CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

INVESTIGATIONS

IN

CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

1927

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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Annual reports on Mines Branch investigations are now issued in four parts, as follows:—

Investigations of Mineral Resources and the Mining Industry.

Investigations in Ore Dressing and Metallurgy (Testing and Research Laboratories).

Investigations of Fuels and Fuel Testing (Testing and Research Laboratories).

Investigations in Ceramics and Road Materials (Testing and Research Laboratories).

Other reports on Special Investigations are issued as completed.

MINES BRANCH INVESTIGATIONS IN

CERAMICS AND ROAD MATERIALS, 1927

INTRODUCTION

Howells Fréchette

Chief of Ceramics and Road Materials Division

The year 1927 has been one of marked activity in this Division. Several investigations which, for unavoidable reasons, had been suspended were again taken up and considerable progress was made on them. Other investigations were commenced. During the year J. F. McMahon, Ceramic Engineer, who had been on the temporary staff, was made permanent, and J. G. Phillips, Ceramic Engineer, was appointed to the staff on the temporary list.

At the request of the Mining Bureau of the Winnipeg Board of Trade, the writer visited Manitoba to study the difficulties being encountered in the attempts to produce high-grade face brick within the province. Visits were made to the various plants and the nature of their problems ascertained. As a result of advice given, a considerable improvement of ware was attained at one plant to the west of Winnipeg, but the problem confronting the operators at Winnipeg was found to be much more serious. At Winnipeg two clays are available for brickmaking. A shallow surface clay which burns to a very light buff has been used for many years in the manufacture of common brick. The supply of this clay is being rapidly depleted, and the cost of winning and transporting it to the brick plants is becoming a very serious item. Underlying this surface clay is a thick bed of red-burning clay which, were it not for one very serious fault, would produce good face brick. This is a tender-drying clay of the type known as gumbo. When moulded into bricks it is almost impossible to dry them without cracking. At one of the Winnipeg plants, face brick is being manufactured from this underclay mixed with a silty clay obtained about 100 miles west of Winnipeg. The cost of transportation is high and the results are not very satisfactory. The manufacturers, the Alsip Brick, Tile, and Lumber Co., Ltd., are anxious for a means of overcoming the drying difficulties, which will permit them to use the local underclay alone. On the writer's recommendation the Department undertook the problem, and appointed J. G. Phillips to assist in an exhaustive research on this clay to determine means of processing it so as to overcome the cracking in drying. Coincident with the request for aid from Winnipeg, the Redcliff Brick and Coal Co., Ltd., of Redcliff, Alberta, asked the assistance of the Department in overcoming the difficulty of drying their brick without excessive breakage. This problem, being the same as that of the Winnipeg brick manufacturers, was included in the research. A very comprehensive study of possible means for solving the problem has been made and a large amount of experimental work done on the clays from Winnipeg and Redcliff. The report on this investigation appears on page 4.

The writer made a reconnaissance of the clay and shale deposits of Prince Edward Island, preliminary to a detailed study of these resources which is planned for 1928.

The writer visited the Grand Lake coal area of New Brunswick where he studied the possibilities for the utilization of the large tonnage of shales hoisted incidental to the mining of the coal. Representative samples were collected and were subjected to thorough testing by J. F. McMahon to determine their suitability for the manufacture of ceramic wares.

During the summer J. F. McMahon made a study of the excavation and transportation of clays at thirty brick and tile plants in Ontario. Information as to the cost of the various operations was secured and much general data gathered which will serve a useful purpose in determining the most economic methods of operation under specific conditions. While this investigation has not been completed, a preliminary report has been prepared and appears on page 17.

Grey face brick is in fairly strong demand in Ontario and Quebec and the market is being supplied from foreign sources as the local manufacturers have been unable to produce them. Several manufacturers have asked that a method of production be worked out for their clays. L. P. Collin was assigned this problem, and has it now under way. It is usual to produce this grade of brick from a low-grade fireclay, into which is mixed a small percentage of manganese dioxide. The low refractoriness of the Canadian brick clays has been found to constitute the main difficulty, as they cannot be burned to a sufficiently high temperature to produce the reaction which seems to be necessary between the manganese and the clay to develop the grey colour. Though the work has not progressed to a point where a definite statement can be made, a degree of success has been attained which is decidedly encouraging.

Much progress was made during the year on the investigation of ceramic bodies for electrical heating devices, by L. P. Collin. More than 4,000 test pieces were burned to various temperatures. Impact tests were made on about half that number of test pieces to determine their toughness. The percentage of shrinkage and the percentage of water absorption were determined on each set of test pieces. A number of plants manufacturing this type of ware were visited and samples of the mixture used were obtained at three of them. Test pieces have been made from these and will be used to determine the relative value of the bodies compounded in the laboratory and the commercial bodies now being manufactured.

During the year 133 samples of clays and shales were tested. Tests were also made on one sample of mineral pigment, four samples of limestone, three samples of marl, three samples of pyrophyllite, and four samples of talc.

Transverse strength was determined on three samples of building brick.

A series of tests was made for a manufacturer desirous of producing dry-press brick from a clay previously used for another type of brick.

Tests were run to determine whether spraying would be more advantageous than dipping in the manufacture of glazed brick.

Experiments were made on the production of buff brick from a red-burning clay.

Four samples of firebrick were tested and reported on for Government departments.

Numerous refractory shapes were made for use in the ceramic laboratory and for other laboratories of the Department.

The facilities of the laboratories and the assistance of the staff were, on several occasions, placed at the disposal of other departments for special tests.

In co-operation with the Research Council of Canada, an exhaustive laboratory investigation of the suitability of the magnesite from Grenville township, Quebec, for the manufacture of high-grade refractory brick, has been under way during the entire year. This work was conducted at first by R. T. Watkins, and later by J. W. Craig, Ceramic Engineers, and the results so far obtained showed good prospects of success.

During the early part of the field season R. H. Picher, Road Materials Engineer, visited thirteen stone quarries in the province of Quebec, in districts not covered by the field work of previous years, and eight samples were collected for testing. Most of these quarries are not worked for the production of road metal, but have a large amount of waste rock which constitutes an important and easily available source of supply for road material and concrete aggregate.

Following a study of the requirements of Prince Edward Island for road materials and preliminary examination by the writer, R. H. Picher began a detailed investigation of the road material resources of the province. The work consisted of prospecting for materials suitable for road construction and investigating the economic advantages of using them for road surfacing in preference to the gravel which is now brought in for that purpose from outside the province. Seven samples were collected for testing.

The laboratory work consisted in testing the samples collected during the field season and also in conducting an investigation on cement mortars with various types of stone aggregates.

I

AN INVESTIGATION ON THE TREATMENT OF CERTAIN WESTERN CLAYS TO OVERCOME DRYING DEFECTS

Howells Fréchette and J. G. Phillips

Many of the clays in the western provinces possess a great tendency to crack when any attempt is made to dry them from the plastic state. The two clays taken as the subjects of this investigation comprise only a small portion of this group, but the results obtained can be considered more or less applicable to all such clays, and since the need of overcoming this troublesome tendency was most urgent in the case of the two selected, our efforts were concentrated on these.

The two clays upon which this investigation was conducted may be described as follows:

The Winnipeg Clay

The clay from Winnipeg is a Lake Agassiz deposit, and is of a type known as gumbo. It is decidedly laminated with numerous thin partings of a very fine silt. In the plastic state it is extremely sticky, tough, and works with difficulty. In the bank it contains roughly 33 per cent moisture. In drying it exhibits an extremely high shrinkage and severe cracking.

This clay underlies about 4 feet of a buff-burning calcareous clay, which is now being used for brick manufacture, and the supply of which is rapidly becoming exhausted. The underlying gumbo has a depth of from 30 to 40 feet, and is therefore available in almost inexhaustible quantities.

The Redcliff Clay

The clay bank at the Redcliff Brick and Coal Company, as it is worked at present, comprises the following general section from the top down to about a 50-foot level.

First 2 feet.	Sandy, buff-burning clay containing limestone pebbles.
2- 4 "	Buff-burning clay containing less sand and fewer limestone pebbles than the above.
4-20 "	Red-burning, tender-drying clay containing much sand.
20-50 "	Very plastic shale—used in making stiff-mud and pressed face brick.

The run of bank material for about the first 6 or 8 feet is now being used to make common stiff-mud brick, building tile, and drain tile. The buff-burning material from the first two feet is used more particularly for building tile and drain tile where colour is not so important.

The pure shale is mined separately for manufacture into pressed bricks. The shale is also used in the manufacture of tapestry face brick, between 20 and 30 per cent being added to the top material. This addition is made to give the brick better strength and to improve colour.

With the exception of the first two feet of clay, all of these materials have a decided tendency to crack in drying, the shale being the most troublesome in this respect. It is very desirable that the shale be added to the clay in order to obtain a hard firm brick, but the shale even when added in small percentages greatly increases the tendency to crack. In fact it is next to impossible to dry such brick, even at slow rates, without having a large number of them cracked beyond use.

The sandy upper material can be dried without cracking when great care and long drying periods are used, but even when 8 or 9 days are taken for drying, a great number of the brick are often cracked too badly to be set in the kiln.

Since it is the desire of this company to have their brick, particularly their face brick, composed partly of shale, all of our experiments were made on a mixture of upper soft clay and shale in equal proportions. Therefore, throughout this report where Redcliff clay is mentioned, it is to be understood that this mixture of soft clay and shale is referred to.

With the view of devising a means of processing the clays from Winnipeg and Redcliff so as to permit safe drying at reasonably rapid rates, a thorough investigation was undertaken.

A review of the literature brings out three methods of clay treatment for remedying troublesome drying properties of clays:—

1. The use of some non-plastic material, such as sand or grog, which would reduce shrinkage and stickiness, and provide for an easier capillary travel of the water to the surface of the brick.
2. The use of chemical coagulants.
3. A preheating treatment of the clay sufficient to reduce the stickiness and to destroy the colloidal property to such an extent that the clay would be more permeable to water.

The first two methods have found practical application in several cases of tender-drying clays. However, in no case was the tendency to crack so great as in the clays in question. In previous investigations the only effective treatment suggested for these particular clays was the last method, viz., preheating. However, rather exhaustive search has revealed only one plant that has tried preheating on a commercial scale, and in this case faulty design and operation prevented its success.

Preheating

The effect of preheating was first investigated and it was found that the clays respond quite readily to such a treatment. When preheated to temperatures approximately between 450° C. and 550° C., the clays showed decidedly improved properties. The percentage of tempering water was considerably reduced (in the case of the gumbo clay, from 54 per cent to 33 per cent), a great deal of the stickiness had disappeared (the working properties thus improved), and drying could be accomplished safely at rapid rates.

The results of the preheating experiments are tabulated at the end of this section.

There is, however, a rather narrow margin within which preheating is effective. Our tests show that below 450° C. there is not sufficient alteration of the clay to permit safe drying, and above 550° C. the plasticity has been reduced to so great an extent that the clay is left too short, and is not workable. This brings up the problem in the commercial application of the process of how to control the temperature within these limits. While it is quite easy to control temperature in the laboratory within even much narrower limits, the problem becomes much more difficult when handling quantities of clay necessary to meet a plant capacity.

Commercially, preheating would best be carried out in a rotary type kiln. Many plants dry the clay as it comes from the bank in rotary driers, but in no case is the temperature carried very much above 100° C. Several rotary drier and rotary kiln manufacturers who were consulted suggested methods of adapting their machines to the process. Preheating can unquestionably solve the problem, and can very probably be carried out successfully on a commercial scale in rotary kilns. However, it would require a considerable initial expense, and some experimenting, to bring about the correct adjustment of flow of clay, temperature, etc.

The investigation has been carried as far as is possible in the laboratory, and there remains the solution of the engineering problem involved in applying the process commercially, which must necessarily be worked out in the plant.

It has been concluded, after considering experiences of clay manufacturers in the past with rotary driers, that, in order to obtain a uniformly preheated material, and to maintain accurate regulation of temperature, it will be necessary to first dry the clay before it is put through the preheater. This would apply particularly in the case of one clay which comes from the bank containing roughly 33 per cent moisture. In such a condition the clay when charged into the colder end of the kiln (as would be necessary to preheat the material uniformly) would undoubtedly ball together and stick to the sides of the kiln. However, in the case of drying the clay, it could be fed into the hot end and pass in a direction parallel to the flow of gases. In this manner, the wet clay in striking the comparatively hot surface of the kiln would tend to explode and the heat would prevent any sticking.

Thus, in order to preheat clay with a high initial moisture content, two operations would be necessary. First, the clay would have to be passed through a rotary drier, and the moisture content reduced to at least 4 or 5 per cent. The dried clay could then be mechanically conveyed to and charged into the preheater. It may be found necessary to pass the clay through a crusher, between drier and preheater in order to reduce the clay aggregate to such size that it will be uniformly preheated throughout.

In cases where the clay comes from the bank in a comparatively dry condition (not more than 10 per cent moisture) it could probably be charged directly into the preheater, and the preliminary drying process would be unnecessary.

The following are quotations on drying and preheating equipment from one of the rotary kiln manufacturers:

For a capacity of 180 tons of dry clay per day, when drying from 33 per cent initial moisture, there would be required:—1 drier, 104 inches diameter by 100 feet long. The price exclusive of brickwork, foundations, drives and motors, but including dust collector, would be $21,000, f.o.b. factory (Pennsylvania).

For preheating this same amount of clay to 850° F., one kiln, 5 feet diameter by 40 feet long, would be required. The price of this kiln complete, but without brickwork, foundations, drives and motors, would be $5,300, f.o.b. factory.

It is estimated that in drying clay with an initial moisture content of 33 per cent, 13·3 Imperial gallons (16 American gallons) of fuel oil would be required to produce one ton of dry clay. To preheat one ton of the clay with about 4 per cent moisture to 850° F. would require 4·4 to 5 Imperial gallons (5 to 6 American gallons) of fuel oil.

Non-Plastic Materials and Chemical Coagulants

Considerable work has been done by previous investigators on the treatment of tender-drying clays with chemicals or with non-plastic materials. Preliminary tests show that the addition of non-plastic material, or grog, finely ground, causes some improvement in drying, and the treatment of the clay with chemical coagulants brings about a considerable improvement in the drying properties, but neither method alone completely solves the problem.

It was considered possible that a combination of the two treatments might be effective. Accordingly an extensive investigation was carried on as to the effect of additions of grog with varying percentages of different chemicals on the drying properties of the clays. The work of previous investigators was studied and additional information was obtained by a preliminary investigation on the flocculating power of the various chemicals in the following manner: Into each of a number of settling-tubes two grammes of the clay were placed. The various chemicals were then added in proportions of 0·5 per cent, 0·8 per cent, 1 per cent, 2 per cent, and 3 per cent of the weight of the clay, making a series of five trials for each chemical. A fixed amount of distilled water was added to all the tubes which were then shaken vigorously for five minutes. The tubes were then allowed to stand one hour after shaking and the amount of *settle* measured. These tests brought out very well the comparative coagulating power of the various chemicals, and also gave an indication of the amount of chemical necessary to produce marked coagulation. Among the chemicals which gave particularly good results was ferric chloride. The writers find no record of previous investigators having used it for this purpose. Having selected those chemicals which, in conjunction with additions of grog, gave the greatest promise of overcoming the drying defects of the clays, many mixtures of clay, grog, and chemical were made up. The grog was added in percentages varying between 25 and 50, and beginning with 0·5 per cent, the additions of the different chemicals selected for study were successively increased, but only to the limit of the range of their economic practicability.

In all cases the grog, which consisted of completely dehydrated clay, was ground to pass a 16-mesh screen.

The resulting mixtures were tempered with water and full-size bricks were moulded, as well as briquettes for water of plasticity determinations and air- and fire-shrinkage measurements. Water of plasticity was determined by taking the wet and dry weights of the briquettes, and linear shrinkage measurements were made for air and fire shrinkage.

The bricks and the briquettes, immediately after being formed, were placed in an electric drier which was accurately maintained at 65° C., and were allowed to remain in the drier until completely dry. Observations were made as to the nature of any cracking, and degree of improvement resulting from the various additions, from which results further variation of chemical and grog was governed.

All bricks and briquettes were labelled, and set aside to be fired to several temperatures in order to observe the effect of the chemicals on the fired colour.

The data of this investigation, on the effectiveness of additions of grog plus different chemicals on the correction of the drying defects of the clays in question, as well as the effect on burning properties, are given at the end of this section. The results may be summed into the following general statements.

The Redcliff clay responded quite readily to the treatment with small additions of several separate chemicals, and a minimum of 25 per cent of 16-mesh grog. The Winnipeg gumbo clay was much more resistant to the treatment and required greater quantities of chemical and grog.

Hydrochloric acid in small quantities (0·5 per cent to 1 per cent) with 33 per cent grog completely corrected the drying defect of the Redcliff clay, but was entirely unsuccessful in the case of the Winnipeg gumbo. The corrosive action of hydrochloric acid would probably be an objectionable feature in the brick plant.

Ferric chloride was effective in the case of both clays. However, a larger amount with a greater percentage of grog was necessary in the case of the Winnipeg gumbo. The drying defects were corrected in the Redcliff clay with additions of 1 per cent ferric chloride and 33 per cent grog, while the gumbo clay required 2 or 3 per cent ferric chloride with 40 per cent grog.

Ferric chloride being rather expensive, it would be practical only within certain limits. Sodium chloride plus a small percentage of ferric chloride was tried, and a mixture of 40 to 50 per cent grog plus 1 per cent sodium chloride and 0·5 per cent ferric chloride was found to be effective in the case of the more resistant gumbo.

Aluminium chloride was found to be less effective than ferric chloride and was rejected.

Barium chloride, because of its scum-preventing properties, was considered promising. It was found, however, to be much less efficient in overcoming drying defects than ferric chloride, and could not be made effective within the allowable limits.

Lime was tried on the Winnipeg gumbo clay only, and was found to be very effective. When 2 per cent is added to the clay with 33 per cent grog, there is a pronounced change in the working properties, and the clay can be easily dried at 65° C. without any cracking. Lime has a detrimental effect on colour, but could well be added to the clay used for common brick. When 1 per cent sodium chloride is added with the lime, this detrimental effect is considerably decreased.

It has also been found, after firing briquettes of the various mixtures in the laboratory kiln, that ferric chloride, sodium chloride, and mixtures of the two reduce scumming and improve colour.

The percentages of chemical as well as grog used in these tests are very probably much higher than necessary. This would be particularly true when working under plant conditions where the benefit of a certain amount of humidity is realized. In the laboratory investigation all bricks, immediately after being formed, were placed in an electric drier, which was maintained at 65° C. with no humidity conditions (the outlet ports remaining open), and thus the drying treatment given them was much more severe than is the case in most plants.

Although an effort was made to keep the various additions low, the extreme lower limits of effectiveness were not established for laboratory conditions.

The main objective in the investigation on the chemical treatment of the clay has been: to find a reagent or reagents which, when used within economic limits, would solve this problem; and finally to select the most efficient of these.

Ferric chloride and a mixture of ferric chloride with sodium chloride have been found to be far the most effective of those tried. Sodium chloride being cheaper than ferric chloride, a substitution for a portion of the ferric chloride with sodium chloride was considered advisable. Sodium chloride, if added in sufficient quantities, can be made to correct the drying troubles of some clays, but, in the case of those clays possessing this difficulty in a very high degree, the amount necessary is detrimental to the firing properties of the brick.

CONCLUSIONS

It has been demonstrated in the laboratory that the drying defects of the two clays in question can be overcome by either of two methods:

(1) By preheating the material to a temperature between 450° C. and 550° C.

(2) By the use of grog plus one or more of the various chemical coagulants; ferric chloride and a mixture of ferric chloride and sodium chloride most efficiently corrected the drying defects of these clays.

There remains, then, the application of these processes to plant scale, and, finally, the selection of the most effective and most economical method.

The tables on the following pages give the results in detail of the investigation both on preheating and the use of non-plastic materials with chemical coagulants. Table I covers the results for the Winnipeg clay and Table II covers those obtained on the Redcliff clay.

In the column giving the percentages of grog in the various mixes the letters " v " or " w " are inserted just over the numerals. These letters refer to the method of calculating the percentage. The letter " v " signifies that the grog and clay were proportioned by volume, and the letter " w " signifies that the ingredients were added by weight.

The remainder of the table is self-explanatory. The briquettes were fired to several temperatures, but cone 06, for the chemically treated specimens, and cone 03, for the preheated material, are the only temperatures included in the table. Both clays mature at cone 06.

TABLE

Drying Tests on Clay, Gumbo, and Underclay from

Pre-heat temp. °C. (½ hr.)	Grog			NaCl		FeCl₃		BaCl₂		HCl		AlCl₃		CaO		Drier temp. °C
	Nature	Mesh	Per cent added	Per cent	Added	Per cent	Added	Per cent	Added	Per cent	Added	Per cent	Added	Per cent	Added	
000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75
300	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75
400	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75
450	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75
500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75
	Clay[a]...	16	25[w]	...	...	...	...	...	...	...	...	...	...	...	...	65
	Clay...	16	33[v]	...	...	...	...	...	...	...	...	...	...	...	...	65
	Clay[a]...	...	25[w]	...	...	0·6	Dry	...	...	...	...	...	...	...	...	65
	...	...	...	...	...	2·0	Dry	...	...	...	...	...	...	...	...	65
	Clay...	10	25[w]	...	...	1·0	Dry	...	...	...	...	...	...	...	...	65
	Clay...	16	25[w]	...	...	2·0	Dry	...	...	...	...	...	...	...	...	65
	Clay...	16	33[w]	...	...	1·0	Dry	...	...	...	...	...	...	...	...	65
	Clay...	16	40[w]	1·0	Dry	...	...	...	...	...	...	...	...	...	...	65
	Clay...	16	33[w]	2·0	Dry	...	...	...	...	...	...	...	...	...	...	65
	Clay...	16	40[w]	3·0	Dry	2·0	Dry	...	...	...	...	...	...	...	...	65
	Clay...	16	40[w]	...	...	2·0	Dry	...	...	...	...	...	...	...	...	65
	Clay...	16	25[w]	...	...	...	...	...	...	...	...	2·0	Dry	...	...	65

I

the Alsip Brick, Tile, and Lumber Company

Drier condition	Air shrinkage	H_2O plasticity	Drying behaviour	Cone	Fire shrinkage	Remarks
	%	%			%	
....	11	54	Briquettes cracked at all temperatures—very sticky	03	8·0	Dark brown, scummed, checked, warped.
....	8	45	Briquettes cracked—still very sticky.	..	....	....
....	5	36	Briquettes showed a small amount of cracking—greatly improved.	03	11·6	Dark brown, scummed, no warping.
....	5	41	Working properties very good, briquettes showed no crackes.	03	12·0	Dark brown, very little scum, no warping.
....	3	33	Briquettes showed no cracking, plasticity too greatly reduced, clay somewhat too short.	..	....	....
....	9	44	Small briquettes did not crack much. (Brick not made.)	06	9·0	Brownish red, badly scummed, checked.
....	8	32	Brick cracked badly........	06	9·0	" "
....	10	45	Briquettes did not crack. (Brick not made.)	06	9·0	" "
....	13	47	Brick cracked rather badly, but much improved.	06	9·0	Brown red, badly scummed, warped, checked.
....	9	41	Brick, greatly improved—one long crack on side.	06	9·0	Brownish red, badly scummed.
....	10	44	Brick, greatly improved—only slight shallow cracks.	06	8·0	" "
....	9	40	Brick, cracking almost entirely overcome, one crack in centre.	06	7·0	" "
....	8	37	Brick, great improvement—some small surface cracking in centre.	06	4·0	Fair red, scum reduced.
....	8	36	Brick, improved—but rather badly cracked in centre.	06	5·0	" "
....	9	38	Brick, some slight surface cracking in centre. Much improved.	06	4·0	Fair red, little scumming.
....	7?	33	Brick, checked and cracked badly in centre, apparently from badly tempered brick	06	7·0	Dark red, scum much reduced
....	10	43	Brick, rather bad cracking in centre, not deep.	06	8·0	Brownish red, badly scummed.

TABLE I

Drying Tests on Clay, Gumbo, and Underclay from the

Pre-heat temp. °C (½ hr.)	Grog			NaCl		$FeCl_3$		$BaCl_2$		HCl		$AlCl_3$		CaO		Drier temp. °C
	Nature	Mesh	Per cent added	Per cent	Added	Per cent	Added	Per cent	Added	Per cent	Added	Per cent	Added	Per cent	Added	
	Clay[s]....	16	33[v]	....	......	1·0	Dry	....	......	....	....	....	......	....	......	65
	Clay[s]....	16	33[v]	....	......	1.0	Dry	....	......	....	....	....	......	....	......	65
	....	....	....	....	......	1·0	Dry	1·0	Dry	....	....	....	......	....	......	65
	Clay....	16	33[v]	....	......	0·5	Dry	0·5	Dry	....	....	....	......	....	......	65
	Clay....	16	33[v]	....	......			0·5	Sol.	0·5	Sol.	....	......	....	......	65
	Clay....	16	33[v]	....	......	1·0	Dry	0·5	Dry	....	....	....	......	....	......	65
	Clay....	16	33[v]	....	......	1·0	Sol.*	....	......	....	....	....	......	....	......	65
	Clay....	16	50[w]	1·0	Dry	0·5	Dry	....	......	....	....	....	......	....	......	65
	Clay....	16	25[w]	2·0	Dry	0·5	Dry	....	......	....	....	....	......	....	......	65
	Clay....	16	33[w]	1·0	Dry	0·5	Dry	....	......	....	....	....	......	....	......	65
	Clay....	16	33[w]	2·0	Dry	0·5	Dry	....	......	....	....	....	......	....	......	65
	Clay....	16	33[w]	2·0	Dry	0·5	Dry	....	......	....	....	....	......	....	......	65
	Clay....	16	33[w]	....	......	....	......	0·5	Sol.	1·0	Sol.	....	......	....	......	65
	Clay[a]....	16	33[w]	2·0	......	0·5	Dry	....	......	....	....	....	......	....	......	65
	Clay[s]....	16	33[w]	....	......	....	......	....	......	....	....	....	......	4·0	Dry	65
	....	....	....	....	......	....	......	....	......	....	....	....	......	4·0	Dry	65
	Clay[s]....	16	33[w]	1·0	Dry	....	......	....	......	....	....	....	......	2·0	Dry	65

a Sandy clay from Alsip. v Grog and clay proportioned by volume.
s " Firdale. w " " " weight.
* $FeCl_3$ added to clay in solution. Grog then added and mixed in wet pan.

—Concluded

Alsip Brick, Tile, and Lumber Company—Concluded

Drier condition	Air shrinkage	H_2O plasticity	Drying behaviour	Cone	Fire shrinkage	Remarks
	%	%			%	
Covered with wet rags	10	35	Brick cracked badly........	06	4·0	Colour improved, little scum.
Covered with wet rags	9	33	Brick cracked badly.........	06	4·0	Scum much reduced.
....	13	50	Brick cracked badly—deep in centre.	06	8·0	Good red, colour improved, no scum.
....	10	38	Brick cracked badly—deep.	06	5·2	Good red, little scum, colour somewhat improved.
....	8	32	Brick cracked badly—deep.	06	4·5	Fair red, little scum.
Covered with wet rags.	10·5	36	Brick greatly improved. Considerable shallow surface cracking.	06	5·0	Better red, colour improved, little scum.
....	8·5	29	Brick cracked badly........	06	4·3	Good red, little scum. $FeCl_3$ improves colour.
....	8·8	33	Brick cracking almost entirely overcome. Very minute surface cracks.	06	3·0	Good red, little scum. NaCl improves colour.
Covered with wet rags	9·4	33	Brick cracked badly........	06	4·0	Fair red, no scum. NaCl improves colour.
....	9·5	35	Brick cracked rather badly.	06	4·0	Fair red. NaCl improves colour, no scum.
....	10·0	37	Brick, some cracking, but only on surface—very shallow as of skin.	06	3·0	Better red, colour improved.
....	8·6	31	Brick, only very little surface cracking. Great improvement.	06	3·6	Good red, colour improved, no scum.
....	8	30	Brick cracked very badly...	06	2·6	Fair red, no scum.
....	7·5	36	....	06	2·6	Fair red with salt deposit, no apparent scum.
....	8·0	40	A great change in working properties—stickiness gone. Brick shows no cracking.	06	3·0	Completely white coated.
....	11·0	57	A great change in working properties—stickiness gone. Brick shows no cracking.	06	4·5	White coated from lime.
....	11·0	46	Works well. Brick shows no cracking.	06	....	Some white coating, improvement due to NaCl.

TABLE II

Drying Tests on Clay from Redcliff Brick and Coal Company, Redcliff, Alberta

Clay	Preheat. temp. °C. (½ hr.)	Grog. Nature Mesh	Grog. Per cent added	NaCl Per cent	NaCl Added	$FeCl_3$ Per cent	$FeCl_3$ Added	HCl Per cent	HCl Added	$AlCl_3$ Per cent	$AlCl_3$ Added	Drier temp. °C	Condition of drier	%Air shrinkage	%H_2O plasticity	Drying behaviour	Cone	%Fire shrinkage	Remarks
Soft clay.....	—	....	....	....	......	....	......	....	......	....	......	....	....	......	....	This clay, in the size of briquettes used, showed no tendency to crack, so was not studied alone.			
Soft clay and shale.......	—	....	....	....	......	....	......	....	......	....	......	75	....	7·0	28	Briquettes very badly cracked—deep.			
Soft clay and shale, 50–50	350	....	....	....	......	....	......	....	......	....	......	75	....	6·5	28	Briquettes showed an improvement, but still showed cracking.			
Soft clay and shale, 50–50	400	....	....	....	......	....	......	....	......	....	......	75	....	6·0	27	Briquettes were much improved. Only very slight cracking. Working properties improved.			
Soft clay and shale, 50–50	450	....	....	....	......	....	......	....	......	....	......	75	....	6·0	26	Briquettes showed no cracking whatever. Working properties very good.	....	....	In all cases, after being fired, the preheated material showed less scum than the untreated clay.
Soft clay and shale, 50–50	500	....	....	....	......	....	......	....	......	....	......	75	....	4·0	22	Briquettes showed absolutely no cracking. Plastic-			

																ity slightly too much reduced.			
Shale only...	— 350	....	....	....	....	....	....	....	....	....	....	75 75	....	....	....	Briquettes so badly cracked data could not be taken.			
Shale only...	400	....	....	....	......	....	......	....	......	....	......	75	....	8·0	35	Briquettes showed bad cracking. Little change. Also little change in working properties.			
Shale only...	500	....	....	....	......	....	......	....	......	....	......	75	....	7·0	30	Briquettes showed much improvement, but there was still some cracking. Working properties improved, but still a little sticky.			
Shale only...	550	....	....	....	......	....	......	....	......	....	......	75	....	3·3	21	Briquettes showed no cracking whatever. Working properties good.			
Soft clay and shale, 50-50	......	16	w 33	....	......	....	......	....	......	....	......	65	....	4·6	20	Briquettes cracked badly. Full size brick made, placed in drier, covered with wet rag, cracked badly.	06	0·0	Good light red—well burned—no scum. Colour somewhat improved. Could well stand higher firing.
Soft clay and shale, 50-50	......	16	w 25	....	......	1·5	Dry	....	......	....	......	65	....	7·0	29	Brick showed no cracking whatever.	06	0·0	Good red colour—somewhat improved. Could be fired higher.
Soft clay and shale, 50-50	......	16	w 33	0·6	Dry	....	......	....	......	....	......	65	....	5·8	22	Briquettes did not crack. (Brick not made.)	03	0·0	A somewhat deeper red was brought out by NaCl. No scum.
....	......	....	25	....	......	....	......	0·5	Dry	....	......	65	....	4·8	16	Brick cracked badly			

TABLE II—*Concluded*

Drying Tests on Clay from Redcliff Brick and Coal Company, Redcliff, Alberta—*Concluded.*

Clay	Preheat. temp. °C. (½ hr.)	Grog: Nature Mesh	Grog: Per cent added	NaCl: Per cent	NaCl: Added	$FeCl_3$: Per cent	$FeCl_3$: Added	HCl: Per cent	HCl: Added	$AlCl_3$: Per cent	$AlCl_3$: Added	Drier temp. °C	Condition of drier	%Air shrinkage	%H_2O plasticity	Drying behaviour	Cone	%Fire shrinkage	Remarks
Soft clay and shale, 50–50	......	16	w 33	....	......	1·0	Dry	....	......	....	......	65	....	5·0	20	Brick did not crack. Dried very well. With 33 per cent grog, green brick somewhat lacking in strength.	06	0·4	Colour improved by $FeCl_3$—a deeper red—no scum.
Soft clay and shale, 50–50	......	16	w 33	....	......	....	......	....	......	1·0	Dry	65	....	4·6	20	Brick showed some surface cracking—fine shallow cracks.	06	0·0	Fair red.
Soft clay and shale, 50–50	......	16	w 33	....	......	....	......	0·4	Sol.	....	......	65	....	5·3	22	Brick dried very well. There was no cracking whatever.	06	0·3	Good light red.

w Grog and clay proportioned by weight.

II

PRELIMINARY REPORT ON CLAY GATHERING

J. F. McMahon

The data in the following report are derived from figures obtained by the writer in the course of an investigation on clay gathering during the summer of 1927.

The object of the investigation was to assist the clay-worker to cut down the cost of manufacture and to present cost figures which might aid him in his choice of clay-gathering equipment.

Beginning at Windsor, in the southern part of Ontario, the investigation was continued northeast as far as Ottawa. Eight plants were visited in the former locality, which, because of their similarity, are grouped together for comparison.

Operations 1 to 8

The clay, which is a fine-grained, slightly calcareous material containing stones (some of which are boulders), burns to a fair red colour. It lies in beds of from 12 to 48 inches in depth underneath a varying thickness of black loam.

At every plant the clay for 25 to 50 feet ahead of the working was kept in a moist condition by the addition of water; in some cases to such an extent as not to require further water for the manufacture of the ware. The water for this purpose was obtained by piping out to the excavation, by hauling in tank cars, or from the draining of the property.

Stripping. The black soil which covers the clay is a high shrinkage material and when present in the ware causes cracking and warping. Stripping is not necessary at the plants where the depth of clay is 30 inches or more, and where the digging is done by machinery, since the amount of overburden is a small and fairly constant percentage of the total. On the other hand, where the clay is less than 30 inches the percentage of black soil is too high to allow of its being used. Moreover, where the clay is dug by hand, stripping is necessary as the men find the soil much easier to dig than the clay, and frequently throw in too much if the clay has not been stripped. Stripping is done by ploughing a deep furrow and removing the soil by hand shovel or scraper, sufficient material being removed at one time to allow for a month's or six weeks' working.

Removal of Clay. At four plants the clay was dug by hand, and at four, by a Bay City dredge carrying a $\frac{3}{8}$-yard bucket. One dredge was operated by a 4-cylinder engine equipped for burning natural gas; one, by a 1-cylinder gasoline engine; one, by a 4-cylinder gasoline engine; and the fourth, by an electric motor. In two of the hand plants, two men dug; in the other two, three men were employed in the digging and loading.

Transportation. The clay was carried in cars on rails over distances varying up to one-half mile. The cars were pulled by home-made locomotives, or by horses. The gauge of rail varied from 20 to 36 inches and the weight from 12 to 30 pounds per yard. Due to the flatness of the country the only grade was that which entered directly to the plant. Hoisting drums were used to overcome this grade at all plants but one, in which an elevator was provided for carrying the clay to a point above the plant machinery.

Car Equipment. No standard type of car was used (excepting that they were all side-dump). They varied in capacity, shape, and the material of which they were made.

Storage. No provision for storage was made at any plant, the clay going directly from the car to the machine.

Removal of Stone. Only one plant provided any special mechanical means for the removal of stone. This was a roller arrangement, which crushed the clay and rejected the stones; by means of a mechanical arm that worked back and forth between the two rolls, the stones were removed. Usually the men loading the cars were depended upon to rid the material of the stone. At one plant a man stood on top of the car, and as the machine loaded the clay into it, he worked the clay over with a fork and threw the stones out. It should be remarked that quite often these stones cause breakage of the brick-making machinery, thus causing shut-downs.

Drainage. Due to the low elevation of the country, digging is hampered by the spring freshets and rains, and at all the pits certain drainage arrangements are necessary. In most cases either tiled or open drains are used. It is quite necessary in some pits to advance the ditch with the working, for water is usually present. It is only in extremely dry weather that the workings are entirely free of water.

Costs of Operation

Manual Labour Chart for 10-hour Day:

Plant No.	Hand digger	Dredge operator	Locomotive operator	Horse drivers	Daily tonnage
	$	$	$	$	
1					
2		3.50	3.25		30
3		3.50	3.25		30
4		3.50		3.25	28
5	2 at 3.00			3.00	20
6		3.50		3.00	39
7	3 at 3.00			3.00	35
8	2 at 4.00		4.00		35
	2 at 4.00			4.00	20

Cost of Operation of Dredge:

Plant No.	Source of power	Fuel		Lubricant		Running cost	Daily tonnage
		Consumption	Cost	Amount	Cost		
			$	qt.	$	$	
1.......	Gasoline...........	4 gal.	1.00	1	0.30	1.30	30
2.......	10 h.p. motor......	22 kw.h.	0.45	2½	0.75	1.20	30
3.......	Gasoline...........	3½ gal.	0.88	1	0.30	1.18	28
5.......	Natural gas........	600 cu. ft.	0.21	1	0.30	0.51	39

Cost of Operation of Locomotives:

Plant No.	Source of power	Fuel		Lubricant		Running cost	Daily tonnage	Length of haul
		Consumption	Cost	Amount	Cost			
		gal.	$	qt.	$	$		feet
1.........	Gasoline...	8	2.00	1	0.30	2.30	30	1,280
2.........	Gasoline...	4	1.00	1	0.30	1.30	30	819
7.........	Gasoline...	2	0.50	¼	0.07½	0.575	35	581

Cost of Operation of Horses:

Plant No.	Running cost	Daily tonnage
	$	
3..	1.25	28
4..	1.50	20
5..	1.00	39
6..	1.00	35
8..	1.00	20

Yearly Cost Repairs:

Plant No.	Shovel	Cars	Locomotive
	$	$	$
1..	50	20	10
2..	50	20	10
3..	50	20	....
4..	....	25	....
5..	50	30	....
6..	....	20	
7..	....	100	10
8..	....	25	....

Road-bed:

Plant No.	Length (double)	Gauge	Weight	Condition track
	feet	inches	pounds	
1	2,560	36	12	Fair
2	1,638	36	12	Poor
3	1,100	36	12	Fair
4	1,038	30	12	Poor
5	1,155	24	16	Fair
6	1,350	24	16	Fair
7	1,848	24	30	Fair
8	1,162	24	*15	Fair

*Various weight of rails.

Car Equipment:

Plant No.	No. of cars	Value each	Material made of	Dump	Capacity	Capital	Tonnage
		$			cubic yds.	$	
1	2	65	Wood	S.D.	2	130	30
2	2	65	"	"	2	130	30
3	2	65	"	"	2	130	28
4	5	75	"	"	2	375	20
5	6	65	Steel	"	1	390	39
6	4	65	"	"	1½	260	35
7	13	100	"	"	1	1,300	35
8	5	*25	Wood	"	1	125	20

*Second-hand equipment.

Digging Equipment:

Plant No.	Type	Traction	Value
			$
1	Bay City Dredge	Forward caterpillar	1,000
2	Bay City Dredge	Traction	1,000
3	Bay City Dredge	Four track	1,000
4			
5	Bay City Dredge	Four track	1,000
6			
7			
8			

Summary of Costs:

Plant No.	1	2	3	4	5	6	7	8
	$	$	$	$	$	$	$	$
Wages per ton	0·225	0·225	0·241	0·450	0·167	0·343	0·343	0·600
Fuel and lubricant per ton (dredge)	0·043	0·040	0·042		0·013			
Fuel and lubricant per ton (locomotive)	0·077	0·043					0·016	
Cost horse per ton			0·045	0·075	0·026	0·029		0·050
Repairs	0·010	0·010	0·010	0·004	0·008	0·002	0·010	0·007
Interest and depreciation per ton	0·042	0·042	0·023	0·041	0·034	0·019	0·046	0·029
Total cost per ton	0·397	0·360	0·361	0·570	0·248	0·393	0·415	0·686

Operation No. 9

This plant is on an elevation considerably higher than the pit and 2,325 feet from it. The clay, which is quite sandy and easily dug, lies in a bed 4 feet in thickness, and rests upon silt. It is covered with 6 inches of a high shrinkage loam which has to be removed. As the pit is in the lowlands it is not easily drained and shut-downs are frequent because of the wetness of the pit. There is no provision made for storing the clay. The average daily output from the clay working is 90 tons which is used in the manufacture of soft-mud brick. The clay is dug by hand and loaded into steel side-dump cars, drawn by horses to the base of an incline, up which the loaded cars are drawn by a drum and cable run off the main shafting of the plant. The man in charge of the brick machine also operates the drum which draws the clay up. The digging force is composed of five men, and one man takes charge of the two horses and the haulage to the base of the incline.

The overburden is removed by the pit crew once every six weeks. The plant is operated on an average of 7½ months in the year.

Costs per ton:

	$
Removal of overburden	0·0083
Digging	0·1790
Hauling: wages	0·0992
maintenance	0·0121
Total	0·2986

Operation No. 10

The plant is located at an elevation of 25 feet above the clay bed and very close to it (350 feet). There is no overburden but the clay is somewhat tough for hand-digging and requires watering down. The bed, which consists of two clays—upper and lower, has an average thickness of 5 feet. The upperclay burns to a much deeper red than the lower one. Both are worked at the same time by the two diggers, one digging the upper bed, the other the lower one, and both loading the same car. The beds are practically free from stones. The pit is naturally drained, and it is only in very wet weather that trouble is met with from this source. The clay is hauled by means of a drum and a cable working off the main shaft of the plant. The plant is operated on an average of 7 months in the year. The daily consumption of clay is 30 tons, all of which is used in the manufacture of drain tile.

Costs per ton:

	$
Digging	0·266
Haulage	0·0045
Depreciation	0·0045
Total	0·2750

Operation No. 11

The plant was operated in such a fashion as not to allow any accurate cost figures to be taken.

The clay lies in a 7-foot bed and is very tough. Dynamite is used to loosen it, and the clay is then shovelled by hand into a horse-drawn dump cart. The pit is 250 feet from the clay machinery; it is poorly drained and worked intermittently.

Operation No. 12

The clay bed has a thickness up to 20 feet, but at present only the top 8 feet is being worked. No appreciable overburden is present. The dumping point is located about 25 feet above the pit bottom. In the morning, clay sufficient for the afternoon's run is loosened by a team and small scoop shovel and piled in a spot convenient for loading on cars. In the afternoon, two men shovel the clay into cars which are drawn out of the pit to a point above the clay machine by a drum which receives its power from the main shaft. The plant operates on an average of 6 months in a year and uses 12½ tons of clay per day. The drainage of the pit being naturally poor, a gasoline-driven pump has to be run all day, except in very dry weather.

Costs per ton:

	$
Digging	0·32
Haulage	0·012
Draining	0·0054
Depreciation	0·02
Total	0·3574

Operation No. 13

The plant, which consists merely of a soft-mud brick machine, is located very close to and at a slightly higher elevation than the clay pit. The clay, which is fairly tough and free from stones, has an average thickness of 8 feet. Digging is done by one man operating a Fordson tractor, which draws a Miami scraper having a bucket of one-half yard capacity. The clay is dug on a down grade, at a place 6 feet below the dumping point and within 30 feet of it. The tractor turns about and climbs back with the load to the dumping point travelling about 300 feet. During wet seasons traction becomes rather difficult, but, as a rule, drainage is not a serious problem due to the slope from which the clay is taken. The plant operates on an average of 4 months in a year, using 50 tons of clay per day. Stripping is done once a year, before work commences.

Costs per ton:

	$
Stripping	0·0083
Digging and hauling	0·1583
Depreciation	0·0238
Total	**0·1904**

Operation No. 14

The clay bed, which is located at a higher elevation than the clay machinery, is made up of a fairly tough upperclay which contains a few stones, and a sandy lowerclay. Both beds are worked together and in even quantities. The overburden, which is 6 inches thick, is removed by hand twice a year. The clays are kept well watered down to promote ease of hand-digging. The clay is loaded by hand into horse-drawn carts, and transported to the plant about a quarter of a mile distant. Wet weather makes hard going for the horses over the clayey road to the plant, but, because of the natural drainage, causes no particular trouble in the pit. The plant operates on an average of 6 months a year, using 50 tons of clay daily in the manufacture of soft-mud and stiff-mud brick.

Costs per ton:

	$
Stripping	0·017
Digging	0·225
Haulage	0·0816
Depreciation	0·003
Total	0·3266

Operation No. 15

The plant is located in level country. The clay, which is a surface one, lying in a bed averaging 2½ feet in thickness under 6 inches of loamy overburden, is dug and loaded into dump carts by hand. Some transportation trouble is met with during rainy weather, but as the pit is drained by a ditch, the chief difficulty is lack of water in the working.

The plant is located 1,037 feet from the clay operation and the dumping point is about 10 feet above the ground level; this grade is overcome in 75 feet. The plant operates on an average of 6 months in the year, and consumes 40 tons of clay daily in the manufacture of hollow ware and building brick. There is a 6-inch layer of high shrinkage loam over the clay bed, which is removed as the digging progresses.

Costs per ton:

	$
Digging	0·162
Haulage	0·054
Depreciation	0·0064
Total	0·2224

Operation No. 16

This working is located in level country. The clay lies in a bed averaging 2 feet in thickness underneath a 6-inch covering of high shrinkage loam which is removed as the digging progresses. The material is quite easily dug by hand shovel. The working is located about 1,400 feet from the dumping point. There are no grades or other natural hindrances between the loading place and the dumping place, and haulage is done by horse-drawn dump wagons. The working is naturally drained and offers no trouble except in extremely wet weather. The clay is dumped into a bin to be soaked, from which it is shovelled by hand into the clay machine. The plant operates on an average of 6 months in the year, utilizing 43 tons of clay per day in the manufacture of hollow ware and building brick.

Costs per ton:

	$
Digging	0·163
Haulage	0·1386
Shovelling	0·146
Depreciation	0·0065
Total	0·4541

Operation No. 17

This is a shale operation. The shale lies in a bank up to 75 feet, covered with a 6-inch overburden but which is not troublesome. The face worked is about 100 yards wide and the working has gone into the bank 70 feet. The shale is blasted with dynamite and shovelled by hand into cars, which when full are pushed by the digger to the plant, for a distance varying from 75 to 150 feet. A crew of four men, including the foreman, who takes charge of the blasting, delivers on an average 58 tons of shale per day to the plant. A compressed air drill is used for drilling. A drainage system has been installed under the present working level to ensure good working in wet weather. The plant is located at the base of the bank, and practically next to it. The plant operates on an average of 172 days in the year. No provision is made for storage.

Costs per ton:

	$
Blasting, loading, hauling	0·3312
Drainage	0·0012
Depreciation	0·0259
Total	0·3583

Operation No. 18

This is a shale operation. The shale is in a bank up to the height of 70 feet covered with 3 feet of overburden which is removed by hand before blasting. The shale is blasted loose and loaded by hand into horse-drawn dump carts which carry it 100 yards to the dumping point. The face of the bank worked is about 200 yards wide. The plant is located on a lower level than the digging operation and haulage is not difficult. Drainage is provided by a gentle slope in the base of the workings. The plant operates on an average of 260 days in the year, consuming 55 tons daily in the manufacture of dry-press brick.

Costs per ton:

	$
Stripping	0·029
Blasting, loading	0·307
Hauling	0·117
Depreciation	0·0023
Total	0·4553

Operation No. 19

The plant is located at the base of the hill from which the clay is obtained. The drop from the present clay working to the dumping point at the plant is 40 feet. The clay has been worked out in benches back for a distance of 575 feet. The clay, which is dug by hand, is a tough one and requires watering down. The face worked is 6 feet deep and is 30 feet wide. The one-foot bed of overburden is removed by hand. The clay is shovelled by hand into horse-drawn dump carts which carry it to the plant. In wet weather transportation is difficult on the clay road. Drainage is natural and good.

Costs per ton:

	$
Digging and loading	0·291
Haulage	0·0729
Removal of overburden	0·060
Total	0·4239

Operation No. 20

This pit is operated by a contractor who loads the clay into railroad cars for 45 cents per ton. The company furnishes him with a steam shovel, together with the necessary fuel and oil. The operation is a surface one; the clay has an average depth of 2 feet and is easy to dig. At the bottom of the clay is a very limy clay which, when mixed with the top clay, produces considerable trouble in the finished ware. Although the country is quite hilly and drains fairly well, heavy rains make the operations a very difficult one; not only is working inconvenient but the wet clay is very undesirable for the manufacture of the product. From the present digging to the dumping pit is approximately a quarter of a mile. The hauling is done by teams in bottom-dump carts of 2-yard capacity, which are furnished by the contractor. Five teams are usually employed. The company has a large storage bin in which is stored the supply of clay for the winter and early spring, hence the need for hurried work on the fine days of the year. The daily production is 99 tons.

Costs per ton:

	$
Digging and loading	0·45
Interest and depreciation	0·085
Fuel and oil	0·043
Total	0·578

CONCLUSIONS

The problem of " clay delivery costs " requires a good deal of careful study in order to arrive at comparable figures. The factors to be considered are many and are found in many different combinations with one another. The past summer's work covered thirty-five plants, and it is to be regretted that it is not possible to give reports on the other fifteen at this time. However, sufficient has been given to show the importance of the study. If the study is to be successful the co-operation of the manufacturers is necessary, for only by their help can the work be completed in an acceptable form, and truly significant figures be presented.

III

CLAYS AND SHALES OF THE GRAND LAKE AREA, NEW BRUNSWICK

Howells Fréchette and J. F. McMahon

In the mining of coal from the thin seam of the Grand Lake coal area in New Brunswick, it is necessary to mine and hoist a large tonnage of shale to provide for working space.

The coal seam which is mined throughout the Grand Lake coal area varies in thickness up to a maximum of about 29 inches, but it is rarely more than 22 inches and in some workings is not over 18 inches in thickness. It may be regarded as having an average thickness of 20 inches in the section mined. The coal is underlain by a hard, almost structureless shale and is overlain by softer and thinner bedded shales. In taking out the coal the general practice is to remove from 14 to 18 inches of the overshale. Along the haulage ways a greater height of shale is removed. In general about an equal tonnage of coal and shale is raised to the surface, but where longwall mining is practised the proportion of shale is somewhat lower.

At present the undershale, owing to its hardness, is rarely disturbed except in the digging of drainage ditches and sumps.

A striking feature about all of the mines in this district is the immensity of the waste shale dumps which surround them. Probably very close to two million tons of shale are already mined and thus stored within an area of about 10 square miles.

The establishment of a clay-working industry which could profitably make use of this waste material and thus convert it from a source of expense to an asset is not a new idea. The late Joseph Keele[1] pointed out various uses to which the shales associated with the coal could be put.

With the object of ascertaining whether any recent developments had revealed further clays and shales of importance and again directing attention to the shales of this district as raw material worthy of consideration, the area was visited in September, 1927, and a number of samples collected. These samples were subjected to testing by J. F. McMahon whose report appears on page 27.

The geology of the area has recently been described by W. S. Dyer, whose report[2] is accompanied by a map showing the topography and the location of the mines.

In the collection of samples particular attention was given to the shales immediately above and below the coal seam, which will be referred to as the undershale and the overshale.

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1 "Clay and Shale Deposits of New Brunswick," Geol. Surv., Canada, Mem. 44, pp. 46-57 (1914).
2 "Minto Coal Basin, New Brunswick," Geol. Surv., Canada, Mem. 151 (1926).

The Undershale

In general, the undershale which averages somewhat over 3 feet in thickness, may be described as a fine-textured, hard, massive shale which, on exposure to the weather, rapidly breaks down and becomes a clay. When finely ground the shale develops good plasticity and near its outcrops it occurs as a very plastic clay. In the Minto field it appears to vary in refractoriness. As found in the mines of the Minto Coal Company, 1½ miles north of Minto post office, the shale is of very low refractoriness. The refractoriness increases to the southward as shown by the samples from the Rothwell Coal Company's mine and the old workings of Welton and Henderson, three-quarters of a mile southeast of Minto. Three and one-half miles south southeast of Minto samples were taken from weathered outcrops near the shore of Grand lake. Here the shale has been completely altered to a clay which may be classed as a low-grade fireclay.

As has already been stated, very little of the undershale has been mined, and should it be desired to utilize it for the manufacture of ceramic wares, it would be necessary to alter the present method of mining by undercutting the coal and developing head room by the removal of the hard undershale instead of the more easily worked overshale. Or the undershale could be won by a secondary operation following the removal of the coal.

The mining of the plastic clay of the outcrop would be a simpler operation but would not have the benefit of direct railroad facilities which exist at the coal mines.

The Overshale

Dr. Dyer states[1] that the overshale or coal shale averages 5 feet in thickness, although there is considerable variation. It is a dark grey, fine-textured, thin-bedded shale which on exposure breaks first into small chunks and finally disintegrates into thin flakes intermixed with clay. As regards refractoriness it is very uniform throughout the entire district, being a low fusion shale. As has been pointed out, about two million tons of this shale are stored in huge piles about the shaft heads, and there is a steady production of many tons per day at all the mines. One colliery alone raises from 70 to 80 tons each working day.

The properties of the various shales and clays sampled, and the products for which they would serve as raw material are treated by J. F. McMahon in his report which follows.

TESTS

General Remarks

The samples were first dried thoroughly between 105 and 110° C. and then ground to pass a 16-mesh screen.

All standard procedures mentioned may be found in the year book of the American Ceramic Society of 1922.

In the case of the stiff-mud tests, sufficient water was added to each material to promote its best working consistency. The amount of water is noted as per cent of the dry clay weight. This water is termed *water of plasticity*.

[1] *Op. cit.*

The amount of water used in the dry-press tests was just sufficient to cause a bond when the tempered mass was squeezed in the hand. The amount of water is noted as per cent of the dry clay weight. The water might be termed *press water.*

Drying shrinkages and fire shrinkages are all given in linear shrinkage. The percentages are all calculated from the volume shrinkages and referred to the dry dimension as a basis.

The dry transverse strengths were found by the standard procedure.

Comment is made concerning the drying properties of each material when moulded into shape. Some of the plastic mass was made into a 3-inch cube, and placed immediately into a drying oven having a temperature of 110° C. If the material dried without cracking or bursting, it was considered capable of withstanding comparatively fast drying. If, however, the material did crack or burst, such facts are noted in the report.

The stiff-mud briquettes were of standard size, 2 inches by 1 inch by 1 inch, and were made according to standard procedure.

The dry-press briquettes were 3¼ inches by 1¾ inches by ⅞ inch, the latter dimension varying slightly with various materials.

Before burning, all briquettes were dried slowly and thoroughly in a drying oven. The drying being finished between 105° and 110° C.

The slaking tests were run according to standard methods.

The burning schedule in all instances was the same, the burns being run in a down-draught, gas-fired, muffle kiln. The temperature of the kiln was brought to 100° C. in the first two hours, held at this temperature for four hours, then raised at the rate of 70 degrees per hour for five hours, then 30 degrees per hour for five hours, then 15 degrees per hour for fourteen hours, then increased at the rate of 50 degrees per hour to the finish of the burn.

The 03 burn was under slightly reducing conditions which emphasized the liability of the materials to develop carbon core.

Remarks on the finished product may be interpreted as follows:—

Good Condition. This refers to the outward appearance of the burned briquettes and signifies that there was no checking, cracking, warping, nor scumming. If any of these faults developed, such facts are noted.

Good Structure. This refers to the interior of the burned briquettes and signifies that there was no carbon core, no apparent developed voids, nor other visible defects. If any such faults developed, such facts are noted.

Hardness. To express this quality, an arbitrary set of terms was chosen which includes: soft (easily scratched with a steel point), quite hard, hard, very hard, and steel hard (not scratched by a steel point).

Soundness. If the briquettes give a ring when tapped together they are sound, if not, they are punky or not sound.

Per cent absorption represents the amount of water the product carries when saturated.

The *firing range* covers the burning temperatures at which the material can be expected to produce the most marketable product.

The *softening point* represents the temperature at which the material, made into a standard cone shape, softens sufficiently as to bend and touch the plaque upon which it is mounted. The result is given in terms of standard cones and their approximate temperature equivalent.

Salt glaze tests were all run at cone 1 (1125° C.) in the same kiln, at the same time. Such terms as *good, fair,* and *poor* represent the comparative quality of the developed glaze.

Sample No. 1

Location

Sample taken from shaft 3 C of the Minto Coal Company's property at Minto.

Nature of Material

This was a fresh, light grey, non-calcareous, rather hard undershale which was free from any visible objectionable materials.

Working Properties

Slaking. The average slaking time was three minutes.

Wet Properties. When tempered with 25 per cent of water, it developed into a very plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 9·5 per cent.

This material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 67·5 pounds per square inch.

Softening Point. The softening point of this material was found to be cone 6 + (1180° C +).

Burned Properties

When burned to cone 010 (890° C.) the resulting product was of a light salmon colour and fairly hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 0·7 per cent and the average absorption was 11·1 per cent.

When burned to cone 06 (1005° C.) the product was of a fair brick-red colour and very hard. The briquettes showed a tendency to form a carbon core, and were slightly distorted by bloating. The fire shrinkage averaged 2·7 per cent and the average absorption was 5·8 per cent.

When burned to cone 03 (1080° C.) the briquettes were of a fair brick-red colour and very hard. They showed a tendency to form a carbon core and were slightly bloated and distorted. The fire shrinkage averaged 4 per cent and the average absorption was 4·1 per cent.

When burned to cone 01 (1110° C.) the product was of a fair brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 8·1 per cent and the average absorption was 1·5 per cent.

When burned to cone 2 (1135° C.) the product was similar to that of the previous burn. The fire shrinkage averaged 9·4 per cent and the average absorption was 1·2 per cent.

When burned to a temperature above 1135° C. the product begins to swell.

DRY-PRESS TESTS

Tempering and Pressing. This material when tempered with 6 per cent of water, developed a consistency suitable for dry-pressing. A few cracks were noted on the sides of the pressed briquettes, but the corners and edges were good.

Burning. When burned to cone 01 (1110° C.) the dry-press product was of a fair brick-red colour, hard and sound. The briquettes were in good condition and their structure was good. The average absorption was 4·5 per cent.

When burned to cone 2 (1135° C.) the dry-press product was similar to that of the previous burn.

Remarks

For the manufacture of stiff-mud products from this material there does not seem to be any extra caution necessary other than the usual careful manipulation of the material.

For the manufacture of dry-press products, particular care will be needed in the tempering and pressing of the material to rid the product of side cracks. A little experimental work would be necessary in this connexion.

The material has a tendency to form a carbon core. This could be remedied by a proper burning schedule.

The best burning range lies between 1005° C. and 1130° C. After 1080° C. is reached, the material begins to shrink and vitrify at a rather fast rate. Care will be needed in the finishing of the burn lest the temperature rise beyond the high limit and cause failure.

The material is not suitable for salt glazing.

Recommendation

This material is suitable for the manufacture of a good grade of building brick and hollow building tile. The process most applicable is the stiff-mud process.

It could also be used for the manufacture of dry-press building brick and tile.

Sample No. 2

Location

Sample was taken from shaft 3 C of the Minto Coal Company's operation at Minto.

Nature of Material

This was a fresh, light grey overshale which was free from any visible objectionable material, and non-calcareous.

Working Properties

Slaking. The average slaking time was $5\frac{1}{2}$ minutes.

Wet Properties. When tempered with 20 per cent of water, the material was of a greenish grey colour and very plastic.

Drying Properties. Briquettes made of the tempered clay and dried thoroughly showed an average drying shrinkage of 6·7 per cent.

The material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 67·5 pounds per square inch.

Softening Point. The softening point was found to be cone 4 (1165° C.).

Burned Properties

When burned to cone 010 (890° C.) the product was of a light salmon colour, and fairly hard. The briquettes were in a good sound condition and their structure was good. The fire shrinkage averaged 1·8 per cent and the average absorption was 12·1 per cent.

When burned to cone 06 (1005° C.) the product was similar to that of the previous burn. The fire shrinkage averaged 5·9 per cent and the average absorption was 10·1 per cent.

When burned to cone 03 (1080° C.) the briquettes were of a fair brick-red colour, hard and sound, but contained carbon cores. The fire shrinkage averaged 6·2 per cent and the average absorption was 3·6 per cent.

When burned to cone 01 (1110° C.) the product was of a dark red colour and steel hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 5 per cent and the average absorption was 2 per cent.

When burned to cone 2 (1135° C.) the product was of a dark red colour and steel hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 10 per cent and the average absorption was 2 per cent.

When burned to cone 4 (1165° C.), the product was similar to that of the previous burn in colour and hardness. The briquettes were in good condition and their structure was good.

DRY-PRESS TESTS

Tempering and Pressing. When tempered with 8·5 per cent of water, the material balled slightly. A few cracks were noted on the sides of the briquettes as they came from the press.

Burning Tests. When burned to cone 01 (1110° C.), the dry-press product was of a good brick-red colour, sound and hard. The average absorption was 3·5 per cent.

When burned to cone 2 (1135° C.), the dry-press product was similar to that of the previous burn. The average absorption was 4·4 per cent.

Remarks

For the manufacture of dry-press products, a little experimental work will be necessary in order to ascertain the proper pressing consistency and pressure.

In burning, the material tends to promote a carbon core if the oxidation period is hurried.

The material swells when burned above 1135° C., as is indicated by the drop in fire shrinkage in the burn at cone 4.

The best burning range lies between 1080 and 1110° C. This allows a safety factor of a few degrees, but the burning should not be taken much beyond 1110° C.

The material is not suitable for salt glazing.

Recommendation

The material is suitable for the manufacture of a good grade of building brick and hollow building tile. The process most applicable is the stiff-mud process.

It could be used also in the manufacture of dry-press building brick.

Sample No. 3

Location

Sample taken from the east bank of Newcastle creek, opposite operations of the Minto Coal Company.

Nature of Material

This was a light grey clay free from any visible objectionable materials, and non-calcareous.

Working Properties

Slaking. The average slaking time was 7 minutes.

Wet Properties. When tempered with water it developed into a very plastic mass.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 3·5 per cent.

This material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 66·1 pounds per square inch.

Softening Point. The softening point was found to be cone 9 (1250° C.).

Burned Properties

When burned to cone 010 (890° C.) the resulting product was of a very light salmon colour and soft. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 2·5 per cent and the average absorption was 16·4 per cent.

When burned to cone 06 (1005° C.) the product was of a salmon colour and soft. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 2·5 per cent and the average absorption was 14·9 per cent.

When burned to cone 03 (1080° C.) the product was of a light brick-red colour and hard. The briquettes had carbon cores. The fire shrinkage averaged 9·1 per cent and the average absorption was 3·0 per cent.

When burned to cone 2 (1135° C.) the briquettes were of a dark brick-red colour and steel hard. They were in good condition and their structure was good. The fire shrinkage averaged 7·5 per cent and the absorption was negligible.

When burned to cone 4 (1165° C.) the product was of a dark brick-red colour on the outside and of a chocolate colour inside. The material was vitrified and the briquettes were in good condition. The fire shrinkage averaged 13·6 per cent and the absorption was negligible.

Remarks

This material has sufficient carbonaceous matter in it to cause the development of a carbon core if the necessary precautions are not taken.

There will be noted a discrepancy in the cone 01 and cone 2 burns. This is undoubtedly due to the formation of a carbon core in the cone 2 briquettes which caused bloating.

The best burning range lies between 1080 and 1150° C., the material being easily overburned above 1150° C.

Recommendation

This material is suitable for the manufacture of building brick and hollow building tile by the stiff-mud process.

Sample No. 4

Location

Sample taken from a 4-foot outcrop on the property of the Avon Coal Co., Ltd., near the mouth of Little river.

Nature of Material

This was a light brown, weathered undershale which was free from any visible objectionable materials, and non-calcareous.

Working Properties

Slaking. The average slaking time was 8 minutes.

Wet Properties. When tempered with 26 per cent of water, it developed into a brown, plastic mass.

Drying Properties. Briquettes made of the tempered material and dried thoroughly showed an average drying shrinkage of 18·5 per cent.

This material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 66·6 pounds per square inch.

Softening Point. The softening point was found to be cone 20+ (1520° C+).

Burned Properties

When burned to cone 010 (890° C.) the resulting product was of a light salmon colour and fairly hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 2·7 per cent and the average absorption was 15·3 per cent.

When burned to cone 06 (1005° C.) the product was of a slightly pinkish buff colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 6·2 per cent and the average absorption was 14·8 per cent.

When burned to cone 03 (1080° C.) the product was similar to that of the previous burn. The fire shrinkage averaged 7·4 per cent and the average absorption was 12·9 per cent.

When burned to cone 01 (1110° C.) the product was similar to that of the previous two burns. The fire shrinkage averaged 8·4 per cent and the average absorption was 10 per cent.

When burned to cone 2 (1135° C.) the product was similar to that of the three previous burns. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 8·4 per cent and the average absorption was 9·8 per cent.

When burned to cone 4 (1165° C.) the product was similar to that of the four previous burns. The fire shrinkage averaged 8·8 per cent and the average absorption was 8·5 per cent.

DRY-PRESS TESTS

Pressing. The material pressed into briquettes which had good corners and edges, although a few pressure cracks were on the sides of the briquettes as they came from the press.

Burning. When burned to cone 01 the product was of a pinkish buff colour and rather hard. The briquettes were in good condition and their structure was good. The average absorption was 11·5 per cent.

When burned to cone 2 the product was of a pinkish buff colour and quite hard. The briquettes were in good condition and their structure was good. The average absorption was 11·2 per cent.

When burned to cone 4 the product was of a pinkish buff colour and hard. The briquettes were in good condition and their structure was good. The average absorption was 7·6 per cent.

When burned to cone 6 (1190° C.) the product was of a pinkish buff colour and very hard. The briquettes were in good condition and their structure was good. The average absorption was 6·7 per cent.

Remarks

For building brick purposes it would be necessary to burn this material to a comparatively high temperature—cone 6 (1190 °C.). A slightly higher temperature will produce a better product.

As concerns a dry-press operation, it will be necessary to do a little experimenting in order to ascertain the proper pressing consistency and pressure to be used so as to avoid side cracking.

The best burning range for this material would be between 1165 and 1250° C. Little trouble will be found from overburning.

The material takes a fine salt glaze at cone 1.

Recommendation

The material is suitable for the manufacture of a good grade of building brick and hollow building tile by the stiff-mud process. It might also be used for the manufacture of dry-press building brick.

It is very suitable for the manufacture of conduits and sewer pipe.

Sample No. 5

Location

Sample was taken from the property of B. B. Flowers, on the north shore of Flower cove.

Nature of Material

This was a light brown, weathered undershale which was free from any visible objectionable materials, and non-calcareous.

Working Properties

Slaking. The average slaking time of this material was 8 minutes.

Wet Properties. When tempered with 35 per cent of water, it developed into a brown, plastic mass.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 14·5 per cent.

This material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 94·5 pounds per square inch.

Softening Point. The softening point of this material was found to be cone 18 (1485° C.).

Burned Properties

When burned to cone 01 (1110° C.) the resulting product was of a salmon colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 8·2 per cent and the average absorption was 9·7 per cent.

When burned to cone 2 (1135° C.) the product was of a salmon colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 13·6 per cent and the average absorption was 9·1 per cent.

When burned to cone 4 (1165° C.) the product was similar in colour to that of the previous burn. The briquettes were in good condition and their structure was good. The average fire shrinkage was 15 per cent and the average absorption was 5·4 per cent.

When burned to cone 6 (1190° C.) the product was brown in colour and steel hard. The briquettes were in good condition and their structure was good. The average absorption was 1·3 per cent.

DRY-PRESS TESTS

Pressing. This material when tempered with 14 per cent of water did not ball. The briquettes had cracks along the sides as they came from the press.

Burning Properties. When burned to cone 2 (1135° C.) the product was of a light salmon colour and fairly hard. The briquettes were in good condition and their structure was good. The average absorption was 12 per cent.

When burned to cone 4 (1165° C.) the product was of a light salmon colour and hard. The briquettes were in good condition and their structure was good. The average absorption was 3·4 per cent.

Remarks

The colour of the burned product is not particularly pleasing to the eye, hence it cannot be recommended for use in the manufacture of building brick.

Some non-shrinking material must be added to the mix for the manufacture of sewer pipe due to the high shrinkage occurring at temperatures around 1190° C.

The best burning range of this material lies between 1110° C. and 1190° C. Below 1110° C. the product is very porous.

The material takes a good salt glaze at cone 1 (1125° C).

Recommendation

The material is suitable for the manufacture of sewer pipe and conduits. It is also suitable for the manufacture of hollow building tile.

Sample No. 6

Location

This sample was taken from the property of B. B. Flowers on the north shore of Flower cove.

Nature of Material

This was a light grey, weathered overshale which was free from any visible objectionable materials, and non-calcareous.

Working Properties

Wet Properties. When tempered with water, it developed into a good plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made from this tempered mass and dried thoroughly showed an average drying shrinkage of 5·1 per cent.

The material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 55·3 pounds per square inch.

Softening Point. The softening point was found to be cone 8 (1225°C).

Burned Properties

When burned to cone 01 (1110° C.) the resulting product was of a good brick-red colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 4·9 per cent and the average absorption was 12·1 per cent.

When burned to cone 2 (1135° C.) the product was of a good brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 11·6 per cent and the average absorption was 10·9 per cent.

When burned to cone 4 (1165° C.) the product was of a good brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 12·6 per cent and the average absorption was 8·2 per cent.

When burned to cone 6 (1190° C.) the product was of a good brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 14·8 per cent and the average absorption was 5 per cent.

Remarks

The burning range lies between 1110° C. and 1165° C.

Recommendation

The material is suitable for the manufacture of a good grade of building brick and hollow building tile. The process most adaptable is the stiff-mud process.

Sample No. 7

Location

The sample was taken from alongside the old Welton-Henderson workings at South Minto.

Nature of Material

This was a very light grey, weathered undershale which was free from any visible objectionable material, and non-calcareous.

Working Properties

Slaking. The average slaking time was 5 minutes.

Wet Properties. When tempered with 26 per cent of water it developed into a light grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 8·6 per cent.

This material will withstand comparatively fast drying.

When burned to cone 6 (1190° C.) the product was brown in colour and steel hard. The briquettes were in good condition and their structure was good. The average absorption was 1·3 per cent.

DRY-PRESS TESTS

Pressing. This material when tempered with 14 per cent of water did not ball. The briquettes had cracks along the sides as they came from the press.

Burning Properties. When burned to cone 2 (1135° C.) the product was of a light salmon colour and fairly hard. The briquettes were in good condition and their structure was good. The average absorption was 12 per cent.

When burned to cone 4 (1165° C.) the product was of a light salmon colour and hard. The briquettes were in good condition and their structure was good. The average absorption was 3·4 per cent.

Remarks

The colour of the burned product is not particularly pleasing to the eye, hence it cannot be recommended for use in the manufacture of building brick.

Some non-shrinking material must be added to the mix for the manufacture of sewer pipe due to the high shrinkage occurring at temperatures around 1190° C.

The best burning range of this material lies between 1110° C. and 1190° C. Below 1110° C. the product is very porous.

The material takes a good salt glaze at cone 1 (1125° C).

Recommendation

The material is suitable for the manufacture of sewer pipe and conduits. It is also suitable for the manufacture of hollow building tile.

Sample No. 6

Location

This sample was taken from the property of B. B. Flowers on the north shore of Flower cove.

Nature of Material

This was a light grey, weathered overshale which was free from any visible objectionable materials, and non-calcareous.

Working Properties

Wet Properties. When tempered with water, it developed into a good plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made from this tempered mass and dried thoroughly showed an average drying shrinkage of 5·1 per cent.

The material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 55·3 pounds per square inch.

Softening Point. The softening point was found to be cone 8 (1225°C).

Burned Properties

When burned to cone 01 (1110° C.) the resulting product was of a good brick-red colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 4·9 per cent and the average absorption was 12·1 per cent.

When burned to cone 2 (1135° C.) the product was of a good brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 11·6 per cent and the average absorption was 10·9 per cent.

When burned to cone 4 (1165° C.) the product was of a good brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 12·6 per cent and the average absorption was 8·2 per cent.

When burned to cone 6 (1190° C.) the product was of a good brick-red colour and very hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 14·8 per cent and the average absorption was 5 per cent.

Remarks

The burning range lies between 1110° C. and 1165° C.

Recommendation

The material is suitable for the manufacture of a good grade of building brick and hollow building tile. The process most adaptable is the stiff-mud process.

Sample No. 7

Location

The sample was taken from alongside the old Welton-Henderson workings at South Minto.

Nature of Material

This was a very light grey, weathered undershale which was free from any visible objectionable material, and non-calcareous.

Working Properties

Slaking. The average slaking time was 5 minutes.

Wet Properties. When tempered with 26 per cent of water it developed into a light grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 8·6 per cent.

This material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 64·3 pounds per square inch.

Softening Point. The softening point of this material was found to be cone 14 + (1390° C+).

Burned Properties

When burned to cone 01 (1110° C.) the resulting product was of a dark salmon colour and very hard. There was a white scum on the briquettes, but the structure was good. The fire shrinkage averaged 8·6 per cent and the average absorption was 5 per cent.

When burned to cone 2 (1135° C.) the product was of a dark salmon colour and very hard. The briquettes had a white scum, but the structure was good. The fire shrinkage averaged 4·5 per cent and the average absorption was 4·7 per cent.

When burned to cone 4 (1165° C.) the product was of a poor brown colour and steel hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 13·2 per cent and the absorption was negligible.

When burned to cone 6 (1190° C.) the product was of a poor brick-red colour and steel hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 14·5 per cent and the absorption was negligible.

DRY-PRESS TESTS

Pressing. When tempered with 10 per cent of water this material did not ball. It pressed nicely into briquettes which had good edges and corners, and were free from cracks along the sides.

Burning. When burned to cone 2 (1135° C.) the resulting dry-press product was salmon-coloured and hard. The surfaces of the briquettes were pitted, but the structure was good. The average absorption was 8·9 per cent.

When burned to cone 4 (1165° C.) the product was of a dark brown colour and very hard. The surfaces of the briquettes were pitted, but the structure was good. The average absorption was 3·7 per cent.

When burned to cone 6 (1190° C.) the product was dark salmon-coloured. The surfaces of the briquettes were pitted, but the structure was good. The average absorption was 2·8 per cent.

Remarks

The lack of a good burning colour prevents this material being used for the manufacture of building brick.

The burning range lies between 1080° C. and 1190° C.

The scum mentioned in the 01 and 02 burns is not a serious defect.

The material takes a very good salt glaze at cone 1.

Recommendation

The material is suitable for the manufacture of sewer pipe and similar products. It would also make a good hollow building tile.

Sample No. 8

Location

This sample was taken from the Black Diamond shaft of the Welton-Henderson colliery, ½ mile northwest of Newcastle Bridge.

Nature of Material

This was a light grey shale free from any visible objectionable material but very calcareous, and is representative of 20 feet of material lying above the upper coal shale.

Working Properties

Slaking. The average slaking time was 5 minutes.

Wet Properties. When tempered with 26 per cent of water it developed into a greenish grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 5 per cent.
The material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 53·1 pounds per square inch.

Softening Point. The softening point of this material was found to be cone 4 (1165° C.).

Burned Properties

When burned to cone 010 (890° C.) the resulting product was of a light salmon colour and soft. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 0·5 per cent and the average absorption was 12·8 per cent.

When burned to cone 06 (1005° C.) the product was of a good brick-red colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 4·5 per cent and the average absorption was 3·9 per cent.

When burned to cone 03 (1080° C.) the product was of a darker red than that of the previous burn, and harder. The briquettes were slightly scummed but their structure was good. The fire shrinkage averaged 5·5 per cent and the average absorption was 2·8 per cent.

When burned to cone 01 (1110° C.) the product was of still a darker red than that of the previous burns. The briquettes were slightly scummed but their structure was good. The fire shrinkage averaged 5·5 per cent and the average absorption was 2·8 per cent.

When burned to cone 2 (1135° C.) the briquettes swelled.

DRY-PRESS TESTS

Pressing. This material balled up badly when tempered with 8 per cent of water. When pressed the sides of the briquettes were badly cracked.

Burning. When burned to cone 01 (1110° C.) the product was of a good brick-red colour and steel hard. The average absorption was 3·4 per cent.

Remarks

The burning range lies between 1005° C. and 1110° C.

The material might be adapted to the dry-press process but considerable experimental work would be necessary.

The vitrification begins at a low temperature. Hence care will be needed in the burning to prevent the formation of a carbon core.

The scum mentioned is not a serious matter.

Recommendation

This material is suitable for the manufacture of building brick and hollow building tile by the stiff-mud process.

Sample No. 9

Location

This sample was taken from the property of the Rothwell Coal Company, located three-quarters of a mile southeast of Minto.

Nature of Material

This was a brown, gritty, weathered undershale which was non-calcareous.

Working Properties

Slaking. The average slaking time was 4 minutes.

Wet Properties. When tempered with 17 per cent of water, it developed into a muddy brown, flabby mass of poor working quality.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 3·4 per cent.

The material will withstand comparatively fast drying.

Softening Point. The softening point of this material was found to be cone 18 (1485° C.).

Burned Properties

When burned to cone 010 (890° C.) the product was of a light salmon colour and very soft. The briquettes were scummed red. The fire shrinkage averaged 2 per cent and the average absorption was 16·1 per cent.

When burned to cone 06 (1005° C.) the product was of a light salmon colour and very soft. The briquettes were scummed red. The fire shrinkage averaged 3·9 per cent and the average absorption was 15·5 per cent.

When burned to cone 03 (1080° C.) the product was of a light salmon colour and soft. The briquettes were scummed red. The average absorption was 14·7 per cent.

When burned to cone 01 (1110° C.) the product was of a light salmon colour and soft. The briquettes were scummed red. The average absorption was 14·3 per cent.

When burned to cone 2 (1135° C.) the product was of a light salmon colour and soft. The briquettes were scummed red. The fire shrinkage averaged 3·9 per cent and the average absorption was 14·3 per cent.

When burned to cone 4 (1165° C.) the product was of a light salmon colour and fairly hard. The average absorption was 13·5 per cent.

Recommendation

The material has no property that would make it of any value for the manufacture of ceramic products.

Sample No. 10

Location

This sample was taken from the property of the Rothwell Coal Company, located three-quarters of a mile southeast of Minto. It was taken from points two feet under the surface, from a heap that had been exposed for 11 years.

Nature of Material

This was a grey, weathered overshale and was free from any visible objectionable material, and non-calcareous.

Working Properties

Wet Properties. When tempered with 20 per cent of water, it developed into a greenish grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of the tempered mass and dried thoroughly showed an average drying shrinkage of 7·1 per cent. It will withstand comparatively fast drying.

Softening Point. The softening point of the material was found to be cone 8 (1225° C.).

Burned Properties

When burned to cone 010 (890° C.) the product was of a salmon colour and soft. The briquettes were in good condition and their structure was fair. The fire shrinkage averaged 2·7 per cent and the average absorption was 17·7 per cent.

When burned to cone 06 (1005° C.) the product was of a deeper salmon colour and fairly hard. The briquettes were in good condition and their structure was good.

When burned to cone 03 (1080° C.) the product was of a light brick-red colour and fairly hard. The briquettes were bloated and scummed white; each briquette had a carbon core. The average absorption was 8·2 per cent.

When burned to cone 01 (1110° C.) the product was of a good brick-red colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 8·9 per cent and the average absorption was 6·3 per cent.

When burned to cone 2 (1135° C.) the product was of a good brick-red colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 11 per cent and the average absorption was 6 per cent.

When burned to cone 4 (1165° C.) the product was bloated and very hard. The average absorption was 4·8 per cent.

Remarks

The material contains a sufficient amount of carbonaceous matter to cause carbon coring if care is not taken in burning. This is evidenced by the bloating which took place in the 03 burn.

The bloating which took place in the cone 4 burn was due to over-firing.

The scum mentioned in the 03 and 01 burn is slight.

The burning range of this material lies between 1080° C. and 1135° C. and the best product will be obtained at cones 01 and 2.

Recommendation

The material is suitable for the manufacture of building brick and hollow building tile by the stiff-mud process.

Sample No 11

Location

This sample was taken from the property of the Rothwell Coal Company, located three-quarters of a mile southeast of Minto.

Nature of Material

This was a light grey, fresh undershale which was free from any visible objectionable material, and non-calcareous.

Working Properties

Slaking. The average slaking time was 4 minutes.

Wet Properties. When tempered with 26 per cent of water, the material developed into a dark grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 3·7 per cent.

The material will withstand comparatively fast drying.

Dry Strength. The average modulus of rupture was 67·5 pounds per square inch.

Softening Point. The softening point was found to be cone 15 (1410° C).

Burned Properties

When burned to cone 010 (890° C.) the product was of a fair buff colour and fairly hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 5·2 per cent and the average absorption was 11·9 per cent.

When burned to cone 06 (1005° C.) the product was similar to that of the previous burn in colour and hardness. The fire shrinkage averaged 5·9 per cent and the average absorption was 11·2 per cent.

When burned to cone 03 (1080° C.) the product was of a darker buff colour and hard. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 5·1 per cent and the average absorption was 8·5 per cent.

When burned to cone 01 (1110° C.) the product was a darker buff colour and harder than that of the previous burns. The briquettes were in good condition and their structure was good. The average absorption was 6·2 per cent.

When burned to cone 2 (1135° C.) the product was similar to that of the previous burn in colour and hardness. The briquettes were in good condition and their structure was good. The fire shrinkage averaged 8 per cent and the average absorption was 6·1 per cent.

When burned to cone 4 (1165° C.) the product was of a greyish buff colour and steel hard. The briquettes were in good condition and their structure was good. The average absorption was 4·3 per cent.

When burned to cone 6 (1190° C.) the product was of a dark buff colour and steel hard. The briquettes were in good condition and their structure good. The average absorption was 4·3 per cent.

DRY-PRESS TESTS

Tempering and Pressing. When tempered with 10 per cent of water, this material balled up slightly. Briquettes pressed from this tempered mass were cracked on the sides.

Burned Properties. When burned to cone 03 the resulting product was of a good buff colour and hard. The buff colour was mottled with red. The briquettes were in good condition, and their structure was good. The average absorption was 8 per cent.

When burned to cone 01, the product was similar in colour and hardness to that of the previous burn. The briquettes were in good condition and their structure was good. The average absorption was 7·2 per cent.

When burned to cone 2, the product was similar in colour and hardness to that of the two previous burns. The briquettes were in good condition and their structure was good. The average absorption was 6·6 per cent.

Remarks

The burning range of the material lies between 1110° C and 1190° C. The material takes a good salt glaze at cone 1.

Recommendation

The material is suitable for the manufacture of building brick and hollow building tile by the stiff-mud process.
It is also suitable for the manufacture of conduits and sewer pipe.

Sample No. 12

Location

This sample was taken from the workings of the Burpee Construction Company, near Wilson brook, 3 miles south of Chipman and about 10 miles east of Minto Coal Company's workings.

Nature of Material

This was a grey, weathered overshale which was free from any visible objectionable materials, and non-calcareous.

Working Properties

Slaking. The average slaking time was 4 minutes.

Wet Properties. When tempered with 23 per cent of water, the material developed into a dark grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes made of this tempered mass and dried thoroughly showed an average drying shrinkage of 4·9 per cent.
It will withstand comparatively fast drying.

Softening Point. The softening point was found to be cone 8 (1225° C.).

Burned Properties

When burned to cone 010 (890° C.) the product was of a pinkish buff colour and very soft. The fire shrinkage averaged 2·9 per cent and the average absorption was 15·5 per cent.
When burned to cone 06 (1005° C.) the product was of a very light salmon colour and soft. The fire shrinkage averaged 5·9 per cent and the average absorption was 14·3 per cent.
When burned to cone 03 (1080° C.) the product was of a very poor buff colour and hard. There was a tendency toward a red colour in spots. The briquettes were distorted by a carbon core. The fire shrinkage averaged 9 per cent and the average absorption was 5·4 per cent.
When burned to cone 01 (1110° C.) the product was of a poor brick-red colour and hard. There were some red spots. The fire shrinkage averaged 8·7 per cent and the average absorption was 3·2 per cent.
When burned to cone 2 (1135° C.) the product was similar in colour and hardness to that of the previous burn. The fire shrinkage averaged 7·5 per cent and the average absorption was 2·2 per cent.

DRY-PRESS TESTS

Tempering and Pressing. When tempered with 10 per cent of water, the material did not ball up. When pressed, the briquettes cracked on the sides.

Burned Properties. When burned to cone 03 the product was of a greenish buff colour, and steel hard, but the briquettes were bloated. The average absorption was 6 per cent.

When burned to cone 2 the product was of a greenish buff colour in places and of a light red in others. The briquettes were sound and steel hard.

When burned to cone 4 the product was badly bloated.

Recommendation

This material is suitable for the manufacture of common brick and hollow building tile.

Sample No. 13

Location

This sample was taken from the workings of the Burpee Construction Company, near Wilson brook, 3 miles south of Chipman and about 10 miles east of Minto Coal Company's workings.

Nature of Material

This was a dark grey, weathered undershale which was free from any visible objectionable material, and non-calcareous.

Working Properties

Slaking. The average slaking time was 8 minutes.

Wet Properties. When tempered with 25 per cent of water, the material developed into a dark grey, plastic mass which was easily moulded into briquettes.

Drying Properties. Briquettes showed an average drying shrinkage of 7·2 per cent and the material will withstand comparatively fast drying.

Softening Point. The softening point was found to be cone 6 (1190° C.).

Burned Tests

Briquettes were burned to various temperatures. The product contained a large carbon core and was heavily scummed. The briquettes were distorted badly and of a poor colour.

Recommendation

This is a poor material and cannot be recommended for the manufacture of any ceramic product.

IV

ROAD MATERIALS IN PRINCE EDWARD ISLAND

R. H. Picher

During part of the field season of 1927, investigations were conducted in Prince Edward Island, with a view to finding suitable material for surfacing the main highways. At present all materials used for that purpose are brought in from outside the province, at considerable expense, and it is felt by the highway officials that the cost of road improvement would be materially reduced if suitable surfacing material in large enough quantity could be located within the borders of the province.

A brief inspection of the various types of rock available showed that there was only one type, conglomerate, that could probably give satisfactory results in the improvements of highways. Loosely bonded conglomerate, which closely resembles ordinary gravel, is found associated with sandstone, and more or less mixed with it. The sandstone, which underlies the whole province and is exposed at the surface at numerous places, is too friable to make a good road metal and is generally unsuitable for use in the building of sand-clay roads because of its fineness of grain. The detailed field investigation was, therefore, almost exclusively confined to the conglomerate deposits. These are few in number, and none of them is very large, but their importance is greatly enhanced since they are the only source of satisfactory road metal within the province. In conducting the investigation, particular attention was paid to deposits within reasonable distance of the railroad, as it was the expressed intention of the highway officials, if any large deposit could be located within a short distance of a railway, to connect it by spur to the latter and distribute the material by rail to points less favourably situated as regards road stone. The province has large areas which are absolutely devoid of any kind of stone.

The field work was started in the western part of the province where, due to the bad condition of the soil roads when wet, the need for road improvement was more urgent. Moreover, in the western part of the province, all railway lines are of standard gauge, whereas in the eastern part, there is a large district served by a narrow gauge line, which cannot haul material outside of the district without additional cost. Due to the lateness of the season and unfavourable weather conditions, part of the field work had to be postponed till another year.

Following is a description of the several deposits examined. Apart from No. 3 and No. 11, which are gravels, all the others are conglomerate.

NOTE.—In this report, the term *pebble* refers to all material retained on a screen with ¼-inch round openings, while that material passing through the ¼-inch screen is referred to as sand. All sand retained on a 28-mesh Tyler sieve is designated as *coarse sand* and all passing same as *fine sand*.

Deposit No. 1

One Mile West of Hartsville, Lot 67. On the farm of Eastgate Humphrey, and half way between the Junction road and the new Bedeque road, a small pit, 7 feet in depth and 150 cubic yards in size, shows conglomerate composed of about 55 per cent rounded, very hard and smooth quartz and quartzite pebbles, and 45 per cent fine, dusty quartz sand. A large proportion of the sand is fine, but the material as a whole may be considered suitable.

The conglomerate forms two small, ridge-like elevations on top of a wide, flat hill. Some years ago test pits were dug by the Canadian National Railway Company, to ascertain the extent of the deposit. From test pit records it would appear that the conglomerate areas are limited to the two small ridges and that the remainder of the hill is underlain by soft, friable sandstone. The maximum height of the conglomerate ridges above the sandstone hill is 7 feet. No pits were dug to ascertain the depth of the conglomerate. At the main pit, it is said to have a depth of 13 feet, which may be considered as a maximum thickness. Measurements give 7,300 square yards as the extent of the conglomerate, so that with an assumed average depth of 2 yards, which may be considered a conservative estimate, the deposit would be 14,600 cubic yards in volume, and would yield enough material for surfacing over 12 miles of road to a width of 12 feet, and average depth of 6 inches.

The deposit lies at a distance of 1½ miles from the railway. The whole area between the deposit and the railway was prospected for suitable road surfacing material with negative results. The conglomerate appears to be suitable for use in road improvement, but there is not enough to warrant building a spur line and shipping the material by rail. It is within reasonable truck hauling distance of the Princetown road, and could be used to surface part of this road on both sides of Fredericton. Prospecting was also carried on along the line of strike of the rock strata, that is, in a northwest—southeast direction. One mile northwest of Humphrey's pit, similar material to the one just described was found on the farm of Hedley MacPherson.

Deposit No. 2

Two-thirds Mile North of Springton, Lot 67. On the farm of Hedley MacPherson, and along the road between Fredericton and Springton, two very small excavations, 1 and 2 feet in depth respectively, show material very similar to No. 1.

The conglomerate occupies the lower slope of a small, flat-topped sandstone ridge, and in places forms the bed of a small creek running at the foot of the ridge and parallel to it. The deposit is covered with a thick growth of fir and spruce, and in order to determine its full extent, as well as its depth, tree cutting will be necessary. With the aid of a pick, the presence of conglomerate was ascertained over an area of approximately 300 by 30 yards, or 9,000 square yards. With an assumed depth of 1 yard, there would be 9,000 cubic yards of material. Not more than half of this amount could be obtained without interference by water, unless the digging is done after a prolonged spell of dry weather.

The deposit is about the same distance from the railway as No. 1. Although not important enough in volume to justify being tapped by rail, the conglomerate could be used with advantage in the improvement of local roads. In order to avoid trouble arising from lack of drainage, the lowest part of the deposit, that is, that part west of the road, should be excavated first, and as much material as possible should be taken out in one season, as the probabilities are that once the excavation is flooded, it will remain flooded the whole year. That part of the deposit east of the road, which is at a higher level, could then be worked as the need for more material is felt.

Deposit No. 3

One-third Mile South of Bonwell, Lot 30. Along the road between Kelly's Cross and New Wiltshire, coarse, stratified sandstone gravel is seen in several road cuts, both sides of a brook which runs into the Eliot river. The gravel, although regularly graded, is composed of very soft and friable sandstone and shaly sandstone pebbles. These crumble readily on the road, even under light traffic, and for that reason the gravel is not considered suitable for road surfacing. It could be used locally, at best, to fill low, soft places on the road, where it would impart to the soil a greater supporting power. The amount of gravel available is apparently small, and due to the low grade of the material, no attempt was made to determine approximately the extent of the deposit.

Deposit No. 4

One Mile North of Millvale, Lot 22. On the farm of Wendell Murphy and the next farm to the west along the road there are several small, irregular excavations in medium fine conglomerate, composed of 50 per cent of rounded, hard, smooth quartz pebbles and 50 per cent of fine, dusty quartz sand. A large proportion of the sand is fine but not to such an extent as to affect seriously the suitability of the conglomerate for road purposes.

The conglomerate is found at many places near the surface of a ridge which trends approximately in a northwest-southeast direction and is traversed at an angle by a road in its middle part. At both ends of the ridge the conglomerate runs close to the surface, but in its middle part, where the road traverses it, the ditches do not show any sign of conglomerate. It may be that it is here deeply covered with soil. The thick bush which grows over the larger part of the ridge renders prospecting difficult, and in order to determine the extent and depth of the deposit, it will be necessary to cut trees and dig test pits. For the present, the estimate of the amount of conglomerate available will not include the middle part of the ridge. In the southeast end there is an area of 6,000 square yards, and in the northwest end an area of 3,000 square yards underlain by conglomerate. All the excavations referred to above are in the southeast part of the ridge and along its edge, that is, at a lower level than the average of the deposit. The largest pit, which is 4 feet deep, does not reach the bottom of the conglomerate, so that an average depth of 6 feet may be conservatively assumed for the whole deposit. On that basis there would be 18,000 cubic yards of material available, or enough to surface 15 miles of road. A large pit can be easily kept dry.

The deposit is 5 miles in a straight line from the railway, and the intervening country is quite hilly. Under these conditions, the deposit is not important enough to connect it by spur line to the railway. Hauling by road is the only means of transporting the material, but the many long and steep grades encountered on certain roads would considerably limit the economical length of haul.

Deposit No. 5

Two and Three-quarter Miles South of Port Hill, Lot 14. On the farm of Leslie MacLean, and along the road between Port Hill and Black Point ferry landing, a deposit of conglomerate forms a small flat-topped ridge trending approximately east-west. There is no pit opened in the deposit. A sample collected on the surface, after removing the thin soil covering, shows the conglomerate to be made up to 45 per cent of small, hard and smooth quartz and quartzite pebbles, and 55 per cent of fairly coarse, dusty quartz sand. The proportion of pebbles to sand is rather low, although not unduly so. The material is said to become less sandy with depth.

It does not appear that the conglomerate extends over the whole ridge, but it certainly covers at least two acres, as judged by surface indications. According to information received from the owner of the place, in drilling a well on top of the ridge, conglomerate was encountered to a depth of 6 feet, then sandstone to a depth of 9 feet, and conglomerate to a depth of 17 feet, the latter coarser, that is containing less sand than the conglomerate resting on top of the sandstone. The well was drilled near the east end of the ridge, on which the owner's house and farm buildings are located. It is not practicable to give a fair estimate of the amount of conglomerate until the depth at the west end of the deposit has been determined. If it is assumed that the same depth prevails all along the crest, and also that the thickness of the sandstone layer is the same, then 14 feet may be considered as the maximum depth, after the thickness of the sandstone layer has been deducted, and 9 feet as the average depth. Under this assumption, the amount of conglomerate would be between 25,000 and 30,000 cubic yards.

Because of the relatively small size of the deposit and its distance from the railway, which is 4½ miles in a straight line, connexion by a spur line is out of the question. As road surfacing material it can be used only on local roads, that is, as far as it can be economically hauled by trucks. The removal of the sandstone would materially increase the cost of getting the conglomerate, but this should not prove a serious obstacle, since the sandstone is thin-bedded, quite friable, and should thus be easy to dislodge. Of course, before starting to work this deposit, it would be advisable to wait until similar material found in already opened pits in other parts of the province has been tried and proved to be a satisfactory surfacing material.

Another deposit of conglomerate occurs along a side road, two-thirds of a mile west of the one just described, but is too small in extent to be of any value.

Deposit No. 6

One and One-quarter Miles South of Freeland, Lot 11. Along the road between Freeland and Tyne Valley, on the farm of Thomas Boyle and on three other farms, there is a deposit of conglomerate, composed of about 60 per cent of hard, smooth quartz and quartzite pebbles, and 40 per cent of fairly coarse, dusty quartz sand. It is on the whole very regularly graded, and should prove a good surfacing material.

The deposit is level with the surrounding land which is quite flat. Apart from the small outcrop along the road there are but few surface indications of the underlying conglomerate. The extent of that part of the deposit lying east of the Freeland-Tyne Valley road was fairly accurately determined by digging test pits. The test pits were opened primarily with a view of determining the thickness of the conglomerate deposit, but it was found impracticable to proceed any deeper than 4½ feet on account of underground water.

Following is a section of the several test pits:

Pit A, 190 yards east of main road: top soil, 12 inches; strongly cemented conglomerate, 18 inches; loose conglomerate, 24 inches. The pit, which was 4½ feet deep, did not reach below the conglomerate. Sample 6A (*see* Table) was taken from near the bottom of the pit.

Pit B, 330 yards east of the main road: top soil, 6 inches; strongly cemented conglomerate, 18 inches; friable sandstone, 6 inches; loose conglomerate, 24 inches. The pit, 4½ feet deep, did not reach below the conglomerate. Sample 6B was taken from near the bottom of the pit.

Pit C, approximately 600 yards east of main road: friable sandstone under sandy soil. No conglomerate. Depth of pit, 2 feet.

Pit D, approximately 800 yards east of main road. Same material as in Pit C. Depth of pit, 2 feet.

Pit E, 70 yards east of main road: top soil, 6 inches; friable, black sandstone, 8 inches; rather loose conglomerate, 13 inches. The pit, 2¼ feet deep, did not reach below the conglomerate.

West of the Freeland-Tyne Valley road, prospecting work was limited to making soundings with an iron bar to ascertain the presence of conglomerate and the thickness of overburden. The latter increases in thickness towards the north and west. In the area mapped as conglomerate, the thickness of overburden does not exceed 3 feet. Outside of this area, conglomerate was reached only at two places along the Conway road under 3 feet of covering, although it may extend much farther towards the west and north, and possibly join deposit No. 7.

An average depth of 3 feet, exclusive of the overburden, has been assumed for the conglomerate area, which, according to information received from one of the owners, would be a very conservative estimate. There would then be 150,000 cubic yards of conglomerate, of which 80,000 cubic yards lie east of the main road and 70,000 west of it. All the material east of the road could be easily excavated without much stripping, but west of the road the overburden is much thicker (up to 3 feet in places along the Conway road) although it apparently decreases in thickness towards the south, where 20,000 cubic yards could be obtained as easily as the 80,000 cubic yards east of the main road. This would be enough to surface 85 miles of road, without touching the 50,000 cubic yards lying under the thicker overburden.

There is a distance of 1½ miles from the deposit to the railway siding at Conway. The same spur line could conveniently tap both this deposit and deposit No. 7, which lies farther to the west and close to Conway.

Deposit No. 7

One-third Mile East of Conway. On the farms of "Old" Charles Palmer, Charles Palmer, Nelson Palmer, and R. C. Henderson; a small pit, 4 feet in depth, on Charles Palmer's farm, shows the conglomerate to be very similar to No. 6.

The deposit is in the form of a long, narrow tongue, and rises but very slightly above the level of the land which is quite flat. The conglomerate does not outcrop at any place, but lies very close to the surface. The extent of the deposit was fairly accurately determined by digging test pits but, as in the case of No. 6, underground water prevented digging the pits deeper than 4½ feet, so that the thickness of the deposit could not be ascertained.

Following is a section of the several test pits:—

Pit A, approximately 550 yards east of Palmer's pit: depth, 2 feet; top soil, 18 inches; sandstone, 6 inches. No conglomerate.

Pit B, approximately 400 yards east of Palmer's pit: depth, 4½ feet; top soil, 12 inches; conglomerate and sandstone, 24 inches. Sandstone only below 3 feet.

Pit C, approximately 300 yards east of Palmer's pit: depth, 2 feet; sandstone below 18 inches of top soil. No conglomerate.

Pit D, 135 yards north of Palmer's pit: depth, 2 feet. Sandstone only below 12 to 18 inches of top soil. No conglomerate.

Pit E, 140 yards east of Palmer's pit: depth, 4½ feet; top soil, 18 inches; conglomerate with a little sandstone, 3 feet. The pit did not reach below the conglomerate. Sample 7E (*see* Table) was taken at depth of 4 feet.

Pit F, 70 yards southeast of Palmer's pit: depth, 4½ feet; top soil, 6 inches; conglomerate to the bottom. The pit did not reach below the conglomerate. This is an old test pit, now completely refilled, said to have been dug by the Canadian National Railway Company to a depth of 10 feet, and conglomerate found to a depth of 9 feet.

Pit G, 200 yards northwest of Palmer's pit, at the corner of a field: depth, 2 feet; no conglomerate.

Pit H, approximately 80 yards north of Nelson Palmer's house: depth, 4½ feet; top soil, 12 inches; conglomerate to the bottom. The pit did not reach below the conglomerate. Sample 7H was taken at bottom of pit.

Pits I, approximately 120 yards north of Nelson Palmer's house. Two pits were dug, 2 yards distant and 3½ feet deep, at the edge of the deposit. One pit shows conglomerate, and the other sandstone, with but few pebbles.

Pits J, approximately 50 yards northwest of Nelson Palmer's house. Three pits were dug, a few feet apart and 4 feet deep, at the edge of the deposit. One pit shows conglomerate with a little sandstone; another is through sandstone only; while the third pit, dug half way between the two others, shows sandstone on one side and conglomerate with a little sandstone on the other. At both pits I and J, the line of separation between the sandstone and the conglomerate is well defined and is highly inclined on the horizontal.

Pit K, approximately 325 yards north of Nelson Palmer's house: depth, 3 feet; top soil, 12 inches; conglomerate with much sandstone to the bottom. Sample 7K was taken at the bottom of the pit.

Pit L, 30 yards southwest of pit K: depth, 2½ feet; top soil, 12 inches; fine conglomerate with much sandstone to the bottom.

Pit M, 30 yards northeast of pit K, same as pit L. Pits K, L, and M did not reach below the conglomerate.

Along the road between Conway and Lot Eleven, there are outcrops of sandstone, but a careful examination of the ditch sides and soundings with an iron bar failed to reveal the presence of conglomerate. If there is any conglomerate north of pits K, L, and M, it is probably mixed with so much sandstone as to be unsuitable for road-surfacing purposes. The presence of conglomerate was ascertained at several points between deposits Nos. 6 and 7, but it is not known whether these are isolated patches or are continuous with Nos. 6 and 7, and they were not considered in estimating the amount available.

The area underlain by conglomerate measures 81,750 square yards. At Charles Palmer's pit, the thickness of conglomerate is said by owner to be 10 feet, and at two old test pits nearby, dug by the Canadian National Railway Company, and now completely refilled, the thickness is said by the same man to be 9 feet. With an average depth of 2 yards assumed for the whole deposit, there would be 163,500 cubic yards of material, or enough to surface 140 miles of road. It will be, of course, necessary to sound the depth of the deposit at several points in order to accurately measure the amount of conglomerate available. The assumed depth of 2 yards is thought to be less than the actual average depth of the deposit.

The deposit is hardly one-third mile from the railway siding at Conway, and is crossed by a railroad bed that leads to an old Canadian National Railway pit, on Thomas Boyle's farm, near Freeland. At the Conway end of the road-bed, there is a "Y", so the only thing that remains to be done to connect the deposit with the railway is to lay the ties and the rails on that part of the road-bed between the end of the "Y" and the deposit. In order to excavate the conglomerate to its full depth, it will be necessary to lower the road-bed over a certain distance, so as to reduce the grade down the pit.

The most serious difficulty that will be encountered in the work of excavation will be providing for adequate drainage. The land is level, badly drained, with two marshes close to the deposit. The latter was visited towards the end of October, after a prolonged spell of very wet weather, and at no place within the conglomerate area was the underground water-level more than 3 feet below the surface. Even under normal weather conditions, it is doubtful whether the conglomerate could be successfully excavated to its full depth without provision being made for pumping out the water. There are two houses and other farm buildings that would have to be removed before the excavating of the conglomerate is commenced. A large pit extending over the whole deposit would cut across three farms, but on one side of it, the east side, there is very little cultivated land, and the soil, which is fine sand, does not seem well suited for agricultural purposes.

Of all the deposits examined, Nos. 6 and 7, because of their size and proximity to the railway, appear to be most advantageous for linking by rail and working on a large scale. An additional advantage is that in the matter of grading, they more closely approach the College Bridge conglomerate of New Brunswick, which has been extensively used on roads with good results.

Deposit No. 8

Near Freeland. On the farm of Thomas Boyle, a deposit of quartz conglomerate was worked some years ago by the Canadian National Railway Company for the production of ballast material. It is now abandoned, and the rails and ties have been removed from the road-bed between the deposit and the " Y " at Conway. The depth of the old pit varies from 6 to 10 feet, with sandstone in the bottom. There is a certain area, including the owner's house and farm buildings, which is underlain by conglomerate, and which was not excavated by the railway company. The estimated amount is over 25,000 cubic yards, with an assumed average depth of 2 yards, exclusive of the overburden.

The conglomerate is a little over a mile from the railway at Conway. The amount of material available would not justify the expense incurred in securing the land and connecting the deposit by rail, unless some other equally important deposit could be tapped by the same spur line. As a result of a careful examination of the surrounding district, there were found only two other deposits, Nos. 9 and 10, which are very small in size.

Deposit No. 9

Freeland. On the farm of W. C. Palmer, and along the main road, a small deposit of very sandy, quartz conglomerate, forms a small, flat dome, and is covered with about 2 feet of sandy loam.

Two test pits were dug, one on the very top of the dome, to a depth of 4 feet, through 2 feet of sandy soil and 2 feet of conglomerate with much sandstone, the latter crumbling quite readily into sand. Sample 9A (*see* Table) represents material from the bottom of this test pit. The other pit was dug a short distance south, in the upper slope of the dome, through much the same material as pit 9A. Neither pit reached the bottom of the conglomerate, but in the lower slope of the dome sandstone only is found.

The deposit is too small and the conglomerate is mixed with too much sand (very friable sandstone), to be worth considering as a source of road-surfacing material.

Deposit No. 10

Freeland. On the farm of Wesley Palmer, an old pit, now all talus-covered, shows quartz conglomerate very similar to Nos. 6 and 7.

The pit, which is 4 feet deep, is on the top of a small, flat dome. A small test pit was dug in the bottom of the old pit, through 1 foot of conglomerate and then sandstone, so that the total thickness of conglomerate, overburden included, would be 5 feet on top of the dome. A second test pit, 3 feet in depth, was dug in the slope of the dome, east of the old pit, and 10 feet below the top of the dome. Under 2 feet of sandy soil, sandstone only was found. Apparently the conglomerate is confined to the upper 5 feet of the dome, and amounts to 9,000 cubic yards, overburden included.

The deposit lies a short distance from the old railway pit on Thomas Boyle's farm, with a swampy depression intervening. The amount of suitable road material that it contains is too small to warrant its being linked to railway.

Deposit No. 11

Northeast of Lot 11. On the farm of Joshua Henderson, between the owner's house and the bank of Eel creek, there is a steep-sloped bluff where three test pits were dug, one of which was 5 feet in depth. The material found was a gravelly sand, with at least 90 per cent sand, and with but few hard pebbles. It cannot be considered a durable material for road surfacing.

On the opposite side of the road from the owner's house, and a short distance from it, there is a fairly large deposit of sandy gravel. Six years ago test pits were dug by the Canadian National Railway Company, and, according to the owner, this gravel was found to depths of from 10 to 12 feet. All the pits are now more or less completely refilled, but in some of them the upper 3 to 4 feet of the bank is still visible. The material consists of about 50 per cent of hard quartz and quartzite pebbles, and 50 per cent sand. The deposit has an overburden of about 3 feet of sand.

On account of the distance from the deposit to the railway, which is 2½ miles in a straight line, the necessity of building two bridges over creeks, if connected to the railway, and the thickness of overburden on top of the gravel, the latter would be more costly to extract than either No. 6 or No. 7, and its durability as a road-surfacing material would probably not measure up to either No. 6 or No. 7.

Deposit No. 12

One Mile West of Portage. On Lewis' farm and along the railway, a deposit of quartz conglomerate forms a small elevation surrounded by low, swampy ground.

About 17 test pits were opened on the deposit by the Canadian National Railway Company. At the time of the visit (October, 1927), all pits were partly filled with water, with only the upper foot above groundwater level, and their depth varied from 3 to 6 feet; part of the material from the pit walls had fallen into the bottom. As judged by the pit dumps, the conglomerate would form an elongated deposit running roughly parallel to the railway, with sandstone on both sides of the conglomerate. The pits with dumps composed of conglomerate (more or less mixed with sandstone) run in a line across the small elevation, while on both sides of this line or strip, the pit dumps show sandstone exclusively. An approximate estimate gave 10,000 square yards as the conglomerate area, which would make 20,000 to 30,000 cubic yards of material (a depth of from 2 to 3 yards being assumed).

In digging out the conglomerate it will be necessary to pump the water out of the pit, since the encasing sandstone layers are too porous to prevent the water of the surrounding swamp from finding its way into the excavation.

Deposit No. 13

Goff Bridge, Lot 10. On the south bank of Trout river, and immediately east of the main road, quartz conglomerate is exposed over a distance of 150 feet and a thickness of 8 feet. The conglomerate is coarse, and is in places interstratified with thin layers of very friable sandstone which readily crumbles into sand. It is made up approximately of 65 per cent pebble and 35 per cent sand. A large proportion of the sand is rather fine, but the material as a whole may be considered quite suitable for roads. Sample 13 (*see* Table) was taken from the exposed face along the south bank of the river, where conglomerate has been dug to surface a short stretch of the main road south of the bridge.

The extent of this deposit has not been determined, on account of lack of time. It will be necessary to dig test pits south of Trout river and on both sides of the main road, to determine not only the depth of the conglomerate, but also its extent, since surface indications are very meagre. The deposit is said to cover 4 to 5 acres, and to be 16 feet deep near the shore. It is apparently thicker than all other deposits considered so far, except No. 5, which is a decided advantage since, for the same amount of road material, less land has to be acquired, less stripping is necessary, and a steam shovel can be operated more satisfactorily. With regard to connecting the deposit to the railway and transporting the material by rail, conditions here are less favourable than in the case of Nos. 6 and 7. The total amount of conglomerate available is much smaller, and the distance to the railway greater. More than two miles of track would have to be built to connect with the railway siding at Portage. But the deposit is very favourably situated for easy working and truck hauling, and should be developed to the utmost for that purpose. It lies right along the main highway, with but a gentle grade from the bottom of the excavation to the road, and the stripping and disposal of waste material would present no difficulty, since the excavation is right in the river bank.

Conglomerate of the same character is also exposed in the north bank of Trout river, and is just as easy of access, but the amount is apparently smaller than on the south bank.

Deposits Nos. 14, 15, and 16

No detailed investigation has been conducted on these three deposits, the location and grading of which are shown in the Table.

SUMMARY

The suitability of the Prince Edward Island conglomerates as surfacing material cannot be judged yet by service tests, as very little material has been used so far for that purpose. The few short stretches where it had been used were on secondary roads subjected to light traffic and these were found to be in excellent condition. As to the behaviour of the conglomerate under a moderate amount of fast-moving motor traffic, it should be easy to judge by surfacing short stretches on some of the main highways, and more information could be obtained in this way than by any laboratory test. The material could be hauled from some of the more easily accessible deposits, such as Nos. 1, 7, and 13. This should be the first step to be taken, if an extensive use of the conglomerate for road improvement is contemplated.

The only material that has been used to some extent in surfacing the main highways of the province is the College Bridge conglomerate and the Sussex gravel, both brought in from New Brunswick. The College Bridge conglomerate has given very good results. It does not make a very smooth surface, but compacts quite readily, with the result that very little sinks into the subsoil. It is a good material to use as a first step towards the improvement of earth roads, as it quickly builds up a good and strong course which may serve as foundation for further improvement. The Sussex gravel has not proved so satisfactory. It is a river gravel, devoid of fine material, and is too uniform in size. Used on an already built base, it makes a very good and durable surface, but if used on an earth road, a large proportion sinks into the soil before it becomes sufficiently compacted. This is not a serious disadvantage where the gravel is easily available at low cost, but it becomes expensive where it has to be transported a long distance, and such is the case for this province. There is little doubt that the Prince Edward Island conglomerate will give better results than the Sussex gravel, and may even be compared with the College Bridge conglomerate.

One striking feature of the conglomerates of Prince Edward Island is that they are all alike in character. They are all composed of rounded, very hard and smooth, quartz and quartzite pebbles, and dusty quartz sand. Their only difference lies in the coarseness of pebbles and sand and the relative proportion of both. As road material they are probably somewhat inferior to the Nova Scotia and New Brunswick conglomerates, because of their rounded, very hard and smooth pebbles and their high content of fine sand, although some of them are free from the latter defect. The probable effect of these defects would be that the material would not compact so readily on the road. This could be partly offset by crushing the conglomerate before using, but it would bring the cost of road improvement considerably higher, and besides, most of the conglomerates, on account of their small content of large pebbles, would have to be crushed too fine to produce the necessary amount of angular material, with the result that their durability as surfacing material would be decreased.

The Prince Edward Island conglomerates are unsuitable for use as concrete aggregates, and this applies also to all New Brunswick and Nova Scotia conglomerates. Even washing the material does not sufficiently improve it to warrant its use for such purpose. Stratified gravels and sands, no matter how poorly graded, give much better results as concrete aggregates than any of these conglomerates.

In excavating the conglomerate it will be found that that part of the deposit immediately below the overburden is very strongly cemented together. This applies only to the upper 12 to 18 inches. Below this crust, the material is easier to handle, although not so easy as gravel, and the use of a pick will be necessary in any case. If worked on a large scale it should be easy to excavate by steam shovel, without resorting to blasting. The steam shovel could not be operated so advantageously in shallow deposits, such as Nos. 6 and 7, but even in these it would be more economical than the hand pick and shovel.

Results of Tests on Conglomerate Samples

Sample No.	Location	Proportion of pebble to sand		Granulometric Analysis													Per cent passing 200 mesh	Remarks
				Pebble							Sand							
				Per cent retained on screens							Per cent retained on sieves							
		Per cent pebble	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
1	1 mile west of Hartsville.	55	45	0	6	6	15	15	24	34	24	7	8	26	23	4	7	Sample from regular pit. Total per cent of fine sand (27) too high.
4	1 mile north of Millvale.	51	49	0	0	7	13	15	22	43	24	8	7	37	20	3	1	Sample from regular pit. Total per cent of fine sand (30) too high.
5	2¾ miles south of Port Hill.	44	56	0	0	0	3	8	27	62	30	16	13	26	10	3	2	No pit. Sample from surface. Per cent of pebbles too low. Coarseness said to increase with depth.
6	1¼ miles south of Freeland.	61	39	0	0	7	15	15	25	38	39	12	6	10	21	5	7	No pit. Sample from road cut. Grading very regular.
6A	....	63	37	0	0	0	11	19	32	38	36	12	8	28	11	2	3	Sample from test pit, 190 yards east of road. Grading very regular.
6B	....	49	51	0	0	5	16	19	29	31	15	4	4	62	12	2	1	Sample from test pit, edge of deposit, 330 yards east of road. Total per cent of fine sand (39) too high. Conglomerate grades into sandstone.
7	⅓ mile east of Conway.	62	38	0	0	2	9	9	24	56	37	14	6	12	23	4	4	Sample from regular pit. Grading fairly regular.
7E	....	22	78	0	0	0	6	16	28	50	10	4	4	44	28	6	4	Sample from test pit. Per cent of pebbles too low and total per cent of fine sand (64) much too high.
7H	....	61	39	0	3	2	15	12	25	43	33	12	7	20	18	5	5	Sample from test pit. Grading very regular.
7K	....	47	53	0	0	5	15	17	21	42	29	14	8	27	14	3	5	Sample from test pit. Per cent of pebbles too low and per cent of fine sand (26) too high.

9A	Freeland...........	34	66	0	0	0	7	20	33	40	8	6	11	20	36	10	9	Sample from test pit. Per cent of pebbles too low and total per cent of fine sand (50) much too high.
13	Goff Bridge, lot 10.	64	36	0	3	16	24	18	17	22	17	3	2	18	42	8	10	Sample from bank cut along Trout river. Total per cent of fine sand (28) too bigh.
14	2 miles northeast of West Point.	55	45	10	0	15	29	13	15	18	11	3	3	22	38	9	14	Sample from test pit. Total per cent of fine sand (37) too high.
15	1½ miles northeast of Surrey Station....	67	33	0	13	20	20	13	17	17	11	2	2	35	36	4	10	Too little material retained on ¼-inch, 8, 14, and 28 mesh.
16	1 mile northeast of Peters Road, lot 63.	71	29	0	0	14	30	11	17	28	38	10	6	20	17	4	5	Grading fairly regular.

V

STONE QUARRIES IN QUEBEC

R. H. Picher

Part of the field season in 1927 was spent in visiting and sampling stone quarries in the province of Quebec. This work was a continuation of the investigation undertaken at the end of 1925 which consisted of obtaining information on stone quarries in Ontario and Quebec, having regard to the character of the stone and its road-making qualities, the plant equipment and capacity, the sizes of the product, and the transportation facilities. Most of the quarries visited since the beginning of the investigation are operated for the production of crushed stone. Some quarries, although not operated for crushed stone, were included in the work on account of the stone being the most suitable as road metal in the districts where the quarries are located.

The ordinary commercial sizes of crushed stone are 3, 2, $1\frac{1}{2}$, $1\frac{1}{4}$, 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ inch. The 3-inch stone is that passing a 4-inch screen and retained on a 3-inch screen; the 2-inch stone, passing a 3-inch and retained on a 2-inch screen, and so on. What passes the $\frac{1}{4}$-inch screen is called screenings, and is more or less waste material, except in the case of high-calcium limestone screenings, which find various uses. Some quarries in high-calcium limestone have equipment for pulverizing the screenings for asphalt filler and for agricultural purposes. In nearly all important crushed stone quarries the crushing and screening plant is so designed that any commercial size can be obtained, or several sizes recombined at will in specified proportions. The sizes of crushed stone produced at these quarries are largely governed by the demand.

Crushed stone is sold by weight and the price quoted per short ton. Of the various sizes, the $\frac{1}{4}$-inch stone commands the highest price. It sells for $1 f.o.b. quarry in Montreal. The price decreases a few cents for each succeeding larger size. Screenings sell lower than any of the other sizes, except high-calcium limestone screenings, for which there are special prices. In Quebec and Hull, the prices are about 10 per cent higher than in Montreal. These prices apply to crushed limestone. The Quebec sandstone is quoted at the same figures as the local limestone, and the Montreal "banc rouge" slightly higher than the local limestone.

In the following description of the quarries visited, the results of tests on samples from quarries Nos. 1, 3, 4, 5, and 7 are given in Geological Survey Memoir 114, "Road Materials in the City and District of Montreal," 1917, by Henri Gauthier; those on Nos. 12, 13, 15, 16, 18, 19, 20, and 21, in Mines Branch Report No. 645 "Investigations in Ceramics and Road Materials, 1924."

1. *The Villeray Quarry Co., Ltd., 848 du Rosaire St., Montreal.*

There are two excavations, the newer and larger measuring approximately 130 by 100 by 25 yards, and the older and smaller, 60 by 50 by 10 yards; each quarry has a separate crushing and screening plant. The blasted stone from the larger excavation is loaded into two 3-ton skips, which run between vertical steel guides fixed to the quarry wall. At the surface, the skips automatically dump the stone into the coarse crusher, which is a No. 7½ Gates gyratory. The fine crusher is a No. 4 Gates gyratory, and the combined capacity of both is 800 tons per day. The stone from the smaller quarry is loaded into boxes which are lifted by derrick to the crusher. These are two in number, the coarse, a No. 5 Gates gyratory, and the fine, a 24-inch Symons disk, with a combined capacity of 300 tons per day. The product is crushed limestone exclusively and the maximum capacity of the plant is 100 tons per hour. The company employs on the average 25 men. The plant is electrically operated, and connected by spur to the lines of the Montreal Tramways Company.

2. *Stone and Quarry, Limited (Operators for Montreal Quarry, Ltd.) —800 Bellechasse St., Montreal.*

The quarry is irregular in size and part is used as dumping ground by the city. The excavation covers approximately 130 by 130 yards, with a depth of from 30 to 45 feet. The blasted stone is loaded into skips which are hauled up an inclined track by cable and electric hoist. The product is crushed limestone and rubble, and the maximum capacity of the plant is 55 tons per hour. Hauling is done by motor trucks.

3. *Maisonneuve Quarry Co., Ltd.—Office: 4740 Iberville St.; Quarry: 4415 Boulevard Rosemont, Montreal.*

The company owns and operates a quarry on the north side of the street (formerly, Maisonneuve Quarry Co.), and operates another one, owned by the Commission du Parc de Maisonneuve, on the south side of the street. The quarried stone from the latter is carried on a conveyer belt over the street to the company's crushing plant. Both quarries are about 28,000 square yards in area; the company's quarry is 50 feet deep, and the Commission's, 35 feet deep. The upper 10 to 15 feet of the wall is "banc rouge" (tinguaite), while the rest is limestone. All the quarried stone is crushed and the maximum capacity of the plant is 100 tons per hour. It is connected by spur to the lines of the Montreal Tramways Company. Hauling is also done by trucks.

4. *O. Martineau & Fils, Ltée.—Office: 371 Marie Anne St. East; Quarry: Masson St., Montreal.*

There are two excavations, the larger covers 27,000 square yards and is 60 feet deep, and the smaller, 7,000 square yards and is 40 feet deep. The quarried stone is loaded into boxes which are brought up to the crushers by four steel cranes and hoists. The product is crushed limestone and "banc rouge" (tinguaite), also limestone rubble. The maximum capacity of the plant is 150 tons per hour. It is connected by spur to the lines of the Montreal Tramways Company, and the hauling of the stone is done by the Tramways Company's electric cars or by motor trucks.

5. *Delorimier and Rogers Quarries Co., 1701 Iberville St., Montreal.*

The quarry is about 17,000 square yards in extent and 30 to 40 feet deep. It shows a sheet of "banc rouge" (tinguaite), 10 to 15 feet thick, overlying limestone. The quarried stone is loaded into boxes which are hoisted by derrick to the crushers. The product is all crushed and the maximum hourly output is 35 tons. Hauling is done by trucks. The company employs 25 to 30 men on the average.

6. *Consolidated Crushed Rock, Ltd., 3656 Masson St., Montreal.*

This quarry is operated for the production of crushed "banc rouge" (tinguaite) only. Thirty men are employed on the average and the maximum capacity of the plant is 50 tons per hour. Hauling is done by trucks.

7. *L. Deguire Quarry Co., St. Laurent, R. H. Miner, Owner.*

The quarry covers approximately 15,000 square yards and is 35 to 40 feet deep. The plant which has a maximum capacity of 60 tons per hour, is electrically operated for the production of crushed limestone only. It is connected by spur line to the Canadian National railway. The company operates another smaller quarry at 7411 De Lanaudiere St., Montreal, for the production of crushed limestone.

8. *A. Dupré Quarry Co.—Office: 4735 Delorimier St., Montreal. Quarry: Ville St. Michel.*

The excavation, which is in limestone, covers not less than 3,500 square yards. Quarrying is done at three levels, forming steps or benches, with a vertical distance of about 15 feet between each level. The quarried stone is loaded into boxes which are lifted by electric derrick to the crushers. Part of the quarried stone is sold for lime-burning to O. Limoges & Cie., Montreal. The maximum hourly output, including both stone for lime and crushed stone, is 20 to 30 tons.

9. *Carrière St. Michel, Ville St. Michel.*

The quarry covers about 550 square yards and is 15 feet deep. It is operated for the production of crushed limestone, and the maximum hourly output is 20 tons.

10. *Joseph Varin (Old Limoges Quarry)—Office: 7775 St. Denis St.; Quarry: Côte St. Michel Road, Montreal.*

This is an old quarry which has been idle for several years. At the time of the visit (October, 1926) operations had just been resumed for the production of crushed limestone, rubble, and stone for lime-burning. The installation of new machinery was not yet completed and the maximum hourly output was 4 tons.

11. *Montreal Crushed Stone Co., Ltd.—Office: 590 Union Ave., Montreal; Quarry: St. Vincent de Paul, Emile Vanier, Owner.*

The excavation, which is irregular in shape, has a maximum length of 400 yards and a maximum width of 150 yards. The stone is quarried at several levels, the latter in the form of benches or steps, and the total height of the quarry wall from the lower level is 35 feet. The quarried stone is loaded by 2 double-truck electric shovels into side-dump cars. The quarry cars are electrically operated between the working face and the crushing plant from a control tower. Tracks on each level or bench are connected to the main track leading to the crushing and screening plant outside of the excavation. The product is crushed limestone exclusively and the maximum hourly output is 300 tons. The plant is connected by siding to the Canadian Pacific railway nearby.

12. *Standard Lime Co. Office: Joliette; Quarry: St. Paul de Joliette.*

The quarry covers about 50,000 square yards and is 60 feet deep. The blasted stone is loaded by 2 steam shovels into side-dump cars which are hauled up an inclined track by hoist to the crushing plant, which consists of a primary No. 7 gyratory crusher and 4 secondary No. 2 crushers. The larger fragments of the quarried stone do not go through the crushers, but are diverted to kilns where they are burned for lime. The maximum hourly output of the plant is 60 tons, including both crushed limestone and stone for lime-burning. The company employs 20 men on the average. A spur connects the quarry with the Canadian National railway.

13. *St. Maurice Lime Co., Ltd. Office: Three Rivers; Quarry: St. Louis de France. Leased to J. H. Giroux, Three Rivers.*

The plant is equipped for the production of crushed stone and for lime-burning, with a maximum capacity of 20 tons per hour. It is at present idle.

14. *La Carrière de Quebec—Giffard.*

The quarry extends over 20,000 square yards and has a maximum depth of 50 feet. It is excavated in the form of benches or steps, 3 in number in the deepest part. The blasted stone is loaded by two steam shovels into dump cars, which are hauled up an inclined track by hoist to the crushing plant. The crushers are 6 in number, ranging in size from No. 10 to No. 3. A belt conveyer carries the screened stone to stock-piles. The product is exclusively crushed limestone and the maximum hourly output 150 tons. The number of men employed varies from 30 to 60. The plant is connected by spur to the Quebec Electric railway.

15. *La Carrière de Giffard—Office: 194 du Pont St., Quebec; Quarry: Giffard.*

The quarry covers about 10,000 square yards with a maximum depth of 50 feet and is excavated in the form of benches or steps. Limestone is quarried for building purposes and for crushing. The crushers are 2 in number, with a maximum capacity of 50 tons per hour. There are 20 to 25 men employed. Hauling is done by motor trucks.

16. *Jos. Pagé—Charlesbourg West.*

The excavation covers 3,000 square yards and is 30 feet deep. The stone is quarried at two different levels, in the form of benches, 15 feet high. Limestone is quarried for rubble and for crushing. There are two crushers of the jaw type, and one portable screening plant. Twelve men are employed. Hauling of the stone is done by trucks.

17. *Château Richer Quarry, Ltd.—Château Richer. W. Baker, Owner.* The excavation is in the slope of a ridge and covers 9,000 square yards, with a face showing over 50 feet of stone. Limestone is quarried for masonry work and for crushing. There are two gyratory crushers, No. 5 and No. 3. The maximum capacity of the plant is 40 tons per hour. Ten to fifteen men are employed. A siding connects the quarry with the Quebec Electric railway. The siding is approximately 100 feet below the level of the quarry floor, where the crushing, screening and storage plant is located, and the loading of the stone into railway cars is done by means of a chute.

18. *Ed. L. Gravel—Château Richer.*

The excavation is in the form of a sidehill cut in the slope of a ridge and covers approximately 2,500 square yards, with a face showing over 50 feet of limestone. The stone is quarried for masonry work and for crushing. Twenty men are employed at the quarry. The maximum hourly output of the plant is 20 tons. The quarry lies close to the Quebec Electric railway, but is not connected to it.

19. *Joseph Blais—8 Mont-Marie Ave., Lévis; Quarry: Sorosto.*

The quarry covers an area of 2,000 square yards and has a depth varying from 15 to 20 feet. The product is exclusively crushed sandstone and the maximum hourly output 10 tons. Hauling is done by motor trucks.

20. *Joseph Vézina—Ste. Foye.*

The quarry forms an irregular sidehill cut in the slope of a rocky knoll. The quarry face is about 150 yards long and has a maximum height of 25 to 30 feet. The product is crushed sandstone exclusively and the maximum daily output 50 tons.

21. *P. Baillargeon—St. Jean; Quarry, along St. Luc Road.*

The quarry covers about 8,000 square yards and is 20 feet deep. The excavation is in white, finely crystalline syenite. The plant is operated for the production of crushed stone exclusively and the maximum daily output is 150 tons. Operations ceased at the end of 1926.

22. *Corporation Quarry—Sherbrooke.*

The excavation is in the form of an irregular trench through the crest of a rocky ridge and covers approximately 2,500 square yards, with an average depth of 18 feet. The stone is a fine-grained quartzite, having in places a marked schistose structure. The quarry is intermittently operated by the city for the production of crushed stone, most of which is used for concrete work and pavements. There is a crushing and screening plant at the quarry, and the crushed stone is stored in separate stock-piles according to size. Samples were collected from the piles, sample A representing the massive phase, and sample B, the schistose phase of the rock. The results of laboratory tests made on the samples are given in the accompanying table.

23. *Scotstown Granite Corporation—Scotstown.*

The quarry, which is in the slope of a granite knoll, has a length of about 100 yards and a face up to 50 feet in height. The stone is greyish white, medium fine-grained. The quarry is operated chiefly for the production of building stone, and its equipment consists of a 50-ton derrick, a 20-ton derrick, steam boiler, hoist, and air compressor. It is idle at present. It is connected by a one-mile spur to the Canadian Pacific railway at Scotstown. Several other excavations in the vicinity are no longer worked. A large amount of waste rock in the several quarries could be easily crushed into good road metal, should the demand for it arise.

24. *Silver Granite Co., Ltd.—Office: 117 Côte d'Abraham; Quarry: St. Samuel. Ernest Jobin, President and Manager.*

The quarry is situated in the steep slope of a granite hill. The quarry wall is over 100 yards in length and up to 50 feet in height. The stone is greyish white and medium fine-grained, and is quarried for building and monumental purposes. The quarry equipment consists of two 15-ton derricks with steam hoists, one boiler, and one air compressor run by two oil engines. The shop where the stone is cut and dressed has a travelling crane, and a gang saw is being added. The quarry is connected by spur to the Quebec Central railway. The quarry lies at a higher elevation than the railway, and the grade of the spur line gradually decreases from quarry to railway. The stone is loaded by derrick on small, standard gauge flat cars which are let down the inclined spur by cable and hoist. When the cars have travelled a certain distance, they are disconnected from the cable and run by gravity for the remainder of the distance. At the railway a derrick transfers the load from the small flat cars to the standard railway cars. When empty, the small cars are pushed up by hand a certain distance, and pulled up by cable and hoist the rest of the way to the quarry.

25. *La Carrière Bussière, Ltée.—St. Sébastien.*

The quarry is opened in a low-lying, flat outcrop, a short distance from a granite hill. It covers an area of approximately 5,000 square yards and is 40 feet deep. It is kept dry by intermittent pumping. The granite is much the same as No. 24 and used for similar purposes. Some of the waste rock is occasionally sold as rip-rap or for crushing. The equipment consists of a 15-ton derrick, 10-ton derrick, and two air compressors. The shop where the stone is cut and dressed has a travelling crane. The quarry lies close to the Quebec Central railway, to which it is connected by spur, and the stone is directly loaded by derrick into railway cars.

26. *F. Voyer & Frère—Rivière à Pierre.*

There are three excavations, only one being worked at present. The latter is in the flank of a bare granite hill with gentle slopes. It has a face 200 feet long and up to 30 feet high. The granite is pinkish grey, coarse-grained, and contains a relatively small proportion of black minerals. It is quarried chiefly for building and monumental purposes and is cut and dressed at the quarry. The equipment consists of a 15-ton derrick operated by steam hoist, 5-ton derrick, boiler, air compressor, a steam drill for deep holes, and compressed air drills. The quarry lies about one mile from the Canadian National railway and the hauling, which is mostly down grade, is by horse and wagon.

27. *Arthur Dumas & Cie., Enrg.—Rivière à Pierre.*

The quarry, which is in the flank of the same granite hill as No. 26, covers 3,500 square yards and has a face up to 25 feet in height. The quarry face shows two varieties of stone, one similar to No. 26, but of finer grain, the other just as coarse as No. 26, but with a decidedly more reddish cast. The stone in the two quarries is the same, as far as composition goes. The granite is cut and dressed at the quarry for building and street curbing purposes. The equipment consists of two 5-ton derricks and steam hoists, boiler, air compressor, steam and compressed air drills. The quarry lies at the same distance from the railway as No. 26, and hauling is done in the same manner.

28. *Dumas & St. Pierre—Rivière à Pierre.*

The quarry has just been opened in the lower slope of a granite hill. It is now about 900 cubic yards in size with a face up to 12 feet in height. The stone is a whitish grey, medium fine-grained granite with a gneissoid structure and carries a relatively high proportion of black minerals. It is cut and dressed at the quarry for building and monumental purposes. The equipment consists of a boiler, air compressor, 2-ton derrick and compressed air hoist. The quarry lies about one mile from the Canadian National railway and hauling is done by horse and wagon.

There are three other large quarries, at present idle, near Rivière à Pierre, two of which are owned by Arthur Perron, Rivière à Pierre, and the other by Silver Granite Co., Ltd., 117 Côte d'Abraham, Quebec.

29. *Auguste Bernier—Roberval.*

The quarry is in the slope of a bare granite knoll, and has a face about 200 feet long and up to 50 feet in height. There are two varieties of granite. The more common variety is a light red, very coarsely crystalline stone, consisting mostly of large red feldspar crystals. The other is medium coarse-grained and of a darker colour, due to the smaller amount of red feldspar. The latter variety is locally known as "blue granite", to distinguish it from the one of lighter red colour. The stone is cut and dressed at the quarry for building and monumental purposes. The equipment consists of a derrick with horse-winch and air compressor run by oil engine. The quarry lies about one mile from the Canadian National railway and hauling is done by motor trucks and horse-drawn wagons.

Note:—In all the granite quarries above described, that is, from No. 23 to No. 29 inclusive, there is a very large amount of waste rock which could be easily broken and would make a good road metal or concrete aggregate.

Results of Tests upon Rock Samples

Sample No.	Location and Owner	Rock type	Physical Properties: Wear, per cent	French co-efficient of wear	Toughness	Hardness	Cementing value	Specific gravity	Water absorbed, lb. per cu.-ft.	Remarks
22	Sherbrooke.................... Corporation quarry.	Quartzite A B	2·71 2·40	14·8 16·7	17 10	15·8 16·6	115 87	2·78 2·92	0·22 0·25	A: Massive stone. B: Schistose stone.
23	1 mile north of Scotstown....... Scotstown Granite Corporation	Granite.....	3·40	11·8	9	18·6	40	2·67	0·60	Sample from waste stone exposed to the weather for several years.
24	4 miles west of St. Samuel ...... Silver Granite Co.	Granite.....	2·38	16·8	11	18·6	46	2·66	0·62	
25	3¾ miles south of St. Sébastien.. La Carrière Bussière, Ltée.	Granite.....	2·33	17·2	11	18·7	30	2·65	0·60	
26	1½ miles north of Rivière à Pierre F. Voyer & Frère.	Granite.....	5·49	7·3	8	18·8	43	2·70	0·36	
27	1½ miles north of Rivière à Pierre Arthur Dumas & Cie, Enrg.	Granite.....	5·81	6·9	9	18·5	35	2·71	0·41	
28	West of Rivière à Pierre........ Dumas & St. Pierre.	Granite.....	3·21	12·5	9	18·2	43	2·76	0·35	
29	2½ miles northwest of Roberval.. Auguste Bernier.	Granite...A B	3·78 2·94	10·6 13·6	8 10	18·7 18·7	41 57	2·64 2·73	0·35 0·36	Coarse-grained stone. A: coarser than B.

VI

THE TESTING OF NON-BITUMINOUS ROAD MATERIALS

R. H. Picher

Natural deposits of bedrock, boulders, gravel, and sand are the most common sources from which road materials are derived.

Tests on bedrock are made to determine its resistance to abrasion, its toughness, hardness, specific gravity, water absorption, cementing value, and crushing strength. The tests on boulders include all those made on bedrock, but in most cases for reasons explained under "Sampling" the abrasion and cementing tests are the only ones practicable. Those on gravel and sand include granulometric analysis, character and shape of the constituents, specific gravity, percentage of voids, wear, percentage of silt and clay, organic impurities, and strength in cement mortars.

Description of Tests on Bedrock and Boulders

Resistance to Abrasion. The material is broken into angular pieces, 2 to 2½ inches in size; and a charge of approximately 50 pieces, weighing within 10 grammes of 5,000 grammes, is put into a rattler, known as the Deval abrasion machine. This machine consists of a rotating shaft, upon which closed cylinders are mounted in such a way that the axes of the cylinders are inclined at an angle of 30 degrees with the axis of rotation. The usual rattler consists of four cylinders, so that four samples can be tested at one time. The machine is run for 10,000 revolutions at a rate of 30 per minute, after which the sample is screened on a $\frac{1}{16}$-inch sieve. The material retained is thoroughly washed, dried in the oven and again weighed. The difference between the two weighings, expressed in terms of percentage, represents the percentage of wear. Another way to express the wear is by the *French coefficient,* which is equal to *40 divided by the percentage of wear.* This gives a factor which varies directly as the wearing quality of the stone, that is, the better the stone, the higher the coefficient.

The abrasion test is probably the most satisfactory of all laboratory tests, as it simulates the abrasive action that takes place on the road surface, and the method of sampling and testing is such that the result obtained approaches the average for the whole deposit.

The resistance to abrasion of a stone used in the wearing course of a road ranges as follows:

	Per cent wear	French coefficient
Very resistant stone	2·0	20·0
Good stone for any traffic	3·5	11·4
Good stone for light traffic	5·7	7·0
Softest stone permissible	8·0	5·0

Toughness. For this test one-inch cores are drilled from blocks of the material by means of a diamond core drill. Pieces, a little over 25 millimetres long, are next cut from the rock cores by means of a diamond saw. The ends are then ground plane on the grinding lap, making the length of the test piece when completed exactly 25 millimetres. Three specimens are usually prepared for one test. The test piece is placed on the anvil of a Page impact machine, and a plunger, with its lower end spherical in shape, lowered so as to rest directly on the top and centre of the test piece. A two-kilogram hammer is then caused to fall on top of the plunger from a height of one centimetre, this distance being increased by one centimetre for each blow until failure of the test piece occurs. When the three specimens have thus been broken, the average number of the blows causing failure is recorded as the toughness of the material.

This and the abrasion test are the two more important of the laboratory tests on road stone. The toughness of the stone used in the wearing course of a road ranges as follows:

Particularly tough stone	20
Good stone for any traffic	13
Good stone for light traffic	7
Least tough stone permissible	5

Hardness. Two cores are drilled in the same way as for the toughness test, and one end of each core cut with the diamond saw and ground plane on the grinding lap. The test is performed with a Dorry hardness machine which consists of an iron disk, revolving in a horizontal plane. Two grips carrying the specimens are held in a vertical position over the disk by inserting them in sleeves, which are of such size as to form a sliding fit allowing free vertical but no sidewise movement of the grips. An abrasive, which is crushed quartz, not more than 5 per cent of which will be retained on a 30-mesh sieve and not more than 25 per cent of which will pass a 40-mesh sieve, is fed on to the disk through funnels. After the mounted specimens are brought to a weight of exactly 1,250 grammes by means of lead shot, they are inserted in the sleeves and allowed to bear on the revolving disk and the machine run 1,000 revolutions at the rate of 30 per minute, after which they are again weighed. The hardness coefficient is obtained by subtracting from 20 one-third of the loss of weight. The average coefficient of the two test pieces is taken as an indication of the hardness of the rock.

The hardness test is not so important as the abrasion and toughness tests, and, in the opinion of many engineers, can be dispensed with in most cases, since it is found that a stone which satisfactorily answers the requirements of both abrasion and toughness tests usually possesses sufficient hardness. The hardness coefficient of stone used in the wearing course of a road ranges as follows:

Very hard stone	19·0 to 19·5
Ordinary hard stone	17·0 to 19·0
Medium hard stone	15·0 to 17·0
Soft stone	12·0 to 15·0

Specific Gravity. About 10 pieces of the rock, 1½ to 2 inches in size, and having a total weight of approximately 1,000 grammes, are dried to constant weight at a temperature between 100° and 110° C., cooled in a dessicator, and weighed to within 0·5 gramme. They are then immersed in water for 24 hours and weighed in water. The weight in water is obtained by placing the pieces in a wire basket which is suspended in water from the centre of the scale pan. The difference between this weight and that of the empty basket suspended in water is the weight of the saturated sample in water. After the pieces have been taken out of the water, they are surface-dried by means of a towel or blotting paper and immediately weighed in air. The specific gravity is calculated by dividing the weight of the dry sample by the difference between the weights of the saturated sample in air and in water. The weight in pounds per cubic foot of the rock is obtained by multiplying the specific gravity by 62·4, which is the weight in pounds of a cubic foot of water.

This test is of value in converting yardage into tonnage, or vice versa. Since loose crushed stone has, on the average, 50 per cent of voids, the weight of a cubic yard of crushed stone is readily obtained by dividing the weight per cubic foot by 2 and multiplying by 27. A 40-ton carload of trap rock of specific gravity 3·0 will contain 3·5 cubic yards less than the same weight of limestone of specific gravity 2·7.

Water Absorption. This is computed from the results obtained in determining the specific gravity, and is equal to the difference between the weights in air of the saturated, and the dry sample. If this difference is divided by the difference between the weights of the saturated sample in air and water, and the quotient multiplied by 62·4, the result represents the water absorption in pounds per cubic foot of the rock, this being the way that it is usually expressed.

The test for water absorption gives an indication of the ability of the stone to resist disintegration through frost. In general the stones with lowest water absorption are the most resistant to this disintegrating action. The water absorption, in pounds per cubic foot of stone used in the wearing course of a road, ranges as follows:

Low absorption	0·05 to 0·50
Moderate absorption	0·50 to 1·50
High absorption	1·50 to 3·00

The majority of stones used for roadmaking have a water absorption of 0·20 to 1·00 pound per cubic foot, and are quite safe from disintegration through frost.

Cementing Value. A 500-gramme sample of the rock is crushed to pass a ¼-inch screen and placed in a ball mill with 18 per cent (90 c.c.) of water and 2 steel shot weighing 20 pounds each. After 5,000 revolutions of the mill, at the rate of 30 per minute, the resulting dough is removed and, under a pressure of 132 kilograms per square centimetre, is moulded into cylinders 25 millimetres in diameter and 25 millimetres high. Five cylinders should be made from each sample. They are allowed to dry in the air at room temperature for 20 hours after making, and are then dried at a temperature of 100° C., for 4 hours, cooled for 20 minutes in a dessicator, and immediately tested. The testing machine consists of an anvil on which the test piece is placed, a plunger which is held in position on top of the test piece by two spiral springs, and a 1-kilogram hammer which is made to rise 1 centimetre and drop on top of the plunger by means of a motor-driven camshaft, at the rate of 40 blows per minute. The average number of blows necessary to cause the failure of the five test pieces is taken as an indication of the cementing value of the rock.

The cementing test is of value on a stone which is to be used in the wearing course of a waterbound macadam or gravel road. The stone is considered suitable, if the test pieces stand at least 25 blows before failure. The test is omitted when an artificial binder, such as Portland cement or some sort of bituminous binder, is used to bind the stone on the road.

Compression. Three cylindrical test pieces, 2 inches in diameter and 2 inches high, are prepared by the same method as previously described under the toughness test, except that a 2-inch core drill is used. Great care should be taken that both ends of the test pieces be ground perfectly plane and parallel with each other. The cylinders are crushed in a 200,000-pound compression testing machine, a piece of blotting paper being placed between the ends of the test piece and the plates of the machine. The average of at least three determinations, calculated in pounds per square inch, is reported as the crushing strength.

This test is not ordinarily made on road-building rock, but is prescribed in some specifications.

Description of Tests on Gravel and Sand

Granulometric Analysis. The sample is first separated into two classes by means of a screen with round holes ¼ inch in diameter; that part retained on the screen is weighed and recorded as "pebbles", while that part passing through is weighed and recorded as "sand." The pebbles are then subjected to screen analysis, using screens with round holes of the following sizes: 2½, 2, 1½, 1, ¾, ½, and ¼ inch; and the weight of material retained on each screen is reported in terms of percentage of the total weight of the pebbles. About 500 grammes of the material passing the ¼-inch screen is then run through standard Tyler sieves of the following mesh: 8, 14, 28, 48, 100, and 200; that retained on each sieve, as well as that part passing the 200-mesh sieve is weighed separately, and all weights are finally converted into percentages. This test gives an indication of the coarseness of texture or grading of the material.

On account of the wide variations in size of particles between different gravels, it is not advisable to set too strict rules as to what proportion of each size a gravel should have, to be considered suitable. In general a good road gravel should contain at least 50 per cent of pebbles, and that part passing the ¼-inch screen should be fairly coarse, that is, the percentage retained on each sieve should decrease with the sieve opening.

Character and Shape of Constituents. About 100 pebbles are picked at random from the sample, and their nature and soundness determined by breaking and examining them. The usual way followed by this laboratory is to classify them into three grades: *Durable,* which includes all very hard rocks; *Intermediate,* which includes sound rocks of medium hardness, and partly weathered rocks which still retain a certain hardness; and *Soft,* which includes fresh rocks which are soft and friable and rocks which are partly disintegrated due to weathering. The shape of the pebbles varies from rounded to angular, and from flat to about equal in all dimensions. The shape of the largest number of the picked pebbles is judged and recorded as the average shape of the pebbles. The nature and soundness of the gravel pebbles greatly influences the ability of the road surface to resist the grinding action of traffic, while their shape has a direct bearing on its resistance to disruption.

The gravel should not contain more than 15 per cent of soft or disintegrated particles. The ideal shape for gravel pebbles is that of broken stone fragments, that is, angular and chunky. Flat pebbles and rounded, smooth-surfaced pebbles are particularly objectionable. The shape of the pebbles is more important as their hardness increases.

Specific Gravity. A separate test is made for pebbles and sand. For pebbles the test is made by the same method as already described for rock. The specific gravity of sand is determined by the same method as that for Portland cement and other fine aggregates, i.e. by the use of the Le Chatelier specific gravity bottle. A pouring funnel is inserted into the bottle, the latter filled with kerosene or benzene to a point on the stem between the zero and the 1 c.c. graduation, and the level of the fluid read. The funnel is withdrawn and 64 grammes of the sand is slowly introduced, care being taken that the material does not adhere to the inside of the flask above the liquid. The material is freed from air by rolling the bottle in an inclined position. The level of the fluid is read as before. The specific gravity is calculated by dividing the weight of the sample (64 grammes) by the difference between the two readings.

Percentage of Voids. In this test a truncated steel cone having a capacity of 5975 cubic centimetres is completely filled with gravel, thoroughly compacted by oscillation. Then, if A equals the weight in grammes of the cone empty, B equals the weight in grammes of the cone filled with compacted aggregate, C equals the specific gravity of the aggregate, the percentage of voids equals

$$\left(1 - \frac{(B\text{-}A)}{5975C}\right) 100$$

The specific gravity and voids tests are useful in converting yardage into tonnage and vice versa.

Abrasion. The gravel is first sized through screens having circular openings 2, 1½, 1, ¾, and ½ inch in diameter. The material retained on the 1½-, 1-, ¾- and ½-inch screens is separately washed and dried. Then 1,250 grammes of each are taken and mixed together, making a sample weighing 5,000 grammes. This material is placed in the cylinder of a Deval machine. Six cast-iron balls, 1·875 inches in diameter and weighing approximately 0·95 pound (0·45 kilogram) each, are placed in the cylinder as an abrasive charge. The machine is run 10,000 revolutions at the rate of 30 to 33 per minute. At the completion of the run, the material is taken out and screened over a $\frac{1}{16}$-inch mesh sieve. That part retained on the sieve is washed, dried and weighed, and the percentage loss by abrasion of the material passing the $\frac{1}{16}$-inch mesh sieve calculated.

This test is in the experimental stage, and no definite factor has yet been established for comparing the wearing quality of a gravel and its percentage of wear as obtained by the laboratory test.

Percentage of Clay and Silt. This and the following tests are made on gravel and sand intended for use as aggregate in concrete mixtures. For this test, the sample is moistened and thoroughly mixed, then dried at a temperature between 100° and 110° C. The pan or vessel used in the determination should be approximately 12 inches in diameter and 4 inches deep. A representative portion of the dry material weighing not less than 50 times the weight of the largest stone in the sample is selected from the sample and placed in the pan which has been dried and accurately weighed. Sufficient water is poured into the pan to cover the gravel, which is then agitated vigorously for 15 seconds with a trowel or stirring rod. After it has settled for 15 seconds the water is poured off, care being taken not to pour off any sand. This is repeated until the wash water is clear. The washed material is finally dried to constant weight in a hot-air oven at a temperature between 100° and 110° C., and weighed. The percentage of clay and silt is equal to one hundred times the difference between the intial and final weights, divided by the initial weight.

While a certain proportion of clay and silt is not objectionable, if this proportion amounts to 5 per cent or more, a mortar test should be made to determine whether the material is suitable.

Organic Impurities. For this test, all particles retained on the $\frac{1}{4}$-inch screen having circular openings are first removed and from the residue 200 grammes are taken for testing. This is added to 100 c.c. of a 3 per cent solution of sodium hydroxide. The sand and solution are then allowed to stand for 24 hours, with occasional stirring. If organic impurities are present in the sand, the solution will have a colour varying from light yellow through red to black. By comparing the colour of the solution with a colour scale made up of 10 different solutions of alkaline sodium tannate, an indication is given of the amount of impurities and of their effect on the strength of mortars made with the sand.

The solutions for the colour scale are numbered from 1 to 10, starting with the paler one. The percentage reduction in compression strength of 1:3 mortars by the presence of organic impurities is given as follows:

Colour value 2 to 3,	reduction:	10 to 20	per cent
" 5,	"	15 " 30	"
" 10,	"	20 " 40	"

Mortar Tests. By comparing the tensile and compressive strengths of a 1:3 mortar composed of Portland cement and the sand to be tested, with a 1:3 standard Ottawa sand mortar made with the same cement, an indication is given of the suitability of the sand for concrete work. The pebbles are first removed from the sample by screening through a $\frac{1}{4}$-inch screen with circular openings. The sand is mixed with one-third its weight of Portland cement, after which it is brought to a definite consistency with water and moulded into briquettes and cylinders. Six briquettes and six cylinders are made for each sand to be tested. They are left in the moulds and allowed to stand 24 hours in moist air. They are then taken out of the moulds and immersed in water. A similar number of briquettes and cylinders are prepared the same way with one part cement and three parts Ottawa standard sand. Ottawa sand is furnished by the Ottawa Silica Company of Ottawa, Illinois. It is of such size as to pass a 20-mesh sieve and be retained on a 30-mesh sieve. On the seventh day after mixing and moulding, one-half the number of briquettes for each sample and the standard are tested for tensile strength in the briquette testing machine, and one-half the number of cylinders for compressive strength in the compression testing machine. On the twenty-eighth day the remaining briquettes and cylinders are tested the same way. For a sand to be used in concrete pavements, the results of the tests should be at least equal to those obtained on the standard mortar; and for concrete foundations, culverts, and retaining walls should be at least 80 per cent of the standard.

Sampling

Bedrock. In undeveloped deposits of bedded rocks the samples are collected from the outcrops, by taking pieces at equal intervals, and in such a way as to truly represent all the beds exposed. In massive deposits the samples should be taken across the zones of variation where they exist. In sampling quarries, the pieces are taken at equidistant points across the quarry face from top to bottom. In quarries where the beds or zones of variation are highly inclined, the direction followed in sampling should be such as to include all the beds or zones of variation exposed in the quarry face. In any case great care should be taken to include only fresh stone in the sample, and the pieces selected should be approximately cubical in shape and as close to 2 inches in size as possible. Since at least 50 pieces are required for the abrasion test, and more in certain cases, the number should not be less than 55. To this should be added a block or number of blocks about 6 by 4 by 3 inches in size, broken if possible by the plug and feather method. From these the cores used in the toughness and hardness tests are to be drilled. To facilitate the drilling of cores the blocks should be as nearly rectangular as possible. In sedimentary rocks, one block is not entirely satisfactory; three or four blocks taken from different beds are better, to represent the average of the deposit. If a test for crushing strength is required, at least one additional block, not less than 6 by 6 by 3 inches in size, should be included in the sample.

In sampling quarry faces, care should be taken not to take stone too close to where blasting charges were placed, as the samples so taken may have been weakened by the blast.

Boulders. Boulder deposits in their natural state are seldom used for road purposes. Boulders which in the process of clearing the land have already been piled in heaps or rows along fences are in most cases the only ones used for such purpose. Because of the heterogeneous character of the boulders, it is necessary to make, in the field, an approximate determination of their composition, before a satisfactory sample can be taken. For the abrasion and cementing tests, the rock fragments should be so selected as to conform to the composition given by the field determination. The other tests would have to be made separately for each rock type represented in the boulders. Because of the amount of laboratory work it would require, they are not ordinarily made. When a particular rock type predominates over all the others, the whole series of tests are made on boulders of this type, and the results judged as applicable to all, provided that the boulders of other types appear to be as sound and hard as those of the predominating rock type. Disintegrated boulders, even if fairly numerous in the piles, are not included in the sample, and should not be used as road material. With the aid of a hammer or a pick, it is relatively easy, even for the unskilled man, to distinguish them from the sound ones.

Gravel and Sand. There are two general classes of natural gravel and sand deposits: the bank, and the beach or river deposits; and the methods for sampling them are different. In sampling a pit face in a bank deposit, a narrow strip of material running the full depth of the face should be taken, with the exception of the top soil and that part of weathered material usually lying immediately below the top soil. If the excavation is of large size, several samples should be taken in this way at equal distances along the face, since only in exceptional cases will a single sample be a fair representative of the average of the deposit. In most deposits the coarseness varies both in depth and in the horizontal direction. If the pit face is partly talus-covered, the latter should be shovelled off so as to uncover the full face, or else only the material from that part of the face above the talus should be included in the sample. A sample which is to be tested for coarseness or grading in size of particles should never include any talus material. In order to collect samples from undeveloped deposits, it is necessary to dig test pits over the surface. The pits should be dug as deep as practicable and the samples taken in the same manner as in ordinary pits, that is, by removing a vertical strip of material to the full depth of the test pit, not including, however, the top soil and weathered material below it. In fine gravel and sand deposits, satisfactory samples can be taken by boring auger holes. The method of sampling beach deposits will vary with the method of exploitation. When the gravel is loaded directly with hand shovels into carts or trucks, the material is usually dug to a very shallow depth, but over a comparatively large area. In this case the way to sample the deposit would be to take strips of material at right angles to the shore and at regular intervals along it. Since the surface material is generally much coarser than that farther down, the strips should be dug deep enough to include also the fine material, but not so deep as to include material that will not be used.

Samples of gravel should weigh at least 25 pounds, and samples of sand, 10 pounds. When an abrasion test on gravel is required, an additional sample of pebbles, weighing at least 20 pounds, is included. The pebbles should range from one-half to 2 inches in size. One sample of pebbles is generally sufficient, since the composition and shape of pebbles are in most cases fairly uniform within the same deposit.

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493. Summary report of the Mines Branch for 1917.
   Investigation of clay and shale resources, Nova Scotia, New Brunswick, Northern Ontario (with special reference to the fireclays of the Missinaibi and Mattagami rivers), Manitoba, and British Columbia.
   Pottery clays.
   Magnesite.
   Silica.

*509. Summary report of the Mines Branch for 1918.
   Tests on certain clays from British Columbia and Ontario.

542. Summary report of the Mines Branch for 1919.
   Tests on various clays from British Columbia.
   Clays and shale in the vicinity of Fort William and Port Arthur, Ont.
   Kaolin in Gatineau valley, Que.
   Aluminium and its sources.
   Structural materials in Dundas, Stormont, and Glengarry counties, Eastern Ontario.
   Pottery clays.

574. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1920.
   Reports on clays from various parts of Canada.
   Pottery clays.
   Clay-working industry (structural materials), special clay wares, white tableware.
   Field examination and testing of clays.

586. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1921.
   Reports on clays from various parts of Canada.
   Pottery clays.
   Art pottery industry.
   Scum on face bricks.
   Working stony clays for brick and tile.
   Method for sampling clay deposits.
   Clay-working industry in Canada.
   Ball clay in southern Saskatchewan.

605. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1922.
   Notes on ceramic materials.

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619. Investigations in ceramics and road materials, 1923.
   Ceramic exhibit for the British Empire Exhibition.
   Reports on clays from various parts of Canada.
   Tunnel kilns for burning brick.

645. Investigations in ceramics and road materials, 1924.
   Ceramic industry in the Maritime Provinces.
   Reports on clays from various parts of Canada.
   Cost of burning brick and tile in Ontario and Quebec.

672. Investigations in ceramics and road materials, 1925.
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   Texture of ceramic materials.

690. Investigations in ceramics and road materials, 1926.
   Brick sizes in Canada.
   Methods of using barium for scum-prevention in stiff-mud brick.
   Manufacture of grey brick.
   Refractoriness of moulding sand.
   Kaolin and associated clays of Punk island, Manitoba.

697. Investigations in ceramics and road materials, 1927.
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   Preliminary report on clay gathering.
   Clays and shales of the Grand Lake area.

   List of manufacturers of clay products.

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16 E. Clay and shale deposits of Nova Scotia and portions of New Brunswick. By Heinrich Ries and Joseph Keefe, 1911.

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113. Geology and mineral (kaolin) deposits of a part of Amherst township, Quebec. By M. E. Wilson, 1919.

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(B) ROAD MATERIALS

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493. Summary report of the Mines Branch for 1917.
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    Bed-rock in the city of Montreal.

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    General limiting values for broken stone.
    Interpretation of results of physical tests.
    Results of tests on bed-rock and gravel in Nova Scotia, Quebec, Ontario, Manitoba, Alberta, and British Columbia.
    Alberta bituminous sands for rural roads.

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    Road materials in Rocky Mountains Park, Alberta.
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    Road materials, Gananoque-Napanee section, Ontario.
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    Laboratory tests on road building stone and gravel.
    Road material surveys in Nova Scotia; Prescott and Russell counties, Ontario; and Rocky Mountains Park, Alberta.
    Abrasion test on concrete.

605. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1922.
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672. Investigations in ceramics and road materials, 1925.
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