MEMOIR 85

ROAD MATERIAL SURVEYS IN 1914

BY

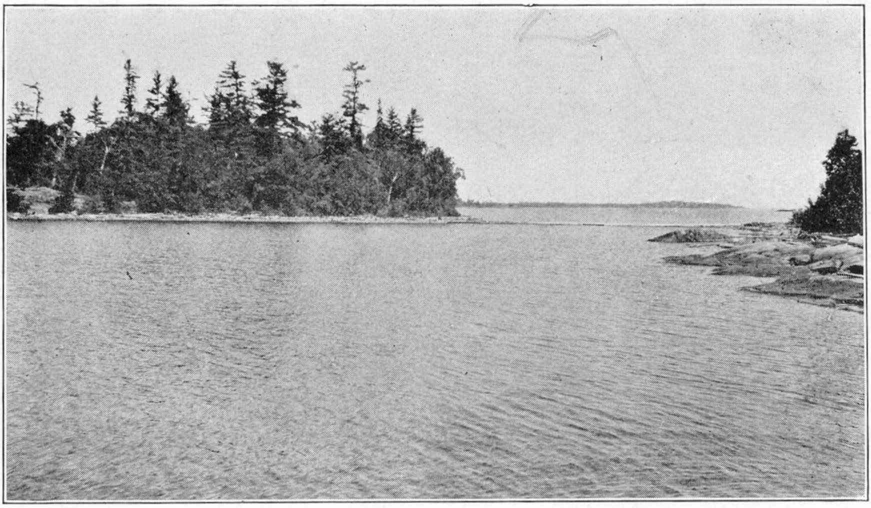
L. REINECKE

GEOLOGICAL SURVEY

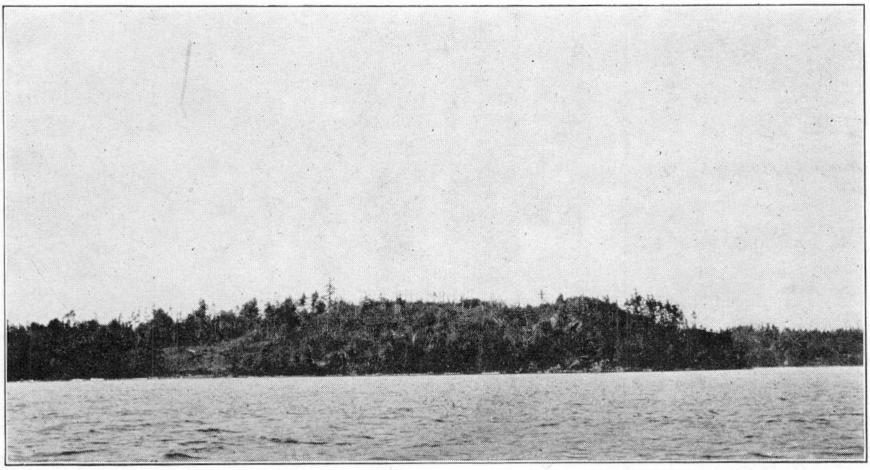
DEPARTMENT OF MINES

OTTAWA

1916



A. The linking of two rocky islands by a gravel bar, in Lake Huron near Clara island, to illustrate the growth of certain islands in this neighbourhood.



B. A portion of the northwest shore of Green island. The island is a flat-topped mass of diabase with abrupt shores.

CANADA
DEPARTMENT OF MINES
HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

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Road Material Surveys in 1914

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L. Reinecke

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PREFACE.

The movement for the improvement of country highways throughout Canada has been growing in public favour within the last few years, until now good roads are thought of as necessities. The construction and maintenance of roads absorb a great deal of public money and in order to obtain service from them in proportion to their cost, the greatest care has to be observed both in their construction and in the selection of the materials with which they are surfaced.

Country roads are made mainly of gravel or broken stone and, since the cost of transporting material of such weight for long distances is great, they are usually made from deposits of stone and gravel which are to be found within a few miles of where the roads are located.

Stone and gravel vary widely in their road-making qualities; and the quality of stone which can be economically used on a road surface is dependent on the amount of traffic which passes over it. A stone of poor quality which would stand up well and give good service in a road-bed over which the traffic did not exceed 100 vehicles per day, might wear out in a short time if subjected to the heavier traffic of 500 vehicles per day. If the poorer stone occurred close to a road over which the traffic were light enough, it would be more economical to use it as a surfacing material, than a better stone which had to be hauled from a distance. On the other hand if the traffic were heavy the money spent in quarrying and placing it on the road might be utterly wasted. It is, therefore, of importance to the highway engineer to know the extent and quality of the deposits of stone and gravel which lie within practical hauling distance of the road he is to construct. Such knowledge often cannot be obtained without detailed surveys on both sides of the road in question and the careful mapping and examination of the deposits found in the area worked over.

Men on the staff of the Geological Survey have been mapping and studying deposits of stone and gravel in all parts of Canada for more than seventy years. The Survey has, therefore, considerable information at hand and is in a position to advantageously do work of the kind required. In order to assist engineers and road builders throughout Canada, special surveys for road materials were begun last summer and the results of the first season's work, which was confined to the province of Ontario, are incorporated in this report. In the summer of 1915, surveys will be made in Quebec and New Brunswick as well as in Ontario. The Geological Survey hopes to co-operate with the Road Departments of the various provinces, as far as possible. The results of the work will be published by the Survey. Under certain restrictions, reports upon the materials available for certain roads will be furnished those who are building roads as soon as possible after the field work upon the materials available for the roads in question is done. This will be done only if it is necessary for road-building to commence before the reports are printed and distributed to the public.

This report is published in four parts. Part I is a description of the various kinds of country roads, of the materials used in their construction, of the different varieties of stone outcropping at the surface of the earth, and of their comparative value as road-making materials. Part II is a description of certain large deposits of diabase upon the north shore of Lake Huron. Part III is a report on road materials in Essex and Kent counties, Ontario, and Part IV a report on road materials along a portion of the north shore of Lake Ontario.

PART I.

ROADS AND THE MATERIALS USED IN THEIR CONSTRUCTION.

Part I.

Roads and the Materials Used in Their Construction.

CHAPTER I.

INTRODUCTION.

The following section contains descriptions of the various kinds of country roads, the varieties of stone and gravel used in their construction, the tests made upon stone for determining its road-making qualities, and finally a comparison of the rock families in regard to their relative value as road-makers. Some knowledge of the subjects treated of in this section is necessary to an understanding of the remaining parts of the report and the information is, therefore, placed at the beginning. The topics enumerated have been treated very briefly, too briefly to be of value to the highway engineer, but it is hoped that they will be of interest to the general public and to road-builders who may wish to get a more general knowledge of road stone and gravel than can be had from a study of the materials in their immediate neighbourhoods.

The sections dealing with the tests made upon broken stone are based upon work done by the men on the staff of the Office of Public Roads in Washington, and the writer is indebted to them for many courtesies and a great deal of assistance.

CHAPTER II.

TYPES OF COUNTRY ROADS.

Roads may be conveniently classified according to the materials used in their construction. Thus, a road covered with broken stone is known as a broken-stone or macadam road, and one in which the surface is of concrete, as a concrete road.

In this chapter the different types of country roads are discussed and an outline of the method, and some data regarding the cost of their construction are given. Data upon the cost of construction are inserted only with the object of comparing the different classes of roads. Costs are so largely dependent upon local conditions that one cannot use such figures in estimating the probable expenditure for the construction of similar roads in other places, without a careful study of all the conditions involved in both places.

Country roads may be classified as follows: earth, sand-clay, gravel, water-bound macadam, bituminous macadam, and concrete roads. Roads paved with brick, stone, or wooden blocks are not generally used outside of towns because of the great expense of constructing them.

EARTH ROADS.

A road in the construction of which native soil alone is used, without the aid of a foreign protective covering, is known as an earth road. More than 90 per cent of the roads in the United States are of this type and the proportion is probably larger for Canada.

The material used in the construction of an earth road varies according to the make-up of the soil over which it passes from place to place. Of the various types of soil over which a road may pass, one containing a large proportion of gravel is probably the best, and that which is nearly all sand, the worst.

Heavy clay is generally fairly good in dry weather and very bad in wet. Earth roads are, however, very seldom located with regard to the quality of the underlying soil as a road-maker. They are of importance in the discussion of road metal only, because when properly constructed, they duplicate in form and make-up the foundation or bottom of all roads. Earth roads, even when properly constructed and maintained, are suited only to the very lightest traffic. Their cost varies greatly. In prairie country, roads 36 feet wide with a 6-inch crown have been graded and compacted with machinery at a cost of about $40 per mile. This is probably a minimum. Estimates on the costs of making earth roads in the Yellowstone National Park vary from $2,529 to $4,382 per mile. The roads were 18 feet wide, clearing 30 feet, 6 inches higher in the middle than on the side, and covered with 9 inches of earth and clay.

SAND-CLAY ROADS.

A sand-clay road is one in which an earth road made up of either sand or clay has been surfaced by the addition of clay to the sand, or sand to the clay, as the case may be. Such roads are of value in districts where either one or the other of these types of soil predominate. They give good service when carefully maintained. In the southern sections of the United States sand-clay roads have been built at a cost of from $200 to $1,200 per mile, the cost varying with the distance which either the sand or the clay has to be hauled.[1]

GRAVEL ROADS.

Gravel roads are those which have a protective covering of gravel laid upon a foundation of earth. The gravel may be laid in one course, or it may consist of two courses, the upper layer being composed of finer material than the lower. The usual thickness of gravel, after it has become compact, is from 4 inches to 1 foot. The road gravel generally contains a certain percentage of sand and sometimes a little clay.

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[1] Page, L. W. "Roads, paths, and bridges," Sturgis and Walton Co., New York, 1912, p. 124.

Cost of Gravel Roads.

In the state of Indiana, which is comparatively level, the cost of building gravel roads has varied from $800 to $3,500 per mile. Except in a few counties, the cost varied from $1,000 to $2,500 per mile. When the gravel had to be hauled one mile only, the cost for hauling was from 15 cents to 30 cents per cubic yard of gravel, and the total cost 40 cents to 50 cents per cubic yard in place. The average total cost of construction varied from $1,000 per mile, when the gravel had to be hauled 1 mile, to $2,000 per mile when it had to be hauled 5 miles. These costs were compared by Baker with those of roads constructed in Ohio and Illinois and found to be fairly representative.[1] In contrast to these, we give, in the table below, a number of data regarding the costs of gravel roads in New York state. The difference in cost is marked, both between individual roads in the state, and between the average of these roads and those of Indiana. A part of this variation is due to the varying amounts of grading done on the New York roads.

Table Showing the Cost of 16 Gravel Roads in New York State.[2]

Ref. No.	Width of macadam in feet.	Width of roadway in feet.	Cub. yards excavated per mile.	Thickness of macadam in inches.	Cost per mile $
1	16	21	13,000	6	8,124
2	....	16–22	3,455	6	2,030
3	....	22	4,502	6	2,296
4	....	16	2,811	6	1,489
5	....	22	3,333	6	5,230
6	....	16	2,554	6	2,646
7	....	20	6,870	6	11,877
8	16	22–26	6,545	6	6,240
9	12	20	4,917	6	4,511
10	....	22	10,097	6	8,256
11	18	22	4,741	6	5,815
12	....	22	5,731	6	4,569
13	12	22	5,609	6	6,072
14	....	18	3,344	6	4,719
15	16	24	7,501	8	6,455
16	16	22–24	2,195	8	3,846
Average.	15·14	20·81	5,450·31	6·25	$5,260.94

[1] Baker, I. O., "A treatise on roads and pavements," John Wiley and Sons, New York, 1913, p. 172.

[2] State Commission of Highways of New York. "Report of the State Commission of Highways of New York for 1911": pp. 449-480.

The cost of gravel roads in certain parts of Canada where the topography is relatively flat will probably compare with that in Indiana. Where the topography is rougher, these roads would probably approach some of the New York State roads in cost.

The cost of hauling the material is one of the largest items of expense in making roads. It takes 3,129 cubic yards of gravel to make a mile of finished compact road surface 16 feet wide and 8 inches deep. Byrne[1] calculates that one team can haul 7 cubic yards of gravel per day, if the haul is not over $1\frac{1}{2}$ miles. The amount, of course, decreases with the distance to haul. One cubic yard of gravel weighs from 1·3 to 1·7 tons. The amount that one team can haul, and the cost of teams, vary greatly, however, and these items will have to be determined separately for every locality where a road is to be built or a gravel deposit opened.

WATER-BOUND MACADAM OR BROKEN-STONE ROADS.

Broken-stone roads are built on the same principle as gravel roads. In both, a covering which is essentially resistant to wear and is, after compacting, very nearly, if not entirely, impervious to water, is placed over a well-drained foundation. The covering distributes the weight of traffic over a larger area of the foundation and prevents water from percolating down and softening it. This type of highway was first successfully built by Tresauget in France in 1775. John Macadam, a Scotch engineer, introduced the broken-stone road into England in 1816 and built many good roads of that type. The name "macadam" has been applied to roads of that kind ever since.

Roads of this type are made by placing one, two, or three courses of broken stone upon a foundation of earth. The earth foundation is generally rolled and thoroughly drained, either by side drains and ditches, or by drains in the middle of the road. In certain instances the foundation is paved with stone blocks which are generally set on edge with their longer dimensions across the length of the road. The crevices between the

[1] Byrne, A. T. A treatise on highway construction. John Wiley and Sons, New York, 1910, p. 351.

larger stones are filled with smaller stones and projections are hammered off. This is known as a Telford foundation and its upper surface is in most cases parallel to that of the finished road. The crushed stone is put on in two or more courses. One of the latest sets of specifications[1] calls for one course of stone of sizes passing over a $2\frac{1}{4}$-inch ring and through a $3\frac{1}{4}$-inch ring. This is rolled to a finished depth of $3\frac{1}{2}$ inches. Over this are placed two courses of stone of sizes passing over a $1\frac{1}{4}$-inch ring and through a $2\frac{1}{4}$-inch ring. Each course is rolled separately to a finished thickness of $2\frac{1}{2}$ inches. Stone screenings between $\frac{1}{4}$ and $\frac{5}{8}$-inch in size are rolled into the top of each course. At the same time water is sprinkled on to wash the smaller stone into the voids in the road surface. The ordinary macadam varies in thickness from about 4 inches to 1 foot. The top course is known as the "wearing course" and the screenings are referred to as the "binder." In a great many cases only two courses are placed on the road and the stone used in the wearing course may be much smaller than specified above. The larger size is probably best when the stone is rather soft as is the case with many of the limestones.

The action of the roller and of traffic compacts the rock fragments together and decreases the number of voids. This is hastened by the fine screenings or "binder" material that is thought to act as a sort of lubricant, which helps the rock surfaces to slide over each other and the smaller fragments to get into the spaces between the larger.

Since fine material dissolves more rapidly than coarse, the fine screenings in the top dressing are also supposed to furnish the cementing solutions, or rather the plastic colloidal bodies, which finally bind the road surface into a solid mass.

Comparison of the Effects of Traffic upon Gravel and Macadam Roads.

As a general rule it may be said that macadam, or broken-stone roads are superior to gravel roads, and this is, without doubt, due to the fact that in the average macadam road the

[1] Specifications for broken stone and gravel roads adopted October, 1914: Amer. Soc. of Municipal Improvements, 702 Wulson Building, Indianapolis, Ind. pp. 4-6.

angular particles have become more firmly bound together than is possible in the ordinary gravel road. The fine stone fragments are generally sufficient to keep up this bond under ordinary wagon traffic, and as they are blown or washed out of the top surface, horses' hoofs and steel wagon tires wear off more fragments to take their place. The action of automobile traffic, however, is not so much a pounding or grinding, as a shearing one, and it draws the fine binder out of the surface without grinding off more to take its place. Increase of automobile traffic, therefore, has brought about the use of binders other than rock screenings. These binders are usually some form of bitumen, and roads so constructed are known as bituminous macadam roads. The ordinary macadam is known as water-bound macadam. The following table was compiled by Col. Wm. I. Sohier, of the Massachusetts Highway Commission, and gives some idea as to the comparative wearing qualities of gravel and macadam roads. The table also shows how greatly gravel and macadam roads may be improved by the addition of bitumen to their surface. Bituminous macadam roads proper will stand even heavier traffic than resurfaced water-bound macadam roads like Nos. 7 and 9 in the table.

Effects of Travel on Different Road Surfaces.[1]

Ref. No.	Character of road surface.	Character and amount of travel.			
		Light teams per day.	Heavy loads, 1 horse. Per day.	Heavy loads, 2 horses or more. Per day.	Automobiles per day.
1	*Gravel road:* a good one will wear reasonably well and be economical, with	50 to 75	25 to 30	10 to 12	100 to 150
2	It will need to be treated with oil, with..................	....	....	....	over 150
3	If fairly good, should be treated with one-half gallon of hot or cold heavy oil annually, with	75 to 100	30 to 50	30	500 to 700
4	*Water-bound macadam:* will stand with.................	100 to 150	175 to 200	60 to 80	[2]
5	A dust preventive will be serviceable with..............	....	....	....	50 to 100
6	Will stand, but stones wear some with......................	....	....	....	300 to 500
7	A hot-oil blanket coat will be economical with...........	250 to 300	75 to 100	25 to 30	[3]
8	Will crumble and perhaps fail with (if narrow-tired)........	100	50		
9	With a good coat of tar will stand with.................	30 to 50	25 to 30	10 to 15	1,800

Cost of Water-Bound Macadam Roads.

The cost of construction of certain water-bound macadam roads in the states of Illinois, Massachusetts, New York, and Maryland is given below.

In Illinois, where the country is comparatively flat, the cost is lower than in the other states where grading often is an important item in the construction. An estimate of the cost of

[1] Baker, op. cit. pp. 681-682.
[2] Not over 75 at high speed.
[3] 1,400 and more if the teams are fewer. Will stand at least 50 more trucks.

construction of one mile of macadam road 16 feet wide by 9 inches thick is given in the report of the Highway Commission of Illinois for 1910 to 1912.[1] This estimate is based upon the actual cost of roads built by the Commission between 1906 and 1912. It varies from $5,659 per mile, where stone had to be hauled by wagon for one-half mile, to $7,115 where the hauls averaged 3 miles. The cost of crushed stone is presumed to be $1.25 per cubic yard f.o.b. cars at destination.[2] The average cost of 220 miles of broken-stone roads built in Massachusetts, between 1894 and 1899, was $9,931.23 per mile. The cost of grading was about 18 per cent of the total.[3]

The average cost of twenty roads of this type in Maryland was $11,141 per mile. The expense of grading ran from 10 to 25 per cent of the total, with a maximum of 50 per cent.[4]

The costs of several thousand water-bound macadam roads are given in the report of the New York Highways Commission for 1911. The macadam on these roads is from 10 to 16 feet wide and 6 inches thick. Their cost ranges from $6,000 to $15,000 per mile and by far the greater number cost from $7,000 to $10,000 per mile. In New York grading was often an important item in the cost of construction.

BITUMINOUS MACADAM ROADS.[5]

Bituminous materials are used to prolong the life of macadam roads already built, or as binders in roads when they are first constructed.

In resurfacing a water-bound macadam road, it may be sprinkled with petroleum or treated with either a "paint coat" or "bitumen carpet." In treating with a "paint coat" the road is swept clean of dust, holes filled with new stone, and the surface covered with a thin coating of tar or petroleum, and later with coarse sand. The bitumen carpet is laid in the same way,

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[1] The Illinois Highway Commission, "Fourth report of the Illinois Highway Commission for the years 1910, 1911, 1912": 345 pp., with photographs and tables, Springfield, Ill. 1913: p. 81.

[2] Ibid, p. 81.

[3] Baker, op. cit. pp. 240, 241.

[4] The average was obtained by taking costs given for twenty of the roads mentioned in the report of the Maryland State Roads Commission for 1908-1911, pp. 30-31.

[5] This description is summarized from I. O. Baker's "Roads and Pavements," pp. 658-681.

but may consist of more than one layer of tar or asphalt separated by screenings or coarse sand.

Bituminous macadam roads, properly so-called, are constructed with a wearing course of broken stone and a binder of tar or asphalt. This tar or asphalt is put on either by the "penetration" or the "mixing" method. In construction by the "penetration" method the wearing course is first laid down and rolled and the bitumen then poured or sprayed over it in sufficient quantities to bind the surface together. In the "mixing" method the wearing course of stone with or without the addition of sand, shell, or slag, is first mixed with the bitumen, and the mixture is then placed over the foundation course and rolled down.

In a report issued recently by a special committee of the American Society of Civil Engineers, roads made by the penetration method have been designated "bituminous macadam" and those made by the mixing method "bituminous concrete."[1]

In addition, sandstones impregnated with asphalt have been crushed and used directly on roads as a rock-asphalt binder.

Cost of Bituminous Macadam Roads.

The average cost of applying a bituminous carpet to about 11 miles of road in the state of New York was 5·62 cents per square yard or $527.53 per mile of road 16 feet wide. The average cost of treating several hundred miles of road in Massachusetts in this manner in the four years 1908-1911 was 7·66 cents per square yard or $719.02 per mile of road 16 feet wide.

The cost of two roads of bituminous macadam constructed in Massachusetts by the penetration method averaged 74·66 cents per square yard or $7,007.15 per mile of 16-foot road. The average cost of 70 miles of road in New York was 28·53 cents per square yard or $2,678.02 per mile of 16-foot road. The latter cost, no doubt, does not include the cost of grading, preparing the foundation, etc., but only that of adding the bitumen. This supposition is based on the fact that the costs of bituminous macadam roads, as given by the reports of the

[1] "Good Roads" Vol. XLVII, No. 6, Feb. 6, 1915, pp. 51-52. The E. L. Powers Co., 150 Nassau St., New York City.

New York Highway Commission, generally average higher than that of water-bound macadam in that state. The cost of construction by the "mixing" method is higher than that by the "penetration" method.

CONCRETE ROADS.[1]

In a concrete road the foundation is prepared as in a macadam road and the protective covering is made of concrete laid in one or two courses. The materials used consist of coarse aggregate, fine aggregate, and Portland cement. The aggregate may consist of broken stone or of gravel and sand. Nearly 100 miles of concrete roads have been constructed in Wayne county, Michigan, where they have given good satisfaction. The roads there are built in 9, 12, and 16-foot widths and the concrete is generally 6 inches thick on the sides and 8 inches in the middle. They are finished off with 8-foot shoulders on either side, the inner 4 feet of which is gravel and the outer earth. Practically no excavation and grading is necessary on the roads in Wayne county as the country is very flat. The concrete is made of Portland cement, sand, and gravel in the proportion of 1:2:4 or thereabouts, the proportion varying with the fineness of the gravel. In other localities the methods of construction and the proportions of aggregate used have varied slightly from that outlined for Wayne county.

Cost of Concrete Roads.

The following data upon the cost of roads in Wayne county, Michigan, were obtained from the road commissioner, Mr. Edward M. Hines. The cost per mile varies from $11,000 to $16,000. Gravel costs about $1 per ton and sand 85 cents delivered at the railway siding nearest the road under construction. The freight rate averaged about 60 cents per ton so that the cost of gravel at the pit was about 40 cents and sand about 25 cents per ton. The cost of teams ranged from $5 to $7.50 per day; common labour $2.25 per day; skilled labour from $2.50 to $5 per day.

A well written paper by H. J. Kuelling upon the methods of constructing concrete roads, as practised in Milwaukee county, Wisconsin, is to be found in "Good Roads" Vol. XLVII, No. 6, Feb. 6, 1915, pp. 68-70. The E. L. Powers Co., 50 Nassau st., New York city.

CHAPTER III.

MATERIALS USED IN THE CONSTRUCTION OF ROADS.

The foundation and wearing courses of all country roads are made of soil and various types of rock, and under rocks are included sand, clay, and gravel, since they are rocks in an unconsolidated form.

Broken stone and gravel form the bulk of the protective covering in all country highways. The "binder" of a country road is either fine rock chips, gravel, bitumen, or Portland cement.

BROKEN STONE.

The following is a summary of: (1) the chief rock types, (2) the tests which have been made upon them to determine their relative merits in the making of broken-stone roads, and (3) the deductions which can be drawn from these tests and from the actual tests of traffic.

PRINCIPAL ROCK TYPES.

Rocks are the materials which make up the outer crust of the earth. They consist of minerals, that is, substances of definite chemical composition and crystalline form, or of amorphous substances with no such definite form and composition, or a combination of both. Rocks are classified according to their modes of origin, as igneous, sedimentary, and metamorphic.

Igneous rocks are those which from the way they occur in the earth's crust and from their mineralogical makeup are considered to have been formed by the cooling of molten masses. Sedimentary rocks are those made up of fragments of other rocks or precipitates from solution, which have been deposited in layers or beds, either under water or on land. Metamorphic rocks are those which have been altered from their original state by later accessions of heat and pressure. The main types of rock are given in the table below. No attempt has been made to include the rarer classes, since they form an insignificant portion of the crust and do not concern us in a study of road materials.

Igneous Rocks.

	Plutonic, intrusive (far below surface)	Intrusive (near the surface)	Volcanic, extrusive
	Texture, granitoid	Texture, porphyritic	Texture, glassy or amygdaloidal
Acid	Granite Syenite Monzonite	Quartz porphyry Trachyte porphyry Phonolite porphyry	Rhyolite Trachyte Phonolite
Intermediate	Diorite	Dacite porphyry Andesite porphyry Augite porphyrite	Dacite Andesite Augite andesite
Basic	Gabbro Peridotite Pyroxenite	Diabase	Basalt
		Rare types of dark, heavy rocks; Usually somewhat porphyritic.	

Sedimentary Rocks.

Unconsolidated.......... Sand and silt
Gravel
Clay
Marl

Consolidated............ Sandstone
Conglomerate
Shale
Limestone
Rare types formed from organic remains or as precipitates from solution: coal, gypsum, chert, some types of ores.

Metamorphic Rocks.

Foliated................	Gneiss Schist Slate
Unfoliated..............	Quartzite Marble Greywacke Certain altered igneous rocks.

Igneous Rocks.

Igneous rocks are either partly or wholly crystalline, that is, they are either made up entirely of crystalline particles or are partly of crystalline particles, these being bound together by an amorphous or glassy mass of material, which has something of the nature of a frozen slag. Again the whole mass may be amorphous, with practically no crystalline particles present.

Igneous rocks which are wholly crystalline are thought to have cooled and consolidated deep inside the crust of the earth, those which are partly crystalline close to the surface, and those which are amorphous or glassy on the surface.

Those which are entirely crystalline are called plutonic or deep seated intrusives, and their texture is known as granitoid. They generally occur in large bodies. To this class belong the granites, syenites, monzonites, diorites, and gabbros. The granitoid texture is generally well shown in the polished slabs or pillars of granite used for the decoration of buildings and in monuments. The component mineral crystals do not vary greatly in size and they interlock to form a sort of irregular mosaic.

Those in which very few or no distinct crystals can be seen with the naked eye are called volcanics or extrusives. Their texture is called glassy, or amygdaloidal, the last term being used when the rock mass contains small cavities. They generally occur in large irregular sheets or beds. To this class belong the rhyolites, trachytes, dacites, andesites, and basalts. Furnace slags generally have glassy and amygdaloidal textures. A subordinate group of the volcanic rocks are the volcanic breccias and tuffs. They consist of angular fragments of rock embedded in a groundmass or matrix of volcanic matter. The fragments are often quite distinctly different in makeup and composition from the rock matrix.

Igneous rocks, which are partly crystalline, form a connecting link between the plutonic and volcanic types. They have porphyritic structure, that is, one in which a number of well formed crystals lie embedded in a matrix of glassy matter. They occur in comparatively small bodies. In naming a rock of this type the word porphyry is generally added to the name of the volcanic rock corresponding to it in composition. Thus a porphyritic rock having the same composition as the andesite family is known as an andesite-porphyry. The porphyry corresponding to rhyolite, however, is known as quartz-porphyry. The term diabase is used for a rock which corresponds to basalt in composition, but has peculiar texture, in that the feldspar minerals in it are lath-shaped and that the feldspar crystals penetrate other crystals in the rock, generally the augites.

According to their mineralogical and chemical composition, igneous rocks are divided into acid and basic. Between the two is a group which we shall call intermediate.

The acid rocks contain more silica, either as silica in the form of quartz or combined in other minerals, especially feldspar, than the basic. They are lighter in colour, varying from white to grey, while the basic range from grey to black. The basic rocks are generally heavier than the acid. The intermediate rocks combine some of the characteristics of both and form a gradation between the two main types.

With some knowledge of the more common rock forming minerals and with the aid of a hand lens, one can generally easily distinguish the main classes of the coarser grained igneous rock in the field. The porphyritic and volcanic rocks are not always so easy to separate, however, and one can only draw broad distinctions, based on differences in colour and weight, or upon the ability to recognize one or two crystals. The study of thin sections of rocks under the microscope has made their accurate classification possible.

The more obvious distinctions which exist have given rise to terms in the stone trade such as granite, greenstone, porphyry, felsite, and trap, each one of which includes a number of rock types which vary greatly in their mineral composition. A popular classification of this kind is nevertheless useful, since the differences in colour and fineness of grain upon which it is based are accompanied to some extent by broad differences in physical characteristics, such as weight and toughness. In an attempt to classify rock types according to their road-making qualities, the writer has found it convenient to divide the igneous rocks into four types, granitic rocks, gabbroic rocks, felsites, and traps. The granitic rocks include the lighter coloured, coarse-grained or granitoid igneous rocks such as granites, syenites, monzonites, and quartz-diorites which, in the quarrying trade, are all classed together as granites. The gabbroic rocks include the darker, coarse-grained igneous rocks, the diorites proper, augite-diorites, gabbros, pyroxenites, and peridotites. They are often called greenstones because of their tendency to turn green upon alteration. Greenstone is not a good word to use since it is as often applied to banded metamorphic rocks which differ widely in their physical properties from massive igneous rocks. Under the term felsites are included the fine-grained, light-coloured volcanic and porphyritic rocks, rhyolites, trachytes, phonolites, and dacites, the quartz-porphyries, trachyte-porphyries, etc. The traps include fine-grained, dark volcanic rocks, the andesites, augite-andesites, basalts, and other more basic, black volcanic rocks, and the porphyritic equivalents of these rocks, including *diabase.*

The grouping has been made upon the basis both of texture—that is, coarseness or fineness of grain, granitoid rocks being considered coarse-grained and porphyritic and volcanic rocks fine-grained—and upon acidity and basicity, that is, practically upon the proportion of light and dark coloured minerals in the rocks.

Sedimentary Rocks.

The sedimentary rocks include both unconsolidated materials such as sand, gravel, clay, and marl, and hard rocks such as sandstones, conglomerates, shales, and limestones. Sandstones are solid rocks which were originally laid down as beds of sand, either in water or on land, and have later become hardened and bound together by pressure and cementing solutions. In a similar way conglomerates and shales are hard rocks derived from beds of gravel and clay, respectively. Limestones have been formed by the action of living organisms, such as corals, by the cementation of beds of shells, and by direct precipitation from sea water and from the water of salt lakes. Just as there are sandy clays which carry varying proportions of sand, so one finds rocks which grade all the way from sandstones to shales. Limestones also include varying amounts of sand and clay and may grade from siliceous limestones to calcareous sandstones or from argillaceous limestones to calcareous shales. Chert is a very dense, fine-grained form of silica which is often associated with limestone either as masses in the limestone or as separate layers interbedded with it.

Metamorphic Rocks.

The metamorphic rocks, may, for our purpose, be grouped as foliated and unfoliated. The foliated types have a banded appearance and generally part with more or less ease in directions parallel to the bands. Such are the gneisses, schists, and slates. Unfoliated varieties lack this banded appearance, but are generally completely crystalline. Quartzites, marbles, and greywackes are examples of unfoliated metamorphic rocks which were originally sedimentary rocks. Unfoliated rocks of igneous origin are often found with foliated rocks of the same composition.

Quartzites are derived from sandstones, marbles from limestones, greywackes from shaly sandstones.

METHODS OF TESTING ROCK MATERIALS FOR ROAD-MAKING.[1]

In discussing the types of rock best suited for the making of roads we shall in general refer to those making up the top

[1] Goldbeck, Albert T. and Jackson, Frank H., jun., "The physical testing of rock for road building": U. S. Department Agriculture, Office of Public Roads, Bulletin No. 44, 96 pp, illustrated with drawings and tables. For fuller details of laboratory practice see U.S. Dept. Agric., Bull No. 347, by Frank H. Jackson, 1916.

course of a water-bound macadam road. The stone in the foundation of a road need only be strong enough so that it will not crush when the roller passes over it. Almost any rock of average crushing strength will, therefore, do for the foundation. The wearing course, however, has to be hard enough to withstand the grinding of steel-tired wheels, and tough enough to withstand the impact of horses' hoofs, passing traffic, and the abrasion which takes place between fragments in the mass as it gives slightly under the weight of passing vehicles. It has to compact easily, and have the power to cement quickly into a solid mass.

In the bitumen-bound macadam road it is important that the rock have the first three qualities, but not the last. Hardness and toughness are really the only essentials in rock which is to be used with a bituminous binder.

Laboratory tests of various kinds have been devised to furnish some rapid means of judging of the value of a rock as a road metal. In these tests an attempt is made to approximate the conditions which will obtain in a road-bed under traffic. Since these conditions are variable and rock types also vary much, the tests are not an absolute measure of the quality of the rock for road purposes. A number of the tests are described below and the value of the different rock families as road metals is discussed farther on.

Road materials are tested for their hardness, toughness, resistance to abrasion, cementing value, absorption, and specific gravity. At the Office of Public Roads in Washington, D.C., a number of machines have been devised for comparing the cementing power and toughness of various rocks. The hardness and the mutual abrasion of pebbles, one against the other, are tested by machines which were designed and used in France many years ago.

Hardness.

A cylinder of the rock to be tested, 25 centimetres in diameter, is ground on a revolving disk under constant load of 1,250 grammes, with the aid of 30- to 40-mesh quartz sand. The hardness is expressed by an arbitrary number derived from the equation, *Hardness* $= 20 - \frac{1}{3} W$ where W is equal to the weight in grammes lost through 1,000 revolutions of the disk. This operation is an attempt to duplicate the grinding action of the steel tires of vehicles passing over a road.

Toughness.

In the toughness test, a cylinder of the rock to be tested, with its lower end standing on a firm foundation, is struck on the other end by a 2-kilogram hammer, falling 1 centimetre. The process is repeated, the height of the fall increasing by 1 centimetre each time, until the rock breaks. The number of blows struck is used as the measure of the toughness.

The impact of the hammer in this test represents the blows of horses' hoofs and of wagons passing over irregularities on the road.

An investigation carried on by Mr. Frank H. Jackson[1] of the Testing Division in the Office of Public Roads in Washington, has shown that the results obtained from the tests for hardness and toughness of several thousand rock samples bear the following relation to one another: the hardness of a rock is no criterion of the toughness, that is, a rock may be very hard and yet be brittle enough to break easily under impact. On the other hand, rocks which have a fair toughness value, say 12 or over in the scale of toughness, will also be quite hard. The test for toughness should, therefore, be a fairly reliable measure of the resistance of the rock to the wear of traffic.

In present-day practice, however, the cores tested for toughness are taken from only one block of stone in any given sample. And because nearly all rock bodies vary decidedly in character throughout their mass, the toughness of any one block very seldom represents an average of the whole rock body. The toughness test is not, therefore, as good a criterion of the value of the rock body sampled as it would be if it were possible to get an average of the toughness of a number of fragments representing the main variations in the mass of the deposit.

[1] "Relation between the properties of hardness and toughness on roadbuilding rock" by Prevost Hubbard and Frank H. Jackson, jun. Journ. Agric. Research, pp. 903-907, Washington, D.C., Feb. 7, 1916.

Abrasion.

In the abrasion test 50 particles of the rock, of nearly uniform size and weighing about 5 kilograms, are thrown back and forth in cylinders, set at an angle to a revolving axis. This axis revolves at the rate of 30 to 33 times per minute and 10,000 revolutions constitute the test.

The amount of substance which is worn off during the operation and passes through a one-sixteenth-inch mesh sieve is weighed and the percentage which this forms of 5 kilograms, the original weight of the material, is used to express the amount of wear or abrasion. An arbitrary factor the "French coefficient of wear" is also used. This is equivalent to 40 divided by the per cent of wear.

During the revolving of the cylinders the particles are thrown against each other and the ends of the cylinder, and are subject to both grinding and impact. This is, therefore, a test of both their hardness and toughness.

Cementing Value.

In the cementing value test, the rock is ground to a fine powder in a ball mill in the presence of water; it is then formed into cylindrical briquettes, under a pressure of 132 kilograms per square centimetre. These briquettes are dried in air for 20 hours and then in a hot-air bath at 200 degrees F. for 4 hours. They are then cooled for 20 minutes in a desiccator. After cooling, they are placed in a machine, where they are subject to the rhythmic fall of a 1 kilogram hammer through a distance of 1 centimetre. The number of blows struck before the cylinder breaks is used as a measure of the cementing value.

Investigation[1] has shown that a certain portion of the "dough" which comes out of the ball mill, has passed into colloidal solution. The colloidal bodies coagulate and form gelatinous membranes upon the undissolved rock particles, Upon being subject to the pressure incidental to briquetting, and to drying, the superfluous water is removed and the some-

[1] "The effect of water on rock powders" by Allerton S. Cushman, U. S. Dept. Agric. Bureau of Chemistry, Bulletin No. 92.

what plastic colloidal bodies are presumably squeezed into the voids and set there as a cement.

The process is thought to be duplicated in a road surface, where wet rolling and later on the wetting of the surface by rains, accompanied by the pressure and grinding action of traffic, cause the fine particles on the upper surface to dissolve partially and the solutions or colloidal bodies formed, to sink down into the binder, and to cement it into a solid mass. It has been found, however, that this test is not always a criterion of how the material will act under traffic. This may be due to the fact that traffic and weather conditions vary widely from place to place, while the conditions of the test are always uniform. Thus the quantity of dust and fine particles produced would be greater under heavy than light horse-drawn traffic, and hence the material available for the making of cement would be greater. Alternate spells of wet and hot dry weather, if they succeed each other rapidly, should aid cementation, while long periods of either the one or the other would cause the binder either to wash out of the road or to be blown out as a fine dust. Another variable quantity is the mechanical ease with which broken stone compacts, a factor not taken account of in the laboratory test. Thus trap rocks break into wedge shaped particles and presumably compact better than the coarser grained igneous rocks which break into rectangular particles.[1]

Absorption.

The amount of water that a rock can absorb is found by weighing a sample of it in air, immersing it in water and re-weighing, and finally weighing it after 4 hours' immersion. Let $Wa =$ weight of the specimen in air, $Ww =$ its weight in water just after immersion, and $W4 =$ its weight after 4 hours' immersion.

Then the weight of water absorbed by the rock after 4 hours is $W4 - Ww$.

[1] "Relation of mineral composition and rock structure to the physical properties of road materials" by E. C. E. Lord, U. S. Dept. Agric., Bull. 348, p. 13, Washington, D.C., 1916.

The weight of water displaced by the sample is $Wa - Ww$. $\frac{W4 - Ww}{Wa - Ww}$ is, therefore, equal to the volume of the rock which is occupied by water after absorption is complete, divided by the total volume, that is, it is a measure of the absorption per unit volume. If this be multiplied by 62·37, which is equal to the weight of a cubic foot of water in pounds, it will give the absorption in pounds per cubic foot of rock.

Absorption determines, to some extent, the effect which frost will have upon a rock mass. Most rocks which are good for road metal have a very low absorption.

Specific Gravity.

The specific gravity of rock is the proportion that its weight bears to that of an equal volume of water. Since the weight of a cubic foot of water is a known quantity, one has only to multiply the weight of a cubic foot of water, 62·37 pounds, by the specific gravity to find the weight of a cubic foot of rock. Specific gravity is determined by weighing a sample in air and immediately after in water.

If Wa is the weight in air and Ww is the weight in water, then $Wa - Ww =$ weight of a volume of water equal to the volume of the sample. The specific gravity is, therefore,

$$\frac{Wa}{Wa - Ww}.$$

COMPARISON OF THE VALUE OF DIFFERENT ROCKS IN ROAD BUILDING.

Satisfactory data as to the wearing qualities of the different classes of rock in roads, under actual traffic conditions, are not easy to obtain. Such data would have to be definite enough so that one would know the exact type of rock used, and would also have to include examples from many localities before general conclusions could be drawn from them. Data of this type would be further complicated by the factors of engineering, construction, and maintenance, which enter into the question fully as much as does the quality of material used.

Laboratory tests such as we have outlined above are, of course, not affected by these variable factors and, when properly performed, give comparative data as to the behaviour of different types of rock under the same conditions. In the Office of Public Roads, in Washington, such tests have been carefully carried on by trained men for a period covering many years. Materials from practically every state in the United States and from localities in Europe and Canada have been tested and compared there. In Bulletin 44, published by the Office of Public Roads, the results of tests upon 2,453 samples of road material from localities in the United States are given in tabular form. The tables are accompanied by a discussion of the value of the tests as applied to different rock types, and as compared to their qualities under actual traffic conditions. The conclusions drawn there are based upon the experience of a number of highway engineers, who have built roads in every section of the United States.

From a study of this bulletin and a discussion of the various problems, both with the engineers and men in charge of the tests in the laboratory, the writer has attempted to draw some general conclusions as to the varieties of stone for which it would be most profitable to explore in a survey of the road materials of Canada.

It was hoped that data could be compiled from the tables given which would make a direct comparison between the different rocks possible. It was found, however, that there were so many varieties present that it would be necessary to group related species together to save time and to avoid confusion. They were, therefore, grouped as traps, felsites, granitic rocks, gabbroic rocks, sandstones, shales, limestones, foliated and unfoliated metamorphic rocks.

Experience has shown that certain of these types practically never give satisfactory results in the roads, although they may occasionally show up well in the laboratory tests. Such are the sandstones, shales, the foliated metamorphic rocks (schists, gneisses, etc.), and the two main types of unfoliated metamorphic rocks of sedimentary origin, that is, quartzites and marbles. Instances are known in which certain varieties of these types, such as calcareous sandstones, have made good roads, but stone of the kinds mentioned are generally worthless, except for the making of foundations or where bitumen or Portland cement is used as a binder, for which purpose some of the harder varieties are often useful.

There remain then the traps, felsites, gabbroic rocks, granitic rocks, limestones, and unfoliated metamorphic rocks (other than quartzites and marbles). The latter class are generally altered igneous rocks, and the larger bodies of them in many cases derivatives from the traps. We shall, therefore, class them for convenience with the traps.

The unconsolidated sediments are in a class by themselves in that they do not enter into the construction of macadam roads properly so-called. Gravel is the important member of this group as it is used largely in the construction of gravel and concrete roads. It can, however, be best discussed apart from broken stone.

Laboratory tests are intended to determine the way a rock will stand up on the road, how it will cement or bind, how frost will affect it, and its comparative weight. The tests for wearing quality are hardness, toughness, and abrasion. Binding power is measured by the cementing tests, and comparative weight is determined by the test for specific gravity. As was indicated in the discussion of the tests themselves, the abrasion test is a measure of the combined hardness and toughness of a rock, and those rocks which are fairly high in the scale of toughness are also quite hard. In selecting any one test to judge the wearing quality of a rock by, it would seem advisable to go either by abrasion or by toughness.

The following table is taken from Bulletin 44 of the United States Office of Public Roads. It represents the relations of the laboratory measures of abrasion, toughness, and hardness to the results obtained under heavy, medium, and light wagon traffic on water-bound macadam roads. The lower line in the table is not given in the original table.

Suitable for	Results of tests. Per cent of wear.	Hardness.	Toughness.
Heavy traffic.............	2·5 or less	18 or over	19 or over
Medium "	2·5 to 5	14 to 18	14 to 19
Light "	5 to 8	10 to 14	8 to 14
Unsuitable for road-making.	8 and over	1 to 10	1 to 8

The toughness required by this table is perhaps a little higher than the corresponding percentage of wear. It is usual for instance for a stone of a toughness between 8 and 14 to have a wear of from 2·5 to 5, for one having a wear of 5 to 8 to have a toughness lower than 8 and so forth.

The following specifications for the stone used in water-bound and bitumen-bound macadam roads are of interest because they represent the result of more recent comparisons by engineers between laboratory tests and the wear of the stone in practice. They were adopted by the American Society of Municipal Improvements in October, 1914.

For a broken stone road without a bitumen binder the stone shall have a French coefficient of wear of not less than 7 (per cent wear of about 5·7) and its toughness shall not be less than 6.

For a broken stone road with bitumen binder the lower courses shall conform to the above specifications, but the stone in the top course shall have a French coefficient of wear of not less than 11 (per cent of wear of about 3·6) and a toughness of not less than 13·0.

In an attempt to compare the toughness of the five groups of rocks from the results given in the tables, the writer has plotted a series of five curves as shown in Figure 1. Ordinates are plotted upon four equally spaced lines representing the four divisions in the scale of toughness, as given in the table. Abscissae represent percentages of the total number of samples tested.

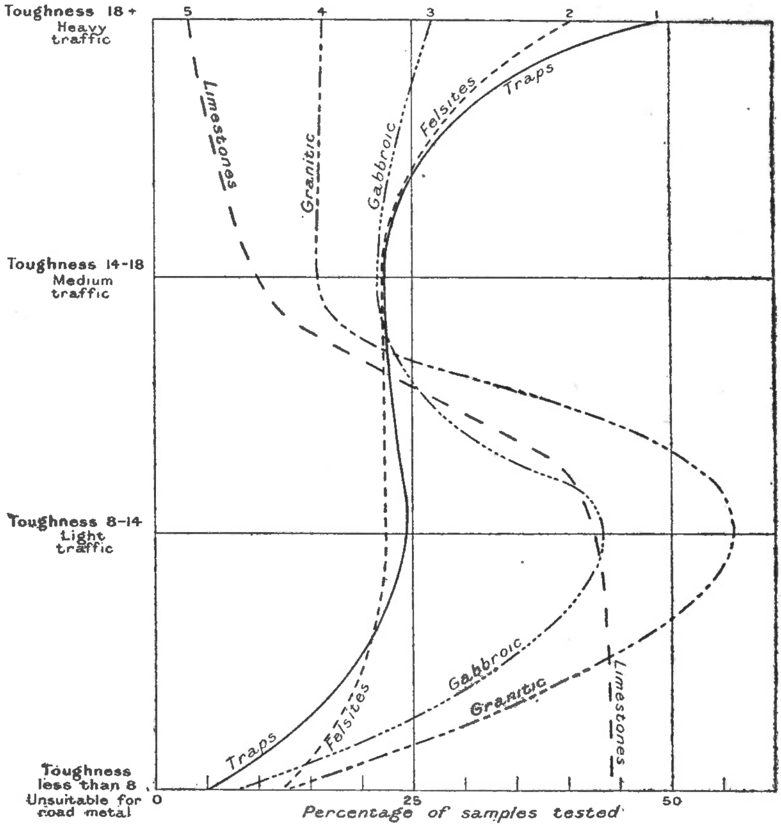

Figure 1. Curves showing the relative toughness of various groups of rocks and their consequent behaviour under traffic (based upon tests made in the laboratory of the Office of Public Roads, U.S. Department of Agriculture, Washington, D. C.).

Rock grouping used in the diagrams.

1. *Traps*, including the finer-grained dark coloured igneous rocks: andesite, augite andesite, basalt, diabase, basaltic and andesitic tuff, breccia, etc.
2. *Felsites*, including the finer-grained, light coloured igneous rocks: rhyolite, quartz-porphyry, trachyte, etc.
3. *Gabbroic rocks*, including the coarser-grained, dark coloured igneous rocks: diorite, augite-diorite, anorthosite, gabbro, peridotite, pyroxenite, etc.
4. *Granitic rocks*, including the coarser-grained, light coloured igneous rocks, granite, syenite, monzonite, granodiorite, quartz-diorite, etc.
5. *Limestones*, including all varieties of limestone and dolomite.

It will be seen that in their suitability to withstand the wear of heavy traffic, traps, felsites, gabbroic rocks, granitic rocks, and limestones range in the order named. Traps are the best; nearly 50 per cent of the samples of trap tested show extreme toughness, while only 3 per cent of the limestones tested are tough enough to withstand heavy traffic. In the

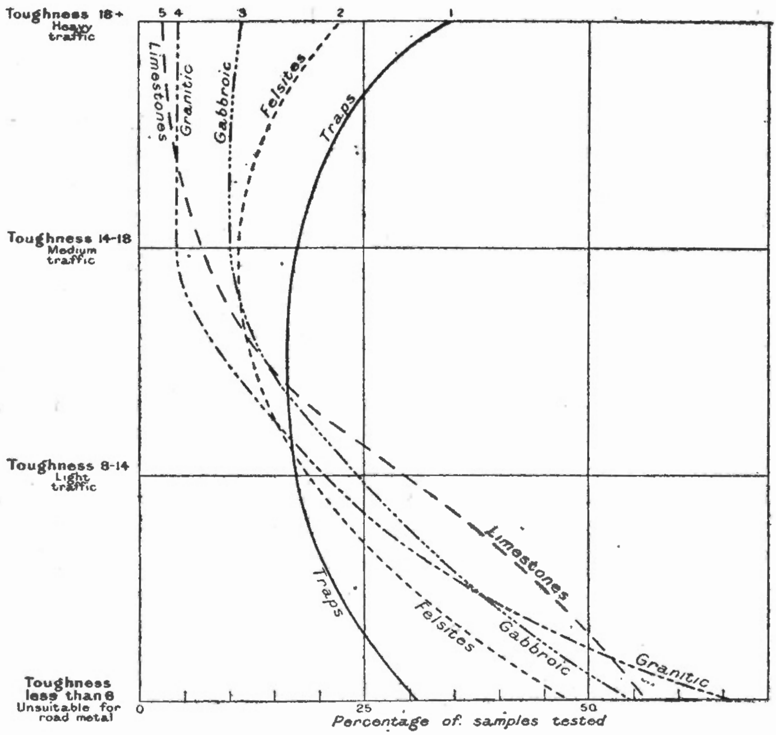

Figure 2. Curves showing the relative toughness and consequent behaviour under traffic of such rocks as have a cementing value high enough to permit of their use on macadam roads (based upon tests made in the laboratory of Office of Public Roads, U.S. Department of Agriculture, Washington, D.C.)

class unsuited to traffic, the order is reversed, limestone having the greatest percentage, 44, while the four classes of igneous rocks are bunched together between 5 and 13 per cent. A further study of the curves will show that the fine-grained igneous rocks have nearly the same toughness, and that over 70 per cent of them range over 14, that is, the lowest limit for medium horse-drawn traffic. The gabbroic and granitic rocks are also comparable, a slightly larger per cent of the gabbroic varieties showing great toughness. The percentage of very tough limestone is small, but over 40 per cent of the samples tested were tough enough to withstand light traffic and 20 per cent suitable for medium traffic. In these curves the cementing value was not taken into consideration.

In Figure 2 this has been done, as far as all samples having a cementing value of less than 25 were considered unsuitable.[1] The five classes of rocks are grouped in about the same relative way as in Figure 1, and this grouping may perhaps be taken as a fair representation of their relative values in the roads, with such qualifications as are given below.

Traps and Felsites.

Traps, even when their cementing value is below 25, generally bind well in the road. This is probably also true of the felsites. Trap and felsite are, therefore, far better road materials than is indicated by Figure 2. The binding property of trap and felsite is partly due to the wedge-shaped particles into which these rocks break; these particles assist mechanical compacting in the road surface.[2] The curve of toughness may be used with safety in judging of the value of trap and felsite as road-makers. Altered traps have a higher cementing value than the fresh rock, but highly altered trap is not as durable.

Gabbroic and Granitic Rocks.

The dark coloured igneous rocks of coarse texture are generally fair road-makers, while the light coloured or granitic ones are not. This is probably due to the ease with which the gabbroic rocks alter and their slightly higher toughness. Altered

[1] Goldbeck, Albert T., and Jackson, Frank H., jun., Op. cit. p. 29.
[2] Lord, E. C. E., Op. cit. p. 13.

rocks of both types have a higher cementing value than the fresh types. Figure 2 indicates that as a class the granitic rocks are not as suitable for the making of water-bound macadam roads as the limestones.

Limestones.

Limestones vary greatly in their composition and physical qualities. While limestones as a class make poor road materials, certain types rival the traps in excellence. The great majority of limestones have good cementing qualities, but are soft and do not wear well. A tough hard limestone can, therefore, almost always be depended on to give good service. This is especially true of cherty limestones. The following table is inserted to give some idea as to how the different varieties, in the main divisions we have outlined, compare. It is taken from a table compiled by Lord[1] which gives the average results of 3,000 tests.

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[1] Lord, Edwin, C. E., "Examination and classification of rocks for road-building": U.S. Department of Agriculture, Office of Public Roads, Bulletin No. 37, 28 pp.

Grouping used in this report.	Rock varieties.	Physical properties.				
		Per cent wear.	Tough-ness.	Hard-ness.	Cement-ing value.	Specific gravity.
Trap.......	Andesite.......	4·7	11	13·7	189	2·50
	Fresh basalt...	3·3	23	17·1	111	2·90
	Altered basalt..	5·3	17	15·6	239	2·75
	Fresh diabase..	2·0	30	18·2	49	3·00
	Altered diabase	2·5	24	17·5	156	2·95
Average....		3·6	21	16·4	149	2·82
Felsite.....	Rhyolite.......	3·7	20	17·8	48	2·60
Gabbroic rocks	Diorite........	2·9	21	18·1	41	2·90
	Augite-diorite..	2·8	19	17·7	55	2·98
	Gabbro........	2·8	16	17·9	29	3·00
	Peridotite.....	4	12	15·2	28	3.40
Average....		3·1	17	17·2	38	3·07
Granitic rocks.....	Granite.......	3·5	15	18·1	20	2·65
	Biotite-granite .	4·4	10	16·8	17	2·64
	Hornblende-granite......	2·6	21	18·3	30	2·76
	Augite-syenite..	2·6	10	18·4	24	2·80
Average....		3·3	14	17·9	23	2·71
Limestone..	Limestone.....	5·6	10	12·7	60	2·70
	Dolomite......	5·7	10	14·8	42	2·70
Average....		5·6	10	13·8	51	2·70

GRAVEL.

Gravel is used in the construction of gravel roads proper and of concrete roads.

ROAD GRAVEL.

The requisites for a good road gravel are primarily that the pebbles shall be hard and tough, and the whole capable of binding into a solid mass under the action of traffic. Hardness and toughness enable the gravel surface to withstand the grinding and pounding effect of traffic. The binding of the material into a solid mass reduces the grinding of the pebbles, one against the other, to a minimum, and stops rain water from percolating through the mass and softening the earth foundation below.

Wearing Quality of the Pebbles.

Both hardness and toughness vary largely according to the type of rock of which the pebbles are composed. The hardness and toughness of the various types of rock have been referred to in the discussion of broken-stone roads. In judging the quality of a gravel, from the viewpoint of its probable resistance to traffic, it is enough to know that pebbles composed of the igneous rocks—rhyolites, traps, granites, diabases, gabbros, etc.—and of quartzite, are in general much harder and tougher than those composed of limestones, sandstones, shales, or finely banded gneisses and schists. In many cases, however, a gravel containing 80 per cent and more of a fairly durable type of limestone will make an excellent road if the traffic is light. A gravel in which more than 30 per cent of the pebbles are of sandstones, shales, or very soft limestones will, in most cases, soon wear to dust under moderately heavy traffic.

Cementing Value.

The cementing values of gravel and of broken stone seem to be determined by two factors: the mechanical ease with which the mass compacts under the action of the roller or of traffic, and the intensity of the physical and chemical reactions which cause recementation to take place between its constituent particles.

The action of compacting carries with it a reduction in volume of the whole mass and an accompanying diminution of voids in the mass. Large pebbles are pressed together until they are in contact and small pebbles are squeezed into the voids between the larger. As the voids diminish there is an increased number of points of contact between particles within the mass.

A gravel in which the pebbles vary greatly in size will compact better than one in which they are about the same size, since the smaller pebbles occupy voids among the larger.

A gravel composed of angular pebbles will compact more readily than one in which the pebbles are rounded. For the firmness or rigidity of a road bed varies according to the relative ease with which individual particles within the mass change their position with respect to each other, under the strains imposed by moving vehicles; when the particles or pebbles are angular such movement is restrained by mutual interference to a greater degree than when they are rounded. Moreover, because a sphere has a smaller surface than any other shaped solid of equal volume, gravel in which the pebbles are approximately spherical will furnish less points of contact, and so will not cement as well as gravel in which the pebbles are angular. When the pebbles of a gravel break under the impact of traffic, the broken splinters often work down into voids below the surface and so help in binding the road.

The reactions which accompany cementation increase in intensity with the number of points of contact and also with the increase of pressure between particles. It has been proved by experiment that if a number of solid bodies are in contact under pressure, and moisture is present, there will be a tendency for solution to take place at the point of contact, where the particles are in a state of strain, and the resulting solutions will tend to precipitate at the point where such strain is not present. In a moist mass of gravel, great pressure is exerted on the pebbles by the roller at their point of contact, and this is later duplicated to some extent under the traffic. Cementation by colloids is probably affected by pressure in the same way as cementation by solutions, that is colloidal bodies are apt to form at the points where particles touch, and these plastic bodies are apt to move into the voids where the pressure is low and remain there to bind the pebbles together. This action accompanies mechanical compacting and it increases in intensity as compacting progresses because of the increased number of points of contact. In an ideal case of road construction compacting and chemical cementing go on together until all voids are filled and the gravel has been knit into a solid and impervious mass.

Many authorities believe that cementing power should have first consideration in judging of the desirability of gravel as a road-maker; this is because gravel as a rule has a low cementing power. Smooth round pebbles slide around more easily inside the mass than angular fragments of broken stone, they are less susceptible to solution, and hence to cementation.

Gravels in which a large proportion of the pebbles are made up of limestone, also rock containing iron oxide, or carrying clay, generally cement well. Too much clay is not desirable since it cracks in drying and becomes soft in wet weather. A road-making gravel should not contain more than 20 per cent of clay.

A large amount of quartz sand increases the proportion of material in the gravel which is insoluble, that is, furnishes no cementing solution, and sand wears to dust more readily than the coarser pebbles in the gravel; too much sand is, therefore, undesirable. It is considered advantageous to screen gravel and get rid of some of the sand when the material runs over 25 per cent fine sand. Pebbles over $2\frac{1}{2}$ inches in diameter should be eliminated, as they work up and form hard knobs in the road.

Two instructive tables appear in I. O. Baker's book on "Roads and Pavements" pages 156-157. One of these compares sieve and the other mineralogical analyses of twelve kinds of gravel from different parts of the United States. All of them have made satisfactory road material. In the sieve analysis the materials were sorted into eight sizes, from over 2 inches to less than one-fortieth of an inch, and the percentage of clay was measured by the amount of material left in suspension in water. If material not in suspension and smaller than one-quarter inch be considered as sand, the samples given in the tables range from 23 per cent to 73 per cent of sand, and nine out of the twelve are over 57 per cent. In all cases, however, where the percentage of sand was high, there was plenty of binding material present, either in the form of limestone or clay.

Several of the samples shown in the tables have high percentages of limestone, as much as 74 per cent in one case, and have, nevertheless, made good road materials.

To sum up: a good road gravel should contain a fairly large proportion of hard pebbles or of durable limestone pebbles to withstand the abrasion of the traffic; it should compact easily under the roller, and contain some form of binder to hold the mass together. The maximum amount of soft pebbles, that is sandstones, shales, and schists, can be put down at 50 per cent for very light traffic. Variation in the size of pebbles and angularity of form are desirable, since such material compacts easily. The amount of sand should not run over 60 per cent and of clay not over 20 per cent of the mass.

CONCRETE, GRAVEL, AND SAND.[1]

The building of concrete roads is undergoing rapid development and opinions differ as to the best types of gravel and sand which should be used in the making of concrete roads. There is a good deal of doubt also as to the relative merits of broken stone and gravel in concrete roads. Certain types of broken stone screenings make a concrete with higher resistance to compression than good sand and this is doubtlessly due to the angularity of the stone particles which interlock and tend to prevent movement among the particles to a greater extent than is the case when rounded sand grains are used. In actual practice stone screenings do not in all cases make stronger mortars than sand, however, and the factors which affect its strength are only partly understood and cannot be discussed here. In concrete roads the factor of abrasion must be considered as well as the strength of the concrete bond and a soft stone is, therefore, in all cases undesirable for road work.

[1] The summary given here is largely derived from the following publications.

Humphrey, R. L., and Jordan, William, jun., "Portland cement mortars and their constituent materials." Bull. U.S.G.S., No. 331, which gives the results of 25,000 tests upon twenty-two sands, twelve gravel, and twenty-five broken stone screenings.

Sabin, L. C., "Cement and concrete": 572 pp. McGraw Publishing Co., New York city.

Pamphlets published by the Universal Portland Cement Company, Chicago, Ill.

The strength of the concrete mass and its resistance to the abrasion of traffic are the two factors to consider in comparing the merits of various types of sand and gravel aggregates which are to be used in road building. The strength of concrete varies as the percentage of voids in the aggregate before it is mixed with the cement, the smaller the percentage of voids the greater the strength. The percentage of voids depends upon the proportions of different sizes of aggregates present. If the aggregate is all of one size, the percentage of voids is large independently of the size of the grains. The smallest volume of voids is obtained where the aggregate is uniformly graded, that is, where the proportions of the different sizes are about the same. On the other hand, if other conditions are equal a coarser sand gives a stronger mortar.

In actual practice the aggregates are divided into two classes, coarse and fine; and the coarse and fine aggregate and cement are mixed in such proportions as to give the most desirable results.

In the specifications adopted by the American Concrete Institute[1] for concrete highways, it is recommended that the coarse aggregate should be such as would pass a 1½-inch round opening and be retained in a screen having one-quarter-inch openings; and the fine, that which would pass when dry through a screen with one-quarter-inch openings. Not more than 20 per cent of the fine shall pass a screen having 50 meshes per linear inch and not more than 5 per cent a screen having 100 meshes to the linear inch. It is recommended that not over 40 per cent of the total aggregate used be fine and that not more than 5 parts of total aggregate be used to 1 of cement. Vegetable matter, loam, and clay are a source of weakness in concrete and the Institute recommends that not more than 3 per cent of the aggregate should consist of these impurities.

In order to resist abrasion the aggregate should be composed largely of hard and tough pebbles. Certain authorities specify that the coarse aggregate used, show a French coefficient of wear of

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[1] "Recommended practice and standard specifications for the construction of concrete roads and pavements": Reprinted by the Universal Portland Cement Company, Chicago, Ill., 1914, p. 619.

10 or over upon testing in the abrasion machine. If the proportion of hard igneous and metamorphic pebbles be high and that of shales, sandstone, and schists in the gravel be low, the gravel will resist abrasion. Shale and schist pebbles in the coarse aggregate not only lower the resistance of the gravel to abrasion, but they also affect the strength of the bond in the concrete.

BITUMEN.

The bitumens used for road purposes are mainly natural asphalt and tar. Natural asphalt is a dark brown, viscous to hard substance, consisting of carbon, hydrogen, varying percentages of oxygen, usually some nitrogen, as well as various impurities. It is found in various places, either mixed with earthy matter or impregnating limestone or sandstone. The most important locality is a lake on the island of Trinidad which supplied over 90 per cent of the world's production for many years.

Natural asphalt is usually fluxed with petroleum residuum to make it soft enough for use on the roads. Paraffin residuum, the end product obtained by distilling what is known as the paraffin petroleums, is useful as a flux for asphalt although it cannot be used by itself for road purposes, except as a dust preventive. Asphalt is considered the most serviceable road binder in use to-day.

Tar is a by-product formed in the manufacture of illuminating gas and of coke. Illuminating gas may be made from bituminous coal or from petroleum. The various tars are known as coal-gas tar, coke-oven tar, and water-gas tar. Of these coke-oven tar is the most suitable for the making of roads.

PART II.

DEPOSITS OF DIABASE ALONG THE NORTH SHORE OF LAKE HURON.

Part II.

Deposits of Diabase Along the North Shore of Lake Huron.

CHAPTER I.

INTRODUCTION.

OBJECT OF THE REPORT.

Within the last few years there has been a marked increase in the number of macadam roads built in the southern and more thickly settled portion of Ontario. This section is underlain by sedimentary rocks and very few deposits of good road-making stone are to be found within it. North of a line extending from Kingston to Georgian bay, however, the rocks are of igneous and metamorphic origin, and good road-stone can be obtained in certain localities. A number of railway lines connect the two areas, but railway freight rates are comparatively high, and the distribution of stone by rail from north to south is, therefore, limited.

The cost of transportion by water is lower than by rail, however, and stone occurring on navigable waters along the northern shore of Lake Huron can be transported to various ports on the Great Lakes in southern Ontario at a comparatively cheap rate. It is precisely on and near the shores of Lakes Erie and Ontario, and the St. Lawrence river that the population is thickest, and the largest number of roads are to be built. The existence of good road-making stone along the shore of Lake Huron is, therefore, of exceptional interest to road-builders in the province.

Work done by members of the Geological Survey many years ago showed that large areas of diabase rock existed along the north shore of Lake Huron, and on the nearby islands. Diabase is in general as good a type of stone as can be obtained for road-making purposes.

In order to discover what the extent and character of the deposits were, whether they could be quarried economically, and lay near navigable waters, the writer spent a few weeks in the summer of 1914 in examining certain diabase occurrences which were marked on the Geological Survey maps. The results were satisfactory in that several large deposits of diabase were found which could be developed economically and which lay so near to deep water that the loading of crushed stone into vessels of deep draught could take place within a few hundred feet of the quarry.

A quarry was visited, moreover, in active operation in a diabase deposit at Bruce Mines, which is capable of producing 1,200 tons of crushed rock per day, and from this quarry crushed stone is sold for road-making in Detroit and Cleveland.

This report and the map accompanying it do not include an account of all the trap localities in this region, but the report describes the more important deposits and the greater number of those which can be economically exploited for the southern Ontario market.

LOCATION.

The localities treated of lie on, or near, the north shore of Lake Huron between Sault Ste. Marie and a point opposite Little Current, near the east end of Manitoulin island.

Bruce Mines, some 30 odd miles east and south of Sault Ste Marie, was the most westerly point visited during the field work. High island, which lies directly north of Little Current and about 90 miles from Bruce Mines, was the farthest point to which the field work extended toward the east.

ACKNOWLEDGMENTS.

The writer wishes to thank Mr. S. B. Martin of the Martin International Trap Rock Company at Bruce Mines, and Mr. T. J. Foster of the Huron Trap Rock Company of Sault Ste.

Marie, for information regarding their quarries at Bruce Mines and St. Joseph islands, respectively. He is indebted to Mr. J. W. Norcross, Vice-President and Managing Director of the Canada Steamship Lines, Limited, for information regarding freight rates on the Great Lakes. The deposits of diabase shown on the accompanying map as occurring near Bruce Mines and Blind river, along the north shore, were mapped by Mr. W. H. Collins of the Geological Survey.

REFERENCES.

Further details regarding trap deposits within the area reported on, may be obtained from the Manitoulin sheet, Geological Survey of Canada, No. 605; a report upon the Bruce Mines Desbarats district, by E. D. Ingall, and Theo. Denis, Geol. Surv., Canada, Vol. XVI, pages 179-190A; and from maps and a report upon certain areas along the north shore which are being prepared by W. H. Collins of the Geological Survey. Information regarding the geology of the region is to be had from Museum Bulletin No. 8, Geol. Surv., Can., "The Huronian formations of Timiskaming region, Canada," by W. H. Collins.

Details regarding the depths of water in the north channel of Lake Huron and of other parts of Lakes Huron, Erie, and Ontario, are found on the Admiralty charts. These are sold by various firms throughout the country, a list of whom can be obtained from the Department of Marine and Fisheries, Ottawa.

TOPOGRAPHY.

From Great Cloche to St. Joseph islands the shore of Lake Huron trends slightly north of west. South of it a large body of water, the North channel, is almost entirely separated from the rest of the lake by Manitoulin, Cockburn, and Drummond islands. The North channel is about 90 miles long and 16 miles at its widest point. It ends at St. Joseph island to the west and is connected by several narrower channels and St. Mary river to Lake Superior. To the east it terminates at Great Cloche island. The northern shore is fairly even at its western end and only a few islands lie off-shore. From the mouth of

Serpent river eastward it becomes much more irregular and that end of the North channel contains an archipelago of small islands.

The islands in this region vary in size from numerous rocks of less than an acre in extent to Manitoulin which is 80 miles long from east to west. Along the north shore they consist of low rounded rock hills or ridges rising to elevations of 80 or 100 feet from the water, and seldom over that. They may consist of one mass of rock or of several rocky ridges and knobs connected by lower land underlain by gravel and sand. It is probable that many of them have grown by the forming of gravel bars between rocky islets (Plate I A). All stages of this growth were seen on the islands visited, from those in which the top of the gravel is just under the surface of the water to others which are made up of numerous rocky hills connected by gravel ridges and flats. On the latter, small bays, swamps, and lagoons are found which evidently represent portions of the lake partly or wholly enclosed during the growth of the island. Clara island is an example of such a composite of gravel bars and rocky hills. The hills themselves are invariably gently rounded and in places nearly flat on top and in very many cases steep sided. In some of the islands the steep hill-sides rise directly from the water and in such places there is often deep water close to shore (Plates I B, II). None of the small islands examined in the course of the field work contained permanent streams.

The topography along the main shore is of somewhat the same character as on the larger islands. Low ridges and irregular hills with rounded tops are separated by flat areas which are in places occupied by swamps or lakes. The hills rise from about 20 to 100 feet above the flat areas and over the waters of Lake Huron. Toward the east, opposite the end of Manitoulin island, they are comparatively rugged and ascend to higher elevations. The mean elevation of the surface of Lake Huron is 581 feet above the sea.

Depth of the North Channel. The depths of the water, where it exceeds 10 fathoms (60 feet), are shown on the accompanying map. Just north of Mississagi strait the lake is over 40 fathoms in depth, but the greater part of the North channel is under 20 fathoms. Shallow reaches occur off-shore toward the western end, notably at such places as the mouth of the Mississagi river. In the archipelago toward the eastern end the water is, in many instances, quite deep close into the islands and the main shore, and this is almost always so in places where steep cliffs rise abruptly from the water. Rocks are numerous, however, and some of them lie just below the surface.

INDUSTRIES.

The whole area is forested and a large proportion of the inhabitants are engaged in lumbering. Sawmills are in operation at Nestorville, Blind River, on St. John island, at Spanish Mills, and in other places. A number of fisheries have been established in this region. The fish are trapped in pond nets packed in ice, and shipped to eastern points. Farming is extensively carried on at certain points on the north shore, but the small islands off-shore are rocky and not in general fit for agriculture. Outside of the trap quarry at Bruce Mines there are no mines nor quarries in operation in the area visited during the course of this work. One or two other trap quarries are said to have been opened west of Bruce Mines. The whole region is at present sparsely inhabited.

GEOLOGY.

The north shore and immediately adjacent islands are underlain by rocks of Pre-Cambrian age. The large islands to the south, including Manitoulin, are formed of sedimentary rocks of Palæozoic age.

The Pre-Cambrian rocks consist of sediments, of igneous and of metamorphic rocks. The sediments are bedded, that is they lie in flat tabular masses, one bed overlying or overlapping the other. The igneous and metamorphic rocks are in more or less irregular masses, and form a basement upon which the sediments lie, but some of the igneous rocks are intruded or thrust into the sediments and lie inside the bedded rocks.

Earth movements have faulted, that is broken across the rock formation, and along these breaks movements have taken place so that the relative positions of the formation along these fault lines have been changed.

The sediments consist of conglomerates, quartzites, greywackes, and limestones, the quartzites and greywackes making up the bulk of their mass, while the limestones occur in very subordinate amounts.[1] The metamorphic rocks are either schists or gneisses and are simply sediments or igneous bodies which have lost their original texture through certain agencies, principally pressure and heat, and have become banded or laminated. The igneous rocks met with in our work were either red granites or dark coloured diabases.

Diabase.

Since this report is chiefly concerned with the deposits of diabase, their occurrence and the appearance of the rock will be discussed here in more detail. The diabases are in all cases intruded into the other rocks found within the region. They lie in thick tabular bodies along the original direction of the bedding planes of the sediments or less often at an angle to these planes.

When the diabase body lies along the bedding planes of the surrounding rocks it is called a sill. When the sedimentary beds dip at high angles the sills do also, and the diabase masses then stand up as narrow ridges over the surrounding rocks. Many of the islands visited were made up entirely of these diabase sills with small patches of the surrounding sediments clinging to their sides. Alfred, De Celles, and the end of Dewdney islands are parts of a sill standing nearly on end, with thin patches of quartzite, which had escaped erosion, clinging to its southern side. Smaller dykes of nearly the same character are found cutting the larger sills. They also contain veins of quartz and epidote. The veins tend to prevent the rock from breaking in quarrying operations. The sills are all more or

[1] Collins, W. H. The Huronian formations of Timiskaming region, Canada, Geol. Surv., Museum Bulletin No. 8.

less sheared and along some of the larger shearing planes they are much altered, but in any given sill the shear planes are fairly widely spaced through the larger part of the mass and the blocks between shear planes are not closely fissured. This tends to yield a tougher average rock product in quarrying, for the intensely altered rock found in certain of the shear zones is less tough and durable than the more solid part of the rock mass. The diabase is generally on higher ground than the adjacent rock formations and that is, of course, of advantage in quarrying operations.

The rock is grey to greyish-black, and generally of rather fine texture. In the largest part of the sills, however, it is coarse enough so that its crystalline character can be easily detected, and one can, on a freshly broken surface, distinguish white feldspars and black augites or hornblendes. In some places a coarse-grained black variety is found and again the rock mass will grade insensibly into rather coarse reddish material, or reddish patches sharply divided from the rest of the rock are seen inside the diabase. From work done on the diabase of the mainland by W. H. Collins[1], it is believed that these light coloured patches formed from the melting and assimilation of blocks of quartzite by the diabase when in a molten condition. The mineral composition of a specimen of the reddish variety, taken from Frechette island, is given in the table on page 47 and its physical character is described on page 68.

Microscopic Characters. Thin sections of diabase from seven localities were examined under the microscope. The rock consists essentially of plagioclase feldspar and augite. Many of the specimens contain quartz. The secondary minerals, hornblende and chlorite, are invariably present, epidote is also a common alteration product, calcite and sericite are not common but were seen in one or two of the sections examined. Titanite and magnetite are found in small amounts and biotite is present in one of the thin sections. The augites are partly or wholly altered to small fibrous individuals of secondary hornblende and the latter not only take up the space

[1] Oral communication.

once occupied by the augite, but project into the surrounding feldspar crystals and in places lie in veinlets cutting through them. Part of the feldspar is in places intergrown with quartz. The greater number of feldspars were too badly altered to determine their original character but are believed to belong to the varieties andesine and labradorite.

The texture of the rocks is diabasic, that is the feldspars and augite crystals, which make up the greater part of it, are intergrown, a lath-shaped feldspar for instance projecting into a stout augite crystal. The alteration into secondary hornblende, moreover, has produced a felt-like mass of hornblende crystals which lie in all directions through the rock and tie the adjacent original minerals still more firmly together. This texture has undoubtedly much to do with the toughness of diabase and its resistance to impact.

The following table gives the approximate proportions by weight of the minerals found in six of the sections examined. The specimen from Frechette island was taken from a reddish patch in the diabase mass. It contains high percentages of quartz and biotite but augite is absent. The texture is a granular mosaic, the crystals interlocking but not penetrating. One would expect less toughness in this variety.

Mineral Composition of Diabases near the North Shore of Lake Huron.

Locality.	Plagioclase feldspar.	Augite and secondary hornblende.	Biotite.	Quartz.	Magnetite.	Titanite.	Chlorite (secondary).	Epidote (secondary).	Calcite (secondary).	Sericite (secondary).	Total.
Near Roman Catholic graveyard, Blind River, Ont.	42·0	20·7	....	12·3	1·6	....	15·6	4·4	0·4	2·9	99·9
Scott island.......	30·7	43·9	....	....	....	0·4	22·2	0·5	0·8	1·6	100·1
North shore of Green island.....	17·4	45·3	....	....	....	1·6	10·6	21·8	3·2	....	99·9
Shoepack bay.....	30·2	37·4	....	1·8	....	....	27·8	1·2	1·6	....	100·0
High island, south shore...........	37·8	44·3	4·3	1·7	1·3	....	10·6	....	....	....	100·0
Frechette island, southeast point (acid variety)...	34·2	....	15·2	37·2	present	....	11·2	....	present	2·2	100·0

CHAPTER II.

CONDITIONS AFFECTING DEVELOPMENT.

QUARRYING.

The conditions which affect quarrying operations naturally differ in the various localities where diabase occurs in quantity. They are mentioned again in the separate description of each locality which is given in the next chapter.

The factors which make for economical quarrying are:

(1) The large quantities of diabase available.

(2) The small amount of waste material which will have to be handled.

(3) The general elevation of the diabase masses above the surrounding flat land and the level of the lake.

(4) The nearness of the diabase to deep water.

Single masses of diabase ranging from 800,000 to over 5,000,000 cubic yards were found in eight of the localities examined. In places like Shoepack bay (Plate III) there is more than 5,000,000 cubic yards. The quantities available allow of production on a large scale and the consequent lowering of the cost per ton crushed.

The amount of unsaleable material which will have to be handled will be comparatively small. This is due to the small amount of overburden present, the general uniformity in the quality of stone in any given mass, and the fact that in a crushed rock product practically none of the fine stone produced in blasting operations is lost.

In nearly all of the localities visited the amount of overburden on the diabase hills is present in insignificant amounts. Over a large proportion of the hills the rock outcrops at the surface and there is no overburden. The debris present is thin and pockety and can be easily removed. The diabase masses as a whole do not vary sufficiently in texture or composition to justify the belief that their physical properties will fluctuate very widely. That is, average durability of the stone in one section of, say, 50,000 cubic yards of a diabase sill is apt to be very nearly the same as that in another section of the same size taken at some distance away. Material of less toughness and durability is found in zones of intensely sheared rock and where the rock is much more acid than the average. But such occurrences form small percentages of any one given mass and can generally be avoided in quarrying or can be mixed in with the general product without seriously impairing its value. The loss which is incurred in quarrying for building stone through the unsaleable character of small fragments is practically eliminated in a quarry producing crushed rock, for even the fine dust can, in certain instances, be utilized. The absence of waste products means a great saving in the cost of excavating, separating, and transporting waste, which is, in many quarries, the principal item of expenditure.

The elevation of the diabase above the surrounding flat land and the lake level is generally sufficient to ensure a high quarry face and adequate drainage on the quarry floor. In a number of the localities visited the diabase lies in rather steep sided hills standing 40 to 100 feet above the nearby flats or the level of the lake (Plate I B). At Bruce Mines the quarry face is about 30 feet high and the floor 20 feet over the level of the lake; the diabase hill at Nestorville is steep sided and about 100 feet over the flat ground of the lake shore (Plate IV A).

The nearness of the material to deep water permits of the building of a crushing plant on the water's edge (Plates III, IV B) from where loading can be done directly into lake vessels, and ensures short hauls from the quarry faces to the plant and loading point. The elimination of long hauls and of reloading is, of course, of first rate importance.

The economical handling of the stone between the quarry face and loading point has been admirably carried out at Bruce Mines where crushing plant and quarry are both near the water's edge. At Shoepack bay and Green island crushing plants can be erected near deep water with good shelter for the boats loading and the quarry can be opened up within a few hundred feet of the crusher (Plate III). In places, like High and Scott islands, conditions are similar, but the shelter for vessels loading is not as good. Details of the harbourage at other localities are given in the next chapter.

The factors which will tend to increase the costs of quarrying in this region are:

(1) The toughness and hardness of the rock.

(2) The presence of veins of quartz and epidote.

(3) The absence of breaks or joint planes at regular intervals through the rock.

(4) The severity of the winter weather.

(5) Difficulties in erecting crushing plants.

In rock of the toughness of diabase the speed of drilling is low and the wear on drill bits, crushers, and other machine parts is great, so that they must be frequently renewed.

Veins of quartz and epidote increase the difficulties of breaking, for where such veins are abundant, drilling becomes difficult and large fragments of the rock mass tend to remain unshattered, and have to be broken separately by small shots. This has been the experience at Bruce Mines and at the Ontario Rock Company's quarry near Havelock.

The joint planes in the diabase masses are rather irregular in their occurrence, and are not evenly developed through any one mass. The absence of well-defined planes of weakness increases the difficulties of placing the bore-holes in blasting so as to get the greatest efficiency out of the charges. It also tends to develop a very rough quarry floor.

The severe winter weather must prove a great handicap, tying up quarrying operations and transportation from the islands and practically closing the market.

On certain of the islands the erection of a large crushing plant may involve some difficulty. On Scott, Dewdney, and Green islands, for instance, the diabase rises steeply from the water's edge (Plates I B, II) and the few low spots available are very rough, so that the erection of a plant may involve the expense of preliminary blasting of the rock and levelling of the ground upon the site chosen.

There is no water-power available on the islands visited and power will have to be generated by steam. Almost all of them can be reached by vessels of deep draught, and coal, machinery, and supplies should be obtainable at reasonable figures.

TRANSPORTATION.

The crushed stone can be transported conveniently by rail from Bruce Mines, Nestorville, Blind River, and perhaps Thessalon. It can be transported by water only, from all the island localities and from Shoepack bay. It is best transported by water also from Bruce Mines, Nestorville, and Thessalon. Rail connexions are by the Canadian Pacific railway via the Sault Ste. Marie, Sudbury line. By boat the material can be transported to over seventy ports in Ontario along the shores of Lakes Huron, Erie, and Ontario.

The main steamer routes are marked on the accompanying map. From a study of the Admiralty chart[1] it seems that the localities near the shore from High to Scott islands can be reached from the main channels by boats drawing up to 19 feet of water. The strait of Mississaga and False Detour channel are deep and should present no difficulties in affording short cuts to the main channels for vessels carrying rock from the islands. Information as to the mileage along the regular steamer routes is obtainable from the map. A general schedule of freight rates is given under the heading of "Costs".

Ports of Discharge. The ports of discharge, and rail connexions from them, are given on the map and details regarding wharfage, rail connexions, etc., are incorporated in the table which follows. The table has been compiled from data given in the "Port directory of the principal Canadian ports and harbours," issued by the Department of Marine and Fisheries, Ottawa, in 1913.

Boats drawing 20 feet of water can navigate through the Detroit river, but the present Welland canal has only 14 feet

[1] "Lake Huron—North Channel, Clapperton island to Meldrum point."

of water on the sills of the locks, and that places a limitation upon the size of vessels crossing from Lake Erie to Lake Ontario. The new Welland canal, which is now under construction, however, will, when completed, be 25 feet deep in the cuts and 30 feet on the sills of the locks. When the canal is completed, the cost of transportation of North Shore trap to points on Lake Ontario will, no doubt, be lowered.

The costs of transportation depend largely upon the rates at which boats can be loaded and discharged. With mechanical loading machines of the capacity used at Bruce Mines, the cost of loading is comparatively low. Certain ports in Ontario have mechanical unloading devices installed on some of their wharves. Self-loading and unloading boats, a few of which are in commission on the lakes, will be found very convenient and economical for the transport of rock between points where no machinery for loading or discharge is obtainable.

Ports on the Great Lakes in Ontario.

Port.	Wharves. Owners, etc.	Length in feet.	Depth of water in feet.	Rail connexions.	Remarks.
Algoma........			$14\frac{1}{2}$	East and west C.P.R.	
Amhertsburg	Dominion Government	1,500	21 for 800	East M.C.R.	Coaling station, steam derricks and clams for cargoes. Depth of anchorage $19\frac{1}{2}$ feet.
Bath	(1) (2)	280 225	17 12		Good anchorage, depth 15 to 40 feet.
Belleville			14	East and west C.P.R., G.T.R., and C.N.R., north G.T.R.	Channel to mouth river 1,000 × 200 to 450 feet.
Blind River	(1) Dominion Government (2) Eddy Lumber Company.		15	East and west C.P.R.	
Bowmanville	—	1,600	16	East and west C.P.R. and G.T.R.	Channel entrance 150 feet wide, 14 to 16 feet deep.
Brockville	(1) Water works (2) Jas. Bresnan (3) R. Bowie and Co. (4) Ault and Reynolds (5) C.P.R. (6) J. Smart Mfg. Co. (7) C. C. Coal Co. (8) Electric Light Works	240 70 160 218 650 400 100 100	12 to 16 12 to 16 12 to 16 	East and west G.T.R., north C.P.R., northwest C.N.R.	Railway siding to wharves 5 and 6, depth of anchorage 16 to 40 feet.

Ports on the Great Lakes in Ontario—Continued.

Port	Wharves.			Rail connexions.	Remarks.
	Owners, etc.	Length in feet.	Depth of water in feet.		
Bronte		(1) 900 (2) 730	9 to 14 4 to 10	East and west G.T.R.	
Bruce Mines	(1) Bruce Mines Copper Co. (2) Dominion Government (3) Martin International Trap Rock Co.	1,200	15 at end 15 at end 19	East and west C.P.R., inland for 14 miles, Bruce Mines and Algoma railway.	Good anchorage east MacKay island 18 feet deep.
Byng Inlet	(1) C.P.R. (2) Holland and Graves Lumber Co. (3) C. E. Begin	500 long by 500 wide. Short	20	North and south C.P.R.	C.P.R. wharf with two steel oval towers for unloading coal, capacity of 500 tons per hour. Harbour 1 mile long and 22 deep.
Cardinal	3 wharves		6 to 18	East and west G.T.R.	
Chatham	10 wharves			East and west C.P.R., G.T.R., Wabash R., and north and south Pere Marquette.	One wharf has a railway siding. Entrance from Lake St. Clair about 11 feet, river dredged to 13 feet.
Cobourg	3 piers	2,015 1,200 780	13 to 19	East and west G.T.R., C.N.R., C.P.R.	

Collingwood	(1) G.T.R. lumber wharf. (2) G.T.R. elevator wharf. (3) G.T.R. freight wharf. (4) Collingwood ship building Co. (5) Dominion Government (6) Collingwood Meal Co. (7) Charlton Sawmill Co.	500 1,100 1,200 400 650 800 2,500	16 22 22 22 22 16 16	Northwest and south G.T.R.	300 acres inside breakwater. Ship canal 220-1,000 feet wide. Extensive plants for building and repairing boats.
Cornwall	Wharf south of town; two other wharves.	1,170	14	East and west G.T.R., north Ottawa and New York R.	Connected to St. Lawrence river by Cornwall canal, depth on sills of locks 14 feet.
Courtright	One wharf	1,000	16	Southeast M.C.R., north and south Pere Marquette R.	3 railway sidings on wharf.
Cutler	Several		18 to 24	East and west C.P.R.	Anchorage 20 to 25 feet in bay.
Depot	(1) Elevator and coal (2) Cement (3) Package freight	1,200 800 1,200	18 to 20 18 to 20 21 to 35	East G.T.R.	Harbour $1\frac{1}{2} \times \frac{1}{4}$ mile with 30 feet of water and clay bottom; steam derrick and buckets for unloading and loading. Six railway spurs to wharf No. 1, two railway sidings to wharf No. 2, two railway sidings to wharf No. 3.
Deseronto	(1) Four wharves (2) 8 others		(1) 14 at high water (2) less than 14	East and west C.N.R.	Good anchorage. One coal hoist can unload four vessels drawing not over 12 feet.
French River	(1) Ontario dock (2) Boom Co. dock (3) Wabbs dock	275 120 120	10 to 16 18 to 22 6 to 12	North and south C.N.R.	Entrance somewhat dangerous.

Ports on the Great Lakes in Ontario—Continued.

Port.	Wharves.			Rail connexions.	Remarks.
	Owners, etc.	Length in feet.	Depth of water in feet.		
Gananoque	(1) Town Water works	144	9	East and west G.T.R.	
	(2) Taylor and Green Co.	375	11		
	(3) T. I. Railway cement	240	13		
	(4) T. I. Railway coal and lumber	134	9		Railway siding on wharf (4).
	(5) Town	60	10		
	(6) Gibson's coal	100	10		
	(7) Britton's coal and freight	200	12		
Goderich	South dock	1,400	19 to 20	Southeast C.P.R. and G.T.R.	Good anchorage.
	East dock	650	shallow		
	North dock	800	8 to 17½		
Gore bay, Manitoulin island	Merchants		15		Good anchorage 24 to 60 feet deep.
	Public		14		
	Farmers		12		
	Fish		12		
Hamilton	(1) Brown (wharfage on three sides)	550 (total for 3 sides)	16 to 18	Rail connexions in all directions, G.T.R., C.P.R., M.C.R.	Harbour 6 miles by 1 mile in 50 feet of water. Close to docks 13 to 21 feet.
	(2) McIlwraith	Total about 700 to 800	14		
	(3) McKay	Total over 500	14		
	(4) Hamilton Steamboat Co.	110			
	(5) Hamilton Ferry Co.				

	(6) Turbinia Steamship Co.				
	(7) Intercolonial Harvester Co.	600	16 to 18		Two sidings on wharf No. 7.
	(8) Hamilton Steel and Iron Co.	200	16		
Key	(1)		16	North and south C.N.R.	Good anchorage.
	(2)	500	24		
Kincardine	Several docks		11	South and southeast G.T.R.	Anchorage up to 15 feet.
Kingston	(1) Portsmouth pier	610	4 to 17	East and west G.T.R. Northeast and west C.N.R. North C.P.R.	Harbour several miles long, water 12 to 40 feet deep.
	(2) Penetentiary	270			
	(3) Clarks Malt House	320	21		
	(4) Rathbun	275	11 to 17		
	(5) Maitland street	120	17		
	(6) Waterworks	155	14 to 18		
	(7) Waterworks	220	27 to 29		
	(8) Moder's		20		
	(9) Kingston Locomotive Works	675	18		
	(10) Craig	145	10 to 11		
	(11) Grand Trunk freight	272	12 to 14		
	(12) Swift	400	12		
	(13) Ferry	214	9		
	(14) Richardson elevator	394	10½		
	(15) Mrs. Harty	304	8		
	(16) Crawford	196	8		
	(17) Montreal Transportation Co.	970	13½ to 17		
	(18) Montreal Transportation Co. Elevator wharf	645	10 to 16		
	(19) Kingston and Pembroke Railway Co.	400			Railway tracks on 19, 20, and 21.
	(20) Do.	925			
	(21) Do.	760			

Ports on the Great Lakes in Ontario—Continued.

Port.	Wharves. Owners, etc.	Length in feet.	Depth of water in feet.	Rail connexions.	Remarks.
Kingsville	East pier	800	16 for 200	East and west Pere Marquette.	Electric railway carries freight to Windsor.
Leamington	East pier	1,050	14 at end 11	East and west Pere Marquette R. and M.C.R.	
Lion's Head					Partial shelter for vessels of light draught.
Little Current	Several wharves			Northeast Algoma Eastern R.	Fair depth along wharves 22 feet in entrance channel.
Meaford	East and west wharves	Total 1,500	17 to 19	Southeast G.T.R.	Elevator on east wharf.
Midland	(1) Grand Trunk elevator		25	G.T.R. south and east	Spacious harbour, depth 25 to 100, one shoal 12 feet, good shelter, railway sidings on wharves Nos. 1, 2, 3, 7, 9, 12, 14, and one alongside of 11.
	(2) Aberdeen elevator		25		
	(3) Midland elevator		22		
	(4) Manly Chew mill		15 to 20		
	(5) Georgian Bay Shook Mills Co.		16 to 18		
	(6) N. L. Playfair mill		12 to 16		
	(7) Jas. Playfair and Co.'s mill		12 to 22		
	(8) Midland Towing and Wrecking Co.		22		
	(9) Midland Coal Dock Co.		22 to 24		
	(10) Government		14 to 22		

	(11) Government dock at end of G.T.R. dock		10 to 22		
	(12) G.T.R.		10 to 22		
	(13) Chew Bros. mill		22		
	(14) Steel Works and Canada Iron Furnace Co.		14 to 22		
Morrisburg	Old Wharf	400	12	East and west G.T.R.	
	New Wharf	600	12		
Napanee	Eleven wharves			East and west G.T.R. and C.N.R.	Entrance channel 11 feet deep.
Newcastle			9½ to 14	East and west C.P.R., G.T.R.	Entrance 14 feet deep.
Niagara-on-the-Lake	(1)	600	15	M.C.R. west.	Railway tracks along side wharf (1).
	(2)	100			
Owen Sound	(1) Town dock on east side	450	22	South and east C.P.R. and G.T.R.	Wharves Nos. 1 to 11 are on the east, and 12 to 20 on the west side of the harbour. Railway tracks near many of the wharves. Anchorage well sheltered in 36 feet of water and deeper.
	(2) Davis and Malone	200	22		
	(3) Northern Navigation Co.	400	22		
	(4) C.P.R.	1,900	22		
	(5) C.P.R. slip	1,200	22		
	(6) Keenan Bros.	400	22		
	(7) McQuay Tanning Co.	100	22		
	(8) Maitland and Rixon	200	22		
	(9) Imperial Cement Co.	600	22		
	(10) Carney Lumber Co.	1,000	22		
	(11) Keenan Bros. sawmill	100	22		
	(12) Town dock on west side	625	22		
	(13) J. R. McLauchlan	383	22		
	(14) G.T.R.	1,000	22		
	(15) N. A. Bent Chair Co.	316	22		
	(16) John Harrison and Sons	400	22		

Ports on the Great Lakes in Ontario—Continued.

Port.	Wharves.			Rail connexions.	Remarks.
	Owners, etc.	Length in feet.	Depth of water in feet.		
Owen Sound (*continued*)	(17) Sun Cement Co.	235	22		
	(18) Owen Sound Cement Co.	290	22		
	(19) John Harrison	800	22		
	(20) Grey and Bruce Cement Co.	370	22		
Parry Sound	(1) Parry Sound	901	15 to 18	North and south C.P.R. and C.N.R.	Railway siding on wharf (2).
	(2) C.N.R.	465	18 to 23	East G.T.R.	
	(3) Parry Sound shore wharf	83	11		
	(4) Rose Point	73	18 to 20		
	(5) Government	300	18		
	(6) Extensive lumber docks		15 to 20		
Penetanguishene	(1) Tannery	360	9 to 15	South G.T.R.	Anchorage sheltered, water 24 to 50 feet deep.
	(2) Penetanguishene dock, Government		7 to 13		
	(3)	1,250	9 to 13		
	(4) McGibbon	110	7½		
	(5) First Brook	500	7½		
	(6) Chas. Beck (5 wharves)		7 to 12		
Picton	Several small wharves			North C.N.R.	12 feet of water in harbour.
Point Edward	(1)	600	22	East G.T.R.	Railway sidings to all the wharves. Machinery for loading and unloading.
	(2) Iron ore dock	300	22		
	(3) Shed docks	1,500	22		
	(4) Elevator docks	600	22		

Port Burwell	Several wharves	16 and less		C.P.R. north	Entrance dredged to 20 feet
Port Colborne	(1) Government grain elevator (2) Dock from No. 1 to canal entrance	700	22 22	North and east G.T.R.	Sidings on both sides of the harbour, wharves (1) and (2) on west side.
Port Dalhousie	3 wharves, small			South and west G.T.R.	Depth of water in harbour 16 to 17 feet.
Port Dover	Two long piers partly used as wharves		11 to 12	Northeast and northwest G.T.R.	G.T.R. siding along side west pier.
Port Elgin	One wharf			South G.T.R.	Harbour of small size dredged to 14 feet.
Port Hope	Wharves total length $1\frac{1}{2}$ mile		16 for 1,600	East and west C.P.R., C.N.R., G.T.R., north G.T.R.	Harbour entrance between piers 120 feet wide and 14 feet deep.
Port McNicoll or Victoria, Simcoe county	C.P.R. elevator and other docks.		25	Southeast C.P.R.	Harbour a project of the C.P.R. Company.
Port Rowan	Landing pier		5–6	North G.T.R.	
Port Stanley	2 harbour piers Pere Marquette R. pier	783	17–19	North Pere Marquette R.	Harbour well sheltered.

Ports on the Great Lakes in Ontario—Continued.

Port.	Wharves.			Rail connexions.	Remarks.
	Owners, etc.	Length in feet.	Depth of water in feet.		
Prescott	(1) Prescott waterworks and electric plant	Total for 11 wharves ¾ mile	20	North C.P.R., east and west G.T.R.	Anchorage in 50 feet of water opposite the town.
	(2) J. P. Wiser		20		
	(3) Dominion lighthouse depot, 2 wharves		{20 18		
	(4) I. W. Plumb's coal wharf		20		
	(5) M. J. Buckly's coal wharf		20		
	(6) I. Purkiss coal and ferry wharf				
	(7) Grain elevator				
	(8) C.P.R.		24		
	(9) George Hall Coal Co.		24		
Rondeau	Two piers 250 feet apart		23	North Pere Marquette R.	Basin 600 feet × 400 varying from 8 to 20 feet. Two hoists on coal slip, railway siding alongside.
	Pere Marquette coal slip		23–26		
Sarnia	(1) G.T.R.	450	Aver. depth of Nos. 1 to 5 about 20	East G.T.R., south Pere Marquette R.	On wharf (1) are three steam power ore hoisting machines with total capacity of 1,000 tons per hour. On (2) platform, operated by steam, for unloading flour. On (3) hoists with unloading capacity of 800 tons per day. On (24) coal unloading
	(2) G.T.R. (open wharf)	340			
	(3) Northern Navigation Co., coal wharf	110			
	(4) Point Edward Elevator Co.	500			
	(5) Ontario Lumber Co.	1,400			
	(6) Sarnia Sawmills Co.	100	8–14		
	(7) W. A. Brown	400	8		

(8) John Garroch	262	13		machinery, capacity 400 tons per day. Railway tracks upon and alongside all but two or three of the wharves. Anchorage 9 to 30 feet, good shelter.
(9) Sutherland Wire Fence Co.	128	13		
(10) Loughead Hub and Spoke and Bent Goods Mfg. Co.	200	16		
(11) Reid Wrecking and Towing Co.	360	Aver. depth of Nos. 11-23 about 20		
(12)	200			
(13) Waterworks	225			
(14) King's Milling Co.	200			
(15) Gardner's wharf	65			
(16) Municipal Lochill St. wharf	60			
(17) Clark's wharf	235			
(18) Municipal wharf	100			
(19) G.T.R. passengers' wharf	1,100			
(20) G.T.R. and Northern Navigation Co's. joint terminal wharf	180			
(21) G.T.R. Elevator wharf	180			
(22) G.T.R. Lumber wharves	1,300			
(23) Sarnia Salt Co.	400			
(24) Imperial Oil Co.	400	16 to 25		
(25) Pere Marquette R. Co.	350	20		
(26) Standard Chain Mfg. Co.	152	18		

Ports on the Great Lakes in Ontario—Continued.

Port.	Wharves.			Rail Connexions.	Remarks.
	Owners, etc.	Length in feet.	Depth of water in feet.		
Sault Ste. Marie	(1) Dominion Government (2) Algoma Coal and Metal Co. (3) New Ontario Dock and Coal Co. (4) Lake Superior Corporation (a) Ferry dock (b) International dock (c) North and South docks (d) Commercial (e) Ore wharves (f) Sawmill wharves	100		East C.P.R., north Algoma Central and Hudson Bay	Slip 520 feet long by 75 feet wide alongside wharf (3). Facilities for handling machinery at wharf 4 (c); wharf 4 (d) has rail connexions and is available for general service. Canal approaches, one with 17 to 19 feet of water and one with 21 feet; depth of water on lock sills 20 feet, good anchorage in 21 to 40 feet of water.
Southampton	(1) G.T.R. pier wharf (2) Government wharf	1,100	12–13 12	South G.T.R.	(1) On No. 1 is a siding connecting with steam boat landing. Anchorage more or less exposed.
Thessalon	Two wharves		18–25	East and west C.P.R.	Good anchorage in 30 to 36 feet of water.
Tobermory	Two wharves in eastern arm			None	40 to 50 feet of water along shore in southwest arm.

Toronto	Total frontage on mainland of wharves is about 1 mile long with various slips between. Depth of water 14 to 20 feet. Berths for vessels up to length of 400 feet.			East, north, and west C.N.R., C.P.R., G.T.R.	Harbour well protected. Area of harbour 6¼ sq. miles, depth 14 to 25 feet; eastern entrance 20 feet of water between piers; western entrance 18 feet of water between piers. Harbour is being improved at present and information given here is incomplete. Two ship building companies. Sidings to a number of wharfs.
Trenton	5 wharves		14	East and west C.N.R., C.P.R., G.T.R., north and south C.N.R.	Railway siding to one wharf, steamer entrance 14 feet deep.
Wallaceburg	(1) Sydenham Glass Co. (2) McMairnie Bros. (3) Premier Electric Light Co. (4) Wallaceburg Cooperage Co. (5) Public wharf (6) Wallaceburg Sugar Co.	600 150 50 100 50	18 18 18 18 18 18	North and south Pere Marquette R.	Vessels can be safely moored along river banks. Nos. (1) and (6) have railway sidings. No. 6 is equipped with a McMyler clam operated by steam for unloading coal.
Walkerville	One wharf	800	26	South and east Pere Marquette east G.T.R. Wabash R.	Railway siding on wharf.

Ports on the Great Lakes in Ontario—Continued.

Port.	Wharves.			Rail connexions.	Remarks.
	Owners, etc.	Length in feet.	Depth of water in feet.		
Welland				West M.C.R. and Wabash R., north G.T.R. and Toronto, Hamilton, and Buffalo.	On the Welland canal.
Whitby	Two piers		11	East and west C.P.R., G.T.R., north G.T.R.	Entrance to basin 11 feet.
Wiarton	Crown Portland Cement Co. Other wharves	350	16	South G.T.R.	Anchorage in less than 60 feet over an area of 1½ by 1 mile.
Windsor	(1) G.T.R. (2) C.P.R. (3) M.C.R. (4) J. T. Hurley and Co. (5) Detroit Belle Isle and Windsor Ferry Co. (6) Dominion Government	600 700 500 250 300 484	25 25 19 20 17½	East G.T.R., C.P.R., M.C.R. and Wabash R. South and east Pere Marquette R.	Railway tracks on Nos. 1, 2, and 3.

COSTS AND PRICES.

Quarrying. The cost of quarrying and crushing stone varies so greatly with the different factors involved that general statements as to cost are not of great value. A number of the conditions which will affect the cost of operations along the north shore are referred to at the beginning of this chapter.

The cost of labour, fuel, and powder in quarrying and crushing trap at Bruce Mines was 23 cents per ton according to Mr. S. B. Martin, manager of the company operating there. That did not include interest upon the capital invested nor depreciation of the plant, which must be high in the case of a quarry with an equipment as extensive as that at Bruce Mines. The cost of power, which will probably have to be steam generated by coal, should be uniform for nearly all the larger deposits, and so should the cost of labour, machinery, and supplies, for practically all of them can be reached by the larger lake vessels. Prospective quarrymen would do well, however, to figure on a higher cost than that quoted for Bruce Mines.

Freight. The Managing Director of the Canada Steamship Lines, Limited, has kindly furnished the following statement regarding freight rates on crushed stone from Bruce Mines to various ports in Ontario. The writer asked for a general statement regarding rates between the points mentioned. Certain ports at increasing distances from Bruce Mines were specified in order to make the statement more concrete, and to give definite standards for comparison. The rates from other localities on the north shore would compare with those from Bruce Mines.

The rates given are figured on the assumption of the ship requiring 24 hours to load and 24 hours to discharge. The costs of loading and discharge vary largely according to the time taken. The statement follows:

"From Bruce Mines to	Owen Sound,	35 cents per gross ton.		
" " "	Windsor,	35	"	"
" " "	Rondeau Harbour,	45	"	"
" " "	Port Colborne,	45	"	"
" " "	Toronto,	$1	"	"
" " "	Kingston,	$1.15 to $1.20 per gross ton.		

These rates would all be free to the ship, the unloading and loading cost to be paid by shipper or consignee. With a modern loading plant, which could be built on the water front, having a bin capacity of from 2,000 to 3,000 tons, a vessel could no doubt be loaded in 3 hours. In other words, if you have the modern loading apparatus available, crushed rock can be handled at practically 5 cents per ton; on the other hand if the ship is compelled to load herself and use her own winches, it would probably run from 25 cents to 35 cents. The same rates would apply to unloading. If sufficient business could be secured the simplest plan and probably the cheapest method of handling this rock would be to carry in a self-unloading vessel, of which there are several on fresh water now. These vessels could land anywhere and discharge the cargo on the dock or into cars as the case might be, and would simplify the whole transportation proposition so far as rock is concerned."

The price charged for railway transportation from the lake ports is about 60 cents per ton for the first 100 miles; it is seldom under 40 cents per ton even for very short hauls. Freight by rail from Bruce Mines via Sudbury to Toronto costs $1.75 per ton.

Prices of the Stone. At Bruce Mines and St. Joseph island prices of from 80 cents to $1 per ton were obtained f.o.b. the quarry dock. Crushed diabase sells in Toronto at from $1.80 to $2.25 per ton.

QUALITY OF THE ROCK.

The diabase occurrences examined consisted in general of large masses in which the greater part of the rock is of nearly the same mineralogical make up. The masses vary in texture from dense material, in which few mineral crystals are visible, to a rock in which the crystalline character can be seen without the aid of a lens and the individual crystals average about one-twentieth of an inch in diameter. The samples from High island, Shoepack bay, Scott islands, and Blind River are representative of the type. Near shear zones the rock is occasionally very highly altered to the green minerals epidote and chlorite; in other places it varies locally to a reddish rock of less specific

Tests Made upon Samples of Diabase and Basalt from the North Shore of Lake Huron.

Locality.	Lithological character.			Physical properties.								Physical tests made by.
	Rock type.	Percentage of alteration products.		Toughness.	Hardness.	Per cent wear.	French co-efficient of wear.	Cementing value.	Specific gravity.	Weight per cubic foot in pounds.	Absorption in pounds per cubic foot.	
		Secondary hornblende and original augite.[1]	Chlorite, epidote, calcite, etc.									
High island, south shore	Altered diabase	44	11	23	....	2·5	16·0	72	2·945	183·4	0·0806	G. C. Parker, office of the Engineer of Highways, Toronto.
Frechette island, southeast point	Acid variety of diabase	....	13	15	....	3·3	12·0	67		171·5	0·077	G. C. Parker, office of the Engineer of Highways, Toronto.
Shoepack bay, north shore	Altered diabase	37	31	23	....	3·79	10·6	62	2·90	180·9	0·191	
Green island, north shore	Altered diabase	45	36	19	....	4·37	9·15	40		183·4	0·49	G. C. Parker, office of the Engineer of Highways, Toronto.
Scott island, north shore	Altered diabase	44	25·+	22	....	2·12	18·9	60	2·975	185·5	0·0934	
Blind River, near R. C. cemetery	Altered diabase	21	23	18	....	2·8	14·3	25		184·5	....	G. C. Parker, office of the Engineer of Highways, Toronto.
Thessalon, east of North Thessalon river	Basalt	?	not high	10	....	....	....	17	2·91	181·5	0·0	
Bruce Mines quarry	(1) Altered diabase (2) Altered diabase	....	....	27 20	18·3 18·7	2·8 2	14·2 20	100 excellent	2·9 2·9	180 ·184	0·116 0·25	Highway Laboratory, University of Michigan. Office of Public Roads, Washington, D.C. (?)
	(3)...........	....	....	18	19·1	3·00	13·3	41	3·01	188	0·10	Ohio State Highway Department.
	(4) Altered diabase	42	....	18	18·5	2·2	18·2	good	3·00	187	0·17	Office of Public Roads, Washington, D.C.
St. Joseph island	(1) Diabase	....	....	17	18·6	2·3	17·4	good	3·00	187	0·09	Geo. E. Stewart, Engineer U.S. War Dept. Sault Ste. Marie, Mich. Results furnished by T. J. Foster, Sault Ste. Marie.
Humbug point, north shore	(2) Highly altered diabase	high	high	9	18	2·5	15·8	good	2·9	181	0·18	Office of Public Roads, Washington, D.C.
Poole island	Highly altered diabase	high	high	10	17·3	....	....	excellent	2·85	178	0·86	Office of Public Roads, Washington, D.C.

[1] The amount of augite in the specimens examined is quite small and it was, therefore, calculated with the alteration products.

gravity or to dark coarser-grained types. The altered portions and the extreme varieties, whether of lighter colour or more coarse-grained and darker colour, form, except in places like Clara island, a small percentage of the whole diabasic mass.

The tests upon samples representing the main portion of the rock masses show a uniformly high toughness and low percentage of wear with fair to good cementing value.

Samples in which the toughness is lower than the average and the wear poor are highly altered rock or belong to the acidic variety. Even these give fairly good tests, as good and better than some of the limestones. Although the samples were collected from a very small part of any one mass, the general uniformity of the greater part of the mass and the small proportion of the less durable rock in it, justifies the belief that the average product of any one of the larger diabase sills will be both tough and highly resistant to wear. An exception must be made of an occurrence like that in Clara island, where a large proportion of the outcropping rock is of coarse texture. The results of the tests made are shown in the table on page 68. The table indicates that the percentage of wear varies partly according to the percentage of the secondary minerals chlorite, epidote, calcite, etc. That is, when the rock is highly altered to those minerals its resistance to abrasion is less than when fresh. On the other hand it is thought that alteration to secondary hornblende increases the toughness of the diabase up to a certain point.[1]

The sample from Frechette island in which the texture is a granular mosaic and not the penetrating diabasic texture of the other specimens is of lower toughness than the average. The basalt at Thessalon is also of lower toughness than the diabases. With these two exceptions the samples from all the localities, which were visited during the field work, show a high toughness and except where highly altered, a low percentage of wear. The quarries at St. Joseph and Poole island were not visited.

[1] W. C. E. Lord, Office of Public Roads, Washington, oral communication.

CHAPTER III.

DESCRIPTION OF OCCURRENCES OF DIABASE.

In this chapter a brief description is given of some of the localities visited in the course of the field work. A number of trap deposits along the north shore and on the islands were not visited, and some of the deposits which were examined are not described here, but it is thought that the places mentioned include the larger deposits which are so situated that they can be quarried economically and their product transported in lake vessels of deep draught.

All of the deposits mentioned, except those at Bruce Mines and St. Joseph island, are, at present, undeveloped. Of the undeveloped deposits those at Shoepack bay, on Green, Dewdney, Scott, and High islands, appear to the writer to present the most favourable opportunities for the starting of a crushed trap industry. The deposits are mentioned in the order of their comparative value, Shoepack bay being the best. They are described according to their geographic position from east to west beginning with High island and ending with the quarry on Poole island. A constant reference to the accompanying maps is advisable in reading this chapter.

The results of tests made upon samples of diabase collected at some of these localities and the microscopic description of the rocks so tested are given in the preceding chapter. They cannot be used to compare the quality of the various deposits, for no attempt was made to collect samples to represent an average of any given mass. It is probable that there is no very great difference in the quality of the rock in any two of the large diabase masses.

HIGH ISLAND.

This is a somewhat round island rising about 175 feet out of the water. It lies some 24 miles east of Spanish Mills and 6 miles north of Little Current on Manitoulin island. The diabase, of which, except for one or two outcrops on the southern side, this island is wholly composed, rises steeply from the water on all sides but the southern. On the southeastern side there is a flat area about 30 feet above the water upon which a crushing plant and other buildings can be erected. The water off the east shore appears to be fairly deep and toward its southeastern end is protected from east and west winds. It is also partially protected from north winds by the proximity of the main shore. The island offers a good prospective quarry site, although difficulties are apt to arise because of excessively high faces which may necessitate the working of the diabase in successive terraces. The petrographic and physical character of the sample of diabase collected from this island is described on pages 47 and 68.

FRECHETTE ISLAND.

Frechette island lies some 8 miles east of Spanish Mills and less than one mile from the mainland. It is roughly triangular, nearly a mile across its eastern end, and a little over one mile in length. The northern and part of the northeastern side of the island have an abrupt rocky shore which rises to a flat topped plateau 20 to 40 feet over the water. The southern and eastern ends are decidedly flat and rarely rise 20 feet above the level of the lake. In the middle there is a lake lying east and west through nearly the whole length of the island, which is rock-rimmed on at least three sides.

With the exception of narrow strips of quartzite on the northern side, the island is composed of diabase. The specimen collected was from an acid variation of the diabase covering a small area on the southeastern point. The mass of diabase on the island is of the same character as the average rock on High island, and the specimen described on page 47 is not an average of the diabase on the island.

A 30-foot quarry face can be developed above water level along part of the northern half of the island, but the southern half is too flat and low for the development of more than 10 to 15-foot faces. The supply of diabase is large, and enough to justify the erection of a small crushing plant. While other and larger deposits such as that at Green island and Shoepack bay are available, however, it is not likely that this deposit will be worked.

SHOEPACK BAY.

South of the mouth of Spanish river a long projection runs into the lake from the mainland in the form of an L with the lower end pointing south. Inside the L is an almost land-locked harbour known as Shoepack bay (Plate III). The south end of the L is separated from Aird island at Spanish Mills by a deep water passage which is not over 300 feet wide. The north-south prong of this L and part of the east-west portion are composed of diabase rising steeply out of the water to a height of 60 to 80 feet. On the north side of Shoepack bay is a flat area which passes across the peninsula from the north to its south side, the land being only about 400 feet wide at this place. This would form an excellent site for a quarry and crushing plant. The flat is large enough to accommodate a fair-sized plant, and a face at least 50 feet high can easily be developed in the nearby hills. The peninsula surrounding Shoepack bay contains almost unlimited quantities of trap and is one of the best looking prospects examined along the north shore. The character and physical properties of a sample of diabase collected from this island are described on pages 47 and 68.

There is a deep wide passage up the bay from Spanish Mills to a small wharf at the south end of the flat mentioned above. Just west of it is a perfectly sheltered harbour with anchorage in 24 to 30 feet of water.

GREEN ISLAND.

Green island lies between Spanish Mills and Brennan harbour at the mouth of Spanish river. The island is about 1½ miles long and its greatest width is one-quarter mile to more than one-half mile. The sides rise sharply out of the water to an irregular plateau which is from 40 to 70 feet above the lake (Plates I B, II). There are only one or two places along the shores where the hills are not so steep, and in searching for a position for a crushing plant only one place was found where an area of about an acre was flat enough for the erection of the necessary buildings. The steep-sided island is surrounded by fairly deep water on all sides except off part of the northwest shore.

The island is a mass of from fine porphyritic to medium-grained holocrystalline diabase. A thin tabular body of quartzite is found on the northern side of the southwest point of the island, but it forms a very small portion of the mass. The rock is massive throughout, that is at none of the points examined were there large areas of closely fractured or foliated rock.

This island contains an enormous tonnage of trap and the topography ensures the development of a face of 40 feet or more at practically any part of the island with a quarry floor above water level and, therefore, well drained. The best available site for a crushing plant and other quarry buildings is on the southeast side of the island. On that side there is a small cove not far from its northeastern end, and north of a larger bay. Southwest of this cove is a small triangular flat about 200 feet along shore and 200 feet deep, which might serve as location for a plant. About 20 feet above it is a terrace on which other necessary quarry buildings may be erected. The water off this place appears to be fairly deep and it is well sheltered from heavy seas. It would pay to sound the water off-shore, however, before building a crusher. On the northwest side there is al arge flat sandspit which affords more room for buildings. The water is very shallow, for several hundred feet out from the spit, and the lack of deep water nearby offsets any other advantages the place may possess as a site for a quarry and crushing plant.

This island contains one of the most promising of the trap deposits which were examined. The petrographic and physical characters of a sample of diabase collected on its north shore are described on pages 47 and 68.

ISLANDS NORTH AND WEST OF AIRD ISLAND.

The long string of islands lying between Klotz and Green islands on the north side of Aird are apparently all formed of diabase, quite possibly part of one sill. They are narrow and steep sided and rise from 20 to 80 feet over the water. A traverse was made across Jackson (Otter) and partly across Shanly, the two largest of the group, and only diabase was seen on them. Between them and Aird island is a well sheltered channel several miles long with an anchorage of 18 to 35 feet of water.

Hills of diabase 30 to 50 feet high are found on the extreme northwesterly point of Aird and on the northwest portion of Klotz islands. On Klotz there are several hills containing from 50,000 to 100,000 cubic yards each. The rest of the island is underlain by drift and red cross-bedded quartzites. Aiken island, west of Klotz, contains several areas of diabase, but quartzite occurs in larger amounts. The northeastern half of this island is all diabase.

DEWDNEY ISLAND.

Dewdney island lies immediately southwest of John island, one of the larger islands along the north coast. The two are separated by a channel 600 to 1,500 feet wide. Dewdney consists of a long ridge of rock with the usual broadly rounded top. The rocks rise steeply from the water's edge over practically all of the island. The top of the ridge is 40 to 60 feet high over the western half of the island; the eastern half rises to perhaps 80 or 100 feet above the lake.

For one mile the western half appears to be composed entirely of diabase with the exception of a few small patches of quartzite on the south side. At the eastern end where the island widens out it appears from a traverse made across it that it is wholly underlain by quartzite. There are several million cubic yards of trap in the western end of the island. There is no favourable site for a crushing plant except near a small bay on the north shore south of the west end of John island. Between Dewdney and Gowan islands, is a well sheltered harbour with over 25 feet of water. The entrance is from the west and is 20 feet deep just south of Gowan island.

DE CELLES AND ALFRED ISLANDS.

A long narrow ridge of diabase forms the backbone of De Celles island and practically all of Alfred island. The narrow channel between the islands forms a break in this ridge and at the west end of De Celles another channel a few hundred feet wide separates the trap ridge from a small hill of diabase on David island.

On De Celles island the sill of diabase is about 200 feet thick. It has intruded along the bedding planes of the quartzite but in places cuts across the beds, generally at a low angle but occasionally nearly at right angles. In places, smaller dykes from the igneous mass, a few feet wide, penetrate the quartzite. The ridge of diabase on De Celles stands 30 to 60 feet over the water and a strip of quartzite 100 feet wide lies to the south of it. To the north in the middle of the island there is a flat drift-covered land several hundred feet wide which is protected by diabase outcrops on the north shore. There is from 250,000 to 400,000 cubic yards of solid trap available on De Celles island above water level. This can be quarried to advantage from the north side. On Alfred there is less rock and the island is narrow with steep sides.

SCOTT ISLAND.

Scott island lies about 2 miles southeast of Turnbull. It is roughly circular or oval in shape, and about 400 yards across from north to south and 500 yards east to west, and is one huge mass of diabase jutting out of the lake. Along its middle there is a ridge about 100 feet above the water. Outside of a strip of quartzite approximately 100 by 30 feet, which was seen at its southeastern corner, and a few dykes of aplite the island is made up of solid diabase.

There is deep water on the south side of the island and a site for a crushing plant, but no protection for boats loading. On the north side the shore is partially protected from north and east winds by a reef of rocks about 400 feet off-shore to the north, and partially sunken reefs to the east. The channel so formed is about 21 feet deep, 200 feet out from shore, and from 10 to

18 deep at 60 feet from shore. On this side there is, however, only one place on which a crushing plant can be erected and this is about 150 by 100 feet; all the rest of the north side along the protected channel is very rough and steep.

According to an approximate calculation there is over 2,000,000 cubic yards of trap above water level on the island. The petrographic and physical characters of a sample collected from the north side of this island are described on pages 47 and 68.

CLARA ISLAND.

Clara island is 2 miles south of Algoma on the north shore of Lake Huron. This island is of more interest geologically than as a quarrying undertaking. It is one of the composite islands formed by the linking of several rocky islets by wave-formed deposits so that the shore has an irregular outline. Its northern half is apparently underlain by a diabase mass or by isolated patches of diabase with intervening gravel and sand deposits; on the southern half outcrops of quartzite predominate. The quartzite strikes from northeast to east and dips from 45 to 70 degrees in a southerly direction; on the northwesterly point there is a patch of quartzite striking roughly east and west and dipping 33 degrees to the north. An outcrop of diabase occurs on the southeasterly point.

The diabase becomes very coarse in several places on this island. The coarse variety is made up of feldspar and hornblende, probably secondary after augite. The hornblendes are in places 1½ inches in length and arranged in star-shaped clusters. Two-thirds of the coarse rock is in places made up of feldspar. The rock varies in character over short distances. The quartzites are thin-bedded to massive, of a sugary texture, and in places micaceous. On the north shore a strong set of joints strike 65 degrees (magnetic) and dip 75 degrees to north; they are accompanied by cross joints at right angles and by irregular breaks cutting at all angles. Aplite dykes are intruded along the joints.

Gravel beaches are found along the shores and as ridges inland, near the shore, the highest seen lying in the middle of the island at an elevation of about 30 feet over the water. These beaches make up a large part of this island. The gravel is made up of hard pebbles of the Huronian sediments; of diabase, granite, etc.; they are sub-angular to rounded. Sand bars are also present. The middle of the island is strewn with large boulders 3 to 6 feet in diameter, evidently of glacial origin.

The deposits of diabase are small, never over a few hundred feet long and usually not over 15 feet above water. The best hill is on the northwest end of the island overlooking a little bay. This is 30 feet high within 100 feet of the water, about 200 feet long, and perhaps 100 feet wide. A large part of the stone exposed is too coarse for first-class road work. The shore is shallow near the northwest end and here there is not over 10 feet of water for 200 feet and more out. Big boats cannot, therefore, get near it. This island is not a favourable locality for quarrying and shipping diabase.

ISLANDS NEAR CLARA ISLAND.

Certain small islands near Clara contain diabase, all of them in small quantity. The ones visited were Struthers, Turnbull, and Bassett. Loughlin and Ramsey were also examined but no diabase was seen on them.

Struthers Island.

This island is a small body of rock and gravel situated about one-quarter of a mile west of Clara island. It stands about 30 feet above the water at the highest points which are small hillocks of rock, or in the middle of the island ridges of gravel and boulders. The rock outcrops consist entirely of fine to medium-grained holocrystalline diabase containing red feldspars and varying in acidity. On the south side joint planes strike 145 degrees and dip 75 degrees east; others strike 195 degrees and dip 65 degrees west.

The diabase is in small hills containing about 25,000 cubic yards. The whole amount visible on the island is not over 100,000 cubic yards. Deposits of gravel lie among the hills.

Soundings off its south shore gave from 15 to 24 feet within 150 feet of shore and 6 to 13 feet within 80 feet.

Turnbull and Bassett Islands.

These two islands are separated by a passage 30 feet wide. Turnbull is mostly quartzite with occasional intrusions of diabase on the south side. On its north side is a hill of diabase which holds about 25,000 cubic yards. Beds of quartzite under the diabase strike 85 degrees and dip 55 degrees south. Bassett island, nearby, is composed of diabase on its northern side. The stone extends from the water's edge to an elevation of about 70 feet, but the diabase is not more than about 6 yards wide, the southern half of the island being quartzite of the same dip and strike as on Turnbull. Numerous small islands west of Turnbull contain diabase, but are very low and small. The diabase on Bassett and Turnbull might be worked on a small scale.

BLIND RIVER.

A number of low hills of trap are found at the town of Blind River and a band of trap extends for several miles to the east of it. The trap occurrences in this neighbourhood are not favourably situated for transportation by water and no time was spent in their examination. The sample described on pages 47 and 68 was collected on a hill just north of the Roman Catholic cemetery, less than one-quarter mile north of town and east of the Blind river.

THESSALON.

A dense black basalt underlies a part of the town of Thessalon. It occurs in flat-topped hills from 10 to 15 feet above the water. The basalt is not as good road material as the diabase and in the neighbourhood of the harbour the basalt hills are too low for effective quarrying operations. The depth of water at the two wharves in the harbour is from 18 to 25 feet. The rock belongs to an older formation than the numerous diabase occurrences described in this report. Its physical characters are described on page 68.

NESTORVILLE.

At Nestorville, about 4 miles west of the town of Thessalon, there are extensive outcrops of diabase. A hill just east of the sawmill is 100 feet high, and contains about 800,000 cubic yards of solid trap (Plate IV A). This hill forms one end of a ridge which apparently extends eastward along the shore with interruptions for one-half mile or more. North of this and of the Canadian Pacific Railway track are other hills of trap of the same character and appearance, and many million cubic feet of diabase is available in this locality. The base of the diabase hill east of the sawmill is within 300 feet of the water's edge, and about one-half mile from the end of the lumber companies private pier, where from 16 to 18 feet of water is maintained.

The diabase is fine-grained holocrystalline and in places inclined to be rather acid. It does not differ essentially from the material found in other places along the shore and on the islands.

QUARRY AT BRUCE MINES.

Location. A large quarry in diabase is in operation at the old Bruce copper mines about one-half mile east of the town of Bruce, Ontario, on the north shore of Lake Huron, and 30 miles or more east of Sault Ste. Marie. The crushing plant lies at the water's edge and the quarry is directly behind it (Plate IV B). The quarry and crushing plant are owned and operated by the Martin International Trap Rock Company, whose office is at Bruce Mines. The quarry has been in operation for a number of years and was taken over by the present company in the beginning of 1913.

The company owns 1,057 acres at the quarry and to the northeast of it. The quarry lies upon the eastern end of a ridge running north of west from the shore for at least 400 yards. This is the only part of the property which has been developed so far.

Topography and Geology. The diabase lies in ridges with lower land between. The top of the ridge on which the quarry is situated is about 50 feet above water level and 30 feet over the irregular floor of the quarry. The ridge is approximately

150 feet wide on its flat top and about 350 feet at the base. The other ridges at some distance from it were not examined.

On the ridge itself there is little overburden and the diabase appears everywhere at the surface with some small pockets of soil lying in hollows on it. In the low-lying ground immediately to the northeast the overburden of soil and drift is said to be deep.

The quantitative mineral composition of a sample of diabase from Bruce Mines which was tested in the Office of Public Roads, Washington, sample 4, page 68, is given by Mr. Lord of that office as follows:

Plagioclase (labradorite) 45·5, kaolin augite and secondary hornblende together 41·9, hornblende 4·2, magnetite 4·0, biotite 1·4, and epidote 3 per cent.

The diabase is of the same average character as that at Shoepack bay and in other places.

Amount Available. The ridge in which the quarry has been opened is at least 400 yards long. If it is taken to be 50 yards wide on the top for that distance, and 120 yards at the base, and if it is assumed that it can be economically extracted down to 14 feet above water level, the quantity available for extraction in the first 400 yards of this ridge is over 400,000 cubic yards or about 1,000,000 tons of solid rock. The total quantity available in this and the other neighbouring ridges is very great.

The Quarry. The exact date of opening of the quarry was not ascertained ; it is said to have been in operation for many years. The quarrying has proceeded from the present site of the crushing plant in a northwesterly direction and the quarry floor is a rough surface, about 20 feet above lake level. It is 300 to 400 feet wide with only one face developed, the others being entirely removed. The water level lies below the floor.

The drilling is done with churn drills, using 5-inch bits; down holes are sunk to a depth of from 55 to 65 feet. They are placed 25 feet from the face and 35 feet apart. Four hundred to 700 pounds of dynamite, running 60 per cent nitro-glycerine, is used in one charge and this is tamped down with clay.

The shattered rock is handled with a Bucyrus steam shovel carrying a 5-cubic yard dipper. When the rock contains seams of quartz, pieces of stone too large to handle with the dipper are often left after blasting, and these have to be broken by small shots. The shovel can handle 1,200 tons per day. The material is conveyed to the crusher over a standard-gauge track in 15-ton steel cars, by two 45-ton industrial locomotives. The crushing plant contains one 5- by 7-foot jaw crusher, two No. 9 gyratory crushers, and two 24 by 54 rolls. The screening is done by two 7 by 20-foot revolving screens and two sets of jigs. The capacity of the crushing plant is 500 tons per hour. The material is screened to six sizes which are numbered as follows: No. 1, $\frac{1}{4}$ inch and under; No. 2, $\frac{1}{4}$ to $\frac{5}{8}$ inch; No. 3, $\frac{5}{8}$ to 1 inch; No. 4, 1 inch to $1\frac{1}{2}$ inches; No. 5, $1\frac{1}{2}$ inches to 2 inches; No. 6, 2 inches and over. The percentage produced is about as follows: 15 per cent of No. 1; $12\frac{1}{2}$ per cent of No. 2; $12\frac{1}{2}$ per cent of No. 3; 25 per cent of No. 4; 25 per cent of No. 5; and 10 per cent of No. 6.

The material is stored outside in separate piles, the total storage capacity being estimated at 75,000 tons. From under each pile the crushed rock is moved through a concrete tunnel by an endless belt conveyer to the loading platforms at the dock. The stone is loaded over an automatic weighing machine directly into the boats at the rate of 18 tons a minute. There is 19 feet of water at the loading dock.

The material is shipped by boat to lake ports, especially to the larger cities on the United States side, Detroit, Cleveland, and Buffalo. It is also shipped by rail over the Canadian Pacific railway, to which the quarry is connected by a spur. Some trap has gone partly by boat and partly by rail to Toronto.

Utilization. Trap from Bruce Mines was used in construction of the ship locks at Sault Ste. Marie, Michigan. It has been largely used in the construction of roads and boulevards in the city of Cleveland. The results of a number of laboratory tests to determine the road-making qualities of this trap are given on page 68.

Costs. The cost of labour, fuel, and powder, in quarrying and crushing, is about 23 cents per ton. The cost of freight by boat is 35 cents to Detroit and 40 cents to Cleveland, without the cost of unloading. The freight on trap shipped to Toronto via Midland by water and rail cost $1.20 per ton, by an all-rail route via Sudbury $1.75 per ton. The prices quoted at the quarry in July, 1914, were $1 per ton for sizes Nos. 1 to 4, and 80 cents per ton for sizes 5 and 6. A cubic yard of the crushed rock weighs about 2,650 pounds.

ST. JOSEPH ISLAND.

The quarry of the Huron Trap Rock Company of Sault Ste. Marie, Ontario, is situated on the north end of the island near Richard Landing, lot 22, concession D. The company owns 25 acres underlain by diabase. This quarry was not visited by the writer and the information given here was furnished by Mr. T. J. Foster, of Sault Ste. Marie, who is treasurer of the company.

The material is diabase and lies in hills rising to 35 feet in height. The result of a test made upon a sample from this place is given on page 68. According to Mr. Lord of the Office of Public Roads, Washington, D.C., the sample tested is a coarse-grained, dark greenish-grey diabase composed essentially of epidote, chlorite, and hornblende, replacing augite and plagioclase.

The company supplied rock for the building of locks at Sault Ste. Marie, Michigan, in 1913. They own a crushing plant with one No. 7½ and two No. 5 crushers made by T. L. Smith Company, of Milwaukee. Their screens separate the crushed product into four sizes, 3-inch, 2-inch, 1-inch, and finer material. The rock is loaded at the company's dock where there is 18 feet of water and sells at about $1 per ton f.o.b. at the dock. The quarry has local and long distance telephone connexion. No quarrying is being done at present, May, 1915.

POOLE ISLAND.

A quarry is said to have been operated on Poole island by the Soo Trap Rock Company, Limited, whose office address is given as 12 Harris Block, Sault Ste. Marie, Michigan. Poole island is a small island lying just off the southwest shore of Dawson island in St. Josephs channel. Its location is indicated on the accompanying maps.

The result of a test upon diabase from this locality is given on page 68.

PART III.

ROAD MATERIALS IN ESSEX COUNTY.

Part III.

Road Materials in Essex County.

INTRODUCTION.

The following is a report upon the materials suitable for the surfacing of country roads in Essex county.

The writer is indebted to Mr. M. E. Brian, engineer of the city of Windsor, Mr. John Millen, of Sandwich, treasurer of Essex county, and the Rev. Thomas Nattress of Amherstburg for their courtesy and assistance. The report contains a short description of the topography and geology of the county, a summary of the materials available for roads in the county, and a detailed description of the materials in the various townships. It is accompanied by a map. Three samples of gravel and two of stone from this county have been tested in Toronto by Mr. G. C. Parker, assistant engineer to the Commissioner of Highways of Ontario.

TOPOGRAPHY AND GEOLOGY.

Essex county is situated at the southwesterly end of southern Ontario. It is a peninsula with Lake St. Clair on the north, Lake Erie on the south, and the Detroit river on the west. The topography is that of a flat featureless plain. The highest ground cuts through the county in a southwesterly direction from the neighbourhood of Windsor to Leamington and forms the watershed between Lakes St. Clair and Erie.

The watershed is marked by a low, narrow ridge from Essex village to Oldcastle and slightly more irregular topography between Ruthven and Leamington. The highest area lies east of Leamington, and where the Pere Marquette railway crosses it the elevation on the hill top is 734 feet above sea-level or 162 feet above Lake Erie. The old Talbot military road follows the crest of the divide nearly all the way from Windsor to Leamington. Several sluggish streams empty into the lakes and the river. The largest are the Canard river and Cedar creek on the south and Pike creek, Belle and Ruscom rivers on the north side of the divide. The shores of Lake St. Clair and a part of the Detroit river are low and swampy and so is a section of the Erie shore west of Kingsville. East of Kingsville the shore is a high wave-cut bank as far as Leamington. Point Pelee farther east is a long low sand spit projecting into the lake.

The bedrock in the county is covered by a thick deposit of boulder clay with a few ridges and flat areas of sand and gravel on top. This deposit probably averages nearly 100 feet in thickness over the county. The only outcrops of rock are at Amherstburg and on Pelee island. Information obtained from well borings indicates that the larger part of the county is underlain by the lower formations of Devonian age, while a small section in the southwest corner may be of upper Silurian age. The rocks in these formations are largely limestones with some shales.

The boulder clay is a blue clay carrying fragments of stone and weathering yellow at the surface. West and south of Leamington it is overlain by fine sand and silt which is often bedded. West and northwest of Leamington is a large deposit of sand and gravel in which the beds are irregular in shape and dip. This deposit apparently overlies the fine-bedded sand just referred to. In other places deposits of gravel and sand rest directly on the boulder clay. The bank sands and gravels in the county have probably been deposited largely by glacial streams. The boulder clay is a deposit left by the ice sheets which covered this part of the continent during the Glacial period. Deposits of sand and gravel on the beaches have been formed by the action of waves and are in formation to-day.

ROAD MATERIALS.

SUMMARY.

There is very little road material in Essex county. The northern tier of townships along Lake St. Clair is practically devoid of road metal. In the western townships the materials are of poor quality and in small amount. Gravels and sands are found in large quantity between the villages of Essex and Leamington lying in the southwestern part of Essex county and in smaller scattered deposits elsewhere. Field stone occurs in abundance in a small area just north of the village of Colchester and in small amount in other parts of Colchester South, and Gosfield South townships. Bedrock is to be had at Amherstburg and Pelee island.

GRAVEL.

The gravels of Essex county are as a rule rather sandy and weathered to a depth of several feet from the surface. They differ in their properties of durability and resistance to the wear of traffic. Almost any of these gravels would improve the many miles of clay roads in the county over which the traffic is comparatively light. Practically none of them would stand up for more than a very short time under, say 300 vehicles per day, without an artificial binder. The gravels would give much better wear if as little weathered material as possible were used. The weathered material binds quicker because of the clay it contains, but is softer than the clean unweathered gravel. If the unweathered gravel be placed on a clay bottom there is every reason to believe that enough clay will eventually mix into the road surface to bind it together. The screening out of the fine sand in deposits which contain large quantities of sand will be found advantageous, since coarser gravel will not grind to dust as rapidly as fine.

All the samples tested are fine, that is they contain more sand than gravel and this is characteristic of nearly all the deposits in Essex county. The percentage of wear of the coarse aggregate in the sample from Talbot street 4½ miles southeast of Essex is 6·6, the cementing value of the coarse aggregate was not determined, that of the fine was 115. The cementing value of the pit near Oldcastle was 86 for coarse and 40 for fine. The sample tested by Mr. Parker from Sandwich had a cementing value of 6 for coarse and 15 for fine. The wear of the last two

The following is the result of granular-metric analyses made by Mr. G. C. Parker of the office of the Commissioner of Highways of Ontario, Toronto, upon three gravels from this county:

Locality.	Retained on ¼ inch screen.	Passing ¼ inch screen.	Total.	Percentage of sand (passing ¼ inch screen) retained on									Percentage of silt.
				⅛ inch.	No. 10	No. 20	No. 30	No. 40	No. 50	No. 100	No. 200	Passing No. 200	
East half of lot 303, near Oldcastle, Sandwich South.	7·5	92·5	100	......	25·0	57·6	60·5	75·3	85·0	95·7	97·2	2·8	1·5
Bedford street, Sandwich village.	17·7	82·3	100	15·0	21·0	37·3	50·5	64·3	80·5	95·9	97·5	2·5	1·0
Pit No. 12 on Talbot road, lot 267.	30	70	100	......	26·6	47·4	61·9	72·7	83·5	95·8	97·6	2·4	....

In the analyses given below, percentages retained on the smaller screens are expressed in terms of the whole sample and not of the sand alone as in the table preceding. Those from Sandwich were made by the Detroit River Tunnel Company, and sampled in 1906. That from near Leamington was analysed by The Canadian Inspection and Testing Laboratories Limited.

Locality.	Per cent of whole sample retained on screens.														
	No. 4	No. 8	No. 10	No. 12	No. 20	No. 30	No. 40	No. 50	No. 60	No. 74	No. 80	No. 100	No. 200	Passing No. 200	Total.
Princess old pit, Sandwich village.	43·75	54·69		60·94	65·64	73·45		85·95			98·45		98·45	1·50	99·95
Princess new pit, Sandwich vilage.	25·00	40·62		53·12	64·02	81·20		93·70			98·40	trace	98·40	1·50	99·90
Sand from property of Windsor Sand and Gravel Co., near Leamington.	19·8		54·7		89·2	95·7		97·3		97·55	97·82	97·87	98·15	1·85	100

samples and the cementing value of coarse aggregate in the first could not be determined because of the small amount of coarse aggregate in the sample. The high percentage of wear in the sample from Talbot street southeast of Essex is due in a great measure to the fact that the weathered portion of the deposit was included in the sample.

The character of the different deposits is discussed in the detailed description of them. The unweathered portions of the gravels in Sandwich South, and Colchester North, and those on the Talbot road southeast of Essex are fairly durable material. The weathered portion, which is softer, however, forms over one-half of the deposits. The big deposit northwest of Leamington varies in character, the more durable gravel lying toward its southeast end. The cementing value of the gravels is apt to be good, except where the material is very sandy.

Considerable sand and gravel from the local deposits have been successfully used in nearby concrete construction, especially in building barn foundations. A good many miles of concrete streets have also been laid down in the town of Windsor, but the gravel and sand used in their construction have come practically entirely from outside the county.

CRUSHED STONE.

The field stone in Colchester South and Gosfield South townships is very largely made up of hard durable boulders and if crushed it would make an excellent foundation and wearing surface for any of the county roads in Essex. It would require a gravel or other binder. The material in Gosfield South, is not present in large amount and is scattered over such a wide area that it would probably not be economical to haul it to any particular road and install a crusher to prepare it for the road surface. A mile or two north of the village of Colchester there is much more stone to be had and probably enough to pay for the installation of a small portable crusher.

The stone at the quarry near Amherstburg and that on the side of the Livingstone cut in the Detroit river is very soft. Several miles of road near Amherstburg have been surfaced with stone from the quarry. It wears easily to a fine palpable dust and it cannot be recommended for use on roads. The Pelee Island stone is also quite soft.

Locality.	Toughness.	Per cent wear.	French coefficient of wear.	Cementing value.	Weight per cubic foot.	Absorption.
Cut in Livingstone channel, Detroit river.	3	5·87	6·80	15·0	164·6	1·84
Quarry of Capt. John McCormick, Scudder P.O., Pelee island.	4·5	..	..	13·0	163·4	0·637

The result of the tests shows that the stone from both localities is unsuitable for the making of macadam roads.

OUTSIDE SOURCES OF SUPPLY.

Sand and gravel, dredged from the St. Clair river near Point Edward in Lambton county, is sold by the Cadwell Sand and Gravel Company at Sandwich, Windsor, and Walkerville for concrete and other uses. At Sandwich the gravel is unloaded with a McMillan crane and a 1½-cubic yard bucket. The material is screened in dredging and part of it again on the dock. Four or five sizes are produced and the gravel is sold at $1.37 per cubic yard. The coarser gravel piled on the dock consists of about 75 per cent of hard rock pebbles and only of 20 to 25 per cent of limestone and soft pebbles. It should make very durable road material, of better quality than any of the bank gravel seen in the county.

Crushed Hagersville limestone is said to sell at Leamington at $1.37 per cubic yard. This is one of the better classes of broken stone produced in Ontario for road metal. The railway freight rates from Hagersville are from 60 to 65 cents per ton. Crushed dolomite of practically the same quality is to be had from the Canada Crushed Stone Corporation at Dundas.

Bruce Mines trap rock can be delivered at Detroit opposite the town of Windsor at about $1.35 per ton f.o.b. boats at the dock. To these charges would be added the cost of unloading, which would vary from 5 cents to 30 cents per ton depending upon the speed at which the boats can be discharged. There is no doubt that Bruce Mines trap rock is of much better quality for road-making than any limestone or gravel that can be obtained in southern Ontario, and it is to be hoped that some of the trap rock from the north shore of Lake Huron will be used in the neighbourhood of Windsor and other ports.

DETAILED DESCRIPTION OF DEPOSITS.

TOWNSHIPS OF SANDWICH EAST, MAIDSTONE, ROCHESTER, TILBURY NORTH, AND TILBURY WEST.

For about 30 miles along the shore of Lake St. Clair is a more or less continuous strip of beach sand from 10 to 100 feet wide and 1 to 5 feet deep. It is underlain by clay and contains coarse material up to 1 inch in a few places, but in very small amounts and of very poor quality. The coarsest material was seen in lots 15 and 16 along the lake front in Tilbury North. A good deal of sand is obtained from this place in winter.

Field-stone is said to have been obtained from the lake at low water near the village of Stony Point in Tilbury North. There is very little to be had now.

Outside of small patches of coarse gravel in Pike creek, less than one wagon load to the 100 yards of creek bed, we saw no other road material in the first four townships mentioned. No road material of any sort was found in Tilbury West.

SANDWICH WEST.

Underlying more than one-half of the area of the village of Sandwich and extending south to Ojibwa post-office are more or less discontinuous patches of sand and sandy gravel. The boundaries of the gravel so far as they could be determined are sketched on the map. In and just south of Sandwich the gravel lies in ridges about 10 feet high trending north and south. The ridges are underlain by boulder clay which outcrops in the low spots between them. To the south the gravel lies in a terrace extending to the shore of the Detroit river and on this terrace there are a few ridges of the same kind as those found in Sandwich.

All through this area the material is mostly sand with the gravel (material over one-quarter inch) occurring in streaks. The pits that have been worked in Sandwich are said to have produced two parts of sand to one of gravel, and the old pits north of Ojibwa post-office may have yielded nearly the same proportions. A sample taken from an excavation on Bedford street, Sandwich, carried over 80 per cent sand (page 90). Southwest of Sandwich from the golf links south, the ridges are practically all sand. The gravel is fine and the pebbles seldom over 1 inch. The deposit is weathered to a depth of several feet and the weathered part contains a large proportion of clay. Hard pebbles vary in amount from 30 to 70 per cent of the whole, sandstones and shales up to 40 per cent. They are subangular in shape. Stratification is absent or poorly developed.

A good deal of gravel and sand has been dug in the town of Sandwich. According to local authorities the supply that was available in the town has been exhausted, and what remains cannot be developed. North of Ojibwa several hundred cubic yards have been taken from a number of pits, which have apparently been abandoned for a long time. There is more gravel to be had in that neighbourhood, however, and it compares favourably in quality with that seen at Sandwich.

The deposit as a whole varies from 3 to 10 feet, and is in one or two places 18 feet deep. The extent of the gravelly portions is not known. There is as a rule so much sand with the gravel that the amount which is available for economical extraction must be a small proportion of the whole deposit. The material is on the whole of poor quality; it contains a large proportion of soft pebbles, and is in general too sandy for good road metal. A granular metric test of a sample from the main street in Sandwich is given on page 90.

A small deposit of the same kind lies in a low ridge near the Wellington hotel on the Detroit River shore 1¼ mile south of

Ojibwa. No other deposits of road metal were seen in Sandwich West township.

ANDERDON.

A deposit of coarse sand was seen in a creek flowing into the Canard, lot 12, concession IV, and streaks of gravel can be seen on the banks of the Detroit. No other gravel deposits were found in this township. The deposit in lot 12, concession IV, has to be dredged out of the creek bed. It is a coarse sand with 10 to 15 per cent over one-quarter inch in size. The sand is said to extend for one-half mile downstream. It is 3 to 4 feet deep in places and the bed of the stream was 30 feet wide at the point examined, but sand is not to be found all over it.

Outside of Pelee island, Anderdon contains the only quarry in Essex county, and probably the only outcrop of bedrock. The quarry is 1½ miles north and east of Amherstburg. It lies west of the road between concessions I and II, just south of the Michigan Central tracks, to which it is connected by a spur. The surface of the quarry is about 30 feet over the level of the Detroit river and the following geological section is exposed from the top down.

	Thickness in feet.	Total thickness in feet.
1. Drift clay with a few boulders on the surface		8 to 11
2. Onondaga formation.		
(a) Crinoidal limestone..............	1	
(b) Thin-bedded limestone...........	6	
(c) Dolomitic limestone.............	8	
(d) Dolomitic limestone with more magnesia than in c and d....	18	
		33
3. Anderdon formation.		
(a) High grade limestone carrying from 97 to 99 per cent. $CaCO_3$....		
(b) Low grade limestone carrying about 60 per cent of $CaCO_3$		a+b 30
Total................		71 to 74

The details of this section were obtained from Rev. Thos. Nattress of Amherstburg. According to Mr. Nattress a small centroclinal basin underlies the site of the quarry. The drift is 29 feet thick one-quarter mile to the southwest, 60 feet thick one-quarter mile to the northwest, and 45 feet deep 2½ miles north by west.

The quarry has been in operation for over one hundred years. The old workings lie to the southwest of the present site. The new quarry has not been worked for two or three years, and the hole is filled with water. It is irregular in shape, and about 800 by 400 by 10 to 50 feet. A small crushing plant and loading crane stand partly immersed in water on the south-eastern side of the hole. Loading bins over the railway spur, an engine house, and other quarry buildings are on the north-eastern side. The quarry was operated by the company; the pure limestones found in it were used as reagents in their chemical works, and only an occasional load of waste was sold. The writer examined every layer of limestone exposed in the quarry and found all of them very soft. The stone has been used on the nearby roads and is said to cement well, but to wear to a fine and extremely troublesome dust in a short time. The stone is not recommended for use on roads.

Along the Livingstone ship channel which has been excavated in the middle of the Detroit river great piles of stone have been dumped. A sample was collected nearly opposite Gordon station, north of Amherstburg. In the summer of 1914 it was being dug by the Dunbar and Sullivan Company of River Rouge, Michigan, with a steam shovel dredge having a 2½-cubic yard dipper, loaded on barges, taken to the Michigan side for crushing, and sold for macadam and concrete work. The dump on the Canadian side is large, 200 feet wide at the base, 50 feet high in places, and more than 3,000 feet long.

The rock is light buff, somewhat porous and banded. It is a magnesian limestone carrying about 10 per cent of magnesia and a very little silica. Under the microscope the grains of calcite appear angular and close fitting. The results of a test made by G. C. Parker of the staff of the Commissioner of Highways of Ontario, upon the sample collected is given on page 93. These results indicate that this stone is unsuitable for road work.

SANDWICH SOUTH, AND COLCHESTER NORTH.

Narrow discontinuous ridges of gravel extend from near Pelton, lot 12, concession VI, of Sandwich South, in a direction south by east to the Canard river near Gesto in Colchester North. The location of the ridges sketched from such information as could be obtained in the field is shown on the map.

The so-called "ridges" are seldom over 4 or 5 feet high, and about 400 feet in width. They are not easily recognized as ridges by the inexperienced observer, but are generally so referred to by the inhabitants. The upper few feet of the deposit is weathered and contains clay and other impurities; the lower 2 or 3 feet is fairly free from clay. The gravel and sand rest directly on the boulder clay which lies at the surface all over the rest of the township. Stratification is absent from the deposits. The gravel is fine, pebbles rarely being over one-half inch in diameter. They are angular to rounded and from 20 to 50 per cent of them are hard and durable. Sand is present in large quantities, but it is often coarse and rather sharp. A number of small pits 3-9 feet deep have been dug in the deposits and a total of some 30,000 cubic yards removed. Water is apt to stand in the bottom of any of these pits. The upper 2 or 3 feet of the material is as a rule put on the roads, the lower foot or two which is unweathered is used in local concrete work. From a pit about one-half mile north of Oldcastle on the east half of lot 303 the weathered portion has been sold at 20 cents per yard and the unweathered at $1 per yard. The result of a test made upon a sample of the unweathered gravel from this pit is given on page 90.

The gravel from these deposits has been used to surface certain of the neighbouring roads, and where the roads are properly maintained and the traffic is not very heavy, it has given fairly good satisfaction. One or two miles of road leading northwest from the village of Oldcastle was first surfaced with gravel, presumably from a neighbouring pit, fifteen years ago. Since then it has been kept in repair and is now scraped after every rain. A traffic census taken in August 1914 showed that one hundred and fifteen vehicles a day passed over this road, of which perhaps 80 per cent were automobiles. The traffic at other times of the year is said to be greater. This road, when seen, was in very good shape, and is an example of what can be done with gravel of this type, when the road surfaces are properly maintained and the travel over them is light. The weathered portion which is usually used exclusively on the road is not as durable as the lower and cleaner gravel and better results would be obtained if the whole bed or the clean gravel only were used.

Tests made upon the gravel from the pit near Oldcastle, referred to above, showed that it had a high cementing value and was composed largely of sand under one-quarter inch. The sample included the unweathered part of the gravel only. The amount of gravel available for road making in these deposits is not very great.

A considerable amount of field-stone is to be found on lots 1, 2, and 3, concession VI, of Colchester North, but no field-stone was seen in any other part of the two townships.

MALDEN AND COLCHESTER SOUTH.

Several small deposits of gravel and sand, lying in a string, trend southeast from near North Malden, in Malden township, to a point about 4 miles west of Harrow, in Colchester South; one or two deposits of gravel are found north and east of Harrow; and a considerable amount of field-stone occurs between the villages of Colchester and Harrow and in other places.

The gravel deposits which extend from North Malden to the southwest are very small, their usual depth is from 3 to 4 feet, and they are rarely more than 300 feet across. Several of the more northerly ones are entirely worked out; the two southerly are the largest. The deposits are underlain by boulder clay and are in a number of places weathered right down to the clay. The material is fine, the pebbles as a rule under 1 inch, from 50 to 80 per cent is sand, and clay is always present. The pebbles are subangular to rounded and about 25 per cent are of durable rock types. The gravels are not of a durable type, but should improve the neighbouring clay roads if properly spread and carefully maintained.

Three small ridges of gravel are found in concessions II and III just north and east of Harrow. Their locations are given on the map. In the westerly pit, lot 9, concession III, 50 per cent of the deposit is sand, the gravel pebbles average from one-half to 1 inch in diameter, are subangular, and 80 per cent of them are of shale or soft limestone. The deposit is unstratified, about 7 feet deep, and the upper 3 feet is weathered. It lies upon yellow boulder clay. It is located on the farms of G. C. McLean, Andrew Cuther, and William Affleck. The material in the ridge in lot 12, concession II, is of the same character as that just described. It is 12 feet deep in places. There is a good deal of gravel to be had in the three ridges, but it is not durable material and would not last long on a road.

The beach of Lake Erie is very sandy in Colchester South, and the streaks of gravel along it are scarcely more than coarse sand.

There is a fairly large amount of field-stone in Colchester South, but practically no boulders are found in Malden. The location of the deposits which were seen is given on the map. There are probably others which were not seen. In the upper half of lot 71 just north of Colchester is a morainal ridge about 800 feet long by 100 wide and from 10 to 15 feet high. If the boulders are as numerous throughout the ridge as on the surface there must be over 30,000 cubic yards in this place and a good many thousand more in the neighbourhood. There are scattered occurrences of stone up the road running northwest from this place. In concession I, lot 15, there are two fairly large ridges of boulders, one of them 300 feet long by 70 feet wide. Other deposits contain less than 100 yards. The field-stone is generally composed of durable rock and it varies up to 3 feet in diameter. It is the best material obtainable in this neighbourhood.

GOSFIELD NORTH, GOSFIELD SOUTH, AND MERSEA.

Several deposits of sand and gravel occur in these three townships. The two main deposits are a narrow ridge running southwest from the village of Essex to a point 2 miles west of Olinda post-office in Gosfield South, and a broader irregular sheet whose southern end lies between the villages of Leamington and Ruthven and which extends north to concession V. A small deposit lies in concessions VIII and IX north of Wheatley in Mersea, and gravels occur in places along the Lake Erie shore. Field-stone is found in Gosfield South, but was not seen in quantity in Gosfield North, or Mersea.

The Ridge Southeast of Essex.

A narrow ridge of sand and gravel extends from lot 282 in the village of Essex, Gosfield North, in a southeasterly direction as far as lot 260, Gosfield South, and two smaller detached deposits lie between this point and Olinda post-office. The ridge is 8½ miles long and the Talbot road follows along its crest for nearly the whole way. The crest of the ridge is from 5 to 12 feet above the general level of the flat country on both sides. It is from 300 to nearly 1,000 feet wide, averaging perhaps 500 feet, and the elevation is so slight that its ridge-like character is not always apparent. In a number of places on the northeastern side there is often a rather abrupt slope down to the flat, but the southeastern slope is very gentle.

The sand and gravel lie on a bottom of boulder clay which appears to be at about the level of the surrounding plain. The gravel is unstratified and weathered to a depth of from 2 to 5 feet. At the bottom just over the boulder clay there is in many places a rather fine sandy bed. From 30 to 60 per cent of the deposit appears to be sand.

About 30 per cent of the pebbles over one-quarter inch in diameter are composed of some hard rock such as granite, trap, or quartzite, the remainder being largely limestone with some shale and sandstone. In the weathered portion the shales and other pebbles are in many cases entirely decomposed. As a result this part of the deposit contains a large percentage of clay and is stained with iron oxide. The unweathered part contains no iron oxide and little or no clay.

More than a dozen small pits have been opened on this ridge and some of them are no longer worked. Judging from their respective areas and depths the amount of material removed from them is over 175,000 cubic yards. The weathered part has probably nearly all gone on the neighbouring roads, the unweathered bottom part is used for local concrete work and for cement blocks.

If the length of the ridge is taken as 8 miles, its average width 400 feet, and depth all over 3 feet, the amount of sand and gravel present is about 1,700,000 cubic yards. Of that quantity about 50 per cent is weathered material which contains a good deal of clay. Thirty to seventy per cent of the remainder is sand under one-quarter inch in diameter. The ridge has a great many buildings on it and gravel land is very expensive, some of it being held at $1,000 per acre. It is probable that only a small portion of the sand and gravel present will ever be excavated.

The gravel contains 30 per cent of hard pebbles and the unweathered portion should be fairly durable material. The weathered part is much softer, but contains considerable clay which helps in binding the road surface.

On a road with clay bottom the clean gravel will bind and it will make a better road if the weathered material on top is left out. Traffic on the Talbot road is too heavy for this gravel without an artificial binder.

Details of the pits are given in the following table. The results of tests upon pit 12 are given on page 90.

Gravel Pits on the Essex Olinda Road, Gosfield, North and South.

Map No.	Lot No.	Owners.	Size of pit in feet.	Character of the material.				Remarks.
				Percentage of sand ¼ inch and under.	Depth of weathering in feet.	Impurities in unweathered portion.	Percentage of hard pebbles, igneous rocks, etc.	
1	278	Township of Gosfield, North	Depth 6 and less	50	3	Coated with lime carbonate.	30+	Unstratified; clay bottom.
2	276	?	200 × 50 × 3 to 7	....	....	....	....	Ridge 400 feet wide drops more abruptly to northeast than to southwest.
3	275	....	Greatest depth 9	30	2	?	30 to 40	5 feet unweathered gravel lying over 2 feet of sand. Pebbles in gravel not over 2 inches.
4	274	....	350 × 200 × 8	....	....	....	....	....
5	272	....	300 × 100 × 7	....	....	....	....	....
6	272	Village of Essex	400 × 300 × 12 12 is the max., shallower to S.W.	60	8	....	30	Greatest depth of deposit 14 feet.

Gravel Pits on the Essex Olinda Road, Gosfield North and South.—Continued

Map No.	Lot No.	Owners.	Size of pit in feet.	Character of the material.				Remarks
				Percentage of sand $\frac{1}{4}$ inch and under.	Depth of weathering in feet.	Impurities in unweathered portion.	Percentage of hard pebbles, igneous rock, etc.	
7	271	....	300 × 150 × 6 to 8	....	....	....	....	Near this pit gravel found in well to depth 10 feet, overlying clay.
8	271	....	400 × 200 × 6	....	....	....	....	....
9	269		200 × 150 × 4	....	....	....	....	Pit abandoned.
10	268		100 × 150 × 4	....	....	....	....	Pit abandoned, steep face on ridge to north 5 to 10 feet high.
11	268		400 × 300 × 4	....	....	....	....	Pit abandoned.
12	267		600 × 250 × 4 to 6	....	5 ±	None	....	The unweathered part $1\frac{1}{2}$ feet thick is used for concrete.
13	264	Albert Helkie	Depth 4	70	....	....	25	Gravel unstratified.

The Sand and Gravel Deposit West of Leamington.

A large deposit stretches from near the lake shore southwest of Leamington northward for 4 miles. Its outlines are quite irregular and it lies partly in Mersea and partly in Gosfield South.

The deposit lies in a flat-topped ridge about one-half mile wide on top and resembling an irregular horseshoe. A low bar connects the two prongs. The main ridge drops abruptly about 20 to 30 feet to the south, west, and north. Its slope to the east is more gentle.

The deposit is fairly well stratified and from the Michigan Central to the Pere Marquette pit the beds, where seen, dip east and north, or in general toward the inside of the horseshoe. In Smith's pit on the south edge there is a northerly dip. All the beds in any one cut do not all dip at the same angle, and in many instances a flat bed will lie over or under one made of a number of steeply dipping layers. Many of them are lens shaped and in places they overlap like shingles on a roof. They consist of alternate layers of sand and gravel which occur in no definite order. The following is a section in the pit of the Windsor Sand and Gravel Company:

	Thickness in feet.
(a) Sandy rusty gravel loam	3
(b) Fine gravel dipping east	2½
(c) Finely cross-bedded sand having a feathery appearance	1½–3
(d) Alternate layers of fine sand and fine gravel well bedded	3–4
(e) Sand, cross-bedded in places	5
(f) One-half inch sandy gravel	1½
(g) Gravel with clay, pebbles ½ to 1 inch	4
(h) Sand	1
(i) Gravel ¼ to ½ inch	1
(j) Sand	2
(k) Gravel	3½
(l) Sand	1½
	29 to 32

The upper part of the section from a to d is shown in Plate V. The beds are not of great lateral extent, and at points 100 feet apart the succession will be entirely different. From the Michigan Central pit to the Talbot road the gravel is said to lie largely toward the eastern front of the main ridge, the western portion being mainly sand.

The alternation of the sand and gravel beds is shown in the section. The proportion of sand varies as indicated and it is high in the two largest pits. Layers of fine silt are found in many places and a thin bed of clayey sand is found in a few pits. Clay occurs in the 1 to 5 feet of weathered material on the surface, but the unweathered material is practially free from clay. The durability of the gravel varies as indicated in the accompanying table. The hardest material is apparently found in the southeasterly pits. The percentage of soft material in this gravel indicates that it is not suited for heavy traffic. The road going south from Leamington between the corner of Oak street and the north end of concession I is said to have been surfaced with gravel from Fraser's pit in the summer of 1912. When seen in the late summer of 1914 it was in fair condition, but furrows 6 inches wide were worn all along the length of it. This road is subjected to moderately heavy traffic and if kept in repair the surface will doubtlessly last for a few years longer.

Two very large pits have been excavated in these ridges and a number of smaller ones, the sizes of which are given in the accompanying table. A total of more than 2,000,000 cubic yards of sand and gravel has been excavated from them and about 80 per cent of the total amount came from the two larger pits, Nos. 17 and 22, mentioned in the table. The amount available must be enormous. Opposite the Michigan Central pit (No. 17) gravel has been found from 16 to 25 feet down; near the Talbot road it is from 40 to 50 feet deep with the last 10 feet in places in fine sand. The total of sand as well as gravel may run to 100,000,000 cubic yards. What proportion of that is sand cannot be estimated with the data at hand, but it is probably present in greater amount than the gravel.

The gravel seen in the various pits is fairly free from impurities, but contains much sand and fine silt; it is also, except in a few pits, composed of rather soft material. Details regarding pits within this large deposit are contained in the following table.

Two small deposits, one in a lot west of Kingsville and another in concessions VIII and IX north of Wheatley, complete the list of bank gravel deposits found in the three townships. The deposit north of Wheatley consists of sand and very fine gravel. It is about 5 feet deep and not for sale. There are small quantities of gravel in places along the Lake Erie beach and gravel has been dredged off Point Pelee. A beach deposit on the Erie shore just east of the county line is described with the deposits in Kent county. Southwest of Kingsville the beach is practically all sand, with a little fine gravel in spots; east of Kingsville there is very little gravel and the steep high banks place it out of practical reach.

Field-Stone.

From the foot of the ridge of sand and gravel deposit which lies between Ruthven and Leamington westward to lot 4, and south to the lake, there are numbers of large boulders scattered through the fields and gathered up in heaps or strung along the fences. They are not present in large quantity at any one place, and an estimate of the cubic yardage is difficult to make without a detailed examination, which the amount available does not justify. The writer estimated the total amount seen at less than 1,000 cubic yards in an area of some 10 to 12 square miles. Even if only half of the stone had been seen the quantity is too small and scattered for its utilization as road metal. On the west line of Gosfield South, between concessions I and II, there are about 100 cubic yards of stone. No field-stone was found in Mersea township. The field-stone consists of a high percentage of hard and durable boulders and would make good foundations and wearing surfaces for country roads. It may require a binder of some sort.

Sand and Gravel Pits in the Ridges Directly West of Leamington.

Map No.	Owners.	Size of pit in feet.	Character of the material.						Remarks.
			Percentage of sand $\frac{1}{4}$ inch and under.	Depth weathering in feet.	Percentage of impurities in weathering portion.	Composition. Percentage of			
						Hard pebbles.	Limestone pebbles.	Soft pebbles.	
14	Township of Mersea	200×100×10	50	....	....	......	......	......	8 feet unstratified gravel with pebbles from 1-2 inches; underlain by sand.
15	....	200×300×9	high	....	....	25	......	......	Material cements well, said to be 13 feet deep.
16	Township of Gosfield South	100×100×4	....	....	....	......	......	......	Abandoned.
17	Michigan Central railway	300×300 to 500 × 20 to 25	50 to 60	....	....	......	......	......	Small proportion gravel pebbles over 1 inch. First 9 feet down well stratified, dip of beds to east at low angles Walls stand up. Probably dug by steam shovel, not in operation summer 1914.
18	Township of Gosfield South	Depth about 15.	60	Very much 1½. Partly 12 to 15	Clay in weathered part and in a streak near bottom	20			Beds dip at low angle to east. Township owns 1 acre north of road.

19	Two pits and 3 lots of gravel land owned by village of Kingsville.	Small							Same character as 18.
20	Bruce Fox, Ruthven, and Gosfield South, township.	Small							do.
21	Township of Mersea.	Irregular 100×150×3 to 10.	....	Very much 1 to 2	Calcareous coating.	20	60	20	Most of gravel fine up to ½ inch. Dip of lower beds toward north.
22	North of the railway, Pere Marquette railway. South of the railway, Windsor Sand and Gravel Company, Walkerville.	2100 × 200 to 350×25 to 35.	60	2 to 4	Clay in one or two streaks, silt layers.	15	....	....	The Windsor Sand and Gravel Co. owns 65 acres south and 50 acres about ½ mile northwest of the pit. Water level about 40 feet from surface. The weathered part removed by scraper, rest worked by derrick and clam shell.
23	....	170×75× 12 to 20.	40	2	Little or none.	15	60	25	Sold at 20 cents per cub. yd., dip of some of the layers to southwest.
24	Village of Leamington	200×150× 15 to 20							Same character as 18.
25	Windsor, Essex, and Lake Shore electric railway.	350×200×27.	35	5	....	....	....	....	Opened in 1909.

Sand and Gravel Pits in the Ridges Directly West of Leamington—Continued.

Map No.	Owners.	Size of pit in feet.	Character of the material.						Remarks.
			Percentage of sand ¼ inch and under.	Depth of weathering in feet.	Percentage of impurities in weathering portion.	Composition. Percentage of			
						Hard pebbles.	Limestone pebbles.	Soft pebbles.	
26	J. W. Smith	350×100×25 to 30	25	3	....	....	....	....	Sold at 20 cents per cub. yd. in bank. 25 acre farm for sale at $1,000 per acre. Gravel well stratified, lens-shaped beds dipping north. Fine sand at bottom.
27	Known as Fraser's pit	L-shaped, 300 on sides, 10 to 15 deep.	....	....	....	....	....	....	Next to electric railway track
28	....	200×75×8	60	....	....	30	60	10	....
29	....	Small	....	....	....	....	....	....	....
30	....	700×400×10 to 20.	....	....	....	30	....	....	Abandoned.

PELEE ISLAND

Stone outcrops along the northern shore and across about one-third of the southern part of Pelee island. On the northern shore is a quarry owned by Captain John McCormick, Scudder, P.O., Pelee island. The excavation lies within a few hundred feet of a small pier. It is about 400 × 200 × 20 feet. From the top down it consists of:

(a) Thin-bedded grey fairly tough limestone beds each 4 inches thick..................................	6 feet
(b) Grey sandy or shaly limestone, beds each 9 inches thick	4 "
(c) Buff limestone weathering grey, beds irregular from 1 to 3 feet thick..................................	9 "
	19 feet

The stone is sold as rubble at Wheatley at from $8 to $10 per cord. The quarry was opened about 18 years ago.

On the west side of the island not far from the west wharf is a quarry owned by Mr. William McCormick. The quarry lies in a ridge standing about 30 feet over flat land to both the south and north of it. From the top down the beds in the quarry are:

(a) Thin-bedded limestone..............................	4 feet
(b) Heavy massive bedded limestone......................	15 "
(c) Massive bed of limestone..........................	3 "
	22 "

Water stands at 22 feet from the top of the rock, but can be let down another 5 feet or so to near lake level. The beds lie flat and are rather soft under the hammer; large blocks can be obtained from this quarry.

An old pier about 400 feet away had at one time 16 feet of water alongside. The harbour is open to the west. The quarry was worked 25 years ago and the stone sold for construction in the Welland canal at 25 cents per yard in the quarry.

On the south end of the island stone outcrops over a large area. It is of somewhat the same character as that at Wm. McCormick's quarry. The Kelly Island Stone Company of Kelly island have bought 100 acres of stone at this place.

The result of a test made upon stone from Captain John McCormick's quarry is given on page 93.

PART IV.

ROAD MATERIALS IN KENT COUNTY.

Part IV.

Road Materials in Kent County.

INTRODUCTION.

The following is a description of deposits of stone and gravel in the county of Kent, suitable for the surfacing of roads. A few of the better classes of deposits occurring outside the county, but within economical hauling distance, are also mentioned. The writer is indebted to Mr. W. G. McGeorge, Engineer of Chatham township, and to Mr. Joseph Hadley, of the town of Chatham, for information regarding gravel deposits in the bed of the Thames river in Chatham township.

The physical tests upon gravel samples from this county and granular-metric analyses of them have been made by Mr. G. C. Parker of the staff of the Commissioner of Highways of Ontario.

Kent county lies in southwestern Ontario with Essex to the southwest and Lambton, Middlesex, and Elgin to the north and east of it. On the west are the St. Clair river and lake, and on the south the shores of Lake Erie. Kent has at least two good harbours, Wallaceburg and Rondeau, where vessels drawing up to 19 feet of water can unload. Boats drawing up to 12 feet can go up the Thames river as far as Chatham.

TOPOGRAPHY AND GEOLOGY.

From the Pere Marquette railway northward Kent county is a flat plain with a few sand hills in the northeastern portion. South of the Pere Marquette from the neighbourhood of Cedar Springs a well-defined narrow ridge trends northeast toward Blenheim. To the east of that place the ridge widens and merges into an area of low irregular hills and here it is from 5 to 6 miles wide. The western part of the county, and nearly three-fourths of its total area, is not over 50 feet over the level of Lake Erie. A few places northeast of Ridgetown rise to over 750 feet above sea-level, that is about 180 feet over Lake Erie. The shores of Lake St. Clair are flat and so are those of Lake Erie near Rondeau bay, but the greater part of the Erie shore-line is a steep clay cliff which is in places 100 feet high. The greater part of the county is drained by the Thames river, which crosses nearly through its centre in a southwesterly direction, and the Sydenham which flows along its northern boundary.

The bedrock in this county is overlain by boulder clay and other unconsolidated materials to a depth, almost everywhere, of over 50 feet and in some places of 200 feet. No outcrops of bedrock were seen in the county. Borings for oil and gas have shown that the highest beds of rock under the clay are of middle Devonian age.

The boulder clay is a stony blue clay which weathers to a yellowish colour. Over it and in places within it are deposits of sand and gravel. The clay was probably deposited by ice-sheets which covered southwestern Ontario during the Glacial period and the greater part of the gravels lying between Cedar Springs and the Elgin County line were probably laid down by streams connected with these continental ice-sheets. East and north of Ridgetown there are many areas of fine sand which seem to lie on top of the other deposits. The gravels which are found along the Thames and Sydenham rivers were laid down by the rivers themselves.

SUMMARY DESCRIPTION OF ROAD MATERIALS.

GRAVELS.

The road materials found within the county consist of gravel, sand, and some scattered deposits of field-stone. Gravels occur along the Lake Erie beach, but none were seen on the shore of Lake St. Clair. The Erie gravels are of fairly good quality and because of the absence of weathered pebbles the beach gravels are more durable than pit gravels of the same composition. On a clay formation they should cement readily and make a good road.

Pit gravels occur along the Sydenham and Thames rivers and a number of deposits lie in the southern part of the county south of the Pere Marquette railway. The gravel belt crosses the railway near the village of Highgate and extends from there northward to Clachan.

The gravels found in the Sydenham river are too fine and soft to make good road materials. This is the case, also, with most of the material in the immediate neighbourhood of the Thames river. Good gravel was seen, however, on the farm of Mr. Dubbs on the northwest bank of the Thames near Moraviantown, pit number 24, and in a number of places in the bed of the Thames river.

The best gravels observed in the belt south of the Pere Marquette railway are those at the western end of a ridge in Romney township, gravels found in a ridge at the village of Cedar Springs, pits 1 and 2 (Plates VI A and B), and a large deposit of gravel on the Talbot road east of Morpeth, pit 11 (Plate VII). The other gravels in this belt vary in quality, but are not as good as those mentioned. Their comparative durability varies largely according to the percentages of soft pebbles which they contain. By comparing the field estimates of the composition of the different gravels with those of the gravels which have been tested in the laboratory (table following) an idea may be obtained of their comparative value in road work. The composition of the various gravels is to be found in the detailed description of the deposits, pages 120 to 137.

Results of Tests made on Gravels in Kent County.

Map No.	Cementing value.		Per cent wear.	French coefficient of wear.
	Coarse material over ¼ inch.	Fine material under ¼ inch.		
1	37	39	4·80	8·3
11	70	70	3·07	13·0
23	52	not determined	8·40	4·8
24	75	88	3·54	11·33

Granular-metric Analyses of Gravels from Kent County.

Map No.	Percentage of gravel retained on ¼ inch screen.	Percentage of sand passing ¼ inch screen.	Total.	Percentage of sand retained on.									Percentage of silt.
				⅛ inch.	No. 10.	No. 20.	No. 30.	No. 40.	No. 50.	No. 100.	No. 200.	Passing 200.	
1	43·1	56·9	100	24·6	34·4	57·2	69·1	77·2	84·0	94·8	96·6	3·4	5·5
11	59	41	100	40·7	53·2	74·7	82·3	87·0	91·3	95·8	97·0	3·0	4·5
24	47·5	52·5	100	22·0	28·6	43·5	60·5	79·2	90·8	97·6	99·0	1·0	2·0

All of the four gravels have fairly high cementing values. The best of the four, the gravel from pit 11, contains 40 per cent hard and 10 per cent soft pebbles. The next best, No. 24, contains only 15 per cent hard and 20 per cent soft pebbles. The percentage of wear is probably related to the percentage of soft pebbles present. The gravel from pits 11 and 24 should be capable of withstanding medium country traffic and should bind well in the road beds. Actual experience has shown that they do. Pit No. 1 is less durable and the material from pit 23 is poor. The material from pit 11 should be suitable for concrete road work. The gravel from No. 1 is rather soft for that type of construction and pits Nos. 23 and 24 contain too many impurities.

FIELD-STONE.

Some field-stone is found near Blenheim and more of it in the southeastern extremity of the county. About 600 cubic yards were seen in an area of about 300 acres, east of Clearville; the other occurrences are smaller and more scattered. The quantity present in any locality is too small to allow the use of the stone in practical road construction.

OUTSIDE SOURCES OF SUPPLY.

Gravel is being dredged from the St. Clair river near Sarnia and can be obtained from the Cadwell Sand and Gravel Company of Windsor. Boats drawing 12 feet of water could unload this material directly at Chatham. Larger boats can unload at Wallaceburg and Rondeau.

Fairly good crushed limestone can be had from the Hagersville Contracting Company's quarry at Hagersville and the Canada Crushed Stone Corporation at Dundas. The stone from these two quarries is of about the same quality and sells at from 60 to 75 cents per ton at the quarries. Railway freight rates to Kent should range from 70 to 80 cents per ton. Trap rock of much better quality than the limestone can be had from the Martin International Trap Rock Company at Bruce Mines at 80 cents to $1 per ton f.o.b. quarry. The freight by boat to

Wallaceburg would be 35 cents and to Rondeau harbour 45 cents per ton; but that does not include the cost of unloading which varies from 5 to 35 cents per ton according to whether or not mechanical unloading devices have been installed at the ports of discharge.

DETAILED DESCRIPTION OF THE DEPOSITS.

The townships north of the Thames river are Dover, Chatham, Gore of Chatham, Camden, Gore of Camden, and Zone.

No road materials were found in Dover, Chatham, nor the Gore of Chatham. A deposit of sand lies for one-half mile along the St. Clair beach just north of the mouth of the Thames river and another sandy patch was found a few miles west of Kentbridge on the river road in Chatham. The top soil over these townships is practically all clay.

CAMDEN, GORE OF CAMDEN, AND ZONE TOWNSHIPS.

Gravels occur along the Sydenham river east of Dresden and along the Thames northeast of Thamesville.

Sydenham River.

The deposits seen on the Sydenham river are really coarse sands and are of value only because of the general lack of gravel in this region. The boundaries of the deposits examined are sketched on the map, except in the case of one on the farm of Mr. H. Webster, north of the river near Dresden; of this only the pit is shown. The deposit on Webster's farm is said to cover about 10 acres. The sand and gravels lie in terraces which are the remains of an old flood-plain or a set of old channels of the Sydenham river. From the terraces banks 5 to 15 feet high rise to the level of the surrounding plain. The terraces lie on both sides of the river which flows in a narrow trench 20 feet below.

The material is very fine, only from 10 to 30 per cent being over one-quarter inch in diameter, and the coarser part is rarely over three-eighths inch. Fully 80 per cent of the gravel is made up of pebbles of soft shales and sandstones. The pebbles are angular to rounded. The deposits are stratified, weathered to a depth of about 5 feet from the surface, and overlain by light yellow sand from 2 to 8 feet deep. They contain clay in the weathered part and in one place a lens of clay in the unweathered part. The pits are small in extent and have been excavated by hand. The gravel and sand sells at from 60 to 75 cents per yard, in place in the pit, and is used almost entirely for cement work. The extent of the deposits is hard to determine. They vary in thickness from 4 to 6 feet and the four deposits examined vary in area from 5 to about 80 acres.

The material is entirely too soft and fine for first-class road work. It would perhaps improve local clay roads, but for any road except those on which the traffic is very light, stone or gravel should be imported from the outside.

Thames River.

The gravels on the banks of the Thames river occupy the same position relative to the river as those on the Sydenham, that is they lie on an old flood-plain of the Thames and in places the river still floods part of this land during high water. From Thamesville up the river eastward to near Moraviantown a rather extensive area is underlain by gravels and sands. The gravel is nearly everywhere overlain by 3 to 10 feet of clay and the limits of the deposit as sketched on the map are, therefore, only approximate. One or two pits have been dug at Thamesville and one pit, No. 24, on Mr. Dubbs' farm in concession VII. The Thamesville gravels are very fine. In the exposures examined the coarser material over one-quarter inch in size, occupied from 0 to 20 per cent of the whole mass. Most of the pebbles are of limestone, some of shale and sandstone. The gravel and sand bed is 6 feet thick in places, but probably varies greatly in that respect.

On the farm of Mr. Dubbs, lot 2, concession VII, a lens of gravel is exposed on the river bank. This gravel is quite coarse and the pebbles range up to 3 inches in diameter. The gravel deposit is from 1 to 6 feet thick in the bank and several hundred feet long. It is overlain by 4 feet of clay and soil and underlain by boulder clay. The gravel is composed of 15 per cent hard pebbles, 65 per cent limestone, and 20 per cent of shale and sandstone. It has been used on the neighbouring roads and for cement work. A stretch of the river road northeast of Dubbs' farm was surfaced with gravel from this pit in 1909. This is the main road between Thamesville and Bothwell and the traffic over it is fairly heavy. The road has some bad holes in it, but the road bed as a whole is still holding up and is in places in good shape. The material is sold at 25 cents per yard in the pit. The results of granular-metric analyses and of physical tests upon a sample of this gravel are given in the tables on pages 117 and 118.

A deposit of gravel is found on the flat land north of the river about 1 mile west of the county line. The flat is bounded by a 20-foot terrace to the north and by the river to the south. One pit was examined in the deposit. The boundaries of the gravel area are said to extend along the flat for one-half mile, both east and west from the pit marked on the map. The material in the pit is over two-thirds sand and about 75 per cent of the pebbles are of sandstone and shale. The pit, which is 100 $\times$ 70 $\times$ 6 feet, is owned by Mr. J. McRoberts.

Deposits of gravel and sand lie in the bed of the Thames river at various points east of Chatham. Their location is shown on the map. According to surveys made by Mr. W. G. McGeorge, C.E., of Chatham, in 1912, the deposits between the town of Chatham and Kent Bridge village lie under from 3 to 12 feet of water, and are from 6 inches to 8 feet thick. The three patches marked on the map together covered in 1912 an area of 145 acres of river bottom. The material shifts with every river flood. The writer examined one pile of coarse sand which came from this part of the river. About one-fifth of the deposit consisted of pebbles between one-quarter and one-half inch, the rest was sand. The coarser portion consisted of about 70 per cent soft shale pebbles, about 10 per cent hard pebbles, and the rest of limestone pebbles and shell fragments. The sand and gravel are dredged from the river bottom by the firms of C. and T Hadley and Capt. Crow of Chatham, with suction pumps transported in scows, and sold in Chatham and on the river front below at about 65 cents per cubic yard. The material is very soft and fine for road work, but like the gravels on the Sydenham river it is of value because of its position in a district practically devoid of road-making materials.

From Kent Bridge up as far as Moraviantown gravel has been taken from the river bottom at a number of places. The greater number of these gravel deposits lie near some bend in the channel, a fact that is not brought out on the accompanying map, on which the details of the course of the channel are in places wrongly shown. The deposits are small, seldom over a few hundred feet long and from a few inches to about 3 feet deep. The material is generally fairly coarse and parts of it may be practically free from sand. Nearly two-thirds of the pebbles are of limestone, shale and sandstone make up from 15 to 20 per cent, and the remainder is of hard pebbles. The deposits are renewed from year to year by material washed down by the river.

A stretch of the river road south of the river from lots 2 to 6, Howard township, was surfaced and is maintained by Mr. G. C. Williams from a gravel deposit in the river. This road is scraped once or twice a year and the holes filled in as they form. This stretch of road is in very good shape.

TILBURY EAST, ROMNEY, AND RALEIGH TOWNSHIPS.

The road metal deposits in these townships are confined to gravel deposits on or near the Lake Erie beach. A few scattered occurrences of field-stone are shown on the map, but they are present in entirely too small quantities to make them of practical value in road building.

The gravel deposits are found upon the present Lake Erie beach and in a long narrow gravel ridge lying parallel and very close to the shore in Romney township. A large ridge of gravel lies in the southeast corner of Raleigh, but as it forms part of a long ridge which extends northeastward through Harwich and Howard townships, it can more conveniently be described under Harwich and Howard.

Beach Gravel.

The beach gravel was seen at the point where the boundary between Essex and Kent counties intersects the Erie shore. From this place gravel is hauled for the roads on both sides of the line. It consists of 70 per cent of coarse sand and only about 30 per cent gravel. The gravel is made up of about 60 per cent limestone, 15 per cent hard pebbles, and 25 per cent soft shale. The deposit is about 30 feet wide, from a few inches to 3 feet deep, and may be continuous for nearly a mile. Farther east patches of gravel lie on the beach; but the banks are from 40 to 80 feet high and the material has to be hoisted up with an engine. Between the county line and the east line of Raleigh the beach gravels were examined in two places. Near Port Alma they proved to be of the same character as that of the deposit just described. Close to the east end of Raleigh they were of better quality, fully 50 per cent being composed of hard pebbles and only about 15 per cent of soft shale.

Parts of the Talbot road for several miles on both sides of the village of Wheatley have been surfaced with gravel from the beach and the road on the whole was in good shape in the summer of 1914, in spite of fairly heavy traffic. The beach gravel is hauled for 10 miles and more into the townships to the north and used in concrete work. It contains no weathered pebbles and, therefore, tends to be durable and wear well.

Gravel Ridge in Romney.

The ridge in Romney township is from 8 to 15 feet high and from 100 to 300 feet wide for about 4 miles at its western end. Eastward it gradually becomes lower and is partially cut into by the shore cliffs until finally no pronounced ridge is visible. The Talbot road follows the ridge all the way. On its western end the road runs south of it but crosses to the north about the middle of the ridge. Toward the western end of the ridge the gravel is quite coarse and is composed of about 25 per cent hard pebbles, 25 per cent soft, and 50 per cent limestone. Toward the east it becomes finer, especially that part of it which lies south of the Talbot road, and the pit on lot 187, some 2 miles from the east end of the deposit, is nearly all sand. In this pit soft shales and sandstones make up 80 per cent of the deposit. The gravel is weathered from 2 to 4 feet from the surface. The portion of the Talbot road adjacent to this ridge has been surfaced with gravel taken from it and was in very good condition in September 1914. The western end of the ridge is composed of much better road gravel than the eastern end. It stands up well on the Talbot road and would do even better on the lighter travelled roads to the north of it. Renwick and Coatsworth stations on the Pere Marquette railway are within 2 miles of the gravel.

Because of the slight rise in the ground and the superior drainage afforded by it, this ridge has become the site of a great many farm houses and there are buildings of some kind on it at intervals of about 200 yards. This will tend to prevent the excavation of much of this gravel.

HARWICH AND HOWARD TOWNSHIPS.

Numerous gravel deposits occur in the southern portion of these two townships.

Cedar Springs, Blenheim, Ridley, Morpeth Ridge.

A ridge of sand and gravel begins on the lake shore about 1½ miles southwest of Cedar Springs and continues with a few interruptions through Blenheim, Ridley, and Morpeth to a point near the Orford town line. Its length is nearly 18 miles with a few interruptions where it is crossed by creeks. Near Blenheim it branches into two, but the southern arm is only a few miles long. The southwestern end of the ridge is a prominent topographic feature rising some 30 feet over the plain, and is from 200 to 700 yards in width. At Blenheim it is still sharply defined especially on its northwestern side, but east of Blenheim the ridge widens out and passes into a broad area of irregular clay ridges whose northern and southern ends are defined by short steep slopes which fall to the plain on both sides of it. The gravel itself lies in a narrow ridge along the southern edge of this hilly area. A few miles to the east of Morpeth it runs into the southern edge of a series of clay hills and the best gravel ends there, although two narrow ridges of sand, with gravel in them, which pass through and south of Palmyra, are continuations of the same deposit.

The character of the material in a ridge of this size can only be imperfectly estimated from an examination of the excavations in it. The southwesterly extremity appears to become very sandy. Near Cedar Springs the gravel is coarse, there are great quantities of it, and it appears to be of good quality. At Blenheim it seems to be sandy and of poor quality especially in the southerly branch of the ridge. At the cemetery east of Blenheim the gravel is sandy and not of very good quality. From this point to the large pits east of Morpeth there are few openings in the ridge.

The deposit near the main pit at Morpeth, No. 11, is irregular in shape and forms the southern face of extensive clay hills. The gravel from this pit is considered the best road material in the neighbourhood.

The road between Cedar Springs and a point one mile east of Blenheim, which is surfaced in part with gravel from this ridge, was in poor shape during the summer of 1914. This is due in part to poor maintenance; but the composition of the gravel near Blenheim indicates that it is not durable enough for the heavy traffic which passes over the road; the material at Cedar Springs should do much better.

From the cemetery east of Blenheim to Ridley the traffic is lighter, although a great many automobiles pass over it, and this stretch of road is on the whole in good condition. In this stretch the road lies for the most part on the gravel ridge, it is surfaced from pits along the ridge and kept scraped with split-log drags. The condition of various parts of this stretch varies apparently according to the care with which it is maintained. The Talbot road from a mile or so west of Morpeth to near Palmyra is surfaced with gravel from pit 11. Practically all of it is in good shape; parts of it are in very good shape. The traffic over this part of the road is light. The gravel from pit 11 has been used on one small stretch of the main street in Ridgetown with satisfactory results. The results of physical tests upon two gravel samples from this ridge are given on page 117.

All the pits appear to have been dug by hand. Those at Cedar Springs (Plate VI A) and Blenheim are either directly connected with or are not far from railway lines. The nearest railway station to the pits near Morpeth is at Ridgetown 6 miles away.

The amount of gravel available is, of course, very large, but it varies greatly in quality and in fineness. At Cedar Springs the gravel is from 20 to 35 feet deep (Plates VI A and B) for a width of about 200 yards on the main ridge, but it continues to the nearby plain although it is much thinner there. In and near Blenheim the maximum depth of the gravel is from 15 to 17 feet, at Ridley about 14, and just west of Morpeth about 12. At the big pit east of Morpeth, No. 11 (Plate VII) the gravel is in places 60 feet deep. On the farm of Mr. James McLarty across the Talbot road from the pit, about 6 to 8 acres of the hill is underlain by from 50 to 60 feet of gravel; and to a point 600 yards south of the road, there is from 5 to 10 feet of gravel under the plain, at the foot of the hill.

A conservative estimate of the amount of gravel on this farm places it at 950,000 cubic yards. The total amount underlying the higher part of the deposit in this neighbourhood must be several million cubic yards. For 1½ miles from the eastern end the deposit is only a few feet thick and is sandy.

The following table gives details of excavations and gravels in the ridge:

Gravel Pits in the Cedar Springs, Blenheim, Ridley, Morpeth Ridge.

Map No.	Owners.	Size of pit in feet.	Percentage of sand under $\frac{1}{4}$ inch.	Character of the material.					Remarks.
				Depth of weathering in feet.	Impurities in unweathered part.	Composition. Percentage of			
						Hard pebbles.	Limestone.	Soft pebbles, shales, etc.	
1	Chatham, Wallaceburg, and Lake Erie (Electric) Railway Co.	Large, depth 25							Resembles No. 2 and is adjacent to it. Loaded on flat cars by hand at $1.35 per car, cars take about 12 cubic yards. Used for ballast and concrete work. Railway owns 10 acres, 30 acres to west for sale.
2	Townships of Raleigh and Harwich	235 × 80 × 30	35	2 at surface; another bed at 20 feet down slightly altered		35	40	25	Pit walls stand up well. Water level at 35 feet from surface. Gravel $\frac{1}{2}$ to 3 inches, well stratified. See Plate VIB.
3		Small, depth 12–17	25	3	....	30	55	15	Well stratified, cross-bedded, beds in west face conform in dip to surface over them.

4	A. E. Young, Blenheim, 4 acres	Large irregular	....	3	....	....	....	....	This pit is practically abandoned, it is adjacent to No. 5.
5	Mr. Ross, Blenheim	500 × 14 × 100	65	3 to 4	Coating of lime carbonate	15	50	35	Pebbles up to 3 inches, material bedded. Excavation in either 4 or 5 began 22 years ago. Sold at 50 cents per load.
6	....	Small	....	....	....	....	....	....	....
7	....	350×150 × 12 to 15	60 to 90	4	....	....	....	High percentage of shale.	Very little excavating done at present.
8	....	210 × 75 × 9–12	80+ coarse	4	....	....	....	....	....
9	....	50 × 50 × 6	50+	3	....	....	....	....	....
10	....	150×100 × 9	50	4	....	....	....	....	Sold at 10 cents per yard.
11	Gravel hill across road to south owned by James McLarty	500 × 50 to 100 × 15 to 25	Low in west end, high in places, gravel fairly coarse	2+	Slight coating lime carbonate or clay	40	50	10	Gravel said to be 50 feet deep. Talbot road, surfaced with this material, in very good shape. This gravel favourably known for miles around
12		100×120 × 25	....	....	....	Probably like No. 11			Abandoned.

Ridgetown Deposit.

An irregular ridge-like deposit of sand and gravel lies on the northen edge of the clay hills. It begins just south of Wilkie station in Harwich township and extends northeastward through the village of Ridgetown, to a point about 1½ miles from Highgate in Orford township. It may conveniently be referred to as the Ridgetown deposit. The details of the excavations examined are given in the following table. The area as mapped broadens out to the east of Ridgetown. Near the Orford line, it contains gravel in the hills only and clay is likely to crop out in the low places. The gravel in this ridge is sandy, weathered down 2 to 6 feet and carries a large percentage of shale pebbles. The depth of the deposit ranges from about 10 to 18 feet and the amount available is large. Except in a few places the gravel is of poor quality. It should cement well in a gravel road, but will wear out quickly.

Minor Areas South of Ridgetown Deposit.

More than a dozen small patches of sand and gravel are mapped between the two large deposits in Harwich and Howard townships. Three of them are in Harwich, concessions VI and VII near the Howard line. The one in concession VII is 1½ miles long and 5 to 9 feet deep. All three are very sandy.

Several patches of gravelly soil are mapped in concession XII of Howard. The easterly three areas lying three-quarters of a mile north of Ridley appear to be shallow. The two in lots 4 and 5 are said to be 14 feet deep in places and appear to contain a large proportion of hard pebbles. The boundaries of the large patch in lots 6, 7, and 8 are sketched partly according to information supplied by J. R. Serson, the former owner of one section of the deposit. A gas well driven near the middle of this large deposit is said to have encountered 44 feet of gravel. Three pits within this patch were examined, and the gravels in them differ in quality. The one shown on the map, near the middle of the deposit, appeared to be made up of nearly one-third durable pebbles, while the other two pits carry a larger quantity of shale and soft pebbles. The amount of sand also

Pits in the Ridgetown Deposit.

Map No.	Size of pit in feet.	Percentage of sand under ¼ inch.	Character of the material.					Remarks.
			Depth of weathering in feet.	Impurities in unweathered gravel.	Durability, percentage of.			
					Hard pebbles.	Lime-stone.	Soft pebbles, shales, etc.	
13	100 × 75 × 7 to 10	20	3 to 4	Coating of lime carbonate in abundance.	20	60	20	
14	100 × 1,850 × 6 to 10	Varies along pit face	2	?	20	50	30	Probably worked by steam shovel. Thought to belong to the Pere Marquette railway. Gravel overlain to south by 10 to 15 feet of sand.
15	200 × 300 × 6 to 8.	30	4	....	....	....	....	Bottom of pit on clay, lower bed bouldery.
16	800 × 200 × 5 to 14	Sand at bottom	2 to 4	....	25	50	25	Very bouldery. The ridge has been excavated here across its whole width.
17	....	40	2 to 6	Iron oxide, lime carbonate, clay	20	60	20	Rather bouldery near surface. West bank of creek.

Pits in the Ridgetown Deposit—Continued.

Map No.	Size of pit in feet.	Percentage of sand under ¼ inch.	Character of the material.					Remarks.
			Depth of weathering.	Impurities in unweathered gravel.	Durability, percentage of.			
					Hard pebbles.	Lime-stone.	Soft pebbles, shales, etc.	
18	Depth 13	60+	Badly to 4 partly to 10	....	10	50	40	Used in Ridgetown side-walks which started to fail when 6 years old.
19	Small depth gravel 16	....	4	Iron oxide and lime carbonate	....	....	40	Proved very poor material for adjacent Ridgetown road on which the traffic is moderately heavy.
20	30 × 30 × 10	Small	2 to 6	....	15	60	25	Gravel down to 18 feet.
21	150 × 75 × 12	....	6	Lime carbonate, dirty	....	....	High	Gravel owned by Mr. Ed. Smith, sold at 15 cents per load.
22	Small	....	5	Dirty, organic impurities, iron oxide	....	....	....	Overlain by 1 to 4 feet of yellow sand.

varies and the gravel passes laterally into clay near the boundaries of the deposits. The road passing over this deposit south of concession XII is surfaced with this material and is in good condition.

Three small patches of gravel appear on the map north of the area just described and between it and the Ridgetown gravel ridge. They range in maximum depth from 6 to 10 feet. The gravel is very sandy in all three cases and weathered to a depth of 6 feet in one place. The gravel in the pit on lot 12, concession XI, contains 15 per cent hard pebbles, 50 per cent limestone, and 30 per cent soft pebbles including shales.

McGregor Creek Deposit.

A small deposit lies north of McGregor creek in concessions XII and XIII, lots 15 and 16, Harwich. A pit 500 × 400 × 8 to 12 feet is excavated in it. The material varies from coarse sand to boulders. The pebbles are largely limestone with some shale and hard material. An overburden of from 1 to 2 feet lies over it at the pit. Messrs. R. Adams, J. F. Jordan, and D. Johnson own land on this deposit. The gravel varies greatly in depth, but has been proven to 14 and 16 feet on the north and east sides of the pit.

Rondeau Park.

A sandy gravel may be obtained from the Lake Erie beach at Rondeau park. The deposit was from 5 to 10 feet wide in September 1914, and from 2 inches to as many feet thick. It is renewed periodically by the waves and currents of the lake. The pebbles are approximately 35 per cent hard igneous rock, 45 per cent limestone, and 20 per cent soft shale and sandstone. The best gravel road seen in Kent and Essex counties is that running north for one mile from the park buildings. It is said to consist of a clay course on the original sand foundation with a top dressing of gravel and to have been resurfaced in 1911. The traffic over it is light and it was in splendid condition in 1914. The exact locality from which this gravel was derived was not ascertained.

Field-Stone.

Occurrences of field-stone are shown on the map near the village of Blenheim and on the lake front east of Morpeth. The occurrences northwest of the railway at Blenheim do not amount to more than a few hundred cubic yards all told. The same is true of the occurrences southeast of the town.

Between Morpeth and the town line several hundred cubic yards of stone were seen lying close to the gravel and sand deposit and across five lots. It is possible that there is more field-stone southeast of the Cedar Springs Morpeth ridge.

ORFORD TOWNSHIP.

Duart Ridge.

A long, narrow sand and gravel ridge passes through Duart and crosses the county line just south of the Michigan Central railway. The ridge is narrow and usually well defined and the gravel in it from 10 to 20 feet deep. The material is very sandy throughout and in the pit west of Duart it is weathered to a depth of about 5 feet. It is not a very durable gravel.

A couple of pits have been opened on the county line in two ridges which begin just north of the one described and continue to the northeast into Elgin county. This material is weathered to 3 feet, carries about 20 per cent of hard pebbles, and is thoroughly coated with lime carbonate. The pits are long and narrow, one belongs to Aldborough township and the other probably to the Pere Marquette railway.

Highgate Deposit.

A deposit of sand and gravel some 2½ miles long and trending in a northwesterly direction lies just to the south of the village of Highgate. The boundaries of this deposit are only approximately located on the map. Two pits have been opened and they indicate that the gravel passes into sand toward the boundaries of the deposit. Sand hills lie to the north of the area. The northwesterly pit on the farm of Mr. J. W. Ward appears to lie on the southeasterly side of a gravel core which passes into sand on its outer edge. The pebbles in this pit are about 50 per cent shale, 20 per cent hard igneous pebbles, and 30 per cent limestone. Its size is 300 × 150 × 9 feet. In the south-westerly pit the gravel is overlain by 4 feet of sand in places and its upper few feet contain a great deal of clay. The material is of poor quality.

Three deposits are mapped just west of Muirkirk. Their boundaries are based on the limits of gravelly soil exposed, for only one excavation was seen. In this the gravel carries about 50 per cent of shale pebbles and is weathered to from 2 to 4 feet. The size of this pit is 290 × 150 × 5 to 12 feet. A gravel ridge is mapped one-half mile northeast of Muir kirk. It is sandy, and farther in that direction there are plenty of sand ridges.

Gravel is found in the higher ridges within two mapped areas which lie about one-half mile north of Highgate, but the depth or character of the material was not discovered.

Clachan Gravels.

A broad flat area of gravel extends nearly south of Clachan post-office for about 3 miles and apparently passes to the north and east into Elgin county. As in other of the deposits in this neighbourhood the boundaries could be drawn in an approximate manner only. This area is sometimes spoken of as the gravel plains. A fairly large pit, No. 23, has been opened on the road between concessions IX and X a little over one mile south of Clachan. Its size is 400 × 200 × 10 feet. The gravel is well sorted, and the pebbles vary from a coarse sand to 2 inches. It is weathered to a depth of 8 feet and is thickly coated with lime carbonate so that the character of the pebbles could not be determined. In a pit in the same deposit, but lying in Elgin county within one mile of Clachan, the proportion of hard pebbles is about one-fifth of the whole. The gravel from pit No. 23 has been used on the county line road which passes to Clachan, and appears to wear away rapidly. The results of laboratory tests made upon the gravel from pit 23 are given in the table on page 117. The physical tests indicate that the wearing quality of the gravel is very poor. The gravel deposit appears to vary from 10 to 18 feet in depth over this area and averages about 12 to 14 feet. There is a large quantity available.

Minor Deposits in Orford.

A narrow ridge of sandy gravel $2\frac{1}{2}$ miles long passes through the village of Palmyra. The gravel is only 2 to 3 feet thick and is practically valueless.

A small deposit of sandy gravel lies in lots 4 and 5, 2 miles northeast of Palmyra. It is very sandy and does not look promising for road purposes.

A deposit is found just east of the township line in concession IV. Forty acres of this is on the farm of Mr. A. Gillander, Highgate P.O. There is about 12 feet of gravel and, where exposed at the surface, the upper 6 feet is badly weathered. In places just north of the boundary marked on the map the gravel is overlain by 18 feet of sand. The pebbles are largely limestone and are thickly coated with lime carbonate.

A deposit of gravel 4 to 6 feet thick lies under an overburden of clay and sand on the south bank of the Thames river a few miles east of Thamesville. From the town line east to lot 5 and for one-half mile south of the river, gravel is found within 10 feet of the surface. It becomes sandy to the south. Only one excavation was seen and in that 4 feet of sandy gravel was overlain by an overburden of sand 6 feet thick.

A pit $1\frac{1}{2}$ miles northeast of Moraviantown contains sandy gravel with limestone and shale pebbles. This gravel sells at 15 cents per cubic yard.

Beach Gravel.

The Erie shore in Orford township consists of perpendicular clay banks, so that the gravel is available in a few places only. One of these is south of Clearville where the deposit is about $500 \times 15 \times 3$ feet in size, but is renewed periodically by the wash of the waves. This material contains 25 per cent hard igneous pebbles and the rest is equally divided between limestone and soft pebbles. The beach gravel is, as usual, clean and well rounded.

Field-Stone.

About 600 cubic yards of field-stone was seen in an area of about 300 acres, 1 mile west and north of Clearville. There is more stone in the immediate neighbourhood, but none was recorded from other parts of the township.

PART V.

ROAD MATERIALS ALONG THE NORTH SHORE OF LAKE ONTARIO BETWEEN PORT HOPE AND HAMILTON.

Part V.

Road Materials Along the North Shore of Lake Ontario between Port Hope and Hamilton.

INTRODUCTION.

The following section deals principally with the road-making qualities of a series of deposits of gravel and sand which lie in a belt from 1 to 7 miles wide along the north shore of Lake Ontario. To the description of these gravels has been added an account of the bedrock occurring near the gravel deposits, and of such outside occurrences of stone as might be considered practically available for road-making in the immediate neighbourhood of the lake.

The field work on the gravel and sand deposits was done in the summer of 1914 by Mr. J. K. Knox under the direction of the writer. Mr. Knox's work was done in a most painstaking and thorough manner. Laboratory tests upon gravel and stone sampled by the writer and Mr. Knox were made by Mr. G. C. Parker, Assistant Engineer, in the Office of the Commissioner of Highways of Ontario.

The field work covered a belt about 130 miles long and from 1 to 7 miles wide, extending from Trenton to Hamilton and from the lake shore north to an old lake beach-line. The information upon about 36 miles of this, the section lying between Trenton and Port Hope, is not published in this report, but is available at the office of the Geological Survey.

TOPOGRAPHY AND GEOLOGY.

The main belt of the sand and gravel deposits forms part of the beach-line of an ancient lake which has been named

Lake Iroquois. The beach-line approaches the present shore of Lake Ontario in places and in others lies 7 miles from it. At Hamilton the top of the gravel on the old beach is 116 feet above the Lake Ontario level.[1] It increases in elevation to the east and at Port Hope, where it is 7 miles from the lake, the top of certain gravel bars on it lies more than 300 feet above the water of Lake Ontario. The beach-line is marked by a series of bluffs cut in the clay hills (Plate VIII A). It is very winding, with numerous small embayments where streams cross it. A bar of sand and gravel lies across, or partly across the mouth of every one of the embayments. The bars are up to 3 miles in length and usually from 50 to 100 yards wide, although a few are more than 500 yards across. Their tops are from 10 to 30 feet over the country to the south of them (Plate VIII B). Their southern slopes are usually gentle and the northern, although they may not descend so far, are usually more abrupt (Plate IX A). Occasionally the ridges branch into two with a low depression between them and at times they give off branches or hooks to the north and south.

Lakeward from the old shore-line is a more or less flat terrace which slopes gently toward Lake Ontario. The shore of the present lake is in many places a wave-cut cliff of boulder clay and in others it is flat and swampy.

As a rule, gravel bars on the old beach-line are distinctly stratified (Plates IX A, X B). The different strata or beds are made of pebbles of different sizes (Plate IX B). These beds are elongate in the direction of the bar and narrow laterally. They often dip toward the old shore, but not invariably, and their direction of dip is so irregular that one can hardly state a set rule with regard to it. The irregular way in which beds of varying sizes lie over one another has given rise to great variation in the proportions of sand and gravel, found in different parts of the deposits.

Brooks cut across many of the bars and wash the gravel downstream. The load of gravel and sand acquired from the bars is in time laid down by the streams at bends in their chan-

[1] Coleman, A. P., "Iroquois beach in Ontario": Bull. Geol. Soc. Am., vol. xv, June, 1904, pp. 347-368.

nels, and other places where the current slows down, to form deposits of valley gravel. The valley gravels have been exploited for road purposes in many places, but are generally of small extent.

The flat terrace in front of the old shore-line, if one may judge from a similar terrace in the present lake, has been formed by the cutting action of waves. Many large boulders or field-stones, too heavy to be carried away by the wave action, are strewn over the terrace. They represent the remains of the hills of glacial boulder clay which stood on the site of the present terrace. In low places on this terrace, small deposits of gravel are found, probably swept in there by the waves of the old lake. Other deposits, associated with hills of clay on the terrace, probably owe their origin to ice as well as water action.

The underlying bedrock over the greater part of this belt is covered by deposits of boulder clay, sand, and gravel, but outcrops are found in certain places, sometimes in the beds of streams and occasionally in cliffs along the lake shore. For 12 or 13 miles west of Port Hope, and many miles east of it, the underlying rock is the Trenton formation. From the neighbourhood of Newcastle to Pickering township the underlying formation is the Utica shale. The Lorraine formation underlies the belt from Pickering township west to the Credit river. From the Credit river westward to the Niagara escarpment, north of Hamilton, the unconsolidated clay, sand, and gravel is underlain for many miles northward from the lake shore by the Queenston or upper part of the Richmond formation and by the Cataract, a member of the Medina. The Niagara escarpment near Hamilton consists of formations ranging from Queenston at the bottom through Cataract, Medina, Clinton, Rochester, and Lockport. All of these formations are of Palæozoic age. Their lithology is described more fully under "Deposits of Stone" pages 200 to 216. The bedrock is all of sedimentary origin and the different beds lie flat or dip at low angles.

DEPOSITS OF GRAVEL AND SAND.

CHARACTER OF THE GRAVELS.

The results of the examinations of exposures of sand and gravel in the various deposits between Port Hope and Hamilton are summarized in the table on pages 150 to 167. In nearly all the bars along the old beach-line, one or several pits and road cuttings were available for examination, but the exposed portion of the gravels forms in every case a very small part of the deposit in which they are found. In the cuts examined estimates were made of the proportions of sand, gravel, and boulders present and of the composition of the pebbles in the gravelly portion.

No account was taken of the composition of the weathered portion of the deposits. The weathered portion contains numerous impurities not found in the rest of the deposit; it is never more than a few feet thick, generally less than 2 feet, and should always be removed before quarrying the gravel, as it is of inferior quality for road purposes.

The proportion of sand and gravel varies greatly from point to point in practically all the deposits and the estimation of sizes is not of very great value. The composition of the pebbles is more constant and it is thought that where the proportions have been determined in two or three pits in one bar an average of the composition of the pits will correspond to that of the bar as a whole. Field estimates are necessarily approximate, but it is thought that the composition of the gravel has been calculated within the limits of a possible error of 10 per cent. In the table on page 148 the results of laboratory tests made upon three samples of gravel within this area are placed side by side with the field observations and the results of the tests upon gravel from the Iroquois beach-line in Northumberland county a few miles east of Port Hope have also been added. A comparison of the two tables pages 150 to 167 and page 148 affords a basis for the following general estimate of the variation in character and quality of the gravels along the old beach-line:

Gravel can be used in road-making either as a surface for gravel macadam roads or in the construction of concrete roads.

Their Value as Macadam Gravels.

A good gravel for gravel macadam road should compact readily into a solid impervious mass under the action of the roller and of traffic and should wear well in the road bed.

Cementing Value. The probable ability of a gravel to cement together in a road bed is indicated by the degree to which the mass is cemented together in the deposit itself, and a rough measure of that is obtained by the length of time in which a newly cut vertical or overhanging wall of gravel in a pit will stand up without collapsing. The gravel is cemented together in the deposit by clay and by solutions which filter through it and deposit carbonate of lime and other substances on the pebbles and in the voids between them.

In the table on page 148 the results of laboratory tests upon five gravels are shown. Their cementing values are, except in the case of the first one, all fairly high, and in all, except the first one, clay or lime carbonate coating was detected in the deposit during the field examination. The table shows that where lime carbonate is abundant the cementing values are high even when clay is absent.

In gravels which lie at the surface, as these considered here do, the amount of lime in the solutions which filter down and compact them together will depend partly on the amount of limestone present, and also on the solubility of the type of limestone of which they are composed.

The percentage of limestone in the gravels between Port Hope and Hamilton is uniformly high, averaging about 70 per cent, and eastward from Port Hope to Trenton the percentage is higher. The amount of lime carbonate coating, which indicates the solubility of the rock, and the clay content, vary. Both of them are rare in the gravels east of Toronto; and clay is found only in a few places and in small amount in the beach gravels, except between the towns of Oakville and Burlington, near Hamilton, where the gravels contain considerable clay. Lime carbonate is difficult to detect in the field when present in small amount. Because of the high percentage of limestone present, the writer believes that the gravels, along the belt of deposits examined, will generally be found to have higher cementing values than the field estimates in the table pages 150 to 167 would indicate.

Durability. The table on page 148 indicates that the percentage of wear, as found in the laboratory, is not dependent on the amount of limestone present but varies according to the proportion of soft pebbles in the gravels. The limestones vary in toughness and hardness from place to place, but it is difficult to make satisfactory field estimates of such variations. Since at least one-third of the various deposits consists of sand, which wears to dust more easily than coarser material of the same composition, and the laboratory tests for wear were made on the coarser materials only, the gravels will in general be somewhat less durable than indicated by the laboratory tests. The gravels between Port Hope and Toronto are quite uniform in composition with an average content of: limestone 70 to 80, hard pebbles 20 to 30, and soft pebbles 0 to 10 per cent. Their wearing qualities should resemble that of the first three samples in the table on page 148, that is they should be fairly durable. From Toronto as far as Erindale the proportion of soft pebbles is still low and the hard pebbles in some of the pits range over 30 per cent. They should approach sample 117, which is from a pit near Summerville west of Toronto, in durability. From Oakville to Burlington the amount of soft material is high and the gravels are of poor wearing quality. The bar lying in the city of Hamilton carries a low percentage of soft pebbles, but that directly north and across the bay from the city is of less durable material.

Observations on gravel macadam roads constructed of these gravels showed that they nearly always gave satisfactory results when subjected to light country traffic except in certain cases where the proportion of soft pebbles ranged over 30 per cent. A few roads subjected to medium traffic have stood up for 2 or 3 years; such a one is the road from Erindale to Cooksville. Where the gravels are subjected to fairly heavy traffic, as in parts of the Toronto-Kingston road, they do not give satisfactory results when simply waterbound.

Concrete Road Gravel.

The gravel and sand used in concrete roads should be durable, free from impurities, and properly sized. The durability of the gravels is discussed in the paragraph preceding this.

The impurities which must be taken account of are clay, coatings of lime carbonate, iron oxide, and organic matter. The gravels are remarkably free from impurities as is indicated in the table on pages 150 to 167. Certain deposits do contain both clay and lime carbonate in abundance and they are not fitted for first-class concrete construction.

The advantage of using gravel and sand in which the proportions of the various sizes of particles present shall be such as to give the best result in concrete work has been discussed in Part I, pages 34, 35. The field examination of these deposits shows that they vary greatly from place to place in the proportions of the various sizes of particles present. In the construction of a concrete road from this material, therefore, it will always be found advisable to screen the pit-product to the required sizes. The cleanness and good wearing quality of a great number of these deposits indicate that they are good materials for concrete road work. Pit No. 50 near Oshawa has furnished the aggregate for a concrete road in that town. This road is subjected to fairly heavy traffic and was in good condition in November, 1914, three years after its construction.

Laboratory Tests and Composition of Gravels from the Iroquois Beach.

Location.	Cementing value.		Attitude of pit walls.	Composition.					Wear.	French coefficient of wear.
	Coarse aggregate, $\frac{1}{4}$ to $\frac{1}{2}$ inch.	Fine aggregate, under $\frac{1}{4}$ inch.		Clay.	Lime carbonate.	Estimated percentage in the gravel portion of				
						Limestone pebbles.	Hard pebbles, granites, traps, etc.	Soft pebbles, shales, sandstones, schists, etc.		
Lot 8, con. IV, Hamilton tp., Northumberland co.	0	34	....	None.	None.	85	10	5	2·2	18·2
Lot 23, con. II, Murray tp., Northumberland co.	42	66	7 ft. walls stand up well.	None	Moderate amount.	90 to 95	Small	Small	2·73	14·7
Pit 117	113	117	12 ft. walls stand vertical where recently excavated.	None.	Abundant	70	20	10	2·48	16·1
Pit 143	31	89	9 ft. walls stand vertical and overhang; firmly cemented; cuts new when examined.	5 to 10 per cent.	Present with clay	50	Rare	50	7·45	5·4
Pit 146	31	72	18 ft. walls stand vertical	Small amount	Abundant	50	25	25	3·65	11

Granular-metric Analyses of Five Gravels from the Iroquois Beach-line North of Lake Ontario.

Location.	Per cent gravel retained on ¼ inch screen.	Per cent sand passing through ¼ inch screen	Total.	Percentage of sand retained on screen.									Per-centage of silt.
				⅛ inch.	No. 10	No. 20	No. 30	No. 40	No. 50	No. 100	No. 200	Passing No. 200	
Lot 8, con. IV, Hamilton tp., Northumberland co.	60·3	39·7	100	26·0	32·9	49·5	61·3	70·7	79·0	92·0	96·7	3·3	4·15
Lot 23, con. II, Murray tp., Northumberland co.	60·5	39·5	100	19·6	28·5	65·3	86·5	91·1	92·6	94	95·2	4·8	4·5
Pit Number 117	50	50	100	......	48·4	70·1	83·7	90·7	95·1	97·6	98·0	2·0	2·8
Pit Number 143	75	25	100	66·4	80·4	94·5	97·2	97·2	98·4	98·5	98·5	1·5	0·5
Pit Number 146	62	38	100	39	54	68·5	76·5	84·7	93·3	98·2	98·6	1·4	2·25

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario.

Pits.	Sizes, estimated percentage of.			Impurities.			Composition. Estimated percentage of			
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.	Shape of pebbles.	Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sandstone, schist, etc.	Remarks.
1	....	....	....	....	....	....	75	25	....	One small bed visible
2	....	....	....	....	....	....	....	....	....	No development.
3	0	10	90	....	....	....	....	....	....	Sand pit.
4	0	....	....	None	....	....	..Soft	30	....	Gravel not over 2 inches.
5	Large	....	....	....	....	....	Soft	....	....	Boulders and pebbles rather flat.
6	15	60	25	....	To depth 4 feet	....	80	20	....	Well stratified.
7									....	Same character as No. 4. Well stratified.
8			50				Largely limestone			Well stratified, walls stand up fairly well (Plate X A).

9							Limestone and shale			
10	20	65	15	None	....	Angular to sub-angular	75	20	5	Maximum size boulders 8 to 9 inches, stratified.
11	20	65	15	None	Absent	Subangular	75	20	5	Beds dip 45 degrees to west (Plate IX B).
12	10	80	10	....	Absent	Angular to subangular	70	30	....	Stratified, walls stand perpendicular.
13	10	80	10			Subangular	70	30	....	Walls largely covered, upper 4 feet resembles No. 12.
14	50+	....	....	....	....	....	Soft	30+	....	
15	Occasional	....	....	....	Moderate amount	Rounded to sub-angular	80	15	5	
16	10	75	15	....	Moderate amount	Rounded to sub-angular	80	20	....	Walls stand up well; lime carbonate in upper beds; strata dip 45 degrees to west.
17	Maximum size 2 feet, occasional	80	20	....	In upper 2 feet	do.	80	20	....	Walls stand perpendicular.
18	5	35	60	....	0	do.	80 Soft	20	....	Walls stand well.

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.			Composition. Estimated percentage of			
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.	Shape of pebbles.	Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sand-stone, schist, etc.	Remarks.
19	10 Maximum size 1 foot	80	10	....	Moderate in top beds	do.	75	20	5	Walls partly fallen in; stratified; dip both ways across length of deposit.
20	10 Maximum size 1 foot	40	50	None	0	Rounded	80	20	....	Walls do not stand up well.
21		40	60	None	0	do.	80	20	....	do.
22	5	80 Average 1 inch to 2 inches	20	Small amount	Moderate amount	Rounded to subangular	80	15	5	Walls stand up well; clay in one bed, strata dip north.
23	5	70	25	None	0	....	75	25	....	Walls do not stand well. Beds dip northwest and lie in series from coarse to fine.

24	5	55	40	0	Very little	....	75 Soft	25	....	Not used recently, walls fallen in; boulders flat limestone, slabs up to 18 inches across and 2 inches thick.
25	15	75	10	....	Abundant	Round to subangular, some flat	80	20		Not used recently, walls fallen down.
26	5	60	35	....	0	Rounded to subangular	80	20	....	Walls fallen in.
27	15	70 Average 2 to 3 inches	15		0	Rounded to subangular	55	45	....	
28	Little	85 to 90	10	0	Abundant	....	70	30		Walls fallen in.
29	Little	85 to 90	10	0	0	....	70	30	....	Old pit.
30	0	30	70	....	....	Rounded to subangular	....	....	....	Walls fallen in.
31	0	50	50	0	Moderate	do.	75	25		Walls do not stand well.
32	0	85 Average 1 inch	15	0	0	Rounded to subangular	80	20	....	Walls fallen in.
33	Rare	80	15 to 20	....	Little	do.	80	20		
34	25	60	15	....	Moderate	Rounded to subangular	80 soft	20	....	

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.		Shape of pebbles.	Composition. Estimated percentage of			Remarks.
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.		Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sand-stone, schist, etc.	
35	Rare	30	70	0	0	Subangular	80	15	5	Walls perpendicular where new, dip north to northwest.
36	....	....	60+	....	....	....	....	....	....	Yellow sand.
37	Few	70 av. 1 to 2	30	Present in one bed	Little	Rounded to subangular	75	20	5	Walls fallen in except where new; thinly bedded.
38	Few	80	20	0	do.	do.	80	20	....	Walls fallen in.
39	Surface g	ravelly in s	pots, no	pits						
40	10	75	15	Present in certain beds	Moderate	Rounded to subangular	70	30	....	Walls fallen in, strata cross-bedded.
41	0	70	30 to 40	0	Abundant	do.	80	20	....	Walls fallen in.
42	0	90	10	0	Little	do.	80	20	....	Walls stand well.
43	5	55	40	Present in one bed	0	Rounded to subangular	80	20		Walls fallen in.

44	20	70	10	0	0	....	70 to 75	25·30	10	Walls stand up well.
45	5	85	10	0	Moderate amount	....	70 to 75	25	5	Walls stand where new.
46	15	65 to 70	10	5 to 10 per cent	Small amount	....	70	20	10	Walls stand well.
47	10 Max. 1½ feet.	50	40	0	0		75	20	5	Walls fall down, material too fine.
48	5	60	35	Little	Very little	Rounded to subangular	75 Soft	20	5	Well stratified, walls stand up well.
49	3	57	40	None	None	Rounded to subangular	70	30 hard and soft		
50	5 Max. size 1 to ½ feet	70	25	None	None	do.	70	30 Hard and soft		
51	10 to 15	60 to 65	25	None	None	....	?	30	?	Well stratified.
52			60 to 80	?	?	?	?	?	?	
53	0	85	15	?	?	Rounded to subangular	70	25	5	
54										Old and fallen in.
55	0	40 Average under 1 inch	60	?	?	Subangular to rounded.				Walls fall down, stratified.
56	30	60	10	Probably low	....	Subangular to rounded	75	25	0	Walls stand up 18 feet high.

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.			Composition. Estimated percentage of			
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.	Shape of pebbles.	Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sand-stone, schist, etc.	Remarks.
57	15	70 Aver. 1 to 2 inches	15	0	0		70	25	5	Stratified.
58										Walls of pit fallen in.
59	0+	40 to 50	50 to 60	0	0	Subangular	70	25	5	
60										Walls of pit fallen in.
61										Probably resembles Pit 62.
62	8 to 10	50	40	?	?	Rounded to subangular	75 Soft type	25	0	Gravel uniform and fine, walls stand up fairly well, well stratified.
63										Walls overgrown.
64	5	75	20	0	0	Rounded to subangular	?	?	?	Cuts less than a year old, stand up, rest fallen in.

65	0+	50 to 60	40 to 50	?	?	do.	75	25	0	Walls fallen in.
66	5	75 Averages 1 to 1½ inches	15 to 20	0	0	do.	75 Soft type	25	0	This is a test pit, others in this lot similar.
67	21	44	32	3%	Little in spots	do.	70 to 75	25	5	Walls do not stand up well.
68	10	60	25 to 30	0	?	Flat and rounded	70	20	10	
69	10	65	13	12%	0	Subangular to rounded	70	30 Hard and soft		Practically no stratification, walls stand up well.
70	....	....	....	....	....	Subangular to rounded	80	20	....	Pit overgrown, gravel seen in groundhog burrows.
71	15 Maximum 1 foot	75 Av'ge less than 1 inch	10	0	Well coated	....	70	25	5	Strong dip of strata to north.
72	3 to 4 Maximum 1 foot	55	40	0	Very little	Subangular to rounded	70	25	5	Walls stand well, strata horizontal.
73	High	....	....	....	....	....	....	....	....	Small cut in creek bank.
74	0	55 Average ¾ to 1 inch	45	0	Slight coat in places	Rounded, a few flat	80	20	....	Stratified walls stand up.
75	0	50 Bean size	50	....	....	....	....	....	....	....
76	10	63	22	5%	A little	Angular to rounded	70	25	5	Walls stand well.

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.		Shape of pebbles.	Composition. Estimated percentage of			Remarks.
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.		Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sandstone, schist, etc.	
77	Few	....	80+	....	....	....	....	....	....	Sand deposit.
78	15	70	15	0	0	....	75	25	....	Small deposit.
79	10 Maximum 18	75	15	0	0	Subangular and rounded	80	20 Largely hard granite		
80	5 to 10	75 to 80	10 to 15	0	0	do.	80	20	....	Crusher and screens needed here.
81	0	70 Average 1 inch	30	....	....	....	....	....	....	Walls stand up well.
82	10	60 to 70	5 to 10	10 to 15 %	....	Angular and subangular	80	20	....	Walls stand up well.
83	....	....	60+	....	....	....	....	....	....	Sand, yellow.
84	0	85 Uniform and clean	15	0	0	Subangular to rounded	70	25	5	Walls stand perpendicular.

85	10	60	20 to 30	....	....	Subangular to rounded	80	?	?	No pit.
86	15	75	10	....	A little in places	....	80	15 to 20	A few schist pebbles	Walls stand well.
87	10	80	10	....	....	Rounded to subangular	80	20 Soft and hard		Average of several small pits, strata lie flat.
88	Very few	90	10, varies to 40% in places	5% in spots only	....	Rounded to subangular	80	20 Hard and gneiss		
89										Resembles pit 88. Walls stand up well.
90	0	50 Average 1 inch	50	....	....	Rounded	80	15	5	Requires screening, poor stuff.
91										Resembles pit 90 close by.
92	0	80	20							Rough estimate, pit old and disused.
93	5 slabs 2×12 inches	80	15 to 20	0	0	....	80	....	....	No good exposures.
94	20	65	15	0	0	Angular to subangular	75	15	10	Not stratified.
95	0	25 to 85	15 to 75	0	0	....	....	....	....	Small pit and road cut nearby.
96										On surface resembles pit 95.

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.			Composition. Estimated percentage of			
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.	Shape of pebbles.	Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sand-stone, schist, etc.	Remarks.
97a	0	90	10	......	......	......	70	20	10	(a) North side crown of bar.
b	5 to 10	80 to 85	10	......	......	......	......	......	......	(b) 300 feet east of (a).
c	25	65	10	......	......	......	......	......	......	(c) Crown bar south side.
d	?	?	70	......	......	......	......	......	......	(d) 50 feet west of (c).
e	......	......	yellow 100	......	......	......	......	......	......	(e) West end of pit.
f	Coarse east of crown of bar	Gets finer from crown west	......	......	......	......	......	......	......	(f) Average for pit.
98	15	65	20	0	0	Rounded to subangular	70	15	15	Walls stand up only fairly well.
99			70+							Walls stand up poorly.
100	No pit									

101	0	70 to 80	20 to 30	....	....	Subangular to rounded	75 to 80	20 to 25	....	Whole bar more sandy than in the pit.
102	0	65	35	0	0	Subangular to rounded	65	25	10	Walls perpendicular, gravel uniform.
103	....	20	80	....	....	....	....	....	....	....
104										Small bar, no pit.
105	0	0 to 30	70 to 100	Very little	Not abundant	Subangular to flattened	50	50	0	105 indicates the neighbourhood of the York Sand Co. pits, those of Booth Bros., and others. The York Sand Co.'s product contains a small proportion of gravel, that of Booth Bros. more. The gravel averages 1 inch in the latter pits.
106	....	....	Very high	....	....	....	....	....	....	Fine sand.
107			Very high							Fine sand
108	....	....	....	....	....	....	Good gravel	....	....	River gravel in a terrace, amount small.
109		?	High							Largely sand

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.		Shape of pebbles.	Composition. Estimated percentage of			Remarks.
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.		Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sandstone, schist, etc.	
110	....	....	High	Present in the screened gravel in lumps	....	....	....	....	....	....
111										Walls fallen in.
112	0	5	75	20%	Little or none	....	....	....	....	Output of pit principally sand.
113	0	0 to 30	70 to100	None	do.	....	65	35	0	Over 75 per cent of output is sand.
114	....	....	..75+	....	do.	....	....	....	....	Small hole.
115	....	....	High	....	....	....	....	....	....	Road cutting.
116	0	80 to 85	15 to 20	None	?	....	....	....	....	Much of gravel is under ½ inch.
117	0	30 to 90	10 to 70	None	Abundant	....	60	20 to 30	10	Sample from this pit tested, see tables pages 148, 149.

118	5	65	25 to 30	None	?	....	....	....	....	Boulders, slabs of limestone, and shale; gravel fine.
119	0	70	30	None	Abundant	Rounded	70	20	10	Resembles 115. Pebbles small.
120	Rare	40 to 50	50 to 60	None	Thin or absent	....	70	20	10	Dip to northwest 45 degrees.
121	30 to 40	50	10	None	?	Smaller pebbles disk shaped, also rounded	60	30	10	Limestone boulders up to 18 inches. Crushing necessary.
122		20 to 75	75 to 80	....	....	....	....	....	....	Pit long disused, poor exposures.
123	Rare	40 to 55	45 to 60	None	Not abundant	About 20 per cent flat	55 to 60	30 to 55	10	Product rather fine,
124	....	....	....	....	....	....	....	....	....	Pit exhausted.
125	0	75	25	None	Present	....	60+	30	10	Strata dip steeply to north.
126	Rare	35 to 40	60+	None to 15%	Not thick	Largely disk shaped	....	....	Quite high	Boulders, flatslabs of limestone, and shale.
127	....	....	95 to 100	....	....	....	....	....	....	Light yellow sand.
128	....	....	....	....	....	....	....	....	....	Stone produced as a by-product of a brick plant. Sample of stone tested.
129	....	....	....	....	....	....	....	....	....	Not developed.

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of			Impurities.			Composition. Estimated percentage of			Remarks.
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.	Shape of pebbles.	Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sandstone, schist, etc.	
130	25 to 35	40 to 60	10 to 15	5 to 10 %	Abundant	....	60 to 65	20 to 25	15	River gravel, boulders, slabs up to 2 feet across. One out of three shale or sandstone, rest limestone.
131	15 to 20	45 to 55	30 to 35	Little	Abundant	....	65	25	10	Strata dip southwest, mass firmly cemented, about 80 per cent of large slabs of a fairly hard limestone.
132	....	....	100	....	....	....	....	....	....	Very fine sand.
133	0	75	25	....	Abundant	....	65	25	10	Strata dip northeast, walls stand straight for 30 feet.
134	....	....	....	Little	Abundant	....	50 to 60	20	20	
135	....	....	....	....	....	....	....	....	....	Gravel not seen

136	....	5	95	Little	....	Flat	....	....	....	Sand fairly sharp.
137	0	50	40 to 45	5 to 10%	Abundant	....	....	....	....	Gravel under 2 inches.
138	....	....	....	10 to 20%	?	....	High	Low	?	River gravel in lenses and cross-bedded.
139	....	....	....	10 to 20%	?	....	60+	Low	?	River gravel.
140	25 to 30	45	20	10%	?	Flat to rounded	50	10 to 20	30 to 40	Nearly all boulders are flat limestone slabs up to 3 feet across.
141	15	50	25	15%	?	....	50	10 to 20	30 to 40	Concrete made from pits 140 to 142 not of good quality.
142	Rare	75	10	10 to 15%	?	....	50	0 to 5	45 to 50	
143	5	75 to 85	5 to 10 The bar gets sandy toward its western end	5 to 10	Present	Flat	50	0	50	Boulders in lens-like layers of flat slabs. Concrete made from this gravel chips and flakes. Sample tested from this pit. The Appleby Freeman road is said to have been built from this pit 12 years ago. It is worn through in places for 100 yards or so. Recently repaired with broken stone.

Character of the Deposits of Sand and Gravel on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.

Pits.	Sizes, estimated percentage of.			Impurities.			Composition. Estimated percentage of			
Map No.	Boulders 3 inches and over.	Gravel ¼ to 3 inches.	Sand ¼ inch and less.	Clay.	Lime carbonate coating.	Shape of pebbles.	Limestone pebbles.	Hard pebbles, traps, granites, etc.	Soft pebbles, shale, sand-stone, schist, etc.	Remarks.
144	....	....	....	....	....	....	....	....	....	Pit abandoned, no section seen.
145	45	40 to 45	10	Very little	Abundant	....	50 Soft	25	25	Crusher needed, old pit.
146	10	40 to 50	40	Little	do.	Flat to ovoid	50	25	25	Two superposed beds dip one north, other south; sample tested from this pit.
147	?	65+	25+	Little	Very abundant	....	50	25	25	Resembles 146.
148	0	25	75	0 to 5 %	do.	Subangular to rounded	70	20	10	Screening plant in this pit.
149	0	50	50	None	?	....	85+	10	?	Composition of pebbles taken from the ¼ inch screened product.
150										Resembles pit 149.

151	3	22	75+	5 to 10%	Abundant	....	80	10 to 15	5	In addition to the clay in the gravel there is an overburden of 10 feet of clay.
152										Resembles pit 151 near by.
153	0	65	25	5 to 10	Abundant	Subangular to rounded	High	25	Low	
154	5	50	30	15	Abundant	....	50	20	30	Thinly bedded gravel in series of varying coarseness overlain by 2 feet of clay. Beds dip south and southeast.
155	Gravel v	ery similar	to that in	pit No.	154					
156	....	25	60	15						Gravel fine grained and dirty. Beds dip south and southeast.
157			High							Pit overgrown, resembles 159.
158	Gravel ve	ry similar t	o that in	pit 154						Beds dip southwest.
159			High							

COMMERCIAL DEVELOPMENT OF THE GRAVELS.

Information obtained in the field upon the commercial development of the deposits is summarized in the table on pages 170 to 199. The numbers generally refer to pits, occasionally when no pits are present, to deposits. The information upon each deposit has been grouped together between horizontal lines, except in certain cases, where the manner of grouping has been indicated in the last column of the table.

Location. With the location and names of the owners of pits, are placed the location and names of owners of other parts of the deposits, wherever such information could be obtained. The pits have been numbered on the maps to correspond to the numbers in the tables.

Development. A rough estimate has been made of the amount of material removed from the different pits and of the probable extent of the deposits in which the pits occur. In each case the linear dimensions upon which the calculations are based are stated as well as the total volume removed. The horizontal dimensions of pits and deposits have been obtained by pacing and the depths of the pits by estimation. The depths of the deposits have been estimated from all available data obtainable from pits, well records, etc. The data so obtained are in most cases extremely scanty and unsatisfactory. The sizes of the pits as given are only approximate because of the methods used in their determination.

The scant data obtainable regarding the depths of the deposits makes the calculations of their volume of even less value, but in spite of the approximate nature of the data given, it is believed that the information will be of value in affording a rough means of comparing the relative sizes of the deposits.

The larger pits have been dug by the railway companies and used for ballast on their lines while the smaller pits have been opened by private companies and individuals, who have used the gravels for concrete construction and for the surfacing of gravel roads. Cement-brick and cement tiles are made from the sand in one or two places, and some of the fine sand near Toronto is used for building purposes. One or two screening plants are in operation and one or two companies other than the railways use mechanical devices for excavation, but the larger number of pits are excavated by hand and the material used unscreened.

Future Development. The amount of material available runs into many millions of cubic yards. The gravels generally lie at slight elevations over the immediately surrounding country and good working faces can be obtained without going below the ground-water level. There is generally also a railway within 1 or 2 miles of the deposit and spurs can in almost all cases be run to the deposit without great expense. Before extensive development of these gravel and sand bars is attempted it is necessary that they be thoroughly prospected with augers or test pits. The importance of such preliminary prospecting work cannot be too strongly urged, not only in order to obtain an estimate of the volume available, but much more for the sake of determining the relative volumes of sand and gravel in the deposits. The proportions vary from one deposit to the next and since the demand for, and prices of, coarse and fine aggregate may vary widely, a knowledge of the relative amounts present is of great importance.

Transportation. The distance of the deposits from nearby railway lines can be ascertained in part from the map. The Canadian Pacific Railway line between Port Hope and Toronto is not, however, on the map and this line in its course approaches one or two large deposits and may be utilized for shipping purposes. The Canadian Northern follows the beach-line closely all the way from near Port Hope to the Rouge river and it is the logical avenue of transport for the gravels in that section of the belt. The Grand Trunk railway follows the Lake Ontario beach closely between these two points and it is usually several miles away from the gravels. At the east end of the city of Toronto the Grand Trunk railway cuts across a large bar of sand and gravel and large quantities of sand have been shipped over that railway from pits in the bar. From Toronto west to Erindale a branch of the Canadian Pacific lies within a few miles of the larger deposits. From Oakville west to Hamilton the Grand Trunk railway is close to the deposits and cuts through some of them.

Commercial Development of the Gravels on and Near the Ancient Lake Iroquois Beach-line Between Port Hope and Hamilton, Ontario.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
1	Lot 2, con. IV, Hope	Durham	Thos. A. G. Bray, Port Hope, R. R. 2	Product screened	250 × 50 × 1 = 12,500	Used on Port Hope-Peterborough roads, also side roads and in cement work	....	Enough field-stone nearby to justify installation of a small crusher.
2	Lot 2, con. V, Hope Lot 1, con. IV, Hope	" "	John Ramsey, Quay. Wm. Moon, R.R. 2, Pt. Hope	....	None	....	Bar 6 to 8 feet deep. 25 yds. wide by 800 yds. long.	No face exposed anywhere.
3	Lot 4, con. V, Hope Lot 5, con. V, Hope	" "	Moses Robinson, Quay Albert Robinson, Quay	....	Probably 2,000 Probably 2,000	....		Pit not measured, all sand
4	Lot 6, con. V, Hope	"	Road allowance	....	15 × 15 × 1 =225	....	1,000	
5	Lot 6, con. VI, Hope	"	....		1 × 20 × 15 = 300		2,500	Looks like a river deposit.
6	Lot 8, con. V, Hope	"	G.T.R.	....	140 × 15 × 5 = 10,500	Ballast?	150 × 35 × 5 = 26,250	
7	Lots 10 and 11, con. V, Hope	"	Road allowance	....	25 × 1½ × 20 =750	On local roads?	Small	

8	Lot 12, con. V, Hope	Durham	....	....	35 × 10 × 9 = 3,150	....	Approx. 18,000	
9	Lot 15, con. IV, Hope	"	....	....	24 × 10 × 12 = 480	....	Small	
10	Lot 9, con. II, Hope	"	Hope tp.	....	9,450	Used for road work and some for cement sidewalks in Port Hope	Approx. 400,000	Water level at 10 feet. Estimate very approximate.
"	Lot 9, con. II, Hope	"	Town of Port Hope	....	2,340	do.		Other owners of this bar are S. J. Smith, W. J. Pomeroy, J. Reynolds, A. Mountain, J. Halliday. Pits 10 and 11 are in one deposit.
11	Lot 9, con. II, Hope	"	J. Sleemans, Port Hope	....	90 × 80 × 4 = 28,800	Concrete viaducts on C.P.R. and C.N.R. Cement work in Pt. Hope by farmers, also on roads		
12	Lot 18, con. III, Hope	Durham	H. H. Walker, Port Hope	....	60 × 50 × 2 =6,000	Roads and cement work. A local east-west road surfaced from this pit under light traffic, is in good shape	53,000	Pits 12 and 13 are in one deposit.

[1] Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
13	Lot 18, con. IV, Hope	"	Canadian Northern R.R.	Steam shovel	270 × 70 × 5 = 94,500	Ballast?	130,000	Fifty acres of land including this gravel brought by C.N.R. Not used this year. Tracks still in place, drainage good.
14	Lot 24, con. V, Hope	"	Peter Sowden, Osaca	....	40 × 20 × 1 = 800	Used on local roads	Unknown	Large stones sorted by hand.
15	Lot 24, con. V, Hope	"	Arthur Austin, Osaca	....	8 × 3 × 1 = 24	Cement work by owner	Unknown, probably well over one-half million	
16	Lot 26, con. III, Hope	"	Hope tp., Port Hope	....	50 × 40 × 2 = 4,000	....		Larger stones hand sorted.
17	Lot 27, con. III, Hope	"	Henry Irvine, Port Hope R. R. 3	....	10 × 7 × 2 = 140	Cement work and on York Road. This road is hard but very rough		Parts of this bar are also owned by Ebenezer Beebe, Lorenzo Beebe, and John Hamilton, R. R. 3, Port Hope.
18	Lot 32, con. II, Hope	Durham	Ishey, Tice, Newtonville	......	23 × 20 × 4 = 1,840 + 1,000 = 2,840	Used for roads and cement work	If average depth of bar is 4yards amt. is over 500,000	

19	Lot 33, con. II, Hope	"	Jos. Sexsmith, Newtonville	....	$70 \times 60 \times 3 = 12,600$	....	This is far below real content.	
	Lots 34 and 35, con. II, Hope	"	T. Raby	....	....	....	The character varies considerably in different parts.	Plenty of field-stone south of this bar.
	Lot 1, con. II, Clarke	"	Bert McCulloch	....	....	....		
	Lot 1, con. II, Clarke	"	W. Sanesbury	....	....	....		
	Lot 2, con. II, Clarke	"	J. McCulloch	....	....	....		
20	Lot 3, con. II, Clarke	"	Wm. Whittaker, Newtonville	....	$60 \times 40 \times 2 = 4,800$	Roads and local cement work	do.	Large stones in gravel make the roads here very rough.
	Lot 4, con. II, Clarke	"	Stan. Thompson	....	....	....	do.	
21	Lot 5, con. II, Clarke	"	Unknown		....	....	do.	Cut in the bar where a creek flows in from north. Gravel removed by stream is distributed on flats to the south.
	Lot 6, con. II, Clark	"	"	....	....	....	do.	
22	Lot 14, con. I, Clarke	Durham	Clarke tp.	....	$120 \times 40 \times 2\frac{2}{3} = 12,800$	....	This bar probably contains more than one million cubic yards	Acre owned by township nearly worked out. Water level in Nos. 22 and 23 at 14 ft. from surface.
23	Lots 14 and 15, con. I, Clarke	"	Canadian Pacific R. R.	Steam shovel $2\frac{1}{2}$ cub. yd. dipper	$700 \times 60 \times 5 = 210,000$	Ballast		

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
	Lot 16, con. II, Clarke	"	N. Morrisey, Newcastle	....	....	....	....	
	Lot 16, con. II, Clarke	"	R. Graham, Newcastle	....	....	....	....	
	Lot 17, con. II, Clarke	"	Unknown	....	....	....	....	
24	Lot 12, con. III, Clarke	"	Jas. Reddick, Port Hope	....	$100 \times 20 \times 3 = 6,000$. Pit on road	Used by C.N.R. in the construction of a concrete subway.	$1,100 \times 100 \times 3 = 330,000$	
	Lot 13, con. III, Clarke	"	J. Couch, Orono R. R. 1	....	$40 \times 40 \times 2\frac{1}{2} = 4,000$. Pit in field			
25	Lot 17, con. III, Clarke	"	Mrs. W. Graham, Newtonville	....	$20 \times 20 \times 4 = 1,600$	Used on roads	$550 \times 40 \times 4 = 88,000$ less $1,600 = 86,400$	Ownership of lots 17 and 18, con. III, unknown.
	Lot 16, con. III, Clarke	"	T. H. Cowan, Orono R.R. 1.	....	....	....	....	....
26	Lot 20, con. III, Clarke	"	Melville Graham	....	$50 \times 20 \times 1\frac{1}{2} = 1,500$	Used on roads	$1,100 \times 50 \times 2 = 110,000$	The gravel under a house and barn on this bar was not estimated with the total.

	Lot 20, con. IV, Clarke	"	W. A. Layton, Orono R.R. 1.	....	....	....	....	....
27	Lot 22, con. IV, Clarke	Durham	Unknown	....	A few loads taken off surface	....	Part of same bar as pit 26.	
28	Lots 24, 25, and 26, con. IV, Clarke	"	Canadian Northern railway	Steam shovel	1,200 × 75 × 4 = 360,000	Ballast	50 × 50 × 4 = 10,000 east of creek	
	Lot 26, con. IV, Clarke	"	F. J. Hall, Orono	....	....	....	250 × 50 × 4 = 50,000 west of creek	
29	Lot 29, con. V, Clarke	"	Canadian Northern R.R.	....	130 × 25 × 2 = 6,500	Ballast ? and road-making	3,200 × 50 × 2 = 320,000	Includes pits 29, 30, and 31.
30	Lot 30, con. V, Clarke	"	Canadian Northern R.R.	....	18 × 10 × 1½ = 270	Building sand		
31	Lot 31, con. V, Clarke	"	T. Cowan, Orono	....	20 × 10 × 2 = 400	Roads	do.	Sandy, screening necessary.
	Lot 32, con. V, Clarke		G. Cain, Orono	....		....	....	
32	Lot 1, con. IV, Darlington	"	Aron Simas, R. R. 4, Bowmanville	....	100 × 30 × 1 = 3,000	Roads and local cement work	400 × 40 × 2 = 32,000 less 3,000 = 29,000	Estimate does not include bar east of pit 32 nor sandy western part.
	Lot 2, con. IV, Darlington	"	John Fogg, R. R. 4, Bowmanville	....	....	....	....	
33	Lot 6, con. IV, Darlington	"	Mrs. Ellen Reid, Port Hope	....	10 × 6 × 1 = 60	Used by owner in building	1,000 × 75 × 2 = 150,000 − 8,000 = 142,000	Includes pits 33 and 34 and lies in lots 6 and 7.

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
	Lot 7, con. IV, Darlington	Durham	G. H. Stevens, R. R. 4, Bowmanville	....	....	....	do.	
34	Lots 6 and 7, con. IV, Darlington	"	Darlington tp.	....	50 × 20 × 2 = 2,000. 120 × 25 × 2 = 6,000	Used by tp. in road	do.	In vicinity, ridge is pretty well worked out; crusher required.
35	Lot 9, con. IV, Darlington	"	Robt. Collicot, R. R. 4, Bowmanville	....	70 × 15 × 3 = 3,150	Used by C.N.R. to build concrete viaducts, piers, and culverts, also local roads.	100 × 25 × 3 = 7,500	Considerable gravel washed down by spring freshets in Soper brook to east.
36	Lot 12, con. III, Darlington	"	Canadian Northern railway	....	Small	Ballast	Small	Bar already half used.
37	Lot 13, con. III, Darlington	"	Steve Hovey, R. R. 1. Bowmanville	....	70 × 13 × 2 = 1,820	....	600 × 100 × 2 = 120,000	Includes pits 37 and 38.
38	Lot 15, con. III, Darlington	"	F. W. Allin, R. R. 1, Bowmanville	....	130 × 50 × 2 = 13,000 + 13,000 = 26,000	Used on Bowmanville Hampton road; road in good shape in summer, 1914	do.	

39	Lot 17, con. III, Darlington	"	Mr. Foster, Bowmanville	...	None	...	...	Includes lots 16, 17, and 18.
	Lot 18, con. III, Darlington	"	Mrs. Jefferey, R. R. 3, Bowmanville	...	...	...	50 to 100 yds. wide and ½ mile long, no pits	
	Lot. 16, con. III, Darlington	Durham	W. Lin, Bowmanville	...	...	...		
	Lot 20, con. II, Darlington	"	Wm. Lymen, R. R. 3, Bowmanville	...	30 × 15 × 2 = 900	Roads and concrete culverts		This deposit lies in lot 20, con. II, and lots 20, 21, 22, 23, and 24, con. III, and includes pits 40 and 41.
40	Lot 21, con. III, Darlington	"	Thos. Snowden Bowmanville	...	170 × 50 × 3 = 25,500	...	1,400 × 75 × 3 = 315,000	
	Lot 20, con. III, Darlington	"	John Snowden, Bowmanville	...	...	...	less, 27,400 = 287,600	
	Lot 22, con. III, Darlington	"	Wm. Snowden, Bowmanville	...	...	...		
	Lot 23, con. III, Darlington	"	John Alsworth, Bowmanville	...	...	...		
41	Lot 24, con. III, Darlington	"	Mr. Oak, Bowmanville	...	1,000	Road work		
42	Lot 24, con. III, Darlington	"	John Montgomery, Hampton	...	28 × 30 × 2 = 1,680	Roads and building work	100 × 100 × 2 = 20,000 less 1,680 approx. = 18,320	
	Lot 27, con. III, Darlington	"	Jas. Armon, Courtice	...	...	...	1,300 × 50 × 3 = 195,000	This deposit lies in lots 27 and 28, con. III, and 29, con. IV.

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
43	Lot 28, con. III, Darlington	"	James Sulley, R. R. 1, Hampton	....	$35 \times 20 \times 1\frac{1}{2} = 1,050$	....		
	Lot 29, con. IV, Darlington	"	Rich. Mitchell, Hampton	....	....	....		
44	Lot 29, con. III, Darlington	Durham	Blake Courtice, Courtice	....	$30 \times 50 \times 2 = 3,000$	Used on Kingston road, wears well	$550 \times 75 \times 3 = 123,750$	Crushing necessary.
45	Lot 32, con. IV, Darlington	"	Mrs. Murton, Oshawa	....	$50 \times 50 \times 2 = 5,000$	Used on roads	$200 \times 40 \times 2\frac{1}{2} = 20,000$	
	Lot 33, con. IV, Darlington	"	John Flintoff, Taunton	....	....	....		
46	Lots 34 and 35, con. III, Darlington	"	Unknown	....	$7 \times 10 \times 3 = 210$	....	$500 \times 100 \times 3 = 150,000$	Crusher necessary.
	Lot 34, con. IV, Darlington	"	Wm. Pierce, Taunton	....	$70 \times 40 \times 1\frac{1}{2} = 4,200$	Gravel roads and concrete work	$880 \times 50 \times 1\frac{1}{2} = 66,000$	Screening necessary.
47	Lot 35, con. IV, Darlington	"	Fred Clemens, Oshawa	....				
	Lot 1, con. III, Whitby	Ontario	Richard Flintoff Taunton					

48	Lots 6 and 7, con. III, Whitby	Ontario	S. Burgoyne, Oshawa	....	60 × 25 × 3 = 6,000	Local gravel roads	220 × 50 × 3 = 33,000 less 6,000 = 27,000	Screening necessary.
49	Lot 8, con. IV, Whitby	"	Fred Grierson, Oshawa	....	110 × 50 × 2 = 11,000	Gravel roads	Very little near this pit	Bar in lot 8 used up.
50	Lot 9, con. IV, Whitby	"	Wm. Thomas, Oshawa	....	140 × 60 × 3 = 25,200	Used in Oshawa for cement side-walks and building. Also for concrete road in Oshawa.	In lot 9, 550 × 100 × 3 = 165,000. Also 36,000 Approx. 129,000	Twelve acres of this lot owned by Oshawa Cement Brick Co. Part of Kingston road in Oshawa of concrete built of materials from this pit in 1911. In good condition in 1914.
51	Lots 9, and 10, con. IV, Whitby	"	Oshawa Cement Brick Co.	Screening plant	90 × 40 × 3 = 10,800	Cement blocks	do.	This deposit includes pits 50, 51, 53, 54, and 55.
	Lot 11, con. IV, Whitby	"	Dan Jacks, Oshawa					
52	Lot 12, con. III, Whitby	"	Canadian Northern railway	Steam shovel, 1½ cub. yds. dipper	440 × 40 × 2 = 35,200	Ballast	Extent unknown	
53	Lot 13, con. IV, Whitby	"	Unknown		200			
54	Lots 14 and 15, con. IV, Whitby	"	Road allowance		55 × 22 × 2½ = 3,025	Gravel roads	In lot 15 about 123,750	Cutting on road allowance.

[1]Dcposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroqouis Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
55	Lot 16, con. IV	Ontario	Joseph Wray, R. R. 3, Oshawa	....	200	Gravel roads and concrete work	In lot 16, about 150,000	
	Lot 17, con. IV, Whitby	"	Rob. Michael, R. R. 3, Oshawa	....	....	....	....	
56	Lot 17, con. II Lot 17, con. III.	"	M. Howden, A. Robinson, Whitby; town of Oshawa; tp. of Whitby	....	130 × 50 × 6 = 39,000	Local gravel roads nearby and in Oshawa	Unknown	Crusher necessary
57	Lots 18, 19, con. IV, Whitby	"	Road allowance	....	40 × 20 × 2 =1,600	Local gravel roads	75,000 in lots 18, 19	Gravel carried down by creeks to south.
	Lot 18, con. IV, Whitby	"	Alfred Sedgeworth, Oshawa	....	....			....
58	Lot 20, con. IV, Whitby	"	Canadian Northern railway	Originally excavated with steam shovel	400 × 70 × 5 = 140,000	Ballast	75,000 on C.N.R. property (Lot 20?)	
	Lot 19, con. IV, Whitby	"	John Woodworth, R.R. 3, Oshawa	....	....	....	....	

59	Lots 20, 21, con. IV, Whitby	"	Tp. Whitby owns pit	....	160 × 22 × 3 = 10,500	Local gravel roads, and cement work	On lot 21, 300 × 160 × 3 = 144,000	Road allowance.
	Lot 21, con. IV, Whitby	"	Wm. Arksey, Brooklin	....	....	....	....	....
60	Lot 23, con. IV, Whitby	"	Grand Trunk railway and Wm. Arksey, R.R. Whitby	Steam shovel	400 × 80 × 5 = 160,000	Ballast ?	Total for whole bar 160,000	Screening necessary. Deposit includes pits 60, 61, 62, and 63.
61	Lot 24, con. V, Whitby	Ontario	Grand Trunk railway	Steam shovel	375 × 100 × 4 = 150,000	Ballast	Total for whole bar 160,000	Deposit includes pits 60, 61, 62, and 63.
62	Lot 24, con. V, Whitby	"	Whitby tp.	....	12,600	Gravel roads and local cement work	do.	
63	Lot 26, con. V, Whitby	"	Unknown	....	30 × 20 × 1½ = 900	....	do.	
64	Lot 26, con. III, Whitby	"	Unknown	....	3,300	Local gravel roads and cement work	Limits hard to define, no estimate attempted	Deposit includes pits 64 and 65.
65	Lot 27, con. III, Whitby	"	Unknown	....	5,000	Cement work on C.P.R. station		
66	Lot 32, con. V, Whitby	"	A contracting firm in Toronto		Test pits, some of them 30 feet deep		750,000 for whole bar, *i.e.*, 500 × 300 × 5	C.N.R. spur can be easily put in.

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits	Location.		Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
Map No.	Township, etc.	County.						
67	Lot 32, con. V	"	Whitby tp., 2 acres	....	7,000 + 4,000	....		Deposit includes pits 66 and 67.
	Lot 33, con. V, Whitby	"	Wm. Sadler, R.R. Brooklin	....	....	....	....	....
68	Lots 34 and 35, con. V, Whitby	"	Road allowance	....	$22 \times 75 \times 1\frac{1}{2} = 2,475$	Local gravel roads	$200 \times 75 \times 1\frac{1}{2} = 22,500$	
69	Lot 35, con. IV.	"	Whitby tp.	....	1,700	Local gravel roads and concrete work on C.P.R.	Unknown, hard to estimate	Gravel from streams nearby used in limited quantities. Deposit lies in lots 34 and 35.
	Lot 35, con. IV	Ontario	Theodore McGillivray	....	....	....	....	....
	Lot 34, con. IV	"	D. M. McGillivray, Whitby	....	....	....	....	....
70	Lot 2, con. V, Pickering	"	Mr. Richardson, Whitby	....	Small, 5 feet deep	....	Half of small bar left	....
71	Lot 3, con. V, Pickering	"	Mr. O'Connor, Whitby	....	$30 \times 25 \times 3 = 2,250$	Local gravel roads in good condition, light traffic	.... $1,100 \times 100 \times 3 = 330,000$	Crushing and screening would be necessary.

72	Road allowance	"	....	....	190 × 20 × 3 = 11,400	Local gravel roads	-	Deposit includes pits 71 and 72.
	Lot 4, con. V, Pickering	"	Mr. O'Connor, Whitby	....	....	....	....	....
	Lot 5, con. V, Pickering	"	Ed. Redmond, Kinsale	....	....	....	....	....
73	Lot 7, con. V, Pickering	"	Wesley, Gee, Kinsale	....	20	....	Whole bar = 990 × 100 × 3 = 297,000	Deposit includes pits 74 and 75.
74	Lot 8, con. V, Pickering	"	John Brown, Kinsale	....	25 × 25 × 3 = 1,875	Used on gravel roads to east	....	....
	50 acres south side lot 8	" "	Godson Contracting Co., Toronto	Screening plant, one rotary 12 × 4 feet	Just opening August, 1913	....	do.	Company hopes to handle about 10 cars per day.
75	Lot 9, con. V, Pickering	Ontario	Thos. Wilson, Greenwood	....	100	....	....	....
	Lot 12, con. IV, Pickering	"	W. H. Todd, Stouffville	....	....	....	1,760 × 100 × 3 = 528,000 for whole bar	Railway spur could be easily put in from C.N.R. track.
76	Lot 13, con. IV, Pickering	"	F. L. Green, Greenwood	....	100 × 45 × 3 = 12,500	Used on gravel roads		do.
	Lots 14, 15, con. IV, Pickering	"	Canadian Northern railway	....	....	....	....	....
	Lot 16, con. IV, Pickering	"	Harry Ellicott, Brock Road	....	....	....	....	....
77	Lot 17, con. IV, Pickering	"	Unknown	....	None	....	Not estimated	....

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
78	Lot 12, con. V, Pickering	"	Partly in road allowance	....	300	Used on road	Small	....
	Lot 18, con. IV, Pickering	"	F. Simpson, 736 Yonge st., Toronto	....	....	....	....	....
79	Road allowance	"	....	....	100 × 25 × 3 = 7,500	Used on Brock Road, fair condition	Whole bar estimated 1,700 × 100 × 3 = 510,000	Bar varies in width, it includes pits 79, 80, 81, and 83.
	Lot 19, con. IV, Pickering	"	Miss Ella Robson, 261 Wellesley st., Toronto	....	....	....	....	....
80	Lot 20, con. IV, Pickering	"	Michael Fitzpatrick, Brock Road	....	80 × 20 × 2 = 3,200	Used on roads	....	....
81	Lot 21, con. IV, Pickering	Ontario	John White, Brougham	....	40 × 20 × 2 = 1,600	Used on roads	....	The pit is really on the road allowance.
	Lot 22, con. IV, Pickering	"	C. H. Hume, Brock Road	....	....	....	....	....
82	Lot 20, con. IV, Pickering	"	Michael Fitzpatrick, Brock Road	....	30 × 15 × 3 = 1,350	Used on gravel roads	Unknown, probably small	The ownership of this pit may be wrongly given.

83	Lot 22, con. III, Pickering	"	Thos. Reeveley, Brock Road	....	40 × 40 × 1 = 1,600	....	....	....
84	Lot 22, con. III, Pickering	"	Thos. Reeveley, Brock Road	....	7 × 7 × 1½ = 75	Cement work in building	....	Cellar excavation.
85	Lot 19, con. II, Pickering	"	D. Pugh, Pickering	....	....	....	....	....
	Lot 20, con. II, Pickering	"	Jas. Palmer, Pickering	....	300 loads every season	Local gravel roads	Renewed by freshets every year	Stream laid gravel.
	Lot 21, con. II, Pickering	"	F. H. Richardson, 1012 Wellington st. E., Toronto	....	....	....	....	....
86	Lots 24, 25, con. III, Pickering	"	Canadian Northern R. R. (part owners)	....	Few hundred yards	Concrete piers in railway bridges	Unknown	....
87	Lot 32, con. II, Pickering	"	Can. Northern and C.P.R. own pits, Geo. Hollinger, Cherrywood, owns lot	....	C.N.R. 130 × 25 × 3 = 9,750. 90 × 10 × 1 = 900 excavated by township	Used locally on gravel roads, light traffic, in good shape.	On the farm alone there is app. 5,000	....
88	Lot 33, con. II, Pickering	Ontario	Geo. Gates, Cherrywood	....	30 × 20 × 2½ = 1,500	Local gravel roads and cement work	330 × 80 × 2 = 52,800. + 100 × 75 × 3 = 22,500. Total for bar 75,300.	This bar includes pits 87, 88, and 89.
89	Lot 34, con. II, Pickering	"	Can. Northern Railway and Geo. Gates	Steam shovel	220 × 120 × 3 = 79,200	Ballast ?	....	....

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
90	Lot 35, con. II, Pickering	"	Wm. Petty, Cedar Grove	....	40 × 15 × 1½ = 900	Local gravel roads	In lot 35: 260 × 60 × 3 = 46,800	Very sandy.
91	Lot 1, con. IV, Scarborough	York	Mr. Smith	....	None	....	Unknown	Gravelly surface, no pit.
92	Lot 2, con. III, Scarborough	"	Asa Pearse, Highland Creek	....	25 × 15 × 5 = 1,875	Local gravel roads	Whole bar west to creek 550 × 150 × 5 = 412,500	Owner objects further excavation at pit. Material at west end bar bounded by gullies to south and west.
	Lot 3, con. III, Scarborough	"	Geo. Pearse, Highland Creek	....	....	....	....	....
93	Lot 4, con. III, Scarborough	"	Geo. Pearse, Highland Creek	....	10 × 10 × 3 = 300	Concrete bridge over Rouge river, also gravel roads	The bar fragment in which pits 93 and 95 are situated contains approx. 165,000	Can be hauled to north only, 150-foot gully to south.
94	Lot 33, range I, Pickering	Ontario	Joe Pearse, Rouge Hill	....	16 × 16 × 3 = 768	Gravel roads and concrete bridge	225 × 75 × 3 = 50,000	Crusher necessary.

95	Lot 5, con. III, Scarborough	York	J. H. Chapman, Highland Creek	....	200	Gravel road nearby	....	....
96	Lot 4, Con. III, Scarborough	"	Geo. Pearse, Highland Creek	....	None	....	Area 250 × 80 depth unknown	A detached fragment of bar.
	Lot 6, con. III, Scarborough	"	Robert Dixon, Highland Creek	....	....	....	....	....
97	Lots 7, 8, con. III, Scarborough	"	C.P.R. owns part of bar north of road, except 2 acres owned by township of Scarborough	Marion shovel model 75 dipper $2\frac{1}{2}$ cub. yds.	500 × 175 × 6 = 525,000	Ballast; used near Humber river	About 1,000,000 left in 60-acre property including pit	Opened 1911. 97 and 98 are in the same deposit
98	Lot 8, con. III, Scarborough	"	Scarborough tp. 2 acres	....	120 × 60 × 4 = 28,800	Local gravel roads, in good shape	2 acres nearly exhausted	....
	Lot 9, con. II, Scarborough	"	York Sand and Gravel Co., Toronto	....	....	....	50 acres owned by this company contain approx. 150,000	Estimates of amounts available approximate only.
	Lot 9, con. II, Scarborough	"	Mr. Bolson, Highland Creek	....	....	....	Bolson and Crowe, together own perhaps 900,000	
	Lot 9, con. II, Scarborough	"	Mr. Crowe, Highland Creek	....	....	....	....	....

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
	Lot 9, con. III, Scarborough	"	Wm. Shuter, R. R.1, Agincourt	....	....	....	1½ acres 10 yards deep	
	Lot 10, con. II, Scarborough	"	David Taylor, Highland Creek	....	....	....	Amount not estimated	
	Lot 11, con. II, Scarborough	"	Chas. Humphreys, Highland Creek	....	....	....	....	
99	Lot 10, con. II, Scarborough	York	Scarborough tp.	....	25,000 approximately	Formerly used on local gravel roads	Unknown	Terrace; stream laid valley gravel in bed creek.
100	Lots 12, 13, con. I, Scarborough	"	N. Johnston, West Hill	....	None	....	Small	....
	Lot 13, con. D, Scarborough	"	Wm. Batty, West Hill	....	....	....	....	....
101	Lot 12, con. I, Scarborough	"	Unknown	....	300	....	Unknown	The bar in which pits 101, 102, and 103, are has not been estimated.
	Lot 14, con. D, Scarborough	"	Thos. Westlake, West Hill	....	....	....	....	....

102	Lot 14, con. D, Scarborough	"	R. Johnston, West Hill	....	26 × 50 × 3 = 3,900	Concrete	....	
103	....	"	York Radial railway.	....	80 × 70 × 3 = 16,800	Ballast on electric road	....	....
104	Lot 9, con. I, Scarborough	"	Mr. Lash, West Hill	....	None	....	Small	Small bar in creek valley, largely sand.
105	South of the G.T.R. and directly east of the limits of the city of Toronto	York	York Sand Co., 48 acres	Brown Locomotive, crane capacity 600 to 1,000 cub. yds. per day; derrick and clam shell bucket capacity 600 cub. yds per day; industrial locomotive; revolving screen, ¼ inch mesh	Very large. Present company had removed about 600,000 in autumn of 1913	In concrete for sidewalks and road foundations. Cushion under paving blocks, ballast for car lines, etc.	A large amount of sand and gravel in the eastern end. The western end is in the city and very little of it is available.	No. 105 shows the approximate location of several pits of the York Sand Co. and of Booth Bros. directly southwest of them and of other operators. Openings within the city limits have furnished gravel, but were not examined. Booth Bros. sell pit gravel at rate of 220 wagon loads for $100 f.o.b. pit. The York Sand Co. sell pit gravel at 50 cents and screened gravel at 90 cents per yard f.o.b. quarry. Railway freight to Toronto 25 to 40 cents per ton. Information obtained in 1913.

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
			Booth Bros.		150,000	do.		
106	West bank Don river near Leaside Junction, city of Toronto	"	....	....	....	Building sand		Fine sand, too fine for concrete.
107	Eglington ave., Toronto	"	....	....	....	Building sand		do.
108	East bank, Don river, city of Toronto	"	....	....	....	....	Very small	....
109	Christie st., city of Toronto	"	....	....	....	....	Small amount of coarse material	Produces sand and gravel.
110	Where Weston road crosses Black creek, northwest of city of Toronto	"	Wm. Maher	Machine driven screens	40-foot face	Sand for building purposes, gravel for roads	....	Gravel as excavated carries clay.
111	....	York	Canadian North. R.R., city of Toronto Abattoir Co., Swift's Can.	....	....	....	From pits 111 to 112 the bar is practically exhausted. Between 112 and	Pits Nos. 111, 112, 113, 114, and 115 are in the same bar. Eastern end of bar is built on.

			Co., Gunns, Ltd., etc.				113 nearly two-thirds of the upper part of the bar is removed. South-west of 113 there is a good deal of sandy gravel available	
112	The bar in which pits 111, 112, 113, 114, and 115 are found lies in west Toronto from the Canada Foundry Works on Davenport road to the Lambton Golf links on the east bank of the Humber	"	....	....	40 × 30 × 10 = 1,200	Cement bricks	....	Ground-water level at about 50 feet from surface with sand underneath.
113	....	"	Home Smith, Toronto	Wheel scrapers and carts and small screening plant	260 × 100 × 4 = 104,000	Building sand in Toronto. Cement brick, etc.	....	Three sizes produced: sand, materials over 1 inch, and an intermediate size; gravel sells at $3 per load, sand at 75 cents per load.
114	....	"	do.	....	Few hundred	....	....	....
115	do.	York	Road allowance	....	....	....	....	....

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
116	East of Mimico creek at Islington village N. of Dundas street	"	Owned by number of householders in Islington village	....	Few loads	....	100,000	Village built on deposit and very little of the bar will be available.
117	Pits 117 to 121 in a bar which lies along Dundas street on both sides of Etobicoke creek, Peel county	Peel	Chadwick Rodgers, Real Estate, Toronto.	....	40 × 40 × 4 = 6,400	Building and road work	3,520 × 150 × 3 = 1,584,000	Pits 117 to 121 are in one bar which is over 3 miles long.
118		"	Toronto Suburban R.R.	....	100 × 3 × 5 = 1,500	Ballast	....	....
119		"	Thos. Fenwick, Summerville	....	50 × 20 × 3 = 3,000	....	....	Neighbouring deposit occupied by house, roadway, etc. Sold at 75 cents per waggon load.
120		"	Unknown	....	30 × 10 × 3 = 900	Building materials		
121		"	Small holdings on Dundas st., Toronto tp.	....	50 × 25 × 4 = 5,000	....	....	
122	Pits 122 to 127	"	Unknown	....	100 × 20 × 2 = 4,000	....	Exhausted near this pit	Pits Nos. 122 to 127 are in one large bar.

123	Lie in one bar north of Cooksville, Toronto tp.	"	Toronto suburban C.N.R.	Barnard special No. A. steam shovel, dipper 1½ yds. capacity	110 × 70 × 4 = 30,800	Ballast	There is 250 × 100 × 4 = 100,000 east of this pit	
124		Peel	Can. Pac. R.	Steam-shovel	220 × 100 × 4 = 88,000	Ballast	None	
125	Lot 14, con. I, Toronto	"	Britnell Construction Co., Toronto. Toronto tp.	Engine and clam shell bucket	200 × 100 × 4 = 80,000	Building purposes in Toronto	"	
126	Lot 15, con. I, Toronto	"	Can. Pac. R....	....	60 × 60 × 5 = 18,000	On local gravel roads	500 × 100 × 3 = 150,000 is to be had between this pit and the creek	The Brampton road for 1 mile north of the C.P.R. track surfaced with this gravel in 1913; was worn out in 1914.
127		"	Unknown		Few hundred	....		
128		"	Ont. National Brick Co., Cooksville	No. 7, Marion steam-shovel 1½ yds. capacity			Several thousand	This stone is a by-product of a brick-making plant. The amount available will be small.
129		"	Unknown	....	None		do.	

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario.—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
130	Erindale, Toronto tp.	"	Toronto tp.	Crusher	50 × 50 × 3 = 7,500	Erindale Cooksville road surfaced with this gravel in 1912, fair condition 1914, medium traffic	200 × 100 × 3 = 60,000	Pit 130 is in a river deposit.
131	Lot 29, con. I, Toronto	Peel	J. H. Pinchin, Clarkson	Mitchell No. 2, crusher	20 × 20 × 5 = 2,000	Sand used in cement tile plant		Pits 131, 132, 133, and 134 are in one deposit. Pit gravel 50 cents per load. Crushed gravel $1 per load. Blasted out of bank.
132	Lot 30, con. I, S. D. S. Toronto	"	Wm. Oughtred, Clarkson	....	30 × 10 × 4 = 1,200	Building sand	1,800 × 200 × 5 = 1,800,000 is the amount available for the whole bar	Useless for road work.
133	Lot 30, con. I, S. D. S. Toronto	"	do.	....	30 × 30 × 5 = 4,500	Gravel roads and building purposes		Can be used without crushing. Hauled 6 miles for road work. Material well cemented and must be blasted.

134		"	Road allowance F. Mullet, Clarkson, Wm. Fletcher, Clarkson		75 × 20 × 3 = 4,500	....		
135	Lot 17, con. II, S. D. S. Trafalgar	Halton	Wm. Maynard, Toronto	....	None	....	Not estimated, about one mile wide by 10 ft. long by 60 yds. deep	
	Lots 18 and 19, con. III, S. D. S. Trafalgar	"	W. C. McKay, Oakville	....	....	....	....	
	Lot 20, con. III, S. D. S. Trafalgar	"	W. J. Carter, Oakville	....	....	....	....	
136	Lot 31, con. II, S. D. S. Trafalgar	"	Paul Campbell, Merton	....	200	Local concrete work	The bar in which pits Nos. 136 and 137 occur is about 1,200 yards long by 100 to 150 wide	
	Lot 32, con. II, S. D. S.	"	Henry Breckon Merton	....	....	....		
137	Lots 31, 32, con. III, south of Dundas street, Trafalgar	Halton	Henry Breckon, Merton	....	30 × 30 × 1 = 900	Building sand		
138	Lot 31, con. III, south of Dundas street, Trafalgar	"	Henry Breckon, Merton	....	....	Concrete work	Unknown	Not very good for concrete or macadam construction. Thoroughly cemented together, must be blasted.

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
139	Lot 31, con. III, south of Dundas street, Trafalgar	"	Mr. Hall, Bronte	....	Few hundred yards	Concrete work and on roads	Unknown.	Cemented to hard mass.
140	Lot 8, con. III, south of Dundas street, Nelson	"	Excelsior Brick Co.	....	40 × 15 × 2 = 1,200	Concrete work	....	The concrete made from this gravel did not give satisfaction.
141	Lot 10, con. III, south of Dundas street, Nelson	"	M. B. Clive, Appleby	....	30 × 20 × 3 = 1,800	Concrete work, gravel roads	....	Barn floor made from this gravel said to be in good shape, after a few years use.
	Lot 11, con. III, south of Dundas street, Nelson	"	F. Parsons, Freeman	....	....	....	....	Pits 140, 141, 142, 143, are in one deposit.
	Lot 12, con. III, south of Dundas street, Nelson	"	W. Alton, Freeman	....	....	....	Bar contains several million	....
142			A. Pedditt Freeman	....	50	Concrete work	....	The concrete made from gravel in this pit did not give satisfaction.

143	Lot 14, con. II, S. D. S., Nelson	Halton	Collins Dynes, Freeman	....	40 × 40 × 3 = 4,800	Gravel roads	....	The road from Appleby to Freeman is said to have been constructed 15 years ago with this gravel. Part of this road is worn out.
144	....	Wentworth	Road allowance	....	50 × 15 × 3 = 2,250	Gravel roads	Very small near this pit	
145	....	"	Grand Trunk R.	Steam shovel	525 × 150 × 5 = 393,750	Ballast	(300 × 100 × 3 = 90,000) + (400 × 50 × 5 = 100,000) = 190,000. From pits 144 to 146	Pits 144 to 147 in same bar.
146	Lot 6, con. I, E. Flamborough	"	C. Brown, Hamilton		60 × 60 × 4 = 14,400	Concrete gravel roads	500 × 200 × 5 = 500,000	Parts of this bar have been extensively planted on. The gravels are in places well cemented, but some of them have been handled by steam shovel without blasting.
	Lot 7, con. I, E. Flamborough	"	E. Taylor, Aldershot				4,840 × 7 × 5 = 169,400	
	Lot 8, con. I, E. Flamborough	"	N. H. Howard, Aldershot				Lots 8 and 9 contain nearly as much as lot 7	
	Lot 9, con. I, E. Flamborough	"	Smiley Bros., Aldershot				Approximate amount from pit 146 to west end of bar = 2,600 × 15 × 5 = 1,950,000	
147	Lot 9, con. I, Hamilton	"	Nat'l Brick Co., Hamilton		50 × 10 × 5 = 2,500	Concrete		

[1]Deposits are separated by horizontal lines.

Commercial Development of the Gravels on and near the Ancient Lake Iroquois Beach-line between Port Hope and Hamilton, Ontario—Continued.[1]

Pits. Map No.	Location. Township, etc.	Location. County.	Owners and addresses.	Equipment.	Amount of gravel and sand excavated, cubic yards.	Uses.	Amount of gravel and sand available, cubic yards.	Remarks.
148	North end of city of Hamilton	Wentworth	Hamilton Sand and Gravel Co. 806 Bank of Ham. Bldg., Hamilton	Screening plant and crusher	$40 \times 30 \times 10 = 12,000$	Used in the city of Hamilton for building, etc.	$27 \times 4,840 \times 10 = 1,306,800$ in 27 acres. Between pit No. 148 and the high level bridge there is about $700 \times 50 \times 10 = 350,000$ Total, therefore, 1,656,800	Plant produces three sizes $\frac{3}{16}$ inch, $\frac{3}{4}$ inch, and coarser material. Sells at $1 per load f.o.b. pit. 75 per cent of this material is sand. South of the high level bridge the bar is not available for excavation. It is steep sided and 116 feet over the water at the north end.
149	Northeast side of York north of high level bridge within city of Hamilton	"	W. H. Cooper, 67 York st., Hamilton (lessee)	Screening plant and crusher	67 feet deep 4 acres in area	Used for asphalt construction	Pits 148, 149, and 150 lie within this part of the bar	Plant of No. 149 produces three sizes $\frac{1}{8}$ inch, $\frac{1}{4}$ inch, and larger material. 50 per cent of output is below $\frac{1}{4}$ inch. Sells at $1.25 per load for all sizes. Production in the autumn of 1914, 120 loads per day.
150	Across road from pit No. 149	"	Armstrong Supply Co.	Hand screens	....	Sold in Hamilton	5 acres owned by company	

151	North and west of junction of King st. and the Dundas road, Hamilton	"	W. H. Yates, Building Contractor, 18 Leamington st., Hamilton	Screening plant	....	Concrete work in Hamilton	22 ft. of sand and gravel in pit	Three sizes produced, ⅛ inch, and coarser than 1 inch. Output 80 loads per day in 1914. Twelve feet of clay overburden.
152	100 yds. west of No. 151	Wentworth	Ollman Bros., Brick Mfgs., Hamilton		....	....	Not estimated	Overburden of 10 feet of clay. By-product of a clay pit.
153	On Dundas road one-quarter mile south of No. 152	"	R. Tope, Hamilton		....	....	20 to 24 feet	By-product of a clay pit, overburden of 8 feet of clay.
154	Lot 12, con. V, Nelson	Halton					The deposit, in which pits 154 to 159 occur, is roughly outlined on map. It is covered nearly everywhere by from 1 to 2 feet of clay and the amount present is, therefore, problematic	
155	Just south of 154, con. IV, Nelson	"			40-foot face			
156	Lot 11, con. V, Nelson	"			30-foot face			
157	Lot 10, con. IV, Nelson	"						
158	Lot 11, con. IV, Nelson	"			30-foot face			
159	Lot 10, con. IV, Nelson	"				Gravel roads		East—west road to Milton built of this gravel was in good shape in September, 1914.

Deposits are separated by horizontal lines.

DEPOSITS OF STONE.

STONE UNDERLYING THE AREA.

The formations underlying the district along the north shore between Trenton and Hamilton are, in order from east to west, the Trenton, Utica, Lorraine, Queenston, and Cataract. Their approximate boundaries are the Trenton from east of Port Hope to Pickering township, Utica from Pickering township to the Rouge river, Lorraine between the Rouge and Credit rivers, and Queenston and Cataract from the Credit river west to Hamilton.

No section of the Trenton was obtained. The upper beds of this formation are exposed near Oshawa and Bowmanville and are thought to be rather soft limestones. The Utica formation lies next in order to the west and is composed for the greater part of shale. No bedrock which could be considered good road-stone was seen between Port Hope and Toronto, in the course of this work.

From Toronto west to the Credit river the underlying rocks of the Lorraine formation are exposed in a number of places. The formation consists of grey shales with interbedded layers of sandy limestone or calcareous sandstone. The sandstones are seldom over a foot thick and form a small proportion of the formation. The result of a test made upon stone quarried at the shale pit of the Ontario National Brick Company in Toronto township, Peel county, pit 128, is given on page 205 and it shows that the stone is of excellent wearing quality. The quantity available in any one place is not, however, large enough to make it of importance for road-making stone.

The outcrops of the Queenston and Cataract formations, which lie between the Credit river and Hamilton, consist of red and green shales with a few thin shaly sandstones. These outcrops cannot be looked upon as sources of road-stone.

The chances of obtaining an adequate supply of stone from the rock underlying the area examined are, therefore, small.

FIELD-STONE.

Large rounded boulders of glacial origin are found on the wave-cut terrace which lies between the old Lake Iroquois beach-line and the present shore of Lake Ontario.

Some of the localities, where such stone is present in fairly large quantities, have been indicated on the map. No attempt was made to see and map all the field-stone present and there is undoubtedly more stone to be had than was examined in the course of this work. The stone is made up very largely of boulders derived from hard rock and if such stone is crushed and if proper binding material is added to it, it often makes an excellent road. Unfortunately, there are very few localities in the area examined where stone is present in sufficient amount within a few miles of any particular road to make the use of it in roadwork practicable. That is to say the building of a road say 10 miles long, in any one locality, of crushed field-stone, would require that the bulk of the stone be hauled for very long distances.

In Durham county field-stone was seen in concessions IV and V of Hope, in concessions III and IV of Clarke, and in concession II of Darlington townships. The amount of stone lying within one-quarter mile on either side of the lines of stone marked on the map at these various points, is probably less than 1,000 cubic yards in all cases.

In Ontario county there is about 500 cubic yards of stone within one-half mile of the village of Kinsale in Pickering township. In the other localities in this county which are shown on the map there is less stone. From Ontario county west to the city of Hamilton there are scattered occurrences of boulders within the map-area, but they have been used for local building purposes and were nowhere seen in quantities sufficient to justify their exploitation for roadwork.

OUTSIDE SOURCES OF SUPPLY.

Among the sources of supply of crushed stone, which are available for the area examined, are the limestone quarries at Hagersville, certain quarries and deposits along the Niagara escarpment, the Point Anne quarries at Belleville, and trap quarries at Havelock and on the north shore of Lake Huron.

CHARACTER AND QUALITY OF THE STONE.

In order to compare the rock derived from the various quarries the results of tests made upon them are placed together in the table following, pages 204 to 206.

The quarry of the Canada Crushed Stone Corporation at Dundas was sampled by the writer and the results of the tests made upon the five samples from this quarry are instructive, in that they may serve to interpret the results of tests made upon stone from other localities. The quarry is about 50 feet deep and 1,400 long by 300 to 500 feet wide. Five samples were taken as nearly equi-distant along the face as the sheer walls would permit. The main part of each sample was taken from the quarry floor to the top of the wall by breaking off small chips at nearly equal intervals up the face. Since the beds lie flat this gave a sample representative of all the beds at that point. The blocks which were selected for the toughness and hardness tests, were taken from a different bed in each of the five samples, the beds being several feet apart in a vertical direction.

The percentages of wear made on the main portion of the samples are nearly identical for the five, whereas the toughness varies considerably. This proves that each bed does not vary greatly in character within itself, but the beds do vary much one from another, that is the character of the face varies in a vertical direction. This is true in nearly all limestones and other sedimentary rocks. Toughness and hardness tests may, therefore, vary greatly for stone from the same quarry. If samples be properly taken, however, at frequent intervals across the strike of the beds, and toughness tests be made on more than one bed the average result should represent the quality of the material in the quarry as it undoubtedly does in the case of the results given for the quarry at Dundas. On the other hand, the results of one test, especially if no data are at hand as to the method of sampling, cannot be looked upon as representing the average physical character of the whole output of the quarry.

The results given in the table must be read with this in mind. Good stone suitable for light to medium country traffic is obtainable at Hagersville, near Vinemount, and at Dundas. The writer visited quarries at each of those localities and a description of them is given below. The stone from the quarry of the Ontario National Brick Company is limited in quantity and its abnormally high toughness does not, in all probability, represent the run of the harder rock produced there. The trap rock at Havelock is, of course, greatly superior to the limestones or any other sedimentary rocks available, and so are the traps from the north shore of Lake Huron, which are quarried at Bruce Mines and described in Part II of this report. The traps are suitable for roads which carry heavy traffic. In order to arrive at an estimate of the traffic which any one of the stones sampled will bear, see table comparing the results of traffic and laboratory tests on stone, Part I, page 25.

DETAILED DESCRIPTION OF DEPOSITS OF STONE.

Only a few of the larger quarries from which stone of fairly good quality can be economically hauled to the area in question were visited by the writer, and they are described below. The occurrences are described in the following order: (1) the quarries at Hagersville, (2) those along the Niagara escarpment at Hamilton, and (3) the trap rock at Havelock. Trap rock deposits on the north shore of Lake Huron are described in Part II of this report.

The Point Anne quarries near Belleville were not visited, but the result of a test made on the rock from them is given on page 205. It is reported that the operators of this quarry can ship stone very cheaply by boats to points on Lake Ontario.

Limestone Quarries at Hagersville.

The stone at Hagersville is worked in a number of quarries, of which those operated by the Hagersville Contracting Company and the Michigan Central railway at Hagersville are the largest. Other quarries in stone wholly or partly of the same kind are those of the Hagersville Crushed Stone Company, Oneida town-

Laboratory Tests upon Stone Available for Road-making Along the North Shore of Lake Ontario.

Location.	Lithology.	Toughness.	Hardness.	Per cent wear.	French coefficient of wear.	Cementing value.	Specific gravity.	Weight per cub. ft.	Absorption lbs. per. cub. ft.	Physical tests made by.
1. A. Quarry of the Hagersville Contracting Company, Hagersville	Cherty limestone. Silica 47, calcium carbonate 53%	7·5	......	4·9	8·16	22	....	167	0·70	G. C. Parker, Toronto.
1 B. do.	Argillaceous limestone	9·0	......	6·24	6·41	34	....	167·2	0·08	do.
1 C. do.	Cherty limestone	12·0	18·8	Not determined	....	100+	2·65	165	0·93	Office of Public Roads, Washington, D.C.
2. Average for 1-A, B, and C.		9·5	18·8	5·57	7·23	50+		166	0·57	
3. Quarry of the Hagersville Crushed Stone Co., Hagersville	Sandy and cherty limestone. Silica 42, calcium carbonate 58%	15		5·88	6·80	48	....	165	0·76	G. C. Parker, Toronto.
4. Quarry of the Wentworth Quarry Co., Saltfleet tp., Wentworth co.	Magnesian limestone 10·15% MgO with argillaceous and organic matter	11	Not determined	5·41	7·39	46·0	....	168·4	0·53	do.

Ancaster Tp. quarry, Saltfleet. Wentworth county	Magnesian limestone, magnesia 10 to 15 per cent; some argillaceous and organic matter	10	Not determined	4·04	9·9	24	....	166	1·00	G. C. Parker, Toronto.
6a. Quarry of the Canada Crushed Stone Corpor. Ltd., Dundas	Dolomite CaO 54%, MgO 44%	13	15·8	3·9	10	Over 26 and under 75	2·80	175	0·35	Office of Public Roads, Washington D.C.
6b. do.	do.	9	16·2	3·66	10·9	do.	2·80	175	0·57	do.
6c. do.	do.	11	16·0	3·6	11·1	do.	2·80	175	0·24	do.
6d. do	do.	10	13·5	3·8	10·5	Over 10 and under 25	2·70	168	0·66	do.
6e. do.	do.	6	15·8	3·82	10·5	Over 25 and under 75	2·75	172	0·52	do.
Average for No. 6		9·8	15·5	3·76	10·6	do.	2·77	173	0·47	
7. Quarry of the Ontario National Brick Co. Pit No. 128, near Cooksville	Limestone probably sandy	20	Not determined	5·7	7·0	48	....	166·5	1·130	G. C. Parker, Toronto.
8. Point Anne quarries, Belleville, Ont.	Limestone?	5·3	Not determined	4·26	9·39	21		168·5	0·102	G. C. Parker, Toronto.

Laboratory Tests upon Stone Available for Road-making Along the North Shore of Lake Ontario—Continued.

Location.	Lithology.	Tough-ness.	Hard-ness.	Per cent wear.	French coeffi-cient of wear.	Cement ing value.	Specific gravity.	Weight per cub. ft.	Absorp-tion lbs. per cub. ft.	Physical tests. made by.
9a. Quarry of the Ontario Rock Co., near Havelock	Highly altered trap (diabase)	13	17·9	2·9	13·6	Over 25 and under 75	3·00	187	0·19	Offices of Public Roads, Washington, D.C.
9b. do.	Trap less altered than a	24	18·3	Not determined	....	Over 75 and under 100	3·00	187	0·31	do.
9c. do.	Trap (diabase)	22	Not determined	2·3	17·33	Not determined	....	190·5	0·10	G. C. Parker, Toronto.
9d. do.	Trap (diabase)	....	......	2·40	16·6	39	3·02	188	....	Quoted in booklet issued by the operators.

For tests on trap rock from Bruce Mines and other places on the north shore of Lake Huron see Part II.

ship, west half of lot 38; of the Haldimand County Good Roads Association, Dunn township, Earl tract 6; and the quarry owned by Jackson and Kyd, Dunnville, all of which are in Haldimand county.

Only the quarry of the Hagersville Contracting Company is described in detail here. That of the Michigan Central railway is of nearly identical stone, but is used largely for ballast by the railway. The others were not visited. The results of tests upon the Hagersville Crushed Stone Company's product is given on page 204 and indicates that it will bear light to medium traffic on a water-bound macadam road.

Quarry of the Hagersville Contracting Company. The quarry is owned by J. C. Inglis of Hagersville and operated by the Hagersville Contracting Company. It is situated on the north side of the Michigan Central Railway's double track, is about one-half mile from the Michigan Central and Grand Trunk stations at Hagersville, and has direct connexion with both lines.

The following section was exposed in the quarry and is described from the top down.

		Thickness in feet.
1.	Hard, dark grey to black limestone in beds up to 5 inches thick, containing a good many corals and other fossils, and from 10 to 25 per cent of chert in lenticular layers and nodules. Wavy bituminous partings between beds........................	9
2.	Lighter grey limestones of the same type as No. 1, but with less chert and weathering to whitish rock....	5
3.	Even bedded dark grey limestone, beds up to 18 inches and thicker than Nos. 1 and 2. This stratum contains little or no chert and is softer than the others exposed here................................	4
4.	Dirty grey limestone full of chert; resembles Nos. 1 and 2..	5

The beds are thin and irregular except for the middle stratum of grey limestone. The latter does not carry chert and the layers are more uniform and slightly thicker. The strata are practically flat-lying. The dip is west or southwest. No attempt was made to study the regional geology, but the contact with the underlying Silurian is not far to the north and the beds must lie in the lower part of the Onondaga formation. A well put down in the quarry is said to have penetrated 170 feet of hard limestone. If this is the case, it does not prove that the Onondaga is 170 feet thick at this place, for the material brought up in a well has been pounded to pieces and its lithological character is hard to distinguish. The lower part of the well must have penetrated into the Lower Helderberg of the Silurian. Fracturing is very irregular, there are no sharply defined joint planes; one irregular nearly vertical parting lay in a direction between northwest and north.

There are plenty of outcrops on the surface of the flat surrounding plain and the overburden is never much over 1 foot thick. The company owns 64 acres and if it is assumed that there are 18 feet of the cherty beds, described in the preceding section as Nos. 1, 2, and 4, present over all 64 acres, the amount available before quarrying began was 4,088,832 tons.

The quarry was first opened in 1874. The present owner obtained it in 1891. The rock has been quarried to a depth of 14 feet over an area of about 100 by 200 yards. About 1 acre in the middle of it has been quarried to a depth of 28 feet.

The water in this pit stands at 10 feet below the floor of the main quarry, but is being continually pumped out. Water a few inches deep stands in puddles on the main floor of the quarry; the permanent water level is probably near the surface, but according to the foreman of the quarry water has not seriously inconvenienced the work of excavation.

The drilling, hauling, and crushing equipment is as follows: one steam hammer, two Rand, and one Mac drills using from $1\frac{1}{4}$ to $1\frac{3}{4}$ inch bits; one No. $7\frac{1}{2}$ Gates gyratory crusher; one No. 5 Austin and one No. 3 Gates crushers; two screens, one 60 inch and one 72 inch. The crushed stone is screened to $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, $\frac{3}{4}$ inch, 1 inch, and 2 inch sizes. There are fourteen storage bins with a capacity of 40 tons each. Mucking is done by hand and hauling to the crusher by horse-drawn dump cars.

The product is loaded from the bins directly into cars. The quarry is connected by a spur to both the Grand Trunk and Michigan Central Railway systems. A small quantity is hauled from the quarry by wagon for use in the neighbourhood. The crushed stone is used either in concrete or on macadam roads.

The results of tests made on this stone indicate that it can bear light traffic in a water-bound macadam road.

The cost for quarrying and crushing rock is about 50 cents per ton and the price, f.o.b. quarry, is from 60 to 75 cents per ton. The freight rate to Toronto is 60 cents per ton. The weight of one cubic yard of crushed stone is about 2,300 pounds, but the weight varies with the method of loading.

Three hundred carloads of stone were used for road metal in St. Thomas in 1886. Between 1903 and 1908 about 50,000 tons per year were produced. In 1912 the quarry produced 83,822 tons of crushed rock.

Limestone Quarries near Hamilton.

Four localities on the escarpment in the neighbourhood of Hamilton are considered here as possible sources of road metal for the region reported on. They are the quarries at Vinemount, Saltfleet township; Ancaster, in Ancaster township; near Dundas in Flamborough West, and Waterdown in Flamborough East, townships. Between these quarries the upper part of the escarpment consists of rocks, which although they vary in a lateral direction, nevertheless do in a general way resemble the types found in the quarries and described here. The best known and largest of these quarries is that of the Canada Crushed Stone Company at Dundas, the results of tests upon which are given upon page 205. The quarries at Vinemount and Ancaster are much smaller. The writer did not see the quarries at Waterdown, but they were visited by one of the staff of the Geological Survey and the description given here was obtained from him.

The quarries are described in the following order: Vinemount, Ancaster, Dundas, and Waterdown.

Wentworth Quarry Company at Vinemount. The quarry is situated upon lot 4, concession V, Saltfleet township, Wentworth county. It is connected by a spur to the Toronto, Hamilton, and Buffalo railway and is owned by the Wentworth Quarry Company. The quarry was visited in the autumn of 1914. The rock in this quarry consists of limestone underlain by and interbedded with shale. In the southwestern end of the quarry the face is made up of about 8 feet of limestone overlying 4 feet of shale. The formations dip slightly to the northeast and a section taken on the south wall about 800 feet from the west and 200 feet from the east end consists of:

1.	Overburden of soil..............................	1 foot
2.	Grey to buff, siliceous, compact to coarse, thin-bedded, limestone; beds 2 to 4 inches with occasional shale partings....................................	6 feet
3.	Dove coloured, fine, even-grained, thin-bedded, limestone getting shaly toward the bottom...........	7 "
		14 feet

The floor of the quarry is rather shaly. No. 2 is the most suitable material for roadwork and the upper part of No. 3, although softer, should be useful. Four hundred feet north of this, on the north face, 14 feet of limestone, such as is described in numbers 2 and 3 of the above section, overlies 1 foot of shale and this is in turn underlain by another bed of limestone.

To sum up: The rock in this quarry consists of fairly tough limestone underlain by a bed of shale which varies from 4 feet at its southwest end to 1 foot toward the northeast. The limestone increases from 8 to 14 feet from southwest to northeast. The limestone may be useful in road metal work, the shale will not be.

It may be of interest to know that these rocks form part of the Barton member of the Lockport or Niagara formation. The Barton member contains more shale than the rest of the formation, which is largely made up of tough limestone or dolomite.

The quarry operated by the Wentworth Quarry Company is a roughly rectangular opening in the level plateau about 1,000 × 300 to 500 × 14 feet in size, that is something over 200,000 cubic yards has been removed from it. The water level at the time of our visit, November 6, 1914, was at about

16 feet from the surface of the ground or 2 feet below the main floor of the quarry.

The drilling is done by one gravity well drill. The blasted rock is handled by a No. 61 Marion steam shovel with a dipper capacity of $1\frac{3}{4}$ cubic yards, which loads the rock on to small cars. These are drawn by horses to the foot of an incline and from there hauled by cable to the crusher. There are two crushers, one No. 7 and one No. 5 McCuddy. One rotary screen with a device for blowing out the dust separates the crushed material into various sizes including "stone sand" and one-quarter inch chips. The storage capacity of the bins in 1914 was 500 tons, which is not enough to take care of one full day's output. The company is said to be planning the erection of larger bins.

The capacity of the plant is 600 tons per day and the output for 1913, 81,300 tons. The cost of production, including maintenance and depreciation, was 33 cents per ton in 1913. Common labour is paid $17\frac{1}{2}$ and engineers $37\frac{1}{2}$ cents per hour. The material is sold at 55 cents per ton f.o.b. quarry, if purchased in large quantities. It is delivered at Hamilton for $1.05, and in Toronto for $1.25 per ton.

The company owns 49 acres, of which more than 9 acres have been excavated to a depth of 14 feet, yielding over 200,000 cubic yards of solid stone. There is, therefore, allowing for the ground on which the quarry buildings stand, about 30 acres left for development. The overburden is apparently thin and the depth of limestone that is fairly free from shale appears to increase toward the north and east, where, according to the manager, future development is to take place. Trouble with water will be encountered at about 16 feet from the surface. The flat surface topography and the lay of the beds present no serious difficulties in further development.

As far as could be determined by field examination the upper 7 to 12 feet of limestone exposed in the quarry was fairly tough and should be useful in water-bound macadam under light traffic conditions, or in concrete work where the stone was not directly exposed to wear. The shale which occurs under the limestone cannot be regarded as anything but poor road metal, and in purchasing stone from this quarry the material should be specified free from shale.

The results of laboratory tests on this stone are given on page 204.

Quarry at Ancaster. This quarry, the property of E. J. Guest, is located on lot 47, concession II, Ancaster township. It lies immediately south of the Hamilton Ancaster stone road and close to the village of Ancaster. It was visited in the autumn of 1914.

The quarry has been opened in the face of the escarpment and a vertical section of about 45 feet of rock is exposed. The succession from top to bottom is as follows:

		Thickness in feet.
1.	Overburden of soil and clay	4
2.	Coralline buff coloured limestone	3
3.	Massive buff coloured limestone or dolomite, beds from 1 to 4 feet thick	15
4.	Thin-bedded sandy buff coloured limestone	3
5.	Irregularly bedded somewhat mottled limestone or dolomite with many cavities	10
6.	Thin-bedded grey to buff limestone or dolomite with many bituminous partings, beds under 6 inches	7
7.	Grey limestone with bituminous partings, beds from 6 to 9 inches in thickness	6
	Total rock exposed	44

The material in this quarry resembles that found in the quarry at Dundas, nearly 3 miles across the valley to the north of it, and if one take the relative positions of the two localities into consideration and the gentle southwest dip of the formations in this region, it seems quite possible that the upper 21 feet in this quarry come from the same bed as the upper 18 feet in the Dundas and that the lower 23 feet represent the lower member of the Dundas quarry section. This lower member, Nos. 5 to 7 of the section, is made up of fairly tough rock which ought to make good road metal; the upper 21 feet, Nos. 2 to 4, is a softer stone but still nearly as tough. Both the Dundas and Ancaster stone are ascribed to the Guelph and the Lockport or Niagara formation. It seems fair to assume that they will have nearly equivalent road-making qualities.

Canada Crushed Stone Corporation's Quarry at Dundas. This quarry is situated on top of the escarpment of the town of Dundas. The double track of the Grand Trunk railway runs along the face of the hill below it and separate inclined spurs connect the quarry and the crusher with the main line. The quarry is owned by the Canada Crushed Stone Corporation of Dundas, formerly Doolittle and Wilcox. It was visited in 1913 and 1914.

Two types of rock are exposed and worked in the quarry: a dark grey to black, dense dolomite which is quite tough under the hammer and has wavy bituminous partings, and a coarser buff to yellow grey dolomite which is not so tough. The dark grey tough rock is 32 feet thick and is overlain by 18 feet of the buff rock.

The beds are from 1 to 4 feet thick and lie practically flat. If there is any dip it would be difficult to determine in an area the size of this quarry.

The upper 18 feet probably belong to the Guelph dolomite, while the lower 32 feet are the top of the Lockport or Niagara dolomite. Overlying the upper limestone is about from 14 to 20 feet of unconsolidated glacial till.

The overburden is about 14 feet thick on the north side of the quarry and increases to 20 feet as one proceeds farther to the north. The surface of the bedrock under the overburden pitches to the north and east.

The company owns 160 acres. If the lower bed in the quarry is 30 feet thick all over that area, the amount of rock available from that bed should be 7,744,000 cubic yards or 18,275,840 tons. Up to the autumn of 1913 about 1,250,000 tons had been taken out of the quarry.

The quarry was first opened in 1905. A long pit runs along the top of the escarpment for about 1,200 to 1,400 feet; it is from 300 to 500 feet wide and 50 to 60 feet deep in places. The water level is below the lowest workings of the quarry.

In blasting, the holes are put down to a depth of 35 feet. Five Cyclone well drills with 5-inch bits are used. The charge consists of 150 pounds and less of Parks No. 252 to 253 powder. Two steam shovels handle the rock after blasting. One of these can load 2,000 tons a day and the other nearly the same quantity. The material is transported from the quarry to the crusher by dump cars, with a capacity of 4 cubic yards, over a 36-inch track. The hauling is done by three industrial locomotives.

The crushing plant contains seven crushers as follows: one McCuddy No. 21, one No. 8, one No. 7½, and one No. 7 Austin, two 72 Power and Mining Company rolls and one 30-inch roll.

The rock is screened to ½ inch, 1 inch, and 2 inch sizes for road and concrete purposes and to 3, 4, 5, and 6 inch sizes for blast furnace work. The company's storage bins can hold 1,500 tons and additional material is stored in stock piles.

The quarries are connected by two spurs with the Grand Trunk railway, and the material is shipped by rail; Toronto is the principal market. About 30 per cent of the total production and the entire upper bed are sold as flux for blast furnaces. The rest is sold for road metal and concrete work. Lately, some of the rock screenings have been used in making cement bricks. Alfred Roger's Ltd., of Toronto, acts as the company's agent in Toronto and handles all their products.

Unskilled labour is paid at the rate of 20 cents an hour. The company sells crushed stone at 65 cents per ton f.o.b. quarry. The freight rate for small shipments over the Grand Trunk is 55 cents per ton to Toronto.

About 2,000 tons of rock are quarried per day. The crusher capacity is said to be 6,000 tons per day. Two hundred and forty thousand tons of rock were quarried in 1912. The total production to date is about 1,250,000 tons.

The results of tests (page 205) made in the office of Public Roads, Washington, D. C., from samples taken by the writer, show that the rock is capable of withstanding from light to medium wagon traffic in a water-bound macadam road.

Stone at Waterdown. Two localities near Waterdown were examined by Mr. M. Y. Williams of the Geological Survey. At the quarry of Mr. Galivan, 1 mile southwest of Waterdown and on the face of the escarpment, the section is as follows, from the top down:

		Thickness in feet.
1.	Rather porous Lockport or Niagara dolomite in irregular beds	8
2.	Ironstained shaly limestone with soft green shale at base of Rochester formation	2½
3.	Tough limestone ("nigger-head"), of Clinton formation	4½
4.	Shale of the Clinton formation	½
5.	Limestone with shale parting at base of the Clinton formation	1
6.	Limestone of the Clinton formation	1½
	Total	18

One-half mile southeast of Waterdown, east of the Waterdown Aldershot road, in and near the quarry of Mr. Hugh Carson, the section exposed from the top down is as follows:

		Thickness in feet.
1.	Fairly tough, Lockport or Niagara dolomite	26
2.	Rochester shale	3
3.	Clinton limestone (including 5½ feet of the tough or nigger-head bed at top)	13
4.	Sandstone and shale, 10 feet above the base, there is a soft bed of limestone (Cataract and Medina formations)	100
5.	Queenston shale	?

The openings at Galivan's quarries are small. Some of the upper or Lockport stone from them has been used on the nearby roads, but with what result is not known. The nigger-head bed was not quarried at the time of Mr. Williams' visit in 1913, because of its toughness and the consequent difficulty experienced in working it. The rock in this bed is probably good road metal.

Mr. Williams has the following note upon the material exposed at Carson's quarry southeast of Waterdown. "There is an opportunity here of quarrying 20 feet of the Lockport dolomite for road metal; cleaning away the Rochester shale below, which may be dumped over the bank and then quarrying the $5\frac{1}{2}$ feet of tough 'nigger-head' limestone below it for road metal. The lower 7 feet of the Clinton below the nigger-head can then be quarried for dimension stone."

This material is only $2\frac{1}{2}$ miles by wagon road from the "Plains" road at Aldershot. The road is metalled and there is a down grade all the way from the quarry to Aldershot.

Trap Quarries.

Two companies in Ontario produce crushed trap rock in large quantities; they are the Ontario Rock Company, whose quarry is at Havelock, and the Martin International Trap Rock Company, who operate at Bruce Mines.

The Ontario Rock Company's Quarry. This quarry is operated by the Ontario Rock Company, whose main office is in the Crown Office building, Toronto. The quarry is situated 3 miles east of Havelock and 1 mile north of the Canadian Pacific railway from Toronto to Montreal. A spur connects the quarry to the main railway line. It was visited in the autumn of 1913.

In the quarry the material appears as a dense black igneous rock with occasional vugs or cavities in it. In places it is foliated but the foliated material forms a very small part of the whole mass quarried.

The trap outcrops in ridges from 40 to 60 feet above the surrounding drift-covered country. The excavation lies at the southwestern end of one of these ridges and a face of rock about 40 feet high is exposed over the floor of the quarry. There is very little overburden on top of the ridge.

The following information regarding quarrying, equipment and operations, tonnage of rock available, and sizes and prices of crushed rock produced were obtained from Mr. G. W. Rayner, managing director of the company, in April, 1916.

Drilling is done with three $3\frac{1}{4}$-inch steam piston drills. A Cyclone well drill with $5\frac{5}{8}$-inch bit has also been tried, but was not found very satisfactory. The rock breaks into large pieces so that a good deal of it has to be rebroken with small shots.

The material is conveyed from the quarry face to the crusher by means of Austin 2-cubic-yard, end-dumping cars, of which twelve are in use. The crushing mill is equipped with a 24 by 36-inch Farrel-Bacon jaw crusher, a No. 5 Austin gyratory specially reinforced crusher, a 36-inch Symons disk crusher, and a 24-inch Symons disk crusher.

The material is screened into 2-inch, 1-inch, $\frac{3}{4}$-inch, $\frac{3}{8}$-inch, and $\frac{1}{4}$-inch sizes. The storage capacity of the plant is between 4,000 and 5,000 tons; and its production can be increased to 12,000 tons per month with the present equipment. The amount shipped up to April 1916 from this quarry, has been 67,000 tons of crushed stone; and the annual production is about 20,000 tons. About 50 acres of the company's property is underlain by trap, which lies in two hills. Mr. Rayner estimates that there is nearly 3,000,000 tons of trap lying above the ground-water level, on the company's land at the present quarry site.

The prices for crushed stone in carload lots are quoted as follows, f.o.b. quarry: 2-inch stone, $1.15; 1-inch, $1.65; $\frac{3}{8}$-inch, $1.75; $\frac{1}{4}$-inch, $1.65. The freight rate to Toronto is 60 cents per ton. The prices for larger shipments would be materially less than those quoted above.

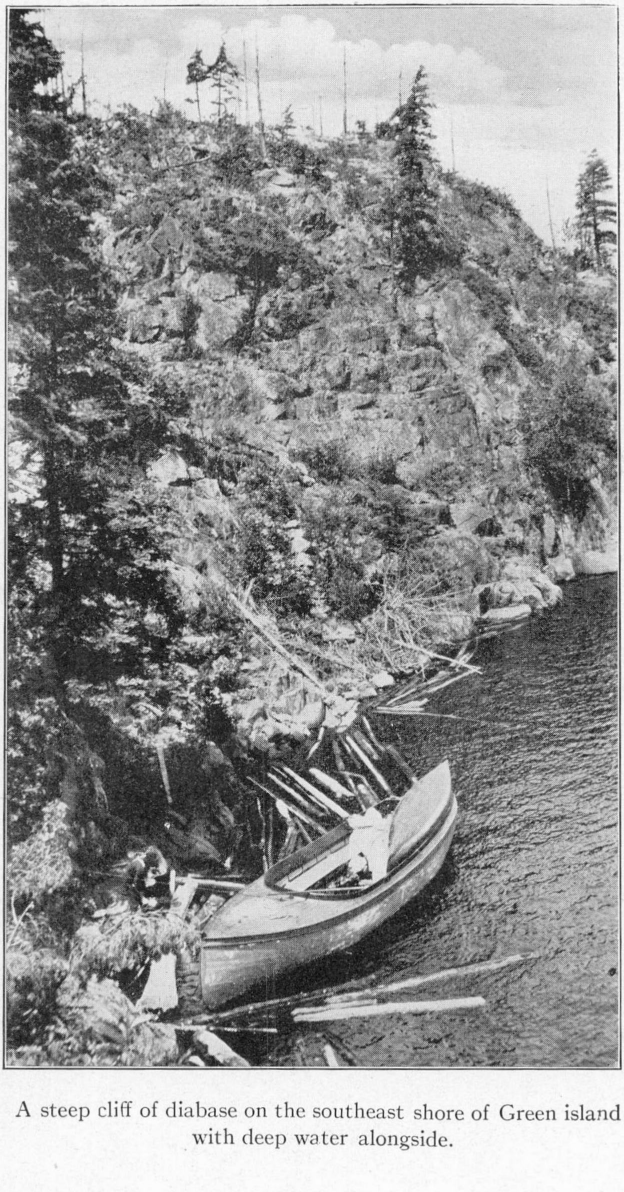
Trap Deposits on Lake Huron. The deposits of trap rock on the north shore of Lake Huron are described in Part II.

Granite Quarries.

A granite quarry is operated for crushed macadam rock by Robert Keys $1\frac{1}{2}$ miles from the town of Gananoque, Leeds county. This place is on the Grand Trunk. The quarry is probably of small dimensions. D. J. Gordon and Son, and Street and O'Brien are large operators in the same place, but whether they produce crushed stone is not known.

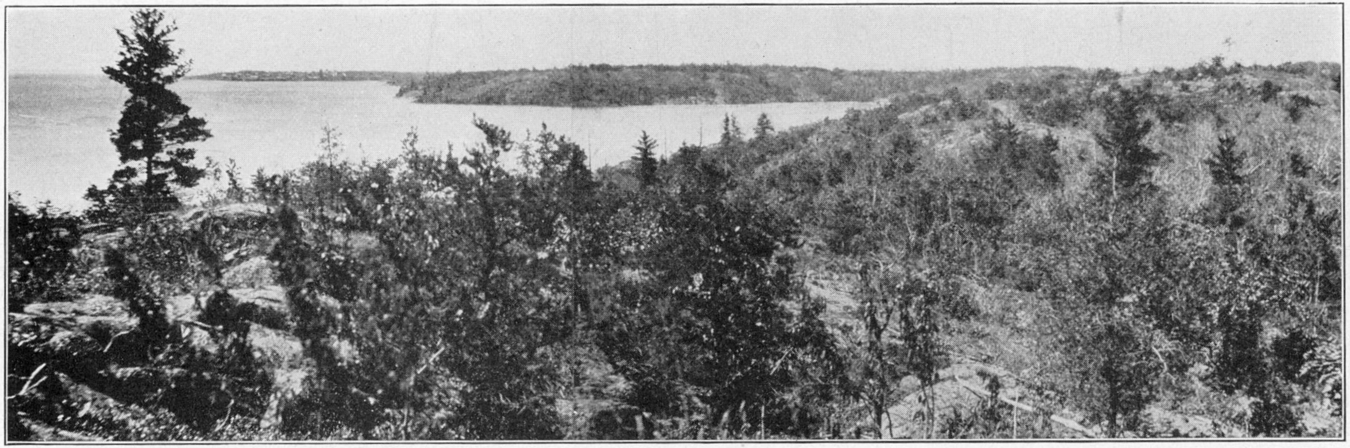
The "List of Stone Quarry Operators in Canada," published by the Mines Branch at Ottawa, contains the names of the Ontario Granite Crushed Stone company, with quarries at Gravenhurst and office address care of A. C. Coulson, accountant, Toronto; and of the Granite Crushed and Dimension Company, Ltd., with quarries at Washago, Rama island, Ontario county, and offices at 152 Bay st., Toronto.

PLATE II.



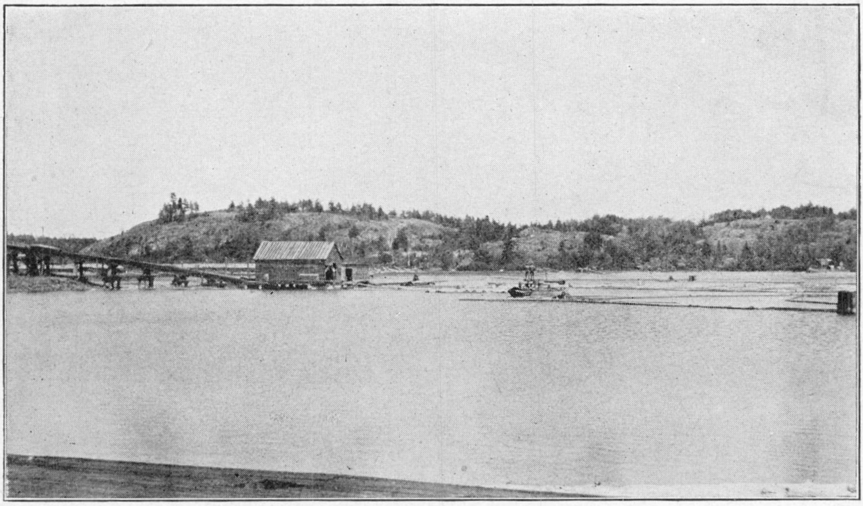
A steep cliff of diabase on the southeast shore of Green island with deep water alongside.

PLATE III.

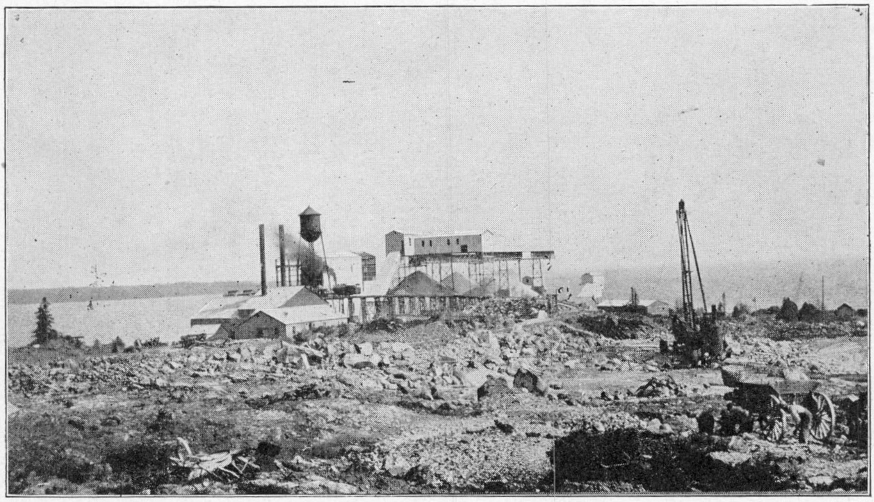


A portion of the peninsula and harbour of Shoepack bay looking south. The flat in the middle foreground is suitable for the location of a crushing plant. The water in the left foreground is deep near the shore.

PLATE IV.

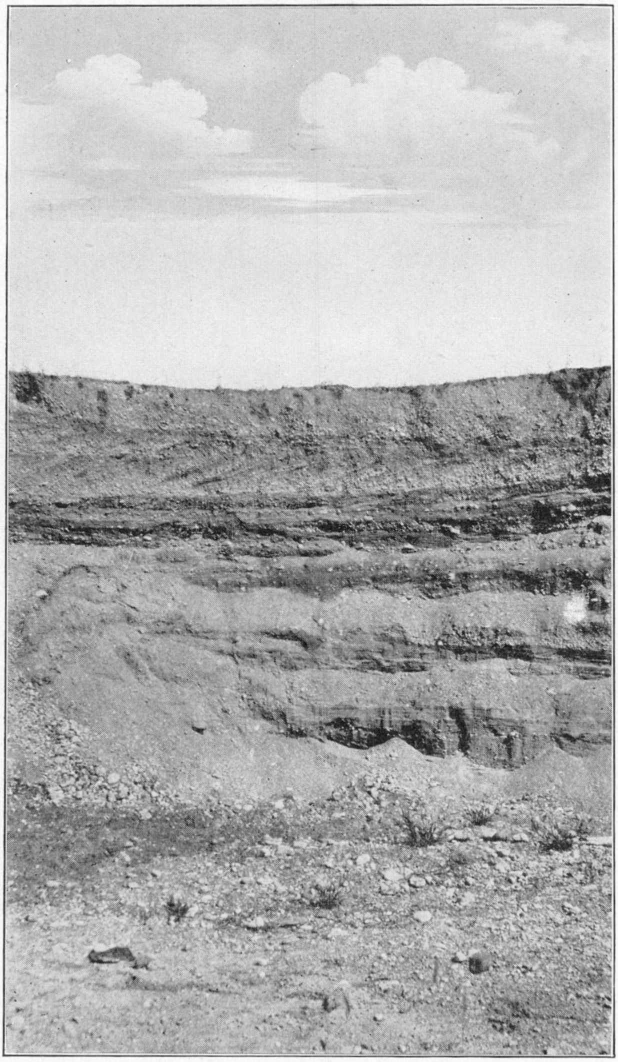


A A hill of diabase at Nestorville. The top of this hill is about 100 feet over the level of the lake.

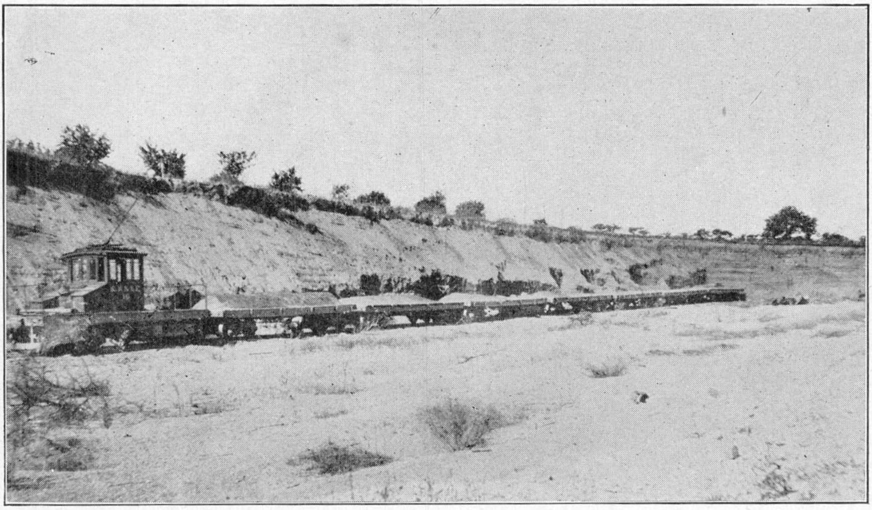


B. Crushing plant and part of the quarry floor, Martin International Trap Rock Company, Bruce Mines.

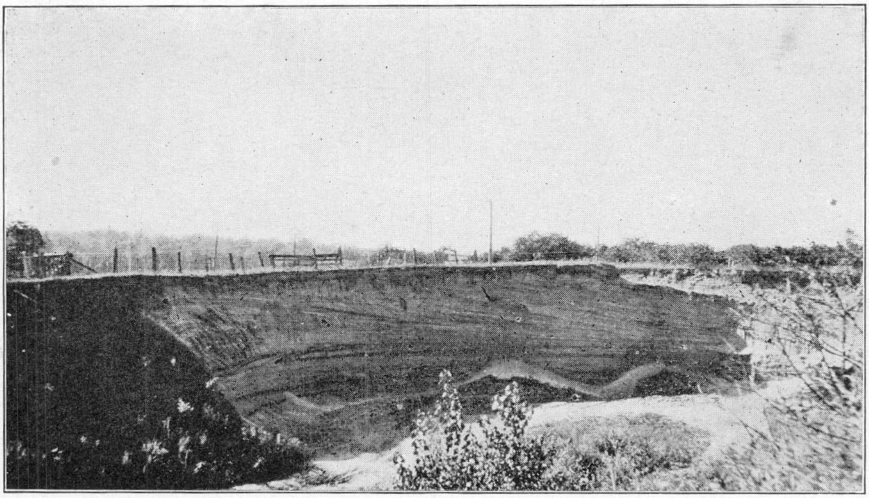
PLATE V.



A portion of the south wall of the Windsor Sand and Gravel Company's pit near Leamington. The wall was about 23 feet high in 1914.

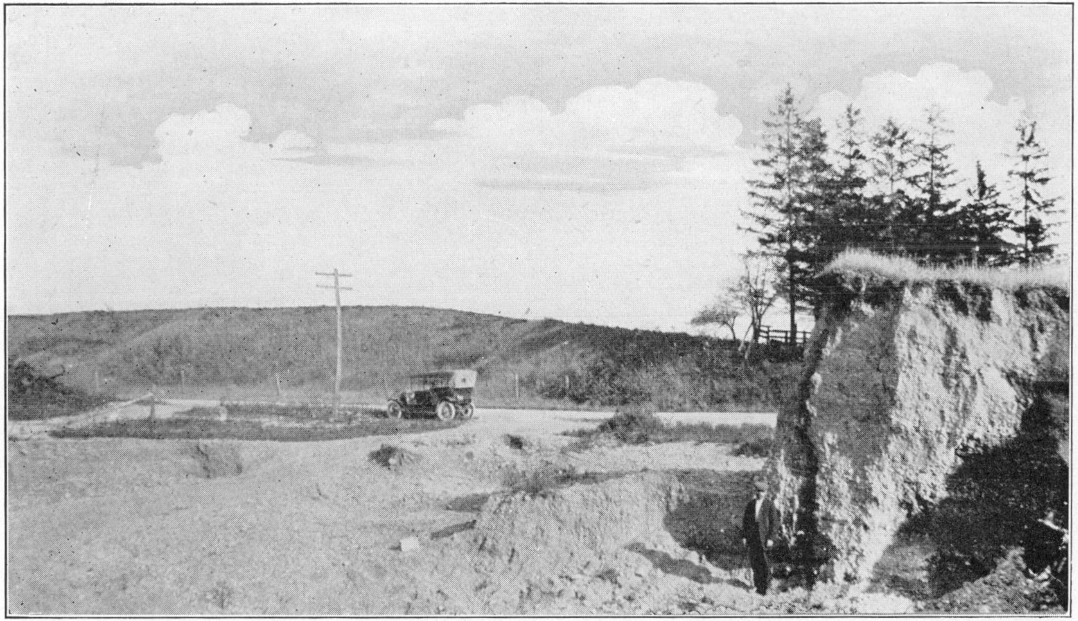


A. West wall of the electric railway's gravel pit No. 1, at Cedar Springs, 1914. The trees in the view form part of a peach orchard. The intensive cultivation of the surface of this ridge adds much to the cost of the gravel land.



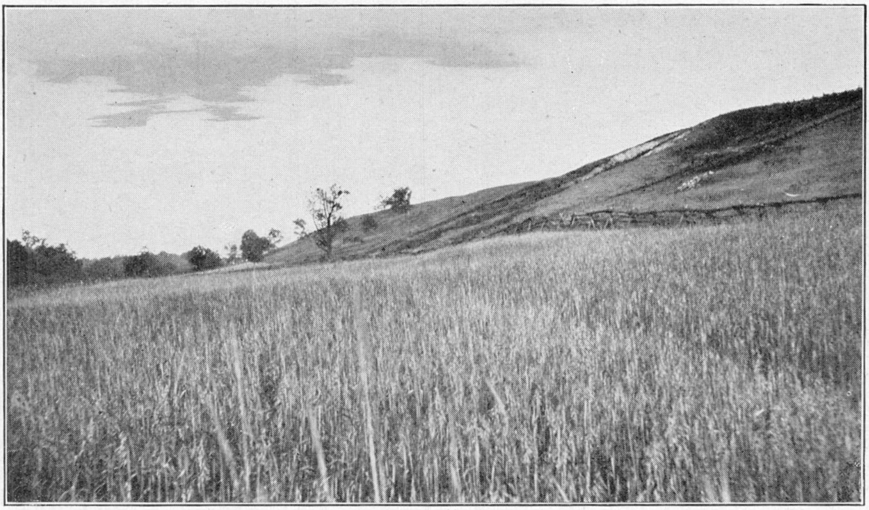
B. Southwest wall of the township gravel pit, No. 2, at Cedar Springs, 1914.

PLATE VII.



Portion of the large gravel pit, No. 11, on the Talbot road east of Morpeth, 1914.
The cut bank across the road is composed entirely of gravel.

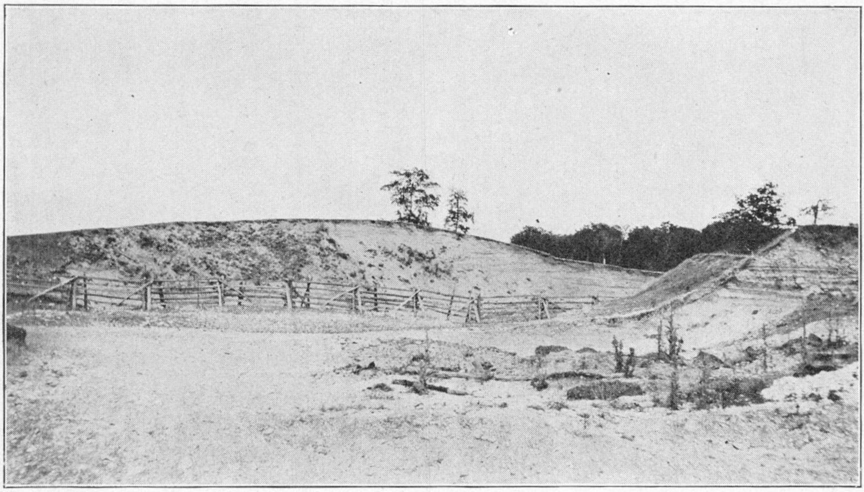
PLATE VIII.



A. Shore cliff of Lake Iroquois $1\frac{1}{2}$ miles north of Colborne, Northumberland county. The hill is of boulder clay.

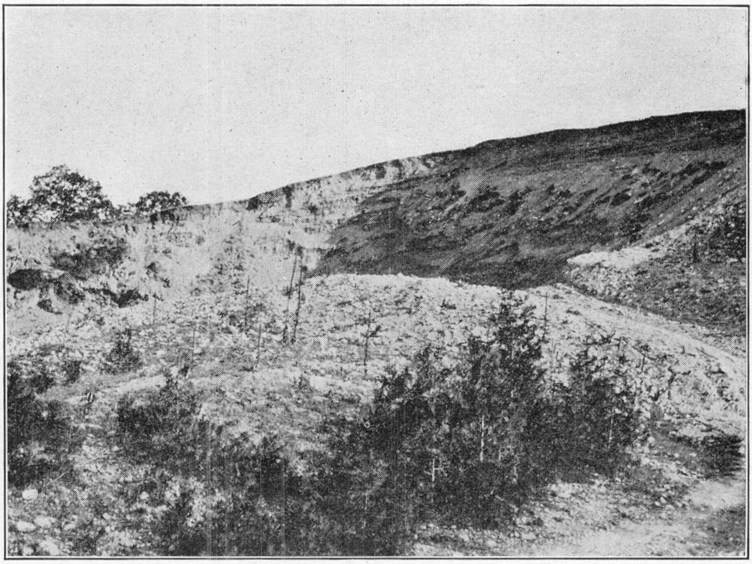
B. The ridge is a Lake Iroquois gravel bar near McCracken pit 3 miles northeast of Colborne, Northumberland county.

PLATE IX.



A. An excavation across a gravel bar on the old shore-line northeast of Cobourg, Northumberland county, showing a typical profile of the surface and the bedded character of the gravels.

B. South wall of Sleeman's pit, No. 11, northwest of Port Hope, Durham county.



A. Wall of pit No. 8, northwest of Port Hope, Durham county.

B. Sand pit on the property of the York Sand Company near No. 105, east of Toronto.

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PUBLICATIONS OF THE GEOLOGICAL SURVEY.

The Geological Survey was established in 1842 and "Reports of Progress" were issued, generally in annual volumes, from that date to 1885, the first report being that for the year 1843 published in 1845. Beginning with the year 1885, "Annual Reports" (new series) were published in volumes until 1905, the last being Vol. XVI, 1904. Many of the individual reports and maps published before 1905 were issued separately and from 1905 to the present, all have been published as separates and no annual volume has been issued. Since 1910, the reports have been issued as Memoirs and Museum Bulletins, each subdivided into series, thus:—

Memoir 41, *Geological Series 38.*
Memoir 54, *Biological Series 2.*
Museum Bulletin 5, *Geological Series 21.*
Museum Bulletin 6, *Anthropological Series 3.*

In addition to the publications specified above, a Summary Report is issued annually; and miscellaneous publications of various kinds including Reports of Explorations, Guide Books, etc., have been issued from time to time.

Publications Issued 1910-1915 Inclusive.

MEMOIRS.

MEMOIR 1. *Geological Series 1.* Geology of the Nipigon basin, Ontario, 1910—by Alfred W. G. Wilson.

MEMOIR 2. *Geological Series 2.* Geology and ore deposits of Hedley mining district, British Columbia, 1910—by Charles Camsell.

MEMOIR 3. *Geological Series 3.* Palæoniscid fishes from the Albert shales of New Brunswick, 1910—by Lawrence M. Lambe.

MEMOIR 4. *Geological Series 7.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec, 1911—by W. J. Wilson.

MEMOIR 5. *Geological Series 4.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory, 1910—by D. D. Cairnes.

MEMOIR 6. *Geological Series 5.* Geology of the Haliburton and Bancroft areas, Province of Ontario, 1910—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *Geological Series 6.* Geology of St. Bruno mountain, Province of Quebec, 1910—by John A. Dresser.

MEMOIR 8. *Geological Series 8.* The Edmonton coal field, Alberta, 1911—by D. B. Dowling.

MEMOIR 9. *Geological Series 9.* Bighorn coal basin, Alberta, 1911—by G. S. Malloch.

MEMOIR 10. *Geological Series 10.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in south-western Ontario, 1911—by J. W. Goldthwait.

MEMOIR 11. *Topographical Series 1.* Triangulation and spirit levelling of Vancouver island, B.C., 1909, issued 1910—by R. H. Chapman.

MEMOIR 12. *Geological Series 11.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906, issued 1911—by Anton Handlirsch.

MEMOIR 13. *Geological Series 14.* Southern Vancouver island, 1912—by Charles H. Clapp.

MEMOIR 14. *Biological Series 1.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia, 1911—by William H. Dall and Paul Bartsch.

MEMOIR 15. *Geological Series 12.* On a Trenton Echinoderm fauna at Kirkfield, Ontario, 1911—by Frank Springer.

MEMOIR 16. *Geological Series 13.* The clay and shale deposits of Nova Scotia and portions of New Brunswick, 1911—by Heinrich Ries assisted by Joseph Keele.

MEMOIR 17. *Geological Series 28.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., 1913—by Morley E. Wilson.

MEMOIR 18. *Geological Series 19.* Bathurst district, New Brunswick, 1913—by G. A. Young.

MEMOIR 19. *Geological Series 26.* Geology of Mother Lode and Sunset mines, Boundary district, B.C., 1914—by O. E. LeRoy.

MEMOIR 20. *Geological Series 41.* Gold fields of Nova Scotia, 1914—by W. Malcolm.

MEMOIR 21. *Geological Series 15.* The geology and ore deposits of Phoenix Boundary district, British Columbia, 1912—by O. E. LeRoy

MEMOIR 22. *Geological Series 27.* Preliminary report on the serpentines and associated rocks, in southern Quebec, 1914—by J. A. Dresser.

MEMOIR 23. *Geological Series 23.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C., 1914—by J. Austen Bancroft.

MEMOIR 24. *Geological Series 16.* Preliminary report on the clay and shale. deposits of the western provinces, 1912—by Heinrich Ries and Joseph Keele.

MEMOIR 25. *Geological Series 21.* Report on the clay and shale deposits of the western provinces, Part II, 1914—by Heinrich Ries and Joseph Keele.

MEMOIR 26. *Geological Series 34.* Geology and mineral deposits of the Tulameen district, B.C., 1913—by C. Camsell.

MEMOIR 27. *Geological Series 17.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911, issued 1912.

MEMOIR 28. *Geological Series 18.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario, 1912—by Charles D. Walcott.

MEMOIR 29. *Geological Series 32.* Oil and gas prospects of the northwest provinces of Canada, 1913—by W. Malcolm.

MEMOIR 30. *Geological Series 40.* The basins of Nelson and Churchill rivers, 1914—by William McInnes.

MEMOIR 31. *Geological Series 20.* Wheaton district, Yukon Territory, 1913—by D. D. Cairnes.

MEMOIR 32. *Geological Series 25.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C., 1914—by R. G. McConnell.

MEMOIR 33. *Geological Series 30.* The geology of Gowganda Mining Division, 1913—by W. H. Collins.

MEMOIR 34. *Geological Series 63.* The Devonian of southwestern Ontario, 1915—by C. R. Stauffer.

MEMOIR 35. *Geological Series 29.* Reconnaissance along the National Transcontinental railway in southern Quebec, 1913—John A. Dresser.

MEMOIR 36. *Geological Series 33.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C., 1914—by C. H. Clapp.

MEMOIR 37. *Geological Series 22.* Portions of Atlin district, B.C., 1913—by D. D. Cairnes.

MEMOIR 38. *Geological Series 31.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II, 1913—by Reginald Aldworth Daly.

MEMOIR 39. *Geological Series 35.* Kewagama Lake map-area, Quebec, 1914—by M. E. Wilson.

MEMOIR 40. *Geological Series 24.* The Archæan geology of Rainy lake, 1914—by Andrew C. Lawson.

MEMOIR 41. *Geological Series 38.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick, 1914—by Marie C. Stopes.

MEMOIR 42. *Anthropological Series 1.* The double-curve motive in north-eastern Algonkian art, 1914—by Frank G. Speck.

MEMOIR 43. *Geological Series 36.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec, 1914—by J. J. O'Neill.

MEMOIR 44. *Geological Series 37.* Clay and shale deposits of New Brunswick, 1914— by J. Keele.

MEMOIR 45. *Anthropological Series 3.* The inviting-in feast of the Alaska Eskimo, 1914—by E. W. Hawkes.

MEMOIR 46. *Anthropological Series 7.* Classification of Iroquoian radicals and subjective pronominal prefixes, 1915—by C. M. Barbeau.
MEMOIR 47. *Geological Series 39.* Clay and shale deposits of the western provinces, Part III, 1914—by Heinrich Ries.
MEMOIR 48. *Anthropological Series 2.* Some myths and tales of the Ojibwa of southeastern Ontario, 1914—by Paul Radin.
MEMOIR 49. *Anthropological Series 4.* Malecite tales, 1914—by W. H. Mechling.
MEMOIR 50. *Geological Series 51.* Upper White River district, Yukon, 1915—by D. D. Cairnes.
MEMOIR 51. *Geological Series 43.* Geology of the Nanaimo map-area, 1914—by C. H. Clapp.
MEMOIR 52. *Geological Series 42.* Geological notes to accompany map of Sheep River gas and oil field, Alberta, 1914—by D. B. Dowling.
MEMOIR 53. *Geological Series 44.* Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition), 1914—by D. B. Dowling.
MEMOIR 54. *Biological Series 2.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts,1914—by C. K. Dodge.
MEMOIR 55. *Geological Series 46.* Geology of Field map-area, Alberta and British Columbia, 1914—by John A. Allan.
MEMOIR 56. *Geological Series 56.* Geology of Franklin mining camp, B.C., 1915—by Chas. W. Drysdale.
MEMOIR 57. *Geological Series 50.* Corundum, its occurrence, distribution, exploitation, and uses, 1915—by A. E. Barlow.
MEMOIR 58. *Geological Series 48.* Texada island, 1915—by R. G. McConnell.
MEMOIR 59. *Geological Series 55.* Coal fields and coal resources of Canada, 1915—by D. B. Dowling.
MEMOIR 60. *Geological Series 47.* Arisaig-Antigonish district, 1915—by M. Y. Williams.
MEMOIR 61. *Geological Series 45.* Moose Mountain district, southern Alberta (second edition) 1914—by D. D. Cairnes.
MEMOIR 62. *Anthropological Series 5.* Abnormal types of speech in Nootka, 1915—by E. Sapir.
MEMOIR 63. *Anthropological Series 6.* Noun reduplication in Comox, a Salish language of Vancouver island, 1915—by E. Sapir.
MEMOIR 64. *Geological Series 52.* Preliminary report on the clay and shale deposits of the Province of Quebec, 1915—by J. Keele.
MEMOIR 65. *Geological Series 53.* Clay and shale deposits of the western provinces, Part IV, 1915—by H. Ries.
MEMOIR 66. *Geological Series 54.* Clay and shale deposits of the western provinces, Part V, 1915—by J. Keele.
MEMOIR 67. *Geological Series 49.* The Yukon-Alaska Boundary between Porcupine and Yukon rivers, 1915—by D. D. Cairnes.
MEMOIR 68. *Geological Series 59.* A geological reconnaissance between Golden and Kamloops, B.C., along the line of the Canadian Pacific railway, 1915—by R. A. Daly.
MEMOIR 69. *Geological Series 57.* Coal fields of British Columbia, 1915—D. B. Dowling.
MEMOIR 70. *Anthropological Series 8.* Family hunting territories and social life of the various Algonkian bands of the Ottawa valley, 1915—by F. G. Speck.
MEMOIR 71. *Anthropological Series 9.* Myths and folk-lore of the Timiskaming Algonquin and Timagami Ojibwa, 1915—by F. G. Speck.

MEMOIR 72. *Geological Series 60.* The artesian wells of Montreal, 1915—by C. L. Cumming.
MEMOIR 73. *Geological Series 58.* The Pleistocene and Recent deposits of the Island of Montreal, 1915—by J. Stansfield.
MEMOIR 74. *Geological Series 61.* A list of Canadian mineral occurrences, 1915—by R. A. A. Johnston.
MEMOIR 75. *Anthropological Series 10.* Decorative art of Indian tribes of Connecticut, 1915—by Frank G. Speck.
MEMOIR 76. *Geological Series 62.* Geology of the Cranbrook map-area, 1915—by S. J. Schofield.
MEMOIR 77. *Geological Series 64.* Geology and ore deposits of Rossland, B.C., 1915—by C. W. Drysdale.
MEMOIR 78. *Geological Series 66.* Wabana iron ore of Newfoundland, 1915—by A. O. Hayes.
MEMOIR 79. *Geological Series 65.* Ore deposits of the Beaverdell map-area, 1915—by L. Reinecke.
MEMOIR 80. *Anthropological Series 11.* Huron and Wyandot mythology, 1915—by C. M. Barbeau.
MEMOIR 81. *Geological Series 67.* Oil and gas fields of Ontario and Quebec, 1915—by Wyatt Malcolm.
MEMOIR 82. *Geological Series 68.* Rainy River district, Ontario. Surficial geology and soils, 1915—by W. A. Johnston.

MUSEUM BULLETINS.

The Museum Bulletins, published by the Geological Survey, are numbered consecutively and are given a series number in addition, thus: Geological Series No. 1, 2, 3, etc.; Biological Series No. 1, 2, 3, etc.; Anthropological Series No. 1, 2, 3, etc.

In the case of Bulletins 1 and 2, which contain articles on various subjects, each article has been assigned a separate series number.

The first Bulletin was entitled *Victoria Memorial Museum Bulletin;* subsequent issues have been called *Museum Bulletins.*

MUS. BULL. 1. (*Issued 1913*).
Geological Series 1. The Trenton crinoid, Ottawacrinus, W. R. Billings—by F. A. Bather.
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