CANADA MINES BRANCH

REPORT NO. 722

CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR

INVESTIGATIONS

IN

CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

1928-1929

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1931

No. 722

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, 1928-1929

INTRODUCTION

Howells Fréchette

Chief of Ceramics and Road Materials Division

The usual annual report on Investigations in Ceramics and Road Materials was not issued for the year 1928. It was considered desirable for several reasons to hold the material over and incorporate it into a report covering the two calendar years 1928 and 1929. The present publication therefore covers the period of two years.

It is gratifying to be able to report much progress along various lines of investigation, some of which have been carried to successful conclusion with resulting benefit to industry.

A preliminary report appears on pages 4 to 6 in which L. P. Collin synopsizes the results to date of his research on ceramic bodies for electrical heating devices. The objective of this research is the formulation of ceramic bodies suitable for insulating shapes for supporting heating elements. Resistance to temperature shock and mechanical strength are prime requisites. To a great measure success has been attained but there yet remain certain adjustments to be made to overcome features which are unsatisfactory from an industrial viewpoint.

Incidental to his research on ceramic bodies, L. P. Collin had occasion to determine the bonding values of various ball clays. The standard method of procedure as adopted on this continent gave results at variance with actual bonding power as observed from practical results. The ball clays from southern Saskatchewan when the standard tests were employed gave lower results than did many imported clays, whereas it was known that their actual strength was as high or higher than the foreign clays with which they were compared. In view of the unfavourable results obtained on the Saskatchewan clays by the standard test, it was decided to investigate the reasons for the failure of this test method to give actual values and to demonstrate a method which could be relied upon. Mr. Collin's report, Section II, pages 7 to 21, reveals the cause of trouble and points out desirable changes in procedure which would make the test fair to all clays. The importance attached to this is because of the marked interest in the Saskatchewan ball clays which is being taken by ceramic manufacturers of the United States.

Considerable time was spent by Mr. Collin on the investigation for the production of grey brick. Six manufacturers have shown a very keen interest in this investigation. Samples of clay submitted by four of these have been mixed with varying percentages of limestone dust and manganese dioxide. A satisfactory grey has been developed in the laboratory from two of these clays and attempts have been made to duplicate this colour at the plants on a commercial scale, but without success. A new line of experiments is now being followed as it is evident that admixtures of limestone dust and manganese dioxide with these clays will not produce, economically, a grey brick of as high a quality as the imported grey brick. Experiments were made in the laboratory to find a suitable grey slip which could be sprayed on the faces of the brick and satisfactory results were obtained. Tests made at the Citadel Brick Company's plant at Boischatel, Quebec, gave results quite different from those obtained in the laboratory. After trials with many mixture adjustments good grey colours were obtained but the degree of vitrification was not satisfactory and further adjustment of fluxes will be necessary.

The investigation, in the field, of the clay and shale resources of Prince Edward Island, commenced in 1927, has been completed by the writer. The samples collected have been subjected to very thorough testing in the laboratory by J. F. McMahon to determine their various properties and the industrial purposes for which they are suitable. A preliminary report appears on pages 24 to 27. This will be amplified and later published as a separate report.

Mr. McMahon has continued the study of the excavation and transportation of clays, commenced in 1927. In 1928 fifty brick and tile plants were visited. Information as to the cost of the various operations was secured and much general data gathered which will serve in determining the most economic methods of operation under specific conditions. His progress report appears on pages 28 to 45. It is planned that a full report on this subject will be prepared for separate publication, combining the two progress reports with general conclusions and a discussion of the various types of operation and equipment used in gathering and transporting clay.

During 1929 Mr. McMahon visited the Maritime Provinces, gathering samples from all the known deposits of refractory clays. This was in connexion with a general investigation of the refractory resources and industry of Canada. He also collected samples of clays and shales to determine suitable deposits for the manufacture of roofing and promenade tile. These samples were tested in the laboratory and following plant trials a report will be prepared.

The investigation on the treatment of certain western (Prairie Provinces) clays to overcome drying defects, conducted by the writer and J. G. Phillips, having been brought to successful conclusion in the laboratory by April, 1928, full-scale tests were made by Mr. Phillips at the plant of the Redcliff Brick and Coal Company, Limited, Redcliff, Alberta, in April, May, and June. The report on pages 46 to 55 shows the very gratifying outcome of these tests with the immediate introduction of the process into plant operation.

During 1929 Mr. Phillips conducted experiments on the preheating of clays at Redcliff. Several trial runs were made with a small rotary kiln to learn the effect of bulk treatment.

The success of chemical treatment as a means of improving the drying behaviour of clays in Alberta prompted a request from the Montreal Terra Cotta Company, Limited, for an investigation of the clay used by them for the manufacture of building tile to determine whether similar treatment would permit faster drying of their ware and reduce the loss through breakage. Since this clay is of a different type from that dealt with in the former investigation and similar to much of that occurring in

St. Lawrence valley, the problem was considered to be one that would develop new data on chemical treatment and, if successful, would be of general value to the clay workers of the district. Chemical treatment of the clay was again found by Mr. Phillips to be effective and well within the limits of economy. Plant trials resulted in the adoption of chemical treatment for regular operation.

At the request of the Turner Valley Gas Commission, an investigation was undertaken of the clay resources of Turner valley and adjacent territory to determine the character of the clays and shales which might constitute sources of supply of raw material for possible clay-working industries which could utilize the available natural gas for fuel. Professor W. G. Worcester, of the University of Saskatchewan, was engaged to carry out this investigation. His technical assistants were J. W. Craig and Cameron Worcester. Eighty-two samples were collected and were later subjected to standard tests by Mr. Craig. Text of Professor Worcester's report, with numerous diagrams and photographs, has been conveyed to the Commission.

During the two years, in addition to those collected by officers of the Division, 245 samples of clays and shales were tested. Tests were made on seven samples of mineral pigment; three samples each of bentonite and sericite; two each of volcanic ash, diatomite, and soapstone; and one each of pyrophyllite and limestone. Determinations of strength were made on three samples of brick and tile.

The research on the manufacture of high-grade refractory brick from Canadian magnesite has been continued. This investigation is being made in co-operation with the National Research Council of Canada.

In 1928, R. H. Picher, road materials engineer, completed his surveys and sampling of the deposits of conglomerate and gravel in Prince Edward Island, and also examined and sampled several deposits in New Brunswick at the request of the Provincial Department of Public Works.

In 1929, he made a survey of the road gravel resources and collected samples for testing in the area lying to the north of the Ottawa and St. Lawrence rivers between Waltham and Quebec and also in a portion of the Eastern Townships of Quebec. Under the supervision of Mr. Picher the samples collected in the field were tested in the Road Materials Laboratory. In addition 30 samples of rock and gravel, submitted by provincial governments or by individuals were tested to determine their suitability for road purposes.

Several samples of gumbo soils were obtained from Alberta and were subjected to a series of experiments by J. G. Phillips to learn whether chemical treatment with coagulants would so alter their characteristics as to materially improve them as road-building materials.

I

CERAMIC BODIES FOR ELECTRICAL HEATING DEVICES

L. P. Collin

The rapidly increasing use of electrical heating devices, especially electric ranges, in Canada, has been responsible for the interest shown in the manufacture of the bases in which the heating elements are embedded. These bases are for the most part a ceramic product and require certain characteristics different from those of porcelain and other ceramic materials which are so commonly used in electrical apparatus. The principal characteristics required in this type of ware are high resistance to temperature shock, and good mechanical strength.

Magnesia has long been considered a good material to use in ceramic bodies subjected to frequent marked changes of temperature. This investigation, consequently, was based on mixtures containing magnesia, using talc and magnesite as its source. Two series of mixtures were prepared; Series I consisting of varying percentages of talc, china clay, and ball clay; and Series II, magnesia, china clay, and ball clay. The talc was obtained from Madoc, Ontario, and the magnesia was obtained by calcining a hydro-magnesite from British Columbia. There were 35 mixtures in Series I containing from 0 to 50 per cent of talc, and 24 mixtures in Series II containing from 10 to 40 per cent caustic magnesia.

The mixtures were proportioned carefully and mixed with water by blunging for one hour, after which they were filter-pressed and dried at a temperature not exceeding 100° C. They were then ground to pass a 16-mesh sieve and moistened with a sufficient amount of water to make them suitable for dry-pressing. Two shapes of test pieces were pressed, one a plain cylinder slightly more than 1 inch high and 1 inch in diameter, the other, a disk with a diameter of about 1½ inches and a height of only ¼ inch. The cylinders were for use in the impact or toughness test, and the disks for the resistance to temperature change test. These disks had two concentric ridges, thus producing a condition of varying thickness which is of importance in resistance to temperature change tests on ware of this character. Thirty cylinders and fifteen disks were made from each of the mixtures. Trial burns and fusion tests were made to determine the proper burning temperature of each mixture. The test pieces were divided into three lots and were burned at 2-cone intervals. That is, if the proper burning temperature of a mixture was judged to be cone 8, one lot was burned at cone 6, one at cone 8, and the third at cone 10.

As has already been stated the test pieces were designed for resistance to temperature change and impact tests. The former consisted of heating the disks to a temperature of 780° C. and immersing them in cold water. After examination for cracks they were reheated and then immersed again, this being repeated until the test piece was noticeably cracked. The impact test consisted of a one-kilogram weight falling on the cylindrical test piece from a height of one centimetre for the first blow, two centimetres for the second blow, and progressively higher until failure occurred.

Samples of commercial body mixtures were obtained from two manufacturers in the United States and two in Canada. Test pieces made from these commercial mixtures withstood a maximum of 65 immersions in the resistance to temperature change test and 27 blows in the impact test.

Only four of the mixtures in Series I withstood more than 4 immersions but several of them withstood more than 30 blows in the impact test. As the resistance to temperature change is a more important property than mechanical strength, none of these mixtures would be suitable for use in electrical heating devices. In Series II, however, the five mixtures containing 30 per cent magnesia showed exceptionally high resistance to temperature change. The mechanical strength in these was rather low but appeared to be sufficiently high for all practicable needs. Table I shows the composition of these five mixtures.

TABLE I

Mixture No.	Magnesia	China clay	Ball clay
6	30	60	10
7	30	50	20
8	30	40	30
9	30	30	40
10	30	20	50

Table II gives the results of the spalling resistance test and impact test, as well as the burned shrinkage at cone 12 which appeared to be the best burning temperature.

TABLE II

Mixture No.	Per cent burned shrinkage	Number of blows in impact test	Number of immersions in resistance to temperature change
6	20·5	16	338
7	19·7	22	339
8	19·5	17	253
9	16·0	10	332
10	11·4	10	200

While the above mixtures gave such excellent results in the resistance to temperature change, which, in itself, makes them superior to the products on the market, there are two defects which should be overcome to make them readily acceptable by manufacturers. The more important of these is the high burning shrinkage. Electric stove plates were successfully made from these mixtures at a Canadian plant, and although they dried well and came out of the kilns sound and with little or no warpage, the manufacturer would hesitate to use mixtures with such a high shrinkage because of the danger of producing variable sized ware. In addition to this the working qualities of these mixtures were not entirely satisfactory. Some trouble was experienced in pressing the stove plates and while this might have been due in a large measure to the press operator working with an unfamiliar material, it was evident that the bodies lacked green transverse strength.

With a view to overcoming these defects as well as to finding a substitute for the British Columbia hydro-magnesite which was not being marketed, further work was done substituting calcined magnesites with a low lime content from Washington, California, and India. The results were very similar to those obtained from the use of British Columbia material. The resistance to temperature change continued to be excellent but the shrinkage was not markedly decreased nor were the working qualities greatly improved. Finally a relatively pure dead-burned magnesite was obtained which did decrease the shrinkage but which did not improve the working qualities.

It was then found that when higher pressures were used in forming test pieces, the green transverse strength was materially increased. It was also found that the higher pressures had a marked effect upon the size of the test pieces produced. Thus it would appear that the use of higher pressures than are now being used in commercial production would help greatly to overcome the defects mentioned, first by producing a much stronger bond and second by compressing the material to such an extent that the firing shrinkage would be very much lower.

Additional work along this line is under way and from what has been done so far it is expected that the defects will be largely or completely overcome and that the results obtained will enable the specification of body mixtures much superior to those being used at the present time.

II

TRANSVERSE STRENGTH OF BALL CLAY-SAND AND BALL CLAY-FLINT MIXTURES

L. P. Collin

INTRODUCTION

In the investigation "Ceramic Bodies for Electrical Heating Devices," bodies with insufficient bonding power were produced, and as the clay content was already high it was thought that a more plastic ball clay might give better results. Subsequently, a sample of clay from Saskatchewan was chosen for testing as it appeared to be much more plastic and to have a higher bonding strength than any other available ball clay. Tests were made of the transverse strength of the English ball clay which had been used, and of the Saskatchewan ball clay, according to the Tentative Standard adopted by the American Ceramic Society. The results were exceedingly surprising. The test bars of the Saskatchewan ball clay had a very low strength, the modulus being less than 100 pounds per square inch. Upon examination of these test bars it was found that the surface was covered with a network of cracks around the sand grains. These cracks were large enough to be seen very easily with the naked eye. It seemed that the high shrinkage of the clay around the comparatively coarse non-yielding grains of sand was responsible for this cracking. Upon subsequent examination of a cross-section of the bar, it was found that these cracks were present throughout the body. The working properties of this Saskatchewan clay were such that it seemed absolutely certain that it was much stronger than the English ball clay.

When Professor Worcester's paper on an "Investigation of Twenty-one Saskatchewan Ball Clays"[1] was published showing the extremely high bonding power of these clays, it was decided to make tests of the dry transverse strength of representative ball clays in an effort to determine the fitness of the Tentative Standard as applied to representative ball clays of different types.

The Tentative Standard test for transverse strength is as follows:

TRANSVERSE STRENGTH[2]

(A) Preface

While the results of a considerable amount of work have already been published in Transactions of the American Ceramic Society on this subject, it is still not sufficient to permit writing such definite specifications to cover this test as would be desired. However, the method which is presented below represents the best present practice and will give quite consistent and reliable results as has been shown elsewhere.

(B) Method

(1) *Preparation.* The clay shall be thoroughly dried at 64° C. or above, but under 76° C., crushed and screened to pass a No. 20 sieve. It shall then be thoroughly mixed dry with an equal amount by weight of standard silica sand that passes a No. 20 sieve (Tentative Standard Series of Testing Sieves), and is retained on a No. 30 sieve. The mixture shall then be made up to soft plastic consistency with water and thoroughly pugged by hand.

[1] Jour. Am. Cer. Soc., vol. 12, No. 5, pp. 360-81 (1929).
[2] Jour. Am. Cer. Soc., vol. 11, No. 6, pp. 460-1 (1928).

(2) *Shape.* The test piece shall be made in a suitable metal or wooden mould. It shall be 17·5 cm. (7 inches) long and have a 2·5 cm. (1 inch) square cross-section, in the plastic state.

(3) *Forming.* The mould shall be evenly and thinly oiled with kerosene and placed on a firm, smooth surface. A lump of the clay mixture, somewhat larger than is required to fill the mould shall be thrown forcibly into the mould so as to completely fill out the lower corners. The excess shall then be cut off with a spatula, and the top slicked off and appropriately marked. The marking should be near the ends so as not to deform the centre of the bar.

(4) *Drying.* The test pieces shall be allowed to dry under a cloth at room temperature for two days, then exposed at room temperature until air dry. During this period they shall be turned every twelve hours to make the drying more uniform. They shall then be placed in a dryer operating between 64° C. and 76° C. for at least five hours, and from there transferred to a drying oven, operating at 110° C., where they shall remain until approximately constant in weight.

(5) *Breaking.* The test pieces shall be cooled in a desiccator and then broken in a suitable machine, having knife edges with a 6 mm. (¼ inch) radius and 12·5 cm. (5 inches) apart. The machine should have an automatic shut-off for the shot and the rate of loading should be about 45 kg. (100 lb.) per minute. The depth and breadth of the bar should be taken at the break, and each shall be the average of three measurements taken to the nearest 0·25 mm. (0·01 inch).

(6). *Modulus of Rupture.* The modulus of rupture shall be calculated by the formula

$$M = \frac{3Pl}{2\,bd^2}$$

where M = modulus of rupture in kg. per sq. cm.
P = breaking load in kg. (read to the nearest 0·1 kg.)
l = distance between knife edges in cm.
b = breadth of bar in cm.
d = depth of bar in cm.

or, if the English system is used, the units will be pounds and inches, and the modulus will be obtained in pounds per square inch, by the same formula.

Ten bars shall be broken and the average modulus of rupture reported. Two faulty test pieces are permissible, in the case of which, the average of the eight or nine remaining shall be reported.

(7) *Variation.* A variation of plus or minus 15 per cent from the average modulus of rupture is permissible. Test pieces showing a greater variation shall be considered faulty and discarded; but as indicated in (6) preceding, if more than two are thus discarded, the test shall be repeated.

The foregoing first appeared in the Journal of the American Ceramic Society in 1922. While it is true that a considerable amount of work had been published on this subject previous to that time, very little has been done before or since on the transverse testing of dry clays to show the difference in results obtained by using a coarse non-plastic and a fine non-plastic. The one notable exception to this is the work of Bleininger and Howatt.[1]

The transverse tests in this investigation were made on bars of 50 per cent sand and 50 per cent clay, and on bars made of 100 per cent clay. The sand was used to improve drying conditions. Tables show that the deviation from the average modulus was greater on the whole with the bars of clay alone than with those of the clay-sand mixture. However, most of the greater deviations occur in those with the lower moduli while several of the clays with the higher moduli show less deviation from the average with the 100 per cent clay bars than with those made of the mix-

[1]Trans. Am. Cer. Soc., vol. XVI, 271-83 (1914).

ture. There is no doubt that additions of coarse non-plastics will reduce warpage and shrinkage, but when deviations are greater in the stronger clays when mixed with a coarse non-plastic than with the clay alone, it is evident that something more than the warpage and shrinkage is responsible for the deviations.

Potter's flint has been used by many as the non-plastic to obtain improved drying conditions of transverse test bars. Watts[1] states "a mixture of 50 per cent, by weight, clay and 50 per cent, by weight, non-plastic (potter's flint recommended) gives a very reliable and satisfactory means of indicating the bonding strength of the clay." Worcester[2] used potter's flint as the non-plastic and obtained very satisfactory results.

There is no doubt that mixtures of sand and clay will shrink and deform less than mixtures of potter's flint and clay, but as sand has caused cracking during the drying of certain highly plastic clays, it was determined to directly compare the effect of sand and potter's flint as non-plastics.

PROCEDURE

Representative samples of clay from England, the United States, and Canada were obtained for a series of tests. As these samples were mostly in small quantities (30 to 50 pounds) it is probable that they are not all true samples of the deposits from which they were taken. However, this is not important as the object was simply to compare the conditions and results obtained using sand against potter's flint as the non-plastic, following the Tentative Test as closely as possible in other respects.

The clays were thoroughly dried between 64° C. and 76° C. and were then crushed and screened to pass a No. 20 sieve. Ten-pound batches were made, using 50 per cent clay plus 50 per cent 20- to 30-mesh standard silica sand in one case, and 50 per cent clay plus 50 per cent potter's flint in the other. The screen analysis of the potter's flint was as follows:—

	Sieve No.	Per cent
On	100	0·00
"	150	0·10
"	200	2·19
"	270	65·31
Through	270	32·35
		99·95

The clay and non-plastic were thoroughly mixed dry and were then tempered with a sufficient amount of water to make them of a soft plastic consistency. (Particular care was taken to have all of the mixtures as nearly the same consistency as possible.) The batches were then thoroughly wedged and allowed to age for 24 hours after which they were wedged again and the transverse bars made.

A brass mould was used which had a cross-section of slightly more than 1 inch by 1 inch, and was 8 inches long. Trouble was encountered in attempting to form the bars as required by the Tentative Test method, namely, by throwing the mixture forcibly into the mould so as to completely fill the corners. Many attempts were made to do this and finally a set of ten good bars was obtained. However, as nearly three hours were required to produce these ten bars, it was decided that this method

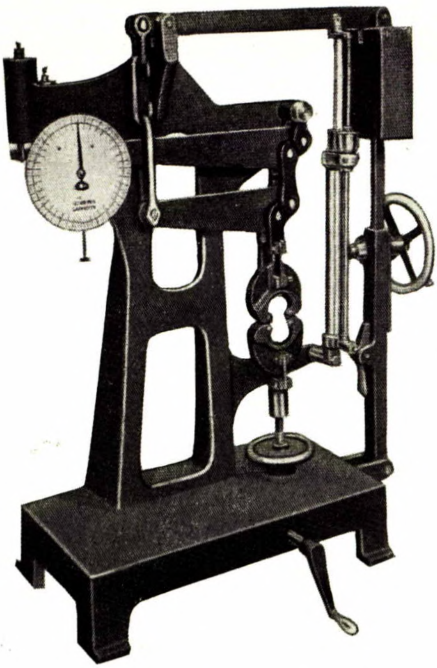
[1] Jour. Am. Cer. Soc. vol. 3, No. 3, p. 250 (1920).
[2] Op. cit.

of forming was impracticable. It is extremely difficult to throw a piece of clay into a mould which is so narrow, especially when its depth is equal to its width, without having the entrapped air prevent the clay from satisfactorily filling the mould. The method finally adopted was to cut the wedged clay into bars of a length and width slightly smaller than the mould but with a depth sufficiently greater to ensure more than enough material to completely fill the mould. These bars were slipped into the mould and the clay was forced into place by striking with the heel of the hand, beginning at the middle and working to the ends, then back and forth until the mould was completely filled, after which the excess material was struck off with a wire and the surface slicked with a spatula. The bars were suitably numbered near the ends before being removed from the mould. Twenty bars were made of each mixture.

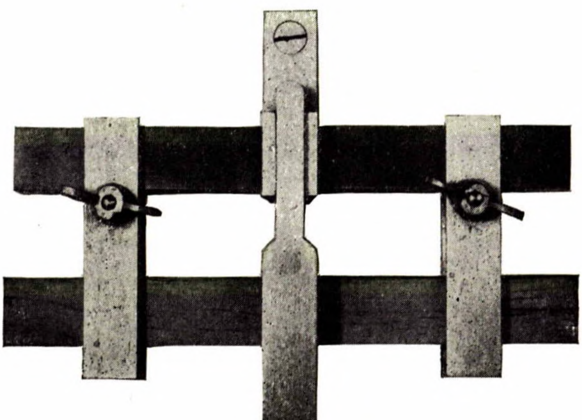
The drying was carried out in accordance with the method given in the Tentative Test. The bars were allowed to dry under cloth at room temperature for two days, then placed in a dryer operating between 64° C. and 76° C. for one day. They were then finally dried at a temperature of 110° C. for one day, which was found to be plenty of time for them to become practically constant in weight. The test pieces were allowed to cool in desiccators and were then broken.

Ten bars of each mixture were broken with the load applied at the rate of 100 pounds per minute, and ten at 50 pounds per minute. After each break careful measurements were made of the cross-section of the bar and observations made as to the internal structure and the character of the fracture. The modulus of rupture was determined by the formula specified in the Tentative Test. An average was made of the moduli from each set of bars and deviations from this average greater than 15 per cent were struck out, and a new average was calculated from the moduli of the eight or nine remaining bars.

The machine used for breaking the test bars was the latest model Olsen-Boyd Automatic Cement Tester as shown in Plate IA. It is equipped with a special tool for transverse tests as shown in Plate IB. This machine in general appearance closely resembles the ordinary type of automatic cement tester, but the load is applied by means of a suspended weight which is governed hydraulically. This weight is set in motion by releasing a latch (shown at the lower right). As the weight moves down, the load is applied to the test bar through the action of the weighing system. The rate of descent of the weight and consequently the rate of application of the load may be regulated hydraulically by a valve at the bottom of the vertical cylinder. This load is indicated on the dial shown at the extreme left of the machine. To make a test the weight lever is raised by the hand wheel at the right to the top position and the pointer on the dial is set at zero. The test bar is then placed in position, and a small initial load is applied by the hand wheel below the transverse tool, then the latch is released, thus applying the load to the bar until fracture occurs. The pointer on the dial remains in the position at which the break occurs, and is returned to the zero position by pushing up the plunger below the dial after the reading is taken. The usual capacity of the machine is 2,000 pounds, but a special spring is used in the weighing apparatus for testing dry clays which gives the dial a maximum reading of 200 pounds with an accuracy of 0·5 pound. The transverse tool is

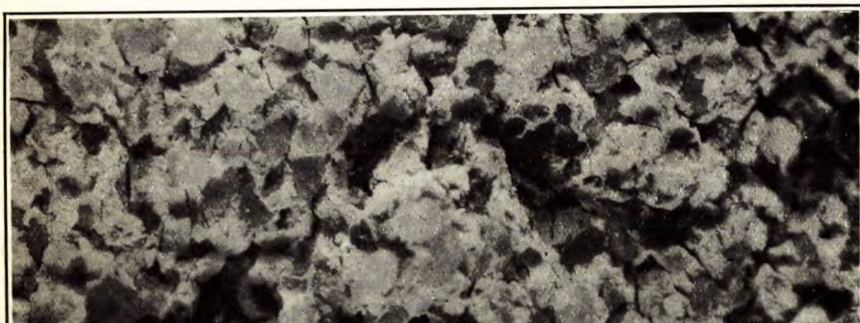


A. Automatic cement tester



B. Transverse-strength tool

A. Surface of clay-sand bar ($\times = 15$ approx.)



B. Cross-section of clay-sand bar ($\times = 15$ approx.)

A. Surface of clay-flint bar ($\times = 15$ approx.)

B. Cross-section of clay-flint bar ($\times = 15$ approx.)

worthy of special mention as it has features which simplify centering of the bar and save a great amount of time in work of this kind. As shown in Plate IB, it consists of the usual three rounded knife edges, the lower two supporting the test piece, the upper one being applied on top of the bar at the middle of the span. This upper knife edge is held at a constant centre by sliding up and down through grooves in the piece supporting the lower knife edges. A scale is cut into the steel of this supporting piece and the standards of the lower knife edges may be slid along this scale and clamped at any desired span by wing nuts. Thus, once the tool is set with the proper span the test piece is simply slid into place and no further centering is required.

The simplicity of this machine and the fact that the knife edges are automatically centered and held parallel to one another permit the bars to be placed in position much more rapidly and much more securely than in the old type automatic shot machine.

An examination of the test bars before breaking showed that cracking had occurred during drying in practically every bar in which sand had been used. In many cases these cracks were plainly visible to the naked eye and in others they were more or less microscopic. When the bars were broken it was quite evident that these fine cracks were not only on the surface (as shown in Plate II A), but that they were present throughout the entire structure of the test bar (as shown in Plate II B).

The clay-flint bars while they showed no evidence of drying cracks were found in many cases to contain small voids. Plates III A and B show the surface and cross-section of a clay-flint bar. These bars had more diagonal breaks than those of the clay-sand mixtures. This might be due to the higher load at which the breaks occurred. However, neither the air holes nor the diagonal breaks gave any indication of affecting the modulus of rupture in any of the tests made.

TABLE I

Modulus of Rupture (Load applied at Rate of 100 pounds per minute)

Clays	Sample No.	Clay-Sand					Clay-Flint				
		Average	Maximum	Per cent above average	Minimum	Per cent below average	Average	Maximum	Per cent above average	Minimum	Per cent below average
English	100	170	191	12	151	11	190	217	14	175	9
	101	186	211	13	173	10	219	237	8	206	6
	102	156	170	9	136	13	194	216	10	174	10
	103	137	144	4	125	9	181	203	10	156	14
American	104	170	178	5	153	10	189	194	3	178	6
	105	86	89	3	79	8	108	111	4	105	3
	106	222	239	8	211	5	306	324	6	291	5
	107	141	158	12	123	13	276	309	12	263	5
	108	210	226	8	199	5	280	293	5	265	5
	109	121	136	13	107	11	307	336	9	287	7
	110	70	73	4	64	9	102	109	7	95	7
Canadian	111	124	130	5	116	7	517	552	6	470	9
	112	52	55	6	47	8	634	643	1	603	5
	113	102	106	4	97	5	376	420	12	344	9
	114	165	189	15	145	12	193	204	6	181	6
	115	85	89	5	82	3	312	340	8	266	15
	116	161	166	3	151	6	419	485	15	404	4
	117	68	71	4	60	12	495	528	7	448	9
	118	114	123	12	105	7	380	431	13	328	14
	119	115	127	10	99	14	893	1,000	12	801	12
	120	137	153	12	127	7	538	617	15	470	13
	121	125	140	12	106	15	171	195	14	146	14
	122	185	193	4	179	3	340	380	12	308	9
	123	162	173	7	144	11	792	820	11	732	8
	124	126	131	4	114	10	628	723	14	540	14
	125	299	341	14	259	13	546	585	10	493	8
	126	66	70	6	57	14	343	393	15	326	5
	127	180	201	12	164	8	551	573	5	525	5
	128	84	92	10	75	10	322	354	13	282	10
	129	65	73	13	59	9	548	575	5	486	11

TABLE II

Modulus of Rupture (Load applied at Rate of 50 pounds per minute)

Clays	Sample No.	Clay-Sand					Clay-Flint				
		Average	Maximum	Per cent above average	Minimum	Per cent below average	Average	Maximum	Per cent above average	Minimum	Per cent below average
English	100	176	198	11	151	14	205	227	11	185	10
	101	198	222	12	169	15	246	260	6	214	13
	102	147	161	10	136	7	174	201	15	152	13
	103	143	211	10	126	12	188	204	12	165	12
American	104	152	169	11	141	7	176	195	13	152	14
	105	91	104	14	80	13	134	151	13	121	10
	106	225	248	11	194	14	[illegible]80	298	6	259	8
	107	165	173	5	144	12	291	332	14	250	14
	108	208	225	8	196	6	297	336	13	255	14
	109	140	144	3	124	10	247	261	6	235	5
	110	78	84	8	74	10	104	112	8	100	4
Canadian	111	124	131	6	117	6	472	521	10	431	9
	112	66	75	14	62	6	617	669	8	576	7
	113	96	105	9	88	8	419	449	7	401	4
	114	158	180	14	139	12	169	184	9	143	15
	115	72	81	13	64	11	355	385	9	340	4
	116	118	135	11	95	11	512	576	12	446	13
	117	74	80	8	63	15	452	520	15	399	11
	118	102	108	6	95	6	483	550	14	418	13
	119	119	127	7	109	8	859	993	15	785	10
	120	129	143	11	122	5	532	595	12	456	14
	121	131	143	9	120	8	165	189	15	149	9
	122	161	189	18	141	12	341	377	11	308	1[illegible]
	123	224	252	13	201	10	767	877	14	678	12
	124	128	131	3	122	4	633	729	15	565	11
	125	294	319	9	266	10	386	446	15	345	11
	126	69	79	15	64	7	379	394	4	349	9
	127	184	204	15	159	10	592	616	8	543	8
	128	80	84	6	77	3	344	370	8	298	13
	129	63	69	10	54	14	363	385	6	352	3

TABLE III

Per Cent Shrinkage

Sample No.	100% Clay	50% Clay, 50% Sand	50% Clay, 50% Flint
100	6·0	4·0	5·7
101	7·2	5·7	6·6
102	7·3	4·0	5·7
103	8·3	4·5	5·2
104	7·4	4·0	4·9
105	7·9	4·0	4·0
106	8·7	4·9	5·7
107	7·2	4·9	4·9
108	9·1	5·3	5·7
109	7·9	4·5	5·7
110	7·5	4·0	4·0
111	9·7	4·9	5·3
112	13·2	7·5	10·3
113	10·7	4·9	5·7
114	7·2	4·0	4·9
115	8·3	4·0	5·7
116	10·5	5·3	6·6
117	12·5	4·0	5·3
118	10·4	5·3	6·2
119	9·5	6·2	7·5
120	8·7	5·3	6·6
121	6·6	5·1	5·2
122	10·1	4·0	5·3
123	10·7	6·6	7·5
124	11·9	4·9	6·2
125	10·5	4·9	4·9
126	8·5	4·0	5·3
127	8·7	5·7	7·5
128	8·3	4·0	4·9
129	9·5	4·0	5·3

The tests with the load applied at 50 pounds per minute were made to ascertain whether a slower rate of load application than that specified would make any material difference in the moduli obtained. Tables I and II show that the differences in moduli were, for the most part, negligible. A study of the averaged maximum deviations from the average modulus brings out two interesting points. With the clay-flint mixtures these were 10·8 per cent above and 10·1 per cent below when the load was applied at the rate of 100 pounds per minute, as compared with 9·1 per cent above and 8·6 per cent below when the load was applied at the 50-pound rate. In the clay-sand mixtures they were 10 per cent above and 9·2 per cent below when the load was applied at 100 pounds per minute and 8·3 per cent above and 9·3 per cent below when the load was applied at the 50-pound rate. The average deviation of the clay-flint bars was greater than that of the clay-sand bars both above and below when the load was applied at the rate of 100 pounds per minute, but when the load was applied at the rate of 50 pounds per minute, the deviation above the average modulus was greater with the clay-flint bars while the deviation below the average modulus was greater with the clay-sand bars. The reason for this is not apparent, however the total deviations were less with both the clay-flint and clay-sand mixtures when the load was applied at the rate of 50 pounds per minute. This indicates that a slower rate of load application would give more consistent results, but as the differences were not great no definite conclusion should be drawn until tests have been run on a much greater number of clays.

Analysis of Results

The clay-sand moduli range from a minimum of 50 pounds to a maximum of 300 pounds, while the clay-flint range from 100 pounds to 900 pounds. The clay numbers being arranged in ascending order of clay-sand moduli naturally present a more or less steadily rising curve. In this arrangement of clay numbers the curve of the clay-flint moduli is very jagged and is markedly similar to the clay shrinkage curve. Generally high shrinkage clays are more plastic and have a higher bonding

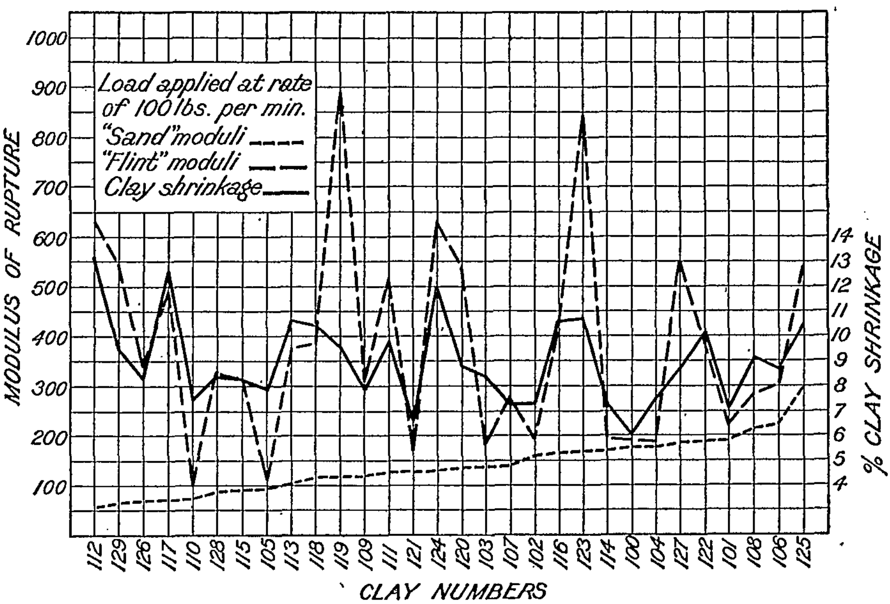


Figure 1. Clay numbers arranged from low to high clay-sand moduli, 100 pounds per minute.

strength than those with a low shrinkage. There are notable exceptions to this as shown in particular by clays No. 119 and No. 123. These clays evidently possess some particular physical characteristic not found in the others to account for their extremely high bonding strength. The main points illustrated by these curves are the much wider gradient between the strongest and weakest of the clay-flint mixtures when compared to the narrow gradient of the clay-sand mixtures, and the striking similarity between the curves showing clay shrinkage and clay-flint modulus, whereas the curves of clay shrinkage and clay-sand modulus give no evidence of any relationship. Furthermore, there are no proportional relationships of the clay-flint and clay-sand moduli curves. In some cases the clay-flint modulus approximately equals the clay-sand modulus and in others it may be several hundred per cent higher than the clay-sand modulus.

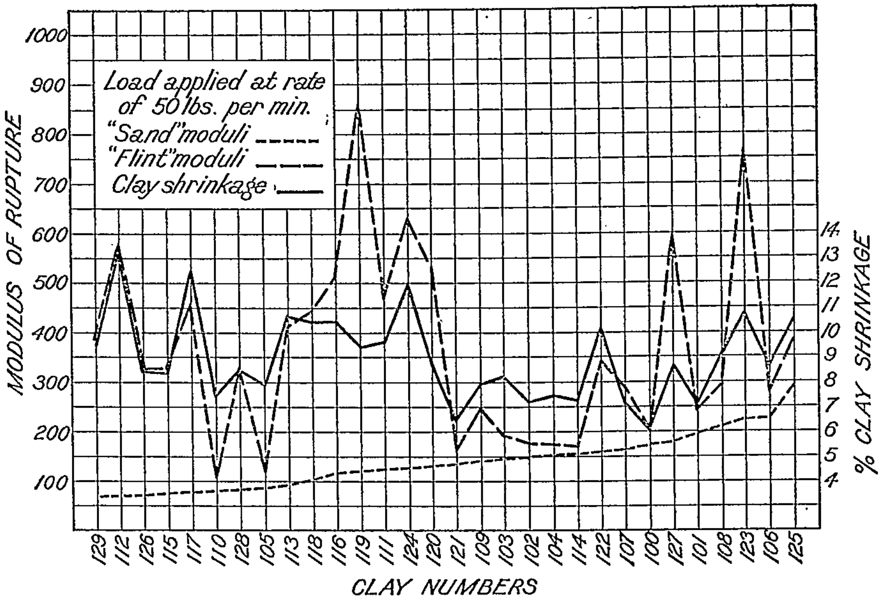


Figure 2. Clay numbers arranged from low to high clay-sand moduli, 50 pounds per minute.

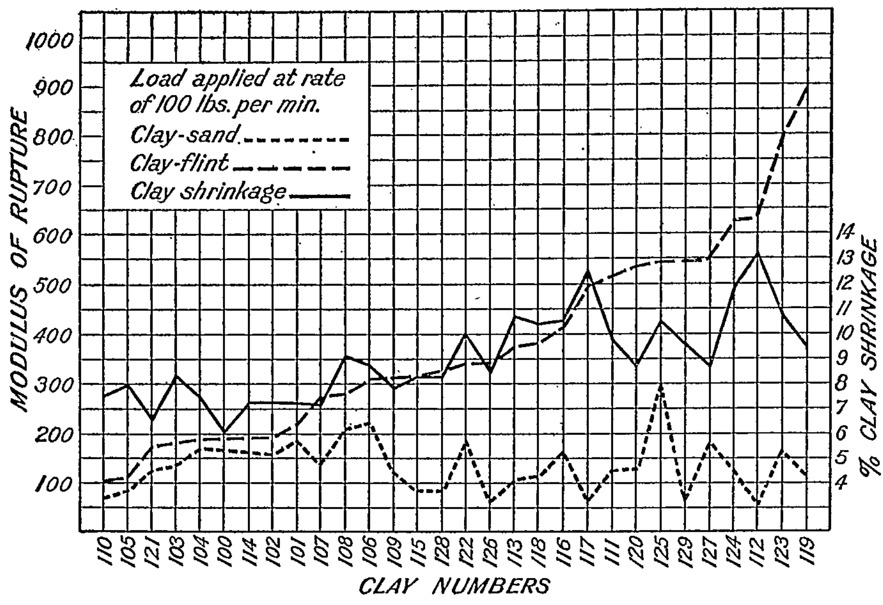


Figure 3. Clay numbers arranged from low to high clay-flint moduli, 100 pounds per minute.

The very small differences in the moduli of many of the clay-sand mixtures have caused some rearrangement of the clay numbers when the bars were broken with the load applied at the rate of 50 pounds per minute. However, the curves are very similar to those in Figure 1, and the same points are clearly illustrated, in fact, the similarity between the shrinkage and clay-flint modulus curves is much closer than in Figure 1.

At first glance the curves may appear to show a closer relationship between clay shrinkage and clay-sand moduli when the clays are arranged from low to high clay-flint modulus, as in Figure 3, but on further examination it will be seen that the clay shrinkage and clay-flint moduli curves are much more conformant than the clay shrinkage and clay-sand moduli curves. In fact, the general trend of these latter curves is divergent, which, incidentally, is even more evident. As the shrinkage increases the modulus of the clay-sand mixtures decreases, so that, as in the case of clay No. 112, the clay with the highest shrinkage and a very high clay-flint modulus, has the lowest clay-sand modulus of any of the clays tested. Such extremes occur because of the shrinkage of the fine-grained clays around the sand grains with consequent cracking as was shown in Plates II A and B.

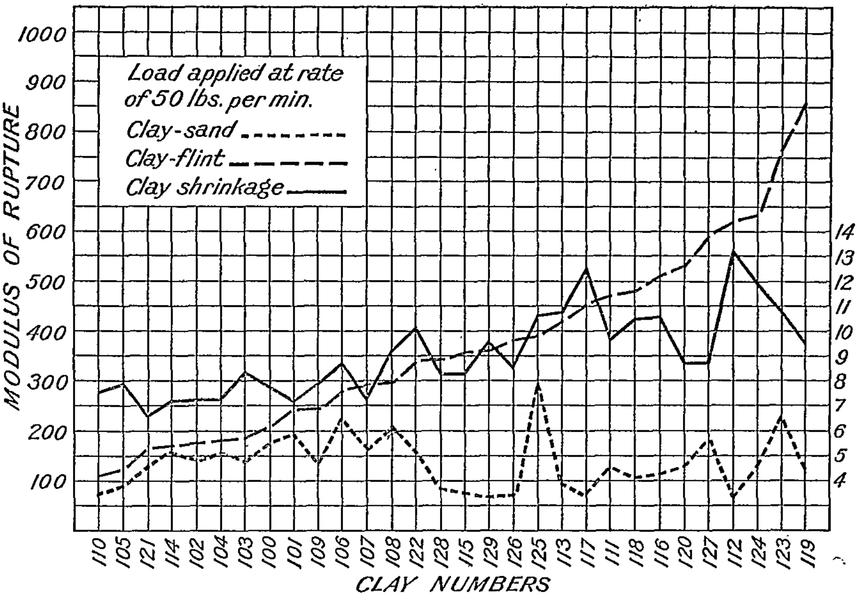


Figure 4. Clay numbers arranged from low to high clay-flint moduli, 50 pounds per minute.

The curves here are so similar to those in Figure 3 that no additional explanation is deemed necessary.

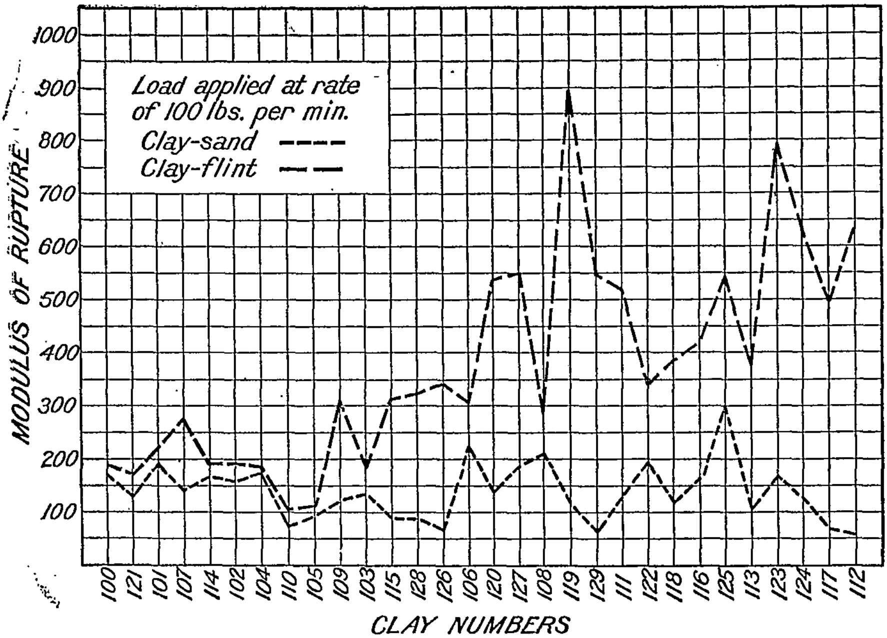


Figure 5. Clay numbers arranged from low to high clay shrinkage. Moduli at 100 pounds per minute.

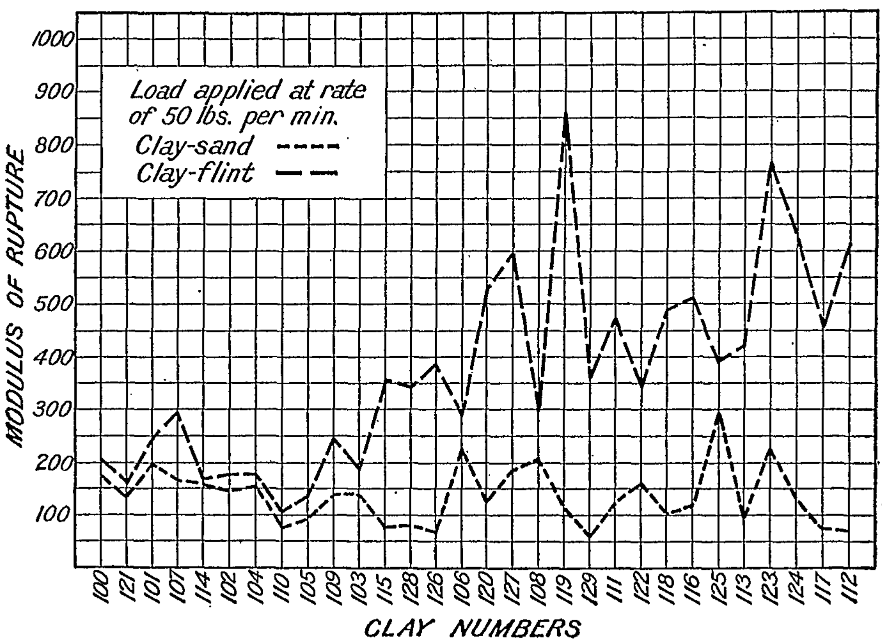


Figure 6. Clay numbers arranged from low to high clay shrinkage. Moduli at 50 pounds per minute.

The curves produced by arranging the clays in order of low to high clay shrinkage are nearly identical in both the 100 pounds per minute and the 50 pounds per minute rate of load application. These curves illustrate better than any of the others the extreme differences of moduli between the clay-flint and clay-sand mixtures. The first nine clays with the exception of No. 107 have only the small differences which might be expected between the clay-sand and clay-flint moduli. No. 107 breaks away from the ordinary in the same manner but to a lesser extent than Nos. 120, 119, 118, 123, and 112. These clays in particular illustrate that while high moduli are obtained from the clay-flint mixtures, the moduli of the clay-sand mixtures are lower, by far, than those of much weaker clays as judged by working properties and clay-flint modulus. The area between these curves shows that these divergences occur more often and to a greater extent as the shrinkage increases. In these figures (Nos. 5 and 6) as in the others the clay-sand moduli make a much flatter line than those of the clay-flint.

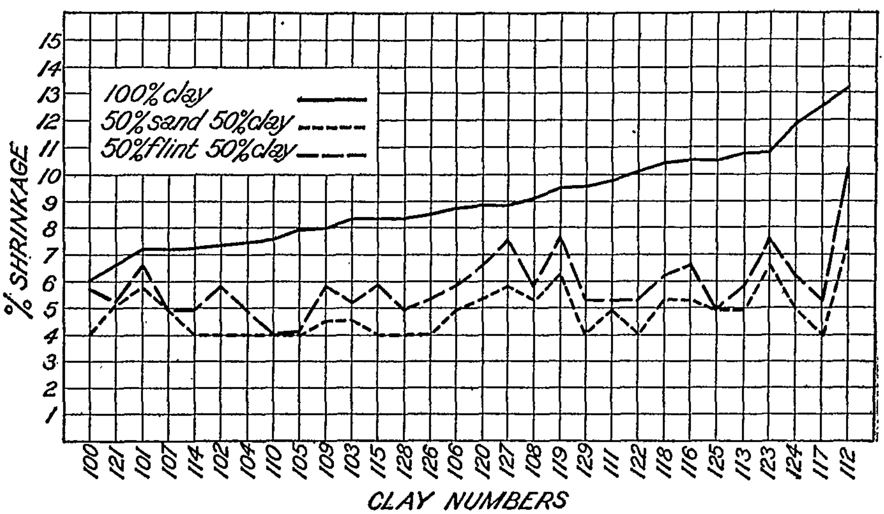


Figure 7. Clay numbers arranged from low to high clay shrinkage.

These curves show the shrinkage of the clay mixtures as related to the shrinkage of the clays without the addition of non-plastic. The surprising feature is the relatively small differences between the clay-flint and clay-sand mixtures as compared with the generally increasing difference of the clay shrinkage. That is, as the clay shrinkage increases the difference between the clay-flint and clay-sand shrinkages remains the same and in some cases even decreases. This proves that drying conditions especially as applied to shrinkage and warpage are improved little more when sand is the non-plastic than when potter's flint is the non-plastic. Such results disprove the argument used by many that the coarse non-plastics improve drying conditions to a much greater extent than fine ones.

Table IV is somewhat in the order of a summary of the preceding graphs. The clay numbers in the first column are arranged according to ascending clay-sand moduli with the load applied at the rate of 100 pounds per minute. The second column therefore runs from 1 to 30 consecutively. The third column gives the position of the clays in the clay-sand modulus graph with the load applied at the 50-pound rate. The fourth and fifth columns give the position of the clay numbers as arranged on the clay-flint ascending moduli at the 100-pound and 50-pound rate respectively. The last column gives the position of the clays on the graph arranged in order of clay shrinkage ascendancy. That is, clay No. 112 is 1st on the graph arranged to ascending clay-sand modulus at the 100-pound rate, 2nd at the 50-pound rate, but is 28th on the ascending clay-flint modulus graph at the 100-pound rate, 27th at the 50-pound rate, and is 30th on the ascending clay-shrinkage graphs.

The columns showing clay-sand modulus arrangement at the two rates of load application as compared with those showing clay-flint modulus arrangement are very different. These columns when compared with that of clay-shrinkage show very plainly the close resemblance of arrangement between clay-shrinkage and clay-flint modulus, and the very different arrangement between clay-shrinkage and clay-sand modulus.

TABLE IV

Index of Arrangement

Clay No.	Clay-Sand		Clay-Flint		Clay shrinkage
	100 lb./min.	50 lb./min.	100 lb./min.	50 lb./min.	
112	1	2	28	27	30
129	2	1	25	17	20
126	3	3	17	18	14
117	4	5	21	21	29
110	5	6	1	1	8
128	6	7	15	15	13
115	7	4	14	16	12
105	8	8	2	2	9
113	9	9	18	20	26
118	10	10	19	23	23
119	11	12	30	30	19
109	12	17	13	10	10
111	13	13	22	22	21
121	14	16	3	3	2
124	15	14	27	28	28
120	16	15	23	25	16
103	17	18	4	7	11
107	18	23	10	12	4
102	19	19	8	5	6
116	20	11	20	24	24
123	21	28	29	29	27
114	22	21	7	4	5
100	23	24	6	8	1
104	24	20	5	6	7
127	25	25	26	26	17
122	26	22	16	14	22
101	27	26	9	9	3
108	28	27	11	13	18
106	29	29	12	11	15
125	30	30	24	19	25

CONCLUSIONS

The results obtained with this series of 30 representative ball clays definitely prove that sand when used as the non-plastic does not give a true indication of the dry transverse strength. Clays having working properties and physical characteristics which mark them as amongst the strongest of the series, when mixed with 50 per cent of standard silica sand have a modulus which would place them amongst those clays whose working properties and physical characteristics definitely mark them as the weakest of the series. Furthermore, the narrow range between the lowest and highest clay-sand modulus as compared to the wide range of the clay-flint moduli does not permit the proper allocation of clays in reference to their dry transverse strength. In addition to this the use of any non-plastic which causes numerous drying cracks to appear throughout the structure of test bars should not be considered in any tentative test.

The results obtained when potter's flint was used as the non-plastic were quite satisfactory in every way. The clay with working properties and physical characteristics which mark them as having a high bonding power actually have a high transverse strength. While not holding true in every case the shrinkage curves and moduli are similar, the moduli increasing as the clay shrinkage increases. The most notable exceptions to this are clays which have an unusually high modulus and this must be attributed to some other physical characteristics than that indicated by shrinkage. The wide range between the highest and lowest clay-flint modulus facilitates the placing of clays in order of their true strength, whereas the narrow range of the clay-sand moduli makes such placing very uncertain. The drying of clay-flint test bars offers no difficulties if the drying method prescribed in the tentative test is carried out. No trouble was encountered in this investigation with extreme warpage and practically none of the clay-flint bars showed any evidence of drying cracks. The use of a finely ground non-plastic makes the test conditions much closer to actual conditions of use as in whiteware bodies and for this reason, if for no other, the use of potter's flint is desirable.

Mention was made in the procedure of the impracticability of forming the test bars by the method described in the tentative test. It cannot be said that the method of forming bars used in this investigation is perfect or that it is the best method in use, nevertheless, the concordance of results proved it to be very satisfactory.

The difference shown to exist between results obtained with the rate of load application at 50 pounds per minute and at 100 pounds per minute, even though they were not great, should make this worthy of further work.

The following suggestions for revising the tentative method of testing dry transverse strength have been submitted to the American Ceramic Society:

(1) That a fine non-plastic (preferably potter's flint) be specified in place of standard silica sand.

(2) That the method of forming the test bars be changed to one that is practicable.

(3) That further consideration be given to the rate of application of the load.

III

PRODUCTION OF GREY BRICK

L. P. Collin

I. ADDITIONS OF MANGANESE DIOXIDE AND LIMESTONE DUST

Grey brick are generally produced by adding small percentages of manganese dioxide to light buff-burning clays. There are only a few good quality buff-burning clays in Ontario and Quebec, and these are of a quite different type from those from which grey brick are made. It was considered advisable to add limestone dust to the Canadian materials used so that the bleaching action of the lime might produce a lighter background than is natural with these materials.

The clays and shales used in this experimental work were obtained from the Citadel Brick, Ltd., of Quebec, and the Don Valley Brick Works, Ltd., of Toronto. These materials were considered representative of the buff-burning clays of Ontario and Quebec, and the above companies were the first to request aid for making grey brick.

The manganese dioxide used was obtained from E. J. Lavino and Company, and from the National Paint and Manganese Company. The air-floated manganese of E. J. Lavino was used for the most part and the larger grain sizes from the National Paint and Manganese Company were used in only a few mixtures to determine the effect of grain size, as it was found that the best results were obtained with the air-floated material.

The limestone dust is a product of a high calcium stone and was obtained through the Citadel Brick, Ltd., from Deschambault, Quebec. A screen analysis of this stone dust is as follows:—

	Screen mesh	Per cent limestone dust
On	65	4·40
"	100	51·20
"	150	11·55
"	200	18·90
"	270	10·10
Through	270	3·40
		99·55

Mixtures were made containing from ½ per cent to 4 per cent of manganese dioxide and from 2 to 12 per cent of limestone dust. Briquettes made from these mixtures were burned in both oxidizing and reducing atmospheres. Satisfactory grey shades were obtained in the oxidizing burns with the materials from both the Citadel Brick, Ltd. and the Don Valley Brick Works, Ltd. Following this laboratory work plant tests were made in the kilns of the companies named above. The results were not the same as were obtained in the laboratory kilns. However, it would seem that a satisfactory colour could be obtained in commercial kilns, but not economically. Probably 4 per cent manganese dioxide and 8 per cent limestone dust would be required, and this would make the cost prohibitive. In addition to this the bricks made with such a large percentage of lime would not be so hard and strong as is desirable.

The above work has shown that it is not economically feasible to produce a grey brick from these materials, capable of competing with the imported product, by additions of manganese dioxide and limestone dust.

Upon examining several of the imported grey brick under the microscope, it was found in every case that their structure was quite vitreous. It may be that the light reflecting properties of this vitreous structure are of great importance in producing the grey effect. It is well known that the clays and shales of Ontario and Quebec cannot be burned commercially to a vitreous condition as their vitrification range is very short. It is also known that manganese does not have the same reaction at the burning temperature of the Ontario and Quebec materials as it does at the higher burning temperature of the low-grade fireclays from which the imported brick are made. It would seem that if grey brick are to be made from the raw materials of Ontario and Quebec, it will only be through some process quite different from that employed by the manufacturers of the imported brick.

IV

CLAYS AND SHALES OF PRINCE EDWARD ISLAND

Howells Fréchette and J. F. McMahon

A general survey of the clay and shale resources of Canada was made by the late Joseph Keele in part with the collaboration of Prof. H. Ries, and reported in several volumes published by the Geological Survey.[1]

In this series of reports only brief mention of clay in Prince Edward Island was made, no detailed work having been done in that province. In order to round out our general knowledge of the clay and shale resources of Canada it was decided to survey the situation in Prince Edward Island.

During 1927 and 1928 the senior author covered the province very thoroughly, studying the general structure and examining and sampling outcrops of clay and shale.

The samples collected were tested by standard methods by J. F. McMahon. A complete report covering the occurences of clays and shales and the results of the tests from which conclusions are drawn regarding their qualities and suitability for definite economic uses will be published in a separate bulletin.

The present report will deal with the subject only in a general way, outlining the general distribution and characteristics of these resources.

Prince Edward island is somewhat saddle-shaped in outline, having a length of about 125 miles from southeast to northwest and an average width of about 20 miles. The coast line is deeply indented by bays and tidal rivers, particularly on the southern or Northumberland Strait coast. At two points these indentations almost completely sever the island.

Along the north or Gulf of St. Lawrence coast are long stretches of sand beaches and dunes, but at intervals and particularly towards the eastern end of the island the shores are abrupt cliffs up to 40 feet or more in height. The southern and western coast in general is bluff with cliffs rising in places to upwards of 100 feet.

These coastal cliffs are largely red sandstone with beds of red shale which are usually very sandy. The prevailing dip is at a low angle to the north and east with local moderate rolls both with and across the general strike. In general, the topography of the island is undulating with decidedly hilly sections in the central portion. The rocks are exposed in but few places in the interior, being mantled with a covering of sandy loam and boulder clay.

[1]Geol. Surv., Canada, Mem. 24E, 25, 47, 64, 65, 66, and 142.

SHALE

The prevailing rocks of Prince Edward Island are soft, red sandstones and arenaceous shale probably of Permian or Upper Carboniferous age. The sandstones predominate and are usually thin bedded. They generally contain a considerable percentage of clay matter and in some horizons may be regarded as sandy shales which are very gritty and contain mica or sericite flakes in noticeable amount. While these shales as a rule are unsuitable for the production of clay products, some beds were observed which are of sufficient purity for the manufacture of heavy clay products and even pottery.

The lateral persistence of these shales could not be determined from continuous exposures but in one locality a fairly thick bed was definitely traced for over half a mile. It is evident that the shale is subject to pinching out and gradual displacement by sandstone or very sandy shale, but it is probably of common occurrence, though masked by overburden, especially in the northwestern part of the province. This assumption is based on the numerous swampy areas where the water-table is raised to the surface by impermeable shale, or clay to which it has weathered.

The shale generally is thin bedded with interlaminations of very thin sandstone and silt partings. In several localities one or two layers of limestone about one-quarter inch thick were observed in the shale; however, the quantity present is so small that it would not be particularly harmful in the manufacture of heavy clay wares. In addition to these shales which show the usual foliated shale structure, some beds are massive and chalk-like in texture and hardness. This type of shale goes by various names in different sections of the island, chalk, marl, red ochre, and keel. Keel would seem to be the most satisfactory term to use since the material is a red chalky substance similar in character to the keel which is used as a crayon for marking lumber. In some localities the keel occurs in beds several feet thick associated with the laminated shale. Elsewhere it is found as isolated masses in the sandstones. These masses range from less than an inch in diameter to four or five feet. No attempt was made to work out the origin of these occurrences. They are not of commercial importance and are referred to here only for the purpose of pointing out that an exposure of keel in a small outcrop should not be accepted as an indication of a continuous deposit.

All these shales are bright red and quite soft when finely ground, even those containing considerable sandy matter develop good plasticity; the clay substance itself being of a very plastic nature. From the ceramic point of view they may be classed as red-burning shales of low refractoriness. Under heat they soften and deform at temperatures corresponding with pyrometric cones 4 to 12. They are thus limited in use to the production of heavy clay products and certain types of pottery. Their most outstanding characteristic is colour, in most cases burning to very pleasing shades of red.

Many of the exposures of shale show rather deep weathering which has disintegrated the shale and caused it to revert to clay. This clay, due to the keel and the purer laminated shales, is very plastic and strong and while not great in quantity might be used to advantage for the production of pottery. The use of it for the manufacture of brick and tile is possible, but as it has a marked tendency to laminate in the auger machine, special precautions would have to be taken to prevent the development of this fault.

The principal exposures of shale are found in the coastal cliffs as has already been mentioned, particularly along the Northumberland Strait side of the island. Following this coast from east to west important beds were observed at various points between Bothwell and Broughton river, Orwell bay, Lobster point, Hillsborough bay, cape Egmont, and at many points between West point and North point. Along the northern coast shale is much less common and the beds observed were not regarded as of commercial importance. Very few exposures of shale were seen inland due to the mantle of soil which hides the rock formations. In the Devil's Punch Bowl, a valley south of Granville, in lot 21, a thick bed of keel is exposed where water from a spring flows down the valley side. A similar occurrence was seen near Rose Valley. While no other actual outcrops were observed inland, keel was uncovered at a number of points underlying clay, particularly within the central section of the province. It is said that it is frequently encountered in the digging of wells and cellars.

CLAYS

Three main types of clay occur in Prince Edward Island, namely, marine clay, boulder clay, and the clay resulting from the weathering of the shales in place.

Much of the island is covered with soil deposited under marine conditions when the province was overlain by the ocean or impounded glacial waters. These marine sediments are largely sand impregnated with red clay in widely varying proportions. Generally, the sand predominates, but in places the percentage of clay matter is sufficiently high to classify the soil as a sandy clay. These marine clays are seldom more than two or three feet in thickness and do not constitute important deposits as a source of clay for the manufacture of clay wares though most of the brick plants which have operated in the past within the province drew upon such beds for their clay. The plasticity, as might be expected, varies greatly due to the variations of sand content. The burned colour is usually a good red.

Boulder clay is of common occurrence. Like the marine clay it is red and frequently is very sandy. The rock fragments which it contains are usually sandstone or sandy shale and very small limestone pebbles, particularly west of Summerside. In general, the contained boulders are similar to the rocks of the province and there is evidence that it has not been transported a great distance, in fact in some places it seems that the weathered surface of the underlying rocks had merely been ploughed and shoved short distances by moving ice. The boulder clay is usually rather shallow, though deposits of considerable thickness exist particularly in the northeastern part of the central portion of the island. In most localities the boulder clay is not suitable for the manufacture of clay products due to the high sand content and the numerous sandstone fragments. At several points within the province boulder clay apparently was used for the manufacture of brick. Such brick were usually made by the soft-mud process but, though of a good red colour, they were marred by the inclusions of fragments of sandstone. At one old plant where boulder clay and marine clay were used small pebbles of limestone caused considerable trouble from popping, that is pitting of the surface of the ware due to the hydration of small masses of lime to which limestone pebbles had burned.

In general the clays do not offer so good a promise as do some of the shales as a source of raw material for a clay-working industry.

TESTS

Extensive laboratory tests have been made on the samples of shale and clay, collected from representative beds, to determine their physical properties. Various classes of ware have been made in order to judge with some degree of certainty the classes of product for which the available material is best suited.

The complete report on the clays and shales of Prince Edward Island and the results of the tests will be issued as a separate publication in the near future.

V

PROGRESS 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 1928.

The object of this investigation which was commenced in 1927[1] was to present production cost figures which might aid the clayworker in his choice of clay-gathering equipment, and assist him to cut down his cost of manufacture.

During the course of field work the writer was able to make suggestions to many of the operators relative to economies which could be effected in the winning and haulage of their raw material.

Operation No. 21

Output. Sufficient clay is moved for the manufacture of 24,000 soft-mud brick per day for an average of 50 days per year.

Method of Winning. The clay deposit has been uncovered to an extent of some 5,000 square yards. This exposure permits of a certain amount of weathering which facilitates ploughing and harrowing. A portion of this exposed area, having been broken by a tractor-drawn plough and harrow, is traversed by a horse-drawn Quincy clay-gatherer which with its rotating shovels loads the loosened clay into its drum. A carload having been collected in the drum, it is drawn to the loading trap and dumped into a waiting car.

Haulage. The car is then pulled by cable to the brick plant where the clay is dumped directly into the brick machine. The haulage distance is 200 yards, part of which consists of a climb of 25 feet to the dumping point at the plant.

Comment. The system which provides a large area for evaporation has a distinct advantage for the operation of clay deposits which have a tendency to hold such a high percentage of moisture as to make the clay too wet for use in the brick machine.

This system adequately supplies the need of the plant excepting in wet weather when going is particularly hard for the horses and the clay tenacious both *in situ* and in the drum of the gatherer. Reserve storage would be highly desirable in an operation of this type in order to overcome this deficiency.

[1]Mines Branch, Dept. of Mines, Canada., Invest. in Ceramics and Road Materials, 1927 (No. 697).

Cost per Ton of Clay

Digging:		
Labour	$ 0·15713	
Equipment	0·04848	
		$ 0·20561
Haulage:		
Labour	$ 0·02428	
Equipment	0·03446	
		0·05874
Total		$ 0·26435

Operation No. 22A

This operation and operation No. 22B are worked together, furnishing a plant with shale and clay respectively for the manufacture of hollow building tile.

Deposit. A pit, 50 feet by 400 feet, has been opened to a depth of 25 feet into hard grey shale. The shale underlies a 6-foot bed of overburden, a sufficient amount of which is removed once every year to permit the operation of the shale to progress. The shale lies to an undetermined depth under the present working floor. The immediate countryside wherein this pit is located is quite hilly.

Output. An average of 100 tons of shale is removed daily.

Winning. A compressed air drill is used for boring holes into the shale, dynamite being used to blast the shale loose. Six men make up the pit crew which loads the shale into cars by hand and shovel.

Haulage. The shale is loaded into steel, side-dump cars (of which there are six), each of 2-yard capacity. When loaded the cars are hitched separately to a cable which winds about an electrically-operated drum and hauls them out of the pit, a distance of 190 yards. The cars are then hauled, three at a time, by gasoline locomotive to the plant 300 yards distant.

The track is kept in good condition and the locomotive has no trouble taking the load up the slight grade between the pit and the plant.

Drainage. In heavy rains it would be difficult to operate the pit if it were not for some drainage system. A deep sump, to which the pit drains, helps in keeping the pit workable.

Cost of Clay Gathering

The pit crew, consisting of 6 men, is paid "en masse" per ton of shale loaded. The total number of men employed is 9, plus half the time of one man.

The plant operates year round on a 10-hour day, and maintains a comparatively good system of cost keeping.

The following figures have been calculated on a 300-day year and a 100-ton daily output.

Cost per Ton of Shale

Quarrying:		
Labour (absorbed by loaders):		
Equipment	$ 0·02140	
Material	0·03410	
Digging and Loading:		$ 0·05550
Labour	$ 0·32000	
Equipment	0·00585	
Haulage:		0·32585
Labour	$ 0·12300	
Equipment	0·07548	
Material	0·00513	
General:		0·20361
Equipment	$ 0·00295	
		0·00295
Total		$ 0·58791

Operation No. 22B

Nature of Deposit. This is a Pleistocene clay deposit which underlies a slight depth of loamy soil (6 inches to 1 foot). The clay is free of stone and has been dug to a depth of 4½ feet. The face exposed shows no bedding of sand or silt. The clay lies to an undetermined depth below the present working.

Output. This operation provides on an average 200 tons of clay per day which is used in the manufacture of building tile. The operation is worked year round on a 10-hour day.

Overburden. The overburden is removed by one man who keeps ahead of the working, shovelling the loam into the old working.

Winning. The clay is dug and loaded by a Buckeye side-wheel clay digger, the rotating bucket knives cutting the clay, catching it, and dumping it onto a belt which carries it to and deposits it into waiting cars.

Haulage. The operation is provided with 6 steel side-dump cars of 2-yard capacity. The loaded cars are hauled by a 3-ton gasoline locomotive, three to a trip, from the operation to the plant, a haul of 700 yards.

Storage. Storage has been provided for. On severe wintry days and in early spring the efficiency of the bank operation is greatly impaired. At such times the reserve storage is drawn upon to keep the plant operating at average capacity.

Cost per Ton of Clay

Overburden:		
Labour	$ 0·01650	
Digging and Loading:		$ 0·01650
Labour	$ 0·03400	
Equipment	0·02115	
Material	0·00925	
Haulage:		$ 0·06440
Labour	$ 0·04350	
Equipment	0·02393	
Material	0·00240	
		$ 0·06983
Total		$ 0·15073

Operation No. 25A

Nature of Deposit. This is a hard shale interstratified with limestone. The depth of the bed worked is 75 feet. The limestone strata make up approximately 50 per cent of the face, varying in thickness from 2 to 5 inches. The limestone adds considerably to the cost of winning the shale; the stone must be removed before the shale goes to the machines, since no removal is feasible at the plant.

Overburden. Over this shale deposit lies a 21-foot bed of sand, the removal of which is dealt with under No. 25B, page 32.

Output of Shale. On an average, 125 tons of shale per day is removed from this pit, which is 1,000 feet long, 500 feet wide, and 75 feet deep. The shale is used in the manufacture of a good grade of stiff-mud building brick and hollow building tile.

Winning. The shale is dynamited from benches, working gradually from the top in a series of 10-foot steps toward the bottom of the pit. A good deal of shale is blasted loose during the course of a year and this shale is allowed to weather for two reasons: first, to permit the development of more plasticity; and second, to facilitate the separation of the limestone from the shale. This weathering is allowed to go on for two years usually, but occasionally it becomes necessary to use the shale much sooner.

Removal of Stone. As the benches are being prepared for drilling and blasting, a good deal of the stone is separated by the drilling crew; also, falling as it does when blasted loose from such a height, a great deal of the shale is shattered free of the limestone; then, after weathering, the stone is picked by hand from the shale and loaded into cars.

The stone can sometimes be sold for building purposes and sometimes for road material, but there is not a steady market for the material. The stone not sold is usually dumped along the incline to the plant, or used for filling in those parts of the pit from which shale has been removed. The shale is loaded by steam shovel into cars.

Haulage of Shale. The loaded cars are pushed by hand to the base of an incline and hauled by cable to the plant where the cars are dumped by hand into a small bin from which the shale goes directly to the dry pans.

Drainage. Drainage is accomplished by means of small ditches which lead to a well from which the water is pumped free of the pit by a pulsometer.

Storage. No provision is made for storage.

Comment. As can readily be seen this is a rather difficult operation to carry on cheaply. The pit has three high, perpendicular faces. The material probably could be worked more economically as a series of benches, but it is difficult to see where radical improvements can be made. However, the larger size of the pit is advantageous in that the shale weathers to a great extent due to exposure at the pit faces, but from a mining standpoint it is a drawback as winning is made so much more difficult.

Cost per Ton of Shale

Quarrying:		
Supervision	$ 0·01427	
Labour	0·11880	
Equipment	0·01216	
Material	0·04096	
		$ 0·18619
Separating and Loading:		
Supervision	$ 0·01427	
Labour	0·13504	
Equipment	0·06880	
Material	0·02448	
		$ 0·24259
Haulage:		
Supervision	$ 0·01427	
Labour	0·08920	
Equipment	0·03661	
Material	0·00920	
		$ 0·14928
General:		
Equipment	$ 0·00592	
		$ 0·00592
Total		$ 0·58398

Operation No. 25B

The deposit is a sand and boulder clay bed directly overlying the shale described in operation No. 25A. The bed in cross-section shows 3 feet of sand with alternating layers of gravel and sand down to a 3-foot bed of boulder clay, 21 feet in all.

While some of the sand is used in manufacture it is mostly discarded along with the boulder clay.

The material is blasted free of the bank, loaded by hand into Hoosier wagons and hauled to a dumping place 500 yards distant.

The figures given are in cost per ton of shale (25A) removed and really represent the cost of removal of overburden for that operation.

Drainage is natural.

Cost per Ton of Shale

Supervision	$ 0·01080	
		$0·01080
Quarrying:		
Labour	$ 0·00360	
Material	0·00680	
		$ 0·01040
Digging and Loading:		
Labour	$ 0·12960	
Equipment	0·00187	
		0·13147
Haulage:		
Labour	$ 0·06480	
Equipment	0·03813	
		$ 0·10293
Total		$ 0·25560

Operation No. 26

Nature of Deposit. A section of the deposit shows 6 feet of sand and gravel overlying 70 feet of clay. The top of the clay bed is sandy but the bottom is clean, the intervening section gradating from a sandy clay to a fat clay.

Output. This operation provides an average of 80 tons of clay per day for use in the manufacture of soft-mud and stiff-mud brick.

Overburden. The 6 feet of sand and gravel is removed by an electrically-driven Bay City dredge. Three days' stripping is sufficient for the removal of overburden for a year's supply of clay.

Winning. The clay is blasted loose from the bank and loaded by hand into cars.

Haulage. Four wooden, side-dump cars, holding 1½ yards, are used to transport the clay. The loaded cars are attached to a ⅜-inch steel cable and hauled by electric hoist up an incline to the plant, a haul of 230 yards with an 85-foot rise.

Storage. Storage is provided for a 2-day run without operation of the pit.

Drainage. A sump, 25 feet below the working floor of the pit, provides drainage. An electrically-driven pump lifts the water free of the pit. However, in wet weather the working of the pit is very difficult.

Cost per Ton of Clay

Overburden:		
Labour	$ 0·00270	
Equipment	0·02325	
		$ 0·02595
Winning:		
Labour	$ 0·27000	
Equipment	0·00731	
Material	0·01000	
		0·28731
Haulage:		
Labour	$ 0·01687	
Equipment	0·02149	
		0·03836
General:		
Equipment	$ 0·00400	
Power	0·00300	
		0·00700
Total		$ 0·35862

Operation No. 27

Nature of Deposit. A face, 65 feet in height, shows a cross-section of 8 feet of very sandy loam underlain by a soft clay, the sand content of which decreases as the base of the deposit is approached.

Output. This operation provides 85 tons of material per day which is used in the manufacture of a good grade of soft-mud brick. The operation is worked 9 hours per day for 9 months of the year.

Winning. The loam is dug and mixed with the sandy clay and the fat clay in the manufacture of brick. The clay is blasted loose from the bank and loaded by hand into wooden, side-dump cars.

Haulage. The loaded cars are carried by gravity for 50 feet in the direction of the plant. A horse then draws them 150 feet to a switch at the base of an incline to the plant. A cable is attached and the cars are drawn by electric hoist up the grade (75 feet in 300 feet) to the plant. The clay is dumped into the brick machine as fast as the machine will take it. When empty, the cars are lowered to the pit.

Storage. No storage space is provided.

Drainage. In wet weather the water drains to a sump from which a pump elevates it to the city sewer.

Cost per Ton of Clay

Digging and Loading:		
Labour	$ 0·16941	
Equipment	0·00666	
Material	0·02300	
		$ 0·19907
Haulage:		
Labour	$ 0·09293	
Equipment	0·02639	
Power	0·01412	
		0·13344
General—		
Equipment	$ 0·00635	
		0·00635
Total		$ 0·33886

Operation No. 29

Nature of Deposit. At the time the data here presented were obtained, a pit 100 feet wide and 200 feet long with a 20-foot face had been opened up. The material is a grey, hard shale interstratified with limestone. The country about is very level.

Overburden. There is no overburden.

Output. An average of 120 tons of shale per day is used in the manufacture of common and face brick.

Winning. The shale and stone are blasted loose from the bank, sorted and loaded by hand into cars. The blasting is done by contract at $10 per hole, which furnishes sufficient material for 175,000 brick.

Haulage. The shale is carried in 1-yard, steel, side-dump cars, the cars being pushed by hand to the base of an incline (a distance varying from 40 to 50 yards) and then attached to a cable, electrically operated, and hauled up the incline to the plant.

Storage. There being no provision for storage the shale is dumped direct into a hopper feeding the dry pans.

Cost per Ton of Shale

Quarrying:		
Labour	$ 0·01666	
Material	0·05056	
		$ 0·06722
Loading:		
Labour	$ 0·35000	
Equipment	0·02528	
		$ 0·37528
Haulage:		
Labour	$ 0·03300	
Equipment	0·00766	
Power	0·00200	
		0·04266
General:		
Equipment	$ 0·00191	
Power	0·00133	
		0·00324
Total		$ 0·48840

Operation No. 30

Nature of Deposit. A 15-foot bed of buff-burning, hard shale, underlying a 6-foot bed of clay overburden, is worked. The shale contains some limestone which must be removed.

Output. The operation provides sufficient material for the daily manufacture of 17,000 dry-press brick. It is operated 10 hours a day for 8 months in the year.

Overburden. Two feet of the overburden is used in the manufacture of drain tile, the remaining 4 feet being discarded. The work of one man is sufficient for removing the overburden.

Winning. The shale is blasted free, the limestone separated by hand sledge from the shale and each is loaded by hand into separate cars.

Haulage. The full cars are pushed from the loading point to a point nearby, a distance of from 10 to 100 feet, where a cable is attached, and the car hauled by electric hoist approximately 100 yards to the plant.

Drainage. No special provision is made for drainage, the pit some days being quite unworkable but not frequently so.

Storage. No provision is made for storage.

Cost per Ton of Shale

Supervision		$ 0·07000
Overburden		0·06000
Quarrying:		
Labour	$ 0·12000	
Material	0·06800	
		0·18800
Loading:		
Labour	0·18000	
Equipment	0·00876	
		0·18876
Haulage:		
Labour	$ 0·03000	
Equipment	0·01754	
Power	0·00800	
		0·05554
Total		$ 0·56230

Operation No. 32

Nature of Deposit. Shale is exposed to a depth of 40 feet underlying a clay overburden which is seen to increase as the workings penetrate the bank. The overburden averages 10 feet in depth and is not used. The top 30 feet of shale is red-burning, while the lower 10 feet is buff-burning. The bank is free from any appreciable amount of stone or undesirable material.

Output. From this operation 350 tons of shale are taken per day for the manufacture of building brick by the stiff-mud and dry-press processes. Two plants are operated from this one deposit. The plants operate 10 hours per day for 10 months of the year.

Winning. In order to operate this face so as to obtain the overburden, the red-burning shale, and the buff-burning shale separate from one another, it has been found expedient to work the face on three levels.

The materials are dynamited loose and loaded by power shovel (there being one on each level) into motor trucks.

Haulage. The motor trucks haul the material from the bank to the plant, a distance of 500 yards.

Overburden. The clay which overlies the desired shale workings is removed in a similar manner to the shale removal. Three months' work on the removal of overburden suffices for a year's operation of the shale.

Storage. No provision is made for storage.

Drainage. Drainage is natural.

Cost per Ton of Shale

Overburden:		
Labour	$ 0·02571	
Equipment	0·03400	
Material	0·00801	
		$ 0·06772
Quarrying:		
Labour	0·014280	
Equipment	0·004175	
Material	0·045710	
		0·064165
Loading:		
Labour	$ 0·038560	
Equipment	0·088245	
Material	0·020000	
		0·146805
Haulage:		
Labour	$ 0·05142	
Equipment	0·03611	
Material	0·02114	
		0·108670
Total		$ 0·387360

Operation No. 33

Nature of Deposit. In this deposit the hard grey shale is interbedded with limestone and sandstone. The pit opened shows a 45-foot bed underlying 10 to 15 feet of clayey overburden.

Output. From this pit 110 tons of shale are removed daily for the manufacture of hollow building tile. A small percentage of clay is added to assist the flow of the shale through the dies.

Winning. The shale, with its associated rocks, is blasted loose from the face of the pit, then separated and loaded by hand into wooden cars.

Haulage. The wooden cars which have a rated capacity of $1\frac{3}{4}$ yards but usually carry 2 yards, are hauled separately by cable out of the pit to a crushing plant.

Overburden. The heavy overburden is removed by steam shovel, the work being done, not by the operators themselves, but by a hired crew. The cost of removal is based on the yardage which the hired crew removes. Sufficient overburden is removed in one season for the following three seasons' work.

Drainage. It is necessary to keep a pump working in the pit for 12 hours per day. This centrifugal pump, operated by a 15 h.p. motor, raises the water 103 feet at a rate of 275 gallons per minute. As the pump is capable of lifting to a height of 120 feet at a rate between 400 and 500 gallons per minute, the pit can be kept workable even during abnormally wet weather.

Cost per Ton of Shale

Supervision		$ 0·04727
Overburden		0·04000
Quarrying and Loading:		
Labour	$ 0·13363	
Equipment	0·00196	
Material	0·03000	
		0·16559
Haulage:		
Labour	$ 0·03272	
Equipment	0·02304	
Material	0·01818	
		0·07394
General—		
Equipment	$ 0·00368	
Material	0·01091	
		0·01459
Total		$ 0·34139

Operation No. 34

Nature of Deposit. The 23 feet of shale exposed at this working underlies a 10-foot bed of boulder clay. The shale bed itself has the following cross-section from top to bottom:

3 ft. Light buff-burning shale.
8 " Light red-burning shale.
2 " Dark buff-burning shale.
10 " Dark red-burning shale.

Output. Sufficient shale is removed from this working to run a plant having an average capacity of 20,000 dry-press brick per day. The plant operates 10 hours per day for a period of 9 months.

Overburden. This is removed by hand as the operation progresses.

Winning. This shale is blasted loose from whichever shale bed material is required; it is sorted and loaded by hand into steel cars.

Haulage. The loaded cars are drawn to the plant, a distance of 450 feet, by cable working in connexion with a drum which receives its power from the plant main shaft.

Storage. No provision has been made for storage.

Drainage. No special provision has been made in this connexion.

Cost per Ton of Shale

Quarrying:		
Labour	$ 0·05416	
Material	0·04000	
		$ 0·09416
Overburden:		
Labour	$ 0·15000	
Equipment	0·00433	
		0·15433
Loading:		
Labour	$ 0·20000	
Equipment	0·00433	
		0·20433
Haulage:		
Labour	$ 0·05000	
Equipment	0·00600	
		0·05600
Total		$ 0·50882

Operation No. 36

The general procedure for handling the material in this operation is quite different from any other met with during the course of this study.

At this deposit there are two clays: on top, a bed of red-burning averaging 11 feet; and underlying this, a bed of buff-burning clay averaging 4·feet; the former varying in places from 4 feet to 18 feet, and the latter from 1 foot to 7 feet.

The plant, after having operated for about 100 days in the course of the summer months, and having produced an average of 15,000 soft-mud brick per day, is generally closed down. By this time the stock-pile has been used up, and more clay must be hauled from the deposit to an out-of-doors storage-pile. Two wagons are used in hauling the clay which a two-wheeled scraper has gathered. The clay is allowed to weather during the winter in the pile and is ready for brick production in the spring.

From what figures were available it has been computed that the clay winning cost, per ton of clay, is as follows.

—	To pile	To plant	Total
Red clay	0·36	0·27	0·63
White clay	0·50	0·27	0·77

The place where the clay has been piled year after year is a regular water hole. The water which gathers here, especially in the spring, is removed by a belt pump operated by a 10 h.p. motor which runs on an average of 120 hours per manufacturing season.

Comment. The double handling of this material adds considerably to the cost of manufacture, and it is doubtful whether the weathering effect is of such value to the soft-mud product as to warrant its continuance.

Operation No. 37

Deposit. In the pit 10 feet of wet, grey stoneless clay is exposed, under which can be seen 18 inches of a wet, blue sandy clay.

Output. From the clay bed 85 tons of clay is taken daily to be used in the manufacture of hollow building tile. The plant operates on an average of 9 months in the year and very little trouble is met with in the clay operation.

Winning. An electrically-operated shovel provided with a $1\frac{1}{4}$-yard bucket digs into the clay bank and loads the clay into waiting cars.

Haulage. The cars are hauled by a Fordson locomotive a distance of 460 feet to the plant where the clay is dumped into bins.

Storage. No great amount of storage is provided.

Drainage. No special provision is made, the natural slope of the hill upon which the pit is located providing efficient drainage.

Cost per Ton of Clay

Digging and Loading:		
Labour	$ 0·10176	
Equipment	0·04235	
Material	0·00118	
		$ 0·14529
Haulage:		
Labour	$ 0·04294	
Equipment	0·03788	
Material	0·01764	
		0·09846
Total		$ 0·24375

Operation No. 38

Deposit. The shale covers a large acreage and underlies a bed of clay which averages 1 foot in thickness. Limestone strata are met with at intervals, and at some places there is more stone than shale, while in other places the shale is clean. The deposit is worked from the surface to a depth of 8 feet, but more shale lies beneath.

Winning. The removal of the stone from the shale presents quite a problem, and at present it is accomplished as follows: The bed is ripped by a large steam shovel carrying a 3-yard bucket, the loosened material being turned over and placed into ridges as the shovel advances. It is allowed to weather for five or six years. At the end of this time the stone can be removed separately as all the shale has weathered free of the rock.

In the weathered state the shale is loaded by a $1\frac{1}{4}$-yard steam shovel into cars. If, however, the stone is broken up much, it must be removed by hand. In certain parts of the working it is necessary to have two men so occupied.

In winter the weathered shale freezes in place, necessitating the use of the large shovel for loading.

Haulage. Wooden, side-dump cars, containing 3 yards, are loaded and hauled by locomotive to the base of an incline, up which they are hoisted and dumped into bins.

Overburden. The shale is mixed with the clay overburden to promote better working properties.

Drainage. No mechanical means of drainage is necessary, water draining naturally to previously worked holes.

Cost per Ton of Shale

Digging, Loading, and Cleaning:		
Labour	$ 0·06433	
Equipment	0·08054	
Material	0·02422	
		$ 0·16909
Hauling and Unloading:		
Labour	$ 0·05957	
Equipment	0·05429	
Material	0·01483	
		0·12869
General:		
Equipment		0·01153
Total		$ 0·30931

Operation No. 40

Deposit. This deposit is an 8-foot bed of grey clay, which contains not only boulders but also streaks of blue and lenses of silt. The grey clay is desired, though the blue clay, clay and silt are taken as encountered; the boulders are removed when digging, the smaller stones being removed at the plant. The overburden consists of 1 foot of top soil which is mixed with the clay and sent to the machine.

Output. Sufficient clay is removed daily for the manufacture of 50,000 soft-mud brick. The plant operates 10 hours per day for 4½ months in the year.

Winning. The clay is won by the use of a ¾-yard steam shovel loading directly from the bank into a wooden car.

Haulage. One car is used to haul the clay. Being loaded, the car is lowered by cable, 220 feet, to a point from which a drum operating in the plant hauls it up 12 feet over a distance of 260 feet to the hopper of the brick machine, into which it is emptied.

Overburden. There is no removal of overburden, the top soil being dug and mixed with the clay.

Drainage. Drainage is natural. As there are no men working on the ground, wet weather does not interfere to any extent with the working.

Cost per Ton of Clay

Digging and Loading:		
Labour	$ 0·07550	
Equipment	0·08628	
Material	0·02930	
		$ 0·19108
Haulage:		
Labour	0·03750	
Equipment	0·01910	
		0·05660
Total		$ 0·24768

Operation No. 42

Deposit. This deposit is in hilly country and the opening made into one of the hills shows 6 inches of loamy soil, overlying 11 feet of grey clay streaked with two 2-inch bands of sand. Drilling has shown blue clay to a known depth of 18 feet underneath the grey clay. One third of the clay bed is too wet, while the other two thirds are suitable for working.

Output. This operation provides sufficient clay daily for the manufacture of from 35,000 to 40,000 soft-mud brick.

Overburden. The 6-inch layer of loamy soil is removed by hand as the operation progresses.

Winning. The clay is removed by a 1-yard steam shovel which takes the clay direct from the bank and loads it into horse-drawn wagons.

Haulage. The clay is hauled in horse-drawn wagons to the plant where it is placed directly into the hopper of the brick machines. The haulage distance is 500 yards.

Storage. There is no provision for storage of the clay.

Drainage. The pit drains naturally.

Cost per Ton of Clay

Overburden:		
Labour	$ 0·02000	$ 0·02000
Digging and Loading:		
Labour	$ 0·05333	
Equipment	0·12307	
Material	0·02706	0·20346
Haulage:		
Labour	$ 0·08000	
Equipment	0·05632	0·13632
Total		$ 0·35978

Operation No. 43

Deposit. This operation is located in rather hilly country. The opening made into one of these hills shows 9 feet (the working face) of hard, dark grey clay, underlying 16 inches of top soil.

Output. This operation provides sufficient clay daily for the manufacture of from 50,000 to 55,000 stiff-mud brick. The plant operates 10 months in the year.

Winning. The clay is removed by a $\frac{3}{4}$-yard steam shovel which takes the clay direct from the bank and loads it into waiting cars.

Haulage. The clay is hauled in two 2-yard cars which are hitched together and are drawn by cable to and from the plant, a distance of 650 feet. Power for the cable is obtained from the main shaft of the plant.

Storage. There is no provision for storage of the clay.

Drainage. Drainage is natural.

Cost per Ton of Clay

Digging and Loading:		
Labour	$ 0·05000	
Equipment	0·03640	
Material	0·01620	
		$ 0·10260
Haulage:		
Labour	$ 0·02666	
Equipment	0·01053	
		0·03719
Total		$ 0·13979

Operation No. 44

Deposit. Underlying a clayey overburden which varies in thickness up to 25 feet, and averages 5 feet, is a tilted bed of hard, grey shale. The bank as exposed shows a height of 200 feet of shale.

Output. This operation provides 350 tons of shale daily for the manufacture of building brick and building tile. The plant operates 10 hours per day for 10 months in the year.

Winning. The shale is blasted loose and loaded by steam shovel into waiting cars. The overburden, being a rather plastic clay, is mixed with the shale.

Haulage. The loaded wooden cars are hauled by drum and cable arrangement to the plant, a distance of 100 yards, where they are dumped into storage bins.

Drainage. Drainage is natural.

Cost per Ton of Shale

Quarrying:		
Labour	$ 0·02014	
Equipment	0·00566	
Material	0·01262	
		$ 0·03842
Loading:		
Labour	$ 0·02286	
Equipment	0·02057	
Material	0·03514	
		0·07857
Haulage:		
Labour	$ 0·04742	
Equipment	0·02128	
Material	0·00285	
		0·07155
Total		$ 0·18854

Operation No. 45

Deposit. This deposit is located in level country. The pit shows 14 feet of a tough, wet, fine-grained, brown clay containing small stones, the greater percentage of which is removed at the plant. The upper part of the clay is very short while the lower part is very plastic. The clay in the bank contains approximately 22 per cent of water the year round.

Output. This operation produces 50 tons of clay per day which is used in the manufacture of drain tile and building tile. The plant operates 10 hours per day for 7 months in the year.

Winning. The clay is dug by hand from 4-foot benches, the ordinary spade being used. The top clay and bottom clay are mixed as they are loaded in the cars.

Haulage. The wooden cars which carry the clay are hauled by drum and cable operated from the plant. The haulage distance is 516 feet including 150 feet of a 20 per cent grade from the pit bottom to the plant.

Storage. No provision is made for storage of the clay.

Drainage. In the spring the pit is flooded with water. This necessitates operating an electric pump for 72 hours steadily. This removes water sufficiently to permit working. When this water has been removed, a steam syphon is put in place of the electric pump and keeps the pit sufficiently dry all season.

Drying Clay. Containing 22 per cent of water, the clay is too wet for use in the machine. To overcome this, clay is gathered from the top of the deposit which being exposed to the sun is kept fairly dry and put into a dry storage shed from which it is fed through the floor to cars and hauled to the plant to be mixed with the wet clay.

Cost per Ton of Dry Clay

Dry Clay—		
Labour	$ 0·32700	
Equipment	0·06140	
		0·38840
Digging and Loading:		
Labour	$ 0·23200	
Equipment	0·00660	
		0·23860
Haulage:		
Labour	$ 0·11200	
Equipment	0·02528	
		0·13728
General:		
Equipment	$ 0·01260	
		0·01260
Total		$ 0·77688

Operation No. 46

Deposit. The exposed bank here shows 50 feet of hard, grey shale, the bedding of which is tilted. On top of this shale is 3 feet of clayey overburden which is not removed, but added as wanted to the shale to promote plasticity. The deposit is located in very hilly country, the operation being carried on at the base of a high hill, with the plant close by.

Output. This operation provides 180 tons of shale per day for the manufacture of building brick and building tile. The plant operates year round on a 10-hour day.

Winning. The shale is blasted loose, and loaded by a $\frac{5}{8}$-yard steam shovel into waiting cars.

Haulage. The material is hauled in $\frac{3}{4}$-yard steel cars by drum and cable, operated from the main power shaft, a distance of 275 feet to the plant.

Storage. No provision is made for storage.

Drainage. Drainage is natural.

Cost per Ton of Shale

Quarrying:		
Labour	$ 0·05411	
Equipment	0·00688	
Material	0·02500	
		$ 0·05410
Loading:		
Labour	$ 0·08776	
Equipment	0·01500	
Material	0·01294	
		0·11570
Haulage:		
Labour	$ 0·01805	
Equipment	0·01060	
		0·02865
Total		$ 0·19865

Operation No. 47

Nature of Deposit. Overlying a 21-foot bed of sand, gravel, and boulder clay, lies a 65-foot bed of fairly clean clay.

Output. From this operation 90 tons of clay is moved daily for the manufacture of soft-mud common brick. The operation continues for 9 months in the year, on a 9-hour day.

Winning. The clay is blasted loose from the bank and loaded by steam shovel into waiting cars. The shovel operator attends to the boiler.

Haulage. The clay is loaded into 1½-yard steel cars, of which there are two, and hauled by horse over fairly well kept tracks to the plant, a distance of 750 feet.

Storage. There is no provision for storage.

Drainage. Drainage is natural.

Cost per Ton of Clay

Supervision	$ 0·02988	
		$ 0·02988
Blasting:		
Labour	$ 0·00500	
Material	0·00944	
		0·01444
Loading:		
Labour	$ 0·05133	
Equipment	0·04488	
Material	0·03399	
		0·13020
Haulage:		
Labour	$ 0·04500	
Equipment	0·02403	
		0·06903
Total		$ 0·24355

Operation No. 48

Nature of Deposit. At this deposit a tough, clean, buff-burning clay lies in a 40-foot bed under a light silty overburden.

Output. For nine months in the year this operation provides a plant with an average of 100 tons of clay per day. The clay is used in the manufacture of common and face brick.

Winning the Clay. The clay is blasted loose and loaded by steam shovel into cars.

Haulage. The $1\frac{1}{2}$-yard cars are hauled by mule, two at a time, some 240 yards to the top of an incline down which the full cars gravitate singly (hauling an empty car up as they descend). At the bottom they are hauled by horses to the plant, a distance of 50 yards.

Storage. No provision is made for storage.

Drainage. Drainage is natural. On very wet days the travelling is hard but generally little trouble is met with in this connexion.

Cost per Ton of Clay

Supervision		$ 0·02690
Overburden:		
Labour		0·04500
Quarrying:		
Labour	$ 0·00450	
Equipment	0·00234	
Material	0·00850	
		0·01534
Loading:		
Labour	$ 0·09120	
Equipment	0·07440	
Material	0·02460	
		·19020
Haulage:		
Labour	$ 0·08100	
Equipment	0·03921	
		0·12021
Total		$ 0·39765

CONCLUSION

A general report on this investigation in which a summary of the work reported and a discussion of the general principles and theories of clay gathering will be included is in course of preparation and will be issued as a separate publication.

VI

THE CONTINUATION OF THE INVESTIGATION OF THE TREATMENT OF CLAYS TO OVERCOME DRYING DEFECTS

J. G. Phillips

The first report covering the laboratory phase of this investigation was given in the report of Investigations in Ceramics and Road Materials for 1927. This report described an extensive laboratory research in an effort to find a practical and economical means of treating clays having extremely tender-drying properties so that they might be dried from the plastic state at reasonably rapid rates without cracking. The two clays taken as the subjects of this investigation, which have been called the Winnipeg clay and the Redcliff clay, were described in the previous report. Both clays possessed extremely bad drying properties, and the results obtained from experiments with these could be considered as more or less applicable to all such clays of the middle West.

The laboratory investigation brought out two methods of treatment that would overcome the drying defects: (1) By preheating the clays to a temperature between 450° C. and 550° C.; (2) By the use of grog plus one or more coagulating chemicals. Preheating had been suggested by several previous investigators, but an exhaustive search showed that this method had never been successfully applied on a commercial scale. While preheating is considered promising (especially where fuel is cheap), it could not be recommended until additional data had been collected for the purpose of determining the factors governing equipment, construction, and method of operation.

Previously these clays had been considered too extreme in bad-drying properties to be remedied by chemical treatment. However, our experiments in the laboratory with the combined use of grog and coagulating chemicals yielded encouraging results, and after an extensive research with numerous reagents (costs being a prime consideration), the use of ferric chloride with a small amount of grog was proved to be successfully effective. It was also found that while sodium chloride alone, in order to be effective, was required in such large percentages as to give other troubles, when used in conjunction with ferric chloride, small additions would effectively replace some of the more expensive ferric salt.

PLANT TRIALS

The laboratory investigation yielded such encouraging results, especially with the Redcliff clay, that it was decided to conduct full-scale tests at the plant at Redcliff. In these tests all ingredients were carefully weighed and mixed by hand. The resulting mixtures of clay, grog, and chemical (when added dry) were shovelled into the feed bin from which they went to the pug-mill and then through the auger machine. The brick, set on cars, were immediately placed in the dryer.

The dryers at this plant are of the radiated heat type, gas-fired, and, for the purpose of the tests, were speeded up so that the test brick would be subjected to a drying period of three or four days, as compared to a normal period of eight to nine days.

The tests conducted were as follows:—

Test No. 1.

Clay (67% soft clay, 33% shale)		75%
Grog		25%
Ferric chloride	1·0% } added dry.	
Sodium chloride	0·5% } added dry.	

Test No. 2.

Clay (33% soft clay, 67% shale)		80%
Grog		20%
Ferric chloride	0·5% } added dry.	
Sodium chloride	1·0% } added dry.	

In Tests Nos. 1 and 2, the chemicals were added in the dry powdered state and mixed by hand. In each batch there was sufficient material to make 500 brick. (These were immediately placed in the dryer.) In Test No. 2 the proportion of shales was increased from 33 to 67 per cent. The shale, while it adds strength to the brick and imparts a better fired colour than the upper soft clay, greatly increases the tendency of the brick to crack.

Trial No. 1 came through the dryer in four days, with all the brick sound, there being practically no signs of cracking. Trial No. 2, with its high percentage of shale and only 0·5 per cent ferric chloride was also dried in four days. These test brick showed some tendency to crack, but there was a great improvement and about 80 per cent of the brick was good.

These tests proved conclusively that this treatment would solve the drying problem of this clay. It was noted, however, on examining the brick after drying, that a portion of the ferric chloride in lumps had remained undissolved and was not distributed throughout the brick. Ferric chloride because of its deliquescent character after being ground has a tendency to ball together which prevents its being uniformly mixed with the dry clay, and thus its entire value is not realized. It was then decided that the chemicals should be added with the tempering water. Subsequent tests were conducted by first dissolving the required amount of chemical in sufficient water to temper enough of the clay-grog mixture to make 500 brick. The solution was then added from buckets at the pug-mill.

Test No. 3.

Clay (shale only)	80%
Grog	20%
Ferric chloride	1%—added in solution.

The test brick made from this mixture came through the dryer in three and one-half days, with practically no signs of cracking in any of the brick.

Test No. 4.

In all the previous tests the percentage of grog added was rather high, it being not less than 20 per cent. In this test the percentage of grog was reduced, the batch mixture being as follows:—

Clay (50% soft clay, 50% shale)	85%	
Grog	15%	
Ferric chloride	1·0%	added in solution.
Sodium chloride	0·5%	

The brick made from this mixture came out of the dryer after three and one-half days, completely dried with no signs of cracking. These bricks were quite satisfactory in every respect. Due to the reduction of grog content, they possessed a better texture and greater strength in the green state.

Test No. 5.

In this test the clay-grog proportion used was the same as had been regularly used in the plant, the chief difference from the other test being a reduction in the grog content. In the operation of the plant, the mixing of soft clay, shale, and grog is accomplished as follows: the soft clay after having passed through conical rolls to remove limestone pebbles, is conveyed to a dry pan. The grog is made from brick bats which are ground separately. The grog is fed to the soft clay from the grinder as the clay is conveyed to the dry pan, and the amount of grog added is roughly estimated by the speed with which it is fed to the crusher. The shale is mixed by shovelling, at intervals, a quantity of it into the soft clay and grog as it is being ground in the dry pan. It can be seen that the mixture is only an approximation, but an effort is made to keep the proportion of soft clay, shale, and grog as follows:—

Soft clay	67%	85 to 90%
Shale	33%	
Grog	10 to 15%	

To this mixture was added:—

Ferric chloride	1·0%	added in solution.
Sodium chloride	0·5%	

The resulting brick dried very satisfactorily, with about a three-day drying period, and there were no signs of cracking.

THE INSTALLATION OF THE PROCESS FOR REGULAR OPERATION

The effectiveness of this process in correcting the drying troubles of this clay having been demonstrated, the company decided to install the process immediately. To do this, two tanks of sufficient size to supply pugging solution for 4,000 brick were installed. While the solution is being delivered from one tank, the other is being replenished. Wooden tanks with lead pipe, and acid-resisting valves are used in order to ensure against the corrosive action of the chemical.

The process has been in operation at the Redcliff plant for about one year and has given thorough satisfaction. The drying which used to require from seven to eight days has been reduced to three days, and the dryer loss has been reduced from 40 per cent or more to almost nothing.

It has resulted in an increase of output from 24,000 to 40,000 brick per day. Another advantage obtained by the use of ferric chloride is that it improves the fired colour of the brick and prevents the popping of limestone pebbles. Notwithstanding the extra cost for chemicals, the cost of manufacture has been reduced and the product sells for an increased price owing to its greatly improved quality.

General Application

While the treatment with chemicals was entirely successful in the case of the Redcliff clay, there are clays where this process is not quite applicable. The case of the Winnipeg gumbo is one where the chemical treatment will not meet with entire success. First, this clay did not respond to the treatment in the laboratory tests as readily as had been hoped. Second, this clay as it comes from the bank is wet and needs no further addition of water for tempering. In such conditions the addition of any chemical is made very difficult. There would be required a long mixing process in order to get the chemical uniformly mixed throughout the wet clay, and since ferric chloride must be added in solution this reagent cannot be used. Sodium chloride may be used to some advantage and it is planned to conduct plant tests on the Winnipeg gumbo clay, using this chemical.

In such cases as that of the Winnipeg gumbo clay, preheating is the most promising process, providing it can be shown to be practical. In order to obtain information that would make possible a foresight as to the probable success of preheating on a commercial scale, and to collect data that would forecast the proper method of construction and operation, a semi-commercial pre-heating unit has been constructed at Redcliff by the Redcliff Brick and Coal Company, Ltd. This preheater is of the rotary type with the fire-box at one end and a fan at the other. The revolutions of the drum can be controlled, thus a regulation of the speed of travel of the clay as it moves from the cold to the hot end can be maintained.

As mentioned in the previous report, the range of temperature within which preheating is effective is narrow for commercial work, and the success of the preheating process will depend on whether or not a sufficient control of temperature can be maintained. It is hoped that this question will be answered by the results obtained from the experiments on the machine at Redcliff.

Several papers that have been presented covering the investigation and the results obtained are as follows:

(1) "A Preliminary Report on the Treatment of Certain Western Clays to Overcome Drying Defects,"* given by Howells Fréchette at the meeting of the Canadian National Clay Products Association, held in Montreal, June, 1928.

(2) A joint paper by Howells Fréchette and J. G. Phillips, entitled "Correction of an Extreme Case of Cracking in the Drying of Brick," given at the Chicago meeting of the American Ceramic Society, February, 1929.

*Mimeographed for distribution. Memorandum No. 33, Mines Branch.

(3) A paper entitled "New Method of Treating Clays to Overcome Drying Defects—An Important Contribution to the Brick Industry of the Prairie Provinces," by J. G. Phillips, given at the Winnipeg meeting of the Canadian Institute of Mining and Metallurgy, held in March, 1929.

FURTHER LABORATORY STUDY OF TENDER-DRYING CLAYS

More recent laboratory experiments on the Redcliff clay have clearly proven that its poor drying properties are due to a very low permeability to water. A laboratory method of studying the movement of water from the interior to the surface of the plastic piece as drying proceeds has been worked out. This method enables a comparative measurement of the permeability of clays to water, and clearly shows that in the case of the Redcliff clay the cracking during the drying process is due to a retarded movement of wacer from the interior of the piece to the surface. It is well known that in drying clay ware there must be a steady and uniform movement of water from the interior to the surface of the piece, otherwise the surface will become much drier than the interior thus producing a large difference in shrinkage and consequent cracking. Briefly, this method consists in determining the percentage of moisture in successive sections (surface to interior) of a partly dried clay piece in the following manner: Two-inch cubes were moulded from the clays which had been tempered with the optimum percentage of water. Having determined the correct percentage of water for the particular clay, this amount was used with this clay in all cases. The cubes were then placed in an automatically controlled dryer, set for a definite temperature, and allowed to dry for several hours depending upon the temperature. The cubes were allowed to remain in the dryer until drying had progressed to a point that previous trials had shown to be just past the critical point, that is, the point that the differential water content between surface and interior was at a maximum and the greatest shrinkage strains prevailed which cause the cracking. This point would depend upon the temperature of drying, so that at higher temperatures a shorter drying period was used.

The effect of various treatments on tender-drying clays was also studied in this manner, and in order to avoid variations in drying conditions, clays or treatments that were to be compared were dried simultaneously in the same dryer. Thus the same conditions of temperature and humidity affected the specimens being compared.

The partly dried cubes, immediately after having been drawn from the dryer, were then cut so as to give a core that had occupied the centre of the cube and extended from surface to surface. From this core ¼-inch intervals were cut, proceeding from the surface to the centre, and placed in weighing bottles. After weighing, the sections were allowed to dry at 100°C., were reweighed, and the moisture content of each section thus determined. The percentage of moisture in the section was calculated on the basis of the dry weight. Figure 8 gives the results obtained with the Redcliff clay compared with a normal drying clay from Prince Edward Island and the effect of treatments with ferric chloride toward improving permeability. The curve of the Redcliff clay shows steep rises and abrupt changes between sections, indicating quite abnormal drying properties

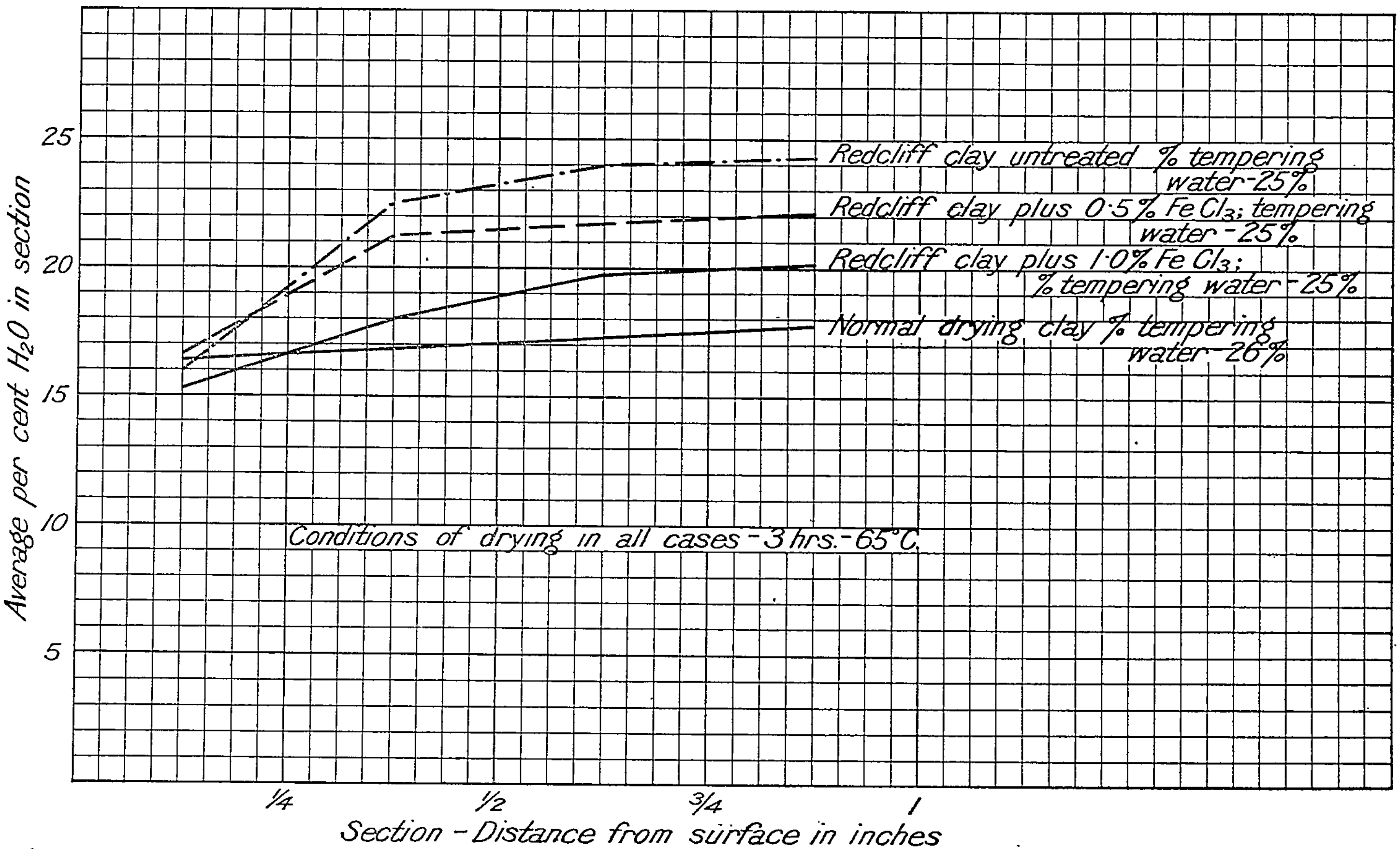


Figure 8. Effect of reagents on moisture distribution.

while the straight line curve with very little slope of normal drying Prince Edward Island clay shows good drying properties. The curves of the Redcliff clay treated with ferric chloride give a much straighter line, and an approach to the normal drying curve, which means greatly improved permeability which results in better drying properties.

Clays that are tender-drying in a minor degree often will not show defects when tested in the laboratory. The test piece is usually small and while strains due to uneven shrinkage may be present in the small piece, they are not sufficient to cause cracking. By plotting curves in the manner just described, irregularities in drying properties can be detected even in those clays that are only slightly abnormal. Also the degree in which a clay may possess defective drying characteristics can be estimated, and the kind and amount of any treatment that may be necessary can be prescribed. A clay that is found to be only slightly abnormal in drying properties may have its defects overcome by a more careful drying process with, probably, high humidity condition, or in some cases the addition of a reasonable percentage of a non-plastic, as sand or grog. Chemical treatment is to be recommended only where a clay will not respond to regulations, within reasonable limits, of the drying process.

THE APPLICATION OF THE CHEMICAL TREATMENT TO AN EASTERN CLAY.

As an outgrowth of the investigation with the western clays, a request came from the Montreal Terra Cotta Company to assist them in overcoming the drying troubles given by a clay they are using. A visit was made to the plant to ascertain the nature and degree of the trouble. The situation at this plant may be described as follows: A very sticky high shrinkage clay is used for the manufacture of hollow building tile. The clay as it comes from the bank is wet, and needs no further addition of water for tempering. In fact, at times, it is necessary to add dried clay in order to stiffen it for working. Sawdust is added in percentages that are roughly estimated at between 25 and 30 per cent by volume. It serves the double purpose of aiding in drying the ware, and giving porosity to the burned tile. Even with the sawdust, and a drying period of 7 or 8 days, a large percentage of the ware comes out of the dryer badly cracked. At times the loss is as high as 40 per cent.

A sample of the clay was sent to the Mines Branch laboratories for testing. This clay possesses properties as follows:—

Working properties	Sticky
Water of plasticity	38·0%
Average drying-shrinkage	11·1%
Drying behaviour	Cracks badly in drying.

Fired Properties

Cone	Fire shrinkage	Absorption	Colour	Hardness
010 (1634° F.)	1·0	15·3	Salmon	Fairly hard
06 (1841° F.)	3·8	9·3	Fair red	Hard
04 (1922° F.)	8·4	0·2	Reddish brown	Hard
1 (2057° F.)	8·4	0·0	Reddish brown	Very hard

Water of plasticity	41·0%
Average drying shrinkage	9·8%

With clay, 3 parts, sawdust, 1 part (by volume).

Fired Properties

Cone	Fire shrinkage	Absorption	Colour	Hardness
06 (1841° F.)	2·4	17·1	Fair red	Hard
04 (1922° F.)	8·8	4·2	Reddish brown.	Hard

In endeavouring to find a treatment for this clay that would correct the drying difficulties, and also that would be practical, the type of ware produced and the conditions of operation must be borne in mind. The product manufactured from this clay is hollow building tile, one of the cheaper grades of clay products. The cost then of the treatment that could be added to the operating costs must necessarily be low. Because of this, ferric chloride can be eliminated as it is slightly too expensive for such ware. Sodium chloride is cheap and since it is soluble and easily handled in the dry state, was considered the most promising reagent for this case.

The following tests were made on the effectiveness of sodium chloride in improving the drying properties of this clay. In all cases full-size bricks were moulded, as well as briquettes, and were placed in a dryer that was maintained at 65° C.

Test No. 1:

Clay, 3 parts; sawdust, 1 part (by volume); and sodium chloride, 1 per cent (by weight).

Water of plasticity	45·0%
Average drying shrinkage	10·3%

The brick made of this mixture cracked badly, but there was some improvement.

Test No. 2:

Clay, 3 parts; sawdust, 1 part (by volume); and sodium chloride, 3 per cent (by weight).

Water of plasticity	42·0%
Average drying shrinkage	10·0%

The brick made from this mixture also cracked, but there was still further improvement.

Test No. 3:

Clay, 3 parts; sawdust, 1 part (by volume); and sodium chloride, 3 per cent (by weight).

Water of plasticity	40·0%
Average drying shrinkage	9·0%

The brick made of this mixture showed a great improvement, but there was still cracking.

This was considered the limit of the amount of sodium chloride that could be added in practice. From these tests, while there was still considerable cracking with even 3 per cent salt, judging from the degree of improvement caused by the salt, it was considered probable that sodium chloride would assist greatly in improving the drying situation at the plant, where the drying treatment would be much less severe than in the laboratory.

Curves were made of the water distribution after partial drying for this clay in the manner described earlier in the report. Also curves were made for comparisons between the clay alone and treated with sodium chloride and sand.

The curves shown in Figure 9 bring out the following points:—

1. While this clay gives a curve that is much less erratic than that for the Redcliff clay, it is divergent from the normal drying clay. This was to be expected as the cracking tendency was not nearly so severe as in the case of the Redcliff clay.

2. The addition of sodium chloride not only retards the rate of water evaporation but it eliminates the abrupt changes between sections (thus straightening out the curve), and lessens, somewhat, the slope. In other words, sodium chloride causes the curve to more closely approach that of the normal drying curve.

3. The addition of sand produces little change in the shape of the curve, which indicates that little benefit can be expected from sand additions towards improving the drying properties. The lower percentage water content in the sections is caused by the fact that the percentage of tempering water added was on the basis of the amount of clay present, not on the amount of clay plus sand.

4. Drying at faster rates (85° C.) produces a slightly greater departure from the normal drying curve and the improvement caused by the addition of 1 per cent sodium chloride is less apparent.

What is considered the most important inference drawn from these curves is that non-plastic materials such as sand give very little aid in the movement of water during drying in clays with low permeability. It has been thought that non-plastic materials caused the clay mass to become more open and afforded a means of communication between the pores that gave an easier path for the water. While additions greater than 20 per cent may accomplish this to some extent, a large amount of non-plastics is not considered practical. Apparently with sand additions up to 20 per cent there is sufficient clay between the sand grains to offset any ease of movement afforded by the sand grains. Therefore it can be concluded that the addition of sand to tender-drying clays for the purpose of correcting drying defects is of little worth.

It has also been thought that cracking in clays was due to a high shrinkage. Experiences and studies of the tender-drying clays in this investigation make it seem that final drying shrinkage has little to do with cracking, and that the cause is entirely due to a low permeability to water. While low permeability is usually associated with high shrinkage clays this is not always true. The Redcliff clay exhibited a total linear shrinkage of about 7 per cent, yet its tendency to crack during drying was much greater than in the case of the Montreal clay which showed a linear shrinkage of approximately 11 per cent. In determining the drying properties of a clay the problem then is one of finding its permeability to water, and the method of determining water distribution after partial drying from the plastic state, devised during this investigation, has been found quite applicable.

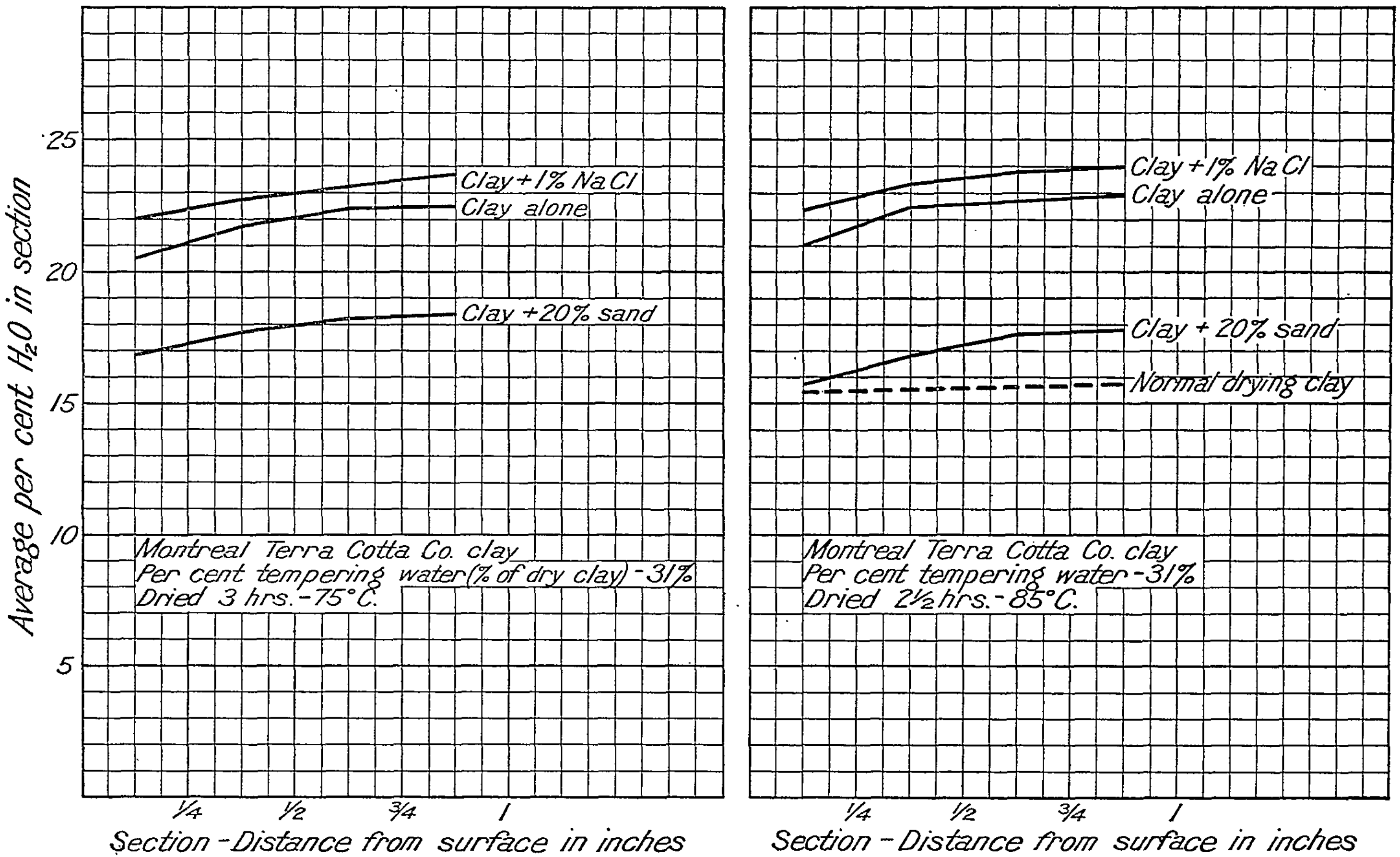


Figure 9. Moisture distribution curves, Montreal clay.

VII

PLANT TRIALS TO OVERCOME DRYING DIFFICULTIES

J. G. Phillips

The results of the laboratory investigation to correct the drying difficulties arising from the clay used by the Montreal Terra Cotta Company were given in the foregoing report. At this plant a sticky, high shrinkage clay is used for the manufacture of hollow building tile. The tile are dried in radiated heat, coal-fired, tunnel dryers, and a drying period of from 7 to 9 days has been necessary in order to dry the ware as slowly and carefully as possible. It has been the practice to add approximately 25 per cent sawdust to the clay for the dual purpose of assisting in drying and to give porosity to the tile after firing. Even with such slow drying and the addition of sawdust a 40 per cent dryer loss has been a common occurrence. Also, such a long drying period holds up the capacity of the plant and the number of tunnels now in use are considered to be at the maximum.

In using a chemical on a clay from which a common ware is made, it must be borne in mind that the additional cost that could be added to operating costs must be low. As was shown in the report of laboratory investigations of the chemicals tested, sodium chloride seemed the most promising for this clay. It is cheap, easily handled dry, and from the laboratory tests it showed favourable indications that it would greatly assist in improving the drying properties of this clay. It was decided then to make large-scale tests at the plant.

Plant Trials

The clay as it comes from the bank is wet enough so that ordinarily little or no tempering water is necessary. During a rainy season the clay is often too wet and it is necessary to add dried clay to stiffen it. It was thought that a small addition of lime in conjunction with the salt (during the rainy spells when the clay is too wet) would dry up the clay considerably, thereby eliminating the necessity of adding dried clay (an expensive operation) and also assist somewhat in the drying.

In making the trials series of batches were run through the machine, in which were incorporated salt only and salt plus lime. The salt additions varied between 0·5 per cent and 2·0 per cent. The lime was added in percentages also varying between 0·5 per cent and 2·0 per cent. These ingredients were added to the clay as it was fed to the pug-mill. This was done by hand, and the rate of feed estimated. The sawdust was added at the same point. The cars containing the trial pieces were labelled and placed in the dryer, which was speeded up so as to give a 5- to 6-day drying period. The tests brought out the following facts:—

1. Sodium chloride greatly aids in the drying of the tile, and with a 1 per cent addition (dry clay basis) the ware can be dried in 5 to 6 days without cracking.

2. Lime very effectively stiffened out the clay and facilitated the drying of the ware, but when added in quantities greater than 0·5 per cent, it lessens the fired strength.

The results of these tests proved the effectiveness of such treatment and the company decided to put it into regular operation. The percentage additions agreed upon were roughly 1 per cent sodium chloride (dry clay basis) and in wet weather 0·5 per cent of lime. The salt is added to the sawdust as it is fed to the elevator. The sawdust containing the correct amount of salt to make a 1 per cent addition to the clay is fed by means of a belt conveyer. The lime is added separately at the pug-mill as it is necessary only when the clay is excessively wet.

This process has been in regular operation since May, 1929, and has benefited the company greatly. Due to the increase in drying capacity the plant can operate to its full capacity (formerly it was possible to operate to only about two-thirds capacity), and the dryer loss has been reduced from an average of about 30 per cent to almost nothing.

VIII

ROAD MATERIALS IN PRINCE EDWARD ISLAND

R. H. Picher

An investigation of the materials suitable for use in road construction in the province of Prince Edward Island was commenced in 1927 and completed during the field season of 1928. As mentioned in the report of 1927, conglomerate and gravel are the only local materials which may be used with any degree of success in road surfacing. Both are relatively scarce, and conglomerate particularly does not form large deposits.

All the conglomerate deposits are strikingly alike in character, being made up of very hard, smooth and rounded pebbles of quartz, quartzite, and flint in a matrix of weakly cemented fine quartz sand. Very little has been used so far in road surfacing, but judging by the good results obtained and the similarity of character of the deposits, it may be said that they are all suitable. The conglomerate is much harder to excavate than gravel, and very slow progress is accomplished by hand pick and shovel. The most economical way to excavate the material would probably be by means of a steam shovel with caterpillar traction. Since the harder part of the conglomerate is usually the upper 1½ or 2 feet, the shovel could dig in the lower part in its forward motion and break up the upper crust in its upward motion.

The gravels are more variable in character, and while some of them are totally unfit for use on account of being either too soft or too sandy, or both, others may be classed as satisfactory for local use. None of the gravels, however, would be worth transporting any distance, except No. 18, which, if crushed and screened, would make a good road material. Material of good quality is also found in the beach deposits of fine gravel and coarse sand of the west coast. Particular importance is attached to them from the fact that, as far as known, they are the only deposits of coarse sand in the island. (Good sand-clay surfaces could be built on clayey stretches of road by the addition of coarse sand.)

Most of the work done in 1928 consisted in finding the extent and depth of the conglomerate deposits, and investigating conditions affecting the development of the deposits for road material. The present report is largely the result of personal observations and measurements. The depth of several deposits, however, was obtained from the Canadian National Railway Company, which, in prospecting for ballast material some years ago, examined the larger conglomerate and gravel deposits and dug many test pits in them. The records of the company regarding the depth of the two large conglomerate deposits east of Surrey station, could not be easily found at the time of the investigation.

This report supplements rather than supersedes the 1927 report, and many observations written in the first report are not repeated here.

Deposit No. 1

One Mile West of Hartsville, Lot 67. On the farm of E. Humphrey, of Springton, this deposit lies about half way between the new Bedeque road and the Junction road. It is a fairly coarse conglomerate, made up of about 65 per cent pebbles and 35 per cent sand.

An approximate determination of the extent of this deposit was included as part of the general survey of the district, made in the field season of 1927. In 1928, a more detailed investigation was conducted on this deposit, so as to ascertain the total volume of material available and any variation in its grading or quality for road purposes. In determining the outline of the deposit, particular care had to be taken not to include areas of gravelly drift lying alongside of the conglomerate. This drift, besides being very shallow, is very poorly graded from the standpoint of use as road material, it being made up of very fine silty and clayey sand, and coarse pebbles, with very little material of intermediate size.

Figure 10 shows the extent of the conglomerate deposit. In the area bounded by dotted lines, the presence of the conglomerate was ascertained only in places. The conglomerate probably underlies the whole area, but the soil covering varies in thickness. Test pits A, B, C, D, E, and F were dug years ago by the railway company. None of the pits show any conglomerate except pit E, which shows interstratified conglomerate and sandstone, and is assumed to be at the edge of the deposit. Test pits G, H, I, and J were dug in connexion with the present investigation. At pits G, I, and J, the conglomerate has a depth of 9, $9\frac{1}{4}$, and $11\frac{1}{2}$ feet, with $\frac{1}{2}$, $1\frac{2}{3}$, and 3 feet of soil covering of gravelly loam. Pit H was dug to a depth of $3\frac{1}{2}$ feet, through $1\frac{1}{2}$ feet of loam and 2 feet of drift, the latter made up of about two-thirds very fine sand and one-third coarse pebbles. The conglomerate, which lies on top of a wide, flat hill, forms two parallel strips, trending in a northwest-southeast direction. Between the two strips there is a certain area underlain by conglomerate, which probably forms a continuous deposit from one strip to the other. Except for a small hump directly underneath the Geodetic Survey tower, the surface of the deposit conforms with the surface of the hill. There is a difference of elevation of 19 feet between the lowest part of the deposit and the highest point.

The two strips of conglomerate cover about 16,225 square yards. With an assumed average depth of 2 yards, exclusive of the overburden, the deposit would contain 32,450 cubic yards, or approximately 50,000 tons of conglomerate, enough to surface over 27 miles of road having a width of 12 feet and an average depth of 6 inches. The area marked with dotted line on Figure 10, if wholly underlain by conglomerate would add another 5,000 cubic yards to the amount given above.

For road-surfacing purposes, the conglomerate contains a rather high percentage of fine sand (material passing 28-mesh sieve), but becomes more regularly graded at depth, as seen by the test pits. Also the lower part is somewhat looser than the upper part, although the use of a pick would be necessary if dug by hand. The most economical way to extract the material would be by steam shovel. On account of the relatively shallow depth of the deposit, a steam shovel could excavate to the full depth in a single operation. It would be necessary, of course, to strip the conglomerate of its overburden ahead of the extraction work.

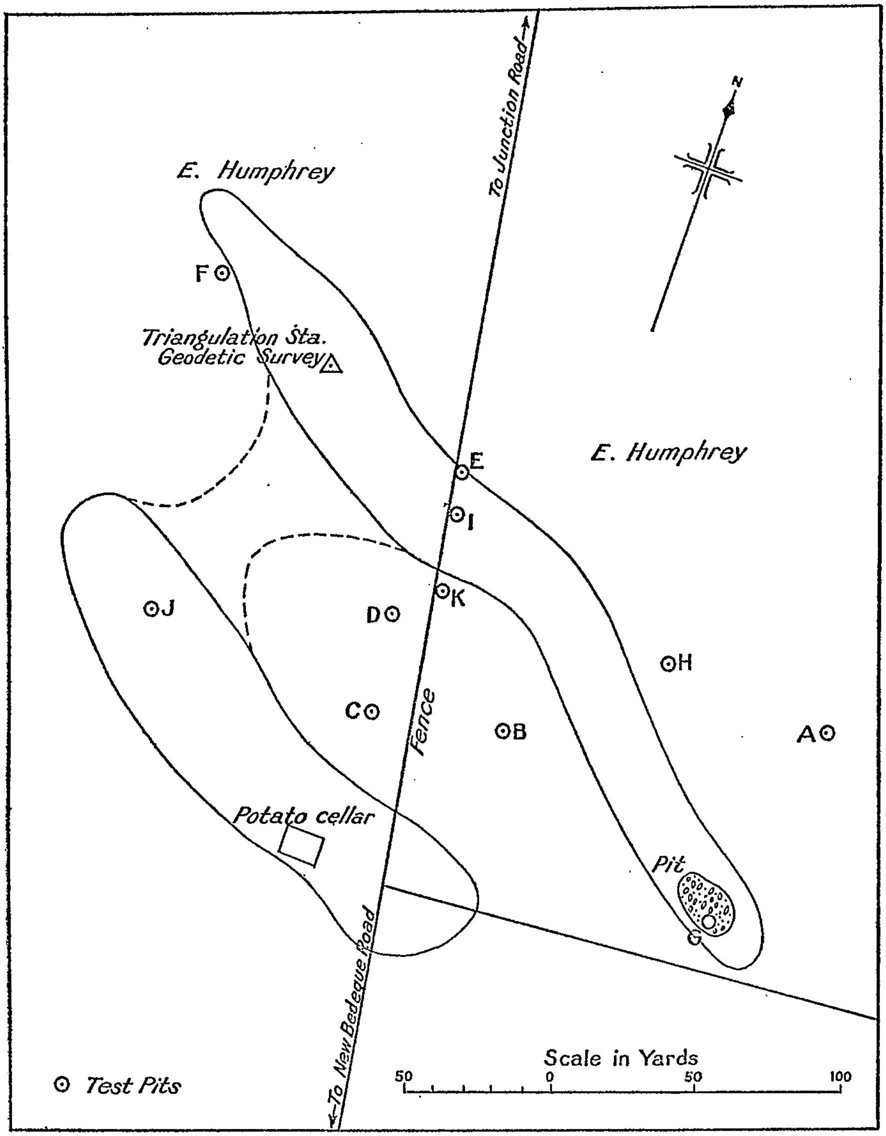


Figure 10. Conglomerate deposit No. 1.

Apart from filling up holes and depressions, the conglomerate has not yet been used in regular road-surfacing work, but there is no reason to believe that the material would not prove entirely satisfactory judging by results obtained elsewhere in the province with conglomerate of similar character.

Deposit No. 2

Two-thirds of a Mile North of Springton, Lot 67. The deposit lies on the farm of Hedley MacPherson, about half way between the new Bedeque road and the Junction road, and about 1 mile west of deposit No. 1. It is composed of about two-thirds pebbles and one-third sand, and looks much the same as No. 1.

This deposit, as determined by soundings in 1927 and 1928, forms a narrow strip approximately 300 yards in length and 30 yards in width, and trending in a southeast-northwest direction, along the southwest slope of a low sandstone ridge. Near the southeast end, a small pit, dug to a depth of 6 feet, shows conglomerate with a few thin sandstone layers, and clay-stone in the bottom with a few inches of loam as overburden. The northwest end of the deposit is at least 20 feet lower than the southeast end, so that the bottom of the deposit has a slope corresponding to the surface, if not parallel with it. If an average depth of 1 yard be conservatively assumed, the deposit would contain about 9,000 cubic yards, or approximately 14,000 tons. As is the case with nearly all conglomerate deposits of this province, the upper 1 or 2 feet are much harder to loosen than the rest. If dug by hand shovel, it will be necessary to loosen the material with a pick throughout the whole depth.

Although the northwest end of the deposit lies on comparatively low ground, an excavation in that part should be easy to drain if dug during the dry season. When the deposit was visited in the summer of 1928, a small creek which runs at the foot of the ridge and in places over the surface of the conglomerate, was found to be dry. An excavation in the southeast end could easily be kept free from water at any time.

Deposit No. 4

One Mile North of Millvale, Lot 22. On the farm of Wendell Murphy, Peter McNamee, and Alfred Parsons; two small excavations at the western end of the deposit show conglomerate, made up of about one-half pebbles and one-half sand.

This deposit was surveyed in 1927, but borings made in 1928 showed it to have a much larger extent than was at first determined. The conglomerate forms three separate deposits, two of which are shown in Figure 11. The other, much smaller in extent, lies one-third mile to the northwest. The areas underlain by conglomerate were fairly accurately determined, but no attempt was made to ascertain the depth and volume of the deposits by digging test pits, for the following reasons: Transportation by rail or water would be practically unfeasible, because of the remoteness of the deposit and the hilly character of the country; even the economical length of haul by motor truck would be comparatively short due to the heavy grades encountered on all local roads. Under these conditions the material could be used only locally in road improvement, and for that purpose, the amount of conglomerate available is more than sufficient.

The largest of the three deposits occupies the upper slope of a sandstone hill and covers approximately 100,000 square yards. Where the road to Stanley Bridge crosses the deposit, there are two small pits, 3 and 4 feet in depth respectively, showing conglomerate, firmly cemented near the surface, and looser farther down. There are many surface indications of conglomerate all over the deposit, except along its northern and eastern edge, where the overburden is thicker. The centre and top of the deposit is 70 to 75 feet above the level of the road to Stanley Bridge and 100 feet above the level of the west end of the deposit. The other deposit shown

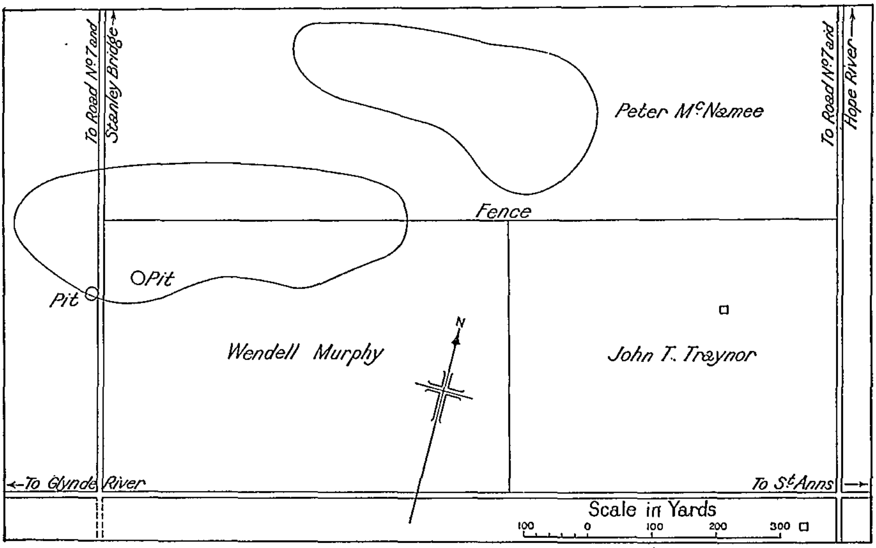


Figure 11. Conglomerate deposit No. 4.

in Figure 11 to the northeast of the one just described forms a regular flat-topped ridge on top of a larger sandstone ridge which slopes rather steeply north and south. It covers an area of approximately 71,500 square yards. Soundings show that the conglomerate lies very close to the surface. The third deposit forms a very flat ridge rising but a few feet above the level of the surrounding ground and covering an area of 4,200 square yards.

An average depth of 2 yards may be assumed for the two larger deposits, and possibly also for the smaller deposit. This would give 351,000 cubic yards for the total volume of conglomerate, which would be enough to surface nearly 300 miles of road. For truck hauling, the most convenient point to start digging operations evidently would be where the road to Stanley Bridge crosses one of the deposits, particularly on the up-hill, or east side of the road. An excavation, no matter how large and deep, would be very easy to drain, as the conglomerate lies on high ground everywhere.

Deposit No. 5

Two and Three-quarter Miles South of Port Hill, Lot 14. On the farm of Leslie MacLean, a deposit of conglomerate lies close to the road between Port Hill and Black Point ferry landing.

The work done on this deposit during 1928 consisted of making soundings to determine the area underlain by conglomerate. The latter forms an irregular ridge trending approximately in a northeast-southwest direction, and covering an area of about 38,000 square yards. While the conglomerate deposit at its northeast end rises about 40 feet above the level of the surrounding ground, it is almost flat at its southwest end. The depth of the conglomerate at the owner's house, shown in Figure 12,

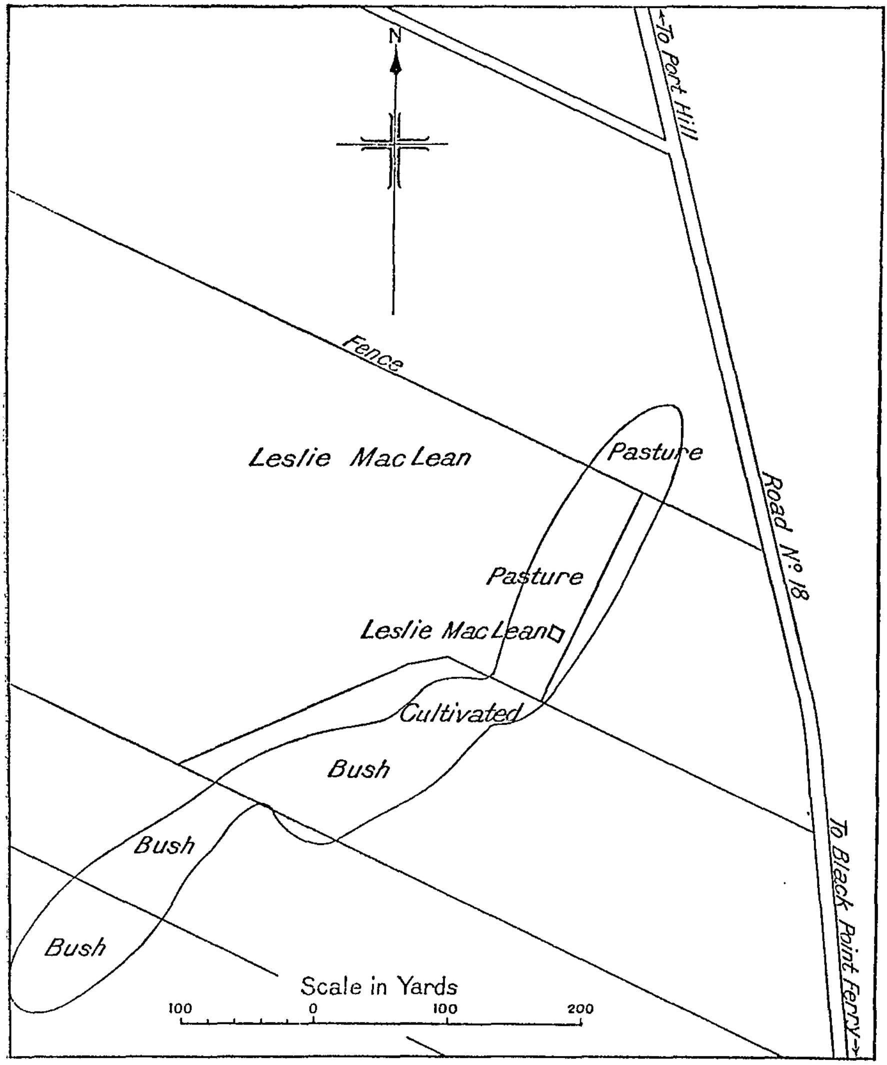


Figure 12. Conglomerate deposit No. 5.

is said to be 17 feet, including a 3-foot bed of sandstone 6 feet from the top. This is apparently deeper than most other deposits of this nature found in the island. With an average depth of $2\frac{1}{2}$ yards assumed for the whole deposit, there would be about 95,000 cubic yards of conglomerate, which would surface 80 miles of road.

There is no pit opened in the deposit. A sample collected near the surface in 1927 showed the material to be composed of about 44 per cent pebbles and 56 per cent sand. While the percentage of sand is rather high, a large proportion of the latter is coarse, so that the sample as a whole shows a lower proportion of fine sand than most other deposits. It may be mentioned, however, that a sample of surface material only cannot be regarded as representative of the whole deposit, but on the other hand the objectionable feature of a high proportion of fine sand is, in nearly all deposits, most pronounced in the upper part. There is little doubt that the material is just as suitable for road purposes as similar material found in other deposits.

Deposit No. 6

One and One-quarter Miles South of Freeland, Lot 11. On the farm of Thomas Boyle and other farms, along the road between Freeland and Tyne Valley, there is a small outcrop of conglomerate made up of about 60 per cent pebbles and 40 per cent sand. No other outcrop is seen elsewhere, but the conglomerate lies close to the surface for a certain distance along the road and on both sides of it.

The extent of this deposit was determined in 1927 by sounding and digging test pits. Deeper digging and closer soundings effected in 1928 proved that the estimates given in the report of 1927 were somewhat too high. Figure 13 shows the extent of the deposit as determined in 1928. The area underlain by conglomerate covers about 115,000 square yards, and, except for a slight rise along the south fringe, is perfectly level with the surrounding land. The maximum depth of the deposit is 5 feet, exclusive of the overburden. The latter is not over 1 foot thick on the east side of the road, but thicker on the west side, although probably not over 3 feet within the mapped area. If 1 yard be taken as the average thickness of conglomerate for the whole deposit, there would be 115,000 cubic yards, or enough to surface approximately 100 miles of road. To the south and west of the conglomerate there are certain areas underlain by drift material, composed largely of fine, clayey sand and pebbles, which, from surface indications, is hard to distinguish from the conglomerate. This drift is a poorly graded material for road purposes and particular care was taken not to include it in the measurements with the conglomerate.

The conglomerate appears to be more regularly graded, that is, carries a lower proportion of fine sand than other deposits, and for that reason should give good results in road surfacing. Owing to the shallow depth of the deposit and thickness of overburden over part of it, a steam shovel while not working as advantageously as in the case of deeper deposits, should prove more economical than digging with pick and shovel, even if the haulage is done by motor trucks. While some difficulty was caused by underground water in digging test pits, during a prolonged spell of wet weather in the fall of 1927, pits dug to the full depth of the deposit in the summer of 1928 remained perfectly dry.

Deposit No. 7

One-third Mile East of Conway, Lot 11. On the farm of Charles Palmer, "Old" Charles Palmer, Nelson Palmer, and R. C. Henderson, a conglomerate deposit in the shape of a long narrow tongue, trends approximately in a northwest-southeast direction. In character it is very similar to deposit No. 6, being made up of about 60 per cent pebbles and 40 per cent sand. At both ends of the tongue, the conglomerate grades into sandstone.

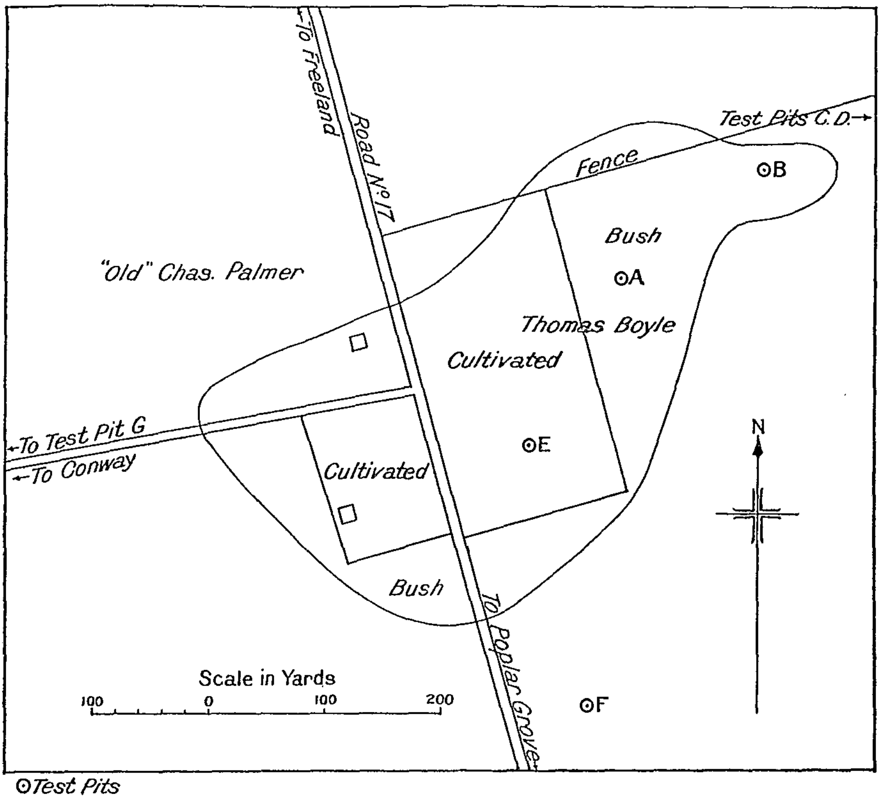


Figure 13. Conglomerate deposit No. 6.

The extent of this deposit was estimated in 1927. In 1928 the work consisted of digging test pits to the full depth of the conglomerate and making further soundings, so as to obtain a closer determination of the area underlain by conglomerate, the thickness of overburden over it, the depth and volume of the deposit, and of ascertaining any variation in coarseness of the material. Figure 14 shows the outline of the deposit and the location of test pits dug both in 1927 and 1928. Shallow deposits of very sandy conglomerate and drift carrying pebbles were found east of the mapped area, but after ascertaining their character, were deemed

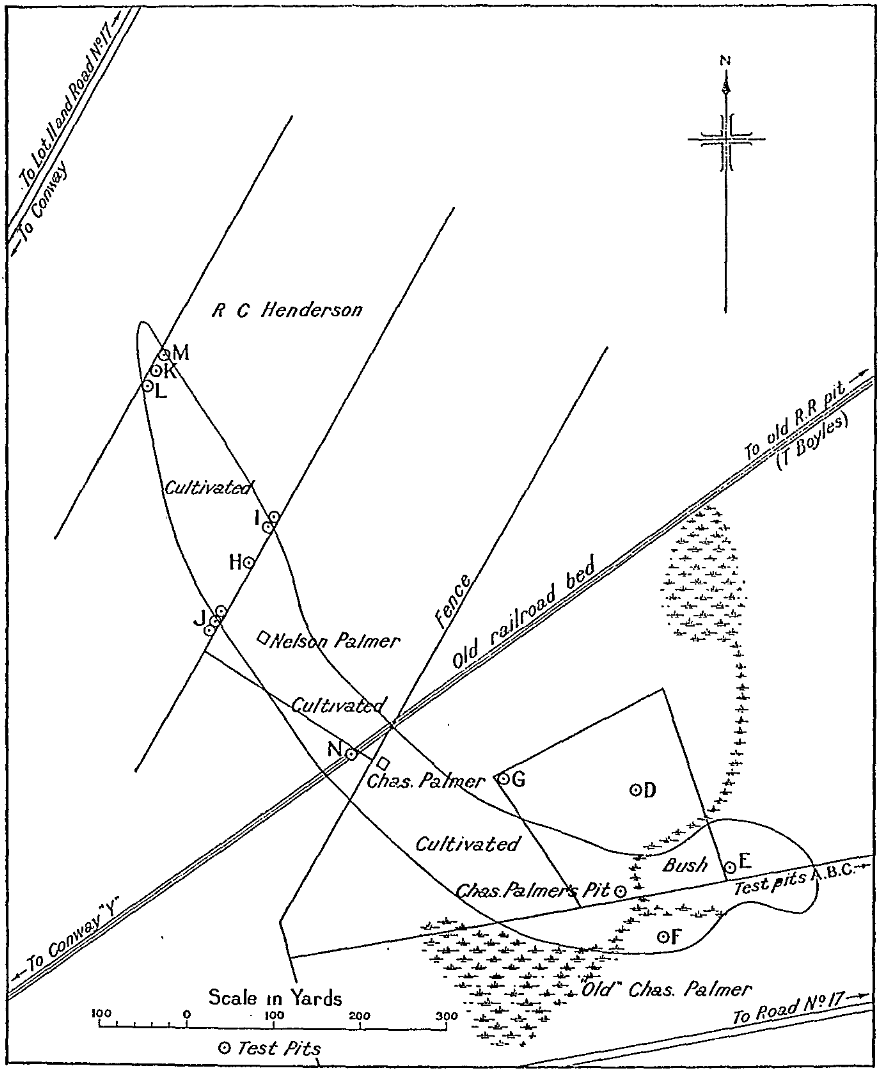


Figure 14. Conglomerate deposit No. 7.

unsuitable for roads and were not given further consideration. Test pits H, N, and Charles Palmer's pit were dug to the full depth of conglomerate, which is 9, $6\frac{1}{2}$, and $7\frac{1}{2}$ feet respectively. Deducting $1\frac{1}{3}$ feet as the average thickness of overburden leaves $6\frac{1}{3}$ feet for the average thickness of conglomerate along the centre line of the strip, and $4\frac{1}{2}$ feet, or $1\frac{1}{2}$ yards, as the average thickness of the whole deposit, which extends over an area of 105,000 square yards, giving a volume of about 157,500 cubic yards, which would be enough to surface 133 miles of road.

The road-making qualities of the conglomerate are nearly the same as those of the material from deposit No. 6. While the thickness of overburden is not over 1 foot on most of the deposit, it goes up to $2\frac{1}{2}$ feet in places along the southwest edge, between Charles Palmer's house and pit. Leaving out of consideration the margin of the deposit lying under more than $1\frac{1}{2}$ feet of cover would reduce by 10 to 15 per cent the total amount given above. Conditions for excavating the deposit are the same as at deposit No. 6. As already pointed out in the 1927 report, this is the most favourably situated deposit for connecting with the railway. The same spur line connecting this deposit to the main line at Conway could be later extended to the east so as to reach deposit No. 6, after deposit No. 7 had been worked out.

Deposit No. 7 was visited in the fall of 1927 during a period of prolonged wet weather, and underground water was reached 3 feet below the surface of the deposit. In 1928 it was visited in August, during normal summer weather, and in digging pits to the full depth of the deposit, water was encountered only in the southeast end, where the land is badly drained. Water trickled in one of the pits just as the bottom of the conglomerate was reached, at a depth of $7\frac{1}{2}$ feet, which is 3 feet below the level of the marshes nearby. The marshes were dry at the time, but the soil was quite moist a few inches below the surface. If the work of excavation is carried on during the summer, water should not cause serious interference.

Deposit No. 11

Northeast of Lot 11. On the farm of J. Henderson is a very extensive deposit of sandy gravel, carrying at least 50 per cent sand. The material looks very much the same as No. 18, from which a sample was taken. (*See* Table I, No. 18). Sample No. 11 was taken from a sand deposit close to the gravel deposit.

Test pits dug some years ago by the railway company were partly filled at the time the deposit was visited in 1928, and showed sandy gravel covered with about 3 feet of sand. According to the information obtained from the railway company, sandy gravel was found to a depth of 6 to 7 feet, and sand farther down. This would leave only 3 to 4 feet of sandy gravel, after making a deduction of 3 feet of sand on top. The sandy gravel is irregularly graded, that is, it carried a large proportion of coarse pebbles and fine sand, but only a small amount of medium-size material. Under these conditions, it would be an expensive proposition to dig the gravel out, since two yards of material have to be handled for every yard of sandy gravel obtained, and to crush the low-grade sandy gravel in order to turn it into a road material of fair quality would still add to the cost.

Deposit No. 12

One Mile West of Portage. On Lewis' farm and along the railway, a deposit of conglomerate forms a flat dome rising a few feet above the level of low, swampy ground.

As already mentioned in the 1927 report, this deposit was examined some years ago and test pits were dug by the railway company. When the deposit was first visited in October, 1927, during a prolonged spell of wet weather, the test pits were almost filled with water, only the upper foot of the pit walls being above water. At another visit, in August, 1928, with normal summer weather, the water level in the pits stood at 4 to 5 feet from the surface. An excavation to the full depth of the conglomerate will be hard to keep free from water without pumping, even in dry weather. From information obtained at the railway company's office in Charlottetown, the thickness of conglomerate in the test pits varies from 4 to 10 feet. This would give an average thickness of 2 yards for the conglomerate, and a total volume of approximately 20,000 cubic yards. The deposit could be easily connected to railway, but it is probably too small to warrant such an expense. The deposit is also well situated for truck hauling. Deposit No. 20, which lies a short distance from this deposit, is still better situated, as it is right along the main highway, but deposit No. 12, besides being the larger of the two, lies on slightly higher ground, and would be more easily kept free from water.

Deposit No. 13

Goff Bridge, Lot 10. On the farm of A. MacDonald, on the south bank of Trout river, conglomerate interstratified with thin sandstone layers is exposed for a distance of 85 feet east of the bridge. The conglomerate is made up of about two-thirds pebbles and one-third sand.

As determined by soundings made in 1928, the area underlain by conglomerate covers about 20,000 square yards. The deposit is in the shape of a narrow tongue, trending approximately north-south. From information supplied by the railway company, test pits were dug some years ago, and the depth of the conglomerate found to be 12 feet. The pits were completely refilled and no trace of them now remains. If a thickness of 1½ feet of top soil as overburden be deducted from the total depth, the average depth of conglomerate would be 3½ yards and its volume 70,000 cubic yards, enough to surface nearly 60 miles of road. In order to excavate the deposit to its full extent it would be necessary to move the owner's house. Of all the island deposits this is the most favourably situated for truck hauling; it lies right along a main highway and two miles from another main highway, the Western road. Before an extensive use of the conglomerate occurring on the island is undertaken for road improvement, it will be strongly advisable to give the material a trial by surfacing experimental stretches on some of the main highways, and for that purpose this deposit is more favourably situated than any other in the province. The conglomerate deposits throughout the province are so much alike in character, that if one proves successful for road purposes, it is more than likely that all will be suitable. This conglomerate is also looser and easier to handle than most of the other conglomerates.

On the north shore of Trout river, conglomerate is also exposed on the river bank for a short distance east of the bridge. The conglomerate covers an area of about 7,500 square yards. If the depth, which is unknown, be the same as on the south side of the river, there would be over

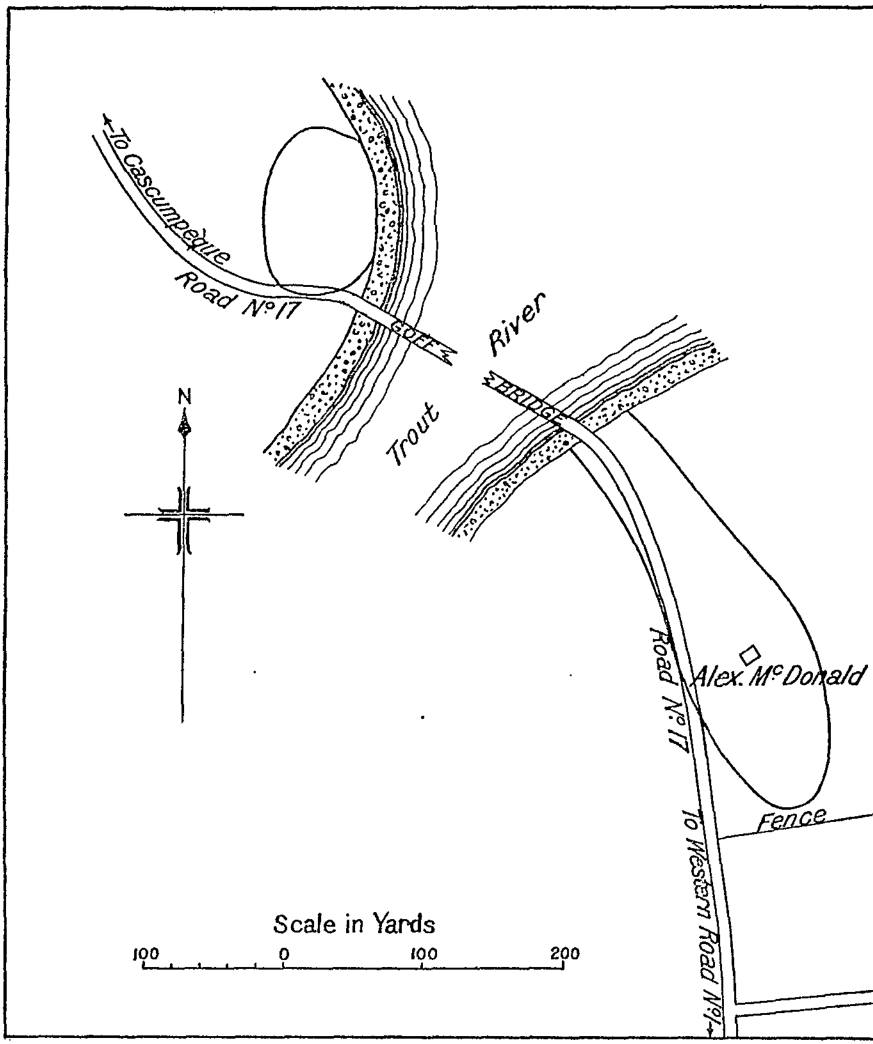


Figure 15. Conglomerate deposit No. 13.

26,000 cubic yards of material just as easily available as that on the south shore. In Figure 15 which shows both deposits the north shore of the river has been drawn closer to the south shore than it should be according to the scale.

Deposit No. 14

Two Miles Northeast of West Point. On the farm of John A. Stewart is a deposit of sandy conglomerate, that is, conglomerate interstratified with thin layers of friable sandstone It is made up of about half pebbles and half sand.

The deposit forms a small, flat dome, rising but a few feet above the surrounding land and covering an area of 17,000 square yards. Figure 16 shows the conglomerate deposit marked by a full line. The area

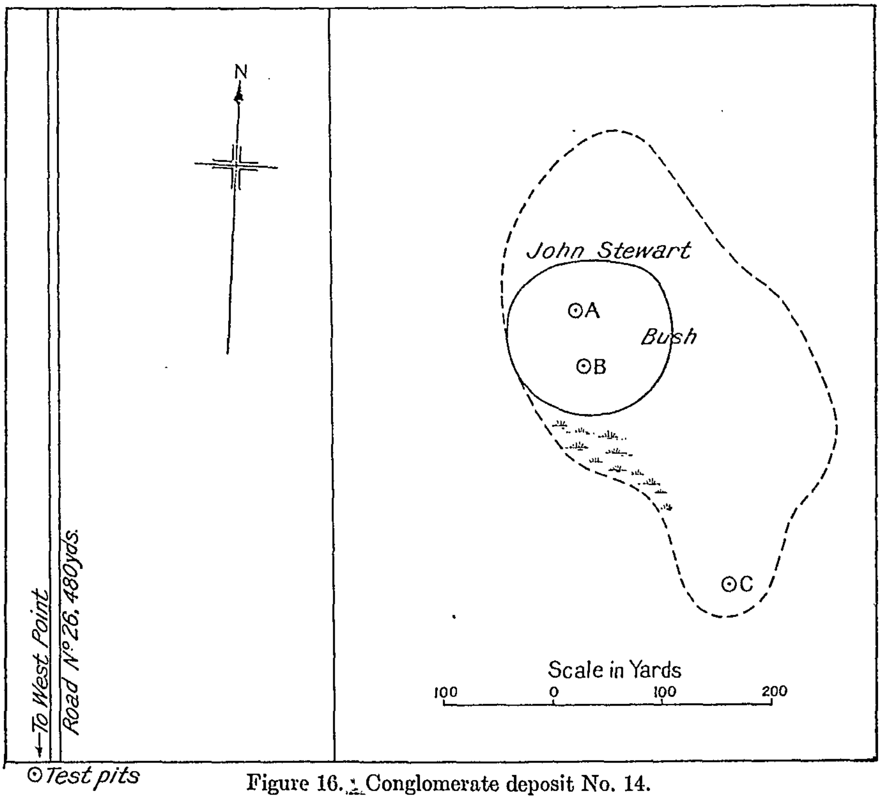


Figure 16.—Conglomerate deposit No. 14.

bounded by a dotted line is underlain by either gravel or gravelly drift, or possibly by conglomerate. It is more probably underlain by gravelly drift, as the sounding drill penetrated this material more easily than the conglomerate within the full-line area. Test pit C, which was dug to a depth of 4 feet by the road superintendent, and is now completely refilled, was through gravelly drift. The ground around this pit, and in the marsh west of the pit, is lower and more clayey than the remainder of the area, indicated by dotted line, where the sandy soil is very similar to the one covering the conglomerate. From information supplied by the road superintendent, test pits A and B were dug by himself through conglomerate interstratified with thin sandstone layers. The bottom of the conglomerate was reached at a depth of 9 feet, including 15 inches of soil as overburden. The pits are now partly filled with material fallen from the side walls. Since test pits A and B are located in the centre of the dome, they may be assumed to pierce the deposit in its thickest part, and an average depth of $1\frac{1}{4}$ yards for the whole deposit would be a fair estimate. On that basis there would be 28,000 cubic yards of conglomerate available, enough to surface over 23 miles of road. This estimate includes only the material, within the full-line area, as shown in Figure 16. The dotted-line area quite probably underlain by gravelly drift, covers about 62,000 square yards. It has been mapped as a possible additional supply of conglomerate. Gravelly drift is not absolutely worthless, but is not so good as conglomerate for road surfacing.

Except for being more sandy, this deposit looks very much like No. 13. In both deposits Nos. 13 and 14 the conglomerate from the upper part is just as easy to loosen as that farther down, which is an advantageous feature not found in most other deposits of this nature.

Deposit No. 15

One and One-half Miles Northeast of Surrey Station. An old railway pit shows coarse conglomerate, made up of about two-thirds pebbles and one-third sand.

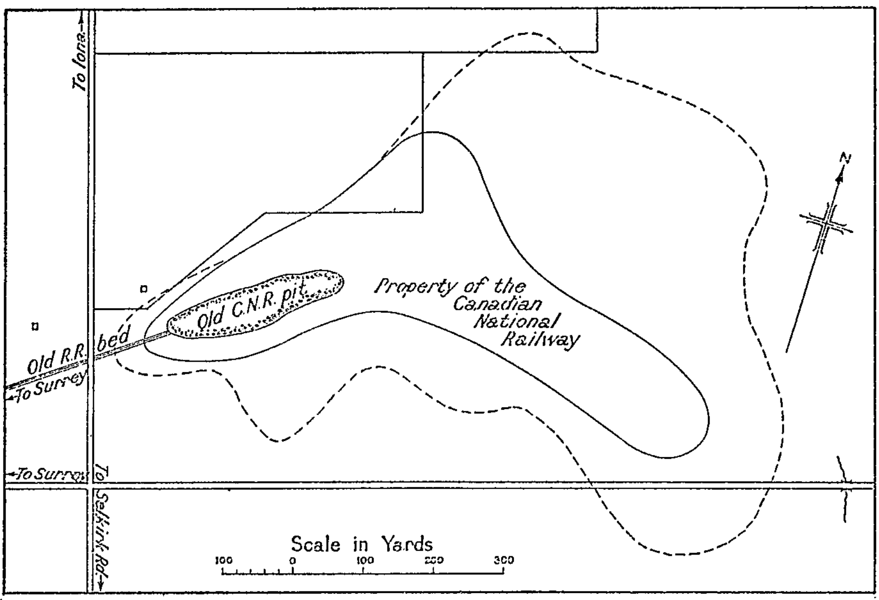


Figure 17. Conglomerate deposit No. 15.

The excavation is at the west end of a large conglomerate deposit in the form of a ridge on top of a sandstone hill. There are really two ridges joined together. In the western half of the deposit, the ridge trends southwest-northeast, while in the eastern half it trends northwest-southeast, so that the whole deposit has the shape of an open "V". This is plainly shown by the full line in Figure 17. The area covered by the conglomerate is about 133,300 square yards and that of the excavation 13,125 square yards. The depth at the pit varies from 5 to 13 feet, including overburden, which consists of a few inches of sandy loam. The bottom of the pit is sandstone which dips slightly south. So the average depth of conglomerate is 3 yards at the pit, and since the latter is located along the crest of the ridge, where the depth is greatest, an average depth of 2 yards may be conservatively assumed for the whole deposit. There would thus be 227,000 cubic yards of material, deduction having been made for what has already been taken out of the excavation. This amount of conglomerate would be sufficient to surface over 190 miles of road.

Outside of the conglomerate deposit there is an area of about 240,000 square yards underlain by gravelly material, possibly conglomerate, but more probably drift. In Figure 17 this area has been marked by a dotted line. The overburden over this drift is also thicker than over the conglomerate. As indicated by soundings, the proportion of stony or gravelly material, as also the thickness of soil covering, varies from place to place. At the east end of the conglomerate deposit, soundings reveal very gravelly or stony material, thinly covered with soil, and it is possible that the conglomerate extends farther east and south than indicated in Figure 17.

Other gravelly areas in the vicinity of deposit No. 15 were prospected for conglomerate, but found to be only shallow deposits of gravelly drift. These deposits of gravelly drift are common throughout the southeast part of the island and their use is largely responsible for the good condition of the unsurfaced roads in this part of the province.

Another conglomerate deposit, probably the largest of this kind on the island, lies one-half mile southeast of deposit No. 15, in the shape of a straight ridge trending approximately north-south. It is nearly one mile long, 500 feet wide, and 25 feet high. Some years ago it was examined and test pits were dug by the railway company. At the time the deposit was visited in 1928, the test pits had been refilled. From approximate measurements, this deposit would be over 1,000,000 cubic yards in size. From surface indications the material appears to be coarser than deposit No. 15, and even small boulders are not uncommon.

A third conglomerate deposit lies two-thirds of a mile south of deposit No. 15, and is crossed by the road to Selkirk Road. It is much smaller in extent than either of the two other deposits, but judging from surface indications looks the same as No. 15.

Conglomerate from these three deposits is somewhat coarse, but screening out the larger pebbles would make it a suitable road material. A much better plan would be to pass the whole through a crusher. Apart from breaking down the larger pebbles to the maximum size desired, the crushing would also improve the material in other ways. It would provide for a certain amount of angular material which is badly needed. It would also improve the grading by increasing the proportion of the medium-size material, that is, the material passing the ½-inch screen and retained on the 28-mesh sieve. On account of the great hardness of the pebbles, the crushing would not unduly increase the proportion of fine, of which there is a sufficient amount. The angular stone and the more regular grading of the material as a whole would make it easier to compact solidly on the road surface. The increased cost incurred by crushing the conglomerate would be more than compensated by the improved quality of the material and the greater durability of the road surface.

Of all the large deposits, No. 15 is the most favourably situated for connecting with the railway, with the exception of No. 7. As compared with the latter, deposit No. 15 has the advantage of greater average depth, larger volume, thinner overburden, good drainage at all times, and lower price for acquiring the land. The narrow gauge of the railway would limit the distribution of the conglomerate to the southeast part of the province. It is thought, however, that the line will be changed to standard gauge in the near future. Between deposit No. 15 and the large deposit to the southeast, there is a deep depression which would have to be bridged across by a trestle, if both deposits are connected to the railway by the same spur line. After deposit No. 15 has been worked out and the material from it proved successful for road surfacing, it may be deemed more economical to build the trestle and tap a very large supply of good stone than to get the road material from elsewhere.

Deposit No. 16

One Mile Northeast of Peter's Road. On the farm of Peter Morrison, is a deposit of medium coarse conglomerate, made up of about 70 per cent pebbles and 30 per cent sand.

The deposit occupies the northwest end of a steep-sloped ridge which gradually flattens out towards its southeast end. Southeast of the conglomerate, the ridge is underlain by gravelly drift, but the line of separation between the two materials could not be exactly determined by soundings. It is quite possible that part of the drift is underlain by conglomerate. Figure 18 shows the drift area in dotted line and the conglomerate deposit in full line. The latter covers about 15,000 square miles. Apart from a few shallow holes, there is no excavation in the deposit. As judged by surface indications and the height of the deposit, the latter may be conservatively estimated as being 2 yards deep on the average, so that there would be 30,000 cubic yards of material.

From the road material standpoint, the conglomerate appears to be more regularly graded than most other deposits of this character. On account of the location of the deposit the material could be used only locally in road improvement. Its distance to the nearest road is over three-quarters of a mile. In normal weather the soil is firm enough to support heavy loads, and the land is nearly level, so that motor trucks could be used and carry full loads from the deposit to the road.

About 500 yards northwest of deposit No. 16, there is another smaller deposit, approximately 3,800 square yards in extent. It is about level with the surrounding land, and its average depth is probably not over 1

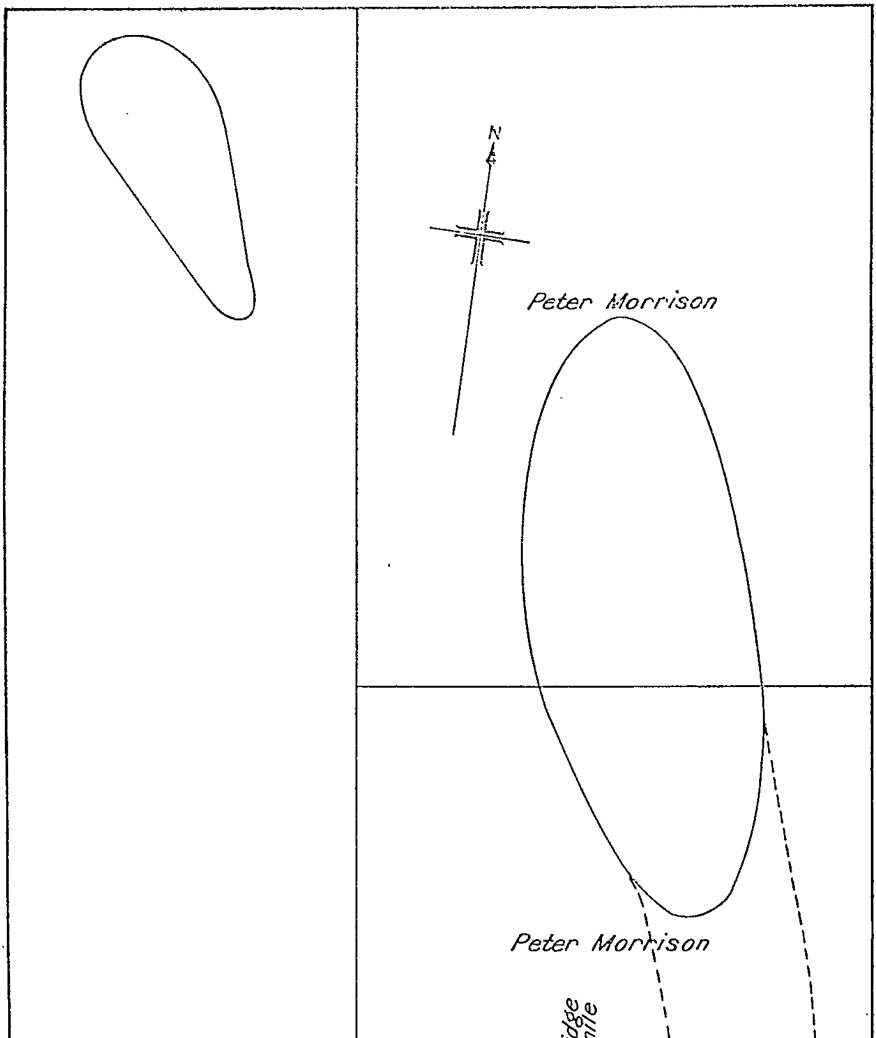


Figure 18. Conglomerate deposit No. 16.

yard. Between the two deposits the soil is in places very gravelly, but soundings showed only loose drift material and no conglomerate.

Deposit No. 17

Two and One-half Miles North of West Point. On the farms of E. J. Sabine and Andrew Stewart, several small conglomerate deposits lie close to the surface for a distance of over one-half mile between the shore road and the next road east. They are on a line running approximately east-west. A small pit dug in the most easterly deposit shows 2½ feet of sandy conglomerate, carrying at least two-thirds sand, and covered with 1½ feet of sandy soil. Sandstone is found at depth of 4 feet. As determined by soundings, this deposit is covered with 1½ to 3 feet of sandy soil. The other deposits to the west are said to be not over 2 to 2½ feet in thickness and to be thinly covered with soil.

Deposit No. 18

Two and One-quarter Miles Northeast of Poplar Grove. On the farm of Douglas Milligan, a large deposit of sandy gravel occurs on the south bank of Conway river, near where it empties into the gulf of St. Lawrence.

The gravel is estimated by the owner to cover about 300 acres. An examination of the gravel from a test pit showed that this material is very similar to that of deposit No. 11, but somewhat less sandy. It is quite likely that deposits Nos. 11 and 18 are parts of a long beach deposit of sand and gravel. The surface sand carries pebbles at many places between deposit No. 11 and No. 18. The whole area was prospected for gravel by the railway company. The beach deposit from No. 11 to No. 18 is very large, and while it is composed mostly of sand, it carries also a considerable amount of gravel, a large proportion of which is thickly covered with sand. That part of the deposit at the mouth of Conway river appears to be more gravelly and the gravel less thickly covered than the remainder of the beach deposit. At one place near the river bank the owner dug two test pits in the spring of 1928. The pits are said to have been dug to a depth of 13 feet, all through gravel. When the deposit was visited in August the only pit that could be located was 11 feet deep, all through sandy gravel. The smaller depth recorded in August was apparently due to some material from the side having fallen into the bottom of the pit, since the material is fairly loose.

Sample No. 18 probably represents the best phase of the deposit from the road standpoint. As seen by Table I, the gravel carries a high proportion of large pebbles and fine sand, but not enough medium-size material; the boulders average 5 per cent. Most of the boulders are not over 5 inches in size, although 1-foot size is not uncommon. While the gravel cannot be said to be unsuitable, crushing it would greatly improve its road-making qualities. As compared with the conglomerate, the gravel is looser and easier to handle. The pebbles also have the advantage of not being so hard and smooth. On the other hand the gravel is less regularly graded and carries more large pebbles and boulders. On the road, the gravel would not compact so readily as the conglomerate because of its higher proportion of fine sand.

TABLE I

Results of Tests on Conglomerate and Gravel Samples

Sample No.	Location	Granulometric Analysis															Per cent passing 200 mesh	Remarks
		Proportion of pebble to sand		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 westof Hartsville; E. Humphrey.	55	45	0	6	6	15	15	24	34	24	7	8	26	23	4	7	Sample from owner's pit. Total per cent of fine sand (27) too high.
1I	....	60	40	0	0	8	25	17	21	29	25	9	11	21	23	7	4	Sample from test pit I, at depth of 5 feet.
1I	....	64	36	0	0	1	4	8	23	64	56	13	6	10	8	3	4	Sample from test pit I, at depth of 8 feet. Very regularly graded for roads.
1J	....	71	29	0	7	13	25	16	20	19	21	9	10	27	23	5	5	Sample from test pit J, at depth of 9 feet. Very regularly graded.
2	⅔ mile north of Springton; H. MacPherson.	68	32	0	0	9	25	18	22	26	21	7	10	38	15	5	4	Sample from owner's pit, at depth of 5 feet. Fairly regularly graded. Material about the same as at deposit No. 1.
4	1 mile north of Millvale; W. Murphy.	51	49	0	0	7	13	15	22	43	24	8	7	37	20	3	1	Sample from owner's pit, near surface of deposit. Total per cent of fine sand (30) too high.
5	2¾ miles south of Port Hill; L. MacLean.	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; T. Boyle.	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 A, at depth of 4½ feet. Very regularly graded for roads.
6B		49	51	0	0	5	16	19	29	31	15	4	4	62	12	2	1	Sample from test pit B, edge of deposit, at depth of 4½ feet. Total per cent of fine sand (39) too high; conglomerate grades into sandstone.

7	⅓ mile east of Conway; C. Palmer.	62	38	0	0	2	9	9	24	56	37	14	6	12	23	4	4	Sample from owner's pit, at depth of 2 feet. Grading fairly regular for roads.
7		75	25	0	1	9	30	24	21	15	21	7	4	15	38	10	5	Sample from owner's pit, at depth of 7 feet. Grading not so regular as above.
7E		22	78	0	0	0	6	16	28	50	10	4	4	44	28	6	4	Sample from test pit E, at depth of 4 feet. Per cent of pebbles too low and total per cent of fine sand (64) much too high: conglomerate grades into sandstone.
7H	R. C. Henderson....	61	39	0	3	2	15	12	25	43	33	12	7	20	18	5	5	Sample from test pit H, at depth of 4½ feet. Grading very regular for roads.
7H		53	47	0	0	0	10	14	29	47	29	8	3	15	39	3	3	Sample from test pit H, at depth of 8½ feet. Total per cent of fine sand (28) too high; grading otherwise regular.
7K		47	53	0	0	5	15	17	21	42	29	14	8	27	14	3	5	Sample from test pit K, edge of deposit, at depth of 3 feet. Per cent of pebbles too low and total per cent of fine sand (26) too high: conglomerate grades into sandstone.
7N	Railway property...	59	41	0	0	0	9	15	26	50	40	13	5	13	19	6	4	Sample from test pit N, at depth of 5 feet. Grading regular for roads.
9A	Freeland; W. C. Palmer.	34	66	0	3	16	24	18	17	22	17	3	2	18	42	8	10	Sample from test pit in centre of deposit, at depth of 4 feet. Per cent of pebbles too low and total per cent of fine sand (50) much too high: too sandy for roads.
11	Northeast of lot 11; J. Henderson.	1	99	0	0	0	0	0	0	100	1	2	8	47	39	2	1	Sample from owner's pit. Grading poor: sand too uniform in size.
13	Goff bridge, lot 10; A. MacDonald.	64	36	0	3	16	24	18	17	22	17	3	2	18	42	8	10	Sample from cut in the bank of Trout river. Total per cent of fine sand (28) too high.
14	2 miles northeast of West Point; John A. Stewart.	55	45	10	0	15	29	13	15	18	11	3	3	22	38	9	14	Sample from old test pit. Total per cent of fine sand (37) too high.
14	....	50	50	0	0	10	14	13	25	38	19	8	9	21	21	9	13	Sample from old test pit, taken at depth of 2 feet. Conglomerate rather sandy. Total per cent of fine sand (32) too high.

TABLE I—Continued

Results of Tests on Conglomerate and Gravel Samples—Concluded

Sample No.	Location	Granulometric Analysis															Per cent passing 200 mesh	Remarks
		Proportion of pebble to sand		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		
15	1½ miles northeast of Surrey station; railway property.	67	33	0	13	20	20	13	17	17	11	2	2	35	36	4	10	Sample from old railway pit. Too little material retained on ¼ inch, 8, 14 and 28 mesh, and total per cent of fine sand too high.
15	....	72	28	5	3	15	27	15	16	19	19	3	6	33	30	4	5	Sample from old railway pit, taken at depth of 4 to 8 feet. Very coarse material with about 3 per cent boulders (over 3 inches).
16	1 mile, northeast of Peter's Road; P. Morrison.	71	29	0	0	14	30	11	17	28	38	10	6	20	17	4	5	Sample from small hole, taken near surface. Grading fairly regular for roads.
18	2¼ miles northeast of Poplar Grove, D. Milligan.	50	50	5	0	17	22	14	19	23	10	6	4	36	41	2	1	Sample from dump of test pit, dug by owner to a depth of 13 feet. Gravel contains 5 per cent boulders. Total per cent of fine sand (40) too high.
24	West Cape.........	59	41	0	4	14	19	11	21	31	29	15	9	32	10	3	2	Sample from shore bank, at depth of 6 to 8 feet and includes coarser material than average of deposit. Large proportion of friable pebbles.
25	1 mile west of Murray River; Horton's farm.	28	72	....	....	....	....	....	....	....	6	6	11	36	28	7	6	Sample from old test pit, taken at depth of 2½ feet. Sample more gravelly than average of deposit. Pebbles very friable. Total per cent of fine sand (56) much too high.

In order to make deposit No. 18 easily accessible by road, a small bridge would have to be built across one arm of Conway river. It could be reached very easily by small boats or barges, since it lies alongside of fairly deep water.

Deposit No. 20

One-half Mile Northwest of Portage. Conglomerate covered with from 1½ to 3 feet of soil is seen in a road ditch and in a shallow pit along the Western road. The area underlain by conglomerate is apparently small. The thickness of the conglomerate is not known, but even if fairly thick, a deep pit would be difficult to drain, as the land is low and swampy. The pit, while covering about 1,450 square yards, is only from 2 to 3 feet deep, and when visited in August, in a period of normal summer weather, the material in the deepest part of the pit was water soaked. It is very doubtful whether the conglomerate could be excavated to its full depth without some provision being made for pumping the water out. A large, shallow excavation would be easy to keep free from water but would necessitate the removal of much worthless material on top of the conglomerate, at least one cubic yard of useless soil for every cubic yard of conglomerate obtained.

Deposit No. 24

West Cape. Stratified gravel and sand are seen in the upper part of the bank along the sea coast. The bank is 25 to 35 feet high, but sandy gravel is seen only in the upper 10 feet. The deposit is made up of about one-third pebbles and two-thirds sand. Sample No 24 (Table I) was taken from a thick layer of coarse gravel, and represents material more gravelly than the average. A large proportion of the pebbles is composed of friable sandstone and shaly sandstone. The gravel can be traced for several hundred yards along the coast, and the amount available is undoubtedly very large. While the material may be quite suitable for the improvement of local roads, it is too sandy and soft to be worth transporting any distance.

At several places along the shore between West point and North point, also between North point and cape Kildare, fine beach gravel is seen. The gravel carries a large proportion of hard, medium-size pebbles, and if not too sandy, would make a satisfactory road material. Even if the material carries a large proportion of sand, the latter is as a rule coarser than that found inland, and could be used with good results on the clayey stretches of road in the building of sand-clay surfaces. These sand-clay roads, while not so durable as gravel roads, possess a surprisingly high supporting power, and are not so adversely affected by weather changes as plain earth roads. It is said that the amount of gravel available on the beach varies from time to time, as one storm may pile up great quantities, while another storm may partly or completely wash it away.

The gravel is certainly worth trying as a road-surfacing material. Immediately after a storm has washed it ashore, at some easily accessible point of the shore, the gravel could be carted away and dumped in a stockpile along the nearest road, from where it could be taken when needed. Another plan would be to drag the gravel inshore, out of reach of storm waves, by means of drag shovels, and cart it away later when needed.

Deposit No. 25

One Mile West of Murray River. On Horton's farm is an old railway pit in gravelly sand. In the upper part of the bank, the material is made up of at least 80 per cent sand and hardly 20 per cent pebbles. The pebbles are almost exclusively composed of friable sandstone. Farther down the bank the material is still more sandy. Sample No. 25 was taken from a test pit, at a depth of 2½ feet, and represents the most gravelly phase of the deposit.

The deposit is very large, but much too sandy for road purposes. Other large deposits of similar character are found in this part of the island.

Mortar Tests

Mortar tests were made on conglomerate, gravel and sand, crushed sandstone and limestone to determine their suitability as aggregates in concrete work. Twenty-three tests were made, of which fifteen were on conglomerate, four on gravel and sand, three on crushed sandstone, and one on crushed limestone. Only limestone proved suitable for that purpose. The worst results were obtained with the conglomerate. A number of test pieces had not set after 28 days, and could be crumbled with a slight pressure of the hand. Washing the material before using improves it a great deal, but not enough to render it suitable. Samples of conglomerate interstratified with sandstone, such as those from deposits Nos. 9, 13, and 14, and samples from the edge of other deposits where conglomerate grades into sandstone, gave much better results than those of straight conglomerate. Curiously enough, the samples of conglomerate mixed with sandstone carry a much higher proportion of fine material passing the 200-mesh sieve than those of straight conglomerate. The very poor results obtained with the latter are explained by the fact that they carry exceedingly fine, rusty powder, probably ferruginous clay, which screening and washing alone will not remove, since part of it clings to the larger particles. This powder gives to the straight conglomerate a dirty, rusty appearance, while the conglomerate mixed with sandstone has a cleaner, fresher appearance. Gravels and sands gave divergent values, the better results being shown by the coarser materials. Crushed sandstones gave very concordant results, due to their uniform grading. The only sample (No. 23, Table II) which gave good results was taken from a thin bed of red limestone outcropping on the north shore of Trout river, east of Goff bridge, near conglomerate deposit No. 13. Unfortunately limestone is very scarce on the island and is mostly confined, as far as known, to the west shore, between North point and West point, where an occasional bed is encountered.

TABLE II

Mortar Test

Sample No.	Fineness modulus	Per cent of water used	Sand Mortar — Tensile strength, per cent of standard		1 Cement: 3 Sand — Compressive strength, per cent of standard[1]		Remarks
			7 days	28 days	7 days	28 days	
1......	2·47	11	0	0	0	0	Had not set after 28 days
4......	2·67	19	0	0	0	0	" "
5......	3·15	15	0	0	0	0	" "
6......	3·02	9	0	0	0	0	" "
6A.....	3·19	12	0	63	8	53	
6B.....	2·39	14	97	78	80	74	Conglomerate mixed with sandstone.
7......	3·06	17	0	0	0	0	Had not set after 28 days.
7E.....	1·94	16	39	72	39	48	Conglomerate mixed with sandstone.
7H....	2·92	15	0	49	3	28	
7K....	2·93	20	0	0	0	0	Much clay. Had not set after 28 days.
9A.....	1·73	17	45	61	31	44	Conglomerate mixed with sandstone.
11......	1·70	16	40	63	40	76	Very fine sand.
13......	1·81	19	146	103	112	87	Conglomerate mixed with sandstone.
14......	1·58	11	141	105	112	78	" "
15......	1·75	12	0	0	0	0	Had not set after 28 days.
16......	3·05	11	0	0	0	0	" "
18......	1·95	15	50	74	57	66	Very fine sand.
21......	3·70	15	72	85	104	120	Crushed sandstone artificially graded.
23......	3·70	12	124	145	194	198	Crushed limestone artificially graded.
24......	3·06	15	89	119	97	127	Fairly coarse sand.
25......	1·90	15	63	75	40	80	Fine sand.
27......	3·70	16	50	70	76	89	Crushed sandstone boulders artificially graded.
29......	3·70	15	71	88	92	114	Crushed sandstone artificially graded.

[1]Samples testing at least 100 per cent of standard are considered suitable for all kinds of concrete works. Those testing at least 75 per cent of the standard may be used in foundation work.

IX

ROAD GRAVELS IN QUEBEC

R. H. Picher

During the field season of 1929 investigations were made on the character of the gravels in the province of Quebec with a view to determine their suitability for road construction. The extensive use of this material during the last few years for the improvement of the highways in that province afforded a good opportunity to study the wearing qualities of many types of gravel under actual service conditions.

Previous work of this nature in the province was done only in Vaudreuil and Soulanges counties in the years 1916 and 1917. At that time nearly all the improved roads of these two counties were surfaced with waterbound macadam built out of crushed field boulders and in some cases out of quarried rock, very little gravel being used in road improvement.

Area Covered

The present investigation covered the territory lying immediately north of the Ottawa and St. Lawrence rivers and extending from Chichester township in Pontiac county to the city of Quebec; south of the St. Lawrence, it included an area roughly triangular in outline, limited on the east by the Levis-Armstrong highway, on the south by the International border and on the west by a line running from Levis to Waterloo. On account of the large extent of the territory covered, and the wide variations in the distribution and quality of the gravels in the different parts of the area examined, it was thought best to proceed by counties in writing out the information gathered from the investigation. The description by counties proceeds in a regular way from west to east north of the Ottawa and St. Lawrence rivers, and less regularly from east to west south of the St. Lawrence. Of the 375 deposits examined, 180 are briefly described in this report, and 145 samples were collected for testing.

Road Material and Concrete Aggregate

While the investigation was primarily concerned with road gravels, sand and gravel deposits that have been developed almost exclusively for the production of cement mortar and concrete aggregates were also examined. A large number of deposits carry material which is suitable for both road and concrete purposes. Nearly all samples, however, were collected for testing as road material, regardless of their value as concrete aggregates. Even the few samples collected for the mortar test were not taken from that part of the deposit carrying the higher grade material. As a matter of fact no sample was taken of concrete gravel which had proved to be of high grade in actual service conditions, in order not to have an unnecessary large number of samples on hand. This explains the relatively small number of samples showing high results in Table III.

Effect of Weathering

In all gravel deposits, that part near the surface is always more or less oxidized and disintegrated, due to long exposure to the weathering agents. The weathering is most intense at the surface and gradually decreases in depth, so that at a certain depth fresh gravel is found. The depth of weathering is very variable with the different deposits and in many cases even within the same deposit, and there is usually no sharp outline between the fresh gravel and the weathered material above it. There are many cases, however, where an impervious layer at a certain depth limits the weathering action to that depth, giving a sharp outline between the fresh and weathered material. In developing gravel deposits for any particular purpose, an effort is made to get as fresh material as possible, but because of the great expense incurred in obtaining strictly fresh material, a certain proportion of weathered, friable, or soft particles in the fresh material is tolerated, the proportion depending on the use for which the gravel is intended. Most specifications for road gravel require that the material shall not contain more than 15 per cent of soft, friable, or disintegrated pebbles. For high-grade concrete aggregate the requirements are much more strict. The necessity for this was strongly emphasized in conducting the mortar test on samples of gravels dealt with in this report, by comparing a number of samples carrying various amounts of disintegrated material, but all of similar grading as regards size of particles, as determined by the granulometric analysis. The strength, particularly the tensile strength, decreased with an increasing amount of weathered material. Hence the importance of taking gravel to be used as concrete aggregate deeper in the bank than is required for road gravel. Colour is usually a good guide for differentiating fresh from weathered material. North of the St. Lawrence and Ottawa rivers the average gravel carries a high proportion of gneiss or granite and weathers to a deep buff or rusty yellow colour. In the hilly land south of the St. Lawrence valley the average gravel carries a high proportion of slate and quartzite and weathers to a pale buff or dirty brown colour. Everywhere the fresh gravel when seen in the bank beside the weathered material appears to have a bluish tint.

Explanation of Terms

In this report, all stones retained on the 3-inch screen are called boulders; those passing the 3-inch screen and retained on the ¼-inch screen are called pebbles; all material passing the ¼-inch screen is called sand. The term "Oversize Pebbles" applies to pebbles larger than the maximum size allowed in the specifications. In Quebec, 1¼ inches is the maximum size of stone permissible for the wearing course of a gravel road. That part of the sand passing the 200-mesh sieve is designated as silt and clay. Under the term soft pebbles are included, not only friable or disintegrated pebbles but also those of an objectionable shape, such as very flat or much elongated pebbles, which may or may not be soft. Flat or elongated pebbles are very common in some gravels south of the St. Lawrence river, but are rare north of it.

Pontiac County

The investigation work covered that part of the county bordering the Ottawa river, from Chichester township to the eastern limit of the county, and extended a distance inland varying from 1 to 7 miles. All the deposits which have been developed to some extent are quite probably included in the area examined, since the balance of the county is very sparsely settled.

Deposits are fairly common between Vinton and the eastern border of the county, very scarce from Vinton to Chapeau, and totally wanting west of Chapeau. The country west of Vinton, apart from a narrow strip along the Ottawa river, is thickly wooded, and prospecting along the several streams emptying into the Ottawa would very likely reveal the presence of workable gravel deposits without proceeding too far inland.

Of the thirty deposits examined, the following are the more important:

1. Highway pit; along main highway, just north of Chapeau.
2. Highway pit; along main highway, 2 miles east of Chapeau.
5. Desjardins; north of main highway, 3½ miles east of Fort Coulonge.
6. W. Cole; just east of Goldwin.
7. Village of Campbell's Bay.
13. Mrs. Paul; 2½ miles south of Bryson.
16. M. Dale; Shawville.
18. H. Hodgins; south of main highway, southeast of Shawville.
20. W. Thompson and others; along main highway, 1 mile west of McKee Station.
21. Moyle; along main highway, southeast of McKee Station.
22. J. Dodds; 1¼ miles south of main highway, on road to Norway Bay.
27. S. Walsh; 4 miles north of Quyon.
28. W. Westbrook; 1¼ miles north of Beechgrove.
29. Clark; 2 miles northeast of Beechgrove.
30. Robertson; 1½ miles east of Mohr Station.

The gravels from Nos. 1, 2, 16, and 30 are irregular in size and generally coarse and bouldery. Passing them through a crusher would improve the grading and make use of the oversize which otherwise would go to the waste pile.

Nos. 5 and 28 are shallow deposits of gravel, more or less weathered throughout, but very regular and uniform in size. Very good results have been obtained in road surfacing with this material.

Nos. 6 and 7 are large deposits in a high steep-sloped bluff facing the Ottawa river. Large pits in the form of side-hill cuts have been opened in both deposits, and show gravel which varies in size, but is generally coarse and somewhat bouldery. Apart from the material close to the surface of the deposits, the gravel is free from weathering, and half of the pebbles is made up of fresh limestone and dolomite. Thick layers of gravelly sand (approximately 75 per cent sand) are exposed in part of the lower bank of deposit No. 7. While any size gravel can be obtained by digging at the proper place, crushing and screening would be the more logical and economical plan in large-scale development work, as all the oversize would thus be utilized. Conditions are particularly favourable for extensive development, since on account of the height of bank, comparatively little stripping would have to be done, and a plant could be so designed that the gravel would move by gravity nearly all the way from bank to storage bin. Sample No. 7, Tables I, II, and III contains less large pebbles and less sand than pit average. It was taken in fresh material from the lower bank.

Large excavations have been opened in Nos. 13 and 20. More sand than gravel is now seen in the exposed parts of the pit banks.

Deposit No. 16 is a pocket of gravel in a large ridge of glacial drift and is now almost completely exhausted. Test pits along the ridge would probably uncover other similar pockets.

Deposit No. 18 contains much more sand than gravel. A large pit in the steep bank of a brook shows sand interstratified with thin layers of gravel, the whole very fresh and clean. A great deal of this material has been used as aggregate in concrete works with good results. The opposite bank appears to be more gravelly, as judged by several shallow test pits dug by the owner.

In No. 21 there is a large excavation, oval in outline, cutting through part of the flat top of a low ridge, and measuring 280 by 140 feet, with a maximum depth of 40 feet. The gravel deposit proper is in the shape of a steep-sloped ridge or knoll and is overlain by sand, the latter in the form of a flat-topped ridge, so that the thickness of sand cover varies from 2 feet at the crest of the gravel ridge to 10 feet and more towards the foot of the slopes. The gravel is coarse and bouldery at the northwest end of the pit, and decreases gradually in size towards the southeast end, where it is straight sand, so that any desired size material can be obtained by digging at the proper part of the bank. Gneiss and crystalline limestone make up about two-thirds of the pebbles. Sample No. 21 represents the coarse material at the northwest end of the pit; sample No. 21a was taken in fine and fresh gravel overlain with 10 feet of sand in the southwest bank; sample No. 21b is fine sand from the southeast end of the pit. The low result obtained in the mortar test on sample No. 21b (Table III) is due to the fineness of the sand, over 70 per cent of which passes through the 28-mesh sieve. The coarser sand and gravel are undoubtedly suitable as aggregates in concrete mixtures. There is a large amount of both gravel and sand available, but the removal of the weathered and useless sand covering the more suitable material increases the cost of winning.

The gravel from deposit No. 22 is very regularly graded, made up of about half sand and half pebbles. Trap rock and crystalline limestone constitute about two-thirds of the pebbles. The surface of the deposit is level with the surrounding land, and the amount of gravel unknown but apparently not very large. A pit opened two years ago is now 260 cubic yards in size. The quality of the material for road-surfacing purposes would warrant further investigations regarding the amount that can be obtained.

Deposit No. 27 is in the lower southern slope of a hill and is of large extent. Along the road skirting the foot of the hill, a round pit, 140 feet in diameter and with a maximum depth of 50 feet, shows very regularly graded gravel carrying from 40 to 50 per cent sand. About 65 per cent of the pebbles is gneiss, half of which is highly micaceous. The gravel in the upper ten feet of the bank is all more or less weathered, below that depth the bank is concealed behind a high talus so that the depth of weathering could not be ascertained. Fresh, hard gravel is seen in the bottom of the pit. Sample No. 27 (Tables I, II, and III) was taken at depth of $2\frac{1}{2}$ to 5 feet, in partly weathered gravel with a high proportion of soft stones. Sample No. 27a is fresh, medium fine sand taken at the edge of the deposit. For road purposes the gravel is very regularly graded, but the great depth of weathering is a serious disadvantage. The low results obtained in the mortar test (Table III) are probably due to the mica and weathered grains contained in the sampled material.

Deposit No. 29 covers part of the lower south slope of a large syenite hill. A large pit, over 15,000 cubic yards in size and with a maximum height of bank of 50 feet, shows medium fine, fairly uniform gravel, averaging half sand, the proportion of the latter varying with the different layers from 30 to almost 100 per cent. Apart from an occasional big block of syenite, there are no boulders. The gravel is fresh, and the pebbles made up almost exclusively of hard syenite and syenite-gneiss. The amount of gravel available is undoubtedly very large, but the depth of the deposit varies a great deal from place to place, as the gravel lies directly on the syenite, the surface of which is very irregular.

Hull County

All developed deposits, outside of those situated in the township of Hull and part of the township of Wakefield, have been covered by the present investigation.

Gravel is fairly common throughout the larger part of the county, particularly along the Gatineau river, but a large proportion occurs in shallow, small, or sandy deposits. Large deposits of good road gravel are common around Maniwaki and for several miles northward, but scarce elsewhere. A large sand area extending from Gracefield to several miles south of Kazubazua and covering almost four townships shows hardly any surface gravel.

The more important deposits are included in the following list:—

31. P. E. Chartrand; along main highway, 1½ miles northwest of Luskville.
33. W. Meehan; along main highway, 2 miles north of Alcove.
36. S. O'Rourke; along main highway, south of Brennan.
38. J. Heeney; Danford Lake.
39. P. Pétrin; 1⅓ miles southwest of Marks Station.
41. N. Bénard; along main highway, 2 miles north of Glenbean.
43. O. Saumur; 3 miles northwest of Bouchette.
44. E. Lafontaine; along main highway, 2 miles northeast of Messines.
45. P. Brascoupé; along main highway, 5 miles south of Maniwaki.
46. L. Thériault; 5 miles east of Maniwaki.
47. J MacSheffrey; 3 miles northeast of Maniwaki.
53. L. Brunet; along main highway, 6 miles northeast of Ste. Famille.

Gravel from deposits Nos. 31 and 41 lies under a thick cover of sand, and is generally fine and fresh. Sample No. 31 represents coarser material than pit average.

Deposits Nos. 33 and 47 are very sandy and more suitable for mortar and concrete than roads.

Deposit No. 36 is in the west bank of Gatineau river, which forms at this point a steep-sloped bluff, about 100 feet in height. Besides O'Rourke's pit, which cuts through the upper 15 to 20 feet of the bluff and over 5,000 cubic yards in size, there is a much larger excavation, which cuts along the face of the bluff and to its full height. The Hull-Maniwaki line of the Canadian Pacific railway skirts the foot of the bluff and passes alongside of the larger excavation which is owned by the railway company. The gravel is on the whole very coarse and bouldery, and half of the pebbles are crystalline limestone, mostly fresh. The importance of this deposit lies not so much in the high quality of the material as in its large extent and its close proximity to the provincial highway. The gravel is not deeply weathered and, if passed through the crusher, would make a good road-surfacing material.

Deposit No. 38 lies about at the border line between Pontiac and Hull counties. The gravel from this deposit is partly weathered and rather soft, but very regularly graded and very uniform throughout as regards the size of its constituents. Pebbles are mostly granite-gneiss. Particular importance attaches to this deposit on account of being the only gravel available for many miles to the east. The deposit is of limited extent.

Gravel No. 39 is very similar to No. 38, but is somewhat finer and not so deeply weathered. It lies at the western limits of the large sand area already referred to above. The deposit is of limited extent.

The gravel from deposit No. 43 is rather fine, carrying over 75 per cent of sand, but is otherwise regular and very uniform in size, as seen all around an excavation over 3,000 cubic yards in size and with a maximum depth of 18 feet. The zone of weathering is rather thick and if the gravel is used as aggregate in concrete, great care should be exercised in taking only fresh material. The low result obtained in the mortar test (sample No. 43, Table III) is due to slightly weathered material in the sample, which was taken at a depth of from 8 to 12 feet. For road purposes the gravel is somewhat too fine, but otherwise quite suitable. Much has been used for roads and more will be used, as it is the best local material, and there is a large amount available.

A large pit, 2,350 cubic yards in size and with a maximum height of bank of 25 feet, in deposit No. 44, shows gravel which is generally fine and mixed with much sand. Sample No. 44, Tables I and II, represents the coarser phase and sample No. 44a a finer phase, thelatter nearer the edge of the deposit. The gravel is comparatively free from weathered material, and 75 per cent of the pebbles are made up of granite and granite-gneiss. The deposit forms a large ridge, but a great deal of it is too fine for road work. The coarse gravel lies apparently in pockets or zones underneath the crest of the ridge. Another large excavation a short distance from Lafontaine pit, is now abandoned, as all the coarse gravel at that place has been taken out. Sample No. 44a, Table III, gave a rather low result in the mortar test. The part of the bank from which this sample was collected contains some clay, but by far the larger part of the gravel in the deposit is clay-free and quite suitable for use in mortars or concretes.

The excavation in deposit No. 45 measures 4,810 cubic yards with a maximum height of bank of 25 feet. The gravel is fresh and uniform in size. The surface of the deposit is level with the surrounding land and the amount of gravel it contains is unknown but apparently large. Sand pockets up to 4 feet in thickness found in places on top of the gravel, would increase the cost of stripping. The pit is located along the provincial highway.

At the time that deposit No. 46 was visited, a pit was being opened for material to surface the road leading to Montcerf. Outside of the new excavation, several shallow test pits were dug by the owner and all show gravel which is very uniform in size throughout, being medium coarse with not more than half sand. The deposit covers only a small area and its depth is unknown. The gravel possess good road-making qualities, and looks very much like No. 53.

Deposit No. 53 forms a low, flat-topped knoll. Along the northern slope, an excavation, 6,500 cubic yards in size, has exposed a bank 300 feet in length and from 10 to 15 feet in height. All the excavated material has recently been used in the surfacing of the new provincial highway between Maniwaki and Mont Laurier and has proved very good for that purpose. The gravel is rather deeply weathered, only moderately hard, and carries a high proportion of sand, but the sand is mostly very coarse, and the size of the gravel is on the whole very regular and uniform throughout, as judged by the exposed part in the long pit face. Gneiss and granite make up from 80 to 90 per cent of the pebbles. A test pit dug 100 feet back of the main pit face shows similar material, so that the amount of gravel available is apparently large. For mortar and concrete, gravel should be taken sufficiently deep so as not to include weathered material. Sample No. 53, Table III, was taken at a depth of 6 to 9 feet and was not entirely free from weathered material.

Labelle County

Investigation work was confined to that part of the county adjacent to the Maniwaki-Mont Laurier-Montreal provincial highway, and quite probably includes all the developed deposits of the county.

Gravel is comparatively scarce throughout the area examined, and most of it is hardly of size suitable for road surfacing. Fairly large deposits of good gravel are found only near Mont Laurier, Nominingue, La Conception, and west of St. Jean, while large areas around Labelle and Guenette are almost totally devoid of gravel. Drift boulder deposits are everywhere of common occurrence. In these are occasionally found pockets of coarse and bouldery gravel, some of which have been excavated and the material crushed to the proper size for road work. The scarcity of good gravel has resulted in an intensive search being made for such material, as attested by the large number of small pits, particularly along that section of the highway between Mont Laurier and the eastern border of the county.

Of the deposits visited, the following are the more important:—

54. Highway pit; 3 miles west of St. Jean.
55. F. Fleurant; 1 mile west of St. Jean.
61. M. Valiquette; 1 mile east of Mont Laurier.
67. J. Gagnon; 1½ miles northwest of Nominingue.
71. T. Fortin; 7½ miles southeast of L'Annonciation.
73. La Fabrique; La Conception.

Deposit No. 54 forms a steep-sloped ridge over 75 feet in height. The provincial highway crosses the ridge through a large cut 50 feet in depth, from which gravel is taken for surfacing the highway. The large cut faces show very coarse and bouldery gravel directly underneath the crest of the ridge, and finer material down the slopes. Crushing the gravel would make it more suitable and would prevent the oversize stones from going to waste. The size and shape of the deposit make conditions favourable for large-scale development. The importance of the deposit is further enhanced by the fact that for many miles west no other large deposit is found close to the main highway.

Gravel from deposit No. 55 is uniform in size and grading, but very sandy, and the amount available is probably not more than 6,000 cubic yards. It makes a fairly smooth road surface, but does not compact to a hard and dense mass. For a distance of 2 miles west of deposit No. 55, as far west as deposit No. 54, there are surface indications of gravel at several places.

A large excavation 16,600 cubic yards in size and 30 feet in maximum height of bank, in deposit No. 61, shows regularly graded gravel varying in size from medium coarse to very fine and sandy. On the average the gravel carries a rather high proportion of sand. Granite and granite-gneiss make up over three-quarters of the pebbles. In the upper part the material is partly weathered and in places strongly rusty. Sample No. 61b, Table III, taken in fresh gravel at a depth of 7 to 8 feet, gave good results in the mortar test. The amount of gravel available is in all probability very large, but is difficult to estimate, since the gravel is concealed under a blanket of sand of variable thickness.

A large quantity of gravel has been taken from deposit No. 67 by the Canadian Pacific Railway Company for ballast. The large pit bank, up to 50 feet in height, shows gravel that is interstratified with much sand.

The size of the gravel constituents varies a great deal between the different layers. A large amount of good road gravel is in the bank, but it is too thickly covered with poorer material to be economically available.

Gravel from deposit No. 71 varies in size from coarse and slightly bouldery to fine and sandy. The coarse gravel has given satisfactory results in road surfacing. The fine phase is represented by sample No 71, Tables I and II. The gravel is on the whole quite fresh and makes a suitable aggregate in concrete work. The deposit is of small extent.

A deep road cut in deposit No. 73, west of the village of La Conception, has exposed a high bank of fresh, medium coarse gravel, very regular in size and carrying about one-third of very coarse, clayey sand, while the other bank on the opposite side of the road cut shows largely sand. Very good results have been obtained in road surfacing with material from the gravelly part of the cut, but its clay content would render it unsuitable as aggregate in concrete work. Back of the gravel bank the ground surface slopes down steeply towards the Rouge river, so that the deposit appears to be of limited extent.

Papineau County

All deposits covered by the investigation are included in a strip of land bordering the Ottawa river and varying in width from 4 to 9 miles, and occur in groups in four different localities, namely: near Perkins, Buckingham, Valdor, and Montebello. Outside of these, gravel is exceedingly scarce.

None of the deposits examined are of outstanding value from the road-surfacing standpoint. Some of them are almost exclusively worked for cement mortar, and concrete aggregates.

The following deposits have been extensively drawn upon for both road and concrete works:—

74. Madore; 1½ miles south of Perkins.
76. Mrs. Charette; 2½ miles northeast of Perkins.
78. H. Gorman; along main highway, 5¼ miles north of Buckingham.
79. Laframboise; along main highway, 5 miles north of Buckingham.
80. W. Newton; 3 miles northwest of Buckingham.
81. W. Newton; 3 miles northwest of Buckingham.
82. A. C. Smith; 2½ miles northwest of Buckingham.
83. M. Burke; 3½ miles northwest of Valdor.
85. E. Arbique; 3 miles north of Montebello.
86. A. Périard; 2 miles north of Montebello.
88. O. Gagnon; 4 miles north of Montebello.

Deposit No. 74 holds a large amount of fresh coarse sand and fine gravel which proves a very good aggregate in concrete mixtures. There is very little gravel of size suitable for road purposes.

In deposit No. 76 the size of the gravel, although not uniform throughout, varies in a regular way from coarse in the upper part to fine in the lower part. The proportion of sand, which is largely coarse, varies in the same way from one-third to two-thirds. The material is rather deeply weathered, but not too friable. It is almost exclusively used for surfacing local roads, for which it is entirely satisfactory. The deposit is of fairly large size. There are several other deposits near this one, as judged by surface indications.

In deposit No. 78, the gravel is deeply weathered and rather sandy, but the sand is very coarse, and the size of both pebbles and sand is very uniform throughout. Good results are obtained with the gravel in road surfacing, but the mica content of the sand lowers the value of the material as aggregate in concrete work. Sample No. 78, Table III, was taken at a depth of 15 feet, in slightly weathered gravel.

A large excavation in deposit No. 79, which lies in the steep slope of a bluff, shows very coarse and bouldery gravel in the upper part, and mostly coarse sand in the lower part. The zone of weathering is rather thick, but apart from the intensely weathered material in the upper three feet, the gravel is fairly hard and would be quite suitable for roads if crushed to the proper size. Sample No. 79, Table III, was taken in the bottom of the opening in coarse gravelly sand, and tests show that the fresh material is suitable for concrete mixtures.

Deposit No. 80 occupies the north slope of a sand hill and half way up the slope there is a large pit, over 13,000 cubic yards in size and 50 feet in greatest depth. The gravel varies much in size from place to place and is rather deeply weathered. It lies under a thick overburden of sand all round the excavation, except in the east end, where there is still a large amount under thin cover. Gravel of any desired size can be obtained by digging at the proper place.

Deposit No. 81 lies a short distance from No. 80 and may be continuous with it. A large excavation in the steep slope of a gully, shows that the deposit at this place contains much more sand than gravel, and very little gravel of proper size for roads. Sample No. 81, Tables I and II, represents the coarse phase. The material is fresher than that from No. 80, and the pit is worked almost exclusively for the production of mortar and concrete sand and gravel. Sample No. 81, Table III, was collected in the upper part of the pit bank and contains some weathered material.

In deposit No. 82 the high bank of the pit, which is in the shape of a side-hill cut over 21,000 cubic yards in size, shows coarse and bouldery gravel, while the low bank on the down-hill side, where sample No. 82 was taken, holds finer material. It is probable that the pit was originally opened in gravel of the right size for road work, but has now reached up hill into the more bouldery gravel.

Very fine gravel is seen in a large excavation over 18,000 cubic yards in size and 40 feet in greatest depth in deposit No. 83. The gravel is very uniform in size all around the pit, and holds at least 75 per cent sand which is rather too sandy for best results in road work.

In deposit No. 85 the gravel varies much as regards the size of pebbles, and the weathered zone is rather thick, as judged by that part of the deposit exposed in a large excavation over 10,000 cubic yards in size. Most of the excavated gravel has been used in road surfacing, and the good results obtained are probably due to the fact that the gravel carries just about the right proportion of sand almost everywhere throughout the exposed part of the deposit, and even in the few places where the sand content is high the sand is invariably coarse. Sample No. 85 was taken in sandy material near the pit entrance.

A pit in deposit No. 86 has recently been opened in what promises to be good road gravel. The pit is now about 1,900 cubic yards in size. Although somewhat sandy, the gravel is fairly uniform in size and quality throughout the exposed part, and comparatively fresh. The deposit occupies the very steep slope of a high creek bank, so that conditions are very favourable for large-scale excavation without excessive stripping.

The gravel in deposit No. 88 is irregularly graded, being deficient in small pebbles and coarse sand. Although remarkably fresh throughout, it carries a rather high proportion of friable material. Sample No. 88, Table III, was taken at a depth of 10 to 13 feet, in material free from weathering. The low result obtained in the mortar test is due to the mica content of the sand.

Argenteuil County

The work covered nearly all the townships fronting the Ottawa river, and a small area in the northwest corner of the county.

In the territory immediately north of the Ottawa river, gravel is found only near Pointe au Chêne. Farther north the deposits are numerous, but they are all of small size with the exception of one found near the border between Argenteuil and Two Mountains counties. One striking feature of the gravel deposits is that they are all alike in coarseness and character, with the exception of one large deposit just mentioned. They are all of small extent, shallow depth, and are made up of very hard, strongly rusty material, with hardly any oversize pebbles or boulders. They have been found to be very good road material but most of them are unsuitable in mortar and concrete mixtures. These shallow gravels are particularly numerous in Chatham township, and common at many other places. The following list includes a few of the larger ones:—

90. Alex. Campbell; 1 mile west of Pointe au Chêne.
91. Archie Campbell; Pointe au Chêne.
92. A. Page; 2 miles south of Rivington.
94. Graves; 2 miles north of Arundel.
97. W. Lafleur; 4 miles southeast of Rawcliffe.
98. A. Lavigueur; 4½ miles southeast of Rawcliffe.
101. Highway pit; 1 mile north of Pine Hill.

No. 103 is a very large gravel deposit found near the eastern border of the county, along the main highway between Lachute and St. Hermas. As it is the only local deposit, it has been extensively worked for road material. The gravel is well exposed in several large excavations, and an old railway pit of much larger size than the present excavations, is now nearly all talus-covered. The gravel is softer and much less regular in size than the rusty gravels from the other parts of the county. It is on the whole very coarse and bouldery. The upper part of the deposit carries in places large streaks of finer gravel interstratified with much sand. The coarser and more bouldery gravel, when crushed to the proper size, makes a good road material. It is more uniform in size than the finer gravel overlying it. As the excavation proceeds farther into the bank the finer gravel becomes scarcer.

Terrebonne County

Nearly all gravel deposits which have been worked for road or other purposes are found along or very close to the route of the Mont Laurier-Montreal highway, so that the present investigation was confined to a narrow strip of land bordering that highway.

Gravel is fairly common all along the road except west of St. Jovite and between St. Agathe and Ste. Adèle, but the deposits, while numerous, are nearly all of small size.

Large deposits of good road gravel are found east of St. Faustin, north of Ste. Agathe, south of Shawbridge, and west of St. Jérôme, the latter by far the largest of all.

Surface indications of gravel were noted at many places following a cursory examination of the ground for a short distance both sides of the highway, so that systematic prospecting work for gravel would probably reveal the presence of numerous other deposits.

The more important deposits, either on account of the quality of the material or extent of development, are included in the following list:—

109. W. Levert; $\frac{2}{3}$ mile east of St. Faustin.
110. J. Ouellet; $\frac{1}{2}$ mile east of Nantel.
111. D. Lajeunesse; $\frac{3}{4}$ mile west of Degrosbois.
113. Highway pit; 2 miles north of Ste. Agathe.
115. A. Lalande; $\frac{1}{2}$ mile north of Piedmont (Achille Lalande).
116. Arthur Lalande; Piedmont.
117. J. Clavel; $\frac{3}{4}$ mile south of Shawbridge.
119. A. Durant; $3\frac{1}{2}$ miles northwest of St. Jérôme.
120. A. Lemay; 1 mile west of St. Jérôme.
121. H. Danis; 1 mile southwest of St. Jérôme.
122. A. Lebeau; 1 mile southwest of St. Jérôme.
123. Coulombe and Limoges; $2\frac{1}{2}$ miles southwest of St. Jérôme.

Gravel from No. 109 is fairly uniform in size but rather coarse and bouldery. It is comparatively free from weathered particles, and would be a good road-surfacing material if brought to the proper size by passing through a crusher. The deposit, which is flat-lying, extends on both sides of a brook and abuts on one side against a boulder clay ridge. A large excavation measuring over 20,000 cubic yards in size cuts through both banks of the brook over a distance of 400 feet and an average depth of 15 feet. Parts of the deposit carry streaks of rust-coated gravel which should not be used in mortar or concrete mixtures. Sample No. 109, Table III, was taken in rust-coated material.

Nos. 110 and 111 are small deposits not over 6 feet in depth. Similar shallow deposits are seen at several other places in the flat land bordering Noire river between Nantel and Degrosbois. They all carry good road gravel, very uniform in size throughout, although somewhat sandy in places.

A very large, shallow excavation, over 37,000 cubic yards in size, in deposit No. 113, shows fine gravel carrying from 50 to 75 per cent sand and no oversize stones, apart from an occasional large anorthosite boulder. The gravel is hard and fresh, and very uniform in size throughout, but the high sand content is a disadvantage. Pebbles are almost exclusively gneiss and anorthosite. The material wears well on roads, once sufficiently compacted.

No. 115 is a shallow deposit, not over 7 feet in depth, in fresh, very regularly graded, but rather sandy gravel. Pebbles are 75 per cent anorthosite.

Gravel from No. 116 is hard and fresh, but varies much in size from very coarse and bouldery to medium fine, and thickly covered with sand in places. Pebbles are 85 per cent anorthosite. Sample No. 116, Tables I and II, is from a depth of 4 to 7 feet in medium coarse, regularly graded gravel overlying coarser and more bouldery material.

No. 117 is a large deposit in the upper steep slope of a high bluff facing North river. A fairly large section of the deposit is exposed in the high bank of a pit. The gravel from the upper part shows much variation in size between the different layers, from very bouldery material to almost straight sand. The gravel from the lower part is more uniform and considered better for road purposes. A large part of the gravel used in concrete sidwalks in Shawbridge comes from this deposit. A very high-grade concrete aggregate can undoubtedly be obtained by digging with hand shovel into layers of proper size material. The gravel is generally hard and fresh, and composed almost exclusively of anorthosite. The deposit extends all the way down the slope, but the necessity of hauling the material up hill has limited the excavation work to the upper part of the bluff.

Nos. 119, 120, 121, 122, and 123 are five large excavations, measuring 17,800, 8,400, 16,800, 40,500, and 8,800 cubic yards, in a very large, flat-lying deposit over 4 miles in length in a north-south direction. In No. 119, the most northerly excavation, the gravel is very fine, carries not less than 75 per cent sand, and is very uniform in size throughout. No 120 is in a thick layer of gravel dipping to the east, with sand below and above it. Both the east and west banks have reached beyond the gravel layer and show mostly sand. The gravel varies in size, but is on the average coarse and carries from 35 to 50 per cent sand. Pits Nos. 121 and 122 are on neighbouring properties and show gravel which is generally coarse but varies within a wide range of sizes, so that any desired size material can be easily obtained. In No. 121, the gravel lies under a thicker sand covering, which accounts for its smaller depth of weathering. No. 123 the most southerly excavation, is in fine gravel carrying about half sand. The size of the material varies very little throughout the exposed part. No. 123 excepted, all excavations show generally fresh and hard gravel composed almost exclusively of anorthosite. Gravel from No. 123 is slightly rusty and not quite so hard as the other ones, but of a size more suitable for road purposes. It is composed of 75 per cent anorthosite and 25 per cent granite and gneiss. Nos. 120, 121, and 122 are the only excavations deep enough to show gravel which is sufficiently free from weathered particles to be safely used as concrete aggregate.

Montcalm County

All deposits which have been worked for road or other purposes are located in the south part of the county and are included in the present investigation.

Gravel deposits are of common occurrence everywhere except in the southeast corner of the county, where they are very scarce in the sandy area bordering Joliette county, and totally wanting in the clay land bordering L'Assomption county. Gravel is particularly abundant near Ste. Julienne and Rawdon. Very high-grade road-surfacing material has been obtained from the Ste. Julienne deposits, which have been extensively drawn upon for improving the roads throughout the large clay area lying immediately to the south.

The more important deposits examined are included in the following list:—

125. Ste. Julienne.
126. N. Landry; Ste. Julienne.
127. Highway pit; 3 miles southwest of Ste. Julienne.
128. L. Tremblay; St. Théodore.
132. La Fabrique's pit; Notre Dame.
133. I. Lavoie; ½ mile southeast of St. Donat.
134. E. Riopel; 3 miles southeast of St. Donat.
135. J. Brousseau; 1 mile west of Rawdon.
139. Brouillet Sand and Gravel Co., Ltd.; Hamilton Crossing.

No. 125 is a large deposit said to cover over 100 acres and to have a maximum depth of 20 feet, as determined by test pits which are now refilled. The gravel is exposed in several large pits in the northern part of the village of Ste. Julienne, and is found to be remarkably uniform in size throughout. It is a fine gravel carrying about 75 per cent of exceedingly coarse sand. A peculiar feature of this gravel is its grading. Over 90 per cent of the total material is smaller than ¾ inch and is retained on the 14-mesh sieve. The great success attained with this type of gravel in road surfacing, particularly on clay roads, is chiefly due to its grading. The gravel is fresh, very hard, slightly clayey in the upper part of the deposit, and composed of over 75 per cent anorthosite. The failure of the gravel in the mortar test, as shown in Table III, is due to the clay coating on the particles. In two of the excavations, under 7 feet of gravel similar to the one just described, is seen a 1-foot layer of bouldery sand, and under it 7 feet of fine gravel and coarse sand as represented by sample No. 126. Very fine white sand lies at the bottom of the two excavations. The gravel from the lower 7 feet is very different from the upper gravel, in that it carries more large pebbles and more fine sand, or, in other words, it carries a wider range of sizes. The extent of the lower gravel could not be ascertained. It is a very good road material, but not of such high grade as the upper gravel. As a mortar and concrete aggregate it is entirely satisfactory.

In deposit No. 127 there is a very large excavation, 20 feet in depth, connected by spur to the Canadian National railway. The gravel is loaded by gasoline shovels directly into standard gauge railway gondolas and distributed by rail to outside points for use in surfacing highways. It is a very high-grade road material, being similar to the upper part of No. 125, but somewhat coarser.

Good, fresh gravel and sand suitable for mortar and concrete mixtures is seen in deposit No. 128. Thick layers of gravel, sufficiently coarse for road work, are exposed in one side of a large excavation, over 5,500 cubic yards in size, but the largest part of the deposit is too sandy for that purpose. The gravel is hard and comparatively free from weathered material.

Nos. 132 and 133 are small, very shallow deposits of sandy gravel of very uniform size, which has been used successfully in surfacing the main highway from Notre Dame to St. Donat. The gravel is partly weathered, yet fairly hard.

Gravel from deposit No. 134 varies much in size. One end of a deep pit shows very coarse and bouldery material, but the largest part of the pit shows coarse sand carrying a small proportion of pebbles and few boulders. Sample No. 134 represents the average run of the bank. The material is slightly rusty and more or less weathered throughout the exposed part.

Very good road gravel is seen in a pit, 200 feet in length and 5,000 cubic yards in size, in deposit No. 135. The gravel is fine and sandy, but the size is very uniform and the sand is very coarse. The grading of the material approaches that of Nos. 125 and 127, with 80 per cent of the total passing a $\frac{3}{4}$-inch screen and retained on a 14-mesh sieve.

No. 139 is a large sand deposit in the slope of a bluff facing east. A pit originally opened in the lower slope has gradually been extended up the slope. The excavation is now of very large size and has reached almost the top of the bluff, cutting through a thick layer of gravel which overlies the sand, and which gradually becomes thicker as the digging operations progress farther into the bluff. Where the pit bank now stands, the gravel measures a thickness of from 10 to 17 feet. Underlying the gravel there is 12 feet of medium coarse sand, underlain by 35 feet of coarser sand, which is in turn underlain by 10 feet of fine sand. The pit has a depth of 75 feet, measured from the top of the upper bank, and is worked in four different levels, corresponding to the changes in coarseness of material as given above. The fine sand from the lower level is shipped to Montreal as moulding sand, and the coarser sand is used as concrete aggregate. Some of the gravel from the upper level is sold for road purposes. The grading of the gravel closely approaches that of Nos. 125 and 127. Two samples of gravel were collected, 139 from the upper 3 to 7 feet, 139a from the next 3 feet. The low results obtained in the mortar test are due to the material not being strictly free from weathered particles. Gravel taken deeper into the bank has been successfully used as concrete aggregate in the building of foundations for power-line towers. The pit is connected by spur to the Canadian National railway which passes along the foot of the bluff.

Joliette County

Sand covers most of the southern part of this county, and the few gravel deposits encountered are shallow and small in extent.

Gravel layers are seen in one part of the high bank of a very large sand pit, situated at the border between St. Félix and Ste. Emilie parishes, and owned by Standard Sand, Ltd., Joliette. The pit is operated for the extraction of sand suitable for asphalt, plaster, mortar, and concrete. Samples Nos. 153 and 153a are not representative of that part of the deposit best suited for cement mortar and concrete. The pit is connected by spur to the Canadian Pacific railway, and most of the product is shipped to Montreal.

Berthier County

Gravel is scarce in the area examined, which comprises most of the southern half of the county, and totally wanting in the flat land of the southern end of the county, underlain by Palæozoic rocks. The few developed deposits are all very sandy, and the following ones, found immediately west of St. Gabriel, are the only deposits of fairly large size:—

159. N. Ducharme; 1 mile west of St. Gabriel.
160. A Bacon; 1½ miles south of St. Gabriel.
161. J. D. Gaudet; St. Gabriel.
162. P. Lavallée; ½ mile west of St. Gabriel.
163. L. Rondeau; ¾ mile west of St. Gabriel.

No. 159 is a very shallow deposit, about 3½ feet in average depth, in fine gravel, very uniform in size. Although somewhat high in sand, it is found satisfactory as a road-surfacing material.

No. 160 is a deposit of fine sandy gravel in the steep slope of a bluff, covered with 4 to 6 feet of sand as overburden on top of the bluff. Upslope hauling has limited the development to the upper part of the bluff.

Four large excavations, including Nos. 161 and 162, are seen in a big deposit extending westwards from the village of St. Gabriel. No. 163 is a smaller pit recently opened in the same deposit. All openings show very much the same material, namely, gravelly sand, made up on the average of 30 per cent pebbles and 70 per cent sand. The deposit holds also a considerable amount of straight sand, and occasional layers of coarse and bouldery gravel in the upper part. The material has been extensively used for road surfacing and concrete works, including all the concrete sidewalks in the village. Excavation work has now been abandoned in one of the large openings, due to the material being too sandy. The fineness of the sand lowers its value as mortar and concrete aggregate, but does not render it unsuitable for that purpose.

Maskinongé County

Gravel investigations were made in that part of the county bordering lake St. Peter and extending 10 to 20 miles inland. The southern half of this territory is clay-covered and totally devoid of gravel, while in the northern half, there are numerous small and shallow gravel deposits, many of which have so far remained untouched. Two deposits of fairly large size are found northwest of Ste. Ursule station and one south of St. Alexis.

The most important deposits are included in the following list:—

165. Canadian National Railway Co.; 1 mile southwest of Ste. Ursule Station.
166. W. Michaud; E. Bergeron; 1½ miles northwest of Ste Ursule Station.
167. Highway pit; 2 miles northwest of Ste. Ursule Station.
168. G. Béland; 5 miles northwest of St. Léon.
172. T. St. Louis; 3½ miles west of St. Paulin.
173. J. St. Onge; just south of St. Alexis.
175. S. Lambert; 1½ miles south of St. Alexis.

A very large railway pit in deposit No. 165 is worked intermittently for ballast. The deposit is mostly sand. At one end of the pit, the sand is underlain by a thick layer of gravel of proper grading for road work.

Very good road and concrete gravel is seen in a large excavation, over 21,000 cubic yards in size, in deposit No. 166. The gravel is fresh and hard, uniform in size and carries very coarse sand, the proportion of sand increasing with depth from one-third to two-thirds. At a depth of 19 feet the gravel is underlain by sand. The gravel pebbles are about two-thirds granite. No. 167 is a very large deposit of much the same material as No. 166. The proportion of sand in gravel No. 167 decreases with depth from 60 to 40 per cent, and the gravel as a whole is more uniform in size than No. 166.

No. 168 is a shallow deposit on top of boulder clay. Five excavations, totalling over 11,000 cubic yards in size, and dug to the full depth of the deposit, vary in depth from 3 to 10 feet. The great variation in depth is due to surface irregularities in the underlying boulder clay. The gravel, which is slightly rusty and more or less weathered, but regularly graded and uniform in size, has been used with good results in surfacing local roads in that part of the clay land lying south of the deposit. In two of the excavations, gravel is now exhausted. It is difficult to estimate the amount of gravel available, on account of the irregular layout of the deposit, filling up, as it does, depressions in the boulder clay.

No. 172 is a glacial deposit of stratified gravelly sand with pockets of partly sorted drift, made up largely of boulders and clayey sand. The material compacts readily on the road to a hard and smooth surface. Sample No. 172 was taken from a large pile that had just slid down from the high bank of a large side-hill excavation.

Immediately south of the village of St. Alexis several pits, including No. 173, have been dug in the steep west bank of rivière du Loup, and in knolls a short distance from the river bank. Sand forms the bulk of the deposit, but the upper part shows gravel layers pitching at a high angle, so that the depth of gravel varies widely from place to place. The gravel is of about the right size and grading for road purposes. Nearly 16,000 cubic yards have already been taken out from the several pits, and the amount available is very large. There are numerous surface indications of gravel for a distance of 4 miles south of the village.

No. 175 is a very shallow gravel deposit on top and edge of a high sand bluff facing rivière aux Ecorces. A long cut over 3,500 cubic yards in size, shows that the gravel is very uniform in size throughout, although high in sand, the proportion of sand increasing with depth from one-half to two -thirds. The underlying sand is reached at a depth varying from 3 to 6 feet along the face of the bluff. Conservative estimates give 30,000 cubic yards as the size of the gravel deposit.

St. Maurice County

Gravel is very scarce throughout the southern part of this county and there are but few places where deposits have been developed. Sand covers most of the southern part of the county, and more detailed investigations may reveal the presence of gravel lying close to the surface, particularly along the St. Maurice river. For several miles to the northeast of St. Elie, there are numerous surface indications of gravel, and unless the deposits prove very shallow in depth, there should be a considerable amount of gravel available.

The following two large deposits have been extensively worked for road gravel.

178. Highway pit; 1 mile north of Charette.
180. E. Dupont; 3 miles southeast of St. Boniface.

Highway pit No. 178 is a very large excavation, 20 feet in depth and over 15,000 cubic yards in size, opened in the west end of a gravel ridge. The gravel is generally coarse and uniform in size. In the east end of the pit fine gravel carrying 75 per cent sand is seen in the upper 10 feet. Sample No. 178 is a fair representative of the average run of the gravel, and 178a is from the fine phase in the upper east bank. The gravel is partly weathered to a depth of 10 feet, and fresh below that depth. Very good results are obtained in road surfacing with this material.

No. 180 is a shallow deposit in the form of a flat-topped ridge trending north-south on top of a high clay bluff facing St. Maurice river. In the north end of the ridge, a large pit, 7,000 cubic yards in size and 6 feet in average depth, shows very coarse gravel, very uniform in size. The coarseness is due to the high proportion of oversize pebbles, i.e. 2-inch pebbles. A portable screen easily removes the oversize, and a good road material is thus obtained, as the gravel is otherwise very regularly graded. A smaller pit 350 yards farther south shows gravel which is not quite so coarse.

Champlain County

Gravel is very scarce in the southern part of the county and totally wanting over large areas bordering the St. Lawrence river. The following are the more important of the developed deposits.

182. E. Gagnon; 4¾ miles southwest of St. Tite.
183. Highway pit; 2 miles northwest of St. Tite.
185. O. Champagne; 2¾ miles northeast of Ste. Thécle.
186. F. St. Arnaud; 1½ miles northwest of Ste. Anne.

No. 182 is a flat, low-lying deposit of unknown extent. Four excavations, varying in depth from 3 to 18 feet and totalling 25,000 cubic yards in size, have been dug in the deposit, which is largely composed of sand carrying large layers or pockets of gravel. While the run of the bank is generally fine, any size gravel can be obtained by selection.

Deposit No. 183 forms the core of a ridge, with sand in both slopes. The gravel is fairly uniform in size, regularly graded, medium fine, and carries as an average 50 per cent of sand, mostly coarse. The depth of weathering is about 5 feet. Sample No. 183 is from the upper 2 to 5 feet in the weathered zone, and sample No. 183a from a depth of 22 to 25 feet in fresh material. The gravel has been extensively used for road purposes and the excavation now measures over 10,000 cubic yards, with a maximum depth of 30 feet underneath the crest of the ridge.

No. 185 is a flat-lying shallow deposit with a maximum depth of 7 feet. The gravel is fairly coarse, carries about 40 per cent sand and is very uniform in size throughout that part exposed by an excavation which is 1,640 cubic yards in size.

Deposit No. 186 forms several large flats along both shores of St. Anne river. A considerable amount of this material has been hauled for surfacing local roads as it is the only gravel found for many miles. Horse-drawn drag shovels carry the gravel up an incline to a large bin, from where it is loaded by gravity into motor trucks. Near the surface of the flats the gravel is of about the right size and grading for road surfacing but becomes very sandy at depth. For that reason not more than the upper 1 to 2 feet of the deposit is used.

Portneuf County

There is very little gravel throughout the southern part of the county, and the few deposits encountered are nearly all of small extent. One large deposit is found in the high, steep bluff facing the St. Lawrence river, half way between Neuville and St. Augustin.

The more important deposits are:—

193. E. Moissan; 2 miles north of St. Raymond.
195. A. Denis; 1 mile southeast of Ste. Catherine.
198. P. Paradis; 3¼ miles northwest of St. Augustin.
200. A. Soulard; 4½ miles west of St. Augustin.

No. 193 is a very shallow deposit, not more than 4 feet deep, in medium coarse gravel carrying about 45 per cent sand. The gravel is very uniform in size and carries much iron oxide which gives the material a strong rusty colour and in places cements it together in lumps. There are several other similar shallow deposits, but No. 193 shows probably better gravel than the others.

Deposit No. 195 forms a very slight elevation in otherwise perfectly level land. As seen in the exposed bank of a large, shallow excavation the gravel is regularly graded, medium coarse, and carries about 40 per cent sand, mostly coarse. The deposit has a maximum depth of 7 feet and covers several acres.

No. 198 is a pocket of gravel in the lower slope of a large sand ridge. A large excavation reaches the bottom of the gravel at a depth of 12 feet. The pit bank shows very coarse and bouldery gravel. Boulders make about one-third and sand about one-quarter of the material. Crushing is necessary in order to make it a satisfactory road material. Other smaller pockets in finer and more regularly graded gravel are seen in the slope of the same ridge.

Coarse and bouldery gravel is exposed in a cut in deposit No. 200, which lies in the slope of a steep bluff facing the St. Lawrence river. Boulders form about 20 per cent of the material. Over 75 per cent of the boulders and pebbles is limestone. The gravel is used for surfacing shoulders on both sides of the Montreal-Quebec paved highway, which at this point skirts the upper edge of the bluff. A very good material for surfacing local roads could be obtained by passing the whole through a crusher, since the gravel is generally free from weathering. Development of the deposit has been limited to the upper slope of the bluff, owing to the necessity of hauling up slope.

Quebec County

Gravel is nowhere common in any section of the southern part of the county, and is very scarce along the St. Lawrence river and for several miles inland. It forms small, shallow deposits, and is of poor quality wherever exposed in road cuts or pits. Two miles west of Loretteville, there is a large gravel pit, over 25,000 cubic yards in size, owned and operated by the Dominion Government. The excavation which is in the lower slope of a rocky hill shows more glacial drift than gravel in the up-hill bank, so that the gravel is now almost exhausted.

Dorchester County

The work of investigation was confined to that part of the county traversed by the Levis-Armstrong provincial highway, and the following are the more important deposits encountered.

206. J. Brousseau; 4 miles north of St. Isidore.
207. E. Plante; 1½ miles east of St. Isidore.
208. Highway pit; 2¾ miles east of St. Isidore.
209. A. Allen; 1¼ miles southeast of St. Isidore.
210. H. Binette; A. Giguère; 2½ miles north of St. Maxime.

Nos. 206, 207, 208, and 209 are shallow deposits not more than 6 feet in depth, and show much the same kind of material. The gravel is generally fine with a small proportion of boulders, is more or less weathered throughout the whole depth and carries a high amount of shale pebbles. No. 207 is coarser and more bouldery than the others, but in all of them the shale pebbles and boulders readily break down to smaller sizes. The gravel compacts very smoothly on the road but wears fast.

No. 210 is a fairly large deposit in the slope of a bluff facing rivière le Bras. In a large cut over 400 feet in length along the bluff, gravel is almost completely exhausted except at one end of the pit, where a 30-foot section shows fresh, medium fine, regularly graded gravel carrying about half sand, mostly coarse. The overburden is very thick and composed of 3 to 5 feet of loam and clay, with a thick layer of very bouldery material underlying the clay. Sample No. 210, taken in fresh gravel at a depth of 15 to 18 feet, represents coarser material than average. The gravel carries about 20 per cent of calcareous shale pebbles. Shale pebbles are harder, fresher, and in a lower proportion than in the shallow deposits found farther north.

Beauce County

The present investigation work covered that part of the county west of the Levis-Armstrong highway.

Gravels are fairly common and evenly distributed throughout the northern part of the area examined. In the southern part bank gravel is scarce, but a larger supply of river gravel from the bed and flats of several streams is easily available at low water level. A great deal of river gravel is hauled at low water and stored in stock-piles for use in road improvement. River flats composed of proper size road gravel are particularly common south of St. Georges.

Of the bank deposits, the following are the more important:—

213. H. Gagnon; along main highway, 2½ miles northwest of Ste. Marie.
214. E. Cliche; along main highway, Ste. Marie.
215. A. Nadeau; along main highway, 1½ miles southeast of Ste. Marie.
218. Highway pit; along main highway, Valley Junction.
220. J. Jacques; along main highway, 1⅓ miles southeast of St. Joseph.
227. J. Routhier; 3½ miles northwest of Armstrong.
230. H. Roy; along main highway, 5 miles north of St. Martin.
239. G. Gravel; E. Gravel; along main highway, 2 miles northeast of East Broughton.
240. T. Beaudoin; along main highway, northeast of Leeds.
241. S. Paquette; 2⅓ miles south of Leeds.

Good gravel is seen exposed in a large pit in deposit No. 213, which lies in the bank of a brook. The gravel is moderately hard, fresh and clean, very uniform in size and carries about 50 per cent sand. Sample No. 213, taken at depth of 5 to 8 feet, and not entirely free from weathered material, gave good results in the mortar test, as seen in Table III. The pit cuts through the full depth of the deposit and has a maximum height of bank of 12 feet on the up-slope side. Other deposits are seen south of No. 213, but apparently carry more sandy material.

Deposit No. 214 lies in the steep bank of Chaudière river, and is said to cover an area of about 350 by 275 feet. A large excavation, over 5,600 cubic yards in size, reaches the bottom of the deposit at an average depth of 12 feet. The up-slope pit face has a maximum height of 17 feet and shows partly weathered, coarse and slightly bouldery gravel in the upper 6 to 8 feet, and fresher and finer gravel below. The gravel is very regularly graded and carries about 50 per cent sand. The gravel deposit is underlain by clay and carries in its lower part rounded clay lumps resembling pebbles and boulders.

A large excavation in deposit No. 215 is almost entirely talus-covered. The material looks about the same as No. 214.

Deposit No. 218 forms a high steep-sloped knoll protruding from a terrace along Chaudière river. A large side-hill cut reaching a height of almost 100 feet in the slope facing the river shows gravel which varies widely in coarseness from place to place, but carrying on the average a high proportion of sand. Several much smaller pits have been dug in the lateral slopes of the knoll and in places have exposed material which is of more proper grading for road surfacing than in the main excavation.

Gravel from deposit No. 220 is very uniform in size and properly graded for road surfacing, although somewhat high in sand. Sample No. 220 was taken at depth of from 2 to 7 feet and represents about the average run. The deposit, which is underlain by clay, has a maximum thickness of 10 feet. The amount available about equals that already removed, that is, over 15,000 cubic yards. The partly weathered gravel from the upper part of the deposit should not be used as mortar or concrete aggregate.

Deposit No. 227, which is underlain by clay, occupies the edge of a river terrace and averages about 10 feet in depth. The gravel is medium coarse to fine, very fresh and slightly clayey. Sample No. 227 represents material which is coarser than average. Clay and sand lenses, which are seen in places in the up-slope bank of an excavation 3,900 cubic yards in size, are said to increase in size as the excavation work proceeds farther into the bank, so that the deposit is now largely worked out. The river terrace shows strong indications of gravel at several other points in the vicinity of this deposit.

No. 230 is a large deposit in the lower slope of a hill. Three pits have been opened, two of which are now talus-covered. In the third one, a 15-foot face shows very coarse and somewhat bouldery gravel in the upper 10 feet, and medium fine, sandy gravel in the lower bank. The material is on the whole rather irregularly graded and covered with a thick overburden.

Gravel deposit No. 239 forms a flat ridge and has an average depth of 10 feet, as seen in pits on both sides of a road crossing the deposit. Good gravel, of about the right size and grading for road purposes occurs in the upper two thirds of the deposit, while the lower third is rather fine and very sandy. Sample No. 239, taken in the upper two thirds, represents slightly finer gravel than average for that part. About 12,900 cubic yards of material have already been taken out, and there is a larger amount yet available.

A large pit, 6,750 cubic yards in size, cuts through the full depth of deposit No. 240, which averages 10 feet, with a maximum of 15 feet in the central part. The upper two thirds of the pit bank show more regularly graded material than the lower third. Sample No. 240 is from the upper, and No. 240a from the lower part. While the relative proportion of pebbles and sand is the same in both, the pebbles are much coarser in the lower part. The clay of the lower gravel explains the poor showing of sample No. 240a in the mortar test. Curiously enough the lower gravel, although fresher, carries a higher proportion of soft pebbles than the gravel from the upper part. All gravels in this part of the county are relatively soft and wear fast under traffic.

Deposit No. 241 forms a large irregular ridge 30 feet in height at the crest. A large excavation, 11,500 cubic yards in size, shows more sand than gravel. Streaks of gravel suitable for road work are mostly confined to the upper part near the crest, but large sections of the bank carry fresh, fine gravel and coarse sand suitable for concrete and mortar aggregates.

Frontenac County

All the developed deposits of the county, apart from a few very small ones, have been included in the present investigation.

Gravel is fairly common in the eastern half of the county and comparatively scarce in the western half. On account of the high proportion of soft pebbles none of the gravels can be regarded as high-grade, durable road material, and more than half of them are either too coarse or too fine to make a satisfactory road surface. Between Megantic and St. Hubert, gravel is more common and of somewhat better quality for road purposes than in other sections of the county.

Of the twenty deposits examined, the following are the more important as regards quality of the material.

243. J. Bélanger; 5 miles northeast of Lambton.
248. N. Roy; 4 miles northwest of Megantic.
250. J. Breton; 2¾ miles northeast of Megantic.
251. A. Roy; 1 mile northwest of Woburn.
252. Highway pit; 5½ miles southeast of Megantic.
253. F. Bédard; 4 miles north of Megantic.
254. A. Couture; 5¾ miles north of Megantic.
255. Highway pit; 4 miles south of St. Hubert.
256. Township pit; 1½ miles west of St. Hubert.

Large streaks of very good road gravel are seen in parts of a large excavation in deposit No. 243. Sample No. 243, Tables I and II, represents the average run. The streaks, however, form only a small proportion of the whole deposit, which carries more boulders and sand than gravel.

Gravel from deposits Nos. 248 and 256 is rather soft and bouldery, but very regularly graded and uniform in size. A fair road material can be obtained by screening out the boulders or passing the whole through a crusher.

Deposit No. 250 forms a steep ridge, over 600 feet in length, and from 150 to 300 feet in width. The height at the crest varies from 15 in the wider part to 30 feet in the narrower part of the ridge. A large excavation, over 12,800 cubic yards in size, cuts into the full depth and two-thirds of the width of the deposit, and shows coarse and slightly bouldery gravel, fairly uniform in size throughout, and carrying about 35 per cent sand, mostly coarse. Boulders form 5 per cent of total and are uniformly distributed throughout, although somewhat more numerous near the crest. The lower part of the deposit only carries gravel which is absolutely free from weathered particles, and the material as a whole is only moderately hard and durable.

Deposit No. 251 forms a steep ridge or knoll 60 feet in height. A large pit measuring over 38,800 cubic yards in size cuts through the full depth and width of the deposit. Apart from a few bouldery and sandy pockets in the upper part of the large pit bank, the gravel is fairly uniform in size and generally fairly coarse and somewhat sandy. The deposit is very large and exclusively worked for road-surfacing purposes, as its clay content precludes its use as aggregate in mortar and concrete.

Gravel in deposit No. 252 is regularly graded, very fine and very sandy. The deposit carries also a considerable amount of sand, apart from the sandy gravel. Gravel of proper size for road surfacing is very scarce for several miles to the south.

Deposit No. 253 lies in the steep slope of a bluff, 1½ miles from the main highway. In a 25-foot pit face there is exposed regularly graded, medium coarse gravel carrying about 5 per cent boulders, and 45 per cent sand, topped by 4 to 5 feet of bouldery, clayey and rusty gravel, thickening to 7 feet in one place. The thickness of the upper bouldery gravel, which is worthless and may be considered as part of the overburden, constitutes a serious obstacle to the development of this deposit, which, outside of the bouldery topping, carries good surfacing material. The ground surface in the slope and top of the bluff shows mostly sand and the extent of the gravel deposit is unknown.

Deposit No. 254 forms a ridge over 11,000 cubic yards in volume, and carries coarse gravel which is very uniform in size, as judged by that part exposed in the face of a side-hill cut, 135 feet in length, in the slope of the ridge. The uniformity of size is broken only at one end of the pit face by a large layer of bouldery gravel. Outside of this layer, the gravel carries on the average 5 per cent boulders and 40 per cent sand. The many rusty streaks through the gravel are an advantage from the road-surfacing standpoint, but preclude the use of the material in mortar and concrete works.

A side-hill cut, 60 feet in height, in deposit No. 255 shows coarse and bouldery gravel alternating with fine gravel in a series of thin layers. The gravel carries on the average 40 per cent sand and not more than 5 per cent boulders. Except near the surface, the material is fresh throughout and carries some clay in the lower part of the cut. The deposit forms a steep ridge or knoll and holds a considerable amount of gravel.

Megantic County

Outside of Inverness and Leeds townships, the county was almost entirely covered by the present investigation.

Gravel is nowhere common and occurs mostly in shallow deposits of small or moderate extent, scattered throughout the county. A large part of the gravel is hardly suitable for road work, either on account of being very irregularly graded, or because of carrying a large proportion of soft pebbles. For that reason gravel from river flats, fresher and harder than the bank gravel, is extensively used for road purposes wherever available, such as at Thetford Mines, Black Lake, St. Ferdinand, Plessisville and Ste. Anastasie. The bank gravel from the following deposits, although only moderately hard and durable is more regularly graded than the average found in the county.

264. F. Binette; 3½ miles west of Black Lake.
265. J. Provencher; 5 miles southeast of St. Ferdinand.
272. O. Gagné; Ste. Julie Station.
273. J. Lacasse; 4 miles southwest of Lyster.

Deposits Nos. 264 and 265 carry good road-surfacing gravel, but are very shallow and small in extent; No. 264 is now nearly exhausted.

Deposits Nos. 272 and 273 cover several acres but do not average more than 7 to 8 feet in depth. Over one-third of the pebbles are composed of soft and friable slate or shale.

Lotbinière County

Investigation covered only part of this county, and included the following deposits.

275. N. Charest; 2 miles northeast of Dosquet.
276. A. Poulin, 4½ miles southeast of Ste. Croix.
277. J. B. Demers; 2¾ miles northeast of St. Flavien.

Gravel from deposit No. 275 has been extensively used for road surfacing. It is of the proper size and grading, but carries a rather high proportion of soft material and wears fast on the road. The deposit covers a large area but does not average more than 8 feet in depth.

Deposit No. 276 forms a ridge covering 25,000 square yards with a height of 13 feet at the crest. Two different kinds of gravel are exposed in a long excavation dug to the full depth of the deposit. In the upper 4 to 5 feet of the bank, there is a very sandy gravel carrying only 25 per cent pebbles, 75 per cent of which are flat and friable sandstone. The remainder of the bank shows fresher, coarser, and more regularly graded gravel, carrying about 35 per cent sand near the crest and 50 per cent in middle slope. Limestone makes up about 50 per cent of the pebbles and sandstone hardly 5 per cent. The lower gravel is a very good road material but the upper sandstone gravel is worthless and a serious obstacle in the development of the deposit.

Gravel from deposit No. 277 is coarse, regularly graded, fairly uniform in size. Limestone makes up about 35 per cent of the pebbles, and trap, some of which is amygdaloidal, about 25 per cent. A peculiarity of this deposit is the high proportion of trap pebbles which are derived apparently from local intrusive rock. Good results have been obtained with this material in surfacing part of the new provincial highway between Dosquet and Ste. Croix. The deposit is said to have been traced over a distance of several miles in a northeast-southwest direction. Sample No. 277 is from coarser and less regularly graded material than average of deposit.

Lévis County

The following two deposits only have been examined in this county:—

279. A. Olivier; 3 miles northeast of St. Nicolas.
280. J. A. Paquette; 2 miles west of St. Nicolas.

Both gravels are alike in composition, being made up almost exclusively of angular and much elongated shale fragments, but No. 279 is much coarser than No. 280, and of more proper size and grading for road purposes. Both make very smooth but fast-wearing road surfaces. For local roads carrying very light traffic they are found very satisfactory on account of compacting and binding very quickly after being laid on the road. When wet, No. 280 turns muddy, while No. 279 remains firm. The better showing of No. 279 is due to its much smaller content of fine particles.

Arthabaska County

Investigations in this county have been confined to the eastern part, where gravel deposits are fairly common, but nearly all of small size or very sandy so that good gravel of proper size for road surfacing is rather scarce. In certain sections river flats carry a great deal of gravel which is extensively used for roads. The river gravel is found to have better wearing qualities than the local bank gravel.

The more important bank deposits of road gravel are:—

285. W. Gauthier; 1 mile southwest of Warwick.
287. Z. Leblanc; 2¾ miles northwest of Chesterville.
289. D. Gauthier; 3 miles southeast of Chesterville.

A large excavation over 5,100 cubic yards in size in deposit No. 285 shows good road gravel, regularly graded, although somewhat sandy, and varying gradually in size from very fine to coarse and slightly bouldery. Sample No. 285 represents the least sandy and the better grade, from the road material standpoint. The sample was taken at a depth of 15 to 20 feet, in material which is suitable for use as mortar and concrete aggregate. A 4 to 5-foot layer of very bouldery and sandy material in the upper part of the pit bank renders the extraction of the more suitable gravel costly.

No. 287 is a large deposit of irregularly graded and bouldery gravel. The gravel is very little used in road surfacing on account of its coarseness.

While it could be much improved by crushing, it could at best be only a moderately durable road material, on account of carrying a rather high proportion of soft pebbles.

Deposit No. 289 is very shallow and does not average more than 6 feet in depth. The upper half only carries good road gravel; the lower half is nearly all sand. The deposit forms a small, flat-topped elevation, one-third of which, or approximately 5,800 cubic yards, has already been excavated.

Wolfe County

Investigation in this county has been largely confined to the eastern half. While gravel is by no means uncommon, most of it occurs in small or moderately small deposits. The large amount of work done for highway improvement during the last few years has absorbed most of the higher grade gravel from the deposits lying close to the improved highways, so that lower grade material only is left exposed in the pits. A great deal of good road gravel would quite probably be found by sounding and digging test pits in both banks of the St. Francis river between St. Gérard and the south end of the county.

The more important deposits examined are:—

291. H. Ramsay; $3\frac{1}{4}$ miles northwest of North Ham.
292. O Aubert; $\frac{3}{4}$ mile southwest of North Ham.
295. A. Gagnon; $1\frac{1}{2}$ miles east of D'Israeli.
296. Brompton Pulp and Paper Co., Municipality of D'Israeli; also other owners; $1\frac{1}{8}$ miles east of D'Israeli.
301. C. Pelchat; 4 miles west of Stratford.
305. J. Labrecque; 3 miles southwest of Dudswell Centre.

Gravel from deposit No. 291 is of about the right size and grading for road surfacing. Sample No. 291 represents the average run of the bank. Apart from a few large lenses of very fine sand seen in one part of the pit bank, the gravel is very uniform in size throughout the part exposed in a large excavation covering 1,760 square yards. The deposit extends over several acres and averages 7·5 feet in depth.

Deposit No. 292 runs through a low, flat-topped sand knoll, and forms a band or streak, over 100 feet in width and 7·5 feet in average depth. The gravel is coarse and slightly bouldery, carries on the average 5 per cent boulders and 35 per cent sand, and is very uniform in size, but becomes much finer on both sides where it merges into the sand.

A large shallow excavation, 8 feet in average depth, cuts across nearly the full width of deposit No. 295 and shows very regularly graded, fine gravel, carrying a high proportion of sand, from 60 per cent in the central part of the deposit, where sample No. 295 was taken, to 75 per cent towards the sides. The objectionable feature of a high proportion of sand is somewhat lessened by the fact that the sand is exceedingly coarse. The gravel is slightly rusty and more or less weathered to the full depth of the pit.

Several large excavations, totalling over 25,000 cubic yards in size, have been dug in deposit No. 296, which lies in the bank of St. Francis river. Gravel of suitable size for road work is seen only in the pit owned by Brompton Pulp and Paper Company. The face of this pit shows medium coarse gravel, very uniform in size, topped by 2 to 3 feet of coarser material. The proportion of sand increases with depth from 40 to 65 per cent. The lower half of the bank is in places almost exclusively sand.

On the whole, gravel covers but a small proportion of the total area of bank exposed in the several pits, and the deposit is probably nearly exhausted.

A large excavation in deposit No. 301 cuts nearly all around a small knoll, leaving only the central part of the knoll which is composed of very bouldery gravel. The part left over could be turned into road material of fair quality by passing it through a crusher, since it is fairly fresh and carries about 50 per cent of limestone boulders and pebbles.

A 50-foot cut in deposit No. 305, which forms a high, steep ridge, shows gravel which is generally bouldery in the upper slope, and becomes finer at depth. The lower part of one slope is almost exclusively sand. On account of the wide variation in size, it would be preferable to pass the whole through a crusher, leaving out only the sandy part in the lower slope. This would be the only practical plan in any large-scale development scheme, and advantage could be taken of the height of the deposit in designing a gravity system of crushing and screening.

Compton County

Investigations in this county were largely confined to the territory adjacent to the Sherbrooke-Beauceville and East Angus-Hereford highways. Gravel is very common in three different areas, where deposits appear to be grouped together. The first group, including the largest deposits, occurs between Bury and past East Angus; the second group lies between East Clifton and past St. Malo; and the third group between East Hereford and the International boundary. Outside of these areas, suitable road gravel is scarce. In some places there are large deposits of gravelly sand, the coarser part being occasionally used for road maintenance. Very bouldery material from exhausted gravel deposits is also crushed for road purposes, where no suitable gravel is available. Near Sawyerville and Waterville good results are obtained in surfacing local roads with river gravel.

The following are the more important deposits examined in the area under investigation.

306. A Gilbert; 1½ miles north of East Angus.
307. Corporation of East Angus; 1¼ mile north of East Angus.
311. A. Veilleux; 4½ miles west of Bury.
312. C. Ord; Township of Bury, 2 miles northwest of Bury.
313. Township of Lingwick; Department Highways; Gould.
314. J. Smith; Department Highways; 8 miles northeast of Gould.
316. J. Reid; 1¼ miles south of East Clifton.
317. Mrs. L. St. Germain; 1¾ miles south of East Clifton.
319. H. Roy; 3 miles south of St. Malo.
320. F. Rowell; 1 mile north of Hereford.
322. Mrs. Wark; 5 miles west of Birchton.

About two-thirds of the gravel available in deposit No. 306, which averages 8 to 9 feet in depth, has been taken out from a large pit measuring over 14,000 cubic yards in size. In the upper half of the pit bank is seen coarse and slightly bouldery gravel fairly uniform in size and carrying 5 per cent boulders and 30 per cent sand; in the lower half the gravel is much finer, with about two-thirds sand, and not so uniform in size as in the upper half, on account of sand layers running through it.

Good road gravel is seen in two out of three large pits totalling over 23,000 cubic yards in size in deposit No. 307. The gravel is fairly uniform in size throughout, but somewhat high in sand. Samples Nos. 307 and 307a represent less sandy material than the average of deposit. The remainder of the deposit may contain more sand than in the exposed part; excavation work has been stopped in one of the pits on account of the material becoming too sandy.

The greater part of deposit No. 311 was excavated years ago for ballast by the Canadian Pacific Railway Company. There are now no traces left of former railroad operation, not even the road bed. A large pit opened in the remainder of the deposit, which still holds a considerable amount of gravel, and operated by the owner of the land, has a 30-foot face, the upper part of which shows coarse and slightly bouldery gravel, which gradually merges into finer material at depth. Small clay lenses are seen in the lower bank gravel.

Good gravel of proper size and grading for road purposes is seen in two large pits, aggregating over 35,000 cubic yards in size, in deposit No. 312 which forms a large, steep-sloped, flat-topped ridge. The gravel is fresh, with calcareous slate and limestone making up 50 per cent of the pebbles. While it is not uniform in size and grading throughout the large exposed area, on account of sandy streaks running through the regular gravel, most of the sand is very coarse. The upper part near the crest is too coarse and bouldery for use as road-surfacing material.

Deposit No. 313 averages 18 feet in depth, and carries in the upper half, as seen in a large excavation over 10,000 cubic yards in size, coarse and bouldery, partly weathered gravel, regularly graded and uniform in size, while the lower half carries fresh, sandy gravel, not so uniform in size as in the upper half. A good road gravel could be made out of the upper material by crushing or screening out the boulders, but the lower gravel is somewhat too sandy.

Gravel from deposit No. 314 is partly weathered, very regularly graded, varying gradually in size from very coarse at one end of a large pit 300 feet in length, to very fine at the opposite end of the pit. Weathered slate pebbles and boulders crumble readily into black dust which acts as a strong binding medium. Roads surfaced with this gravel are remarkably smooth. The gravel is, however, only moderately durable.

Deposits Nos. 316 and 317 carry regularly graded, fine, fresh, medium hard gravel, somewhat high in sand in places, but the latter is everywhere very coarse, and the gravel is on the whole fairly uniform in size and quality throughout, and has proved very satisfactory on roads, although not very durable.

Deposit No. 319 lies in the lower slope of a low knoll, composed largely of glacial drift. The gravel is regularly graded, coarse, fresh, and carries a low proportion of sand, probably not much over 25 per cent, and most of the sand is very coarse. Medium soft schist or slate forms a high proportion of the pebbles, and the material presumably is not very durable. Except for coarseness it closely resembles Nos. 316 and 317.

Deposit No. 320 is one of many shallow deposits found between East Hereford and the International boundary, not less than 15 cuts or pits being encountered in that distance. All these deposits lie in the bank of Hall stream, which empties into the Connecticut river just past the border, and may be more properly regarded as a single deposit, since the gravel is everywhere similar in size and composition. It is very regularly graded and of about the right coarseness for road surfacing, but carries a rather high proportion of medium soft schist or slate pebbles, and for that reason is not thought to possess very good wearing quality.

Good gravel of uniform size is seen in a large pit, over 7,300 cubic yards in size in deposit No. 322, which averages not more than 6 feet in depth and is of rather small extent. In the vicinity of this deposit a number of flat-topped knolls similar to the one in which deposit No. 322 lies may profitably be investigated for gravel, which is very scarce in this part of the county.

Stanstead County

The northern part of the county was fairly thoroughly examined for gravel, while in the southern part investigation was confined to the territory adjacent to the Sherbrooke-Stanhope, Sherbrooke-Rock Island, and Magog-Coaticook highways. Most of the gravel deposits are of large size and of common occurrence in the northern half of the county, while in the southern half good surfacing gravel is very scarce along the three main highways. The majority of excavations measure well over 10,000 cubic yards in size, and very few under 5,000 cubic yards. Highway improvement work has absorbed by far the larger part of the gravel excavated.

The more important deposits are:

325. Canadian National Railway Co.; just west of Coaticook.
326. Municipality of Coaticook; just west of Coaticook.
327. C. Smith; 3 miles south of Hatley.
328. Township of Hatley; ½ mile west of Hatley.
329. H. Lebaron; 2½ miles south of North Hatley.
333. Municipality of Beebe; township of Stanstead; 1½ miles west of Rock Island.
336. J. Ingalls; 5½ miles southeast of Magog.
338. Highway pit; 3½ miles east of Magog.
343. Highway pit; 4 miles northwest of Magog.

A large railway pit cuts through the central part of deposit No. 325. The pit has a maximum depth of 80 feet, a maximum width of over 600 feet, and a length several times the width. Except near the entrance, the large pit bank shows gravel throughout, which is of about the right size and grading for road purposes, and remarkably uniform in size considering the large area exposed. The sand is everywhere very coarse. Sample No. 325 is from weathered coarse gravel from near the top of the deposit; sample No. 325a is from fresh fine gravel, depth of approximately 60 feet; sample No. 325b is from fresh, coarse gravel, near bottom of pit. The gravel is in places strongly cemented together with calcium carbonate and has to be occasionally loosened by blasting. Calcareous slate and limestone make up about half of the pebbles.

No. 326 is a large pit in the form of a side-hill cut in the steep north slope of the same deposit as No. 325. The gravel is here coarser and less uniform in size than in the railway pit. It carries a rather low proportion of sand, mostly very coarse. The weathered material from the top of the deposit is first removed and sold for filling. The fresh gravel is then crushed and screened into four different sizes, from 1¼ inch down, and is used in various municipal works, or sold for road surfacing. Sample No. 326 represents unscreened material as it comes out of the crusher.

Deposit No. 327 carries coarse and bouldery gravel, with a rather low proportion of sand, mostly very coarse. The gravel is crushed and screened for road purposes. The gravel is in places strongly cemented together with calcium carbonate. Pebbles are about 75 per cent calcareous slate.

In deposit No. 328, a large side-hill cut in the slope of a hill shows material which is similar to Nos. 325, 326, and 327 as regards composition and low proportion of sand, but coarser and more bouldery. It seems that the up-hill pit bank has now reached beyond the more regular road-size gravel into bouldery material.

Deposit No. 329 is rather shallow, but of large extent. In a large excavation, over 30,000 cubic yards in size and reaching the bottom of the deposit at an average depth of 11 feet, there is exposed more or less weathered gravel, which varies much in size from place to place but is generally coarse and bouldery. It is being crushed and screened for use in road surfacing. This is the only gravel available for miles around.

Two large excavations aggregating over 28,000 cubic yards in size have been dug in deposit No. 333 which lies in the upper slope and part of the top of a high, very steep bluff forming the bank of a brook. The gravel varies in a gradual and regular way from coarse to fine, but the regularity of grading is broken by sand layers running through the gravel. The sand layers increase in size and number at depth. The extent of the gravel deposit is unknown as the ground surface everywhere shows sand exclusively.

Deposit No. 336 carries almost exclusively coarse sand. Gravel is seen only in places near the top of the deposit and is generally fine and sandy. The fresh sand makes a good aggregate in mortar and concrete. It is found satisfactory as a road-surfacing material on local clay roads carrying a very light traffic.

Deposit No. 338 forms a large ridge, at one end of which there is exposed in a large excavation over 11,000 cubic yards in size, very regularly graded, medium fine, fresh, and hard gravel, very uniform in size. The gravel carries a rather high proportion of sand, mostly coarse, but is on the whole a high-grade road material. Sample No. 338 represents about the average of deposit as to grading and size. There is a very large amount available.

Deposit No. 343 is very large in size and forms an irregular knoll in the lower southern slope of Orford mountain. A large railway pit in the shape of a long side-hill cut at the foot of the knoll shows much more sand than gravel, and a great deal of the gravel exposed is very coarse and bouldery. A highway pit in the upper slope of the knoll shows gravel which varies much in size, but is generally very coarse and bouldery. Gravel from this deposit is somewhat harder than the average of the county and since regular size road gravel is very scarce in this section, the additional expense of crushing this material to proper size for road surfacing would in all probablity be justified by the results obtained.

Sherbrooke County

Developed deposits are almost exclusively found in the eastern half of the county which was thoroughly examined for gravel. Nearly all large deposits lie along the St. Francis river and have been extensively developed northwest of the city of Sherbrooke.

The more important deposits of the county are:

345. Highway pit; 4 miles southwest of lake Magog.
347. J. Mallory; Municipality of Lennoxville; ½ mile south of Lennoxville.
349. J. Bélanger; Ascot.
350. Corporation of Sherbrooke; 1¾ miles northwest of Sherbrooke.
351. W. Brault; 1¾ miles northwest of Sherbrooke.
352. Corporation of Sherbrooke; 3¼ miles northwest of Sherbrooke.
353. K. Moe; 3½ miles northwest of Sherbrooke.
354. S. Clark; 2½ miles south of Bromptonville.

No. 345 is a large flat deposit of about 8 feet average depth, carrying fine sandy gravel very uniform in size throughout. The sand is mostly coarse and makes up about two-thirds of the deposit, which is rather high for road purposes. Samples Nos. 345 and 345a taken one at each end of a large pit represent the coarser, less sandy and more suitable part of the deposit for road surfacing.

Deposit No. 347 is very large and carries an almost unlimited amount of gravel, which, however, is in places thickly covered with sand. While the gravel varies much in size, there are many thick streaks of material of proper size for roads, from which a very large amount is available. On the whole the gravel is coarse, slightly bouldery, and carries a low proportion of sand, mostly coarse, outside of an occasional large pocket of straight sand. Fresh, fine gravel suitable for concrete works is also available in large quantity.

Deposit No. 349 forms a steep knoll which is part of a high bluff facing St. Francis river. A large excavation opened in the lower slope has now reached the central part of the knoll, with the inner pit bank cutting into the other slope past the top. The peculiar funnel shape of the pit is due to the method of excavation. Men with shovels loosen the gravel from the bank, the loosened material forms a talus, while a mechanical loader, consisting essentially of a rotating chain of buckets, digs into the foot of the talus. The gravel is remarkably well-graded and uniform in size, taking into consideration the large area exposed, and is generally fine with about two-thirds sand. It carries a rather high proportion of sand, but the latter is exceedingly coarse, 90 per cent being retained on the 28-mesh sieve, as seen by sample No. 349, Table II, which was taken at the foot of the talus directly in front of the loader, and is thought to represent the average run of the bank. While the gravel carries a rather high proportion of soft particles and is not free from weathered material, it is sufficiently fresh for use as aggregate in mortar and concrete.

Nos. 350 and 351 are two large excavations in the same deposit in the bank of St. Francis river. In both pits there is exposed regularly graded, medium coarse to fine gravel, fresh and hard, with from one-third to two-thirds of sand, mostly very coarse. The gravel is excellent for road work and makes a very good concrete aggregate. Part of the deposit around pit No. 350 is covered with a great thickness of sand, which, however, finds its way into various municipal works or is sold to individuals, except the upper 10 feet where the sand is much weathered and rusty, so that it is treated as overburden and dumped into a waste pile. Pit No. 351 measures over 100,000 cubic yards, while No. 350 is at least twice that size, including the sand above the gravel.

Deposit No. 352 is mostly very coarse sand which is used as fine aggregate in municipal concrete works. Sand for that purpose is now being taken from the lower part of No. 350, and No. 352 has been idle for some time.

Gravel from deposit No. 353 is fresh and hard, varies much in size but is generally coarse, slightly bouldery, and sandy. The sand is exceedingly coarse, 95 per cent being retained on the 28-mesh sieve, as seen by sample No. 353, Table II. Layers of sand running through the gravel in the upper 10 feet of the deposit make the grading irregular. The sand segregated in layers is not so coarse as the one mixed with the gravel. Below the upper 10 feet there are no straight sand layers, and the gravel is finer and more uniform in size.

Deposit No. 354 is of small extent and not more than 8 feet deep on the average. Close to 6,000 cubic yards of gravel have been taken out, and about as much remains in the deposit, but is covered with at least 3 feet of sand as overburden. The pit bank is now largely talus-covered. At one end, there is exposed in the upper half, fairly regularly graded, coarse gravel carrying about 40 per cent sand. The material is said by owner to become finer at depth.

Richmond County

Investigations in this county were confined to the territory adjacent to the Sherbrooke-Three Rivers and Richmond-Levis highways. Gravel is very common, although very sandy in places, along the Sherbrooke-Three Rivers highway, which in this county follows the St. Francis river, and is very scarce along the other highway. Deposits holding material of fair quality have been much drawn upon for road purposes, and the excavations in these deposits range in size from 4,000 to 14,000 cubic yards. One large pit in deposit No. 367 north of Danville measures over 30,000 cubic yards.

Of the thirteen deposits examined, the following are the more important:—

355. H. McLeod; 2 miles south of Bromptonville.
356. J. Ross; 2 miles south of Bromptonville.
357. A. Paquette; 3 miles southeast of Windsor Mills.
358. J. St. Pierre; 1⅝ miles northwest of Windsor Mills.
359. J. Leclair; 5¼ miles southeast of Richmond.
360. W. J. Ewing; 2 miles southeast of Richmond.
363. R. Barr; 1 mile northwest of Melbourne.
365. W. H. Healy; 2½ miles southeast of Richmond.
366. Highway pit; 4 miles northeast of Richmond.
367. A. Allison; 3½ miles north of Danville.

Nos. 355 and 356 are two pits in the same deposit, which lies in a low, steep bluff facing the St. Francis river. In both pits there is exposed fresh, hard, fine sandy gravel. The uniformity in size and grading is broken by sand layers interstratified with the gravel. These sand layers are more common at No. 355 than at No. 356 and materially increase the total proportion of sand. Samples Nos. 355 and 356 are both less sandy than pit average. The gravel makes a suitable aggregate in ordinary concrete works, but holds too much fine sand to be considered a high-grade material.

Deposit No. 357 lies in the edge and upper slope of a high, steep bluff facing the St. Francis river. A large pit shows medium coarse gravel carrying about 40 per cent sand in the inner bank, which gradually turns very fine and sandy towards the outer edge. Up-slope hauling limits development work to the uppermost part of the deposit.

Good road gravel varying regularly from coarse to medium fine and carrying about 50 per cent sand is seen exposed in deposit No. 358, which lies near the top of a high bluff facing the St. Francis river. The gravel is not more than 9 feet thick and is covered with $2\frac{1}{2}$ to 4 feet of fine loamy sand as overburden.

In the upper bank of a large excavation, over 11,700 cubic yards in size, in deposit No. 359 which lies in the steep slope of a knoll, there is exposed very coarse gravel, which turns very bouldery in the lower bank. The bouldery part in the lower bank marks probably the edge of the gravel deposit, which would be more than half exhausted.

A large excavation over 10,000 cubic yards in size in deposit No. 360, which is in the form of a steep-sloped knoll, cuts away almost half of the knoll, and shows mostly coarse sand. Very fine sandy gravel is seen in the lower slope of the knoll at one end of the pit, and very coarse and bouldery gravel in the lower part of the opposite slope, at the opposite end of the pit, where sample No. 360 was taken. The sample did not include the boulders which make up 15 per cent of the material represented by the sample. The bouldery gravel carries a relatively small amount of weathered or otherwise soft stones, and could be made into fair road material by crushing it to proper size.

Gravel from deposit No. 363 is very fine, fresh, and hard, and is thickly covered with fine clayey sand which is worthless. The gravel, on account of its fineness, is more suitable as a concrete aggregate than as a road-surfacing material.

Deposit No. 365 forms a large, steep knoll well over 75,000 cubic yards in size. A high cut in the slope is now all talus-covered, the talus material being composed of fresh, hard gravel of about the proper size for road surfacing. According to the owner, a few layers of straight sand run through the gravel.

A large shallow pit, over 13,700 cubic yards in size, in deposit No. 366, shows gravel which varies regularly in size from coarse and slightly bouldery at one side of the pit to fine at the opposite side. The fine gravel is mixed with a high proportion of sand but the sand is everywhere very coarse, and in places carries some clay. Sample No. 366 is from medium coarse, clayey gravel. The gravel is all more or less weathered and carries a rather high proportion of soft pebbles.

Deposit No. 367 forms a high steep ridge in the slope of which there is a large excavation over 30,000 cubic yards in size. In the high pit bank there is exposed fresh and hard gravel which varies much in size but is generally coarse and bouldery. A portable crushing and screening plant is installed in the pit. The crushed and screened product makes a good road material, which is extensively used in this part of the county, where good gravel of suitable size and grading for road purposes is very scarce. Another smaller excavation cutting through the crest of the same ridge, 750 feet north of the main pit, shows mostly coarse sand.

Drummond, Shefford, and Brome Counties

Part of the investigation work planned for these counties had to be curtailed, due to the lateness of the season, and the following were the only important deposits visited.

368. A. Cross; ½ mile southeast of Ulverton, Drummond.
369. L. Pye; 1¾ miles southeast of Ulverton, Drummond.
371. Highway pit; 3 miles south of Waterloo, Shefford.
373. R. Stretch; 1½ miles northeast of Waterloo, Shefford.
375. J. Crawford; 3 miles south of Eastman, Brome.

No. 368 is a small deposit of sand with a few gravel pockets under 4 to 12 feet of sand. Both gravel and sand make very good aggregates in concrete works. Sample No. 368 was taken from the coarser of the gravel pockets. The weathered sand above the fresh sand varies from 1 to 8 feet in thickness.

Several large pits have been opened in deposit No. 369 which lies in the slope of a bluff facing St. Francis river. The gravel is generally very coarse in the upper slope and medium coarse in the lower slope, where it is interstratified with layers of sand. Outside of the sand layers, the gravel is very uniform in grading. Sample No. 369 was taken from an excavation in the lower slope and includes both gravel and sand layers. Although only moderately durable, the material is found satisfactory for roads.

Deposit No. 371 forms a large flat-topped ridge. A side-hill cut, 40 feet in height, in the slope of the ridge, shows very coarse and bouldery gravel in the upper 8 feet, and more regular size gravel in the remainder of the bank. Outside of the upper bouldery zone the material is fairly uniform in size throughout the large pit bank and varies regularly from medium coarse underneath the bouldery zone to very fine in the lower bank. The coarser phase carries about one-third sand, and the finer carries about two-thirds sand, which is everywhere very coarse. Sample No. 371, taken at depth of from 15 to 18 feet in central bank, and No. 371a, taken at depth of 5 to 9 feet farther down the slope of the ridge, represent intermediate phases as regards coarseness. The gravel is found very satisfactory as a road-surfacing material.

In deposit No. 373 a rectangular pit, 7,000 cubic yards in size, cuts through the crest and upper slopes of a small ridge. At both ends of the excavation, directly underneath the crest of the ridge, there is exposed regularly graded, coarse gravel carrying on the average 40 per cent sand, while the side banks show sand almost exclusively. The gravelly zone has a width of about 60 feet and an average depth of 12 feet. The ridge can be traced for a distance of over 1,000 feet, which would give approximately 25,000 cubic yards as the size of the deposit.

Very good, regularly graded gravel is seen in a round pit opened in deposit No. 375. The gravel is fresh and hard, and covered with 1 to 5 feet of fine sand. The amount of gravel available is difficult to estimate even approximately, because of the sand cover which varies much in thickness. A considerable amount of gravel has been taken out of this deposit, as judged by the size of several old pits.

TABLE I

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Shape of pebbles	Per cent of silt and clay	Extent of deposit	Size of pit, cubic yards
	Pontiac County							
1	¼ mile north of Chapeau; Highway pit.	35	50	15	Angular.............	1·7	Large.........................	Large.
1a	" "	40	45	15	Angular.............	1·6		
5	3½ miles east of Fort Coulonge; Desjardins.	5	75	20	Angular to subangular	0·6	Flat deposit of unknown extent; average depth 5 feet.	7,870
7	Campbell's Bay................	35	60	5	Angular to subangular	0·4	Very large...................	Very large.
8	4½ miles north of Campbell's Bay.	65	30	5	Angular.............	0·3	Small.........................	Small.
12	1 mile east of Portage du Fort; Howard.	75	15	10	Subangular...........	0·4		
13	2½ miles south of Bryson; Mrs. Paul.	55	35	10	Angular to subangular	0·8	Shallow deposit; greatest depth 5 feet; of fairly large extent.	Large.
15	2 miles northeast of Radford; C. Chamberlain.	30	45	25	Angular.............	1·0	Shallow deposit of unknown extent; average depth 6 feet.	Small.
16	Shawville; M. Dale............	45	45	10	Angular to subangular	1·6	Large gravel pocket almost exhausted.	Large.
20	1 mile west of McKee; W. Thompson.	50	40	10	Angular.............	1·1	Small.........................	4,890
21	1 mile southeast of McKee; Moyle.	25	55	20	Angular.............	3·0	Large but thickly covered with sand.	27,460
21a	" "	50	40	10	Angular.............	0·8		
21b	" "	(Sand)	....	....	....	0·5		
22	¾ mile south of Maple Ridge; J. Dodds.	50	40	10	Variable.............	1·1	Probably small..............	260
23	2½ miles southeast of Weirstead; M. T. Gallagher.	90	10	0	Angular and flat.....	1·7	Unknown.....................	300
27	4 miles north of Quyon; S. Walsh	45	35	20	Angular.............	1·1	Large.........................	14,960
27a	" "	(Sand)	....	....	....	1·0		

	Hull County							
31	1½ miles northwest of Luskville; P. E. Chartrand.	75	20	5	Angular..............	0·5	Half exhausted; thickly covered with sand.	8,315
38	Danford Lake; J. Heeney.......	50	25	25	Angular..............	0·9	Fairly large; average depth 9 feet.	3,590
39	1⅓ miles southwest of Marks Stn.; P. Pétrin.	50	30	20	Subangular...........	0·3	Fairly large.................	1,805
41	2 miles north of Glenbean; N. Bénard.	45	35	20	Angular..............	0·3	Large; thickly covered with sand.	5,145
43	3 miles northwest of Bouchette; O. Saumur.	60	25	15	Subangular...........	0·7	Large........................	3,000+
44	2 miles northeast of Messines; E. Lafontaine.	60	25	15	Angular to subangular	0·5	Large but may include much sand.	2,355
44a	" "	(Sand)	....	....	....	0·5		
45	5 miles south of Maniwaki; P. Brascoupé.	60	30	10	Angular..............	0·6	Large........................	4,810
53	6 miles northeast of Ste. Famille; L. Brunet.	55	25	20	Angular to subangular.	0·7	Large........................	6,540
53a	" "	40	40	20	....	0·4		
	Labelle County							
55	1 mile west of St. Jean; F. Fleurant.	65	25	10	Angular..............	0·7	Probably not over 6,000 cubic yards; maximum depth 9 feet.	2,880
61	1 mile east of Mont Laurier; M. Valiquette.	35	50	15	Angular..............	0·5	Large, thickly covered with sand in places.	16,590
61a	1 mile east of Mont Laurier; M. Valiquette.	70	20	10	....	0·8		
61b	" "	40	30	30	....	0·7		
71	7½ miles southeast of L'Annonciation; T. Fortin.	40	45	15	Angular..............	0·4	Small........................	3,600
73	La Conception; La Fabrique...	60	35	5	Angular..............	0·9	Probably small...............	Large road cut.
	Papineau County							
76	2⅔ miles northeast of Perkins; Mrs. Charette.	75	15	10	Angular..............	1·0	Fairly large.................	1,565
76a	" "	60	25	15	....	0·6		
78	5¼ miles north of Buckingham; H. Gorman.	55	20	25	Angular..............	0·7	Large........................	3,535

TABLE I—Continued

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Shape of pebbles	Per cent of silt and clay	Extent of deposit	Size of pit, cubic yards
79	5 miles north of Buckingham; Laframboise.	55	35	10	Angular.............	1·6	Large........................	Large.
79a	" "	(Sand)	....	....	....	0·7		
80	3 miles northwest of Buckingham; W. Newton.	70	20	10	Angular.............	0·9	Large, thickly covered with sand in places.	13,100
80a	" "	65	15	20	....	1·1		
81	Same as No. 80................	90	5	5	Angular.............	1·0	Large........................	Very large.
82	2½ miles northwest of Buckingham; A. C. Smith.	75	15	10	Angular.............	3·5	Almost exhausted............	12,800
83	3½ miles northwest of Valdor; M. Burke.	75	15	10	Angular.............	0·8	Large........................	18,375
85	3 miles north of Montebello; E. Arbique.	45	25	30	Angular.............	0·6	Large, upper 5 feet very bouldery in places.	10,170
86	2 miles north of Montebello; A. Périard.	55	35	10	Angular.............	0·6	Large........................	1,890
88	4 miles north of Montebello; O. Gagnon.	40	35	25	Angular to subangular	0·6	Large........................	1,350
	Argenteuil County							
90	1 mile west of Pointe au Chêne; A. Campbell.	55	25	20	Angular.............	0·5	Very shallow deposit of fairly large extent, average depth 3 feet.	3,900
92	2 miles south of Rivington; A. Page.	80	10	10	Angular.............	0·4	4,800 cubic yards shallow deposit, not over 7 feet deep.	127
98	4½ miles southeast of Rawcliffe; A. Lavigueur.	90	5	5	Angular.............	1·3	Large, but very shallow, not over 4 feet deep.	7,000+
101	1 mile north of Pine Hill; Highway pit.	70	20	10	Angular.............	0·6	Small, shallow deposit not over 7 feet deep. Other small deposits.	1,742

	Terrebonne County							
109	⅔ mile east of St. Faustin; W. Levert.	60	30	10	Angular..............	1·1	Large, but thickly covered with sand.	20,250
111	¾ mile west of Degrosbois; D. Lajeunesse.	80	15	5	Angular..............	3·2	Small, shallow deposit, not over 6 feet deep, other small deposits.	4,000+
113	2 miles north of Ste. Agathe; Highway pit.	70	20	10	Angular to subangular	0·3	Large, average depth 7 feet....	37,185
115	½ mile north of Piedmont; Achille Lalande.	75	20	5	Angular..............	0·2	Extent unknown, depth not over 7 feet.	1,880
116	Piedmont; Art. Lalande........	90	5	5	Angular..............	0·5	Probably large, thickly covered with sand in places.	Large.
119	3½ miles northwest of St. Jérôme; A. Durant.	100	0	0	Angular to subangular	0·2	Very large, averages 6 feet in depth at pit 119, but much deeper elsewhere.	17,800
	Montcalm County							
125	Ste. Julienne; Municipality of St. Esprit.	90	5	5	Angular to subangular	0·6	Very large, maximum depth 20 feet.	Large.
126	Ste. Julienne; N. Landry........	95	5	0	Angular to subangular	0·8	Same as 125..................	Large.
127	3 miles southwest of Ste. Julienne; Highway pit.	95	5	0	Angular to subangular	0·9	Very large, maximum depth 20 feet.	Very large.
127a	"	95	5	0	....	1·1		
128	St. Théodore; L. Tremblay.....	80	15	5	Angular..............	1·0	Large.......................	5,535
128a	"	(Sand)	....	....	....	10·5		
132	Notre Dame; La Fabrique.....	75	15	10	Angular..............	0·7	Small and not over 8 feet in depth.	1,375
134	3 miles southeast of St. Donat; E. Riopel..................	85	10	5	Angular..............	0·5	Large.......................	2,100
135	1 mile west of Rawdon; J. Brousseau.	90	5	5	Angular..............	0·2	Large and not over 10 feet in depth.	5,000
139	3¾ miles south of Rawdon, Brouillet Sand and Gravel Co., Ltd.	80	15	5	Subangular...........	1·8	Very large..................	Very large.
139a	....	100	0	0	....	0·4		
	Joliette County							
147	5 miles southeast of St. Alphonse; G. Marchand.	70	15	15	Angular..............	0·7	Large.......................	1,975

TABLE I—Continued

Sample No.	Location and owner	Character of material					Extent of deposit	Size of pit, cubic yards
		Composition of pebbles			Shape of pebbles	Per cent of silt and clay		
		Durable	Intermediate	Soft				
	Joliette County—Con.							
153	4¼ miles southwest of St. Félix; Standard Sand Ltd.	70	25	5	Subangular...........	1·2	Very large....................	Very large.
153a	" "	(Sand)	....	....	....	2·5		
	Berthier County							
157	St. Damien; Mrs. P. Phaneuf...	55	35	10	Angular..............	1·9	Probably small, maximum depth 8 feet.	1,265
159	1 mile west of St. Gabriel; N. Ducharme.	50	35	15	Angular..............	0·7	Probably small, very shallow, depth averages 3½ feet.	4,550
159a	" "	50	35	15	....	0·5		
162	½ mile west of St. Gabriel; P. Lavallée.	60	30	10	Angular to subangular	0·7	Large	Large.
163	¾ mile west of St. Gabriel; L. Rondeau.	45	40	15	Angular..............	0·4	Large..........................	865
	Maskinongé County							
166	1½ miles north of Ste. Ursule Station; W. Michaud, E. Bergeron.	70	25	5	Angular..............	0·4	Large, average depth 20 feet..	21,720
166a	" "	70	25	5	Subangular to rounded	1·4		
167	2 miles north of Ste. Ursule Station; Highway pit.	70	25	5	Subangular...........	0·3	Very large..................	8,665
168	5 miles northwest of St. Léon Station; G. Béland.	50	20	30	Angular..............	0·6	Large, shallow depth varies from 3 to 10 feet.	11,675
172	3½ miles west of St. Paulin; T. St. Louis.	80	15	5	Angular..............	1·2	Probably very large..........	5,725
	St. Maurice County							
178	1 mile north of Charette; Highway pit.	60	30	10	Angular..............	0·5	Very large..................	15,920
178a	" "	55	30	15	....	0·4		
179	St. Elie; J. Lessard............	55	35	10	Angular..............	0·6	Apparently very large.	

	Champlain County							
183	2 miles northwest of St. Tite; Highway pit.	45	40	15	Angular..............	0·6	Over 50,000 cubic yards......	10,000+
183a	" "	60	35	5	....	0·8		
186	1½ miles north of Ste. Anne; F. St. Arnaud.	70	25	5	Subangular...........	0·2	Large......................	River flat.
	Portneuf County							
193	2 miles north of St. Raymond; E. Moissan.	60	30	10	Subangular...........	0·7	Large, but very shallow, maximum depth 4 feet.	860
	Dorchester County							
206	4 miles north of St. Isidore; J. Brousseau.	40	20	40	Angular to flat........	0·3	About 5,000 cubic yards, maximum depth 6 feet.	5,000
210	2½ miles north of St. Maxime; A. Giguère, H. Binette.	35	30	35	Angular..............	1·2	Fairly large, but thickly covered with clay, maximum depth 30 feet.	Very large.
	Beauce County							
213	2⅔ miles northwest of Ste. Marie; H. Gagnon.	55	20	25	Angular..............	0·6	Probably large, maximum depth 12 feet.	4,920
220	1⅓ miles southeast of St. Joseph; J. Jacques.	30	45	25	Subangular...........	0·8	About 15,000 cubic yards, maximum depth 10 feet.	15,000
222	Beauceville....................	50	40	10	Subangular...........	1·1	Large amount at low water level.	River flat.
225	Touffe de Pins; H. Poulin.......	25	25	50	Angular to flat........	1·1	Deposit covers 1,250 square yards, average depth 5 feet.	1,230
227	3⅔ miles northwest of Armstrong; J. Routhier.	15	55	30	Subangular to flat....	1·1	Nearly exhausted, probably other deposits, judged by surface indication.	3,900
229	3⅓ miles south of Jersey Mills...	50	45	5	Subangular to flat....	0·6	Large......................	River flat.
233	St. Gédéon; A. Pelchat.........	15	40	45	Subangular to flat....	3·2	Small......................	955
239	2 miles northeast of E. Broughton; G. & E. Gravel.	20	55	25	Angular to flat........	0·8	Large, average depth 10 feet..	12,890
240	Leeds; T. Beaudoin............	20	50	30	Angular to flat........	1·9	Large, average depth 10 feet...	6,750
240a	" "	10	45	45	....	2·3		
	Frontenac County							
243	5 miles northeast of Lambton; J. Bélanger.	25	40	25	Flat to angular........	2·0	Large, but may include much bouldery material, average depth 10 feet.	7,780
251	1 mile northwest of Woburn; A. Roy.	30	40	30	Subangular...........	5·1	Very large..................	38,860

TABLE I—Continued

Sample No.	Location and owner	Character of material					Extent of deposit	Size of pit, cubic yards
		Composition of pebbles			Shape of pebbles	Per cent of silt and clay		
		Durable	Intermediate	Soft				
	Megantic County							
266	2½ miles southeast of St. Ferdinand.	35	45	20	Angular to flat........	0·5	Large.........................	River flat
273	4 miles southwest of Lyster; J. Lacasse.	15	50	35	Angular to flat........	1·7	At least 10,000 cubic yards, average depth 7 feet.	1,650
274	Ste. Anastasie..................	50	35	15	Angular to subangular	0·5	Unknown, gravel covered at high water level.	River bed.
	Lotbinière County							
275	2 miles northeast of Dosquet; N. Charest.	30	25	45	Angular..............	1·6	Large, average depth 8 feet...	18,150
277	2¾ miles northeast of St. Flavien; J. B. Demers.	45	35	20	Angular to subangular	1·1	Probably very large..........	12,960
	Levis County							
279	3 miles northeast of St. Nicolas A. Olivier.	0	5	95	Angular and much elongated.	0·6	Probably large, average depth 5 feet.	1,040
280	2 miles west of St. Nicolas; J. A. Paquette.	0	5	95	Angular and much elongated.	0·4	Probably large, average depth 4 feet.	1,350
	Arthabaska County							
281	Princeville....................	65	25	10	Angular..............	0·8	Large amount at low water level.	River flat.
285	1 mile southwest of Warwick; W. Gauthier.	30	55	15	Subangular...........	0·3	Large, but may include much sand.	5,130
286	4 miles southeast of Arthabaska	55	20	25	Angular..............	1·6	Large amount at low water level.	River flat.
	Wolfe County							
291	3 miles northwest of North Ham; H. Ramsay.	30	50	20	Angular to flat........	0·9	Covers several acres, average depth 7½ feet.	4,400

295	1⅓ miles east of D'Israeli; A. Gagnon.	40	30	30	Angular............	0·7	Large........................	7,660
	Compton County							
307	1¼ miles north of East Angus;	40	40	20	Angular..............	0·6	Large, but may include much sand.	23,500
307a	Municipality of East Angus...	40	50	10	....	0·4		
312	1½ miles northwest of Bury; C. Ord.	30	55	15	Angular to flat........	0·9	Very large..................	35,000
314	7½ miles northeast of Lingwick; J. Smith.	50	30	20	Angular..............	4·0	Large........................	9,155
320	1 mile north of Hereford; F. Rowell.	5	75	20	Flat, angular, and sub-angular.	1·0	Very large..................	Small.
321	2 miles west of Birchton; Mrs. McMurray.	40	40	20	Crushed gravel......	....	Exhausted gravel deposit, large amount of bouldery material available.	Large.
	Stanstead County							
325	Coaticook; C.N.R.............	30	35	35	Angular to subangular and flat.	5·2	Very large..................	Over one million.
325a	"	30	50	20		1·0		
325b	"	15	80	5		2·1		
326	Coaticook; Municipality of Coaticook.	25	60	15	Crushed gravel......	5·6	Same as 325................	25,000+
327	3 miles south of Hatley; C. Smith.	10	85	5	Angular to flat........	2·5	Large, but may include much bouldery material.	5,000
336	5½ miles southeast of Magog; J. Ingalls.	(Sand)	....	....	....	0·4	Very large..................	5,495
338	3½ miles east of Magog; Dept. Highways.	40	45	15	Angular to flat........	0·9	Very large..................	11,125
	Sherbrooke County							
345	4 miles southwest of lake Magog;	45	40	15	Angular to flat........	0·4	At least 15,000 cubic yards, average depth 8 feet.	8,575
345a	Dept. Highways.	30	40	30	....	0·8		
346	2 miles west of Sherbrooke; B. Charest.	25	55	20	Angular to flat........	1·1	Probably large, maximum depth 10 feet.	7,130
349	Ascot; J. Belanger.............	35	40	25	Subangular to flat....	0·8	Very large..................	Very large.
350	1¾ miles northwest of Sher-	65	30	5	Angular to subangular	0·9	Very large..................	Very large.
350a	brooke; City of Sherbrooke..	75	20	5				
353	3½ miles northwest of Sherbrooke; K. Moe.	65	30	5	Subangular...........	0·5	Very large, but thickly covered with sand in places.	6,600

TABLE I—Concluded

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Shape of pebbles	Per cent of silt and clay	Extent of deposit	Size of pit, cubic yards
	Richmond County							
355	2 miles south of Bromptonville; H. McLeod.	65	25	10	Angular..............	1·1	Large........................	5,020
356	2 miles south of Bromptonville; J. Ross.	60	30	10	Subangular...........	0·8	Same as 355.................	12,420
360	2 miles southeast of Richmond; W. J. Ewing.	25	55	20	Subangular to flat.....	3·1	Large, but may be thickly covered with sand.	10,000+
363	1 mile northwest of Melbourne; R. Barr.	65	20	15	Angular..............	0·5	Probably large, but thickly covered with clayey sand, maximum depth 15 feet.	3,650
366	4 miles northeast of Richmond; Dept. Highways.	20	40	40	Angular to flat........	1·7	Large........................	13,770
	Drummond County							
368	½ mile southeast of Ulverton; A. Cross.	20	70	10	Subangular...........	1·5	Small........................	3,695
369	1¾ miles southeast of Ulverton; L. Pye.	50	20	30	Subangular...........	2·3	Large, but thickly covered in places with silt or sand.	10,000+
	Shefford County							
371	3 miles south of Waterloo;	40	50	10	Subangular...........	0·7	Very large....................	8,240
371a	Dept. Highways............	35	50	15	Angular..............	0·8		
	Brome County							
375	3 miles south of Eastman; J. Crawford.	60	30	10	Angular..............	0·5	Unknown, thickly covered with sand.	3,000

TABLE II

Tests of Gravel Samples

Sample No.	Proportion of pebble to sand		Granulometric Analysis														Per cent passing 200 mesh	Suitability
			Pebbles							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	64	36	8	6	13	30	14	11	18	38	10	10	17	16	4	5	Very coarse and bouldery, but hard and fresh, 1a is fine, regularly graded. Needs crushing.
1a	39	61	0	0	2	12	13	29	44	25	24	21	15	8	4	3	
5	59	41	0	0	16	32	16	15	21	22	13	23	32	8	1	1	Partly weathered, but fairly hard and well graded. Good gravel.
7	65	35	0	0	0	19	14	23	44	53	14	7	13	10	2	1	Coarseness variable. Sample represents average. Good hard gravel.
8	27	73	0	0	3	9	13	28	47	17	20	27	27	8	1	0	Very sandy.
12	29	71	0	0	0	0	3	12	85	42	17	14	19	6	1	1	Very fine and sandy, but very uniform and fairly good.
13	39	61	0	0	2	14	11	30	43	17	13	21	33	13	2	1	Very sandy. Sample coarser than pit average. Coarser phase good.
15	19	81	0	0	0	0	7	25	68	17	21	28	25	6	2	1	Very sandy.
16	69	31	0	4	22	21	13	19	21	14	16	23	24	13	5	5	Varies much in coarseness. Holds streaks of very good gravel.
20	33	67	0	5	5	20	10	20	40	25	33	23	11	4	2	2	Very sandy. Sample coarser than pit average.
21	72	28	0	4	12	17	12	20	35	41	11	9	10	8	10	11	Varies regularly in coarseness. Deposit holds good road and concrete gravel.
21a	26	74	0	0	0	9	7	19	65	29	26	22	16	5	1	1	
21b	(Sand)	....	0	0	0	0	0	0	0	2	5	22	48	20	3	0	
22	55	45	0	11	12	25	10	16	26	31	26	20	13	6	2	2	Very regularly graded. Good hard gravel.
23	74	26	0	0	0	3	16	46	35	20	4	4	33	26	6	7	Too low proportion of coarse sand.
27	58	42	0	5	8	18	11	23	35	36	20	17	14	7	3	3	Deeply weathered, but very well graded. Good where not too weathered.
27a	10	90	0	0	0	5	0	15	80	18	24	30	18	7	2	1	
31	54	46	6	0	5	15	10	25	39	32	19	18	17	10	13	1	Good road and concrete gravel.
38	43	57	0	0	0	12	15	27	46	29	14	11	24	17	3	2	Partly weathered, but well graded. Good.
39	37	63	0	0	0	14	17	28	41	19	19	34	15	10	2	1	Sample coarser than pit average. Very good where not too sandy.
41	20	80	0	0	9	20	7	21	43	17	26	36	17	3	1	0	Too sandy for roads. Holds good concrete sand and gravel.

TABLE II—Continued

Tests on Gravel Samples—Continued

Sample No.	Proportion of pebble to sand		Granulometric Analysis														Per cent passing 200 mesh	Suitability
			Pebbles							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		
43	23	77	0	8	20	18	6	16	32	17	26	36	16	3	1	1	Too sandy, but otherwise well graded.
44	39	61	0	15	5	18	15	17	30	22	30	31	12	3	1	1	Good where not too sandy. Holds good concrete
44a	15	85	28	0	26	12	0	10	24	16	33	33	13	3	1	1	sand and gravel also.
45	46	54	0	0	6	15	12	28	39	27	25	28	14	4	1	1	Good hard and fresh gravel.
53	43	57	0	6	15	18	8	15	38	34	29	21	9	4	2	1	Partly weathered and rather sandy, but very
53a	41	59	0	9	12	23	9	16	31	25	32	31	8	2	1	1	well graded. Very good.
55	17	83	0	0	0	7	9	24	60	18	20	27	23	9	2	1	Very sandy, but grading very uniform.
61	56	44	15	20	18	12	9	12	14	16	22	34	20	5	2	1	Coarseness varies gradually. Good road gravel.
61a	42	58	17	7	20	17	9	11	19	14	21	39	18	5	2	1	Fresh part suitable for concrete.
61b	18	82	0	0	5	12	7	12	64	29	30	24	12	3	1	1	
71	40	60	0	12	20	17	9	13	29	25	19	23	23	7	2	1	Sample more sandy than pit average. Good road and concrete gravel.
73	64	36	0	2	2	10	13	26	47	62	14	6	6	6	3	3	Well graded and sand very coarse. Very good.
76	50	50	4	3	5	11	13	19	45	41	26	16	8	5	2	2	Well graded. Gradually finer in depth. Weath-
76a	36	64	0	0	12	6	5	21	56	40	29	17	8	4	1	1	ered, yet fairly hard.
78	30	70	0	6	4	9	6	18	57	41	34	15	5	3	1	1	Weathered and sandy, but well graded. Sand very coarse.
79	81	19	0	5	13	24	15	22	21	25	15	14	14	14	10	8	Good road gravel where not too weathered.
79a	5	95	0	0	0	3	6	10	81	19	33	27	15	4	1	1	Good concrete gravel in lower bank.
80	37	63	0	0	9	16	12	22	41	27	24	19	17	9	3	1	Grading variable. Holds streaks of good road
80a	26	74	0	0	0	12	7	26	55	25	25	22	15	8	3	2	gravel.
81	34	66	0	6	2	15	11	27	39	23	22	19	19	12	4	1	Too fine for roads, suitable for concrete. Sample coarser than pit average.
82	65	35	0	0	9	15	20	27	29	22	15	16	17	12	8	10	Sample represents the better grade gravel, which is almost exhausted.
83	20	80	0	12	0	10	11	17	50	18	22	25	15	15	4	1	Very uniform in grading, but too sandy.

85	35	65	0	7	5	17	7	13	51	40	31	16	8	3	1	1	Grading variable. Sand very coarse. Sample more sandy than pit average.
86	43	57	0	0	3	10	13	20	54	45	27	13	7	5	2	1	Well graded and sand very coarse. Good road gravel.
88	38	62	0	10	13	14	10	17	36	25	22	19	17	13	3	1	Irregular grading and too much fine sand.
90	33	67	0	0	8	16	9	19	48	24	24	23	18	9	1	1	Sample less sandy than pit average. Very good where not too sandy.
92	45	55	0	0	24	21	14	17	24	21	23	25	22	7	1	1	Grading variable. Holds streaks of very good gravel.
98	16	84	0	0	0	0	8	14	78	34	33	23	4	2	2	2	Too sandy for roads, but sand very coarse.
101	55	45	0	5	16	24	14	16	25	28	22	24	17	6	2	1	Sample coarser than pit average. Very good where not too sandy.
109	59	41	0	16	21	21	10	14	18	21	18	23	24	8	3	3	Good hard gravel, but deficient in small pebbles and coarse sand.
111	41	59	0	0	0	8	19	30	43	25	17	22	15	9	7	5	Very good where not too sandy.
113	49	51	0	0	7	23	20	23	27	29	25	24	16	4	1	1	Sample from coarser phase. Gravel hard and very good where not too sandy.
115	33	67	0	0	0	26	22	22	30	20	16	21	34	8	1	0	Uniformly well graded, hard gravel, too sandy.
116	65	35	0	6	3	11	11	22	47	59	21	9	6	3	1	1	Grading variable. Sample from streak of well graded gravel.
119	23	77	0	0	0	5	3	14	78	31	32	25	10	2	0	0	Well graded but too sandy. Other pits show coarser and fresher gravel.
125	55	45	0	0	2	4	4	29	61	73	24	1	1	0	0	1	Grading uniform and sand exceedingly coarse. Very good road gravel.
126	35	65	0	0	8	13	12	20	47	29	38	11	9	9	3	1	Too sandy, but sand very coarse. Good road and concrete gravel.
127	58	42	0	0	0	5	5	20	70	63	29	3	1	1	1	2	Grading uniform and sand exceedingly coarse.
127a	29	71	0	0	0	3	4	13	80	55	38	3	1	1	1	1	Very good road gravel.
128	38	62	7	11	3	16	8	19	36	23	16	17	26	13	3	2	Sand and gravel suitable for mortar and concrete.
128a	(Sand)	....	0	0	0	0	0	0	0	0	0	0	6	55	28	11	Very little road gravel.
132	27	73	0	0	5	13	16	23	43	20	21	25	25	7	1	1	Well graded, but too sandy.
134	23	77	0	9	22	13	10	13	33	29	44	18	5	2	1	1	Very sandy gravel, sand very coarse.
135	47	53	0	0	0	1	6	38	55	33	34	18	14	1	0	0	Uniformly well graded and sand very coarse. Very good.
139	43	57	0	0	0	1	7	22	70	54	29	5	2	3	4	3	Well graded for roads. Holds sand and gravel
139a	35	65	0	0	3	1	6	25	65	40	28	14	10	6	1	1	suitable for mortar and concrete.
147	63	37	0	0	5	22	16	22	35	27	5	23	32	9	2	2	Grading varies much, with low proportion of sand.
153	60	40	0	0	0	9	20	32	39	26	10	11	16	18	16	3	Holds very little road gravel. Worked almost
153a	4	96	0	0	0	0	6	21	73	7	10	26	29	13	12	3	exclusively for sand.

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TABLE II—Continued

Tests on Gravel Samples—Continued

Sample No.	Proportion of pebbles and sand		Granulometric Analysis													Per cent passing 200 mesh	Suitability
			Pebbles							Sand							
			Per cent retained on screens							Per cent retained on sieves							
	Per cent pebbles	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
157	11	89	0	11	0	10	15	18	46	11	14	16	28	21	7	2	Much too sandy.
159	27	73	0	6	4	19	10	16	45	24	22	25	21	6	1	1	Uniformly well graded, but too sandy.
159a	31	69	0	0	0	19	9	22	50	25	23	26	17	7	1	1	
162	27	73	0	27	9	21	10	12	21	8	12	23	37	16	3	1	Too sandy.
163	29	71	0	9	10	22	10	14	35	21	29	32	14	3	1	0	Too sandy.
166	70	30	0	0	10	22	20	24	24	42	24	14	9	8	2	1	Well graded and sand coarse. Very good road and concrete gravel.
166a	40	60	0	0	6	14	11	19	50	45	28	12	7	4	2	2	
167	38	62	0	0	2	5	7	19	67	42	23	16	13	4	1	1	Uniformly well graded and sand coarse. Very good road gravel.
168	45	55	0	8	5	15	14	21	37	29	31	27	9	2	1	1	Weathered and not very hard, but well graded and sand very coarse.
172	33	67	0	14	9	15	14	16	32	19	18	19	18	18	6	2	Grading variable. Streaks of very good, slightly clayey gravel.
178	60	40	0	7	12	16	17	18	30	39	30	19	7	3	1	1	Partly weathered, yet fairly hard. Uniformly well graded. Good road gravel. Upper part sandy in places.
178a	26	74	0	0	0	10	16	35	39	18	22	37	17	5	1	0	
179	66	34	0	13	20	21	10	15	21	33	23	17	13	9	3	2	Too coarse, but the finer part is well graded.
183	45	55	0	0	11	23	8	22	36	28	24	26	16	4	1	1	Uniformly well graded. Sample 183 is from upper weathered part. Very good road gravel.
183a	52	48	0	0	0	13	20	33	34	31	25	22	12	4	4	2	
186	54	46	0	0	0	19	23	29	29	23	14	23	30	9	1	0	Well graded gravel from surface of river flat; sandy in depth.
193	56	44	0	0	8	22	19	26	25	25	17	22	22	10	2	2	Very rusty and fairly well graded. Very good road gravel.
206	38	62	8	0	7	11	12	21	41	21	17	23	25	12	1	1	Sandy and soft. Wears very fast.
210	61	39	0	0	9	19	16	22	34	36	21	16	14	7	3	3	Very well graded and fresh but rather soft. Sample coarser than pit average. Good concrete gravel.

213	50	50	9	3	9	13	12	22	32	28	19	22	24	5	1	1	Coarse, but otherwise well graded. Good, medium hard road gravel.
220	44	56	0	1	10	20	16	18	35	24	20	26	23	5	1	1	Medium hard, uniformly well graded, slightly high in sand.
222	37	63	0	0	2	13	12	28	45	19	11	15	32	16	5	2	Sandy river gravel.
225	40	60	0	5	0	18	11	21	45	23	20	23	23	7	2	2	Sandy and very soft gravel.
227	55	45	0	4	10	28	13	16	29	28	21	20	18	8	3	2	Grading variable. Sample coarser than pit average. Fresh but soft gravel.
229	58	42	0	2	2	26	22	21	27	24	17	22	28	7	1	1	Sample from well graded river gravel. Coarseness varies much.
233	47	53	0	12	7	18	11	22	30	25	17	22	19	8	3	6	Weathered and soft.
239	47	53	0	0	20	12	11	21	36	28	22	25	19	3	1	2	Fairly good coarse gravel. Becomes very sandy in depth.
240	57	43	0	0	2	7	8	21	62	43	14	10	14	10	5	4	Upper part well graded, lower part fresher, but softer and less regularly graded. Gravel is everywhere rather soft.
240a	53	47	4	3	19	20	10	16	28	24	23	22	14	8	4	5	
243	58	42	0	62	10	16	11	19	38	42	26	12	8	5	2	5	Grading varies much. Sample from streak of well graded gravel.
251	51	49	16	6	7	22	9	14	26	26	23	20	13	5	3	10	Grading variable. Fresh, clayey gravel of medium hardness.
266	40	60	0	0	0	11	15	27	47	28	22	21	17	9	2	1	Sandy river gravel of better wearing quality than local bank gravel.
273	57	43	0	0	0	3	8	22	67	62	20	4	4	4	2	4	Well graded but soft and sandy. Sample less sandy than pit average.
274	40	60	0	0	3	8	7	22	60	26	16	16	28	11	2	1	Sandy river gravel of better wearing quality than local bank gravel.
275	54	46	0	19	9	20	12	15	25	24	24	22	18	6	3	3	Grading varies gradually. Soft and wears fast.
277	73	27	5	13	20	25	14	13	10	21	12	12	24	19	8	4	Sample not so sandy and not so well graded as pit average. Somewhat coarse but good hard road gravel.
279	76	24	0	0	0	5	9	29	57	61	21	7	4	3	1	3	Well graded shale gravel, but very soft. Wears smooth but fast.
280	22	78	0	0	0	5	8	23	64	33	36	20	7	2	1	1	Very sandy shale gravel. Too fine and much too soft. Wears very fast.
281	30	70	0	0	0	18	12	27	43	15	11	15	40	16	2	1	Very sandy river gravel. Sand is rather fine.
285	49	51	15	8	11	17	13	14	22	20	19	29	27	3	1	1	Coarse and sandy. Sample less sandy than pit average. Good concrete sand and gravel.
286	45	55	0	0	15	16	14	22	33	23	16	21	26	9	2	3	Medium hard, fairly well graded river gravel, better than local bank gravel.
291	57	43	0	15	5	24	13	18	25	27	20	20	19	10	2	2	Fairly well graded and coarse. Good road gravel.

TABLE II—Concluded

Tests on Gravel Samples—Concluded

Sample No.	Proportion of pebble to sand		Granulometric Analysis														Per cent passing 200 mesh	Suitability
			Pebbles							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			
295	39	61	0	0	8	17	12	21	42	32	33	23	8	2	1	1	Sandy but well graded and sand very coarse. Sample less sandy than pit average. Weathered but good gravel.
307	49	51	0	10	17	19	9	16	29	20	18	24	31	5	1	1	Good road gravel, but sandy. Samples less
307a	42	58	0	12	11	11	11	18	37	32	24	17	20	5	1	1	sandy than pit average.
312	59	41	6	8	11	15	9	19	32	40	25	17	11	4	1	2	Grading varies. Large streaks of good road and concrete gravel.
314	35	65	0	6	7	22	6	19	40	28	33	20	8	3	2	6	Well graded, varies gradually in coarseness. Weathered, but good gravel.
320	57	43	0	0	12	26	18	17	27	28	25	26	14	4	1	2	Uniformly well graded. Good medium hard road gravel.
321	(Crushed)	....	....	....	4	32	42	21	1	....	....	....	....	....	....	....	Crushed gravel, takes long to compact properly on the road.
325	62	38	0	2	6	21	16	23	32	31	24	12	8	6	5	14	Uniformly well graded and sand very coarse.
325a	38	62	0	0	7	20	8	17	48	36	30	21	8	2	1	2	Outside of weathered upper part, good road and
325b	60	40	0	8	3	23	16	21	29	44	30	12	6	2	1	5	concrete gravel.
326	62	38	....	3	8	23	3	23	40	26	14	14	13	11	7	15	Coarser and not so uniform as 325. Sample is of crushed unscreened gravel. Wears well on the road.
327	73	27	4	18	15	26	12	10	15	34	26	17	7	4	3	9	Very coarse and bouldery. Sand also very coarse. Good road gravel when crushed.
336	5	95	0	0	0	7	8	24	61	11	29	49	10	1	0	0	Good, fresh, coarse concrete sand.
338	45	55	0	0	2	20	16	22	40	32	23	20	15	6	2	2	Uniformly well graded; coarse sand. Very good, fresh and hard road gravel.
345	60	40	6	14	22	8	9	14	27	38	33	19	6	2	1	1	Very sandy. Samples less sandy than pit aver-
345a	48	52	17	3	7	20	9	15	29	26	29	30	10	2	1	2	age. Good where not too sandy.

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346	65	35	0	4	14	26	16	18	22	29	19	18	20	9	2	3	Coarseness variable. Sample represents average. Good medium hard road gravel.
349	35	65	0	0	2	7	10	23	58	44	34	13	5	2	1	1	Too sandy, but sand very coarse, and uniformly well graded. Good concrete gravel.
350	65	35	0	6	4	27	12	18	33	53	28	8	3	3	2	3	Very good road and concrete gravel, carrying very coarse sand. Gravel very fresh and hard.
350a	39	61	0	0	0	9	12	29	50	38	33	14	4	7	3	1	
353	45	55	0	0	13	16	13	21	37	40	39	16	3	1	0	1	Grading irregular in upper 10 feet, more regular below and sand exceedingly coarse. Good road gravel.
355	46	54	0	0	5	8	17	31	39	21	14	18	26	14	5	2	Very sandy and sand fine. Sample less sandy than average. Well graded and good where not too sandy.
356	55	45	0	0	9	26	19	20	26	19	10	19	35	13	2	2	Similar to 355, but less sandy.
360	62	38	0	19	11	23	10	14	23	35	29	16	7	3	2	8	Holds 15 per cent boulders. Gravel fresh and hard. Needs crushing.
363	25	75	0	0	0	15	11	22	52	20	21	27	27	3	1	1	Too sandy. Makes good concrete aggregate.
366	66	34	6	2	5	22	12	19	34	45	28	12	5	3	2	5	Coarseness varies gradually. Sample from medium coarse phase. Weathered and rather soft, but well graded.
368	45	55	0	0	10	25	15	21	29	18	14	28	27	8	2	3	Deposit holds mostly sand, suitable for concrete. Sample from gravel pocket.
369	40	60	0	3	2	14	17	26	38	18	13	17	26	17	5	4	Coarse, partly weathered, well graded gravel Sample more sandy than pit average.
371	54	46	3	6	5	18	12	18	38	40	27	18	9	3	1	2	Gradually finer in depth. Well graded, good road and concrete gravel. Upper 8 feet weathered, bouldery and poor.
371a	45	55	26	0	9	15	12	12	26	25	29	29	11	4	1	1	
375	39	61	0	0	8	11	11	23	47	42	32	12	7	5	1	1	Uniformly well graded, rather sandy, but sand very coarse. Good road and concrete gravel.

TABLE III

Mortar Test*

Sample No.	Fineness modulus	Per cent of water used	Sand mortar: 1 cement, 3 sand				Remarks
			Textile strength, per cent of standard		Compressive strength, per cent of standard		
			7 days	28 days	7 days	28 days	
5	3·03	12·0	86	58	89	94	Tensile strength decreased at 28 days.
7	3·78	11·4	118	113	159	151	Sample at depth in bank.
12	3·64	11·6	97	89	157	137	Slightly weathered.
13	2·79	13·8	39	51	66	70	Deposit very shallow and sand weathered.
20	3·52	13·8	61	68	92	125	Sample taken near surface.
21b	2·12	13·8	82	77	93	99	Fresh but too fine.
27	3·46	12·8	70	83	119	121	From depth of 2·5 to 5 feet; weathered and holds mica.
27a	3·19	11·9	73	90	116	118	From depth of 10 to 12 feet. Slightly weathered and holds mica.
43	3·32	12·8	87	101	118	142	From depth of 8 to 12 feet. Slightly weathered.
44a	3·40	13·1	90	88	140	128	Holds some clay.
53	3·71	11·6	108	88	156	145	From depth of 6 to 9 feet. Slightly weathered.
55	3·06	12·7	67	63	97	94	Deposit shallow and sand weathered.
61b	3·64	11·9	105	101	158	145	From depth of 7 to 8 feet.
78	3·99	11·4	98	106	157	158	From depth of 15 feet. Slightly weathered.
79a	3·42	11·4	124	124	176	176	Sample at depth in bank.
81	3·10	12·0	92	82	135	136	From depth of 4 to 7 feet. Slightly weathered.
88	3·17	12·0	97	76	133	140	From depth of 10 to 13 feet. Holds mica.
90	3·30	13·0	56	65	109	103	Deposit shallow and sand rusty.
98	3·81	11·3	90	76	110	121	Deposit very shallow and sand weathered.
109	3·02	11·9	15	50	4	61	Sand grains rust coated.
119	3·80	10·6	92	68	167	155	Tensile strength decreased at 28 days.
125	4·66	11·4	62	62	78	105	Sand grains dust coated.
126	3·57	10·9	138	107	211	203	From depth of 9 to 12 feet.
134	3·87	11·7	85	81	137	156	From depth of 7 to 9 feet. Slightly rusty.
135	3·84	11·2	126	79	178	183	Tensile strength decreased at 28 days.
139	4·08	10·3	117	74	188	141	Tensile strength decreased at 28 days.
139a	3·80	10·5	145	87	217	181	Tensile strength decreased at 28 days.
153	2·53	13·8	100	97	128	125	Sand too fine.
153a	2·24	13·8	81	78	123	109	Sand too fine.
162	2·47	12·7	93	86	139	123	From depth of 6 to 8 feet. Sand too fine.
166a	3·91	10·0	138	111	240	195	From depth of 10 feet.
172	2·78	12·4	112	90	164	133	From run of the bank. Sand holds mica.
179	3·43	12·0	58	74	131	131	From depth of 3 to 6 feet. Sand holds mica.
210	3·47	12·8	130	123	177	147	Sample at depth in bank.
213	3·35	12·4	107	117	160	138	From depth of 5 to 8 feet. Slightly weathered.

TABLE III—Continued

Mortar Test*—Continued

Sample No.	Fineness modulus	Per cent of water used	Sand mortar: 1 cement, 3 sand — Tensile strength, per cent of standard: 7 days	Tensile strength, per cent of standard: 28 days	Compressive strength, per cent of standard: 7 days	Compressive strength, per cent of standard: 28 days	Remarks
220	3·29	12·5	110	92	136	110	From depth of 2 to 7 feet. Fairly fresh sand.
240	3·39	13·8	106	102	121	133	From depth of 5 to 7 feet. Slightly dusty.
240a	3·14	15·0	94	98	96	112	From depth of at least 10 feet. Sand holds some clay.
243	3·71	15·4	98	106	103	117	From depth of 7 to 11 feet. Slightly weathered and dusty.
275	3·24	15·0	73	72	107	87	From depth of 3 to 6 feet. Shaly and dusty.
285	3·20	11·4	112	120	126	130	Sample from deep in the bank.
291	3·23	12·4	86	99	129	115	From depth of 5 to 9 feet. Slightly weathered.
295	3·79	13·8	96	92	107	117	From depth of 2·5 to 6 feet. Slightly rusty.
312	3·77	11·3	123	127	170	150	Sample at depth in bank.
314	3·51	13·8	84	81	105	130	From near surface. Dusty sand.
325a	3·81	11·4	150	143	209	175	Sample at depth in bank.
325b	3·90	12·4	138	130	172	158	Sample at depth in bank.
327	3·43	13·8	113	110	140	132	From depth of 7 to 10 feet, dusty sand.
336	3·39	12·1	111	120	116	144	Sample at depth in bank.
349	4·07	11·9	136	139	149	164	Sample from run of the bank. Deep pit.
350	4·10	11·0	157	142	217	170	Sample at depth in bank.
350a	3·79	12·1	122	136	139	163	Sample at depth in bank.
355	2·81	13·5	96	88	129	113	Sand slightly too fine.
363	3·22	12·5	110	102	138	112	From depth of 6 to 10 feet.
368	2·92	13·8	115	114	125	138	Sample at depth in bank.
375	3·93	11·2	134	133	171	173	From depth of 5 to 9 feet. Sand fresh and coarse.

*Only the material passing a ¼-inch screen (sand or fine aggregate) is used for this test. The fineness modulus is an indication of the fineness of the sand; the finer the sand, the lower its modulus. The standard test referred to is made on a mortar composed of one part of cement and three parts of standard Ottawa sand. Mortars giving results of at least 100 per cent of the value of the standard test are considered suitable for all conditions and are classified as high grade; those testing over 70 per cent and less than 100 per cent of the standard are suitable only for certain classes of work; those testing less than 70 per cent of the standard should be rejected.

As already stated, nearly all samples were collected primarily for testing as road material, and are not therefore truly representative of that part of the deposit best suited for mortar or concrete work.

X

LIME TREATMENT FOR GUMBO ROADS

J. G. Phillips

In wet weather the roads in some sections of the Prairie Provinces are notoriously poor, in fact, after prolonged rains many are unusable for heavy haulage and motor traffic. These conditions are due to the nature of the soil upon which the roads are built. This soil is a type of clay known as gumbo which, when wet, is very sticky and of low stability, that is, it is a poor sustainer of loads and the wheels of traffic sink into it, producing deep ruts. Even when surfaced with gravel or stone its poor properties still manifest themselves. The wearing surface is disrupted by heavy vehicles and the surfacing materials are forced deep into the subsoil.

In an investigation on the treatment of somewhat similar clays with chemicals to improve them for brick-making, lime was found to be very effective in altering their physical properties when wet. The possibility of using lime to improve the stability of gumbo soils for road purposes had been investigated in the United States with encouraging results. These two considerations suggested that the possibility of lime treatment on the western Canada gumbo soils would be worthy of investigation.

Several samples of gumbo surface soils were obtained from Alberta for experimentation to determine whether any marked improvement in their properties could be effected by the admixture of lime.

Laboratory experiments were made on these samples and the results obtained indicate beneficial effects as regards the stickiness and the stability of the soil. Little, however, can be learned from laboratory work as to the practicability of such treatment and it is proposed to conduct road trials by making test sections on selected gumbo roads. Observations over a period of years, and comparison with untreated sections would be necessary to prove the effectiveness of the treatment and furnish cost data that would permit conclusions as to its practicability.

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(B) Road materials.

Those which are marked * are out of print, but may be consulted at many of the public libraries throughout the country.

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