transition from the fully formed clay at the surface into the parent rock beneath. The only exception to this is found in clays derived from limestone, where the passage from clay to rock is sudden. The reason for this is that the change from limestone into clay does not take place in the same manner as granite. Limestone consists of carbonate of lime, or carbonate of lime and magnesia, with a variable quantity of clayey impurities, so that when the weathering agents attack the rock, the carbonates are dissolved by the surface waters, and the insoluble clay impurities are left behind as a mantle on the undissolved rock, the change from rock to clay being, therefore, a sudden one, and not due to a gradual breaking down of the minerals in the rock, as in the case of granite.

Kaolin.—A residual clay derived from a rock composed entirely of feldspar, or one containing little or no iron oxide, is usually white, and, therefore, termed a kaolin. Deposits of this type may contain a high percentage of the mineral kaolinite,[1] this being assumed, because, after washing the sand out of such materials, the silica, alumina, and water in the remaining portion are in much the same ratios as in kaolinite, although, as previously mentioned, other aluminous silicates may at times be present.

A clay made up entirely of kaolinite is sometimes termed a pure clay, but since the term clay refers to a physical condition, and not a definite chemical composition, it would perhaps be more correct to term kaolin the simplest form of clay.

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[1] The terms *Kaolinite*, referring to the mineral, and *Kaolin*, referring to the clay-mass, are often carelessly confused, even by scientific writers, although there seems to be little excuse for so doing.

Form of Residual Deposits.—The form of a residual clay deposit, which is also variable, depends on the shape of the parent rock. Where the residual clay has been derived from a great mass of granite or other clay-yielding rock, the deposit may form a mantle covering a considerable area. On the other hand, some rocks, such as pegmatites (feldspar and quartz), occur in veins, that is, in masses having but small width as compared with their length, and in this case the outcrop of residual clay along the surface will form a narrow belt.

Clay derived from a rock containing much iron oxide will be yellow, red, or brown, depending on the iron compounds present. Between the white clays and the brilliantly coloured ones others are found representing all intermediate stages, so that residual clays vary widely in their colour.

The depth of a deposit of residual clay will depend on climatic conditions, character of the parent rock, topography, and location. Rock decay proceeds very slowly, and in the case of most rocks the rate of decay is not to be measured in months or years, but rather in centuries. Only a few rocks, such as some shales or other soft rocks, change to clay in an easily measurable time. With other things equal, rock decay proceeds more rapidly in a moist climate, and consequently it is in such regions that the greatest thickness of residual material is to be looked for. The thickness might also be affected by the character of the parent rock, whether composed of easily weathering minerals or not. When the slope is gentle, or the surface flat, much of the residual clay will remain after being formed, but on steep slopes it will soon wash away.

In some cases the residual materials are washed but a short distance, and accumulate on a flat or very gentle slope at the foot of the steeper one, forming a deposit not greatly different from the original ones, although they are not, strictly speaking, residual clays.[1]

Deposits of residual clay are exceedingly rare in all parts of the Dominion of Canada, for the reason that nearly all of those formed have been swept away by glacial action. The only ones referred to in this report are the weathered felsites at Campbellton and Louison river.

These are termed *Colluvial clays* by G. P. Merrill.

TRANSPORTED CLAYS OR SEDIMENTARY CLAYS.

Origin.—As mentioned above, residual clays rarely remain on steep slopes, but are washed away by rainstorms into streams, and carried off by these to lower and sometimes distant areas. By this means residual clays, possibly of different character, may be washed down into the same stream and become mixed together. This process of wash and transportation can be seen in any abandoned clay bank, where the clay of the slopes is washed down and spread out over the bottom of the pit.

As long as the stream maintains its velocity it will carry the clay in suspension, but if its velocity be checked, so that the water becomes quiet and free from currents, the particles begin to settle on the bottom, forming a clay layer of variable extent and thickness. This may be added to from time to time, and to such a deposit the name of sedimentary clay is applied. All sedimentary clays are stratified or made up of layers, this being due to the fact that one layer of sediment is laid down on top of another. These layers may also vary in thickness, and since there is less cohesion between unlike particles, the two layers will tend to separate along their line of contact.

As the finer material can only be deposited in quiet water, and coarse material in disturbed waters, so from the character of the deposit we can read much regarding the conditions under which it was formed. If, therefore, in the same bank, alternating layers of sand, clay, and gravel are found, it indicates a change from disturbed to quiet water, and still later rapid currents over the spot in which these materials were deposited. The commonest evidence of current deposition is seen in the cross-bedded structure of some sand beds where the layers dip in many different directions, due to shifting currents which have deposited the sand in inclined layers.

Sedimentary clays can be distinguished from residual clays chiefly by their stratification, and also by the fact that they commonly bear no direct relation to the underlying rock on which they may rest.

Structural Irregularities in Sedimentary Clays.—All sedimentary clays resemble each other in being stratified, but aside from this, they may show marked irregularities in structure.

Thus, any one bed, if followed from point to point, may show variations in thickness, pinching, or narrowing in one place and thickening or swelling in others.

Occasionally a bed of clay may be extensively worn away or eroded by currents subsequent to its deposition, leaving its upper surface very uneven, and on this an entirely different kind of material may be deposited, covering the earlier bed, and filling the depressions in its surface.

The general character of sedimentary clays is more or less influenced by the locality and conditions of deposition, which enables us, therefore, to divide them into the following classes:—

Marine Clays.—This class includes those sedimentary clays deposited on the ocean bottom, where the water is quiet. They have, therefore, been laid down at some distance from the shore, since nearer the land, where the water is shallower and disturbed, only coarser materials can be deposited. Beds of clay of this type may be of vast extent and great thickness, but will naturally show some variation, horizontally at least, because the different rivers flowing into the sea usually bring down different classes of material. Since most marine clays have become deeply buried under other sedimentary rocks subsequent to their deposition, they are often changed to shale: these shale beds, moreover, are sometimes interstratified with sandstones. The shale is now found exposed, because the ocean bottom has been uplifted, and the overlying rocks worn away.

Some of the shale beds in the areas underlain by Middle Carboniferous rocks, in New Brunswick, are of this type.

Estuarine Clays.—These form a second type of some importance in certain areas. They represent bodies of clay laid down in shallow arms of the sea, and are consequently found in areas that are comparatively long and narrow, with the deposits showing a tendency towards basin shapes. If strong currents enter the estuary from its upper end, the settling of the clay mud may be prevented, except in areas of quiet water in recesses of the bay shore. Or, if the estuary is supplied by one stream at its head, and this of low velocity, the finer clays will be found at a point more distant from the mouth of the river. In such cases, we should anticipate an increase in coarseness of the clay beds, or series of beds, as they are followed from what was formerly the old shore line up to the mouth of the former river that brought down the sediment.

Estuarine clays often show sandy laminations, and are not infrequently associated with shore marshes, due to the gradual filling up of the estuary, and the growth of plants on the mud flats thus formed.

The surface clays at St. John, Fredericton, Bathurst, Campbellton, and St. Stephen, are of the estuarine type.

Swamp and Lake Clays.—Swamp and lake clays constitute a third class of deposits, which have been formed in basin-shaped depressions occupied by lakes or swamps. They represent a common type, of variable extent and thickness, but all agree in being more or less basin-shaped. They not infrequently show alternating beds of clay and sand, the latter in such thin laminæ as to be readily overlooked, but causing the clay layers to split apart easily. Many of the lake clays are directly or indirectly of glacial origin, having been laid down in basins or hollows along the margin of the continental ice sheet, or else in valleys that have been dammed up by the accumulation of a mass of drift across them. This wall of drift serves to obstruct the drainage in the valley, thus giving rise to a lake. in which the clay has been deposited. Clay beds of this type are extremely abundant in all glaciated regions. They are usually surface deposits, of varying thickness, often highly plastic, and more or less impure. Their chief use is for common brick and earthenware, and they are rarely of refractory character.

Flood-Plain and Terrace Clays.—Many rivers, especially in broad valleys, are bordered by a terrace or plain, there being sometimes two or more, extending like a series of shelves, or steps, up the valley side. The lowest of these is often covered by the river during periods of high water, and is consequently termed the flood-plain. In such times much clayey sediment is added to the surface of this flood terrace, and thus a flood-plain clay deposit may be built up.

Owing to the fact that there is usually some current setting along over the plain when it is overflowed, the finest sediments cannot settle down, except in protected spots, and consequently most terrace clays are rather sandy, with here and there pockets of fine, plastic clay. They also frequently contain more or less organic matter. Along its inner edge the terrace may be covered by a mixture of clay, sand, and stones, washed down from neighbouring slopes.

Drift or Boulder Clays.—In that portion of Canada formerly covered by the continental ice sheet, there are occasional deposits of clay formed directly by the glacier. These are usually tough, dense, gritty clays, often containing many stones. The material deposited by the ice (till) is usually too stony and sandy to serve for brickmaking, although often known as boulder clay. Locally, however, although the ice-transported material has been largely ground to a fine rock flour, the boulder clay is plastic enough, and not too full of stones for use. Such deposits are mostly of limited extent, impure, and of little value.

In addition to this type of clay, formed directly by the ice, there were clays deposited in lakes or along flood-plains by the streams issuing from the glacier. These were composed of material derived from the ice, but since they were deposited by water they were stratified, and may properly be classed as lacustrine, estuarine, or flood-plain clays of glacial age. Boulder clays, although abundantly distributed, are often too stony to be of much value for the manufacture of clay products.

SECONDARY CHANGES IN CLAY DEPOSITS

Changes often take place in clays subsequent to their deposition. These may be local or widespread, and in many cases either greatly improve the deposit or render it worthless. The marked effect of some of these changes is often well seen in clay beds of which only a portion has been altered. These secondary changes are of two kinds, viz., mechanical and chemical.

MECHANICAL CHANGES

Formation of Shale.—Clay deposits laid down on the ocean floor often become covered by many hundreds of feet of other sediments, whose weight alone is often sufficient to cause a consolidation and hardening of the clay mass. Deposition of mineral matter around the grains may cement them together and aid in the hardening process. Such a consolidated clay is termed a shale. When ground and mixed with water, it may develop high plasticity. Shale deposits have thus received their properties by deep burial, but are now often exposed at the surface because the overlying strata have been worn away.

Shale beds were originally formed in a more or less horizontal position, but since then have often become more or less tilted by uneven movements of the earth's crust. As evidence of this the shale bearing formations, on the north shore of Chignecto bay and Cumberland basin, are steeply tilted, while those in the Grand Lake coal area have not been disturbed by crustal movements so that they still retain their horizontal attitude.

CHEMICAL CHANGES

Nearly all clay deposits are frequently changed superficially, at least, by the weather, or by surface waters. The changes are chiefly chemical, and can be grouped under the following heads: (1) change of colour; (2) leaching; (3) softening; (4) consolidation.

Change of Colour.—Many clay deposits which are yellow, red, or brown, near the surface, are grey or greyish-black below. This is due primarily to the iron in the clay being oxidized, that is, changed from ferrous to ferric oxide (See under iron oxide). This change in colour will extend to a variable depth below the surface, depending on the distance to which the weathering agents have penetrated the clay.

Leaching.—Clays usually contain at least some soluble materials, the commonest of which is lime carbonate. Surface waters seeping into the clay may take this lime carbonate into solution, and thus the upper layers or portion of the deposit may be freed from it. The lime carbonate so removed may be carried off by the infiltrating waters, or deposited in the lower layers. In a deposit of calcareous clay, therefore, the upper layers may be red burning, while the lower beds are buff-burning. This change is more common in moist than in arid climates, and, at any rate, is characteristic only of highly calcareous clays. The idea held by some that lime, or even other impurities, will decrease with the distance from the surface, is erroneous.

Some clays contain considerable gypsum, often in a finely divided condition. Such clays sometimes show coarse crystalline masses of gypsum on the outcrop, due to the fact that water entering the deposit has dissolved the gypsum, and brought it to the surface in solution, where, on the evaporation of the water, it has crystallized out in large crystals. This process takes place chiefly in arid regions.

Softening.—Many shales become softened on exposure to the weather. This is largely a simple process of disintegration, and usually involves little change in composition, except in the case of calcareous shales, which may show but little lime at the surface. Outcrops of Carboniferous shales, softened by prolonged exposure to weathering, are common in New Brunswick. The shaly structure often becomes obliterated from this process. Softened shales may be mistaken for surface clays at their outcrops.

Consolidation.—Clays, especially those of a sandy and porous character, sometimes become hardened along certain layers, or along joint planes, due to the deposition of iron oxide. This may result in the formation of a number of crusts, or hard layers in the deposit, which have to be crushed or thrown out if the clay is to be used. In some localities these are so numerous as to render an otherwise good clay worthless.

SUBSTANCES PRESENT IN CLAY AND THEIR EFFECT.

SILICA

This is present in clay in two different forms, namely, uncombined as silica or quartz, and in silicates, of which there are several. Of these, one of the most important is the mineral kaolinite, which probably occurs in all clays, and is termed the clay base, or clay substance. The other silicates include feldspar, mica, glauconite, hornblende, garnet, etc. These two modes of occurrence of silica, however, are not always distinguished in the ultimate analysis of a clay, but when this is done they are commonly designated as "free" and "combined" silica, the former referring to all silica except that contained in the kaolinite, which is indicated by the latter term. This is an unfortunate custom, for the silica in silicates is, properly speaking, combined silica, just as much as that contained in kaolinite. A better practice is to use the term sand, to include quartz and silicate minerals other than kaolinite, which are supposedly not decomposable by sulphuric acid. In most analyses, however, the silica from both groups of minerals is expressed collectively as total silica.

The percentage of both quartz and total silica found in clays varies between wide limits.

The free silica or quartz is one of the commonest constituents of clay, and ranges in size from particles sufficiently large to be visible to the eye down to the smallest grains of silt.

SAND

This (quartz and silicates) is an important anti-shrinkage agent which greatly diminishes the air shrinkage, plasticity, and tensile strength of clay, its effect in this respect increasing with the coarseness of the material; clays containing a high percentage of very finely divided sand (silt) may absorb considerable water in mixing, but show a low air shrinkage. The brickmaker recognizes the value of the effects mentioned above, and adds sand or loam to his clay, and the potter brings about similar results in his mixture by the use of ground flint. If too much sand is added to the brick mixture it makes the product too porous, and soft.

It is thought by some that because of the refractoriness of quartz its addition to any clay will raise its fusion point, but this is true only of those clays containing a high percentage of common fluxes and silica, and which are burned at low temperatures. Its effect on highly aluminous low flux clays reduces their refractoriness.

In considering the effects of sand in the burning of clays, it must first be stated that the quartz and silicates fuse at different temperatures. A very sandy clay will, therefore, have a low fire shrinkage, as long as none of the sand-grains fuse, but when fusion begins a shrinkage of the mass occurs. We should, therefore, expect a low fire shrinkage to continue to a higher temperature in a clay whose sand grains are refractory.

IRON OXIDE: SOURCES OF IRON OXIDE IN CLAYS.

Iron oxide is one of the commonest ingredients of clay, and a number of different mineral species may serve as sources of it, the most important of which are grouped below:—

Hydrous oxide, limonite; oxides, hematite, magnetite; silicates, biotite, glauconite (greensand), hornblende, garnet, etc.; sulphides, pyrite; carbonates, siderite; sulphate, melanterite.

In some, such as the oxides, the iron is combined only with oxygen, and is better prepared to enter into chemical combination with other elements in the clay when fusion begins. In the case of the sulphides and carbonate, on the contrary, the volatile elements, namely, the sulphuric-acid gas of the pyrite, and the carbonic-acid gas of the siderite, have to be driven off before the iron contained in them is ready to enter into similar union. In the silicates the iron is chemically combined with silica and several bases, forming mixtures of rather complex composition, and all of them of low fusibility, particularly the glauconite. Several of these silicates are easily decomposed by the action of the weather, and the iron oxide which they contain combines with water to form limonite. This is usually in a finely divided condition, so that its colouring action is quite effective.

Effects of Iron Compounds.—Iron is the great colouring agent of both burned and unburned clays. It may also serve as a flux, and even affect the absorption and shrinkage of the material.

Colouring Action of Iron Oxide in Unburned Clay.—Many clays show a yellow or brown coloration due to the presence of limonite, and a red coloration due to hematite.

Colouring Action of Iron Oxide on Burned Clay.—All of the iron ores will, in burning, change to the red or ferric oxide, provided a sufficient supply of oxygen is able to enter the pores of the clay before it is vitrified; if vitrification occurs, the iron oxide enters into the formation of silicates of complex composition. The colour and depth of shade produced by the iron will, however, depend on: (1) the amount of iron in the clay; (2) the temperature of burning; (3) condition of the iron oxide; and (4) the condition of the kiln atmosphere.

Clay free from iron oxide burns white. If a small quantity, say 1 per cent, is present, a slightly yellowish tinge may be imparted to the burned material, but an increase in the iron content to 2 or 3 per cent often produces a buff product; while 4 or 5 per cent of iron oxide in many cases makes the clay burn red. There seem, however, to be not a few exceptions to the above statements. Thus, we find that the white-burning clays carry from a few hundredths per cent to over 1 per cent of iron oxide, the more ferruginous containing more iron than the purer grades of buff-burning clays. Again, among the buff-burning clays we find some with an iron oxide content of 4 or 5 per cent, an amount equal to that contained in some red-burning ones.

The facts would, therefore, seem to indicate that the colour of the burned clay is not influenced solely by the quantity of iron present.

The brilliancy of the colour appears to be influenced by the texture, as the more sandy clays can be heated to a higher temperature, without destruction of the red colour, than the more aluminous ones. Alkalies appear to diminish the brightness of the iron coloration.

Among the oxides of iron two kinds are recognized, known respectively as the ferrous oxide (FeO), and ferric oxide (Fe_2O_3). In the former we see one part of iron united with oxygen, while in the latter one part of iron is combined with one and one-half parts of oxygen. The ferric oxide, therefore, contains more oxygen per unit of iron than the ferrous salt, and represents a higher stage of oxidation. In the limonite and hematite the iron is in the ferric form, representing a higher stage of oxidation. In magnetite both ferrous and ferric iron are present, but in siderite the ferrous iron alone occurs. In the ultimate analysis the iron is usually determined as ferric oxide, no effort being made to find out the quantity present in the ferrous form, although if there is any reason to suspect that much of the latter exists it should be determined. Iron passes rather readily from the ferric to the ferrous form. It also oxidizes easily unless carbon and sulphur are present, in which case its oxidation is not possible until these two substances have been oxidized. Indeed they are sometimes supplied with oxygen at the expense of the iron, which may be left in a ferrous, magnetic, or even spongy, metallic condition; so if there is a deficit of oxygen in the inside of the kiln the iron does not get enough oxygen, and the ferrous compound results, but the latter changes rapidly to the ferric condition if sufficient air carrying oxygen is admitted. If, however, the oxidation of the iron does not begin until the clay has become so dense as to prevent free circulation of the air through it, then it may form ferrous silicates, which impart black or dark colours to the clay.

Moreover, in the burning of ferruginous clays it is usually desirable to get the iron thoroughly oxidized to prevent trouble in the later stages of burning. To accomplish this the iron must be freed of any sulphur or carbon dioxide which may be combined with it, and other volatile or combustible elements in the clay must be driven off, so as to allow the oxidizing gases to enter the clay and unite with any ferrous iron that may be present.

Sulphide of iron (pyrite) loses half its sulphur at a red heat, and the balance will, under oxidizing conditions, pass off probably by 900° C.; while siderite or ferrous carbonate loses its carbon dioxide between 400° and 500° C.; magnesium carbonate and calcium carbonate lose their CO_2 at about 500° C., and 800° to 900° C. respectively. Carbonaceous matter or sulphur, if present, must also be carefully burned off. If the clay contains much volatile or combustible matter the burning must proceed slowly below 1000° C., in order to remove it and allow the iron to get oxidized while the clay is still porous.

After oxidation the clays will show a more brilliant iron colour than they do at the end of the dehydration period. They are also harder, and show a slight decrease in volume.

If the clay has been improperly oxidized it shows later when vitrification is reached, by the dark ferrous silicate cores in the centre of the brick. This may form, however, without the development of any swelling. When swelling does accompany the formation of this black core it is to be traced to sulphur.

Fine-grained clays are more difficult to oxidize than coarse-grained, because of the small size of their pores, and grog is, therefore, added at times to open the grain of the material.

Since the stage of oxidization of the iron is dependent on the quantity of air it receives during burning, the condition of the kiln atmosphere is of great importance. If there is a deficiency of oxygen in the kiln, so that the iron oxide, if present, is reduced to the ferrous condition, the fire is said to be reducing. If, on the contrary, there is an excess of oxygen, so that ferric oxides are formed, the fire is said to be oxidizing. These various conditions are often used by the manufacturer to produce certain shades or colour effects in his ware. Thus, for example, the manufacturer of flashed brick produces the beautiful shading on the surface of his product by having a reducing atmosphere in his kiln, followed by an oxidizing one. The potter aims to reduce the yellow tint in his white ware by cooling the kiln as quickly as possible to prevent the iron from oxidizing.

In those clays which are of grey or black colour the iron may be present in both the ferrous and ferric form; the quantity present in that from several localities is shown below:—

	FIELD NUMBER.				
	41.	42.	47.	91.	94.
Fe_2O_3..............	1·56	1·96	1·34	2·46	1·91
FeO...............	4·97	3·19	6·12	2·29	3·61

41. Shale from Standard Drain Pipe Works, New Glasgow.
42. Lower shale, Brooks' brickyard, New Glasgow.
47. Shale, Intercolonial Coal Company, Westville.
91. Shale under coal seam, King mine, Minto, N.B.
94. Shale under coal, Canadian Coal Company, Salmon bay, N.B.

All analysed by H. A. Leverin, analyst, Mines Branch.

As these clays and shales all contain small amounts of sulphur and carbon, it is highly important to fire the material slowly, in order to burn off the carbon, and as much sulphur as possible, as well as to cause the large amount of ferrous iron to become oxidized.

Fluxing Action of Iron Oxide.—Iron oxide is a fluxing impurity, lowering the fusing point of the clay, and this effect will, in general, be more pronounced if the iron is in a ferrous condition, or if silica is present.

LIME CARBONATE

Lime is probably most effective in the form of the carbonate, and if finely divided is an active flux. When clays containing it are burned, they not only lose their chemically combined water but also their carbon dioxide, but while the water of hydration passes off between 450° C. (842° F.) and 600° C. (1112° F.) the carbon dioxide (CO_2) does not seem to go off until between 600° C. (1112° F.) and 725° C. (1562° F.). In fact, it more probably passes off between 850° C. (1562° F.), and 900° C. (1652° F.). The result of driving off this gas, in addition to the chemically combined water, is to leave calcareous clays more porous than other clays up to the beginning of fusion.

If the burning is carried only far enough to drive off the carbonic acid gas, the result will be that the quicklime thus formed will absorb moisture from the air and slake. No injury may result from this if the lime is in a finely divided condition and uniformly distributed through the brick, but if, on the contrary, it is present in the form of lumps the slaking and accompanying swelling of these may split the brick.

Limestone pebbles, if present in the clay, should be either removed, if this can be done cheaply, or crushed before the clay is moulded.

GYPSUM

Gypsum in the clay has probably often been formed by sulphuric acid, liberated by the decomposition of iron pyrite, acting on lime carbonate. Lime, if present in the form of gypsum, seems to behave differently from lime in the form of carbonate, although few clays contain large percentages of it.

If present in grains or lumps these burn to a white powder, but unlike lime do not slake and swell.

MAGNESIA

Magnesia (MgO) rarely occurs in clay in larger quantities than 1 per cent. When present, its source may be any one of several classes of compounds, that is, silicates, carbonates, and sulphates.

It is to be regarded as a flux, but perhaps not as active a one as lime. It is always present in a finely divided form.

ALKALIES

The alkalies commonly present in clays include potash (K_2O), soda (Na_2O), and ammonia (NH_3). There are other alkalies, but they are probably of rare occurrence.

Several common minerals may serve as sources of the alkalies. Feldspar may supply either potash or soda. Muscovite, the white mica, contains potash. Greensand, or glauconite, contains potash. Other minerals, such as hornblende or garnet, might serve as sources of the alkalies, but are unimportant, as they are rarely present in clays in large quantities.

The alkalies are strong fluxes, but they are rarely present in large amounts.

TITANIUM

Titanium is an element which is found in several minerals, some of which are more common in clays than is usually imagined, although they appear rare because they are seldom found in large quantities. The two commonest of these are rutile and ilmenite. So far as known, neither of these is ever found in clays in sufficiently large grains to be visible to the naked eye, so that a microscopic examination would be necessary to identify them. Although titanium is such a common constituent of clay, it is rarely shown in an analysis, because its determination by chemical methods is attended with more or less difficulty and is rarely carried out. In the ordinary process of chemical analysis it is usually included with the alumina.

Titanium may be regarded as a flux, but since the quantity present in most clays is usually small, it seems to operate mainly at high temperatures. Thus, a clay whose fusion point lay between cones 34 (1810° C.) and 35 (1830° C.), fused at cone 32 (1770° C.), when 5 per cent of titanium oxide was mixed with it.

WATER IN CLAY

Under this head are included two kinds of water: (1) mechanically combined water or moisture; (2) chemically combined water.

Mechanically Combined Water.—The mechanically combined water is that which is held in the pores of the clay by capillary action, and fills all the spaces between the clay grains. When these are all small, the clay may absorb and retain a large quantity, because each interspace acts like a capillary tube. If the spaces exceed a certain size, they will no longer hold the moisture by capillary action, and the water, if poured on the clay, would fast drain away. The fine-grained clays, for these reasons, show high powers of absorption and retention, while coarse, sandy clays or sands represent a condition of minimum absorption. This same phenomenon shows itself in the amount of water required for tempering a clay. Thus, a very coarse sandy mixture from one deposit may require only 15 per cent of water, while a very fat one from another deposit may take 45 per cent of water. It is not the highly aluminous ones, however, that always absorb the most water.

The total quantity of water found in different clays varies exceedingly. In some air dried clays it may be as low as 0·5 per cent, while in those freshly taken from the bank, it may reach 30 to 40 per cent without the clay being very soft.

Clay is very hygroscopic, and when thoroughly dry, greedily absorbs moisture from the atmosphere; indeed it may absorb as much as 10 per cent of its weight.

Water held mechanically in a clay will pass off partly by evaporation in air, but can all be driven off by heating the clay to 100° C. (212° F.). The evaporation of the mechanical water is accompanied by a shrinkage of the mass, which ceases, however, when the particles have all come in contact, and before all the moisture is driven off, because some remains in the pores of the clay. This last portion is driven off during the early stages of burning. The shrinkage that takes place when the mechanical water is driven off varies, ranging from 1 per cent, or less, in very sandy clays, up to 10 or 12 per cent in very plastic ones.

Since most clays having a high absorption, shrink a large amount in drying, there is often danger of their cracking, especially if rapidly dried, owing to the rapid escape of the water vapour. Mechanical water may hurt the clay in other ways. Thus, if the material contains any mineral compounds which are soluble in water, the latter, when added to the clay, will dissolve a portion of them at least. During the drying of the brick the water rises to the surface to evaporate, and brings out the compounds in solution, leaving them behind when it vaporizes. It may also help the fire gases to act on certain elements of the clay, a point explained under "Burning."

Chemically Combined Water.—Chemically combined water, as its name indicates, is that which exists in the clay in chemical combination with other elements, and which, in most cases, can be driven out only at a temperature ranging from 400° C. (752° F.), to 600° C. (1112° F.). This combined water may be derived from several minerals, such as kaolinite, which contains nearly 14 per cent white mica, or muscovite with 4 to 5½ per cent, and limonite with 14·5 per cent. Unless a clay contains considerable limonite or hydrous silica, the percentage of combined water is commonly about one-third the percentage of alumina found in the clay. In pure, or nearly pure kaolin, there is nearly 14 per cent, and other clays contain varying amounts, ranging from this down to 3 or 4 per cent, the latter being the quantity found in some very sandy clays. The loss of its combined water is accompanied by a slight but variable shrinkage in the clay, which reaches its maximum some time after all the volatile matters have been driven off.

In many clay analyses the chemically combined water is determined as loss on ignition, which is incorrect if the clay contains carbon dioxide sulphur trioxide, or organic matter all of which are driven off, in part at least, at a dull red heat.

CARBON

Carbon may be present in clay in the form of: (1) vegetable matter; (2) asphaltic carbon, and (3) fixed carbon. Only the second and third of the groups mentioned need be considered. The first alone causes trouble when it occurs in the form of sticks or thick roots, and has to be screened out. It is, therefore, not included in what follows.

Carbonaceous matter often serves as a strong colouring agent of raw clays, tinging them grey, bluish-grey, or black. Indeed, so strong may this be that it masks the effect of other colouring agents, such as iron. In fact, two clays coloured black might burn red and white respectively, because one had much iron and the other none, and yet, owing to their black colour, this could not be foretold with definiteness.

Asphaltic carbon, aside from its colouring action, often causes much trouble in burning, causing black cores, or even swelling and fusing of the brick. More than this, it may keep the iron in a ferrous condition and prevent the development of the best colour effects in the ware.

The reason for this is due to several causes.

Carbon has a strong affinity for oxygen, much stronger than that of iron, therefore as long as it remains in the clay it will monopolize the supply of oxygen and keep the iron in a ferrous condition, the form in which much of it is, in grey or black clays and shales. Now, in burning a clay, one of the aims of the clay worker is to get the iron into a ferric condition, so as to fully develop its colouring properties and prevent other troubles. As long as any carbonaceous matter remains the oxidation of the iron is prevented or retarded, and consequently the carbon must be burned out.

The experiments of Orton and Griffin have shown that between 800° and 900° C. is the best temperature interval for burning off the carbon, as below this its oxidation does not proceed as rapidly, and above this there is danger of vitrification beginning, and the oxidation being stopped.

The method of procedure would, therefore, be to drive all moisture out of the clay first, then raise the heat as rapidly as possible to a temperature between 800° and 900° C., and hold it there until the ware no longer shows a black core denoting ferrous iron.

In order to burn off the carbon and oxidize the iron, air supplying oxygen must be drawn into the kiln during burning, for the gases of combustion from the fuel will supply none. Oxidation may be accelerated by increasing the amount of air entering the kiln, and by reducing the density of the clay as much as possible. In case this is not done, and the pores of the clay close up before all the carbon is burned off, it also interferes with the expulsion of sulphur present which may result in a swelling of the clay.

This may be even followed by complete fusion of the interior of the mass, caused by the formation of an easily fusible ferrous silicate. When the carbon is all burned off the iron has a chance to oxidize. If the clay contains much asphaltic carbon the oxidation must be carried on with as little air as possible, otherwise the heat generated by the burning hydrocarbons may be so intense as to vitrify the ware before the oxidation is completed.

Since dense clays are more difficult to oxidize than those which are porous, the process of manufacture may also influence the results, and in this connexion it has been found that bricks made by the soft-mud process are most rapidly oxidized, followed by either the stiff-mud or dry-press (there being no difference between the two), and lastly by the semi-dry-press.

EFFECT OF WATER ON BLACK CORING

It is often stated by brick makers that black cores are caused by the brick being set too wet. This is not strictly true, and the relation is a very indirect one. While carbon burns off most rapidly between the temperatures of 800° and 900° C., it also passes off somewhat at much lower temperatures. If the brick is set wet it requires so much more heat in the early stages of firing to drive out or evaporate the water that other changes, such as the oxidation of the carbon, will be retarded, and brick begins to vitrify before the process is completed.

SULPHUR

Many clays contain at least a trace of sulphur, and some show appreciable quantities. Sulphur might be present in a clay, as: (1) sulphate, such as gypsum (CSO_4, $2H_2O$), epsomite ($MgSO_4$, $7H_2O$), or melanterite ($FeSO_4$, $7H_2O$); (2) sulphide, as pyrite (FeS_2), or marcasite (FeS_2).

Iron sulphide exerts an extremely bad influence during the burning process. Should it be necessary to use shales containing pyrite in considerable quantities some method of removing it is ordinarily resorted to. This may be accomplished by exposing the shale to the weather for some time—several months—before it is used. The removal may be hastened by wetting the clay at frequent intervals. This not only hastens the oxidation of the sulphide to the sulphate, but also carries away the latter as fast as it is formed. In addition it removes other soluble salts which may be present. Calcium sulphate or gypsum is a constituent of some of the clays in New Brunswick. It is slightly soluble in water and is carried to the surface of the ware in the drying process and deposited as a scum or efflorescence on the surface. This causes a white discoloration of the burned ware known as "whitewash."

PLASTICITY

Plasticity is probably by far the most important property of clay, lacking which it would be of comparatively little value for the manufacturer of clay products. Seger has defined it as the property which solid bodies show of absorbing and holding a liquid in their pores, and forming a mass which can be pressed or kneaded into any desired shape, which it retains when the pressure ceases, and on the withdrawal of the water, changes to a hard mass. The term hard, of course, refers to its hardness as compared with its wet condition, for some air-dried clays are rather soft.

TENSILE STRENGTH

Definition.—The tensile strength of a clay is the resistance which it offers to rupture or being pulled apart when air-dried.

Practical Bearing.—The tensile strength is an important property, and has a practical bearing on problems connected with the handling, moulding, and drying of the ware, since a high strength enables the clay to withstand the shocks and strains of handling. Through it, also, the clay is able to carry a large quantity of non-plastic material, such as flint or feldspar, ground bricks, etc.

Relation to Plasticity.—Although it was formerly believed by many that tensile strength and plasticity were closely related, this view is no longer generally accepted. High tensile strength and high plasticity often go together, but a clay low in tensile strength may have high plasticity, and vice versa.

SHRINKAGE

All clays shrink in drying and burning, the former loss being termed the air shrinkage, and the latter the fire shrinkage.

Air Shrinkage.—In a clay which is perfectly dry, all the grains are in contact, but between them there will be a variable amount of pore space, depending on the texture of the clay. The volume of this pore space is indicated somewhat by the quantity of water that will be absorbed without the clay changing its volume, this water filling in the space between the grains. It may be termed pore water.

The presence of more water than is required to fill the spaces between the grains produces a swelling of the mass, and in this condition each grain is regarded as being surrounded by a film of water; but while the grains still mutually attract each other the attraction is less than in the dry clay, and the mass yields readily to pressure. An excess, however, separates the clay particles to such an extent that the clay softens and runs. A clay will, therefore, continue to swell as water is added to it, until the amount becomes too great to permit it to retain its shape.

The amount of air shrinkage is usually low in sandy clays, at times being under 1 per cent in coarsely sandy ones, while it is high in very plastic clays, or in some of very fine grain, reaching at times as much as 12 or 15 per cent. Five or six per cent is about the average seen in the manufacture of clay products.

All clays requiring a high percentage of water in mixing do not show a high air shrinkage. The air shrinkage of a clay will not only vary with the amount of water added, but also with the texture of the materials.

Sand or materials of a sandy nature counteract the shrinkage, and are frequently added for this purpose, but, since they also render the mixture more porous, they facilitate the drying as well, permitting the water to escape more readily, and often reducing the danger from cracking. If the sand added to dilute the shrinkage is refractory it also aids the clay in retaining its shape during burning.

Fire Shrinkage.—All clays shrink during some stage of the burning operation, even though they may expand slightly at certain temperatures. The fire shrinkage, like the air shrinkage, varies within wide limits, the amount depending partly on the quantity of volatile elements, such as combined water, organic matter, and carbon dioxide, and partly on the texture and fusibility.

Fire shrinkage may begin at a dull red heat, or about the point at which chemically combined water begins to pass off, and reaches its maximum when the clay vitrifies, but does not increase uniformly up to that point. The clay worker, however, always tries to get a low fire shrinkage, using a mixture of clays if necessary in order to prevent cracking and warping. After the expulsion of the volatile elements the clay is left in a porous condition, until the fire shrinkage recommences.

FUSIBILITY

All clays fuse at one temperature or another, the temperature of fusion depending on: (1) the amount of fluxes; (2) the size of grain of the refractory and non-refractory particles; (3) the homogeneity of the mass; (4) the condition of the fire, whether oxidizing or reducing; and (5) the form of chemical combination of the elements contained in the clay.

When clays undergo a fusion process they do not soften at once, but melt with comparative slowness. This is not surprising when we consider their heterogeneous composition, and may account for their slow softening, as one kind of mineral after another fuses. As soon as a softening of one or more of the mineral grains occurs, interreactions between the different grains begin, the number involved increasing until all constituents of the mass are involved. In most cases no reaction occurs between any of the grains until one melts, but it is not necessary to reach the fusion point of each before it can react with the others.

Incipient Vitrification.—In this stage the clay has softened sufficiently to make the grains stick together, and enough to prevent the recognition of any, except the larger ones. The particles have not, however, softened sufficiently to close up all the pores of the mass.

Complete Vitrification.—A further heating of the clay, through a variable temperature interval ranging from about 27·7° C. (500° F.) to 111·1° C. (200° F.), or sometimes even more, produces an additional softening of the grains sufficient to close up all the pores and render the mass impervious. Clays burned to this condition of complete vitrification show a smooth fracture, with a slight lustre. The attainment of this condition also represents the point of maximum shrinkage.

Viscosity.—A still further variable rise in the temperature is accompanied by both swelling and softening of the clay, until it flows or gets viscous.

It is sometimes difficult to recognize precisely the exact attainment of these three conditions, for the clay may soften so slowly that the change from one to the other is gradual.

CONTROL OF TEMPERATURE

In most of the brick plants in Canada the temperature to which the product is burned is judged by the eye, the wares being burned to a dull red, cherry red, or white heat. This method results in much variation in the burned products, and depends on the experience of the man in charge of the burning. There may also be a wide difference in temperature in different parts of the kiln which will not be apparent to the eye.

The matter of controlling the temperature and of obtaining a uniformly burned product is comparatively simple. One of the methods best adapted to commercial plants is the use of the Seger pyromet [illegible].

Seger Cones.–[illegible] ones are small triangular pyramids about one-half inch dimension at the base, and tapering to a point at the top. They are about 3 inches long.

These test pieces consist of a series of mixtures of clays with fluxes, so graded that they represent a series of fusion-points, each being a few degrees higher than the one next to it. They are so called because originally introduced by H. Seger, a German ceramist. The materials which he used in making them were such as would have a constant composition, and consisted of washed Zettlitz kaol [illegible] örstrand feldspar, Norwegian quartz, Carrara marble, and pure ferric oxide. Cone 1 melts at the same temperature as an alloy composed of one part of platinum and nine parts of gold, or at 1150° C. (2102° F.). Cone 20 melts at the highest temperature obtained in a porcelain furnace, or at

1530° C. (2786° F.). The difference between any two successive numbers is 20° C. (36° F.), and the upper member of the series is cone 39. Cone 36 is composed of a very refractory clay slate, while cone 35 is composed of kaolin from Zettlitz, Bohemia. A lower series of numbers was produced by Cramer, of Berlin, who mixed boracic acid with the materials already mentioned. Hecht obtained still more fusible mixtures by adding both boracic acid and lead in proper proportions to the cones. The result is that there is now a series of 61 numbers, the fusion-point of the lowest being 590° C. (1094° F.) and that of the highest 1940° C. (3470° F.). As the temperature rises the cone begins to soften, and when its fusion-point is reached it begins to bend over until its tip touches the base. For practical purposes these cones are very successful, though their use has been somewhat unreasonably discouraged by some. They have been much used by foreign manufacturers of clay products, and their use in the United States and Canada is increasing.

In actual use they are placed in the kiln at a point where they can be watched through a peep-hole, but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones of different numbers in the kiln, so that warning can be had, not only of the end point of firing, but also of the rapidity with which the temperature is rising (Plate II).

In determining the proper cone to use in burning any kind of ware, several cones are put in the kiln, as, for example, numbers '08, 1, and 5. If '08 and 1 are bent over in burning, and 5 is not affected, the temperature of the kiln is between 1 and 5. The next time numbers 2, 3, and 4 are put in, and 2 and 3 may be fused, but 4 remains unaffected, indicating that the temperature reached the fusing-point of 3.

While the temperature of fusion of each cone is given in the preceding table, it must not be understood that these cones are for measuring temperature, but rather for measuring pyrochemical effects.

The following list gives the approximate fusing-points of some of the members of the series of cones used for this report:—

No. of Cone.	Fusing point. Degrees F.	 Degrees C.
010	1742°	950°
05	1922°	1050°
03	1994°	1090°
1	2102°	1150°
3	2174°	1190°
5	2246°	1230°
9	2390°	1310°
20	2786°	1530°
25	2966°	1630°

The cones used in the different branches of the clay-working industry in the United States and Canada are approximately as follows:—

Common brick	012–01
Paving brick	01–5
Sewerpipe	3–7
Buff face brick	3–9
Hollow blocks and fireproofing	05–1
Terra-cotta	02–7
Conduits	5–8
Firebricks	5–14
White earthenware	8–9
Red earthenware	010–05
Stoneware	6–8
Porcelain	11–13
Electrical porcelain	10–12

CHAPTER II

KINDS OF CLAYS.(1)

As shale is merely a hardened clay, the terms clay and shal are regarded as one and the same thing by the clayworker. Mos shales, when pulverized finely enough to pass through a scree of 20 meshes to an inch, can be tempered with water, and worked up until they have a plasticity equal to that of some clays which occur in a soft or unconsolidated state.

Slates are also hardened clays, but the process of hardening has proceeded to such a degree that they no longer possess the property of plasticity, which is so important in the clay-working industry. Slates may resemble shales in colour and structure, but the fact that they cannot be moulded into shape renders them useless for the purposes of this report.

Clays have a wide variety of colour in the raw state, varying from white to almost black. The prevailing colours of the clays or shales in New Brunswick are light and dark grey, brown, and red. Most of them turn to various shades of red, when burned in kilns, the red colour developed in burning being due to the oxidation of the iron contained in the clay, the iron being an active colouring agent. Clays in which there is a very low percentage of iron will burn to white, grey, or buff tones,(See Chapter I.) Clays which have a very high percentage of lime, like the Erie clay in Ontario, will burn to a buff colour, the lime exercising a bleaching action on the iron.

KAOLINS AND CHINA-CLAYS

The name kaolin is commonly applied to natural deposits of white burning residual clays, which are composed mostly of silica, alumina, and chemically combined water, but having a very low percentage of fluxing impurities, especially iron.

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(1) For a more detailed discussion on the subjects treated of in this, and the foregoing chapter, see Ries,—"Clays, their Occurrence, Properties, and Uses". Wiley and Sons.

Deposits of kaolin generally contain quartz fragments, and mica grains as impurities. When these are separated from the mass by washing, the fine grained washed product is called "china-clay." China-clays are used in the manufacture of white table ware, electrical porcelain, wall tile, as a paper filler, and an ingredient of slips and glazes in ceramics. The white ware and porcelain bodies are made up of: china-clay, which gives whiteness and refractoriness, ball clay to give plasticity and bond, ground quartz (called flint) to reduce the shrinkage and give stiffness to the body, and feldspar to serve as a flux.

Some small veins or pockets of kaolin are said to occur in crystalline rocks situated near the headwaters of the Miramichi river, but a workable deposit has not yet been discovered in New Brunswick.

The only workable deposit of kaolin, so far known in Canada, occurs at St. Remi d'Amherst, about 70 miles northwest of Montreal. As shown by the following chemical analysis, it is a kaolin of high purity.

Silica (SiO_2)	46·13
Alumina (Al_2O_3)	39·45
Ferric oxide (Fe_2O_3)	0·72
Lime (CaO)	none
Magnesia (MgO)	none
Potash (K_2O)	0·20
Soda (Na_2O)	0·09
Loss on ignition	13·81
	100·40

BALL-CLAY

This is the plastic ingredient in white ware bodies. The raw clays of this class should combine high plasticity with good tensile strength, and burn white or nearly so. No true ball-clay has been found in Canada, but the white beds among certain sedimentary clays in the Musquodoboit valley, Nova Scotia, approach it in character.

FIRECLAYS

The most important property of this class of clays is refractoriness or ability to withstand a high degree of heat without softening. They may vary widely in other respects, showing great differences in plasticity, density, shrinkage, and colour.

It is customary for miners to apply the term fireclay to all clays and shales found underlying coal beds. While it is true that in Great Britain, and in several of the States, valuable fireclays underlie coal seams, still there are many of the clays under the coal in these countries, that are not refractory.

None of the clays and shales underlying the coal seams in the Maritime Provinces, as far as they have been tested, proved to be fireclays.

The standard adopted in these reports is, that the material shall stand up, without softening under fire at the fusing point of cone 27 (3038° F.) before it can be termed a fireclay.

The most refractory clay at present known in New Brunswick, that occurs in workable quantities, is found underlying a coal seam at Flower Cove, in the Grand Lake Coal area. This material fuses at cone 23 (2894° F.), hence it is not a fireclay.

Some authorities in the United States refer to clays which will stand cone 30 or better as a No. 1 fireclay, from cone 20 to cone 30 as No. 2, and from cone 10 to 20 as No. 3 fireclays. While some of the lower grade clays may be worked up into shapes for various industrial uses, such as stove linings, sewer pipes, electrical conduits, etc., they would not be suitable at all for metallurgical work, where slags are formed, or where intense heat is used.

For several years bricks have been manufactured at Westville, N.S., from a hard greyish black clay shale found under the No. 3 seam at the mine of the Intercolonial Coal Company. This material fuses at about cone 14, and the bricks made from it are used at the Steel Works in Sydney as linings for ladles, into which molten steel is poured from the reverberatory furnaces. They are said to be better for this purpose than the more refractory bricks used in the blast furnaces, as the molten metal does not penetrate them so far, and hence the life of the linings made from the Westville bricks is longer.

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

The two following chemical analyses are given to illustrate the composition of fireclays. No. 1 is from Shubenacadie, N.S., No. 2 is from Murphy brook, Middle Musquodoboit, N.S.

	No. 1.	No. 2.
Silica	74·03	55·14
Alumina	17·30	28·84
Ferric oxide	1·15	1·91
Titanic oxide	1·04	2·37
Magnesia	0·16	0·25
Lime	0·38	0·38
Soda	0·53	0·48
Potash	0·88	1·88
Water	4·78	9·24
	100·25	100·49

STONEWARE CLAY

While this material is often as refractory as the clay used for firebrick, it differs from it in burning to a very dense body at comparatively low temperatures. It should have sufficient plasticity and toughness to permit it being turned on a potters' wheel. Its fire shrinkage should be low, its vitrifying qualities good, and sufficiently refractory so that the wares made from it will hold their shape in burning. Most stoneware is now made from a mixture of clays, so as to produce a body of the proper qualities, both before and after burning.

Stoneware clays are found at a few localities in the Maritime Provinces, the following chemical analysis gives their composition.

Analysis of Stoneware Clays

	I	II	III
Silica (SiO_2)	63·68	55·52	63·91
Alumina (Al_2O_3)	23·80	26·80	18·60
Ferric oxide (Fe_2O_3)	1·20	2·58	5·75
Titanic oxide (TiO_2)	+	1·50	+
Lime (CaO)	0·40	0·25	trace
Magnesia (MgO)	0·20	1·05	trace
Soda (Na_2O)	1·43	0·73	+
Potash (K_2O)		3·43	+
Water (H_2O)	8·77	8·39	10·30

+ Not determined.

I. Grey shale under coal seam at Flower Cove, N.B.

II. Very plastic grey clay over 13-foot coal seam at Inverness N.S.

III. Very plastic red and grey mottled clay at Middle Musquodoboit, N.S.

Stoneware clays are used not only for the manufacture of all grades of stoneware, but also for yellow ware, art pottery, earthenware, and architectural terra-cotta.

Stoneware clay is used largely in Great Britain for the manufacture of sewerpipe. Owing to its smoothness, and the fine salt glaze which it takes, added to the hardness and strength of the body, this class of ware is the very highest grade of sanitary drain pipe.

SLIP CLAYS

These clays contain such a high percentage of fluxing impurities, and of such texture, that at a low temperature they melt to a greenish or brown glass, thus forming a natural glaze. While easily fusible clays are common, few of them produce a good glaze on melting.

A good slip clay makes a glaze which is free from defects common to artificial glazes. It will fit a wide range of clays, and since it is a natural clay, it will undergo the same changes in burning, as the body on which it is placed. Artificial mixtures of exactly similar composition to the natural slip clays have failed to give the excellent results as to gloss or colour that are attained by the natural clay.

In applying the glaze to the ware the clay is mixed with water to a creamy consistency, and applied to the ware either by dipping or spraying. The most satisfactory slip clay is obtained from Albany, N.Y., it is shipped to all parts of the United States, and to St. John, N.B., for potters' use in glazing stoneware.

PAPER CLAY

In paper making, a clay may be used as a filler or as a coating material. Since clay enters into the composition of all the ordinary printing and bond papers, as well as many wrapping papers, its most important use in this industry is as a filler. Whiteness and freedom from grit are essential, in the best grades of paper clay.

FULLERS EARTH

The name fullers earth is made to include a variety of clay-like materials of a prevailing greenish-white or grey, olive green or brownish colour, soft and with a greasy feel. This type of clay has a high absorbent power for many substances. It was originally used for fulling cloth, that is, cleansing it of grease. Its most important use, at the present time, is for bleaching cotton oil and lard oil. Mineral oils are also filtered through it. There is no record of fullers earth occurring in Canada.

PIPE-CLAY

So-called because tobacco pipes are made from it, is an impure kaolin containing free silica. This term is also used in referring to clays or shales suitable for making sewerpipe.

SEWERPIPE CLAY

Clays or shales that burn to a vitrified body, or one of lo absorption, that hold their shape in burning, and also take salt glaze, are essential in the manufacture of this class of war Fireclay is often added to a vitrifiable shale, or a mixture of tw or more shales may be used.

The clays used for this purpose are similar to those used fo paving bricks so that the two products are sometimes made i the same factory from the same clay.

Materials suitable for the manufacture of sewerpipe are foun in the Grand Lake coal area, Stonehaven, Moncton, etc., an occur in the middle Carboniferous formation.

BRICK CLAYS

The clays or shales used for common brick are generally o a low grade, and in most cases red burning. The main requisite are that they will mould easily, and burn hard at as low a temperature as possible, with a minimum loss from cracking anc warping. Since many common clays or shales when used alone show a higher air or fire shrinkage than is desirable, it is customary to decrease this by mixing some sand with the clay, o by mixing a loamy or sandy clay with a more plastic one. Brickmakers call a clay "strong" or "fat," when it is highly plastic, somewhat stiff and sticky, and "lean" when a clay is gritty or sandy and works easily.

Bricks used for facing buildings are moulded with special care, or re-pressed, if made by the wet moulded processes. When dry-pressed bricks are required, the best results are obtained by using shale. Smoothness of surface, and uniformity of colour, are no longer required, as formerly for this purpose, so that special methods are resorted to by face brick manufacturers to produce roughness in surface, and variety in colour.

PORTLAND CEMENT CLAY

Shales or clays are largely used in the manufacture of Portland cement. This material is essentially an artificial mixture of lime, silica and alumina. The first ingredient is usually supplied by some form of calcareous material, such as limestone marl or chalk, while the other two are obtained by the selection of a clay or shale, the mixture consisting approximately of 75 per cent of lime carbonate to 25 per cent clay or shale.

Clays or shales to be used for Portland cement manufacture, should be as free as possible from coarse particles or lump sand, gravel, or concretions. These conditions are best met by the transported clays, since residual clays are frequently sandy or stony, and many glacial clays notably so.

Several of the surface clays and shales in New Brunswick will probably be found suitable for this purpose. For economic reasons they should be located in the vicinity of marl, or limestone deposits, and convenient for transportation.

MARL

Shale or clay that contained a large percentage of lime were formerly referred to as "marly," hence certain soft red shale beds occurring in the lower Carboniferous formation in New Brunswick and Nova Scotia are often called "marls" in the Geological Survey reports. These shales, however, do not contain an excessive quantity of lime, and burn to a red colour.

The term marl is now restricted to those soft, chalky, deposits containing shells, which occur sometimes in the bottom of fresh water lakes.

There are several occurrences of marl in the bottom of small lakes lying on the lower Carboniferous rocks or on the highly calcareous Silurian strata in New Brunswick. Owing to its softness, white colour, and slight plasticity, it has frequently been mistaken for white clay, but it is lime carbonate.

CHAPTER III

METHODS OF TESTING CLAYS.

There are two methods of testing clays, the chemical and the physical.

CHEMICAL METHOD

This consists usually in making a chemical analysis, which shows us the percentage of the different ingredients present in the clay, but gives us few or no clues regarding the physical properties of the material. In the ordinary chemical analysis the substances usually determined are silica, alumina, ferric oxide, lime, magnesia, and alkalies. Carbon, and sulphur trioxide, both deleterious substances, are rarely determined. A special application of chemical examination would be a determination of the amount and kind of soluble salts present.

The chemical analysis is, however, of such small practical value that no analyses were made for this report.

PHYSICAL METHOD

This is the much more important method of testing, for it gives us valuable information regarding the possible uses of the clay or shale, and consists in a determination of their plasticity; water required for mixing; tensile strength; air shrinkage; fire shrinkage, colour, and absorption at different temperatures; and fusing point.

The method of making each of these determinations is given below.

TENSILE STRENGTH

The determination of the tensile strength of the raw material is made because it gives a clue to the clay's ability to stand strains in handling before burning, and possibly also of its bonding power or its ability to stand the addition of non-plastic materials like sand or "grog."

The clays and shales submitted to the physical tests were first thoroughly dried, then ground in a jaw crusher and afterwards sifted through a 20 mesh sieve.

A weighed quantity of the sifted material, sufficient to make the necessary number of test pieces, was mixed with just enough water to give it the greatest plasticity, and thoroughly kneaded and wedged so as to render it perfectly homogeneous and free from cavities. The consistency generally arrived at was about midway in stiffness between a soft-mud and stiff-mud brick in practice.

In making briquettes for the tensile test, a small piece of the kneaded clay was clamped into the briquet mould, and struck by the hand until it filled the mould completely, the excess of clay being struck off by a fine wire.

The clay was removed from the mould on a dry clay briquet—a set of them being kept for the purpose—and the wet clay briquet was not handled until it had hardened on its support, so that they were not distorted while soft.

The briquets when hard were dried to 100° C., the cross section at the waist carefully measured, and then broken in an ordinary tensile strength machine.

The results for the various tensile strengths given in this report are the average of 10 to 12 briquets.

SHRINKAGE

All clays shrink more or less in drying and burning. The shrinkage that occurs while the clay is drying is termed air shrinkage, while that which occurs during the burning is known as fire shrinkage.

Air Shrinkage.—A portion of the kneaded clay was made into bricklets in a mould 4″ × 1½″ × ¾″ in size. Two fine lines, exactly 3 inches apart, were impressed with a steel stencil on the wet clay bricklet immediately after leaving the mould. When the bricklets were thoroughly dry the distance between these lines was measured, and the percentage of air shrinkage calculated. The average of 6 to 8 bricklets is given in the results for air shrinkage.

Fire Shrinkage.—The burning of the bricklets at the lowe cones was done in a down-draft muffle kiln, the fuel used being coke, and the time of burning from 12 to 18 hours. For the higher temperatures a gas-fired muffle kiln was used.

The lines on the burned bricklets were again measured afte each successive firing, and the total amounts of shrinkage calculated. The difference between the total shrinkage and the air shrinkage represents the fire shrinkage.

The air and fire shrinkages are given separately in the results, but their sum would represent the total shrinkage of any clay from the time it was taken from the mould.

FUSIBILITY

Small pyramids or cones of the ground clays or shales were burned in the gas fired furnace until they were deformed or melted. The temperatures at which the test cones melted are expressed in terms of the standard Seger cones.

A Deville furnace, fired with coke, under air blast, was used for determining the fusing points of the more refractory clays, including those which did not fuse until a temperature ranging from cone 18 to cone 32 was reached.

ABSORPTION

The bricklets were carefully weighed after each burning, and immersed in water to about three-fourths of their thickness. This permits the air from the burned clay body to escape freely, allowing the water to better and more quickly fill the pores. After standing at least 24 hours in water, the saturated bricklets are weighed, the increase in weight recorded, and the percentage of absorption calculated as follows:—

$$\frac{\text{Saturated weight—Dry weight}}{\text{Dry weight}} \times 100.$$

DRY-PRESS TESTS

The clay or shale used for the dry-press test was ground to pass a 20 mesh sieve, and moistened with 5 to 10 per cent of water. A mould was filled with the damp clay, and pressed in a hand screw press, the size of the bricklet produced being 4″ × 1½″ × 1″.

RAPID DRYING

For this test the clay or shale was ground to pass a 12 mesh sieve, and kneaded up with sufficient water to a fairly stiff mass, from which a full-sized building brick was made by hand in a wooden mould.

Immediately after coming from the mould the moist brick was placed on a rack in a box open at the bottom and with a perforated top, which stood on a steam heated radiator. The temperature in this box ranged from 120° to 150° F. which is the heat usually attained in commercial dryers. If the brick cr[illegible] this treatment it was stated that it would not stand [illegible].

CHAPTER IV

SHALE FORMATIONS

The bed-rock, which underlies the Province of New Brunswick, ranges in age from the Pre-Cambrian to the Triassic.

For the purposes of the clayworker the Province may be divided into two portions, a western area which is generally barren of deposits of value, and an eastern area which is of importance to him.

If a line be drawn from Bathurst to Macadam junction, passing through Boiestown and Fredericton, and another line due eastward to the Bay of Fundy, then the roughly triangular area included between these two lines and the eastern seaboard contains most of the rocks of Carboniferous age in the Province. In the three subdivisions of this system, the lower, middle, and upper Carboniferous, is found the shale beds, from which most of the clay wares used for structural purposes may be manufactured. Certain areas of the middle Carboniferous formation contain a thin coal seam, which is mined in a few localities.

As compared with the broken hilly region, which confines it on the west and south, this area is with few exceptions, low, and except for river valleys, it presents no marked inequalities of surface (Plate IV). Its elevation rarely exceeds 600 feet, and the general average is probably about 400 feet above sea-level.

The beds of the lower Carboniferous formation are largely conglomerates and sandstones in the lower portion, but often there are thick beds of soft red shales, or sandy shales in the upper part.

The middle Carboniferous or Coal Measures are made up principally of grey sandstones and grey shales, and carry a thin seam of coal at some localities. This formation is the most widespread of the Carboniferous subdivisions, it is of no great thickness and patches of the older rocks protrude through it at various points. The rocks of the Coal Measures are in a horizontal attitude over the greater part of the area. The shale beds of the formation, owing to their friable character, are easily eroded, so that they are rarely seen in exposed position, the more resistant sandstones being most in evidence. A large portion of the area is also covered with a forest growth, or by swamp, or by drift deposits. The shales, then, must be looked for principally on sea coast cliffs or in stream banks, and where coal is being mined or in railway cuttings.

The upper Carboniferous rocks are confined to the south-eastern corner of the Province. This group consists generally of soft reddish, or purple brown sandstones, grits, and shales. The shales are soft, and of red or brown colour, resembling those of the lower Carboniferous in quality.

No sampling has been done over the greater part of the Carboniferous area, because much of the material it contains is inaccessible at present, and transportation facilities are necessary to the development of deposits of this class.

The following details of the samples collected are from localities already provided with transportation, and taken from deposits which occur in workable quantities. The materials tested are believed to be fairly representative of all the shales which occur in the Carboniferous area in New Brunswick.

LOWER CARBONIFEROUS

WELDON CREEK, NEAR ALBERT MINES

A thick bed of red gritty clay shale, which softens readily on exposure to weathering, outcrops on the bank of the creek at the wagon road crossing.

When tempered with 19 per cent of water, this shale, notwithstanding its sandy character, works up into a fairly plastic mass. Its working and drying qualities are good. Its shrinkage when air dried is 5·6 per cent, and the average tensile strength of the raw clay was 74 pounds per square inch. At cone 010 the fire shrinkage was 1 per cent, and absorption 13 per cent. At cone 05 the fire shrinkage was 1·3 per cent, absorption 11 per cent, and colour dark red. At cone 03 the fire shrinkage, absorption, and colour remain about the same. The shales make a good common or dry-pressed face brick.

SHALE FROM FREDERICK BROOK,

NEAR ALBERT MINES

This material is a somewhat hard grey shale when fresh, b weathers down to a fairly soft mass. The sample worked with 21 per cent of water to a plastic body of good worki quality. The air shrinkage when dried was 6·2 per cent and t average tensile strength 137 pounds per square inch. In burni it behaved as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0·3	13·0	Red
05	0·6	14·5	"
03	1	13·4	"
1	5·3	7·3	Brown
3	softened		

This shale burns to a good colour, has a fair ring at 010, an becomes steel hard at 03. It will make either common or presse brick, but must be fired slowly on account of the carbon it con tains. The shale will probably work well for the manufacture o fireproofing.

DORCHESTER

About 1½ miles north from Dorchester on the road to th right of the Court House, some shale beds are exposed in a narrov valley, near some sandstone quarries. The shales are similar t those at Pugwash, N.S., but less weathered. The outcrops ar small but there may be an abundance of the material. Tw samples were taken, one from each side of a small brook, and ar alike in character. When tempered with 17 per cent of water they worked up into a fairly plastic body. The air shrinkage was 5 per cent. Burning tests are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	4·5	13·5	Red
03	5·6	3·6	Dark red

The shale is a good common brick material, and is suitable for use by the dry pressed process.

HARCOURT

About 2 miles southwest of Harcourt a bed of red shale outcrops along the banks of the Salmon river. It underlies sandstone and drift at a depth of about 14 feet, and an attempt was made to work it by underground methods for brickmaking. A small kiln of bricks was built, but they were not burned sufficiently hard, so that exposure to weather caused them to crumble and disintegrate (Plate VI B.)

The shale, though gritty, makes a fairly plastic body when tempered with 16 per cent of water. Its drying shrinkage was 5 per cent. The burning tests were as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0·6	11·2	Red
05	0·6	9·9	Red
03	0·6	7·0	Dark red
1	Fused	.	. .

This shale contains a rather high percentage of calcium carbonate in rather coarse particles. Owing to the high lime content, the brick, if burned only to cone 010, will disintegrate from the air slaking of the lime particles. The shale would have to be burned to cone 05 or higher to ensure a safe product.

CHIPMAN

A weathered grey shale, covered with a thin layer of sanc loam, occurs near the National Transcontinental Railway statio The section, as exposed in a trench, shows a thickness of not le than 5 feet. It is fairly plastic, works easily, and has a dryi shrinkage of 5·2 per cent. When burned to cone 010, it had buff colour, a low fire shrinkage, and an absorption of 12·5 p cent. At cone 03, the colour was red, fire shrinkage 5·7 per cen and 4 per cent absorption. It can be used for common, or dr pressed brick.

Beds of lower Carboniferous red clay shale occur on tl National Transcontinental railway line about 1½ miles west Chipman, and also on the New Brunswick Coal and Railwa line between Chipman and Midland. They are similar to tho described from Weldon brook.

PLASTER ROCK

A short distance east of Plaster Rock station on the Nationa Transcontinental railway, some red and green banded shales ar exposed in a cutting. The shales are weathered at the outcrop into a soft mass. The upper part of the bank is concealed b slide materials, but the shale beds are probably 10 to 12 fee thick. They are interbedded with sandstones.

The shale, although gritty, makes a good plastic, easily workin body when tempered with water. Its shrinkage when air drie is 5 per cent, and the tensile strength 120 pounds per square inch

Observations on burning are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	2·0	8·0	Red
05	3·6	3·8	"
03	5·0	0	Dark red
1	..	..	..

This is a good brick material for use by the stiff mud process.

When dry-pressed and burned to cone 05, it makes a dark red, steel hard, face brick, with a fire shrinkage of 4 per cent, and an absorption of 4 per cent.

This material makes a rather smooth pipe in the hard screw press machine. When burned to cone 07 (1850° F.) these pipes were strong and sound, with an absorption of 4·2 per cent. This material will make a better and denser field drain tile than any of the surface clays.

A small sample of red shale was taken from one of the beds in the upper part of the bank of Tobique river at the town of Plaster Rock (See Plate III). This material contained more grit than the one last mentioned, but it makes a better working body, and one having a small air and fire shrinkage. Its softening point is too low to permit its being used in the manufacture of vitrified wares, but it will make an excellent building brick, of a rich red colour.

CAMPBELLTON AND DALHOUSIE

There are a few small patches of lower Carboniferous rocks along the south shore of Chaleur bay in the vicinity of Campbellton and Dalhousie. These rocks were found to consist mainly of sandstones and conglomerates, and no workable shale beds were observed in them.

There is a remarkably fine bed of shale, in rocks of the same age, on the Gaspe coast opposite Dalhousie (Plate VIII) which will be referred to here, as this shale could easily be brought to Campbellton in barges, if a clay product factory were established there.

FLEURANT POINT, GASPE.

Greenish shales, interstratified with hard bands, having a total thickness of about 30 feet, without overburden, occur at this locality. The shale beds are from 2 to 8 feet thick, and exceedingly plastic, the hard bands are gritty, but the whole section could probably be worked for some purposes. A small sample of the shale was ground and tempered with 19 per cent water. It formed a very smooth plastic mass, with good working and drying qualities. Its drying shrinkage was 4 per cent.

The burning tests are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0	13·2	Red
05	1·5	10·6	Red
03	5·0	5·3	Dark red
1	7·0	Vitrified	Dark red
3	5·6	Vitrified	Chocolate
5	Softens	. .	. .

The body is steel hard at cone 010, and vitrified at cone 1, b the material does not appear to be injured by firing sligh higher than this.

It would be an excellent material for the manufacture of fi proofing, and owing to its good working qualities and fine r colour when burned, would probably be suitable for the man facture of roofing tile. It produces a fine red face brick of go body and solid colour when burned to cone 03, the absorpti being only 4·5 per cent. The entire thickness of hard and s bands which make up this deposit could probably be used f the manufacture of paving bricks.

MIDDLE CARBONIFEROUS

This formation is of importance, for in addition to the sever useful beds of shale which it contains, it also carries, over a lar part of its area, a seam of coal. This coal seam, although thi is mined at several points, and it is generally in those mini areas that the shale beds are most accessible.

GRAND LAKE COAL AREA

The most extensive coal mining operations are carried on i the Grand Lake area, within the limits of Queens and Sunbur counties and near the villages of Minto and Newcastle.

The coal seam is found at a depth of 30 to 60 feet below the surface; it averages about 20 inches in thickness. About 2 feet or more of a fine grained grey shale, overlying the coal, is brought to the surface and piled in waste dumps, during mining operations. This shale is quite hard when fresh, but it slakes and softens after a few months exposure to weathering.

The following sections of rocks were obtained from a boring made by the Crown Land department on the property of the Rothwell Coal Company, at a point about one mile south of Minto.

Section No. 1

	Feet	Inches
Clay and gravel	9	0
Sandstone, interbedded with purple and blue shale	10	0
Shale, red and blue	8	0
Massive blue shale	18	0
Grey shale—coal shale	6	0
Coal	1	6
Hard, grey clay shale	6	0
Shale, red and blue	16	0
Fine grained blue sandstone	18	0
Coarse sandstone	102	0
Fine grained sandstone	35	0
Red shale	21	0

This boring, as well as several others in this district, was made with the object of finding another coal seam at a lower level than the one at present worked. The coal measures of the middle Carboniferous, however, are thin in the Grand Lake basin, and it is probable that the red shale at the bottom of the above section belongs to the lower Carboniferous formation, which is barren of coal. The following approximate section was obtained south of Minto station, measured from the level of Gilchrist brook to the surface at the New Brunswick Syndicate mine.

Section No. 2

	Feet	Inc
Drift	14	0
Grey and purple shale with thin sandstone bands.	11	0
Massive grey clay shale	8	0
Grey shale—coal shale	16	0
Coal	1	8
Light grey clay shale	4	6
Fine grained grey sandstone, with shaly bands	8	0
Purple and grey shale	12	0
Coarse grained grey sandstone	15	0
	90	2

The three lower members of the section are exposed at t brook, and on the road. The upper part of the section was se in a shaft, before the timbering was placed. The sections se exposed in shafts on both the King and Barnes mines, a sho distance north of Minto, consist mostly of sandstone beds in t upper portion, above the coal shale.

Nearly all of the upper shale and sandstone beds are missi in some of the mines at Newcastle. These have been erode and replaced by a thick covering of boulder clay, some of t shafts having been sunk the entire depth from the surface the top of the coal seam through this material, a depth of 50 fee

The general surface of the Carboniferous area, north of Gra Lake, is level (Plate IV), but the rivers, and some of the small streams, such as Newcastle brook, have cut deep trenches in t plateau, affording at places good natural exposures of portio of the coal measures. No sampling was done, however, except the vicinity of the mines.

Shale Overlying Coal

The shale over the coal, referred to by the miners as the "co shale," is the most important material in the area. As a sufficie thickness has to be removed, to obtain head room while minir the thin coal seam, this shale has accumulated in enormo quantities as waste heaps on the surface.

It is remarkably uniform, both in colour and texture, over several square miles, and contains the most perfectly preserved fossil plants found in any of the rocks of the Carboniferous period in the Maritime Provinces. The shale weathers speedily on exposure, and when fresh, if finely pulverized and tempered with 16 per cent of water, works up to a mass of good plasticity which can be readily moulded in almost any type of clay working machinery. The shapes moulded from it can be dried safely in commercial driers working at 130° to 160° F. in about 24 hours.

The following table gives the data for five samples, selected at different points in the district, from the freshly mined shale on the dumps.

1602	Canadian Coal Corporation, Salmon bay.
1594	Barnes coal mine, Minto.
1817	Weltons coal mine, Minto.
107	Rothwell Coal Co., Minto.
111	New Brunswick Syndicate, Minto.

The mine of the Canadian Coal Corporation is situated on Salmon bay on Grand lake, at a distance of about 7 miles east of Minto. The other mines mentioned above are within a radius of 1½ miles from Minto station (See Fig. 1.)

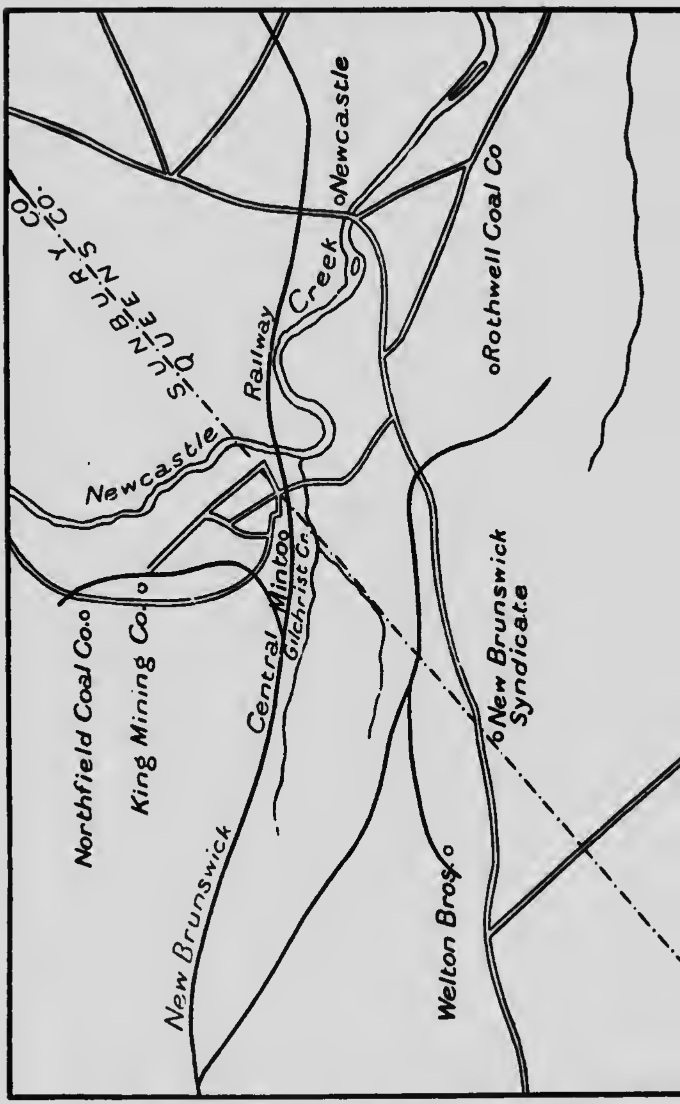


Fig. 1. Position of coal mines in vicinity of Minto, N.B.

Laboratory number	1602 %	1594 %	1817 %	107 %	111 %
Air shrinkage	4·7	4·6	4·0	4·0	4·0
Cone 010					
Fire shrinkage	0	0	1·0	..	2·0
Absorption	12·6	11·0	7·8	..	8·8
Cone 05					
Fire shrinkage	2	..	2·6	1·3	2·0
Absorption	9·2	..	5·5	10·0	8·0
Cone 03					
Fire shrinkage	2·3	4·0	3·7	3·0	4·4
Absorption	7·8	5·3	2·9	6·0	3·0
Cone 1					
Fire shrinkage	3·3	4·7	4·0	4·7	4·6
Absorption	3·9	1·3	1·2	4·0	2·2
Cone 3					
Fire shrinkage	3·6	4·6	4·0	3·0	5·7
Absorption	2·4	2·3	1·0	2·9	0
Cone 5					
Fire shrinkage	Softens	Softens	4·7	3·0	5·7
Absorption	..	..	0	1·7	0
Cone 9	..	..	Softens	Softens	Softens

These shales all burn to a light red steel hard body at cone 010. The colour becomes deep red at cone 03, and brown or chocolate colour at cone 5.

The shale to the north of Minto, and the one from Salmon bay, do not stand quite as high firing as the others, but in other respects their properties are similar. When made up by the dry-pressed process, and burned to cone 03, a good, dense, steel hard body was produced from all samples. The test pieces thus made had a shrinkage of 3·5 per cent, and an absorption of about 4 per cent. The red colour of the dry-pressed bricklets was not so good as that produced from some of the other shales in the district

All of the samples burned, show that this shale will produce structurally sound building materials, like common brick, face brick, sewer brick, and fireproofing.

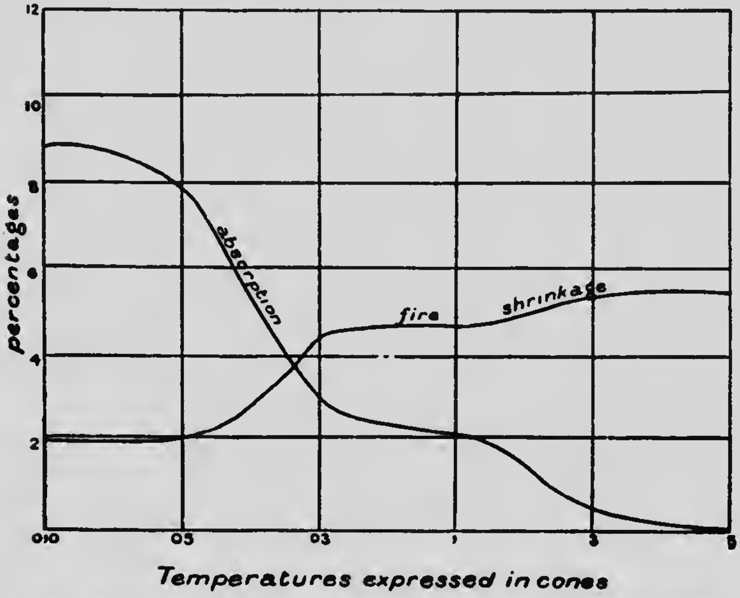


Fig. 2. Fire shrinkage and absorption curves of shale overlying coal seam, New Brunswick Syndicate, Grand Lake coal area, N.B.

The fairly wide vitrification range of the shale from three localities would indicate that these should be useful for the manufacture of vitrified products. For this test, some short lengths of 3 inch pipe were made in a hard screw press, and burned in a commercial sewerpipe kiln at a temperature of cone 4. The sample from the Rothwell Coal Company mine came out with a rich coloured bright salt glaze. The body was vitrified, but did not appear to be overfired. The sample pipe made from the shale at the New Brunswick Syndicate mine gave the same results; the salt glaze, and the condition of the body being good. The sample from the Welton Bros. mine (See Plate V) did not appear to give quite as good results, but this may be due to the position of the piece in the kiln.

According to the results obtained from the preliminary tests, the shales overlying the coal at these three localities are suitable for the manufacture of sewerpipe, but it would probably be better to do the salt glazing at cone 3.

Shale Underlying Coal

The underclay or shale underlying the coal seam is rather massive in structure, with an irregular cleavage, and varying in thickness from about 6 inches to 4½ feet. It forms the floor in the drifts at the coal mines and is not removed, unless where trenches are sunk in it to provide drainage. The material when in place is hard, and difficult to remove, but when carried to the surface and exposed to weathering, it soon disintegrates into a soft clay.

Samples of the underclay were taken for testing at six different localities, as follows:—

1601	Canadian Coal Corporation, Salmon bay.
1595	Northfield Coal Company, Minto.
1593	King Mining Company, Minto.
112	New Brunswick Syndicate, Minto.
1818	Welton Bros., Minto.
108	Rothwell Coal Company, Minto.
1819	Flower Cove, Grand lake.

The following table gives the behaviour of each of these materials in firing, when made up wet moulded.

Shales Underlying Coal, Grand Lake Coal Area

Laboratory number	1601 %	1595 %	1593 %	112 %	1818 %	108 %	1819 %
Water required	15	24	14	15	16	15	23
Air shrinkage	4·8	6·6	3·0	4·0	5·0	3·5	8·5
Cone 010							
Fire shrinkage	0	·15	0	1·0	0	0	0
Absorption	10·2	13·3	10·0	10·0	10·6	15·0	14·0
Cone 05							
Fire shrinkage	2·6	..	..	1·0	1·7	0	1·6
Absorption	4·6	..	..	7·0	6·0	12·0	12·0
Cone 03							
Fire shrinkage	2·3	4·0	1·6	2·7	2·3	1·0	2·0
Absorption	2·6	7·4	6·8	4·3	4·8	11·0	10·5
Cone 1							
Fire shrinkage	2·3	5·0	4·6	2·7	..	1·0	3·0
Absorption	·8	·8	2·3	4·2	..	10·7	10·2
Cone 3	Softens						
Fire shrinkage	..	6·0	..	4·0	3·0	1·3	..
Absorption	..	0	..	3·2	2·4	10·0	..
Cone 5		Viscous	Viscous	Swells	Swells	.....	..
Fire shrinkage	..	..	..	..	..	2·0	3·7
Absorption	..	..	..	..	..	8·0	6·8
Cone 9				Viscous	Viscous		
Fire shrinkage	..	..	..	..	..	2·3	3·7
Absorption	..	..	..	..	..	9·4	4·5
Cone 20	..	..	..	..	..	Softens	..
Cone 25	..	..	..	..	..	..	Softe

All of these underclays work well when ground and tempere with water. They have sufficient plasticity to enable them to b worked into shape by any type of clay working machiner Their drying qualities are good, so that they can be safely drie in any type of commercial drier in use.

The underclays vary far more widely in their behaviour in burning, than the shales overlying the coal. Two of them are refractory enough to be classed as second grade fireclays, while some of the others soften so readily that they cannot even be used for the manufacture of vitrified wares.

Shales Nos. 1601, 1595, 1593, 112, and 1818, are red, burning and only of value for building brick manufacture, but could probably be used for fireproofing. They would scarcely be worth extracting, especially as the shale overlying the coal, which has to be removed in mining, will give as good or better results for these purposes.

If the whole series of shales were opened up, and worked in an open face, then these underclays could be used, either in mixtures with the upper shales or used alone for special purposes. These underclays would require to be burned slowly, as, owing to the carbon which they contain, they have a tendency to swell at the higher temperatures.

An experiment was made in order to ascertain the value of these shales for use in a sewerpipe body. A sample consisting of two parts of the shale over the coal, and one part of the underclay, both taken from Weltons Bros. mine, was made up into short lengths of 3 inch pipe. These samples were burned in a sewerpipe kiln, firing to cone 4. The pieces took a good salt glaze, but the body was slightly swelled. Better results would probably be got by firing only to cone 3. Shales Nos. 108 and 1819 are high grade, buffing burning materials. The clay from the Rothwell Coal Company mine (108) could be used for many purposes where a semi-refractory brick was called for, such as boiler settings, coke oven blocks, stove linings. When dry-pressed and burned to cone 3, it makes a very desirable brick for facing buildings or for mantels. Fused iron specks begin to appear on the surface of the bricks at this temperature, and these dark specks in contrast with the buff tone seem to add to its appearance.

A sample of this shale was made up into short lengths of 3 inch pipe, and burned in a commercial sewerpipe kiln at cone 4. It takes a good salt glaze, with the buff colour of the body showing through it. The body was not vitrified in this test, but the glaze with which it is covered protects the body and renders the ware impervious to moisture. A high grade sewerpipe, with a denser body, could probably be obtained by salt glazing it at cone 6.

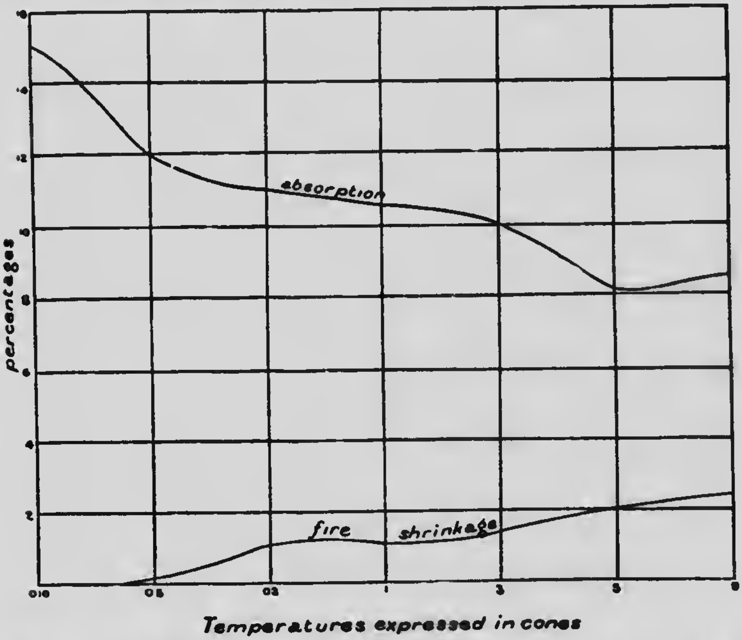


Fig. 3. Fire shrinkage and absorption curves of shale under coal seam, Rothwell Coal Co., Grand Lake coal area, N.B.

It is quite likely that this shale when mixed with a portion of the shale overlying the coal, would produce a good quality of electrical conduits.

Flower Cove

Situated about 4 miles south of Minto, on an inlet of Grand lake. The shale underlying the coal seam at this locality is light grey in colour and about 4 feet in thickness. It is the most plastic of any of the underclays in this district, and also the most refractory. It burns to a denser body than the underclay at the Rothwell mine, which is most like it in character. The softening point of the material falls about two cones below that of the requirements of a fireclay, but it is refractory enough to be classed as a No. 2 fireclay. It burns to a buff coloured body at the lower temperatures, while at cone 5 and higher the colour becomes grey.

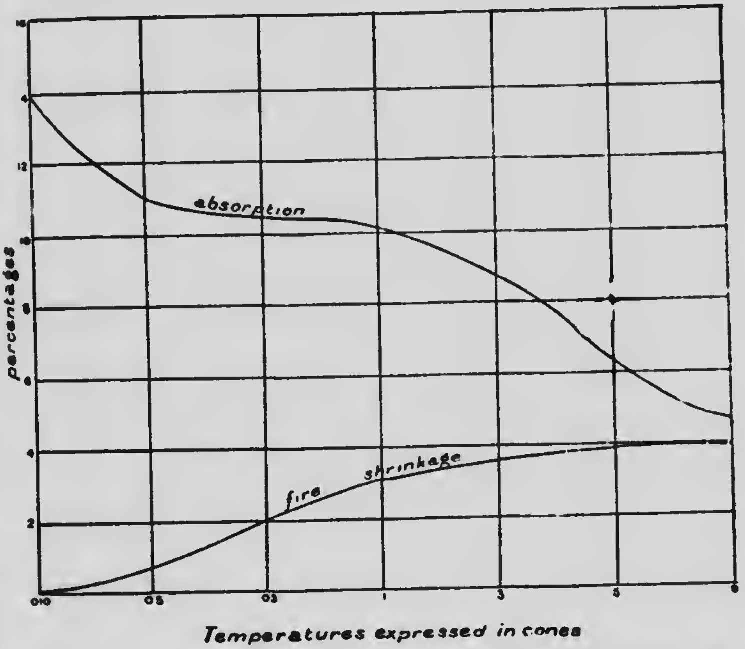


Fig. 4. Fire shrinkage and absorption curves of shale under coal seam, Flower cove, Grand Lake coal area, N.B.

This material has the characteristics of a stoneware clay, and a quantity of it was sent to Foley Bros.' pottery at St. John, for trial in the manufacture of stoneware articles. It has a rather high shrinkage, but if sufficient "grog" were added, it could probably be used for the manufacture of architectural terra-cotta, electrical conduits, and sewerpipe. The curve for shrinkage and absorption of this material is given in the diagram, Fig. 4.

OTHER SHALES AT MINTO

A shaft which was being sunk on the property of the New Brunswick Syndicate gave an opportunity of sampling the shales in the upper part of the shale beds at Minto. The sample corresponding to member No. 2, as given in Section 2, page 50, when finely ground, took 15 per cent of water in tempering. It was very gritty, and had only a low plasticity. The shrinkage on drying was only 3 per cent, and it can be dried as rapidly as desired with safety. In burning, it behaves as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0	11·4	Light red
05	0	10·4	Light red
03	1·0	9·8	Red
1	1·5	8·0	Dark red
3	1·7	9·3	Dark red

The low plasticity and shrinkage of this shale are probably owing to thin layers of sandstone, interbanded with it. The burned test pieces show no sign of vitrification at cone 3. This material would probably give better results when mixed with the more easily vitrifiable shale which lies immediately below it in the shaft. This is a massive grey, hard shale marked No. 3 in Section 2, and lies just above the coal shale. When ground and mixed with 13 per cent of water, this shale, although very gritty, had a fair amount of plasticity. Its working qualities are good and it can be dried as rapidly as desired with safety, the drying shrinkage being only 3 per cent. The tensile strength is about 50 pounds per square inch.

The burning tests are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0	11·0	Light red
05	1·0	8·2	Light red
03	4·4	4·0	Dark red
1	4·7	3·0	Dark red
3	Softened	. .	. .

This shale burns to a steel hard body at cone 05. When burned to cone 1, it has a dense tough body, somewhat of the character required in a paving brick. Its limit of safe burning is about cone 2, as when fired higher the shale will soften and deform. It is a good material for use in the manufacture of common brick, sewer brick or drain tile. When dry-pressed and burned to cone 03, it will produce a good red face brick, with a dense steel hard body and an absorption of only 5 per cent.

The shale marked No. 8 in Section 2 (page 48) is exposed on the road which crosses Gilchrist brook, leading southward from Minto. The outcrops occur on the old portion of this road, at its steepest grade, near its junction with the main road. The shale is banded in olive and reddish colours, and softens readily on exposure to weathering.

The sample taken from this deposit, when finely ground and mixed with 15 per cent of water, worked up to a mass of medium plasticity. It was very gritty, but worked and dried well.

The drying shrinkage was 3·5 per cent, and the tensile strength 98 pounds per square inch. Burning tests are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	1·0	12·2	Red
05	1·7	4·4	Red
03	5·0	4·0	Dark red
1	5·7	3·0	Dark red

This is a good brick material; it burns to a dense steel hard body at cone 05. Its plasticity is not very high, but could be improved with wet pan grinding, so that the material could be used for hard burned fireproofing, wire cut brick, and drain tile. When made up by the dry-pressed process and burned to cone 05, it gives a solid bright red colour without specks, the body being hard and the absorption 9·5 per cent. It burns to a deeper red colour at cone 03, when the body becomes steel hard and the absorption 5·5 per cent. This shale gives the best results for dry-pressed, red face brick, of any so far tested in the Province.

It may be readily seen from the results of the foregoing tests that the Grand Lake district is worth the attention of clayworkers in search of various materials. The New Brunswick Coal and Railway Company's line, which hitherto had its terminus at Minto, is now being extended to Fredericton. This will afford a direct outlet from the district toward the west for manufacturers.

DUNSINANE

There is a comparatively small area of the rocks of the coal formation at Dunsinane, in Kings county, about 30 miles southwest of Moncton, near the line of the Intercolonial railway. The coal seam that occurs here was opened for working in 1910, at a point on the bank of a small brook about half a mile northeast of Dunsinane station. The coal seam is 22 inches thick; it is underlain by sandstone and shale, and overlain by sandy shale, a portion of the latter being removed and brought to the surface, in order to provide head room for working the coal. The coal mine was operated for about six months, but water came in so fast, that the work was stopped.

The shale that occurs over the coal is apparently a massive rock when freshly mined, but it develops thin laminæ on weathering, and after prolonged exposures breaks down to a soft crumbling mass.

A sample of this shale taken for testing was mixed with 15 per cent of water, and found to work up easily into a fairly plastic, but very gritty body. It developed greater plasticity than its sandy nature would lead one to suspect. The drying shrinkage was 3·5 per cent, and the tensile strength only 33 pounds per square inch. It behaved as follows in burning:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0	11·4	Light red
05	·6	9·4	Light red
03	3·3	5·6	Red
1	4·0	4·1	Dark red
3	3·7	6·0	Dark red
5	Swollen	. .	. .

This material has a dense tough structure, and is burned almost to vitrification at cone 1. It has a considerable temperature range above cone 1, before it begins to swell and deform. The behaviour of the test pieces in burning, and the character of the body produced, suggest its use for paving brick. Its working qualities in the raw state could be improved by grinding in wet pans so that it could be worked in stiff mud machinery, and flow through a die in a compact bar.

BEERSVILLE

Beersville lies about 10 miles southeast of Harcourt, a station on the Intercolonial railway, and is connected with the main road by a switch. It lies in the Coal Measures area, and the beds outcrop on the slopes of a crescentic hill, formed by a bend in the river.

The coal bed, which is about 16 inches thick, is roofed by a very smooth shale, with some plant remains, and not over 4 to 5 feet thick, as sandstone outcrops that distance above the coal seam. Underlying the coal is a soft, dark bluish-grey shale, which is called fireclay. These two are found in all the drifts which are run in on the seam (See Plate VI A).

The coal is worked by the Imperial Coal Company.

The over clay, which is the harder of the two, is not highly plastic, and works up with 16·5 per cent of water to a mass whose air shrinkage was 4·5 per cent, and average tensile strength when dried 87 pounds per square inch.

At cone 010 its fire shrinkage and absorption were respectively 0 per cent and 10·23 per cent.

At cone 03 they were respectively [illegible] cent and 1·6 per cent.

The shale burned to a hard body with a fair ring at cone 010, but was barely hard enough; it became steel hard at cone 05, and at cone 1 was a little beyond vitrification. When moulded dry-press it gave a hard body at cone 03. The clay needs to be slowly burned on account of its carbonaceous character, but could be used for pressed brick. It would, however, have to be worked in conjunction with the coal.

The under clay, when freshly taken from the mine, is not highly plastic, but weathering would no doubt improve its quality in this respect. In the laboratory it worked up with 20·2 per cent of water to a mass whose air shrinkage was 7 per cent, and average tensile strength 103 pounds per square inch. It gave a fair brick at cone 010, with a fire shrinkage of —2·3 per cent, and absorption of 13·64 per cent, but not very good colour.

At cone 05, the fire shrinkage was 2 per cent, absorption 8·67 per cent, bricklet steel hard, and colour red. It was vitrified at cone 1, and a good dry-pressed brick obtained at cone 03. The shale has to be fired slowly on account of its carbon contents. The material is not a fireclay.

STONEHAVEN

Upon the shore of Chaleur bay, about 50 feet of fine shales, grey, green, or red in colour, with limestone nodules, extend for several miles in the coastal cliffs about Stonehaven resting upon grey sandstone (Plate VII). An average sample of the upper 15 feet of the shale was taken from the cliff, at a point beside the road, and near the Presbyterian church. The shale was soft on the surface, from exposure to weathering, but on stripping a foot or so from the outcrop, the harder shale was reached. The portion sampled contained no sandstone band, or any material which would have to be discarded in mining. The shale effervesces when acid is applied, but is not highly calcareous. When ground and mixed with 17 per cent of water, it works up to a mass of medium plasticity. It would probably give good plasticity if ground in a wet pan. It can be dried rapidly, after moulding, in any type of commercial drier. The drying shrinkage was 5 per cent, and the tensile strength of the raw clay was 139 pounds per square inch.

The burning tests were as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	1'0	12'5	Red
05	3'5	8'8	Red
03	4'4	5'0	Red
1	5'0	3'0	Red
3	6'6	0	Dark red
5	7'0	0	Brown
9	Fused	. .	. .

A dry-pressed bricklet was burned to cone 03; it had a fire shrinkage of 3'5 per cent and the absorption, 4 per cent. The bricklet was steel hard, but shows numerous buff specks on the red faces. This shale is suitable for the manufacture of wire cut brick, face brick, drain pipe, fireproofing, and probably for paving brick.

A portion of the shale was ground to pass through a 10 mesh sieve, and made into short lengths of 3 inch pipe in a hand press. The pipe samples were burned in a sewerpipe kiln at cone 4, they came out structurally sound and with a good even salt glaze. They appeared, however, to have been fired at a temperature rather too high for the material. If ground finer and burned to cone 3, this shale would probably have given better results in the sewerpipe test.

The shale is not suitable for making a soft burned product, because if underburned, the lime particle will air slake, and cause the bricks to crumble. When fired to cone 03 or higher, the material is perfectly safe, as the lime at these temperatures is rendered harmless, by entering upon the vitrification stage.

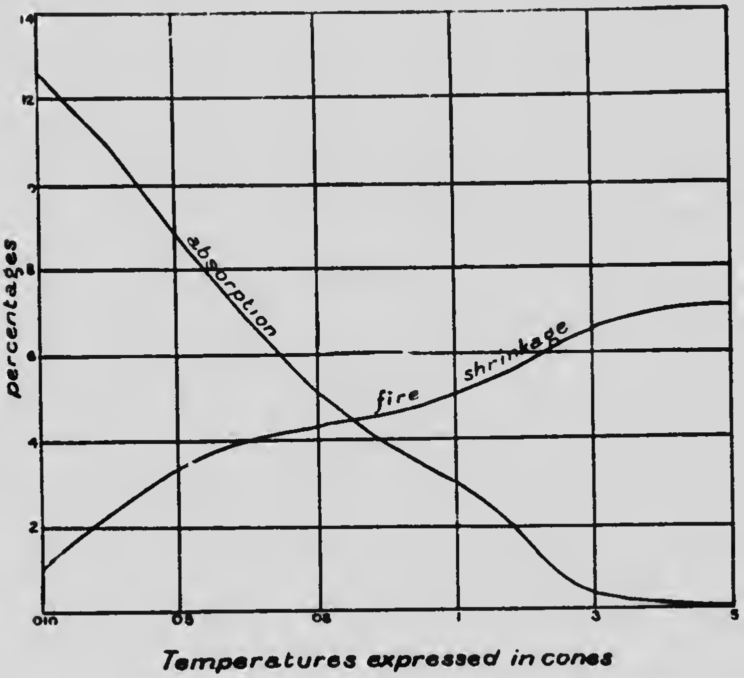


Fig. 5. Fire shrinkage and absorption curves of shale, Stonehaven, Gloucester county, N.B.

The deposit has little or no overburden, and is well situated for transportation either by steamer or railway. It is unlikely that it could be worked for any length of time at the point sampled, but it can probably be found a short distance back from the seashore, on the line of the Caraquette railway.

CLIFTON

The sea-shore cliff is over 100 feet high at Clifton, and shows a section of alternating beds of sandstone clays, coal, and shale. These beds do not appear at Stonehaven—which is about 2 miles northeast of Clifton—as the dip of the rocks carries them to below sea-level at that point. None of the beds of shale at Clifton are thick enough to be workable, but two of the clay beds are of interest, as they were said to be fireclays.

The lower clay bed occurs at about 6 feet from the bottom of the section; it is about 4¼ feet thick and varicoloured. It underlies a thin coal seam.

The upper clay is about 50 feet above the beach; it is about 4 feet thick, and grey in colour. Like the lower bed, it is much softened at the outcrops, and also underlies a seam of coal a few inches in thickness. A small sample of each bed was taken for testing, but as they are both very much alike in character, only the results for the upper one are given.

This clay or shale when mixed with 20 per cent of water forms a highly plastic, smooth body, which has a drying shrinkage of 6 per cent.

The results obtained in burning are given below:—

Cone	Fire shrinkage %	Absorption %	Colour
1	1·0	13·4	Buff
3	1·3	11·3	Buff
9	1·4	6·6	Buff
15	Fused	..	..

The material is not a fireclay, but it will make a good face brick for buildings or mantels, and is of a desirable colour when burned for this purpose.

If dry-pressed and burned to cone 1, it makes a beautiful golden buff brick with 2 per cent fire shrinkage and 11 per cent absorption.

If burned to cone 3, fused iron spots will appear on the surface, giving that speckled effect, so much esteemed in the higher class building brick. If burned to cone 9, the bricks become overfired and will stick together.

Both beds of clay are rather high in their lime content, and if underburned will crumble after short exposure to the weather, but they are perfectly safe if burned to cone 1.

In the vicinity of Clifton, these beds would have to be worked by drifting and timbering, but the expense of doing so would be too great, as the clays are not valuable enough. The dip of the beds would carry them to the surface at a point a short distance southwest of Clifton, when a considerable quantity of the clay might be mined at the outcrops or by doing a slight stripping.

The following localities in which shale beds and coal seams are known to occur in combination were not visited, as no development work has been done at these points up to the present. It is impossible to arrive at any definite conclusions regarding the character and extent of these materials, unless they are opened up in the processes of mining, or where natural sections are exposed, which is not the case in these localities.

CLONES, QUEENS COUNTY

Shales associated with coal seams occur on the Nerepis river, about a mile above the mouth of Wilson brook. The coal seam is 2 feet 8 inches in thickness but contains a clay parting of 2 inches; and is said to be underlain by soft grey shales; and several shale beds occur on the Nerepis river below the coal outcrop. Transportation facilities do not exist at present for the working of this locality.

COCAGNE RIVER

In the county of Kent, a coal seam about 7 inches in thickness, overlain by grey shales, is exposed on the north bank of the Cocagne river, about 3 miles from its mouth. In a record of a boring made at this point in 1901, this shale is referred to as being marly, or calcareous, so that in all probability it is not a fireclay.

CAPE ENRAGE

The middle Carboniferous rocks are exposed in a narrow belt in the southern part of Albert county, extending from Cape Enrage to the mouth of Shepody river, with an average breadth inland of half a mile. The rocks for the greater part of this distance are grey sandstones, grits, fine conglomerate, with some extensive beds of grey shale. Irregular streaks of coal from half an inch to two inches or more in thickness, together with carbonized remains of plant stems and tree trunks, occur in some of the sandstone beds, but there is no workable coal seam in this locality, and no transportation facilities.

CHATHAM

A bed of shale occurs about 2 miles southeast of Chatham. It is exposed at the roadside on the west bank of Morrison brook, its thickness being about 15 feet. The shale is banded in red and green colours, it weathers very readily and becomes quite softened at the outcrops. The plasticity and working properties of the sample taken from this locality were good. Its drying shrinkage was about 5 per cent. The burning tests are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0	15·0	Light red
05	2·0	10·0	Light red
03	2·3	6·4	Red
1	5·0	0	Dark red
3	6·0	0	Brown
5	Swells slightly	. .	. .

This shale burns to a steel hard body at cone 05, and becomes vitrified at cone 1. It will stand firing at cone 3 or 4 without softening or deforming. If burned to a lower temperature than cone 03, wares made from this shale will disintegrate and crumble on exposure to air, so that a soft burned product cannot be made from it. The crumbling of the underburned ware is caused by the slaking of numerous coarse particles of lime which the shale contains. When the shale is burned to cone 1, the lime particles become fused with the remainder of the body, and the wares burned to this temperature are perfectly safe to use.

This shale flows smoothly through a die, and may be used for the manufacture of hollow ware. It takes a good salt glaze at cone 2 or 3, so that it might be used for making sewerpipe. It also makes a good sound dry-pressed brick if burned sufficiently hard.

This was the only workable shale bed noted in the locality. Some thin beds of shale occur in the vicinity of Newcastle, and along the north bank of the Miramichi river, but they occur mostly underlying sandstone beds, so that they are inaccessible to the clayworker.

MONCTON

The middle Carboniferous formation underlies the district in the vicinity of the city of Moncton, and the shales of this series outcrop at a few points. Some small samples were examined from a bank of shales which occur almost within the city limits. They were submitted by Mr. Matthew Lodge. The upper part of the bank is a reddish brown clay, resembling the surface clays used for brickmaking in several parts of the Province, but it may be a weathered shale. It makes a good quality of red brick at cone 010; the clay is almost vitrified at cone 03, and it softens at cone 3. The air and fire shrinkages of this material are high, and it is not suited for the manufacture of vitrified wares.

The sample from the middle of the bank was undoubtedly a weathered grey shale. It burned to a light red, steel hard body at cone 010, with an absorption of only 8 per cent. It burned to a greyish body, which was almost vitrified, at cone 3, but at this temperature it shows a tendency toward swelling and black coring. It is, however, a good building brick material, and could probably be used for fireproofing.

The sample from the bottom of the bank was also a weathered grey shale. It was very plastic, and appeared to have good working and drying properties. It burned to a salmon coloured steel hard body at cone 010, with low fire shrinkage and absorption. When burned to cone 3, the body was buff coloured and vitrified.

As this clay was the most refractory of the three, one of the bricklets made from it was burned in a commercial sewerpipe kiln at cone 4. Although the shale took a good salt glaze, the surface was pitted and roughened by the fusing out of iron specks, and the body was slightly swollen, showing a black core, with vesicular or honeycombed structure. It is possible that this trouble is due to the presence of both iron pyrite and carbonaceous matter in the clay.

If the pyrite occurs in large pieces, it may be picked out in mining and discarded, but if it occurs disseminated throughout the shale, then the shale should be exposed to weathering for a few months before using. The bad effects due to the carbonaceous content might be overcome by slow firing during the oxidation stage in burning. If this treatment were carried out in the processes of manufacture the material should give good results for sewerpipe.

A small sample of clay and one of shale were obtained from the Wilbur farm, a few miles from Moncton. The clay was reddish in colour, and had good plasticity and working qualities. The tests made on it show that it is probably the red Pleistocene clay, used for the manufacture of common brick and drain tile.

The shale was evidently one of the middle Carboniferous beds. It burned to a clean buff coloured body, and took a good uniform salt glaze, so that it is a proper sewerpipe material. This shale appears to be free from the defects found in the lower shale at Moncton.

UPPER CARBONIFEROUS

The strata of the upper Carboniferous in the southeastern part of New Brunswick consist generally of soft reddish or purple brown sandstone, grits, and shales. They occupy the central portion of the Maringouin peninsula; the sea-coast cliffs on the eastern side exhibit a fine section of the rocks.

SACKVILLE

In the vicinity of Sackville, the upper Carboniferous strata are well exposed at several points. The rocks here are principally soft brownish or red sandstones with interstratified conglomerate and shale. The shale beds appear to be rather thin, and owing to their positions in the series are not very accessible for working.

A small sample of shale from about one mile north of Sackville was tested, and found to have good plasticity and working qualities. It burned to a good sound red body at cone 010. This shale would make good common brick, but could not be used for the manufacture of vitrified ware as its fusing point was too low.

CHAPTER V

CRYSTALLINE AND METAMORPHIC ROCKS.

Rocks of this character are mostly confined to the western and southern portions of the Province, and the areas underlain by them are more rugged and stand at higher elevations than those which the Carboniferous formations underlie.

The crystalline rocks include granites, diorites, felsites, etc., while the metamorphic rocks are generally slates and quartzites. These are all of Pre-Carboniferous age. None of these rocks are of plastic character, nor do they become plastic when finely ground, and while they have no doubt weathered down to fairly extensive deposits of residual clay in the past, these have been mostly removed by glacial action.

There are evidences that post glacial weathering of some of the crystalline rocks has resulted in small deposits of residual clay which will be referred to briefly.

RESIDUAL CLAY

Several extensive outcrops of dolerite and felsite occur in the northern portion of the Province. These rocks form high ridges or hills which sometimes have an elevation of 1,500 feet above the sea. They contain small pockets and seams of residual clay but none of them was found which was large enough to be of economic value.

Reddish grey or buff coloured felsitic rocks, occurring along the line of the Intercolonial railway at Campbellton, contained some softened portions, a sample of which was collected for testing.

As it is possible that the large bodies of these rocks that occur in this neighbourhood may contain a deposit large enough to be workable, the results of these tests are given to show the value of the material.

The residual clay when tempered with water has good plasticity and working qualities and a shrinkage on drying of 5 per cent. It burns to a hard buff coloured body at cone 3, which had an absorption of 8 per cent. When burned to cone 9, the fire shrinkage is 5 per cent, and the absorption 3 per cent. As the clay softens at cone 20, it is not a fireclay, but it could be used for purposes where a semi-refractory material would answer. It is likely to make an excellent sewerpipe body, or even be suitable for the manufacture of architectural terra-cotta. The fresh or hard felsite, when crushed and ground to pass a 20 mesh sieve, is not plastic but it could be used by the dry-pressed process for making a high grade face brick for buildings.

A sample of the ground rock was dry-pressed and burned to cone 3. It produced a very fine ornamental face brick of attractive and unusual colour, with an absorption of 12 per cent, and a steel hard body, but would probably give better results if burned to cone 5. A brick of this quality and colour would bring a high price for use in large cities. The cost of grinding such a hard material fine enough to use would probably be prohibitive.

A small outcrop of mottled red and white clay, which is probably due to the decay of felsitic rocks, occurs on the shore near sea-level on the property of Mr. Robt. St. Onge, about 3 miles east of Campbellton.

It was very plastic, but quite gritty; its air shrinkage was high, and the moulded test pieces cracked slightly in drying. It burns to a vitrified body at cone 3, the total shrinkage being 13 per cent, at this temperature. The softening point is about cone 10.

As the results were poor when made up wet moulded, a sample was dry-pressed and burned to cone 1. This resulted in a very fine face brick of rich buff colour. The extent of the deposit is unknown, but it is inaccessible at the locality sampled.

The largest amount of residual clay resulting from the weathering of felsite was seen on Louison creek, at a point about 5 miles southwest of Jaquet River station on the Intercolonial railway. Quite a large extent of reddish felsite was softened to a depth of several feet, the weathered portions being light and dark grey or red in colour. A small sample of the clay collected from this deposit was tested, but the results were poor, and the material has little or no value in the clay working industry.

SILURIAN SLATES

The slates of Silurian age are the most widespread of the metamorphic rocks. For the most part they are compact and massive in appearance, but, in some localities, their cleavage is so well developed, and they break down so easily, that they resemble shales. Although these rocks were originally sediments of the same character as those which produce shales, the metamorphic processes to which they were subjected has altered them so much that they are not plastic.

The shaly appearance of the Silurian rocks exposed in the Matapedia River valley, along the line of the Intercolonial railway, is very pronounced. A small sample of them was collected at Matapedia junction for the purpose of testing. This material, when finely ground and tempered with water, did not possess enough plasticity to be properly moulded into shape.

When burned to cone 03, it produced a soft, chalky body having a high absorption. It contains a large percentage of lime, and is quite useless for the manufacture of clay products.

CHAPTER VI

PLEISTOCENE CLAYS

The unconsolidated clays that occur on, or near, the surface. so largely used for brickmaking, are of recent origin, and belong to this group. These clays frequently have a stratified or banded structure; they are free from pebbles, and have good plasticity. They are generally underlain by boulder clay, a material which is too stony for use in the clay industry (See Plate IX B).

The boulder clay is a glacial product, consisting of a heterogeneous mass of materials from various sources, moved and distributed by an ice sheet. The overlying stratified clay is of marine origin, accumulated during a depression of the sea coast and the main valleys of the Province. A good deal of the clay has been eroded or worn away since its emergence, so that it only occurs in patches of various extent. It is found in terraces on the sea coast or along the principal rivers, up to a height of 200 or 300 feet above sea-level. The stratified clay varies in thickness from a few feet to 40 or 50 feet, but it is frequently overlain by sand beds which may be so thick as to render the underlying clay inaccessible to the clayworker.

The stratified surface clay is useful to the small industry, of limited means, inasmuch as it is easily mined, and can be sent to the brick machine without any previous preparation. It can be burned to a sufficiently dense body for building brick in the ordinary clamp or scove kiln, which requires no outlay of capital, other than the cost of labour in setting the brick.

This clay is usually very fine in grain, and highly plastic, but its softening point is low, so that it cannot be used in the manufacture of vitrified wares. Its usefulness is limited to the manufacture of common brick and field drain tile.

The surface clays in New Brunswick will produce probably as good quality of common red building brick as any made from a similar source in Canada.

ST. JOHN

Several large patches of surface clays occur in the vicinity of St. John, which are worked for brickmaking at two points.

A small sample for testing purposes was taken from the clay bank at Mr. John Lee's brickyard at Courtney bay.

This was a reddish brown, stratified clay, free from pebbles, and without any appreciable overburden. It was very fine grained, 95 per cent passing through a 200 mesh sieve. When tempered with water it forms a smooth, plastic body, which works easily, and gives no trouble in drying. Its drying shrinkage is 6·5 per cent. The burning tests are as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	1·0	16·0	Light red
05	3·0	13·0	Red
03	9·0	Vitrified	Dark red
1	Softens	. .	. .

The clay burns to good red body, which is almost steel hard at cone 010. When burned to cone 05, the body is quite steel hard, and the colour better. When fired to higher temperatures, it shrinks considerably, and is liable to soften and deform.

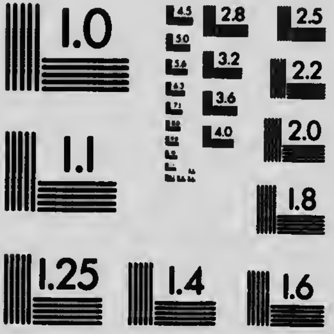
It is an excellent common brick clay, and, owing to its smoothness and good working qualities, is also suitable for the manufacture of drain tile and flower pots, but vitrified ware cannot be made from it.

ST. STEPHEN

The sample of clay from this locality was taken from Mr. Hartford's brickyard, situated at the outskirts of the town. The clay bank is about 9 feet thick; it is overlain by about a foot of gravelly and sandy loam. The clay is stratified and of a mottled blue and yellowish colour. A considerable thickness of blue clay underlies the portion which is worked.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



The working and drying qualities of this clay are very good. It comes through a die in a very smooth pipe, and is suitable for the manufacture of farm tile.

Its shrinkage on drying is 6 per cent. It burns to a light red steel hard body at cone 010, with an absorption of 12·4 per cent, but the fire shrinkage is rather higher than usual for this variety of clay. When burned to cone 03, the shrinkage is excessive, and the body vitrified.

The clay makes good common brick, but a small quantity of sand should be added to it so as to reduce the shrinkage. The commercial limit of burning would be about cone 07 (1850° F).

The clay deposit from which the sample was taken is part of a marine terrace, which extends for a considerable distance up the valley of the St. Croix river.

FREDERICTON

There is a good exposure here of estuarine clay, about one mile north of Fredericton. The clay is clearly laminated (Plate X B), yellowish above and bluish below. The total thickness ranges from 18 to 27 feet, the clay being underlain by a stony sand. It is evident that the top and bottom surfaces of the clay are uneven. Thus, to the south the clay thins out up the slope, while toward the St. John river it dips under the flood-plain sand deposit, having a thickness of 6 to 14 feet.

The blue bottom clay outcrops in the river bank at low water, it is evidently part of an extensive deposit, as clay of this type is said to underlie the whole of the city of Fredericton. The clay used at Ryan's brickyard is classed as a good grade of common brick clay, and has the following qualities, which are characteristic of the New Brunswick estuarine clays.

The material is very plastic, and works up with 23 per cent of water to a good working body. The shrinkage on drying is 7·8 per cent, and average tensile strength 109 pounds per square inch. On full sized bricks the drying shrinkage is somewhat less.

The material is quite free from sand, as 94 per cent of it passes through a 200 mesh sieve. It behaves as follows in burning:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0	22·0	Red
05	3·6	1·7	Dark red
03	10·3	0	Chocolate
1	Fused	..	..

The clay burns to a fair colour, and good hard body at cone 010, but if burned to cone 05 the shrinkage is too great. The best results for brickmaking would probably be produced by burning to cone 08 or about 1800° F. This material will also make field drain tile.

SUSSEX

No brick clay occurs in the immediate vicinity of the town of Sussex, but at a distance of about 3 miles to the northwest of the town, a small patch of reddish clay 3 to 10 feet deep is worked by Mr. John Heffer (Plate XI A).

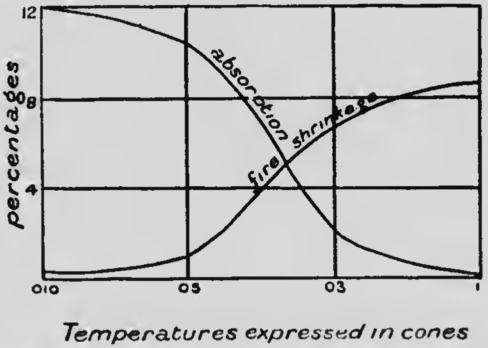


Fig. 6. Fire shrinkage and absorption curves of non-calcareous surface clay, Sussex, N.B.

This clay, when tempered with 21 per cent of water, forms a very plastic body with good working qualities. It contains some small angular rock particles, but as these are not limestone, they give no trouble in the burnt brick. The drying shrinkage is 5·5 per cent, and the tensile strength 180 pounds per square inch. The clay will stand fast drying. Burning tests were as follows:—

Cone	Fire shrinkage %	Absorption %	Colour
010	0·5	12·0	Red
05	0·8	10·4	Red
03	7·0	1·8	Dark red
1	Vitrified	. .	. .
3	Softened	. .	. .

This is a good brick clay, burning to a red, almost steel harc body at cone 010, with a low shrinkage and absorption. A dense hard brick with low absorption suitable for lining trunk sewer can be obtained by burning to cone 05 or a little higher. Sample of 3 inch pipe, made in a hand press and burned to cone 07 wer smooth and sound in structure, the absorption being 11 per cent showing that the clay would make good field drain tile.

CHATHAM

Marine clays are worked at two points in the vicinity of thi town, for making common building brick. One of these plant is situated near the Nappan river about 3 miles east of Chatham

The clay in the Nappan River valley is reddish in colour an stratified, its thickness at the brick plant is 7 feet, and is underlai by bed-rock. The clay appears to be much thicker; nearer t the river.

When tempered with 22 per cent of water, this clay forms smooth, highly plastic mass of good working qualities, the dryin shrinkage of which is 7 per cent. It burns to [illegible] .d hard re body at cone 010, with 1·7 per cent for shrinkage, and 16·9 p cent absorption. If burned somewhat higher, it has a dark re body with a lower absorption. It is a good brick clay and shoul make a strong, smooth drain tile.

The clay bank worked at Nelson, 6 miles southwest of Chatham, consists of about 10 feet of stratified clay. The upper 7 feet of this is of a yellowish colour, and contains sandy layers, the bottom portion of the deposit is a smooth, blue clay.

A small sample of the blue clay was tested. When mixed with 24 per cent of water, it had good plasticity, but appeared to contain much fine grit. Its drying shrinkage was 6 per cent. The shrinkage on burning was less than the Nappan clay, the absorption was about the same. Both clays have a high fire shrinkage at cone 03, and are vitrified. Their melting point is about at cone 2. These are excellent common brick clays, when used by the wet moulded process, but are not suitable for the dry-pressed process, or for the manufacture of vitrified wares.

The stratified clay that occurs at Nelson is part of a narrow terrace which borders the valley of the Miramichi, at a short distance from the bank of the river. The stratified clay only occurs in patches along the river, being worn away for the most part, so that the terrace consists mostly of the boulder clay which formerly underlaid it.

BATHURST

A highly plastic, red, stratified clay occurs in terraces along the Intercolonial Railway line south of Bathurst station. It is used to a limited extent for brickmaking, a horsepower machine being operated in the manufacture of common brick (Plate XII). The upper part of the terraces is composed of beds of stratified sand, which is available for mixing with the clay to reduce shrinkage in the latter. The clay from this point was not tested, but it appears quite similar in properties to that used at Nappan river, near Chatham. The deposit is well situated for transportation purposes.

CAMPBELLTON

Terraces of marine clay occur along the line of the Intercolonial railway, between Campbellton and Moffat station. It is a yellowish, rather stiff, plastic clay, containing streaks of pebbles and sand, and some scattered pebbles, but parts of the deposits are altogether free from them.

A small sample was taken from a railway cutting about 1½ miles east of Campbellton. The deposit at this point appears to have a considerable thickness, is free from pebbles, and has a light overburden of sand. This clay required 30 per cent of water for mixing, its plasticity was fairly good, but the body worke rather short. The drying shrinkage was about 6·5 per cen Burning tests are as follows:—

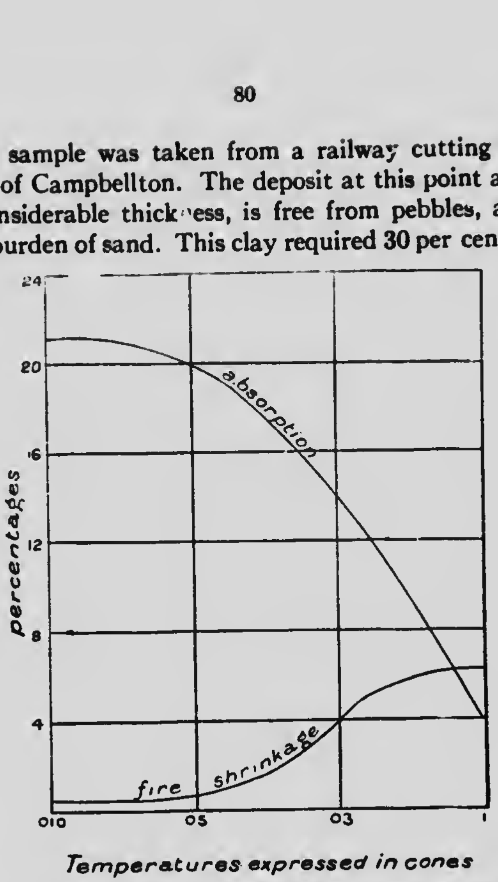


Fig. 7. Fire shrinkage and absorption curves of calcareous surface clay, Campbellton, N.B.

Cone	Fire shrinkage %	Absorption %	Colour
010	0·7	21·0	Light red
05	0·7	20·0	Red
03	4·0	14·0	Red
1	6·0	4·0	Red
3	Softened	..	..

CHAPTER VII

THE CLAYWORKING INDUSTRY

Up to the present time the clay deposits of New Brunswick have only been developed to a very limited extent.

Wooden construction prevails, to the exclusion of almost all other kinds, except in the business portions of the cities and towns, because lumber has hitherto been plentiful and cheap in this Province.

The danger from extensive fires is always present when wooden construction is so freely used in closely built communities. This was evident in the total destruction of the town of Campbellton by fire during the summer of 1910. Since then, the demand for structural clay wares is increasing, but they are not yet used as largely as they might be, because everything except common brick has to be imported.

New Brunswick possesses in its Carboniferous rocks, certain shale beds, adapted for making those higher grades of claywares which cannot be produced in the Provinces of Quebec or Ontario, where these raw materials are absent. Clayworkers will probably find it to their advantage to locate works for the production of materials, not only for home consumption, but also for export.

Proximity to markets, although desirable, is not so essential to manufacturers of the higher grades of clay wares, such as face bricks, paving bricks, sewerpipe, electrical conduits, fireproofing, etc., as these materials are frequently transported for long distances. A plant equipped for a large output of common brick can only be maintained close to cities, where the demand for them is constant during the greater part of the year. These plants frequently represent a considerable expenditure of capital, being furnished with artificial driers, continuous kilns, and machinery driven by steam or electric power. The surface clays can be worked in a primitive manner, with a small outlay of capital, to suit the demands of small towns or rural communities. Such plants are able to maintain their position, because the price of common brick would not pay the cost of carriage from large centres where their manufacture is carried on more scientifically.

When the need for underdraining the cultivated areas in th Province becomes more generally known, these clays will hav a much wider application. Drain tile can be made from any the surface clays mentioned in this report. Tile are made fro stiff mud, usually by an auger machine having a circular di although different styles of plunger machines and also har presses are used in their manufacture. They are made in siz varying in diameter from 2 inches to 3 feet. Any mea of drying and burning may be used with the smaller sizes, b the larger sizes require considerable care to prevent crackin Contrary to the popular notion, it is not necessary for drain ti to be porous, so that they should be hard burned. Besides su ficient hardness, the important requirements for drain tile a straightness, uniformity of diameter, and smoothness of ends.

The only pottery in operation in the Province is located St. John, on Loch Lomond Road. It is owned by J. W. Fol and Company, who manufacture butter crocks, teapots, jars, a flower pots (Plate IX A). Most of the raw material is import from the State of New Jersey.

The following details concerning the clay-working industry the present time in New Brunswick are briefly given.

FREDERICTON

M. Ryan and Son are the only brick manufa[illegible] this ci (Plate 10A). The material used is a surface cl[illegible] tuar type, somewhat similar in character to t[illegible] in t Annapolis, and Shubenacadie valleys of Nov[illegible] he c is moulded in a soft mud machine, without [illegible] prelimina pugging, but nevertheless makes a good grade of brick. T freshly moulded bricks are hacked out on the ground to dry the air, but since the writer's visit, Mr. Ryan has installe steam drier. Burning is done in a patent double chambe downdraft kiln, each half having a capacity of 90,000 bric The brick settles 12 inches in 31 courses during the burning.

ST. JOHN

Two brickyards are in operation in the vicinity of this city. The clays used are all similar, being evidently remnants of marine or estuarine deposits laid down at a slight elevation above present sea-level. The clays are smooth and plastic, and free from pebbles. Any pebbles found in the finished bricks have probably come from gravels overlying the clays.

The brickyard of Mr. John Lee is located on Courtney bay at the Little river. The material used here is a tough, reddish brown clay and worked to a depth of 6 or 7 feet below the surface. The brick clay rests on a very hummocky boulder drift, which crops out in a few places in the bottom of the pit. The clay, after being broken down from the bank, is dumped into soak pits (Plate XIV B) along with some sand, and kept there for a day or so before going to the machine. Sand moulded or soft mud bricks, some re-pressed bricks for facing buildings, and field drain tile are manufactured. The freshly moulded bricks are placed on covered pallet racks and air dried (Plate XIV A). There are two downdraft kilns, two updraft case kilns, and one scove kiln. The output is 25,000 bricks per day during the season, which are mostly sold in St. John.

ST. STEPHEN

There are two brick yards in operation near this town, making soft mud brick and drain tile. The material used is taken from a terrace of marine clay which occurs along the valley of the St. Croix river.

Mr. John Laming has made bricks here during the last 31 years. He uses a small stiff mud machine for making wire cut brick for facing, and for drain tile. He also makes soft mud bricks, which form the greater part of his output. The demand for drain tile is intermittent, these are only made to order, and not stocked. The principal object of interest is the tiles with which the building is roofed (Plate XV). These tiles were made by Mr. Laming, 22 years ago, from the clay in his own pit. These tiles are S shaped, and although not hard burned, are still quite intact for the most part.

SUSSEX

The brickyard operated by Mr. John Heffer is situated a f miles northwest of Sussex. The material used is a stiff, reddi clay, from 3 to 10 feet in thickness, overlying boulder clay. stiff mud machine driven by horse-power is used. The bricks hacked out on the open ground to dry, and afterwards burn in a scove kiln.

The burned bricks contain some scattered, small pebbles a clay lumps, showing the need of passing the clay through ro or through a long pug mill, to prepare the clay for the machi As the clay is becoming too thin for working at this locality, plant will shortly be moved to a fresh clay deposit in the nei bourhood.

MONCTON

The brickworks are located at Lewisville, 2 miles fr Moncton (Plate XVI). The material made is a glacial c situated almost at tide level, and underlain by boulder cl The maximum depth of the clay is 7 feet. This plant is equip with a stiff mud machine, and steam driers. The burning is do in scove kilns. The brick clay also occurs at various points arou the city of Moncton, but is worked only at this locality at prese

CHATHAM

There are two brick plants in the neighbourhood of Chatha owned by the W. S. Loggie Company. The plant at Napp river uses a stratified, reddish clay, about 12 feet deep, lying bed-rock, to which is added about 10 per cent of sand. Sa moulded bricks only are made; they are dried on pallet roc and burned in scove kilns. The bricks are set 36 courses high the kiln, and the fuel used is dry spruce and tamarack. output is hauled in wagons to the railway, and shipped pr cipally to Campbellton. The working season lasts from middle of May to December. An excellent deep red, hard, bu ing brick is produced at these works.

The plant at Nelson (Plate XI B) is worked in a simi manner, and produces common brick of a quality very m like those at Nappan. This plant is better situated for transp tation, as the bricks have only to be hauled over the bridge ac the Miramichi river, to the railway station on the north ba

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PLATE II.

Seger cones showing effects of high temperatures.

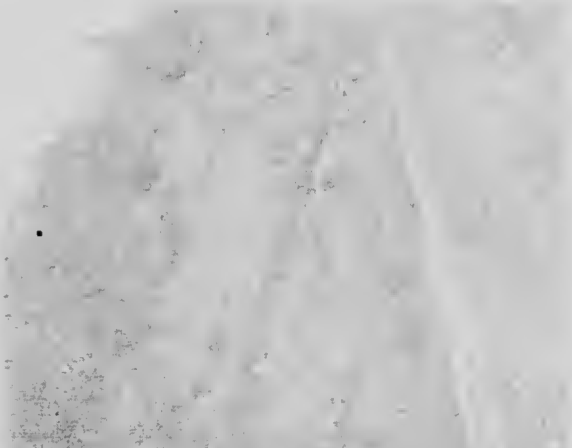


PLATE III.

Lower Carboniferous red shales, interbedded with nodular limestone, Plaster Rock, Victoria county.

PLATE IV.

View of Minto and vicinity, in the Grand Lake coal area. The general level character of the Carboniferous plateau is shown in the distance.

PLATE V.

Shale dump at Welton Bros. coal mine, Minto, Sunbury county

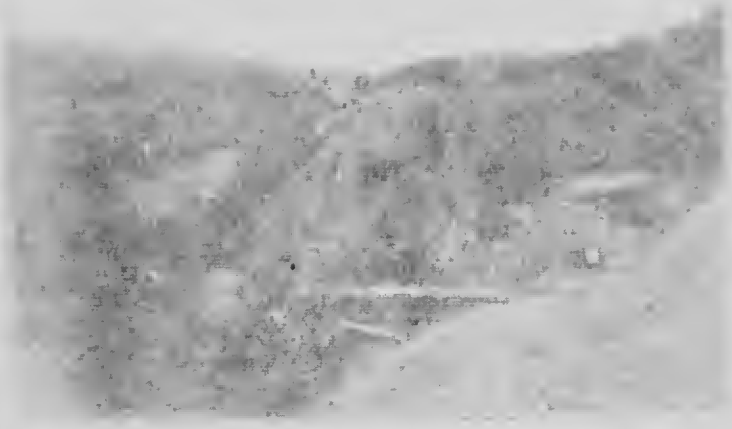


PLATE VI.

A. View of coal mine at Beersville, Kent county.

B. Disintegrated brick in scove kiln made from underburned Lower Carboniferous shale, Kent county.

PLATE VII.

Middle Carboniferous shales at Stonehaven,
south coast of Chaleur bay.

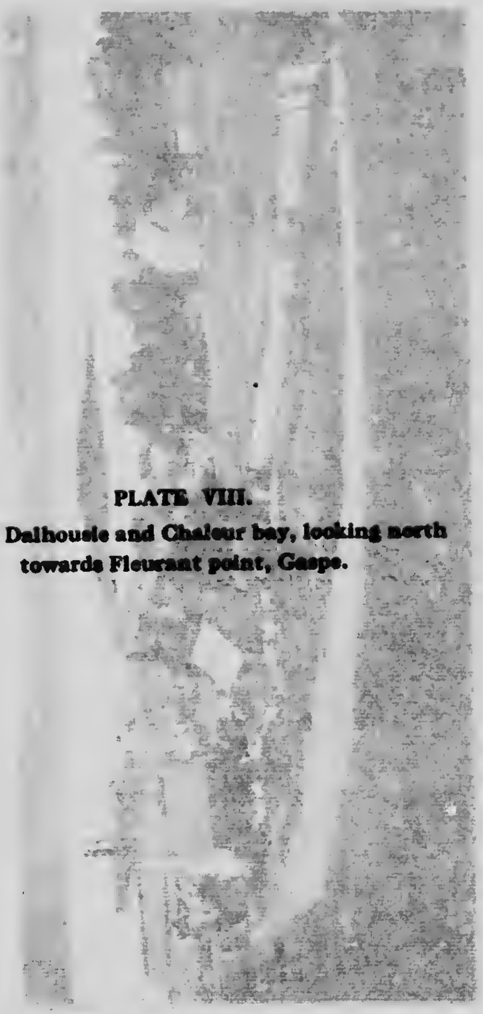
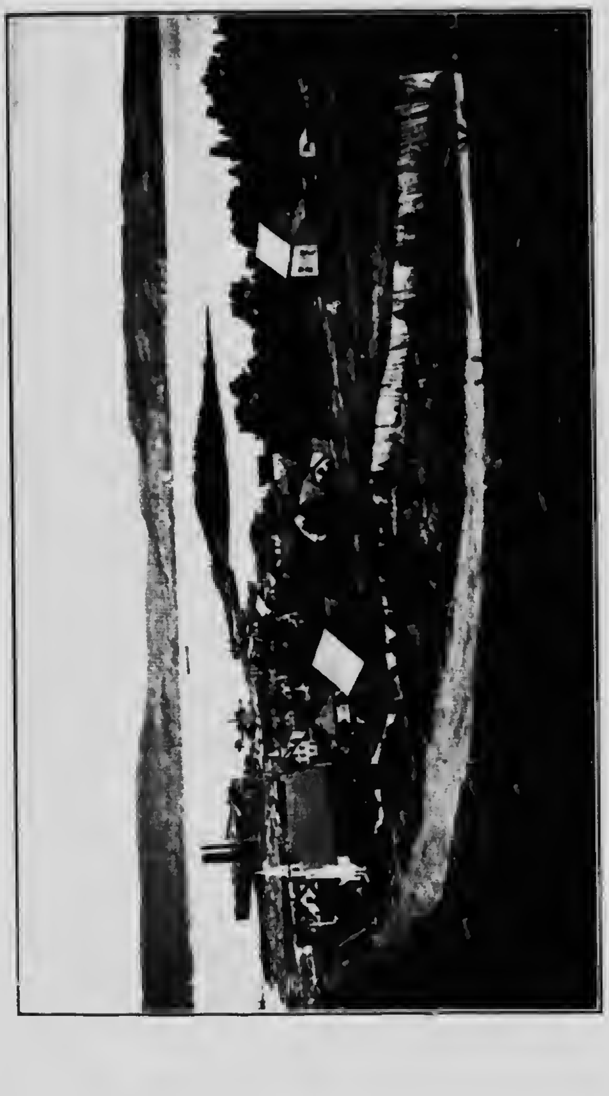


PLATE VIII.

View of Dalhousie and Chaleur bay, looking north towards Fleurant point, Gaspe.



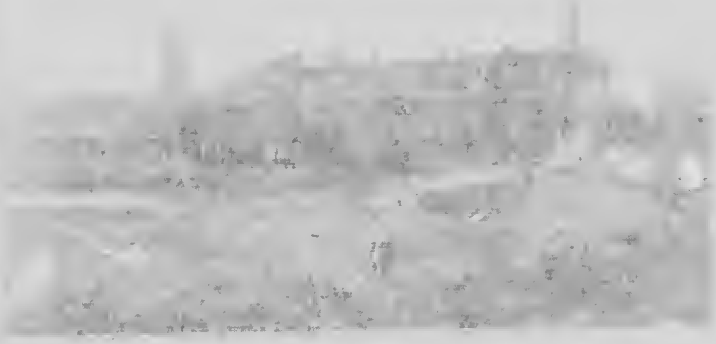


PLATE IX.

A. Foley Bros.' pottery, St. John.

B. Stratified marine clay, overlying boulder clay, Mooney's brickyard, St. John.

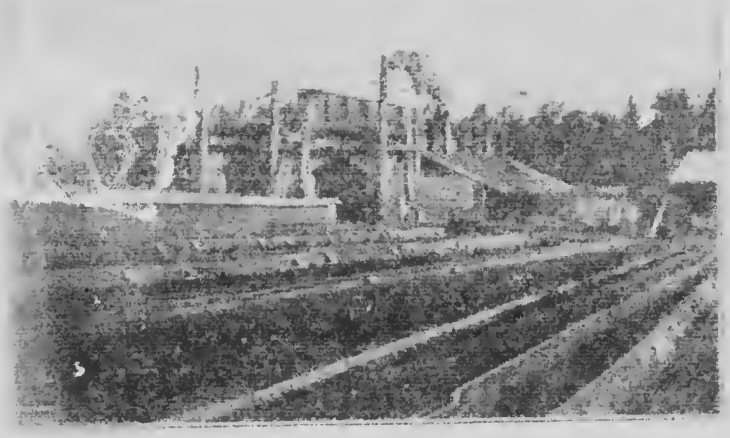


PLATE X.

A. Kilns at Ryan's brickyard, Fredericton.

B. Clay bank at Ryan's brickyard, Fredericton.

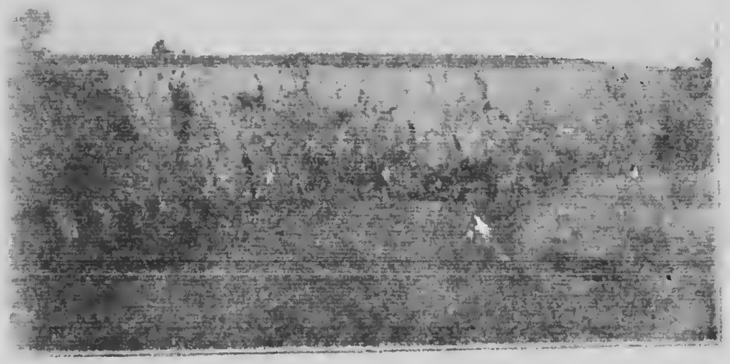


PLATE XI.

A. Thos. Heffers' brickyard, Sussex

B. Loggie Company's brickyard, Nelson.

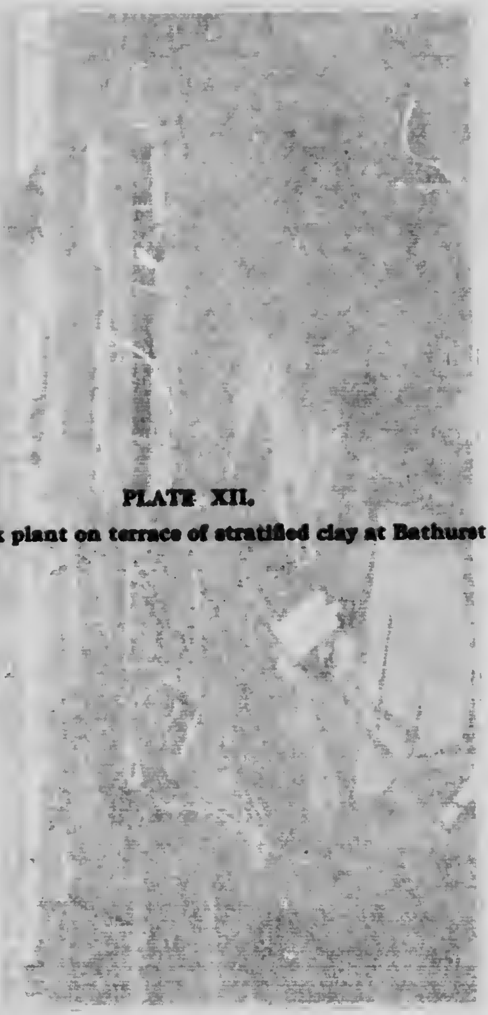


PLATE XII.

Small brick plant on terrace of stratified clay at Bathurst.

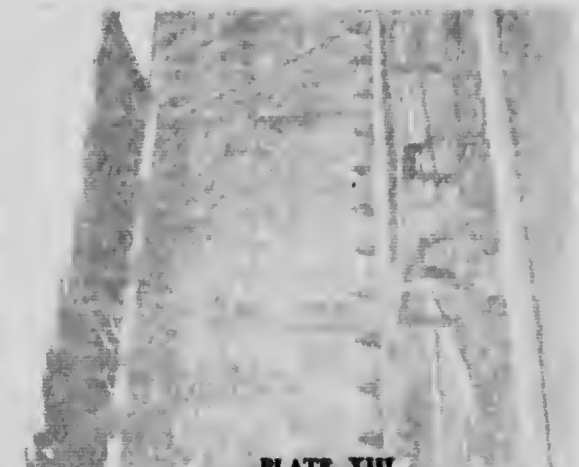


PLATE XIII.

Scove kiln, a temporary kiln, generally used for burning common brick.

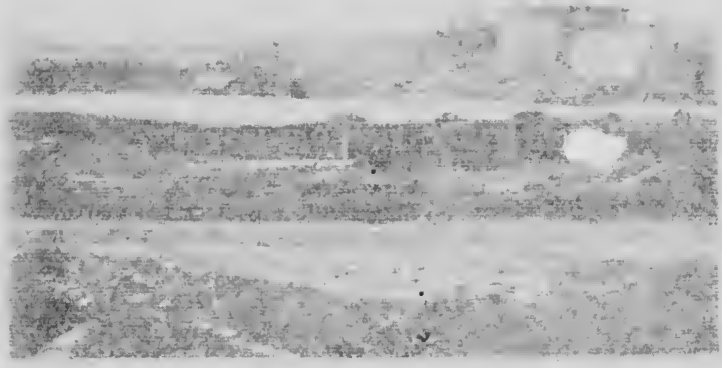


PLATE XIV.

A. Drying racks, Lee's brickyard, St. John.

B. Soak pits and clay bank, Lee's brickyard, St. John.

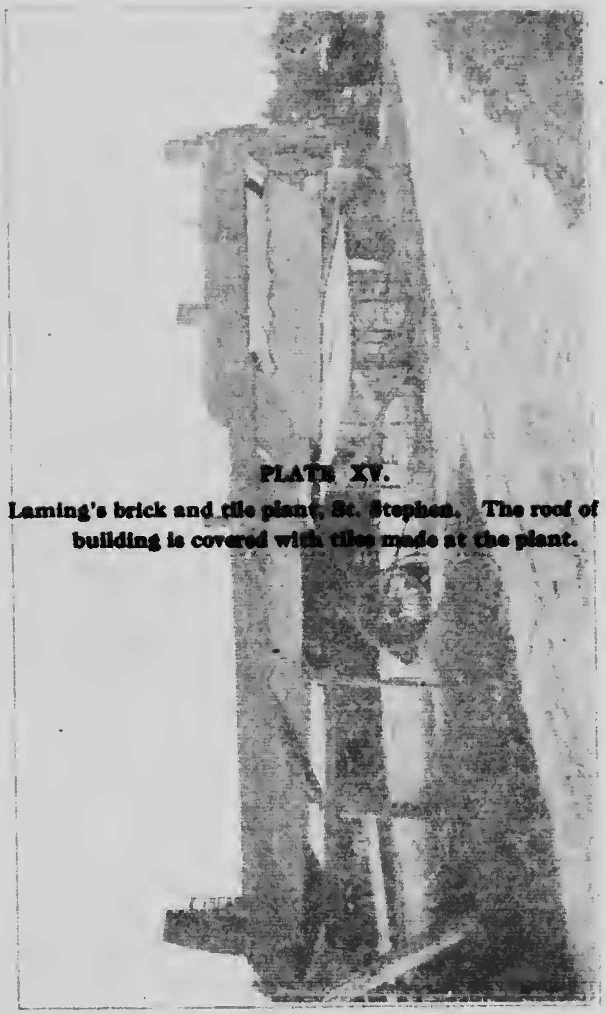


PLATE XV.

Laming's brick and tile plant, St. Stephen. The roof of the building is covered with tiles made at the plant.

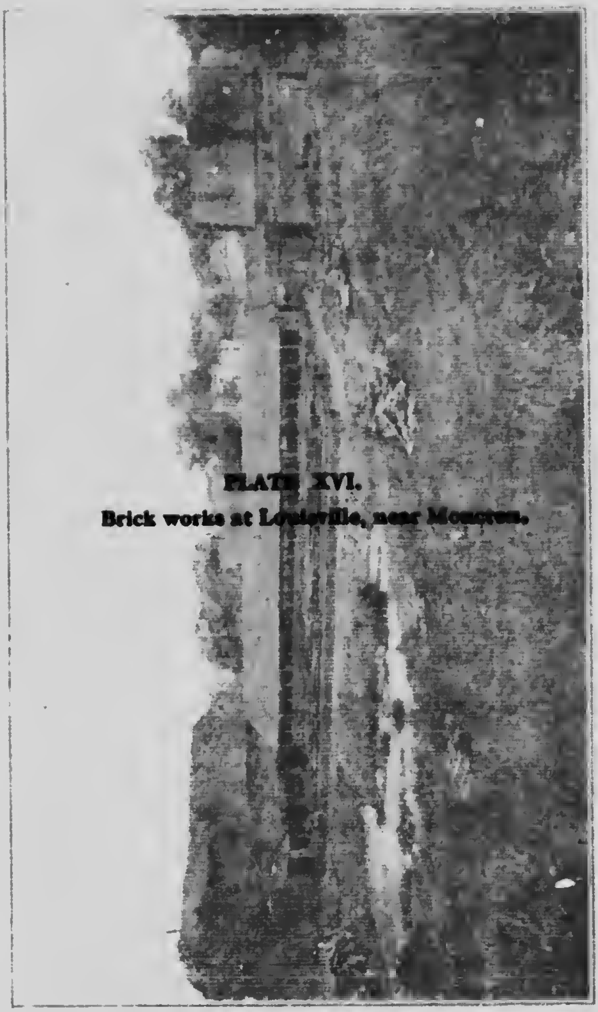


PLATE XVI.

Brick works at Louisville, near Moncton.

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CLASSIFIED LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No [illegible].

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

Memoir 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley Mining district, British Columbia—by Charles Camsell.

Memoir 3. *No. 3, Geological Series.* Palaeoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

Memoir 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiold Rivers coal district, Yukon Territory—by D. D. Cairnes.

Memoir 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

Memoir 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, Province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

Memoir 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

Memoir 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

Memoir 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

Memoir 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

Memoir 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

Memoir 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

Memoir 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

Memoir 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs Published During 1912.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.
Memoir 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.
Memoir 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.
Memoir 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.
Memoir 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs Published During 1913.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.
Memoir 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.
Memoir 26. *No. 34, Geological Series.* Tulameen Mining district, B.C.—by C. Camsell.
Memoir 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.
Memoir 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.
Memoir 33. *No. 30, Geological Series.* The geology of Gowganda Mining division—by W. H. Collins.
Memoir 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.
Memoir 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.
Memoir 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs in Press, December 31, 1913.

Memoir 25. *No. 21, Geological Series.* Clay and shale deposits of the western provinces (Part II)—by Heinrich Ries and Joseph Keele.
Memoir 23. *No. 23, Geological Series.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.
Memoir 40. *No. 24, Geological Series.* The Archaean geology of Rainy lake—by Andrew C. Lawson.
Memoir 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G. McConnell.
Memoir 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. LeRoy.
Memoir 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks in southern Quebec—by J. A. Dresser.
Memoir 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, B.C.—by C. H. Clapp.
Memoir 39. *No. 35, Geological Series.* Kewagama Lake map-area, Quebec—by M. E. Wilson.
Memoir 43. *No. 36, Geological Series.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec—by J. J. O'Neill.
Memoir 44. *No. 37, Geological Series.* Clay and shale deposits of New Brunswick—by J. Keele.
Memoir 20. *Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.
Memoir 30. *Geological Series.* Basin of Nelson and Churchill rivers—by W. McInnes.
Memoir 42. *No. 1, Anthropological Series.* The double-curve motive in northeastern Algonkian art—by Frank G. Speck.
Memoir 48. *No. 2, Anthropological Series.* Some myths and tales of the Ojibwa of southeastern Ontario—collected by Paul Radin.
Memoir 45. *No. 3, Anthropological Series.* The inviting-in feast of the Alaska Eskimo—by E. W. Hawkes.

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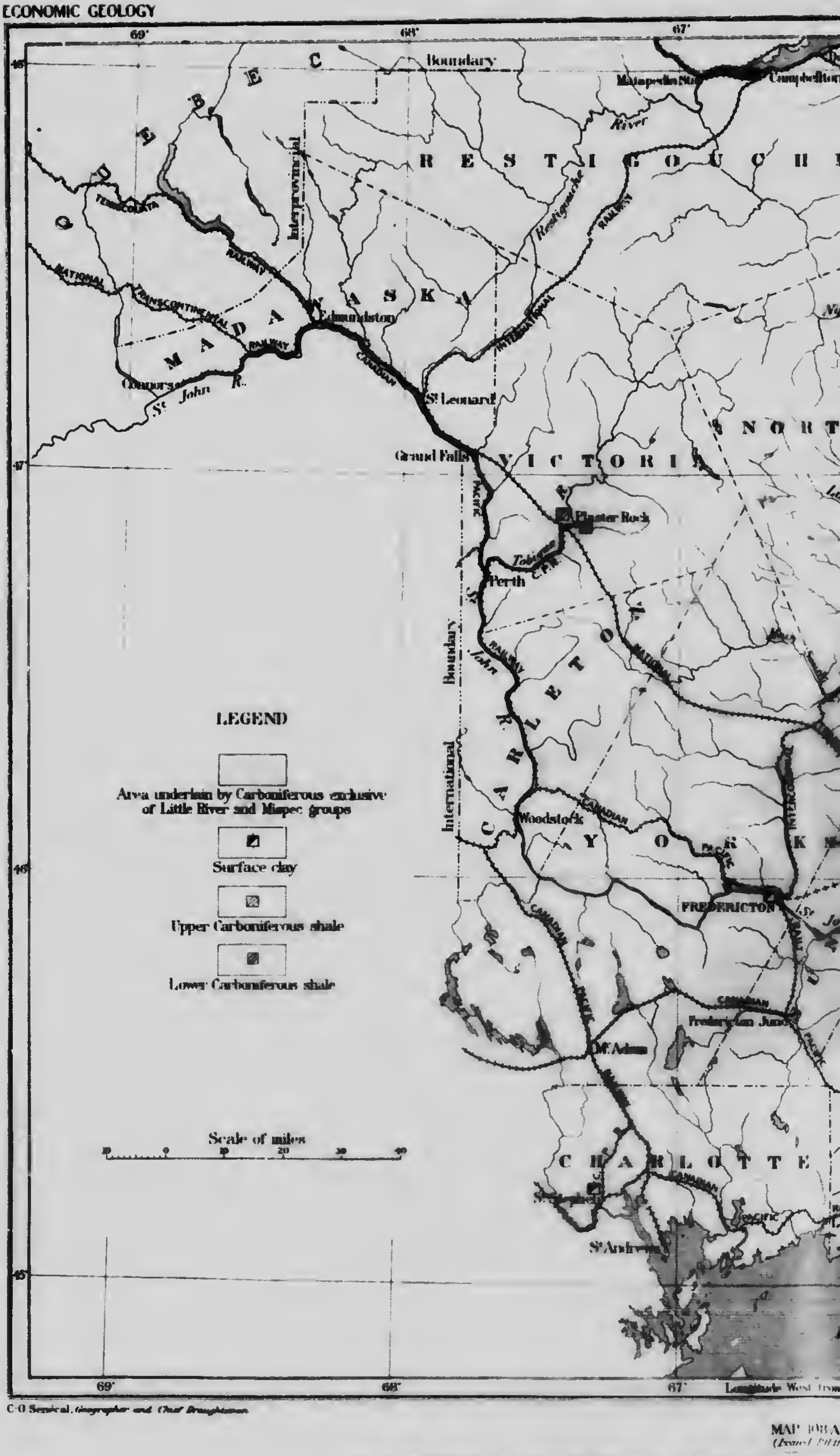
GEOLOGICAL SUR
R.W. Brock, Direct

ECONOMIC GEOLOGY



C-O Senécal, Geographer and Chief Draughtsman

MAP 108A
(Issued 191

NEW BRUNSWICK – CARBONIFEROUS AREAS, AND POSIT

To accompany Memoir by J. Keele

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inister: A P Low Deputy Minister

logical Survey
W Brock Director

OUTLINE MAP

MAP 108A
(Issued 1910)

ND POSITIONS OF CERTAIN SHALE AND CLAY DEPOSITS.