GUIDE BOOK No. 3

Excursions in the Neighbourhood of Montreal and Ottawa

(EXCURSIONS A 6, A 7, A 8, A 10, A 11)

ISSUED BY THE GEOLOGICAL SURVEY

OTTAWA
Government Printing Bureau
1913

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Excursions in the Neighborhood of Montreal and Ottawa.

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Contact of the anorthosite and Laurentian limestone. From about 1 mile N.W. of St. Sauveur, P.Q.

EXCURSION A 6.

THE MORIN ANORTHOSITE AREA.

BY

FRANK D. ADAMS.

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INTRODUCTION.

General Statement concerning the Anorthosite Intrusions of the Canadian Shield.

The Laurentian shield, or great Northern Protaxis of the continent of North America has an area of rather over 2,000,000 square miles (5,000,000 square kilometres) and lies almost entirely within the bounds of the Dominion of Canada.

As is well known, it consists of rocks of pre-Cambrian age, the greater part being made up of the gneisses of the Laurentian System.

Penetrating these rocks of Laurentian age, more especially along the border of the eastern portion of the Protaxis, there are great intrusions of anorthosite. These are typical plutonic intrusions, often of vast dimensions, that which occurs about the head waters of the River Saguenay having an area of not less than 5,800 square miles (13,500 square kilometres). It was from these anorthosite areas in Labrador that the minerals labradorite and hypersthene were first obtained and sent to Europe by the Moravian missionaries.

The greater number of these anorthosite intrusions are situated in very wild and inaccessible districts, but one of them, the Morin anorthosite intrusion, can be reached with comparative ease, and the present excursion has been arranged with a view to enabling the members of the Congress to obtain an idea of the chief characteristics of this great anorthosite area. The various anorthosite bodies resemble one another closely in character, although in some of them certain phenomena are especially accentuated; thus, in the Labrador area to which reference has been made, the beautifully iridescent variety of labradorite ("Labrador Feldspar") is abundant. This occurs less abundantly in the other areas, and in the Morin area is scarcely ever found. The Morin anorthosite area can, be taken however, as a typical representative of the great anorthosite intrusions of Canada.

The anorthosite may be considered as a variety of gabbro in which plagioclase ("anorthose") preponderates so largely that the other components sink to the rank of accessory constituents. It may be said that usually they do not constitute more than five per cent of the rock—the remaining 95 per cent being plagioclase which varies in composition from andesite to anorthite. The other constituents are almost invariably augite, hypersthene and ilmenite. These minerals become relatively more abundant in certain schlieren, while in most of the intrusions places can be found where the ilmenite is segregated into large masses, some of which have been worked as ores of iron.

THE MORIN ANORTHOSITE.

EXTENT AND RELATION TO THE SURROUNDING GNEISS.

The Morin anorthosite area is situated on the margin of the Laurentian protaxis 30 miles (48 kilometres) north of Montreal. It is a nearly circular mass from the south-eastern side of which, however, there is a wide apophysis extending in a southerly direction. The mass is about 37 miles (59·5 km.) in diameter and has a total area of 990 square miles (2,475 square kilometres). It cuts through the gneiss and associated rocks of the Laurentian system by which it is surrounded on all sides, except at the southern extremity of the arm-like apophysis above mentioned, where it is overlain and covered by the much more recent Palæozoic strata of the St. Lawrence valley which here are of Potsdam and Calciferous age.

The country underlain by this anorthosite, leaving out of consideration the arm-like extension above mentioned, is very hilly, but the hills seldom rise to such height as to be properly designated as mountains, and, while often rugged and precipitous, still preserve the smooth flowing contours seen everywhere in the Laurentian in this part of Canada. Between the hills are valleys or plains, generally of no great size, occupied by drift. These valleys, as well as the hill sides, are year by year being cleared of their forest growth and converted into farms that support a hardy population.

Scattered through these valleys are a great number of lakes, some of considerable size, in which North river and other streams take their rise, eventually finding their way into the Ottawa or St. Lawrence rivers.

The highest hills in the area are those about Duck lake in the township of Cartier, and those in the district about Montagne Noire in the township of Archambault. On the whole, this anorthosite area is rather more rugged than that underlain by the surrounding gneiss.

As will be seen on consulting the accompanying map, the gneissic series through which this anorthosite has been intruded, is, so to speak, closely wrapped around the anorthosite mass, its strike for the most part following the sinuosities and curves of the contact. The most notable exception to this is along a portion of the southern boundary where the band of white crystalling limestone interstratified with the gneiss is seen to be cut out off by the anorthosite. The foliation of the gneiss is thus evidently ,in part at least, a secondary structure, induced by great pressure subsequent to the intrusion of the anorthosite. This pressure has affected the anorthosite as well, for the anorthosite, especially near the contact on the eastern side, possesses a distinct foliation coinciding in direction with that of the gneiss.

At a number of places near the limits of the area, especially about the dividing line between the rear ranges of Wexford and Chertsey, near the road to St. Donat, very large masses of orthoclase gneiss occur inclosed in the anorthosite ,and afford additional proof, if any be required, of the intrusive character of the latter.

Composition of the Morin Anorthosite.

The anorthosite throughout the area is pretty uniform in composition, the chief variations being due to a somewhat uneven distribution of the constituent minerals in the schlieren which are in places developed in the rock. The most noteworthy exception is the greater preponderance. of the iron-magnesia constituents in the extreme northwest corner of the area in consequence of which the anorthosite passes over into a gabbro.

Plagioclase, augite, hypersthene and ilmenite are by far the most important constituents. Hornblende occurs in a few places, more especially near the contact with the surrounding gneiss. Garnet, apatite, zircon and other minerals are occasionally found as accessory constituents.

The plagioclase has been found in every case where it has been examined to be labradorite and throughout the area, except where the rock has been granulated by the action of pressure, this labradorite is filled with an infinite number of minute schillerization inclusions, which give to it a deep violet or nearly black colour, so that the massive anorthosite is always very dark.

Augite, while present in much smaller quantity than the plagioclase, is, next to it, the most abundant constituent of the rock. Rhombic pyroxene (hypersthene) is present, however, in nearly, if not quite, equal amount. Both minerals occur in grains of a pale green colour and of irregular shape. The hornblende, when found, occurs in individuals of a similar shape in intimate association with the pyroxenes and frequently forms a border around the pyroxenes. It is usually green, but is sometimes brown. Garnet very seldom occurs as a constituent of the normal anorthosite but is often found near its contact with the surrounding gneiss. It has a pale pinkish colour and is often intimately associated with grains of iron ore.

In nearly every section of anorthosite, some grains of an opaque black iron ore are seen. Those portions of the anorthosite rich in iron ore are very restricted in extent and they fade away into the normal anorthosite of the area which, as above mentioned, is very poor in iron ore.

The other constituents of the anorthosite are found but occasionally and are present in such small amount that they do not merit any especial mention.

Structure of the Morin Anorthosite.

The macroscopic structure of these anorthosites, as well as that of most of the crystalline rocks forming the Laurentian system, is best studied on the great glaciated surfaces of the *roches moutonnées*, which protrude through the drift in all directions. On a freshly fractured surface, or even on a smoothly glaciated surface which has been protected from the weather, the structure is not clearly seen; but, when the glaciated surface has been exposed during the interval which has elapsed since the disappearance of the ice, to the etching action of the weather, the structure of the rock is brought out in a wonderfully clear and striking manner. Such weathered surfaces, moreover are often square yards in extent and enable the structure of considerable masses of the rock to be determined and the relations of different structures to one another to be clearly seen.

If any large weathered surface of the anorthosite, such as is found in the *roches moutonnées* anywhere within the Morin area, be examined (leaving out of consideration for the present the arm-like extension and that part of the main area adjoining it), it will be noticed that the rock, which is coarse-grained and of a deep violet colour, has not that regularity of structure which we see in a typical granite, but presents a more or less irregular structure. This irregularity is sometimes scarcely noticeable, but is at other times striking, and is due to concentration of the bisilicates and iron ore in some parts of the rock. The portions richer in bisilicates may take the form of large irregular-shaped patches occurring at intervals through the rock, or of many small patches occurring abundantly in certain parts of the rock which elsewhere is nearly free from them. In some cases these are arranged so as to form irregular wavy streaks instead of patches. Sometimes these streaks are rudely parallel, giving a sort of strike to the rock, but in other places they are quite irregular in arrangement. Between these patches or streaks rich in bisilicates, and rather badly defined against them, are portions of the rock which are very poor in or often quite free from bisilicates. The structure is well represented in the accompanying photograph of a large anorthosite boulder on lot 5 of range IX. of the township of Chertsey. Here the iron ore and bisilicates are aggregated together in more or less rounded areas of the rock, while the remainder of the rock is almost free from iron-magnesia constituents. In those portions containing the bisilicates and iron ore, these constituents form about one-third of the rock, the rest being plagioclase. Large individuals of plagioclase, irregular in shape and which will be referred to again, occur quite abundantly in the parts of the rock free from bisilicates, but are very rarely found in the patches containing the bisilicates. With the exception of the larger individuals of plagioclase, the rock is uniform in grain throughout. The portions containing the bisilicates weather more readily than the rest of the rock, and thus leave hollows on the weathered surfaces; when the patches are elongated, as is usually the case, irregular sausage-shaped cavities usually result. In the occurrence represented in the photograph, it will be noticed that one of the masses rich in bisilicates and much larger than the others, forms a rude band across the lower portion of the

Boulder of anorthosite, range IX., lot 5, Chertsey, P.Q. Shows the segregation of the Mg-Fe minerals into certain portions of the rock.

boulder. In such cases, the bisilicate individuals are arranged with their larger axes in a direction rudely parallel to the band.

But another structure is also presented by the anothrosites. When any of the anorthosites in the area embraced by the present report are carefully examined, this streaked or irregularly banded structure is seen to be accompanied in most, if not in all cases, by a peculiar breaking or granulation of the constituent minerals of the rock. This is often beautifully displayed on the large weathered surfaces. The rock presents a peculiar brecciated structure, fragments of plagioclase and of the other constituents of the rock being imbedded in a species of groundmass made up of smaller grains. As plagioclase in most cases preponderates almost to the exclusion of the other constituents, the fragments are usually of this mineral, and, although occasionally showing an approximation to good crystalline form, they are almost invariably quire irregular or even tattered in outlines. The groundmass of smaller grains also consists of plagioclase. In some places these fragments constitute the greater part ot the rock; elsewhere they are present very sparingly and the groundmass preponderates. The larger individuals can, moreover, be frequently seen in the very act of breaking up, the several fragments having shifted their position but very slightly.

When examined under the microscope in thin sections, hardly a specimen of any coarse-grained variety can be obtained from any part of the area which does not show at least traces of this clastic or granulated structure; and if a series of specimens be studied, every step can be traced in the passage from massive anorthosite, showing the merest traces of this structure through intermediate breccia-like stages, to anorthosite consisting entirely of broken grains, or with mere remnants of the original large individuals. The three accompanying micro-photographs illustrate successive stages in this granulation. They are taken from three thin sections of anorthosite from different parts of the Morin area, photographed in polarized light between crossed nicols and equally magnified, the enlargement in each case being 18 diameters.

(a) This section, from the large exposures about five miles northwest of the village of Ste. Adèle, in the township of Morin, represents the massive anorthosite. It shows only the merest traces of granulation on the left

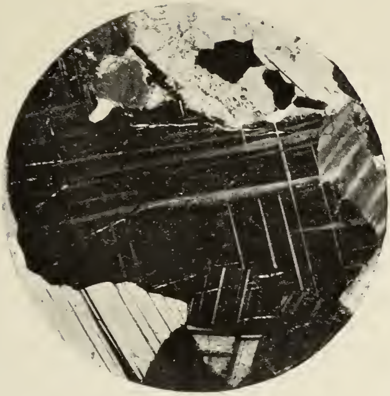

Fig. A.

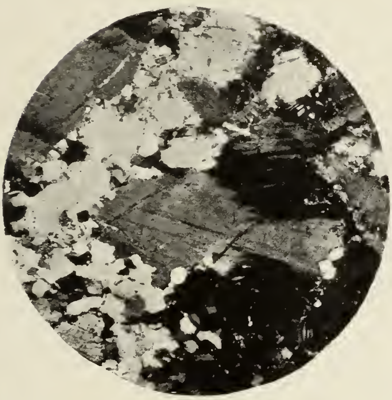

Fig. B

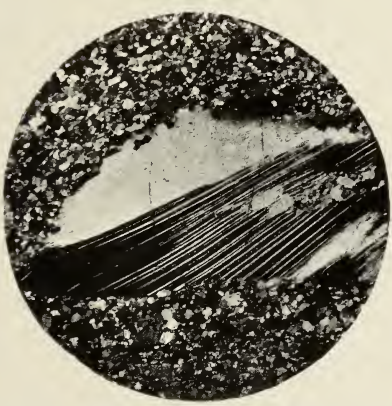

Fig. C.

Microphotographs showing the progressive granulation of the Morin anorthosite under the influence of pressure, + 18 diam:

of the field. The size and shape of the constituent individuals of plagioclase and their polysynthetic twinning are well seen. The rock is composed almost exclusively of this mineral, the individuals of which are neither bent nor twisted, and no strain-shadows are to be observed.

(b) In this section, which was prepared from a specimen collected about three and a half miles north-east of White Lake, in the front of the township of Chilton, a distinct breaking or granulation of the plagioclase can be observed, especially in the lower portion of the slide, while the same process can be elsewhere seen, though not so well marked. The large plagioclase individuals no longer meet along clear well defined boundary lines, but are irregular in shape, cracked, and separated from one another by a mosaic of broken grains. Strain-shadows, twisted twin lamellae and other evidences of pressure are well shown. The rock shows no distinct foliation or banding.

(c) The third section shows the appearance presented by a highly granulated variety of the anorthosite under the microscope. This specimen was obtained from the arm-like extension of the anorthosite mass before mentioned near its western contact with the gneiss, on range XI of the township of Rawdon. In this section, about one-half of the field is occupied by broken grains of plagioclase, while in the middle is a large plagioclase individual in process of destruction. A line of granulated material is being developed in a longitudinal direction through the large crystal, making, as is usual, an angle of about 20° with the lines of twinning, and which, if continued, would cut it in two; while little fragments of the plagioclase can be seen about its edge in the very act of breaking off—first a strain-shadow (excellently seen on the upper edge of the large individual) appearing, then a curved crack extending in from the edge of the crystal, and finally the breaking away of the small piece of the mineral, leaving an irregular indentation. The appearance is precisely that which the mineral would present if little pieces were being broken off the edge with a pair of small pincers. The strain having been relieved by fracture, all evidence of pressure disappears in the broken grain. If a thin section were composed of broken grains alone, it would be impossible in most cases to determine that these had resulted from the breaking down of larger individuals. This rock is excellently foliated, owing to the finely granulated material, which results from the breaking up of each large individual, arranging itself in the shape of a very flat lens about the crystals remnant from which it was derived. This lens, of course, lies in a plane at right angles to the pressure, and in section appears as a long slender tail of broken grains extending from the remnant in either direction.

The pyroxenes, rhombic or monoclinic, when present in the rock, undergo a precisely similar process of granulation with the formation of similar tails of broken grains.

A very remarkable fact in this connection is that the large crystal fragments of plagioclase have a deep violet colour, while the granulated plagioclase is white. This contrast is excellently seen either on the weathered surface or when a thin section is placed on a sheet of white paper, and is due to the fact that the minute dark-coloured or black inclusions, which abound in the large individuals. are absent in the broken material. They seem to have aggregated themselves together into little grains of titanic iron ore, which occur in the granulated plagioclase, but which are absent in the large individuals. So distinctive is this contrast of colour, that when a thin section containing plagioclase in both forms is placed under the microscope, it is possible at once to predict from the colour alone, just what portions will show granulation and what portions will not, before the actual structure has been revealed by the agency of polarized light. This might seem at first sight to indicate a recrystallization in the case of the granulated portions of the plagioclase, but the facts do not seem to support this supposition. At any rate the feldspar does not alter in composition during the process of granulation, but merely breaks, and becomes lighter in colour through the loss of the dark inclusions.

In the Morin anorthosite, the most granulated varieties are found near the sides of the intrusion, especially on the east side, as if the pressure had been exerted from that direction, but more or less distinct evidences of granulation can be seen throughout the entire area. The white granulated anorthosite forms the greater part of the arm-like extension of the Morin mass, protruding through the drift in all directions in the form of hundreds of smooth white hummocks and giving a striking appearance to the landscape, as, for instance, about the village of New Glasgow. Further, it can be observed that everywhere in this arm-like extension and in almost all its occurrences elsewhere, this white granulated anorthosite is more or less distinctly foliated, owing to the arrangement of the bisilicates and iron ores in more or less distinctly parallel lines or streaks. It is often quite evident that these are nothing more than the rounded patches, rich in bisilicates, described for the massive anorthosite and which, owing to a movement in the rock, have been drawn out in one direction. The irregular-shaped patches, differing greatly in size of grain, that have been described as occuring in the massive rock, are also represented here by elongated streaks of similar character. This foliation is best seen where bisilicates and iron ore are comparatively abundant. When, as is sometimes the case, the rock is almost free from these constituents and all the plagioclase fragments have been destroyed, it assumes a nearly uniform granular character, and no trace of foliation can be observed. Along the western border of the arm, the strike is exceedingly regular and remarkably well developed, as at New Glasgow, but is especially well seen along the same contact further north on range XI of the township of Rawdon, on the road between the villages of Chertsey and Rawdon. At this latter locality the rock has a remarkably regular schistose structure, due to the alternation of thin layers of pure plagioclase with still thinner ones of pyroxene. The pyroxene bands might more properly be called leaves, as they are very thin, being frequently represented by mere parallel lines in transverse sections. When examined under the microscope, in thin sections or weathered surfaces, both they and the plagioclase layers are found to contain small cores or remnants of large individuals with tails of grains extending from them in either direction as before described. These give rise to the perfect foliation and the progress of granulation is seen in an astonishingly perfect manner, the cores being in the very act of breaking up.

The question of the origin of the several structures described next presents itself. There is every reason to believe that those structures which have been described as occurring in the massive anorthosite, namely, the irregularity in size of grain and the more or less irregular distribution of the several constituents through the rock, are original structures. These irregularities, frequently seen in intrusive rocks, are certainly not the results of pressure; and the circumstance that the streaks or irregular bands, when present in the otherwise massive rock, assume no definite direction, but twist about as if owing to the movements of the rock while in a pasty condition, indicates that they have been produced by movements before the rock became solid. The unequal distribution of the constituent minerals in the rock, must have resulted either from irregularities in the composition of the original magma, or from processes of segregation at work in the magma during cooling and crystallization.

On the other hand, the granulation of the coarsely crystalline massive anorthosite, usually with concomitant development of a more or less distinctly foliated or schistose structure in the way described, is undoubtedly due to movements in the rock, resulting from pressure which acted subsequent to or possibly during the last stages of its solidification, for, as has been shown, the granulation begins to make its appearance in the massive crystalline rock itself. Under the influence of pressure, the massive rock gradually gave way, and the movements resulted in granulation. Moreover, wherever these movements continued longest or were most intense, this granulation became most complete, until finally the last remnants of the larger individuals disappeared, and in the case of a pure anorthosite, a more or less evenly granular rock resulted. In the anorthosite, however, the remnants of larger individuals are seldom or never entirely absent, and over the greater part of the area the amount of interstitial material is quite small.

ANNOTATED GUIDE.

Miles and kilometres.

0·0 **Montreal—Place Viger Station**—Altitude, 58·49 ft. (17·8 m.).

5·1 m. **Mile End**—Altitude 225 ft. (68·5 m.)

8·2 km. Leaving Place Viger station, the railway passes along the north bank of the St. Lawrence river and then through the western portion of the city, which is underlain by the limestones of the Trenton formation (Ordovician) which are here about 600 feet, thick. The intrusive mass of Mount Royal (one of the Monteregian hills) composed of essexite and nepheline

Miles and kilometres.

syenite, is seen on the left. On its steep slopes are wave-cut terraces, with fossiliferous marine clays and other evidences of the submergence of this portion of the country in post-Glacial times. About Mile End are large quarries from which stone for building purposes and for the production of lime is obtained. The grey limestone of which Montreal is largely built, is obtained chiefly from these quarries.

These Trenton limestones are highly fossiliferous; over 80 specimens of marine invertebrata have been described from them, including *Lingula quadrata*, *Plectambonites sericeus*, *Ctenodonta nasuta*, etc.

The plain traversed by the railway is a portion of the great plain of the St. Lawrence lowlands, which stretches away to the north as far as the margin of the Canadian Shield, which here is 30 miles distant. The Ordovician rocks of the plain are covered by deposits of Pleistocene age, consisting of boulder clay overlain by the Leda clay and Saxicava sand, both of which are in many localities filled with marine shells. The plain, which is very fertile and supports a large farming population, gradually rises to the north and at the margin of the Canadian Shield has an elevation of about 300 feet. (91·4 m.).

Three quarters of a mile beyond Mile End the Trenton is succeeded by the conformably underlying limestones of the Chazy.

9·9 m. 15·9 km. **Bordeaux**—Alt. 75 ft. (22·8 m.) Here the train crosses the Back river, or Riviére–des–Prairies, a branch of the Ottawa river which flows around the north side of the Island of Montreal and enters the St. Lawrence a few miles farther to the east.

The river here runs very rapidly, forming the Sault-au-Recollet, called after Nicholas Veil, a Recollet priest who was drowned here by the Huron Indians in 1626.

10·3 m. 16·6 km. **Parc Laval.**

12·8 m. 20·4 km. **St. Martin's Junction**—Alt 110 ft. (30·8 m.). The line for Quebec leaves here.

Miles and kilometres.

17·3 m. 27·8 km. **Ste. Rose**—Alt. 85 ft. (25·9 m.). Just before reaching this point the Chazy limestone is succeeded by the underlying dolomitic limestones of the Calciferous. The line crosses the Riviére des Milles Iles, another branch of the Ottawa, which to the east becomes confluent with Back river before the latter reaches the St. Lawrence.

18·0 m. 29·0 km. **Rosemere**—Alt. 91 ft. (27·7 m.).

20·0 m. 32·2 km. **Ste. Thérèse**—Alt. 120 ft. (36·6 m.). Lines leave here for Ottawa and St. Eustache.

27·2 m. 43·8 km. **St. Janvier**—Alt. 217 ft. (66·1 m.).

31·7 m. 51·0 km. **Montfort Junction** Alt. 262 ft. (79·8 m.). The Canadian Northern railway crosses.

33·2 m. 53·4 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.) Just before arriving at St. Jérôme the margin of the Laurentian protaxis is reached. The Palæozoic probably comes against the Laurentian here along a line of fault. At this point the abrupt rise of the Laurentian plateau is not so distinct as elsewhere in this district, owing to the fact that the North river here issues from the Laurentian country, running in a rather wide valley up which the railway takes its course. At St. Jérôme, however, the character of the country undergoes an abrupt change, the rough and broken surface of a gabbro intrusion in the Laurentian succeeding the level surface of the Palæozoic plain.

41·9 m. 67·4 km. **Shawbridge**—Alt. 599 ft. (186·6 m.). The country rises and becomes rolling, showing the *roche moutonnèe* surfaces of the Laurentian protaxis. Cliffs of gneiss are seen to the right.

The railroad follows the valley of North river which is filled with drift and shows well defined terraces on either side of the stream. Fine sections are seen at intervals.

46·1 m. 74·2 km. **Piedmont**—Alt. 552 ft. (168·2 m.). The Laurentian gneisses are here cut through by the Morin anorthosite. The actual contact, however, is concealed by heavy drift.

Miles and kilometres.

The country continues to rise and becomes more rugged. Rugged hills of anorthosite with scarred faces are seen on eithei side.

49·1 m. 79·0 km. **Ste. Adele.**

53·7 m. 86·4 km. **Ste. Marguerite**—Alt. 637 ft. (194.2 m.) A mile and a quarter beyond Ste. Marguerite the railroad passes through a heavy cut in deep violet-coloured anorthosite, the walls of which as shown in the accomanying illustration, rise to a height of 50 feet (15·2 m.) on either side.

From the railway track at the entrance to this cut a typical Laurentian landscape is seen Fine glaciated hills of anorthosite are observed as far as the eye can reach, many of them still possessing their original forest covering. The North river runs through the valley below.

This point is well within the Morin anoithosite intrusion, being six miles from the nearest point on its margin.

The rock is composed almost exclusively of labradorite, either reddish-violet or greenish in colour. The only other constituent present is ilmenite, of which an occasional small individual is seen in thin sections. The plagioclase is beautifully twinned and is filled with very minute schillerization products, which are the cause of its dark colour. The rock is practically free from all evidences of pressure. The anorthosite in the cutting is coarse in grain and massive, and occasionally holds larger irregular-shaped individuals of labradorite, having cleavage surfaces measuring as much as three inches (7·6 centimetres) across. It may be taken as typical of the anorthosite which forms the greater part of the intrusion and all the central portion of the stock.

A quarter of a mile east of this cutting, and one mile from the Ste. Marguerite station, a rusty-weathering, garnetiferous variety of the anorthosite is exposed on the north side of the track. This contains, in addition to labradorite, a considerable amount of a pale green augite and ilmenite. It shows in a striking manner the

Cliffs of massive anorthosite in railway cutting a mile and a quarter northwest of Ste. Marguerite.

Miles and kilometres.

action of pressure on the rock, the larger individuals of the constituent minerals being twisted, broken and granulated. This occurrence is on a line of movement in the anorthosite.

53·7 m. **Ste. Marguerite**—Alt. 900 ft. (274·3 m.)

86·4 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.) The
74·2 m. train now returns to St. Jerome. A small
119·4 km. isolated area of gabbro occurs in the Laurentian gneiss at this locality. It is much richer in iron magnesia constituents than the normal anorthosite of the Morin area. It is well exposed on either side of the railway track a few hundred yards south of the Canadian Pacific Railway station.

Here the rock is fine in grain, usually foliated and weathers brownish-grey. In some places it possesses a more or less distinctly banded structure, due to the alternation of portions rather rich in bisilicates with others consisting almost entirely of plagioclase. Individuals of dark coloured plagioclase, usually small in size, but sometimes as much as six inches in length, are abundant in places. They are frequently curved or twisted, and are usually without good crystalline outlines.

Under the microscope, the rock is seen to be composed essentially of plagioclase and pyroxene the former preponderating largely, with hornblende, biotite, garnet, iron ore and pyrite as accessory constituents, and with a few grains of quartz, calcite, chlorite and apatite. The pyroxene is light green in colour, and is for the most part augite, which is often decomposed to calcite and chlorite. Some of it, however, is tiichroic, in red, yellow and green tints, and is probably hypersthene. The hornblende, which is green in colour, and the biotite are present in but very small amounts. The garnet is pink and perfectly isotropic; it is often well crystallized and usually has some approximation to good crystalline form. It is generally associated with the iron ore which is often present in considerable amount. As in certain parts of the Morin

Miles and kilometres.

anorthosite, there are probably two kinds of iron ore associated with one another, one rich in titanium and one poor in, or free from, that element. A portion of it is titanic iron ore, for leucoxene often appears as a decomposition product. The calcite is always present as a

Anorthosite from New Glasgow, P.Q. Microphotograph between crossed nicols. × 28 diam.

decomposition product and the quartz, which is found in very small amount, is associated with the bisilicates, and may also be secondary.

The rock in its present form probably represents an advanced stage of granulation, for although twisted grains and strain-shadows

Miles and kilometres.

are not very common, these, as has been shown in describing the Morin anorthosite, are not distinct when the granulation is complete. On the other hand, the large remnants of plagioclase, which occur abundantly in many places, point very strongly to an advanced stage of crushing.

This gabbro intrusion is surrounded by a zone of rock intermediate in character between the gabbro and the surrounding gneiss and which probably represents a border facies of the gabbro. This gabbro is cut by a few small black dykes of post-Archaean age.

74·2 m. **St. Jérôme**—Alt. 308 ft. (93·9 m.)
119·4 km.

77·5 m. **Montfort Junction**—
124·7 km.

80·3 m. **Paisley**—
129·2 km.

83·1 ,m **Ste. Sophie**—Alt. 251 ft. (76·5 m.)
133·7 km.

85·0 m. **New Glasgow**—Alt. 240 ft. (73·1 m.)
136·8 km. This village of New Glasgow is situtaed near the western side of the long arm-like apophysis of the anorthosite intrusion referred to before. Here the anorthosite, under the great pressure exerted upon it from the east, has undergone great deformation. It is much finer in grain than the anorthosite at Ste. Marguerite, thoroughly granulated and has a distinct foliation. As already explained, the anorthosite loses its colour under these conditions and whenever the iron magnesia minerals are sufficiently abundant to make the structure evident, the rock is seen to be distinctly foliated. The roches moutonnées of white anorthosite, which protrude through the drift in all directions, form a striking feature of the landscape.

These are well seen along the road which runs north from the railway station and follows

Miles and kilometres.

the course of the River L'Achigan. Immediately to the south of the road, at a point two miles from New Glasgow, anorthosite has been quarried for paving sets at two places. The first of these is 160 yards from the road. Here the anorthosite is seen to possess a distinct foliation marked by little lines of the iron magnesia constituents and garnet.

Four fine-grained, black dykes of diabase of much later date, the largest of which is four feet wide, here cut the anorthosite transverse to its foliation. The iron magnesia constituents in the anorthosite are hornblende and augite. The former mineral, as has been already mentioned, is found in the Morin anorthosite only in a few places near the border of the mass. The rock is very fresh and in addition to being granulated has probably been recrystallized, in part at least, under the intense movement to which it has been subjected.

Six hundred yards from the road is a quarry from which over half a million paving sets were taken for use along the harbour front in Montreal. The anorthosite here is pale grey in colour and weathers white. Occasional dashes of dark bisilicates can be seen as well as occasional rennants of larger phenocrysts or individuals which have escaped complete granulation. Like the anorthosite last mentioned, it has probably undergone a considerable amount of recrystallization. The iron-magnesia constituents present are hornblende, augite and hypersthene.

85·0
136·8 km. **New Glasgow**—Alt. 240 ft. (73·1 m.) To the west of New Glasgow excellent exposures of the white foliated anorthosite are seen along the line of the Canadian Northern railway. The fine waterfall on the outskirts of the village is formed by L'Achigan river cascading down over a great exposure of this rock. A microphotograph of a thin section of this rock between crossed nicols is shown in the accompanying plate (p. 23).

Exposures of white anorthosite. Falls of the river L'Achigan, New Glasgow, P.Q.

Miles and kilometres.

A short distance west of L'Achigan river the anorthosite is cut by a great dyke of a nearly black gabbro which can be followed to the north for nine miles. It is strikingly jointed and possesses a very marked streaked or foliated structure parallel to its length. This direction coincides with that of the foliation of the intruded anorthosite. This gabbro holds inclusions of the anorthosite and further north sends a long apophysis into the anorthosite, cutting across the strike of the latter. It is very basic in character and under the microscope displays a most remarkable cataclastic structure, larger twisted remants of the constituent minerals being embedded in a mass of finely granulated material derived from the breaking down of the larger individuals of the several constituent minerals.

The train now returns to Montreal via St. Jerome.

86·9 m.
139·8 km. **Ste. Sophie**—Alt. 251 ft. (76·5 m.) Exposures of a typical orthoclase gneiss of the Laurentian, as well as a small band of limestone belonging to the Grenville series, are seen where the road running west from Ste. Sophie crosses a little stream near the outskirts of the village.

95·8 m.
154·2 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.)

129·0 m.
207·6 km. **Montreal**—

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EXCURSION A 7.

THE MONTEREGIAN HILLS.

BY

Frank D. Adams.

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INTRODUCTION.

In the Province of Quebec, between the enormous expanse of the Laurentian highlands to the northwest, constituting the "Canadian Shield," and the disturbed and folded tract of country which marks the Appalachian uplift, there is a great plain underlain by nearly horizontal rocks of lower Palæozoic age. This plain, while really showing slight differences of level from place to place, seems to the casual observer perfectly flat. Its surface is mantled with a fertile soil consisting of drift redistributed upon its surface by the sea, which covered it at the close of the Glacial times. The uniform expanse of this plain, however, is broken by several isolated hills composed of igneous rocks, which rise abruptly from it and which constitute very striking features of the landscape. It was at the foot of one of these hills rising by the side of the River St. Lawrence, and which he named Mount Royal, that Jacques Cartier on his first visit found the Indian encampment of Hochelaga, the site of which is now overspread by the city of Montreal.

From the top of Mount Royal the other hills referred to can all be seen rising from the plain to the east; while to the north the plain stretches away unbroken to the foot of the Laurentian plateau.

As has been remarked by Sir Archibald Geikie in his Text-Book of Geology: "The word 'mountain' is, properly speaking, not a scientific term. It includes many forms of ground utterly different from each other in size, shape, structure and origin. In a really mountainous country, the word would be restricted to the loftier masses of ground, while such a word as 'hill' would be given to the lesser heights. But in a region of low or gently undulating land, where any conspicuous eminence becomes important, the term 'mountain' is lavishly used. In eastern America this habit has been indulged in to such an extent that what are, so to speak, mere hummocks in the general landscape are dignified by the name of mountain."

The hills under consideration, while by no means "mere hummocks", being situated in such a country of low relief, seem to be higher than they really are and are always referred to locally as "mountains."

View of the Monteregian Hills from Mount Royal. In the foreground the city of Montreal. In the middle distance the River St. Lawrence with St. Helen Island. (Reproduced with the permission of Messrs. William Notman & Son).

These mountains, whose positions are shown on the accompanying map, are eight in number, their names and their height above sea level being as follows:

Mount Royal.................	769·6	feet.	
Montarville or St. Bruno......	715	feet	(O'Neill).
Belœil........................	1,437	"	(Leroy)
Rougemont....................	1,250	"	
Yamaska......................	1,470	"	(Young).
Shefford......................	1,725	"	
Brome........................	1,755	"	
Mount Johnson or Monnoir....	875	"	

They have been called the Monteregian Hills from Mount Royal ("Mons Regius"), which is the best known member of the group and may be taken as their type.

Brome mountain is by far the largest member of the group, having an area of 30 square miles. Shefford comes next in size, having an area of rather less than nine square miles; while Mount Johnson, which is very much smaller than any of the others, has an area of only ·422 of one square mile.

Of these eight, the first six, as Logan* notes, "stand pretty nearly in a straight line." running approximately east and west, Mount Royal being the most westerly, and the others following in the order in which they are enumerated above, until Shefford mountain, the most easterly member of the series, is reached. Mount Johnson and Brome mountain lie on a line parallel to them, a short distance to the south, Rougemont being the nearest neighbour to Mount Johnson and Brome mountain immediately south of Shefford. It is highly probable, in view of this distribution, that these ancient volcanic mountains are, as is usual in such occurrences, arranged along some line or lines of weakness or deep-seated fracture. The "pretty nearly straight line" referred to by Logan, on which the first six mountains of the group are situated, must be considered either as a single line with a rather sharp curve in the middle or as made up of two shorter straight lines, each with three mountains, diverging from one another at an angle of about 30°, with Montarville at the point of intersection. Mount Johnson and Brome mountain might then be considered as situated on short subsidiary fractures.

*Geology of Canada, p. 9.

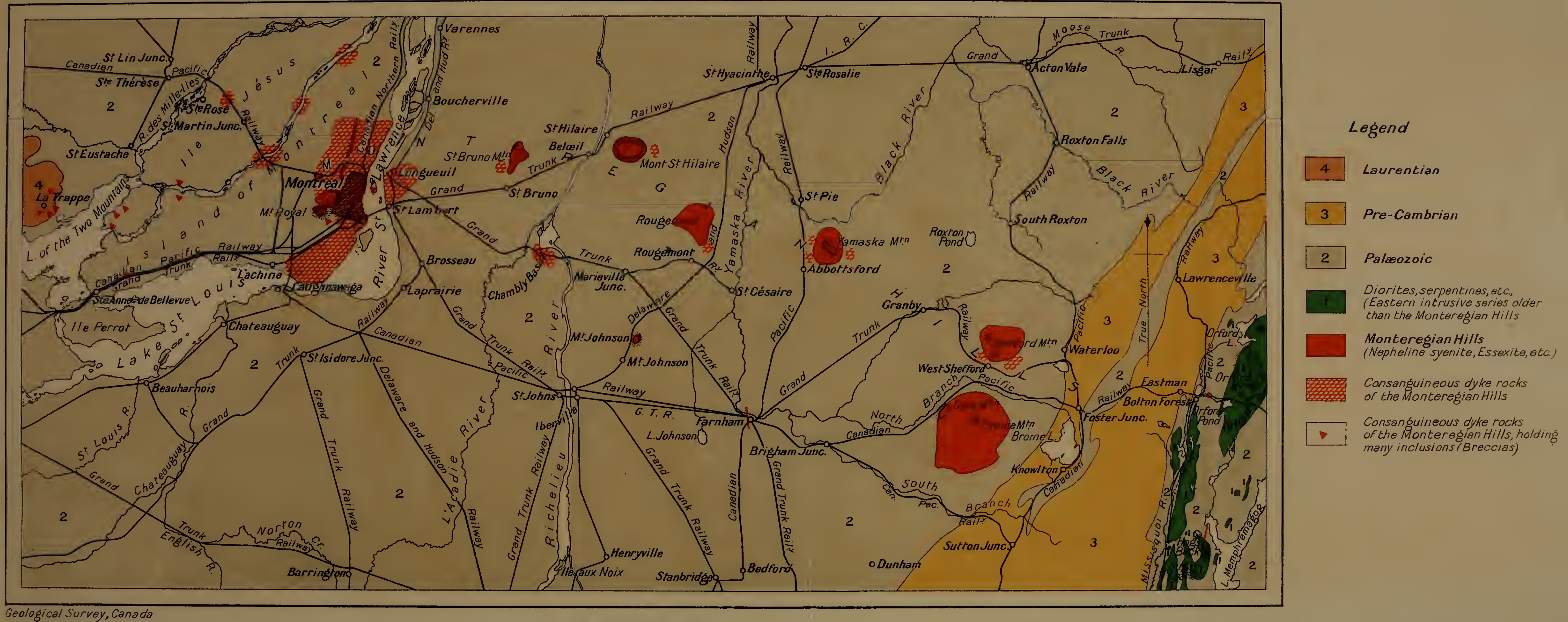
The distance from Brome mountain the most easterly member of the Monteregian Hills, to Mount Royal the most westerly, is 50 miles (80 km.). For a few miles to the east and west of these mountains respectively, however, evidences of the igneous activity of the system are manifested in the occurrence of occasional dykes or small stocks of the consanguineous rocks of the series, the extreme easterly representative of these being a little stock exposed about a mile and a half east of Eastman, on the line of the Canadian Pacific railway, and the most westerly being a series of dykes and a small stock at La Trappe, on the Lake of Two Mountains. Similarly, the most northerly extension is represented by a sheet intercalated between strata of the Chazy limestone in the bed of the Little river, near St. Lin, 15 miles (24 km.) north of St. Lin Junction. It is difficult to say just how far to the south the last evidences of the Monteregian activity are found, but scattered dykes of bostonite, camptonite and monchiquite have been described by Kemp and Marsters from the shores of Lake Champlain (out of which flows the River Richelieu), to a distance of 90 miles (145 km.) or more south of Mount Johnson.

The accompanying map embraces the entire region affected by the intrusions of the Monteregian Hills, so far as its eastern and western extension is concerned: while beyond the limits of the map, to the north and south, the occurence of scattered dykes occur as has been noted, which, from their petrographical character are believed to be related to these intrusions.

The Monteregian Hills are a series of ancient plutonic intrusions. Some of them (e.g. Brome mountain) are apparently denuded laccoliths, one of them (Mount Johnson) is a typical neck or pipe, and it is probable that some, if not all, of them, represent the substructures of volcanoes which at one time were in active eruption in this region.

It is impossible to determine accurately the date of these intrusions. In the case of Mount Royal, however, inclusions of Lower Devonian limestone are found in the intruded rock, so that the intrusions forming the mountain are later than Lower Devonian time.

Since Dresser by another line of evidence, has shown that the intrusion of Mount Shefford probably took place before late Carboniferous time, the Monteregian intrusions probably date back to the late Devonian or early Carboniferous period.



Monteregian Hills

Miles: 0 — 10 — 20

Kilometres: 0 — 10 — 20 — 30

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It must be noted that while six of these mountains rise from the horizontal strata of the plain, the two most easterly members of the group, namely Shefford and Brome, while still to the west of the axis of that range, lie well within the folded belt of the Appalachians, although, owing to the extensive denudation from which the region has suffered, this folding has had but little influence on the local topography. About La Trappe, at the extreme westerly extension of the Monteregian area, the dykes of the series cut rocks of Laurentian age, which here form an outlier of the great Laurentian protaxis on the north.

The Monteregian Hills form an exceptionally distinct and well marked petrographical province, being composed of consanguineous rocks of very interesting and rather unusual type. These are characterized by a high content of alkali and in the main intrusion of almost every mountain two distinct types are found associated with one another, representing the products of the differentiation of the original magma.

These are—

(a) Nepheline syenite, in some cases replaced by or associated with pulaskite, tawite, akerite or nordmarkite.

(b) Essexite, in some cases represented by theralite, yamaskite, rougemontite, or rouvillite.

It may be mentioned that yamaskite is a very basic rock type characterized by a great predominance of pyroxene, basaltic hornblende and ilmenite, with about two per cent of anorthite. Rougemontite consists largely of anorthite with pyroxene as the only important ferro-magnesian constituent. Rouvillite is a highly feldspathic variety of theralite.

GEOLOGY OF MOUNT ROYAL.

Mount Royal consists of a body of intrusive plutonic rock penetrating the nearly horizontal limestone of the Trenton formation (Ordovician). It consists of two main intrusions composed of essexite and nepheline syenite respectively, of which the nepheline syenite is the later. followed by a swarm of dykes and sheets of consanguineous rocks which cut not only the main intrusions, but also penetrate the surrounding limestones in all directions. The intrusive rock in some places tilts up the limestones while elsewhere about the mountain these maintain their horizontal attitude. The intrusion may be essentially laccolitic in character, or it may represent the plutonic basis of a volcano. The erosion has been so long continued that it has been impossible as yet to reach a definite conclusion on this point.

The greater part of the plain through which the mountain rises, and which is underlaid by Ordovician strata, is mantled by drift which also covers the slopes of the mountain. This drift, and in some places the underlying rock, has been terraced by a series of well defined beaches, which mark the successive stages of the retreat of the sea at the close of the Glacial age.

The City of Montreal is built upon these drift deposits, and lies upon the slopes of Mount Royal and upon the plain about its foot. The development of the city was largely influenced by the position of the main beaches above mentioned.

At a number of places on the slopes of Mount Royal and in its vicinity there are remarkable developments of igneous breccia. This has as a matrix one or other of the dyke rocks of the series, while the included fragments consist in part of the Trenton limestone, often associated with fragments of the other underlying stratified rocks traversed by the dykes in their upward passage. These fragments are frequently so numerous that thay constitute a large part of the whole mass. Perhaps the most remarkable of these breccias is that which occurs on St. Helen's island in the harbour of Montreal, and which is unique among these occurrences in that it contains fragments of rocks which are more recent in age than any of the sedimentary strata now found in the district.

At the present time a tunnel, about three and a half miles in length, is being driven through Mount Royal by the Canadian Northern Railway, in order to gain an entrance from the westward to their proposed terminals in the vicinity of the corner of Dorchester and Ste.Monique streets, in the city of Montreal. It has afforded an excellent opportunity of studying the distribution of dykes, sheets, etc,. as well as fresher specimens of many of the rock types of the district. Already about two miles and a half of the sub-heading have been driven. The profile accompanying this guide book (p. 36) shows the geological section which the tunnel is penetrating. As may be seen from an examination of the geological map upon which the position of

View of Mount Royal from the south (Reproduced with the permission of Messrs. William Notman & Son.)

Breccia with camptonite matrix. Rockland avenue, Outremont, Montreal.

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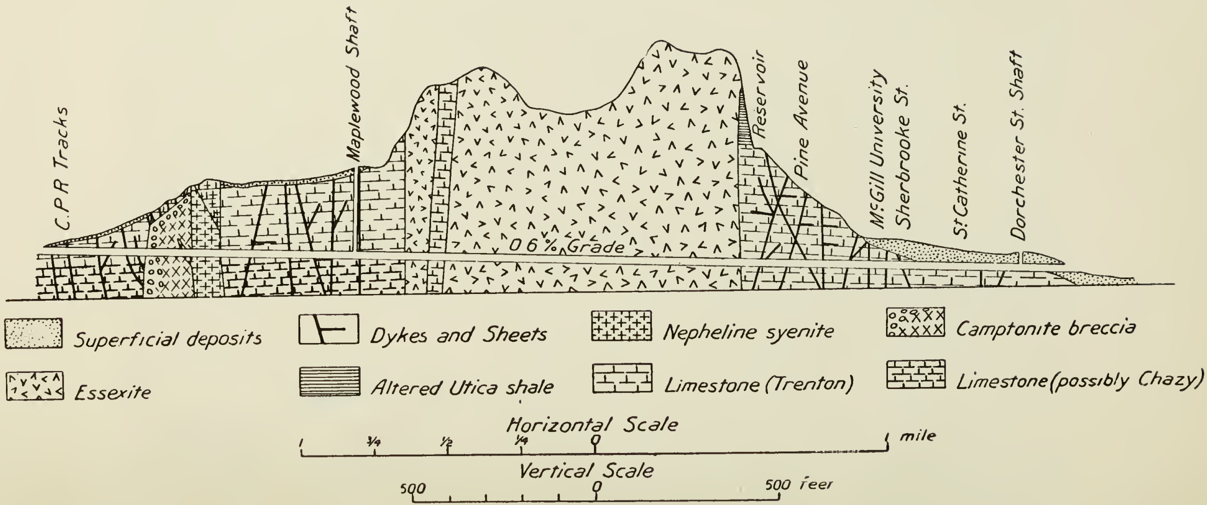


Section through Mount Royal along the line of the Canadian Northern Railway tunnel.

the tunnel is indicated, the presence of the column of limestone which appears to be within the main body of essexite of Mount Royal is due to an embayment in the periphery of the latter.

The Essexite.

The essexite exposed near the Lookout may be taken as representing the main body of the essexite intrusion of Mount Royal. It is coarse in grain, but varies somewhat in texture from place to place. It is composed essentially of pyroxene and hornblende with plagioclase and a little nepheline. The other minerals, which are present as accessory constituents, are olivine, biotite, sodalite (or nosean), orthoclase, apatite, iron ores, pyrite, sphene and zircon.

The plagioclase and nepheline are always distinctly subordinate in amount, the rock consisting predominantly of augite and hornblende. In certain parts of the mountain, olivine becomes relatively much more abundant and the rock passes into an olivine-essexite (see page 38).

The olivine, augite and hornblende have a marked tendency to assume idiomorphic development, some varieties of the essexite consisting of well defined crystals of these minerals embedded in a ground mass consisting chiefly of small laths of plagioclase. The augite and hornblende in a certain rare varieties of the rock are developed as long narrow rod-like individuals, lying in parallel position and thus giving to the rock a peculiar and striking appearance.

Pyroxene is the most abundant constituent in most varieties of the rock. It is of a purplish colour and frequently holds many minute black inclusions. Twinning is common and the individuals occasionally display an hour-glass structure.

Hornblende usually ranks next in abundance. It is deep brown in colour, strongly pleochroic, and frequently occurs intergrown with the pyroxene or as a border about it. The hornblende separated from the coarse-grained essexite occurring in the Protestant cemetery was analysed by Prof. B. J. Harrington, with the results set forth in column III, page 39. As will be seen, it belongs to the class of basaltic hornblendes and is similar in composition to the hornblende occurring in the essexite of Mount Johnson.

The plagioclase is an acid labradorite. It is excellently twinned according to the albite and carlsbad laws. The zonal structure occasionally displayed by the mineral shows that there is a certain variation in composition, even within the same individual. In many specimens of the rock the plagioclase is clearly older than the ferro-magnesian constituents, since it penetrates or is enclosed in the individuals of these latter minerals. In some cases it even occurs as perfect crystals entirely embedded in the iron ore.

Nepheline as has been mentioned, is present only in relatively subordinate amount. It is allotriomorphic and occurs in the interspaces between the feldspar individuals.

The other minerals present as accessory constituents, do not here require further mention.

The analysis of two specimens of the essexite from Mount Royal are given below under No. I and No. II page 39.

The first (No. I) is found in an exposure 100 yards (91 m.)) west of the Lookout; it is a variety containing a relatively large proportion of the salic constituents, although in it as in all the essexite of the mountain, the iron magnesia constituents preponderate very largely.

The second (No. II) is an olivine-rich variety of the essexite from the Côte des Neiges road, near the reservoir. This contains scarcely any salic constituents. In the Quantitative System of classification it occupies a hitherto unnamed subrang. Its position is as follows:—

Class IV. Dofemane.
Order 2. Scotare.
Section 2. Paoliare.
Subrang 2. Montrealose.

At the suggestion of Dr. H. S. Washington this has been called montrealose, and the rock montrealite. In composition it resembles somewhat closely the essexite from Brandberg, Kirchspiel Gran, Norway.

These may be taken as two typical varieties of essexite representing the intrusion as a whole.

	I	II	III
	Essexite near Lookout, Mount Royal. (M. F. Connor).	Olivine essexite (Montrealite) Côte des Neiges Rd. Mount Royal (M. F. Connor).	Hornblende in essexite. Protestant Cemetery, Mount Royal (B. J. Harrington).
SiO_2	43·10	44·66	39·23
TiO_2	2·80	2·27	4·53
Al_2O_3	13·94	9·64	14·38
Fe_2O_3	4·92	4·98	2·92
FeO	6·93	6·65	8·56
MnO	·14	·19	·65
CaO	14·65	13·11	11·70
BaO	·03	none.	
SrO	·03	·03	
MgO	8·86	12·83	13·01
Na_2O	2·50	2·07	3·05
K_2O	·89	1·17	·98
P_2O_5	·27	·24	
CO_2	·64	·37	
Cl	trace.	·07	
SO_3	none.		
FeS_2	S=22	·22	
Fe_7S_8	....	trace.	
H_2O (above 110° C.)	·55	·79	
H_2O (at 110° C.)	·15	·11	·36
	100·62	99·40	99·37

The Nepheline Syenite.

This rock is much lighter in colour than the essexite, being relatively richer in salic constituents. It is usually grey in colour and of medium grain. It is, furthermore, nearly uniform in size of grain and does not display the rapid variations in texture which often characterize the essexite.

It is composed essentially of orthoclase, nepheline and hornblende; pyroxene and mica are often associated with the hornblende; while the following minerals have been found as accessory constituents: albite, anorthoclase, microcline, nosean, sodalite, apatite, sphene, zircon, garnet, fluorite, astrophyllite, mosandrite (?), ainigmatite (?) allanite (?). Of these accessory constituents, nosean, sphene and garnet are very common. An analysis of this rock from the Corporation quarry is given on p. 41 under No. I.

Orthoclase presents the usual characteristics of the species, and is frequently somewhat turbid from the presence of minute inclusions. It occurs in individuals elongated parallel to the clinopinacoid and is intimately associated and at times intergrown with the other feldspars which occur as accessory constituents.

Nepheline is so abundant that the rock gelatinizes readily when powdered and heated with dilute hydrochloric acid. It often occurs in individuals as much as 2 mm. in diameter. It is sometimes quite fresh, but is in places altered to cancrinite, hydronephelite, analcite and natrolite. These minerals also occur in little cavities and veins in the rock. Analyses of them by Dr. Harrington are given under V and VI, page 41. An analysis of the fresh nepheline separated from the nepheline syenite of the Corporation quarry was also made by Dr. Harrington and is given in the same table, No. II.

The *hornblende* often possesses fairly good crystalline form. It is brown in colour and strongly pleochroic. The single individuals sometimes vary in composition, as shown by the varying depth in colour, and they very frequently have a greenish border.

The *pyroxene* is in part a variety having a purplish colour and probably allied to that occurring in the essexite. But in addition to this variety of pyroxene, both aegerine and acmite occur in the rock and are sometimes present in the same slide. An analysis of the aegerine from one of the pegmatite veins of the nepheline syenite is given on p. 41, under No. IV.

The *mica* is pale brown in colour and is present in distinctly subordinate amount. Lepidomelane, found in the pegmatitic segregations of the nepheline syenite, has been analysed by Dr. Harrington.

Nosean which is not usually found as a constituent of nepheline syenite, is quite abundant in the rock, occurring as rather large, well defined idiomorphic crystals. It is usually turbid from the presence of minute inclusions and frequently shows a marked zonal structure.

	I	II	II	IV	V	VI
	Nepheline syenite, Corporation quarry Montreal. (M. F. Connor).	Nepheline from nepheline syenite pegmatite. Montreal. (B. J. Harrington).	Lepidomeane from nepheline syenite pegmatite. Montreal. (B. J. Harrington).	Aegerine from nepheline syenite Pegmatite. Montreal. (B. J. Harrington).	Natrolite Corporation quarry, Montreal. (B. J. Harrington).	Analcite Corporation quarry, Montreal. (B. J. Harrington).
SiO_2	55·90	44·98	32·96	49·51	47·09	54·83
TiO_2	·70		2·80	·61		
Al_2O_3	19·75	32·65	10·34	2·72	26·99	24·20
Fe_2O_3	1·00	·72	8·85	22·26	tr ce.	
FeO	2·05		27·19	5·82		
MnO	·10		2·79	1·51		
MgO	·59		·73	1·09		
CaO	3·10	trace...	·64	7·16	trace.	·08
SrO	trace...					
BaO	·09					
Na_2O	7·25	16·08	·98	8·62	16·46	12·01
K_2O	5·61	4·54	7·75	·38	·01	
P_2O_5	·01		Li_2O ·03			
Cl	trace.		F none.			
S	·64					
SO_3	·04					
CO_2	1·85					
H_2O (above 110° C.) / H_2O (at 110° C.)	2·00	·97	4·36	·57	9·80	8·50
	100·77	99·94	99·42	100·25	100·35	99·62

The *sphene* is abundant in small but perfect wedge-shaped individuals. It sometimes shows a rather remarkable decomposition into calcite traversed by little needles of rutile.

The *garnet* is of dark reddish brown colour and occurs in individuals often of considerable size but of very irregular shape, and which hold numerous inclusions of nosean and orthoclase.

The Dyke Rocks.

The greater part of the district about Mount Royal is covered by drift of varying thickness. There is scarcely a place, however, in the area, where the drift is absent, that the underlying strata are not seen to be cut by dykes consanguineous in character with the rocks forming the intrusive mass of the mountain. Similar dykes, though in smaller number, cut the rocks of the mountain itself.

About 375 of these dykes and sheets have been observed on the Island of Montreal, and evidently a very much greater number are covered by the drift. The dykes range from a mere film to six feet (1·8 m.) or more in width. They are especially abundant on the slopes of Mount Royal about Westmount reservoir, in Outremont, in the area now covered by the waters of the Lower Reservoir (adjacent to the grounds of McGill University and formerly known as the Reservoir Extension), and along the harbour front. Dykes are also excellently exposed at the Mile End quarries, the Corporation quarry, Maisonneuve and elsewhere.

Unfortunately the rocks composing these dykes are, in almost all cases, considerably altered, and it is rare to find one which is entirely free from decomposition products. In many cases the alteration has progressed so far that it is impossible to determine the precise character of the original rock. As a rule, the dykes at Outremont are fresher than those of Westmount or from the Reservoir Extension.

The following types of dyke rocks are represented:—

Bostonite	Monchiquite
Aplite	Fourchite
Nepheline aplite	Camptonite
Tinguaite	Alnoite
Analcite dykes.	

Dykes cutting the Trenton limestone. Near Westmount Reservoir, Montreal.

An approximate determination of the relative abundance of these several rocks is afforded by an examination recently made by Professor Allan of specimens of 65 dykes occurring in various parts of Mount Royal and its vicinity and which may be taken as representative of the whole complex. His results show that the several types above mentioned were present in the following proportions:—

Bostonite	4
Tinguaite	14
Analcite dykes	3
Monchiquite	12
Fourchite	1
Camptonite	30
Alnoite	1
	65

Bostonite.—Dykes of this rock are not very common. One of the largest was exposed in former years at the Reservoir Extension (see p. 49), representing the earliest of the several sets of dykes at this locality. It is of a buff colour and has the structure and appearance of a typical bostonite, but is a good deal altered. Dawsonite a remarkable carbonate of alumina and soda which was originally discovered at this locality occurs on the selvage of this dyke in contact with the limestone. An analysis of the rock after treatment with nitric acid which removed 3·33 per cent. of calcite, and smaller amounts of alumina and ferric oxide, is given under I on page 46. As will be noted, it has a high content of soda as compared with the potash.

A bostonite sheet forms the greater part of Moffat's Island, opposite Montreal. Dykes of the rock are also found in the tunnel which is being driven through Mount Royal.

A small area of a reddish aplite cuts the camptonite breccia at Outremont. This is fresh and contains a little quartz. It is seen on the surface and is also traversed by the tunnel above mentioned. An analysis of the rock from the tunnel is given under II, page 46. It ranks as a phlegrose in the Quantitative Classification.

Tinguaite.—This rock occurs abundantly in dykes and sheets, more especially in the district northeast of

Mount Royal, between Côte de la Visitation and Maisonneuve. It is a fine-grained, greenish-grey rock and is often very fresh. It is quarried for road metal and concrete at several points in the district mentioned above. It very frequently contains nosean and under the microscope is also seen to hold small amounts of rinkite, lavenite and other rare minerals, owing to whose presence it is highly radio-active. An analysis of the rock from the quarry at Papineau avenue is given under III, page 46.

Nepheline Aplite.—Small dykes of this rock, usually quite narrow, are seen at the Corporation quarry and elsewhere in the district. The rock is light in colour, and often nearly white, and is composed of nepheline and orthoclase. It is frequently rather coarse in grain, thus approaching a nepheline syenite pegmatite in character.

Analcite dykes.—These dykes are bluish-grey in colour and have a peculiar pitchy lustre. They contain a large amount of an isotropic base, in which there are embedded a few phenocrysts which are almost exclusively of an alkali feldspar and nepheline. The isotropic base has the refractive index and composition of analcite. The isotropic base of monchiquites has been shown by Pirsson, in certain cases at least, to be analcite and not glass. It is believed that the base in these rocks is also analcite, although it has not been possible as yet to obtain any positive proof that such is the case. One of the largest and most typical of these dykes is to be seen at the Mile End quarries. An analysis of it is given under VI, p. 46. The rock is vey fresh and free from decomposition products. It ranks as laugenose in the Quantitative Classification.

Monchiquite.—These rocks resemble the camptonites in being very dark or black in colour and fine in grain, but differ from them in that they possess a groundmass or basis of some isotropic material. The two rocks cannot as a general rule, be distinguished in the field. Although not so abundant as the camptonites in this region, they are very common and form one of the most characteristic classes of dyke rocks connected with the intrusions of Mount Royal. They occur in all parts of the area, but are usually considerably altered. Analyses of two of these dykes are given (Nos. VII and VIII) on page 46. The first (No. VII) is a hornblende monchiquite from a dyke 18 inches (46 cm.) wide cutting the Trenton limestone at

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
	Bostonite,* Reservoir Ext., Montreal. (T. S. Hunt).	Aplite, West portal of tunnel, Mount Royal. (M. F. Connor).	Tinguaite, Papineau Ave., Montreal. (M. F. Connor).	Nepheline syenite, West portal of tunnel, Mount Royal. (M. F. Connor).	Aegerine Nepheline syenite, West wall of Westmount quarry, Montreal. (M. F. Connor).	Analcite dyke, Mile End quarry, Montreal. (M. F. Connor).	Monchiquite, Reservoir Ext., Montreal. (B. J. Harrington).	Monchiquite, Mile End quarry, Montreal. (M. F. Connor).	Camptonite, Reservoir Ext. Montreal. (B. J. Harrington).	Camptonite, Reservoir Ext. Montreal. (B. J. Harrington).	Camptonite, Mount Royal. (M. F. Connor).	Alnoite, Point St. Charles, near Montreal. (M. F. Connor).	Alnoite, Ste. Anne de Bellevue, near Montreal. (P. H. LeRossignol).
SiO_2	62·90	63·00	50·40	49·96	45·68	53·99	36·69	37·34	45·51	40·95	43·36	29·24	35·91
TiO_2	....	·48	·50	2·73	2·58	·25	5·44	3·93	3·84	3·39	3·00	2·40	·23
Al_2O_3	23·10	17·92	21·83	16·53	18·26	22·89	11·96	11·84	15·84	16·45	14·52	11·40	11·51
F_2eO_3	....	·50	2·51	3·18	2·87	1·04	5·45	5·37	1·90	13·47**	1·45x	5·84	2·35
FeO	....	·90	1·41	4·35	3·98	·44	8·90	6·40	7·59	....	6·13	4·74	5·38
MnO	....	·03	·27	·10	·14	·23	·38	·18	·40	·33	·15	·15	
CaO	·45	1·50	3·17	8·24	8·06	·32	10·28	11·92	8·35	10·53	10·53	18·35	13·59
BaO	....	·02	·33	·05	·01	....	trace.	·04	·12	....	·01	·24	
Sx_2O	....	trace.	·07	·02	·02	....	....	·02	....	....	·01	·15	
MgO	....	·93	·39	3·95	2·63	·07	7·85	9·66	3·85	6·10	7·12	10·38	17·54
Na_2O	8·69	5·93	9·96	4·81	6·41	10·79	3·88	2·91	5·09	4·00	3·35	1·44	1·75
K_2O	2·43	6·08	6·10	2·95	3·81	4·87	2·07	2·05	1·88	1·28	1·88	2·42	2·87
P_2O_5	....	·05	·10	·32	·22	....	·62	·04	·61	·29	·24	2·10	not det.
CO_2	....	1·15	none.	·80	2·90	none.	3·78	5·08	2·23	....	·64	5·02	
Cl	....	·27	·10	·22	·10	·15	·04	·04	·05	....	.10	trace.	
SO_3	....	·03	·62	....	....	·06	·92	....	·60	....	·25	·33	
FeS_2	....	·50	....	·137	·38	....	....	·47	....	....	·47	S. ·17	
Fe_7S_8	....	....	....	....	·80	....	....	trace.	....	....	5·60	....	
H_2O (above 110° C.)	1·40	·50	2·35	·70	·75	4·70	1·70	2·56	1·67	3·84***	1·28	5·05	9·40xx
H_2O at 110° C.)	....	·06	·15	·07	·07	·18	·25	·24	·16	....	·32	1·04	
	98·97	99·85	100·26	100·35	99·67	99·98	100·21	100·09	99·69	100·63	99·84	100·45	100·51

*After treatment with dilute nitric acid. **All the iron is calculated as Fe_2O_3. ***This is "loss on ignition" and is largely CO_2.

xOn account of the evolution of H_2S during analysis, the relative quantities of Fe_2O_3 and FeO as given are as accurate as can be determined. There is, however, probably less FeO and more Fe_2O_3 than the figures indicate.

xxWith CO_2.

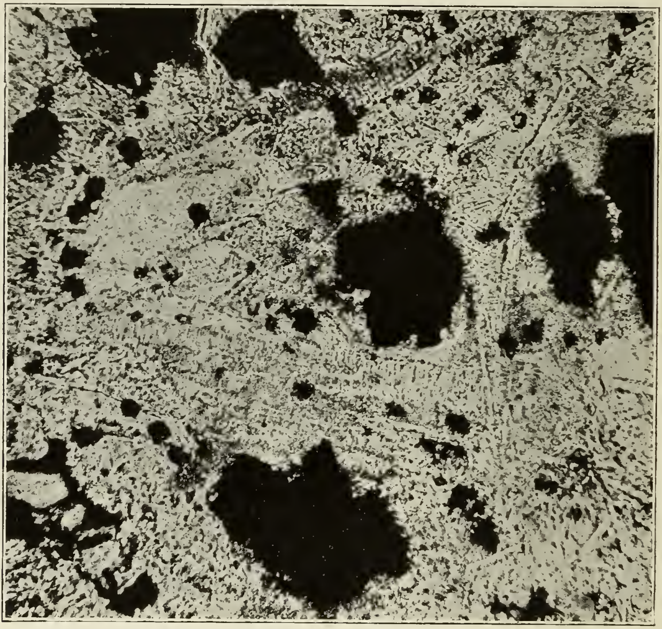
the Reservoir Extension. It is composed of phenocrysts of deep brown hornblende, with iron ore and a small amount of accessory pyroxene and olivine, in an isotropic groundmass which also holds some small laths of plagioclase and a little nepheline. The second (No. VIII) is from a dyke which occurs at the Mile End quarries, but which is now concealed by a recently constructed road.

Fourchite. This is an olivine-free augite hornblende monchiquite which is represented by a few dykes. See St. Helen's Island, p. 59.

Camptonite. The camptonites are dark in colour, fine in grain, holocrystalline and often porphyritic. They frequently show a more or less banded stiucture parallel to the walls, and, like the monchiquites, are occasionally amygdaloidal, the cavities being filled with zeolites or rhombohedral carbonates. They usually belong to the subdivision of the hornblende camptonites, the rock being composed of hornblende (deep brown), pyroxene and plagioclase as essential constituents with accessory nepheline, perowskite, apatite, iron ore, &c.

Analyses of three of these dykes are given on page 46. The first two (Nos. IX and X) occur at the Reservoir Extension and were analysed by Dr. B. J. Harrington. The third (No. XI) is an exceptionally fresh camptonite from Mount Royal recently analysed by M. F. Connor.

Alnoite. These olivine-rich biotite monchiquites, holding melilite and perovskite, are excellently represented in this area. It is one of the few places in the world where these rocks are found. Unfortunately it is impossible for the members of this excursion to see the rock in place, since the localities where it occurs are difficult of access, or the dykes at one time laid bare are now covered by the waters of the St. Lawrence or Ottawa rivers. The first locality in which alnoite was found was in a dyke cutting the Potsdam sandstone in the bed of the Ottawa river at Ste. Anne-de-Bellevue at the west end of the Island of Montreal, where it was laid bare many years ago in a cofferdam put down for the purpose of blasting away an obstruction in the rivei bed. It occurs as a dyke rather over two feet (·6 m.) wide, the rock presenting a very striking appearance owing to the presence of large rounded individuals of red olivine with large plates of brown mica. The melilite and perovskite lie in the finer grained groundmass. An analysis of this rock is given on page 46, under No. XIII.



Microphotograph of alnoite. Point St. Charles, Montreal. The lath-shaped crystals are melilite showing peg structure.

Another dyke of alnoite was laid bare on the river bottom near the approach to the Jubilee bridge at Point St. Charles when the water was very low in 1895.

This is rather more than two feet wide and cuts a smaller fourchite dyke. It contains about 20 per cent. of melilite. A microphotograph of a thin section of this rock showing the melilite is on this page. An analysis of the rock is given under No. XII, page 46.

Alnoite also occurs forming the paste of the igneous breccia on Ile Bizard, as well as in dykes cutting this breccia. In the latter the melilite often forms 25 per cent. of the rock and frequently occurs as wreaths or coronas about the previously crystallized olivines and augites.

Rocks allied to alnoites also occur at La Trappe and St. Lin.

Annotated Guide.

Starting from the main gate of McGill University the party will walk through the southern campus which is situated on one of the marine terraces cut into the slopes of Mount Royal at the time of the post-glacial submergence. This terrace is 152 feet (46·3 m) above sea level. It consists of the Saxicava Sand underlain by the Leda Clay. The latter holds many shells of marine invertebrates which still live in the cold waters on the coast of Labrador. Among these may be mentioned—*Saxicava rugosa, Leda minuta, Leda arctica, Mytilus edulis, Macoma grœnlandica, Balanus crenulatus, Mya truncata, Lepralia quadricornuta* and others. These stratified post-glacial deposits rest on glacial till which in its turn rests on a glaciated surface of the underlying Trenton limestone. This deposit of till and stratified drift is 50 feet (15 m.) thick at the gate of the campus, but the surface of the underlying limestone gradually rises toward the mountain and the drift at the northern end of the playing field is only 18 feet (5·5 m.) thick.

Leaving the University grounds by the western gate and passing up McTavish street, the basset edges of the Trenton limestone will be seen on the cliff behind the Low Level Reservoir. This body of limestone, when the reservoir was being excavated some 37 years ago, presented a striking appearance, being intersected by a swarm of dykes. No less than 30 of these were mapped by Dr. B. J. Harrington in an area measuring 200 yards (182 m.) in length by 100 yards (91 m.) in breath and were found by him to belong to at least seven periods of intrusion. They embraced bostonites, tinguaites, camptonites, monchiquites and probably other allied types, which, however, were all found to be considerably altered, so much so in some cases that it was impossible to ascertain with certainty their original character. Analyses of three of these dykes are given on page 46). It was upon the wall of a large bostonite dyke cutting the limestone here, that the mineral dawsonite was discovered. This rare carbonate of alumina and soda occurred as a beautiful network of colourless transparent bladed crystals on the side of the bostonite dyke along its contact with the limestone.

These dykes, which were so well exposed when the reservoir was in course of excavation, are now concealed beneath its waters, except where some of them intersect the cliff behind the reservoir, but even here they are now but indifferently seen, being concealed by the vegetation and by the wash from above.

On Pine avenue the Trenton limestone is well exposed and is cut by a few small dykes. Above this, the road, winding up the mountain side, passes over almost continuous exposures of the same limestone in heavy beds dipping at a very low angle to the south until the level of the upper reservoir is reached.

Here the Trenton is overlain by a hornstone, representing a remnant of the Utica shale which lies immediately against the essexite, by which it has been intensely altered.

Climbing a steep declivity over this highly altered Utica shale, the essexite which forms the greater part of Mount Royal is reached. This is well exposed near "the Lookout".

From this *Lookout*, if the day is clear, a magnificent view may be had over a portion of the St. Lawrence lowland, with the River St. Lawrence flowing through it, and the city of Montreal situated by the side of the river, at the head of navigation for ocean-going vessels. It was probably from about this point that Jacques Cartier, the first white man to ascend the St. Lawrence, stood when in 1535 he looked over the same landscape, and, here later explorers believing that it must be the land of Cathay for which they were in search, exclaimed: "C'est La Chine," a name (Lachine) which has ever since that time been borne by the rapids which impede navigation just above the city of Montreal, as well as by the little town which has grown up beside them.

Standing here on Mount Royal, all the other Monteregian Hills are in full view and form striking features in the landscape. These are, in their order, Montarville (St. Bruno), Beloeil, Rougemont, Yamaska, Shefford and Brome, while further south the intrusive plug of Mount Johnson is seen, isolated and rising abruptly from the plain.

Beyond the Monteregian Hills in the far east some of the higher points of the Notre Dame mountains, which in Canada represent the Appalachian Mountain folding, are visible, while to the southeast on the horizon are the Adirondack mountains in the State of New York. These latter are of Laurentian age, forming a great outlying island of the Canadian Shield, completely surrounded by sediments of Paleozoic age. About 100 yards west of the Outlook are the exposures of essexite described on p. 37.

Proceeding northward from the Lookout another exposure of essexite traversed by many dykes is seen in a fine cliff by the roadside, in which, however the rock is considerably decomposed. This decomposition is seen in a still more striking manner in exposures occurring at the back of the Protestant cemetery, where the rock has crumbled into a deep brown residual soil. Near this point the highest post-glacial beach deposit (568 feet above sea level) on Mount Royal is found.

Continuing across the mountain, through the Roman Catholic cemetery, the fresh essexite, often very basic in character, is again exposed. In this cemetery the first evidence of the existence of a second great intrusive mass in Mount Royal—the nepheline syenite—is seen.

This rock occurs here in the form of dykes, light in colour, which cut the dark essexite and often enclose angular fragments of it.

Passing down the steep northerly slope of Mount Royal, a fine view across the plain to the north is obtained, with the highlands of the Laurentian Protaxis (Canadian Shield) bounding the horizon. At the foot of this slope is the Corporation (Forsyth's) Quarry.

This quarry was worked for many years, the nepheline syenite obtained from it being used as road metal in the city of Montreal. This rock is seen to be intruded between the essexite of the mountain and the Trenton limestone which here underlies the plain. It cuts through both rocks, sending apophyses into the essexite of which it also holds many inclusions and metamorphosing the blue fossiliferous Palæozoic limestone into a very coarse grained white marble.

A great swarm of dykes, representing the latest phase of the igneous activity, in their turn traverse the whole complex.

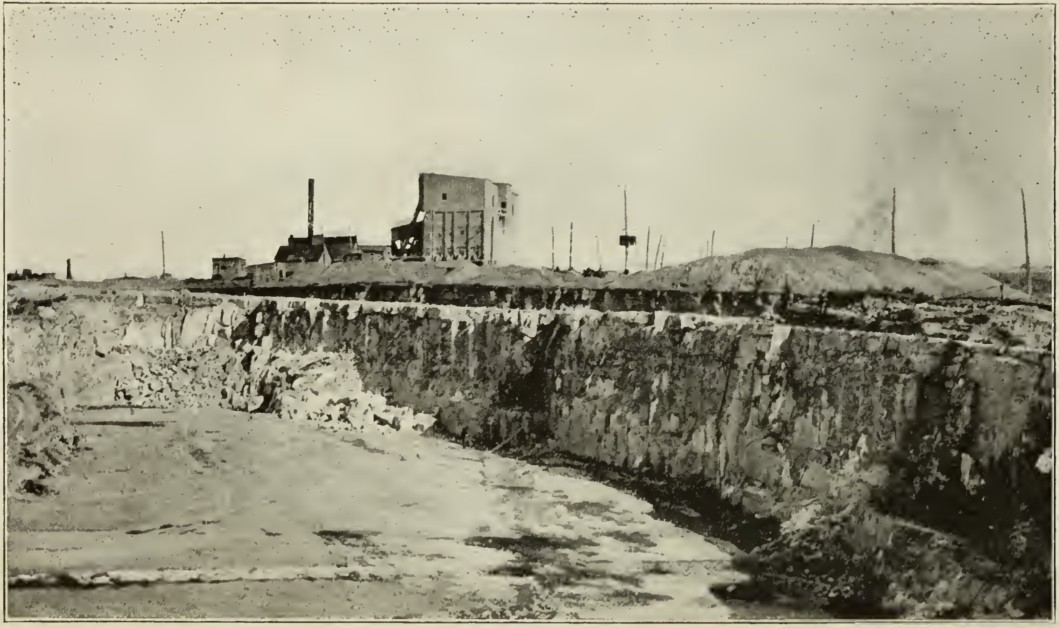
Contact of nepheline syenite (on left) with Trenton limestone (on right). The limestone is highly altered. Both rocks are cut by numerous dykes. Corporation quarry, Outremont, Montreal.

The alteration of limestone by the intrusion of the nepheline syenite is well seen at this quarry. The zone of alteration is not wide, but the alteration along the immediate contact is intense, the limestone in places being changed to a coarse grained white marble. Certain exomorphic contact minerals have also been developed in parts of the altered limestone. In 1892 a vein of nearly pure native arsenic was found cutting the nepheline syenite near the contact, and about 40 lbs. of this mineral was obtained from the vein. The same mineral has been found, although in smaller amount, in driving the Canadian Northern tunnel, which passes through the contact below the surface at no great distance from this quarry.

Many of the dykes and small stock-like intrusions about Mount Royal contain angular fragments of the sedimentary strata through which the magma passed in its upward course. In certain places, these fragments are so abundant within the igneous rocks that the latter become igneous breccias.

An area within which these breccias are developed extensively is situated in Outremont, to the South of St. Catherine road and extending from Rockland avenue through the Golf Links to Mount Royal Heights. Here the prevalent type of breccia possesses a camptonite base and includes a great number of fragments of Trenton limestone, and, in places, a few of Potsdam sandstone. The limestone fragments have been, more or less changed, from their normal blue colour to white, and in some cases have been recrystallized, though in many of them the Trenton fossils can still be distinguished.

Upon Mount Royal Heights, many of the fragments of the Trenton limestone within the camptonite are very large, in places the stratification of this formation has been little disturbed, but it is traversed by irregular tongues of camptonite extending in every direction. Intrusive into the breccia is a small body of nepheline syenite, containing a large number of fragments of Potsdam sandstone. A few dykes of aplite (see analysis II, page 46) which are presumably genetically related to the nepheline syenite also break through the camptonite breccia at this point. At a depth of 160 feet below the surface the tunnel of the Canadian Northern Railway penetrates both of these igneous rock types. At this depth, the fragments of limestone within the camptonite are not so abundant as at the



Tinguaite sheet, with Trenton limestone above forming the floor of the quarry. Quarry at the head of Delorimier avenue, Montreal.

surface, while locally a few inclusions of Potsdam sandstone are present. The nepheline syenite ,which appears in isolated outcrops at the surface, widens below to several hundred feet. It contains many small rounded fragments of Potsdam sandstone which display every stage of absorption by the magma. The occurrence appears to have the form of a small stock which probably did not extend upwards much farther than the present surface of Mount Royal Heights.

In one of the quarries on the eastern outskirts of the city of Montreal, one of the large sheets of tinguaite which penetrate the limestone in this district is exposed. In the quarries of Morrison & Co., at Delorimier avenue this sheet attains a thickness of 25 feet. The Trenton limestone forms both the floor and the roof of the sheet, which is cut by younger dykes of fourchite, etc. In the quarries of Messrs. Rogers & Quick the pipe through which the magma rose to supply material for the sheet is seen, as well as the sheet itself. The tinguaite of this sheet is very fresh and typical. It is rich in nosean and holds also as accessory constituents rinkite, lavenite, rosenbuschite, and other rare minerals.

THE GEOLOGY OF ST. HELEN ISLAND.

The western end of this island is underlain by a soft, easily disintegrating shale of Utica age. This formation overlies the Trenton limestone. The contact of the two formations, which follows approximately the north bank of the river, is concealed by drift.

The remainder of the island is composed of a very remarkable breccia. This shows no signs of stratification and is composed of fragments of rocks of various kinds, which are angular, subangular, or partly rounded but not waterworn, embedded in a very fine grained greyish matrix which weathers to a rusty brown colour. These fragments vary in size from microscopic grains to boulders twelve and fifteen inches in diameter, and their range in age extends from Laurentian to Devonian. The rocks represented are red and black shales; hornstone; limestone—mainly Trenton; red and grey sandstones—the latter probably Potsdam; quartzite; granitic and syenitic gneiss. The red shale and red sandstone were considered by Logan to be probably of Medina age.

At one point only is the breccia to be seen in contact with the Utica. The contact is a brecciated one, the shale being broken up into angular fragments and the interstitial spaces being filled with a yellowish crystalline dolomitic material. Part of this shale has been altered to hornstone. The contact is not sharp, but there is a regular transition from the normal shale through the brecciated facies to the breccia proper.

It will be noted that there has been a distinct bleaching and alteration of the limestone fragments in the breccia about their borders, showing that the paste of the breccia has heated and metamorphosed the included fragments.

In addition to the ordinary inclusions, the breccia holds large masses of limestone which merit special mention. These occur on the north-east side of the island. Of these, the middle exposure is lenticular in shape, and is cut by a dyke which has been subsequently faulted. It has an area of about 100 square feet. The rock is a fine grained, light grey, friable limestone. The north exposure is 200 feet in length, and is a dark grey, fine grained semi-crystalline limestone which is somewhat bituminous. It has been brecciated along the contact with the breccia, and the angular fragments have been cemented by a paste which differs in composition from the limestone. On a weathered surface this matrix stands in relief, forming a complicated network, which shows the most minute detail in structure. Immediately south of these two, there is another large block of granular siliceous limestone also embedded in the breccia. These masses of limestone are all highly fossiliferous and have been made the subject of a careful palæontological study by Dr. H. S. Williams. He finds the first two masses to be of the same age, the Helderbergian of the New York series. The block of siliceous limestone is later and equivalent to the Oriskanian.

An exhaustive study of the fossils discovered in the several masses has furnished the following list of species, which Prof. Williams has severally designated as the *Spirifer arenosus* fauna and the *Gypidula pseudogaleata* fauna from the diagnostic species distinguishing them.

LIST OF SPECIES.

The Spirifer Arenosus Fauna.

(List of species from the northern exposure of limestone in the northeast part of the area of the limestone breccia, St. Helen's island.)

Chaetetes spæricus, Hall.
Small crinoid stems.
Orthis (Rhipidomella), cf. oblata, Hall.
Orthis (Dalmanella) subcarinata, Hall.
Orthis (Dalmanella), cf. quadrans Hall.
Leptæna rhomboidalis, Wilckens.
Orthothetes, cf. Woolworthana, Hall.
Chonetes hudsonicus metytype Gaspensis, Clarke.
Chonetes striatissimus, W. & B. ("cf. canadensis, small var," Bill).
? Camarotœchia sp. indet.
Uncinulus, cf. mutabilis, Hall.
Rhynchonella eminens, Hall.
Eatonia peculiaris, Hall (narrow var.).
Eatonia, cf. Whitfieldi, Hall.
Spirifer arenosus, Conrad.
Spirifer Montrealensis sp. nov. H.S.W.
Spirifer gaspensis, Billings.
Spirifer cumberlandiæ, Hall.
Spirifer cyclopterus, Billings (not Hall? = S. tribulis, Hall).
Cyrtina rostrata, Hall.
Metaplasia pyxidata, Hall.
Modiomorpha Helena sp. nov. (cf. concentrica.)
Palæoneilo ("cf. maxima, Clarke") Helena sp. nov.
Tentaculites Schlotheimi, Koken, cf. T. elongatus, Hall.
Spirifer pennatus, var. Helenæ, H. S.W. (See McGill College Collection, specimen No. 3644.)

The Gypidula Pseudogaleata Fauna.

(List of species from the southern exposure of limestone, the part to the west of the dyke in the breccia.)

Lichenalia, cf. torta, Hall.
Fenestella, sp. incert.
Crinoid stems.
Dalmanella, cf. subcarinata, Hall.
Dalmanella concinna, Hall.
Schizophoria multistriata, Hall.
Rhipidomella oblata, Hall.
Orthostrophia strophomenoides, Hall.
Leptæna rhomboidalis, Wilckens.
Stropheodonta arata, Hall.
Stropheodonta planulata, Hall.
= S. blainvillei, Billings.
= S. perplana, Hall.
Stropheodonta Beckii, Hall.
Stophonella punctulifera, Conrad.
Strophonella cavumbona, Hall.
Strophonella (Amphistrophia), continens, Clarke.
Strophonella Leavenworthana, Hall.
Orthothetes, cf. deformis, Hall.
Gypidula pseudogaleata, Hall.
Uncinulus planoconvexa, Hall.
Camarotœchia ventricosa, Hall.
Rhynchotrema formosum, Hall.
Spirifer concinnus, Hall.
Spirifer concinnus, var. Helenæ, v. nov.
Cyrtina Dalmani, Hall.
Atrypa reticularis (Linnæus).
Meristella princeps, Hall.
Merista lævis (Vanuxem).
Rensselæria, cf. mutabilis, Hall.
Platyceras, cf. clavatum, Hall.

(From the mass on the east side of the dyke in the southern exposure, belonging to the same fauna as above.)

Favosites helderbergiæ, Hall.
Cf. Lichenalia distans, Hall.
Orthis (Schizophoria) multistriata, Hall.
Stropheodonta arata, Hall.
Strophonella punctulifera, Conrad.
Orthothetes, cf. Woolworthanus, Hall.
Leptæna rhomboidalis, Wilckens.
Camarotœchia, cf. ventricosa, Hall.
Rhynchonella, cf. formosa, Hall.
Atrypa reticularis, Linn.
Spirifer, cf. concinnus, Hall.

Dr. Williams states that it seems quite evident from the critical study of the species that neither of these St. Helen's Island faunas is to be correlated exactly with any one of the known faunas of New York or of the interior of the American continent. Nor do they agree exactly with any of the more eastern faunas of Maine, Quebec, New Brunswick or Nova Scotia. Nevertheless, a resemblance is found for the first fauna with the Oriskanian and for the second fauna with the Helderbergian which they bear to no other faunas.

The matrix of the breccia under the microscope is seen to be composed largely of carbonates, as may also be ascertained by treating a hand specimen with dilute acid, but it also contains epidote, pyrite, apatite, perovskite, zircon, and, occasionally a mineral resembling hydronephelite. The original material is now completely decomposed. It was supposed by Sir William Dawson that this occurrence together with the other patches of breccia which occur on Ile Bizard and elsewhere, represented remnants of the ejectamenta from the ancient volcano of Mount Royal. This also was the view taken by Nolan and Dickson in their study of the occurrence. More recent investigations, of these other breccias, however, show that they have a matrix composed of camptonite, alnoite or other allied magmas and that the bodies have the character of intrusive masses. It seems probable, therefore, that the breccia of St. Helen's island also represents an intrusion of similar magma which has subsequently been so completely altered that its original character can be no longer recognized. This explanation also accounts for the distinct peripheral alteration so often seen in the fragments, more especially the limestone fragments, in the breccia.

The presence in the breccia of fragments of Upper Silurian and Devonian age has naturally been a source of much speculation, for no rocks of so recent an age are found in place anywhere in the western portion of the Province of Quebec. Since,however, it has been shown that in all probablity the matrix of the breccia was in a molten condition when it enclosed the fragments, and that the breccia as a whole has acted as an intrusive, the explanation is rendered comparatively simple. The breccia apparently represents the truncated pipe or outlet of a reservoir of molten igneous material, which outlet may have reached the surface and even formed a subsidiary cone on Mount Royal, or else it may have been of the nature of a laccolitic mass, not opening on the surface. In either case the intrusion extended up into the Helderberg and Oriskany which must have overlain the Utica in this district. The intrusive mass stoped off blocks from these higher strata which either sank of their own accord to the level of Utica, or in the surgings of the magma, such as are to be seen in volcanoes to-day, were, at a time when the lava was sinking, carried to the lower level.

The presence of these inclusions in the breccia proves that the intrusion must have taken place subsequent to the deposition of the formations represented by the included fragments. The breccia is therefore of post-Oriskany age.

Similar occurrences in which intrusive masses hold inclusions of fossiliferous sedimentary rocks more recent than any now exposed in the surrounding region have been described by Kynaston and Hall,* as well as by Peach and Gunn and others.**

The Utica shale and the breccia of St. Helen's island are cut by a number of dykes and small sills representing several varieties of the consanguineous dyke rocks of the Mount Royal intrusions. Among these is the faulted dyke referred to above as cutting the mass of Lower Helderberg limestone included in the breccia. This rock is basaltic in appearance and possesses both a porphyritic and an amygdaloidal structure. The amygdules are filled with calcite and analcite, the former mineral usually occupying the centre of the cavity. The rock is composed of phenocrysts of pyroxene and hornblende, embedded in a groundmass consisting of the same ferro-magnesian constituents with much analcite. The rock is a fourchite.

*Diamondiferous Deposits—Geological Survey of the Transvaal. Report for the year 1903, p. 44.

**On a Remarkable Vent of Tertiary Age on the Island of Arran, enclosing Mesozoic Fossiliferous Rock. Q. J. G. S. 1901, p. 226.

MOUNT JOHNSON.

Annotated Guide.

Miles and Kilometres.

0 m. 0 km. **Montreal.**

3 m. 4·8 km. **Point St. Charles.**

Altitude 58·5 ft. (17·8 m.)—Leaving Bonaventure Station by the Grand Trunk Railway the train crosses the St. Lawrence river on the Jubilee bridge. This bridge was built to replace the old Victoria bridge designed by Stevenson. It is 9,184 feet in length, being one of the longest bridges in the world.

From the bridge a very fine view of the city of Montreal is obtained.

6·16 m. 9·9 km. **St. Lambert.**

7·98 m 12·8 km. **Ranelagh.**

11·96 m. 19 km. **Brosseau Junction.**

20·18 m. 32·5 km. **Lacadie.**

The railroad passes over the great plain of the St. Lawrence lowlands underlain here by nearly horizontal strata of Ordovician age. The plain is mantled by drift of no great thickness. In its present form it represents the sea bottom of the glacial estuary of the St. Lawrence laid bare by the retreat of the ocean at the close of the Glacial age.

27 m. 43·4 km. **St. Johns.**

The train here crosses the Richelieu river, a tributary stream which enters the St. Lawrence at Sorel. It is an industrial centre with large pottery works, silk factory, etc., and a military post with Infantry school.

28 m. 45 km. **Iberville Junction.**

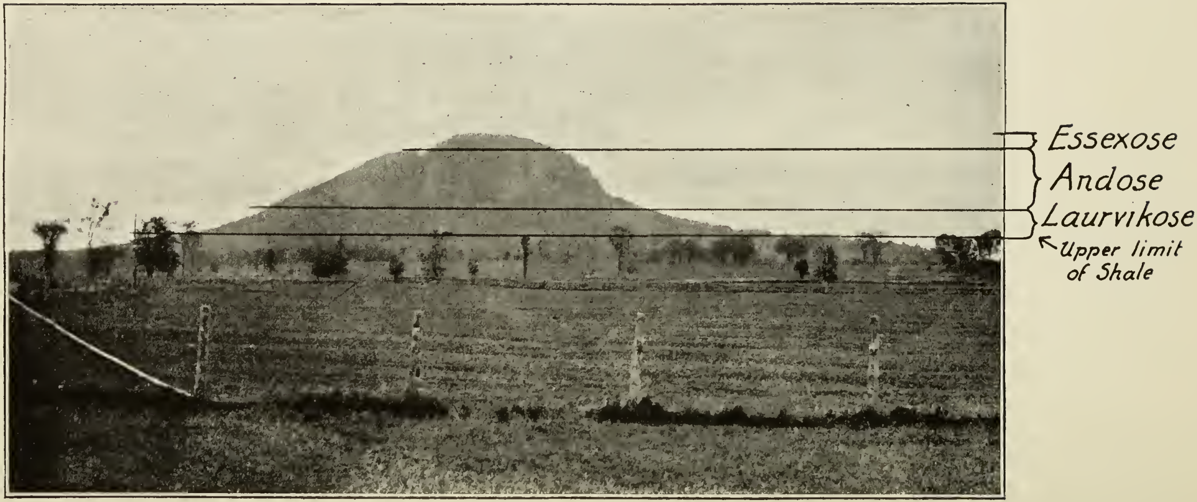
32 m. 51·5 km. **Mount Johnson.**

The Richelieu in early times was called Rivière des Iroquois because the war parties of the Mohawk Indians came up by it from the south when making their raids upon the settlements in the St. Lawrence valley. The English and French armies traversed it incessantly during the Colonial wars, and the names of the places along its banks, such as Sorel, Ours, Chambly are those of officers of one the French regiments, who received the first land grants when these regiments were disbanded.

Geology of Mount Johnson.

Mount Johnson rises from the plain 22 miles (35 km.) east-southeast of the city of Montreal as the crow flies, and 25 miles (40 km.) north of the international boundary. The little village of St. Grégoire is situated near its base. The surrounding country is perfectly flat, forming a fertile and well tilled agricultural district, the nearest mountain being Rougemont, another of the Monteregian Hills, which lies some nine miles distant in a northeasterly direction. In cross-section Mount Johnson is approximately circular. The igneous plug itself has at the base, immediately above the hornstone collar, a somewhat elliptical outline, and measures 3,500 feet (1066 m.) by 2500 feet (761 m.), the longer axis having a direction N. 20° E. This gives the igneous intrusion an area of ·423 of a square mile. The mean of a series of closely concordant aneroid readings, corrected by comparison with barometers at the observatory at McGill University at Montreal, shows that the highest point of the mountain is 685 feet (208·8 m.) above the main street in the village of St. Grégoire opposite the church, that is, above the surrounding plain, or 875 feet (266·7 m.) above sea level, the plain here having an elevation above sea level of 190 feet (58 m.) It has a somewhat dome-like outline, and forms a very striking feature in the landscape. The slope on the southern side is steep, in places precipitous, while to the north it is more gentle. The accompanying photograph taken from the railway station near St. Grégoire, which is about a mile and a quarter distant from the mountain in a direction approximately southwest, shows this profile, as well as the little notch near the summit, caused by a ravine which passes down the side.

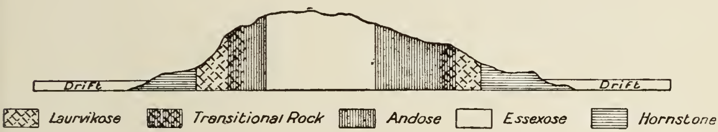
At the foot of the mountain, more especially on its southern, southeastern and southwestern sides, are numbers of large blocks which have fallen from the steep upper



Mount Johnson as seen from the southwest, showing the limits of the several rock types composing the mountain.

slopes; on the southern side is a gentle sloping terraced platform of drift which in part buries these great blocks, forming a "tail" probably due to the drift accumulating here on the lee side of the mountain during the ice movements in the Glacial age. This drift, however, has been in part at least reassorted by wave-action during the period of depression which in this region followed the Glacial age and during which the sea covered the plain to a depth of several hundred feet at least. On the plain about the mountain no rock exposures are seen. A mantle of drift covers it, and numerous erratic blocks and boulders are scattered about. These are composed chiefly of gneiss from the Laurentian highlands, but some of them are plutonic rocks from other hills of the Monteregian group.

On ascending the mountain the first rock which is exposed above the drift mantle is a very fine-grained dark hornstone, uniform in character and lying in undisturbed horizontal beds. It can be seen at intervals all around the base of the mountain, forming a sort of collar, and is undoubtedly a shale such as that usually constituting the Utica formation, here however altered by its proximity



Diagrammatic section through Mount Johnson, showing the relation of the several rock types.

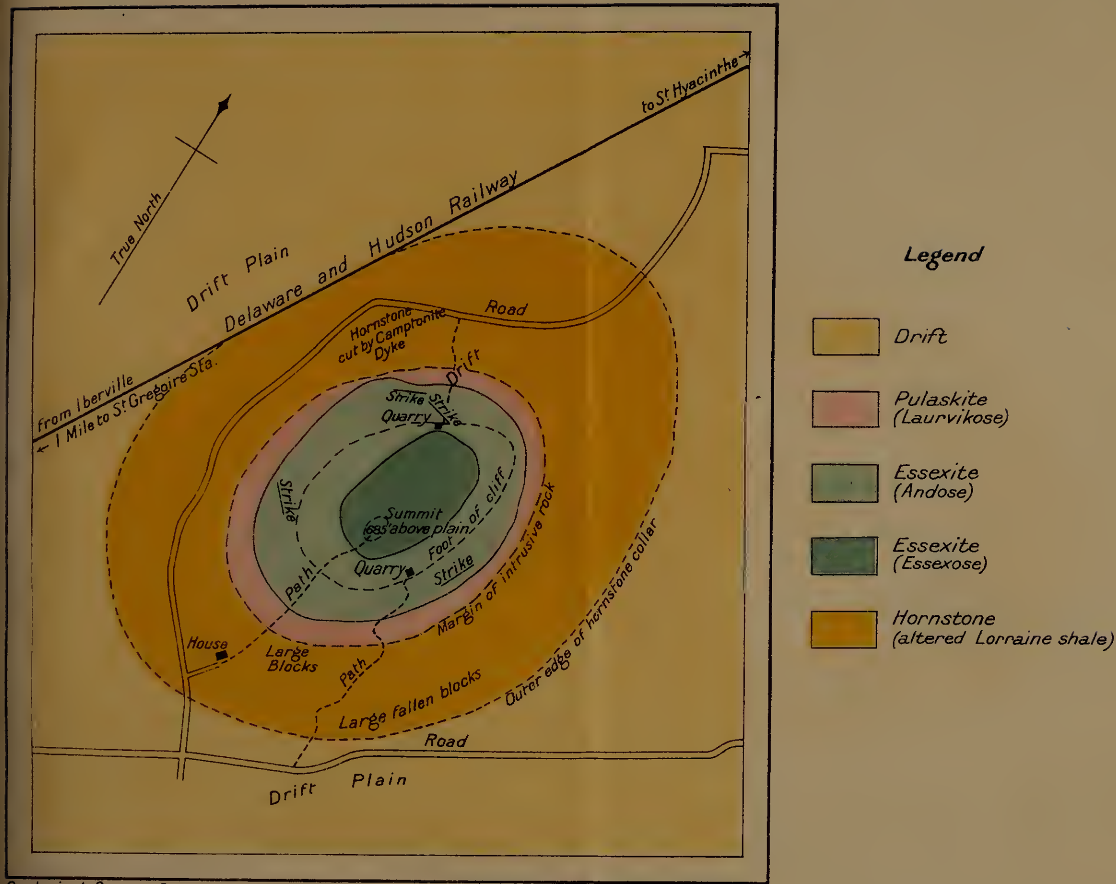
to the intrusion. This shale, wherever seen, lies flat and abuts against the igneous rock of the intrusion, being cut off sharply by it, but is not tilted or upturned. The upper limit of the shale is shown in the accompanying photograph of the mountain.

The mountain above this hornstone collar is made up exclusively of igneous material, which presents a most striking and beautiful instance of differentiation.

Immediately above the hornstone collar, and in contact with it, is a coarse-grained and highly feldspathic syenite, light buff in colour, of the pulaskite type. This, as the mountain is scaled, passes rather abruptly into a dark-coloured rock with large porphyritic white feldspars, which in its turn loses its porphyritic character and passes into a coarse-grained essexite which constitutes the mass of the hill, and which becomes at the summit finer in grain, richer in pyroxene and often holds a little olivine. No sharp lines can be drawn between these several rocks; one passes gradually into the other, the whole constituting one intrusive unit. The approximate limits of these several rock species are shown in the accompanying map and photograph of the mountain, it being impossible sharply to delimit the several species. The mass therefore becomes progressively more basic from the margin of the intrusion to its centre. The two chief rock types are the pulaskite and the essexite which will be separately considered.

The Pulaskite.—This soda-syenite which, as above mentioned, forms the outer zone of the intrusion, girdling the essexite, is less abundant than the latter, and differs greatly from it in appearance. This difference is due chiefly to the fact that it is pale yellow or buff in colour, instead of dark grey, the lighter colour being due to the very small proportion of iron-magnesia constituents present and the marked preponderance of the feldspars. The rock also has a more massive structure without the fluidal arrangement of constituents often met with in the essexite, and it weathers in a somewhat different manner. It possesses, moreover, a species of porphyritic structure, owing to the development of the feldspar in two forms; first, as stout prisms, up to 10 mm in diameter, which are light grey in colour and very abundant; and, secondly, in the form of smaller laths of a yellow or buff colour which, in association with the iron-magnesia and other constituents, form a sort of ground mass in the rock.

The constituent minerals of the rock are biotite, hornblende, soda orthoclase, nepheline, sodalite, apatite, magnetite and sphene. The darker contituents are identical in character with those occurring in the essexite. Not only are they as a class much less abundant in this pulaskite, but the mica here preponderates, while the hornblende is much less abundant and the pyroxene is entirely absent. It may be noted, however, that the hornblende sometimes possesses the greenish tint referred to as occasionally seen about the borders of the hornblende individuals in the essexite, indicating probably that the pulaskite magma being richer in soda, A 7.



Geological Survey, Canada.

Mount Johnson

Feet
100 0 1000 2000 3000
Metres
100 0 500 1000

the hornblende crystallizing out of it had a tendency to take up this element.

The *feldspar* in the pulaskite, as has been mentioned, occurs in part as stout prisms and in part as smaller laths. The latter usually have a somewhat cloudy appearance under the microscope, probably owing to the incipient alteration. The larger feldspars are what is commonly described as soda-orthoclase. When examined under the microscope they are seen to be composed of very minute intergrowths of two, and in some cases perhaps even of three, different feldspars—causing them to present between crossed nicols a mottled appearance. These several feldspars have somewhat different indices of refraction, and frequently under a high power, where two are present, one of them can be seen to possess a very minute polysynthetic twinning, while the other is untwinned. The relative proportion of the several feldspars present differs in different grains. The individuals as a whole occasionally present the form of carlsbad twins, but usually have the appearance of simple crystals and consist of microcline, microcline-microperthite, with probably some anorthoclase

The smaller lath-shaped feldspars, although more frequently composed of a single species, often show an intergrowth of two feldspars, as described in the case of the phenocrysts. Separations of the constituents of several species of the rock by means of Thoulet's solution show that the smaller feldspars have a somewhat lower specific gravity than the phenocrysts, that is to say, the smaller feldspars approach more nearly to pure orthoclase in composition. No lime-soda feldspar can be recognized in any specimen of the rock.

Nepheline and sodalite are quite subordinate in amount, although they are seen in nearly every thin section. Both minerals present the same characters and occur in the same way as in the essexite, lying chiefly in the corners between the other constituents, being penetrated by the latter, but also occurring as inclusions in the feldspar. They are, as a general rule, much altered to the same decomposition product in the nepheline of the essexite and which is either kaolin or muscovite. Probably both are present.

Apatite is present in considerable amount and in the form of perfect crystals, occuring chiefly in the mica, hornblende and sphene. The *iron ore* and *sphene* present the same characters as in the case of the essexite, but the latter mineral is relatively more abundant than in that rock.

An analysis of this pulaskite is given in the accompanying table together with analyses of the pulaskite and the nordmarkite of Shefford mountain described by Dresser. Analyses of three allied rocks from other localities are added for purposes of comparison.

—	I.	II.	III.	IV.	V.	VI.
SiO_2........	57·44	59·96	65·43	56·45	59·01	60·03
TiO_2.......	1·97	0·66	0·16	0·29	0·81	....
Al_2O_3.......	19·43	19·12	16·96	20·08	18·18	20·76
Fe_2O_3.......	1·69	1·85	1·55	1·31	1·63	4·01
FeO........	2·70	1·73	1·53	4·39	3·65	0·75
MnO.......	0·25	0·49	0·40	0·09	0·03	trace.
MgO.......	1·16	0·65	0·22	0·63	1·05	0·80
CaO........	2·66	2·24	1·36	2·14	2·40	2·62
BaO........	not det.	·12	none.	....	·08	....
Na_2O.......	6·48	6·98	5·95	5·61	7·03	5·96
K_2O........	4·28	4·91	5·36	7·13	5·34	5·48
P_2O_5........	0·60	0·14	0·02	0·13	trace.	0·07
SO_3........	not det.	0·08	0·06	....	....	....
Cl.........	trace.	0·14	0·04	0·43	0·12	....
H_2O........	1·03	1·10	0·82	1·51	0·50	0·59
	99·69	100·17	99·86	100·19	99·98	101·07

I.—Pulaskite (laurvikose), Mount Johnson, Quebec.
II.—Pulaskite (laurvikose), Shefford mountain, Quebec.
III.—Nordmarkite (nordmarkose), Shefford mountain, Quebec
IV.—Sodalite syenite, Square Butte, Montana (differentiation product of shonkinite.)
V.—Umptekite, Red Hill, Moltonboro, New Hampshire.
VI.—Pulaskite, Fourche mountain, Arkansas (original locality).

The mineralogical composition (mode) of the Mount Johnson pulaskite (No. I), calculated from the analyses given above, is as follows:—

Albite	48·73	74·03
Anorthite	3·06	
Orthoclase and microcline	22·24	
Nepheline		2·56
Kaolin		4·96
Hornblende		5·08
Biotite		6·29
Magnetite	1·87	2·77
Ilmenite	0·91	
Sphene		2·35
Apatite		1·34
Water (hygroscopic)		0·30
		99·68

The calculation shows clearly the fact, ascertained by the study of the thin sections of the rock, that a considerable percentage of sphene is present, a mineral which does not occur at all in the essexite.

The calculation also brings out clearly the fact that in this rock the nepheline is much more highly altered than in the essexite, as shown by the amount of kaolin present. This kaolin, however, is not entirely derived from the alteration of the nepheline, but appears as a haze through all the smaller feldspars, and hence in the extension of the results should be assigned in part to the nepheline and in part to the feldspar.

In the Quantitative Classification the rock would have the following positions:—

Class I, Persalane.
Order 5, Canadare.
Rang 2, Pulaskase.
Subrang 4, Laurvikose.

It is thus seen that the rocks from Mount Johnson and from Shefford mountain which, following Rosenbusch's classification, have been called pulaskite, and which in the quantitative scheme of classification are pulaskase, are almost identical in composition with one another and with the Norwegian laurvikite, and that the nordmarkite of Shefford mountain is very close in composition to the nordmarkose of the original Scandinavian locality.

The Transition Rock. As has been mentioned, there intervenes in Mount Johnson between the pulaskite border and the central mass of essexite a transitional zone consisting of a rock which is dark in colour and thus resembles the essexite, but which is characterized by the presence of large porphyritic feldspars, sometimes as much as two inches in length, of peculiar form scattered through it and often arranged with their longer axes in the same direction, thus giving a fluidal appearance to the rock. This rock contains a large proportion of the same iron-magnesia minerals, more especially the hornblende, found in the essexite, and passes over gradually into this rock. Its passage into the pulaskite is rather more abrupt and is marked chiefly by the almost entire disappearance of the dark-coloured constituents above mentioned. There is, however, a continuous transition from the pulaskite through this intermediate rock into the inner essexite of the mountain.

This transitional rock is composed of the same minerals as the essexite with the exception of the feldspar, which consists in part of the soda-orthoclase characteristic of the pulaskite, and in part of the plagioclase (in this case oligoclase) which forms the feldspathic element of the essexite. It is thus in mineralogical composition intermediate between these two rocks, although, as above mentioned, being rich in the dark coloured constituents, it more closely resembles the latter.

The large feldspars have frequently a peculiar crystalline form giving to the mineral, when broken across, a perfect hexagonal outline. The six faces represented in this form are apparently T, L, and M. The crystals hold many little inclusions of pyroxene, biotite, hornblende, magnetite, sphene and nepheline, often regularly arranged so as to give a zonal structure to the feldspar individual. The specific gravity of twelve small fragments of the feldspar of these large crystals, collected from a locality on the southern side of the mountain, and as free as possible from all inclusions, was determined. The specific gravity of nine of these lay between 2·59 and 2·607, while that of the other three was between 2·625 and 2·628. This shows the feldspar in the former case to be identical with that of the pulaskite, while in the latter three the specific gravity lies between that of albite and oligoclase. The somewhat greater specific gravity in this case may be due in part to inclusions of other minerals. A separation of the constituents of the rock shows, however, that, as above mentioned, a considerable amount of oligoclase is really present. The feldspar individuals, both great and small, usually show in thin sections the mottled character due to the intergrowth of different species described in the pulaskite. A partial analysis of a specimen of this intermediate rock, from the south side of the mountain, is given in the table of analyses on page 73 (No. VI). As will be seen it is intermediate in chemical composition between the essexite and the pulaskite, occurring on either side of it, thus representing an intermediate zone in which the differentiation was not quite completed. It is, however, much more nearly allied to the essexite.

Essexite.—The rock is dark in colour and rather coarse in grain, and while holocrystalline, usually presents a more or less marked fluidal arrangement of the contituents. This is especially marked in the zone of transition between the essexite and the pulaskite, owing to the presence there of the large feldspar phenocrysts which, being arranged with their longer axes parallel to the direction of flow, serve to accentuate this structure. The finer grained variety forming the summit of the mountain is more massive in character and does not exhibit the fluidal arrangement of constituents. Under the microcsope the rock is seen to be composed of the following minerals: hornblende, pyroxene, biotite, olivine, plagioclase, nepheline, sodalite, apatite, magnetite, sphene, and in some cases a very small amount of orthoclase.

There is a marked tendency on the part of all the constituents to assume an idiomorphic development. The long lath-shaped plagioclases and large hornblende individuals have an approximately parallel arrangement, and between these lie the other iron-magnesia constituents with the smaller plagioclase individuals, the nepheline and the other components of the rock. These interstitial constituents do not differ greatly in size from the others, and show the same tendency to a parrallel arrangement.

Hornblende is present in almost every thin section of the rock along with pyroxene and biotite, but the relative proportion of these minerals varies considerably. The hornblende is distinctly the most abundant, except in the finer-grained variety forming the summit of the mountain, in which it is distinctly subordinate in amount to both pyroxene and mica. It is deep brown in colour and is sometimes hypidiomorphic in its development, but often occurs with perfect crystalline form, showing the prismatic and the orthopinacoidal faces. Its extinction is larger than is usual in brown hornblendes, reaching 20°. It possesses a strong pleochroism. The hornblende in a state of perfect purity was analysed by Professor Norton-Evans, of McGill University. The results of the analysis are given below, together with those of several hornblendes of similar composition which have been added for purposes of comparison:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
SiO_2........	38·633	39·75	40·15	40·14	41·35	39·16
TiO_2........	5·035	5·40	5·21	4·26	4·97	....
Al_2O_3........	11·974	15·00	14·34	14·30	13·48	14·39
Fe_2O_3........	3·903	7·86	7·80	7·07	5·14	12·42
FeO........	11·523	2·89	4·53	6·27	10·33	5·85
MnO........	0·729	....	....	0·21	....	1·50
MgO........	10·200	14·16	13·14	11·62	11·44	10·52
CaO........	12·807	12·97	11·75	12·00	10·93	11·18
Na_2O........	3·139	1·92	2·31	2·22	2·10	2·48
K_2O........	1·489	1·61	1·14	1·35	0·62	2·01
H_2O........	0·330	....	....	....	0·48	0·39
	99·762	101·56	100·37	99·44	100·84	99·90

No. 1.—Hornblende. From the essexite of Mount Johnson, Province of Quebec, Canada.

No. 2.—Hornblende. From Bohemian Mittelgebirge.

No. 3.—Hornblende. From tuff of hornblende basalt, Hārtlingen, Nassau.

No. 4.—Hornblende. Basalt tuff, Hoheberg, near Giessen.

No. 5.—Hornblende. From "hornblende diabase," Graveneck, near Weilburg.

No. 6.—Hornblende. Syntagmatite. Jan Mayen.

The hornblende thus belongs to the class of basaltic hornblendes.

Pyroxene occurs intimately associated and often intergrown with the hornblende, both minerals frequently holding many inclusions of magnetite and apatite. It is pale greenish in colour, with no perceptible pleochroism, but with a marked dispersion of the bisectrices.

It is usually hypidiomorphic, but is frequently idiomorphic, showing a distinct cleavage parallel to the pinacoids, but usually none parallel to the prismatic faces. It belongs to the variety of diopside-like augites which occur in rocks of this class. The extinction is high, reaching 45°.

Biotite is deep brown, almost identical in colour with the hornblende and is strongly pleochroic. It occurs intimately associated with the hornblende and augite, and also frequently as a border around the iron ore. While usually present in comparatively small amount, in the finer grained essexite forming the summit of the mountain it is much more abundant than the hornblende. In this variety of the essexite both the mica and the hornblende often possess a poikilitic structure owing to the presence of numerous inclusions of plagioclase. The plagioclase also often penetrates the individuals of biotite and hornblende in the form of well developed crystals.

Olivine is found in the finer grained variety of the essexite at the summit of the mountain, and was also observed in the thin sections from the essexite at one point on the east side of the mountain not far from the summit. It is very pale green in colour and occurs as little grains inclosed in the biotite and pyroxene.

The *plagioclase* in the rock has well-developed, lath-like forms and is, almost without exception, excellently twinned according to the albite law. Twinning according to the carlsbad and pericline laws is also very common, occurring in the same individuals which show the albite twinning. The laths of plagioclase can in a few cases be seen to be distinctly twisted, evidently owing to pressure exerted upon them by other crystals during the consolidation of the rock, since the rock was subjected to no dynamic action subsequent to its crystallization.

As before mentioned, all the plagioclase individuals are not of the same dimensions. There are larger laths associated with the large hornblende crystals, and between these are smaller laths. The two sets are not, however, sufficiently well marked to cause the resulting structure to be classed as porphyritic. The plagioclase in the rock is not all of the same composition, but varies somewhat even in the same hand specimen, ranging from an extremely acid labradorite to an oligoclase. It, however, is chiefly andesine.

A very small amount of orthoclase is also present in some specimens of the rock, occurring as a subordinate accessory constituent.

Nepheline is quite subordinate to the feldspar in amount. It is sometimes quite fresh, but at other times is found more or less completely altered to a mineral which is either muscovite or kaolin. The nepheline is allotriomorphic and occurs chiefly in the corners between the larger crystals of feldspar and other minerals, and is penetrated by them. It is especially abundant in those portions of the rock which are rich in the dark coloured constituents. When occurring in this manner it appears, with the sodalite, to have been the last constituent of the rock to crystallize out. It is usually much more abundant than the sodalite. The nepheline also occurs in places as as irregular-shaped lath-like inclusions in the feldspar.

Sodalite is usually, although not invariably, present. It strongly resembles the nepheline in appearance and shows the same alteration product. Like the nepheline, it occurs either in the spaces between the other minerals, cementing them together, or as inclusions in the feldspars.

The abundance of *apatite* is a distinct feature in this as in similar rocks occurring elsewhere. It is always present and was the first constituent to crystallize out, being found in the form of perfect hexagonal prisms with double pyramidal terminations imbedded in the iron ore. It also occurs in the sphene as well as in the iron-magnesia constituents, in the nepheline, and also, although much less frequently, in the feldspar. Its large amount is shown by the high percentage of phosphoric acid in the analysis of the rock, 1·23 per cent. Another specimen of the rock in which the phosphoric acid was determined by Dr. B. J. Harrington gave 1·01 per cent. These figures represent 2·79 per cent. and 2·35 per cent. of apatite, respectively. It is usually somewhat turbid from the presence of minute dust-like inclusions.

Magnetite occurs chiefly inclosed in the iron-magnesia constituents, but is occasionally found in the feldspar. It is usually allotriomorphic, but occasionally presents an approximation to definite crystalline outline. As shown by the calculation of the analysis of the rock, this iron ore contains a considerable percentage of titanic acid.

Sphene is not found in more than one half of the specimens examined. When present it is not very abundant and usually occurs as well defined, wedge-shaped crystals, often of considerable size.

In the accompanying table analyses are given of the normal essexite which forms the greater part of Mount Johnson, and of the finer grained, olivine-bearing variety of the same rock found at the summit of the mountain. For purposes of comparison there is presented in the same table the analysis of the essexite from Shefford mountain, which belongs to the same Monteregian province, together with analyses of the original essexite from Salem, Mass., and of allied rocks from two other localities. A partial analysis of the transitional rock between the essexite and the pulaskite of Mount Johnson is also given. The analysis of the Mount Johnson essexite (No. I) as well as for that of the associated pulaskite, which is given below, was made by Professor Norton-Evans, while the analysis of the olivine-bearing variety of the essexite (No. II) was made by Mr. M. F. Connor.

	I.	II.	III.	IV.	V.	VI.
SiO_2........	48·85	48·69	53·15	46·99	47·67	50·40
TiO_2.......	2·47	2·71	1·52	2·92	....	1·17
Al_2O_3.......	19·38	17·91	17·64	17·94	18·22	....
Fe_2O_3.......	4·29	3·09	3·10	2·56	3·65	5·58 (Fe₂O₃ + FeO)
FeO........	4·94	6·41	4·65	7·56	3·85	
NiO+CoO..	not det.	0·05	not det.	not det.	....	not det.
MnO.......	0·19	0·15	0·46	trace.	0·28	0·77
MgO.......	2·00	3·06	2·94	3·22	6·35	....
CaO........	7·98	7·30	5·66	7·85	8·03	6·77
BaO........	....	0·08	0·13	none.	....	....
Na_2O.......	5·44	5·95	5·00	6·35	4·93	6·24
K_2O........	1·91	2·56	3·10	2·62	2·97	2·56
P_2O_5........	1·23	1·11	0·65	0·94	....	0·09
Cl.........	not det.	not det.	0·07	....	....	....
H_2O........	0·68	0·95	1·10	0·65	3·82	....
Total.....	99·36	100·02	99·84	99·60	100·15	

I.—Normal essexite (andose), Mount Johnson, Quebec.

II.—Olivine-bearing essexite (essexose), Mount Johnson, Quebec.

III.—Essexite (akerose), Shefford mountain, Quebec, (American Geologist, 1901, p. 201), (with CO_2 0·39 and SO_3 0·28).

IV.—Essexite (essexose), Salem Neck, Salem, Mass. (Washington, Jour. Geol., 1899, p. 57).

V.—Theralite, Elbow creek, Crazy mountains, Montana.

VI.—Rock forming transition from essexite to pulaskite, Mount Johnson, Quebec. (Partial analysis. The iron present is all calculated as FeO.)

The analyses (Nos. I and II) of two varieties of the essexite from Mount Johnson can be readily calculated out so as to show the quantitive mineralogical composition of the rocks.

The calculation of the mode*—or relative proportion of the minerals actually present gives the following result:

	Essexite (Analysis I.) Mount Johnson		Olivine-essexite (Analysis II.) Mount Johnson.	
Albite	36·75		29·14	
Anorthite	20·23	66·45	13·11	54·79
Orthoclase	9·47		12·54	
Nepheline	3·99	4·77	11·12	11·90
Kaolin	·78		·78	
Pyroxene		6·29		12·22
Hornblende		7·05		2·30
Biotite		2·04		4·08
Olivine		none.		2·84
Magnetite	5·68	9·53	3·94	8·41
Ilmenite	3·85		4·47	
Apatite		2·68		2·59
Water (hygr.)		·58		·85
		99·39		99·98

The calculation further demonstrates that the plagioclase in the case of No. I is a trifle more basic, and in the case of No. II a little more acid, than Ab_2 An_1, which, as has been stated, is shown by the optical character and by the specific gravity of the feldspar to represent its average composition in these rocks.

The small amount of orthoclase recognized in thin sections also appears as mentioned in the description of the rock. The nepheline is in places somewhat altered to a mineral resembling kaolin. The small percentage

*Quantitative Classification of Igneous Rocks (C.I.P.W.) (University of Chicago Press, 1903), p. 147.

of kaolin shown by the calculation has therefore been added to the nepheline in extending the table.

No. I takes the following position in the Quantitative Classification:

Class II, Dosalane.
Order 5, Germanare.
Rang 3, Andase.
Subrang, 4, Andose (grad—polmiric.)

No. II, however, belongs to the next order and is domalkalic. Its position in the Quantitative Classification is as follows:

Class I,, Dosalane.
Order 6, Norgare.
Rang, 2, Essexase.
Subrang 4, Essexose (grad—prepolic).

It is therefore seen that the essexite from the central portion of Mount Johnson (No. II) is practically identical in character and composition with the essexite of the original locality of Salem, Mass. (Analysis IV), while the outer andose is poorer in nepheline and has a somewhat larger proportion of lime as compared with the alkalies.

Dykes—A feature in connection with Mount Johnson, and one possibly connected with its somewhat peculiar structure, is the almost entire absence of dykes. Only five small dykes, each only a few inches wide, have been found. Some of these are camptonite, while the others, although much altered, are apparently solvsbergite.

Structure—The structure of the mountain and the character of the rocks composing it throw some light on the question as to where the differentiation took place. In course of conversation with the foreman of one of the quarries in the essexite on the flank of the mountain, the writer was informed by him that Mount Johnson consisted of three layers of horizontal rock; a fine grained one on top, below which was the coarser grained rock of the quarry, and beneath this a spotted variety. Each of these layers, he considered went through the mountain horizontally and could be seen outcropping at their respective levels on every side. The three rocks referred to were, as will be recognized, the fine grained essexose, the andose, and the transitional rock below the latter, respectively. The pulaskite zone he had not noticed, it being at the base of the mountain and in many places more or less covered with fallen blocks and talus. If this were the true interpretation of the structure, the mountain would have to be considered as the remnant of a laccolite which had been intruded between the horizontal Silurian strata and which had subsequently been almost entirely removed by peripheral denudation. This has been shown to be the true explanation of the origin of some of the occurrences,

Andose in quarry on Mount Johnson, showing vertical flow structure.

formerly supposed to be intrusive stocks, in the western portion of the United States, and it was at first considered as a possible explanation of the origin of MountJohnson. A careful examination of the mountain, however, shows that such an explanation of its origin is untenable, and that it is a true neck, due to the filling up of a nearly circular perforation in horizontal strata by an upward moving magma.

The evidence of this is to be found in the direction of the banding or fluidal arrangement of the crystals in the essexite already referred to and shown in the accompanying illustration. This fluidal arrangement is seen in most large exposures of the essexite and with especial distinctness in the great faces of this rock exposed in the quarries on the mountain side, and it is always vertical, showing that the movement of the rock was upward through the pipe, and not outward and horizontally over the pulaskite, as it would have been in the case of a laccolite. Furthermore, in several cases when the fluidal arrangement is very distinct and has a somewhat banded character due to the alternation of somewhat more feldspathic portions of the rock with others richer in iron-magnesia constituents, a strike can be made out on horizontal surfaces, and this strike curves around the mountain, following its marginal outline, as shown on the map.

It is thus clear that Mount Johnson is a neck in its most typical form. A cross-section of the mountain is shown in the accompanying figure. The opening occupied by the intrusion was, in all probability, formed by the perforation of the horizontal shales at this point by the explosive action of the steam and vapours preceding the eruption proper, as it presents exactly the features reproduced by Daubrée in his highly suggestive experiments on the penetrating action of exploding gases. It is, in fact what he terms a *diatrème.*

"Des perforations aussi remarkables, tant par leurs formes que par les communications qu'elles ont établies avec les profondeurs du sol, constituent, parmi les cassures terrestres, un type assez nettement charactérisé pour mériter d'être distingué par une dénomination précise et cosmopolite. Le nom de diatrème rapelle l'origine probable de ces trouées naturelles, véritables *tunnels verticaux*, qui se rattachent souvent, comme un incident particulier, aux cassures linéaires, diaclases et paraclases.*"

The occurrence is one which presents a close resemblance to the remarkable volcanic necks described by Sir Archibald Geikie** in East Fife, and also to those described by Branco†, in Wurtemberg. Mount Johnson, however, is a neck occurring in an area which has undergone much

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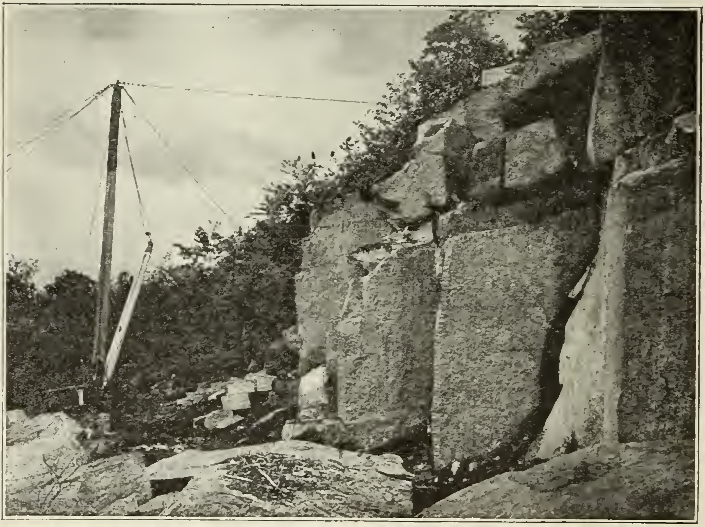
*"Recherches expérimentales sur le rôle possible des gaz à hautes températures doués de très fortes pressions, etc.," Bul. de la Soc. Géol. de France, 3e série, tome XIX. (1891) p. 238.

**The Vocanic Necks of East Fife. Glasgow: Hedderwich & Sons.

†Schwabens 125 Vulcan-Embryonen und deren tufferfüllte Ausbrurhsröhren das grösste Gebiet ehemaliger Maare auf der Erde. Tübingen, 1894.

more extensive denudation since the time of the intrusion than in the cases above mentioned, and as a consequence of this, the fragmental material which fills some, although not all, of the necks referred to above, has been entirely swept away.

In view of the fact, then, that Mount Johnson is a neck or pipe of comparatively small sectional area, in which the differentiation is very complete, but in which the magma did not remain at rest, but was moving upward



Quarry in andose, Mount Johnson, showing vertical flow structure (on right).

long prior to final consolidation, it seems improbable that the marked differentiation of the magma into the several varieties took place while the magma was in the pipe itself. The evidence points rather to the differentiation of the mass having already taken place in the reservoir of molten rock beneath, which was tapped by the pipe. If this be the case, it would seem that the upper and more acid portion of the magma, represented by the lighter pulaskite, had collected in the upper portion of the reservoir, and that the essexite formed a lower, more basic, and heavier stratum or part. When the passage to the surface was opened up, the pulaskite would first rise in it, and, after a more or less continued flow, being followed by the essexite, would be pressed toward the circumference of the pipe, the more basic rock occupying the central portion of the passage, and the most basic variety, originally, lower would be found in the central axis of the neck. The fact that, while the essexite forms the mass of the intrusion, there is a zone of pulaskite about it, would seem to indicate that there had not been at this centre of volcanic activity any very protracted outpouring of the essexite, since, had this been the case, it would seem probable that the pipe would have, in time, been cleared of the upper pulaskite magma.

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EXCURSION A 8.

MINERAL DEPOSITS OF THE OTTAWA DISTRICT

BY

J. STANSFIELD.

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INTRODUCTION.

Scope of Excursion.

This excursion has for its objective an occurrence of Eozoon canadense and certain deposits of apatite, graphite and mica which lie within the southern edge of the Pre-Cambrian region immediately north of the Ottawa river. These deposits, while of minor economic importance and supporting only small and precarious industries, are nevertheless of considerable geological interest. Leaving Montreal by rail the excursion will follow the north shore of the Ottawa river to Ottawa, short northward trips being made from Papineauville to the Eozoon locality at Côte St. Pierre, from Buckingham to the apatite deposit at the Emerald mine and the graphite deposits at the Walker and Dominion mines, and finally from Ottawa to the Nellis mica mine at Cantley.

General Geological Description.

The geology of the region to be traversed admits of a clearly marked three-fold subdivision:

3. Pleistocene and Post-Pleistocene.
   - c. Saxicava sand.
   - b. Leda clay.
   - a. Boulder clay.
2. Ordovician.
   - f. Utica.
   - e. Trenton.
   - d. Black River.
   - c. Chazy.
   - b. Calciferous.
   - a. Potsdam.
1. Pre-Cambrian.
   - c. Anorthosites.
   - b. Ottawa gneiss (granite, diorite, gabbro.).

Pre-Cambrian. The oldest Pre-Cambrian rocks in the region to be visited are a series of highly metamorphosed sedimentary materials, probably the oldest rocks in eastern North America, to which the name Grenville series was first applied in this region [**19**]. These are intruded by immense bodies of granite, diorite and gabbro, collectively known as the Ottawa gneiss, and by a younger group of intrusive anorthosites.

As may be seen by referring to the Grenville map-sheet, the Grenville series occupies only a small percentage of the Pre-Cambrian area. It outcrops in long, narrow bands from one half to one mile (·8 to 1·6 km.) wide, that have a general strike of N. 30° E., although this varies in places to north, and even to west of north. That the series has been subjected to intense pressure is shown by the strong and complicated folding which has taken place, and can be beautifully illustrated even in small specimens. An example of this is to be seen on the north shore of the Ottawa river at Papineauville. The Grenville series is composed of gneisses which have the chemical composition of clay slates, though now so completely metamorphosed, that they retain no sign of their original character. These include many areas of black and rusty-weathering gneisses, with compositions intermediate between those of sandstones and clays, which probably represent original sediments of the Grenville series. Some sillimanite gneisses of this type have been examined and proved to be sediments. Others have indefinite characters which do not allow of a decision as to their sedimentary or igneous origin. A few unimportant bands of quartzite are also encountered, but limestone is by far the most important member of the series. The limestone is very impure. It varies from white crystalline marble to brown, and in composition from limestone to magnesite. Where the latter rock is quarried in Grenville township, the best analyses published show not less than 10·5% of $CaCO_3$. Silicates are common impurities in the limestone, pyroxene and phlogopite, being the most abundant. All the minerals found in the limestone of this district are included in a list of such minerals occurring in the Grenville series in the Haliburton and Bancroft areas that is given by Drs. F. D. Adams and A. E. Barlow [**20**].

These two geologists have shown that the Grenville series, in the above mentioned area, attains a thickness of 17·88 miles, (28·6 km.), or 94,406 feet (28,782 m.), of which thickness 53·35% is limestone. They have also shown that the coarsely crystalline limestones or marbles of the series have been derived from blue limestones of a normal sedimentary type by thermal metamorphism attendant upon their intrusion by immense batholiths of igneous material

[**20**]. That pressure also has played some part in this metamorphism cannot be doubted, but the major part is undoubtedly due to contact action. The same applies to the metamorphism displayed by the limestones in the area to be visited, But here we are unable to compare the metamorphosed limestone with the normal, the latter being hidden from view south of the Ottawa river by a thick covering of Palæozoic sediments.

The Grenville series is intruded by a great suite of granite and syenite batholiths, with subordinate diorites and gabbros which are included under the name Ottawa gneiss [**21**]. As a general rule the granites are older than the diorites and gabbros. The gabbros show all variations of composition from anorthosite to pyroxenite. In the small areas to be visited, typical granites are not well instanced. The oldest intrusives have characters which closely ally them with the charnockites of southern India. Later intrusives usually have the characters of diorite or gabbro. All of these have a more or less strongly marked gneissic structure, and are cut by many pegmatite veins. A younger set of gabbros, in which gneissic structure is typically absent, has been responsible for the formation of the ore-bodies to be visited. These are sometimes cut by a younger set of pegmatite dykes, which often possess peculiar characteristics.

The youngest of all the intrusives, in the areas to be visited, are diabase dykes, which reach a thickness of 60 feet (18·3 m.) or more, and can often be traced across country for many miles. Eastward, beyond the special areas to be visited, are large areas of anorthosite, the youngest of all the Pre-Cambrian intrusives.

Ordovician.—The earliest member of this group is the Potsdam sandstone. It rests unconformably upon the Pre-Cambrian, and is followed conformably and sometimes overlapped by the Calciferous sandy dolomite, which in turn is followed by the other members of the Ordovician system. The Potsdam sandstone is often quartzitic, and lacks definite fossils by which it may be correlated with the Potsdam to the south, which, in Wisconsin and elsewhere, contains the Dicellocephalus fauna. Up to the present worm-burrows and brachiopods are the only fossils found in the Canadian Potsdam. It seems probable that it represents the continuation, during the earliest Ordovician time, of the submergence of the North

American continent, with an attendant northward recession of the coast-line, which began in Upper Cambrian time.

In the western part of the district under consideration, Palæozoic sediments occur south of the Ottawa river, with only a narrow strip along the northshore, while in the eastern part a broader band of them separates the Pre-Cambrian margin from the Ottawa. They lie in almost the same attitude as when they were laid down, having a slight dip to the south or south-east. Further to the south-east, intense folding has taken place in Palæozoic and later times, but in this region, where the Palæozoic may be regarded as a very thin cover on the Pre-Cambrian floor, the latter is responsible for the absence of folding. The Pre-Cambrian acted as a buffer against which the Appalachian folds were thrust, and suffered no folding itself, consequently the thin Palæozoic crust on its surface remain untilted. Nevertheless the Palæozoic rocks have suffered from dislocation, faults being traceable sometimes for long distances across country; for example, the Hull and Gloucester fault, mentioned below. In the vicinity of Ottawa the Palæozoic rocks are much broken up by faults.

Pleistocene and Post-Pleistocene.—A great hiatus exists between the Palæozoic and Glacial periods in this part of Canada. For the greater part of the time represented by this hiatus the region formed a part of the land surface of North America. The Glacial period has left its record in the boulder clay, which has the usual characters of this rock, and which does not allow of any subdivision in this area. Subsequent to the retreat of the ice, but while large masses of ice still covered the country to the north and maintained an arctic climate, the lower part of the St. Lawrence valley was below sea-level. This was probably due to the weight of the great bodies of ice, still existent to the north. The sea occupying this estuary extended almost as far as Kingston. An arm extended down the Champlain valley, probably connecting with the Atlantic by way of the Hudson valley. Another arm reached up the Ottawa river beyond Ottawa. This arm had smaller bays running up the Gatineau, Lievre, and Nation rivers and other tributaries of the Ottawa river. Into this marine arm was emptied large quantities of "rock-flour" brought by the streams from the ends of the glaciers, and doubtless, in part too, within the ice that floated away as icebergs. This fine mud was laid down upon the floor of the sea. Recurrent slight differences in its composition gave rise to a fine lamination which can often be seen in exposures of Leda clay, as these marine sediments are called. The shells found in the clay indicate that the climate of that time was similar to the present climate of the Labrador coast. At Green's creek, near Ottawa, the clay is rich in calcareous nodules which have yielded many fossils, especially *Mallotus villosus*, (Cuvier) and other fishes.

The Leda clay is overlain by the Saxicava sand which was laid down as the sea shallowed and withdrew to its present level. The Saxicava sand is often crowded with shells of *Saxicava rugosa*, Lamarck, though extensive areas may be examined without discovery of a single shell. That the emergence of the land took place in stages is shown by the successive terraces of the lower St. Lawrence, nowhere better shown than on the flanks of Mount Royal, where as many as seven raised beaches, indicating successive halts in the gradual elevation of the land, have been recorded by Sir J. W.Dawson [**24**]. The most conspicuous of these seen in passing along the Ottawa valley is the 220 foot (67 m.) terrace, known at Montreal as the Waterworks terrace. It is constantly in view, especially to the north of the railroad.

ANNOTATED GUIDE.

Miles and Kilometres.

0·0 m. **Montreal** (Place Viger)—Alt. 57 ft. (17·4 m.).

12·8 m. 20·5 km. **St. Martin Junction**—Alt. 110 ft. (33·5 m.).

32·5 m. 52·0 km. **Ste. Scholastique**—Alt. 238 ft. (72·7 m.).

44·2 m. 70·8 km. **Lachute**—Alt. 229 ft. (69·7 m.).

57·6 m. 92·0 km. **Grenville**—Alt. 210 ft. (64 m.).

79·1 m. 126·8 km. **Papineauville**—Alt. 149 ft. (45·5 m.).

83·9 m. 134·3 km. **Plaisance**—Grenville limestone is exposed in the railroad cutting west of Papineauville. Beyond this a granulite batholith, composed in part

Miles and Kilometres.

of a granite which shows no evidence of having undergone pressure, is seen. At first the rounded glaciated surfaces are abundant, but toward and beyond Plaisance they are less numerous, being covered by Leda clay and Saxicava sand. The sea-cliff, which has been noted in the introductory statement, is frequently visible.

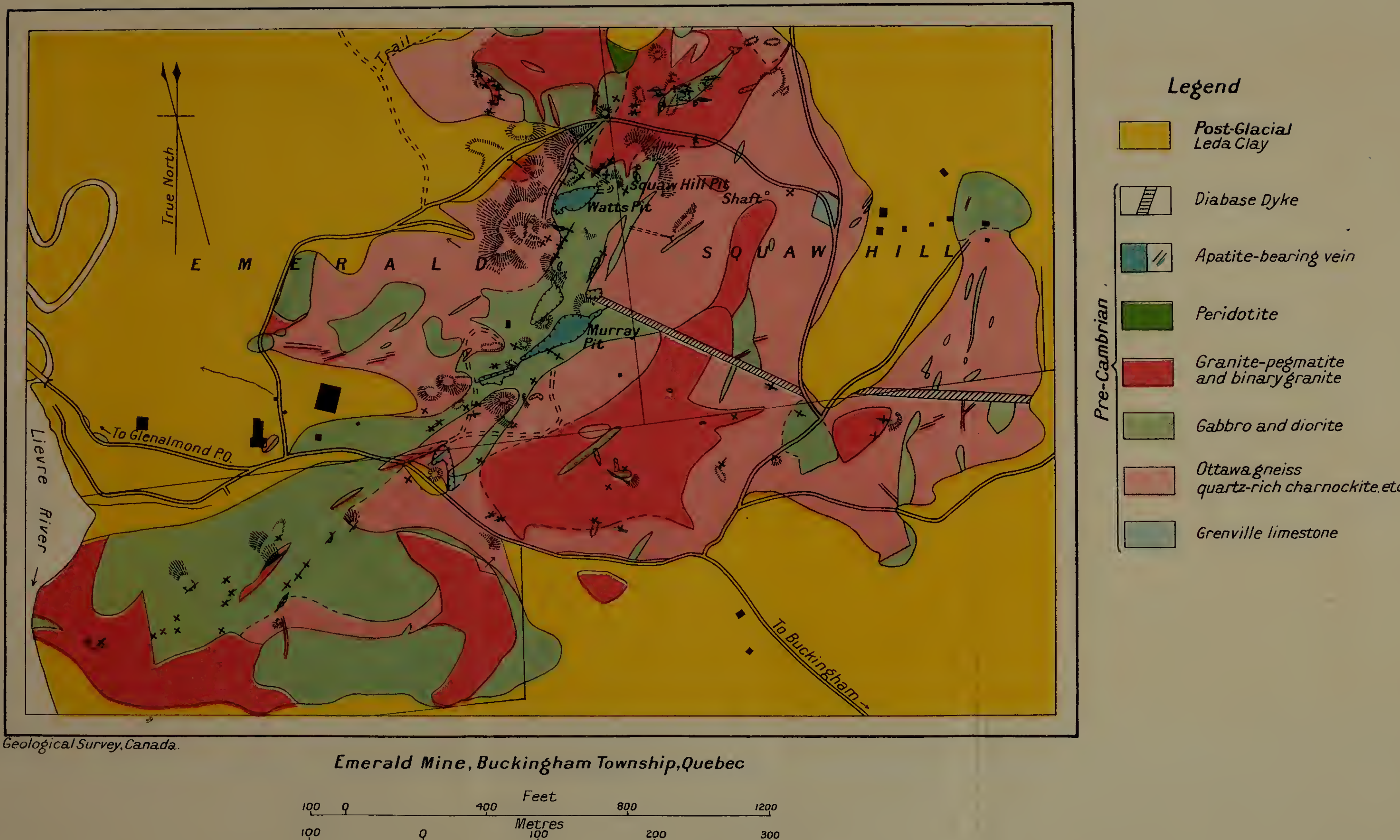
90·6 m. 144·8 km. **Thurso.**—Alt. 186 ft. (56·7 m.). The same conditions continue west of Plaisance, the Pre-Cambrian margin now approaching the railway, now receding for half a mile. Between Thurso and Lochaber the sea-cliff is well-marked.

94·0 m. 150·4 km. **Lochaber.**—At Lochaber there are a few small exposures of well-banded gneiss immediately north of the railway, but from here to Buckingham Junction the Pre-Cambrian margin is again covered.

100·0 m. 160·5 km. **Buckingham Junction**—Alt. 183 ft. (55·8 m.). The journey from Buckingham Junction to Buckingham affords little of interest to the geologist. The road runs over Leda clay to the sea-cliff, which it climbs. Along the upper level, also the index of a former sea-level, the view is interrupted by thick bush. Occasionally the capping of Saxicava sand is visible. Pre-Cambrian exposures occur in Lievre river to the west, but are nowhere visible from the road.

103·0 m. 165·0 km. On the right-hand side of the road, immediately north of the Alexandra hotel at Buckingham, crystalline Grenville limestone is cut by a gabbro dyke. These two are the most important rock types exposed in and around Buckingham. The limestone is part of a band, having a general north-east trend, and the gabbro is important, both as dykes and as larger intrusions. West of the road, at the slight rise where it leaves the town, is a mass of this gabbro. The most important exposures for two miles (3·2 km.) north of Buckingham are of this same type of gabbro. At the bank of the river is a much altered limestone, and limestone is again seen east of the road and the railway.

Miles and Kilometres.	
104·6 m. 167·8 km.	A cliff of gabbro extends along the east side of the road, while, on the west side are black-weathering gneisses of doubtful origin cut by pegmatite veins. These veins do not cut the gabbro on the east side of the road.
107·4 m. 172·0 km.	Thin-banded gneisses on both sides of the road have small areas of limestone associated with them. To the left of the road they are cut by a 40-foot (12·2 m.) diabase dyke belonging to the youngest series.
108·5 m. 174·0 km.	The cliff to the right of the road is composed of well banded gneisses cut by pegmatite dykes. Some of the gneisses appear to be altered sediments. One of these gneisses at the south end of the hill has been prospected for graphite, of which it contains a little. Another prospect in the face of the hill shows ore connected with a dyke of gabbro, very similar in appearance to that found at the Dominion mine. Immediately beyond the next small creek, rises a hill, faced towards the road with Grenville limestone. On the top of this hill is an old prospect, where columnar graphite occurs at the contact of pegmatite and Grenville lime stone.
109·5 m. 175·0 km.	For three-fourths of a mile (1·2 km.) north of this, black-weathering gneisses, mainly of igneous origin, and much cut by pegmatites, which also weather black, are exposed on either hand.
111·4 m. 178·0 km.	The hill on the west side of the road consists of granite gneiss at the southern end, becoming dioritic toward the north. Across the road are gneisses, similar to the hypersthene-granite-gneisses at the Emerald mine and containing the same garnetiferous bands.
113 m. 181 km.	Leda clay with its capping of Saxicava sand, extends from here to the Emerald mine.



Geological Survey, Canada.

Emerald Mine, Buckingham Township, Quebec

THE APATITE DEPOSITS AT THE EMERALD MINE.

Local Geology.

The hill containing the Emerald and Squaw Hill groups of mines rises abruptly from the plain of Leda clay and abuts on the left bank of Lievre river. This proximity to the river facilitated shipmen of the phosphate by water to Buckingham, when the mines were producing.

Grenville limestone, the oldest of the rocks found in this locality, is represented by small remnants of much altered and very impure limestone. Garnetiferous and sillimanite gneisses situated west of the main occurrences of gabbro may represent an argillaceous phase of the Grenville series, though richness in aluminous silicates is about the only evidence of their sedimentary nature. The older gneisses to the east of the gabbro area are for the most part hypersthene-granites rich in quartz. They include garnetiferous bands, and often garnet entirely replaces the pyroxenes, resulting in rocks comparable to the leptynites of French authors. These rocks so closely resemble the charnockites of southern India in their general character and age, that the name charnockite is applied here, due weight being given to Holland's warning regarding the application of this term outside of India.

The older rocks of the above groups have been intruded by binary granite, and again by a younger series of gabbros and diorites, of which the last named often have the form of lenticular dykes. After microscopical study, there appears to be no reason for differentiating these gabbros from each other. Therefore they have received one colour on the map. A later series of pegmatites has cut these and all older rocks, and the pyroxenite dykes carrying the apatite deposits are later than the pegmatites. It has been usual in the past to associate the pyroxenite dykes with the gabbros above mentioned and no evidence contradictory to this opinion has appeared as yet; hence it is probable that these later pegmatites are closely connected in origin with the gabbros, perhaps as acid and basic differentiation products of one parent magma.

The youngest Pre-Cambrian rock in the area is a 50 foot (15·2 m.) dyke of olivine-diabase, which cuts all other rocks indifferently. There is a small area of peridotite on the hill west of the main road whose relations to the other rocks, and age are not discernible. The rock has the characters of a wehrlite.

Character of the Apatite Deposits.

There is a large number of small apatite veins in the hill, but only a few large ones. The smaller veins beautifully illustrate the banded vein structure. Their walls are usually definite and rectilinear, and are covered with a dark green to black comb of pyroxene crystals, light grey granular pyroxene or an aggregate of pyroxene and scapolite. Ordinarily this external layer is not more than a few inches wide. The central part of the vein is filled with apatite or with apatite surrounding a central band of slightly pink calcite, in which are embedded perfectly shaped apatite crystals. The apatite is a green fluor apatite. In the large veins granular masses of "sugar" apatite, which could often be shovelled out without blasting, are more common than the crystalline form. Pyrite and pyrrhotite occur in some of the veins, pyrite being abundant enough in some instances to lower the market value of the mine product. Actinolite has been found only on the dumps. The many and rare minerals associated with similar deposits in Templeton township do not occur here. Rapid local increases in the width of a vein give rise to pockets in which, however, the parallel vein structure persists. Some of these pockets have been worked out to a depth of 50 feet (15·2 m.). Deposits of this type were worked at the Murray, Watt, Boileau and Squaw Hill pits. The pyroxene-scapolite rock is the only vein material that needs description. This veinstone contains, besides pyroxene and scapolite, small quantities of secondary hornblende derived from the pyroxene, tremolite, biotite, titanite, pyrite, calcite, apatite, and aggregates of small mica flakes, which have resulted from decomposition of scapolite. The scapolite has a birefringence which places it nearer to meionite than mariolite. Pyroxene is usually more abundant than scapolite, but examples occur which deserve the name scapolite-gabbro.

The close association of the apatite-bearing veins with the gabbro implies a genetic connection. In further support of this, specimens of gabbro have been collected which contain pockets of apatite about the size of the fist, evidently a constituent of the rock and not displaying banding or vein structure. Apatite-bearing veins cut pegmatites near Watt's pit, on the Lansdowne property south of the main road, and in the north-east corner of the map area.

Petrographical Notes.

Silimanite-gneiss.—Samples of this rock from the northern part of the hill contain a strongly pleochroic, brown biotite as their principal coloured constituent. This mineral occurs in ragged grains and is often micro-poikilitically intergrown with feldspar. Fanlike aggregates are also common. Sillimanite occurs in large grains or as fine needles, at the boundaries between feldspar individuals. Feldspar, including orthoclase and microcline, is an important constituent and is often crowded with inclusions of fine, opaque needles. Quartz, which is subordinate in amount to feldspar, is rich in similar inclusions. The accessory minerals include a small amount of muscovite, zircon—with pleochroic halos when surrounded by biotite—pyrite, leucoxene, and in one case garnet. The pressure to which the rock has been subjected is indicated by strain-shadows in the quartz and feldspar, and by the incipient "mortel-structure," developed more especially in the case of feldspar.

Biotite granulites from the same locality are rich in pink garnets which often have borders of ragged biotite. Brown, strongly pleochroic biotite, orthoclase and microcline are the other essential constituents. Micro-perthite is sparingly represented, and quartz is subordinate in amount to feldspars. Accessory constituents include round grains of zircon, a rich sprinkling of dark brown rutile and very little apatite and pyrite. Strain-shadows are seen in the quartz. Microscopic examination is sufficient to determine whether this is an altered sediment. or of igneous origin.

Muscovite-biotite-gneiss from the same part of the hill consists almost wholly of micas, the biotite being brown and intensely pleochroic. Quartz, a very little orthoclase and some plagioclase are also present, and zircon occurs as an accessory.

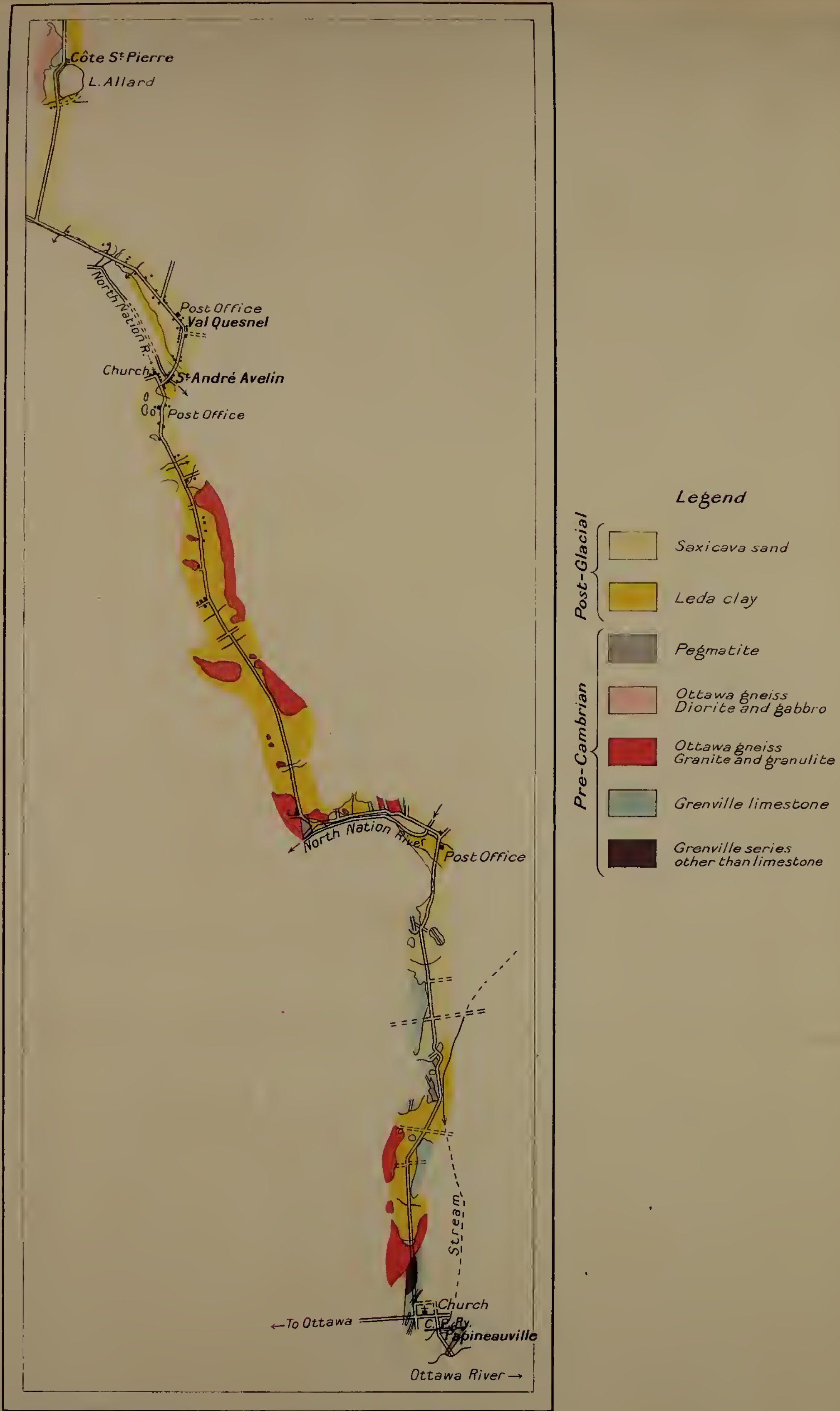
Collectively, these gneisses present evidence of being a series of altered sediments, though if each one were considered separately, it would be difficult to arrive at any definite conclusion regarding its origin.

An altered limestone from the tunnel on the south face of the hill, contains in addition to calcite a green, slightly pleochroic pyroxene, some scapolite and large rounded grains of pink titanite.

Gneiss from the north-east part of the map area has pink titanite as its most important coloured constituent, though biotite and hornblende are also present. Orthoclase and microcline are the two most important constituents; quartz, plagioclase, scapolite and calcite are less important. A very small amount of the quartz is intergrown micrographically with the feldspar. The rock possesses a well-developed gneissic structure due to a parallel arrangement of the mica flakes, to the "mortel-structure," more especially of the feldspars and to the strain-shadows in the quartz. The scapolite shows no evidence of strain-shadows, or granulation, which would indicate that this mineral had been formed subsequently to the application of pressure, or as a result of its application. The micrographic intergrowth of quartz and feldspar indicates an igneous origin for this rock.

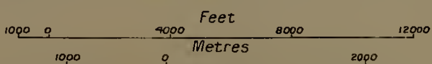
Hypersthene-granite (*charnockite*), typical of the southern part of the hill, is characterized by considerable amounts of strongly pleochroic hypersthene and pink garnet, and a large amount of quartz. In fact, this latter mineral is the only one that catches the eye in weathered hand-specimens. Plagioclase is more important than orthoclase, but both are much subordinate to quartz. Brown biotite and zircon are the only other constituents. The quartz is granulated and both quartz and feldspars show strain effects.

Garnetiferous gneiss. Associated with the hypersthene-granite are quartz and pegmatite veins, and bands of garnet-gneiss, which may be related to the hypersthene-granite in the same manner as similar rock-types are related to the charnockites of southern India. Pink garnet, the most important constituent of this gneiss is very conspicuous in the hand-specimen. It often contains biotite or feldspar inclusions. Brown biotite, an important constituent, has crystallized after the garnet. Orthoclase is much the most important feldspar, though microcline, plagioclase and microperthite are also present. The



Geological Survey, Canada

Route map between **Papineauville** and **Côte St Pierre**



feldspars are crowded with minute inclusions of opaque rods. Ilmenite, with leucoxene borders, apatite, and zircon are accessory constituents.

Gabbro. A specimen of gabbro from the south side of Murray's pit contains a considerable quantity of green hornblende, and of colourless augite surrounded by primary reaction rims of hornblende. There is also a small amount of strongly pleochroic hypersthene. The subordinate remaining portion consists of plagioclase which alters both to scapolite and to paragonite. The rock is a hornblende-hypersthene-gabbro. Osann has described a rock from the same place which carried enstatite instead of hypersthene [**2**].

Exposures of gabbro at the northern edge of the hill differ from this in that they hold reddish-brown biotite and a monoclinic pyroxene having the pleochroism of hypersthene. Some sections of the pyroxene extinguish obliquely at angles like those of augite, while others have straight extinction, and in some sections the former have a slight greenish colour which serves to distinguish them from the latter. It seems likely, therefore, that a part of the pyroxene is hypersthene.

Other exposures near the margins of the hill, more especially on the south and west sides, are intermediate between the gabbro of the centre of the hill and the diorites at the extreme borders. They show the same derivation of hornblende from augite and in some cases a notable amount of primary epidote. Hypersthene is absent, however. Scapolite is a common mineral in these rocks, and in the peripheral diorites.

ANNOTATED GUIDE—(Continued).

Miles and Kilometres.

79·1 m. 126·8 km. **Papineauville**—Alt. 149 ft. (45·4 m.). North of the track at Papineauville railway station is a section showing the relation of the Grenville limestone to other members of the Pre-Cambrian. The limestone which is banded, dips east 65° and strikes N. 42° E. magnetic. Intercalated with it, as illustrated in the accompanying section, is a dioritic gneiss, in part altered to a mica-schist, and also, a more distinctly intrusive binary granite.

Miles and Kilometres.

79·5 m. 127·2 km. The extremely close folding sometimes seen in the impure Grenville limestones, is well shown by an exposure in the bank of the Ottawa river. At 200 feet (61 m.) north of the river bank, a dyke of binary granite, 200 feet (61 m.) wide and continuous with that seen at the railway station, cuts the limestone.

Section in the Pre-Cambrian at Papineauville, Que., north side of railroad.

The slight rise from the river to the level of the village is due to the same sea-cliff which was noticed from the train. Its capping of Saxicava sand is very evident in the streets of the village.

80 m. 128 km. On turning north from the village, exposures of coarsely crystalline Grenville limestone, cut by pegmatite dykes, occur along the road. A broad band of this limestone, more especially developed on the east side of the road, is cut at many places by pegmatite dykes and also by dykes which may be called gabbro-pegmatite.

80.4 m. 128.5 km. A band of richly garnetiferous gneiss is visible on the right side of the road, and farther to the west are exposures of a granulitic batholith, which extends in the direction of Plaisance. The garnet-gneiss is followed by a tongue of the granulite, and this by another small exposure of richly garnetiferous gneiss.

80.8 m. 129.5 km. Leda clay covers the succeding flat area, exposures of the granulite occurring to the west and of limestone to the east.

82 m. 131.5 km. Grenville limestone cut by pegmatite dykes is seen to the right of the road.

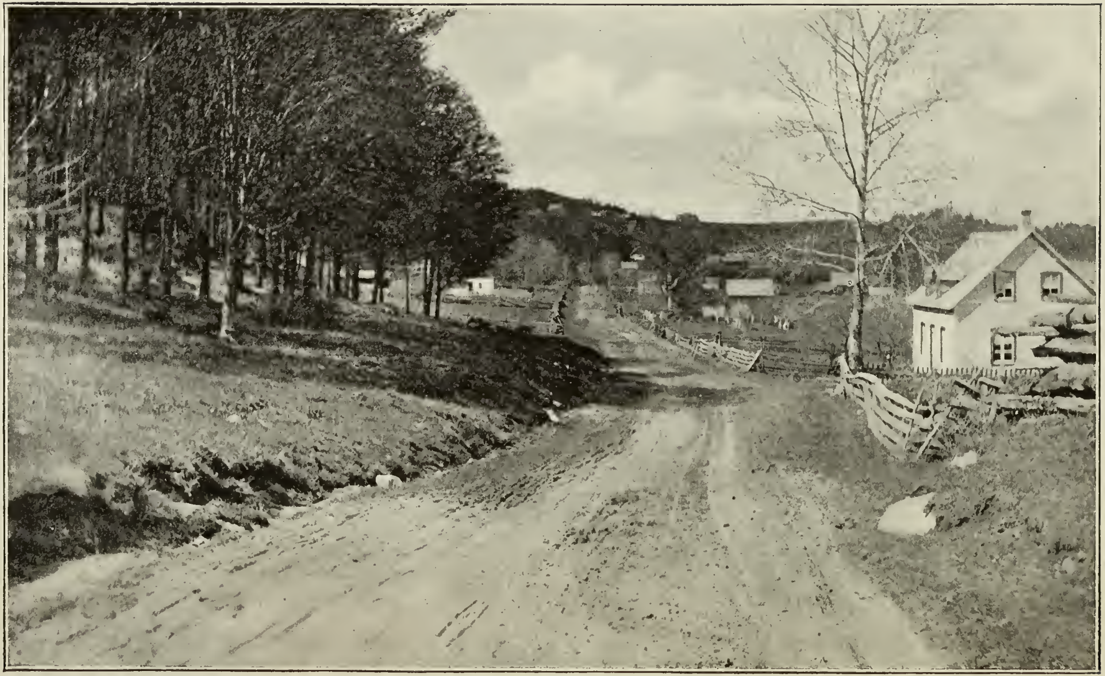
82.6 m. 132.2 km. The Leda clay has a slight capping of Saxicava sand.

Miles and Kilometres.	
83 m. 133 km.	A local pebble beach of the Saxicava sea causes a slight topographic change. Exposures of limestone are passed on either hand, and North Nation river is crossed.
84 m. 134.5 km.	The road follows the north bank of the river, skirting a cliff of granite-gneiss, with which are associated a few minor bands of limestone.
85 m. 136 km.	On both sides of the road Ottawa gneiss of granitic character is exposed. At the turn and rise in the road a binary granite is seen on the left, which obstructs Nation river, causing a fall, the power from which is utilised by a hydro-electric station. After leaving the exposures of granite-gneiss at the top of the hill the road follows a band of Leda clay, through which granite is occasionally exposed at distances of one fourth to one half of a mile (.4 to .8 km.) from the road.
86 m. 137.6 km.	A biotite-tourmaline-granite, typical of the area extending from Nation river to St. André Avelin, is here exposed.
88.6 m. 141.8 km.	A few exposures of impure, banded limestone are observable near St. André Avelin.
89 m. 142.4 km. 92 m. 147.5 km.	Re-crossing North Nation river, the road follows its east bank, in which Leda clay is sometimes exposed beneath a thin capping of Saxicava sand. This continues until Côte St. Pierre is reached.

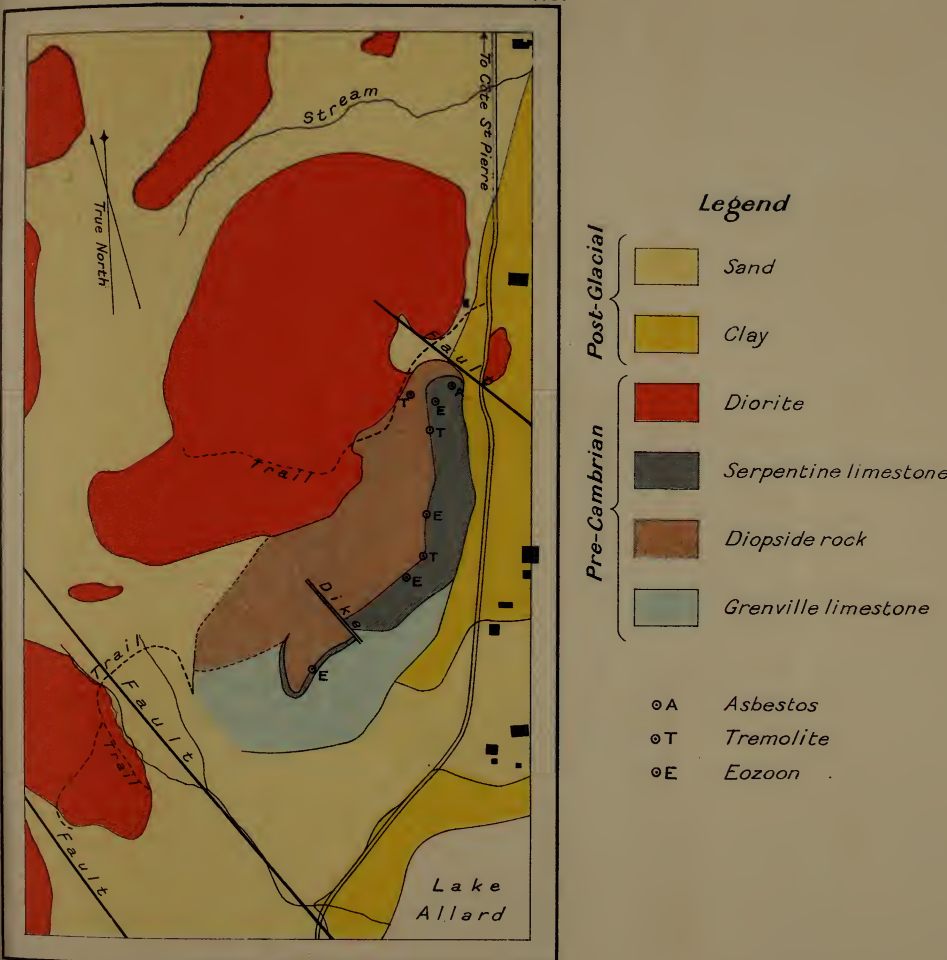
THE EOZOON OCCURRENCE AT CÔTE ST. PIERRE.

Geological Relationships.

In this classic locality the Pre-Cambrian formations are obscured to an unfortunate degree by Leda clay and sand. Two Pre-Cambrian rock-types are present : impure Grenville limestone, and a younger intrusive of plutonic habit, that ranges in composition from biotite-hypersthene-gabbro to quartz-syenite. The contact between the two is characterized by certain important contact metamorphic phenomena. Several N.W.—S.E. faults find topographic expression in the small area included by the map. It would appear from these that either the limestone block had



Côte St. Pierre. Eozoon locality to left of picture.



Geological Survey, Canada

Côte St Pierre

been pushed relatively farther to the north-west than the neighbouring rock-masses, or that these have been moved farther to the south-east than the limestone block.

The Eozoon occurrence can be understood best by first becoming acquainted with the igneous rock, and afterwards working across the contact zone, in which the Eozoon occurs, to the normal limestone. The main part of the intrusive mass is a biotite-hypersthene-gabbro varying in parts of the map area to quartz-diorite or quartz-syenite. So far as the intrusion has been studied there appears to be an increasing basicity towards its margin, probably due to differentiation of the intruded magma.

A quartz-syenite phase of the intrusive from the south-west corner of the map area consists essentially of hypidiomorphic hornblende, orthoclase and biotite, with smaller quantities of augite, micro-perthite, plagioclase, quartz, apatite and ilmenite. A small amount of quartz and feldspar are micrographically intergrown. The hornblende is green and strongly pleochroic : c-very dark green, b-very dark green, a-greenish yellow. Occasionally it encloses kernels of non-pleochroic augite, from which it appears to have been derived during the cooling of the magma. This phenomenon is illustrated by all phases of the intrusive in this locality.

The rock from the north-west corner of the area is composed of the same minerals, but there is no micrographic intergrowth, and plagioclase is relatively more inportant than orthoclase. In a diorite phase from the centre of the map area orthoclase becomes subordinate in amount, and quartz is only sparingly represented. The hornblende is sometimes micro-poikilitically intergrown with feldspar, and the latter mineral is also filled with minute needle-shaped inclusions.

Other specimens, more especially those from near the contact with the limestone, are gabbros. Pyroxenes are more important than hornblende, though still showing incipient reaction rims of that mineral. Both monoclinic and rhombic pyroxenes are present. The rhombic variety has the pleochroism of hypersthene and sometimes occurs as kernels enclosed by augite. Apatite, titanite and magnetite are more concentrated than in those phases which lie further away from the contact.

The actual contact of the gabbro and the altered limestone can be seen at one or two points near the trail which runs from the small boiling-shed at the road-side through the maple bush. For 300 feet (91·5 m.) away from the contact is a light-greenish, almost white rock of coarsely granular texture, which consists almost wholly of diopside, though scapolite, titanite and tremolite are also present. A variety composed solely of tremolite is found more especially at the edge of the diopside rock, away from the igneous intrusion. Between the diopside rock and the normal limestone is a zone of serpentine varying in width from 10 to 100 feet (3 to 30·5 m.). For the most part the serpentine and calcite show the indefinite arrangement of ordinary ophicalcites, but at one or two points they show that arrangement which has given rise to the name Eozoon canadense. It is important in the latter case to note that the width of the serpentine bands varies greatly, some specimens showing 10 bands per inch (4 per cm.), while in others the bands are two inches (4·8 cm.) wide. The normal limestone is found only at the southern edge of the exposure and has the usual impure character, mica flakes being the most conspicuous mineral associated with the coarsely granular carbonates.

Nature of Eozoon Canadense.

Sections of Eozoon have been so often described that it will suffice here to draw attention to the structure of the serpentine. Very often it possesses a "mesh-structure," less often a "knitted," and rarely a "lattice-structure." The two former types are derived from diopside and the latter from tremolite. The meagre development of cleavage in longitudinal sections of diopside is noticeable in thin sections of the diopside rock. For this reason, and also because basal sections would naturally be in a minority in any rock slice "mesh-structure" is more common than "knitted-structure." Mesh-structure is usually regarded as characteristic of serpentine formed from olivine, but in the present case no connexion with any mineral of the olivine family can be established; on the contrary, the serpentine can be found still retaining kernels of diopside.

Osann concluded that this mineral association was the product of thermal metamorphic action on the Grenville limestone [**2**]. The cartographical and further microscopical study made by the present writer support this conclusion. Transfusion of silica in solution, and titaniferous and chlorine-bearing vapours or solutions would provide the conditions necessary for the formation of the minerals found in the field. A later circulation of heated juvenile waters appears to have exercised a selective action upon the outer edge of the altered zone, causing serpentinization of diopside and tremolite, and even at one point forming a vein of asbestos from the serpentine. But while the mineral assemblage found in this locality may be thus explained, no process for the formation of those detailed and beautiful structures which led to the Eozoon controversy is known.

Historical Outline.

Though this is not the locality where Eozoon was first discovered, it has furnished some of the best specimens and it was in specimens obtained here that Sir J. W. Dawson found the structure which he called *Eozoon canadense*. It was first noticed in a specimen from Burgess, Ontario, and was found in place in 1858 at Grand Calumet, Quebec, by Mr. McMullen, of the Geological Survey of Canada. Collections from Côte St. Pierre were made between the years 1863 and 1866 by Mr. J. Lowe, of the Survey. Extensive collections were made by Sir J. W. Dawson and Mr. T. C. Weston, between 1873 and 1877. A great many of these examples were sectioned, carefully examined and faithfully described by Sir J. W. Dawson and Dr. W. B. Carpenter in their final stand in support of the organic origin of the structure, which had been questioned, in some cases by equally careful observers. The importance of the structure from a palæontological point of view, and its recognition in other countries, led to a re-examination of this area by Mr. A. Osann in 1899, under the auspices of the Geological Survey of Canada. In his report he described the igneous rock and its metamorphic effects on the limestone.

ANNOTATED GUIDE—Continued.

Impure Grenville limestone is exposed in the left bank of Lievre river at Buckingham. Close to the water's edge it contains thin bands of apparently igneous material, which have been

Miles and Kilometres.

intensely folded or stretched out, so that a once continuous band of rock has been broken into a string of small isolated blocks. A small inclusion of this character, from the Dominion mine, was examined and proved to be a scapolite gabbro.

130 m. 208 km. For the first mile (1·6 km.) after turning north at McFall's Corners, exposures are not common near the road. The main outcrops are of Ottawa gneiss of igneous origin, chiefly biotite syenites and diorites, with smaller amounts of gneisses similar to the hypersthene-granites at the Emerald mine.

132 m. 211·5 km. Just before reaching the cheese factory, shells (*Astarte laurentiana*, Lyell) are to be seen in the Leda clay on the left hand side of the road. A mass of granulite with included small bands of limestone is exposed opposite the cheese factory.

132·4 m. 212 km. The rise in the road farther north is caused by a bank of sand and coarse gravel, which is exposed just beyond the summit of the rise and shows a stratification parallel to the outline of the hill. This was doubtless a sand-bank in the Saxicava sea close to some local source of fluvio-glacial material.

135·1 m. 216 km. Immediately north of the school-house a small hill of Grenville limestone is visible on the left hand. From here Leda clay continues for two-thirds of a mile (1·1 km.), and for half a mile (·8 km.) along the side road to the mine. The road skirts a hill composed of dioritic gneiss and impure limestone bands cut by pegmatite dykes. Rising over this hill the approach to the Walker mine is covered with Leda clay; while at no great distance on either hand are cliffs and rounded hillocks of dioritic Ottawa gneiss.

THE GRAPHITE DEPOSITS AT THE WALKER MINE.

General Geology of the Locality.

Grenville limestone, the oldest Pre-Cambrian rock in this locality, occurs on the hill above the smaller mill-pond and to the south of the larger pond. Also, in the northwestern part of the area it is represented by a broader band which extends in a direction somewhat east of north. This limestone band is flanked on either side by Ottawa gneiss, the most important member of which is a quartz-rich variety, very similar in appearance to the hypersthene-granites of the Emerald mine. Small graphite bodies are occasionally seen in this gneiss, more especially on joint faces Pegmatitic phases are developed in the extreme north-western corner of the area. Small amounts of para-gneisses may be included in this igneous complex, but as yet none have been definitely recognised.

The larger part of the map area is occupied by more basic varieties of Ottawa gneiss than those just described. They consist of gabbros and diorites with pyroxenite, amphibolite, anorthosite, and hypersthene-gabbro basic variations. Scapolite is of common occurrence in these basic gneisses, which appear to be younger than those described above. In the northern part of the map area a younger gabbro has been separated from the other basic gneisses, but otherwise the relative ages of the intrusions constituting the basic part of the complex remain unknown.

At a distinctly later period in Pre-Cambrian time, the Grenville limestone and Ottawa gneiss were invaded by pegmatite, diorite and gabbro dykes, which probably represent more than one magmatic intrusion. The graphite ore bodies are always found in close association with these dykes. One of the pegmatite dykes has graphite distributed throughout its mass in great abundance.

Geological Relationships of the Graphite Deposits.

The main pit is situated at the foot of a cliff, which, from top to bottom, consists of biotite-diorite-gneiss, a horizontal dyke or sheet of biotite-diorite from 6 to 20 feet (1·8 to 6·1 m.) in thickness and a much altered lime-stone. Immediately to the south the limestone is also in contact with a biotite-rich gneiss different in appearance from the biotite gneiss at the top of the cliff. The graphite ore-body is situated underneath the diorite sheet and at the contact of the limestone with the gneiss. The graphite is in the limestone rather than in the gneiss,

Columnar graphite and altered Grenville limestone, Walker mine [Nelly's pits].

though some of the latter is impregnated with graphite. The ore-shoot is about 30 feet (9·1 m.) wide and the same in length. It strikes N.S. and pitches 57° to the south, and has been worked by means of a tunnel, now filled with water. The ore-body and the igneous sheet above it can be likened to the stalk and head of a mushroom, an analogy which brings out the fact that the ore-body does not lie close to the contact of the intrusive and the limestone.

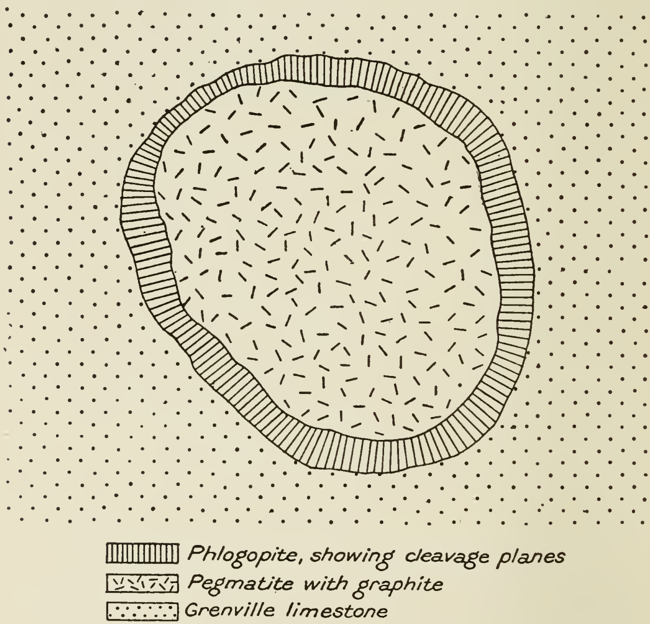
The altered limestone near the ore-body contains in addition to calcite a colourless monoclinic pyroxene, probably diopside; scapolite, which sometimes shows strain-shadows, and, as might be anticipated, has a birefringence near that of meionite; microcline and a little plagioclase, both strained and often broken into small grains; and a considerable quantity of titanite characterized by strong reddish pleochroism. Graphite is associated with calcite and feldspar, more especially with the latter mineral and is for the most part of later formation than these minerals, though in some instances it preceded the feldspar. Pyrite was formed later than the graphite. The rock is banded in structure, some bands being richer in calcite than others. The graphite occurs mostly in the feldspathic bands. The whole rock gives evidence of having been subjected to pressure, subsequent to its alteration, the scapolite showing this more clearly than any other mineral. A thin section of the ore consists chiefly of graphite together with some titanite, a later formed scapolite and still later pyrite which sometimes has grown along the cleavage cracks of the scapolite. The relation of the graphite to the minerals which accompany it is not shown, but the presence of these minerals indicates that the ore is an impregnated altered limestone, a conclusion which is also reached by studying the field relations.

At an opening 500 feet (152 m.) north of the main pit graphite forms bodies one foot in width on both sides of a pegmatite dyke. The flakes of graphite are parallel to the walls of the dyke, and are regarded as impregnations of the country rock. The ore here and at the main pit belongs to the type known as "disseminated ore".

At the now overgrown openings at the extreme south-western corner of the map area (Nelly group of Osann) [**2**], the ore occurs as "vein or columnar graphite". So far as can be seen from the poor exposures, the veins containing graphite are developed near the contact of a gabbro with Grenville limestone. A few specimens of the columnar graphite may be obtained from the dumps, which also furnish apatite, titanite, scapolite and pyroxene, the associated minerals of the graphite veins. Titanite crystals up to the size of a hazel nut can be found and also pyroxene combs like those of the apatite and mica veins. The graphite, where found in place, has its fibres at right angles to the walls of the vein. The veins range up to four inches (·1 m.) in width.

Osann describes a gabbro from this locality [**2**], which has many features in common with the gneiss capping the hill at the main pit. This rock is coloured as gabbro on the map.

At a point above the smaller mill-pond, Grenville limestone is intruded by a small patch of pegmatite, which

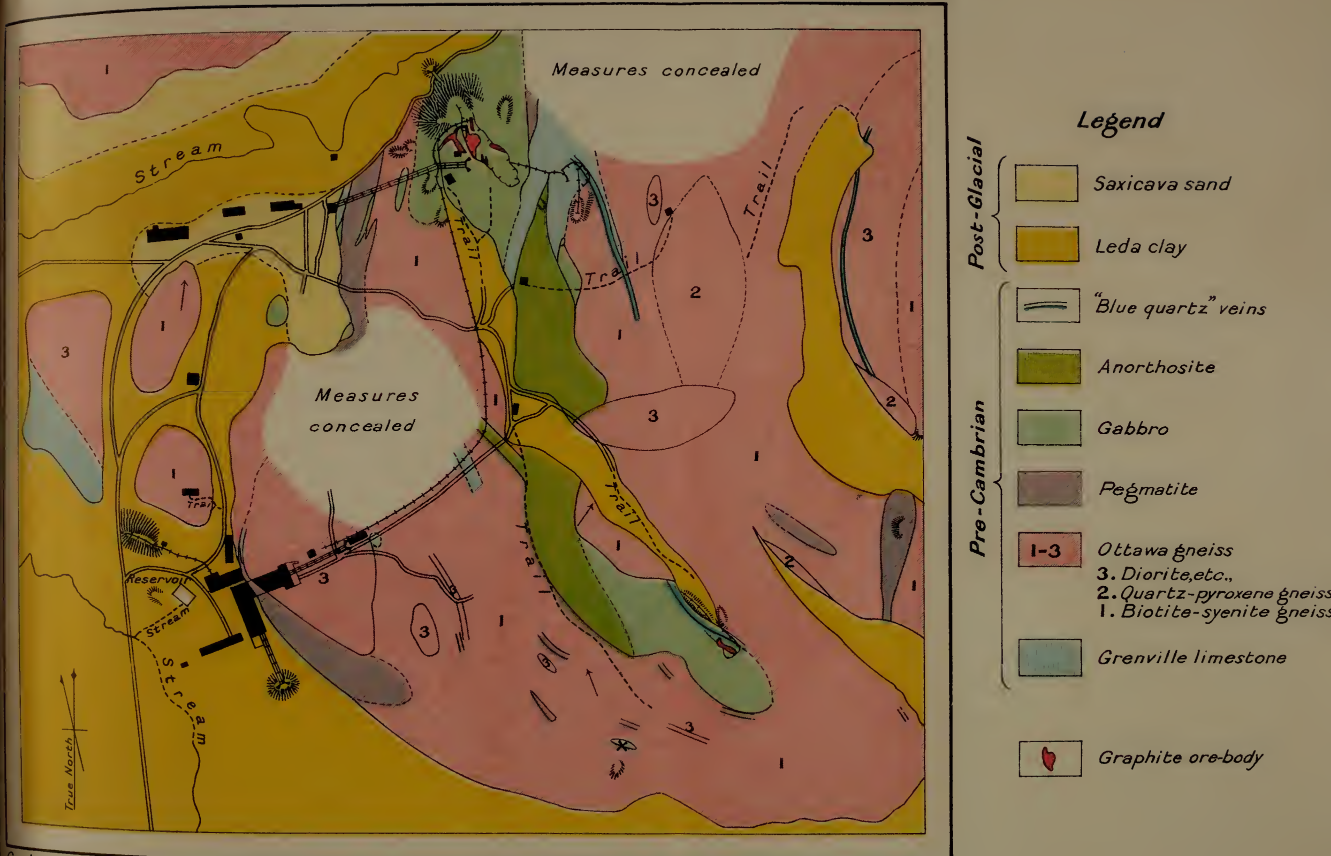


Radially arranged phlogopite rim between graphitic pegmatite and Grenville limestone, Walker mine.

carries graphite within its mass, and is separated from the limestone by a rim of phlogopite in which the flakes of the mica are set at right angles to the margin of the pegmatite block.

Graphite was first shipped from this locality in the seventies, but at that time only columnar graphite was

A.8.



Geological Survey, Canada

Dominion Mine, Buckingham Township, Quebec.

Feet
100 0 200 400 600 800 1000
Metres
100 80 60 40 20 0 200

marketed. The main pit was worked from time to time between 1890 and 1896. The ore was first roasted in kilns and then treated with water to make it more readily crushable, and the graphite was separated by a wet process.

ANNOTATED GUIDE—(Continued.

Miles and Kilometres.

142·8 m. 228 km. The road from Buckingham is followed back to McFall's Corners, and from there a westward direction is taken. The first rock exposed in the road is impure Grenville limestone immediately followed by a rock so rich in garnets that, in the hand specimen this mineral is the most conspicuous constituent. This rock has the character of an altered norite. It is followed by a more normal gabbro, similar in some of its aspects to the diorite which caps the hill above the main pit at the Walker mine. This gabbro is cut by two broad, parallel dykes to which the convenient field name, "blue quartz veins," has been applied. The first one has a width of 200 feet (67 m.), and the second a width of 60 feet (18·2 m.). From this hill to the Dominion mine black and rusty weathering gneisses alternate with Grenville limestone.

THE GRAPHITE DEPOSITS AT THE DOMINION MINE.

In the vicinity of the Dominion mine, Grenville limestone and a small amount of associated sillimanite-gneiss have been intruded by mica-syenite-gneisses. These, in their turn, have been intruded by quartz-pyroxene-gneisses comparable to the hypersthene-granite-gneisses of the Emerald mine, and by diorites, pegmatites and gabbros. The age relations of these various intrusives are not always clear; the nearest approach to a chronological order, at present possible, is shown in the legend of the map. Many small pegmatite and diorite dykes occur in the gneisses of the area.

The rocks that command attention most are the varieties of gabbros with which the graphite ore-bodies are associated. These have intruded the Grenville limestone and older gneisses and have caught up masses of limestone within themselves. Graphite has been deposited either at the junction of the igneous rock with its country rock, or in the included masses of limestone, or in the body of the igneous rock itself. Hence, the ore may be impregnated gneiss, impregnated limestone, or impregnated gabbro or pyroxenite. It occurs in the form known as "disseminated" graphite, but not as "vein or columnar" graphite.

The occurrence at the main pit is the most instructive. Here the ore occurs in a shoot of roughly lenticular cross-section, which sends offshoots or stringers into the surrounding rock. The whole ore-body occurs within a mass of gabbro, in which there are also "horses" of limestones, near which the graphite is more concentrated than elsewhere.

The gabbro appears to be a normal type, except that it sometimes contains small quantities of quartz and of graphite.

Both gabbro and ore are cut by "blue quartz veins," which seem to be the latest products of the gabbro intrusion. These veins are composed largely of quartz filled with minute inclusions, a variety of hornblende showing grass-green, drab and light yellow pleochroic tints being the only other mineral of importance. A little pyrite and graphite are the only other minerals present. The graphite is in part earlier than quartz, and in part later.

A sample of ore from this pit proved to be a pyroxenite composed mainly of grey augite. Brown, strongly pleochroic biotite is common; orthoclase, a smaller amount of plagioclase, titanite with strong reddish pleochroism, interstitial quartz, and a minute quantity of brown hornblende are also present. Pyrite is older than the pyroxene, but graphite is one of the latest minerals to be formed. It occurs along the cleavage cracks of biotite, and at some points can be seen penetrating two adjacent grains of feldspar or of quartz. The presence of quartz in a pyroxenite is another interesting feature.

Other minerals associated with the graphite are apatite, in masses up to the size of a hen's egg, pyrite, sometimes as veins of honeycomb or drusy nature cutting the ore, and molybdenite, of which a few flakes have been recognized.

Some examples of the calcareous ore, from their appearance in hand-specimen, indicate that the calcite, though probably derived from the limestone, was dissolved by the waters accompanying the igneous intrusion and re-deposited from solution, along with the graphite. This calcite has a distinctly different appearance from that of the ordinary Grenville limestone.

About 200 feet (61 m.) southeast of the main pit is another opening, in which one of the blue "quartz veins" is seen cutting Grenville limestone. A dense aggregate of graphite flakes reaching a thickness of one foot was found on both sides of the vein.

At the swamp pit, not now exposed, highly altered limestone is in contact with a biotite-gabbro, which is cut by "blue quartz veins." The ore, which attained two or three feet (·6 to ·9 m.) in thickness, was entirely within the gabbro.

An interesting section is to be seen at the opening in the south face of the Pre-Cambrian area. At this point, where the rocks have a dip of 60° to the north, there is a band of ore one foot (·3 m.) thick at the contact between sillimanite-garnet-gneiss and an overlying limestone. Near the ore the limestone is dark blue in colour with lighter yellowish patches in it up to the size of a hazel-nut. Above this the limestone is coarsely crystalline. The cause of this colouration is not known.

The Dominion mine was opened up in 1910 and the mill was erected in the latter part of that year. Work was continued until the latter part of the summer of 1912. The ore is roasted in kilns at the top of the hill so that it may be more readily crushed, and passes by gravity through a series of crushers. On reaching the mill the graphite flakes are flattened and separated by a dry process, the fine rock powder passing through rotary screens which do not allow the graphite to pass.

ANNOTATED GUIDE (continued).

Miles and Kilometres.	
154·6 m. 247·5 km.	Immediately west of Buckingham Junction station the Lievre river falls over the Pre-Cambrian margin just before joining the Ottawa river. Continuing westward, the railway follows the Pre-Cambrian margin, which is more masked by the blanket of post-Glacial deposits than it is to the east of Buckingham.
158·4 m. 253·5 km.	**Angers**—Alt. 183 ft. (55·7 m.).

Miles and Kilometres.

164·3 m. 263 km. **East Templeton**—Alt. 159 ft. (48·4 m.). Ottawa gneiss of a granitic character is much cut up here by pegmatite and quartz veins, which are easily seen from the railway. A short distance farther west the top of the Potsdam scarp can be seen on the left hand, between the railway and the Ottawa river.

The Gatineau river is crossed about two miles above its junction with the Ottawa.

173·1 m. 276·5 km. **Hull**—Alt. 189 ft. (57·5 m.). Before reaching Hull, quarries in the Trenton limestone are passed, which admirably display the character of this formation in the vicinity of Ottawa. The other members of the Ordovician are not exposed along the railway.

175 m. 280 km. **Ottawa** (Broad St.)—Alt. 175 ft. (53.3 m.).

176.9 m. 283 km. **Hull**—Alt. 189 ft. (57.5 m.) The railroad crosses the Ottawa river a half mile (.8 km.) above Chaudière falls and runs north along the west bank of the Gatineau river which debouches into the Ottawa at Hull. Chaudière falls and the gorge below are in Trenton limestone, which underlies the north and west parts of the city of Ottawa. To the east and south-east, Utica shale, having an estimated thickness of 400 feet (112 m.), conformably overlies the Trenton. It has yielded *Triarthrus becki*, Green, *Isotelus canadensis*, *Leptograptus flaccidus*, Hall, *Orthograptus quadrimucronatus*, Hall, and many other Utica fossils. A half mile (.8 km.) west of the railway bridge across the Ottawa, the Trenton series is terminated by the Hull and Gloucester fault which, starting in the vicinity of Rigaud, runs west toward Ottawa for a distance of 65 miles (104 km.), then curving toward the north crosses the Ottawa river at this point and Gatineau river about Ironsides village. Immediately west of the fault near the Ottawa river the Trenton is succeeded by Black river limestone, with the Chazy series still farther west. All the Palæozoic sediments in the vicinity of Ottawa are nearly horizontal, except near faults

Miles and Kilometres.

where the dip rises to 75°. Excellent exposures of flat-lying Trenton limestone are to be seen on both sides of the railroad in the vicinity of Hull. From these limestones, which have a total thickness of about 600 feet (183 m.), more than 50 species of fossils have been recorded, including *Plectambonites sericeus*, Sowerby, *Pachydictya acuta*, Dekay, *Zygospira recurvirostris*, Hall, and others.

The faulted northern boundary of the Trenton, where it abuts against beds of the Chazy series, is not exposed, being covered by a heavy deposit of Leda clay. This conjunction of clay and limestone, both of a high degree of purity, is as advantageous for the production of cement as any in the country. The large plant of the Canada Cement Co. testifies to these propitious geological conditions. Extensive quarries for building stone, lime and cement have also been opened in the Trenton limestone.

177.6 m. **Maniwaki Junction**—
284 km.

180 m. **Ironsides**—Alt. 182 ft. (55.3 m.). The Chazy,
290 km. Calciferous and Potsdam formations appear in that order toward the north, the Potsdam resting unconformably on the Pre-Cambrian. All of these formations and their faulted western contact with the Pre-Cambrian, are covered along the Gatineau Valley railway by Leda clay which is in turn covered by Saxicava sand, though in places this has been subsequently removed, as for example between Maniwaki Junction and Chelsea.

184.1 m. **Chelsea**—Alt. 365 ft. (110.6 m.). Immediate-
295 km. ly north of Chelsea station the first exposures of Pre-Cambrian are found. On the east side of the track is a richly garnetiferous gneiss with vertical banding, which is cut by pegmatite veins.

185.1 m. Grenville limestone intruded by binary
296 km. granite and mica diorite is exposed in a cutting at this point. The limestone is in highly inclined or contorted bands of various thicknesses. Further north the limestone is followed by more exposures of binary granite.

Miles and Kilometres.

186.6 m. 298 km. **Tenaga**—Grenville limestone is exposed in the bed of the small creek to the west of the track. The Gatineau river has a large and strong whirlpool at this point.

The chute below Kirk Ferry owes its existence to a band of Grenville limestone, followed on the upstream side by a band of syenitic and granitic gneiss. The strike of the contact is approximately at right angles to the river, and the different resistance of the two rocks to erosive forces has given rise to the fall. The limestone is exposed in a cutting just below the fall, where associated intrusions of binary granite and gabbro, the latter with typical veins of the mica-bearing type, can also be seen. A two foot (·6 m.) vein of mountain cork in the same cutting is worthy of passing mention. Immediately north of the cutting, vertically disposed gneissic banding is excellently displayed in the face of a small cliff to the right of the railroad track.

187.9 m. 300 km. **Kirk Ferry**—Alt. 294 ft. (89.9 m.). After crossing the river and climbing up a bank of Leda clay the road runs along the edge of a hill of granite-gneiss which is typical for the district, though in some places, for example the north hill of the Nellis mine, gneissic banding is more strongly developed.

Tourmaline pegmatites are a feature of the district, and several of them, cutting the granite-gneiss, can be seen from the road.

190.7 m. 305 km. Near the bend in the road can be seen an exposure of very impure limestone. In addition to carbonates this rock contains pyroxene, plagioclase, microcline, light brown mica, titanite and pyrite. On the roadside approaching Blackburn creek, Leda clay is exposed. This is one of the few points in the district where the lamination can be seen. Granitic gneiss is exposed just east of Blackburn creek, and the exposures to the south have similar rocks much injected by pegmatitic dykes and veins.

Miles and Kilometres.

192 m. 307 km. An exposure of Grenville limestone at this point is followed by granite-gneiss, which is intruded by pegmatite, and, still later, by two dykes of diorite. South of the post office at

194.7 m. 312 km Cantley, a series of black and rusty-weathering gneisses make a slight rise to the west of the road. Turning in at the road to the mine a small outcrop of limestone is passed and the north hill of the Nellis mine is reached.

THE MICA DEPOSITS AT THE NELLIS MINE.

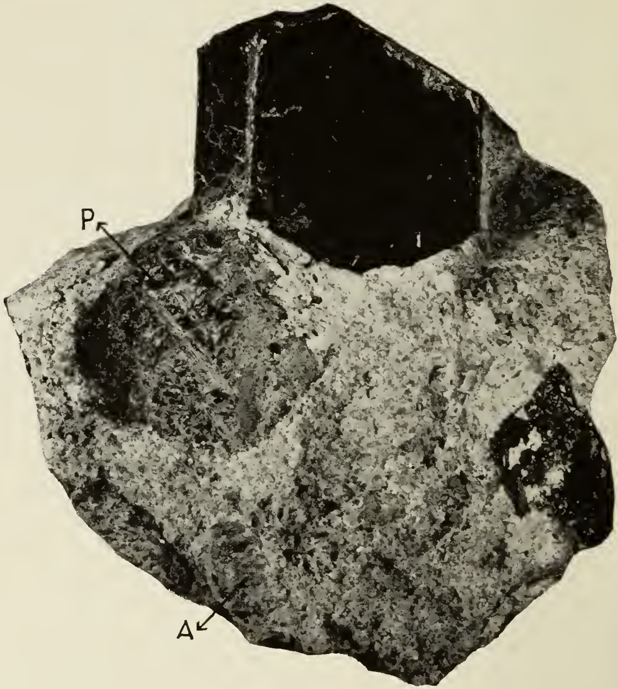
Geological Relationships of the Deposits.

The veins worked at the Nellis mine occur on two "hills" separated from each other by a clay filled hollow, in which a small post-glacial creek has cut a deep valley.

On the north hill, which is shown on the map, the Ottawa gneiss is intruded by a small stock of scapolite gabbro, and by an elliptical intrusion of gabbro-pegmatite. Mica-bearing veins cut all of these rocks. The Ottawa gneiss is an augite gneiss similar to the granite-gneiss seen along the road, except that the gneissic banding is more strongly developed. It is cut, without regard to the direction of the gneissic banding, by mica-bearing veins. The greater part of the gabbro contains an important amount of scapolite in addition to augite and minor amounts of plagioclase, phlogopite, sphene, apatite and sulphides. A sugary anorthosite phase occurs at two points. Another variation from the average type occurs at the east central part of the stock. It is a black amphibolite, in some specimens of which epidote can be seen in the hand-specimen, though hornblende is the sole constituent of importance. The gabbro-pegmatite is composed of feldspar with a little quartz. The feldspar is chiefly microperthite with some microcline and plagioclase.

Character of the Veins.

Mica-bearing veins occur more abundantly in the gabbro area than in the gneiss or gabbro-pegmatite. They form a parallel series, striking N. 68° E. (mag.) at the northern end of the hill, and swinging round to N. 23° E. (mag.), at the southern end. Only one vein runs at right angles to this general direction. The veins are about 15 feet (4·5 m.) apart on the average, and dip to the east from 37° to 87°. The vein walls are rectilinear in the gneiss and gabbro-pegmatite, but in the gabbro they are more inclined to irregularity. A banded vein structure is general, the typical vein having a comb of black or dark pyroxene crystals growing at right angles to the vein-walls



Mica [phlogopite] with pyroxene [P], apatite [A] and calcite. Vein matter,

and possessing terminal faces on the ends which project into the vein. Next to each pyroxene layer is a band of mica crystals, with their cleavage planes more often parallel to the vein-walls than at right angles. Each mica layer is succeeded by one of green apatite, and the centre is

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Nellis Mine, Cantley, Quebec

Feet
100 0 200 400
Metres
50 0 100

filled with pink or white calcite. Individual veins may lack the apatite, or the calcite, but more often the two occur together in the centre, perfectly formed apatite crystals being embedded in the calcite. Sometimes perfect crystals of phlogopite are also found embedded in the calcite. The calcite gives a strong strontium flame reaction. Quartz, fluorite, tourmaline and actinolite are of less frequent occurrence.

Some of the veins follow lines of faulting. Sometimes also they are displaced laterally for a few feet, but whether this is due to subsequent faulting or to an original discontinuity of the fractures cannot be determined under present conditions. Changes in thickness of the veins are more common in the gabbro than in the other types of country rock. Bulging and narrowing of the vein is especially well seen along the main lead. The same variation is shown in depth, a vein which may be only one foot (·3 m.) in width at the surface widening to 10 to 15 feet (3 to 4·5 m.) underground. An example of this can be seen at the south face of the hill. This characteristic is recognized in prospecting, and further work on apparently lean veins at the surface has been rewarded frequently by the discovery underground of wider veins carrying important bodies of mica. At present the veins are being worked for mica, the apatite being taken out and stocked on dumps.

The south hill is occupied by a mass of binary granite intruded by a dyke-like mass of scapolite gabbro similiar to that occurring at the north hill. The veins are found more especially along the eastern face of the hill near the gabbro dyke, and strike parallel to those of the north hill. The veins are exactly similiar to those seen on the north hill, except that calcite is almost lacking, and the apatite is usually of a reddish colour rarely seen on the north hill.

ANNOTATED GUIDE (continued.)

Returning to Kirk Ferry, granite-gneiss and intrusive pegmatites are seen west of Langside farm, and, at the rise in the road, a mica vein is exposed. Opposite Wilson's farm the gneiss is cut by an aplite dyke, composed of plagioclase and quartz, with a little magnetite.

At the bend of the road just beyond, a white Pre-Cambrian quartzite is exposed on the west side of the road. This rock has been thoroughly cemented, quartz being deposited around, and in crystalline continuity with the original grains of sand.

Opposite Farmer's cottage the granitic gneiss of the district is intruded by tourmaline pegmatite, rich in tourmaline. The feldspar of the rock is microcline, and in thin section the tourmaline is brown and shows zones of colouring. North of the road at this point, and distant about 200 yards (183 m.) from it, is a gneiss very rich in pink garnet.

The extensive intrusion of pegmatite veins to which the Pre-Cambrian gneisses have been subjected is illustrated near the ferry by a few patches of granite-gneiss which outcrop through the Leda clay.

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EXCURSION A 10.

PLEISTOCENE—MONTREAL, COVEY HILL AND OTTAWA.

By J. W. Goldthwait, W. A. Johnston and Joseph Keele.

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INTRODUCTION.

BY

J. W. Goldthwait.

The purpose of this excursion is to study certain records of submergence of the St. Lawrence valley by the sea at the close of the Glacial period. The evidences of this submergence are both geologic and physiographic. Clays containing marine shells of an arctic or sub-arctic fauna will be seen at altitudes a few hundred feet above the present level. Wave-built beaches, marking the former stand of the sea against the hillsides will be visited and critically examined at various altitudes up to 570 feet. Particular attention will be given to the determination of the upper limit of submergence.

Of the three localities visited, Montreal lies on an ancient island of the Pleistocene sea, near the middle of what was then the great St. Lawrence embayment. Covey hill lies on the south shore of this Pleistocene estuary in a critical position with reference to earlier, higher water levels; for while the ice sheet still rested against its northern slope great pro-glacial lakes occupied the valleys of Lake Ontario and Lake Champlain. Ottawa lies far up one of the long arms of the Pleistocene embayment, on the north side. Here, as well as in the other localities, the relation of the marine sediments to the earlier, ice-laid deposits will be seen.

On the outline map which accompanies this guide, the south shore of the ancient Champlain Sea is shown from the City of Quebec to Lake Champlain and the Adirondacks; also the altitudes of the highest marine beach, in feet above sea level, at several localities in this district.

THE UPPER MARINE LIMIT AT MONTREAL.

BY

J. W. Goldthwait.

The question of the upper limit of marine submergence at Montreal has long been a disputed one. Unusual interest is attached to the locality because of contradictory opinions of such experts as Sir Charles Lyell, Sir William Dawson, and Baron Gerard deGeer.

Mount Royal is one of several volcanic mountains which rise above the St. Lawrence lowland. The St. Lawrence lowland, which surrounds the mountain on every side, is a plain of subaerial denudation base-leveled during the Tertiary, covered by the North American ice sheet during the Glacial period, and upon its withdrawal deeply submerged by the sea. Marine sediments extend far and wide over it. Exposed at many places are shells of marine species similar to those now living in polar regions. Since the withdrawal of the ice the region has emerged from the sea, in this locality to a height of nearly 600 feet (182 m.). Although the exposed position of the mountain which, during the great submergence, was an island in the sea, was highly favorable for wave work, the side slopes of the mountain were in most places too steep for such action, particularly at higher levels.

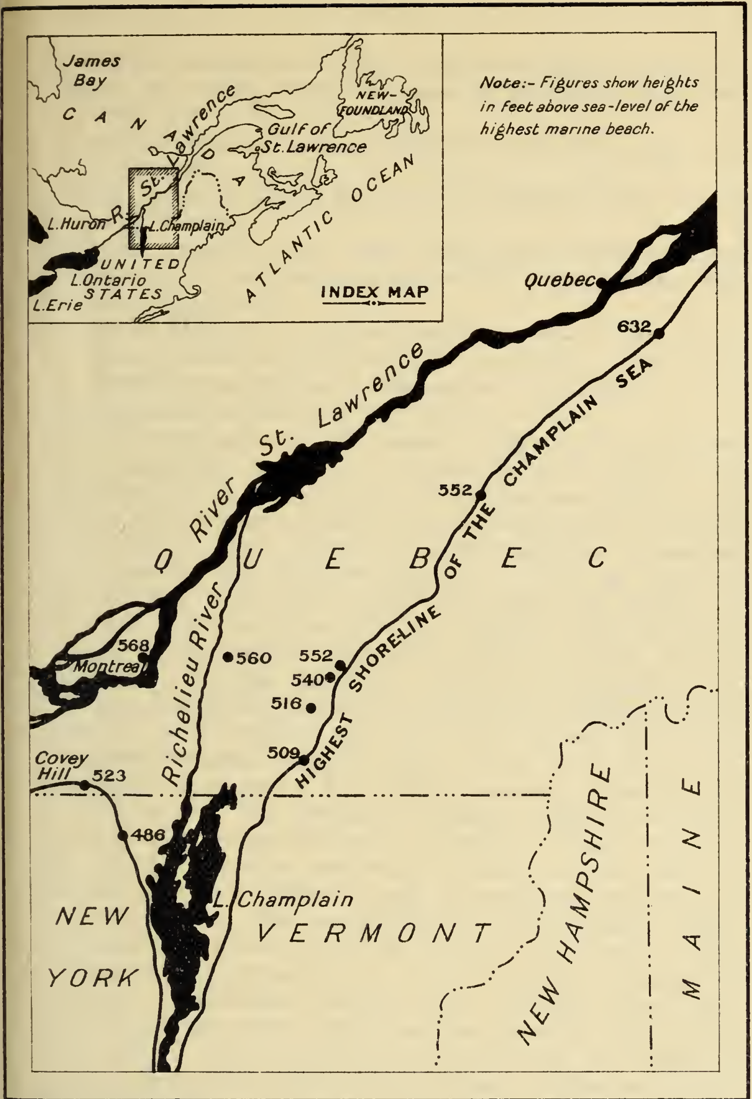
The discovery of marine shells on the grounds of McGill University and at higher places on the mountain long ago raised the question as to how deeply the mountain had been submerged. Sir Charles Lyell reported a beach which contained Saxicava shells at 470 feet (143·25 m.) on the south-west side of the mountain above Côte des Neiges village. His description of this locality given in his "Travels in North America" makes it seem probable that the shell-bearing deposit lies beneath boulder clay rather than above it, and hence is to be interpreted as an inter-glacial marine deposit instead of a deposit formed during the last submergence. In any case it is now known that the recent submergence reached to higher altitudes than this. Sir William Dawson, an ardent follower of Lyell, accepted in full his "drift theory" which accounted for all boulder clay by the grounding of icebergs and pack ice in shallow waters over a temporarily submerged coast. From the occurrence of erratic Laurentian boulders on the summit of Mount Royal he argued, as late as 1893, that the entire mountain had been submerged. This put the minimum limit of submergence above 700 feet (213·3 m.), [**3**, p. 63]. The highest shell locality reported by Dawson was 560 feet (170 m.) above the sea. In 1892 Baron deGeer, accompanied by Professor F. D. Adams, selected as the highest level of submergence a bench and cliff on the northwest side of the mountain behind Mount Royal cemetery. The altitude of this bench was given as about 625 feet (190·5 m.) [**2**, pp 454-457]. DeGeer's determination has since been very generally accepted.

During the last four years detailed studies for the Geological Survey of the records of marine submergence in the St. Lawrence valley have thrown new light upon features which may be expected on Mount Royal. The following points are important:

(1) Transported boulders are of no value as an evidence of marine submergence. While they are plentifully scattered over the area which is known to have been submerged, they also occur at all altitudes above the level of submergence where they have been left by the continental of ice sheet.

(2) In spite of statements to the contrary, wave cut benches and sea cliffs are almost unknown along the upper line of marine submergence in the St. Lawrence valley. From near Gaspe peninsula southwestward 400 miles (643·7 km.) to the Champlain valley, the upper marine limit is marked by weakly built bars of gravel and obscure beaches, never by strong cliffs. This is true even on the exposed headlands. Experience shows that it is a mistake to look for wave-cut benches. Evidently this coast was already rising from the sea when the ice first uncovered it, and the waves did not have opportunity to cut sharply into the shore.

(3) Accurate measurements of altitude on the uppermost gravel beaches in the district between Quebec and Lake Champlain, including that portion of the old shoreline which lies 40 miles (64·4 km.) southeast of Mount Royal, points to the probability that the submergence on this mountain is between 500 and 600 feet(152·4 and 182·8 m.).



Geological Survey, Canada

South shore-line of the Ancient Champlain Sea

Miles: 10 0 20 40 60 80 100

Kilometres: 10 0 50 100 150

(Scale of map is approximate)

Among the localities east and southeast of Montreal are:—

Roxton, 50 miles (80·5 km.) east of Montreal, 552 feet (168·2 m.).

A point 5 miles (8 km.) southwest of the last, 540 feet (164·6 m.).

Granby, 40 miles (64·4 km.) east of Montreal, 516 + feet (157·2 m.).

Dunham, 45 miles (72·5 km.) southeast of Montreal and 12 miles (19·3 km.) north of the Vermont line, 509 feet (155·2 m.).

Mount St. Hilaire, an isolated island 20 miles (132·2 km.) east of Montreal, 560 + feet (170·7 m.).

Nowhere southwest of Quebec has the highest beach been found above 600 feet (182·8 m.).

An examination of the slopes of Mount Royal shows distinct gravelly beaches in several parts of the city up to 300 feet (91·4 m.) and various benches and cliffs on the steeper higher slopes of the mountain, especially in Mount Royal park. There is little if any reason for regarding these benches and cliffs as wave cut. They are discontinuous, not horizontal, cluttered with cliff debris or clay, not with wave-worn beach deposits, and in short are exactly the sort of benches which one might find at any level on these weathered, glaciated mountain sides. The only favourable place for rapid beach building on the mountain between 500 and 600 feet (152·4 and 182·8 m.) is around the park ranger's house and at the back of the Protestant cemetery. Here light gravelly beaches do in fact occur. The ground is gently sloping and well covered with unconsolidated material. Near the rear gate of the cemetery, excavations along a cart road at 600 feet (182·8 m.) show rough unwaterworn rubble and sand formed by the weathering of the eruptive rock. It is hard to see how this loose material could have been submerged without receiving at least a thin sheet of assorted sediment. Proceeding through the cemetery from this point down the gentle slope one comes within 100 yards (91·4 m.) to a low, yet fairly distinct ridge, the form of which is very much like that of a beach. This was being excavated for burial lots in June 1913, and its gravelly composition was then plainly exposed. It can be traced eastward for 150 yards (135 m.) or more through the cemetery, although it has suffered somewhat from artificial grading. It seems to be the highest place where gravels occur in the cemetery. Its altitude is 540 feet (164·6 m.) above the city datum, or 564 feet (171·9 m.) above tide.

The park ranger's house stands on the rim of a wide swampy hollow or cove whose floor is a little below 570 feet (173·7 m.). Across the mouth of this cove just north of the park slide is a low, spit-like ridge of gravel. More distinct spits occur at slightly lower levels southwest of the park slide near the southeast corner of the race track. These appear to have been formed by waves beating around the exposed southeast corner of the island, and trailing beach material into the sheltered cove behind it. According to Mr. Ardley, curator of the Peter Redpath Museum, Sir William Dawson's highest shell locality is here, at the point where the park ranger's ditch crosses the gravel spit. The altitude is 568 feet (173·1 m.).

THE UPPER MARINE LIMIT AT COVEY HILL AND VICINITY.

By J. W. Goldthwait.

Covey hill lies 35 miles (56·3 km.) south of Montreal, and only one mile (1·6 km.) north of the New York boundary. It is the northeasternmost hill of the upland of sandstone which flanks the Adirondack mountains of northern New York. Southeast of it is the great lowland of Lake Champlain; southwest of it is the lowland of Lake Ontario. Northwest, north, and northeast of it is the great lowland of the St. Lawrence, which has already been described and which stretches unbroken from Covey hill far beyond Mount Royal

The presence of marine shells in the clays which cover these lowlands on three sides of the Adirondack foot hills indicates that the late Pleistocene sea extended around it in Vermont and New York. Distinct beaches on the slopes of these foothills mark the old shore lines of this sea. The beaches occur, not only at altitudes close to those of localities where shells have been discovered, but at higher altitudes; indeed there seems to be a development of beaches wherever conditions of exposure, slope, and beach material were favorable, up to 525 feet (160 m.). Shells, however, are almost unknown above 300 feet (91·4 m.).

The question of the altitude of the highest marine beach in this district is complicated by the presence both in the Champlain valley and in the Ontario valley of higher shore lines which have generally been referred to temporary pro-glacial lakes, that is to say, lakes in basins whose natural northern outlets were for a time covered by the ice sheet as it withdrew from the lowlands but still overlapped the Covey Hill highlands and those of northern Vermont. According to Professor J. B. Woodworth [**10**, pp. 66-265] the higher beaches of the Champlain valley which would reach Covey hill at an altitude above 700 feet (213·4 m.), if they extended as far north as that, do not continue around the north side of the hill, but seem to vanish some where between West Chazy, New York and the international boundary. It is inferred from this that the ice sheet covered Covey hill while these beaches formed in a "glacial Lake Champlain." On the contrary, according to Professor H. L. Fairchild there are beaches and deltas of a water plane above 700 feet (213·4 m.) on the Ontario side, which may perhaps be carried around the Covey Hill district by correlation with obscure delta deposits and found to correspond with the distinct beaches at West Chazy. The water plane thus restored is believed by Fairchild to be marine, and to extend over the Champlain-Hudson divide at Fort Edward, N.Y. and down the Hudson river to sea level at New York city. The observations upon which Professor Fairchild bases this conclusion have not yet been published. The importance of so critical a correlation of beaches on the Ontario and Champlain sides of the Adirondacks demands for satisfactory support a very large number of accurate measurements of altitude along the shore line in question.

The determination of the upper marine limit at Covey hill can hardly be reached by a search for marine shells however diligent. Rarely have shells been discovered at or near the line of maximum submergence. Montreal and Rivière du Loup are the only localities where this has been the case. Shells can be relied upon simply as an index to the fact that the sea stood at least as high as they occur; the marine beaches ordinarily extend up to much higher altitudes. This is due not simply to the failure to look carefully for shells at the upper limit but apparently to the fact that shellfish were most numerous and best preserved in the deeper waters off-shore. In the Covey Hill district shells have been found only as high as 260 feet (72·2 m.). Artificial excavations on both sides of the road, a half mile south of Hemmingford village show a large number of *Saxicava arctica* in a loosely packed deposit of very coarse gravel. The presence of complete shells with valves shut together, standing in attitudes of growth between heavy cobblestones, shows a surprising capacity in *Saxicava* to withstand heavy surf. It is perhaps strange that the shells have not been dissolved away, where so much open space is present. The upper three or four feet of the deposit, however, are barren; and the abundance of shells in the underlying strata may be due to the presence until very recently of the water table at that height. The upper, barren zone, shows considerable oxidation of iron, while the fossil-bearing beds are of blue colour.

A better guide to the upper marine limit consists in the wave-built beaches, which in this district are exceptionally fine. As one approaches Covey Hill village by road from the east, well-built ridges of water-worn sandstone shingle make their appearance. The first of these are near the 300-foot (91·4 m.) mark. From this level up to 525 feet (160 m.) there is a rapid succession of them. A very conspicuous group of them crosses the road near Covey Hill Methodist church, half a mile east of the post office. One upon which the church itself is built is 507 feet (154·5 m.). Below this one, at a barn, are two strong ridges of sandstone slabs, at 500 and 496 feet (152·4 and 151·2 m.). Although the slabs of rock are poorly rounded, their imbricated structure shows plainly that they have been slapped up into their present positions by wave action. The crests of the beaches are very uniform, and their front and back slopes very graceful. About 250 yards (228·6 m.) from the church farther up the road is the highest beach of all, at 524 feet (159·7 m.). This is distinct, although not as conspicuous as the lower beaches, because it has very little back slope. On the road which runs northward from the post office, a similar series of beaches is crossed, which correspond closely in altitude to those just mentioned. In descending order these are 524, 517, 506, 500, and 455 feet (159·4, 157·6, 154·2, 152·4, and 138·7 m.). The beach form and the wave-worn shape of the beach material improves with each successive shoreline, as it naturally would do because of the working over in the lower beaches of materials dragged down the slope by the retiring sea. There appear to be no signs of wave action above the 524-foot beach, unless an obscure terrace at 530 feet (161·5 m.) can be thus reckoned. These beaches appear again with full strength and with corresponding height near Stockwell, four miles (6·4 km.) west of Covey hill. Where a road turns due south toward Geraldine, there is a stony pasture in which ridge after ridge rise with characteristic beach forms to the uppermost one at 523 feet (159·0m.). They can easily be traced to Franklin Center, four miles (6·4 km.) farther west, where the altitude of the uppermost one is 525 feet (160 m.). Evidently the 525-foot beach of this district is a continuous one through the stretch of eight miles (12·9 m.).

Since the group of beaches which has just been decribed extends without interruption from 525 feet (160 m.) down to the level of the shell locality at Hemmingford, there appears to be no good reason for not accepting the whole series as marine. Because there appears to be a complete absence of distinct marks of wave action above the 525-foot beach it seems probable that this one marks the upper marine limit at Covey hill.

The strength of the Covey Hill beaches is phenomenal, owing not so much to the wide open exposure to wave action which this hill afforded during the submergence of the St. Lawrence lowland, as to the presence of an abundance of hard discoidal sandstone debris which the waves found it easy to pack up into beach ridges. The contrast between the beaches here and the very obscure strands which mark the opposite shore, northeast of Lake Champlain, makes it evident that, where the sea has washed against disintegrating ledges of slate like that which prevails between Lake Champlain and the city of Quebec, the waves have not had opportunity to construct distinct beaches.

A comparison of the upper marine limit at Covey hill, at 525 feet (160 m.), with the highest beach on Mount Royal, 568 feet (173·1 m.), and the localities northeast of the Champlain valley, given on an earlier page, shows a fair degree of harmony among them. Assuming that all mark the same water-plane, the uplift of this ancient sea-level between Covey hill and Montreal amounts to 43 feet (13·11 m.) in 35 miles (56·3 km.), or 1·2 feet per mile (·23 m. per km.) in a direction about S. 10° W.

On the upland southwest of the top of Covey hill is a broad, deep gorge known as Covey gulf, which has played an important part in the history of the drainage of the St. Lawrence system. Through it the combined waters of the glacial Great Lakes appear to have discharged, while the ice front stood against the north side of Covey hill and dammed the whole upper St. Lawrence. In the floor of the gulf are two deep pools of water marking the positions of plunge pools of the ancient Niagara. The altitude of the lower of these pools is approximately 870 feet (265·1 m.). The river which excavated the gorge must have discharged into a body of water in the Champlain valley whose surface was at least as low as this, not improbably the "Glacial Lake Champlain," which later disappeared when the ice withdrew from the highland north of Vermont and allowed the sea to come in from the Gulf of St. Lawrence. The relation of this abandoned gorge to the higher water-levels of the Ontario and Champlain basins and to the later marine levels of the Champlain sea will be fully discussed in the field. Pending the publication of conflicting observations and conclusions, it seems best not to state in detail the views now held by those who have been carrying on investigations in this field.

THE SUPERFICIAL DEPOSITS NEAR OTTAWA.

by

Joseph Keele and W. A. Johnston.

GEOLOGY OF THE SUPERFICIAL DEPOSITS.

Glacial Deposits.

The superficial deposits of the city of Ottawa and vicinity consist principally of gravels, stratified sands, and clays and boulder clays.

The boulder clays were deposited by ice sheets advancing from the Pre-Cambrian upland in a general southwest direction across the Ottawa valley. That the predominant movement of the ice sheets was in a southwest direction is shown by the general trend of striae and the frequent occurrence of "stossing" of glaciated rock surfaces on the north side. Other striae, which are more local and generally confined to the valley of the Ottawa river, show a movement of the ice in a direction nearly at right angles to this. The two sets of striae are rarely seen on the same rock surfaces in the vicinity of Ottawa, but farther west they are frequently seen crossing each other, and the older course is towards the southwest, while the more recent courses are towards the southeast and appear to have been influenced in their direction by the river valleys.

How many repetitions of glaciation in Pleistocene time there were in this area is not known, but the presence of two till sheets, separated by stratified sands and gravels shows that at least two ice invasions occurred, which are presumably the most recent, and it is possible that there were others of which no record remains.

The boulder clay ascribed to the earlier invasion of the ice sheet is the lowest member of the surface deposits. The boulders of this deposit, which are usually small, are imbedded in a stiff gritty clay, forming a compact resistant material. It occurs in large patches, not in a continuous sheet, and is rarely exposed except in excavations or along river banks. This boulder clay where present generally rests on comparatively fresh rock surfaces, often polished, striated and grooved, and no evidence of residual clays, soils or gravels of pre-glacial age have been found in the district.

Sections of the drift at Ottawa which include the upper boulder clay show it resting on horizontally stratified, or crossed bedded, soft, incoherent sand beds. The upper boulder clay carries many larger boulders, has a larger proportion of rounded stones and contains less clay in the matrix than the lower boulder clay. The erosive action of the ice sheet during its later advance was feeble, for it passed over sand and clay beds with little damage to these soft materials. The principal work accomplished seems to have been the pushing forward and transportation of loose drift materials derived from the earlier ice invasion.

MARINE DEPOSITS.

Following the withdrawal of the last ice sheet a long arm of the St. Lawrence embayment extended far up the Ottawa valley. Marine sediments are widespread in the Ottawa district, and at many places shells of marine species are abundant in the sands and clays which were deposited during this submergence. To what height the district about Ottawa has emerged from the sea since the withdrawal of the ice, and how far westward the embayment extended have long been disputed questions. Marine fossils have been found at various places in the district to a height of 475 feet (144·7 m.) above sea level, but the upper limit of marine submergence has been generally put considerably higher. Baron de Geer in his determination of the highest marine shore line near Kingsmere lake, a few miles north of Ottawa, placed the upper limit in the Ottawa district at 705 feet (215 m.) above sea level [**2,** p. 469]. Sir William Dawson [**3,** p. 294], Dr. Chalmers [**4,** p. 68] and Dr. Ells [**6** p. 222], all maintained that the minimum limit of submergence was at least 1,000 feet (305 m.), and that the Pleistocene sea extended westward over the greater portion of Ontario.

These views as to the extreme height of submergence were apparently based on the general similarity of the unfossiliferous sands and clays at high levels to the undoubted marine sediments at lower levels and the occurrence of waterworn gravel and transported boulders at high altitudes, rather than upon the determination of the height of any definite strand lines.

Of late years comparatively little field work has been done in this district. Partly for this reason, partly because, as has been found in the lower St. Lawrence valley, the upper marine strand line is but faintly marked by wave built features and hence is difficult to locate with any degree of certainty, and partly owing to the widely divergent views held on the subject, it can only be stated that the upper limit of marine submergence near the city of Ottawa was not less than 475 feet (144·7 m.) and was probably higher, though there seems to be little evidence that it greatly exceeded this height.

The highest point in the city of Ottawa is Parliament hill on which the parliament buildings are situated, and during the time of maximum marine submergence this point was submerged to a depth of over 200 feet (60·9 m.).

Some of the highest localities at which marine organisms have been found in the sands and clays of the Ottawa district may be briefly stated. In a cutting a short distance north of Chelsea station on the Gatineau Valley railway, about nine miles (14·5 km.) north of Ottawa, stratified sand, interbedded with clay, contains an abundance of marine shells, the commonest of which are *Saxicava rugosa* and *Macoma fragilis*. These deposits have an altitude of about 425 feet (125·9 m.) above sea level. About six miles (9.7 km.) south of Ottawa along the Rideau river a section is exposed showing 70 feet (21·3 m.) of stratified clay followed by 40 feet (12·2 m.) of stratified sand rich in similar marine fossils, the whole reaching a height of 350 feet (106·6 m.) above sea level. Near Smith Falls, about 45 miles (72·4 km.) southwest of Ottawa, the bones of a whale have been found in a sand and gravel deposit at a height of 440 feet (134·1 m.) above sea level. Marine fossils are also recorded near the village of Galetta, about 30 miles (48·3 m.) west of Ottawa, at an altitude of 475 feet (144·7 m.), which is so far as known the highest point at which marine fossils have been found in the district.

Above the highest point at which marine fossils are found in the vicinity of Ottawa the slopes and character of the surface are unfavourable for the record of wave built features. Below this altitude, however, well defined, though not strongly built beach ridges and terraces, marking short pauses in the emergence of the land from the Pleistocene sea, frequently occur. Several of the terraces are well seen seen along Gatineau river a short distance north of Hull, across the river from Ottawa.

The marine sands and clays are widespread in the Ottawa district and at some points are known to attain a maximum thickness of nearly 200 feet (60·9 m.).

The clays are found either unconformably overlying the boulder clay or resting on bed rock. Occasionally layers of gravel or sand are interposed between the boulder clay and the overlying clay.

The clays are bluish grey toward the bottom of the deposit, changing toward the top to rusty grey or brown, owing to oxidation of their iron content. Stratification is a pronounced feature of a portion of the clays, but other portions show little or no evidence of this, being massive jointed clays. They are very plastic when tempered with water and when mixed with a small proportion of sand are easily moulded. They are impure and easily fusible, so that no higher grade of structural wares than common brick or field drain tiles can be made from them.

Local Descriptions.

The best known localities for marine clay near Ottawa are Green's creek and the shore of Ottawa river at Besserer's wharf, a few miles below the city. At these localities the clay affords great numbers of calcareous concretions which are often found to contain the skeleton of a fish, the commonest species being the capelin still numerous in the lower St. Lawrence. Other nodules have been found to contain plant remains and a considerable flora has been obtained from them. Insects, feathers, bones of birds and bones of seals are found also, but very rarely. The clay in this vicinity is known to have a thickness of at least 140 feet (42·6 m.). The river is here about 118 feet (36·0 m.) above the sea, and the clay banks rise from 20 to 40 feet (6·1 to 12·2 m.) above the water. Similar concretions have been found up the Ottawa river, about 60 miles (96·5 m.) northwest of the city, where they occur at an elevation of 370 feet (112·7 m.).

The marine clays are well seen in terraces along Gatineau river a short distance north of Hull. Brickyards in Ottawa also give excellent exposures of the clay from which a great number of marine fossils have been obtained, including several species of shells, silicious spicules of a sponge and foraminifera. Altogether 28 kinds of plants and at least 33 animals are known to occur in these clays. It should be stated, however, that the great mass of the clay is almost barren of fossils and, except in favoured localities, the marine fossils are mostly confined to the sandy layers near the top of the deposit.

The clay, which is looked upon as a comparatively deep water deposit, is overlain by stratified sands and gravels which were in part deposited along shore lines and as shoals in shallow water during the period of emergence of the land. Marine shells are common in the sands at some localities and are as a rule most numerous towards the bottom of the deposit near its junction with the clay. The sands are generally somewhat barren, however, or contain only a few shallow water species.

In some instances the sands rest on boulder clay or directly on the rock which is often striated below the deposit. When the sands rest upon the clay, as is not infrequently the case, the contact may be either of two kinds. In most cases there is a transition from one deposit to the other, the clay becoming sandy and gradually passing upwards into pure sand and fine gravel. In other cases the surface of the clay has been deeply trenched, apparently by stream erosion, the channels afterwards being filled with cross-bedded sands and gravels. A good example of this is shown by a section uncovered near the sulphite plant of the Eddy paper works in Hull. In such cases the sands and gravels, which are local in character and distribution and have not been found to contain marine fossils, are supposed to be due to stream deposition.

Stratified and unstratified sands and gravels, which are considered to be glacial in origin, also occur in the district. Travelled boulders are numerous, either imbedded in the sands and gravels or lying loose on the surface at all elevations.

It is generally believed that the marine sands and clays were deposited during the time of submergence at the close of the Glacial period and that they were never overlain by a later till sheet. Drift boulders occasionally rest on these beds, but their occurrence may be explained on the supposition that they were carried to their present positions by floating ice during the time of marine submergence or by stream action aided by ice. On account of the general absence of boulder clay from the surface of the clays and the well perserved character of many of the marine strand lines, it does not seem probable that any extensive ice invasion took place after the deposition of the clays. It is possible, however, that local ice tongues advanced from the highlands during the time of marine submergence, or after the partial subsidence of the marine waters and the occurrence of the moraine-like deposit which overlies marine clay and is well seen in Hull, may possibly be explained on this supposition.

The city of Hull is built partly on a ridge of Trenton limestone and partly on a series of wide flat-topped boulder ridges somewhat resembling small terminal moraines.

A section of one of these ridges near a quarry in Trenton limestone shows 10 to 20 feet (3·0 to 6·1 m.) in thickness of large angular blocks of limestone, occasional well rounded boulders of Pre-Cambrian rocks, and a small quantity of waterworn gravels and stones. The limestone slabs lie mostly in an imbricated manner, as if they had been acted upon by some powerful thrust. The following section is from the most southerly ridge near Chaudière street and is in descending order:—

1. Large angular blocks of limestone mixed with sand, gravel, and an occasional rounded boulder of granite, etc., 8 feet (2·4 m.).
2. Fine sand and gravel, 2 feet (·6 m.).
3. Fine, tough, bluish, stratified clay containing marine fossils, $1\frac{1}{4}$ feet (·4 m.)
4. Boulder clay, 3 feet (·9 m.).
5. Limestone rock in place, glaciated, striae, course S. 60° E.

Northeast of this locality, or toward Gatineau river the sections of the ridges show waterworn boulders of smaller size and far more Laurentian pebbles than does the one just described. These deposits are spread out fanwise on an eroded surface of marine clay.

These ridges have been described by Dr. Chalmers [5] and W. J. Wilson [7], and were considered by Dr. Chalmers to be due to both sea-borne and river ice. Mr. Wilson regarded them as possibly of morainic origin.

On account of the unglaciated character of most of the boulders of the deposit, the imbricated position of the boulders suggesting current action, and the general absence of clay in the matrix, the more probable explanation of the occurrence of the ridges seems to be that they are due to river deposition aided by ice action during a late stage of the marine submergence or at a time when the waters of the Ottawa and Gatineau rivers stood at a higher level than they do at present.

Stratified sands and gravels overlain by boulder clay also occur in the Ottawa district and are hence regarded as interglacial in age.

A good section of the upper boulder clay is exposed at the Canadian Northern Railway station, about one mile (1·6 m.) southeast of the Parliament buildings. The principal feature of the boulder clay is the quantity of large limestone boulders which, unlike those of the Hull deposit, are rounded and show marks of strong glaciation. The matrix in which the boulders are imbedded, although very sandy, is stiff enough to sustain the material in a perpendicular face. The boulder clay, which is overlain by a few feet of yellow stratified sand, includes layers of irregularly bedded sands which appear to divide the boulder deposit into two sheets.

A sand pit on the south side of Rideau river about, one mile (1·6 km.) southwest from the Canadian Northern Railway station, exhibits an excellent section of irregularly bedded sands and gravel overlain by the upper boulder clay. The boulders are much smaller and better rounded in the boulder clay of this deposit than in the one last described, and the quantity of clay in the matrix is greater, but it is a more friable deposit than the lower, older sheet. The variation in bedding and the alternation of material in the underlying sands and gravels at this locality are remarkable, and they are said to be at least 30 feet (9·1 m.) in thickness.

Drainage Features.

The principal drainage features of the district may be explained briefly as follows:—

The Ottawa river in the vicinity of Ottawa flows in an easterly direction at the base of the limestone escarpment fronting the old land to the north, and occupies a post-glacial channel in the sense that the probable pre-glacial course of the Ottawa or its predecessor was several miles to the south, where well borings show the presence of a broad, deeply drift-filled valley. The limestone escarpment, however, is believed to be for the most part pre-glacial in origin and due to stream erosion through a protracted period in pre-glacial times.

In post-glacial time it is probable that the Ottawa river has cleaned out and somewhat deepened the old valley in the vicinity of Ottawa, and the steepwalled gorge which extends for a short distance below the Chaudière falls is evidently due to post-glacial erosion.

Rideau river, coming from the south, occupies a shallow post-glacial valley, flows across the old drift filled valley of the predecessor of the Ottawa and enters the Ottawa near the eastern end of the city with a fall over the rock escarpment of about 50 feet (15·2 m.).

Gatineau river, coming from the north and entering the Ottawa nearly opposite the mouth of the Rideau, appears to follow its pre-glacial course, an ancient valley carved in the resistant rocks of the Pre-Cambrian upland. Like all the rivers flowing from the upland into valleys floored with Palæozoic rocks it has its steepest grade near the contact of the Pre-Cambrian with the softer rocks.

ITINERARY OF EXCURSION.

Leaving Dufferin bridge on a C.P.R. local trolley car and crossing the Interprovincial bridge to Hull, sections in a boulder ridge and a quarry in Trenton limestone are first examined. Southeastward about a quarter of a mile from this point several sections of boulder ridges may be seen. Proceeding by trolley car to the sulphite plant of the Eddy paper works, a section showing cross-bedded sands and gravels filling erosion channels in marine clays may be examined next.

Returning by street car to Ottawa over the Chaudière Falls bridge and proceeding from the end of the Bank street line southward to a sand pit near Rideau river, a section of till overlying stratified sand and gravel may be examined.

ALTERNATIVE EXCURSION.

By taking the boat from Queen's wharf down Ottawa river to Besserer's wharf, the marine clay at the latter point may be examined and concretionary nodules containing marine fossils collected.

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EXCURSION A II.

ORDOVICIAN OF MONTREAL AND OTTAWA.

BY

PERCY E. RAYMOND.

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INTRODUCTION.

The great expanse of low, nearly flat land, which borders the St. Lawrence and Ottawa rivers for 200 miles (322 km.) above and below the mouth of the Ottawa, is underlain by strata of Upper Cambrian and Ordovician age. While the greater part of this area is covered with boulder clay or marine sands and clays of Champlain age, there are many exposures along and near the rivers, and good sections of all the Ordovician formations may be seen within a radius of 20 miles (32 km.) of either Montreal or Ottawa.

TABLE OF FORMATIONS.

ORDOVICIAN.

Richmond	Richmond.
Lorraine	Lorraine.
Utica	Utica. Collingwood (Ottawa).

Trenton	Sponge beds (Ottawa). Cystid beds (Ottawa). Prasopora beds. Dalmanella beds. Trinucleus beds (Montreal). Parostrophia beds (Montreal).
Black River	Black River. Lowville. Pamelia.
Upper Chazy	Aylmer.
Beekmantown	Beauharnois. Theresa (Ottawa).
UPPER CAMBRIAN.	
Potsdam	Potsdam.

DESCRIPTION OF FORMATIONS.

POTSDAM.

The Potsdam sandstone is a very hard, white to yellow sandstone, made up largely of quartz sand, cemented by silica. It contains few fossils in Canada, *Lingulepis acuminata* being the only common one. Large and well marked trails, supposed to have been made by huge mollusks, are not uncommon. They were first discovered and are still to be seen at Beauharnois, not far from Montreal. The Potsdam sandstone is employed with good effect as a building stone, and examples of its use may be seen in the Government buildings at Ottawa.

BEEKMANTOWN GROUP.

Theresa.—In some parts of the Ottawa valley the oldest beds of the Beekmantown are composed of reworked Potsdam sand, with a calcareous cement. These beds are therefore softer and weaker than the Potsdam beds. They contain fossils at several localities, the more common of which are *Ophileta complanata* and *Pleurotomaria canadensis.* The upper part of the Theresa is a thin-bedded, gray dolomite, with the same fossils. The Theresa is absent from the section at Montreal, and is thin near Ottawa, but thickens southward, toward Smiths Falls and Brockville.

Beauharnois.—The Beauharnois is probably a composite formation, and a great deal remains to be done on its stratigraphy and fauna. At the typical locality, along the Beauharnois canal, southwest of Montreal, it consists of dolomite and rather pure, blue-black limestone, with a fauna allied to that of the Beekmantown at Beekmantown, New York, and indicating a position low in the Lake Champlain section. Some of the typical fossils in this region are *Hormotoma anna*, *Holasaphus moorei*, *Isoteloides whitfieldi*, *Bathyurus angelini*, *Ophileta complanata*, and several ostracods. Farther west, in the vicinity of Ottawa, the strata are more sandy and there is more light gray, rusty dolomite. The fauna here has some species like the eastern ones, but *Protocycloceras lamarcki*, *Pleurotomaria canadensis* and other mollusca dominate the assemblage. It hardly seems probable that there is anything as modern as the Fort Cassin fauna of the Lake Champlain section in the Ottawa or St. Lawrence valleys.

Chazy.

Aylmer Formation.—The greater part of this formation consists of sandstone and shale, the beds at the base containing in places very coarse material, as in the vicinity of Grenville, Quebec, and Hawkesbury, Ontario, where the contact between the Aylmer and Beauharnois is well shown. The sandstone is not well exposed around Montreal, but may be seen at a number of places in the immediate vicinity of Ottawa. The sandstone has a considerable fauna, a part of which is known only from the Ottawa valley, but there are a few species which are common to this sandstone and the Upper Chazy limestone of the Champlain valley, and still more which range throughout the sandstone and limestone of the Aylmer formation. The limestone in the upper part of the formation is well developed at Montreal, but thins westward, so that at Ottawa the calcareous member of the formation is very unimportant. In the vicinity of Montreal and as far west as Hawkesbury, the limestone is hard, fairly pure, thick-bedded, and frequently a solid mass of such Upper Chazy fossils as *Camarotœchia plena*, *Camarotœchia orientalis*, *Malocystites murchisoni*, *Sigmacystis barrandei*, *Sigmacystis emmonsi*, *Bolboporites americanus*, *etc.* About Montreal this limestone is extensively quarried at St. Martin Junction, Bordeaux, Outer Mile End, and Caughnawaga. As one follows the limestone westward beyond Hawkesbury it becomes thinner, less fossiliferous, and less pure, and west of Ottawa it has not been reported. At Ottawa it still carries *Camarotœchia plena*, but no cystid has been seen west of Rockland, which is 30 miles (48 km.) east of Ottawa.

Black River Group.

Pamelia.—At Ottawa, the thin limestone of the upper Chazy is succeeded by a formation which is shaly and sandy in its lower portion, but consists chiefly of limestone. There are two easily recognized divisions; a lower, composed of dark blue and gray limestone full of ostracods, with sandy shales at the base, and an upper consisting of light buff, fine-grained, pure limestone alternating with beds of bluish magnesian limestone, which weathers yellow. At the base of the upper division is a bed of coarse sandstone. Neither division contains a great variety of fossils, but such species as are found are more nearly akin to the Lowville and Black River faunas than to the Chazy. As this formation is traced eastward it becomes thinner. The last actual outcrop seen in that direction is at L'Original, and at Montreal the Lowville rests directly upon the limestone of the Aylmer formation.

The principal fossils of the lower division are *Beyrichia clavigera* and other ostracods, *Bathyurus acutus*, and *Helicotoma whiteavsiana*. In the upper part *Isochilina armata*, *Leperditia fabulites*, *Bathyurus superbus*, *Tetradium*, and other fossils are found.

Lowville.—The Lowville is a thin formation, consisting mostly of buff, fine-grained, rather pure limestone, with an occasional shaly bed. It is characterized by a great abundance of *Tetradium cellulosum*; *Bathyurus extans* is also a typical fossil. Though only 15 to 30 feet (4·5 to 9·1 m.) thick, the Lowville is very persistent in this region, but disappears to the north-east, where it is absent from the section at Joliette, 50 miles (80·4 km.) north-east of Montreal.

Black River.—This is another thin formation, consisting of thick beds of rather impure, gray to black limestone. The fauna is a large one, some of the more common and characteristic species being *Columnaria halli*, *Hormoceras*, *tenuifilum*, *Bumastus milleri*, *Dalmanella gibbosa*, and *Strophomena filitexta*.

The Black River at and north of Montreal agrees with the Leray formation of New York in having an abundance of flat, disk-shaped masses of black chert; but west of Montreal and in the vicinity of Ottawa the chert seems to be absent. The formation is from 30 to 40 feet (9·1 to 12·2 m.) thick.

Trenton Group.

The Trenton at Montreal is very different from the Trenton at Ottawa, and the exposures in the region between the two cities are so poor that the correlation had to be made through the Champlain and Mohawk valleys, around the Adirondacks into central Ontario, and thence to the Ottawa section. As a result of this correlation, it appears that the oldest beds in the Trenton at Ottawa are younger than the lower 100 feet (30·4 m.) of the Trenton at Montreal; that is, that the *Dalmanella* beds at Ottawa are younger than the *Trinucleus* beds at Montreal (see table above) and that the "Trentons" of the two cities correspond only in a general way. At Montreal, the lower part of the Trenton is well shown, but the upper part is exposed badly or not at all. All the strata there are rather thin-bedded, blue-black limestones, and the lowest beds contain the fauna with *Parastrophia hemiplicata*. A thickness of about 40 feet (12·2 m.) of these strata is overlain by some 50 feet (15·2 m.) of limestone with *Trinucleus concentricus*, *Triplecia nuclea*, *Trematis terminalis*, and other fossils. This same zone can be traced as far west as Trenton Falls in New York, where it is at the very base of the typical section, but it is unknown farther west. At Trenton Falls and elsewhere in New York, this zone is succeeded by the fauna with *Triplecia extans* and *Triplecia cuspidata*, *Orthis tricenaria*, *etc.*, which is the *Dalmanella* fauna at the base of the Ottawa section. Whether or not this fauna is present at Montreal has not yet been determined, but the next zone, with the *Prasopora* fauna, is probably continuous over the whole area. At Montreal the exposed section stops with the lower part of the *Prasopora* beds.

At Ottawa, the following zones have been recognized, beginning with the lowest:—

Dalmanella Beds.—Thin-bedded, pure, blue-black limestone, characterized by *Orthis tricenaria*, etc. These beds are very poorly exposed at Ottawa, and have an estimated thickness of about 40 feet (12.2 m.). They are well shown above the Black River in the Stewart quarry at Rockland, and were also seen on top of the Black River at Fenelon Falls and Kirkfield lift-lock in central Ontario.

Crinoid Beds.—Thick and thin-bedded blue limestone, with a large amount of chert, developed as flat plates parallel to the bedding. These beds are particularly well shown in Hull, and furnish a large part of the building stone and crushed stone used in Ottawa. Just at the top of these beds are the layers from which a large part of the crinoids found in Hull have been obtained. Strata with the same fauna as these beds occur in central Ontario at Fenelon Falls and the Kirkfield lift-lock, where they occupy the same stratigraphic position as at Ottawa. The thickness of these beds is about 65 feet (19.8 m.).

Tetradium Beds.—Massive, coarse-grained, blue-gray limestone with few fossils. This is the horizon in which are located the large quarries on Montreal road, 3 miles (4.8 km.) east of Ottawa. The same beds are exposed in Hull, but are not quarried at the present time. They seem to be absent from the section in central Ontario. The most common fossil is a species of *Tetradium*, very like *Tetradium cellulosum*. The thickness is about 35 feet (10.6 m.).

Prasopora Beds.—Very thin-bedded limestone, with thick shale partings, characterized by abundant large bryozoans of the genus *Prasopora*. This bed seems to have a very wide distribution, and the fossils are well preserved. In spite of their thin-bedded and shaly character, the strata of this zone are extensively quarried. The thickness of the zone is small, usually not more than 25 feet (7.6 m) and frequently less.

Cystid Beds.—Rather thin-bedded light gray limestone with thin shale partings. In the lower portion is the zone with *Pleurocystites* and *Agelacrinites*. Thickness, about 75 feet (22.8 m.).

Sponge Beds.—Heavy-bedded, fine-grained limestone with clay irregularly distributed through it. These layers weather into an irregular rubbly mass, and are characterized by *Hormotoma trentonensis*, *Rafinesquina deltoidea*, and *Cyclospira bisulcata*. The thickness is about 75 feet (22.8 m.).

Utica Group.

Collingwood.—This formation is not present at Montreal; but at Ottawa and in southern Ontario the Trenton is succeeded by a thin formation, 25 to 50 feet (7.6 to 15·2 m) thick, characterized by the asaphoid trilobite, *Ogygites canadensis*, and several other fossils of a type more common in Europe than America. Among them may be mentioned the plicated *Triplecia*, *Oxyplecia calhouni*, and *Schizambon canadensis*. *Dalmanella emacerata*, *Leptobolus insignis*, *Zygospira modesta*, *Triarthrus becki* and *Ogygites canadensis* are the more common fossils, the last being the most common of all. In lithology, the Collingwood represents a sort of transition between the Trenton and the Utica, as it consists of alternate beds of limestone and shale, each a foot or so in thickness.

Utica.—Above the Collingwood at Ottawa and the Trenton at Montreal, are 200 to 300 feet (60·9 to 91·4 m.) of thin-bedded, fine-grained, brown and black carbonaceous shale with a small fauna, mostly graptolites. *Climacograptus typicalis*, *Climacograptus bicornis*, *Diplograptus pristis*, *Leptobolus insignis* and *Triarthrus becki* are common forms everywhere, and near Ottawa *Triarthrus spinosus* and *Triarthrus glaber* are also found.

Lorraine Group.

Lorraine.—The Lorraine and Richmond have not yet been studied in any great detail in this area, but the recent work of Dr. A. F. Foerste shows that both groups may be subdivided. In the case of both, exposures are few, as the formations occur in a very flat country, at a distance from rivers.

The Lorraine has been explored to some extent east of Ottawa. It consists of sandstone and shale in thin layers, and contains numerous, thin, calcareous bands. The common and characteristic fossils are *Catazyga erratica*, *Byssonychia radiata*, *Pterinea demissa*, *Cyrtolites ornatus*, and *Isotelus maximus*.

Richmond Group.

At some distance east of Ottawa there are exposures of shales and sandstone containing a large Richmond fauna, the most common and prominent species being the well known *Catazyga headi*.

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Many other authors have written on the Ordovician at Ottawa, and their papers are mainly descriptive of the fossils. Among these authors are E. Billings, W. R. Billings, T. W. E. Sowter, H. M. Ami, J. F. Whiteaves, and P. E. Raymond, whose papers have appeared in the publications of the Geological Survey, the Annals of the Carnegie Museum and elsewhere.

MONTREAL AND VICINITY.

Parc Laval and St. Martin Junction.

Miles and Kilometres.

5 m. 8 km. **Mile End.**—Leaving Place Viger station, quarries in Trenton limestone may be seen on both sides of the railroad just before reaching Mile End. Near Bordeaux, a large yellow brick building, which is the provincial penitentiary, comes into sight on the right hand side. From this point on, quarries in Chazy limestone are seen on either side of the railroad.

10 m. 16·1 km. **Bordeaux.**—While crossing the bridge immediately beyond Bordeaux, the Aylmer sandstone can be seen in the bed of the river at the right. This sandstone is here near the base of

Miles and Kilometres.

the Chazy but contain the fauna which at Lake Champlain characterizes the upper division of that group.

10·2 m. 16·4 km. **Parc Laval.**—A low cutting in clayey limestone near this point contains a great number of well preserved cystids, and a little search in the beds should reveal *Malocystites murchisoni* and *Sigmacystis emmonsi*.

13 m. 20·9 km. **St. Martin Junction.**—Quarries situated at the top of the hill near this point are being actively worked, and produce a good building stone, but the strata in some of them are not very fossiliferous. In other quarries, however, where the strata are weathered, the rock is seen to be made up of myriads of plates and fragments of cystids and crinoids. The following species are quite common:—*Malocystites murchisoni*, *Sigmacystis barrandei*, *Sigmacystis emmonsi*, *Hebertella borealis*, *Hebertella imperator*, *Bolboporites americanus*, *Blastoidocrinus carcharidens*, *Camarotœchia orientalis*, and *Camarotœchia plena*. This is a modification of the fauna of the upper of the three divisions of the Chazy on Lake Champlain.

Mile End.

The contact of the Lowville and Black River is well shown at several points in the old quarry at the corner of Christopher Columbus and Bellechasse streets, Mile End. Only about one foot of the top of the Lowville is exposed, which is a light buff, pure limestone, full of *Tetradium cellulosum*. The lowest bed of the Black River is a dirty nodular layer, just above which is a four-inch layer, very full of fossils. The whole thickness of the Black River here is 12 feet (3·6 m.). The upper layers, as seen near Christopher Columbus street, in the middle of the block, are full of plates of black chert. The surface of this chert-bearing layer shows a number of large specimens of *Hormoceras* and *Endoceras*.

In the field across Christopher Columbus street, in line with the unopened part of Rue de la Roche, the lowest beds of the Trenton are exposed. These are thin-bedded limestones, with *Platystrophia lynx*, *Parastrophia hemiplicata*, *Dalmanella rogata*, and many other forms. This is the same as the oldest Trenton fauna found along Lake Champlain and in the vicinity of Quebec. These lowest beds are well shown in the extensive quarry north of Normanville street, where, however, few fossils can be obtained.

In another large quarry beyond the railway track, the upper beds, about 10 feet (3·0 m.) in thickness, belong to the *Cryptolithus tessellatus* (*Trinucleus concentricus*) zone, the characteristic fossils of which, beside the diagnostic tribolite, are *Triplecia nuclea* and *Trematis terminalis*. The *Parastrophia* beds are about 35 feet (10·6 m.) thick, and the *Cryptolithus* beds 40 to 50 feet (12·2 to 15·2 m.) thick.

The top of the limestone in the quarry is a well striated surface, on which rests a thin layer of boulder clay. Above the boulder clay is a thin, but very fossiliferous layer of *Saxicava* sand, 1 to 3 feet (·3 to ·9 m.) thick.

The Prasopora beds are exposed in two quarries near the corner of Iberville and Masson streets. In the thin bedded limestone of this zone the following fossils may be found:—*Prasoporæ*, *Dinorthis meedsi*, *Platystrophi lynx*, *and Sinuites cancellatus*.

St. Vincent-de-Paul.

Black River and Trenton, with intercalated Igneous Beds.—The lowest strata in the section in this neighbourhood are exposed at the ferry. The beds dip up-stream, and consequently in going in that direction successively higher beds are crossed. The yellow-weathering beds first encountered belong to the Lowville, some layers of which are quite fossiliferous. The contact with the Black River is 600 feet (183 m.) from the ferry, the lowest layer of the upper formation being 4 inches (10 cm.) thick and made up of a solid mass of so-called fucoids or branching sponges. The hard surface of the Black River beds shows well the effects of glaciation.

Near the last of the small summer houses, the beds begin to show plates of black chert, and some of the layers beyond this point are full of them. The surfaces also show large specimens of *Hormoceras*, *Columnaria halli* and other fossils.

Continuing up-stream, the section is now interrupted by a few rods of sandy and grass-covered beach, and then we come upon the little cliff where igneous beds are intercalated in the limestones, just at the contact of the Black River and Trenton. The thin-bedded layers in the upper part of the cliff contain *Platystrophia lynx*, *Parastrophia hemiplicata* and other Trenton fossils. There are four beds of the igneous rock, separated by thin layers of limestone. The igneous beds are of the same material as the dykes at Mile End, and are probably contemporaneous with them. The thickest is 32 inches (81 cm.) thick and quite coarse grained, but it does not seem to have affected the limestone above and below it more than a quarter of an inch from the contact.

Pointe Claire and Ste. Anne-de-Bellevue.

Black River, Lowville, Aylmer Limestone (*Chazy*), *Beauharnois and Potsdam.*—In the two large quarries south of Pointe Claire the upper 25 feet (7·6 m.) of strata are Black River, with, however, comparatively few fossils. *Columnaria halli*, *Maclurites logani*, and a few cephalopods are present. The lower 7 feet (2·1 m.) are Lowville, exceedingly rich in fossils, of which *Tetradium cellulosum* and *Tetradium fibratum* make up whole layers. There is also a variety of pelecypods, gastropods and cephalopods. This is the typical locality for *Lophospira daphne*, which is quite common here. *Bathyurus extans*, *Isotelus gigas*, *Orthoceras multicameratum*, and *Orthoceras recticameratum*, are other common forms. There is no great lithological difference between the Lowville and the Black River, and the contact can only be found by observing the range of *Tetradium cellulosum.*

The outcrop of the Aylmer limestone (Chazy), which is on a small point extending into Lake St. Louis, is small and a rather unsatisfactory one. The common fossils found here are *Hebertella vulgaris* and *Hebertella costalis*, occurring in a grey, coarse-grained limestone on the right-hand side of the point. It will be noted that the Black River strata at the quarries dip toward the river, so that there is either a syncline or a fault between the quarries and this exposure of Aylmer limestone (Chazy).

A hundred feet (30·4 m.) west of the station of Ste. Anne-de-Bellevue is a small, water-filled, abandoned quarry in the Beauharnois dolomite. On the right hand border of the quarry, some fossils can be found in place, but more and better specimens can be obtained from the loose pieces of rock which are scattered about. This is the typical locality for *Hormotoma anna*, *Leperditia anna*, *Holasaphus moorei*, and other species.

The Potsdam can also be examined at this point. In 1912 a sewer excavation on the street exposed both the Beauharnois dolomite and the Potsdam, though the contact between the two was concealed. The Potsdam here is hard and quartzitic, and there are none of the soft transitional layers usually seen between the Potsdam and the equivalent of the Beauharnois farther west.

St. Helen Island.

Fossiliferous Lower Devonian Limestone in an igneous Breccia.—Utica shale occupies the southern end of St. Helen island. The shale is cut by several dykes and is somewhat altered, so that it is more friable than is usual. Close to the dykes there is usually a narrow band of rock which has been altered to hornstone.

On the eastern side of the island is exposed the breccia which occupies the larger part of the island. This rock is composed of angular and rounded fragments of red and black shale, hornstone, limestone, red and gray sandstone, granite, gneiss, and quartzite. The fragments are imbedded in a fine-grained matrix of igneous origin which weathers to a reddish brown.

At the north-eastern end of the island, near the swimming pool, are large fossiliferous blocks of gray, coarse-grained limestone. The most northern and largest of these blocks contains an Oriskany fauna, with *Spirifer arenosus*, *S. montrealensis*, *Eatonia peculiaris*, and many other fossils. A smaller block to the east of this contains a Helderbergian fauna with *Siberella pseudogaleata*, *Spirifer concinnus*, *Leptæna rhomboidalis*, *Stropheodonta becki*, and other species. The general facies of these faunas is much more like their equivalent in Gaspe than in New York.

No strata of Helderbergian or Oriskanian age occur anywhere in this region, but from the presence of these blocks in the breccia, it is believed that such strata once extended over this area. The presence of the blocks is explained upon the theory that they were stoped off from the parent bed, while the great dyke in which they are enclosed was in a molten condition, and that they either sank of their own weight to the low position they now occupy, or that they were drawn down during the surgings of the intrusive [**3**].

The breccia also contains pebbles of limestone with Trenton fossils, and there are other and smaller pebbles with lower Devonian faunas. Some of these pebbles have weathered out, and may be found loose along the shore, especially on the northern and western sides of the island.

OTTAWA AND VICINITY.

Hull.

Trenton Limestone and the Cement Works.—On leaving the Hull electric station in Ottawa the massive limestone of the uppermost division (sponge beds) of the Trenton can be seen in the cliffs on the right. The same strata are seen in the cliffs above the level of the floor of the Interprovincial bridge, and contain the sponge and *Hormotoma trentonensis* fauna, while the strata below this level belong to the cystid zone and carry *Pleurocystites.*

From the bridge itself can be seen on the one hand the strata of which Parliament hill is built, and on the other the cliffs of Nepean point and other bluffs down the river. The shore on the Hull side is low with no rock exposed.

At the Axe Factory quarry in Hull the contact between the massive beds of the *Tetradium* zone of the Trenton and the thin shaly beds at the base of the *Prasopora* zone is well shown. A fault crosses the floor of the quarry, which lets the strata on the eastern side down about 15 feet (4·5 m.), thus repeating the shaly layers. The shaly layers are very fossiliferous, and this locality has furnished a great variety of fossils, among them the type of *Bumastus billingsi.* The common fossils still to be found are *Prasopora*, several species, *Zygospira recurvirostris*, *Dalmanella rugosa*, *Plectambonites sericeus*, *Parastrophia hemiplicata*, *Ctenodonta levata*, *Calymene Senaria*, and others.

North of this quarry is another situated in the angle between the two railroads. The beds here are about 25 feet (7·6 m.) lower stratigraphically than those in the Axe Factory quarry, and belong to the crinoid zone. This quarry has furnished a large number of crinoids, but specimens are now rare. Among the more remarkable fossils which have been found here are *Edrioaster bigsbyi*, *Comarocystites punctatus*, *Cyclocystoides halli*, *Isotelus latus* and *Amphilichas cuculus*. The strata in this quarry are rather thick-bedded, coarse-grained, gray limestone, separated by black shale partings in which most of the fossils are found.

Farther north near the concrete bridge, is another quarry showing the cherty beds of the crinoid zone, the whole thickness of which may be seen in the Fleming-Dupuis quarry beyond the bridge.

The upper strata in the quarry at the cement works belong to the cherty "crinoid beds" of the Trenton, but the excavation has been sunk through them and the *Dalmanella* beds, into the upper part of the Black River formation, 90 feet (27·4 m.) below the surface.

Cummings Bridge.

Collingwood and Utica Formations.—Cummings bridge spans the Rideau river on the eastern outskirts of the city of Ottawa. On the western side of the bridge is a fault, not however exposed, between the Trenton and the Utica.

On the east side of the river, 100 yards (91·4 m.) below the bridge, black shale outcrops are exposed on the river bank. *Triarthrus spinosus*, *Triarthrus becki*, and *Leptobolus insignis* are common here, and more rarely one finds *Climacograptus typicalis*. These shales are not in place, but have been obtained from trenches dug in the immediate vicinity.

A few minutes walk along the river above the bridge and at a point opposite the Isolation hospital is an outcrop of the limestone and shale of the Collingwood, a formation which comes between the Utica and Trenton. The common fossils are *Ogygites canadensis*, *Triarthrus becki*, *Dalmanella emacerata*, *Leptobolus insignis*, *Schizambon canadensis*, and *Zygospira modesta*.

Rockcliffe.

Chazy.—To the west of Buena Vista station in Rockcliffe park, near the river, there is a low rock cut beside the path. One of the highest layers in this cut is a partially decomposed, impure limestone, with *Camarotœchia plena* and a few other fossils. In the cliffs by the water edge below this, a good opportunity is offered of seeing the shale and sandstone which make up the greater part of the Aylmer formation. Some of the sandstone beds are lenticular. Fossils are not abundant at this point, but burrows such as *Rusophycus grenvillensis*, and trails of various kinds are not uncommon.

An excellent section of the rocks, of which these cliffs are made up, is obtained on the road leading from the ferry to the electric railway, and in some of the beds of sandstone at the turn in the road it is possible to find a few brachiopods, chiefly *Camarotœchia orientalis*. Across the road from the station on the electric line is a low bluff, and in the green shale at the base of the bluff, specimens of *Lingula belli* are quite common.

The Aylmer sandstone, which is that occurring on the road to the ferry, is again well exposed in the quarry at the eastern end of the park. Fossils, however, are very rare here.

On Buena Vista road, and in other high-lying parts of Rockcliffe, the Aylmer is capped by the lower layers of the Pamelia. The Pamelia is not ordinarily exposed here, but trenches dug in 1910 reached the layers and brought to light a considerable quantity of fossils. Debris from these excavations is still to be found along Buena Vista and other streets, and some fossils may possibly be obtained from it. The black shale with *Beyrichia? clavigera*, outcrop at the corner of Buena Vista road and Minto place, and a hard limestone with *Loxoceras allumettense*, *Modiolopsis sowteri* and other fossils was found above it along Buena Vista road.

Mechanicsville.

Pamelia, Lowville, and Black River.—Going north on Carruthers avenue in Mechanicsville the strata of the upper part of the Black River are at or near the surface. These strata can be seen especially well near the crossing of the Canadian Pacific Railway, where they have been recently much quarried. The strata are thick-bedded, rather coarse-grained, light grey limestones, in which fossils are very rare.

The Hull-Gloucester fault, which is a strong break, traceable for a long distance east of Ottawa, runs along the western margin of Nepean bay. At the bay the downthrow is on the east, so that the crinoid beds of the Trenton are brought against the Black River; the displacement being therefore only 50 or 60 feet (15.2 or 18.3 m.). There are, however, several faults parallel to the main one, which considerably disturb the strata to the east and give a steep dip to the beds on the islands in the river. Along the shore to the west is a shallow syncline, which exposes the very fossiliferous strata of the Black River for a considerable distance. Large cephalopods, including *Hormoceras tenuifilum*, are common here, and other fossils such as *Columnaria halli*, *Strophomena filitexta*, *Dalmanella gibbosa*. *Bumastus milleri*, and *Isotelus gigas* can be readily obtained, A great many other species have been found here, and this is the type locality for *Cybele ella*.

Farther west the dip of the beds is reversed, and the Lowville comes out below the Black River. The Lowville here consists of pure, buff-coloured, fine-grained limestone, containing such fossils as *Tetradium cellulosum*, *Bathyurus extans*, and *Bathyurus spiniger*. The lowest layers contain *Beatricea* and *Cyrtodonta huronensis*, as in the section on the hill behind Aylmer. A small fault at this point brings the upper part of the Pamelia against the Lowville. The hard limestone near the water level west of this fault furnished the types of *Bathyurus superbus*. It also contains *Tetradium* and other fossils. Still further along the shore a yellowish magnesian limestone was formerly quarried and used as a natural cement.

Governor Bay.

Trenton, Black River, and Pamelia.—Governor bay is a small indentation in the shore line of Ottawa river near the entrance to Rockcliffe park. The first outcrop encountered in descending to the bay from the electric car barns is the shaly limestone of the *Prasopora* zone of the Trenton. These beds are exceedingly fossiliferous and contain *Dalmanella rugosa*, *Plectambonites sericeus*, *Zygospira recurvirostris*, *Sinuites cancellatus*, *Calymene senaria*, and *Isotelus gigas*. Other fossils, however, can also be found. The *Prasopora* layers rest on the thick gray strata of the *Tetradium* zone, but *Tetradium* itself has not been found here. The strata in the bluff above the *Prasopora* beds belong to the crinoid zone of the Trenton, and the *Prasopora* beds have been faulted down to the south of them. This fault is exposed at the base of the bluff around the point, where the dip of the strata becomes so steep that the cherty beds below the *Tetradium* beds are brought to view.

Another and greater fault in a gully beyond, exposes the Pamelia limestone. Between these two faults is a small block of nearly horizontal strata with Black River at the base, and *Dalmanella* beds above.

Tetradium occurs in the pure blue limestone of the Pamelia, which is followed by yellow-weathering beds, dipping toward the north and containing few fossils. Above the rusty beds, pure dark limestone layers with ostracods, pelecypods and bryozoa, are again encountered, and these strata may be followed around into a cove, where a concealed fault brings them against the shale and sandstone of the Aylmer.

On the path up from the cove to the electric car station *Camarotœchia plena* may be found in a thin limestone interbedded with green shale above the sandy part of the Aylmer limestone. The limestone of the Trenton is in close proximity to this outcrop, but, though it belongs to a horizon below the *Prasopora* beds, its exact position in the section is not known.

Chaudiere Falls.

Trenton.—Near the foot of the hill on Wellington street the perpendicular cliff of Upper Trenton limestone shows, in its lower part, strata belonging to the cystid beds, and in its upper part the *Hormotoma trentonensis* beds.

On the north side of the river at Chaudiere falls are excellent exposures of the thin-bedded limestone of the cystid zone. *Pleurocystites elegans*, *Agelacrinites billingsi* and other rare fossils are found here, in addition to the more common species. These beds are a continuation of those on the Ottawa side of the river, from which Billings obtained the types of many of his specimens of echinoderms.

The strata on the little island between the two bridges belong to the same zone as the rocks on the north shore of the river, and *Agelacrinites* is found in them. The exposures here show well the way in which the fossils are grouped in little depressions in the irregular surfaces of the layers.

Between this island and the next piling ground there is a small fault, beyond which the cherty crinoid beds are exposed in a quarry at the top of the ridge.

Between this ridge and the next one north is a gully, spanned by an iron bridge. The gully represents a fault by which the cherty crinoid beds are again downthrown on the north side. In the lowest layers on the north side of the iron bridge, crinoids may be obtained from the shale between the layers of limestone.

Parliament Hill.

Faults in the Trenton.—In descending to the water's edge from the Supreme Court at the western end of Parliament hill, the first outcrop is an exposure of the rather thin-bedded limestone of the Cystid zone. Following the shore westward other outcrops of the Cystid beds appear, but instead of being horizontal, as at the first outcrop, they dip to the south. One hundred feet (30 m.) beyond the pier, a fault, with an upthrow on the western side, brings the cherty Crinoid beds up against the Cystid beds. This fault is probably the continuation of one of several faults which are visible on the north side of the river, and is probably the same fault which can be traced through Hull into the Axe Factory quarry near Hull station. This fault, which brings up the Cystid layers again, has a four-foot crushed zone, full of fragments of limestone cemented by very coarse calcite, at the contact of the two zones.

Tetreauville and "the Heap."

Lowville, Black River, and Trenton.—From Tetreauville, which is a station on the Hull Electric Railway, a road leads down to Ottawa river. The strata to the right of the end of this road are mostly Lowville with *Tetradium cellulosum* and opposite the end of the road the basal beds of the Black River with *Columnaria halli* may be seen.

Following these beds down stream for a few rods they are seen to be very fossiliferous, and good specimens may be obtained by breaking up the limestone. *Subulites elongatus*, *Trochonema umbilicatum*, *Bumastus milleri*, *Illænus conradi*, and *Thaleops ovata* are some of the more common fossils.

This outcrop is interrupted by the Hull-Gloucester fault, which crosses at this point. Beyond the first fault and along the shore, the cherty beds of the Trenton are exposed.

Returning to the railway track a good section is exposed in a cutting near the switch. First the cherty beds of the Trenton are seen, then the heavier-bedded strata of the over-lying *Tetradium* zone, and, resting on the latter, the thin and shaly beds of the *Prasopora* zone. The fossils of this zone are very common here, and also at the "Heap", a small pile of debris at the right a few rods farther down the track.

Montreal Road.

Trenton, Black River, and Pamelia.—A powder magazine is situated near the Montreal road two and a half miles (4 km.) from Ottawa. A quarry south of the magazine shows a section of strata which belong at a horizon just at the top of the crinoid beds and just below the *Prasopora* zone. From the presence of a species of *Tetradium* in abundance, these have been termed the *Tetradium* beds. This is the typical locality for *Tetradium racemosum*, and specimens can be obtained in the thin, pure layers in the upper part of the quarry. There is a small fault through the quarry, which causes a downthrow of the beds to the north. In the face of the quarry toward the powder magazine, can be seen a reef of *Stromatocerium*.

Between this quarry and Montreal road a fault brings the highest beds of the Trenton and the Utica down in contact with the *Tetradium* beds. The Utica is exposed just at the corner where this road joins the Montreal road.

The Robillard quarries, which are situated in the same beds just seen at the powder magazine quarry, have been worked very extensively, but contain very few fossils other than *Stromatocerium* and *Solenopora*.

Northward beyond these quarries is another quarry showing the upper beds of the Pamelia formation, from which it is possible to collect specimens of *Onchometopus simplex*, ostracods, and a few brachiopods. A part of the way down the hill, just below the house, is a bed of creamy white sandstone, which is the base of the upper division of the Pamelia, and contains many pelecypods, *Isochilina armata*, and a few gastropods. At the foot of the hill is the Aylmer sandstone.

Returning toward the Montreal road, at a point where the road rises over a low escarpment, with a small quarry at the right, the contact of the Lowville and Black River may be seen.

Another quarry between the cemetery of Notre Dame de Lourdes and the river shows the cherty beds of the crinoid zone of the Trenton very well, but the same beds are better seen at Hull. Two hundred yards (182·8 m.) farther north near a small brook, is another quarry in the upper division of the Black River. Fossils are very rare here.

Britannia and Westboro.

Aylmer and Pamelia Formations.—On the shore of Lake Deschênes north of Britannia village, a canal has been dug through the lower sandstone strata of the Aylmer formation, and the debris which has been thrown out on either side provides an excellent collecting place. Fossils other than burrows and trails are not very common, but *Lophospira billingsi*, *Isotelus arenicola* and others have been found here.

At the point where the Richmond road crosses the Ottawa Electric Railway tracks is a small excavation in black shale, where specimens of *Beyrichia* (?) *clavigera* and other ostracods may be obtained.

Near the top of the hill at Westboro a cutting exposes the limestone belonging to the lower part of the Pamelia. At the roots of a bunch of cedars to the left is a small exposure of black shale capped by rusty weathering dolomite, or "cement beds," as they are called here. At the bottom of the hill, a blue-black limestone with wavy, *Stromatocerium*-like structure, can be seen. At a little cove just above the ruins of Skeads' mill one sees the black *Beyrichia* (?) *clavigera* shale, resting on an impure, yellow-weathering limestone and capped by hard sandy beds. The lowest layers here probably belong to the upper part of the Aylmer formation. An escarpment runs back from this point to the Canadian Pacific Railway tracks. In a little cutting here, and in the fields on both sides of the tracks, is found a great quantity of very fossiliferous limestone of the lower part of the Pamelia, from which quite a number of species can be obtained. This is the type locality for *Bathyurus acutus*.

In following the Canadian Pacific Railway track from this point to Mechanicsville, an opportunity is presented of seeing outcrops of the limestone of the upper part of the Pamelia, from the upper layers of which ostracods, cephalopods, and a few tribolites may be collected.

Aylmer and Queen's Park.

Beauharnois, Aylmer and Pamelia.—At Queen's Park, on the shore of Lake Deschênes, and on either side of the wharf, there are outcrops of the rusty-weathering dolomite of the Beauharnois formation. By persistent search, gastropods and a few other fossils may be found, but as the fossils occur sporadically, it is not possible to name any particular locality from which they can be obtained.

Just below the wharf at Aylmer is an outcrop of sandstone near the base of the Aylmer formation. This sandstone contains *Camarotœchia plena*, *Camarotœchia orientalis*, and *Hebertella imperator*. At another locality a low cutting in sandstone and shale shows numerous specimens of *Ctenodonta parvidens*, *Modiolopsis sowteri*, and *Lophospira billingsi*.

A small excavation in the ditch to the right of the road and opposite the house of Mr. T. W. E. Sowter, indicates the position of the *Beyrichia* (?) *clavigera* shale and the base of Pamelia formation. This is the type locality for *Beyrichia* (?) *clavigera* and its variety *clavifracta*.

Along the ditch on the right hand side of the road from this point to the next corner, there are excellent exposures of the lower dark limestone of the Pamelia. This limestone is here very fossiliferous, some of the layers being composed almost entirely of ostracods. At the next corner north, slabs of limestone with silicified fossils may be found in the fields, and near the top of the hill beyond, a quarry at the right shows the upper beds of the Pamelia.

Just beyond this quarry, along the north-line fence of the same field in which the quarry is situated, there is an outcrop of the beds at the base of the Lowville. One of these beds contains an abundance of *Beatricea*, and another, better shown on the other side of the road, is full of specimens of *Cyrtodonta huronensis*. Beyond the next corner north, the Black River follows the Lowville, but it is hardly worth while visiting, as there are no unusual fossils in it.

Division Street and Dow Lake.

Upper Trenton and Collingwood.—Near the corner of Somerset and Division streets is a quarry in the *Hormotoma trentonensis* beds at the top of the Trenton. This quarry has furnished many rare echinoderms, and is the type locality for *Steganoblastus ottawaensis*, for certain crinoids described by W. R. Billings, and for two species of sponges described by Hinde. The fauna of these beds reminds one strongly of the Black River, *Ischadites iowaensis*, *Trochonema umbilicatum*, *Illænus americanus* and various species of *Subulites* and *Fusispira* being found here. Not all these fossils can be found here, but *Hormotoma trentonensis*, *Rafinesquina deltoidea*, *Illænus americanus*, and *Cyclospira bisulcata* are not uncommon.

In a quarry situated on Division street south of the crossing of the Grand Trunk railway the upper part of the cystid beds is exposed and *Agelacrinites* and *Pleurocystites* are found in them. The western border of this quarry is just on the line of the fault between the Trenton and the Collingwood, and this fault crosses Division street just below Norman street.

The low area below Rochester and Preston streets at the north end of Dow lake is underlain by the Collingwood formation, and as extensive sewer trenches have been dug here in the last few years, a considerable amount of fossiliferous material is available along the streets in this district. This is the type locality for *Oxyplecia calhouni*, and entire specimens of the characteristic Collingwood asaphoid, *Ogygites canadensis*, have been found here. The upper Trenton beds come in beneath the Collingwood west of Preston street and Dow lake, and when the water is drawn off, the western side of Dow lake is an especially good collecting ground for *Cyclospira bisulcata*.

The upper part of the cystid zone and the lower part of the *Hormotoma trentonensis* zone are exposed in quarries on Carling avenue, LeBreton and Bell streets.

Hogsback.

Aylmer and Pamelia Formations.—Hogsback is a point on the Rideau river south of Ottawa where the Rideau canal leaves the river. The strata in the bed of the river at Hogsback form a low anticline which is broken by two or three small faults. Standing at the small stairway near the middle of the bridge and facing down stream, the strata to the right belong to the Pamelia, and those to the left to the Aylmer formation. The small faults mentioned show a drop in each case on the eastern side, except in one instance on the eastern side of the stream, where there is a drop to the west of about 4 feet (1·2 m.).

The strata of the Aylmer formation, on the western side of the stream, consist of sandstone and shale with many burrows and trails. The strata directly north of the principal fall also belong to the Aylmer formation, and contain calcareous beds with *Camarotœchia plena* and other fossils.

Across a fault to the east of these beds are dark limestone and shale with many ostracods, *Helicotoma whiteavesiana* and *Bathyurus acutus*. Above these layers are two thick beds of sandstone, containing pelecypods, and then a dark, wavy bedded limestone, the same layer as is seen so well at Westboro.

At the top of the hill on the road leading from Hogsback to the main road, is a quarry in the Black River limestone where a few fossils may be obtained.

The real Utica may be seen in the bed of a small stream entering Rideau river at Billings Bridge. In the brown and black carbonaceous shales here, graptolites, *Triarthrus spinosus* and *Triarthrus becki* are readily obtained.

Hawthorne.

Lorraine Formation.—Hawthorne is a small station on New York and Ottawa Railway 5 miles (8·0 km.) east of Ottawa. Along the brook about half a mile south of the station, there are several outcrops of shale with thin calcareous layers. Fossils are abundant, and include *Byssonychia radiata*, *Catazyga erratica*, and *Isotelus maximus*.

Vars.

Richmond Formation.—Vars is situated on the Grand Trunk Railway 17 miles (27·3 km.) east of Ottawa. Many fossils of Richmond age may be obtained from an excavation in shale and limestone on a small brook a short distance southwest of the station. At other localities in this vicinity there are several outcrops of very fossiliferous strata of this formation.

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GUIDE BOOK No. 4

EXCURSIONS

IN

Southwestern Ontario

(Excursions A 4, B 1, A 12, B 3.)

ISSUED BY THE GEOLOGICAL SURVEY

OTTAWA
Government Printing Bureau
1913.

GUIDE BOOK No. 4.

EXCURSIONS IN SOUTHWESTERN ONTARIO.

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EXCURSIONS A 4 AND B 1.

NIAGARA---IROQUOIS BEACH

BY

F. B. Taylor

AND

A. P. Coleman.

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General view of Niagara Falls, looking south from the west end of the Park bridge.

NIAGARA FALLS AND GORGE.*

(EXCURSION B 1.)

BY

FRANK BURSLEY TAYLOR.

GENERAL RELATIONS OF THE NIAGARA DISTRICT.

NIAGARA DISTRICT DURING THE TIME OF THE LAST ICE SHEET.

During the maximum extent of the last or Wisconsin ice sheet, Niagara district lay under about 3,000 feet (900 m.) of ice and was in or near the axis of the main ice current which moved southwestward through the basins of Lakes Ontario and Erie. One of the most pronounced re-entrants of the ice front at that time was at Salamanca, N.Y., about 67 miles (107 km.) south of Niagara Falls. The general level of the hills around Salamanca is 1,800 to 2,000 feet (550 to 600 m.) above sea level, and from this place to Niagara Falls the surface of the ice rose probably not less than 1,500 feet (450 m.). The altitude of the general surface at Niagara Falls is nearly 600 feet (182·9 m.) above sea level, indicating therefore, a thickness of ice approximating 3,000 feet (900 m.).

The Niagara district remained continuously under the burden of ice, not only during the entire time that the front of the ice sheet was retreating from a point about 10 miles (16 km.) north of the Ohio river at Cincinnati to Niagara Falls, but during an equally long time, probably, in the advancing phase. As the ice front retreated northeastward in the Lake Erie basin, glacial waters followed it and covered the lower ground as fast as the ice withdrew. For a short time after the ice had uncovered the present site of Niagara gorge the lake waters still covered this district, but when it had retreated to a position probably about at the present shore of Lake Ontario north of Lewiston, a lower outlet was opened on the northward sloping hills south of Syracuse, N. Y., and the waters

*The material for this Guide Book, so far as it relates to Niagara Falls and Gorge, is taken mainly from the unpublished manuscript of the Niagara Folio, to be published by the United States Geological Survey, and is used with the permission of the Director.
(Mr. Taylor's text was written before the field and office studies were completed, and he has had no opportunity of reading the proof.—ED.)

in the Lake Ontario basin were drawn down to a level somewhat lower than the present level of Lake Erie. This inaugurated the flow of Niagara river and completed the separation of Lake Erie from Lake Ontario. Niagara Falls then began the work of making the gorge at the escarpment south of Lewiston.

PHYSIOGRAPHIC DEVELOPMENT.

Niagara district lies between Lake Erie and Lake Ontario, in the midst of a region which has the physiographic and geologic characteristics of an eroded, ancient coastal plain. Following the deposition of the Paleozoic sediments, the region as a whole was raised out of the sea about at the close of the Paleozoic era and appears to have been a land surface ever since. In so great a length of time the region has, of course, been extensively modified by subaërial and stream erosion, but it does not appear to have been affected by marine denudation. The highlands of Canada are the oldland, and the beds of the ancient coastal plain dip gently southward from it. Some of these beds are soft and others hard, and in consequence of this difference the softer beds have been reduced to lowlands, while the harder beds remain as uplands of relatively low relief. Thus, through the effects of erosion, the ancient coastal plain has become a belted plain composed of a series of narrow, nearly flat plains separated by northward facing escarpments, like a flight of steps descending to the north. But the tread of each step slants gently backward towards the south and produces the form which in New Mexico is called a cuesta, meaning a low ridge, steep on one side, but with a gentle slope on the other.

South of the oldland lies the Ontario lowland, and the basins of Lake Ontario and of Georgian bay are excavated in it. To the south of this lies the Niagara cuesta with its strongly marked escarpment facing northward over the Ontario lowland and Lake Ontario. South of Lake Erie and extending eastward through New York lies the Alleghany cuesta. It has been customary in the small scale maps usually employed, to recognize only one simple lowland as occupying the whole space between the Niagara and Alleghany cuestas, and this has been called the Erie lowland. But when the region around Niagara is studied in more detail and represented on a larger scale, another less pronounced cuesta and lowland are found to lie between, and their relations to Niagara history increase their present importance. These are the Onondaga cuesta, formed on the outcropping ledges of the Onondaga limestone, and the Huron or Tonawanda lowland north of it. The Tonawanda and Chippawa valleys and the deeper trough of Lake Huron are in this lowland. This division of the belted area restricts the application of the name Erie lowland to the lowland belt which lies south of the Onondaga escarpment and in which lies the bed of Lake Erie. In the early history of Niagara river the Tonawanda lowland was occupied by a temporary lake about 50 miles (80 km.) long and 1 to 7 miles (1·6 to 11·3 km.) wide. Lake Tonawanda covered the lower ground around the city of Niagara Falls and extended east about 40 miles (64 km.) and west 10 miles (16 km.) into Canada.

ORIGIN OF DRAINAGE SYSTEM.

In the early development of drainage on the newly elevated coastal plain, the master streams probably flowed south or southwest over the Great Lakes region and were, as Grabau has said, consequent streams, their course being determined by the direction of the original slope. Subsequent streams began immediately cutting valleys along the lines of the weaker strata at right angles to the main streams, and these side streams ultimately combined and developed a system which became dominant. The final stage in which the deeper lake basins were excavated and the land surface prepared for the Great Lakes and for inter-glacial Niagaras, as well as the modern Niagara, was probably accomplished chiefly after the original drainage system had been broken up and had ceased to be dominant.

STRATA IN NIAGARA GORGE.

The ancient belted plain, with its parallel features of relief, was the ground over which Niagara river began to flow when it first came into existence, and it is into this plain that the cataract has sawn the great canyon. North of Lewiston there was no capping hard layer to produce a vertical fall; the banks are composed of soft red shale and are relatively low. The gorge begins at the escarpment south of Lewiston. From this place to the present falls the arrangement of the strata favoured the continuous existence of a vertical cataract, except at the Whirlpool which was filled with loose glacial drift. The hard, massive bed of the Lockport (Niagara) limestone forms the capping layer and increases in thickness from less than 20 feet (6·06 m.) at the escarpment to about 80 feet (24 m.) at the Horseshoe Falls, 130 feet (40 m.) at the first cascade above the falls and about 250 feet (76 m.) in well borings farther south. At the lower levels the Clinton limestone, with the Medina (upper Medina) sandstone close below and the Basal or Whirlpool sandstone of the Cataract (Medina) formation are hard, but they are relatively thin. The rest of the strata are mainly soft shales, but with occasional thin, sandy, harder beds.

The strata through which the gorge is cut appear to the eye to be horizontal, but in reality they dip toward the south at a nearly uniform rate of 20 feet to the mile (3·8 m. per km.). There are slight variations from this rate, most notably near the mouth of the gorge, where the dip for some distance is slightly greater. From the mouth of the gorge to the Horseshoe Fall all of the strata decline southward 130 to 140 feet (36·6 to 42·7 m.).

The next important hard layer below the Lockport is the Clinton limestone which is about 20 feet (6 m.) thick and forms a distinct bench along the sides of the gorge at some places. Spencer, finds only 12 feet (3·6 m.) of the Clinton limestone above water at the Horseshoe Fall. At Foster's flats the Clinton forms the prominent bench next below Wintergreen terrace and many of the great, fallen blocks rest upon it.

The only other hard layer of importance is the Whirlpool sandstone, which is on the average about 25 feet (7·6 m.) thick. At the mouth of the gorge the top of this sandstone is 142 feet (43·3 m.) above Lake Ontario. At Foster's flats it is about 75 feet (23 m.) above the lake and forms the floor of the flats and of Niagara glen and its bottom is at the waters edge at the head of Foster rapids. At the whirlpool it forms a bench a few feet above the water and is most accessible on the east side below Whirlpool point. Farther south it passes beneath the level of the river. The surface at the whirlpool is about 47 feet (14·3 m.) above Lake Ontario, so that the sandstone declines about 80 feet (24 m.) from the mouth of the gorge. On the west side opposite the American fall, a bench disclosed by Spencer's soundings at 90 to 100 feet (27 to 30 m.) is presumably of this sandstone, indicating a descent of about 50 to 60 feet (15 to 18 m.) from the whirlpool to the falls, for the water surface at the base of the falls is about 100 feet (30 m.) above Lake Ontario.

THE PROCESS OF GORGE MAKING.

The gorge is being elongated by boring at the base of the falls, where the heavy mass of falling water strikes at the end of its vertical descent. The softer strata are slowly worn away by the impact of the water itself, but the hard capping layer is removed chiefly by undermining, until it falls away in huge blocks. The blocks which drop into the caldron at the foot from above become highly efficient tools for grinding away the shale, for no doubt many of them are spun around in the violent currents like pestle stones in the making of potholes. The limestone is much harder than the shale, and while the spinning undoubtedly wears away the blocks, it wears away the shale in the walls and bottom of the caldron much faster.

When the falls had large volume and full height, the thinner, hard layers were bored through and removed, but when the height of the falls was reduced, as it was in one part of the gorge, or where the water sheet passing over the crest became thin, as it did in several places, parts of these beds were not removed and now form benches or terraces of more or less extent as described above. When the volume of the river was relatively small, as it was in two sections of the gorge, these layers were not both bored through by one vertical plunge, but in all probability formed separate cataracts, one for each hard layer. As Spencer has pointed out, this was probably the condition for a time in the older part of the gorge, north of Niagara University. In the gorge of the Whirlpool rapids the Clinton limestone probably formed a separate fall, but the Whirlpool sandstone was not bored through,except towards the north end, and probably now forms the block-covered floor of the channel. At the head of the narrow gorge the sandstone, as suggested by the dip, is 70 feet (21·3 m.) or more below the surface.

After the relatively narrow, shallow sections of the gorge had been made by the small cataracts, the rush of the large-volume river through these sections deepened them still further, not by the action of vertical cataracts, but by the slower and very different process of chute or rapids erosion. The deepening of the Old Narrow gorge north of the University has been substantially completed in this way; that of the gorge of the Whirlpool rapids is now in progress.

RELATIONS OF THE GREAT LAKES TO NIAGARA HISTORY.

Having in mind the foregoing outline of the geological conditions under which the gorge was made and of the physical processes involved, it is important to review briefly the relations of the Great Lakes to the history of Niagara river.

Excepting a few small streams which enter Niagara river above the falls, all the water in the river comes from the Great Lakes above. During two periods the discharge of Lake Erie alone passed over the falls; at other times the full discharge of the four upper lakes. During one period the full four-lake discharge was considerably increased. The lakes are simply storage reservoirs and act as equalizers of flow and Niagara river is merely the overflow of these great reservoirs. On this account the river is characterized by a steadiness and uniformity of volume found in few rivers. It has a slight annual variation of volume, due to spring freshets which raise the level of the lakes and summer droughts which lower their levels, through a total range of about two feet (·61 m.) and it has a longer period of variation amounting to three or four feet (·91 to 1·21 m.) and corresponding roughly to the eleven year wet and dry periods which vary with the frequency of sun spots. Considerably larger variations are caused by cyclonic storms on Lake Erie and by ice jams in the river itself. A heavy southwesterly gale of unusual duration has been known to raise the level of the water at Buffalo nearly eight feet (2·44 m.) and a similarly severe northeasterly gale has lowered it nearly six feet (1·38 m.) making a total variation of about 14 feet (4·27 m.) in the depth of the water at the head of Niagara river. The great ice jam of February, 1909, held the water back so that the American fall went almost entirely dry and the Horseshoe fall was greatly reduced. Niagara river knows no such thing as the great floods that affect rivers like the Ohio and the Mississippi. The shorter periodic variations (annual, eleven year, etc.) are much too slight in amount and also too short in duration to find any expression in the dimensions of the gorge.

When carefully studied in detail, the gorge is found to show certain parts that are relatively wide and deep and others that are relative narrow and shallow, and these sections vary in length from 2,000 feet (600 m.) to $2\frac{1}{4}$ miles (3·6 km.) and are therefore much too large and required vastly too long a time in their making to be referred to anything like the brief and small variations suggested above.

It might be thought that variations of geological structure or lines of weakness in the rocks have been a principal cause of variation in the dimensions of the gorge, but this is surely not so in any important degree. The geological structure throughout the length of the gorge is remarkably uniform. Except the thickening of the capping limestone in going from Queenston to the falls, no variation of structure or lines of weakness are known that would produce a perceptible effect. In the present stage of investigations it does not seem possible to estimate accurately the effect of this variable factor. Its importance, however, dwindles to almost nothing in comparison with a certain other variable factor which has surely been the one great cause of variation in the dimensions of the gorge: variation in the volume of the river.

Beginning at the mouth of the gorge and noting its dimensions, especially its width at the top of the cliffs, any one may easily recognize four clearly defined sections or divisions, not including the whirlpool which lies in a re-excavated portion of the much older, buried St. David gorge. But as a matter of fact there are five sections, the first two occupying the oldest part of the gorge, that between its mouth and Niagara university. The two together are nearly one and a half miles (2·4 km.) long. The remaining portion of the gorge shows three divisions very distinctly. The first is a wide section, the lower part shallow and the upper part deep, extending from the bend at Niagara university up to the upper side of the Eddy basin (excluding the whirlpool). This is about two miles (3·2 km.) long. Then comes the narrow, shallow section of the gorge of the Whirlpool rapids, three fourths of a mile (1·2 km.) long, and finally the wide deep section which the falls are now making, two and one fourth miles (3·6 km.) long. Knowing the uniformity of the geological structure, these variations of width and depth suggested to Mr. Gilbert many years ago the possibility of a variation of volume as the cause. The truth of this interpretation could hardly be fully established from a study of the gorge characters alone, but it might be expected that either strong corroboration or disproof of it would be found in the history of the four Great Lakes which now discharge their surplus waters through Niagara river. A brief statement of that part of the Great Lakes history which is related to Niagara river will show how many and how great have been the variations of its volume and the order of their occurrence.

OUTLINE OF THE GREAT LAKES HISTORY SINCE THE BEGINNING OF NIAGARA FALLS.

THE SUCCESSION OF THE GREAT LAKES.

Since Niagara falls first began, the great lakes have passed through five stages of change. Each of these stages had a different outlet from that of the stages immediately preceding and following it, and the volume of water discharged through Niagara river changed with each change of outlet. The five lake stages were as follows:

1. Early Lake Algonquin.
2. Lake Algonquin, Kirkfield stage.
3. Lake Algonquin, Port Huron stage.
4. The Nipissing Great Lakes.
5. The Present Great Lakes.

Four of the great lakes, including lakes Superior, Michigan, Huron and Erie, lie above Naigara and discharge their waters through it at the present time. But

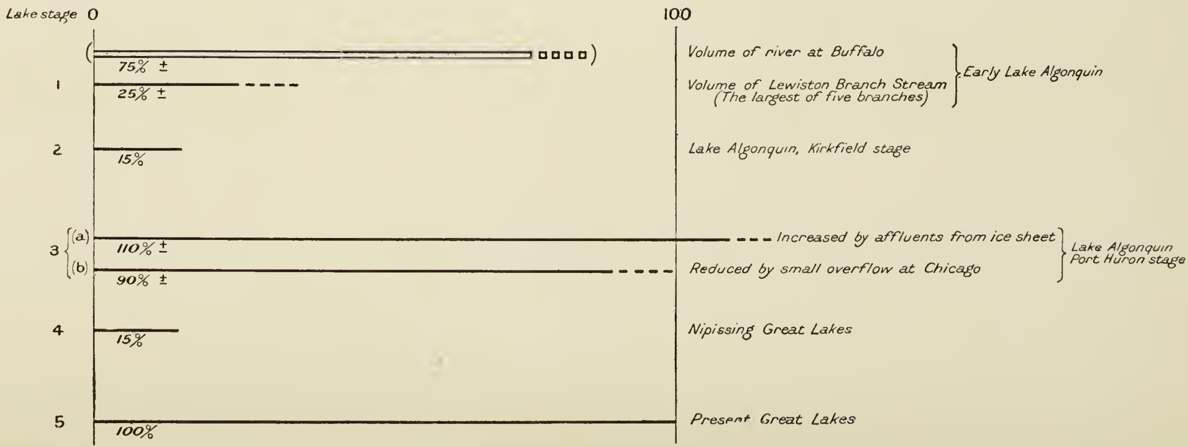

Diagram showing variations in volume of Niagara river.

at two different times in the past the first three of these lakes discharged their whole overflow by another route, not passing through Niagara. Taking the lake stages in the order of their occurrence as named above, and noting the lake area and the approximate frontage of the ice sheet involved in each, with the location of the outlet, the causes and times and approximate amounts of variation of the volume of Niagara river are clearly and fully revealed.

1. Early Lake Algonquin.—This lake occupied the south half of the Lake Huron basin and received a large affluent from smaller lakes in the south part of Georgian Bay basin and the Lake Simcoe basin. The ice barrier spanned Lake Huron from side to side and nothing was received during this stage from the Lake Michigan or Lake Superior basins. The volume of discharge was relatively large however, for the lake and its affluents all received large tributaries directly from the ice sheet all along their northern sides. The outlet of early Lake Algonquin was southward through St. Clair and Detroit rivers to Lake Erie and the discharge through Niagara river was correspondingly greater than that from Lake Erie alone. The whole volume of Niagara river at that time was probably nearly if not quite as large as it is now.

2. Lake Algonquin, Kirkfield stage.—This lake occupied the basins of Lakes Superior, Michigan and Huron and some of the low-lying lands bordering upon them. It did not attain its full extent in this stage, however, because the ice barrier still occupied large areas along its northern side. Thus, besides carrying the full discharge of the upper three lakes, Lake Algonquin at this stage received a large inflow of water directly from the ice sheet, and its total discharge was therefore in all probability slightly greater than the volume of the present St. Clair river. The outlet was at Kirkfield, Ontario, down the valley of Trent river to glacial Lake Iroquois, which was in part a contemporary of Lake Algonquin. The features of this outlet channel, caused by the scouring action of the great river, are strongly developed throughout its course and show unmistakably the great size of the stream.

3. Lake Algonquin, Port Huron stage.—At this stage Lake Algonquin covered nearly the same ground as before. The uplift of northern lands which changed the outlet from Kirkfield to Port Huron raised considerable areas above the level of the lake, but a greater area was added by the progressive withdrawal of the ice sheet. During the first half of this stage, Lake Algonquin received a large inflow of water directly from the ice sheet which still formed an extensive barrier in the north. In the second half, the barrier had dwindled to so small a frontage that its contributions of water were relatively small and unimportant. In the first half of this stage there appears to have been a large discharge at Chicago as well as at Port Huron, but in spite of this the stream at Port Huron was apparently slightly larger than the present St. Clair river. The Toleston beach of the Lake Michigan basin appears to be the same as the Algonquin beach, indicating that the discharge in the first part of this stage must have been very large—so large that it seems hard to account for its excess of volume by affluents from the ice sheet alone. In the first half of this stage the volume of discharge at Port Huron was probably slightly larger than the volume of the present St. Clair river, but in the second half it was a trifle less, on account of a small discharge at Chicago, and the volume of Niagara river was affected in a corresponding manner.

4. Nipissing Great Lakes.—This stage of the upper lakes was inaugurated by the final withdrawal of the last remnant of the ice sheet from the Ottawa valley. These lakes occupied the three upper lake basins and covered an area only a trifle larger than that of the present lakes. The ice sheet having disappeared, no additional water was received from it and the volume of discharge was the same as the present volume of St. Clair river. The outlet during this stage was eastward from the northern part of the Georgian Bay region, its head being at North Bay, Ontario. The scouring effects of the outlet river are well marked in the valleys of the Mattawa and Ottawa rivers and indicate a river having the same volume as that of the present St. Clair river. During this stage, therefore, Niagara river was again left with only the discharge of Lake Erie.

5. The Present Great Lakes.—Continued uplift of northern lands raised the outlet at North Bay, Ontario, and sent the discharge of the three upper lakes to Port Huron and thence to Lake Erie and Niagara. In the transition, both outlets were active at once, but this arrangement did not last long. The change of outlet to Port Huron brought the Nipissing great lakes to an end and inaugurated the present lakes. Thus, the present volume of Niagara river includes the entire discharge from the four lakes above, and this arrangement of overflow has continued ever since the last change of outlet.

INFLUENCE OF THIS SUCCESSION ON THE VOLUME OF NIAGARA RIVER.

The main facts of the lake history stated in the foregoing outline are all firmly established by observations, and the order of the lake stages, with their changes of outlet and the effects of these changes upon the volume of Niagara falls, are fixed beyond peradventure. The variations of volume are fixed primarily by the facts of the lake history, without any reference whatever to the characters displayed in the Niagara gorge. These facts are, therefore, the key to Niagara history and are far more weighty and reliable than any of the characters seen in the gorge; for no matter what characters are found there, it is certain, nevertheless, that the volume of Niagara river and the falls have varied as indicated by the lake stages and in the order named. With these facts in hand, the problem of correlation is relatively simple: can definite correlatives of lake stages be recognized in the gorge, and can *five* such correlative units, corresponding in character and order of occurrence to the five lake stages mentioned, be recognized?

The investigations of Dr. G. K. Gilbert and the writer of this text indicate that the correlation of gorge characters with the lake stages mentioned above is complete. The variations of volume of Niagara as deduced from the history of the great lakes may be represented graphically as in the accompanying diagram (p. 16).

Dr. J. W. Spencer also has contributed many valuable facts to the discussion of these subjects and was a pioneer in the study of the Great Lakes region. He named Lake Algonquin and, although its beach was already known in several places, its continuity and the rate and direction of its deformation in Ontario were first determined by him. He also named Lake Iroquois and made the first extended survey of its shore in Ontario. His views, differing from the views here expressed, sometimes with regard to the meaning of facts, but mainly in the broader interpretations, may be found in his volume on the "Evolution of Niagara Falls" [**10**].

INFLUENCE OF THE ONTARIO BASIN ON NIAGARA FALLS.

The waters in the Lake Ontario basin have had an important influence on the early history of the falls and in the making of the older parts of the gorge. The history of Lake Iroquois and the succeeding waters of the Lake Ontario basin has not yet been fully worked out. There is a remarkable submerged terrace at the mouth of Niagara river known as Niagara bar, which has been supposed to be a delta of the river formed when the lake stood at a somewhat lower level. It is not certain that it is wholly of the nature of a delta. The shallower part extends about three miles (5 km.) out and six miles (9·6 km.) along shore; the deeper part five miles (8·0 km.) out and 15 to 20 miles (24 to 32 km.) along shore. Many soundings on it show "rocky" bottom. It is not known whether these indicate stranded blocks or ledges of bed rock in place.

The place of this formation in Niagara history is not yet definitely known, but it seems certain that it does not belong to the early time of Lake Iroquois. It seems more probable that such part of the deposit as is true delta corresponds to a recent lower level of Lake Ontario. On the other hand, it may be largely of inter-glacial age.

Faint remains of what is supposed to be the first or earliest shore of Lake Iroquois have been found north of Lockport and Lewiston, N. Y., at Hamilton, Ontario, and elsewhere, showing that Lake Iroquois first stood at a lower level than the well known Iroquois beach and was afterwards raised to the level of that beach by an uplift of the land in the region of the Iroquois outlet at Rome, N.Y. At Lewiston the level of the lake was raised about 50 feet (15 m.) and at its higher level stood 125 feet (38 m.) above the present level of Lake Ontario. The effect of this depth of water backing up into the gorge, was much the same as a reduction in the height of the falls, producing a corresponding decrease in the boring of the cataract as well as a higher level for the caldron bored out at the base of the falls.

At a later time the great ice barrier which spanned the St. Lawrence valley somewhere below Kingston and held Lake Iroquois up to the level of the Rome outlet, disappeared and the lake was drained off. The waters in the Ontario basin then fell much below the present level of Lake Ontario. This change revived the downward cutting of Niagara river, and the older parts of the gorge were then deepened by a moderate amount, but this was accomplished chiefly by the wearing action of rapids rather than by the boring of vertical falls. The effects of both the higher and lower stages of the waters of the Ontario basin upon the falls are seen in the gorge from its mouth up to the head of Foster flats.

Soundings in the Niagara gorge.

The U. S. Lake Survey made a number of soundings in Niagara river many years ago, but these were all confined to the upper great gorge from a point opposite the American Falls down nearly to Swift Drift point. All the other soundings within the gorge were made by Dr. Spencer, some of them under conditions of great difficulty. He made three attempts to sound the depth of the water at the base of the Horseshoe falls with two carefully protected Tanner-Blish sounding tubes. One of these attempts failed, but two of them appeared to be successful and he gives the results as 69 and 72 feet (21 and 21.9 m.) respectively. Considering the tremendous turbulence of the water at the base of the falls, however, there seems to be some doubt as to what might happen to the apparatus there. It seems quite as likely that it might be carried backward under the falls so as to strike the wall under the over-hanging ledge as that it should strike the bottom. Three soundings made at the head of the Whirlpool rapids give depths of 52, 86, and 68 feet (15.8, 26.2 and 20.7 m.) going eastward from the west side, and may be correct, but there is considerable possibility of error in this case also. The principal soundings will be referred to in the description of the gorge sections.

GEOLOGY OF NIAGARA GORGE.

At its head at Buffalo the Niagara river flows through a shallow passage in the Onondaga limestone of Devonian age. Thence northward to the falls and down the gorge to the head of Foster's flats all the visible exposures of strata belong to the Silurian system. Below this the only rock exposed is the Queenston shale of Ordovician age, and where not composed of glacial drift, the river banks from Queenston to Lake Ontario are composed of this shale. In a paper read before the Geological Society of America at New Haven, Conn., in December 1912, Prof. Chas. Schuchert of Yale University gave an account of recent investigations by himself, Dr. W. A. Parks of Toronto University and Dr. M. Y. Williams of the Canadian Geological Survey, in consequence of which a revision of the Silurian of the Niagara region is suggested. Prof. Schuchert has contributed the following brief statement of the Niagara gorge section :

Niagara Gorge Section.

Along line of New York Central railway and Grand Gorge trolley line (see Grabau, Bull. 45, N.Y. State Museum, 1901).

Silurian.

Lockport dolomite.—Thickness as exposed 130 feet (39.6 m.).

Rochester shale.—Thickness 68 feet (20.7 m.).

Clinton upper limestone with an occasional bryozoan reef at top (Irondequoit of Rochester, N.Y.). About 10 feet (3.05 m.) thick.

Crystalline, heavy bedded, highly fossiliferous, pinkish limestone. Fossils essentially those of the Rochester shale. Has zones of stylolites.

Clinton lower limestones—(Wolcott or Pentamerus limelimestone at Rochester, N.Y.) About 15 feet (4.6 m.) thick.

Thinner bedded magnesian limestones with *Anoplotheca plicatula*, *Hyattella congesta*, etc.

Clinton shale.—About 5 feet (1.5 m.) thick.

Green to grayish shales with *Anoplotheca hemispherica* and *A. plicatula*.

Probable disconformity.

Medina formation.—Thickness 60 to 70 feet (18.3 to 21.3 m.).

Upper massive, quartzose, whitish, cross bedded sandstones. Gray band of authors. From 8 to 10 feet (2.44 to 3.05 m.) thick.

Reddish and greenish bedded sandstones, much cross bedded and channeled. From 12 to 15 feet (3.65 to 4.57 m.) thick. *Arthrophycus harlani* —2 feet (.61 m.) beneath top—and *Lingula cuneata.* Thin bedded, reddish sandstones, with red shale partings and at least one zone of storm-rolled mud balls. From 35 to 40 feet (10.7 to 12.2 m.) thick. In the upper part of these sandstones occurs the typical Medina marine fauna.

Gray sandstone with green shale partings. Thickness 5 feet (1.5 m.). Poor Medina fossils.

Disconformity and irregular contact, seen best along the Grand Gorge trolley line.

Cataract formation.—To be seen on each side of the small tunnel on N.Y.C.R.R. Thickness about 51 feet (15.5 m.).

Upper dark green shales, 4 feet (1.2 m.) thick.

Thin bedded ,green to yellow magnesian and argillaceous limestone, in lenses abounding in *Helopora* and fragments of *Lingula.* Thickness 3 feet (.91 m.).

Middle green shales, 10 feet (3.05 m.) thick.

Thin bedded argillaceous magnesian limestones, 2 feet (.61 m.) thick.

Helopora common, *Leperditia, Whitfieldella* and fragments of *Lingula.*

Lower green shales, 7 feet (2.1 m.) thick.

Basal or Whirlpool (Grabau) sandstone. Thickness 25 feet (7.6 m.).

Hard, heavy bedded, gray, somewhat coarse, cross-bedded sandstones. Thin bedded in upper 5 feet (1.52 m.). No fossils.

Disconformity with irregular contact in places.

Ordovician.

Queenston (Grabau. Synonym *Lewiston,* Chadwick).

Brick-red sandy shales. Exposed for 115 feet (35.0 m.). No fossils. In Ontario in equivalent strata occur fossils of Richmondian age.

The equivalent strata of the older and newer classifications as used by Grabau and Schuchert respectively are shown in parallel columns below:

(Grabau)	(Schuchert)
Silurian	*Silurian*
Lockport (Niagara) limestone	Lockport dolomite
Rochester (Niagara) shale	Rochester shale
Clinton limestone, two beds	Clinton limestone, two beds
Clinton shale	Clinton shale
Medina formation	Medina formation
Upper Medina sandtone	Medina sandstone
	Cataract formation
Medina sandy shales	Cataract sandy shales
Lower Medina gray shales	Cataract gray shales
Medina gray, quartzose	Basal or Whirlpool sandstone
Whirlpool sandstone	
	Ordovician
Medina red shales	Queenston red shales
Oswego sandstone	Oswego sandstone
Ordovician	

The Lockport limestone is not rich in well preserved fossils where exposed in the Niagara gorge, but Grabau describes one of the lower beds of this foundation, the Crinoidal limestone, as a "highly crystalline limestone, on the weathered surfaces of which joints of crinoid stems and other organisms stand out in relief, particularly in the lower parts of the stratum. The rock is entirely composed of fragments of organisms which were ground up and mingled together in great profusion." The Geodiferous limestone next above also contains fragmentary fossils, but none well preserved.

Grabau gives also a list of the few fossils found in the Clinton upper limestone and 29 species found in the limestone lenses in the Clinton shale.

SUMMARY OF GORGE CHARACTERS AND SECTIONS.

If the study of the Niagara gorge were approached without any previous knowledge of the history of the great lakes, characters of some importance might possibly be overlooked, but the larger variations of width and depth would at once attract attention. From this point of view, the characters clearly suggest a division of the gorge into at least four sections, not including the whirlpool, and there are other characters which more or less vaguely suggest a further subdivision of two of these sections. These subdivisions are indicated in the older two of the four more obvious divisions. One of these is confirmed by the lake history; the other is not. Beginning at the mouth of the gorge, one might conclude at a first glance that the first or oldest section extends all the way from the mouth of the gorge to the bend of the river below Niagara University and that this part of the gorge is therefore a unit in the river history. But such is not the case.

First or oldest Section. (Lewiston branch gorge.)

For about 2,000 feet (610 m.) south from the mouth of the gorge the cliff lines are somewhat irregular and the average top width is about 1,400 feet (430 m.) or about 100 feet (30 m.) greater than the remaining part extending to the university. Based on gorge characters alone, the reasons for making a division point here might perhaps seem insufficient. But in this case, other facts relating to the river history, as well as the greater weight of the lake history, established quite clearly the reality of a division point about at this place. In his studies of the Niagara gorge a number of years ago, Mr. Gilbert found that for a relatively short period Niagara river poured over the escarpment at five different places, the present place being the most westerly. The river, therefore, discharged only a fraction of its volume through any one channel, and yet three of the channels east of Lewiston indicate relatively large volumes. Altogether, the several channels seem to show clearly that the total volume of the river was nearly if not quite as large then as at present and certainly several times larger than the discharge of Lake Erie alone. It seems certain, therefore, that the irregularities and extra width of the first 2,000 feet (610 m.) of the gorge belong to the time of divided flow over the escarpment. In the lake history this correlates with the time of early Lake Algonquin.

The Old Narrow Gorge.

From this division point up to the bend below the university, the gorge is remarkable for the straightness of its cliff lines and the eveness of its top width. This is known as the Old Narrow section and is a little more that a mile long. Its average top width is about 1,300 feet (400 m.). The talus slopes are fully twice as wide in these two old sections as the average in the newer sections. This is partly due to greater age and longer weathering, partly to thinner capping limestone and partly to the exposure of nearly 100 feet (30 m.) more of shale in the gorge walls here than in those above the head of Foster's flats. Spencer's soundings show a depth of 150 feet (45.7 m.) about 1,000 feet (304 m.) from the mouth of the gorge in the middle of the first section, but the Old Narrow section, judged by the few soundings available and by the behaviour of the water, is on the average less than 100 feet (30 m.) deep. In these older parts of the gorge the recent rise of the level of Lake Ontario has backed the water up into the gorge, slackening the current and increasing the depth. On this account the water stands somewhat higher and covers the lower part of the talus slopes. In the lake history this section of the gorge correlates with the Kirkfield stage of Lake Algonquin. It was originally made narrow and not so deep as now, for the cataract then carried only the discharge of Lake Erie, and Lake Iroquois stood about 75 feet (23 m.) higher than the present surface of Lake Ontario.

The Lower Great Gorge.

This section extends from the bend below Niagara university, where the gorge widens, to the upper side of the Eddy basin, but does not include the whirlpool. Its width between the cliff lines from the bend up to a point about 1,000 feet (30 m.) above the head of Foster rapids averages more than 1,600 feet (490 m.), and at the widest is about 1,825 feet (560 m.). It is also characterized by shallowness to the upper end of Foster's flat. Above the north end of Wintergreen terrace the width is 1,300 to 1,500 feet (400 to 460 m.), and shallowness gives place to greater depth at the upper end of Foster's flat. From the point of view of gorge characters alone, these variations of width and depth are not easily explained. But in the light of the lake history their causes seem clear, and although they might seem to furnish good ground for subdividing this section, the lake history shows that they are not of that order of importance. The extra width was due partly to the augmented volume of the river (by water coming directly from the ice sheet) as compared with the present volume, and partly to the wide, flat rock floor above the falls, which caused the water sheet to be spread to unusual width. This last condition led to the formation of Wintergreen terrace and the associated lower rock terraces. The shallowness to the head of Foster's flat was caused mainly by the fact that Lake Iroquois stood 125 feet (38 m.) higher than the present level of Lake Ontario and backed up into the gorge at this level. The original narrowness and shallowness of the Old Narrow gorge just below must have tended to contribute to the same result until it was cut down by the scour of the rapids. The same uplift that raised the Kirkfield outlet sent the augmented discharge of the upper three lakes to Niagara, and it was then that the large-volumed cataract first began gorge making at the bend below the university. It also raised Lake Iroquois about 40 feet (12 m.), or from about 85 feet to 125 feet (25 to 38 m.) above present lake level. When Lake Iroquois fell to a lower level, the water at the base of the falls fell, and the falls immediately became in effect higher and bored deeper. This change occurred when the falls were at the head of Foster's flat, for, from this point up to the upper side of the Eddy basin the river is deep. Spencer's soundings show depths of nearly 100 feet (30 m.) in the stretch between the whirlpool and Foster's flat.

The reef which produces the sharp rapids at the outlet of the whirlpool owes its origin to the breaking away of the east wall of the whirlpool before the vertical fall had time to carve out the sandstone at its base. When the break in the wall came the lowering of the water in the whirlpool must have been quite rapid. Then, continuing their work, the falls cut out the Eddy basin before the volume of the river was reduced. In the lake history, this section is the correlative of the Port Huron stage of Lake Algonquin.

The Gorge of the Whirlpool Rapids.

This section is about three-fourths of a mile long and extends from the upper side of the Eddy basin to the head of the narrows just above the railway bridges. The average top width is about 750 feet (228 m.); the average width at the water line is about 250 feet (106 m.). Knowing this and the volume of the river and the rate of flow in the rapids, Mr. Gilbert estimated the depth to be 35 or 40 feet (10·7 to 12·2 m.). Spencer's soundings from the upper railway bridge show a midstream depth of 86 feet (26·2 m.) shallowing towards the sides, but the water there is only beginning its descent and has not acquired its full velocity. In the lake history, this section is the correlative of the Nipissing great lakes, and was made, therefore, when the falls carried only the discharge of Lake Erie. Spencer interprets this section in an entirely different way, making it 185 feet (56·4 m.) deep and choked up with fallen blocks to a depth of 100 feet (30·4 m.) or more. The views of Pohlman, Grabau and others are given below in the discussion of the Whirlpool and the St. David buried gorge.

The Upper Great Gorge.

This section, reaching from the head of the narrows just above the railway bridges to the Horseshoe falls, is about two and one-fourth miles (3·8 km.) long. Opposite the American fall it is 1,600 feet (487 m.) wide at the top and is wider than the average from there to the south side of Goat island. Its average width north of the American fall is about 1,350 feet (411 m.), with a least width of 1,025 feet (312 m.) at Swift Drift point. The deepest sounding by the U. S. Lake Survey was in the centre opposite Prospect point, where a depth of 189 feet (57·6m.) was found, and Spencer's deepest sounding, below Goat island near the Horseshoe fall, was 192 feet (58·5 m.). The average central depth north of the American fall is not far from 160 feet (48·8 m.), but there are four soundings in that stretch which show 186 feet (56·7 m.). Above the American fall the central depth is 100 to 120 feet (30·5 to 36·6 m.). This section is the correlative of the present stage of the great lakes, and is still in the making.

The gorge characters and sections and their correlatives in the lake history are summarized in the following table:

CORRELATION OF GORGE SECTIONS WITH LAKE STAGES.

Lake Stages.		Gorge Sections.				
Name.	Relative volume of Falls.	Name of sections.	Length	Division points.	Average top width.	Average depth of river.
1. Early Lake Algonquin.	20 to 25 per cent of present volume. (Whole river nearly equal to present volume.)	First or oldest section. (Lewiston Branch gorge).	2,000 feet (610m)	Mouth of gorge to a point about 2,000 ft. (610 m.) south.	1,400 feet (426 m.), but variable.	140 to 150 feet (42·7 to 45·7 m.)
2. Lake Algonquin, Kirkfield stage.	15 per cent of present volume. (Lake Erie alone).	Old Narrow gorge.	About one mile and one eighth (1·8 km.)	From a point about 2,000 feet (610 m.) south of the gorge mouth to the bend below Niagara University.	1,300 feet (396 m.), very uniform. (Originally narrow. Deepened by rapids; widened by weathering).	60 to 70 feet (18·3 to 21·3 m.)
3. Lake Algonquin, Port Huron stage.	First half slightly greater than present. (4 lakes —). Second half, slightly less than present. (4 lakes —).	Lower Great gorge.	Two miles (3·2 km.)	From the bend below the university to upper side of Eddy basin not including whirlpool. The two halves divide about at the head of Foster rapids.	1st half, 1,600 feet, (487 m.), greatest, 1,825 feet (556·2m.), least, 1,300 feet. 396·2 m.). 2nd half, 1,200 feet (365·7 m.) Least, 1,000 feet (304·2 m.), at lower whirlpool reef. At Eddy basin, 1,200 ft. (365·7 m.)	(1st half) shallow. 35 to 70 feet (10·7 to 21·3 m.). (2nd half) deep. 100 feet or more (30·4 + m.).
4. Nipissing great lakes.	15 per cent of present volume. (Lake Erie alone).	Gorge of whirlpool rapids (New Narrow gorge.)	Three-fourths mile (1·2 km.)	From upper side of Eddy basin to the point of expansion above the railway bridges.	750 feet (228 m.), quite uniform.	35 or 40 to 85 feet. (10·7 or 12·2 to 25·9 m.)

CORRELATION OF GORGE SECTIONS WITH LAKE STAGES.

Lake Stages.		Gorge Sections.				
Name.	Relative volume of Falls.	Name of sections.	Length	Division points.	Average top width.	Average depth of river.
5. Present great lakes	Present volume, 4 lakes.	Upper great gorge.	Two and one-fourth miles (3·6 km.)	From the point of expansion above railway bridges to the Horseshoe fall.	1,350 feet (441·5 m.) Widest opposite American Fall, 1,650 ft. (503 m.); between Prospect Point and Carter Cove, 1,600 feet (487·7 m.). Narrowest at Swift Drift Point, 1,025 feet (311·3 m.).	North of the American Fall, 160 feet. (48·8 m.). (Four of 186 feet (56·7 m.), one of 189 (57·6m.) South of American Fall, 100 to 120 ft. (30·4 to 36·6 m.), one 192 feet (58·5 m.)

The river north of the mouth of the gorge has an average width of about 2,000 feet (610 m.) and an average depth of 45 feet (13·7 m.). The deepest point, 183 feet (55·8 m.) (Spencer), is opposite Queenston. The deepest channel over the bar is about 25 feet (7·6 m.) deep.

The whirlpool is 1,700 feet (518 m.) wide between rock cliffs. The mouth of the old gorge in the embayment south of St. David is one mile (1·6 km.) wide, but contracts to five-eighths of a mile (1·0 km.) at a point one half mile (·8 km.) within the mouth, where the last of the rock cliffs in the embayment are seen.

The accompanying map of Niagara Gorge shows the division points where the gorge is divided into sections and the relation of the sections to each other.

THE WHIRLPOOL AND THE BURIED ST. DAVID GORGE.

It has long been recognized that the rock basin of the whirlpool is older than the rest of the gorge and has had a different history. It is a buried, drift-filled gorge of inter-glacial age. The walls surrounding it on the east and west sides are rock cliffs, like those in the gorge immediately above and below. But on the north and northwest sides the entire wall from the top down to an undetermined depth below the water is composed of sand and gravel, stony clay and boulders, all being loose drift of a later age than the rock gorge itself. Bowman creek descends to the whirlpool from the upland about a mile to the northwest and has cut a deep ravine in the soft sediments, reaching far below the ledges that mark the top of the ancient gorge. The ravine itself lies mainly along the western side, for the western rock wall and cliffs are exposed for some distance. The east side of Bowman ravine however, shows no rock, but is composed entirely of drift, even down where the creek enters the whirlpool. Fragments of the rock cliffs on the two sides of the ancient gorge run a short way north-northwest from the whirlpool showing the direction in which the buried gorge extends.

South of the village of St. David there is a strongly marked re-entrant in the front of the escarpment, the head of which shows no rock for about a mile, but is a steep and much-gullied slope of drift. This place is in an almost direct line with the prolongation of the older cliff lines at the whirlpool, and it seems impossible to doubt that the gorge extends through to the break in the escarpment south of St. David. One of the faint terminal moraines of this region crosses its northern part and forms the highest part of the filling.

The greatest depth found in the whirlpool by Spencer's soundings is 126 feet (38·4 m.). This is in the middle of the pool and of the upper part of the ancient gorge, where the river in its recent gorge making had only soft drift to remove and no vertical fall with which to bore the rocks at the bottom. This depth belongs, therefore, to the old buried gorge, and, indeed, may not show its full depth in the rock.

Dr. Spencer made a boring into the drift filling of the old gorge at a point about half a mile (·8 km.) northwest of the whirpool, but at a depth of 269 feet (82·m.) encountered difficulties that stopped the work. The boring was started on the general level of the plain and ended at a level of about 24 feet (7·3 m.) above the water in the whirlpool. No rock was encountered, the material being mainly till, sand and some gravel, with boulders at the bottom. While this boring did not reach the rock bottom of the old gorge, it nevertheless strongly confirms the conclusion that the gorge continues to the northwest.

The discovery and re-excavation of the head of the old buried gorge by the modern river appears to have been merely an accident of topography. When the river first began to flow, the lowest line across the plain happened to carry the river over the upper end of the buried gorge, and when the falls had gnawed back to this point they quickly cleaned out the drift materials and resumed rock cutting by a vertical cataract at the southeast side of the whirpool.

Not only is the ancient gorge filled with glacial drift, but at one point in Bowman ravine north of the electric railway embankment, glacial striæ and polishing were found on the west wall of the gorge 90 feet (27·4m) below the top, showing clearly that the gorge was occupied by a current of the ice sheet before it was filled with drift.

Grabau and others who regard the buried gorge as of pre-glacial age point to the widening towards its mouth south of St. David and attribute this to the subaërial weathering and erosion of the long pre-glacial time. But there is another interpretation. In the first place, the widening is not so great as is stated by Grabau (two miles), but is in fact one mile; and in the second place, the modification which appears to have produced the widening is confined to the west and south side of the mouth of the gorge and appears not to have affected the north side. Supposing the gorge to have been of uniform width when first made, the remnant of the plain on the west side of its mouth would be a salient of the escarpment so situated as to be exposed to the full force of the oncoming ice. On this account it would have been torn away by the last ice sheet and the cliff line would have been driven back and straightened so as to present a more resistant front. The north side of the gorge mouth was not so exposed and would not have been modified in this way.

There are other weighty reasons why this ancient buried gorge should be regarded as inter-glacial rather than pre-glacial. Its top width between the cliffs on the north side of the whirlpool, and also its depth, are so closely identical with the average width and depth of the Upper Great gorge that one cannot resist the impression that it was made by a cataract substantially identical in volume with the present Niagara falls—by an inter-glacial Niagara. So far as the characteristics of the buried gorge are known, it is quite clear that they do not bear out the idea of Pohlman, Grabau and others that it was originally made by a relatively small stream and was widened to its observed width by a long process of subaërial erosion. On the contrary, they seem to show quite clearly that it was made by a vertical cataract of large volume, substantially identical with the present falls.

At the south side of the whirlpool there is a strongly marked reef which produces a sharp separation between the whirlpool and the Eddy basin. This is the upper reef of the whirlpool. When the water is clear the submerged rocks of this reef can be seen for about one quarter of the width out from each shore, and it produces a short but sharply defined rapids. Directly over this reef the top width of the gorge is narrower than over the central part of the Eddy basin. The Eddy basin has not yet been sounded, but the majestic swing of the great return current which sweeps back on its west side shows plainly that the water is deep. The top width and apparent depth of the Eddy basin are almost identical with the average dimensions of the Upper Great gorge between the railroad bridges and the Park bridge. The reef which shuts it off from the whirlpool, coupled with these characteristics of depth and width, compel the conclusion that the Eddy basin was made by a vertical cataract, like the present falls and with substantially identical volume. The deep hole of the eddy is behind the reef which separates it from the whirlpool, and there is no way to account for it, except by the vertical plunge of a great cataract which somehow suffered a slight interruption that allowed the reef to remain—either such an interruption or something equivalent to it.

It seems impossible to explain the depth of the Eddy basin, its separation from the whirlpool by the upper reef and the sudden shallowing and contraction at the mouth of the gorge of the Whirlpool rapids, on the theory that the buried gorge, the Eddy basin and the gorge of the Whirpool rapids were made by a pre-glacial small stream and afterwards weathered out to their present dimensions. The assembled characters in this part of the gorge seem to show clearly that the St. David gorge was made by an inter-glacial Niagara which suddenly ceased at the south side of the Whirlpool basin. But a much smaller stream probably remained and cut a narrow, shallow gorge reaching 100 to 200 yards (90 to 183 m) south from the whirlpool. When the inter-glacial cataract stopped, the ledge of Lockport limestone which formed the crest of the falls at that time, overhung the south edge of the whirlpool and projected somewhat to the north of the ledges of Whirlpool sandstone which form the present reef. Then after the inter-glacial cataract had ceased, the overhanging ledges fell away and normal cliff recession due to weathering drove the cliff line still farther back, until a relatively stable talus slope was produced. When this condition had been reached a talus slope probably 200 or 300 feet (60 to 90 m.) in width separated the top of the cliff from the reef, that is to say, the top of the cliff, measured on a horizontal plane, was that far south of the reef. Then came the last ice sheet, completely filling the old gorge. When the modern great cataract had gnawed back to the whirlpool and cleared out the filling of drift, it resumed the work of gorge making by a vertical fall at the south side of the whirlpool; not however just where the inter-glacial cataract had left off, but as much farther back as the cliff line had receded in the meantime—some 200 or 300 feet (60 or 91 m.). This is the equivalent of the interruption of the work of one great cataract mentioned above. The reef is there mainly on account of the weathering that occurred in the time that elapsed between the cessation of the inter-glacial falls and the arrival of the ice sheet which filled and buried the old gorge. And both the inter-glacial and the later cataracts involved in this history had about as large volumes as the present falls. If the alternative of Grabau be adopted nothing is left in the Niagara gorge which can possibly stand as a correlative of the lake stage represented by the Nipissing great lakes, and the absence of this correlative would certainly be much harder to explain than the characters and relations of the reef and the Eddy basin.

ITINERARY.

Toronto to Niagara river.

Niagara Falls is most easily reached from Toronto by crossing Lake Ontario to the mouth of Niagara river 30 miles (48·3 km.) to the southeast and going up the river seven miles (11·3 km.) to Queenston, where electric cars are in waiting for passengers. The voyage lasts about two hours and gives some idea of the smallest of the Great Lakes, which is 180 miles (290 km.) long and from 30 to 50 miles (48 to 80 km.) wide.

Toronto harbour is formed by a hook of sand and gravel extending westward for two and a half miles (4.0 km.) from the mouth of Don river, and then bending north toward the main shore. The bar, which is called Toronto island, is built of materials transported by the easterly storms from Scarboro heights. Two artificial channels give egress to the lake.

From the stern of the steamer there is a view of Toronto and also of Scarboro heights, ten miles (16 km.) east of the harbour, including the highest point on the actual shore of Lake Ontario, rising 355 feet (108 m.) above the water as pale cliffs of clay.

Before Scarboro heights fade from view the Niagara escarpment may be seen from the bow of the ship. It is

7 miles (11·3 km.) from the south shore of the lake but rises in places 380 feet (115·8 m.) above it, or 625 feet (190·5 m.) above the sea, the elevation of Lake Ontario being 245 or 246 feet (74·7 or 75·0 m.).

The basin of Lake Ontario is not symmetrical, since the deepest soundings occur near the south shore, where depths of 400 or 500 feet (121·9 or 152·4 m.) are frequently found. The greatest depth recorded is 738 feet (224·9 m.), so that the bottom goes 492 feet (151 m.) below sea level. The basin was probably once a river valley, its northeastern end at the Thousand islands having been warped up at the close of the Ice age.

Lake Ontario to Niagara Falls.

The Lower Niagara River—Approaching the mouth of Niagara river, the steamer crosses what is supposed to be a submerged delta of Niagara river called Niagara bar. Its front descends to a depth of over 200 feet (60·9 m.) quite steeply. The depth of the water on it varies from less than 15 feet (4·6 m.) to about 40 feet (12·2 m.). Many soundings in the shallower part show "rocky" bottom, so it is not certain that it is all a delta deposit.

The banks of Niagara river below the gorge are steep and rise from a height of 20 to 30 feet (6 to 9 m.) near the lake to 125 feet (38·2 m.) at Lewiston. The average width is about 2000 feet (610 m.). The banks are red shale with thin drift on top, but two miles (3·2 km.) south of Niagara-on-the-lake the rock disappears and the banks on both sides are wholly of drift for about a mile. This is probably an old river channel of inter-glacial or pre-glacial age and has been regarded by some as a possible continuation of the buried St David gorge. A sharply cut terrace 20 to 25 feet (6·1 to 7·6 m.) above the river at the Stella Niagara school, two miles north of Lewiston, is an abandoned portion of the old bed where the river flowed at a higher level than now. It is floored with coarse gravel and cobbles, which show in the bank. Just opposite, on the Canadian side, there is another fragment of old channel at a slightly higher level. This is three-fourths of a mile (1·2 km.) long, relatively narrow and the outer part of its course is about one-third (·5 km.) of a mile from the river.

Lewiston to Niagara Falls—At the landing at Lewiston there is a good view of the front of the escarpment and the mouth of Niagara gorge.

The railway between Lewiston and Niagara ascends by a loop to the top of the sandstone terrace, passes through a short tunnel and enters the mouth of the gorge more than 140 feet (43 m.) above the water. For about two miles (3·2 km.) the railway runs along the steep face of the gorge wall, cutting the strata obliquely as it ascends. As the rocks dip gently toward the south, and the railroad ascends in the same direction, it cuts all the strata from the Whirlpool sandstone up to the Lockport (Niagara) limestone exposing good sections for examination and for the collection of fossils.

Below Niagara university the railway turns away from the river through a deep cut in the Lockport limestone and soon reaches the level of the plain in which the Niagara gorge is made. After passing Suspension bridge, the train runs for nearly a mile along the brink of the Upper Great gorge and some fine views are obtained of this part of the river, including the falls about two miles (3 km.) away. For a few moments there is a fine view backward from the right side of the train, into the head of the narrow gorge of Whirlpool rapids.

Niagara Falls and the Rapids from the American Side.

Old River Terraces.—Entering Prospect park at the Soldiers monument, the level of the ground is seen to descend by two rather ill-defined steps or terraces. These terraces are composed mainly of gravel and mark old levels of Niagara river when the falls were located probably one and a half miles (2·4 km.) or more below their present site.

Prospect Point.—One of the finest views on the American side is to be obtained from this point. It is at the northern end of the American fall, where the water passes smoothly over the brink. The American fall is seen lengthwise along its crest, the observer's feet being but little above the level of the water. Viewed in this way the protruding and re-entrant angles of the crest seem relatively much greater than they really are, for the crest line is nearly straight. The water sheet passing over this fall is much thinner than that of the Horseshoe fall, being not over three feet (·9 m.) deep in the deepest part and over much of the central part one foot (·3 m.) or less. This fall is about 168 feet (51·2 m.) high, but is about two feet (·6 m.) higher at its south edge than at its north. The water does not plunge directly into the great caldron or pool below, but falls upon a mass of great blocks which have fallen from above. Some of these are of huge size. One known as the Rock of Ages lies below the southern end of the fall.

The American Fall from Prospect point, looking south. The Horseshoe Fall in the distance.

These blocks are fragments of the Lockport (Niagara) limestone from the cliff over which the American fall now passes ; and they rest mainly on a bench of Clinton limestone which projects about 300 feet (90 m.) out from the foot of the fall. The edge of this shelf is in line with the edge of the same shelf both north and south of the American fall, but except under the fall it is covered with a heavy mass of talus. Under the fall the material has all been carried away and only the great blocks remain. Elsewhere the talus contains much fine material which largely conceals the blocks.

A few paces north of Prospect point is Hennepin's View, supposed to mark the spot from which the first white man beheld the falls. The point is higher and affords a better general view.

Slow Recession of American Fall.—The crest of the American fall is about 1,000 feet (305 m.) long and forms a nearly straight line continuous with the cliff on either side, so that that part of the cliff which forms the brink of the fall has receded little if any more than the adjacent parts which have not been the crest of a waterfall. Gilbert, Spencer and others have made estimates of the rate of recession of the American fall based on Hall's and later surveys. Spencer found the rate to be about ·6 feet (·18 m.) per year, but Gilbert found a very large error in Hall's map. The northern part of Hall's crest line is represented as a large salient projecting about 100 feet (30·4 m.) too far. After making this correction from contemporary drawings, Gilbert concluded the rate "is probably as small as ·2 (·06 m.) of a foot per annum." But it may be much less than this, as the following considerations show. The talus slopes north and south of the American fall are no wider than that directly in front of it, except for an interval of 300 or 400 feet (90 or 122 m.) in the central part, where the width is a very little greater. Manifestly, if normal cliff recession due to weathering has produced talus slopes as wide as that in front of the American fall, the production of a slope of the same width along the front of the falls need not be attributed to the work of the falls, but is quite as likely to be due to normal cliff recession.

The sheet of water passing over this fall is thin and feeble and has not been able to remove or wear the blocks away, even in the 400 or 500 years that have probably elapsed since the Horseshoe fall was finally separated from the American fall. If the slight re-entrant in the central part of the crest line was made by the fall as distinguished from cliff recession by weathering, and was deepened even as much as 50 feet (15·2 m.), the average rate would be about ·1 of a foot (·03 m.), or a little more than one inch (2·5 cm.) a year. On the rest of the crest line there is no certain evidence of recession by the action of the falls.

Goat Island.—This island separates the American fall and rapids from the Horseshoe fall and the rapids above it. The surface is nearly flat, and composed of gravel, much of it coarse. Towards its west end the gravel is 10 to 12 feet (3·0 to 3·6 m.) deep and overlies 25 or 30 (7·6 or 9·1 m.) feet of stony till or boulder clay, which in turn rests upon the Lockport limestone.

From Stedman bluff one looks down upon the American fall and the rapids above it and into the mist and spray which largely conceal from sight the great blocks below. In the distance to the north one looks down the upper gorge to the railroad bridges. The turbulent water, with its wonderful foam pattern, its whirls and boils, is a fascinating object to study. The currents show how small is the influence of the water passing over the American fall compared with that

The American Fall, looking north from bluff at northwest corner of Goat Island; Luna Island in the foreground.

which comes from the greater cataract. From this point one sees in the foreground the relatively small but beautiful Luna fall, with Luna island on its north side, beyond which a good view is had of the central part of the Ameiican fall, where the re-entrant angle is deepest and where recession, if any, has been greatest. The thinness of the water sheet here is quite notable as compared with the heavier mass beyond.

The luxuriance of the verdure of Luna island, like that on the other islands and the main land wherever within reach of the spray, is notable. In winter the spray forms great domes of ice reaching more than halfway up to the top of the falls. They do not obstruct the falling water, but rest upon the great blocks and the Clinton ledge just in front. Often the ice domes do not wholly disappear until June or July.

From Goat island, those who wish may make the excursion into the Cave of the Winds. From the foot of the stairs the passage leads behind Luna fall to a point below Luna island, returning through the spray in front of Luna fall. Formerly, visitors went behind the north end of the American fall, and it was there that Mark Twain said the he felt as though he had the Atlantic ocean going down his back.

Fossil Shells (Pleistocene).—When the great cataract was situated a mile or two below its present place, Goat island formed a part of the gravelly floor of the river, which at that time flowed over the site of Goat island with a relatively gentle current, probably such a current as now characterizes the river a few miles below Buffalo. The gravelly bottom of the river on Goat island was then a favorite habitat for certain forms of mollusks. Fossil shells occur in great abundance in a gravel pit in the woods near the western end of Goat island.

In his guide book of 1901, Grabau includes a list of Pleistocene fossils of the Niagara region compiled by Miss Elizabeth J. Letson, of Buffalo. A total of 31 species are given from seven localities. A greater number of species were found on Goat island than at any other place, the number being 28. The localities given are Goat island, Prospect park, Queen Victoria park, Muddy creek, Whirlpool (American side), Whirlpool (Canadian side), and Foster's flats. The species given are as follows:—

Gastropoda.

1 Pleurocera subulare Lea
2 Goniobasis livescens (Menke)
3 G. livescens niagarensis (Lea)
4 G. haldemani Tryon
5 Amnicola limosa (Say)
6 A. letsoni Walker
7 Bythinella obtusa (Lea)
8 Pomatiopsis lapidaria (Say)
9 Valvata tricarinata Say
10 V. sincera Say
11 Campeloma decisa Say
12 Limnæa columella Say
13 L. desidiosa Say
14 L. batascopium Say
15 Physa heterostropa Say
16 Planorbis bicarinatus Say

Pelecypoda.

17 P. parvus Say
18 Sphærium striatinum (Lam.)
19 S. stamineum (Conrad)
20 Pisidium virginicum Bourg
21 P. compressum Prime
22 P. abditum Haldeman
23 P. ultra-montanum Prime
24 P. scutellatum Sterki
25 Lampsilis rectus (Lam.)
26 L. ellipsiformis (Conrad)
27 Alasmidonta calceola (Lea)
28 A. truncata (Wright)
29 Unio gibbosus Barnes
30 Quadrula solida (Lea)
31 Q. coccinda (Conrad)

A gravel bank in Queen Victoria park about opposite the middle of the rapids was accessible before the power instalments and the park improvements and was very rich in fossil shells. Professor Coleman collected fossils at this locality and reports the following species:

Gastropoda.

Pleurocera subulare Lea
Goniobasis livescens Menke
Physa heterostropha Say
Limnæa decidiosa Say

Pelecypoda.

Sphærium solidulum
S. Striatinum Lam.
Unio gibbosus Barnes
U. luteolus
U. rectus
U. clavus
U. occidens
Quadrula solida Lea
Q. coccinea Conrad

The Horseshoe Fall from Porter Bluff and Terrapin Rocks.

From the top of the bluff at the southwestern corner of Goat Island there is a fine view of the western part of the Horseshoe fall, of the nearer part of the rapids above the fall and of the bluffs back from the river on the west side. The water here and for a considerable distance farther out is very shallow; much of the rock is exposed and the surface is dotted here and there with stranded blocks of limestone. The shallows near the island is called Goat Island shelf. A little above the water level, the ledge of the Clinton limestone projects out about 500 feet 150 m.) from the extreme end of Goat island and is covered with the same assemblage of huge fallen blocks as at the American fall. The fine material has been washed away leaving blocks that are on the average considerably larger than those below the American fall.

The view from the Terrapin rocks northward along the western face of Goat island shows very clearly the relation of the American fall to the cliff line, for beyond Goat island and extending substantially in the same line, the front of the American fall is in plain view and also a part of the cliff farther north. The whole front is a nearly straight line which the American fall appears not to have modified perceptibly.

The central part of Horseshoe fall and especially the head or apex of the curved brink are seen here at too low an angle for a clear appreciation of their outline. The deep emerald green water pours over the brink in a graceful unbroken curve. The water there is supposed to reach

20 to 25 feet (6·1 to 7·6 m.) in depth. Twenty years or more ago the angle at the apex of the fall was sharper and more acute. The principal change in the outline in recent years has been a falling away of the crest along the line to the right of the apex as seen from this point.

The water pouring into the angle near the apex sometimes produces a remarkable effect, like an explosion in the depths below. It makes a perceptible booming sound and throws up jets of spray to heights considerably above the top of the falls. This effect is best seen from here and was formerly more marked than now.

The Horseshoe Fall, looking south from bluff at southwest corner of Goat Island. Goat island shelf in the foreground.

The Sister Islands and the First Cascade.—Here is a picturesque spot where small branches of the rapids pass between small rocky islands. The beds of Lockport limestone here are thick and massive, leaving an abrupt descent of five or six feet where they part along their joint planes. One of these beds runs from the shore of Goat island just above the Sister islands directly south across the river. It extends in a nearly straight line and the water falls over it in what is known as the First cascade.

The loosened blocks are gradually pushed away, probably to some extent by the water, but more effectively by the heavy ice cakes in the spring. The Sister islands are remnants of this massive bed.

From the park on the American side one may descend by an elevator to the foot of the American fall, where an impressive idea of the majesty of the falls may be obtained by climbing the path and approaching close to the falling water. A drenching spray is likely to be found at this spot and oilskins may be necessary.

The trip on the Maid of the Mist.

The Maid of the Mist provides one of the most impressive scenic boat rides in the world. This steamer proceeds southward from the landing, passing in front of the American fall 150 or 200 yards (130 or 180 m.) out from the line of rocks at its base. The great height of the fall and the majestic descent of the water is here seen to the best advantage. As the smooth water quietly curves over the brink it glistens in the sunshine to contribute a moment later to the deep roar and the great cloud of spray and mist at the bottom. The spray and mist obscure the view of the lower part of the falling water and sometimes also the rocks along the shore. Along the central and southern part of the falls where the water sheet is thin, a better view is obtained. The cliff along the west side of Goat island is precipitous or overhanging in its upper part, where the face is composed of limestone, but there is a heavy talus with many large blocks along its base. Towards its top one sees a distinct change of angle where the drift and gravel of Goat island rest upon the rock, for these softer sediments make a slope which is steep but not vertical. The steamer passes quite near the great blocks below Goat Island shelf, and then, passing out of the more quiet waters, enters the foamy, turbulent pool below the Horseshoe falls. The deepest sounding in the river (192 feet; 58·5 m.) was found just off the rocks below Goat Island shelf, by Spencer. The steamer approaches through a turmoil of foaming water and spray surprisingly near to the base of the great fall. But a powerful current flows outward from the cataract and into this the steamer turns and is carried swiftly down stream. It is said that the white, frothy water is so surcharged with air that the steamer settles several inches deeper in it than she does in the clear waters farther down. After turning away and floating down the stream a few hundred yards, as though baffled in her attempt to enter the roaring portal, the steamer usually turns back again towards Goat island and makes a second advance into the spray and foam. After the second approach she steams rapidly down the centre of the river keeping well out from the west shore where there are some dangerous rocks opposite the American fall. Before reaching the graceful arch of the Park bridge, she swings around to the west and lands on the Canadian side at a bench or terrace of upper Medina sandstone which rises but little above the water. When the main fall was passing the front of the American fall the crest line was unusually wide, with a consequent thinning of the water sheet. The soundings in this part of the gorge show the deepest part of the channel to be nearer the eastern side, indicating that the heaviest water fell along that line. Toward the west side in Carter cove and south of it the water must have been shallower and lacked power to remove the harder thin layers which now form the bench at that place.

Trip to Falls View.

In many respects the grandest and certainly the most comprehensive view of the falls and of the river, both above and below the falls, is obtained from a point called Falls View on the Canadian side on the edge of the high bluff near the Loretto convent. To reach this spot by the easiest route, the visitor crosses the park bridge and walks up the ferry road from the Clifton hotel to the street railway just opposite Victoria Park station. The westbound car goes out Lundy lane to the Stamford road, which runs south and southeast along the top of the Niagara Falls moraine. A few steps from the corner is the monument on the battlefield of Lundy Lane (July 25, 1814). On the Stamford road the car follows at first a little east of the crest and farther on a little west of it and for half a mile or more the crest of the ridge has the Lundy or Dana beach resting on it as a summit gravel bar. At Falls View one looks down upon the whole scene of the river and rapids above the falls and into the caldron and canyon below. From this point one can make an interesting study of the currents in the rapids above the falls. The three cascades with Sister island and Goat island are directly in front and the course followed by the deeper currents as they approach the brink of the falls may easily be followed. The stony shallows in the lower central part of the rapids are clearly seen. From here one sees also a distant side view of the American fall and may note quite clearly the nearly straight line of the cliff of Goat island, the American fall and the cliff beyond Prospect point. The grand sweep of the bluff forming the embayment between Table Rock house and Dufferin islands is well seen from this point, and also the great depth of the drift. About 100 yards (90 m.) north of Falls View the crest of the Niagara Falls moraine comes out to the edge of the bluff above the Michigan Central railway, and is there abruptly cut off. One sees clearly that its normal continuation would carry it far over the embayment, probably over the edge of the rapids. From the top of the moraine to the bottom of the river at the deepest sounding below Horseshoe fall is nearly 500 feet (150 m.). One may return on the car, or, taking a stairway to the Michigan Central Falls View stopping place, may descend the steep bluff by a rough path to the flats in the park below and thence by a short walk to the parapet at the edge of Horseshoe fall and to the Table Rock house.

The Falls and the Gorge from the Canadian Side.

Views from the Park bridge and the West Cliff— From the Park bridge one gets the best views of the Upper Great gorge, giving a good impression of its dimensions. In order to form a true conception of its depth, however, it is necessary to remember that the average depth of water along its axis of greatest depth is 150 to 160 feet (46 to 50 m.), with a number of soundings showing places 30 to 40 feet (9 to 12 m.) deeper. If the water were taken away the beholder would be looking down into a canyon 350 to 400 feet deep (106 to 120 m.).

The well defined embayment in the cliff line, near the entrance gate to Queen Victoria park, seen by following the trolley line south along the Canadian side, is the curve around the top of Carter cove. A little farther on the foam pattern and swirling of the water shows the presence of a large rock or reef close to the surface of the water. This rock is 300 or 400 feet (90 or 120 m.) out from the shore and apparently rests upon, or is a part of, the submerged terrace which extends southward along the west side. The view of the American fall is finest from this point, being directly in front, and shows the thinness of its water sheet and the mass of blocks along its base. The cliff along the west side of Goat island is also in full view, with the Horseshoe fall in the distance on the right. From this point, or better from one of the little pavilions 100 yards or so farther on, one obtains the best view of the two cataracts at one sweep.

The American Fall from a point directly opposite on the Canadian side.

Horseshoe Fall from the Parapet.—The view from the parapet at Table Rock house affords the climax of the nearer views of Horseshoe fall, which is much the greater and more powerful of the two cataracts. One looks eastward along the curving crest line of the fall toward the angle at the apex 1,000 feet (300 m.) or more away. In the foreground the water is not deep, but beyond this the emerald green of the heavy, unbroken mass of clear water as it bends smoothly and gracefully over the brink, is a most impressive spectacle. One cannot see far down the face of the falling water, on account of the immense volume of spray which obstructs the view, and the surface of the water below the falls is dimly visible only at a considerable distance out from the foot of the cataract On account of its frothy whiteness, it is somewhat difficult to judge of its distance below the observer. From the angle of the parapet it can usually be seen directly below or a little to the left. The view at the parapet varies much with the wind and the drift of the spray cloud. Sometimes one can see far along the crest into the distant angle; while at other times, especially when the wind blows from the southeast, the whole parapet is enveloped in a drenching mist. In the middle or late afternoon in clear weather a magnificent rainbow is seen in the spray.

Western part of Horseshoe Fall from the parapet near Table Rock house; looking southeast.

The greatest amount of recession in recent years has taken place in that part of the falls where the heaviest water is seen passing over, but for about 20 years there has been no perceptible recession where the apex of the falls was so prominent some years ago.

From the top of the Table Rock house a splendid view is obtained toward the centre of the falls. If mist does not obstruct the view of the apex, an interesting detail may be seen at that point. Instead of finding a sheer descent from the brink, the heavy water at the apex strikes a rock shelf, estimated to be about 40 feet (12 m.) below the top, from which it rebounds whitened and foamy before making the final plunge. The shelf must be of large proportions and has existed for many years. Before the recent improvements for power development in Queen Victoria park, a thin water sheet like that which flows over the Goat Island shelf fell over the cliff where the parapet now stands and the edge of the water on the brink was then 415 feet (126·5 m.) nearer Table Rock house than it is now. The total length of the crest line was then about 2,950 feet (900 m.).

For a nominal fee visitors may descend by an elevator to a tunnel leading to a point under the nearer part of the falls, about at the edge of the heavy water, where a window-like opening looking out towards the falling water has been made. Nothing can be seen except a diffused varying light that comes through the water. The thunderous roar of the water is deafening. The trip is worth making for the impression of titanic power which this sound produces and for the realization of one's nearness to the great cataract.

The Recession of Horseshoe Fall.—When it is understood that the gorge extending for nearly seven miles (11·3 km.) from the escarpment at Lewiston up to the Horseshoe fall, was made by the Niagara river itself since the disappearance of the last ice sheet, it becomes a matter of much interest to know at what rate or rates the gorge was lengthened and how long a time has been involved. Those who have studied this problem carefully have reached different results, that varied chiefly according to the authors' conceptions of the history of the Niagara river and of the dependence of that history upon the Great Lakes history. Many other variable factors enter in but no other approaches in importance to the relation of Niagara to the great lakes. If the gorge were exactly seven miles (11·3 km.) long and the rate of recession of the cataract had averaged exactly five feet (1·5 m.) per annum, it would be easy to say that it has been 7,392 years since the falls began at Queenston. Those who have held strongly to the conclusion that the duration of Niagara has been no more than 7,000 to 10,000 years seem to have relied upon a simple calculation of this kind.

But the problem is extremely complicated and involves many elements that are incapable of exact determination. Many assumptions have to be made and the value of the results depend upon their accuracy.

Five instrumental surveys were made between 1842 and 1905, with the object of determining the precise configuration of the crest lines of the two cataracts. The first was begun by E. L. Blackwell under the direction of James Hall, in 1841 and finished in the autumn of 1842. A series of monuments were established by this survey for the use of future investigators. The second survey was made by the U. S. Lake Survey in 1875 under the direction of Major C. B. Comstock, the field work being done by F. M. Towar; the third in 1886 for the U. S. Geological Survey by R. S. Woodward; the fourth in 1890 by A. S. Kibbe under the direction of John Bogart, State Engineer of New York, and the fifth by the U. S. Geological Survey and the State Engineer of New York, the field work being done by W. Carvel Hall in 1905. A survey was also made in 1906 by J. W. Spencer and one or two others have been made more recently.

Based on the five surveys mentioned, Mr. G. K. Gilbert made a careful study of the rate of recession of the falls in a report published in 1907. He concluded that between 1842 and 1905 the main cataract had receded at an average rate of about 5 feet (1·5 m.) per annum. In reaching this value for the rate of recession Mr.Gilbert's calculations tended to a result near 4·5 feet (1·37 m.) per annum, but as he states, he chose the nearest whole number as being, in all probability, as near the truth as a small fraction under that number, since precise results are not to be obtained with such data as are available for this kind of a calculation. By this rate the time taken by the cataract in making the Upper Great gorge would be 2,400 or 2,500 years. He has not given an estimate of the total duration of the falls, but some years ago expressed himself as favouring a long time rather than a short one.

From his exhaustive studies on the rate of recession, J. W. Spencer finds the rate of recession of Horsehoe fall to be 4·2 feet (1·28 m.) per annum, and at the Erie stage ·42 (·128 m.) of a foot per annum. Dr. Spencer made careful allowances for many modifying factors in making his calculations for the total duration of the falls, but did not interpret the great lakes history as it is now accepted. In 1894 Spencer found the total duration of Niagara falls to have been 32,200 years. Later studies (1906-7) led him to change this result to 39,000 years.

In a paper published in 1898, the writer of this text ventured the opinion that the total duration of the falls was probably 50,000 years or more. It seems clear now, however, that this estimate was based on too slow a rate for those sections of the gorge which were made by the cataract with small volume. A review of the data bearing upon the rate of recession of Horseshoe fall has led to the conclusion that the average rate of recession in the Upper Great gorge has been very nearly 4.5 feet (1·37 m.) per annum. This applies to the Upper Great gorge and with slight modification to the Lower Great gorge, but it does not apply to either the New or the Old Narrow gorges, nor to the first or oldest section near Queenston.

At the very outset an assumption has to be made which involves the decision of a difficult question. What part of the crest line or what point upon it shall be taken to represent the rate of recession? In the long run the recession of the apex or extreme re-entrant of the crest line will yield the true rate, but in a relatively short period, like that of the instrumental surveys (1842-1905) this method may prove quite unsatisfactory, as indeed, it has done. In a period preceding 1890 the apex retreated at a relatively rapid rate and became very acute on a line turning to one side from the main axis of the gorge. Then the apex became nearly stationary and has remained so for more than 20 years. There was not a deep enough and large enough caldron beneath the acute angle to undermine the capping hard layers. But while recession ceased at the apex, it continued on a different line passing west of the apex and more nearly on the main axis of the gorge produced from the north. Thus, the former apex will soon cease to be the apex, a new one being established farther west. It seems better to take a certain limited central portion where deep water is passing over, say a width of 400 or 500 feet (120 or 150 m.) and use the measured mean rate of recession there for the rate of elongation of the gorge. This is the method used by Mr. Gilbert.

Again, in a broader sense the recession of the falls tends to be rythmical, not exactly periodical, but recurrent with alternating phases in which the crest line becomes more acute and then less acute in its general form. When acuteness is increasing, the rate is a little more rapid than the mean; when it is decreasing it is a little slower than the mean.

Wherever the rock floor above the falls was unusually flat and wide and without local depressions or small valleys to cause concentration of water in greater depth at some particular place, the water sheet on the crest became relatively thin, the falls widened and the gorge was made wider and proportionally shallower. At such times the rate of recession must have been considerably slower, for the undermining power of the falls was reduced. Such a period affected the falls, while the main cataract was passing in front of the American fall, and Goat island, where the gorge is wider than the average and shallower. The rate here in the widest part was probably reduced one-half.

The slower rate in the wider, shallower part opposite the American fall and Goat island somewhat reduces the average rate for the whole section making it slightly less than Mr. Gilbert's five feet (1·5 m.) a year and indicating a period of 2,700 to 3,000 years for the making of the Upper Great gorge.

But the most uncertain element in attempting to determine the whole duration of the falls is the rate in the two Erie sections, the Old Narrow gorge and the gorge of the Whirlpool rapids; and the oldest section near Queenston. Spencer makes the rate of recession with Lake Erie waters alone ·42 of a foot (·128 m.) a year, the volume then being only 15 per cent of the present volume. But, with a volume so much smaller, the rate may be greatly modified by local conditions, especially by those which affect the depth of the water on the crest of the fall. This is clearly shown by the history of the American fall, which has less than five per cent of the whole volume of the river or less than one-third of the discharge of Lake Erie.

The American fall is a remarkable instance of lack of concentration of water depth on the crest line. The crest is 1,000 feet (304 m.) long and the water on it is not over three feet (·9 m.) deep, while much of it is one foot or less. If the crest was, say, 100 feet (30·5 m.) long the water would be 18 or 20 feet (5·5 or 6 m.) deep and a fall of this description would be an active gorge-making agent, whereas the American fall in its present state hardly bears that distinction.

A cataract of three times the volume of the American fall, such as were the falls in the two Erie sections, would be more powerful, but, other conditions being the same, the rate of its recession in gorge making would be conditioned in the same way, according as the water on its crest was concentrated or attenuated beyond the average. For an average depth of between 5 and 10 feet (1·5 and 3 m.) on the crest, which would signify neither extreme concentration, nor extreme attenuation, and where the capping limestone was thin or of moderate thickness, Spencer's rate of ·42 of a foot (·128 m.) per year seems a little slow. But where the capping limestone had great thickness it is probably too rapid. It seems certain that the cataracts in both of the Erie gorges probably underwent considerable variations of this kind. Indeed, on account of the number and magnitudes of the variable and uncertain elements affecting the rate of recession, especially in the older parts of the gorge, it does not seem possible to state in precise terms the total duration of the falls. It appears to have been somewhere between 20,000 and 30,000 years, possibly even 35,000 years. It is believed that an attempt to set the estimate between narrower limits would add nothing to its value.

The Rapids above the Falls.—From Table Rock house the car runs southward along the shore of the rapids, affording a good view at several places of the powerful current as it rushes swiftly towards the falls. It is easily seen that a deep current flows close along the shore, while farther out there are many rocks projecting above the water. Sixty or seventy years ago there was a low island covered with bushes and small trees in that part of the rapids. There is considerable area lying south and southeast from the apex over which the water is now shallow. A deep, strong current passes north of the shallows and falls over the brink at and north of the apex of the fall and another larger current passes south and west of it and falls over the brink west of the apex. If this arrangement of the deeper currents continues for sufficient length of time an island will appear between them, as Goat island is now between the divided parts of the river. It seems certain also that by the time the falls have cut back half a mile farther the American fall will run dry. These would appear to be natural tendencies of development, but the interference of man may modify them.

The Dufferin Islands.—This group of small, low islands forms part of the abandoned floor of a relatively small embayment cut sharply into the deep drift sheet which forms the southern bank of the river at this point. The islands and the embayment in which they lie are of relatively recent origin. The islands were four in number and were divided by channels 50 to 100 feet (15 to 30 m.) wide through which streams one to four or five feet (1 to 1·5 m.) deep rushed with rapid currents, but recently, dams have been constructed with gates controlling the volume of the two streams and another dam at the outlet produces a large pond in the bend of the main stream south and west of the islands.

The embayment appears to be related to the rock ledges which formed the First and Second cascades at the head of the rapids. The bed rock dips gently toward the south, so that its surface is lower at Dufferin islands than at Sister islands on the north side. On this account the line of deepest water and the strongest current has had a tendency to hug the Canadian shore. In consequence the river has been and is still cutting its bank on the Canadian side. The Dufferin channel starts in just above the First cascade and re-enters the river below the Second cascade. This gives it a rapid descent and high cutting power. The high, steep bluff which borders the embayment shows how effective that cutting was. The surface of the islands is composed mainly of gravel, showing that they formed the floor of the embayment as the cutting progressed.

Chippawa Creek and the River above the Rapids.–It is worth while to make the short trip on the car from the head of the rapids to the village of Chippawa, in order to get a view of the wide, placid river above the rapids. Here the river is seen flowing quietly in a wide shallow bed between banks of drift. At Chippawa the river is a mile wide and its greatest measured depth is 22 feet (6·7 m.), about 1,000 feet (300 m.) from the south shore. For several miles above the rapids the river bank on the Canadian side is a freshly cut bluff of till, while on the New York side the bank is an old, low bluff of till now being abandoned and has wide, reedy shallows all along its base.

The old Drift Banks of Niagara River.—When the falls first began at the escarpment south of Queenston, there was no gorge and the river flowed across the country on the line of lowest level. Although it had no bed at first, it very soon made one for itself in the drift. In consequence of its greater width, fragments of the old drift banks are found at intervals nearly to the mouth of the gorge. Anyone who would doubt the making of the rock gorge by the present post-glacial river will have to explain how the old river banks in the drift could have originated, for evidently the river could have flowed in its old drift bed at any given place only before the gorge had been cut back to that place.

The most remarkable parts are the three embayments on the west side near the falls. The earliest embayment extends southward from a point about 1,000 feet (300 m.) south of Hubbard point nearly to Table Rock house. This appears to have been cut partly during the earlier history of the river, when the falls were somewhere north of Hubbard point, and partly, especially the southern part, while the falls were receding down the southward slope of the old valley mentioned below. This part extends from a point one-fourth of a mile (·4 km.) north of the park bridge to the western end of Goat island. The large embayment south of Table Rock house had not then been made and the western bluff of that time probably extended south and southeast from near Table Rock house out over the present site of the Horseshoe falls and the rapids above, in all probability along a line several hundred feet out from the shore.

At this time the river began to cut the bank at a new place on the west side, where the rapids are now, and soon formed the strongly marked embayment which curves around west of the present rapids. The cutting of this embayment was apparently due to the momentum of the water as it descended the sloping rock floor of the rapids toward the west. The rushing water was turned to the east, but not until it had cut heavily into the drift, and before the process ceased it had carved out the great embayment now seen. This work was probably completed in a relatively brief time and that part of its floor which is now dry ground had probably not been long abandoned by the rapids when Father Hennepin saw the falls in 1678, for there was still a crossfall on the west side, which as Spencer has pointed out, was produced by water following a channel nearer the base of the bluff by several hundred feet than the edge of the present rapids.

The smaller but deeper embayment at Dufferin island was made at a still later time.

The Falls-Chippawa Buried Valley.—The rock floor of the rapids above both cataracts is the eastern slope of what Spencer named the Falls-Chippawa buried valley. This is an old valley in the pre-glacial rock surface and except where excavated by Niagara river is completely buried and obliterated by the drift. Its head appears to have been about at Hubbard point, the valley descending gently and widening toward the south and southwest. According to Spencer, the rock floor of this old valley has determined the height of the falls since they passed Hubbard point and the crest line of the Horseshoe fall is now 50 or 60 feet (15 to 18 m.) lower than formerly. It is the westward sloping side of this old valley which makes the rapids above the falls and it was the same circumstance that caused the two larger embayments in the drift.

The drift composing the deep filling of the old valley at the falls contains a variety of deposits, including a bed of old or pre-Wisconsin till at the bottom. Near Horseshoe fall this is followed by a bed of quicksand above which there is a heavy bed of ground moraine. Excepting occasional thin deposits of sand or gravel or lake clay, the ground moraine is ordinarily the upper deposit of this region. But the top of the bluff west of Horseshoe falls and southward is a terminal moraine, called the Niagara Falls moraine and made by the Lake Ontario lobe of the last ice sheet as it finally withdrew from this region.

The Upper Great Gorge.—The Gorge railway runs from Horseshoe falls to Queenston, returning on the American side. On the Canadian side it follows the cliffs at the top of the gorge to its mouth at Queenston, affording many fine views into the great chasm. On this trip the gorge sections are seen in the reverse order from that in which they were made. The gorge characters and sections have been described above and condensed in a tabulated statement. It is not necessary therefore to repeat here the measurements and statements given there. Attention is directed particularly to those points in the gorge which have a critical bearing upon its history and which stand in definite correlation with the lake history.

The first two and a quarter miles (3·6 km.), from

The Upper Great gorge, looking south from the east end of the cantilever railway bridge. The Park bridge and the Falls are seen in the distance, two miles away. Note the relatively placid water of the great pool and the ripple in the foreground where the water is drawing with increasing velocity into the head of the Gorge of the Whirlpool rapids.

Horseshoe fall to the railway bridges, lie along the cliff of the Upper Great gorge. Noticing particularly the great width of this section and the quietness and apparent great depth of the water, one is prepared to appreciate more fully the contrast in the dimensions of the next section. Soon after passing the west end of the Park bridge the car ascends 40 to 50 feet (12 or 15 m.) to the top of Johnson ridge hear Hubbard point. This ridge is of Lockport limestone and forms the highest rock barrier in the line of the gorge. Two or three sharp embayments occur here, one north and another south of Hubbard point and a smaller one on the east side. There was probably a small and relatively narrow pre-glacial valley or trench at this place which formed the col between the head of Spencer's Falls-Chippawa buried valley and a smaller valley descending gently northward to the whirlpool. This narrow little valley may have had windings which guided the falls in such a way as to produce the embayments now seen.

The Whirlpool rapids and narrow, shallow gorge, looking south (up stream) from near Whirlpool point; the railway bridges in the distance. This view looks into the mouth of the narrow gorge. The wider part in the foreground is a part of the Eddy basin. The widening to the right beyond the edge of the picture is more pronounced than that shown in the middle foreground.

This section of the gorge also shows to best advantage the slight alternate contractions and expansions which seem to record a rythmical tendency in the recession of the falls.

Gorge of the Whirlpool Rapids.—At the cantilever railway bridge one sees the head of the Whirlpool rapids. The sudden sharp contraction of the top width of the gorge is well shown at this point, the narrow section to the north having only a little more than half the average width of the section above. From the quiet pool above, the water moves with increasing speed as it enters the narrows. For 100 yards or so it retains its glassy smoothness, but by the time it passes the second railway bridge it breaks into the tremendous billows of Whirlpool rapids. The old drift banks of the river are well displayed in this section. They are 10 to 25 feet (3 to 8 m.) high and stand 300 to 500 feet (100 to 150 m.) back from the cliff line on either side. The head of the narrow gorge marks the place where the present large-volume cataract resumed gorge making after the smaller cataract had made the narrower section. It is, therefore, a point of correlation with the lake history, for it was the uplift at North Bay, Ontario, which closed the outlet there and sent the discharge of the upper three lakes back to Lake Erie and Niagara. This point in the gorge marks that event, when the volume of the river was suddenly increased nearly sevenfold.

The Eddy Basin.—Half a mile north of the bridges the cliff line turns to the west and the gorge widens perceptibly. This wider part is the Eddy basin. The eddy with its large and gentle return current is in the foreground at the foot of the cliff, while on the far side billows dash across from the mouth of the narrow gorge above. The view to the north looks across the Eddy basin, and the reef and small rapids at its lower side toward the outlet of the whirlpool and the sharp separation of the two deep basins by the upper reef is clearly seen.

At Sinclair point the Eddy basin and the whirlpool may be seen. The contraction in the width of the gorge is as sudden and pronounced here as is the expansion above the railroad bridges. Lake Algonquin came to an end because the retreating ice sheet opened the outlet at North Bay, Ontario. Before this, Niagara had had the full discharge of the four lakes. But the opening of the new outlet took the discharge of the upper three away and left the discharge of Lake Erie alone, equal to only 15 per cent. of the previous volume. The contraction at the upper side of the Eddy basin marks this event in the lake history.

The Whirlpool from Sinclair Point.—Trees largely obstruct the view of the upper reef from this point, but the view northward over the whirlpool is good. In the foreground one sees the tremendous in-rushing current on the right and the great return current on the left with a series of large whirls along the line of contact. One generally sees a considerable accumulation of flotsam in the whirlpool, made up largely of logs and timbers, and the powerful whirls may often be seen turning them on end and sucking them down beneath the surface.

At the far side of the whirlpool the high bluff of the drift mass that fills the ancient St. David gorge is revealed where a part of its face is exposed by a recent landslide.

The basin of the whirlpool is the headward part of

Looking northwest (down stream) from the Eddy basin across the Whirlpool, showing the short, sharp rapids caused by the Upper Reef, which separates the Eddy basin from the Whirlpool.

the buried St. David gorge and is of inter-glacial age. The reef at the outlet was left intact, because the east wall of the older gorge broke through before the boring power of the modern cataract was brought to bear upon the sandstone ledges. The reef separating the whirlpool from the

Eddy basin remains, because, after the older cataract had suddenly ceased the cliff line was driven back by weathering and was notched by a smaller stream, so that the renewed attack of the modern falls missed the ledges now forming the reef, and began their excavation just south of these ledges. Sinclair point is on the edge of the old drift bank of the river.

The Whirlpool from Thompson Point.—The best view of the whirlpool is from this point, where it is distinctly seen that the great current does not turn the sharp angle directly from the inlet to the outlet, but that its momentum carries it onward to the north side of the pool, where it strikes against the rocky wall of the older gorge and is deflected to the west or left in a great swinging curve. Continuing around the north and west sides of the basin, the whole great current turns toward the southeast and at a point opposite the outlet dives under the swifter current and reappears at the surface in the mouth of the outlet. Thus, substantially the whole volume of the river makes a great loop in which it turns backward and downward in order to find a way of escape.

From this point a better view is obtained of the upper reef and of the Eddy basin. The influence of the reef in producing a short, sharp rapids is clearly seen. The view down the river from this point is also fine, showing Foster rapids and the terraced slope on the left.

Wintergreen Terrace and Foster's Flats.—At this point one may descend into the gorge from the old drift bank of the river, first going down 15 or 20 feet (5 to 6 m.) to a flat area of limestone with almost no soil and only thinly covered with trees, a remnant of the old river bottom, which was scoured clean of drift before the falls had passed this point. At the north side of this terrace an overhanging cliff of limestone marks approximately a part of the crest line of the falls as they were at one time. Huge blocks have fallen from this cliff, but it still overhangs on the north, east and south sides enough to suggest the old crest of the falls. This part of the old river bottom was abandoned because a deeper channel was cut, more rapidly around the east side of the terrace.

Descending the stairway the path goes southward under overhanging cliffs, winding amidst great fallen blocks, several of which contain remarkable potholes drilled by the spinning action of pebbles under the falling water of the cataract, probably after the blocks had fallen. Continuing to the west, the path descends to the cove, or Fisherman's eddy, a quiet spot a little above the turbulent waters of Foster rapids. The path is here on the Whirlpool sandstone. To the east, the ledges of this rock overhanging the turbulent waters of the rapids show, in a beautiful way, its cross bedding and laminated structure. At one or two places the path descends below the sandstone and rests on the Queenston shale, which is a soft, dark red mud rock. The contact of the sandstone, where it rests upon the shale, is well exposed and is remarkably sharp and abrupt. This path affords fine views of Foster rapids, some of the billows of which equal or surpass those of the Whirlpool rapids, and the channel here shows more obstructing rocks and reefs.

The path at length emerges upon a wooded terrace called Foster's flats, formed by the surface of the Whirlpool sandstone where the cataract was unable to penetrate it.

Returning, the path to the right is followed through Niagara glen, passing along the north side of a narrow, sharp ridge projecting towards the northeast. This part of the old river bed belonged to that part of the cataract which flowed over Wintergreen terrace. Another lower terrace formed by the Clinton limestone extends along the base of the eastern and southern sides of Wintergreen terrace and is largely covered with huge blocks of Lockport limestone fallen from above. Ascending, one gets a good idea of the size of some of these blocks where the path follows narrow passages between them or under their corners where they lie close together.

Soon after leaving Wintergreen terrace, a low drift bluff is seen running to the north. This marks the drift bank of the river when the falls were near Queenston. When about opposite Niagara university the gorge turns towards the north and grows slightly narrower. This point of correlation with the lake history is not so sharply defined as the two mentioned above, but it is believed that, during the Kirkfield stage of Lake Algonquin, Niagara had only the discharge of Lake Erie, and more than a mile of the gorge north of the university was made at that time. When the uplift of the land closed the outlet at Kirkfield and sent the overflow to Port Huron and Chicago, the volume of Niagara river was greatly augmented, certainly by an amount equal to if not greater than the present St. Clair river. This point in the gorge appears to mark that event in the lake history and the stretch from the bend below the university to the upper side of the Eddy basin, but not including the whirlpool, constitutes the Lower Great gorge.

The Old or Lower Narrow gorge, looking south (up stream) from a point a little south of the mouth of the gorge near Lewiston. Track of New York Central railway in middle foreground. Lower end of Lower Great gorge at bend in distance. Niagara University at top on left. Water moderately turbulent, not placid as in Upper Great gorge or Lower Great gorge above Foster rapids.

Old Narrow Gorge and Smeaton Ravine.—Northward from the university the cliff lines are seen to be remarkably even and the width of the gorge very uniform. These characters extend for more than a mile. Towards the northern part of this stretch the railway makes a sharp detour to the west in order to get around Smeaton ravine, which was made by a diverted or side stream of the river in the early part of the Port Huron stage of Lake Algonquin, when the great cataract was making the gorge at and a little above the university. The rock floor above the falls at that time was extremely flat and broad. A shallow trough leads southwest and south from Smeaton ravine to the old river floor north of Foster's flats. Across this a part of the river found its way for a long enough time to carve out the small ravine which was in all probability 300 or 400 feet (90 to 120 m.) longer than now, when it was first made, the main gorge walls having weathered back this much since then. It does not seem possible that this side ravine could have been made during the preceding Kirkfield stage of Lake Algonquin, when the volume of Niagara river was small.

The Oldest Gorge Section.—At about one-quarter of a mile (·4 km.) north of Smeaton ravine, the cliff line and the railway turn towards the northwest. Fine views into the gorge and out of its mouth over Lewiston and the Ontario plain are obtained here. The cliff lines are more irregular north of this point and the top width of the gorge is a little greater. Near the mouth of the gorge the walls are about 350 feet (106 m.) high, the capping limestone is only about 20 feet (6 m.) thick and over 100 feet (30 m.) more of shale is exposed. All of these factors favour more effective weathering and cliff recession and have produced wider talus slopes than in the newer parts of the gorge. The average top width for a little more than a mile north of the university is only a trifle less than the average width of both of the great gorge sections above. But the narrowness of this section at its bottom, coupled with the characters mentioned, indicates that it was originally narrow and not so deep, having been deepened largely in later times by the long wearing action of rapids or small cataracts and not by a great cataract. The gorge characters indicate that the river had a relatively small volume while making this section, which corresponds with the Kirkfield stage of Lake Algonquin, when Niagara had only the discharge of Lake Erie.

There is no great change in the characters of the gorge north of Smeaton ravine, but the point where it widens slightly [about 2,000 feet (600 m.) south of the mouth] is taken as a division point, not only on account of the slight widening and more irregular cliff line, but because other facts, showing the divided volume of the first flow of Niagara and the relatively brief duration of that condition, point to the same place. This point, if correctly identified, marks the time in the lake history when the Kirkfield outlet first opened and early Lake Algonquin came to an end. Niagara river had a large volume during the making of the first 2,000 feet (610 m.) but it flowed over the escarpment at five different places, the stream at Queenston being probably the largest branch. So far as can be seen, however, this stream was only a little larger than the overflow of Lake Erie alone which made the next section to the south.

Brock's monument stands on the edge of the Niagara escarpment and commands a splendid view northward over the Ontario lowland, the lower reaches of Niagara river and Lake Ontario in the distance. On a clear day the bluffs at Scarboro a few miles east of Toronto are clearly visible, although nearly 40 miles (65 km.) away. In the foreground at the foot of the escarpment lies the village of Queenston and, on the east side, Lewiston. The waves of Lake Iroquois washed against the base of the escarpment south of Queenston and a shore cliff marks the ancient beach for several miles westward. It is seldom more than 25 feet (7 m.) high and is usually cut in the drift. The escarpment itself is a much more ancient feature.

The Cataract Bar at Lewiston.—At Lewiston will be seen the large gravel pits about 100 yards (90 m.) north of the station. The gravels seen in these pits are in several respects remarkable and are quite different from the usual types found in beach ridges, spits, deltas, or in kames or other glacio-fluvial deposits. They are remarkably clean and the pebbles are mostly well rounded though partly also subangular; and are set in steeply inclined beds which dip to the south or southeast in all parts of the excavation. Many of the layers are remarkably coarse, containing numbers of pebbles 6 or 8 inches (15 or 20 cm.) in diameter with occasional ones considerably larger. Some of the beds are composed of finer material but no fine sand is seen in the steeply inclined beds. Some of the coarser layers which have large inter-spaces with no filling of finer material between the pebbles were evidently set in place quickly by the action of powerful currents. No crossbedding or interruption of the layers has been found any where in the deposit, and as they were exposed a few years ago, the steeply inclined layers were seen to descend in even, parallel beds to a depth of 30 to 35 feet (9 to 11 m.).

In his guide book published in 1901 Prof. I. P. Bishop shows a photograph in which the inclined beds are seen to bend southward at their base into a nearly horizontal position.

A large amount of this gravel has already been removed, but it is exposed in the bank of the river for fully half a mile north, gradually thinning out in that direction. A smaller but precisely similar deposit with coarse southward dipping beds is exposed just opposite on the west side of the river. Gravels of the same coarse character extend southeast from the main street of the village to the Presbyterian church and the cemetery east of it.

Section of Cataract Gravel bar ar Lewiston, looking east. The gravels are largely coarse and the beds pitch to the south or southeast to a depth of 30 to 35 feet.

These gravels have generally been described as a part of the Iroquois beach formation. This beach extends through the village to the bank of the river at the gravel pit as a well formed spit, but here its composition and arrangement are of a somewhat different character. At the pit one sees that the highly inclined beds are cut off abruptly at the top and that the fine gravel and sand of the Iroquois beach proper overlie them in an unconformable manner. About 100 yards to the southeast just west of the high school, the beach ridge, which is here in its original state, shows the form of the ridge very clearly. The coarse gravels in the south part of the village rise a few feet higher than the top of the Iroquois spit and show no evidence whatever of shaping or modification by wave action.

Directly south of these gravels and of the village there is a remarkable depression or basin which, from its general form and relations and from its situation just opposite the mouth of the gorge, seems explicable only as the result of the first plunge of the cataract over the escarpment. The terrace of Whirpool sandstone just at the mouth of the gorge was swept clean of all drift, while half a mile east it is covered with till, and many large blocks lie along the edge just below the sandstone terrace and the floor of the depression near the terrace. A knoll about 30 feet (9 m.) high which stands just north of it is literally paved with boulders set close together over the whole surface. The boulders grow fewer and smaller north and northeastward from the terrace, ending in coarse gravels. Farther north the great deposit begins at the pits opposite the station and extends half a mile north, with a smaller deposit also on the Canadian side. The outline of the basin, especially on its east side, is sharply defined by a bluff of drift 30 to 40 feet (9 to 12 m.) high which marks the eastern limit of excavation by the powerful currents from the cataract. On the Canadian side a channel runs through Queenston to the northwest and turns northeast to the river, completing the symmetry of the excavated basin which spreads in the shape of a fan from the mouth of the gorge. The basin is 30 to 40 feet (9 to 12 m.) deep in its deeper parts and the coarse gravels referred to form bars in its northern part and extend beyond its northern side. From these relations it might be concluded that the gravels were accummulated in their present form by the powerful currents which issued from the base of the cataract when it first plunged over the escarpment, and are therefore, true cataract gravel bars. Thus the inclined beds face towards the mouth of the gorge, as though powerful outrushing currents had rolled the gravel out from the base of the cataract and up the face of the bar at the outer edge of the pool. It is, however, believed that the old interpretation is correct and that the peculiar features result from the coarse gravels at Lewiston having belonged to a spit of Lake Iroquois which migrated up the slope as the level of the lake rose 35 or 40 feet to the existing Iroquois spit at Lewiston.

Views in the Gorge from the Lower Level.—The car returns along the bank of the river and enters the mouth of the gorge about 40 feet (12 m.) above the water. The west wall is almost entirely clothed in forest, except for about 20 feet (6 m.) up from the water which was swept bare by the great ice jam of February, 1909. The current is only moderately swift near the mouth of the gorge, but grows swifter and rougher up stream. Up to the Catholic university the river is fairly uniform in width and velocity, but above the bend at the university, it grows much wider and much of it is evidently quite shallow. At the foot of Foster's flats the river begins to grow narrow until at the head of Foster rapids about at Wilson point the narrowest point in the whole river is passed, the surface width here being 300 feet (91·4 m.). The water at the head of Foster rapids descends in a cascade, almost a fall. Indeed, if the volume of the river were small, say one-seventh of the present volume, there would probably be a distinct fall or drop like the upper cascade near Sister island. The rapids just below are the most turbulent in the river and are beset with dangerous rocks.

Where the river widens abruptly just above Foster rapids, it becomes much deeper and the water is more quiet. The contraction at the exit of the whirlpool is quite noticeable and the lower reef which spans the river just here produces a short, sharp rapids. At the entrance of the whirpool there is another contraction and a more strongly marked reef than at the exit.

Leaving the Whirlpool the railway passes along the east side of the Eddy basin with rapids surging from the steep narrow gorge above in the foreground. The rapids do not lose all of their turbulence before they strike the upper Whirpool reef which again throws them into frothy billows. Looking from the car the sharp contraction of the width of the gorge at the upper side of the Eddy basin is quite striking. From the head of the narrows above the railroad bridges the river descends about 45 feet

(14 m.) to the whirlpool. Careful estimates indicate a depth of 35 to 40 feet (10·6 to 12·2 m.) in the lower part of the rapids, but Spencer's soundings indicate nearly twice this depth under the upper railroad bridge.

South of the railroad bridges the electric railway begins the ascent to the top of the Upper Great gorge. This climb affords magnificent views of the northern part of this section and of the place where it suddenly contracts and the narrower gorge of the Whirpool rapids begins. As the car climbs the wall of the gorge good exposures of the Clinton limestone, the Rochester shale and the Lockport limestone are obtained. Just after passing under the steam railway the surface of the limestone shows glacial polishing and scratching.

NIAGARA FALLS TO HAMILTON.

From the station on the Canadian side the train proceeds by the Grand Trunk railway to Hamilton. About a mile north of Niagara Falls, Ontario, the railway passes within a quarter of a mile of the western cliffs of the whirlpool and farther north crosses two or three sharp ravines of the headward streams of Bowman creek. Beyond this the view discloses no evidence of the buried St. David gorge. Instead, one sees to the east a level plain and fertile fields. At the head of the embayment south of St. David there is a great deposit of gravel which has been extensively excavated for ballast. These gravels are of glacio-fluvial origin and were deposited in connection with one of the slender moraines which crosses this region. In passing the gravel pits the cross bedding of the deposits may be seen from the train.

As it passes through the gravels the railway turns to the west and begins a long descent down the face of the escarpment. In a cut about a mile and a half (2·4 km.) west of the pits a few exposures of Lockport limestone may be seen and, about a mile farther on, the Rochester shale. Half a mile west of this and about a mile east of the Welland canal there is a fairly level terrace formed by the Whirlpool sandstone, but only small exposures of the rock are seen. Welland canal which is crossed next, is one of the largest and busiest canals on this continent. Continuing, the railway descends gradually to the flat clay plain below the Niagara escarpment. At the station south of St. Catherines the railway descends to the lower side of a low bluff,the shore cliff of the Iroquois beach, which continues most of the way from Queenston to Hamilton. From the village of Homer, about three miles (4·8 km.) east of St. Catherines, the shore cliff gives place to a strong gravelly beach ridge which runs westward into St. Catherines where it divides into several spits. The shore again becomes a strong gravel ridge in crossing the embayment between Stoney creek and Bartonville.

The route of the railway westward from St. Catherines is over a flat plain which descends gently toward Lake Ontario but is deeply trenched by many small streams. The subsoil is of clay, but the surface is generally gravelly or sandy loam, excellent for agriculture purposes and especially for fruit growing. The climatic influence of Lake Ontario favours the same industry and a little farther west near Grimsby almost all the land is given to the raising of peaches, pears, apples and grapes, forming one of the best fruit growing districts in Canada.

Just west of Jordan station about seven miles (11·2 km.) west of St. Catherines, the railway crosses the drowned valley of Twenty Mile creek. North of the railway the valley of this creek is occupied by one of those landlocked lakes which arise from the backing up of the water into the valley after it had been cut down to a level lower than the present level of Lake Ontario.

Five or six miles (8 or 9·6 km.) west of Jordan, and at two or three places farther on, the railway passes through a bouldery or stony belt, sometimes with low small knolls of bouldery till. In places these appear to be the remains of a moraine which has been mostly washed away, corresponding probably to the Carlton moraine in New York; in others they mark the site of a beach ridge which was washed away when the lake rose to a higher level. At Queenston the Ontario lowland is eight or nine miles (13 or 14 km.) wide. At Jordan it narrows to three, and at Grimsby it is only one mile wide, but thence westward to Hamilton it is generally two to three miles wide.

IROQUOIS BEACH.

BY

A. P. Coleman.

GEOLOGY AND PHYSIOGRAPHY OF THE HAMILTON DISTRICT.

As shown in former pages by Mr. Taylor, the most striking physiographic feature of the Ontario region is the Niagara escarpment, which runs as cliffs facing northward from Queenston to Hamilton, then turns northeast to Waterdown, and finally bends to the northwest to the shore of Georgian bay. The cliff is due to the more rapid attack of the weather upon the soft underlying shales than upon the protecting layer of resistant limestone on top. It ranges in height from 300 to 400 feet (90 to 120 m.) above the plain which slopes gently down between its foot and Lake Ontario.

A short distance inland on each side of the lake there is a less conspicuous feature, to which reference has also been made—the old shore of Lake Iroquois, which occupied the basin toward the close of the Ice Age when the removal of the ice sheet had progressed as far as the Thousand Islands region, though the St. Lawrence valley beyond was still blocked.

The old shore of Lake Iroquois has been mapped by Gilbert and Fairchild in New York, and by Spencer and Coleman in Ontario; and it was early recognized by Dr. Spencer that the beach was no longer horizontal, but had been deformed by the upward warping of the earth's crust toward the northeast. It is commonly very well defined, with cliffs and gravel bars as mature as those of the present lake. At Lewiston and Queenston, as mentioned before, its level is about 125 feet (38 m.) above Ontario, but at Hamilton its height is 116 feet (35·4 m.) and at Toronto 176 feet, (53·6 m.) toward the west and 200 feet (61·0 m.) toward the east. Between Hamilton and Toronto its deformation is at the rate of 2 feet per mile (·38 m. per km.). To the east of Toronto it increases to 3·4 feet and at the far northeastern end reaches 5 or even 7 feet per mile, its last observed point rising 495 feet (150·8 m.) above Lake Ontario. The

Iroquois beach is made use of on each side of Lake Ontario by the main roads, from Queenston to Hamilton and from Hamilton via Dundas street to Toronto. Its old gravel bars are occupied by three cities, St. Catherines, Hamilton and parts of Toronto, though the two larger cities are now spreading far beyond the old shore.

In a few places the Iroquois beach lies at the foot of the escarpment, which must have formed magnificent cliffs against which the waves dashed, but in general its shore cliffs are low and were carved in boulder clay, or more rarely in the soft red Queenston shale.

PHYSICAL FEATURES AT HAMILTON.

The city of Hamilton lies mainly on the Iroquois terrace between the Niagara escarpment to the south and Hamilton bay (or Burlington bay) to the north. The bay, which is about 5 miles (8 km.) long and 4 miles (6·4 km.) broad toward the east, is cut off from the western end of lake Ontario by a very straight gravel bar 4 miles (6·4 km.) long, called Hamilton beach. This is cut by a short canal giving access to the bay, which is in places 78 feet (23·8 m.) deep and forms an excellent harbour. The modern Hamilton bay repeats in essential respects the Dundas bay of lake Iroquois just to the west.

The escarpment to the south of the city, generally called Hamilton mountain, rises in places to 650 feet (200 m.) above the sea, more than 400 feet (122 m.) above Lake Ontario. The upper part of the cliff, formed of the firm Niagara (Lockport) limestone rises boldly, but the lower part of the escarpment is largely hidden by talus. A full description of the section exposed here with the fossils which may be collected from the different formations, will be found in the guide book to Excursion B3. South of the escarpment a tableland generally covered with boulder clay rises gently.

From the top one can look down upon the thriving city, the bay and beach, and the shores of Lake Ontario can be followed by the eye for many miles to the east and to the northeast. Toward the north one sees the ancient gravel bar of Burlington Heights, three miles (4·8 km.) long and with a gentle westward curve. To the west of it stretches Dundas marsh, threaded by the long unused Desjardins canal,which once allowed small vessels to reach the town of Dundas, three miles (4·8 km.) west of Hamilton bay. The old shore of Lake Iroquois can be observed stretching round to Dundas; but its western end is poorly marked in a region of hummocky morainic material where the Ontario lobe of the last ice sheet made its way up an ancient valley cutting the escarpment. Beyond the depression of Dundas bay the escarpment rises in imposing cliffs which turn off to the northeast and after a few miles bend northwards.

Descending the escarpment one passes first the thick sheet of Niagara limestone (Lockport) then the softer gray shales (Rochester) and reaches the Clinton limestone beds, much thinner than the Niagara limestone above. Below this come the gray Cataract sandstone and the red Richmond or Queenston shale, which underlies the talus near the foot of the escarpment and is largely hidden.

The slope occupied by the city between this and the shore of Hamilton bay is formed mainly of Iroquois beach deposits, sand and silt, well stratified and often 20 feet (6 m.) or more thick, as shown in excavations. Rarely the red shale may be seen in unusually deep cuttings.

THE IROQUOIS BEACH AT HAMILTON.

Descending the escarpment toward the east end of the city one stands upon the Iroquois terrace at the foot of what must have been a fine shore cliff 300 feet (90 m.) high. The old beach can be followed westward for a mile at the foot of the cliff and then bends northwest as a gravel bar through the highest part of the city, passing Dundern park and the cemetery and running nearly north as an extraordinary embankment of sand and gravel, less than a quarter of a mile (·4 km.) wide and 116 feet (35·4 m.) high. The bottom is of sand and the upper 66 feet (20·2 m.) of coarse sand and gravel, partly cemented to conglomerate by the deposit of lime between the pebbles. In general the stratification runs horizontally and with great uniformity. At Desjardins canal, an artificial cut across the bar, it is seen in cross section that the materials are often crossbedded. Beyond the canal, which is crossed by railway and road bridges, the bar curves somewhat east of north and ends at the former outlet of the Dundas marsh, now filled in with a railway embankment. The bar evidently pushed out from the foot of the cliff formed by the escarpment across the mouth of the Dundas bay while the water of Lake Iroquois stood perhaps 100 feet (30 m.) lower than its final stage. As the northeast end of the lake warped upwards the water rose toward the west end and the bar grew in height to correspond, till it reached its present wall like form.

To the west of the bar a plain 36 feet (11 m.) lower consists of stratified clay, sand and gravel deposited in the bay, and extending to the town of Dundas. At various places in the gravel bar and the beds to the west fossils have been found including mammoth, wapiti and beaver. The most common fossils are bones, ivory and teeth of mammoth, which occur at various levels, from 33 feet (10 m.) to 70 or 80 feet (21 to 24 m.) above Lake Ontario. An old soil with mammoth bones and remains of trees was found 30 feet (9·1 m.) below the gravel bar in the city, showing a decidedly lower stage of water before the final beach level was attained.

The rise of water at the west end of Lake Iroquois corresponded in character to the later rise in Lake Ontario, leading to the flooding of the lower portions of the rivers and to the growth of Hamilton beach in water now 78 feet (23·8 m.) deep. It appears that there has been a more or less continuous elevation toward the northeast since the departure of the ice, probably with a gradual slowing down until at present the change of level is very slight or completely ended.

The Grand Trunk railway from Hamilton to Toronto follows the Burlington gravel bar to the north shore of the old bay, where red shales begin to show themselves under a shallow deposit of drift. At Waterdown, four miles (6·4 km.) east of Hamilton, another gravel bar of Iroquois age projects two or three miles toward Hamilton bay, to some extent overlapping the great bar just described. The channel of the stream which flowed from the Dundas valley before the cutting of the Desjardins canal seems to have been an entrenched meander dating from Iroquois times.

The railway runs for about 15 miles (24 km.) a little to the south of the Iroquois shore, which can be seen rising as a low cliff from the plain which slopes gently towards Lake Ontario. The rest of the railway journey to Toronto is near the present lake shore and out of sight of the old beach.

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EXCURSION A 12.

THE PALÆONTOLOGY OF THE GUELPH, ONONDAGA AND HAMILTON FORMATIONS IN WESTERN ONTARIO.

BY

William A. Parks.

With Sections by C. R. Stauffer and M. Y. Williams.

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INTRODUCTION.

The comparatively flat upland of the southwestern part of the Province of Ontario is separated from the eastern lowland by the Niagara cuesta which extends from Queenston on the Niagara river to Hamilton at the head of Lake Ontario and thence into the Bruce peninsula between Lake Huron and Georgian bay. The brow of the cuesta is marked by the Lockport (Niagara) dolomite which extends only a short distance back from the edge of the escarpment.

The yellow dolomites of the Guelph formation succeed the Niagara rocks and form a belt about 30 miles (48 km.) wide with a length of 80 miles (129 km.). The actual extent of the formation is probably much greater than this, but the evidence is not very satisfactory owing to the heavy covering of drift. Excellent exposures from which the unique fauna of the formation may be collected occur at Guelph, Galt, Hespeler, and at points farther north.

West of the Guelph formation, the unfossiliferous shales and limestones of the Salina stretch in a broad band from the Niagara river to Lake Huron. The western boundary of this formation runs approximately from Fort Erie to Goderich. Gypsum quarries are located on this formation in the vicinity of Caledonia and Paris, while at Goderich and Windsor it is the source of a large amount of salt.

The Salina is succeeded by the Monroe formation which constitutes the summit of the Silurian series: it is composed largely of dolomitic limestones and is separated into an upper and lower member by a median bed of sandstone (Sylvania). Exposures of this formation are infrequent in Ontario: an unfossiliferous type is seen in the "waterlime" of the Niagara district while a fossiliferous dolomite with an interesting Silurio-Devonian fauna is exposed by the Livingstone cut in the Detroit river opposite Amherstburg. The Sylvania sandstone has no areal extent in Ontario but it is always penetrated in drilling the salt, gas and oil wells of the western part of the province.

The Oriskany sandstone, with a small but unique fauna, marks the opening of Devonian time: the formation is of very limited thickness and is exposed, over a small area only, in the eastern part of the region.

The Onondaga (Corniferous) is the chief Lower Devonian formation: it consists largely of limestone which is highly fossiliferous in places. This formation forms the greater part of the province west of the Salina boundary: it is divided into two areas by a broad belt of Middle Devonian strata (Hamilton) which overlies it. This belt consists largely of shales with some intercalated limestones and presents, in places, an extraordinary profusion of excellently preserved fossils.

The highest member of the Devonian series in Ontario is exposed on the shore of Lake Huron near the south end. The rocks are highly bituminous shales, but fossils are rare or confined to a few obscure plant remains. The rocks are commonly ascribed to the Genessee shale of the Portage and Chemung formations of the New York geologists.

It will be seen from the above sketch that the interesting formations from a palæontological point of view are the Guelph, the Onondaga and the Hamilton. The excursion is planned to afford an opportunity for collecting on these formations as below:

Oriskany and Onondaga—Hagersville and vicinity.
Hamilton—Thedford and valley of Aux Sables river.
Guelph—Guelph, Hespeler and Galt.

TABLE OF FORMATIONS.

The Silurian and Devonian formations of western Ontario are as follows:

Upper Devonian—Genesee shales.	
Middle Devonian—Hamilton.	
Lower Devonian	Onondaga. Oriskany.
Upper Silurian	Upper Monroe. Sylvania. Lower Monroe.
Middle Silurian	Salina. Guelph. Niagara.

Miles and Kilometres.

0. m. 0 km. **Toronto.**—Alt. 254 ft. (77·2 m.). Leaving Toronto, the railway crosses the Humber river immediately to the west of the city. The slack water in the lower reaches of this river and of the other streams at the west end of Lake Ontario is due to the backing of the waters of the lake owing to a differential elevation of the rock basin at the eastern end in post-Glacial times. The clay exposures in the vicinity of the Humber consist of inter-glacial materials worked over by post-glacial agencies.

6·42 m. 10·3 km. **Mimico.**—Alt. 300 ft. (91·2 m.). At Mimico, quarries in the Lorraine shales may be seen to the north of the track: exposures of the same rocks occur in the bed of the Etobicoke river beyond.

13·1 m. 20·9 km. **Credit.**—Alt. 265 ft. (80·6 m.). The invaded valley of Credit river is comparable with that of the Humber. No rock is exposed here, but in this vicinity the Lorraine shales give place to the overlying red shales of the Richmond formation which continue to Hamilton and are exposed in many small valleys along the line of the railway. Beyond the Credit river, the north shore of the post-glacial Lake Iroquois (Iroquois beach) is plainly to be seen along the north side of the track all the way to Hamilton.

31·78 m. 50·8 km. **Burlington.**—Alt. 328 ft. (99·7 m.). At Burlington the flat bottom of Lake Iroquois is well shown with the Iroquois beach beyond, and above that the escarpment of the Niagara cuesta.

Just before entering Hamilton, the gravels of the Burlington beach (Iroquois) may be seen resting on the red Richmond shales. (See guidebook to Excursion A4). At this point, the Desjardins canal is crossed: it marks approximately the position of a pre-glacial river which discharged into the Ontario basin.

Miles and Kilometres.	
38·83 m. 62·1 km.	**Hamilton.**—Alt. 253 ft. (76·9 m.). On leaving Hamilton, the railway at once begins the ascent of the Niagara cuesta. In a distance of five miles (8 km.) an elevation of 383 feet (114·7 m.) is attained. The formations exposed in the face of the cuesta are in ascending order as follows:—

Richmond—Red shales, covered largely by talus.

Cataract—Basal sandstone and overlying limestones and shales. Quarries near the inclined railway at the head of Wentworth street are in the basal sandstone.

Medina—Mottled and white sandstones. Not observable from train.

Clinton—Limestones and shales. } Thin and doubtfully present.
Rochester—Shales.

Lockport (Niagara)—Dolomites. Seen in cut near top of grade. (See guide book, Excursion B3.)

From the left-hand windows, a glimpse may be had of the splendid fruit lands which extend, under the protection of the cuesta, from Hamilton to the Niagara river.

44·98 m. 71·9 km.	**Rymal.**—Alt. 644 ft. (195·7 m.). At Rymal, the railway has reached the level of the upland: differences in elevation are slight between this point and Lake Erie. Extensive quarries in the Niagara dolomite were formerly operated near Rymal.
55·03 m. 88·05 km.	**Caledonia.**—Alt. 652 ft. (198·2 m.). In the short distance between Rymal and Caledonia the Niagara-Guelph and the Guelph-Salina contacts are crossed, but the heavy mantle of drift permits of no exposures being seen.

An important gypsum quarry has been sunk to a depth of 80 feet (24·4 m.) in the Salina

Miles and Kilometres.

rocks near Caledonia. The section presented in the shaft is as follows:—

Drift..............	10 feet (3 m.)
Limestone.........	20 feet (6 m.)
Gypsum...........	4 feet (1·2 m.)
Shale and limestone.	34 feet (10·3 m.)
Anhydrite.........	4 feet (1·2 m.)
Gypsum...........	7 feet (2·1 m.)

64·53 m. 103·3 km. **Hagersville.**—Alt. 729 ft. (222·6 m.). The Pleistocene deposits between Rymal and Hagersville are but slightly modified glacial débris with post-glacial gravels and sands at certain points.

GEOLOGY OF THE REGION AROUND HAGERSVILLE.

BY

Clinton R. Stauffer.

GENERAL DESCRIPTION.

Hagersville is located in the midst of a comparatively level tract of land, although to the north and east the country becomes somewhat rolling. This region is a part of the glacial plain over which the marginal lakes of the receding continental glacier spread. The effect of this water action, however, has been slight and the flatness of the region is due, chiefly, to the position of the underlying bed rock, for the drift covering is often very thin. The land, especially to the south, is excellent for agricultural purposes, the chief crops being wheat, oats and hay. Ten miles (16 km.) to the southwest lies the famous fruit region of Norfolk county where some of the finest apples grown on the North American continent are produced.

The main street of Hagersville is the Old Indian Line which separates the white man's land from that of the red man, the latter being allotted that to the northeast. The reservation has been somewhat reduced by purchase, so that now it lies entirely to the north of town. Other than the copper coloured skin of many of the occupants, there is little about the Indian's land to suggest its ownership, for he has learned to till the soil in much the same way that other farmers do.

The rocks to be seen near Hagersville are chiefly of Devonian age, although the Silurian-Devonian contact comes to the surface but a short distance to the north and east. A notable feature of the Devonian outcrops is their terrace-like occurrence. These are perhaps remnants of old rock terraces connected with the buried pre-glacial valleys, the upper portions of which have been but partially obliterated by drift deposits. The outcropping formations of this immediate vicinity may be grouped together in the following classification; (**9**.)

Devonian	Onondaga.	Onondaga limestone.
		Springvale sandstone.
	Oriskany sandstone.	
Silurian	Cobleskill dolomite (?)	
	Salina beds.	

SALINA BEDS.

The beds, of Salina age, lying immediately below the Devonian of this region are probably the Bertie waterlime. At some places there may be remnants of the Cobleskill, but this is an uncertain matter, as the fossils so far obtained are not conclusive. The Salina beds consist of drab (weathering buff to yellowish brown) to bluish compact dolomites passing into shales and gypsum-bearing deposits below. At some places, these Silurian deposits include thin streaks of sand, while at the top, the coarse sand from the Oriskany has penetrated the cracks and crevices in all directions, there consolidating into thin seams of sandstone. The Silurian-Devonian contact is uneven and the rocks underneath often show the effects of pre-Devonian weathering.

ORISKANY SANDSTONE.

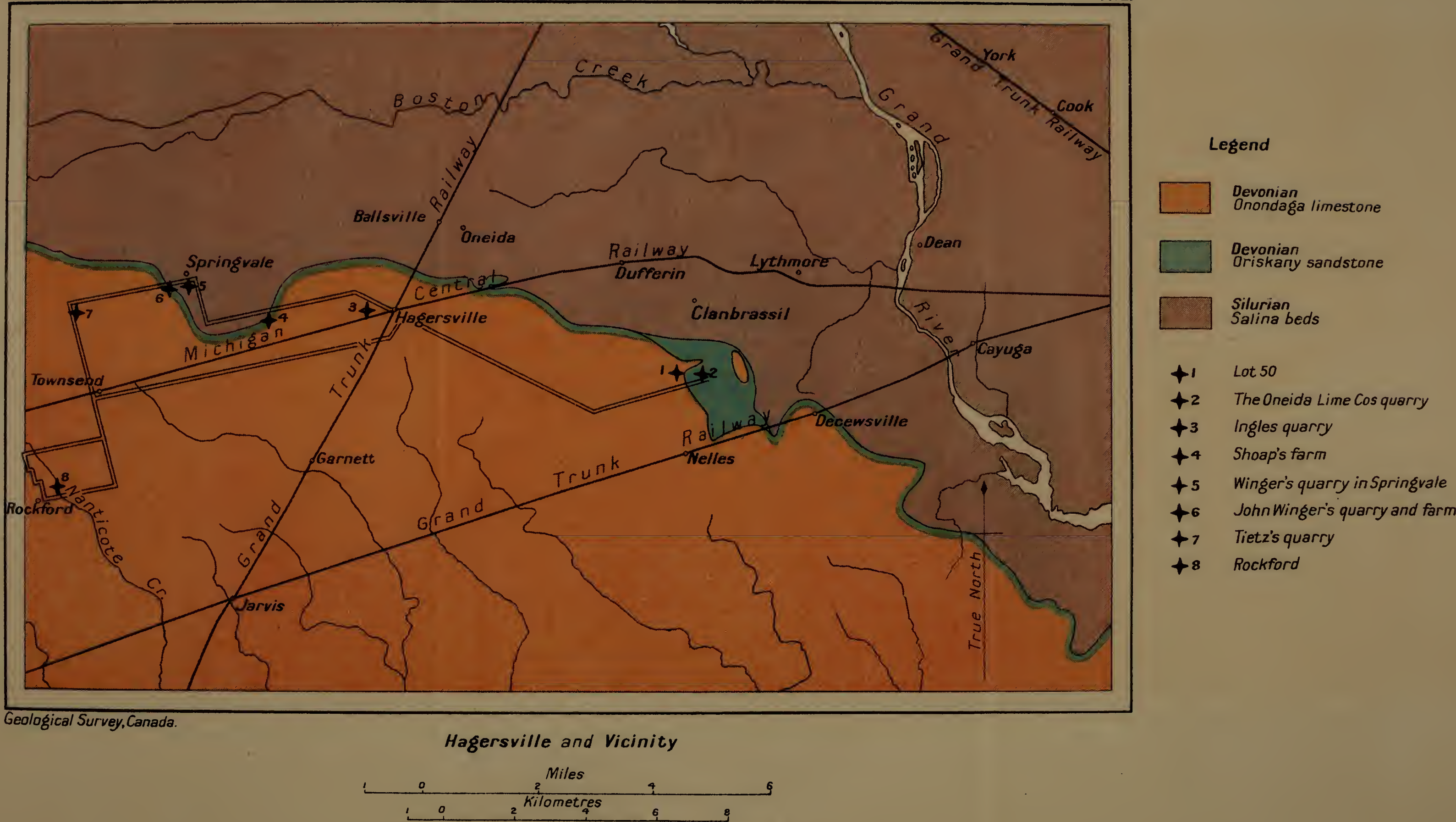
The Devonian often begins with a basal conglomerate composed of sub-angular and rounded pebbles of the Silurian dolomites mingled with sand, the whole cemented into a solid mass. The thickness of this conglomerate is rarely more than six inches (15·2 cm.) to one foot (30·4 cm.) and it is frequently absent. Where found it usually grades into the overlying deposits without a break. Southeast of Hagersville these overlying deposits are beds of true Oriskany sandstone (**10**). At most other places they belong to the Onondaga limestone. The Oriskany (**3**) is usually composed of moderately coarse-grained quartz sand but it is often much coarser and sometimes even pebbly, the individual grains of which are as much as an inch in diameter (**5**). Some parts of the rock are so closely cemented by silica that it resembles a quartzite in appearance. The rock is usually massive and sometimes the entire formation appears as a single bed. The total thickness of the Oriskany sandstone rarely exceeds 20 feet (6·1 m.) and much less is the usual rule. Although a large part of the deposit is almost barren, fossils are often abundant and in a good state of preservation, even the spires of certain brachiopods and the finest external markings being preserved.

Where the true Oriskany sandstone is absent, there is sometimes found a deposit of several feet of chert which has been assigned to the same formation as the sandstone (**5**). However, the fossils so far found in it are so rare and fragmentary that its true age is somewhat in question.

ONONDAGA.

The Onondaga limestone usually rests on an eroded Silurian surface, but occasionally it lies unconformably on the Oriskany sandstone. Where the latter is the case, the unconformity is marked chiefly by the change in fossils, but at some places there may be found a well developed conglomerate in which fossiliferous pebbles of Oriskany sandstone are mingled with the remains of Onondaga corals and fishes.

Where the Oriskany is absent the conglomerate persists, but at such places the pebbles are of Silurian dolomites. The lower portion of the Onondaga limestone, in this region, is usually arenaceous and very cherty. Sometimes the sand is so abundant that the deposit becomes an arenaceous chert, and again a true sandstone. This latter is the case at Springvale, where the lower portion of the Onondaga takes on such a marked resemblance to the true Oriskany that it has often been confused



Geological Survey, Canada.

Hagersville and Vicinity

with it. The fauna, however, is Onondaga (**10**) in every characteristic and cannot be confused. But, because of the decided lithological difference from the ordinary appearance of the formation to which they belong, the beds are here referred to as the Springvale sandstone. This sandstone has a thickness of about 8 feet (2·44 m.) and the material of which it is composed was doubtless derived from the Oriskany sandstone, portions of which were re-worked by the advancing Onondaga sea. The Springvale sandstone is succeeded by cherty grey and bluish limestones attaining a thickness of over 60 feet (18·3 m.) in the vicinity of Hagersville. This mass is all rather fossiliferous: at some horizons the remains of corals especially occur in great abundance.

ONEIDA QUARRIES.

Five and three quarter miles (9·2 km.) southeast of Hagersville, on Lot 49, Concession I of Oneida township in Haldimand county, the Oneida Lime Company has several interesting quarries. At several places along the roadway from Hagersville (old Indian line) the cherty layers of Onondaga limestone come to the very surface. At Gill, 3·75 miles (6·04 km.) southeast of Hagersville the road turns east at the brink of one of the terrace-like outcrops of Onondaga limestone above mentioned.

On the southern part of Lot 50, Concession I of North Cayuga, the Oriskany sandstone comes to the surface and has been quarried on a limited scale. The uneven contact with the Silurian may be seen here while the surface of the sandstone shows the effects of glaciation. The rock is abundantly fossiliferous and, near the old barn at this point, its surface is literally paved with *Stropheodonta magnifica* Hall. If this ledge of sandstone is followed eastwards into the woods, other excellent outcrops will be found and also a greater variety of fossils.

At the cross-roads, a short distance to the east, are the quarries and plant of the Oneida Lime (and Sand) Company. Here a greater thickness of the sandstone may be observed as well as a small quarry in the Silurian limestone.

The massive Oriskany sandstone overlying the Silurian dolomites unconformably, near the Oneida Lime Company's quarry.

The following is a combined section measured at this place:—

	Thickness Feet.	Metres.
6—Soil and drift....................	1·5	·152
Onondaga limestone.		
5—A very cherty, bluish-grey limestone in which fossils are abundant. Much loose material, weathered out of these beds, occurs in the fields to the north, where collecting is good..................................	3·6	1·118
4—Cherty, calcareous layers with an abundance of coarse sand intermingled. This portion sometimes becomes a true conglomerate in which the pebbles are fossiliferous Oriskany sandstone......................	0·6	·203
Oriskany sandstone.		
3—Coarse sandstone, partly covered...	2·5	·763
2—Coarse grained, friable, white to yellowish sandstone with an abundance of fossils in certain spots. At some places, especially in the upper part, this sandstone contains occasional concretion-like bodies, which have been cemented into masses resembling quartzite. The contact of this sandstone with the underlying rock is very uneven, and the lower layers of sandstone contain sub-angular and rounded fragments of the underlying limestone. The thickness varies much from place to place............	17	5·185
1—Buff to brown and drab dolomitic limestones which are rather compact and usually distinctly banded. These beds extend to the bottom of the limestone quarry and contain a few fossils..................	16·5	5·033

The fossils occurring in the different strata at this point are indicated in the first column of the table on page 92.

Onondaga Quarries about Hagersville.

Section at the J. C. Ingles quarry, Hagersville— An excellent section, entirely within the Onondaga limestone, is exposed in the quarry of J. C. Ingles at the northwestern edge of Hagersville (**8**). The strata exposed are as follows:—

	Thickness Feet.	Thickness Metres.
6—Soil and drift......................	1	·305
5—A grey to brownish blue, semi-crystalline limestone containing much dark bluish chert. The layers are inclined to be rather massive, but, where weathered, split into thin uneven layers, which are sometimes shaly. Corals and crinoid fragments are abundant..............................	9·16	2·796
4—Shaly parting, not always conspicuous................................	0·08	·025
3—Bluish grey, semi-crystalline limestone, containing a relatively small amount of grey to white chert. The whole mass is abundantly fossiliferous and sometimes even matted with corals......................	4·6	1·424
2—A dark bluish-grey, fine-grained limestone practically free from chert. The fossils are much less abundant than in the layers above. The upper four inches are often shaly and sometimes shaly partings occur between beds in the upper part.	6·83	2·085
1—Rough, cherty, bluish limestone to the level of water in the lowest water hole..	6·25	1·906

The fossils that may be obtained from the five horizons indicated above are given in the second column of the list on page 92.

Oriskany and Onondaga at William Shoap's quarry.—Near Mr. Shoap's house, about a mile and a half westward from Ingles' quarry, a small run falls over a ledge of Springvale sandstone and cherty Onondaga limestone. There is thus preserved a good exposure of both formations, together with some of the underlying beds. The section at this point is as follows:—

	Thickness Feet.	Thickness Metres.
5—Soil and drift....................	4	1·22
Onondaga limestone.		
4—Cherty, blue to grey limestone. This rock is mostly chert and quite fossiliferous. In the upper part of these beds the corals		

	Thickness. Feet.	Metres.
stand out in relief on the matrix. Near the northeast corner of the house there is exposed a glaciated surface, on which sections of the corals show beautifully....	5·5	1·677
Springvale sandstone.		
3—Coarse white to yellowish sandstone. The lower portion of these beds is rather massive, while the upper layers are somewhat irregular and seem to contain more fossils...	8	2·44
Oriskany (?) *cherts.*		
2—Arenaceous blue shale..............	·58	·175
1—Irregular beds of bluish-grey chert with a few thin calcareous layers. These lower beds contain only a few fragments of fossils and extend to the bottom of the section in the run.............................	3·16	·966

The list of fossils from this locality is given in the third column on page 92.

Section at Springvale.—The slight terrace to the west of the highway near Springvale is caused by the same sandstone ledge that has just been observed at the last section. It lies under a very thin covering of drift and influences the topography for a distance of several miles. In the sugar-bush at the southern end of the village is one of the best gas wells of the locality. It is the chief source of fuel for the lighting and heating of this community. In the village proper is an old quarry and limekiln, in which about 10 feet (3·05 m.) of Silurian dolomite is exposed. These rocks contain a few fossils, such as *Ortholhetes hydraulicus* Whitfield, *Goniophora dubia* Hall, *Leperditia alta* Conrad, etc., which tie them to the Monroe group of the western part of the peninsula.

On John Winger's farm, one half mile west of the village, and at a number of other places along the ridge the Springvale sandstone has been quarried for local use, so that nearly the entire thickness may be seen. In the fields above the quarry the higher beds of the Onondaga are just under the surface, outcropping here and there, and fossils from it are scattered over the surface in great abundance. The most common of these are specimens of the

the large compound corals. This is especially true 100 yards (91·5 m.) along the hill-slope above the sandstone quarry. The section at this point is as follows :

	Thickness. Feet.	Metres.
Onondaga limestone.		
4–Cherts and cherty grey limestone weathering out over the hill side. The upper part contains an abundance of corals chiefly of the compound type..............	15	4·575
3–Arenaceous cherts weathering out in the field..............................	·5	·153
2–Arenaceous grey limestone which becomes chiefly sandy in the lower part......	1·5	·458
Springvale sandstone.		
1–Yellowish to white coarse sandstone containing hard masses resembling quartzite. These layers are best exposed in the quarry face....................................	5·5	1·678

The more common fossils found in the rocks on Winger's farm are indicated in the fourth column of the table on page 92.

Section at the Teitz quarry.—On the Teitz farm, about two and a half miles (4 km.) west of Springvale, quarrying operations have revealed a ridge of limestone which lies under a very thin covering of drift. Although the thickness of rock exposed here is slight, the bottom layers extend downwards to about the horizon of the top of the section on Mr. John Winger's place and thus form almost a continuation of that section. The section is as follows :

	Thickness. Feet	Metres.
4—Weathered, cherty limestone which may have been slighly moved.............	·5	·153
3—A semi-crystalline, grey limestone filled with the smooth variety of *Snathophyllum simcoense* (Billings), and having a few thin layers of chert in it..................	3·5	1·068
2—Semi-crystalline, grey limestone alternating with beds of soft, shaly, bluish-grey limestone. The semi-crystalline layers are usually very crinoidal and contain a good many corals, while the shaly layers contain *Hindia fibrosa* (Roemer)	2·5	·763

	Thickness. Feet.	Metres.
1—Four to six inch layers of blue to bluish-grey, semi-crystalline limestone in which fossils are not abundant...........		2·61

The fossils from Teitz' quarry are given in the fifth column of the table on page 92.

Section of Onondaga at Rockford.—At the mill at the edge of the little village of Rockford, there is a splendid natural exposure of the Onondaga limestone where the creek plunges over a small ledge of rock and a good oportunity to collect fossils is offered. The section follows :

	Thickness. Feet.	Metres.
4—Soil and drift....................	3	·915
3—Uneven bedded, bluish-grey limestone with a considerable quantity of grey chert. Along the west side of the outcrop these beds seem to come down on the bottom beds...	9·5	2·998
2—Semi-crystalline, bluish-grey limestone with a very little chert and full of fossil corals. These layers seem to pinch out out to the west	6	1·83
1—Dark bluish layers of limestone which are fully half chert. These layers present a rough appearance and extend to the bottom of the rock outcrop in Nanticoke creek....		2·61

The fossils from the three horizons at Rockford are given in the last column of the table on page 92.

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
	Oneida Lime Company's Quarry.			Ingles' Quarry.					Shoap's Quarry.		John Winger's Quarry.				Teitz's Quarry.			Rockford Quarry.		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Hindia fibrosa *Roemer*																x				
Stromatoporella granulata *Nicholson*		x	x		x										x	x				x
Stromatoporella (?) tuberculata *Nicholson*								x							x	x			x	x
Acrophyllum oneidaense *Billings*		x												x						
Amplexus yandelli *E. and U.*		x	x																	
Aulopora cornuta *Billings*																			x	
Blothrophyllum decorticatum *Bill.*		x	x		x			x		x	x		x	x			x			
Cayugæa whiteavesiana *Lambe*								x											x	
Chonophyllum magnificum *Billings*																x				
Chonostegites clappi *E. and H.*			x							x				x						
Cladopora cryptodens *Billings*		x	x											x					x	x
Cladopora expatiata *Rominger*														x						
Cladopora francisci *Davis*														x						
Cladopora labiosa *Billings*		x	x			x				x				x	?		x		x	x
Cladopora pinguis *Rominger*														x						
Cladopora pulchra *Rominger*																			x	
Cladopora robusta														x						
Cladopora turgida *Rominger*														x						

Clisiophyllum conigerum *Rominger*																		x			
Cyathophyllum anna (*Whitfield*)																	x				
Cystiphyllum aggregatum *Billings*															x						
Cystiphyllum sulcatum *Billings*			x								x										
Cystiphyllum vesiculosum *Gold*		x	x		x	x		x		x	x		x	x	x	x	x	x	x	x
Diplophyllum arundinaceum (*Bill*)																				x	
Eridophyllum colligatum *Billings*)															x		x	x			
Eridophyllum verneuilanum *E. and H.*			x												x						
Favosites basalticus *Goldfuss*			x					x		x				x	x	x	x	x		x
Favosites canadensis *Billings*								x						x		x	x		x	
Favosites cervicornis *E. and H.*				x				x									x	x	x	x
Favosites clausus *Rominger*			x													x				
Favosites conicus ? *Hall*	x																			
Favosites emmonsi *Rominger*			x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x
Favosites epidermatus *Rominger*			x					x						x		x	x			x
Favosites goodwini *Davis*														x						
Favosites helderbergiæ *Hall*	x																			
Favosites limitaris *Rominger*			x						x	x				x		x	x		x	
Favosites radiciformis *Rominger*																x			x	
Favosites tuberosus *Rominger*														x						
Favosites turbinatus *Billings*		x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Favosites winchelli *Rominger*					x									x	x	x				
Heliophyllum annulatum *Hall*																			x	
Heliophyllum corniculum (*Lesueur*)			x			x		x		x				x			x			
Heliophyllum exiguum *Billings*			x						x	x	x			x						
Heliophyllum fecundum *Hall*																x				
Heliophyllum halli *E. and H.*			x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x
Michelinea convexa *d'Orbigny*		x	x		x	x				x	x			x	x	x				
Michelinea favositoidea *Billings*			x							x				x						
Phillipsastrea gigas *Owen*			x						x					x		x				
Phillipsastrea verrilli *Meek*														x						
Pleurodictyum problematicum *Gold*										x										
Snathophyllum simcoense (*Billings*)			x			x		x	x	x				x		x	x	x	x	x

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Snathophyllum stramineum *E. and H.*																			x	
Syringopora hisingeri *Billings*			x	x	x	x				x	x			x	x	x				
Syringopora maclurei *Billings*			x												x	x	x			
Syringopora perelegans *Billings*		x	x	x		x		x	x	x				x	x	x	x	x		x
Syringopora tabulata *E. and H.*					x															
Zaphrentis davisana *Miller*																	x			
Zaphrentis gigantea *Lesueur*		x	x	x	x	x		x	x	x	x	x		x		x		x		x
Zaphrentis nodulosa *Rominger*														x						
Zaphrentis prolifica *Billings*			x						x	x	x	x		x	?	x	x			x
Zaphrentis rœmeri *Hall*	x																			
Cystodictya gilberti (*Meek*)		x	x						x		x									
Fenestella biseriata ? *Hall*	x																			
Fenestella erectipora					x			x												
Hederella canadensis (*Nicholson*)														x						
Hederella magna ? *Clarke*	x																			
Isotrypa conjunctiva (*Hall*)														x						
Monotrypa tenuis (*Hall*)												x								
Monotrypella sp	x																			
Pinnatopora tenuistriata (*Hall*)					x															
Polypora hexagonalis ? (*Hall*)	?				x															
Polypora robusta (*Hall*)		x	x											x			x			
Amphigenia elongata (*Vanuxem*)	x	x	x		x				x	x	x	x	x	x		x				
Anoplia nucleata *Hall*	x	x	x								x									
Anoplotheca camilla (*Hall*)		x	x		x					x				x						

Anoplotheca flabellites (*Conrad*)	x													
Atrypa reticularis (*Linnæus*)	x	x	x	x	x	x	x	x	x	x	x		x	x
Beachia suessana *Hall*	x													
Brachyprion schuchertanum ? *Clarke*	x													
Camarotoechia barrandei *Hall*	x													
Camarotoechia billingsi *Hall*			x					x	x				x	
Camarotoechia carolina *Hall*										x			x	
Camarotoechia dryope *Billings*	x													
Camarotoechia sappho ? *Hall*													x	
Camarotoechia tethys (*Billings*)			x									?	x	
Centronella glanfagea *Hall*		x	x							x		x	x	
Centronella tumida *Billings*	x													
Chonetes hemisphericus (*Hall*)			x						x	x	x	x	x	
Chonetes hudsonicus *Clarke*	x													
Chonetes mucronatus *Hall*		x	x				x						x	
Chonostrophia complanata *Hall*	x													
Chonostrophia reversa (*Whitfield*)													x	
Crania pulchella *Hall and Clarke*	x													
Crania sp.								x						
Cryptonella fausta ? *Clarke*	x													
Cyrtina biplicata *Hall*													x	
Cyrtina hamiltonensis *Hall*		x	x		x								x	
Cyrtina rostrata *Hall*	x													
Cyrtina varia *Clarke*	x													
Dalmanella lenticularis (*Vanuxem*)										x				
Delthyris raricosta *Conrad*		x												
Eatonia peculiaris *Conrad*	x													
Eatonia sinuata ? *Hall*	x													
Eunella harmonica *Hall*		x												
Eunella lincklæni *Hall*													x	
Hipparionyx proxima *Vanuxem*	x													
Leptæna rhomboidalis (*Wilckens*)	x	x	x					x	x	x	x		x	
Letostrophia oriskania *Clarke*	x													

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Megalanteris ovalis *Hall*	x																			
Meristella lata *Hall*	x																			
Meristella lentiformis *Clarke*	x																			
Meristella nasuta (*Conrad*)		x	x		x	x			x	x	x	x		x	x	x	x		x	x
Meristella walcotti *Hall and Clarke*	x																			
Metaplasia disparilis (*Hall*)					x															
Metaplasia pyxidata *Hall*	x																			
Nucleospira concinna *Hall*		x	x											x						
Nucleospira ventricosa *Hall*	x																			
Orbiculoidea sp.									x											
Oriskania navicella *Hall and Clarke*	x																			
Orthothetes deformis *Hall*	x																			
Orthothetes pandora (*Billings*)		x	x	x					x	x	x	x	x	x		x				
Pentamerella arata (*Conrad*)		x	x					x	x		x	x	x	x						
Pholidops arenaria *Hall*	x																			
Pholidops patina *Hall and Clarke*														x						
Pholidops terminalis *Hall*	x																			
Pholidostrophia iowaensis (*Owen*)			x								x			x						
Productella spinulicosta *Hall*								x												
Rensselæria cayuga *Hall and Clarke*	x																			
Rensselæria ovoides (*Eaton*)	x																			
Rensselæria ovulum *Hall and Clarke*	x																			
Reticularia fimbriata (*Conrad*)	x		x					x		x	x			x						
Rhipidomella cleobis (*Hall*)									?	x			x							
Rhipidomella livia (*Billings*)			x								x					x				

Rhipidomella musculosa *Hall*	x														
Rhipidomella oblata *Hall*	x														
Rhipidomella penelope ? *Hall*												x			
Rhipidomella semele *Hall*												x			
Rhipidomella vanuxemi *Hall*		x	x			x			x	x	x	x		x	
Schizophoria propinque *Hall*									x						
Spirifer acuminatus (*Conrad*)											x				
Spirifer arenosus (*Conrad*)	x														
Spirifer divaricatus *Hall*						x	x		x	x	x	x			
Spirifer duodenarius (*Hall*)		x	x	x		x	x	x	x	x	?	x			
Spirifer gregarius (*Clapp*)					x										
Spirifer macrothyris *Hall*							x		x	x					
Spirifer macrus *Hall*				x										?	
Spirifer murchisoni *Castelnau*	x														
Spirifer plicatus *Weller*	x														
Spirifer saffordi *Hall*	x														
Spirifer tribulis *Hall*	x														
Spirifer (arenosus) unicus *Hall*										x					
Spirifer varicosus *Hall*			x												
Spirifer sp.															x
Stropheodonta callosa ? *Hall*	x														
Stropheodonta concava *Hall*												x			
Stropheodonta demissa (*Conrad*)		x	x	x		x		x	x	x	x	x	x	x	x
Stropheodonta hemispherica *Hall*			x			x	x	x	x	x	x	x			
Stropheodonta inequiradiata *Hall*		x					x					x			
Stropheodonta inequistriata (*Conrad*)			x									x			
Stropheodonta lincklaeni *Hall*	x														
Stropheodonta magnifica *Hall*	x														
Stropheodonta magniventer *Hall*	x														
Stropheodonta patersoni *Hall*						x									
Stropheodonta perplana (*Conrad*)			x					x	x		x	x			
Stropheodonta vascularia *Hall*	x														
Strophonella ampla *Hall*	x	x	x	x			x	x	x	x	x	x	x	x	x

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Uncinulus mutabilis *Hall*	x																			
Actinopteria textilis arenaria (*Hall*)	x																			
Aviculopecten princeps ? (*Conrad*)														x						
Conocardium cuneus (*Conrad*)		x	x		x					x	x	x	x	x		x				
Cypricardinia indenta *Conrad*			x																	
Cypricardinia lamellosa *Hall*	x																			
Goniophora cerusus ? *Clarle*	x																			
Megambonia lamellosa *Hall*	x																			
Pterinopecten plumilus *Clarke*	x																			
Callonema lichas ? *Hall*														x						
Cyrtolites expansus *Hall*	x																			
Diaphorostoma desmatum *Clarke*	x																			
Diaphorostoma lineatum (*Conrad*)		x	x							x					x	x				
Diaphorostoma turbinatum (*Hall*)			x																	
Diaphorostoma unisulcatum (*Conrad*)			x																	
Diaphorostoma ventricosum (*Conrad*)	x																			
Loxonema pexatum *Hall*														x						
Platyceras ammon *Hall*																x				
Platyceras attenuatum *Hall*											x	x		x						
Platyceras bucculentum *Hall*											x									
Platyceras carinatum *Hall*		x												x						
Platyceras concavum *Hall*														x		x				
Platyceras conicum (*Hall*)			x								x			x						
Platyceras dentalium *Hall*			x								x	x								
Platyceras dumosum (*Conrad*)											x					?	x			

Platyceras erectum *Hall*																	x				x
Platyceras nodosum *Conrad*	x																				
Platyceras rictum *Hall*																	x				
Platyceras undatum *Hall*													x								
Platyceras sp.					x																
Pleurorema lucina *Hall*															x						
Pleurotomaria delicatula *Hall*			x																		
Straparollus clymenoides (*Hall*)			x																		
Strophostylus matheri *Hall*	x																				
Tentaculites elongatus *Hall*	x																				
Tentaculites scalariformis *Hall*												x	x		x						
Gomphoceras eximium *Hall*												x									
Gyroceras sp.																x	x				
Orthoceras sp.												x			x		x				
Beyrichia sp.	x																				
Chasmops anchiops (*Green*)	x		x									x	x		x						
Coronura diurus (*Green*)															x						
Hausmania phacoptyx *Hall and Clarke*	x	x	x		x				x	x		x	x		x						
Hausmania pleuroptyx (*Green*)	x																				
Phacops correlator *Clarke*	x																				
Phacops cristata *Hall*		x	x					x		x		x	x	x	x	x					
Phacops logani *Hall*	x																				
Phacops rana (*Green*)			x		x												x				
Prœtus conradi *Hall*	x																				
Prœtus crassimarginatus *Hall*			x									x		x	x						
Prœtus rowi (*Green*)			x						x			x			x						
Synphoria stemmatus *Clarke*	x																				
Antodetus beecheri *Clarke*	x																				

LOG OF WELL AT PETROLIA.

The railway journey from Hagersville to Thedford presents little of geological interest. The whole district is so heavily covered with drift that rock exposures are seen in but few places and only where streams have denuded the mantle of drift. The Onondaga-Hamilton contact is probably situated in the vicinity of London. East of Sarnia and a short distance south of the railway between London and Sarnia, is the centre of the oil district in Ontario at the town of Petrolia. The surface rock is Hamilton yielding the characteristic species of that formation in some abundance. A deep well drilled in the Petrolia oil field gave the following log:—

——	Thickness.		Depth.	
	Ft.	M.	Ft.	M.
Hamilton.				
Blue shale	90	27·36	90	27·36
Shale and limestone	240	72·96	330	100·32
Onondaga				
Limestones (oil horizon)	190	37·76	520	158·08
Monroe?				
Banded grey, brown and black dolomites	690	209·76	1210	367·84
Salina				
Salt	65	19·76	1,275	387·60
Dolomite	20	6·08	1,295	393·68
Salt and dolomite	140	42·56	1,435	436·24
Dolomite	30	9·12	1,465	445·36
Salt	90	27·36	1,555	472·72
Salt and dolomite	50	15·20	1,605	487·92
Salt	25	7·6	1,630	495·52
Grey dolomite	10	3·04	1,640	498·56
Salt	67	20·36	1,707	518·92
Dolomite and salt	40	12·16	1,747	531·08
Salt	138	41·95	1,885	573·04
Dolomite, limestone and grey shales	130	39·52	2,015	612·56
Salt	90	27·36	2,105	639·92
Guelph and Niagara				
Dolomites	275	83·6	2,380	723·52
Cataract (?)	......	......	......	......
Red and dark shales	60	18·24	2,440	741·76
Limestones	90	27·36	2,530	769·12
Richmond (Queenston)				
Red shales	275	83·6	2,805	852·72

—	Thickness.		Depth.	
	Ft.	M.	Ft.	M.
Richmond and Lorraine				
Grey shales and limestone .	205	62·32	3,010	915·04
Collingwood and Utica				
Dark shales..............	165	50·16	3,175	965·20
Trenton and Black River				
Limestones, etc...........	170	51·68	3,345	1016·88
Lowville (?)				
Limestones...............	115	34·96	3,460	1051·84
Chazy				
Shale and limestone.......	317	96·37	3,777	1148·20

THE HAMILTON FORMATION AT THEDFORD AND VICINITY.

BY

M. Y. Williams.

INTRODUCTION.

The villages of Thedford and Arkona are situated in the midst of an excellent farming and fruit growing region. For the most part the land is level, important variations occurring only along the drainage channels. The physiographic features about Thedford are directly related to the underlying formation which lies nearly horizontal. The Aux Sables river has entrenched its course 60 feet (18 m.) or more below the land surface. The stream bed, though fairly well graded, has not developed meanders. The secondary drainage channels are for the most part youthful and descend over falls of considerable height at a distance of 20 rods (100 m.) or more from their confluence with the river. Interstream mounds and rolling hills are occasionally present. The subsoil of the country consists in most places of unsorted gravel of local origin. Much of this gravel was formed on the shores of post-glacial lakes, the strand lines of which are close together at this point. Three distinct beaches are recognized in the vicinity, the Ridgeway, the Arkona and the Forest.

Some of the pebbles are of firm limestone and are fairly smooth as though having suffered wear from wave action, but fossils are frequently found in the gravels from which the surface markings are scarcely removed.

The only Palæozoic formation exposed at Thedford is the *Hamilton*, which is estimated to be about 300 feet (91 m.) thick. The characteristic rocks are blue-grey clay shale and interbedded calcareous shale and limestone. Fossils are very abundant and are found in a remarkably good state of preservation.

Fossils of the Hamilton Formation.

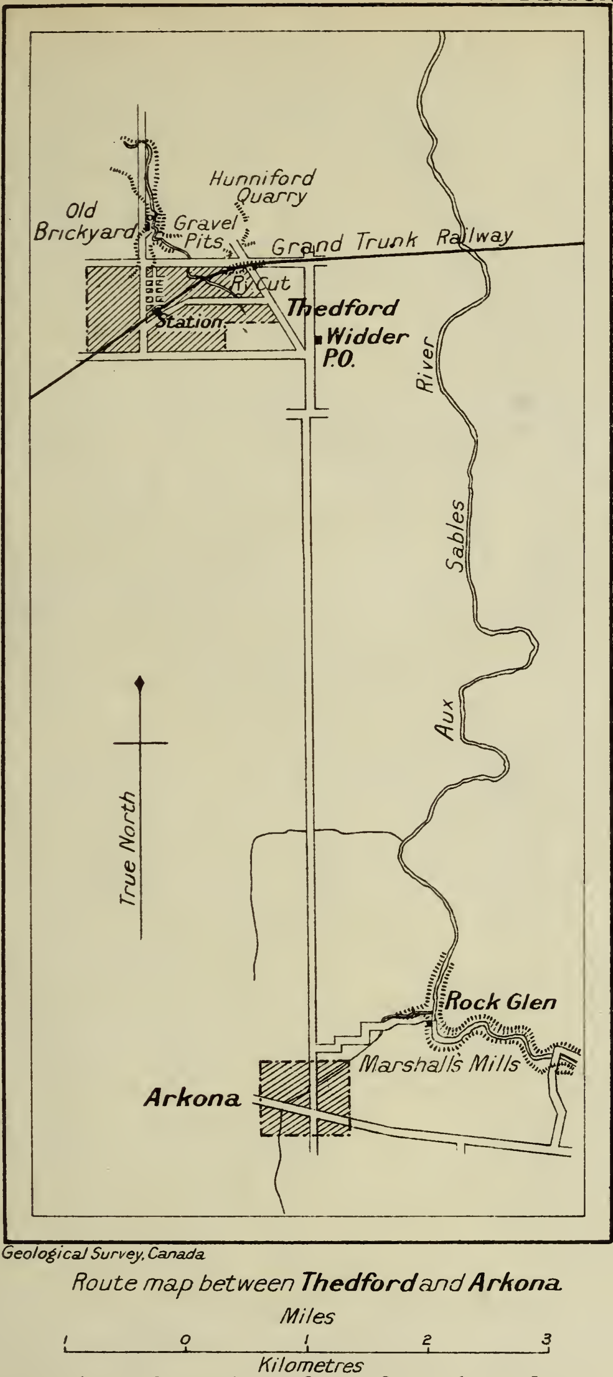
The different strata exposed in the Thedford region are indicated in the accompanying columnar section which has been compiled from the various outcrops in the district.

About 80 feet (24 m.) of Hamilton shales and limestones are exposed in the vicinity of Thedford and along the banks of the Aux Sables river. The shales which make up most of the thickness weather down into fine blue clay. The limestones are blue-grey in colour and are generally firm and resistant. The section is divided into a lower series of shales and an upper series of mixed limestone and shales.

1—The lower shales are not highly fossiliferous except in a few beds. The fauna characterizing them includes:—

Arthroacantha punctobranchiata *Williams*
Chonetes scitula *Hall*
Schuchertella arctostiatus (*Hall*)
Spirifer mucronatus arkonensis *Shimer and Grabau*
Stropheodonta demissa (*Conrod*)
Tentaculites attenuatus *Hall*
Platyceras buccultentum *Hall*
Bactrites obliqueseptatus arkonense *Whiteaves*
Tornoceras uniangularis (*Conrad*)
Phacops rana (*Green*)

2—At the base of the upper division is a four-inch bed of limestone succeeded by six inches of black carbonaceous shale. This black shale is very persistent and always contains many compressed specimens of *Leiorhynchus laura* (Billings) along with *Styliolina fissurella* (Hall).



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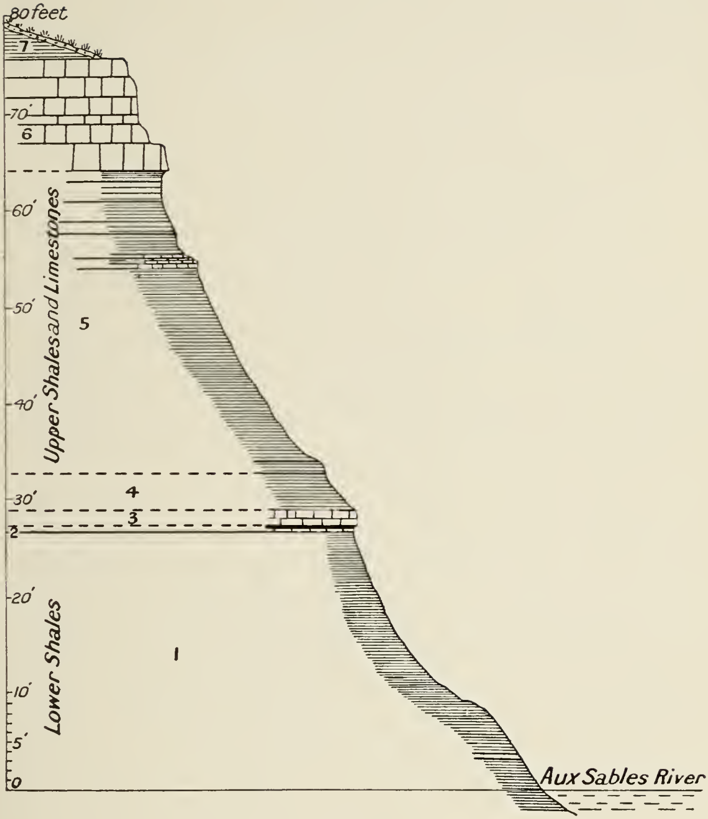
Route map between **Thedford** and **Arkona**.



Composite section of Hamilton formation (Devonian) at Thedford, Ontario.

3—This limestone is referred to as the 'encrinal limestone.' Some of the common fossils are:—

Craspedophyllum archiaci (*Billings*)
Favosites turbinata *Billings*
Leiorhynchus laura (*Billings*)

4—This shale possesses a rich coral fauna with *Heliophyllum* and *Cystiphyllum* predominating. The more common fossils are:—

Corals—
Alveolites goldfussi *Billings*
Cladopora frondosa (*Nicholson*)
Cyathophyllum conatum *Hall*
Cystiphyllum vesiculosum (*Goldfuss*)
Favosites billingsi *Rominger*
Favosites placenta *Rominger*
Heliophyllum halli *E. and H.*
Phillipsastrea verneuili *E. and H.*
Striatopora linnaeana *Billings*
Zaphrentis prolifica *Billings*
Bryozoans—
Fenestella arkonensis *Whiteaves*
Brachiopods—
Athyris fultonensis (*Swallow*)
Camarotoechia thedfordensis *Whiteaves*
Chonetes lepida *Hall*
Cyrtina hamiltonensis *Hall*
Pholidostrophia iowaensis (*Owen*)
Rhipidomella penelope (*Hall.*)
Spirifer mucronatus thedfordensis *Shimer and Grabau*
Worms—
Spirorbis omphalodes (*Goldfuss*) *Nicholson*
Gastropods—
Platyceras subspinosum *Hall*
Trilobites—
Phacops rana (*Green*)

5—The shales and argillaceous limestones of this member contain comparatively few fossils. *Spirifer mucronatus thedfordensis* S. and G., occurs, increasing in abundance towards the top. *Chonetes lepida* Hall, *C. vicina* (Castlenau), *Pterinea flabellum* (Conrad), *Phacops rana* (Green), *Cryphaeus boothii* (Green), occur in the lower beds.

6—This limestone consists of heavy beds separated by shale partings. Some of the characteristic fossils are:—

Ceratopora intermedia (*Nicholson*)
Athyris fultonensis (*Swallow*)
Leiorhynchus laura (*Billings*)
Spirifer mucronatus thedfordensis *S. and G.*
Stropheodonta concava (*Hall*)

7.— This shale is poorly exposed at the top of the formation and appears to be nearly barren of fossils.

Sections of the Hamilton Formation.

The best localities for the examination of the strata and for the collecting of fossils are as follows:—

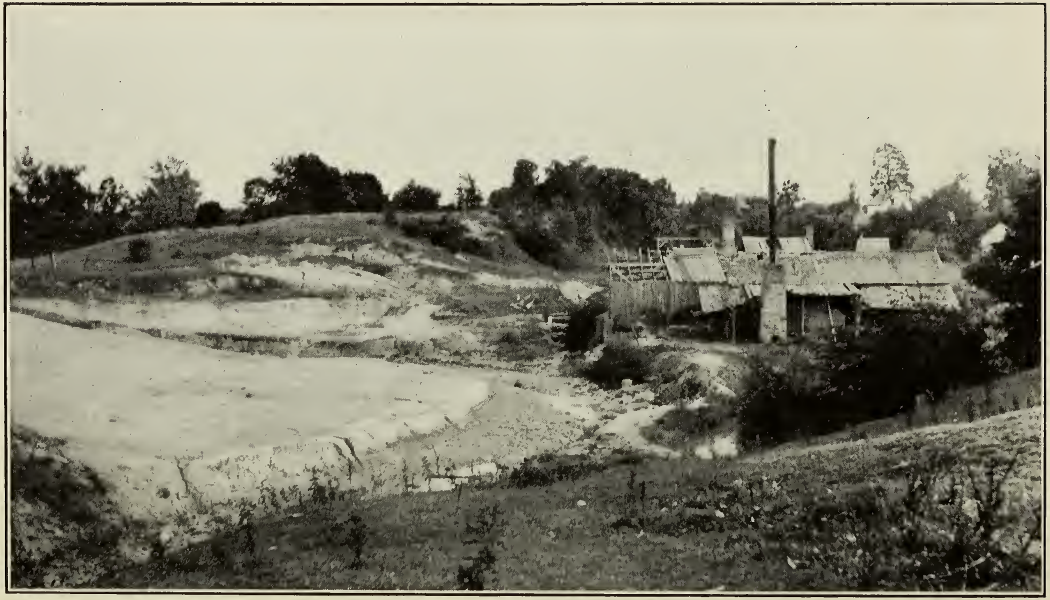
1.—Railway cut, one mile east of Thedford.
2.—Gravel pits and Hunniford's fields north of cut.
3.—The brick yards.
4.—The valley of the Aux Sables river between Rock Glen and Marshall's mills.

Railway cut east of Thedford.—Fossils may be collected from both sides of the railway cut east of Thedford, but the best section is exposed on the south side. The exposure here extends 25 feet (7·6 m.) above the road bed, and consists of limestone and shale representing the upper 15 or 16 feet (4·5 or 4·8 m.) of zone No. 5 and the lower 9 or 10 feet (2·7 or 3 m.) of zone No. 6. The lowest beds of all are obscured, but crinoid remains were formerly obtained from them. The fossils already listed for zones 5 and 6 occur in abundance particularly *Spirifer mucronatus thedfordensis* S. and G., in the lower 10 feet (3 m.).

Gravel Pits and Quarries north of the Railway cut.—A short distance north of the railway cut, a shallow pit in the overlying gravel has exposed the upper layers of the section seen in the cut.

The more common fossils at this point are:—

Pentremites sp.
Athyris fultonensis (*Swallow*)
Cyrtina hamiltonensis *Hall*
Eunella sp.
Meristella sp.
Pholidostrophia iowaensis (*Owen*)
Stropheodonta demissa (*Conrad*)
Platyceras sp.
Phacops rana (*Green*)



Exposure of Hamilton shale at the brickyard, Thedford, Ont.

2.—Northward from the above locality several shallow quarries were opened in the fields for the production of stone from the encrinal layer (No. 3). These shallow pits, long since abandoned, have proved a rich collecting ground for the corals of the overlying shale. This locality has also yielded many examples of the rarer blastoids for which the Thedford section is noted, e.g. *Eleutherocrinus cassedayi* Shumard and Yandell, *Codaster canadensis* Billings, and *Nucleocrinus elegans* Conrad.

3. Hamilton Section at the Brickyard. — The exposed clay surfaces at the brickyard afford excellent collecting ground. Upstream near the first important bend, the black *Leiorhynchus* shale (No. 2), at the base of the upper shale division is about 14 feet (4·2 m.) above the creek bed. The coral shales are the highest strata exposed and from them come most of the fossils that make the brickyard a noted collecting ground for numerous species of Hamilton corals. Abundant and well preserved examples of the various species of *Heliophyllum*, *Cystiphyllum*, *Favosites*, *Acervularia*, etc., may be found here. Many of the other fossils of zones 1, 2, 3 and 4 may also be obtained.

Good exposures with excellent collecting are to be found farther down stream where the spring freshets have cut gullies in the soft strata of zone No. 4. The interesting coral, *Microcyclus discus* Meek and Worthen, occurs at this horizon associated with *Ancyrocrinus* and an occasional *Pentremites*.

4. Hamilton Section of the Aux Sables River.— An excellent section exposing the strata from near the base of zone No. 1 to the top of zone No. 6 extends up the branch stream which enters the Aux Sables river a short distance below the power house (Power glen or Rock glen). The difference in elevation between the mouth of the stream and the top of the limestone above the falls is 66 feet (10 m.).

About 100 yards (91 m.) below the falls, right at the waters edge, is a thin bed of dark argillaceous limestone containing species of *Platyceras* associated with *Arthroacantha* fragments. Small examples of *Schuchertella* are also present. About 29 feet (8·8 m.) above the mouth of the brook, the six inch bed of black shale occurs, marking the top of the lower shale division (See No. 2 of section). *Leiorhynchus laura* is plentiful in this layer. The limestone immediately above furnishes the fossils common in

Falls over Hamilton strata in Rock Glen near Arkona, Ontario.

Marshall's Mills, Aux Sables river, Ontario.

the encrinal limestone (No. 3): it is succeeded by the coralline shales. The overlying shales are not very fossiliferous, but at the top of the falls the heavy bedded limestone carries the fossils characteristic of zone No. 6.

In the river bed below Rock glen, many fine corals of the genera *Heliophyllum*, *Zaphrentis* and *Favosites* are found in association with numerous bryozoans and an occasional trilobite.

At a bend in the river, about ·4 miles (·6 km.) below the bridge at Marshall's mills, a section about 75 feet (22·8 m.) thick is exposed. The top of the lower shales and the bed containing *Leiorhynchus laura* are situated about 27 feet (8·2 m.) above the water. The upper shales are somewhat obscured here by the loose material, and the thick upper limestones are poorly exposed. The characteristic fossils of the coral shale are very plentiful in the débris scattered along the river. The most satisfactory collecting ground is just below the steel bridge near where Marshall's mills used to stand. The section here includes about 27 feet (8·2 m.) of the lower shales succeeded by about 22 feet (6·7 m.) of limestone and shale, all capped by about 4 feet (1·2 m.) of gravel. The best collecting is from the river up to the second firm bed, five feet (1·5 m.) above the *Leiorhynchus* shale (No. 2). Fossils of zones 1, 2, 3 and 4 are very plentiful in this locality. Besides the numerous species of corals, bryozoans and brachiopods, *Tornoceras uniangulare* (Conrad), *Bactrites obliqueseptatus arkonense* Whiteaves, *Pentremites*, etc., are likely to be found. Some of the rarer fossils to be obtained here are:—*Microcyclus discus* Meek and Worthen, *Cladopora* cf. *fischeri* (Billings), *Trachypora elegantula* (Billings), *Nucleocrinus elegans* (Conrad), *Camarotoechia thedfordensis* Whiteaves, *Cyrtina hamiltonensis* (Hall) and, *Phacops rana* (Green).

ANNOTATED GUIDE.—*Continued.*

Miles and Kilometres.

The country is very flat to the eastward of Thedford, with little of geological interest to be observed until the Thames river is crossed at St. Marys. Salt wells were formerly operated near Park Hill.

38·49 m. 61·9 km. **St. Marys**—Alt. 1,082 ft. (38·49 m.). Although no rock exposure is to be seen from the train,

Section of the Hamilton formation near Marshall's Mills, Aux Sables river, Ontario.

Miles and Kilometres.

the underlying Onondaga strata are comparatively near the surface and have been worked in several quarries, besides presenting natural exposures along the Thames river. The Onondaga strata at this point are less coralline, but richer in other forms than at Hagersville. Among the more common species are the following:—

Favosites hemispherica *E. and H.*
Streptelasma prolificum (*Billings*)
Atrypa reticularis (*Linnæus*)
Chonetes hemisphericus *Hall*
Leptæna rhomboidalis (*Wilckens*)
Martinia maia (*Billings*)
Meristella nasuta (*Conrad*)
Spirifer duodenarius (*Hall*)
Spirifer gregarius *Clapp*
Stropheodonta demissa (*Conrad*)
Stropheodonta inequistriata (*Conrad*)
Strophonella ampla *Hall*

Aviculopecten princeps (*Conrad*)
Concardium cuneus (*Conrad*)
Panenka grandis *Whiteaves*
Vanuxemia tomkinsi *Billings*
Paracyclas elliptica *Hall*
Platyceras ventricosum (*Conrad*)

Cyrtoceras sp.
Gomphoceras eximium *Hall*
Gyroceras cyclops *Hall*
Nautilus sp.
Orthoceras sp.
Macropetalichthys sullivanti *Newberry.*

48·5 m.
78 km.

Stratford—Alt. 1,188·8 ft. (48·51 m.). This city, which is an important railway and manufacturing centre, is situated nearly on the summit between Toronto and Sarnia. The drift at this point is heavy, reaching a thickness of 143 feet (43·6 m.). From Stratford to Guelph the country is rolling and of morainic character, with occasional gravel bars of post-glacial origin.

Miles and Kilometres.

88·3 m.
142·1 km.

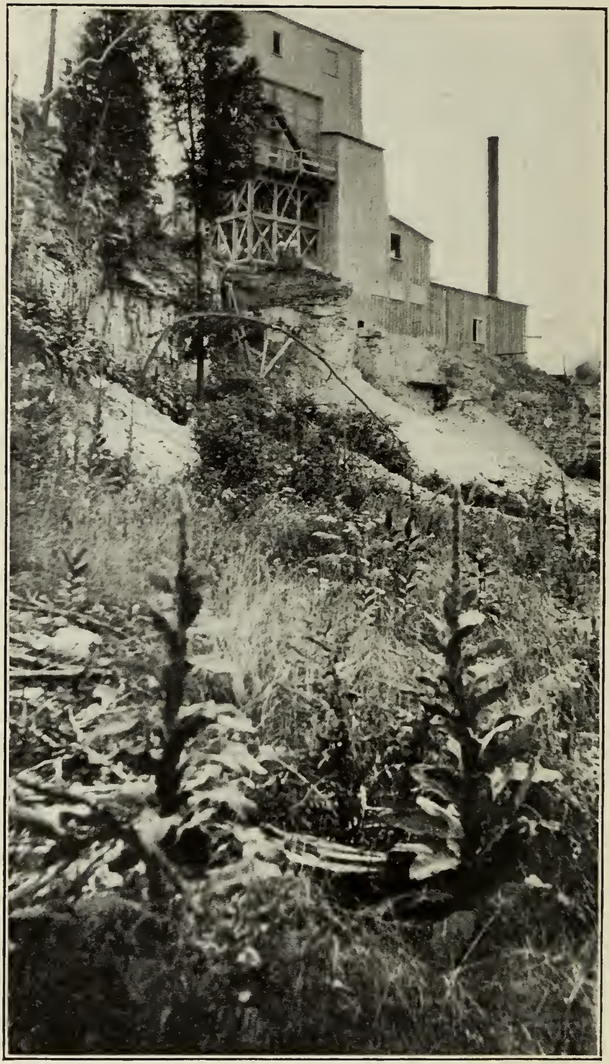
Guelph—Alt. 1,067 ft. (88·3 m.). The uppermost layers of the Niagara may be seen near Guelph, while the characteristic dolomites of the Guelph formation are exposed at several points between Guelph and Galt.

At Kennedy's quarry and limekiln (A) near Guelph, about 30 feet (9·1 m.) of typical Guelph dolomite is exposed in fairly heavy beds. Stromatoporoids and fragmentary corals are the common fossils, but the locality is not a good one for collecting. On the other hand, it presents an interesting dome-like structure in the strata.

At MacFarlane's tavern (B) 14 feet (4·2m.) of thin bedded bituminous limestone of the upper Niagara is exposed. The rock is hard and black, with galena, zinc blende and bitumen in vugs. The fossils consist chiefly of casts, which are difficult to identify. In the lower beds a small form resembling *Whitfieldella nitida* Hall is common. Five feet (1·5 m.) from the bottom is a six-inch zone containing numerous gastropods related to *Trochonema pauper* Hall, and *Straparollus hippolyta* Billings. Higher up are found *Favosites niagarensis* Hall, and a branching coral resembling *Cladopora multipora* Hall. On the same side of the road, farther east and at a slightly higher level, undoubted Guelph strata are seen, with *Halysites catenulatus* Linn, and *Pycnostylus guelphensis* Whiteaves.

Good exposures are presented in the scarped bank of the Eromosa river on the Prison farm (C, D, E). The section is interesting rather from a stratigraphic than from a palæontological viewpoint. In the building-stone quarry the following beds may be recognized in descending order:—

	Thickness. Feet.	Metres.
Guelph—		
Thin-bedded dolomites..........	6	1·8
Thick-bedded, compact dolomites suitable for building stone.....	7	2·1
Thin-bedded dolomites..........	6	1·8



Base of Niagara-Guelph transition beds. Prison Farm, Guelph, Ont.

Niagara-Guelph transition beds with typical Guelph strata at the top.
Prison Farm, Guelph, Ont.

	Thickness. Feet.	Metres.
Niagara—		
Dark, thin-bedded bituminous dolomites......................	6	1·8

The upper beds alone are fossiliferous, with a predominance of corals, *e.g. Favosites niagarensis* Hall, *Heliophyllum* sp., and *Halysites catenulatus* Linn. Indeterminable stromatoporoids are also present in some abundance. Of the Guelph gastropods, *Cœlocaulus bivittatus* Hall, is the most common; farther southward the underlying Niagara beds increase in relative thickness.

Robert Kennedy's quarry (F) situated on Waterloo avenue, shows a good exposure of about 25 feet (7·6 m.) of irregularly bedded, light coloured dolomite. The common fossils are:—

Favosites niagarensis *Hall*
Halysites compacta *Rominger*
Conchidium occidentale (*Hall*)
Trimerella grandis *Billings*.

The large quarry of the Standard White Lime Company is situated in more fossiliferous strata than the other excavations near Guelph. On entering at the southwest angle, many corals are seen in a distinct reef, including:—

Favosites niagarensis *Hall*
Pycnostylus guelphensis *Whiteaves*
Halsyites catenulatus *Linn*
Zaphrentis cf. racinensis *Whitfield*

Higher up and a little farther east, the above corals are to be seen associated with numerous stromatoporoids; the latter are nearly all indeterminable, but the following species are the more common:—

Stromatopora galtensis (*Dawson*)
Stromatoporella elora *Parks*
Clathrodictyon striatellum (*D'Orb*).

The remainder of the fauna consists largely of brachiopods and gastropods, with a small number of cephalopods. The more important

Geological Survey. Canada

Route map between Guelph and Galt

Miles
1 0 2 4 6

Kilometres
1 0 2 4 6 8

species are given in table No. 1 on page 118. At the north end of the quarry a few examples of *Megalomus* are found, but this characteristic genus is not prolific near Guelph.

The débris thrown from the shallow cuts along the Grand Trunk railway north of Hespeler affords one of the richest and most accessible collecting grounds in the district. The common species are given in column No. 2 of the table on page 118.

Excellent exposures occur on both sides of the river above and below Galt. A typical section is seen in the Dickson Park quarry, where *Megalomus canadensis* occurs in great abundance associated with the species given in the third column of the table.

The quarries of Christie and Henderson, beyond Galt, present a face of about 45 feet (13·7 m.) of both thin and thick-bedded stone characterized throughout by a wonderful profusion of *Megalomus canadensis*. The species given in the fourth column of the accompanying table are common in this quarry.

	1 Standard White Lime Company's Quarry, Guelph.	2 Grand Trunk Railway, cut north of Hespeler.	3 Dickson Park Quarry, Galt.	4 Christie and Henderson Quarry, Galt.
Stromatoporoids—				
Clathrodictyon striatellum (*D'Orb.*)	x			
Stromatopora galtensis (*Dawson*)	x			
Stromatoporella elora *Parks*	x			
Corals—				
Favosites niagarensis *Hall*	x	x		x
Favosites hisingeri *E and H.*		x		x
Halysites compacta *Rominger*		x		
Halysites catenulatus *Linn.*	x	x		
Pycnostylus elegans *Whiteaves*		x		
Pycnostylus guelphensis *Whiteaves*	x	x		
Zaphrentis racinensis *Whitfield*	x	?		
Brachiopods—				
Conchidium occidentale (*Hall*)		x	x	x
Monomerella ovata *Whiteaves*	x	x	?	
Monomerella ovata lata *Whiteaves*		x		
Orthis sp.		x		
Rhinobolus galtensis (*Billings*)	x	x		
Spirifer crispus (*Hisinger*)	x	x		
Strophomena sp.		x		

Trimerella acuminata *Billings*		x		
Trimerella grandis *Billings*	x	x		
Whitfieldella hyale (*Billings*)	x	x		x
Branching Bryozoa indet.		x		
Gastropods—				
Bellerophon shelbiensis *Clarke and Ruedemann*		x		
Cœlocaulus bivittatus (*Hall*)		x		x
Cœlacaulus estella (*Billings*)		x	x	x
Cœlacaulus longispira (*Hall*)	x			
Cœlocaulus macrospira (*Hall*)	x	x	x	x
Cœlocaulus turritiformis (*Hall*)			x	
Eotomaria durhamensis (*Whiteaves*)		x		
Eotomaria galtensis (*Billings*)			x	
Euomphalopterus elora (*Billings*)		x		
Euomphalopterus valeria (*Billings*)		x		x
Euomphalus circinatus *Whiteaves*			x	
Euomphalus cf. fairchildi *C. and R.*		x		
Euomphalus galtensis *Whiteaves*			x	
Holopea gracia *Billings*		x		
Holopea guelphensis *Billings*		x		
Holopea harmonia *Billings*		x		
Hormotoma whiteavesii *Clark and Ruedeman*			x	x
Loxoplocus solutus (*Whiteaves*)	x		x	x
Murchisonia billingsana *Miller*		x		
Pleurotomaria viola *Billings*		x		x
Poleumita cf. crenulata (*Whiteaves*)	x			
Poleumita sulcata (*Hall*)		x	x	x
Pycnomphalus salaroides (*Hall*)		x		
Straparollina daphne *Billings*		x		
Trematonotus alpheus *Hall*	x	x		
Turritoma boylei (*Nicholson*)				x

	1 Standard White Lime Company's Quarry, Guelph.	2 Grand Trunk Railway, cut north of Hespeler	3 Dickson Park Quarry, Galt.	4 Christie and Henderson Quarry, Galt.
Pelecypods—				
Megalomus canadensis (*Hall*	x		x	x
Mytilarca acutirostrum *Hall*		x		
Cephalopods—				
Cyrtoceras arcticameratum *Hall*				x
Cyrtoceras orodes *Billings*	x			x
Kionoceras darwini (*Billings*)	x			
Orthoceras cf. abnorme *Hall*	x			
Phragmoceras hector *Billings*	x	x		x
Trilobites—				
Calymmene niagarensis *Hall*		x		
Ceraurus niagarensis *Hall*		x		

Miles and Kilometres.

98·56 m. 135 km. **Rockwood**—Alt. 1,182 ft. (370 m.). Eastward from Guelph, the Niagara limestones are exposed at several places. To the west of Rockwood the strata are thin, but east of that place the heavier dolomites are exposed. Fossils are not well preserved in these rocks but the following species are comparatively common:—

Favosites gothlandica *Lamarck*
Halysites catenulatus *Linnæus*
Rhynchotreta cuneata americana *Hall*
Spirifer niagarensis (*Conrad*)
Trematospira camura (*Hall*)
Fenestella *sp.*
Bellerophon *sp.*
Pterinea *sp.*
Cyrtoceras *sp.*
Orthoceras *sp.*

109·63 m. 175·4 km. **Limehouse**—Alt. 1,002 ft. (304·6 m.). The upper shales of the Cataract formation are exposed in the railway cut at Limehouse: above these, the lower members of the Niagara may be seen. North of this place the basal sandstone of the Cataract is exposed over a considerable area and finally passes under the other members in the face of the cuesta.

107·8 m. 172·5 km. **Georgetown**—Alt. 846 ft. (257 m.). The red shales of the Richmond formation are exposed in the river valley at Georgetown. No further rock exposures are seen before crossing the Humber river where the Lorraine shales are exposed.

136·89 m. 219·2 km. **Toronto**—Alt. 254 ft. (77·2 m.). On approaching the city, the post-glacial sands may be seen between Lambton and Parkdale.

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EXCURSION B3.

THE PALÆOZOIC SECTION AT HAMILTON, ONTARIO.

BY

William A. Parks.

CONTENTS.

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INTRODUCTION.

The sharp escarpment (Niagara cuesta) which separates the upland of western Ontario from the lowland to the east extends from Queenston on the Niagara river to Hamilton at the head of Lake Ontario and thence northward into Bruce peninsula between Lake Huron and Georgian bay. As the difference in elevation between lowland and upland is about 350 feet (106 m.) excellent rock exposures are presented where the face of the escarpment is abrupt. The strata revealed in the southern part of the escarpment consist of the uppermost member of the Ordovician (Richmond) and the lower beds of the Silurian. Towards the north still lower Ordovician strata are exposed. The more favourable points for the study of sections are the following:—

Niagara gorge. (See Excursion B 1.)

Grimsby, half way between Niagara and Hamilton. (Present Excursion).

Hamilton, at the head of Lake Ontario. (Present Excursion).

Credit Forks, about 50 miles (80 km.)north of Toronto. (See Excursion B).

Collingwood, on Georgian bay. (See Excursion C 5).

A generalized section of the cuesta showing the actual strata is indicated in the central column of the accompanying table. The stratigraphic classification adopted in the latest publications of the State of New York is shown on the left. The right hand column presents a classification which has been recently proposed.

TABLE OF FORMATIONS.

Classification of New York State Geologists.				Strata exposed in Ontario.	Proposed Classification.		
Ontaric or Siluric	Niagaran	Lockport	Lockport	Dolomites and dolomitic cherts	Lockport	Niagara	Silurian
		Clinton	Rochester	Grey shales	Rochester		
			Clinton	Limestone and shales	Clinton	Clinton	
	Oswegan	Medina	Medina	Grey sandstones	Medina	Medina	Ordovician
			Medina	Red sandstones and shales	Medina		
			Medina	Shales and limestones	Cataract	Cataract	
			Whirlpool	Grey sandstones	Cataract		
			Queenston	Red shales	Queenston	Richmond	
	Oswego sandstone						

GENERAL DESCRIPTION OF FORMATIONS.

The Queenston formation consists essentially of red shales with an occasional green band. This formation is unfossiliferous in the Niagara and Hamilton sections, but in the Collingwood section, a distinct Richmond (Ordovician) fauna is revealed. It has therefore become necessary to separate the Queenston shale from the Medina formation in which it has been long included. The overlying grey sandstone (Whirlpool sandstone of Grabau) has hitherto been regarded as Medina, but it is now proposed to consider it as the basal member of a new formation-the Cataract—which represents an invasion from the north and west at the commencement of Silurian time. The upper limestones and shales of this formation are highly fossiliferous and present a fauna comparable with that of the Brassfield formation of Ohio and Kentucky.

In the Credit region, this basal sandstone has been confused with the upper or true Medina sandstone of the Niagara gorge; in consequence, the shales and limestones overlying it have been erroneously ascribed to the Clinton.

All the strata exposed in the Niagara gorge continue as far as Grimsby and even to Hamilton, but at the latter place, the Rochester shale, the Clinton and the Medina have become greatly reduced in thickness. At the Forks of the Credit, these formations have disappeared entirely and the Cataract formation has increased correspondingly. At Collingwood the Cataract formation is again decidedly thinner and presents a different petrographic aspect, consisting of limestone with some shale at the top.

The gradual decrease of thickness in the Rochester, Clinton and Medina strata, and the increase in the Cataract in passing northward is indicated in the following table:—

		Niagara.	Grimsby.	Stony Creek.	Hamilton.	Ancaster.	Credit Forks.	Collingwood.
Niagara.	Lockport dolomite, cherts, etc.	ft. 150	ft. 12	ft. 13	ft. 22	ft.	ft. 30	ft. 75
"	Rochester shale	68	45	25	15	12	00	00
Clinton.	Limestones and shales.	32	14	13	12	12	00	00
Medina.	Grey band sandstone.	7½	25 (both)	14	12	11	00	00
"	Red sandstones, etc.	50						
Cataract.	Shales and limestones.	26	74	79	80	??	95	55
"	Sandstone	25	6	6	10	??	16½	00

Richmond. Red shales of great thickness, extending far below the section, except at Collingwood.

Rochester shale and Lockport dolomite between the two falls on Forty Mile creek, Grimsby, Ontario.

DETAILED DESCRIPTION OF SECTIONS.

For a general description of the geology along the line of the railway between Toronto and Hamilton see the guide book for Excursion A 12.

From Hamilton to Grimsby, the railway traverses a fertile plain underlain by the red shales of the Queenston formation (Ordovician). This region forms part of a celebrated belt of fruit lands extending from the Niagara river to Hamilton.

Section at Grimsby.

The valley of Forty Mile creek at Grimsby presents one of the best sections to be seen along the face of the cuesta.

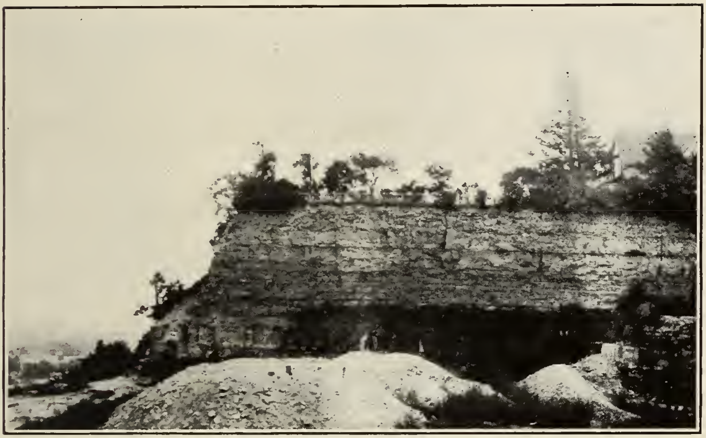
The following table indicates in descending order the thickness of the various layers:—

	Thickness.		Elevation.	
	Feet.	Metres.	Feet.	Metres.
1—Lockport dolomite.......	12	3·6	576	175
2—Rochester shale...........	45	13·7	564	171·4
3—Clinton thick bed.........	4	1·2	519	157·7
4—Clinton thin beds with	10	3·0	515	156·5
5—Pentamerus zone at the base				
6—Medina grey band........	5	1·5	505	153·5
7—Medina mottled sandstone and shale.................	20	6·0	500	152·0
8—Cataract shale and limestone....................	74	22·6	480	146·0
9—Basal Cataract sandstone..	6	1·8	406	123·4
10—Red Richmond shales....			400	121·6
Grimsby station...			287	87·2

1. Lockport Dolomite.— The Lockport dolomite, as exposed near the head of the ravine at Grimsby, consists of heavy-bedded stone; but on the sides of the ravine, nearer the face of the cuesta, a thin-bedded transition zone of about eight feet (2·4 m.) occurs between it and the Rochester shale. The dolomite is not highly fossiliferous at this point but it nevertheless yields some characteristic Niagara species. Brachiopods are by far the most abundant organisms: the following species may be obtained:—

Atrypa reticularis (*Linn.*)
Atrypa nodostriata *Hall*
Camarotoechia neglecta (*Hall*)

Leptaena rhomboidalis (*Wilckens*)
Rhynchotreta cuneata americana *Hall*
Spirifer crispus (*Hisinger*)
Spirifer niagarensis (*Conrad*)
Spirifer radiatus *Sowerby*
Trematospira camura (*Hall*)
Whitfieldella nitida *Hall*
Whitfieldella nitida oblata *Hall*



Brow of the Niagara cuesta, showing Lockport dolomite, Hamilton, Ontario.

2. Rochester Shale.—The lower and more shaly beds of the Rochester shale are rich in fossils among which brachiopods and, more particularly, bryozoans abound. These beds are also noted for rare cystids and crinoids, although with the exception of *Caryocrinus ornatus* and *Stephanocrinus angulatus*, these remarkable forms are but seldom encountered. The following list contains the more common species from these beds:—

Corals—
- Enterolasma caliculus (*Hall*)
- Favosites cf. parisiticus cf. niagarensis *Hall*

Hydrozoans—
- Dictyonema retiforme *Hall*

Crinoids—
- Eucalyptocrinus coelatus (*Hall*)
- Herpetocrinus brachiatus (*Hall*)

Crinoids—*Con.*

Herpetocrinus convolutus (*Hall*)
Homocrinus cylindricus *Hall*
Ichthyocrinus laevis *Conrad*
Lecanocrinus macropetalus *Hall*
Lyriocrinus dactylus (*Hall*)
Periechocrinus speciosus *Hall*
Stephanocrinus angulatus *Conrad*
Thysanocrinus liliiformis *Hall*

Cystids—

Apicoystites elegans *Hall*
Callocystites canadensis, *Billings*
Callocystites jewetti *Hall*
Caryocrinus ornatus *Say*
Gomphocystites tenax *Hall*
Holocystites globosus *Miller*

Asteroids—

Squamaster echinatus *Ringueberg*
Palæaster niagarensis *Hall*
Protaster stellifer *Ringueberg*

Brachiopods—

Atrypa reticularis (*Linn*)
Atrypa rugosa (*Hall.*)
Camarotoechia neglecta (*Hall*)
Camarotoechia obtusiplicata (*Hall*)
Dalmanella elegantula (*Dalman*)
Delthyris sulcata *Hisinger*
Homœospira apriniformis (*Hall*)
Leptæna rhomboidalis (*Wilckens*)
Lingula lamellata *Hall*
Orthis flabellites *Foerste*
Plectambonites transversalis (*Wahlenberg*)
Rhipidomella hybrida (*Sowerby*)
Rhynchonella robusta *Hall*
Schuchertella subplana (*Conrad*)
Spirifer niagarensis (*Conrad*)
Spirifer radiatus *Sowerby*
Whitfieldella nitida *Hall*
Whitfieldella nitida oblata *Hall*

Bryozoans—

Acanthoclema asperum (*Hall*)
Batostomella granulifera (*Hall*)
Bythopora spinulosa (*Hall*)
Callopora elegantula *Hall*

Bryozoans—*Con.*

Chilotrypa ostiolata (*Hall*)
Diamesopora dichotoma *Hall*
Diploclema sparsum (*Hall*)
Eridotrypa solida (*Hall*)
Eridotrypa striata (*Hall*)
Fenestella elegans *Hall*
Fistulipora crustula *Bassler*
Idiotrypa punctata (*Hall*)
Lioclema asperum (*Hall*)
Lioclema multiporum *Bassler*
Lioclemella maccombi *Bassler*
Loculipora ulrichi *Bassler.*
Monotrypa benjamini *Bassler*
Nematopora minuta (*Hall*)
Nicholsonella florida (*Hall*)
Pachydictya crassa (*Hall*)
Phylloporina asperato-striata (*Hall*)
Polypora incepta (*Hall*)
Rhopalonaria attenuata *Ulrich and Bassler*
Semicoscinium tenuiceps (*Hall*)
Stictotrypa punctipora (*Hall*)
Thamniscus dichotomus (*Hall*)
Trematopora spiculata (*Hall*)
Trematopora tuberculosa *Hall*

Vermes—

Cornulites arcuatus *Conrad*

Pelecypods—

Liopteria subplana (*Hall*)
Pterinea emacerata (*Conrad*)
Pterinea undata (*Emmons*)

Gastropods—

Diaphorostoma niagarensis (*Hall*)
Platyceras niagarensis *Hall*

Pteropods—

Conularia longa *Hall*
Conularia niagarensis *Hall*

Trilobites—

Calymmene niagarensis *Hall*
Ceraurus niagarensis *Hall*
Dalmanites limulurus (*Green*)
Homalonotus dephinocephalus (*Green*)
Illaenus ioxus *Hall*
Lichas boltoni (*Bigsby*)

3, 4 and 5. Clinton Formation.—The recognition of the Rochester shale as a stratigraphic unit compels the adoption of another name for the strata between the shale and the underlying Medina sandstone. These strata are the equivalent of those in the Niagara section referred to the Clinton, and the fossils show that they are closely related in time to the Rochester. The *Pentamerus* bed at the base of the formation contains the same form of *P. oblongus* seen in the Clinton of Rochester, New York. Few fossils are to be obtained except at the top, in the heavy 4-foot bed (1·2 m.), and at the base, in the *Pentamerus* zone. The species are nearly all brachiopods as below:—

Atrypa reticularis (Linn)
Camarotoechia neglecta (*Hall*)
Leptæna rhomboidalis (*Wilckens*)
Orthis flabellites *Foerste*
Pentamerus oblongus *Sowerby*
Spirifer radiatus *Sowerby*
Stricklandinia canadensis *Billings*
Whitfieldella cf. cylindrica *Hall*
Whitfieldella intermedia *Hall*
Whitfieldella nitida *Hall*
Whitfieldella nitida oblata *Hall*
Dawsonoceras annulatum americanum (*Foord*)
Platyceras sp.

6 and 7. Medina formation.—The Upper Medina may be best seen on the west side of the ravine of Forty Mile creek. The grey band lies almost immediately below the *Pentamerus* zone and presents excellent examples of *Daedalus* (*Arthrophycus*) *archimedes* Ringueberg. Splendid examples of *Arthrophycus alleghaniensis* Harlan, may be obtained on the under side of the sandstone slabs. The typical Medina fossil, *Lingula cuneata* Conrad, occurs in the lower part of the formation.

8, 9 and 10. Cataract formation.—The Cataract formation was first officially defined by Professor Charles Schuchert of Yale University at the 1912 meeting of the Geological Society of America. The reading of Professor Schuchert's paper evoked considerable discussion. Dr. E. O. Ulrich being strongly of the opinion that the formation should be included in the Medina or at least in the "*Medinian.*" It is to be understood therefore that all American geologists are not prepared to accept the classification herein adopted.

Cataract shales and limestones are not well exposed on the west side of the ravine of Forty Mile creek, but in the cliff on the east side the contacts may be observed. Owing to a heavy talus, this location is not as good a collecting ground as at Stony Creek, between Grimsby and Hamilton, or at Hamilton itself. The more common species are given below; for a more complete list see the guide to Excursion B 4.

Corals—
- Favosites cf. niagarensisa (*Hall*)
- Zaphrentis bilateralis (*Hall*)

Hydrozoans—
- Clathrodictyon vesiculosum *Nicholson and Murie*
- Retiolites venosus *Hall*

Brachiopods—
- Anoplotheca planoconvexa (*Hall*)
- Atrypa reticularis (*Linn*)
- Atrypa cf. rugosa *Hall*
- Camarotœchia neglecta (*Hall*)
- Dalmanella elegantula (*Dalman*)
- Hebertella fausta *Foerste*
- Leptæna rhomboidalis (*Wilckens*)
- Lingula lingulata *Hall and Clarke*
- Lingula cf. clintoni *Vanuxem*
- Lingula oblata *Hall*
- Lingula oblonga *Hall*
- Orthis flabellites *Foerste*
- Platystrophia biforata (*Schlotheim*)
- Plectambonites transversalis (*Wahlenberg*)
- Rhipidomella cf. circulus (*Hall*)
- Rhipidomella hybrida (*Sowerby*)
- Schuchertella sp.
- Whitfieldella sp.

Bryozoans—
- Clathropora frondosa *Hall*
- Helopora fragilis *Hall*
- Phænopora constellata *Hall*
- Phænopora ensiformis *Hall*
- Phænopora explanata *Hall*
- Rhinopora verrucosa *Hall*

Vermes—
 Cornulites distans *Hall*
Pelecypods—
 Posidonomya cf. alata (*Hall*)
 Tellinomya sp.
Gastropods—
 Bucania trilobita (*Conrad*)
 Cyclonema sp.
 Platyostoma sp.
Trilobites—
 Acidaspis sp.
 Encrinurus sp.

Section at Hamilton.

The electric railway between Grimsby and Hamilton runs close along the foot of the escarpment thus affording interesting glimpses of the cuesta to the left and the fruit lands to the right. At Stony creek an excellent section is presented, at which Cataract fossils may be obtained in abundance. The section at Hamilton is best seen by ascending the escarpment at the "Jolly Cut." This section is similar to that at Grimsby, but the various formations appear in different thicknesses, the Rochester and Clinton being greatly reduced.

		Thickness		Elevation	
		Ft.	Met.	Ft.	Met.
Lockport	1—Chert beds	12	3·6	650	197·6
	2—Chert with shaly partings	3	0·9	....	......
	3—Crystalline grey dolomite with green shaly partings.	2·5	0·5	....	......
	4—Heavy dark dolomite with black shaly partings	4·5	1·3	....	......
Rochester	5—Limestone and shales	4·5	1·3	....	......
	6—Ferruginous band } 7—Shale and limestone }	10	3·0	....	......
Clinton	8—Heavy dolomite	4	1·2	....	....
	Thin limestones	4	2·1	....	......
	9—Pentamerus band	2·5	0·7	....	......
Medina	10—Grey sandstone and shale	12	3·6	600	182·4
Cataract	11—Red and grey shales	70	21·3	....	......
	12—Blue limestone	10	3·6	....	......
	13—Grey sandstone	10	3·6	....	......
Queenston	14—Red shales	.....	.....	498	151·4
	Railway station, Hamilton	.....	.....	253	76·9

1, 2, 3 and 4. Lockport dolomite and chert.—While certain differences in the fossil content of these beds are to be observed, the general fauna is much the same throughout. Numerous Lithistid sponges occur in the chert beds, of which the more common are:

Actylospongia præmorsa *Goldfuss.*
Aulocopina granti *Billings.*

Dendroid Graptolites are very characteristic and numerous: Bassler recognizes 11 genera and 52 species. Common species are: —

Acanthograptus granti *Spencer*
Calyptograptus cyathiformis *Spencer*
Dictyonema crassibasale *Gurley*
Dictyonema retiforme *Hall*
Inocaulus plumosus *Hall*

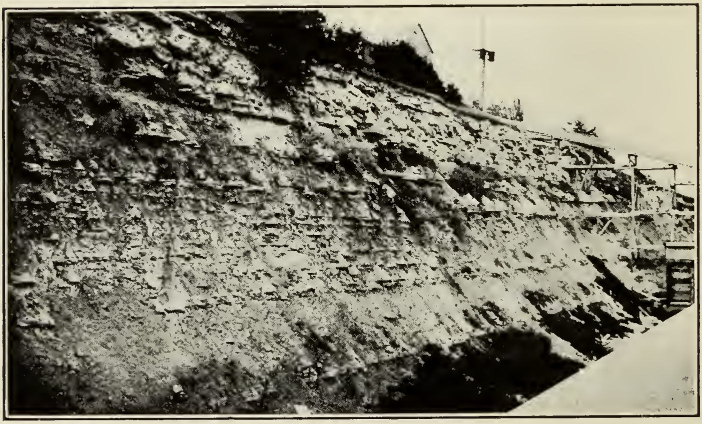
Brachiopods are abundant and are represented by the following species:—

Atrypa reticularis (*Linn.*)
Camarotœchia neglecta (*Hall*)
Crania siluriana *Hall.*
Dalmanella elegantula (*Dalman*)
Delthyris sulcata (*Hisinger*)
Ditcyonella corallifera *Hall*
Dictyonella reticulata *Hall*
Leptæna rhomboidalis (*Wilckens*)
Lingulops granti *Hall and Clarke*
Pholidops squamiformis *Hall*
Plectambonites transversalis (*Wahlenberg*)
Rhipidomelia hybrida (*Sowerby*)
Schizotreta tenuilamellata (*Hall*)
Schuchertella subplana (*Conrad*)
Spirifer niagarensis (*Conrad*)
Stropheodonta profunda *Hall*
Strophonella patenta (*Hall*)
Strophonella cf. striata *Hall*

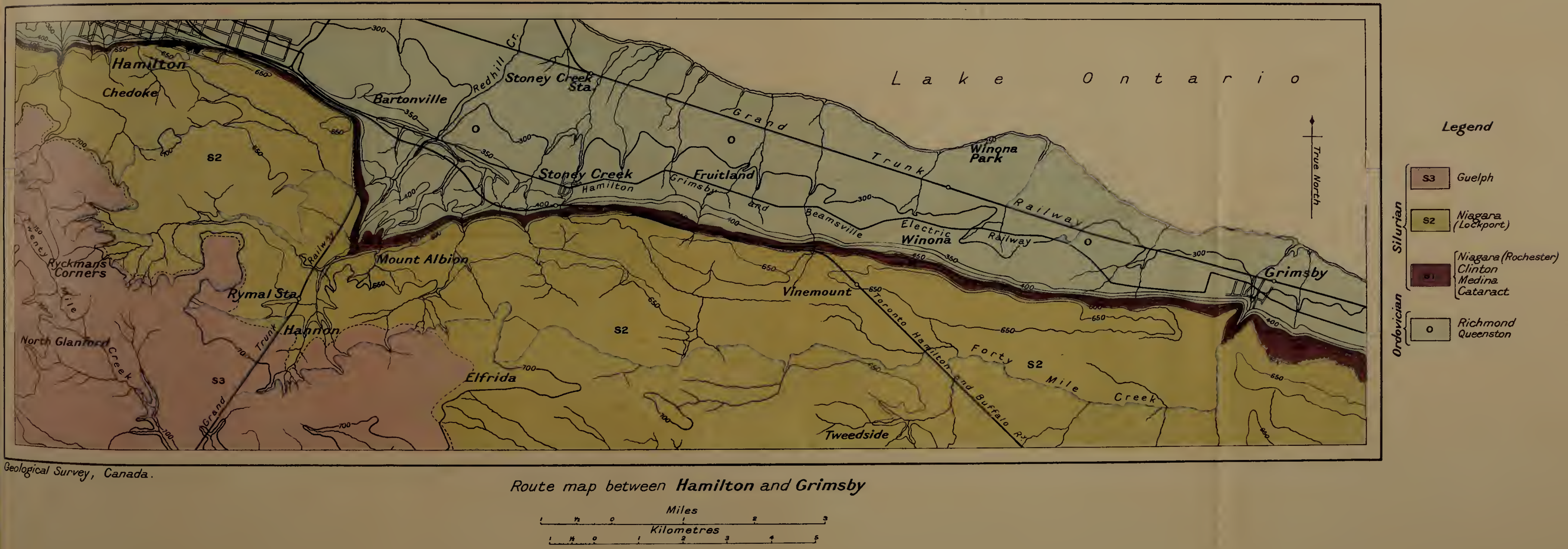
The Bryozoa in these beds are not well preserved and are difficult of recognition. The common species follow:—

Ceramopora imbricata *Hall*
Ceramoporella irregularis (*Whitfield*)
Drymotrypa diffusa (*Hall*)
Fenestella elegans *Hall*
Semicoscinium tenuiceps (*Hall*)

Medina sandstone with "pillow structure" lying unconformably on Cataract shales, Jolly Cut, Hamilton, Ontario.



Section of upper Cataract shales with overlying Medina sandstone, Jolly Cut, Hamilton, Ontario.



Geological Survey, Canada.

Route map between **Hamilton** and **Grimsby**

Miles

Kilometres

Orthoceras bartonense Spencer, is fairly common and numerous tails of *Dalmanites limulurus* (Green) occur. Species of *Conularia* are not infrequent.

5, 6 and 7.—These beds probably represent the Rochester shales but they are not typical either in petrographic character or fossil content. The characteristic Rochester echinoderms have not been found here but *Rhynchotreta cuneata americana* and some of the Bryozoa and Graptolites of the Rochester occur.

8 and 9.—These beds, which represent the Clinton formation, do not differ essentially from those at Grimsby.

10.—The Medina sandstone is less well defined in this section than at Grimsby, but it shows some interesting bedding features.

11, 12 and 13.—The Cataract limestone and shales may be seen in the excavations along the Jolly Cut road, but a better locality for collecting is presented by the quarries farther east. The fossils are the same as those already given for Grimsby.

14.—The Queenston shales are not well exposed along the Jolly Cut road but they may be seen farther west and at numerous places along the line of the railwa y

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GUIDE BOOK No. 5

EXCURSIONS

IN THE

Western Peninsula of Ontario and Manitoulin Island

(EXCURSIONS B 4, B 7, B 9 AND C 5.)

ISSUED BY THE GEOLOGICAL SURVEY

OTTAWA
Government Printing Bureau
1913

35066—1

Gift of

Mary J. Lanier

GUIDE BOOK No. 5.

Excursions in the Western Peninsula of Ontario and Manitoulin Island.

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EXCURSION B 4.

SILURIAN SECTION AT THE FORKS OF CREDIT RIVER, ONTARIO.

BY

William A. Parks.

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INTRODUCTION.

The remarks contained in the introduction to the guide book for Excursion B3 are equally applicable to the section at Credit Forks. In fact the sections at Hamilton and at the Forks of the Credit are both essential to an understanding of the formations exposed along the face of the Niagara cuesta. For the correlation of these sections and for the necessary general information the reader is referred to the guide book for Excursion B3.

ANNOTATED GUIDE.

IROQUOIS BEACH.

Miles and Kilometres.

0. m. 0. km. **Toronto** Alt. 254 ft. 77.2 m.

On leaving the city, the railway traverses a flat area covered with post-glacial sands showing evidence of wind action. At Lambton, the shore of the post-glacial Lake Iroquois is visible to the north, where excavations have been made in the characteristic gravel bars of the ancient beach.

6.7 m. 10.7 km. **Lambton** Alt. 399 ft. 121.3 m.

On crossing the Humber river, good exposures of the Lorraine shales may be seen in the scarped banks of the stream. The Humbervale quarry near here has yielded many excellent examples of the large trilobite *Isotelus maximus*, Locke. Further exposures of the Lorraine shales occur in the valley of Mimico river a short distance beyond the Humber.

14.4 m. 23 km. **Cooksville** Alt. 391 ft. 118.8 m.

At this point the railway approaches so close to the Iroquois beach that exposures of the gravel bars may be seen from the train. Just beyond Cooksville, the beach is ascended and a more rolling aspect is presented by the surface of the country owing to less modification of the glacial accumulations by post-glacial agencies.

Geological Survey, Canada

Route map between **Streetsville** and **Credit Forks**

Miles
1 0 2 4 6
Kilometres
1 0 2 4 6 8

Lorraine and Richmond Formations at Streetsville.

Miles and Kilometres.

20.8 m. 33.3 km. **Streetsville** Alt. 500 ft. 152 m.

In the valley of the Credit river at Streetsville, Lorraine shales are overlain by fossiliferous strata of the Richmond formation. To the west of Streetsville this marine type of Richmond, in its turn, is covered by the red unfossiliferous shales of the Queenston member of

Niagara cuesta at the Forks of the Credit.

the Richmond. While this member is entirely without organic remains in the southern part of the province, it reveals a distinct Richmond fauna at points farther north. Beyond Streetsville the ascent is gradual but continuous. Little of interest is to be observed until

Miles and Kilometres.

the vicinity of Cheltenham is reached when the Niagara cuesta comes into view.

41.3 m. 66 km. **Inglewood** Alt. 896 ft. 272.4 m.

At Inglewood the red Richmond shales are exposed in undulating hills which are surmounted by the sharp escarpment of the Niagara cuesta, topped by the heavy beds of the Lockport dolomite.

45.5 m. 72.8 km. **Forks of Credit** Alt. 1,076 ft. 328 m.

On crossing the high bridge over the Belfontain or west branch of the Credit river, a fine view may be obtained of the face of the cuesta and of the valley of the west branch.

48.2 m. 77.1 km. **Cataract** Alt. 1,313 ft. 399 m.

The sections at Cataract and at Credit Forks are indicated below:

	Cataract		Credit Forks.	
	Feet.	Metres.	Feet.	Metres.
1. Lockport dolomite....	30–35	9–10	100	30
Talus (covered)..................			20–30	6–9
2. Cataract shales with green band at top...	65–70	20–22	35–45	11–14
3. Cataract limestones....	25	7.6	23	7
4. Cataract sandstones...	16.5	5	18	5.5
5. Red Queenston shales.	30+	9+	175	53.2

Cataract Section.

1. A short distance south of Cataract Junction and a few feet above the line of railway to Elora there may be seen an excellent example of post-glacial conglomerate marking the position of a lake beach or river bank. Near this point also Lockport dolomite may be seen resting upon the upper green shale of the Cataract; in this locality only has the actual contact between the two formations been observed in the Credit region.

2. Cataract shales are well exposed on the embankment between the main line of the railway and the branch

The "Cataract" falls over Cataract limestone and sandstone near Cataract Junction, Ontario.

to Elora. The upper part shows a bright red layer, rich in *Helopora fragilis*, beneath which lie grey shales with an increasing number of thin calcareous bands towards the bottom. The fossils of the shale are essentially the same as those in the underlying limestones, but differences in relative abundance are quite marked in the case of certain species.

3. The limestone portion of the formation is well shown along the disused road from Cataract Junction to Credit Forks. This member consists mostly of thin-bedded limestones, but it also contains many bands of interbedded shale. A narrow but persistent layer of shale, about 15 feet (4·5 m.) above the base of the formation, contains a characteristic species of *Whitfieldella*. Most of the fossils of the formation are common to both the shale and the limestone, but there is a difference in the abundance of some species, for example, *Helopora fragilis* is much more common in the shale. The following species occur most frequently:—

Hydrozoa—
- Clathrodictyon vesiculosum *Nicholson*.

Corals—
- Favosites niagarensis *Hall*.
- Zaphrentis bilateralis *Hall*.

Bryozoa—
- Callopora magnopora *Foerste*.
- Helopora fragilis *Hall*.
- Homotrypa confluens *Foerste*.
- Pachydictya crassa (*Hall*).
- Phænopora explanata *Hall*.
- Phænopora ensiformis *Hall*.
- Phænopora punctata *Nichalson and Hinde*.
- Phylloporina angulata *Hall*.
- Rhinopora verrucosa *Hall*.

Brachiopoda—
- Anoplotheca planoconvexa (*Hall*).
- Atrypa cf. marginalis (*Dalman*).
- Atrypa reticularis (*Linnæus*), (rare and doubtful).
- Atrypa *sp. nov.* (numerous and typical).
- Camarotoechia neglecta (*Hall*).
- Dalmanella elegantula (*Dalman*).
- Hebertella fausta *Foerste*.

Lower Cataract limestone with Whitfieldella zone indicated, near Cataract Junction, Ontario.

Leptæna rhomboidalis (*Wilckens*).
Orthis flabellites *Foerste*.
Orthis cf. davidsoni *de Verneuil*
Platystrophia biforata (*Schlotheim*).
Rhipidomella hybrida (*Sowerby*).
Rhipidomella cf. circulus (*Hall*).
Schuchertella cf. subplana (*Conrad*).
Whitfieldella sp.

Trilobita—
Acidaspis sp.
Calymmene niagarensis *Hall*.
Encrinurus cf. punctatus *Wahlenberg*.
Encrinurus sp.

In addition to the above there is a considerable number of forms of doubtful determination, including several gastropods related to *Eotomaria*, *Loxonema*, *Trochonema* and *Platyostoma*, also a large species of *Orthoceras*.

4. The basal sandstone of the Cataract formation may be seen beneath the limestones a short distance along the road. A few fossils may be observed on the surface of some of the sandstone slabs, but they are all of very doubtful determination. Gastropods and pelecypods are by far the most abundant.

5. The underlying red shales o the Richmond, destitute of fossils, may be observed in the bed of the creek.

Credit Forks Section.

The line of old quarries which extends along the nor h side of the ravine of the Belfontain branch affords an excellent opportunity for collecting Cataract fossils. It is interesting to note that the narrow *Whitfieldella* zone referred to in the section at Cataract may also be recognized here.

The basal Cataract sandstone, at this point, was quarried in large quantities formerly, but the increasing overburden has compelled the cessation of operations. A large proportion of both the grey and he brown sandstone used for building purposes in Toronto has been obtained from these quarries.

In the angle between the Belfontain branch and the main river, the escarpment is higher and presents a more complete section, including the Lockport dolomite. This locality is less favourable for collecting than those already referred to, but it is instructive in that it proves the complete absence of both the Rochester shale and the Clinton beds which are exposed on the face of the cuesta at Grimsby and which also occur in the Niagara gorge.

The Lockport dolomite furnishes but few fossils, among which may be mentioned obscure lithistid sponges and indeterminable stromatoporoids. Besides these, the following corals may be obtained:

Alveolites *sp.*
Favosites niagarensis *Hall.*
Halysites catenulatus *Linnæus.*
Syr:ngopora cf. tenella *Rominger.*

The ascent to he top of the cliff is somewhat difficult, but the view well repays the effort.

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EXCURSION B 7.

ORDOVICIAN SECTION ON CREDIT RIVER NEAR STREETSVILLE, ONTARIO.

BY

W. A. PARKS.

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INTRODUCTION.

The upper Ordovician strata of North America occur in formations of so variable a character in different localities that their exact correlation is a matter of difficulty. The practice is now becoming general to embrace the whole series in the term Cincinnatian and to recognize the following formations:

Richmond,
Lorraine,
Eden,
Utica,
Collingwood.

The Richmond is a widespread and highly fossiliferous formation, which has been divided into several members in the Cincinnati area. The Lorraine formation is less well defined, particularly in the Streetsville section, but it seems advisable to retain the name rather than to add to the large number of local formational names.

The Richmond, as exposed in Ontario, consists of a series of marine limestones and shales, and a great thickness of red shales with some green bands and an occasional bed of limestone. The marine type is best exposed in the Manitoulin islands, whence it may be traced with gradually diminishing thickness to the vicinity of Streetsville. The red Richmond shales (Queenston formation) are of great thickness at Niagara and Grimsby, where they are unfossiliferous and rest directly on the Lorraine. Northward the formation diminishes in thickness, overlies the mari[illegible] type and carries fossils characteristic of the Richmor[illegible] a[illegible] Collingwood on Georgian bay.

ANNOTATED GUIDE.

Miles and Kilometres.	
0 m. 0 km.	**Toronto.**—Alt. 254 ft. (77.4 m.)
21.7 m. 34.7 km.	**Streetsville Junction.**—Alt. 549 ft. (107 m. A general account o[illegible] the country along the line of the rai way between Toronto and Streetsville is given in he guide to Excursion B4.

RICHMOND AND LORRAINE FORMATIONS.

The Cincinnatian strata exposed in the vicinity of Streetsville consist of the upper red unfossiliferous shales of the Queenston division of the Richmond, the grey shales and limestones with intercalated coral reefs of the marine Richmond, and the lower arenaceous limestones and shales of the Lorraine formation.

In the valley of the Credit river above the railway bridge, the sha'es and limestones of the marine R'chmond yield an abundant fauna. The lower part of the river valley shows the underlying Lorraine shales and arenaceous limestones of increasing thickness as the river is descended.

Anticline in Richmond strata, Streetsville, Ontario.

Richmond Formation.

The red Richmond shales (Queenston) are not exposed in the valley, but they may be seen in the vicinity. The different beds of the marine Richmond and the Lorraine are not very persistent; in consequence, it is somewhat difficult to correlate the strata of different exposures. The most continuous layer is a heavy bed of limestone with numerous bryozoa which lies near the base of the Richmond.

A cliff of about 25 feet (7·6 m.) of limestone and shale is presented by the scarped bank of the river near the bridge to the northward of Streetsville Junction. The lower portion only is actually exposed and shows the heavy bryozoan layer of about two feet in thickness. Beneath this are thin-bedded limestones and shales, which may belong to the Richmond or to the underlying Lorraine. This is one of the best localities for collecting the typical stromatoporoids and corals:

Stromatocerium huronense *Billings.*
Columnaria alveolata *Goldfuss.*
Columnaria calicina (*Nicholson*).
Streptelasma rusticum (*Billings*).
Tetradium minus *Safford.*

Just below this point an interesting minor anticline is shown: the heavy bryozoan layer forms the surface rock, but it is covered by three feet of boulder clay containing pebbles and also corals and stromatoporoids of the local formation. The northeast side shows glacial grooving and polishing, but the southwest side is much less affected by the passage of the glacier.

The upper limestones, shales and coral reefs are excellently exposed at several points on the west side of the river above the bridge. Besides the stromatoporoids and corals an abundant fauna is presented, of which the following are the more common species:—

Callopora *sp.*
Prasopora *cf.* hospital s (*Nicholson*).
Rhombotrypa quadrata (*Rominger*).

Catazyga headi (*Billings*).
Hebertella occidentalis (*Hall*).
Platystrophia biforata (*Schlotheim*).
Platystrophia laticosta (*Meek*).
Platystrophia clarksvillensis *Foerste.*

Rafinesquina *cf.* alternata (*Emmons*).
Strophomena planumbona *Hall*, S. rugosa *Blainville.*
Zygospira modesta *Hall.*

Cyclonema bilix *Conrad.*
Lophosira bowdeni (*Safford*).
Lophospira *sp. nov.*
Oxydiscus *sp.*
Schizolopha tropidophora (*Meek*).
Schizolopha moorei *Ulrich.*

Byssonychia grandis *Ulrich.*
Byssonychia radiata (*Hall*).
Byssonychia richmondensis *Ulrich.*
Cymatonota typicalis *Ulrich.*
Modiolopsis concentrica *Hall and Whitfield.*
Modiolopsis cf. versaillensis *Miller.*
Opisthoptera casei (*Meek and Worthen*).
Pterinea demissa (*Conrad*).

Lorraine Formation.

Below the point first described the slant of the river bed causes an increasing thickness of the underlying Lorraine to be revealed. Excellent exposures are presented near the bridge on the road between Streetsville and Streetsville Junction, and also immediately above the railway bridge. The section at the former point is as follows:—

Richmond—

1. Corralline limestones and shales.....	18 ft.	5·4m.
2. Grey, thin-bedded limestone and shale	.3 ft.	·9 m.
3. Compact bryozoan limestone........	1·6 ft.	·35 m.

Lorraine—

4. Grey shale and thin-bedded limestone	3 ft.	·9 m.
5. Sandstone.........................	4 in.	10 cm.

Nos. 1 and 3 contain the typical gastropod, brachiopod and pelecypod fauna.

No. 2 is characterized by the presence of *Byssonychia richmondensis*, Ulrich.

No. 4 contains scarcely any organic remains.

No. 5 is not richly fossiliferous, but it presents examples of *Rafinesquina alternata* (Emmons), *Opisthoptera* sp. and *Modiolopsis concentrica*, Hall and Whitfield.

Near the railway bridge the cliff presents a face of about 31 feet (9·4 m.). The lower 17 feet (5·2 m.) consist of sandstones and shales with obscure and fragmentary fossils: these beds, in whole or in part, are to be referred

Lorraine sandstone and shales, Credit river near Streetsville, Ontario.

to the Lorraine. The upper 14 feet (4·2 m.) consist of limestone and shale with brachiopods and bryozoa typical of the Richmond. The coral and stromatoporoid zone does not appear at this point, nor is it encountered farther down the river.

On the east side of the stream, about a half-mile below the railway bridge, a cliff of 25 feet (7·6 m.) in height presents exposures of Lorraine limestones, shales and sandstones. Some interesting features of cross bedding and "pillow structure" in sandstone, with contemporaneous erosion of the underlying beds, are to be seen at different horizons in the exposures.

"Pillow" sandstone with contemporaneous erosion in Lorraine beds, Streetsville, Ontario.

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See also the literature cited for the Manitoulin islands, Excursion C-5.

EXCURSION B 9.

ALGONQUIN BEACH, GLACIAL PHENOMENA AND LOWVILLE (ORDOVICIAN) LIMESTONE IN LAKE SIMCOE DISTRICT, ONTARIO.

BY

W. A. JOHNSTON.

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INTRODUCTION.

The excursion will proceed by Grand Trunk Railway from Toronto to the town of Orillia, which is situated near the narrows between Lakes Couchiching and Simcoe and distant from Toronto in a northerly direction about 85 miles (136.8 km.).

En route, after reaching the Lake Simcoe basin, the Algonquin beach may be seen from the train at several points along the railway. After a closer inspection of the beach at the town of Orillia, a trip will be made by motor to the Longford quarries on Lake St. John about 8 miles (12.9 km.) in a northeasterly direction from Orillia, where a good section may be seen of the Lowville (Birdseye) limestone with basal series of shales, sandstone, etc., resting unconformably on the Pre-Cambrian crystalline rocks. Returning from Longford along the Monck road about 7 miles (11.3 km.) from Orillia, a section may be seen shewing a glacially transported, large boulder or mass of bedded Lowville limestone underlain by till.

The Algonquin beach is well developed in the Lake Simcoe district, where it forms a record of the abandoned shoreline of the immense body of water which occupied the Huron and Michigan basins at the close of Glacial time. In this district, as well as in the northern portions of the Huron and Michigan basins, the beach has an upward tilt towards the northeast. Around the southern ends of Lakes Huron and Michigan, the beach becomes horizontal at an altitude of about 600 feet (182.9 m.) and maintains that height over a considerable area [**1**]. Hence it is supposed that the water of Lake Algonquin stood at this altitude viz. 600 feet (182.9 m.) above sea level.

The lowest point reached by the beach in the Lake Simcoe district is in the valley of Holland river about 15 miles (24.1 km.), south of the extreme head of Lake Simcoe, where the beach has an altitude of 724 feet (220.6 m.), or only 6 feet above Lake Simcoe. It gradually rises to a point about 6 miles (9.6 km.) northwest of Orillia where it has an altitude of 883 feet (269.2 m.), the highest altitude attained by the beach on the west side of Lake Simcoe basin.

About 20 miles (32.2 km.) east of Orillia, near the village of Kirkfield, where for a time the waters of Lake Algonquin discharged eastward into the valley now occu-

Boulder-strewn terrace and bluff of Algonquin beach near Shanty Bay, Ontario.

pied by the Trent chain of lakes and rivers, the beach has an altitude of 883 feet (269.2 m.) and 15 miles (24.2 km.) farther north rises to 925 feet (282.0 m.). Northward from the latter point, on account of the rough and comparatively little drift-covered surface of the country, the beach is difficult to follow and although a strong beach, supposed to represent the Algonquin, has been found at a number of points as far northward as the town of North Bay, sufficient data have not been collected to enable definite correlations to be made.

The maximum tilt rate of the beach in the Lake Simcoe district is in a direction N. 21° E., and the rate increases from 2.3 feet (.7 m.) per mile in the southern portion to nearly 6 feet (1.8 m.) in the northern portion. Lakes Simcoe and Couchiching, and a number of smaller lakes to the east, occupy shallow basins which rarely exceed 100 feet (30.5 m.) in depth, and evidently owe their present existence as lakes to the upward tilting of the land towards the north. Were the land depressed to the relative altitude which it had when the Algonquin beach was made the present outlet of Lake Couchiching, for example, would be about 175 feet (53.3 m.) lower.

North and east of Lake Simcoe, the drift is relatively thin, but in the district to the west and southwest of the lake the drift becomes much thicker, and no exposures of solid rocks are known to occur. Well borings made in this district show the drift deposits to have a thickness of at least 375 feet (114.3 m.), and as the drift hills rise to an altitude of 200 to 300 feet (61 to 91 m.) above the valleys in which the borings were made it is possible that the drift has in places a much greater thickness.

Numerous sections in the drift show two till sheets separated by stratified sands and gravels. The uppermost or last till sheet consists of two distinct portions, an upper part, often with a well bedded character and composed of a loose sandy till, and a lower portion consisting of a more compact, sandy clay till with little or no trace of stratification. Associated with the former and generally crowning the summits of hills and ridges are well stratified deposits of sands and gravels, which often bear a semblance to beach ridges. Their mode of origin is not clear, but they do not appear to be referable to wave built features.

Over a considerable part of the district the till of the lower portion of the last till sheet merely forms a thin veneer which conforms to the contour of the underlying stratified sands, gravels and clays. These interglacial or interstadial beds are of considerable thickness, and appear to have suffered erosion for a long period of time prior to the deposition of the last till sheet, during which time broad valleys were carved in the earlier deposits.

The till of the lower till sheet is generally only exposed in the beds of streams, where it is seen to be composed of hard, compact, sandy clay till, without stratification, containing numerous well polished and striated cobbles and boulders. This till withstands erosion remarkably well, and where trenched by streams is sometimes seen to stand up in vertical sections or to form rock-like ledges which cause rapids.

Well borings in the district show the presence of a still lower till sheet, but this till is not known to be exposed in any sections.

Extensive deposits of stratified sands, gravels and lake clays also occur in the district below the level of the Algonquin beach.

So far as known, no fossils have been obtained in this district from the sands and gravels of the Algonquin beach or from the interglacial beds. Fresh water shells are, however, abundant in the sands and clays of the valley of Nottawasaga river, but at no great height above Georgian bay.

On the northeastern side of Lake Simcoe an area of drumlins of the long narrow type is well developed. The drumlins are generally composed of a sandy unstratified till or boulder clay which appears to be almost entirely derived from the last till sheet. The longer axes of the drumlins coincide with the direction of glaciation as shown by striae on adjacent rock surfaces. The general direction of glaciation throughout the district is towards the south-west, and, as a rule, wherever the surface of the rock has been protected from weathering, striae are abundant and well preserved.

Over a considerable portion of the district around the west and south sides of Lake Simcoe, imperfect drumlin forms are developed, and in fact the greater part of the region appears to have been subjected to some degree of ice moulding beneath the overriding ice of the last sheet. Accordingly terminal moraines or ice marginal deposits are rarely well seen in the district. Some parts of the area, notably the relatively high upland tract lying to the south of the town of Barrie, are gently undulating, nearly flat, till plains characterized by numerous small depressions. The most notable exception to the prevailing "d umlinized" and till plain surface is the range of hills which lies about midway between the towns of Barrie and Orillia and from 7 to 10 miles (11 to 16 km.) west of the 'ake. These hills, the highest of which rises to an altitude of nearly 600 feet (182.9 m.) above Lake Simcoe, are composed, in greater part, of a loose sandy till partially stratified. They are, in part morainic in character and appear to have been formed during the retreat of the last ice sheet.

The greater portion of the area of Lake Simcoe district is underlain by limestones of the Trenton, Black River and Lowville formations (Ordovician), the last of which rests unconformably on Pre-Cambrian crystalline :ocks. The limestones dip gently towards the southwest at a rate generally not exceeding 25 feet (7.6 m.) per mile, and have an estimated maximum thickness in the district of 550 feet (167.7 m.). Eastward from the lake, the limestones are often well exposed and form a rock divide between the waters of Lake Simco and Trent valley.

The northern portion of the district, including the area surrounding the lower end of Lake Couchiching, is occupied by Pre-Cambrian rocks. Near the contact of the limestones with the Pre-Cambrian rocks, an escarpment is generally developed, and fronting the escarpment, and often at a considerable distance from it, are numerous outliers of limestone, showing that the limestone, at one time, extended far over the Pre-Cambrian rocks to the north.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m. 0 km. — **Toronto,** (Union Station). Alt. 254.0 feet (77.4 m.).

14.0 m. 22.5 km. — **Thornhill.**—Alt. 635 feet (193.5 m.).

Leaving Toronto the railway passes northward over a series of drift hills and ridges locally known as Oak Ridges which are, in part, morainic in character, and extend for

Miles and Kilometres.

over 100 miles (161 km.) in a general east and west direction, roughly parallel to Lake Ontario and a few miles north of the lake. The drift in the hills, which rise to an altitude of 600 to 900 feet (182.9 m. to 274.3 m.) above Lake Ontario, is known to be of considerable thickness. At Thornhill, 14 miles (22.5 km.) north of Toronto, a well boring penetrated 640 feet (195.1 m.) of drift before reaching the Trenton limestone which was the first solid rock formation encountered. The boring continued through 585 feet (178.3 m.) of the Tıenton, Black River and Lowville formations to the Pre-Cambrian.

27.2 m. **Chesley.** Alt. 980 feet (298.7 m.). One
43.8 km. mile south of Chesley station, the summit on the line of railway is passed at an altitude of 1,002 feet (305.4 m.). Going northward, the railway rapidly descends in o a broad valley which extends, nearly at the level of Lake Simcoe (low water 718 feet, 218.9 m.), for some 20 miles (32.2 km.) southward from the head of the lake. This valley was occupied by a deep embayment of Lake Algonquin, the shoreline of which is well marked on both sides of the valley. Near the village of Sch mberg, at a point about 15 miles (24.1 km.) south of the extreme head of the lake, the Algonquin beach has an altitude of 724 feet (220.7 m.), only 6 feet (1.8 m.) above the level of Lake Simcoe.

41.2 m. **Bradford.** Alt. 724 feet (220.7 m.) At
66.3 km. the town of Bradford, a well boring penetrated 330 feet (100.6 m.) of drift deposits before reaching the Trenton limestone. The terrace and bluff of the Algonquin beach near the station, has an altitude of 749.0 feet (228.3 m.). At Lefroy 10 miles (16.1 km.) further north, the beach which may be seen on the west side of the railway near the station, rises to 774 feet (235.9 m.).

64.0 m. **Barrie.** Alt. 726 feet (221.3 m.). The
103.0 km. town of Barrie is situated at the head of Kempenfeldt bay, an arm of Lake Simcoe.

Miles and Kilometres.

A broad flat-bottomed valley extends westward for a number of miles from the head of the bay, and is floored by a considerable thickness of sands and gravels derived from the Algonquin beach, which has an altitude, at the town of Barrie, of 785 feet (239.6 m.). The sides of the valley are composed of drift, and rise steeply to an altitude of over 200 feet (60.9 m.) above the valley bottom. The record of a well boring, made near the town of Barrie, shows the surface deposits to have a thickness of 335 feet (102.1 m.) below the level of Lake Simcoe at which point the Trenton limestone was struck. The boring continued through 200 feet (60.9 m.) of the limestones of the Trenton, Black River and Lowville formations to the Pre-Cambrian. The deep borings mentioned above as having been made in the drift deposits at Thornhill, Bradford and Barrie, together with several others made in the district, confirm the existence of a deeply drift-filled pre-glacial valley connecting the basins occupied by Georgian bay and Lake Ontario, the probable existence of which was pointed out by J. W. Spencer. [**4.**]

Between the towns of Barrie and Orillia, a distance of about 25 miles (40.3 km.), the Algonquin beach is well developed and can be followed with nearly perfect continuity all the way. Throughout the greater part of the distance, the railway follows along almost at the same altitude as the bea h. At Hawkestone, about 14 mlies (22.5 km.) north of Barrie, the bluff and boulder-strewn terrace of the ancient shoreline may be seen a short distance west of the station at an altitude of 821 feet (250.2 m.).

86.0 m. 138.5 km. **Orillia.** Alt. 724 feet (320.7 m.).

GEOLOGY OF THE DISTRICT AROUND ORILLIA.

General.

The town of Orillia is situated near the narrows between Lakes Couchiching and Simcoe, and is built in part on a sandy terrace just below the Algonquin beach. In the town, along the Coldwater road, which is the main road leading westward, the cut bluff and boulder pavement of the beach may be well seen. A mile west of the town, a gravel pit shows a section across a great barrier beach having an altitude of 853 feet (260·0 m.) or 135 feet (41·2 m.) above Lake Simcoe.

North and east of Orillia the drift is relatively thin, but west and southwest it becomes quite thick. A well boring made in the town itself shows the surface deposits to have a thickness of 170 feet (51·8 m.). A half-mile north of the station at Orillia, a cutting on the Canadian Pacific railway shows well stratified sand overlain by till, and a half-mile east of the station a cutting affords a section through a drumlin-like ridge composed of boulder clay. Northeast and east of Orillia an area of small drumlins and drumlin-like ridges is developed. The drumlins are generally long and narrow, and range in height from a maximum of 60 feet (18·2 m.) down to 10 feet (3 m.) or even less, and vary in length from two miles to one quarter mile or less. The longer axes of the drumlins are nearly parallel and coincide with the direction of glaciation, which was towards the southwest. The drumlins are generally composed of sandy boulder clay, showing little or no stratification. Occasionally they are seen to be, in part, composed of coarse sand and gravel partially stratified, with numerous boulders and cobble stones. At the north end of one of these drumlins one mile (1·6 km.) east of North Mara post office, along Monck road, a section shows a large boulder or mass of bedded Lowville limestone, which is underlain by drift and was evidently glacially transported or shoved so that it now rests at a steep angle on the northern slope of the drumlin. The section is exposed by the face of the limestone having been opened up as a quarry.

No exposures of solid rocks are known to occur in the immediate vicinity of the town of Orillia, but a short

Section showing glacially transported mass of bedded Lowville limestone underlain by till. The base of the shovel marks the contact.

distance to the north and northeast the limestones of the Black River and Lowville formations, which underlie the Trenton limestone and rest unconformably on the Pre-Cambrian rocks, are well exposed and overlap the Pre-Cambrian. The northern end of Lake Couchiching is occupied by the Pre-Cambrian rocks, and near the contact an escarpment is generally developed in the limestone, which affords numerous sections.

Section of the Lowville Formation.

At the Longford quarries on the west side of Lake St. John, about 8 miles (12·9 km.) northeast of Orillia, a good section is exposed of Lowville (Birdseye) limestone with basal series of shales and sandstone or arkose. The eastern and northern sides of the lake are occupied by Pre-Cambrian rocks, but along the western side a limestone escarpment is developed, in the face of which a number of quarries have been opened. The beds dip slightly towards the southwest, and at the north end of the lake overlap the crystalline rocks. Near the contact the beds have a steep dip and appear to be faulted.

The general section of the Lowville formation is as follows:—

1. **Basal series of sandstones, shales, etc.**—The base of the series consists of a few feet of coarse, calcareous sandstone or arkose, which rest unconformably on the Pre-Cambrian crystalline rocks. These beds pass upward into red and green shales with intercalated lenses or thin beds of sandstone, and occasionally thin beds of fine-grained, dove-coloured limestone. The thickness of the series varies, and the beds are frequently absent on the sides and tops of ridges or domes of the crystalline rocks, where the limestones are seen to rest directly on the old floor. The sandstone and shales are best developed in basins between ridges of the crystalline rocks, where they occasionally have a maximum thickness of about 40 feet (12 m.). They are local in character and derivation, and evidently represent the old soil covering of the Pre-Cambrian rocks somewhat sorted, rearranged and recemented, and it seems probable that they represent the initial near-shore deposit of the next succeeding formation.

2. **Lower Lowville (Beatricea beds).**—The red and green shales pass upward into impure magnesian limestones, which on fresh fracture are greenish-grey in colour and weather yellowish brown. They are characterized by numbers of drusy cavities, occasional quartz grains and crystals of pyrite or limonite, and are generally barren of fossils. They are only a few feet in thickness and are followed by 6 to 10 feet (1.8 to 3 m) of fossiliferous blue-grey to dove-coloured limestone characterized by an abundance of a species of Beatricea. These beds somewhat resemble in physical character the typical fine-grained "Birdseye" limestone, but are less compact in texture and weather to a shaly mass. These beds contain a considerable fauna, among which may be mentioned: *Rafinesquina minnesotensis*, *Zygospira recurvirostris*, *Cyrtodonta huronensis*, *Lophospira bicincta*, *Isotelus gigas and Tetradium halysitoides.* They are overlain by 7 to 10 feet (2·1 to 3 m.) of unfossiliferous magnesian limestone very similar to the beds which immediately underlie them,

3. **Upper Lowville (Birdseye) limestone.**—The Beatricea beds are overlain by about 20 feet (6 m.) of fine-grained, even-bedded, dove-coloured limestone, characterized by such fossils as *Phytopsis tubulosum*, *Bathyurus extans*, *Leperditia fabulites*, and in the upper portion by a great abundance of *Tetradium cellulosum.*

The Lowville limestone, which is sometimes included in the Black River as a sub-formation, is well developed in south central Ontario, and is remarkable for its constant lithological and faunal character not only throughout this district, but as far as Kentucky, Tennessee and Alabama on the south.

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EXCURSION C 5.

GEOLOGY OF SELECTED AREAS ON LAKES ERIE AND HURON IN THE PROVINCE OF ONTARIO.

BY

William A. Parks.

With Sections by C. R. Stauffer, A. F. Foerste, M. Y. Williams and T. L. Walker.

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INTRODUCTION.

Physical Features.

The portion of Southern Ontario which lies west of a line from Georgian bay to Toronto is known as the Western Peninsula. The whole of this region is embraced in the coastal plain of Palæozoic age which was laid down on the western flank of the continental Pre-Cambrian protaxis. The area is divided into two physiographic units by a more or less abrupt escarpment (Niagara cuesta), which extends from Queenston on the Niagara river to Hamilton at the head of Lake Ontario and thence into the Bruce peninsula between Lake Huron and Georgian bay. East of this escarpment lies the Palæozoic lowland of Eastern Ontario which therefore extends only a short distance into the Western Peninsula and appears as a narrow belt along its eastern side. The western and much greater portion of the peninsula constitutes an upland with an average elevation above the eastern lowland of about 300 feet (91.2 metres).

The southern part of the western upland is remarkably flat as shown by the following elevations along the lines of the chief railways:

—	Elevation at Niagara Falls.		Elevation at Summit.		Elevation at Windsor.	
	Feet.	Met.	Feet.	Met.	Feet.	Met.
Michigan Central Ry.—Niagara Falls to Windsor, 225·75 miles.... (361·2 km.)	585	177·8	815	247·8	580	176·3
Grand Trunk Railway—Niagara Falls to Windsor, 229·35 miles.... (366·9 km.)	573	174·2	1007	306·1	579·4	176·1

A little farther to the north, the maximum elevation on the line of the Grand Trunk railway from Toronto to

Sarnia is 1,248 feet (379.4 m.), while in the county of Grey near Collingwood a maximum elevation of 1,706 feet (518.6 m.) is reached in the Blue mountains.

A heavy mantle of drift covers almost the whole of the area and, in places, attains a remarkable thickness. Post-glacial accumulations in the form of stratified sands and clays are widely distributed and the strand lines of post-glacial lakes are marked by beaches of gravel and sand. These glacial and post-glacial soils are of great fertility and, aided by the southerly latitude, render the Western Peninsula of Ontario one of the finest agricultural sections of Canada.

Glacial striæ with a general southwest trend are to be seen wherever the rock is sufficiently hard to retain them and the exposure to the weather has not been too long.

The rock basin of Lake Ontario, at its deepest point, is 738 feet (224.4 m.) beneath the surface of the lake, and Lake Huron reaches a maximum depth of 750 feet (228.0 m.). On the other hand, Lake Erie is nowhere more than 210 feet (64.0 m.) deep, and its average depth is very much less. The deepest part of Lake Ontario is off its southern shore: this lineal depression is thought to represent the bed of a great pre-glacial river which entered the basin of Lake Ontario from the west and drained a wide area in that direction. The waters of the Lake Huron basin are believed to have entered the Ontario valley by a great river whose course was down the western side of Georgian bay, across the Province of Ontario to a point a little east of Toronto and thence southward to a junction with the river in the Ontario basin. It would appear, therefore, that in pre-glacial times, Lake Erie did not exist and that Lakes Huron and Ontario were either absent or of much restricted area.

The enormous accumulations of drift which choked the above mentioned pre-glacial valleys are responsible, with some later modifications, for the present distribution of land and water in this area. Significant of the recent origin of the present system of drainage, is the fact that the water of streams rising 25 miles (40.0 km.) north of Toronto follows a circuitous path of 700 miles (1126·5 km.) in order to gain access to Lake Ontario. The thousands of islands along the eastern side of Georgian bay likewise attest the recent invasion of the waters of Lake Huron into the Pre-Cambrian oldland of Central Ontario.

Grand Manitoulin island and a number of smaller islands in the northern part of Lake Huron are formed of the same series of Ordovician and Silurian rocks that appear in the Western Peninsula. These islands must therefore be included in a general sketch of the Palæozic formations of the region.

The Palæozoic—Pre-Cambrian contact extends across the Province of Ontario from near Kingston to the head of Georgian bay. Northward from this point it is hidden under the waters of Lake Huron except for its occasional appearance on some of the islands along the east side of Georgian bay and on the islands between Manitoulin and the north shore of Lake Huron.

Geology.

The formations exposed in this district are indicated in the following table:—

Devonian....	Genessee (Chemung.) Hamilton. Onondaga. Oriskany.
Silurian.....	Monroe. Salina. Guelph. Niagara. Clinton. Medina. Cataract.
Ordovician..	Richmond. Lorraine Eden. Utica. Collingwood. Trenton. Black River. Lowville.

The brow of the Niagara cuesta is marked throughout its whole extent by a heavy bedded dolomitic limestone— he Lockport dolomite. The more or less precipitous face of the escarpment affords many excellent exposures of the formations beneath; in the Niagara gorge the section extends down to the Richmond, and in Manitoulin island to the Collingwood. The lower Ordovician formations are best seen on the small islands north of Manitoulin. The western peninsula affords numerous exposures of the upper Silurian formations and the different members of the Devonian series, but none of these are to be seen in the Manitoulin islands.

The following list indicates briefly the points at which the various formations may be most conveniently studied:

Chemung	Kettle point.
Hamilton	Thedford.
Onondaga	Port Colborne, Pelee island.
Monroe	Amherstburg.
Niagara	Niagara, Manitowaning, Collingwood.
Medina and Clinton	Niagara.
Cataract	Manitoulin island, Collingwood, Niagara.
Lorraine and Richmond	Clay cliff, Manitoulin island. Near Collingwood.
Collingwood and Utica	Craigleith.
Trenton	Shore near Collingwood.
Lowville, Black River and Trenton	Islands north of Manitoulin.

The relationship of the Cataract, Medina and Clinton formations may be studied to better advantage at Hamilton and at the forks of the Credit. (See Excursions B 3 and B 4). An opportunity to examine the Guelph exposures is presented by Excursion A12.

The crystalline Pre-Cambrian rocks of the continental protaxis occupy the whole of the eastern shore of Georgian bay and extend along the north shore of Lake Huron. The subdivisions of the Pre-Cambrian recognized within the area covered by the excursion are, in descending order, as below:—

Huronian.
Laurentian.
Grenville.

Exposures of the Huronian are to be seen along the north shore and on numerous islands westward from the vicinity of Killarney. Bell has mapped the rocks of this age in two series—a lower series, "*sericite, chlorite, hornblende, and arkose-schists, clay slates, greywackes, quartzites bands and dolomites*", and an upper series consisting of *quartzites.*

The quartzites form prominent ridges with a general east and west direction which constitute a striking physiographic feature of this part of the north shore. Near Killarney an altitude of 1385 feet (421 m.) is attained and even greater heights are reached a short distance inland. Both series of the Huronian are invaded by numerous masses of diabase, diorite and granite which afford interesting contact phenomena.

The gneisses and gneissoid granites of the Laurentian form most of the shore of Georgian bay from Killarney to the Palæozoic contact at its southern end. The continuity of this series is interrupted, however, near Parry Sound by a band of Grenville rocks with which some interesting eruptives are asssociated.

ANNOTATED GUIDE.

Lake Ontario—Alt. 244·99 ft.; 74·37 m. Lake Ontario is 193 miles (310·8 km.) long, 53 miles (85·3 km.) wide and 7,450 square miles (19,310 sq. km.) in area. The mean elevation is 244·99 feet (74·37 m.) and the maximum depth 738 feet (224·9 km.). The north shore of the lake, in the vicinity of Toronto, consists largely of sand, but bold cliffs of glacial material face the lake to the eastward of the city at Scarborough Heights, where one of the finest glacial sections in the world is presented. (See Guide Book to Excursion B-2). Toronto island has been formed by debris swept westward from these heights by a current which sets along the north shore.

To the west of the city a few exposures of Lorraine shales occur at the water level. The red shales of the

Richmond formation underlie the sands and gravels around the western end of the lake and continue to the Niagara river and beyond into the State of New York. Exposures are not to be observed at the water level, but numerous outcrops occur a short distance inland.

A few miles inland from the south shore of the lake the Niagara cuesta rises to a height of about 350 feet (106·7 m.) above the water. The strip of land between the cuesta and the lake, extending from the Niagara river to Hamilton is the finest fruit-growing district in Canada. Grapes and peaches of excellent quality are produced in abundance, as well as many other kinds of fruit. Sixty-six varieties of grapes are raised in the district.

Port Dalhousie—Alt. 250 ft.; 76 m. Port Dalhousie was an important ship-building centre before the advent of railways in Ontario. At the present time it is best known as the northern portal of the Welland Canal, which connects Lakes Erie and Ontario. Two canals have been constructed along this route by the Canadian Government. The first canal, commonly referred to as the "old canal," has a depth of 10 feet 3 inches (3·07 m.); it was begun in 1824 and completed in 1833. Construction work on the new canal began in 1872 and was completed in 1887. The total length is 26·75 miles (43 km.), and the total rise, or lockage, is 326·75 feet (99·6 m.). There are 26 locks, each of which is 270 feet (82·3 m.) long, 45 feet (13·7 m.) wide and 14 feet (4·2 m.) deep.

St. Catharines—Alt. 346 ft.; 105·18 m. Leaving Port Dalhousie, the electric railway crosses the fruit lands to St. Catharines. The ascent is gradual over post-glacial accumulations, which may be seen to the west of the harbour at Port Dalhousie. About half-way, the line of the old canal is crossed.

St. Catharines is noted for its paper and rubber manufactories, but more particularly as the centre of the fruit industry. A saline spring at St. Catharines contains per gallon of water the following solids:

$NaCl$	2200·9370 grains
$CaCl_2$	1104·4100
$MgCl_2$	284·6508

KCl	19·6833 grains
$CaSO_4$	138·5538
$FeCO_3$	3·6470
KI	·0980
$MgBr_2$	·0496

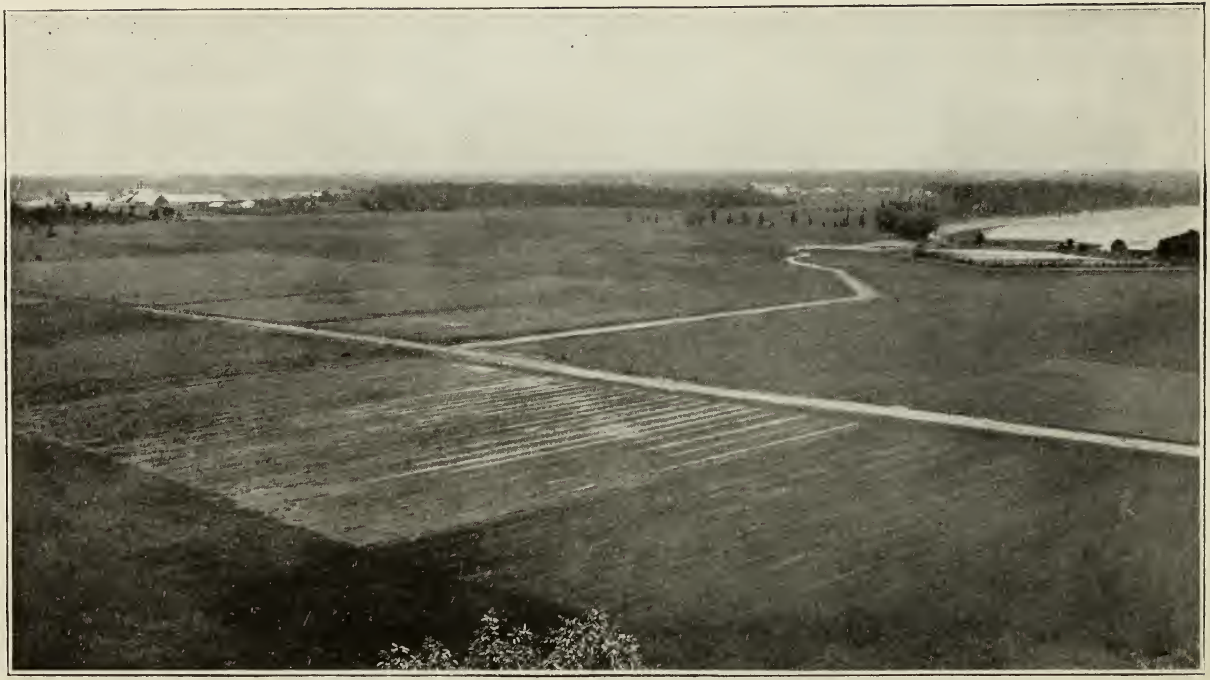
Leaving St. Catharines, the railway begins the ascent of the Niagara cuesta. No exposures of the Richmond or of the overlying Cataract sandstone, shale and limestone are to be seen, but at Merritton (Alt. 411 feet, 125·2 m.) the white and red mottled sandstone and shale of the Medina formation crops out on the west side of the track.

Thorold—Alt. 595 ft.; 180·8 m. On approaching Thorold, the old canal may be seen to the west and the new canal to the east. The dolomitic limestone of the Niagara (Lockport) formation is exposed above the new canal and may be seen in the distance. From this point a large amount of excellent building stone has been quarried. The metallurgical works of the Coniagas Reduction Company in which a large amount of Cobalt ore is treated are situated near Thorold.

Niagara Falls—Alt. 557 ft.; 169·3 m. Between Thorold and Niarara Falls, the railway continues on the upland and, in places, is close enough to the brow to afford an outlook over the lowland to the north. The Pleistocene deposits are of post-glacial character, and the district is better adapted to general agriculture than to fruit raising. A full account of the geology of Niagara Falls and the surrounding country is given in the guide to Excursions A4 and B1; to these the reader is referred.

From Thorold to Port Colborne 18·8 miles (29·1 km.) the country is flat or slightly sloping to Lake Erie. About 15 miles (24·1 km.) from Thorold a peat bog covering six or seven square miles is crossed. Beyond this is an exposure of unfossilife ous shaly limestone, which probably belongs to the Salina formation at the top of the Silurian. The Oriskany sandstone at the base of the Devonian is not exposed, but the Onondaga limestone is represented near Humberstone and continues to the shore of Lake Erie.

Port Colborne—Alt. 583 ft., 177·74 m.



View from the top of Sugar loaf showing lack of relief about Port Colborne.

GEOLOGY OF THE REGION AROUND PORT COLBORNE.

BY

Clinton R. Stauffer.

General Description.

The region about Port Colborne is a nearly level till plain, which was modified by the marginal lakes of the retreating continental glacier. Much of the land to north and west is covered by a great peat bog, which has been utilized to a limited extent in the manufacture of briquettes for fuel. The higher land usually means bed-rock close to the top of the ground, and it is not uncommon to see its smoothed and striated surface in the gutters along the highways and railroad tracks.

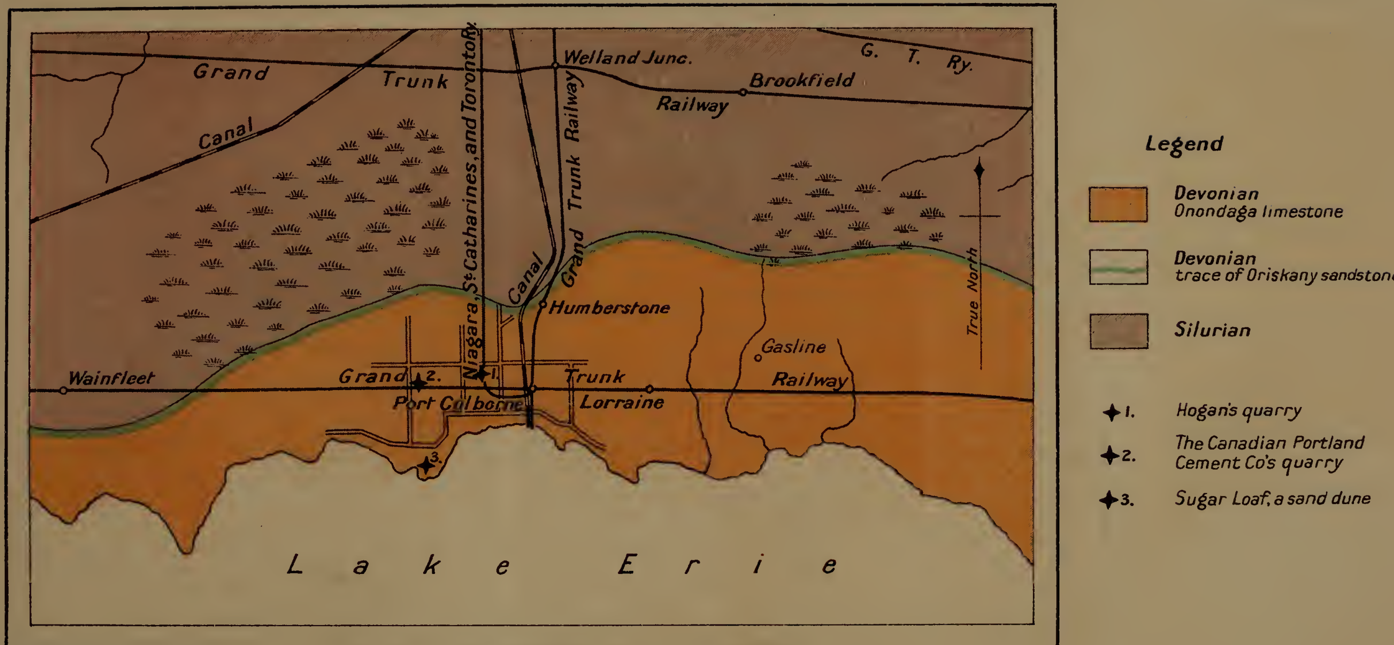
The Lake Erie beach, in the vicinity of Port Colborne, is chiefly sand, and the mounds adjacent to it are of the same material, which the wind has heaped into dunes. In most cases the dunes have been rendered stationary by the growth of vegetation, but to the west of the town some of them are in a semi-active state of migration. The points of land (see the accompanying map) projecting into the lake, however, are almost invariably outcrops of Onondaga limestone (Devonian). This rock rarely rises more than a foot or two above the water level, but forms an effective barrier against wave erosion, which elsewhere has been so destructive.

Port Colborne lies within the Ontario gas belt, and several of the wells may be seen in and about the town. The gas is obtained from a stratum of white sandstone within the Medina (Silurian), which is here about 450 feet (137·2) m.) below the surface. The Medina, which is chiefly red shales and sandstones, was seen outcropping along the Niagara gorge, especially at the Whirlpool Rapids and northward. It also outcrops along the escarpment westward to Hamilton.

The general dip of the bed rock of this region is to the south, but it is usually too variable in amount to

Sugar loaf, a stationary sand dune just west of Port Colburne.

A 12 and C5



Geological Survey, Canada

Port Colborne

Miles
1 0 2 4 6
Kilometres
1 0 2 4 6 8

Here and there fairly well developed anticlines lines appear, while at other places the rock seems arly flat.

e southern part of the Port Colborne region is in by the Onondaga limestone, while the Cobleskill (Silurian) and the Salina beds (Silurian) occur ately under the surface deposits to the north. latter form but meagre outcrops although they are hed by the drill in boring for gas. [6] Great heaps of e Silurian rocks, removed during the construction of he Welland canal, may be seen to the northward from the village of Humberstone. These formations include dolomitic beds and shales of varying thicknesses.

The Onondaga was formerly called the Corniferous limestone [5] because of the abundance of chert which it contains. While chert is a striking characteristic of this formation in Ontario near the eastern end of Lake Erie, it is rare or absent in the same beds which outcrop along the Detroit river and on the islands to the south. It is a most variable formation in its physical appearance. At the Port Colborne locality its upper portion is a dark bluish to brownish black limestone containing a great quantity of dark coloured chert. Just below this, and sometimes separated by a very sharp line, is a highly calcareous, semi-crystalline limestone filled with corals. This rock grades into beds of less purity, as the lower portion of the formation is approached, while the basal part is a conglomerate [9] (shown only in the bottom of the Welland canal) of Silurian pebbles mingled with sand and calcareous mud. The Onondaga limestone is abundantly fossiliferous. Many of the fossils are silicified and stand out in relief with most of the structures preserved as the limestone weathers away under the thin coating of drift. Corals are most plentiful and these are often so numerous as to form true reefs. These coral beds may be traced westward from Fort Erie to Villa Nova—a distance of over 45 miles (72·44 km.) Many of the types described by E. Billings and James Hall, were obtained in the vicinity of Port Colborne.

SECTIONS OF THE ONONDAGA.

The Hogan Quarry. This quarry now abandoned but under the control of the Canadian Portland Cement

Company, is located in the northwestern part of Port Colborne to the west of the interurban track (Port Colborne division of the Niagara, St. Catharines and Toronto Railway) at the crossing of the Grand Trunk switch. Very little quarrying has been done, but quite a large surface has been stripped and this furnishes an ample opportunity for collecting. In general the rock is too hard for successful collecting from the unweathered portions. Corals and stromatoporoids are especially abundant and may be seen studding the exposed surface, while several species of gastropods and a half dozen brachiopods are not uncommon.

Section of the Hogan Quarry.

	Thickness. feet.	metres.
6. Soil and drift	1	·305
5. Hard bluish limestone with rough black chert. Where weathered the chert stands out in relief. These beds are quite fossiliferous and afford good collecting. The top surface is well glaciated at the west end of the quarry.	1·5	·458
4. Dark bluish limestone containing an abundance of silicified compound corals which afford good collecting in the central portion of the quarry	1·5	·458
3. Blue limestone with very little chert. The lower half is filled with corals chiefly of the small branching type. Among these *Cladopora labiosa* (Billings) is abundant. In the cracks and crevices of the eastern portion of the quarry some small but very good specimens may be found	3	·915
2. Blue limestone with some black chert and often with shaly bedding planes. Sometimes the bedding planes are very rough and uneven, chiefly because of the presence of large corals. Crinoid stems of large size are conspicuous but the heads are rare. These beds are shown chiefly in the water hole	5·83	1·78

	Thickness. feet.	metres.
1. Rather compact blue limestone, with little or no chert, and fossils less abundant. This portion extends to the water level in the lowest hole.....	5	1·52

The fossils found in this quarry are given in the first column on page 53.

The Canadian Portland Cement Company's Quarry. One mile westward from the last place discussed, on the Grand Trunk railroad, is one of the Canadian Portland Cement Company's plants. In the manufacture of their product they use the Onondaga limestone and a post-glacial clay, both obtained nearby. This cement plant has a capacity of 3,500 barrels per day—over one and a quarter million barrels annually. The quarry is located a short distance to the west of the buildings, on a small low anticline, the axis of which runs a little to the north of east. In the quarry proper the beds dip off rather sharply to the north-northwest bringing in the higher beds in that portion of the pit. The best collecting is in the weathered portion of these upper beds, although much depends on the most recent stripping. The more massive beds of the interior and eastern side of the quarry, however, are not lacking in interest, for it is in them that the great masses of coral may be found. The surface of the extreme eastern side is well glaciated.

Section of the Canadian Portland Cement Company's Quarry.

	Thickness. feet.	metres.
6. Soil and drift............................	3	·915
5. Dark bluish limestone containing much black chert. Weathered surfaces rough and uneven. These layers are sometimes separated from the underlying beds by several inches of shale..	4·5	1·372
4. Somewhat massive, sub-crystalline, blue limestone with a small amount of chert, and corals rather abundant....	3·5	1·067

	Thickness. feet.	metres.
3. An impure blue limestone with little or no chert and a great many corals scattered through it. Bedding planes rough and irregular, often shaly and containing much carbonaceous matter.	2·6	·714
2. A rather massive, sub-crystalline, bluish gray limestone with partings of a greenish shale. This shale is found chiefly in the middle and lower part, and is said by Mr. Pettingill, chief chemist at the cement plant, to have a composition analogous to that of glauconite. The bedding of this mass is often rough and irregular. Corals are abundant and well preserved, but almost impossible to collect. At the east side of the quarry these layers come to the top and show several sets of glacial striae on the exposed surface, the most prominent of which run S. 40° W. These beds vary considerably in thickness, but the full amount here given is exposed along the east side of the quarry. This massive portion of the Onondaga is quite persistent and may be traced eastward into New York state....................	18·5	5·643
1. Massive grey limestone, passing downwards into a slaty grey to brown impure limestone. These beds are streaked with semi-crystalline bands in which fossils are more abundant. They extend to the bottom of the water hole at the west side of the quarry............................	10	3·05

The fossils found at this locality are given in the second column of the accompanying table.

The large mound, three-quarters of a mile to the south of the cement plant is Sugar Loaf—a sand dune which is covered with vegetation and therefore stationary. Other dunes a short distance to the west are in a partial state of active migration.

ONONDAGA FOSSILS FROM HOGAN'S QUARRY AND THE CANADIAM PORTLAND CEMENT COMPANY'S QUARRY NEAR PORT COLBORNE.

	Hogan Quarry.					Canadian Portland Cement Co's Quarry.				
	1	2	3	4	5	1	2	3	4	5
Sponges										
Hindia fibrosa (Roemer)...........								x		
Hydrozoa										
Clathrodictyon cellulosum *Nicholson.*				x		x				
Stromatoporella granulatum *Nicholson*		x	x	x			x			
Stromatoporella (?) tuberculata *Nicholson*.........................			x				x			
Syringostroma nodulata *Nicholson*...			x	x						
Corals										
Alveolites confertus *Nicholson*.......			x							x
Alveolites distans *Nicholson*.........			x							x
Alveolites ramulosus *Nicholson*......			x							x
Aulopora cornuta *Billings*..........			x							x
Aulopora tubiformis(?) *Goldfuss*.....										x
Bothrophyllum decorticatum *Billings*		x	x	x	x					x
Bothrophyllum promissum *Hall*.....										x
Chonostegites clappi *Edwards and Haime*.........................							x			
Cladopora cryptodens (*Billings*).....			x							x
Cladopora imbricata *Rominger*......										x
Cladopora labiosa (*Billings*).........			x	x	x	x	x	x		x
Cladopora pinguis (?) *Rominger*.....										x
Cladopora pulchra *Rominger*........										x
Cystiphyllum vesiculosum *Goldfuss*..	x	x	x	x	x	x	x	x	x	x
Eridophyllum verneuilianum *Edwards and Haime*.....................							x			
Favosites basalticus *Goldfuss*........		x	x	x	x	x			x	x
Favosites canadensis *Billings*........		x	x	x	x		x		x	x
Favosites cervicornis *Edwards and Haime*.........................			x							
Favosites emmonsi *Rominger*........	x	x	x	x	x	x	x	x	x	x
Favosites epidermatus *Rominger*....			x	x	x					x
Favosites limitaris *Rominger*........			x	x	x					x
Favosites radiciformis *Rominger*.....		x								x
Favosites turbinatus *Billings*........	x	x	x	x		x	x		x	x
Favosites winchelli *Rominger*........						x	x			

	Hogan Quarry.					Canadian Portland Cement Co's Quarry.				
	1	2	3	4	5	1	2	3	4	5
Heliophyllum corniculum (*Lesueur*)			x						x	
Heliophyllum exiguum *Billings*										x
Heliophyllum halli *Edwards and Haime*	x	x	x		x	x	x			x
Michelinia convexa d'*Orbigny*			x			x	x			
Michelinia favositoidea *Billings*				x		x	x			
Romingeria umbellifera (*Billings*)							x			
Snathophyllum arundinaceum (*Billings*)										x
Snathophyllum simcoense (*Billings*)	x	x	x		x		x	x	x	x
Snathophyllum stramineum (*Billings*)							x			
Syringopora hisingeri *Billings*					x	x	x		x	x
Syringopora maclurei *Billings*										x
Syringopora nobilis *Billings*			x			x	x		x	x
Syringopora perelegans *Billings*		x	x	x	x	x	x		x	x
Zaphrentis gigantea *Leseuur*	x	x	x	x	x	x	x	x	x	x
Zaphrentis prolifica *Billings*										x
Bryozoa										
Coscinium striatum *Hall and Simpson*										x
Fenestella parallela *Hall*			x							
Fenestella sp								x	x	x
Fistulipora subcava (*Hall*)			x							
Reteporidra perundata (*Hall*)										x
Unitrypa pernodosa (*Hall*)		x								
Brachiopods										
Amphigenia elongata *Vanuxem*						x				
Atrypa reticularis (*Linnæus*)			x		x	x	x			x
Camarotoechia billingsi *Hall*									x	
Camarotoechia tethys (*Billings*)			x							
Centronella glansfagea *Hall*			x							
Chonetes mucronatus *Hall*					x					x
Cyrtina hamiltonensis *Hall*			x							x
Delthyris raricosta *Conrad*			x							
Eunella lincklæni *Hall*			x							
Leptæna rhomboidalis (*Wilckens*)										x
Meristella doris *Hall*										x
Meristella nasuta (*Conrad*)	x	x	x		x	x	x			x
Metaplasia disparilis (*Hall*)			x						x	x
Orthothetes pandora (*Billings*)			x			x	x			x
Parazyga hirsuta *Hall*										x
Pentamerella arata (*Conrad*)		x	x		x	x				x
Reticularia fimbriata (*Conrad*)										x

	Hogan Quarry.					Canadian Portland Cement Co's Quarry.				
	I	2	3	4	5	I	2	3	4	5
Rhipidomella cleobis (?) *Hall*........										x
Rhipidomella livia (*Billings*)........						x				
Rhipidomella vanuxemi *Hall*........			x							x
Schizophoria propinqua *Hall*........										x
Spirifer duodenarius (*Hall*).........			x		x				x	x
Spirifer varicosus *Hall*..............										x
Stropheodonta demisssa (*Conrad*)....			x				x			x
Stropheodonta hemispherica *Hall*....		x			x					x
Stropheodonta inequistriata (*Conrad*)			x				x			x
Strophonella ampla *Hall*............	x	x				x	x	x		
Trematospira gibbosa (?) *Hall*.......										x
Pelecypods										
Conocardium cuneus (*Conrad*)		x								x
Gastropods..........................										
Diaphorostoma lineatum (*Conrad*)...		x	x	x	x	x	x		x	x
Diaphorostoma turbinatum (*Hall*)...			x							x
Diaphorostoma turbinatum cochleatum *Hall*......................										x
Loxonema pexatum *Hall*...........										x
Platyceras carinatum *Hall*..........					x					x
Platyceras conicum (?) *Hall*.........										x
Platyceras erectum (*Hall*)..........		x	x			x	x			
Platyceras rictum *Hall*.............										x
Paltyceras thetis *Hall*..............			x							
Strophostylus varians *Hall*..........										x
Turbonopsis shumardi (*de Verneuil*)..							x			
Crinoids										
Megistocrinus sp...................										
Trilobites										
Phacops cristata, *Hall*..............										x
Phacops rana (*Green*).............			x							
Proetus rowi (*Green*)...............			x							

Lake Erie—Alt.: 571·57 ft.; 174·2 m. Lake Erie is 239 miles (384·6 km.) long and 59 miles (95 km.) wide; it covers an area of 10,000 square miles (25920 sq. km.); the mean elevation is 571·57 feet (174·2 m.) and the maximum depth 210 feet (64 m.) Lake Erie is the youngest of the great lakes, and owes its existence entirely to glacial and post-glacial agencies.

The north shore of Lake Erie is low and sandy with numerous bars and spits. Dunes form in many places, and shifting sands cause much trouble in the harbours and even to a considerable distance inland. There are few rock exposures on the water line, but near Port Colborne and at the western end of the lake, the Onondaga limestones are encountered a short distance inland.

Rondeau—At Rondeau the drifting sands have been piled up in long ridges parallel to the shore and now present a characteristic undulating contour. Behind the series of bars lies Rondeau harbour, and west of that an extensive peat bog which extends for several miles w th a width of from a quarter to a half mile. In depth, the peat varies from almost nothing to 30 feet (9·1 m.) in accord with the ridge-like bottom. Rondeau point, as well as most of the points along the north shore, owes its existence to a current which sets eastward along the coast.

Rondeau Provincial park occupies the peninsula of Point aux Pins and contains 1,950 acres (589 hectares) of wooded land which is probably the best example of the original forest to be found in the Western Peninsula. The ridge-like arrangement of the sand is well shown and is more pronounced on the lake side than on the harbour side. The tops of the ridges are about 12 feet (3·6 m.) above the water, while the depressions are about three feet (·9 m) above that level. Towards the west, the elevation is so much less that the depressions gradually become marshes and finally disappear beneath the lake. The soil is all fine, white, water-washed sand, and would support little vegetation if any except for the excellent sub-irrigation. Three distinct types of forest growth are presented as below:—

1. White pine belt along the lake front.

2. Hardwood growth on the ridges.
3. Hardwood growth in the depressions.

The most important trees are the following:—

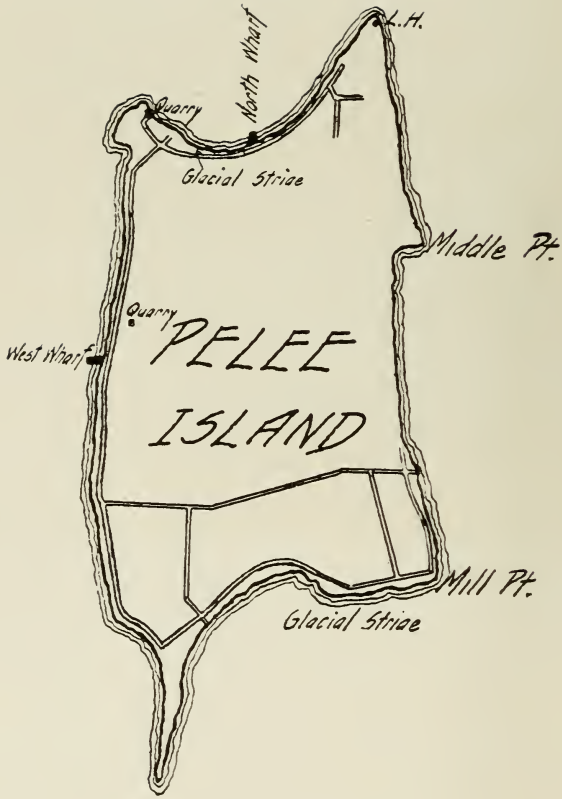
On the ridges—

White pine, *Pinus strobus*, L.
Bur oak, *Quercus macrocarpa*, Michx.
Chestnut oak, *Quercus prinus*, L.
White oak, *Quercus alba*, L.
Hard maple, *Acer saccarinum.*
Beech, *Fagus ferruginea*, Ait.
Tulip tree, *Lyriodendron tulipifera*, L.
Basswood, *Tilia americana*, L.

In the depressions—

Red oak, *Quercus rubra*, L.
Black oak, *Quercus coccinea tinctoria*, Gray.
Scarlet oak, *Quercus coccinea*, Wang.
Swamp white oak, *Quercus bicolor*, Willd.
Black ash, *Fraxinus sambucifolia*, Lam.
White elm, *Ulmus americana*, L.
Silver maple, *Acer dasycarpus*, Ehrh.
Red maple, *Acer rubrum*, L.
Bitternut hickory, *Carya amara*, Nutt.

In addition to the above there occur in less abundance black walnut, butternut, shellbark and mockernut hickories, yellow birch, sycamore, red elm, white ash, black cherry, white birch, aspen, large toothed aspen poplar, balsam poplar, hop hornbeam, blue beech and sassafras.



Sketch Map of Pelee Island.

Pelee Island—Thin and thick bedded dolomitic limestones of the Onondaga formation are exposed at many points on the island. Characteristic fossils may be collected in abundance at most of the

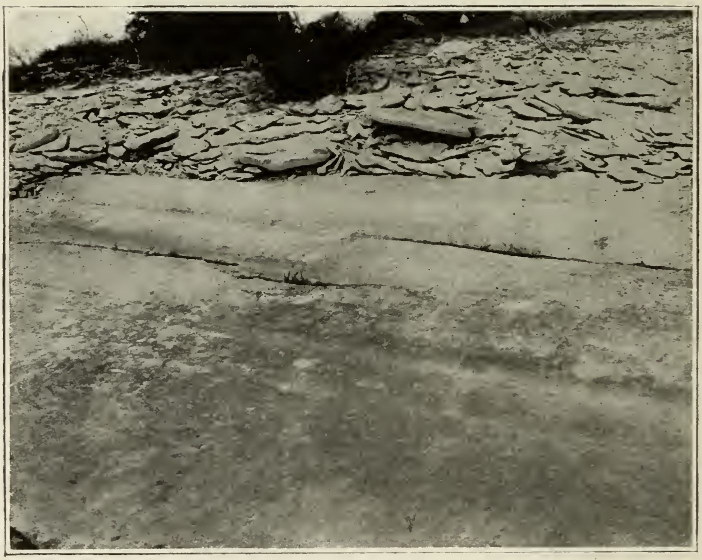
Ridges of Onondaga limestone formed by glaciers and subsequently weathered. Pelee island, Ontario.

outcrops. The more common species as occurring at a quarry on the west side of the island and at one near the north end are given below:—

	West Quarry.	North Quarry.
Rhizopoda—		
Calcisphæra robusta, *Williamson*	x	x
Hydrozoa—		
Clathrodictyon laxum, *Nicholson*	x	x
Stromatoporella granulata, *Nicholson*	x	x
Stromatoporella tuberculata, *Nicholson and Murie*		x
Anthozoa—		
Acervularia rugosa (*E. and H.*)	x	x
Cystiphyllum vesiculosum, *Goldfuss*	x	x
Eridophyllum verneuilianum, *E. and H*	x	x
Favosites emmonsi, *Rominger*	x	x
Favosites pleurodictoides, *Nicholson*	x	x
Favosites radiciformis, *Rominger*	x	x
Favosites turbinatus, *Billings*	x	x
Heliophyllum corniculum (*Lesueur*)	x	x
Heliophyllum halli, *E. and H*	x	x
Syringopora hisingeri, *Billings*		x
Syringopora tabulata, *E. and H.*	x	x
Zaphrentis gigantea, *Lesueur*	x	x
Zaphrentis prolifica, *Billings*	x	x
Bryozoa—		
Coscinium striatum, *Hall and Simpson*		x
Cystodictya gilberti (*Meek*)	x	x
Fenestella parallela, *Hall*	x	
Fenestella sp		x
Monotrypella tenuis, *Hall*		x
Brachiopoda—		
Atrypa reticularis (*Linnæus*)	x	x
Camarotoechia billingsi, *Hall*		x
Camarotoechia carolina, *Hall*		x
Chonetes hemisphercus, *Hall*	x	
Chonetes mucronatus, *Hall*	x	x
Cyrtina hamiltonensis, *Hall*	x	x
Eunella lincklæni, *Hall*		x
Leptæna rhomboidalis (*Wilckens*)		x
Nucleospira concinna, *Hall*	x	x
Pentamerella arata (*Conrad*)		x
Pholidops patina, *H. and C.*		x
Productella spinicosta, *Hall*	x	x
Rhipidomella vanuxemi, *Hall*	x	x
Schizophoria propinqua, *Hall*	x	x
Spirifer acuminatus (*Conrad*)	x	x
Spirifer duodenarius (*Hall*)		x
Spirifer gregarius, *Clapp*	x	
Spirifer manni, *Hall*	x	x
Stropheodonta concava, *Hall*		x

	West Quarry.	North Quarry.
Stropheodonta demissa (*Conrad*)	x	x
Stropheodonta hemispherica, *Hall*	x	x
Stropheodonta perplana, (*Conrad*)	x	x
Pelecypoda—		
Aviculopecten princeps (*Conrad*)		x
Conocardium cuneus (*Conrad*)		x
Paracyclas elliptica, *Hall*	x	x
Gastropoda—		
Platyceras carinatum, *Hall*	x	
Pleuronotus decewi (*Billings*)	x	x
Pleurorema lucina (*Hall*)	x	x
Pteropoda—		
Tentaculites scalariformis, *Hall*	x	x
Crustacea—		
Coronura diurus (*Green*)	x	
Phacops cristata (*Hall*)		x
Prœtus rowi (*Green*)	x	x
Fish—		
Onychodus sigmoides, *Newberry*		x

Glacial grooving of a most pronounced and interesting character is shown at both the north and south extremities of the island; while, in the interior, long ridges of rock mark the path of the glacier. These ridges, modified by post-glacial weathering, present some very fine residual features.



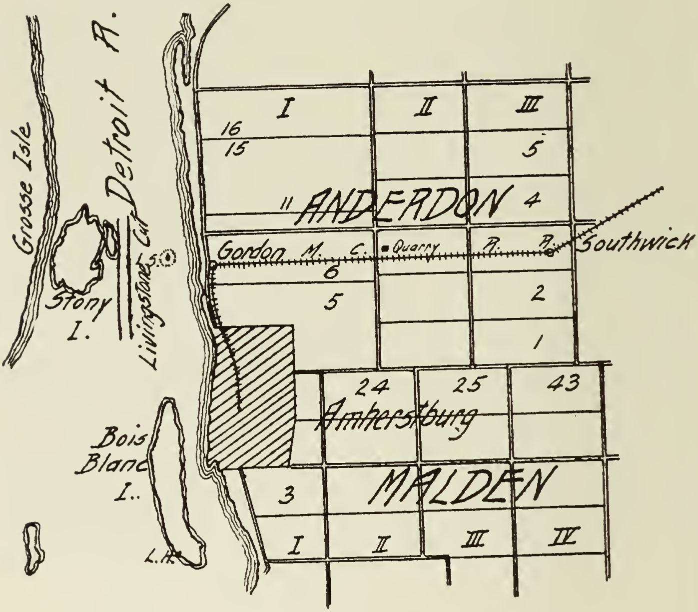
Glacial grooving in Onondaga limestone; south end of Pelee island, Lake Erie, Ontario.

Pelee island is the most southerly part of Canada, and was formerly a centre of the grape and wine industries; but, at the present time, it is largely given up to the culture of tobacco and corn.

Monroe Formation—The extreme western part of the province is so heavily covered by drift that exposures are rare. The upper rock belongs to the Onondaga and is comparable with that of Pelee island. In the Detroit river, however, and in the quarries at Amherstburg as well as at several points in Michigan, it is found that a series of formations lies between the Onondaga and the top of the Salina. American geologists propose to include all these layers in the Monroe formation and to ascribe them to the Silurian. The Monroe formation thus defined is divided into an upper and a lower division by the Sylvania sandrock.

Glaciated surface of Onondaga limestone showing the deflection of the ice around included corals, south end of Pelee island. Lake Erie, Ontario.

Amherstburg—Alt.: 593 feet; 180·27 m. Amherstburg, near the mouth of the Detroit river, is one of the historically important points in western Ontario: its origin during the French regîme is attested by the names of many of the present inhabitants. The first white men to ascend the Detroit river were LaSalle and Hennepin, who made the Amherstburg passage in 1679 in the ' Griffin." Since this time, $12,000,000 have been spent by the American government to improve he route. The necessity for this expenditure is attested by the fact that a laden vessel passes Amherstburg every 13¼ minutes throughout the season of navigation. This vicinity was the scene of many stirring events during the war of 1812-14. The ruins of old Fort Malden may yet be seen within the limits of the present town. On the river Canard to the northward was fought one of the first skirmishes of the war.



MAP of ANDERDON and MALDEN TPS.

The extremely interesting section at the quarries of the Solvay Process Company is no longer visible in its entirety, as the excavation has been allowed to partially fill with water. The upper beds are undoubtedly of Onondaga age, but the underlying strata have been the cause of considerable controversy The section in descending order is as follows:—

	Thickness.	
	Feet.	Metres.
Onondaga (Devonian)—		
1. Dolomitic limestone....................	35	10·64
Monroe (Silurian)—		
2. High grade limestone..................	24	7·29
3. Brown dolomites........................	4–5	1·2–1·5

1. The Onondaga limestones are fossiliferous in places, but the locality can no longer be called a favourable collecting place. The following species are of common occurrence:—

Favosites hemispherica, *Yandell and Shumard.*
Michelinea convexa, *D'Orbigny.*
Streptelasma prolificum, *(Billings), Lambe.*
Syringopora hisingeri, *Billings.*
Atrypa reticularis, *(Linn.)*
Leptaena rhomboidalis, *(Wilckens.)*
Meristella nasuta, *(Conrad.)*
Reticularia fimbriata, *(Conrad.)*
Rhipidomella livia, *(Billings.)*
Spirifer varicosus, *Hall.*
Stropheodonta demissa, *(Conrad.)*
Stropheodonta inaequistriata, *(Conrad.)*
Stropheodonta perplana, *(Conrad.)*
Strophonella ampla, *Hall.*

2. A peculiarly ridged and undulating surface is presented by the beds of high grade limestone, where the overlying Onondaga dolomites have been removed by quarrying. Grabau interprets this surface as of eolian origin and as having been made in early Devonian time. The underlying limestone (Anderdon beds) and the brown

dolomites beneath, he ascribes to the upper part of the Monroe formation, which is made to include all strata between the top of the Salina and the base of the Devonian.

Eroded surface of Anderdon high grade limestone with Onondaga dolomitic limestone in the background. Solvay Process Co's quarry. Amherstburg, Ontario.

The high grade Anderdon limestone is not rich in fossils, but it presents a coral and Stromatopora reef from which Grabau obtained the following species:—

Clathrodictyon ostiolatum, *Nicholson.*
Clathrodictyon variolare, *vonRosen.*
Idiostroma nattressi, *Grabau.*
Stromatopora galtensis *(Dawson.)*
Stylodictyon sherzeri, *Grabau.*
Ceratopora tenella *(Rominger.)*
Cladopora bifurcata, *Grabau.*
Cyathophyllum thoroldense, *Lambe.*

Cystiphyllum americanum anderdonense, *Grabau.*
Diplophyllum integumentum, *Barrett.*
Favosites basaltica nana, *Grabau.*
Favosites concava, *Grabau.*
Favosites rectangulus, *Grabau.*
Helenterophyllum caliculoides, *Grabau.*
Spirifer (Prosserella) lucasi, *Grabau.*
Pleurotomaria cf. velaris, *Whiteaves.*

The three Silurian stromatoporoids are of very doubtful identification; if these are excepted, the remaining fossils have a strong Devonian rather than Silurian aspect. Rev. Thomas Nattress of Amherstburg, who has studied the Anderdon limestone from the stratigraphic point of view, is convinced that it represents a Devonian sedimentation in an enclosed basin.

3. The underlying brown dolomites are not sufficiently exposed to yield important stratigraphic evidence: they appear to be destitute of fossils.

A second exposure of beds belonging to this series is furnished by the cut of the Livingstone canal in the Detroit river. The total length of the cut is 11 miles (17·7 km.), its width is 300 to 800 feet (91 to 244 m.) and its depth 23 feet (7 m.). Just above Amherstburg a section of the canal about a mile long was excavated within a coffer dam and is hence known as the dry cut. The material removed from the river bed, to an amount of 800,000 cubic yards, has been piled on either side of the cut and for a few years at least will be a good collecting ground for Monroe fossils.

Grabau maintains that these beds represent the upper part of the Monroe formation—above the Anderdon limestone, while Nattress as stoutly maintains that they belong to the lower Monroe. For our present purposes it will suffice to consider these beds as yielding an interesting series of fossils with both a Devonian and a Silurian aspect. The commoner species are as follows:—

Hydrozoa

Clathrodictyon ostiolatum, *Nich.*
Idiostroma nattressi, *Grabau.*

Corals

Ceratopora regularis, *Grabau.*
Cladopora dichotoma, *Grabau.*
Diplophyllum integumentum (*Barrett.*)
Favosites tuberoides, *Grabau.*
Heliophrentis alternatum, *Grabau.*
Heliophrentis carinatum, *Grabau.*
Romingeria umbellifera (*Billings.*)
Synaptophyllum multicaule (*Hall.*)
Syringopora hisingeri, *Billings.*

Bryozoa

Fenestella sp.

Brachiopods

Schuchertella amherstburgense, *Grabau.*
Schuchertella interstriata (*Hall.*)
Spirifer (Prosserella) modestoides depressus, *Grabau.*
Spirifer sulcata submersa, *Grabau.*
Stropheodonta praeplicata, *Grabau*
Stropheodonta vasculosa, *Grabau.*

Pelecypods

Conocardium monroicum, *Grabau.*
Cypricardinia canadensis, *Grabau.*
Panenka canadensis, *Grabau.*

Gastropods

Acanthonema holopiformis, *Grabau.*
Eotomaria areyi, *Clarke and Ruedemann.*
Holopea antiqua pervetusta (*Conrad.*)
Hormotoma subcarinata, *Grabau.*
Lophospira bispiralis (*Hall.*)
Strophostylus cyclostomus, *Hall.*
Trochonema ovoides, *Grabau.*

Cephalopods

Cyrtoceras orodes, *Billings.*
Dawsonoceras annulatum americanum (*Foord.*)

Trilobites

Proetus crassimarginatus, *Hall.*

Vermes

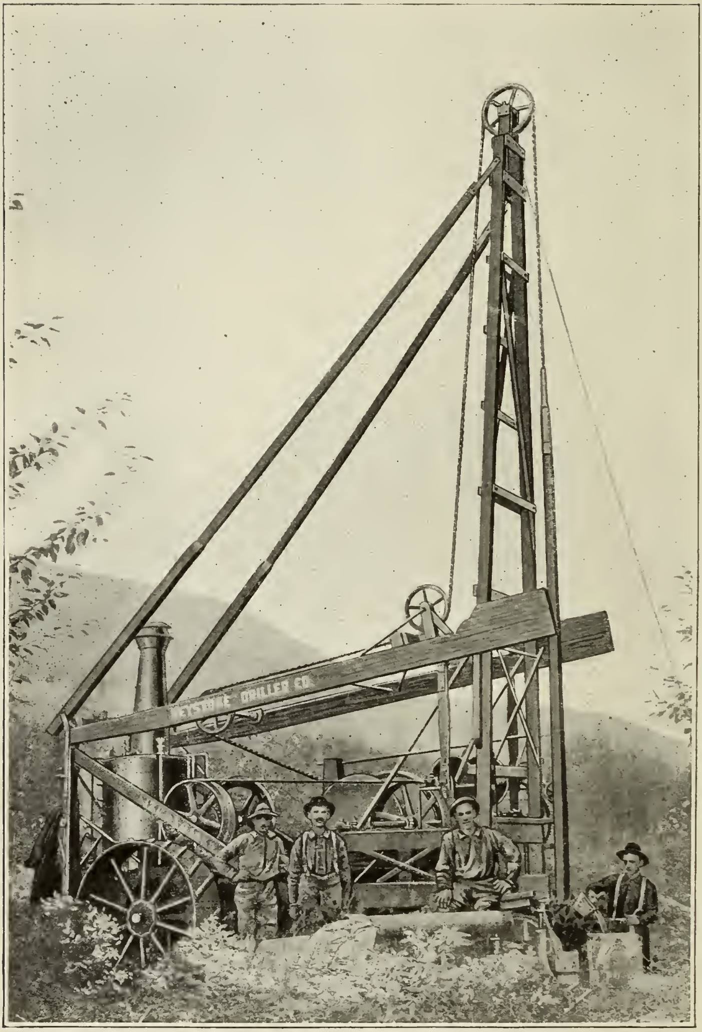
Cornulites armatus, *Conrad.*

Windsor—Alt.: 580 ft.; 176·3 m. The salt producing area of Ontario is situated about the southern end of Lake Huron and along the shores of River St. Clair, Lake St. Clair and Detroit river. The salt is derived from the Salina formation of the Silurian. The beds are encountered at a depth of about 1,000 feet (304·8 m.) from the surface, and they show, in some cases a thickness of more than 200 feet (60·9 m.)

The most important salt wells now in operation are situated near Windsor where the first well was sunk in 1892. The following log will serve to indicate the strata penetrated in this area:—

	Thickness.		Depth.	
	Feet.	Metres.	Feet.	Metres.
Drift	136	41·34	136	41·3
Limestone (Onondaga and Upper Monroe)	434	131·94	570	173·2
Sandstone (Sylvania)	136	41·34	706	214·6
Limestone (Lower Monroe)	350	105·4	1056	321·0
Salina	......	....	......	....

In drilling the wells, a ten inch mud casing is driven down to the solid rock, and forced into the stone sufficiently to render the joint watertight. The hole is then carried down with a diameter of 6¼ inches (15·8 c.m.) into the salt beds. A pipe, of the diameter of this hole, is extended about 800 feet (243·8 m.) to cut off mineral waters: in some cases, it is continued to about 1,300 feet (396·2 m.) in order to exclude the upper salt beds which are not quite as good as the heavier lower beds. A 3½ inch (8·9 cm.) pipe is placed inside the larger pipe and is extended to the bottom of the hole. Water is forced down between the two tubes and is made to ascend the inner tube after becoming saturated with salt. To lift the brine a one-inch air tube is carried down about 600 feet (182·8 m. inside the 3½ inch pipe. From this tube air is allowed to



Machine used in drilling salt wells.

escape under a pressure of 250 lbs., whereby a constant flow of brine is induced.

The average Windsor brine contains about 26·5% of sol ds made up as follows:—

Calcium sulphate..............	1·795
Calcium chloride..............	0·377
Magnesium chloride..........	0·124
Potassium chloride...........	tr.
Sodium chloride..............	24·2

The preparation of salt is effected by both the grainer and vacuum pan processes. At the Sandwich plant of the Canadian Salt Company, caustic soda is made by the electrolytic method, and the liberated chlorine is utilized for the manufacture of bleaching powder. This company produces 350 bbls. of grainer salt, 1,400 bbls. of vacuum salt, 2½ tons of caustic soda and 9 tons of bleaching powder per diem.

Thedford—Alt. 469·89 ft.; 142·84 m. The middle Devonian strata (Hamilton formation) lie in a syncline on the Onondaga limestones, and extend in a broad belt from Lake Huron to Lake Erie. The country underlaid by this formation is heavily covered with drift, so that exposures are seen at a few places only. The most noted localities are the vicinity of Thedford and the valley of the Aux Sables river between Rock Glen and Marshall's Mills.

For a full account of the geology of the Thedford region, with lists of fossils, etc., see the section on Thedford in the guide book to Excursion A12.

Lake Huron—Lake Huron is 207 mi es (333 km.) long, 100 miles (161 km.) wide and has an area of 23,200 square miles (60,134 sq. km.) The maximum depth is 750 feet (228·6 m.) and the elevation 579·86 feet (176 m.) At Kettle point near the southern end of the lake is an exposure of the highest Devonian strata in Ontario. The rocks consist of highly bituminous shales supposed to be equivalent to the Genesee shales of the New York geologists. Spherical concretions of brown crystalline calcite occur in these shales and sometimes reach a diameter of several feet. These concretions when half exposed above the waters of the lake resemble inverted kettles, and are responsible for the name of the point.

Goderich—Northward from this point, rock exposures are infrequent on the shores of the lake, but near Goderich a good section is revealed in the valley of the Maitland river. In descending order the following beds are exposed:—

	Thickness.	
	Feet.	Metres.
1. Soil and drift	50	15·2
Hamilton—		
2. Compact grey to drab limestone	9·5	2·89
Onondaga—		
3. Massive grey to brown crystalline limestone, with fossils	30	9·14
4. Brown crystalline coralline limestone	1·3	·40
5. Grey to brown limestone with numerous fossils at bottom	19·5	5·93
6. Grey crystalline limestone with pebbles of Silurian rock and quartz grains, fossiliferous		
Silurian (Monroe)—		
7. Thin-bedded bituminous limestones	2·5	·760
8. Fractured, buff limestone and dolomites	2·8	·861
9. Soft, mottled, yellowish, porous limestones and dolomites	5·5	1·67

The Hamilton strata are not particularly rich in fossils at this point, but a careful search reveals numerous species, of which the following are the more important:—

Corals

Cystiphyllum vesiculosum, *Goldfuss.*
Heliophyllum halli, *E. and H.*
Zaphrentis prolifica, *Billings.*

Hydrozoa

Stromatoporella sp.

Brachiopods

Atrypa reticularis (*Linnaeus.*)
Chonetes deflectus, *Hall.*

Chonetes mucronatus, *Hall.*
Chonetes scitulus, *Hall.*
Cranaena romingeri, *Hall.*
Crania crenistriata, *Hall.*
Craniella hamiltoniae, *Hall.*
Cyrtina hamiltonensis, *Hall.*
Delthyris consobrina (*d'Orbigny.*)
Eunella lincklaeni, *Hall.*
Leiorhynchus limitare (*Vanuxem.*)
Leptaena rhomboidalis (*Wilckens.*)
Lingula ligea, *Hall.*
Pentamerella arata (*Conrad.*)
Pholidostrophia iowaensis (*Owen.*)
Rhipidomella vanuxemi, *Hall.*
Schizophoria striatula (*Schlotheim.*)
Spirifer divaricatus, *Hall.*
Spirifer macrus, *Hall.*
Stropheodonta concava, *Hall.*
Stropheodonta demissa (*Conrad.*)
Stropheodonta perplana (*Conrad.*)

Pelecypods
Actinopteria boydi (*Conrad.*)
Aviculopecten bellus (*Conrad.*)
Nyassa recta, *Hall.*
Paracyclas elliptica, *Hall.*
Paracyclas linata (*Conrad.*)
Schizodus appressus (*Conrad.*)

Gastropods
Bembexia sulcomarginata (*Conrad.*)
Platyceras erectum (*Hall.*)
Pleuronotus decewié (*Billings.*

Pteropods
Tentaculites scalariformis, *Hall.*

Cephalopods
Centroceras ohioense (*Meek.*)
Gigantoceras inelegans (*Meek.*)
Orthoceras sp.

Trilobites
Proetus rowi (*Green.*)

The Onondaga strata contain typical Onondaga fossils as follows:—

Corals

Acervularia rugosa (*E. and H.*)
Favosites emmonsi, *Rominger.*
Favosites turbinatus, *Billings.*
Heliophyllum halli, *E. and H.*
Zaphrentis gigantea, *Lesueur.*

Bryozoa

Cystodictya gilberti (*Meek.*)
Fenestella parallela, *Hall.*
Fistulipora subcava (*Hall.*)
Monotrypa tenuis (*Hall.*)

Brachipods

Atrypa reticularis (*Linnaeus.*)
Atrypa spinosa, *Hall.*
Chonetes lineatus (*Conrad.*)
Cyrtina hamiltonensis, *Hall.*
Leptaena rhomboidalis (*Wilckens.*)
Pholidops patina, *Hall and Clarke.*
Pholidostrophia iowaensis (*Owen.*)
Productella spinulicosta, *Hall.*
Rhipidomella vanuxemi, *Hall.*
Schizophoria propinque, *Hall.*
Stropheodonta concava, *Ha.l.*
Stropheodonta demissa (*Conrad.*)
Stropheodonta hemispherica, *Hall.*
Stropheodonta patersoni, *Hall.*
Stropheodonta perplana (*Conrad.*)

Pelecypods

Conocardium cuneus (*Conrad.*)
Paracyclas elliptica, *Hall.*

Gastropods

Platyceras carinatum, *Hall.*
Pleuronotus decewi (*Billings.*)

Pteropods

Tentaculites scalariformis, *Hall.*
Proetus crassimarginatus, *Hall.*

Trilobites

Proetus rowi (*Green.*)

Flowerpot Island—Bruce peninsula, separating Lake Huron from Georgian bay, represents the unsubmerged edge of the Niagara cuesta: it is topped by the hard dolomitic limestone of the Lockport formation which rises, at one place in the county of Bruce, to a height of 400 feet (122 m.) above the lake.

Off the north shore of the peninsula are a number of small islands showing interesting residual structures; the chief of these is Flowerpot island, where huge masses of Lockport dolomite resembling giant vases are supported on diminished stalks of the softer underlying formation.

Cuesta topography, Wingfield basin, Manitoulin island.

Manitoulin Island.—The Grand Manitoulin island (The island of the Great Spirit) is stratigraphically a continuation of Bruce peninsula. The Niagara cuesta, which extends into the island, differs from the cuesta in the Bruce peninsula in that it approaches much closer to the oldland of the north shore of Lake Huron. In consequence of this fact, the whole series of Palæozoic formations from the Niagara down to the Lowville is excellently shown within a comparatively short distance. The lower Ordovician deposits occur on the islands north of Manitoulin; the Collingwood is excellently shown near Little Current; magnificent exposures of the Lorraine and Richmond may be seen at the Clay Cliffs near Cape Smyth; and the Cataract and Niagara formations are excellently developed near Manitowaning.

THE GEOLOGY OF THE CLAY CLIFFS, CAPE SMYTH, MANITOULIN ISLAND.

by

August F. Foerste.

Cincinnatian Section at the Clay Cliffs.

The formations between the Trenton and the top of the Ordovician are generally referred to the Cincinnatian series. The order of succession of these formations, as exposed on Manitoulin island, is indicated in the following table.

Formations.	Thickness.	Characteristic Fossils.	Approximate horizon in Cincinnatian area.
Upper Richmond.....	50 to 60 ft. 15·2 to 18·3 m.	*Primitia lativia* *Rhytimya kagawongensis* *Ortonella hainesi* Manitowaning *Stromatocerium* reef.	Saluda with traces of Whitewater.
Middle Richmond.....	30 to 50 ft. 9·1 to 15·2 m.	*Beatricea undulata* *Strophomena vetusta* *Ceraurus Meekanus* Cape Smyth *Stromatocerium* reef Gore Bay *Columnaria* reef.	Saluda with traces of Liberty.
Lower Richmond.....	40 to 50 ft. 12·2 to 15·2 m.	*Strophomena huronensis* *Strophomena sulcata* *Hebertella insculpta* horizon.	Upper Waynesville.
Lorraine.............	100 ft. 30·4 m.	*Whiteavesia pholadiformis* *Modiolopsis concentrica* in upper part.	Bellevue or Middle Maysville fauna in lower part.
Eden...............	20 to 30 ft. 6 to 9·1 m. 100 ft. 30·4 m.	Interbedded limestones with *Cœloclema communis* *Dekayella ulrichi* Clays with *Triarthrus becki*, *Trinucleus concentricus*.	Southgate or Middle Eden.
Utica of New York....		Absent in Lake Huron area.	
Collingwood.........	20 to 30 ft. 6 to 9·1 m.	*Ogygites canadensis*.	

Collingwood formation.—The lowest formation, the Collingwood, formerly correlated with the Utica of New York, has been differentiated recently by Raymond, since it contains a sufficiently distinct fauna, although presenting the same lithological appearance. It consists of fissile black shales, and is well exposed on the hill in the eastern edge of Little Current.

Eden clays.—The lower part of the Eden consists of a great thickness of clay shale, 100 feet (30·5 metres) thick, with scarcely a trace of limestone. The fauna includes *Diplograptus peosta* and species of *Leptobolus* and *Primitia*, in addition to the trilobites mentioned in the table of formations. The best exposures are found three miles (5 km.) southeast of Little Current, along the road to Sheguindah.

Eden limestones.—Along the same road to Sheguindah the basal part of the overlying strata, consisting of limestones interbedded with clays, is exposed. The upper part of these strata may be seen immediately south of the great Richmond exposures on the eastern side of Cape Smyth. Here, owing to the southward dip of the strata, the top of the Eden limestone section is seen at the northern end of the Lorraine exposures which line the shore for several miles. From this upper part of the Eden section Ulrich and Bassler identified provisionally.:—

Amplexopora persimilis (variety of A. septosa *Ulrich*).
Callopora communis *James.*
Callopora sigillarioides *Ulrich.*
Coeloclema communis *Ulrich.*
Dekayella ulrichi *(Nicholson).*
Stigmatella *near* nana *Ulrich and Bassler.*

A much larger fauua has been collected from other localities, as far west as Tamarac point and the eastern shore of Gore bay.

Lorraine.—A visit to the Clay Cliffs in the Cape Smyth area certainly should include at least a brief glance at the Lorraine exposures which line the shore at water's edge for nearly two miles south of the Clay Cliffs. Here, clay shales are interbedded with fine-grained siliceous limestones, some of which weather to a brownish rock resembling fine-grained sandstone. This rock frequently contains an abundant pelecypod fauna, including:—

Clay Cliffs, Manitoulin island, showing Lorraine exposures in the background and Richmond in the distance.

Byssonychia radiata *(Hall)*
Cleidophorus planulatus *Conrad.*
Ctenodonta pectunculoides *Hall.*
Lydrodesma poststriatum *(Emmons).*
Modiolopsis concentrica *Hall and Whitfield.*
Whiteavesia pholadiformis *(Hall).*

These pelecypods are associated at least at one horizon, with *Diplograptus angustifolius* mut. *vespertinus* of the middle Lorraine of New York.

In Ohio, *Whiteavesia pholadiformis* and *Mediolopsis concentrica* come in at the base of the Waynesville member of the Richmond and continue apparently into the Liberty, but the bryozoans, submitted to Dr. E. O. Ulrich, indicate a Bellevue or middle Maysville age, rather than a lower Richmond horizon.

Lower Richmond.—Capt Symth, at the northeastern corner of Manitoulin island, has long been known as a type locality for various Richmond fossils, but it is rarely visited by the geologist. This is due to the expense and the inconvenience attending a hasty visit in the absence of a camping outfit. Four miles south of Cape Smyth, the steep white Clay Cliffs rise to a height of over 200 feet (60 m.) above the level of the lake.

As frequently happens with such steep exposures, more than half of the slope of the cliff is cove ed w th talus, and only along the upper half of the cliff are the strata directly accessible. A Stromatocerium reef occurs 30 feet (9·1 m.) below the top of the cliff, and the overlying limestone strata present such a steep front as to be almost inaccessible. *Herbertella inscuplta,* (Hall), a form which demarcates the base of what here is included in the Lower Richmond, has a vertical range of about 10 feet (3 m.) at a horizon 30 feet (9·1m.) below the Stromatoceruim reef. The total thickness of the Lower Richmond at this locality, therefore, is about 40 feet (12·2 m.) .

The following fossils occur in the strata below the Stromatocerium reef but are not known above it —

Protarea richmond.nsis papillata *Foerste.*
Constellaria polystomella, *Nicholson.*
Rhombotrypa quadrata *(Rominger).*
Catazyga headi *(Billings.)*
Crania scabiosa *Hall*
Hebertella insculpta *Hall.*
Platystrophia clarksvillensis *Foerste.*
Plectambonites sericeus *(Sowerby)* (small variety).
Rafinesquina alternata *(Emmons)* (very flat form).
Strophomena huronensis *Foerste.*
Strophomena neglecta *James.*
Strophomena nutans *Meek.*
Strophomena planumbona *Hall (*S. rugosa *Blainville.*)
Cyclonema bilix *Conrad.*

Helicotoma brocki *Foerste.*
Ascoceras sp.
Spyroceras hammelli *Foerste.*

In addition to these there are many gastropods and pelecypods not as yet identified.

These fossils suggest the upper Waynesville division of the Richmond formation as exposed in Ohio, Indiana, and Kentucky. The following species occur not only below the Stromatocerium horizon, but range also into the strata above —

Strephochetus richmondensis *Miller.*
Stromatocerium huronense *Billings.*
Calapoecia huronensis *Billings.*
Columnaria alveolata *Goldfuss.*
Streptelasma rusticum *Billings.*
Tetradium huronensis *Foord.*
Hebertells occidentalis *Hall.*
Rhynchotrema perlamellosum (*Whitfield*).
Zygospira kentuckiensis *James.*
Zygospira modesta *Hall.*
Pterinea demissa (*Conrad*).

All these are species which can exist under very adverse conditions in fairly muddy water.

Middle Richmond.—The thirty feet of strata which overlies the Stromatocerium reef at the Clay Cliffs belong to the lower part of the Middle Richomnd. Here, occasional specimens of *Beatricea undulata*, and rather numerous specimens of *Liospira helena*, and of various thick-shelled species of *Bucania* and *Bellerophon* occur.

The *Beatricea undulata* horizon is exposed also in the gully a short distance north of the light house at Manitwaning. Here, the Cape Smyth Stromatocerium reef is absent, and the corresponding horizon is approximately indicated by strata in which *Columnaria alveolata* and *Calapoecia huronensis* are fairly abundant. Eastward, this horizon is represented by the Gore Bay Columnaria reef. Three and a half miles south of Little Current, *Strophomena vetusta* and *Ceraurus (Eccoptochile) meekanus*, Miller, occur immediately above this Columnaria reef, and suggest a trace of the Liberty fauna of Ohio and Indiana, while the *Beatricea undulata*, the abundance of *Columnaria alveolata*, *Calapoecia huronensis*, and *Tetradium* indicate the Saluda.

Upper Richmond.—At Manitowaning, a Stromatocerium horizon occurs far above any of the levels at which *Beatricea* has been found. This Manitowaning Stromatocerium reef limits the top of the Middle Richmond. It is widely distributed and has been traced as far west as Barrie island, west of Gore bay. In the vicinity of Kagawong it is overlaid by a horizon rich in silicified pelecypods, including *Cyrtodonta ponderosa*, *Ctenodonta iphigenia*, and *Ortonella hainesi*. The last named species suggests a trace of the Whitewater fauna, although *Leperditia caecigena*, *Primitia lativia*, and other ostracods occurring at numerous localities above the Manitowaning Stromatocerium reef, indicate the Saluda of Indiana.

Possibly the most interesting fact is the evidence that this Upper Richmond ostracod fauna, with some of its associated brachiopod and pelecypod species, occurs also in the western extension of the Queenston shales of New York, as exposed on the southern shores of Lake Huron between Collingwood and Owen Sound

Fossils from the Clay Cliffs.—Among the fossils which have been described from the Clay Cliffs may be mentioned:—

Stromatocerium huronense *Billings*.
Calapoecia huronensis *Billings*.
Stroptelasma canadensis Billings (rusticum *Billings*).
Tetradium huronensis *Foord*.
Strophomena huronensis *Foerste*.
Ctenodonta iphigenia *Billings*.
Cyrtodonta ponderosa *Billings*.
Helicotoma brocki *Foerste*.
Liospira helena (*Billings*).
Cyrtoceras lysander *Billings*.
Cyrtoceras postumius *Billings*.
Orthoceras piso *Billings*.

To these might be added, as coming at least from the Lake Huron area: *Licrophycus hudsonicum*, Billings, from Manitowaning bay, *Cyclocystoides huronensis*, Billings, from the Beatricea undulata horizon on Rabbit island, *Vanuxemia bayfieldi*, Billings, from the Upper Richmond on Bayfield Sound, and *Cyrtoceras ligarius*, Billings, from the Richmond on Drummond island.

GRANITE ISLAND.

The Pre-Cambrian quartzites are exposed on many of the islands north of Manitoulin, and present interesting contacts with the low-lying Palæozoic strata. Extensive masses of granite have invaded the quartzites and are now exposed on several of the small islands between Mani oulin and the mainland. The coarse red granite of Granite

Residual Lowville limestone in cavities in granite. Granite Island, Lake Huron, Ontario.

island presents interesting contact phenomena with the quartzites, but it is particularly worthy of note on account of the occurrence of sedimentary limestone in kettle-like hollows at an elevation of 50 or 60 feet (15 to 18 m.) above the water of the lake. Fossiliferous strata of Lowville age occur along the north shore of the island at water level. These beds show a basal arkose covered by limestone layers with a strong cephalopod fauna represented for the most part by the remains of siphuncles. Numerous gastropods and pelecypods also occur. The residual limestone and arkose, seen in the cavities in the granite, are essentially similar but lie at an elevation of 50 or 60 feet (15 to 18 m.) above the limestone on the shore. As the original hollows in the granite could not have been of great depth and as the length of time since the deposition of the limestone has not been sufficient to entirely wear them out, it follows that the total erosion of the granite since Lowville time has not been very great.

THE MOHAWKIAN (MIDDLE ORDOVICIAN) STRATA NORTHEAST OF MANITOULIN ISLAND.

BY

AUGUST F. FOERSTE.

Little Current—Alt. 579.86 ft. 176.3 m.—Little Current is the most important town on Manitoulin island. The narrow channel between Manitoulin and Goat islands, at this locality, forms the eastern exit for the lumber traffic along the waters of the North Passage. Lumber rafts are sometimes held up two or three days by the peculiar currents (seiches) which have given the village its name. These are due to the wind. When the wind blows strongly for several days in one direction it heaps up the water on one side of the passage at Little Current, and lowers it on the other sufficiently to start a current, the direction of which depends on the direction of the wind, whether from the east or from the west. Hence, such names as Little Current and Swift Current.

The most striking geological feature of the territory bordering the channel north of the main body of Lake Huron is the deposition of Ordovician strata upon a fairly rugged Pre-Cambrian topography. Here, strata as early as the Lowville clays and limestones, and as late as the Trenton and the immediately overlying Cincinnatian s ·ata rest directly upon quartzites and schists mapped by the Geological Survey of Canada as Huronian. There is evidence that these Huronian rocks had been considerably weathered before the deposition of the Lowville, and that the topography probably had become sufficiently dissected to give rise to ranges of hills or low mountains comparable in direction and altitude to those which now traverse the region.

Cloche Island.

An excellent section of the Mohawkian strata is exposed along the line of railway from Cloche peninsula, across Cloche island and Goat island to Little Current.

Lowville.—The lowest Palæozoic strata, exposed for several miles (4 or 5 km.) along the western margin of the Cloche peninsula, consist of red shales of Lowville age. Only the upper part of these shales, 70 feet (21 m.) thick, are exposed above lake level. Fossils are found a mile (1·6 km.) south of the northwestern angle of the peninsula, in a hard brownish clay stratum a short distance above the level of the railway. The southward dip of the strata is sufficient to carry them below lake level about a mile before Swift Current is reached. The following species are to be obtained from the hard brownish stratum:

Pterotheca cf. attenuata *(Hall).*
Cyrtodonta cf. janesvillensis *(Ulrich.)*
Archinacella sp.
Lingula sp.

Leray member of Lowville.—The overlying strata consist chiefly of soft whitish limestones of variable character, which are reddish only where near one of the Pre-Cambrian quartzite ranges or knolls, whose weathered surfaces furnished the ferruginous matter included in the later strata. These limestones are referred to the Upper or Leray division of the Lowville, and terminate, at the top, in a series of very fine grained, much harder limestones, 11 feet (3·3 m.) thick, resembling the "Birdseye" limestone of New York. These "Birdseye" limestones are exposed at intervals for a distance of almost a mile along the railway south of Swift Current, and contain very few fossils. The immediately underlying strata, exposed along the same stretch of railway, especially in the immediate vicinity of Swift Current, where they rest directly on a quartzite knoll, contain a fauna sufficient to identify the horizon, although not usually well preserved. The more common fossils are:—

Escharopora ramosa (*Ulrich*).
Homotrypella instabilis *Ulrich*.
Monticulipora sp.
Rhinidictya fidelis (*Ulrich*).
Rhinidictya mutabilis (*Ulrich*).
Rhinidictya nicholsoni *Ulrich*.
Rhinidictya trentonensis (*Ulrich*).
Dalmanella cf. subæquata group
Rhynchotrema ainsliei *N. H. Winchell*.
Actinoceras bigsbyi (*Stokes*).
Bathyurus sp.

Black River Limestones.—Overlying the Leray division of the Lowville are darker limestones corresponding approximately to the Watertown limestones of New York and the Decorah shales of Minnesota. These are the beds to which formerly the term "Black River" was restricted, and these are the beds which present the best facilities for collecting. The lower part of the section, 80 feet (24 m) thick, with *Columnaria halli*, Nicholson, and a species of *Stromatocerium*, is exposed for a mile south of Swift Current. The upper part of the section occupies the remainder of the distance across Cloche island. The dip of these strata changes constantly, owing to their deposition among the ranges of Huronian quartzites and schists. The angle is so low and variable that it is impossible to determine, even approximately, the thickness of the various formations.

Species occurring only in the lower beds of the Black River:—

Stromatocerium rugosum *Hall*.
Columnaria halli *Nicholson*.

Species occurring in the upper half of the Black River; the forms marked * occur only at the top:—

*Calapœcia canadensis *Billings*.
*Columnaria alveolata *Goldfuss*.
*Petraia aperta *Billings*.
*Protarea vetusta *Hall, Billings*.
Receptaculites occidentalis *Salter*.
Solenopora compacta *Billings*.

Batostoma humile *Ulrich.*
Batostoma varium *U rich.*
Eridotrypa mutabilis *Ulrich.*
Nicholsonella ponderosa *Ulrich.*
Phyllodictya frondosa *Ulrich.*
Phylloporina sublaxa *Ulrich.*
Prasopora insularis *Ulr'ch.*
Dalmanella gibbosa (*Billings*).
Hebertella bellarugosa (*Conrad*).
Rafinesquina inquassa *Sardeson*
Conradella obliqua *Ulrich.*
Maclurea logani *Salter.*
Actinoceras bigsbyi (*Stokes*).
Gonioceras anceps (*Hall*).
*Eurostomites undatus (*Emmons*).
*Plectoceras sp.
Triptoceras sp.

Pleistocene glaciation.—The Black River strata on Cloche island have been planed down to very flat surfaces, exposing glacial striæ over wide areas. *Gonioceras anceps*, *Receptaculites occidentalis* and *Maclurea logani*, fossils abundant in the upper half of these Black River limestones, can be readily identified on the glaciated surfaces.

Goat Island.

Trenton (Curdsville).—The lowest Trenton strata exposed along the line of railway, occur near the northeastern shore of Goat island, and are referred to the Curdsville division of Kentucky. They contain many of the species found in the underlying Black River limestones, but with the absence of *Gonioceras*, *Receptaculites* and *Maclurea*, and with the presence of a number of crinoids and cystids not seen in the underlying strata. Among these, *Carabocrinus vancourtlandi*, Billings, is common, and *Glyptocrinus ramulosus*, Billings, is represented by numerous columns of large size, but by few calices. The crinoids and cystids belong to species characteristic of the lower Trenton at Kirkfield, Ontario, and at Curdsville, Kentucky.

The species confined to this horizon are given below in list A. Species common to this horizon and to the underlying Black River are given in list B.

List A.	List B.
Callopora multitabulata (*Ulrich*)	Streptelasma profundum (*Conrad*)
Eurydictya multipora *Hall*	Batostoma winchelli (*Ulrich*)
Monticulipora? cannonensis *Ulr.*	Homotrypa minnesotensis *Ulr.*
Rhinidictya minima *Ulrich*	Dalmanella testudinaria (*Dalman*)
Rhinidictya mutabilis (*Ulrich*)	Dinorthis pectinella (*Emmons*)
Carabocrinus vancourtlandi *Bill's*	Orthis tricenaria *Conrad*
Cleiocrinus regius *Billings*	Plectambonites curdsvillensis *Foerste*
Cyclocystoides halli *Billings*	Rhynchotrema inæquivalve (*Castlenau*)
Glyptocrinus ramulosus *Billings*	"Rhynchotrema" ottawaense (*Billings*)
Lichenocrinus sp.	Strophomena filitexta *Meek*
Reteocrinus alveolatus *Miller and Gurley.*	Bumastus milleri (*Billings*)
	Leperditia fabulites *Conrad.*

Stromatocerium horizon.—Overlying this Curdsville horizon is one in which *Stromatocerium* is abundant. There probably is an unknown interval between this and the Curdsville, since most of the specimens of *Stromatocerium* are found along the southwestern side of Goat island.

Prasopora simulatrix horizon.—The lowest strata found at the water's edge directly east of Little Current represent a higher Trenton horizon. In the lower part of the section in this locality, 5 feet (1.5 m) thick, *Prasopora simulatrix* occurs in argillaceous limestone, accompanied by other bryozoans suggesting an age approximately comparable with the *Nematopora* bed or upper Prosser of Minnesota. Fossils occurring in these beds are:—

Anthroclema billingsi *Ulrich.*
Callopora multitabulata (Ulrich).
Dekayella trentonensis (*Ulrich*).
Eridotrypa mutabilis *Ulrich.*
Mesotrypa infida (*Ulrich*).
Mesotrypa cf. whiteavesi (*Nicholson*).
Monticulipora arborea *Ulrich.*
Prasopora simulatrix *Ulrich.*
Rhinidictya fidelis (*Ulrich*).
Rhynchotrema inaequivalve (*Castlenau*).
Strophomena sp.

Collingwood black shales.—East of Little Current, at an elevation of 50 feet (15 m.) above the lake, black fissile shales, to which Raymond has applied the term "Collingwood", rest upon Trenton strata containing *Tetradium.* At the base, these Collingwood shales are interbedded with limestones similar lithologically to the Trenton limestones beneath. Formerly, these shales were identified with the Utica of New York, but they contain a different fauna such as the trilobite long known as *Asaphus*, now (*Ogygites*) *canadensis*, also *Triarthrus fischeri*, and others. A thickness of only 11 feet (3.4 m.) of Collingwood shale is exposed on the hill east of Little Current, but the total thickness equals at least twice that amount. Three miles (4.8 km.) southeast of Little Current, on the "shore road" to Sheguindah, the Collingwood shales are overlaid by softer clay shales which form the base of the undoubted Cincinnatian section.

The common Collingwood fossils are:—

Diplograptus quadrimucronatus *Hall.*
Ogygites canadensis (*Chapman*).
Triarthrus fischeri *Billings.*

THE SILURIAN OF THE EASTERN PART OF MANITOULIN ISLAND.

BY

MERTON Y. WILLIAMS.

INTRODUCTION.

History.—Manitowaning to-day shows few traces of its early history. Storehouses and a grist mill occupy the land jutting out from the front of the escarpment; the main town is on a higher level a short distance inland. A few buildings occupy the intermediate terraces, and on the rising slope above the wharves, the low rambling Indian Agency stands with its official flagstaff, though stripped of the stockade which once surrounded it. Where the agency now is, 1,500 Indians representing the Chippewa, Ottawa and Saugin tribes, gathered in council, and consented to give up their control of the islands of Georgian bay and adjacent regions for a home on the Grand Manitoulin. The treaty referred to was made with Sir Francis Bond Head, Governor of Upper Canada (now Ontario) in 1836. Since then most of the island, being unoccupied

Manitowaning from the south. Manitoulin island, Ontario.

by the Indians, has been bought by white settlers and the aborigines are now confined to the reserves, the largest of which lies directly across the bay from Manitowaning. Besides being the home of the Indian Agent and the Indian doctor, Manitowaning enjoys a thriving trade with the Indians from the reserve.

Physiography.—The cuesta land-forms, so characteristic of the Palæozoic formations of the Georgian Bay region, are well developed in the vicinity of Manitowaning. The village is situated upon limestone strata of Richmond age which present a steep though sinuous front to Manitowaning bay. Inland, the firm dolomite of the Cataract formation rises as a low escarpment with irregular outline, and farther south, the Lockport dolomite rises as impressive cliffs 100 to 200 feet (30-60 m.) in height. This remarkable series of escarpments is the result of the wearing back from the Pre-Cambrian oldland of the edges of alternating hard and soft strata. The cliff-forming strata are either limestone or dolomite, and are underlain without exception by soft shales. The land surfaces, excepting the escarpments, are fairly level and tend to dip with the formation to the southwest at about 50 feet per mile (15 m. per 1.6 km.). Locally, glacial abrasion and glacial debris in the form of mounds and ridges have tended to confuse the otherwise symmetrical physiographic forms. Sorted, waterworn gravel, found in some localities, indicates the former submergence of all but the highest parts of the island.

Silurian Section.

The Silurian of Manitoulin island has been divided into two formations. The lower for which the term *Cataract* has recently been proposed, consists of 50 to 60 feet (15-18 m.) of dolomite overlain by 27 to 66 feet (8.2 to 20.1 m.) of red clayey shale. The upper or Lockport (Niagara) formation consists of at least 240 feet (73 m.) of dolomite.

Cataract formation.—The Cataract strata rest with apparent conformability upon the green shales at the top of the Richmond formation. The dolomite near the base is thin-bedded and argillaceous; midway up, thick beds of massive dolomite occur; and thin beds are again present near the top. Bryozoan and coral reefs, several yards in diameter, frequently occur within the upper 20 feet (6 m.) of the formation, and appear to have caused local thickening of the dolomite. In the lower shaly argillaceous dolomite, ramose bryozoans are plentiful and about 10 feet (3 m.) above the base *Leptæna rhomboidalis* has been sparingly found. The characteristic fossils of the formation occur mostly in the upper beds and are:—

Clathrodictyon vesiculosum *Nicholson and Murie.*
Acervularia gracilis (*Billings*).

Diphyphyllum cf. huronicum (*Rominger*).
Diphyphyllum multicaule (*Hall*).
Favosites aspera *d'Orbigny*.
Halysites catenulatus microporus (*Whitfield*).
Zaphrentis bilateralis (*Hall*).
Apiocystites tecumseth (*Billings*).
Pachydictya crassa (*Hall*).
Anoplotheca planoconvexa (*Hall*).
Atrypa cf. marginalis (Dalman).
Camarotoechia neglecta (*Hall*).
Orthis flabellites *Foerste*.
Platystrophia biforata (*Schlotheim*).
Rhipidomella hybrida (*Sowerby*).
Schuchertella subplana (*Conrad*).
Whitfieldella nitida (*Hall*).
Cyclonema cancellatum *Hall*.
Orthoceras sp.

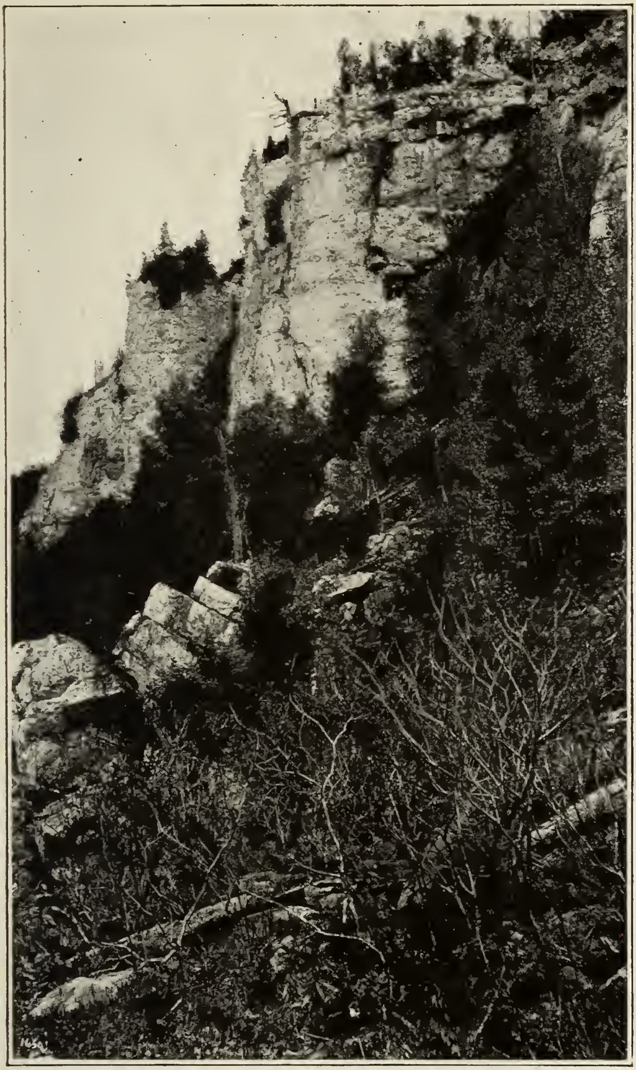
This formation is found to be the same as the *Cataract* at Cataract, Hamilton, and other places along the Niagara cuesta. It was formerly confused with the Clinton, but it undoubtedly lies below the typical Medina sandstone with *Arthrophycus*. On this account it has been erected into a new formation and includes the Whirlpool sandstone. (See guide books to Excursions B3 and B4.)

The shale of the Cataract formation has a clayey texture and is generally of an iron red colour. Some green discoloration occurs near the top due to leaching and consequent reduction of the iron bearing minerals. fossils have been found in the shale.

Lockport (Niagara) formation.—The Lockport formation consists of thin-bedded to thick-bedded, massive dolomites. At the base, directly above the red Cataract shale, the dolomite is thin-bedded and arenaceous, containing numerous *Pentamerus oblongus*.

A sparing coral fauna starts about 80 feet (24·4 m) above the base of the formation and reaches its maximum about 100 feet (30 m.) up. The last 30 feet (9·1 m.) of the formation, as occurring in the thickest sections studied, is massive and nearly unfossiliferous. The most characteristic fossils from the Lockport of Manitoulin island are:—

Arachnophyllum pentagonum (*Goldfuss*).
Arachnophyllum striatum (*D'Orbigny*).



Cliffs of Lockport dolomite, Thornbury, Ontario.

Chonophyllum belli (*Billings*).
Coenites laminata (*Hall*).
Cladopora laqueata *Rominger.*
Cyathophyllum radicula *Rominger.*
Diphyphyllum multicaule (*Hall*).
Favosites gothlandica (*Lamarck*).
Heliolites interstincta (*Linnaeus*).
Heliolites megastoma *McCoy.*
Heliolites pyriformis *Guettard.*
Omphyma verrucosa *Rafinesque and Clifford.*
Syringopora retiformis *Billings.*
Zaphrentis umbonata *Rominger.*
Orthis flabellites *Foerste.*
Atrypa sp.
Pentamerus oblongus *Sowerby.*
Stricklandinia sp. nov.
Platyostoma sp.
Orthoceras sp.

This formation above described is correlated on fossil evidence with the Lockport dolomite of New York State which is of Niagara age. It is this formation which forms the escarpment at Niagara Falls, and the almost continuous escarpment from Niagara to Manitoulin island.

Fossill Hill.

For 1·6 miles (2·57 km. south of Manitowaning the Richmond formation has produced a soil of excellent quality. In a corner of a field near the road the iron casing of a drill-hole may be seen. This is one of the many prospect holes driven within the past few years to test the oil production of the Trenton formation, here lying about 500 feet (152·4 m.) below the surface. Oil has generally been obtained, but so far, it is claimed that the quantity has not been sufficient to encourage the development of the field.

At the foot of a small hill, 1·6 miles (2·5 km.) from the village, the obscured contact between Ordovician and Silurian starata is crossed. East of the road, sorted gravel is exposed in a small pit. About 0·6 miles (0·7 km.) farther south, Cataract dolomite outcrops forming a prominent hill. The rock is composed of fossil coral reefs which appear to have thickened the dolomite locally. Several of the corals common in the Cataract formation occur here. Farther south, the dolomite cliffs may be seen extending to the southeast. The road leads through fair farming country, but the good land is often interrupted by swamps, rock or glacial boulders. South of a small church, glacial mounds and ridges occur, and glacial materials obscure all else from there to Fossil Hill.

A long climb past the exposed edge of Lockport strata leads to the top of a plateau. A short distance to the north, along a beautifully wooded road, opportunity is afforded for collecting from the remains of a remarkable Lockport coral reef. Just below the little south-sloping grade, the ground should be carefully searched on both sides of the road. The Lockport corals are nearly all represented here, as well as other Lockport fossils including *Pentamerus oblongus.*

To the north of Fossil Hill, still higher beds of the Lockport formation are preserved, the dolomites measuring 240 feet (73 m.) in thickmess. The Fossil Hill horizon corresponds with that of maximum faunal development about 100 feet (30 m.) from the base of the formation.

THE ROCK.

The prominent escarpment, known as "The Rock", situated a short distance southwest of Manitowaning, is composed of dolomite of the Cataract formation. If one ascends the rock and continues westward from the brow for half a mile, a rocky knoll covered with sumach bushes will be observed. Here, the massive, jointed rock is composed of the remains of a coral reef. The reef builder appears to have been *Diphyphyllum* cf. *huronicum* which was associated, particularly near its edges, with *Orthoceras* sp., stromatoporoids and crinoid colonies, the latter represented by numerous columnar remains. Other fossils found at this locality are:—

Chonophyllum belli *Billings.*
Diphyphyllum multicaule (*Hall*).
Favosites *aspera d'Orbigny*
Halysites catenulatus micropora *Whitfield.*
Orthis flabellites *Foerste.*
Platystrophia biforata (*Schlotheim*).
Rhipidomella hybrida (*Sowerby*).

Northward the rock drops sheer for about 30 feet (9.1 m.) and great open joints are preparing the way for further recession of the front of the formation. In one place, a pinnacle of rock has been undermined and has tilted away from its original place, forming what is locally known as the "Devil's Needle". East of this point, a descent may be made, and the coral reef and underlying strata may be studied in section. A thickness of 40 feet (12.2 m.) in all is exposed along the cliff front. The upper 12 feet (3.6 m.) of strata are, in places, decidedly massive, the next 3 or 4 feet (.9 or 1.2 m.) are thin-bedded, and below these again the formation is massive. Few fossil remains appear on the edges of the strata.

A general prospect of Manitowaning bay and the surrounding country may be obtained from this cliff. The pole tripod to the north of the main road marks the location of a drill hole which taps the Trenton at a depth of about 440 feet (134 m.) and always contains some oil. Three other wells were drilled nearby, one to the west being 566 feet (172.5 m.) in depth.

From the Devil's Needle, a path leads easterly across partly-wooded pasture land to flat fields with much exposed rock. Some time may be profitably spent here collecting fossils. Nearly all the brachiopods and most of the corals common in the Cataract formation occur at this locality. It was from South bay that the type specimens of *Apiocystites tecumseth*, Billings, were obtained. The species is to be found at this locality. Continuing eastward the edge of the dolomite is soon reached and nearby is a small bryozoan reef, easily located by its outcrop, a mound of massive rock. The reef extends about 100 feet (30 m.) along the edge of the cliff, and is probably 20 feet (6 m.) thick at its centre. Its relation to the regularly bedded strata may be seen from the top of the cliff. Small ramose bryozoa, together with a small branching coral, appear to have been the reef builders. Small growths of *Favosites* and little cup corals lived about the reefs, as did also some brachiopods, e.g. *Platystrophia biforata*. About 0·05 mile farther south, a still larger reef occurs. An opportunity for examining a good section of this repays one for the trouble of climbing down over the edge of the beds among the loose rocks. Massive rock from 12 to 20 feet (3.6 to 6 m.) thick interfingers at its edges with bedded rock, and some of the underlying strata are flexed downwards. The reef has been of elliptical outline and is now about 300 feet (91 m.) long by 20 feet (6 m.) wide. The main rock mass appears to have been made up of the remains of *Diphyphyllum* cf. *huronicum* and small ramose bryozoan remains. Fossil Hill and "The Rock" furnish representatives of the whole Silurian section except the red Cataract shales which are nearly everywhere obscured.

Richmond exposures.—Northward from the fossil reef above described and about .4 of a mile south of the school, good exposures of the Richmond may be seen in a field. This horizon contains *Stromatocerium* and is probably 20 feet (6 m.) below the base of the Cataract dolomite. Some distance northward from this point along the shore of Manitowaning bay, a small water channel has worn its way into the edges of the Richmond limestones and shales. Some rather unsatisfactory exposures of limestone interbedded with shale may be seen between the top of the escarpment and the road. The section down to the water's edge consists of 12 feet (3.6 m.) of limestone at the top, underlain by interbedded grey limestone and soft shale. About 21 feet (6.4 m.) above the lake a six foot (1.8 m.) bed of firm limestone outcrops. Fossils are most plentiful in the lower beds, but may be found throughout the section. The talus along the water's edge contains many of the larger fossils, especially the corals. Graptolites occur in a firm, green, limy shale at the water's edge. Fossils found at this locality include:—

Beatricea undulata *Billings.*
Columnaria alveolata *Goldfuss.*
Streptelasma rusticum *Billings.*
Tetradium fibratum *Safford.*
Rafinesquina *sp.*
Rhynchotrema capax (*Conrad*).
Zygospira kentuckiensis *James.*
Byssonychia radiata (*Hall*).
Orthoceras sp.

THE KILLARNEY PASSAGE.

The little village of Killarney, on the north shore of Lake Huron, is a picturesque and interesting point. As the centre of an extensive fishing industry, Killarney enjoys a certain commercial prosperity, while the magnificent scenery in the vicinity has made it an objective point for the tourist.

On entering Killarney bay from the south-west, the white peaks of quartzite rising to an elevation of nearly 1,000 feet (304 m.) above the lake form an impressive scene, which is enhanced by the scattered patches of dark green evergreens. The quartzite ranges are separated from the Laurentian gneisses to the east by a belt of granite, which forms the greater part of George island, between which and the mainland lies the Killarney passage. This channel is a straight east and west depression in the granite, of sufficient depth to allow the passage of large vessels. On Badgeley point, to the westward, a similar depression is cut almost to the water level. Here several dykes of greenstone run parallel to the depression, and a dyke of like material occurs in the granite south of the Killarney passage. It is probable that these depressions are in some way connected with the occcurrence of greenstone dykes [**33**].

THE PRE-CAMBRIAN OF PARRY ISLAND AND VICINITY.

BY

T. L. Walker.

Along the eastern shore of Georgian bay, from Killarney to the mouth of the Severn river, the rock formations are almost entirely made up of crystalline schists with numerous intrusions of acid and basic rocks. Some of the schists are derived from the alteration of igneous rocks, while others represent metamorphosed sediments.

In the vicinity of Parry Sound the general strike of the schists is north-easterly with a dip toward the south-east. Along the channel between Parry island and the mainland, the rocks are well exposed and exhibit outcrops of crystalline limestone, hornblende and biotite gneisses, and hornblende schist, while the intrusives are represented by anorthosite, gabbro, and granite. These igneous types have been subjected to such great pressure as to present massive and foliated types closely associated with one another.

Locality 1.—Half a mile east of the Indian village on Parry island, the shore rock is entirely made up of massive gabbro. The rock consists of purplish plagioclase, fresh augite, and a little red garnet.

Banded gneiss near Sans Souci, Georgian bay, Ontario.

Locality 2.—On the peninsula to the east of the deep bay one mile and a half east-northeast of Locality 1 the same type of gabbro may be seen, but is here intimately associated with pressure products. Sometimes the only change is the granulation of the rims of the plagioclase, as is shown by the white border surrounding the purplish unaltered plagioclase core. In other places the alteration in structure may be traced through flaser gabbro, augen gabbro, gabbro schist to a garnetiferous gneissoid rock. The shore of Parry island, from the railway bridge to

Locality 1, is composed of rocks genetically related to gabbro.

Locality 3.—At the Bear's Head, near the entrance to the bay at the extreme south of Parry island, three rock types are observed. On the west shore of the bay, anorthosite forms high ridges bordered on the east by crystalline limestone. The strike of these rocks is north-northeast, with a dip to the eastward. The anorthosite exhibits slight parallelism near the contact with the limestone, but a few rods to the west it becomes quite massive. The east shore of the bay is made up of gneisses, more or less hornblendic, and following the same dip and strike as the anorthosite, and limestone.

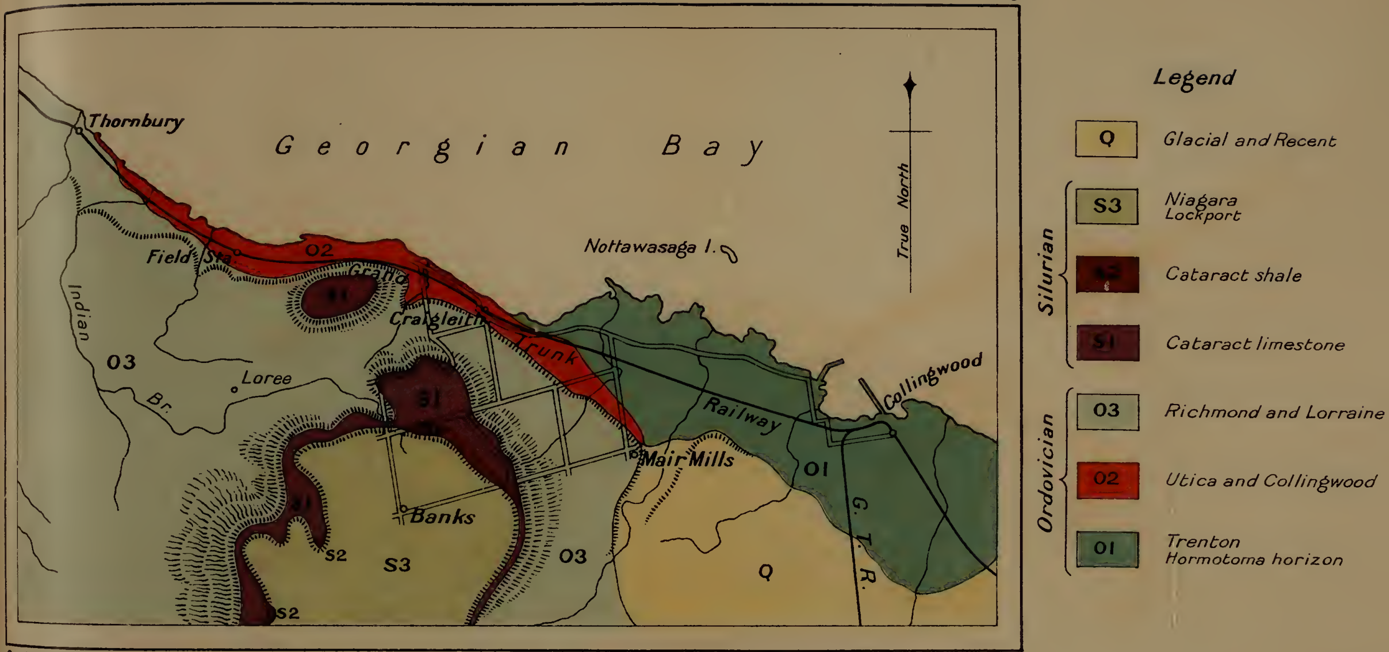
Locality 4.—Pierce island, 3 miles (4·8 km.) south of the Bear's Head, exhibits crystalline schists of a different type. The rock is composed of alternate layers of light and dark bands, wonderful for the sharpness of the boundary lines between the bands and for the persistence of the individual members. This complex strikes north and south and has a vertical dip. The dark bands are largely of hornblende with smaller proportions of plagioclase, while the light bands represent a fine grained granite. The rock in the individual bands is always massive. The material of this banded complex appears to be igneous, but it is difficult to conceive of conditions accounting for the peculiar relationship exhibited.

Locality 5.—The rocks along the east shore of the channel between Pierce island and Parry Sound closely resemble those exhibited at Locality 4, except that the strike swings to the northeast, while the dip to the southeast is quite marked. The channel appears to indicate a line of great pressure, as may be seen at Locality 5 on the east side of Isabella island, where a very granular grey gneiss may be observed showing large augen of orthoclase and hornblende.

PALEOZOIC SECTION AT COLLINGWOOD.

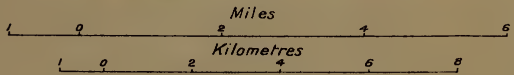
The town of Collingwood has a population of about 8,000: it is situated on an excellent harbour, and has long been known as a port and shipbuilding centre.

The Blue mountains are visible from Collingwood and rise to a height of more that 1,000 feet (304 m.) above the



Geological Survey, Canada

Route map between Collingwood and Craigleith



lake. In the immediate vicinity of the town the elevation i- -bout 850 feet (259 m.) in which the following geological succession is presented:—

	THICKNESS.	
	Feet.	Metres.
SILURIAN.		
10–Lockport dolomite....................	75	22·8
9–Cataract shales......................	35–40	10·6–12
8–Cataract limestone....................	15	4·5
ORDOVICIAN.		
7–Richmond red and green shales.........	235	71·1
6–Richmond grey shales and limestone....	50	15·2
5–Lorraine shales and arenaceous limestone.	190	57·7
4–Eden shales..........................	175	53·2
3–Utica shales (Upper Utica)............	50–55	15.2–16.7
2–Collingwood shales (Lower Utica)......	25	7·6
1–Trenton limestone (at water level)......	?	?

Trenton formation.—The upper Trenton limestone (*Hormotoma* zone) is exposed on the shore line a short distance west of Collingwood. The strata are of little vertical extent, but they are rich in the fossi!s characteristic of the upper zone of the Trenton. The more common species are as follows:—

Corals—
Streptelasma sp.

Brachiopods—
Cyclospira bisulcata (*Emmons*). Abundant.
Dalmanella testudinaria (*Dalman*). Abundant.
Hebertella bellirugosa (*Conrad*). Rare.
Lingula cobourgensis *Billings*. Abundant.
Lingula sp.
Platystrophia biforata (*Schlotheim*). Rare.
Plectambonites sericeus (*Sowerby*). Abundant
Rafinesquina alternata (*Emmons*). Abundant.
Rafinesquina alternata nasuta (*Conrad*). Abundant.

Gastropods—
- Conularia trentonensis (*Hall*). Abundant.
- Cyclonema sp.
- Fusispira notabilis *Ulrich*. Rare..
- Fusispira sulcata *Ulrich*. Rare.
- Hormotoma bellicincta (*Hall*). Rare.
- Hormotoma gracilis (*Hall*). Rare
- Hormotoma trentonensis *Ulrich*. Abundant.
- Liospira angustata *Ulrich*. Rare.
- Protowarthia cancellata (*Hall*). Rare.

Pelecypods—
- Ambonychia sp.
- Vanuxemia obtusifrons *Ulrich*. Abundant.

Cephalopods—
- Orthoceras sp.

Trilobites—
- Bronteus sp.
- Calymmene callicephala *Green*. Common
- Ceraurus pleurexanthemus *Green*. Fairly common.
- Isotelus gigas *Dekay*.

Collingwood formation.—Resting directly on the Trenton limestones is a series of thin bedded limestones and dark bituminous shales, which is characterized more particularly by the presence of *Ogygites canadensis*, (*Chapman*). Raymond considers that this series of limestones and shales lies below the typical Utica of New York and has proposed the name "Collingwood" for the formation. The chief fossils are as follows:—

Graptolites—
- Climacograptus bicornis (*Hall*).

Brachiopods—
- Dalmanella testudinaria (*Dalman*).
- Lingula cobourgensis *Billings*.
- Lingula modesta *Ulrich*.
- Lingula progne *Billings*.
- Rafinesquina alternata (*Emmons*).
- Rafinesquina deltoidea ((*Conrad*).
- Rafinesquina minnesotaensis (*Winchell*)
- Zygospira modesta (*Hall*).
- Conularia trentonensis *Hall*.

Pelecypods—
- Ctenodonta medialis *Ulrich.*
- Modiolopsis nana *Ulrich.*

Cephalopods—
- Endoceras proteiforme *Hall.*

Triolbites—
- Calymmene callicephala *Green.*
- Ceraurus sp.
- Ogygites canadensis (*Chapman*).
- Triarthrus beckii *Green.*

Utica formation.—Overlying the Collingwood formation is a series of shales of a somewhat less bituminous character which is correlated with the typical Utica of New York. The more common fossils are:—

- Dalmanella testudinaria (*Dalman*).
- Leptobolus insignis *Hall.*
- Plectambonites sericeus (*Sowerby*).
- Rafinesquina alternata (*Emmons*).
- Endoceras proteiforme *Hall.*
- Calymmene callicephala *Green.*
- Triarthrus spinosus *Billings.*
- Ostracods *sp. indet.*

Eden formation.—At Craigleith, the Eden shales are exposed directly above the Utica. The common fossils are:—

- Dalmanella testudinaria emacerata (*Hall*).
- Plectambonites sericeus (*Sowerby*).
- Trinucleus concentricus *Eaton.*

Lorraine formation.—The Lorraine shales are not actually exposed at this point but the fossils characteristic of the formation may be obtained from the talus. The species are the same as those already mentioned from the Clay Cliffs, Manitoulin island.

Richmond formation.—The grey Richmond shales and limestones are not exposed in the section at Craigleith, but they show to better advantage on the road between Mair's Mills and Banks. The fossils are practically the same as those from the Richmond exposure at the Clay Cliffs, Manitoulin island.

The red and green shales of the Richmond are not well exposed, but fossils characteristic of the formation are common in the talus derived from this member. This fact is of great stratigraphic importance, as farther south the member is entirely unfossiliferous and has been ascribed to the Medina.

Cataract formation.—The lower Cataract limestones and shales contain practically the same fauna as at Cataract (See guide book to Excursion B 4).

The upper or more shaly part of the Cataract is very much covered with talus, nevertheless some fossils characteristic of the formation may be obtained from this member.

Lockport formation.—The heavy dolomitic limestone of the Niagara (Lockport) forms the top of the section, and, owing to its white appearance, constitutes a conspicuous element in the landscape. Percolating waters have formed some interesting caves in the dolomite near Mair's Mills. A few fossils may be collected here, but the locality is by no means a rich collecting ground for Lockport species.

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GUIDE BOOK No. 6

EXCURSIONS

IN

Vicinity of Toronto and to Muskoka and Madoc

(EXCURSIONS B 2, B 5, B 6, B 8 and B 10)

ISSUED BY THE ONTARIO BUREAU OF MINES
TORONTO, CANADA

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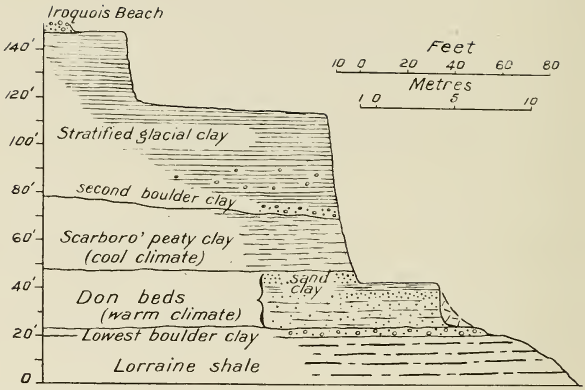
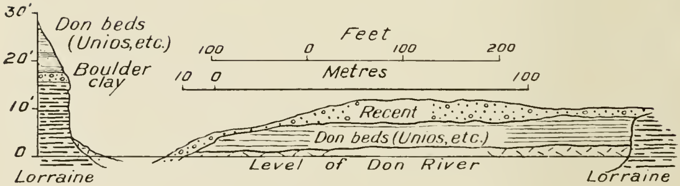


Section at Don Valley Brickyard, Toronto



Section at Bend of Don River

GUIDE BOOK No. 6

Excursions in Vicinity of Toronto and to Muskoka and Madoc.

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EXCURSION B 2.

TORONTO AND VICINITY.

BY

A. P. COLEMAN.

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Map of Toronto and Vicinity, scale of 1 mile to 1 inch.

INTRODUCTION AND GEOLOGICAL SUMMARY.

Toronto began about 100 years ago as a village at the mouth of the small river Don, where a sand bar, now called Toronto island, enclosed an excellent harbor. It has since expanded six miles west to the Humber river, four or five miles to the east and as much to the north. Its geographical centre is not far from the Meteorological Observatory, on Bloor street West, which is in lat. 43° 40′ 0″.8 and long. 79° 23′ 54″. Toronto is situated on the north shore of lake Ontario about forty miles from its western end.

In discussing the geology of the region it will be advisable to include the suburbs of the city as far east as Highland creek, 13 miles from the Don, and as far north as York Mills, 6 miles from Toronto bay.

Physiographically the region may be divided into two parts, a terrace formed by ancient lake Iroquois, sloping gently upwards from lake Ontario to a height of 176 to 200 feet, and a somewhat higher upland formed of rolling hills of glacial origin, reaching at its highest points 380 feet above the lake, which is 246 feet above the sea.

The comparatively level surfaces of the terrace and the morainic region beyond are broken by the deep valleys of the Don and Humber rivers and their tributaries, which have been cut almost to base level for a mile or two from the shore and ramify as steep walled ravines for several miles inland.

The lake shore is greatly varied, including the flat sand and gravel spit which projects westwards from the Don and then bends northward to enclose Toronto bay, as well as the cliffs of Scarboro heights to the east, which rise 355 feet above the water and form the highest point on the whole shore of lake Ontario. This line of cliffs, extending for nine and a half miles, has been carved by wave action from an ancient promontory and has provided the materials which have been transported ten miles west by the easterly storms to build up Toronto island.

The vicinity of Toronto includes only small outcrops of solid rock, Lorraine shale of Ordovician age; but has a varied and interesting series of Pleistocene deposits unequalled in complexity and importance by any other North American locality. Its thick series of interglacial beds, the Toronto Formation, gives evidence of an interglacial time far longer than the post-glacial period and with a warmer climate than that of the present.

The geological succession may be arranged as follows:

Recent—River and lake Deposits.

Pleistocene:
- Iroquois Beach Materials.
- Glacial complex (four beds of till with interstratified clay and sand).
- Toronto Interglacial Formation (Scarboro beds, Don beds).
- Earliest Boulder clay.

Palæozoic—Lorraine shale.

These will be described in succession from below upwards.

THE LORRAINE SHALE.

The bed rock of Lorraine shale (Ordovician or Lower Silurian) is generally buried under the drift deposits of the Pleistocene and comes to the surface at comparatively few points and in a quite inconspicuous way. Along the western lake front on Humber bay there are low outcrops rising not more than two or three feet above the water at Exhibition park and west of the Humber river. The shale rises higher along the sides of the river valleys, forming cliffs that reach 30 or 40 feet within the first three or four miles up the Humber, and 10 to 16 feet at the "Bend of the Don," about two miles from the mouth of the river.

All of these natural outcrops are greatly weathered, as might be expected in so easily attacked a rock as shale, and only the harder limey or sandy layers resist the action of rain and frost.

Artificial exposures in connection with the brickyards give the best opportunities to study the unweathered rock, the one most easily reached being at the Don Valley brickyard, where a great open pit from which shale is being quarried shows 60 feet of the formation. There are thin seams of impure limestone at frequent intervals in the shale and these have to be selected out before it is crushed for brickmaking. The weathered surfaces of the discarded limestones provide the best fossils in the Don region. The brickyard may be reached by taking a Church street car to Glen road, walking north to Binscarth road and then east to the edge of the Don valley, where a path leads down to the shale pit.

There are numerous exposures of the shale along the Humber extending from near lake Ontario to Lambton Mills, two and a half miles up. The best outcrop for a study is just south of the bridge over the Humber at Lambton, where the river flows rapidly over the harder beds, many slabs of which are exposed along its shores. Here, in addition to the limestone layers, there are well ripplemarked sheets of shaly sandstone. The surfaces of the slabs display not only fossils, but a variety of markings supposed to be due to physical causes.

About two miles further up the valley on the west side there is a large shale pit from which materials are got for the manufacture of paving brick. This also affords a good collecting ground. The Lambton outcrops may be reached by taking a Dundas street car to the end of its route and then a Lambton suburban car to Lambton Mills.

The fossils found on the Humber differ somewhat from those at the Don brickyard, as determined by Prof. Parks, the western shale belonging to a somewhat higher horizon owing to a gentle southwesterly dip of the beds. Many of the fossils, however, are common to the two localities, and they are not separated in the list prepared by Prof. Parks. The most striking fossil is *Isotelus maximus* (sometimes called *Asaphus platycephalus*), which is occasionally ten inches in length. The fauna of the Don beds contains some species typical of the Eden of Ohio, while the Humber beds more closely resemble the Lorraine of New York.

List of fossils at Toronto.

Hydrozoa:—
Diplograptus pristis, Hisinger.
Echinoderms:—
Glyptocrinus decadactylus, Hall.
Heterocrinus juvenis, Hall.
Iocrinus subcrassus, M. and W.
Palasterina rugosa, Bill.
Vermes:—
Nereidavus varians, Grinnell.

Brachiopods:—

Leptæna rhomboidalis, Wilckens.
Rafinesquina alternata, Emmons.
Plectambonites sericeus, Sowerby.
Schizocrania filosa, Hall.
Zygospira modesta, Conrad.
Catazyga erratica, Hall.
Dalmanella testudinaria, Dalman.
Lingula sp.
Trematis millepunctata, Hall.
Schizambon cf. *lockei,* W. and S.

Gastropods:—

Crytolites ornatus, Conrad.
Lophospira cf. *perangulata,* Hall.
Protowarthia cancellata, Hall.
Archinacella, sp.

Pelecypoda:—

Byssonychia grandis, Ulrich.
Byssonychia radiata, Hall.
Byssonychia imbricata, Ulrich.
Byssonychia alveolata, Ulrich.
Whiteavesia pholadiformis, Ulrich.
Modiolopsis concentrica, Hall and W.
Modiolopsis modiolaris, Conrad.
Cymatonota recta, Ulr.
Cymatonota, pholadis, Ulr.
Orthodesma parallelum, Hall.
Orthodesma parvum, Ulr.
Lydrodesma poststriatum, Emmons.
Whitella hindi, Bill.
Whitella ventricosa, Ulr.
Cleidophorus neglectus, Hall.
Psiloconcha inornata, Ulr.
Modiolodon obtusus, Ulr
Pterinea demissa, Hall.
Ctenodonta cf. *carinata,* Ulr.

Cephalopoda:—

Orthoceras crebriseptum, Hall.
Endoceras proteiforme, Hall.

Pteropods:—

Conularia formosa, Miller and Dyer.
Tentaculites starlingensis, Meek.

Bryozoa:—

Heterotrypa frondosa, D'Orbigny.
Heterotrypa inflecta, Ulr.
Monotrypa undulata hemispherica, James.
Amplexopora discoidea, Nicholson.
Bythopora delicatula, Nich.
Leptotrypa irregularis, Ulr.
Arthropora schafferi, Ulr.
Peronopora vera, Ulr.
Spatiopora cf. *maculosa*, Ulr.
Atactopora maculata, Ulr.
Dekayella ulrichi, Nich.
Bythopora arctipora, Nich.
Aspidopora, sp.
Paleschara beani, James.
Chiloporella, sp.
Callopora subplana, Ulr.
Callopora dalei, M-E and H.
Bythopora gracilis, Nich.
Hemiphragma whitfieldi, James.

Trilobites:—

Isotelus maximus, Locke.
Calymene callicephala, Green.
Trinucleus concentricus, Eaton.

PLEISTOCENE BEDS.

The surface of the shale beneath the city had a high relief before the first Pleistocene ice sheet moved down upon it. A wide valley had been carved 200 feet below the general level by a great river which flowed south from the present Georgian bay region, the Laurentian river of Dr. Spencer. Probably a thick layer of preglacial weathered material once covered the surface, as the region is supposed to have been dry land since Palæozoic times, but this was completely swept away, perhaps by the advancing ice, leaving no record between the Ordovician and the end of the Pliocene.

Immediately upon the ancient marine shale one finds a sheet of boulder clay formed by land ice; and succeeding it in some places there are four other till sheets, each separated from the one below by interglacial beds of stratified gravel, sand and clay, piled up at Scarboro' to a thickness of nearly 400 feet.

The earliest and most important interglacial series includes 185 feet of delta deposits; but the later ones are seldom more than 30 or 40 feet in thickness, and may represent relatively short recessions of the ice. The retreat of each ice sheet in the series was doubtless followed up by a great glacial lake in which stratified deposits were formed. That of the latest (Wisconsin) ice sheet was accompanied by the waters of lake Iroquois, which lasted for thousands of years and left behind the terrace and gravel bars and shore cliffs which are such marked physiographic features at Toronto.

The earliest sheet of till consists of tough blue clay, evidently made largely from the local shale, and containing many angular slabs of its harder layers picked up close by. With them occur some well rounded polished and striated boulders of blue Trenton limestone, smaller boulders of black Utica shale, and many large or small boulders of granite, gneiss, greenstone or schist from the Archæan. No smoothed or striated surface has been found beneath the lowest boulder clay, which seems to pass down into the disturbed Lorraine shale; but the direction of the ice motion is indicated by the boulders of Utica and Trenton rocks, which are found in place in eastern Ontario.

The lowest boulder clay is usually not more than three or four feet thick, and in a few places it is wanting, having been swept away by interglacial rivers. Its best exposure is in a shore cliff near the west end of King street in Parkdale, where it rises four or five feet above the lake and is capped for 800 feet by a well-laid boulder pavement. Above the pavement there are 25 or 30 feet of less solid till formed by the next ice advance, with no interglacial beds intervening.

The flat upper surfaces of the stones in the boulder pavement are usually well and uniformly striated, the direction ranging from 290° to 315° with an average of 300°. The striæ run 30° north of west instead of south of west, as might have been expected. The glacial lobe which had followed the depression of lake Ontario from the east began to spread out towards its west end. A similar boulder pavement occurs in a shore cliff near Port Credit ten miles to the west.

Such boulder pavements imply a long interval between the two ice sheets in which the weather or running water or more probably wave action could remove the clay and allow the boulders to accumulate on the surface. The second ice sheet must have come on gently at first until the boulders were firmly sunk into the clay below, so as to withstand the later grinding, polishing and striation.

THE TORONTO FORMATION.

After the recession of the first ice sheet there was a long period of erosion and river action, in places removing the boulder clay and cutting down into the shale. Afterwards a great lake filled the basin, laying down the beds of clay, sand and gravel of the Toronto Formation upon the eroded surface.

The Toronto Formation is naturally divided into two parts, the lower being the Don beds and the upper the Scarboro beds. These two divisions differ greatly in their fossils and were formed under different climatic conditions, the Don beds including fossils proving a warmer climate than the present and the Scarboro' beds others that indicate a cooler climate. The two are never well displayed in the same exposure, but the order of succession is certain, and there are places which show the Don beds underlying conformably the lowest portion of the Scarboro' beds. Both were probably delta deposits, though of different types; but in the western part of Toronto there are interglacial beds having the tumultuous cross bedding and irregularity characteristic of strong currents and probably formed by a large river. The exact position of these beds with reference to the others is not quite certain, though they belong to the same interglacial period.

THE DON BEDS.

The best outcrop of the Don beds is to be found just north of the shale pit referred to before in the Don Valley brickyard, to the east of Rosedale. The Pleistocene section is 130 feet in thickness and includes not only the Don beds, but an overlying series of unfossiliferous clays which were formed much later when the ice front was not far off.

The section is divided into three parts corresponding to the three working levels of the clay pit, and rises to the Iroquois terrace.

Resting on the shale there are three feet of boulder clay, followed by from 14 to 17 feet of stratified materials, consisting of a foot or two of bluish clay below and brown or yellow sand with thinner clay beds above, the whole somewhat irregularly distributed probably by a river coming into a lake 60 feet higher than lake Ontario at present.

Interglacial Beds at Bend of Don River.

This exposure is highly fossiliferous, some beds being crowded with shells, while flattened trunks and branches of trees often occur, and in one thin layer of clay, now run out, many leaves of trees have been found.

Ascending above this part of the section one must go about 50 feet farther north to find its continuation. The next bed is of blue clay 3½ feet thick above which there are five feet of yellow and brown sand, the last member of the characteristic Don beds. The total thickness above the lower boulder clay is from 23 to 25 feet. The brown sand was evidently deposited in shallow water where oxidation was taking place, since some of the coarser beds of gravelly sand in the section are cemented with limonite.

Bluish gray finely laminated clay, overlying the Don beds conformably to a thickness of from 7 to 22 feet, was laid down in much deeper water, and shows no fossils except a little peaty matter. It represents the lowest part of the Scarboro beds.

A thin sheet of boulder clay, the second in order, rests upon the eroded surface of the stratified clay just mentioned, followed by 80 feet of rather coarsely laminated clay sometimes containing subangular striated stones. The source from which this clay was derived must have been the ice margin not many miles away. The lower stratified clay, which is interglacial, is formed of well leached material and burns to red brick; while the overlying stratified clay is so strongly charged with lime as to burn to a buff brick.

The top of the section consists of a few feet of brown sand and loam with large boulders, resulting from the wave work of lake Iroquois. The stones have evidently been washed out of an overlying sheet of till, which may still be seen in the old shore cliff half a mile to the north.

The lower 25 feet of Don interglacial beds are crowded with fossils and form the most important part of the section. From them wood or leaves of thirty-two species of trees have been obtained and forty-one species of shell-fish, of which twelve are unios or anodons, in addition to undetermined beetles, cyprids, etc.

The following list of interglacial plants was supplied by the late Professor Penhallow:—

Acer pleistocenicum.
" *spicatum.*
" *torontoniensis.*
Asimima triloba.
Carya alba.
Chamæcyparis sphæroidea.
Clethra alnifolia.
Crategus punctata.
Cyperaceæ sp.
**Drepanocladus capillifolius.*

---

*Determined by Mr. A. J. Grout.

Eriocaulon sp.
Festuca ovina.
Fraxinus quadrangulata.
" *sambucifolia.*
" *americana.*
Gleditschia donensis.
Hippuris vulgaris.
Hypnum sp.
Juniperus virginiana.
Larix americana.
Maclura aurantiaca.
Ostrya virginica.
Picea nigra.
" sp.
Pinus strobus.
Platanus occidentalis.
Populus balsamifera.
" *grandidentata.*
Prunus sp.
Robinia pseudacacia.
Quercus obtusiloba.
" *alba* (?).
" *rubra.*
" *tinctoria.*
" *oblongifolia.*
" *macrocarpa.*
" *acuminata.*
Salix sp.
Taxus canadensis.
Thuya occidentalis.
Tilia americana.
Ulmus americana.
" *racemosa.*
Vaccinium uliginosum.
Chara.

Inadvertently he included two specimens from the Scarboro beds some miles to the east, *Picea nigra* and *Larix americana,* belonging to a later and cooler stage of the interglacial period.

The shell-fish were determined a number of years ago by Dr. Dall and his assistants at the Smithsonian institution, the list being as follows:—

Unio undulatus " *rectus* " *luteolus* " *gibbosus*	Still living in lake Ontario.
" *phaseolus* " *trigonus* " *coccineus*	Still living in lake Erie, but not reported from lake Ontario.
" *occidens* " *solidus* " *clavus* " *pyramidata*	Not known in the St. Lawrence system of waters, but living farther south.

Anodonta grandis.—Not reported from Canada.
Sphærium rhomboideum.
" *similis* (?).
" *solidulum.*
" *striatinum.*
" *sulcatum.*
Pisidium adamsi.
" *compressum.*
" *novaboracense* (?).
Pleurocera subulare.
" *elevatum.*
" *lewisi* (?).
Goniobasis depygis.
" *haldemane.*
Limnæa decidiosa.
" *elodes.*
" *bicarinatus.*
Planorbis parvus.
Amnicola limosa.
" *porata.*
" *sagana.*
" *ancillaria.*
Physa heterostropha.
Succinea avara.
Bithinella obtusa.
Somatogyrus isogonus.

Valvata sincera.
" *tricarinata.*
Campeloma decisa.
Bifidaria armata (land snail).

Of mammals the Don Valley brickyard has supplied a bone of a large bear and bones or horns of bison, of a deer like the Virginia red deer, and of a deer related to the caribou.

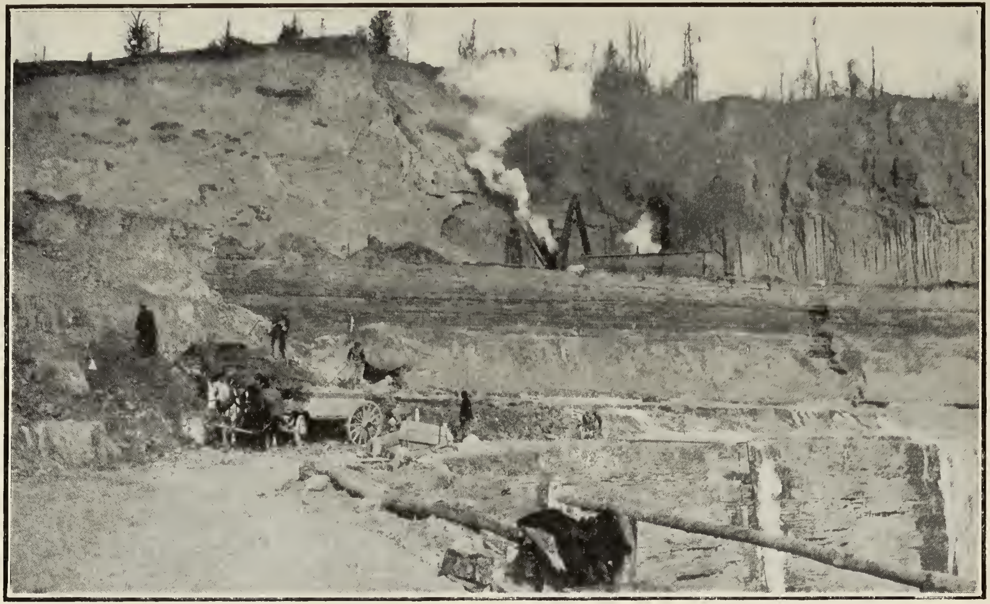
Of the trees, seventeen are near their northern limit and scarcely reach Toronto at present, while ten or eleven of the unios and other shell-fish do not now live in lake Ontario, but inhabit Mississippi waters. The whole assemblage of plants and animals implies a warmer climate than the present, such as that of Ohio or Pennsylvania, as suggested by Prof. Penhallow and Mr. White. There could have been no great ice sheet within hundreds of miles of the region when the rich Don forest grew, with its pawpaws, osage oranges and red cedars.

A walk of half a mile up the Don valley to a second brickyard, just beyond a bend of the river, discloses another section of the Don beds of a somewhat different kind. To the west of the valley Lorraine shale rises 16 feet above the river, followed by boulder clay, on which rests sand with unios like the deposits just described. Two hundred yards to the east the shale can be seen rising eight or ten feet, but between these two points the boulder clay and shale were cut away by an interglacial river, which afterwards began to deposit materials on the shale in the rising waters of a lake.

At the base of the section there are three or four feet of coarse shingle mixed with matted reeds, leaves and wood. Above this there are eleven feet of sand and clay with many shells. The whole is covered by a few feet of recent sand deposited by the Don before its bed had been cut as low as at present. The trees include red cedar, elm, oak and pawpaw, showing that the climate was warm at the earliest stage of the Don beds.

If we add these lower beds to the better exposed section at the Don valley brickyard the total thickness is 40 or 45 feet.

Similar beds of sand and clay containing wood and unios are found at several places along the Don for about



Don Valley Brickyard.

two miles to the south, and wood and shells have been obtained from excavations and wells at many points in the city to the west and below the level of the lake at Scarboro also, so that the Don beds cover several square miles, though the exact boundaries are not known.

A deposit of sand and gravel containing wood and shells has been found near Thornhill, fourteen miles north of lake Ontario, while boring for water. It underlies 200 or 300 feet of clay, and is no doubt the northward extension of the Don beds along the channel of the interglacial river which formed the delta.

THE SCARBORO BEDS.

The upper interglacial beds at the Don valley brickyard, consisting of laminated clay with no fossils except peaty materials, are found at several outcrops to the north and northwest, growing thicker in those directions and reaching, north of Reservoir park, an elevation of about 150 feet above lake Ontario. They are also found to the east of the Don and at Scarboro heights, where they are best exposed. In the brickyard 672 laminæ were counted in a height of 19 feet 9 inches, probably representing as many years of deposition. Above this a foot or two were too much broken up by the later ice advance to be counted. The counting was done by Baron de Geer's method, devised for the marine clays of Sweden, the limits of the layers being marked on strips of paper.

Since the Scarboro cliffs give the best opportunities for the study of these beds, they will be described as typical. The splendid Scarboro section was worked out by Dr. George Jennings Hinde many years ago, demonstrating the first series of interglacial beds recognized in America. His work was so good as to require scarcely any change in later times. At Scarboro the Don beds are not visible in the cliffs, but wells sunk on the beach show that they exist a few feet below the lake and have a thickness of 36 feet. They consist of yellowish sand with some beds of clay, containing unios and pieces of wood as in the Don sections.

Above the water level, where the interglacial section is most complete, there is not only laminated clay like that referred to above, but also a great thickness of sand resting upon it.

The thickest section includes 36 feet of Don beds and 5 feet of peaty clay below water, with 85 feet of peaty clay above water followed by 55 or 60 feet of stratified sand, making in all 186 feet of interglacial beds. The general section shown in the cliffs will be described first, and then the fossils will be taken up.

THE SCARBORO SECTION.

At Victoria park, toward the east end of Toronto, the flat sandy shore ends and boulder clay shows above the water, standing up as a comparatively low cliff capped with Iroquois sand beds. Toward the east the cliff rises and becomes more complex in structure until it reaches a height of 355 feet four miles from Victoria park, after which it descends and finally reaches lake level at Highland creek, 9½ miles from its commencement. This fine section shows not only the greater part of the interglacial beds, but a series of four tills with interbedded stratified sand and clay, and also nearly 100 feet of Iroquois sands towards the western end. The upper series of boulder clays and inter-stratified beds is confined to a small part of the section at its highest point. To the east and west of this only one sheet of boulder clay can be seen, but it stretches almost continuously along the upper part of the section, though with great variations in thickness.

It is evident that the interglacial beds were greatly eroded by river action before the second ice advance, as may be seen at the "Dutch Church," where a river valley was cut to a depth of 166 feet, having a width of 1,200 feet at lake level and nearly a mile on top. The layer of boulder clay, after rising to 150 feet, rapidly dips down to the level of the lake at this point and then rises again beyond it. This is in reality the second sheet of till in the succession, the lowest one being 40 feet below the lake, underlying the unio beds mentioned above.

The waves of lake Ontario undercut the cliff, especially in seasons of high water, after which slices slip down and are removed by storms. Where there are several successive years of low water in the lake much of the face of the cliffs becomes covered with vegetation, though they are too vertical in the neighborhood of the Dutch Church to permit of much plant growth. The earliest reliable survey of Scar-

The "Dutch Church," Scarboro

boro was made fifty years ago, and another survey made during the past year shows an annual recession of 1.62 feet per annum. The boulders from the boulder clay remain at the base of the cliff, when not removed by man, and the interglacial sands when washed by the waves on the shore show thin sheets of red garnet or black magnetite.

The interglacial clay rising about 85 feet above the lake has certain well marked features. It is often well stratified in laminæ running from a fraction of an inch to two or three inches in thickness, though there are a few layers three or four feet thick in which the bedding is indistinct or wanting. Where typically bedded each lamina consists of a darker layer of fine gray clay, and a paler part of a silty nature. Often the silty part widens and contains more or less peaty matter with mica scales. Occasionally the peaty bands expand to half an inch or an inch in thickness, and rarely twigs or small bits of wood are found. Every few feet in the section shows a thin sheet of impure siderite which stands the weather better than the rest of the beds and is broken on the beach into flat shingly pebbles, which slowly oxidise to limonite. The iron ore and the peaty layers make distinctive features by which this interglacial clay is easily recognized. It burns to a red brick.

From the peaty matter mosses, bits of leaves and bark, seeds and parts of beetles may be obtained, by washing away the clay, drying the peat and examining it with a lens. The late Dr. Scudder, of Harvard University, determined seventy-two species of beetles from materials obtained here, the list being as follows:

FAUNA OF COOL CLIMATE, CHIEFLY FROM SCARBORO.

Arthropoda (almost wholly beetles):
Carabidæ (9 gen. 34 sp.).
Elaphrus irregularis.
Loricera glacialis.
" *lutosa.*
" *exita.*
Nebria abstracta.
Bembidium glaciatum.
" *Haywardi.*
" *vestigium.*
" *vanum.*

Bembidium præteritum.
" *expletum.*
" *damnosum.*
Patrobus gelatus.
" *decessus.*
" *frigidus.*
Pterostichus abrogatus.
" *destitutus.*
" *fractus.*
" *destructus.*
" *gelidus.*
" *depletus.*
Badister antecursor.
Platynus casus.
" *Hindei.*
" *Halli.*
" *dissipatus.*
" *desuetus.*
" *Hartii.*
" *delapidatus.*
" *exterminatus.*
" *interglacialis.*
" *interitus.*
" *longævus.*
Harpalus conditus.
Dytiscidæ (3 gen. 8 sp.).
Coelambus derelictus.
" *cribrarius.*
" *infernalis.*
" *disjectus.*
Hydroporus inanimatus.
" *inundatus.*
" *sectus.*
Agabus perditus.
Gyrinidæ (1 sp.).
Gyrinus confinis, LeG.
Hydrophilidæ (1 sp.).
Cymbiodyta exstincta.
Staphylinidæ (11 gen. 19 sp.).
Gymnusa absens.
Quedius deperditus.
Philonthus claudus.
Cryptobium detectum.
" *cinctum.*

Lathrobium interglaciale.
" *antiquatum.*
" *debilitatum.*
" *exesum.*
" *inhibitum.*
" *frustum.*
Oxyporus stiriacus.
Bledius glaciatus.
Geodromicus stiricidii.
Acidota crenata, Fabr. (var. *nigra.*).
Arpedium stillicidii.
Olophrum celatum.
" *arcanum.*
" *dejectum.*

Chrysomelidæ (1 gen. 2 sp.).
Donacia stiria.
" *pompatica.*

Curculionidæ (4 gen. 6 sp.).
Erycus consumptus.
Anthonomus eversus.
" *fossilis.*
" *lapsus.*
Orchestes avus.
Centrinus disjunctus.

Scolytidæ (1 sp.).
Phloeosinus squalidens.

Of these all but two are extinct, as stated by Dr. Scudder.

Mr. A. J. Grout has determined the following mosses from the same beds:—*Hygrohypnum palustre* (?), *Drepanocladus vernicosus* (Lindb), and *Hylocomium* sp.

The Scarboro interglacial sands are less extensive than the clays just described, since they are the uppermost beds and suffered far more from superficial destruction by rain action and river erosion in the later part of the interglacial interval.

Where best developed the sands have a thickness of 55 or 60 feet, the lower four or five feet having clayey layers showing a transition to the peaty clay. The sand is generally coarse, but free from pebbles, and some layers are cross-bedded, showing that the deposit was made in shallow water.

There are in some places many concretions of brown iron ore, once no doubt, siderite.

Toward the bottom of the sand and immediately above the clay there is often a thick bed of coarse peaty materials, including many chips of wood and bark and bits of branches. The trees recognized are *Larix Americana* and *Abies balsamea.* A few small shell-fish are found also, *Sphærium rhomboideum, S. fabale, Limnæa* sp., *Planorbis* sp. and *Valvata tricarinata.*

The sand extends for five miles along the cliffs and has been found in ravines several miles north of the shore.

The Scarboro interglacial beds were formed in a northern bay of an interglacial lake, which reached at least ten miles inland from the present shore. They are delta deposits laid down by a great river coming from the Georgian bay region, draining the basins of the present upper lakes, and they began with a water level somewhat below that of lake Ontario.

Above the second till sheet there is stratified clay and sand, followed by a third sheet of till, and in the highest part of the cliffs a fourth and a fifth sheet of boulder clay have been found with intervening stratified sands and clays. There were three well-defined recessions of the ice during which lake deposits having thicknesses of from 25 to 36 feet were deposited. How long these later interglacial periods lasted is unknown. No important erosion intervals are known in connection with them, and except for a few small shells in one of the beds they are without fossils; so that they seem to have been of much less importance than the Toronto interglacial period.

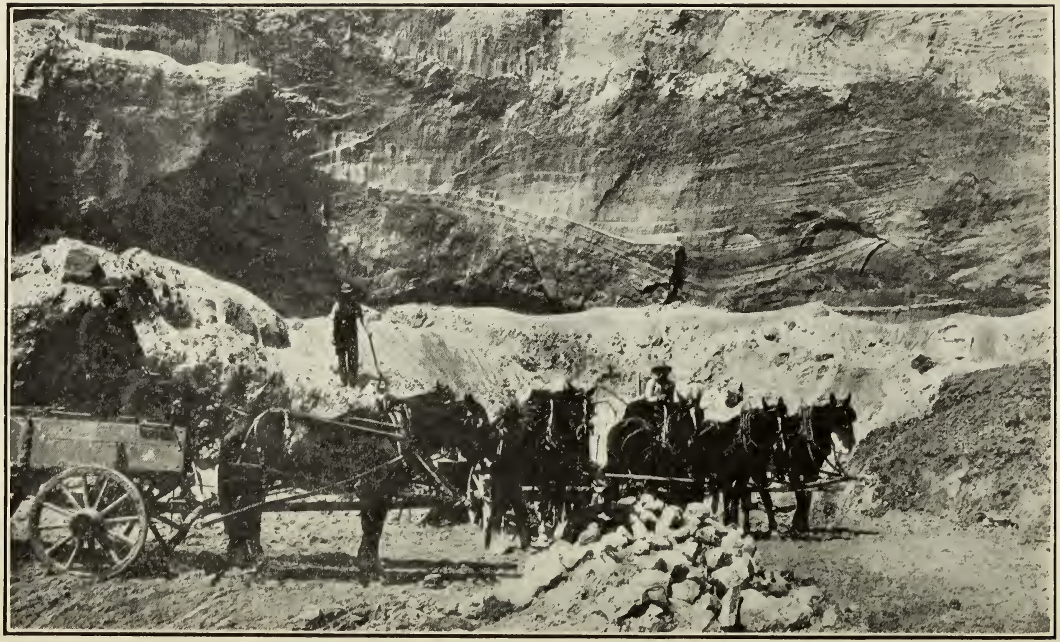
The total thickness of these upper glacial and interglacial deposits at the highest point of the Scarboro section is 203 feet.

The magnificent Scarboro section may be seen to the best advantage by taking a King street car as far east as possible and then walking eastwards along the shore. This, however, demands a good deal of time, and the highest and most interesting parts of the section may be seen more expeditiously by taking a King street car to the Woodbine and there transferring to a suburban car running along Kingston road. This ascends the sandy slopes of the long spit which enclosed the ancient Don bay of lake Iroquois, and then runs for two miles east along the old gravel bar, which is well disclosed by numerous gravel pits. The road then climbs the Iroquois shore cliff to the gently rolling upland of boulder clay. At stop 32 a lane leads south from Kingston road past a Topographical Survey tower to the edge of the cliff, a distance of about three-quarters of a mile. The highest point on the actual shore of lake Ontario is reached a short distance to the east. From this point, 355 feet above the lake, there is a steep descent, mostly through a small growth of trees to the shore. The section described above is shown in bare cliffs on each side of the path, a sheet of boulder clay, followed by stratified clay and sand, another sheet of boulder clay, succeeded by silty sand with its upper layers crumpled by the advancing ice, a third comparatively thin sheet of boulder clay with cross-bedded sand beneath it, and a fourth boulder clay resting on the eroded sand beds of the great interglacial formation, under which the peaty clay extends to the shore of lake Ontario.

The section has been worked out as follows:

		Feet.	
Boulder clay, No. 5		48	Glacial Complex, 203 feet.
Stratified sand and clay		36	
Boulder clay, No. 4		32	
Silty sand, upper layers crumpled		25	
Boulder clay, No. 3		9	
Cross-bedded sand		29	
Boulder clay, No. 2		24	
Scarboro Interglacial beds	Sand	59	Above level of lake Ontario, 151 ft.
	Peaty clay	92	
Don beds (unios and wood)	Peaty clay	5	Below level of lake Ontario, 41 ft.
		36	
Boulder clay, No. 1			
Lorraine shale			
Total Pleistocene beds			395

A walk of less than a mile westwards along the beach brings one to the "Dutch Church," where an interglacial river valley has been filled with the second boulder clay followed by stratified glacial clay. The gradual rise of the boulder clay on each side of the fossil valley is well exposed.



Shaw Street Sand Pit.

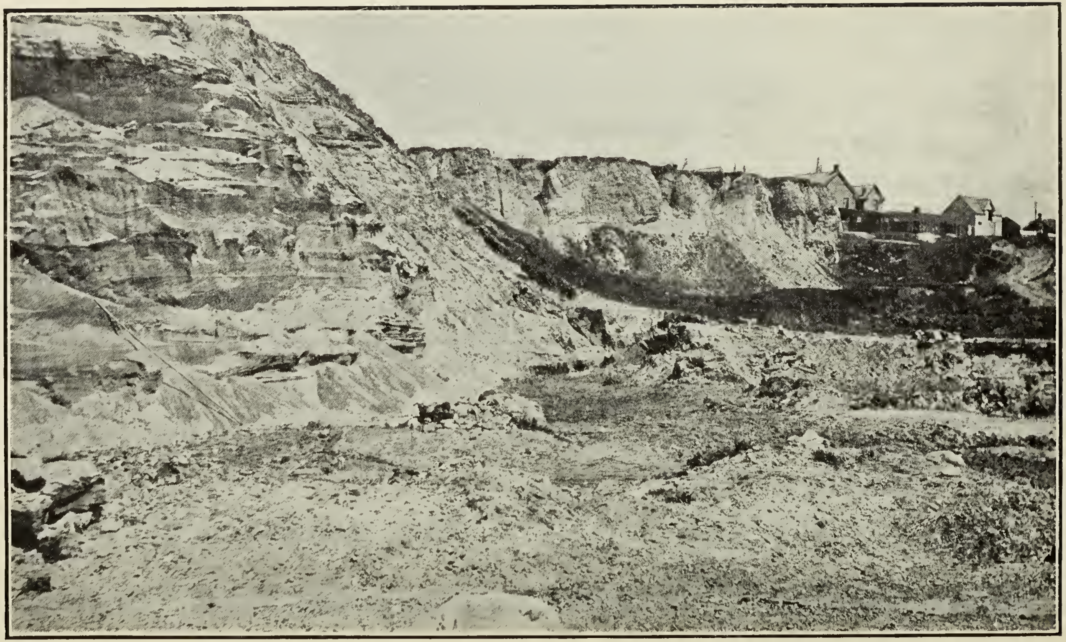
The steepest cliffs of the section are cut from this thick mass of hard clay which stands vertical to a height of 150 feet. Small streams coming in have cut extraordinary ravines, one of them with the aid of rain erosion shaping the tower and buttresses of the "church." A stairway leads up 170 feet from the shore at the Dutch Church to the Iroquois terrace, here beautifully displayed with a shore cliff more than 100 feet high; and a walk of three-quarters of a mile brings one to the Kingston road, at Half-way House, where a car may be taken to the city.

INTERGLACIAL BEDS IN THE WESTERN PART OF TORONTO.

The order of succession and relative ages of the deposits thus far described are well ascertained, but in the western part of Toronto, north of Bloor street and near Christie and Shaw streets, there are fossiliferous beds of uncertain position. Eighty feet of tumultuously cross-bedded sands and gravels here underlie the second till sheet, so that they are clearly interglacial; but they differ so much in character from both the Don and Scarboro beds that they cannot be classed with either. They were evidently formed by a powerful river which sometimes deposited coarse materials in its bed and then cut them away again by some shifting of its channels, a type of work quite different from the quiet deposit of clay and sand in the interglacial delta of the Don and Scarboro sections. They may be older than the Don beds or younger than the Scarboro beds.

These western beds contain a few fragments of unios as well as *Sphæriums, Pleuroceras* and other small shells, all of which occur in the Don beds. A little wood found in these sand pits is still undetermined. The most interesting fossils obtained are scattered bones of mammals, including bison, deer and mammoth or mastodon. A horn of *Cervalces borealis,* as determined by Prof. Bensley, an atlas vertebra of bison and part of a lower jaw of a bear (O. P. Hay) have been found also, and several fragments of ivory have been picked up. All of these remains seem to have been waterworn and may have been transported for some distance. There is no certain evidence as to climate in the fossils thus far found.

From the lists given above it will be seen that the Toronto Formation has furnished a wide range of fossils,



Christie Street Sand Pit (Interglacial). Upper Boulder Clay to Right.

including 42 trees and other flowering plants with several mosses, 41 shell-fish, 72 insects, and 5 or 6 mammals—about 165 or 170 species all told.

OUTLINE OF CLIMATIC AND PHYSICAL CHANGES.

The Toronto interglacial period included great changes in climate and in physiographic features. During the retreat of the first ice sheet no doubt the climate slowly changed from Arctic to subarctic and finally to temperate, and probably the valley was at first occupied by a great glacial lake when thawing had proceeded so far as to free the basin, but not its outlet toward the northeast. These earlier stages of the interglacial time have left no visible record, though they must have required thousands of years to accomplish.

The first episode in the Don beds shows a river flowing into a lake lower than the present, with a rich deciduous forest on its shores. There followed a rise of water in the lake, probably by the upwarping of its outlet, to 60 feet above the present level. This time of warm climate lasted long enough for the deposit of 45 feet of sand and clay in a delta several square miles in area, and for the growth of generations of forest trees.

At length there came a rise of the waters to 150 feet or more above the present lake, when delta beds were laid down covering more than 100 square miles. At one point there are 672 annual layers in less than 20 feet, so that the whole thickness must have required some thousands of years to deposit. The climate had become colder, as shown by the plants and insects, and was like that of northern Ontario at present.

Next, the great lake was drained to a level 16 feet below lake Ontario, and three river valleys were carved in the delta, a wide one toward the west at the present site of Toronto, a narrower one at the Dutch Church and another wide one towards Highland creek. These valleys had gently sloping sides and were much more mature than the present valleys of the Don and the Humber. To cut them the rivers must have required several thousand years.

Finally, Arctic conditions came on and the ice advanced once more from the northeast, covering the eroded surface of the region with a second sheet of boulder clay. The climatic cycle was complete.

THE IROQUOIS BEACH DEPOSITS.

After the last ice age, when the retreat was well under way, the basin of lake Ontario was freed from ice while its outlet at the Thousand islands was still blocked. The water escaped by the Rome outlet, in the State of New York, to the Hudson, and a lake which has been named Iroquois by Dr. Spencer, occupied the basin at a much higher level than that of lake Ontario. The southern slope of Toronto is largely covered with its deposits, the old shore cliff runs east and west through the city, and at each end a great gravel bar extends across the present river valley.

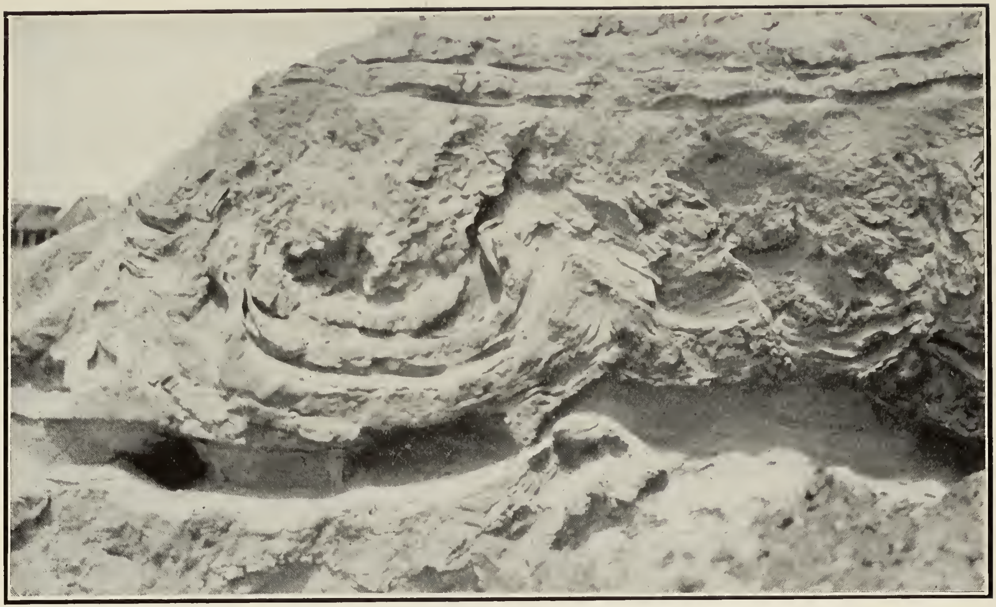
The Iroquois beach is deformed and rises from 176 feet above lake Ontario at the Humber gravel bar toward the west to 196 feet at the York gravel bar crossing the mouth of the ancient Don bay, and to 200 feet at Scarboro heights. The shore cliff within the city north of Davenport road averages about 75 feet in height, but at Scarboro reaches in places 170 feet. At the highest point of the Scarboro cliff it is completely cut off by the shore of lake Ontario for half a mile, the only known point at which the waves of Ontario have encroached on the ancient shore line.

Lake Iroquois began its work at least 70 feet below its latest well marked beach, but none of the earlier stages is shown at Toronto. Beside the cutting of a terrace in the Pleistocene deposits with the cliff at its rear the lake did much work in distributing materials, filling in former depressions in the terrace, and building the two great gravel bars in west and east Toronto respectively. Each of these bars began on the east side of its bay and grew westwards, crowding the river out of its earlier channel and forcing it to the western shore of the bay.

The bar in west Toronto crossing the Humber bay extends west as a uniform and rather narrow ridge of gravel and sand rising 20 feet above the slope to the south, while the York (or east Toronto) bar enclosing the Don bay is more spread out and contained lagoons. It had much the size and shape of the present Toronto island.

Both of these ancient bars are being rapidly destroyed, the sand and gravel being used for building purposes in Toronto.

The Iroquois deposits are sometimes 100 feet thick and include coarse materials in the gravel bars, sand of varying



Crumpled Beds (Iroquois Deposit) Near Pape Ave.

character on the lakeward slope, as well as silt and clay within the Don and Humber bays. At one point near Reservoir park shells have been found in the gravels, species of *Campeloma, Pleurocera* and *Sphœrium,* all still living in lake Ontario. The commonest fossils are horns of caribou, which are often found in the west Toronto gravel bar. Less frequently teeth of mammoth have been obtained. The mammoth and the caribou suggest a cooler climate than the present. The caribou is essentially a northern animal, and has not been found within 150 miles north of Toronto during historic times. It is natural to suppose that the waters of lake Iroquois, which had a shore of ice toward the northeast, were colder than those of Ontario, and that the climate was cool, if not even subarctic.

When lake Iroquois was drained through the melting of the ice dam at the Thousand islands, the water sank to sea level, but there is no evidence of marine deposits on its shore. The marine episode was comparatively short and the water was probably kept fresh by the Niagara river. The outlet was still rising toward the northeast, so that the water was backed up toward the southwest end of the lake. On the lower reaches of both the Don and the Humber there is dead water owing to this rise of the lake level, and well borings near the mouth of the Don show 100 feet of stratified sand built up in the old channel. The growth of Toronto island is, however, the most evident work of lake Ontario near Toronto in recent times. Its materials have been transported westwards from Scarboro heights, and have been built out into deep water enclosing Toronto bay, The growth of the island has been shown by Sir Sandford Fleming, from a comparison of maps more than 100 years old, to have been extensive.

EXCURSION B 5

MORAINES NORTH OF TORONTO

BY

Frank B. Taylor.

The moraines to be visited on this excursion were made at a relatively late stage in the retreat of the last or Wisconsin ice sheet, and are the first moraines formed north of lake Ontario. One was made along the southern edge of the Trent valley-lake Simcoe ice lobe. At the locality visited the ice which made this moraine, was moving towards the south and the moraine faces in that direction. The main movement in that lobe, however, was towards the southwest, shown by the axes of many drumlins and drumloids and by striæ and the direction of boulder transportation in the Trent valley and lake Simcoe regions. The direction in this area was about the same during the maximum extent of the ice and during the whole time of its retreat. The other moraine to be visited lies close south of the first and was formed along the northern edge of the ice lobe which lay in the basin of lake Ontario.

At the greatest extent of the ice sheet, its front reached nearly to Cincinnati, Ohio, about 400 miles southwest from Toronto. The ice which reached this point was part of the great ice stream which moved southwestward through the basins of lakes Ontario and Erie. At the same time the ice front in a direction south-southeast from Toronto reached only to Salamanca, New York, about 120 miles from Toronto. This was on account of the Alleghany plateau, the high mass of which obstructed the southward movement in western New York and Pennsylvania and in northeastern Ohio, and turned the current towards the Southwest along the axis of the lake basins. The central axis of the great ice stream passes about 30 miles south of Toronto, and there was not much change in its position during the retreating phase, until the ice front had receded to the northeast end of lake Erie. By the time it had reached this position, however, the relatively deep basin of lake Ontario became the controlling factor in the ice movements of this region. This was the position of the ice front a short time before the moraines to be visited were made. The ice field was then confluent and continuous over the whole region between the lake Ontario basin on the south and the Trent valley, the lake Simcoe basin and the basin of Georgian bay on the north. At this time the ice front rested against the face of the Niagara escarpment from Hamilton northward to Georgian bay, and the ice lay as an unbroken sheet over the whole region to the east. It was already growing thin, however, over the ridge north of Toronto, and with further steps of retreat the ice soon parted and the ridge began to emerge.

The first parting of the ice lobes in the manner described probably occurred during the time of lake Arkona, but was temporary, for the pronounced readvance of the ice to the Crystal beach (Alden, Port Huron) moraine carried the ice front back again to the base of the escarpment, and the moraines which had just been made were overridden and destroyed. This episode of glacial history is not established on evidence seen in the localities visited on this excursion, but is fully supported by facts recorded in other parts of Ontario and in Michigan and New York. Then, when the ice front retreated again, the ridge was once more uncovered and the moraines now seen on the heights 20 miles north of Toronto began to be formed. This was probably during the times of lakes Wayne and Warren, but later phases farther east were probably correlatives of lake Lundy.

The two moraines were formed on the top of the emerged ridge, first at the west end near the base of the Niagara escarpment, and later at places farther east. As the flanks of the ridge were gradually uncovered, lake waters stood high upon them, but these waters were only narrow arms that reached northward from the main lake in the basin of lake Erie and made no perceptible record by wave action.

At this stage of retreat the ice did not enter the western part of the lake Ontario basin over the ridge north of Toronto, but came in at the northeastern end chiefly in the gap between Trenton, Ontario, and Oswego, New York.

At this time the lake Ontario ice lobe had become sharply differentiated, so that in the western half of the basin the ice was spreading from the central axis towards the margin on all sides except the east, where the ice stream was entering. From this circumstance it happens that the ice at this stage moved towards the northwest over Toronto and vicinity. A few miles east of Toronto its movement was directly north. These movements were respectively transverse and nearly

Bond Lake, Looking East. Probably Due to Partly Buried Ice Block Which Afterwards Melted Out.

opposite to the southwestward movements over this region at the time of maximum extension. The relations in this area afford a fine illustration of the changing and increasing influence of topography upon the movement of the ice as the ice grew thinner.

The drift, as Professor Coleman has pointed out, is quite deep in the vicinity of Toronto. But it is certainly much deeper along the line of the great moraines 20 miles to the north; and its depth is also considerable in the region west and southwest of lake Simcoe. Much the greater part of the deep drift in the region around Toronto is of pre-Wisconsin age, but beyond this general statement its precise age has not been determined even approximately, except by Coleman, in the remarkable exposures in Toronto. It is quite clear, however, that the pre-Wisconsin beds or some of them, have a wide extension in easterly, northerly and northwesterly directions from Toronto. In many localities the Wisconsin drift is only a thin sheet, sometimes even discontinuous, over a great mass of the older drift. The bulky moraines north of Toronto appear to rest upon a deep substructure of these older deposits.

Suburban cars leave the Toronto and York Radial station on North Yonge street. The station stands a little below the level of the beach of glacial lake Iroquois, and the car ascends the old lake cliff immediately after leaving the station. On reaching the top, the traveller finds himself on an undulating plain trenched by small streams running toward the southeast. The stream valleys have been cut to only moderate depths, the deepest being the west branch of the Don river, which at York Mills reaches a depth of about 100 feet.

The surface forms that meet the eye as soon as the car leaves the old lake bluff are readily recognized as products of glacial action, perhaps partly constructional, but mainly destructional in character—a smoothing and rounding off of an uneven surface by the ice sheet. In the first mile or two several hills resembling drumlins are seen, none of them perfect types, however, but sufficiently near to be called drumloid forms. Glacial action is not recorded alone in these hills, for the whole surface is characterized by long drumloid profiles on the interstream ridges, and the troughs have the same character, and both troughs and ridges are strongly alined after the fashion of drumlins in the direction of the latest ice movement. This kind of surface has been happily characterized by Fairchild as "drumlinized," meaning by this that the drumlin-forming process gave the surface its character, although no perfect drumlins were formed.

At York Mills the sands in the high bank south of the Don river and west of the track are reported by Coleman to be of pre-Wisconsin age. Between York Mills and Richmond Hill several partially drumlinized forms are seen towards the east. At Thornhill a bored well penetrated 600 feet of drift, or about to sea level, before reaching rock. A large part of the material was reported to be sand.

Approaching the moraine north of Richmond Hill, the drumloid forms disappear and the plain merges smoothly into the southern slope of the moraine. This slope is notably smooth and lacks the hummocky surface which usually characterizes terminal moraines. The southern margin takes this form all along from King southward to Maple and then northeastward and eastward for 100 miles.

A Pond and Morainic Topography in the Northern Moraine, Looking South Three Miles West of Aurora.

This smooth slope is the side on which the ice front rested while building the moraine. The moraine, therefore, faces northwest and north, its north side being its front slope and its south side its rear.

On reaching the summit of the ridge this and the northward slope are found to be more irregular and hummocky than the south slope, more characteristic of ordinary terminal moraines. There are many knobs and basins, and within two miles there are three moraine lakes and several similar hollows that do not now contain lakes. The car line passes along the west side of Bond lake and the party will walk northward from the power house to Schomberg Junction, noting the very steep slopes bordering this lake and the rugged nature of the ground, and also the sections of the drift exposed along the newly-made highway. Much of the drift in the north slope of the moraine is more or less sandy, suggesting glacio-fluvial deposition, but no extensive bodies of outwash are associated with the moraine in this vicinity. The south or rear slope, in addition to the smoothness described above, is more generally composed of till and shows almost no evidence of glacio-fluvial action. Some of the lakes and basins are no doubt due merely to the irregular heaping of the drift during deposition by the ice, but some, like Bond lake, appear to mark the sites of ice blocks surrounded or partly buried by drift, the lake basin remaining when the ice melted out.

From the Junction one looks to the north and west across a flat valley half a mile to a mile wide, and just beyond it lies a splendid moraine formed by ice moving southward over the lower region to the north. The flat valley is a narrow till plain lying between two moraines that face toward each other. It extends eastward from the Junction to Willcocks' lake, which lies partly in the southern moraine. but mainly in the plain. The party will walk eastward from the Junction along the south side of the plain, gradually ascending the front of the southern moraine and passing along the south and east sides of the lake. From the lake shore the valley is seen to pass on towards the northeast and north. It extends in this direction for about a mile, to where it appears to vanish into the air. But a glacial drainage course marked by a train of sandy gravel comes from the outwash area to the east and appears to connect with it. Northeast of the lake the valley has the character of a large drainage channel or old river bed lying between the two moraines, which form its banks on either side. In the early phase of this pause of the retreating ice, a large river issued from the narrow space between the two ice fronts and flowed out to the west. This river carried the accumulated drainage from a long way to the east and northeast. There are low sand and gravel beds on the valley floor north and northeast of the lake that record the action of the river.

The main bulk of the gravels, however, lies at a slightly lower level than the head of the channel, and marks a change of the drainage by which it continued along the rear side of the northern moraine to another slightly lower passage farther west. Such a passage occurs about eight miles west of Aurora or one mile east of Linton, and the gravels appear to end at that place. Outwash gravels form the crest of the hill along the north side of the creek for two miles west from Van Dorf.

Looking North Over Willcocks' Lake, the Northern Moraine in the Distance

These old river gravels form a sort of terrace along the north or rear slope of the north moraine. It is well defined where the electric line crosses it at the cemetery a mile south of Aurora.

The deposit stands considerably above the lower country to the north. It is cut by many small gullies, but is substantially continuous from the large outwash deposit six or seven miles east of Aurora to the gap east of Linton. This deposit is not outwash issued from the front of the ice while the moraine was being built, for it rests on the rear slope of the moraine. It appears to have been deposited by a river flowing westward along the ice front in the last or closing phase of the relatively long pause during which the moraine was built. The ice had ceased advancing apparently and had become practically inert along its edge. The river during this phase had fallen a little below the passage to Willcocks' lake and probably escaped southward through the gap east of Linton.

Two miles east of Willcocks' lake there are well-developed eskers and associated troughs cutting through the southern moraine from southeast to northwest. These also show with great clearness that the ice here was moving toward the northwest, normal to the trend of the moraine at this place. The esker stream cut through the moraine and issued into the drainage channel a mile and a half northeast of Willcocks' lake.

EXCURSION B 6

MUSKOKA LAKES

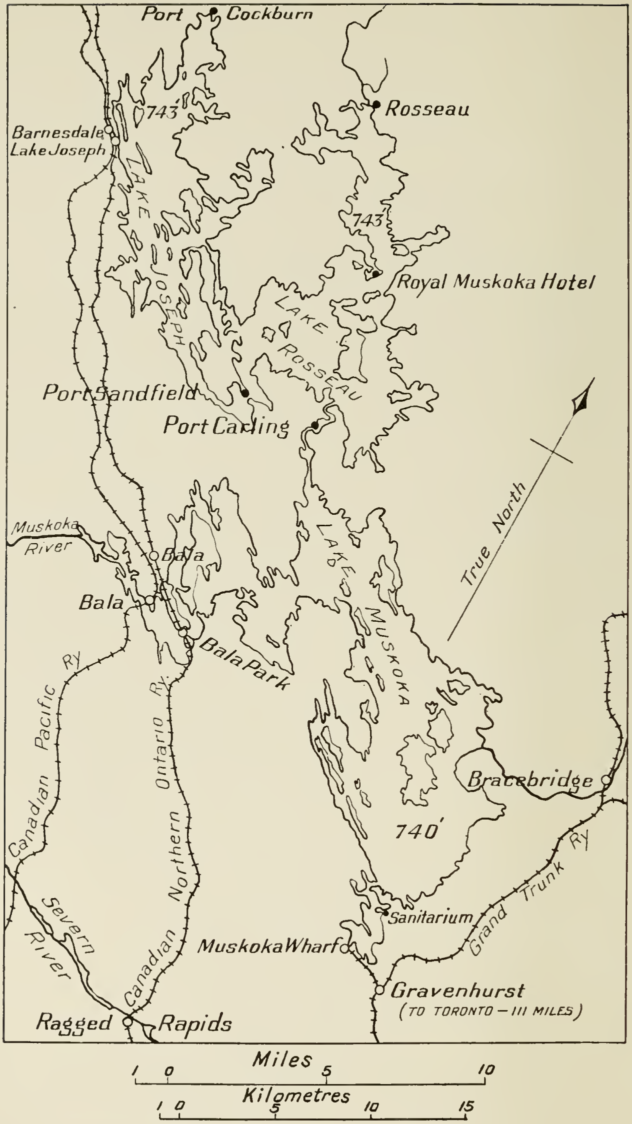
G. G. S. LINDSEY, *Leader.*

The Muskoka lakes region is known as the " Highlands of Ontario." It contains numerous clear-water lakes and many popular summer resorts.

THE LAURENTIAN.

The rock cuttings along the branch railway between Gravenhurst and Muskoka wharf afford excellent sections of the Laurentian, bringing out clearly the method by which the characteristic banded gneiss has been produced. Here and there masses of dark green-grey rock may be seen, sometimes of considerable area. These patches of diorite schist or of biotite schist are, no doubt, metamorphosed basic rocks, such as gabbro, older than the granite which penetrates them as dikes and floats off fragments from their margins. At first the fragments are angular and sharp edged, but at a greater distance from the parent mass they become rolled out as schistose streaks, and along with this goes *lit par lit* injection of granite magma, sometimes as thin, light-colored sheets, at others as distinct granite dikes. The result is a strikingly banded gneiss, grey if the original basic material was in larger amount, and flesh-colored with thin, greenish bands where the granite predominated.

Still later dikes of granite and also of coarse pegmatite have penetrated in all directions the gneisses just referred to, and one may observe the beginnings of a second operation like the first, blocks being broken off, rolled out and injected with granite parallel to the schistosity. Evidently the Laurentian gneisses represent a long continued series of granite intrusions, diluting and attenuating more and more the basic materials which once made the crust through which the eruptions took place.



Muskoka Lakes

In some places the strike and dip of the schistosity may be traced from point to point in such a way as to encircle areas of granite, showing a ground plan of batholithic mountain structures, domes which have lost thousands of feet by later erosion, so that the relief is now comparatively low.

The Muskoka lakes, with their remnants of original greenstones and their much larger area of grey or flesh-colored granitoid gneiss arranged ovally about less schistose centres of granite, afford typical examples of the Laurentian rocks, which cover more than half of northern Canada. They also show admirable examples of the lake basins which occupy nearly a quarter of the original peneplane of the Canadian Shield. After peneplanation had been accomplished the region was elevated some hundreds of feet and rivers eroded valleys, though not to great depths. Then came the ice sheets of the glacial period, scouring off the debris, leaving clean, rounded and striated rock surfaces, and blocking all the valleys with boulder clay or moraine ridges. When the ice departed all the hollows formed lakes, each of which spills over at the lowest point into the next lake below as falls or rapids. The connecting rivers have not yet had time to cut channels in the rock, and their erratic courses add much to the beauty of the wilderness of lakes spread over the Muskoka region. It is typical "rocky lake" country, with lakes and ponds and inlets and islands of all shapes and sizes, making a veritable labyrinth of waters, which reflect rock cliffs and groves and give sheltered navigation for launches and canoes.

ANNOTATED GUIDE.

Toronto to Gravenhurst.

Miles and Kilometres.

0.0 — **Toronto,** Union station, altitude 254 feet
2.2 m. — (77.4 m.). North Parkdale, altitude 391 feet
3.5 km. — (119.2 m.). Leaving Toronto by the Northern division of the Grand Trunk railway, the train passes over a drift-covered area which is underlain by Paleozoic rocks.

Miles and
Kilometres.

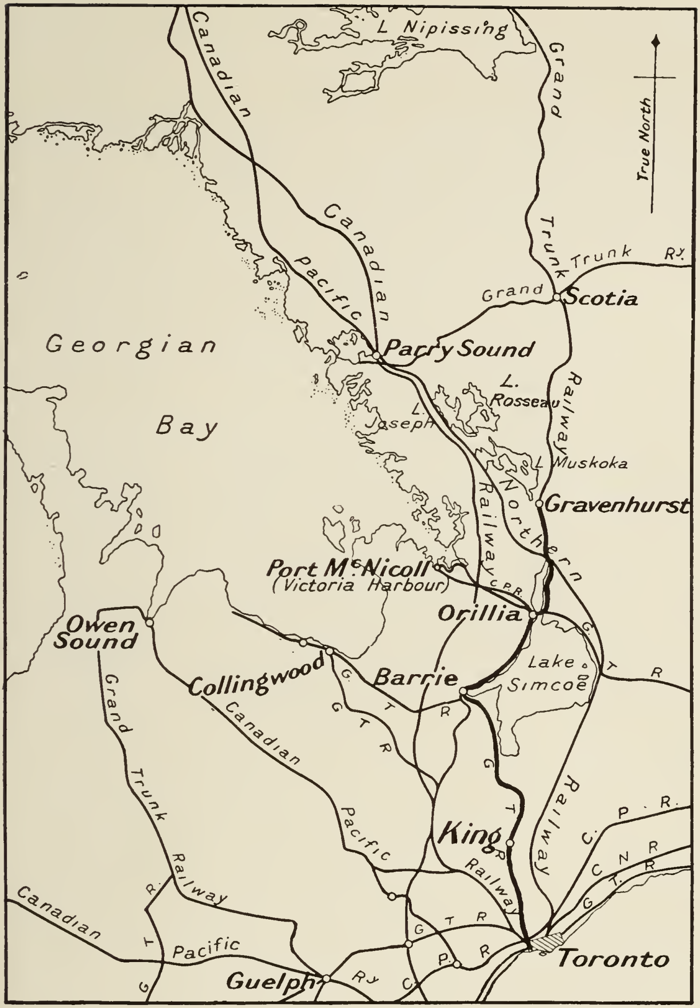
4.6 m. **At Davenport** there are gravel bars of
7.4 km. glacial lake Iroquois, while two miles to the east
the old shore line of this lake is exposed.

22.4 m. **At King** an altitude of nearly 1,000 feet is
36.1 km. attained. The country traversed consists of
rolling ridges of Pleistocene deposits, made up
of stratified clays, sands and gravels, and
material of glacial origin. To the north of King
much of the country is strewn with boulders.

48.7 m. The first view of lake Simcoe is obtained
78.6 km. from a point just south of GILFORD STATION.

62.7 m. **At Allendale** a splendid view is obtained
101.1 km. of the town of Barrie on Kempenfeldt bay. To
64.0 m. the south of BARRIE, as far as the township line,
103.2 km. the drift has an average depth of 300 feet or
more. "Throughout this area of deep drift a
considerable part is made up of water laid or
lake sediments as distinguished from glacial or
ice-laid deposits. Locally, as in the case of the
high mass west of Barrie, a large part is water
laid—chiefly stratified sands and clays. But ice
laid drift is generally dominant" (Taylor).

86.0 m. **North of Orillia** there is a cutting through
138.7 km. boulder clay. All the country from Toronto
north, as far as Longford, is underlain by flat-lying sediments of Paleozoic age, including, from
the south, Lorraine, Utica, Trenton, Black River
and Bird's Eye formations. The first outcropping of rock along the railroad occurs at
93.5 m. LONGFORD, where Black River limestone is seen.
150.8 km. At the Longford quarries, on the west side of
St. John lake, Rama township, four feet of
Black River limestone are exposed at the top, in
two heavy layers containing an abundance of
characteristic fossils, such as *Columnaria Halli*,
Stromatocerium rugosum, etc., and a six-foot
bed at the bottom is a mass of *Tetradium fibratum*. Below this are twelve feet of fine-grained
blue and dove-colored limestone containing
Leperditia, but comparatively few other fossils.
This lower bed has been referred to the Bird's
Eye formation (Johnson).



Route map between **Toronto** *and* **Muskoka**

Miles

25 0 25 50 75 100

Kilometres

25 0 25 50 75 100 125 150

Miles and Kilometres.	
95 m. 153.3 km.	The limestone forms a low escarpment facing northwards, and after a short drift-covered stretch coarse red granitoid gneiss shows itself beyond as a plain with low relief.
98.5 m. 158.8 km.	**At Washago,** the red gneiss, which is exposed in a quarry near the railroad, contains long bands or thin sheets of grey-green biotite schist, sometimes crumpled and slightly faulted. From this point to Gravenhurst the greyish or flesh-colored Laurentian gneiss rises as hills of moderate height, and the shores and islands of the Muskoka lakes the mainly formed of similar rocks.
111.4 m. 179.7 km.	**At Gravenhurst,** altitude 818 feet (249.3 m.), a branch railway extends for a mile and a half to Muskoka wharf, altitude 749 feet (228.3 m.), where steamers are in waiting for visitors. The rock cuttings along this branch afford excellent sections of the Laurentian, bringing out clearly the method by which the characteristic banded gneiss has been produced.

EXCURSION B 8

CLAY DEPOSITS AND WORKS NEAR TORONTO.

BY

M. B. Baker.

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INTRODUCTION.

There are no high-class ceramic industries in Canada using Canadian clays, because there are no kaolin deposits of worth in Canada. Pleistocene glaciation removed all products of rock decay, and therefore all deposits of residual clay, and left only a mixed glacial drift. In some places this has been more or less sorted, so that a clay-like material containing a large percentage of rock flour is found, and this is used for the manufacture of ordinary building-brick, field tile, or common pottery. These impure clays in the fresh and unaltered state are high in calcium carbonate, varying from 13 per cent. to 27 per cent. The iron oxides run about 7 per cent. In burning these clays the iron is prevented from burning to the ferric oxide, but forms instead ferrous carbonates and silicates, which give the buff to cream colors found in these products. There is an unlimited supply of this clay in Canada, but it is of a poor grade and yields only the commonest products.

In flat areas, or in more or less hollow places, where weathering has taken place, and where the products have had little chance to be removed, we find that the meteroic waters have leached out the calcium carbonate from the upper two to eight feet of our glacial clays. This has reduced the calcium carbonate to as low as 6 per cent. in most cases, but since iron oxide is insoluble it remains the same as in the glacial clay. On burning this weathered clay, the iron oxide is now able to change to the ferric condition, and yields as a result the red products with which all are familiar.

Since this red-burning clay is confined to the weathered top of the glacial clay and to interglacial clay, we can see that the supply is limited. Beyond the change in color, the other qualities of the burnt product are not improved.

All higher grade products, including pressed-brick, terra-cotta sewer-pipe, paving-brick, etc., are made in Canada from shales of the Paleozoic series. Three of these are used so far in Canada, namely, the Utica, Lorraine and Medina. The first of these is used in the vicinity of Montreal, but has not yet been used in Ontario. The latter two are used in the vicinity of Toronto.

DON VALLEY BRICK WORKS.

The most interesting clay and shale deposits at Toronto belong to the Don Valley Brick Works, where the following section is seen in descending order:

1-3 feet boulder drift clay.
80 feet glacial stratified clay ....A.
1 foot boulder drift clay.
21 feet interglacial cool water beds. } ....B.
12 feet interglacial warm water beds } of clay and sand.
12 feet reddish sand, often carbonacious..............C.
3 feet boulder drift.
60 feet Hudson River shales, with interbanded limestone ....D.

It is not the writer's intention to describe these clays geologically, as this has been already done by Dr. Coleman in the guide-book to excursion B 2, but the object of this excursion is to study the industrial side of these clays.

The upper glacial clay A has been collected rapidly, and is of the character already described in the introduction above. It has not lost its calcium carbonate, and therefore burns to buff-colored products. This clay is dug by itself and manufactured into sand-stock brick, and hollow-spaced block.

The interglacial banded clays B were slowly-collected weathered clays, which had lost their calcium carbonate before or during the gathering process, they therefore burn, as was described in the introduction, into red ferric products. These two banks, thirty-three feet in all, are therefore dug with a steam shovel and manufactured by themselves into red sand-stock brick and red wire-cut brick. The underlying twelve feet of reddish sand is dug and mixed at times with these interglacial clays B when they, of themselves, are too "fat" or strong for the purpose in hand. The addition of this sand diminishes the shrinkage and cracking on drying or burning.

At the base of these clays there is a three-foot layer of boulder clay, which has to be removed and discarded, when the underlying Lorraine shale comes to view. This shale is blasted out, picked free from limestone beds, and is then finely pulverized, when it is ready for use by itself in the manufacture of dry pressed brick, which burn to a beautiful red color. It is often mixed with other clays, for example the calcareous clay A to form various shades of buff to cream colored products.

It is not advisable to go into any detailed description of the process of brick-making, which is best seen at the brick yard, but it may be briefly summarized as follows:—The various sand-stock bricks, which get their name from being made in sanded moulds; the wire-cut brick, which are cut off in the required sizes from a continuous column of clay by passing a wire; and the hollow block, made in the same way as the wire-cut brick, with variations in the die; are all taken directly to tunnel dryers on steel cars, on which they remain during the drying process. They emerge from the opposite end of the tunnel, and are taken to down-draft kilns. The dry-pressed bricks go directly from the presses to the kiln, as they require no drying. These kilns are single, or double, or continuous, and all burn by soft coal, except the largest and latest one, which is an enormous continuous kiln, burned by producer gas. After seven to ten days burning the kilns are cooled and the products are ready for market.

SWANSEA SEWER PIPE WORKS.

The plant of the Dominion Sewer Pipe Co. is at Swansea, to the west of Toronto. This company uses Medina shale dug near Waterdown, thirty-five miles west of the city, the shale being brought in cars to the plant at Swansea. Only the upper weathered portion of these beds, from which the lime and magnesia have been largely leached, is used in the manufacture of sewer-pipe. The shale is ground as at the Don Valley brick works, and is then mixed to a stiff plastic putty with water. It is now forced by a plunger machine through dies of the required size, turning out thereby the hollow sewer-pipe, which are cut off by wires, as in the case of the wire-cut brick. The pipes are then slowly dried in large rooms with perforated floors, heated very slowly but continuously with ordinary steam radiators.

After thorough drying the tiles are removed to large beehive down-draft kilns, where they are stood on end, the smaller ones being nested inside the larger to conserve space and maintain even drafts. After the ware has been burned to the consistency of red brick, they must undergo the further process of glazing. For this purpose common salt is thrown into the fire-boxes with the fuel, and the temperature raised to such a point that the surfaces of the tile are just fusing. This heat is maintained for a short time, the salt fumes are carried through the kiln, and on meeting the clay, which is just at the fusion point, form a sodium iron silicate with the clay, forming a glaze, covering the tile very perfectly. It is easily seen that this must not be carried too far, or the ware would fuse down and become distorted and quite misshapen. After the glazing the kiln must be cooled very gradually, a process usually distributed over three days, and even then the tile are as hot as the men can handle with buckskin gloves.

Hastings (pre-Cambrian) conglomerate, Southeastern Ontario

EXCURSION B 10

THE MADOC AREA.

BY

CYRIL W. KNIGHT.

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INTRODUCTION.

Madoc, a town of about 1,100 people, in the township of the same name, Hastings county, is situated 123 miles east of Toronto and eight miles north of the main line of the Canadian Pacific railway between Montreal and Toronto. A branch line of the Grand Trunk railway from Belleville runs into the town, which lies a few miles to the north of the Paleozoic escarpment and on the southern fringe of the great pre-Cambrian shield.

The town was the site of early attempts to smelt and mine iron ores, and a small furnace, built in 1837, was operated for eight or nine years, using charcoal. The ore was obtained from the Seymour mine, situated about three miles north of the town. Later, in the year 1866, intense excitement was created by the discovery of a small pocket of gold ore at a point about eight miles north of Madoc. There was scarcely a lot in the immediate vicinity on which pits or shafts were not sunk. Since that time iron ore, copper pyrites, gold and other minerals have been spasmodically mined in a small way in the vicinity. At the present time, however, the Henderson talc mine, on the outskirts of the town, and the Canadian Sulphur Ore Company's pyrite mine, which lies several miles to the northeast of Madoc, are being successfully operated.

GENERAL GEOLOGY.

Briefly, the geology may be summarized as follows: The rocks fall naturally into two great groups: (1) Paleozoic, and (2) pre-Cambrian. The Paleozoic consists of horizontal beds of limestone of Ordovician age (Black River). These beds rest with great unconformity on the pre-Cambrian. The latter consists, beginning with the most ancient, of the Keewatin series, which is made up of greenstone schists, which sometimes retain ellipsoidal structures and amygdaloidal textures. The Keewatin is not exposed at Madoc, but occurs in considerable volume in adjacent areas.

On the Keewatin lavas were laid down a very thick series of sediments, now highly metamorphosed, known as the Grenville, and composed of schistose quartzite, greywacké, iron-formation (jaspilyte), slate and crystalline limestone. Both the Keewatin and Grenville were invaded by the Laurentian gneissoid granite.

Beds of Slate, 1 and 3, Interbedded with Crystalline Limestone "Conglomerate," Pre-Cambrian, Madoc

After the intrusion of the Laurentian there was a prolonged period of erosion, and the Hastings sedimentary series, consisting of conglomerate and other rocks, was laid down.

Finally all the older rocks were invaded by the Moira granite and felsite, and later by basic dikes.

On the surface of the pre-Cambrian rests the Black River limestone, the lower formations of the Ordovician being absent in the district.

The accompanying colored map, scale 1,000 feet to the inch, shows the distribution of the rocks in the Madoc area.

ECONOMIC MINERALS.

TALC. A large body of talc is located on the southern outskirts of the town of Madoc. The deposit occurs in a brown, somewhat quartzose crystalline limestone of Grenville age, an analysis of which shows it to have the following composition: Ca O, 29.29 per cent.; Mg O, 15.53 per cent.; CO_2, 43.67 per cent.; insoluble, 4.62 per cent. The talc has a width which varies from 25 feet or less to 40 feet. The crystalline limestone on each side of the deposit contains bands of white quartz several feet or more wide. A horizontal plan shows the talc to occur in the form of a horseshoe, or the letter "V," due to the strata having been sharply folded. The material has been mined a distance of about 500 feet, but the extent of the body has not yet been determined in the underground workings; and the surface on each side of the hill is covered with drift.

It is probable that the talc has resulted from the alteration of the crystalline limestone, since many parts of the occurrence still show distinct traces of the original bedding or lamination of the limestone. The origin of the talc may be partly connected with the intrusion of the Moira granite from which circulated silica holding waters. The latter probably acted on the dolomitic limestone, giving rise to the hydrated, magnesian silicate, talc.

PYRITE. The pyrite mine of the Canadian Sulphur Ore Company is situated several miles northeast of Madoc near the village of Queensboro. The ore body occurs in Grenville rocks at the contact of a bed of fine-grained, rusty schist and quartzite, both beds resting in almost vertical position.

Henderson Talc Mine, Madoc.

An intrusion of grey felsite, which lies about 100 yards southeasterly from the deposit, is believed to be genetically connected with the ore body. The rusty color of the schist is due to the decomposition of pyrite and pyrrhotite, with which the schist is highly impregnated. Hot solutions accompanying the felsite magma may have effected a concentration of the sulphides originally contained in the schist, resulting in the formation of the ore body. The rusty schist occurs not uncommonly in various parts of south-eastern Ontario. The sulphides accompanying it may have been deposited at the time the rock was originally laid down as a shale.

FLUORSPAR. Several veins of fluorspar, varying in width from a few inches to six or seven feet, occur within a radius of two or three miles of Madoc. They are all probably post-Ordovician in age, since one of them intersects limestone beds of the Black River formation. The others occur in felsite, crystalline limestone and other rocks of pre-Cambrian age. Associated with the fluorspar are subordinate amounts of barite.

BIBLIOGRAPHY.

The geology of the Madoc and surrounding areas is described in Part II of the 22nd Annual Report of the Ontario Bureau of Mines, in which references to earlier literature are given. Seven geological maps accompany the report.

ANNOTATED GUIDE.

TORONTO TO IVANHOE.

Miles and Kilometres.	
0.0	Toronto, altitude at water-line of lake Ontario is 246 feet (74.9 m.).
100.8 m. 162.2 km.	The country between Toronto and Havelock is heavily covered with Glacial and Recent deposits of boulder clay, sand, gravel, etc., and outcrops of Paleozoic rocks are almost lacking. At Toronto the boulder clay is seen to be resting on Lorraine shales. Thus in the Humber and Don valleys contacts of the shales and Glacial deposits may be seen.

Canadian Sulphur Ore Company's Property, Looking East.

Miles and
Kilometres.

103. m. A few miles east of Havelock Black River
165.7 km. limestones are exposed, and the pre-Cambrian
complex also makes its first appearance about
one-quarter of a mile north of the railway track,
where trap is developed on the surrounding
hills, and is being quarried and crushed for
road metal.

122.8 m. Between Havelock and Ivanhoe flat-lying
197.6 km. limestone is exposed, except where covered by
extensive swamps which occur in this area.
These Paleozoic limestones continue to within
132. m. a few miles of Tweed, and the surface of
212.4 km. the country presents a striking appearance owing
to the numberless boulders of the limestone
which cover it. At Tweed pink granite gneiss
and Trenton limestone are exposed.

Ivanhoe to Madoc.

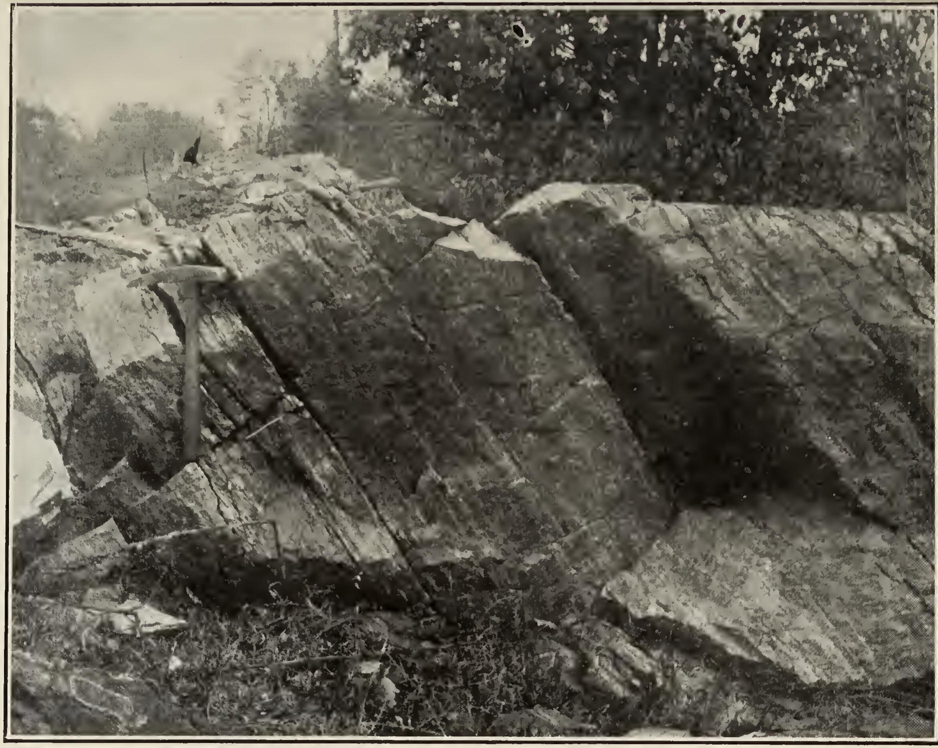
The village of Madoc, which lies about seven miles north of the Canadian Pacific railway, is connected by wagon road with Ivanhoe station, and for four miles north of the station the road passes over horizontal beds of Ordovician (Black River) limestone. The northern face of this limestone presents a steep escarpment, the latter presumably caused by a fault. To the north of the escarpment the great expanse of the pre-Cambrian shield is entered, and the village of Madoc is seen resting on the southern fringe of these ancient rocks. The topography of the country underlain by the Black River limestone is flat or gently rolling, while that presented by the complex peneplain of the pre-Cambrian is comparatively rugged.

Crystalline limestone, Grenville series, Southeastern Ontario.

Eozoon-like structures in crystalline limestone, Grenville Series.

Surface of crystalline·limestone, Grenville Series

Volcanic bombs in ash beds, pre-Cambrian, Southeastern Ontario



Iron formation (jaspilyte) in the Keewatin of Southeastern Ontario

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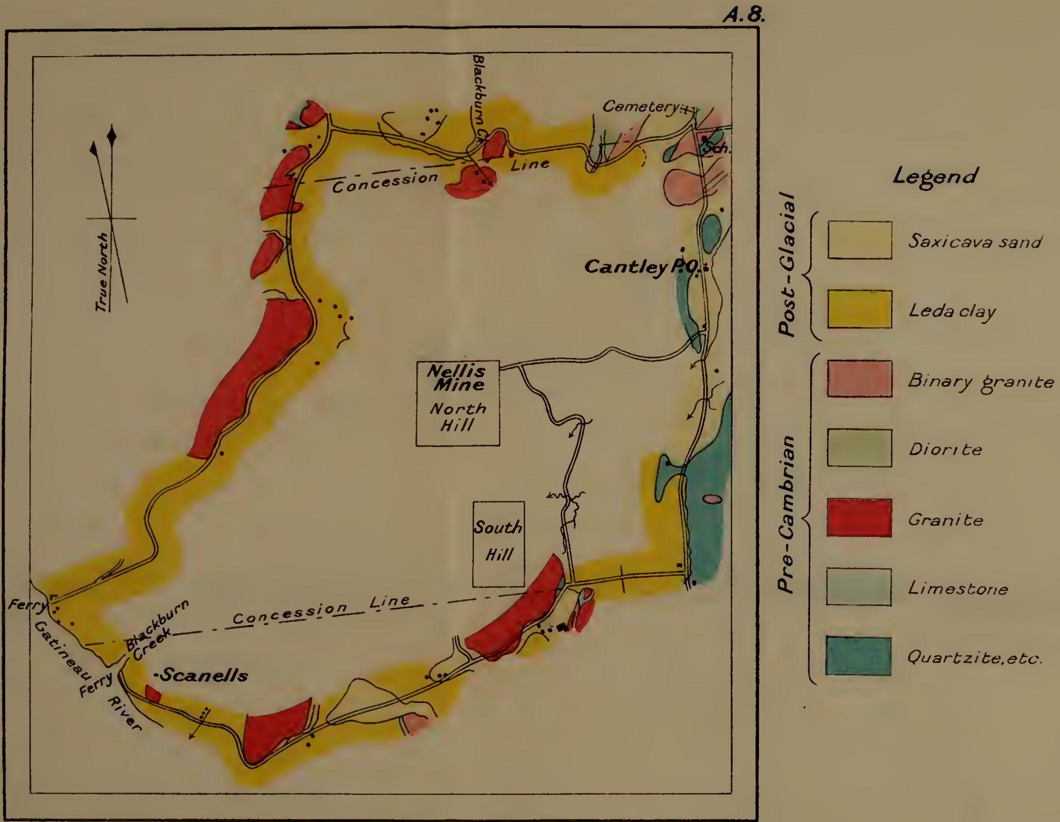
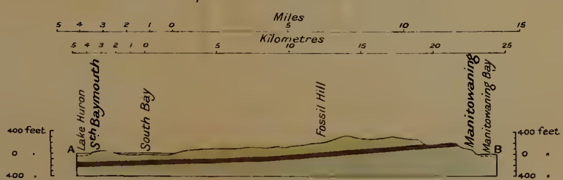


Geological Survey, Canada

Route map, **Cantley, Quebec.**

Geological Survey, Canada.

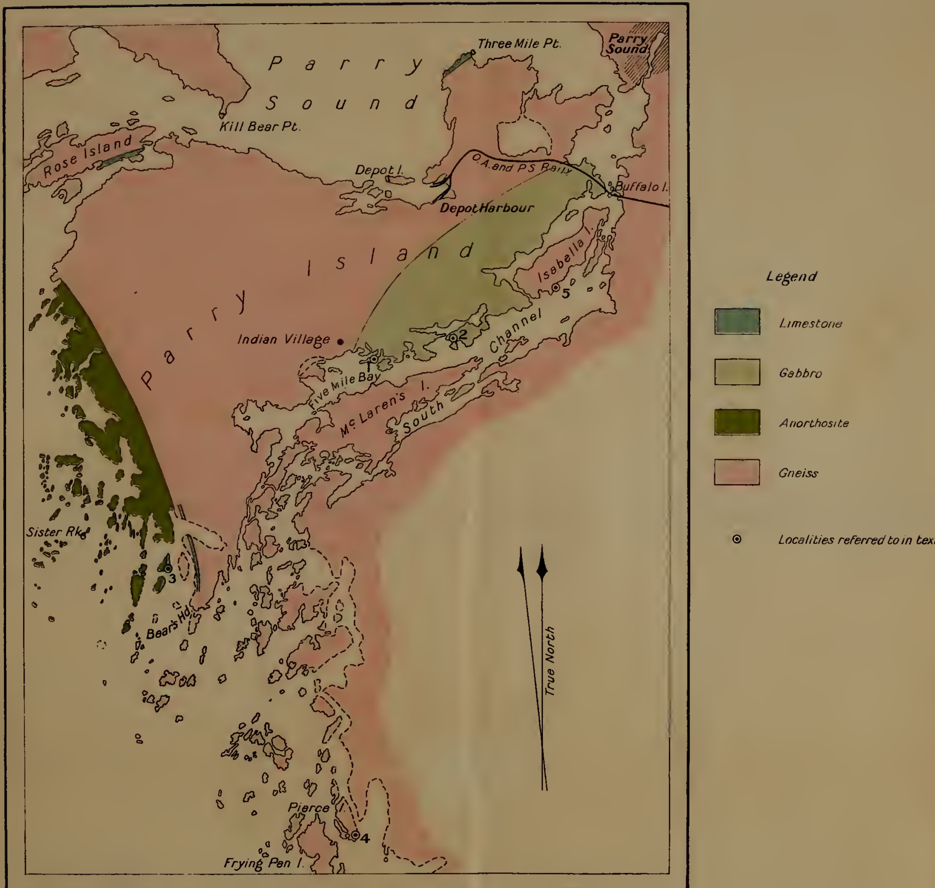
Eastern portion of **Manitoulin Island**



Section along line A B

Horizontal scale 0 1 2 3 4 5 miles

Vertical scale 0 800 1600 feet

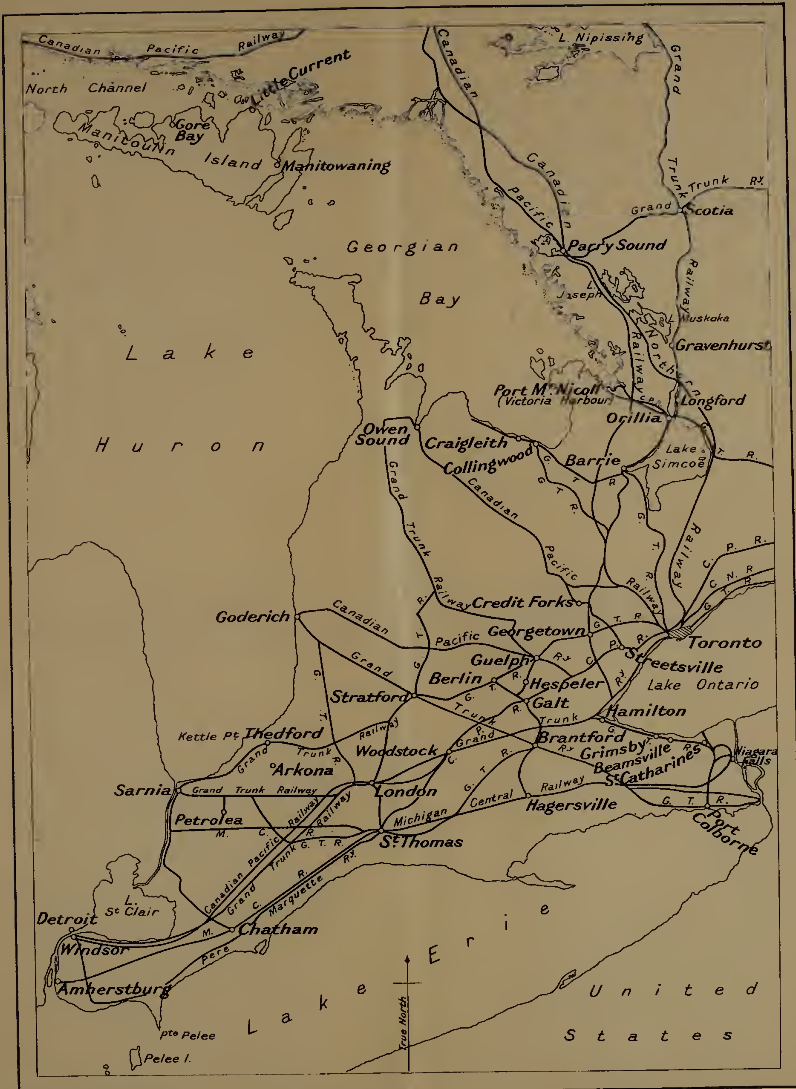


Geological Survey, Canada

Parry Sound and Vicinity

Miles
1 0 1 2 3

Kilometres
1 0 1 2 3 4 5

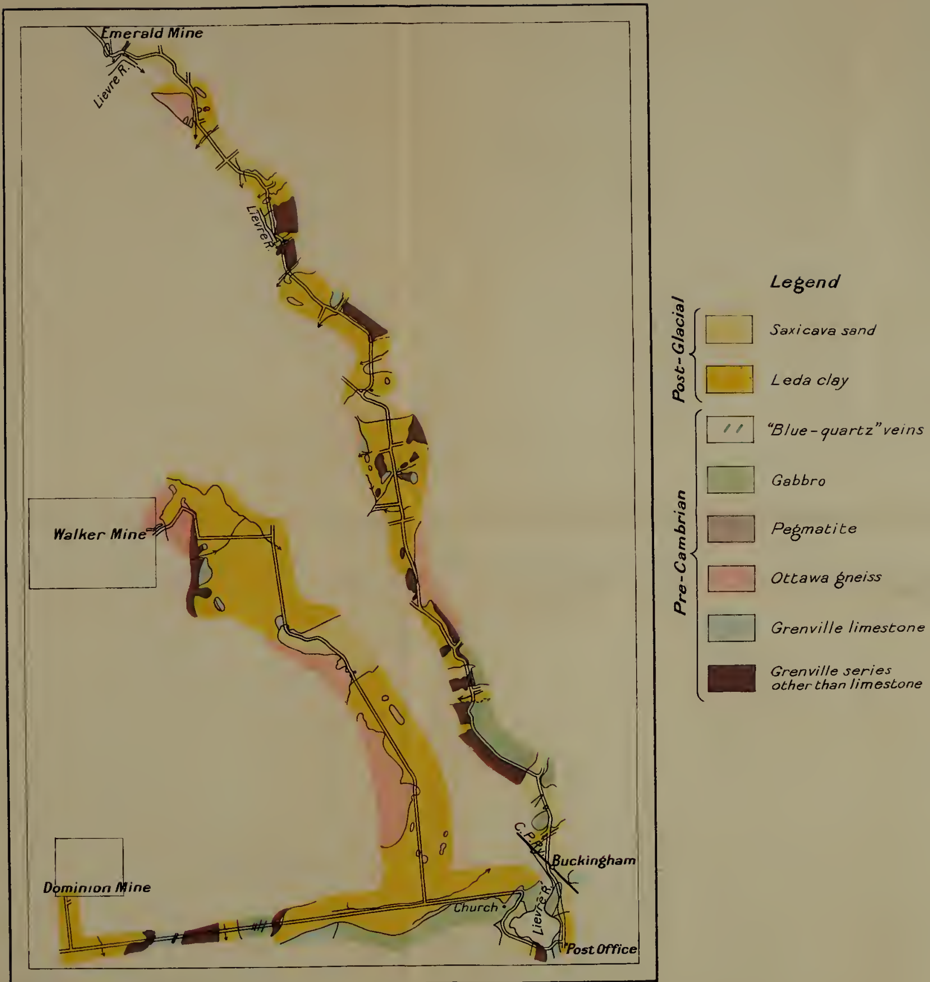


Geological Survey, Canada

Route map between **Toronto** and **Manitoulin Island**

Miles: 25 0 25 50 75 100

Kilometres: 25 0 25 50 75 100 125 150



Geological Survey, Canada

Route map between **Buckingham** and **Emerald Mine**

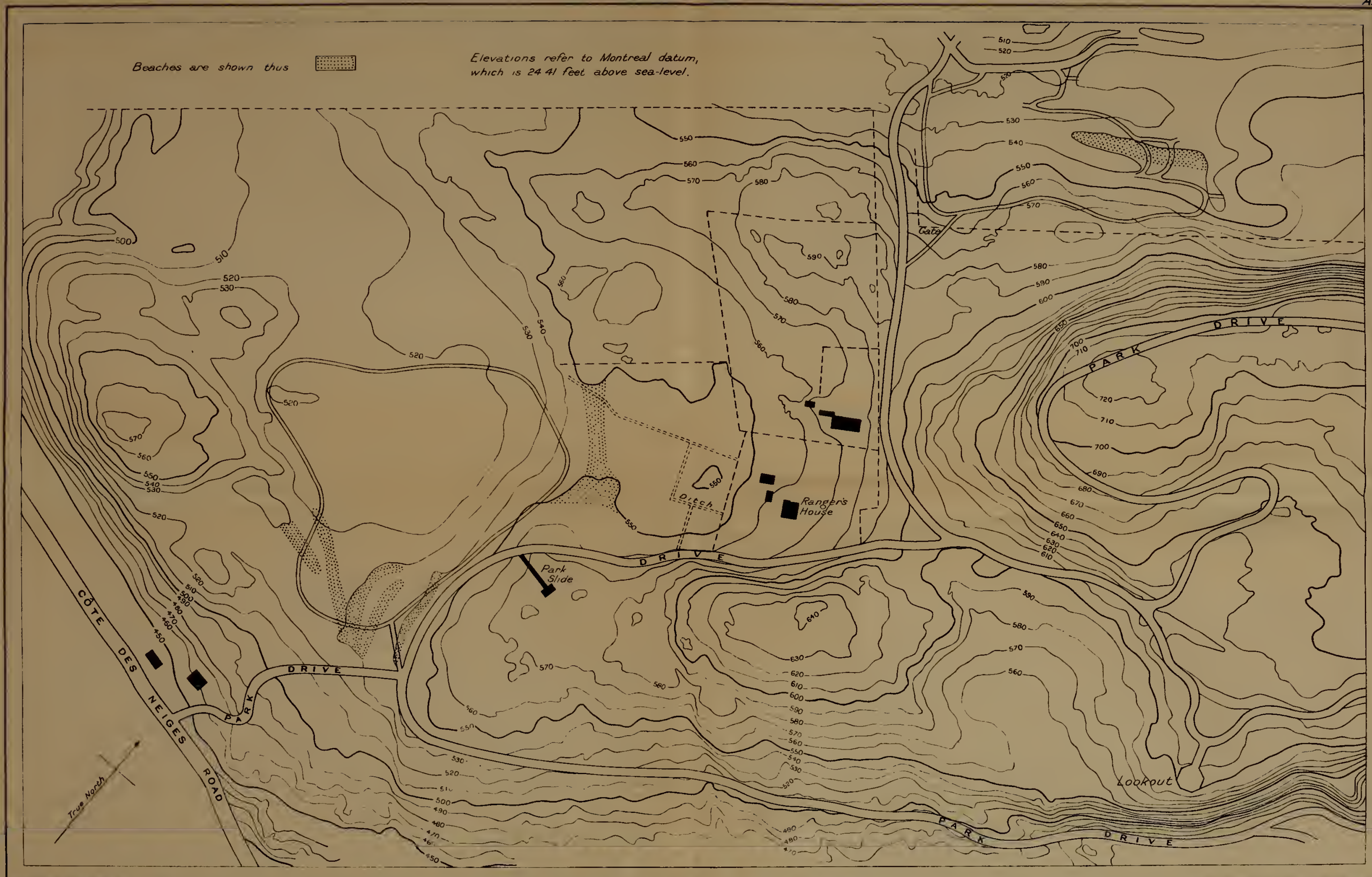
Feet
1000 0 4000 8000 12000
Metres
1000 0 2000

Geological Survey, Canada.

Hamilton and Vicinity

Miles

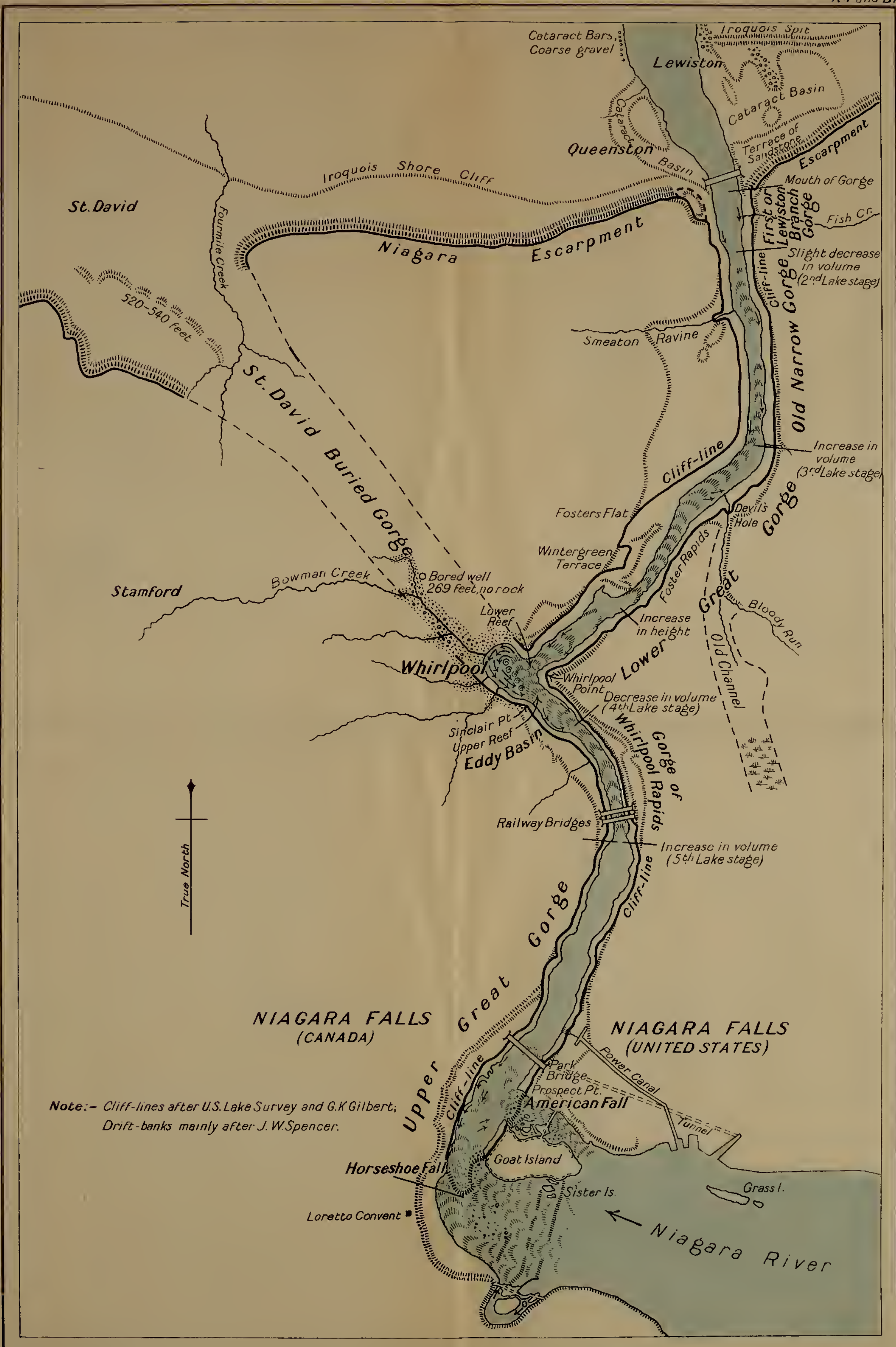
Kilometres



Geological Survey, Canada

Base map from maps ... in the office of the City Surveyor, Montreal

Part of Mount Royal showing Upper Marine Beaches



Geological Survey, Canada

Niagara Gorge

Feet: 1000 0 2000 4000 6000 8000

Metres: 500 0 1000 2000

Geological Survey, Canada

Walker Mine, Buckingham Township, Quebec.

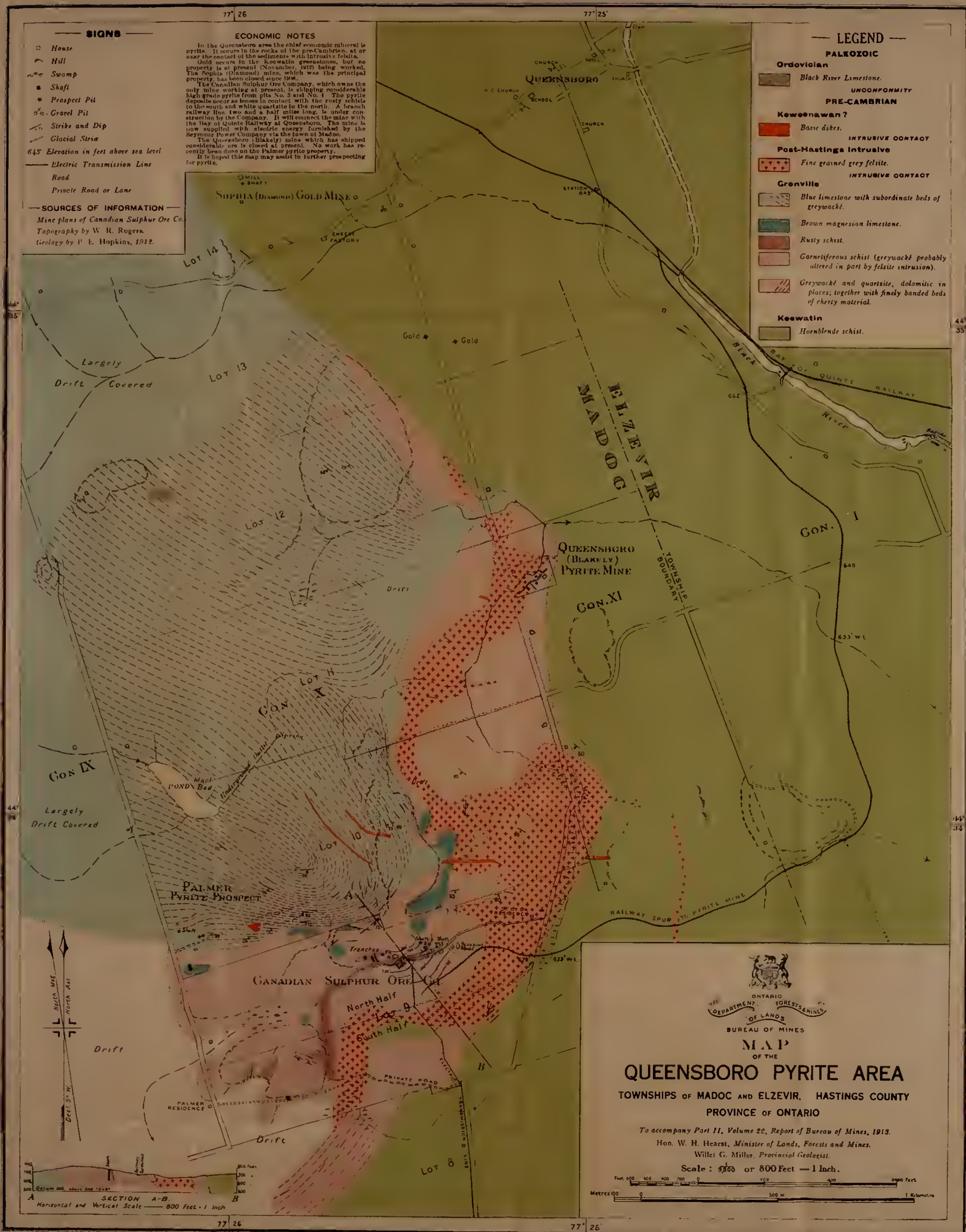
Feet
500 400 300 200 100 0 500 1000
Metres
100 50 0 250

Geological Survey, Canada

Montreal

Miles

Kilometres



SIGNS
House
Hill
Swamp
Shaft
Prospect Pit
Gravel Pit
Strike and Dip
Glacial Striæ
645 Elevation in feet above sea level
Electric Transmission Line
Road
Private Road or Lane
SOURCES OF INFORMATION
Mine plans of Canadian Sulphur Ore Co.
Topography by W. R. Rogers.
Geology by P. E. Hopkins, 1912.
ECONOMIC NOTES
In the Queensboro area the chief economic mineral is pyrite. It occurs in the rocks of the pre-Cambrian, at or near the contact of the sediments with intrusive felsite.
Gold occurs in the Keewatin greenstones, but no property is at present (November, 1912) being worked. The Sophia (Diamond) mine, which was the principal property, has been closed since 1906.
The Canadian Sulphur Ore Company, which owns the only mine working at present, is shipping considerable high-grade pyrite from pits No. 3 and No. 4. The pyrite deposits occur as lenses in contact with the rusty schists to the south and white quartzite to the north. A branch railway line, two and a half miles long, is under construction by the Company. It will connect the mine with the Bay of Quinte Railway at Queensboro. The mine is now supplied with electric energy furnished by the Seymour Power Company via the town of Madoc.
The Queensboro (Blakely) mine which has shipped considerable ore is closed at present. No work has recently been done on the Palmer pyrite property.
It is hoped this map may assist in further prospecting for pyrite.
LEGEND
PALEOZOIC
Ordovician
Black River Limestone.
UNCONFORMITY
PRE-CAMBRIAN
Keweenawan?
Basic dikes.
INTRUSIVE CONTACT
Post-Hastings Intrusive
Fine grained grey felsite.
INTRUSIVE CONTACT
Grenville
Blue limestone with subordinate beds of greywacké.
Brown magnesian limestone.
Rusty schist.
Garnetiferous schist (greywacké probably altered in part by felsite intrusion).
Greywacké and quartzite, dolomitic in places; together with finely banded beds of cherty material.
Keewatin
Hornblende schist.
QUEENSBORO
SOPHIA (DIAMOND) GOLD MINE
MILL
SHAFT
CHEESE FACTORY
STATION
SCHOOL
CHURCH
LOT 14
LOT 13
LOT 12
LOT 11
LOT 10
LOT 8
Largely Drift Covered
Drift
Gold
ELZEVIR
MADOC
TOWNSHIP BOUNDARY
BAY OF QUINTE RAILWAY
Black River
CON. I
CON. XI
CON. X
CON. IX
QUEENSBORO (BLAKELY) PYRITE MINE
POND
Marl Bed
PALMER PYRITE PROSPECT
Trenches
CANADIAN SULPHUR ORE CO.
North Half
South Half
PRIVATE ROAD
PALMER RESIDENCE
RAILWAY SPUR TO PYRITE MINE
TRANSMISSION LINE
North Mag.
North Ast.
Decl. 5° W.
SECTION A-B.
Horizontal and Vertical Scale — 800 Feet = 1 Inch
77° 26
77° 25'
44° 35
44° 34
ONTARIO
DEPARTMENT OF LANDS FORESTS & MINES
BUREAU OF MINES
MAP
OF THE
QUEENSBORO PYRITE AREA
TOWNSHIPS OF MADOC AND ELZEVIR, HASTINGS COUNTY
PROVINCE OF ONTARIO
To accompany Part II, Volume 22, Report of Bureau of Mines, 1913.
Hon. W. H. Hearst, Minister of Lands, Forests and Mines.
Willet G. Miller, Provincial Geologist.
Scale: 1/9600 or 800 Feet = 1 Inch.
Feet
Metres
500 M
1 Kilometre

Map Nº 22 e.

ONTARIO
DEPARTMENT OF LANDS FORESTS & MINES
BUREAU OF MINES

MAP OF TORONTO AND VICINITY

To accompany Part 1. Volume 22. Report of Bureau of Mines, 1913.

Hon. W. H. Hearst, *Minister* — Willet G. Miller, *Provincial Geologist*

Scale: $\frac{1}{63360}$ or 1 Mile = 1 Inch

Miles — Metres — Kilometres

Map Nº 22g

ONTARIO
DEPARTMENT OF LANDS, FORESTS & MINES
BUREAU OF MINES

MAP OF THE MADOC AREA

TOWNSHIPS of MADOC and HUNTINGDON, HASTINGS COUNTY

PROVINCE OF ONTARIO

To accompany Part II, Volume 22, Report of Bureau of Mines, 1913

Hon W. H. Hearst, *Minister* Willet G. Miller, *Provincial Geologist*

Scale: $\frac{1}{12000}$ or 1,000 Feet = 1 Inch

1000 500 0 1000' 2000' 3000 Feet

Metres 100 0 1 Kilometre