# FORTY-FIRST ANNUAL REPORT

OF THE

# ONTARIO DEPARTMENT OF MINES

1932

# PART VII

PROVINCE OF ONTARIO
DEPARTMENT OF MINES

HON. CHAS. MCCREA, *Minister of Mines* THOS. W. GIBSON, *Deputy Minister*

# FORTY-FIRST ANNUAL REPORT

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# ONTARIO DEPARTMENT OF MINES

BEING

## VOL. XLI, PART VII, 1932

# The Pleistocene of the Toronto Region
## (Including the Toronto Interglacial Formation)

By
A. P. COLEMAN

APPENDIX: MORAINES NORTH OF TORONTO

By
Frank B. Taylor

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## COLOURED GEOLOGICAL MAP
### (In pocket at back of report)


Map No. 41g—The Pleistocene of the Toronto Region. Scale, 1 mile to the inch.

# THE PLEISTOCENE OF THE TORONTO REGION

## (Including the Toronto Interglacial Formation)

By A. P. Coleman

## Introduction

The bed-rock geology of the Toronto region has been admirably reported upon by W. A. Parks, professor of geology at the University of Toronto, and his assistants, and the many fossils which occur in its shales have been described in detail by Dr. Parks, W. S. Dyer, Madeleine Fritz, and Helen Stewart (now Mrs. Whitehouse), in reports of the Ontario Department of Mines;[1] but the Pleistocene geology of the region, though commented on by distinguished geologists from time to time for many years, has never been described in detail in any government report. This is not because the drift deposits of Toronto and its environs are not of interest to geologists, for more than a score of references to special features of its Pleistocene beds are to be found scattered through geological literature, beginning ninety years ago with Sir Charles Lyell's brief description of fine terraces in the backwoods at the rear of the little city.

In reality the drift sections in Toronto and along the rivers and lake shores near by include the most complete and interesting record of the Pleistocene in North America if not in the whole world. Two of these sections, one at the Don Valley brickyard and another along Scarborough Heights,[2] have been visited and admired by hundreds of geologists from the Old World as well as the New, and have become famous among students of the Pleistocene. It is to be feared, however, that most Torontonians have never heard of them and take no pride in features that, from the scientific point of view, distinguish Toronto from all other cities.

The history of the last million years is disclosed more or less legibly on the banks of rivers, in cliffs beside Lake Ontario, in muddy brickyards, in the crumbling walls of sand and gravel pits, and in the holes dug by steam shovels for the foundations of skyscrapers; but the story has to be pieced together and pondered over patiently to give it anything like completeness, and, in addition to early accounts of Scarborough and the Don, the following report will include the results of forty years' study of all sorts of outcrops and excavations within twenty miles of the city. Many of the most interesting exposures have been worked out and abandoned, or have been engulfed and built over by the growing city, and except for notes and photographs made at the time, their records are lost forever; but it is hoped that enough has been learned to give a fairly complete account of a most romantic series of events, including the spread of vast ice-sheets, the advent of rich forests, like those of Pennsylvania, with a warmer climate than the present, the carving and filling of river valleys, and the drowning of the region under great lakes far deeper than Lake Ontario.

The drift of the region includes a considerable variety of materials, beginning with glacial deposits, such as till or boulder clay, varves or stratified glacial clay, and stratified glacial sand and gravel. Then come interglacial beds, consisting

[1]Ont. Dept. Mines, Vol. XXIX, 1920, pt. 6; Vol. XXX, pt. 7; Vol. XXXI, pt. 9; Vol. XXXII, pt. 7.

[2]Designated "Scarborough Bluffs" on the geological map accompanying this report.

of old lake or river deposits of clay, sand, and gravel, including land and fresh-water fossils of plants and animals, followed by later sheets of glacial clay and sand, and finally by the shore and shallow water deposits of Lake Iroquois, a glacial lake.

The most widely spread Pleistocene material is till or boulder clay, which almost everywhere covers the original rock surface, recurs at higher levels, and forms the rolling hills and plains east and west and north of the city. The interglacial and post-glacial beds have been mainly derived from them, so that the whole of the drift that covers the region and provides the existing hills and valleys and plains is of glacial origin.

All the familiar features of our landscapes, except the cliffs cut by the waves of Lake Ontario, are due more or less directly to the work of vast ice-sheets coming from the northeast and occupying the country for many thousands of years.

In order to develop the Pleistocene history of the region in a complete and orderly way it is necessary to have a framework showing the succession of events in this latest division of geological time, and as no satisfactory classification has been worked out in Canada, we shall adopt the most widely accepted one in the United States, that of the Upper Mississippi valley. Its latest form is as follows, the most recent till being at the top of the table:—

Wisconsin-Iowan till complex.
    Sangamon interglacial beds.
Illinoian till sheet.
    Yarmouth interglacial beds.
Kansan till sheet.
    Aftonian interglacial beds.
Nebraskan till sheet.

Until recently the classification employed in the Mississippi states included five glaciations, the Iowan and Wisconsin being taken separately; but recently Kay in Iowa[1] and Leighton in Illinois[2] have combined the last two glaciations with the short Peorian interglacial interval between them into a single glacial period.

This rearrangement of the table of glacial and interglacial times brings the classification of the United States Pleistocene into harmony with that of Europe, where four glacial periods separated by three intervals of milder climate have long been recognized in the Alps and other regions, including England. Not all of the subdivisions of the Pleistocene just given have been found in the Toronto region, only three sheets of till and two interglacial series having been recognized with certainty, so that there is still some doubt as to the position of our lower beds. The most probable correlation is as follows:—

Most recent till—Wisconsin.
    Interglacial sand—Sangamon.
Middle complex of tills and varves—Illinoian.
    Interglacial Toronto beds—Yarmouth.
Lowest till—Kansan or Nebraskan (or Jerseyan?).

In the New England states, far to the east, a very ancient till has been named the Jerseyan, from the state where it was first recognized; and our oldest till-sheet is perhaps of the same age as the Jerseyan.

[1]G. F. Kay, "The Relative Ages of the Iowan and Wisconsin Drift Sheets," Am. Jour. Sci., Vol. 21, 1931, pp. 158-173.

[2]M. M. Leighton, "The Peorian Loess and the Classification of the Glacial Drift Sheets of the Mississippi Valley," Jour. Geol., Vol. 39, 1931, pp. 45-53.

In the following report the three till-sheets will be called usually the Lower, the Middle, and the Upper; and the Toronto formation, by far the more important of the two interglacial series, will be subdivided into the Don or warm climate beds, and the Scarborough or cool climate beds. For ordinary purposes our drift may be classified as follows:—

Upper till.
  Interglacial sand.
Middle complex of tills.
  Toronto formation { Scarborough beds. / Don beds. }
Lower till.

It is natural to begin this account of the Pleistocene of the region with a brief description of the floor of ancient rock on which it rests.

### The Original Surface

The rocks beneath the Pleistocene are shales of the Dundas formation, as it has been named by Dr. Parks, and their fossils place them in the Ordovician, one of the lower divisions of the Paleozoic. The beds and their contents have been excellently described in reports of the Ontario Department of Mines[1] and need no further mention here. They were laid down as mud beneath a shallow sea hundreds of millions of years ago and were then raised above its surface to undergo attacks by the weather and by running water ever since. One might have expected to find them worn down to a peneplain with an even and nearly level surface, but this is far from being the case. The region must have been elevated not long before the Pleistocene began so that rivers could cut deep valleys into the rock, leaving a somewhat rugged surface with differences of level amounting to hundreds of feet within a few miles. If the blanket of drift were stripped off, the hills and valleys would present a very different appearance, with a rougher surface and much steeper slopes.

While enough is known to justify the foregoing statement, our information, mainly drawn from deep wells, is far too incomplete to attempt the making of a contoured map of the hidden rock surface, and we must be content with noting some prominent features.

To the west and northwest of Toronto, shale comes almost to the surface in many places. It is seen along the lake shore at various points beyond the mouth of the Humber, as at Long Branch and the Port Credit brickyard; and inland it is found north of the Dundas highway at the Cooksville brick works and rising ten feet above a small creek half a mile southwest of Woodbridge, where it reaches more than 250 feet above Lake Ontario. Near Weston it is found 190 feet above the lake, according to J. B. Tyrrell, and in the golf links north of the town it may be seen in cliffs up to the same level. Similar cliffs, gradually becoming lower, may be followed down the valley as far as the Old Mill and under the Bloor Street viaduct. In contrast with this is the well that was sunk 200 feet without finding rock on the east side of Weston Road near the corner of Church and Jane streets about a mile to the east of the last point, showing that there is here a depression reaching far below lake level; while two or three miles farther south a well sunk by Swift Canadian Company at the corner of Keele Street and St. Clair Avenue is reported to have gone through 250 feet of drift, reaching a depth more than 80 feet below the lake. A well just to the west sunk by Layne Canadian Water Supply Company, for Canadian Packers, found shale at 260 feet, or 90 feet below the lake. This old valley

[1]See footnote on p. 1.

perhaps joins an old channel at the Humber or else connects with the Woodbine channel in the eastern part of Toronto, where the engineers in charge of the new waterworks tunnel found a depression in the rock going 156 feet below the lake, and at the mouth of the Don, not far to the west, a shallower channel 88½ feet below Lake Ontario. How the two ends of the old valley were joined is not known, since the only well records between the Swift Canadian Company's well and the Woodbine indicate bed rock at much shallower depths.

Along the Don valley, rock outcrops are much less frequent than on the Humber, and the shale nowhere rises so high. No rock shows at the surface for two miles up the valley from the mouth of the river; but a sewer trench following the Rosedale Valley road disclosed shale in passing St. James Cemetery and the Necropolis, about at the level of the river; and in the Don Valley brickyard the rock rises 37 feet above Lake Ontario where the shale pit has been opened. At a bend of the Don just south of the Sun brickyard the shale makes a cliff 16 feet high, the only point where the river has cut into the bed rock. Everywhere else its bed is of drift materials.

It is evident that the pre-glacial drainage was very different from our present arrangement. The record of Page's well, two miles west of Thornhill, which is reported to have passed through 650 feet of drift before reaching rock, is very puzzling and does not harmonize with the rest of our information. The locality is about on the contour of 650, so that the rock surface appears to be at sea level, 245 feet below Lake Ontario, and far below any other known record in the region. If there has been no error in this determination a much deeper channel than the one referred to above must somewhere make its way toward the deep water on the other side of the lake. The Page well is about 7 miles east of Woodbridge, where rock shows itself 250 feet above the lake, and 11 miles north of Weston, with rock at 180 feet, so that the only possible outlet seems to be eastward, somewhere between Scarborough, where the rock is only 40 or 50 feet below the lake, and the Rouge river, with shale in its valley, four miles up from its mouth and 55 feet above Lake Ontario.

The deep well records available are as follows:—

DEEP WELLS IN THE TORONTO REGION

| | Thickness of drift | Level of surface above sea |
|---|---|---|
| | feet | feet |
| Whitchurch tp., con. I, lot 64 | 660 | about 1,000 |
| Page's,[1] 2 miles west of Thornhill | 650 | " 650 |
| Vaughan tp., con. III, lot 11 | 198 | " 675 |
| North York tp., corner Sheppard Ave. and Leslie St | 120 | 415 |
| North York tp., corner Sheppard Ave. and Leslie St | 130 | 420 |
| North York tp., Steele Ave. and Leslie St | 170[2] | 479 |
| Weston, corner Church and Jane streets | 200[2] | 375 |
| Swift Canadian Co., corner Keele St. and St. Clair Ave | 250 | 425 |
| J. Van Sickler, 252 Dupont St | 105 | " 400 |
| Royal Ontario Museum, Bloor St. and Avenue Rd | 127 | " 375 |
| Sherwood Park | 115 | " 525 |
| St. Augustine Seminary, Scarborough | 330 | 525 |
| Shore, Scarborough | 40 | 246 |
| Wickett and Craig, corner Cypress and Front streets | 102 | " 255 |

[1]This well was drilled by the Page Oil and Gas Company in 1908.
[2]Rock not reached.

From the account just given of the levels of the ancient rock surface, it is evident that the region was one of high relief with hills and steep-walled valleys through which flowed rapid rivers toward destinations not very certainly known, but probably draining eastward through the St. Lawrence valley toward the Atlantic. There is nothing to show whether the country was bare or forest-covered, or what animals roamed over its hills and valleys, since no Pliocene beds have been found in Ontario. From deposits of that age in the United States we may suppose that the climate, which had been warm, was growing cooler, but that many strange mammals still inhabited the region, such as camels, ground sloths, ancestors of the mammoth and mastodon, and the sabre-toothed tiger. All this was destined to come to an end with the beginning of the Pleistocene and the advance of the Labrador ice-sheet over the whole lake region.

In taking up the study of our Pleistocene it will be advisable to describe certain characteristic deposits in detail and in that way bring out the general features of its complicated history. Two localities are of greatest importance, the Don valley and Scarborough Heights, and we shall begin with the first of them.

## Sections in the Don Valley

The valley of the River Don in the eastern part of Toronto attracted attention very early in the history of the city, and the first important publication of the Canadian Geological Survey, "Geology of Canada, 1863," states that "freshwater shells are found in the banks of the Don, beneath a considerable thickness of sand, at about 30 feet above the level of the lake." In the same publication, Henry Youle Hind is quoted to the effect that "in digging wells in Toronto . . . trunks and branches of trees have been found imbedded in the overlying yellow clay at depths from 10 to 20 feet from the surface."[2]

It was many years later, however, before the real importance of the finds of wood and shells along the Don was recognized, when, in about 1890, the city undertook to straighten the beautiful curves of the little river and to improve it by digging an ugly canal for a mile or two up the valley. In this useless operation, fine sections of the drift were opened up and roused the interest of one of our best known naturalists, Dr. Wm. Brodie, who took many walks up the valley to study its drift deposits and its plants and animals. Another student of nature, a printer named J. Townsend, began to collect shells and bits of wood from beds of sand and clay exposed in the work, and finally secured some fragments of leaves, which were sent to Sir William Dawson in Montreal to be identified. He handed them over to D. P. Penhallow, the botanist at McGill University.

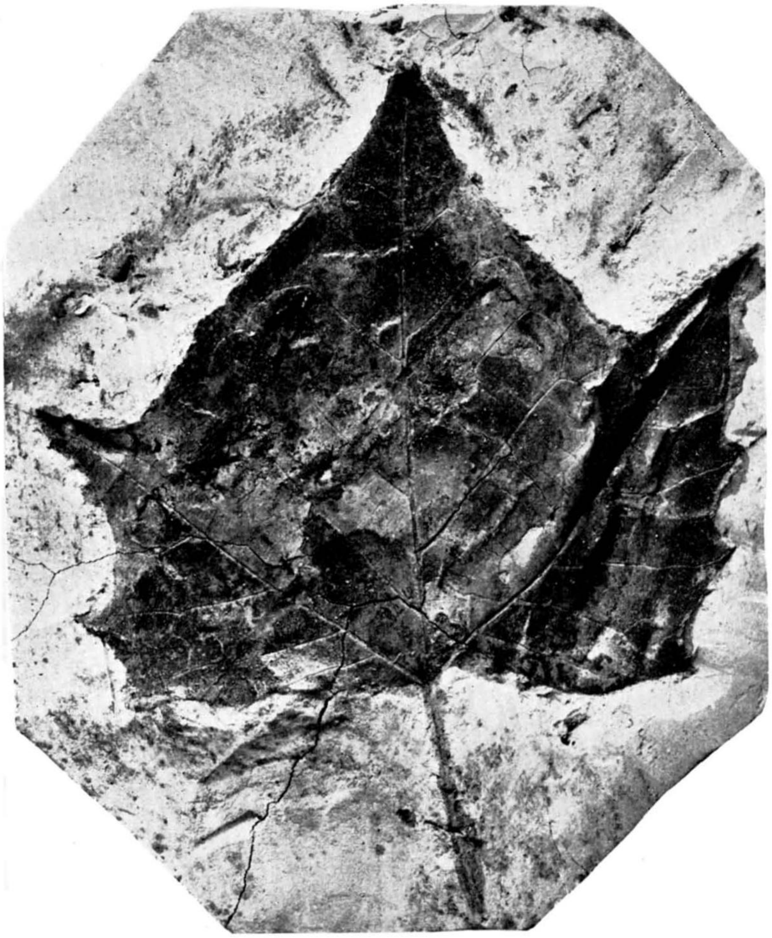
Many of the leaves belonged to familiar trees, but one maple leaf could not be included in any modern species of maple and was named by Penhallow *Acer pleistocenicum*, the Pleistocene maple.[3] The finding of an extinct species of tree in our drift roused fresh interest, and all excavations in the Don valley were carefully watched by the two collectors mentioned and others who had heard of the discovery. Presently another bit of work provided opportunities for collecting, this time the levelling of the bottom of the valley, near the present Riverdale Zoo, for park purposes and to provide occupation for the prisoners in the neighbouring gaol, and more fossils were secured. At about the same time the Belt Line railway was built up the valley, long before the city needed new transport facilities. The road was a failure, but its cuttings on the side of the valley provided quantities of freshwater shells.

[1]"Geology of Canada, 1863," p. 914.

[2]Ibid, p. 904.

[3]Bull. Geol. Soc. Am., Vol. 1, 1890, p. 315.

Finally, toward the end of the last century, the most important exposure of the Toronto Pleistocene was opened in the Don Valley brickyard.[1] This may be described without hesitation as much the most interesting Pleistocene section in Canada or on the continent of America. The continuous operation of the Don Valley brickyard has provided a constant succession of fresh exposures; and its workings as a whole supply the most complete series of drift deposits known from a single locality. It has not alone given the collectors the widest



Leaf of *Acer pleistocenicum* (natural scale).

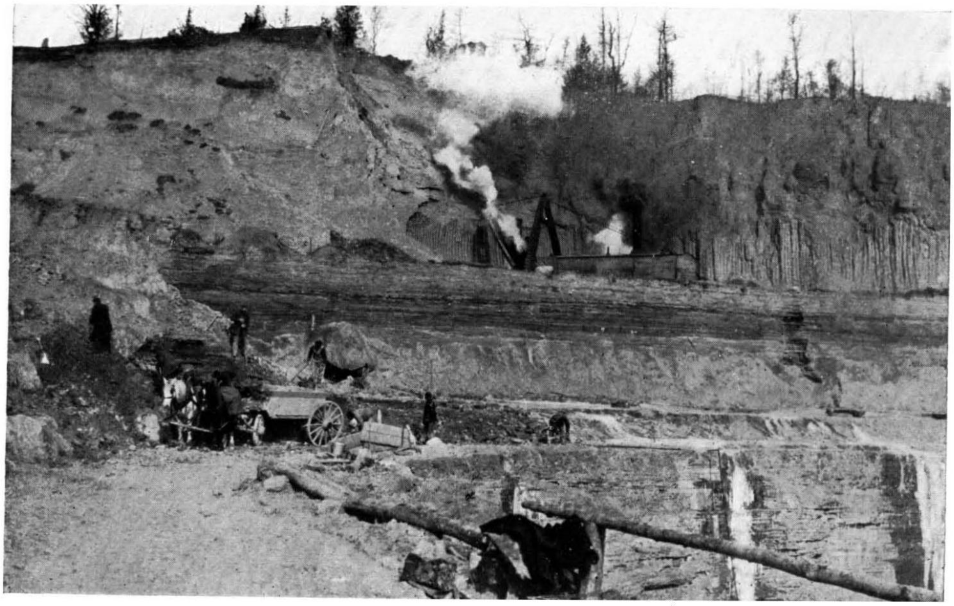
range of interglacial fossils in the country, but has disclosed the relations of the different beds to one another, so that the history of the Pleistocene in southern Ontario could be worked out with some certainty.

It will be seen, then, that our study of the Pleistocene naturally begins with the Don Valley brickyard. This most famous of brickyards is easily accessible, since it is close to Government House and may be seen looking north from the Bloor Street viaduct. It was perhaps not intended, when the Lieutenant-

[1]Taylor Bros. started operations in the Don Valley brickyard in 1889, and were succeeded by the Don Valley Brick Works in 1909, and they in turn by the Toronto Brick Company, Limited, in 1929.

Governor's residence was placed where it is, that the representative of the King should have within sight beneath him the most interesting bit of geology in southern Ontario, but such is the case.

A number of collectors have kept an eye on the Don valley interglacial beds, including the late John McArthur, who lived about half a mile north of the present Bloor Street viaduct, near the former Rosedale Station of the Canadian National Railway, and the late J. Townsend. The present writer has kept a fairly complete record of developments at the brickyard since it opened and has taken the members of the British Association for the Advancement of Science and also the Pleistocene geologists of the International Geological Congress, which met in Toronto in 1913, to see this unsurpassed section of the drift.



Section at Don Valley brickyard. The lowest bench is Lorraine shale.

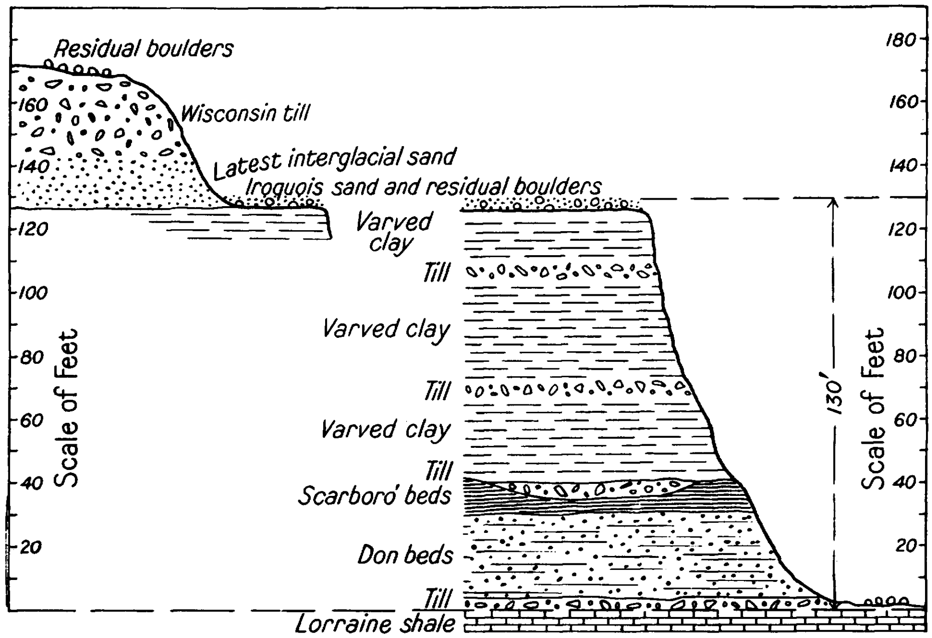
### The Lower Boulder Clay

In our account of the section we shall begin at the bottom and work upwards, following the historic order. The lowest boulder clay at the Don Valley brickyard forms only a thin sheet, from 2 to 3 feet thick, and is bluish-grey like the higher tills, but somewhat harder. It seems surprisingly fresh for so ancient a till and shows no weathered upper surface. Besides many fragments of the underlying shale there are pebbles and boulders of more ancient rocks enclosed in the till, especially of granite and gneiss and greenstone from the Archean to the northeast. Bits of black shale and limestone, similar to the rocks forming the surface along the shore of Lake Ontario to the east, prove that the ice came from that direction. The nearest sources of granite and gneiss are 70 or 80 miles to the north, but the blocks enclosed have probably come from the Thousand Islands region at the east end of the Lake Ontario valley.

It is not hard to find well-polished and striated stones in the boulder clay, characteristic examples of ice work; but a striated surface has nowhere been found on the shale beneath. The lowest boulder clay is to be seen at a number of other places and is often thicker than at the brickyard. Before the Sunnyside improvements were made, the shore cliff at Parkdale and the Exhibition grounds displayed just above the lake a thicker section of this till.

### The Don Interglacial Beds

The boulder clay just described is, of course, a glacial formation, but right upon its unweathered surface there is blue stoneless clay in which are slabs of wood and sometimes whole tree trunks with their branches. Clam shells occur in the same clay, and their two valves are often united and the shells are covered with a greenish epidermis, showing that they lived there on a muddy bottom. The wood includes red cedar and other trees of a climate somewhat warmer than the present, and some of the freshwater clams (unios) are Mississippi forms that do not now live in Lake Ontario.




Sections at Leaside (upper left) and the Don Valley brickyard (lower right).

It is evident that a very startling and dramatic set of changes took place between the laying down of the lowest till and the few inches of mud resting on it containing warm climate trees and unios. The temperature changed from arctic to warm temperate. Instead of thousands of feet of ice, there was a lake much higher than Lake Ontario. There was a connection with the Mississippi allowing shellfish to migrate in; and forest trees demanding warmth and dryness had spread northwards from Ohio and Pennsylvania to the north shore of the interglacial lake.

How long a time was required for these tremendous changes is not known. In the Don section, the two apparently incompatible conditions come close together with all the intervening changes left unrecorded.

Above the blue clay there are 16 or 17 feet of sand with a few seams of clay, followed by 3½ feet of blue sandy clay, and ending with 3 feet of yellow or brown sand, the whole series of interglacial Don beds reaching about 25 feet.

Water-worn shells and bits of wood are frequent enclosures all the way up. These stratified sands and clays were laid down in the shallow water of a lake about 60 feet higher than Lake Ontario, and a river, much larger than the Don, came in from the north bringing down logs of wood from its undercut banks, leaves that fell in the autumn, and sometimes carcasses of animals, which decayed and dropped bones or horns here and there on the muddy or sandy bottom. The wood is generally more or less decayed, and the logs are greatly flattened by the load of ice that burdened the region afterwards. In one of the layers of blue clay about half way up, great numbers of leaves were found by carefully splitting the thin sheets. Most of them were broken, but a number were perfect. The brown remains unless varnished with shellac curled up when dried.

Two kinds of wood were usually well preserved, red cedar and the pawpaw. The cedar retained its reddish colour and was still elastic, and the small stems of the pawpaw were flattened but remained hard, though most of the other wood was soft and rotten. The trees were often large and old, one flattened trunk

Oak leaf (natural size).

being two feet wide. The annual rings of a small trunk of red cedar numbered 130, and others were much thicker and so must have been older.

From time to time wood and leaves were boxed up and sent to Penhallow, who had reported on Townsend's material from the straightening of the Don, and gradually the number of trees recognized increased to 35, restoring to the imagination a forest that flourished hundreds of thousands of years ago on the hills to the north of Toronto. After Penhallow's death similar material was sent to Arthur Hollick in New York, who added several trees to the list.

LIST OF INTERGLACIAL TREES

| Scientific Name | Common Name |
|---|---|
| *Acer saccharum* | Sugar, hard, or rock maple. |
| " *saccharinum* | Silver or white maple. |
| " *spicatum* | Mountain maple. |
| " *pleistocenicum* | Not identified with any modern species. |
| " *torontoniensis* | " " " " |
| *Asimina triloba* | Pawpaw. |
| *Carya ovata* | Shell-bark or shag-bark hickory. |
| *Chamaecyparis thyoides* | Southern white cedar. |
| *Clethra alnifolia* | White alder (sweet pepper bush). |

LIST OF INTERGLACIAL TREES—*Continued*

| Scientific Name | Common Name |
|---|---|
| *Fraxinus quadrangulata* | Blue ash. |
| " *nigra* | Black or swamp ash. |
| " *americana* | White ash. |
| *Gleditsia donensis* | Honey locust (species *donensis* not identified with any modern species). |
| *Juniperus virginiana* | Red cedar, juniper. |
| *Maclura pomifera* | Osage orange. |
| *Ostrya virginiana* | Hop hornbeam. |
| *Pinus strobus* | White pine. |
| *Platanus occidentalis* | Plane tree, buttonwood, sycamore. |
| *Populus balsamifera* | Balsam poplar, Balm of Gilead. |
| " *grandidentata* | Large-toothed aspen or poplar. |
| *Prunus* sp | Cherry or plum. |
| *Quercus stellata* | Post oak, iron oak. |
| " *alba* | White oak. |
| " *rubra* | Red oak. |
| " *velutina* | Black oak. |
| " *macrocarpa* | Bur or mossy-cup oak. |
| " *muhlenbergii* | Chestnut oak. |
| *Robinia pseudacacia* | Black locust. |
| *Salix* sp | Willow. |
| *Taxus canadensis* | American yew, ground hemlock. |
| *Thuja occidentalis* | White cedar, arbor vitae. |
| *Ulmus* sp | Elm. |

As given in this list, some of Penhallow's names have been revised by Arthur Hollick and J. H. White, and since Penhallow's time a number of leaves obtained in the brickyard have been determined by Hollick, giving the following additional species:—

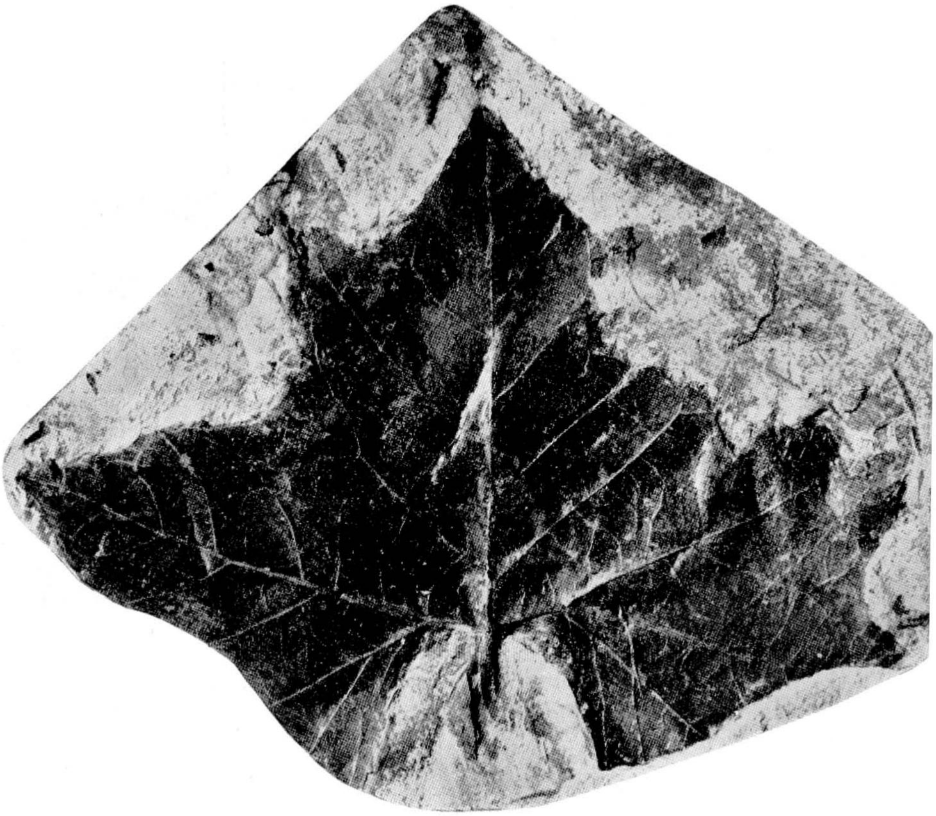
| | |
|---|---|
| *Acer carolinianum*(?), Walt | Red or swamp maple. |
| *Alnus serrulata*, Willd | Smooth alder. |
| *Castanea dentata*, Marsh | Chestnut. |
| *Ilex* sp | Holly. |
| *Tilia* sp | Basswood. |
| *Vitis* sp | Grape. |

Of the 38 species of trees, 3 have not survived the later changes of climate, *Acer pleistocenicum*, *A. torontoniensis*, and *Gleditsia donensis*. Of the others, Professor White states that 7 do not now occur naturally so far north, *Asimina triloba*, *Chamaecyparis thyoides*, *Fraxinus quadrangulata*, *Maclura pomifera*, *Quercus muhlenbergii*, *Q. stellata*, and *Robinia pseudacacia;* though two or three of them survive here when planted. It is agreed by botanists and foresters that the interglacial forest indicates a climate 4 or 5 degrees warmer than at present, about like that of Ohio and Pennsylvania.

The forest growth to the north of Toronto is well recorded, and from the list it will be seen that maples and oaks were strongly represented. Among the extinct maples, one has been named *A. torontoniensis* for the city itself. Among fruits there were the osage orange, the wild cherry, and grapes; and hickory nuts as well as acorns of several kinds ripened in the fall.

Smaller plants are much less known, though Penhallow reported *Cyperaceae* sp., *Eriocaulon* sp., *Festuca ovina*, *Hippuris vulgaris*, *Vaccinium uliginosum*, *Chara* sp., and the mosses *Drepanocladus capillifolius* and *Hypnum* sp. Seeds collected from peaty layers, as determined by W. L. McAtee of Washington, give in addition *Naias* sp., *Scirpus* sp., and *Sicyos angulatus*. Various water plants with sedges, grasses, mosses, and blueberry bushes make up most of the smaller plants.

With the splendid forest growth there must have been many land animals; but only a few are known, and they are represented mostly by separate bones, teeth, or horns that provide a very unsatisfactory record. The skull of a young groundhog (*Arctomis monax*), and horns of two species of deer have been found, and the bones of a bison and of a bear as large as a grizzly, and a single chisel-shaped tooth of the giant beaver (*Castoroides ohioensis*), which, no doubt, felled trees along the river flowing south through the timbered country. The buffalo suggests open glades in the forest. Of the birds that nested in the trees we know nothing.



Leaf of *Acer torontoniensis* (natural scale).

A find of charcoal in sand near the top of the section shows that then, as ever since, forest fires sometimes raged to the north.

As might be expected in a lake deposit, shellfish make a very important part of the fossils, and many species have been collected. The following list has been revised from one prepared years ago by W. H. Dall and his assistants in Washington. In some cases where the name has been recently revised, the former name, as used in some of the earlier lists, has been repeated in parentheses. Where possible a common name has been given for the species as well as an indication of the modern habitat of the present representative of the fossil. The latest revision, common names, and present habitats are taken from "The Fresh Water Mollusca of Wisconsin," by F. C. Baker, Bulletin 70, Wisconsin Geological and Natural History Survey, 1928.

## SHELLFISH FROM THE DON BEDS

| Scientific Name | Common Name | Habitat |
|---|---|---|
| PELECYPODA: | CLAMS: | |
| *Amblema costata* (*Quadrula undulata*). | Three ridge spike | Small rivers and tributaries of large rivers; chiefly in sand, sometimes in mud. |
| *Elliptio dilatatus* (*Elliptio gibbosus*). | Lady finger | Rivers and lakes; in mud and sand. |
| *Fusconaia undata* (*Quadrula undata*). | Pig-toe | Large rivers; deep water; mud bottom. |
| *Lampsilis siliquoidea* (*L. luteola*). | Fat mucket | Quiet water; mud bottom. |
| *Lampsilis ventricosa* | Pocket book | Large rivers; sand and gravel bottom; rarely mud. |
| *Ligumia recta* (*Eurynia recta*). | Black sand shell | Rivers and lakes; stony, gravel, sand bottoms. |
| *Pleurobema clava*. | | |
| *Pleurobema coccineum* (*Quadrula coccineum*). | Pink niggerhead | Small streams or creeks; in sand or gravel. |
| *Pleurobema coccineum solida* (*Pleurobema solidum*). | Small niggerhead | Medium-sized rivers; sand, gravel, or mud. |
| *Pleurobema pyramidatum*. (*Quadrula pyramidata*). | | |
| *Pisidium adamsi* | Finger-nail or pea shell | Quiet water, small lakes and slow streams. |
| *Pisidium compressum* | " " " " | Creeks and rivers; mud bottom. |
| *Pisidium novaboracense*(?) | " " " " | Spring brooks. |
| *Sphaerium rhomboideum* | Sphere shell | Rivers and lakes; mud bottom. |
| *Sphaerium simile* | " " | Rivers; gravel or sand. |
| *Sphaerium simile*, var (*Sphaerium sulcatum*). | " " | |
| *Sphaerium solidulum* | " " | Clear shallow water; gravel and sand. |
| *Sphaerium striatinum* | " " | Rivers and lakes; sand and gravel. |
| GASTROPODA: | SNAILS: | |
| *Acella haldemane* (*Goniobasis haldemane*). | | Sheltered bays in larger lakes. |
| *Amnicola ancillaria*(?). | | |
| *Amnicola limosa* | | Rivers, streams, and quiet bodies of water. |
| *Amnicola porata* | | *A. porata* is a lake manifestation of *A. limosa*. |
| *Birgella subglobosa* (*Somatogyrus subglobosus*). | | Lakes. |
| *Cincinnatia emarginata lacustris* (*Amnicola emarginata*). | | Lakes. |
| *Goniobasis livescens* (*G. depygis*). | | Rivers. |
| *Pleurocera acuta* | | Shores of great lakes where wave action is strong. |
| *Pleurocera acuta tracta* (*P. elevatum*). | | Various habitats. |
| *Pomatiopsis cincinnatiensis* | | On wet earth and roots at margins of small streams. |
| *Valvata lewisii*(?) *Valvata sincera* *Valvata tricarinata* | Valve shells | In lakes for the most part; in sluggish water and ponds; often on vegetation in bodies of water. |
| *Gyraulus parvus* (*Planorbis parvus*). | Pond snail | Small bodies of water; associated with vegetation. |
| *Lioplax subcarinata* (*Limnaea bicarinatus*). | " " | Same as above. |
| *Physella heterostropha* (*Physa heterostropha*). | " " | Mud flats and sewage. |
| *Stagnicola desidiosa* (*Limnaea desidiosa*). | | |
| *Stagnicola palustris elodes* (*Limnaea elodes*). | | Both clear and stagnant water but prefers water not in motion. |
| *Succinea avara* | Amber snail (a land snail) | Terrestrial. |

Present copies of the earlier lists, which are not now available, contain, in addition to the above, the following names: *Gastrocopla armifera* (a land snail) and *Pleurocera lewisii*(?). These two (as also *Amnicola ancillaria*) have not been correlated with the names of any species described or mentioned in the literature at hand.

The first ten of the species are unios, and their large shells are common in most of the Don beds and when freshly exposed are often very perfect, but if allowed to dry they usually fall to pieces. To preserve them they must be soaked with shellac dissolved in alcohol. The smaller shells, especially the slenderly coiled pleuroceras, stand exposure very well, however. Half a dozen of the shellfish do not live in Lake Ontario but are Mississippi forms. There must have been many fish in the lake, but part of a head and one of the fin spines of a large catfish are all that have been found to prove it. The trees and the shellfish are very well represented in the clay and sand beds of the Don section, giving an excellent idea of the climate of southern Ontario in the earlier part of the first interglacial period, but other species of the flora and fauna are scarcely known, with the exception of the few mammals mentioned above.

*Extent of the Warm Climate Beds.*—The Don beds with their warm climate fossils have been followed for more than a mile up the valley from the excavation made for straightening the river to the brickyard just described, and a similar deposit at about the same level is found three-quarters of a mile farther up at the Sun brickyard, so that the formation is continuous for at least two miles. The same sand with wood and shells occurs beneath the brick clay on Greenwood Avenue, two miles southeast, and beneath the level of Lake Ontario 6 or 7 miles east at the foot of Scarborough Heights, as will be noted later.

Wood and sometimes shells, which must have come from the Don beds, have been reported from a number of points to the southwest; for instance, unios and a tree trunk were found on Adelaide Street between Widmer Street and Drummond Place twenty-five years ago, and at a still earlier date Goldwin Smith sent the writer bits of wood from a log encountered below 30 feet of clay in a well sunk on the Grange property (now the Art Gallery of Toronto); and logs or bits of wood have been found in digging foundations for a number of large buildings, such as the Hydro-Electric on University avenue and the new Eaton building on College street. The westernmost point was on the lake shore in Parkdale, where wood was found in boulder clay beneath a boulder pavement. One of the most interesting occurrences was in a well bored at 252 Dupont street by J. Van Sickler, where, under 40 feet of boulder clay, sand, and varves, a thick bed of sand contained wood and three species of shells. Much farther north, at a point about 2 miles west of Thornhill (Page's farm), as already mentioned, one of the deepest wells sunk in the Toronto region passed through glacial clay, sand, and gravel, and at 380 feet struck sand containing a pine cone, wood and bark, and several species of shells, including both coiled forms and unios.

The Don beds extend from Humber bay to Scarborough, a distance of nearly 12 miles from west to east, and within the city have a breadth of 3½ miles, as shown by the known occurrences of wood and shells; and there can be little doubt that their real area is much greater. If the Page well should be included, these warm climate beds reach 14 miles north of Lake Ontario, and the area originally covered by them can hardly be less than 80 or 100 square miles. As the lowest of the interglacial deposits they are naturally the hardest to explore, since only deep cuttings by the river or deep excavations or well-borings will reach their level. It is interesting to note that the Don beds incline toward the southeast. They rise 60 feet above Lake Ontario at the Don Valley brickyard, are about 30 feet above it on Greenwood avenue, and 5 feet below water at the foot of the Scarborough cliffs. As they are shallow-water deposits, this implies a gradual rise of the interglacial lake of about 65 feet during the time of warm climate.

*Cool Climate Clay Beds.*—Resting upon the rusty sand which forms the top of the warm climate beds, there is generally stratified clay of varying thickness from a few feet to at most 23 feet (in the section exposed at the Don Valley brickyard), with no apparent fossils of any kind, although in places there is a little peat between the layers. It appears to follow conformably, without any visible break, the sands and clays just described, but it differs entirely from them in certain important respects.

The warm climate beds were laid down in shallow water, as shown by constant variations in the materials and by thin seams of gravel, and also by the oxidized character of the brown or yellow beds making up more than half the thickness; but the thinly bedded clay above the sand appears to be a deep-water deposit, which settled quietly as annual sheets of mud undisturbed by waves or currents. Wider study has shown that this is the case, and at Scarborough the same variety of clay contains cool climate fossils, which will be mentioned when the Scarborough section is described. In one part of the section where the clay is 19 feet 9 inches thick, 672 thin layers were counted, and others above this, up to 23 feet, were too much crumpled to count. The cool climate clay is valued by the brick-makers since it burns to a bright red, while the glacial clay of the region makes buff brick because of the large amount of lime it contains. It is evident that this interglacial clay was derived from an old surface, which had been leached of its lime, and that the streams that brought it down to the deepened lake were not glacial.

#### An Interval of Erosion

In the warm climate stage the interglacial lake stood about 60 feet above the present Lake Ontario; in the cool stage it rose much higher; but at the end it was drained and the region became dry land. Why these changes of water level took place will be discussed later. With the lowering of the lake, streams began to flow on the exposed surfaces, and gradually valleys were cut down into the stratified clay and sand. One such valley in the Don Valley brickyard was sunk through the whole thickness of the interglacial beds and reached the boulder clay beneath, and it was a serious disappointment to the brick-makers to have lost that section of the clay. How long the streams were at work is not easily determined, but probably a longer time than has elapsed since the last ice age ended.

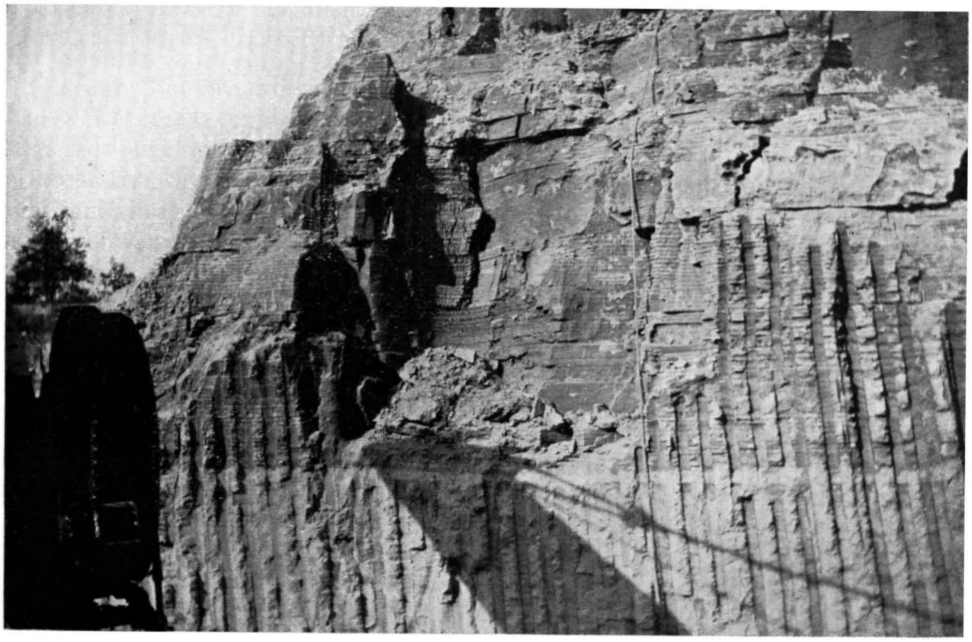
#### The Middle Till Complex

After the great lake of interglacial times was drained, the climate, which had been cooler though still temperate while the red brick clay was being laid down, became arctic, and once more a great ice-sheet gathered in Quebec and spread over the whole region. Its work is shown in the brickyard in the form of a sheet of till of varying thickness over the hills and valleys of the interglacial beds, and in one place resting directly on the oldest till. It is followed by varves of bluish-grey clay, a second thin bed of till, more varves, and finally a third till, the whole complex reaching a thickness of 105 feet.

It appears that the ice front halted in the Toronto region, sometimes advancing a little and then retreating, the varves representing times when it had withdrawn a few miles to the northeast but was still near enough to allow glacial mud to settle to the bottom. The varves consist of a paler and somewhat coarser part, made when the ice was thawing in the summer, and a darker very fine clay settling slowly in winter when the glacial lake was frozen over. The two materials combined to make an annual layer easily separated from the ones above and below.

These varves have been studied and counted by Ernst Antevs, who has estimated that the ice front halted about 1,500 years at this point.[1]

The three sheets of till are not very bouldery, though sometimes large stones are found in them. The varves contain gritty particles and rarely a small polished and striated pebble, as evidence of their glacial origin. As already noted, the varve clays are limy and burn to a buff brick, for which they are largely used. Similar banded clays are widely distributed and extend for at least half a mile northeast to Leaside, where they were found in a tunnel for a trunk sewer, and



Varved clay, Don Valley brickyard (photo taken in 1924 by W. S. Dyer).

as far south as Queen's Park, where they are encountered in digging for foundations, as at Trinity College and the Royal Ontario Museum. They were extensively worked for brick-making years ago west of Yonge Street and south of Gibson Avenue in Pear's brickyard, now Ramsden Park. The water of the Ontario basin was ponded back by the ice gathering from the east and rose once more, this time to a higher level than ever before, reaching at least 180 feet above the present level of Lake Ontario. If varved clays found at the city limits, on McNairn Street near Yonge, are of the same age, the water stood 270 feet above the present lake. The varves at this point grow thicker toward the top, sometimes reaching 6 inches instead of the usual inch or two and ending with three or four sandy layers a foot thick, which must have been formed in shallow water.

The whole complex system of till sheets and varves belongs to one glaciation, probably the Illinoian of the United States classification.

[1]Ernst Antevs, Am. Geog. Soc., Research Series No. 17, 1928, pp. 241-243.

### The Upper Till at Leaside

The section at the Don Valley brickyard ends above the glacial complex just described, except for a sandy soil strewn with huge boulders, which evidently do not belong to the beds below. To find their source it is necessary to go half a mile north to the Leaside region. The path runs over the gently sloping shallow-water terrace of Lake Iroquois, which will be described later, and ends at the old lake's fine shore cliff. The best section is just west of Leaside station, where the series of varve clays occurs a little below the surface. At the foot of the cliff there is stratified sand for 15 feet, belonging to the latest interglacial period. This is usually without fossils, though a few small shells have been found in sand, probably of the same age, west of Yonge Street, near Mount Pleasant Cemetery. Above the sand at Leaside comes the upper till 30 feet thick, consisting mostly of brown sandy materials, though parts are blue and clayey like the two older tills. The latest ice-sheet of Wisconsin age evidently picked up much sand from the surface it passed over. As the third till forms the present surface of the region, it will be described at length later.

## The Section at Scarborough Heights

The magnificent shore cliffs at Scarborough have always attracted attention from geologists and other lovers of nature, and they have the high distinction of being the first place in America where an interglacial formation was recognized. About fifty-five years ago, an amateur geologist, George Jennings Hinde, then living in the small city of Toronto, made the startling discovery that between two sheets of boulder clay, evidently formed by ice, there were at Scarborough many feet of water-laid beds charged with fossils, indicating a long interglacial period. In 1878, Hinde published an important paper on "Glacial and Interglacial Strata of Scarborough Heights" in the journal of the Canadian Institute.[1] It was accompanied by a section showing the relationships of the different beds disclosed in the cliffs. Little attention was paid to his conclusions until the present writer took up the study of the drift near Toronto early in the nineties. In 1894, a paper on "Interglacial Fossils from the Don Valley" was prefaced by a reference to Hind's work, giving a list of the fossils he described, which included diatoms, mosses, spores, seeds, pieces of wood, and remains of beetles. His account of the Scarborough section was excellent, and it is no wonder that in later years, after returning to England, he became a distinguished paleontologist.

When the study of the Don beds was undertaken, it was soon found that the interglacial series from the two localities were absolutely different, although they appeared to lie between the same two sheets of boulder clay and were only 7 miles apart. The correlation was only settled in 1898, the year after the British Association for the Advancement of Science met in Toronto and made a grant of £20 for the investigation of the Pleistocene of the region, which had greatly impressed its geological members.

With these funds in hand, wells were sunk at the foot of the cliff to disclose the lower part of the section, which was under water. The first well was a failure because the well-digger delayed the work too long and was halted by autumn storms, which drove waves into the pit, filling it with water. A second well, dug the following spring, was successful, reaching a depth of 40 feet and showing, beneath a few feet of clay like that above water, a set of sandy beds charged with shells and bits of wood, evidently representing the warm climate beds of the Don valley. Thus it was proved that the interglacial clays of Scarborough

[1]The name of the Institute was changed to Royal Canadian Institute on April 2, 1914.

described by Hinde rest upon the sand with shells and wood of the Don, and therefore are younger, though deposited during the same interglacial time.

For a number of years different parts of the Scarborough cliffs were studied by the writer, providing plenty of practice in climbing and greatly extending the list of fossil beetles found in its clay by Hind. Several papers published from time to time since 1894 refer to it, the most important description being contained in Guide Book No. 6 published by the Ontario Bureau of Mines for the International Geological Congress held in Toronto in 1913, and reprinted in the annual report for that year.[1]

The Scarborough cliffs begin at Victoria Park at the eastern boundary of Toronto and extend northeast for 9½ miles to the mouth of Highland creek. There is a gradual rise from each end toward the centre, where the highest point reaches 350 feet above the lake, and there, including the portion under water, the thickness of drift must be nearly 400 feet.

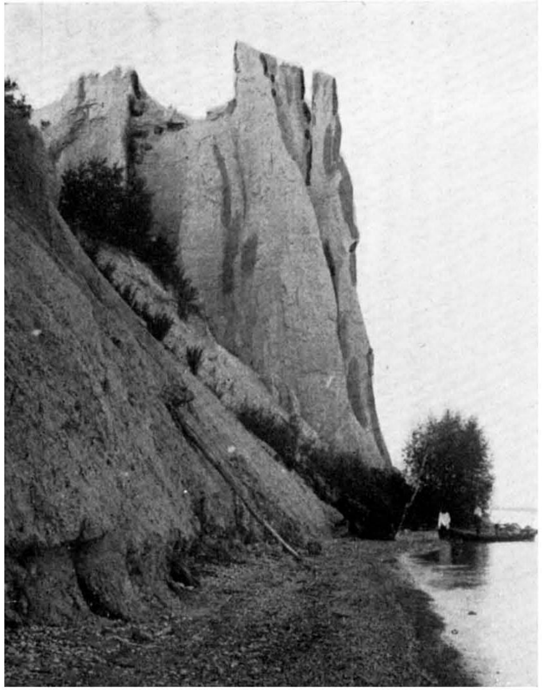
The waves of the lake constantly undermine the cliff, especially in high-water years, such as 1929 and 1930, slowly robbing the owners of adjoining properties of their acres but providing fresh sections for geological study, so that the salient features are better exposed at some times than others. The different members of the section vary greatly from point to point, some being completely cut out in places, and the most complete series is naturally found in the thickest part, in the neighbourhood of the highest point.

Of the dozens of sections measured, one from that region will be noted as typical:—

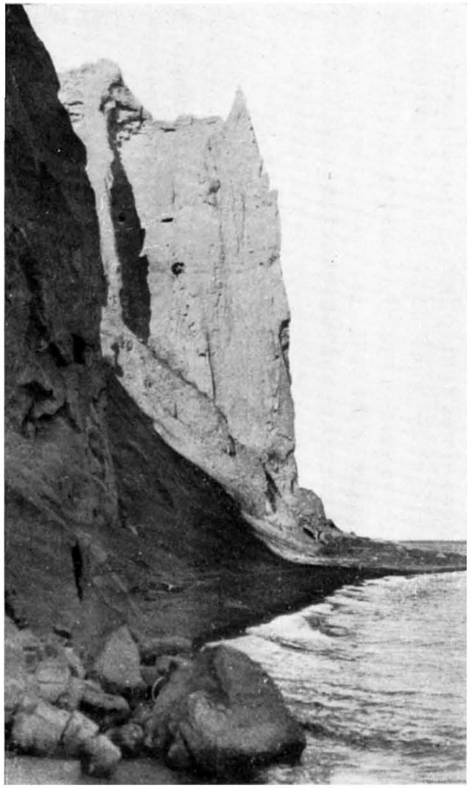
| | Feet | |
|---|---|---|
| Boulder clay | 28 | |
| Stratified clay and sand | 24 | |
| Stratified clay, probably varves | 15 | |
| Boulder clay | 43 | |
| Stratified sand | 21 | |
| Boulder clay | 4 | |
| Stratified sand, cross bedded | 45 | |
| Boulder clay | 25 | |
| Stratified sand | 58 | Cool climate, interglacial. |
| Peaty clay | 85 | |
| Level of Lake Ontario. | | |
| Peaty clay continued below water | 5 | |
| Stratified sand with wood and shells | 35 | (Warm climate.) |
| Total | 388 | |

The part below the level of the lake comes from the well already referred to but probably represents the usual arrangement. In most of the sections measured, only three tills are found instead of the four shown here. The uppermost boulder clay is the Wisconsin; the other three belong to the Illinoian glaciation. For most of the length of the section, however, only one sheet of till is visible, the lowest of the middle complex. A walk along the shore brings out some very interesting points regarding the relations of the boulder clay to the lower interglacial beds. Starting at the east end of Victoria Park, a thick sheet of till rises above the water and lifts itself higher and higher, ascending first over the interglacial peaty clay, then over the interglacial sand, until it is 150 feet above the lake at about 2 miles from the starting point. Presently the till sheet begins to descend, at first slowly after 3 miles, then rapidly, till all the interglacial beds are cut out and for 300 or 400 yards it forms the foot of the cliff; after which it rises rapidly again. For about 3 miles farther northeastwards it keeps much the same

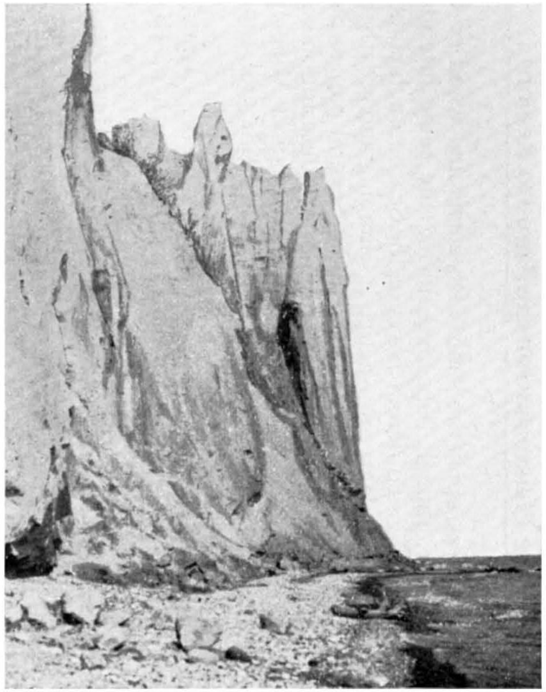
[1]A. P. Coleman, "Glacial Phenomena of Toronto and Vicinity," Ont. Bur. Mines, Vol. XXII, pt. 1, 1913.



1900



1915



1930

Three views of the Dutch church, Scarborough Heights, taken fifteen years apart.

level of 140 or 150 feet as before and then slowly descends, reaching the water near Highland creek at the end of the section.

This lowest sheet of Illinoian till when followed along the cliffs forms a gigantic bow of an unsymmetrical shape, its western arm only half as long as the eastern, and it evidently covers an interglacial tableland in which a valley was cut before the Illinoian ice was thrust over its surface from the east and spread out its sheet of till. Near the northeast end of the section the interglacial clay has been thrown into folds or even tilted into broken slabs where the advancing glacier rose upon it.

The mass of boulder clay at the bottom of the old valley is harder than the interglacial sand and clay on each side and stands up as very striking walls and buttresses; it was christened by some old-time artist "the Dutch church." The "church" forty years ago had a tower rising above the lake and was a very creditable bit of natural architecture; but weather and waves have destroyed the tower, and the resemblance is no longer so impressive. Instead a number of sharp knife-edges and pinnacles of daring forms have developed, changing in number and shape with each successive year, and providing very striking scenery. The lower part of the interglacial valley at the Dutch church is filled with the earliest of the Illinoian till sheets, above which are varved clays with two more tills, much thinner than the first. The varve series has been reported on by Antevs,[1] who finds them the equivalent of the Don varves.

Half a mile east of this old valley the cliff rises to 350 feet and includes three more till sheets, as shown above, the lower ones Illinoian, but the uppermost Wisconsin. The clay and sand between the two belong to the last interglacial time. The Wisconsin boulder clay, here as in the Don valley, is much sandier than the three Illinoian tills.

#### The Cool Climate Interglacial Clay

Too little is known of the sand and clay beds with unios below the level of the lake to justify any attempt to describe them. It is sufficient to correlate them with the warm climate Don beds already discussed. Resting upon them, apparently without a break, we find 85 or 90 feet of well-stratified grey clay, comprising the interglacial beds described by Hind and corresponding to the red brick clay of the Don valley. In most places the bedding is distinct, showing layers from half an inch to 2 or 3 inches thick with a silty parting between, though there are some beds 3 or 4 feet thick in which no lamination can be seen. The silty partings often contain peaty matter and this sometimes thickens up to half an inch or more and supplies the fossils known from Scarborough, including mosses, small leaves, chips of wood and bark, and more rarely small branches. Near the foot of the cliff there is an apparent disconformity. Every few feet in the section shows a thin sheet of impure siderite or clay iron ore, which has stood the weather better than the clay and forms flat pebbles on the beach, which are gradually turning brown from oxidation. This is very characteristic and along with the fact that the clay burns to a red brick makes the distinction between the peaty clay and the glacial stratified clays (varves) very easy. It has already been mentioned that the varve clay makes buff brick.

By washing the peaty matter to remove any intermixed clay and examining it with a lens various plant remains and many wing covers and other chitinous parts of beetles have been found; and from these tiny fossils, as different as possible from the large shells and trunks of trees of the Don beds, it has been

[1]Ernst Antevs, op. cit.

determined that the climate was somewhat cooler than at present. Some of the peat was sent for examination to John Macoun at Ottawa, who found the following species of plants:—

| Scientific Name | Common Name |
|---|---|
| *Salix* sp | Willow. |
| *Alnus* sp | Alder. |
| *Picea* sp | Spruce. |
| *Carex aquatilis* | Sedge (habitat, swamp and shallow water). |
| " *utriculata* | " " " " " " |
| *Equisetum* | Horsetail. |
| *Vaccinium oxycoccos*[1] (*Oxycoccus vulgaris*) | Small cranberry. |
| *Vaccinium uliginosum* | Bog bilberry. |

Seeds which were sent to Dr. W. L. McAtee at Washington were determined as belonging to the following plants:—

| | |
|---|---|
| *Scirpus fluviatilis* | Sedge (habitat, borders of lakes and large streams). |
| *Potamogeton* sp | Pondweed. |
| *Chenopodium* sp | Goosefoot, pigweed. |
| *Brasenia purpurea* | Water shield. |
| *Prunus* (*pennsylvanica?*) | Pin cherry or bird cherry (?). |
| *Polygonum* sp | Knotweed. |
| *Ceratophyllum demersum* | Hornwort. |

In addition several species of moss occur. Dr. Macoun interpreted the plants he studied as implying a cool climate like that of southern Labrador; but I am informed by botanists that all the plants in his list are to be found in swamps near Toronto as well as farther north. Dr. McAtee states that the plants determined from seeds indicate a climate like the present.

S. H. Scudder, from a consideration of the species of beetles, thought that they suggest a climate like that of to-day, or slightly cooler. The list of beetles (*Arthropoda*) from Scarborough which he determined follows:—

Carabidae (9 gen., 34 sp.):
*Elaphrus irregularis*
*Loricera glacialis*
" *lutosa*
" *exita*
*Nebria abstracta*
*Bembidium glaciatum*
" *haywardi*
" *vestigium*
" *vanum*
" *praeteritum*
" *expletum*
" *damnosum*
*Patrobus gelatus*
" *decessus*
" *frigidus*
*Pterostichus abrogatus*
" *destitutus*
" *fractus*
" *destructus*
" *gelidus*
" *depletus*
*Badister antecursor*
*Platynus casus*
" *hindei*
" *halli*
" *dissipatus*
" *desuetus*
" *hartti*

Carabidae.—*Continued*
*Platynus delapidatus*
" *exterminatus*
" *interglacialis*
" *interitus*
" *longaevus*
*Harpalus conditus*

Dytiscidae (3 gen., 8 sp.):
*Coelambus derelictus*
" *cribrarius*
" *infernalis*
" *disjectus*
*Hydroporus inanimatus*
" *inundatus*
" *sectus*
*Agabus perditus*

Gyrinidae (1 sp.):
*Gyrinus confinis*, LeC.

Hydrophilidae (1 sp.):
*Cymbiodyta extincta*

Staphylinadae (11 gen., 19 sp.):
*Gymnusa absens*
*Quedius deperditus*
*Philonthus claudus*
*Cryptobium detectum*
" *cinctum*

[1]*Oxyoccus*, listed in Macoun's report as *Oxycoccus vulgaris*, has become *Vaccinium oxycoccos* in recent catalogues.

STAPHYLINADAE.—*Continued*
*Lathrobium interglaciale*
" *antiquatum*
" *debilitatum*
" *exesum*
" *inhibitum*
" *frustum*
*Oxyporus stiriacus*
*Bledius glaciatus*
*Geodromicus stiricidii*
*Acidota crenata*, Fabr. (var. *nigra*)
*Arpedium stillicidii*
*Olophrum celatum*
" *arcanum*
" *dejectum*

CHRYSOMELIDAE (1 gen., 2 sp.):
*Donacia stiria*
" *pompatica*

CURCULIONIDAE (4 gen., 6 sp.):
*Erycus consumptus*
*Anthonomus eversus*
" *fossilis*
" *lapsus*
*Orchestes avus*
*Centrinus disjunctus*

SCOLYTIDAE (1 sp.):
*Phloeosinus squalidens*

**Interglacial Sand**

For about five miles in the central part of the section sand overlies the peaty clay, except, of course, where interrupted by the Dutch Church valley. Its greatest thickness is 55 or 60 feet. The lower four or five feet have clayey layers, showing a transition to the beds below, and immediately above the clay there is often a thick bed of peaty materials including many chips of wood and bark and bits of branches. From some of this wood Penhallow determined *Larix americana* and *Abies balsamea* (tamarac and balsam), two trees that go naturally with the spruce and willow and alder and blueberries whose leaves occur in the peaty layers of the clay below. There are also some small shells, *Sphaerium rhomboideum*, *S. fabale*, *Limnaea* sp., *Planorbis* sp., and *Valvata tricarinata*, all common in our present waters. Oval concretions of brown iron ore occur, but no determinable fossils were found on breaking a number of them. While the Scarborough section of the interglacial clay and sand is much the most complete there are a few other exposures which deserve mention.

*Greenwood Avenue Clay Deposits.*—It has already been noted that the peaty clay has been leached of its lime and burns to bright red brick, as proved in the Don Valley brickyard. Several important brickyards east and west of Greenwood Avenue and north of the Canadian National railway make use of the same clay and give good exposures of the interglacial beds. Here the overburden has been mostly removed by the waves of Lake Iroquois, leaving a comparatively thin deposit of its own sand, making the exploitation of the clay easier than elsewhere, though the thickness of the beds is much less than at Scarborough and other points. Price's, Logan's, and Wagstaff's brickyards, for instance, make use of the clay. The description of the section at Scarborough will apply also here, though not more than sixty feet of clay is found. A well sunk beneath the bottom of one of the clay pits many years ago reached sand belonging to the Don beds and filled with water through which rose large bubbles of gas. When a match was struck the gas took fire with a slight explosion.

In the clay pit north of the railway and east of Greenwood Avenue, 4 or 5 feet of upper sandy clay contains much peat and has been crumpled into large swirls very different in appearance from the undisturbed clay beneath. This distortion seems due to overriding by the next ice-sheet, and in the northernmost pit on the west side of Greenwood Avenue, there was at one time a section showing a shallow valley in the clay filled with a sandy type of till; but this part of the pit is filled, and no more boulder clay is to be seen, though great Archean boulders in the sand above prove that it once existed.

### Cool Climate Beds on the Don and Little Don

It has already been mentioned that clay belonging to the cool interglacial time occurs at brickyards in the Don valley not far south of Leaside station, but up the river only boulder clay and recent deposits are found in its banks as far as the forks, and for a mile farther the main branch shows only recent sand. Northeast of Leaside about where Eglinton Avenue if extended would cross the river, the cool climate clay is well exposed, especially in a cut bank to the west of a bend where 40 feet of clay, followed by 20 feet or more of sand, belongs to this interglacial stage; 15 or 20 feet of the stratified clay may also be seen on the southeast side of the next bend. Other outcrops are seen on the west bank south of Blythwood Road and below Sunnybrook Park, and half a mile northwest where the high bridge of Bayview Avenue crosses the river; low exposures are found also near Riverview Drive and in the Rosedale Golf Links east of York Mills. None of these cuttings of the river are well adapted for study, though it is probable that the cool climate clay underlies the whole region where not interrupted by old river channels filled with boulder clay.

The most complete section of the cool climate interglacial beds, except the famous one at Scarborough, is found on the banks of the Little Don, the northeastern branch of the river; but the exposures vary greatly from year to year and are sometimes hard to decipher. The best sections measured are along bends of the creek where it is crossed by the eastward extension of Lawrence Avenue. Years ago, cuttings on the Sudbury branch of the Canadian National railway also provided excellent exposures. Measurements made in 1905, when the sections were in good condition, showed peaty clay along the creek, rising 144 feet above Lake Ontario, and over it yellow sand with some clay to 154 feet, and a little farther north to 164 feet. In places a few feet of cemented gravel occurs above it, and boulder clay resting on it reached the general level of the country. How far the peaty clay goes below the creek is unknown. Outcrops of the clay are found here and there along the valley for a mile or more to the south. The contents of the clay are like those already described, but the sand above was charged with small shells, *Sphaerium*, *Valvata*, and one or two others, which are seldom found in the Scarborough interglacial beds. Some of the cuttings along the railway and the Little Don showed nothing but boulder clay, evidence that valleys had been cut before the ice passed over the region.

*Distribution of the Peaty Clay.*—The most important sections of the cool climate clay have been described, the one at Scarborough extending from southwest to northeast for more than 9 miles. The one on Greenwood Avenue lies 3 miles to the west, and the Little Don beds are 5 miles to the northwest. Many other outcrops of the peaty clay are known, the one farthest west being on Brandon Avenue near Dufferin Street. Towards the east it is found at several places on Highland creek, just west of Frenchman bay, at two points on the Rouge river, and along the west branch of Duffin creek, beginning at Dixie,[1] where the Canadian Pacific crosses the creek, and extending a mile northwest to Clarkes Hollow and half a mile beyond. Its known extent from southwest to northeast is 23 miles, and in a direction at right angles to this 7 miles, and it probably lies buried for a long distance beyond the valley just mentioned, since there are no river valleys in that direction deep enough to uncover it.

The interglacial sand overlying the clay for 5 miles at Scarborough is far less extensive and has not been found with certainty elsewhere except on the branches

[1]This should not be confused with the settlement of the same name that lies between Islington and Cooksville.

of the Don. These interglacial beds reach 150 feet above Lake Ontario at Scarborough, 164 feet on the Little Don, and about 215 feet at Clarkes Hollow, according to the contours of the topographic map that accompanies this report. Apparently the beds grow thicker toward the northeast, though the northward tilt of the land since the ice departed may account for the rise in that direction. There is reason to believe that these cool climate clay beds extended considerably beyond the thick exposures on Duffin creek, and they certainly reached much farther toward the south before the waves of Lake Ontario cut back the cliffs at Scarborough; so that their original area may have been much greater than the 140 square miles suggested by the dimensions given above.

#### History of the Scarborough Interglacial Beds

The interglacial beds of the Scarborough series are strikingly different from the Don beds below them, and in spite of the apparent conformity of the two series very important events must have separated them. The Mississippi shellfish and the splendid Pennsylvanian forest, so characteristic of the Don period, disappeared completely before the Scarborough series began. Out of 80 species of fossils belonging to the Don times only two little shellfish of wide distribution, *Valvata* and *Sphaerium*, survive to Scarborough times. Instead of a climate 4 or 5 degrees warmer than the present we suddenly encounter cooler conditions than now. Instead of a shallow lake with a sandy bottom, on which clams lived and forest trees sank and were buried, we find a vast body of water more than a hundred feet deeper than before, on whose bottom far from shore the building of a broad delta was begun.

A great river came from the north into a much more extensive lake than before, bringing down mud and scales of mica and moss and marsh plants and bits of wood belonging to trees of a cool climate, spreading each year half an inch of clay over many square miles of bottom. There were still forest fires to the north, since many partly charred fragments of wood are found in the peaty layers. Insects of all kinds must have swarmed, though only the resistant armour of beetles has been preserved; and of the beetles only 2 out of 72 species have survived to the present.

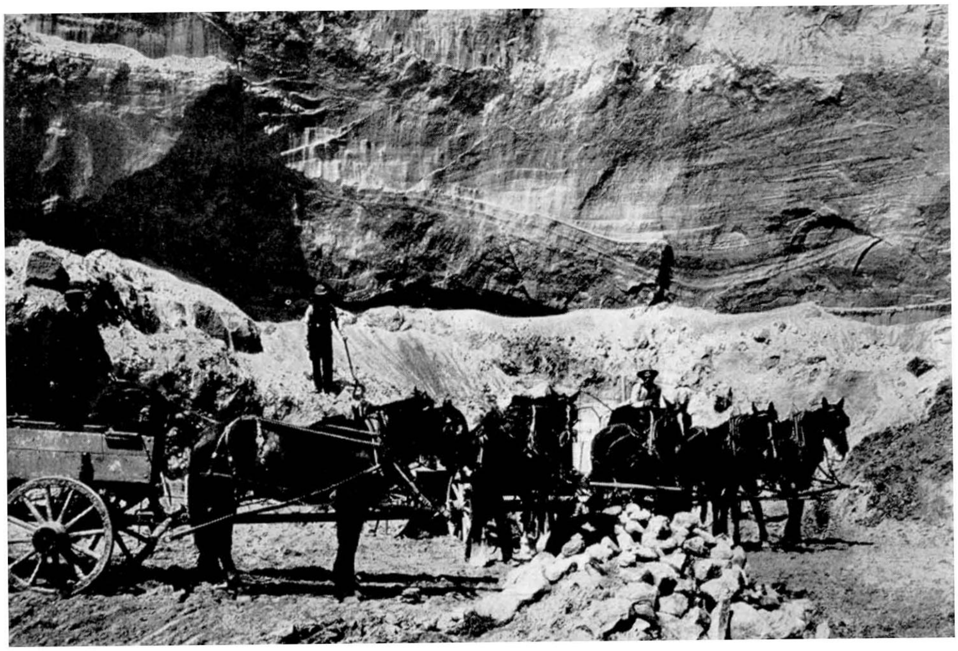
Two of the extinct beetles from Scarborough have been found also in peaty clay at Cleveland, Ohio, suggesting connections toward the southwest and the Mississippi. Beyond this small indication nothing is known of the outlet of a lake more than 200 feet deeper than Lake Ontario. What dam held up the water to that level one can only surmise. Probably the outlet towards the east was warped up 200 feet higher than at present; and this elevation, flooding all the lowland to the west, must have lasted thousands of years to permit of building the immense delta of the Toronto region.

#### Interglacial Valleys

Ultimately the barrier was lowered, and the water fell below its present level. The whole delta became dry land and was carved into deep valleys by rivers and their tributaries. The best known of these valleys is that of the Dutch church already referred to. The cross-section of this valley exposed in the Scarborough cliffs shows it to have been about a mile across on top and 1,100 feet wide at the present level of Lake Ontario.

A well sunk for exploration purposes at the foot of the Dutch church shows that boulder clay extends 16 feet below the lake, indicating the bottom of the interglacial valley. At the time the valley was dug, the water level must have been lower than that to allow the stream to flow, so that there was a change of water level of at least 216 feet. The inland extension of the Dutch Church valley has not been traced, but the width at Scarborough and the gentleness of the valley slopes suggest that it must have reached far to the north. Evidence of interglacial valleys at the Don brickyard and other points some miles northwest of the Dutch church perhaps indicate the head of the valley or of its tributaries. It probably had no direct relation to any modern stream such as the Don.

It is likely that the great Scarborough delta sloped away in all directions except to the north and that broad valleys existed both west and east of it when the water fell, especially so toward the west where no peaty clay has been found. Parts of the present Humber valley may belong to the old drainage system, which will be discussed in a later chapter.



Shaw Street sand pit.

## River Deposits of the First Interglacial Period

Some of the interglacial valleys are filled with boulder clay and varves, as illustrated by the carefully studied Dutch Church valley, and therefore must have been open when the ice advanced, but there are in addition valleys that were not only excavated but also more or less filled again during interglacial times. This applies to certain enigmatic deposits in the western part of the city, just north of Bloor Street and between Christie Street and Ossington Avenue. In former years large sand and gravel pits were opened here and furnished much building sand and gravel for concrete. Only one small pit remains, the rest having been built over or transformed into a park and playground.

The Christie and Shaw streets sand pits displayed entirely different conditions from any of the interglacial deposits thus far described; but boulder clay overlay their beds, so that they must be interglacial also. Exactly how they are related to the Scarborough series is not certain. At one time the writer thought they might correspond to the upper interglacial sand at Scarborough, but that idea had to be given up, since they appear to occupy a valley cut into the peaty clay, which crops out both east and west, and also because they are tumultuously cross-bedded deposits formed by strong currents and not spread out placidly on a lake bottom. The sand and gravel deposits, reaching 80 feet in thickness, were evidently laid down by a powerful river, which sometimes changed its course, cutting away its bed in places and filling up the space with a different arrangement of the strata, none of which can be followed far.

No peat has been discovered in the pits, though bits of wood were found, whose species could not, unfortunately, be determined. One piece was supposed to be cedar and another elm. Many shells were found, such as *Sphaerium*, *Pleurocera*, *Campeloma*, and fragments of unios. *Campeloma* does not occur at the Don brickyard and is said to be a species generally living in flowing water rather than in quiet lakes.

The most interesting fossils were of mammals and consisted of scattered bones, horns, or bits of ivory. The most important finds were a vertebra of bison, part of a lower jaw of a bear, and a horn of the extinct deer, *Cervalces borealis*, as determined by B. A. Bensley, a species somewhere between a moose and an elk. The ivory belonged, of course, to a mammoth or mastodon. All the finds were waterworn and may have been carried some distance by the current. The fossils give no certain evidence as to climate. The sand pits extended for about half a mile from northwest to southeast, and were two or three hundred yards wide. If made by a river, as the cut-and-fill structure suggests, they should extend farther in both directions, but nothing of the sort has been found except far to the northeast near the Don, where three exposures are somewhat similar. It may be that connections are concealed between these two localities, which are 2½ miles apart.

The nearest of the three eastern points is at Government House. When excavations were being made for its foundations, under 31 feet of varve clay there was found yellow sand passing down into grey sand with wood and bark and peat, as well as two small bones, probably of deer. The peat and bones were in a layer about 135 feet above Lake Ontario. Some charcoal also was found. The peaty matter contained many black seeds, some brown ones, and leaves of spruce and white cedar, suggesting a climate like the present or cooler. The deposit was poorly exposed and did not show evidence of strong currents, so that it may really belong with the interglacial sand at Scarborough and not with later river deposits. No beetles were found, however.

A quarter of a mile to the east, on the other side of the Don and just beyond the road leading northwest up the hill towards Leaside station, there was years ago a sand and gravel pit beneath boulder clay which showed the cross-bedding and irregularity of structure belonging to river deposits. Many clam shells occurred in the sand, but none have been preserved. The small pit was long ago buried under land slips from the high bank above.

### The Sun Brickyard[1]

Less than a mile northeast of the Don Valley brickyard and not far south of Leaside railway station, a new brickyard has been opened within the last few years, presenting very interesting but puzzling features. Many years ago, at a bend of the Don a little below the spot where the Sun brickyard was to be located, an old river valley was recognized. The banks of the Don showed a

[1]Sun Brick and Tile Company, Limited.

depression between walls of shale filled with a river deposit charged with wood and shells. To the west of the old valley a cliff of shale rises 16 feet above the river, capped with a thin bed of till and sand with unios like those of the Don Valley brickyard. Two hundred yards to the east the shale rises about 10 feet above the river, but between these two points the lower boulder clay and the shale beneath were cut away below the river level and then filled in with coarse shingle, gravel, and clay, containing many slabs of wood and well-preserved clam shells.

It was thought at first that this small stream valley was cut before the warm climate Don beds were laid down, and this idea was expressed in the Guide Book for the International Geological Congress.[1] The opening of the Sun brickyard just to the north has thrown new light on the relationships and has proved that the valley was cut through the Don beds into the shale, showing that the stream did its work toward the end of the interglacial time instead of at the beginning. In 1917, the following section above the shale pit of the Sun brick plant was measured:—

| | Feet |
|---|---|
| Soil | 2 |
| Middle boulder clay | 4 |
| Coarse gravel and sand (glacial?) | 6 |
| Blue stratified clay (burning to red) | 8 |
| Brown to yellow sand and some clay | 10½ |
| Clay and sand with Don fossils | 21 |
| Lower boulder clay | 2½ |
| Shale (top by aneroid 37 feet above Lake Ontario). | |

The cutting north of the buildings indicated a rather steep slope on the eastern side of the old valley, showing shale, boulder clay, warm climate beds, and cool climate beds (red-burning clay). The western side, except for 16 feet of shale, was covered with slide and trees.

Along the bank of the river to the southwest, the valley filling was of very different materials from those found in the interglacial beds of the older brickyard. Just above the water, there was a mixture of angular pieces of shale with a few rounded pebbles of other rocks, along with slabs and branches of wood and also unios, the whole about 3 feet thick. On it lay blue stratified clay with an inch or two of coarse peaty material, passing up into brown sandy clay. Over all was sand and gravel deposited by the present river before it had cut its valley as deep as at present. The interglacial part was about 14 feet thick. From the coarse shingle at the bottom, wood was collected and sent to Penhallow, who reported red cedar, elm, oak, and pawpaw, showing that the climate was warm. The shells differed considerably from those of the Don Valley brickyard, the smaller species (*Sphaerium*, *Valvata*, *Pleurocera*) being almost absent, while *Campeloma decisum* was very plentiful, and among the bivalves there was a large *Anodon*, not found elsewhere. The coarseness of the shingle, sometimes containing slabs a foot or two long, and the presence of *Campeloma* proved that a strong current must have been at work. Examination of the sheets of peat-like material showed that it consisted largely of chips, bits of bark, blades of sedge or reeds, and fragments of deciduous leaves, with very few mosses. Small twigs of white and red cedar were common, and a few spheres of the water plant *chara* were found. Beetles were very few in number and have not yet been determined. No spruce needles were seen, and the matted sedgy-looking sheets differed greatly from the thin, fine-textured peaty layers at Scarborough.

Recent developments at the Sun brickyard have hidden the section of the Don formation given above and have opened up widely the coarse breccia-like

[1]A. P. Coleman, op. cit.

mass described above, with a thickness of 5 to 10 feet in places, followed by 8 feet of stratified silt and sand with three or four layers of matted reedy-looking peat in the lower part. Sticks of wood were common, and there were many large fragile shells in the upper part. A very perfect oak leaf was found by splitting clay, but no other leaves were obtained. Shells of *Campeloma* were very numerous and well preserved. While the large size of the fragments of shale at the bottom of the section suggests a powerful stream to transport them, their flat surfaces and angular shapes show that they could not have been rolled far on the bed of a river. This, and the lack of any known connections with other deposits of the kind, make it difficult to imagine such an impetuous river unless it joined in some way the beds 2½ miles away on Christie and Shaw streets. The two deposits are, however, very different in character.

Immediately to the north of the Sun shale pit where the shingle bed is exposed, but much higher up, are the varve clays and the cliff of Lake Iroquois showing the Wisconsin till-sheet, and it appears as if the interglacial river valley came out from under it and made its way southward by way of the present Don valley; but unless some future excavation solves the problem, the course of the stream must remain undetermined.

**Wells to the North**

The only known section north of the Sun brickyard suggesting a connection with the valley just described is at the Page well, which was sunk more than twenty years ago on a farm about 2 miles west of Thornhill. In it drift was penetrated to the depth of 650 feet, suggesting a deep channel in interglacial or pre-glacial times. The section is given as follows:—

| | Feet |
|---|---|
| Clay and boulders | 220 |
| Quicksand | 30 |
| Gravel (with water) | 20 |
| Blue clay | 15 |
| Quicksand | 30 |
| Gravel | 10 |
| Clay and sand (a pine log, a pine cone, and shells) | 55 |
| Hardpan | 20 |
| Gravel | 140 |
| Pink clay | 60 |
| Sand | 12 |
| Clay and boulders | 38 |
| | 650 |

Shale, etc., ending at granite at 1,203 feet.

The section as given by the driller indicates a thick sheet of boulder clay above and another at the bottom with interglacial materials between. Some of the wood and the pine cone were shown the writer, but none of the shells were to be found when the well was visited in 1909. At that time bitter water with a high percentage of calcium chloride was flowing from it. The Page farm is about on the 650-foot contour of the topographical map, which indicates a pre-glacial valley reaching sea level and an interglacial valley nearly 300 feet deeper than the one at the Sun brickyard, facts which are very hard to account for.

Recently an even deeper well has been sunk near Bond lake, a few miles farther north, and R. B. Harkness reports the following section:—

| | Feet |
|---|---|
| Clay, sand, and gravel | 350 |
| Quicksand | 10 |
| Sand and gravel | 30 |
| Clay and gravel | 70 |
| Soapstone (clay?) | 60 |
| Sand and gravel | 50 |
| | 570 |

Shale, etc., to granite at 1,292 feet.

No interglacial fossils are reported from this well, and the whole thickness of drift may be morainic, since Bond lake is within the interlobate moraine, a brief account of which will be given later. As Bond lake is nearly a thousand feet above the sea, the bottom of the drift is more than 400 feet higher than at Page's well and cannot be said to suggest a northward continuation of the old channel. Until much more information is available, it will be impossible to trace the directions of interglacial drainage.

## Limits of the Interglacial Beds

All the drift sections thus far described have included more or less interglacial material, and usually fossils have been found in them, often in great numbers, but these occur only in the central and eastern parts of the city and York county for some miles to the northeast and north. The last points to the west at which fossil-bearing interglacial beds are known are the sand pits north of Bloor, between Christie Street and Ossington Avenue, now worked out and covered, except for a little peaty clay found in a well near Brandon Avenue, 200 paces north of the Canadian Pacific railway. Ravines and other exposures to the west have disclosed nothing to suggest either the Don or the Scarborough interglacial beds. There are some silty materials near Grenadier pond and just across the Humber, which Hind placed with the Scarborough peaty clay, but the writer has not been able to find either peat or other fossils and doubts whether they should be included with them.

The best exposures are in two brickyards west of the Humber. At Price and Cumming's clay pit and also at the Toronto Brick Company's pit a quarter of a mile farther west, there is well-stratified silty material, with bands an inch or two thick, which makes yellowish brick from lower layers and red brick from the upper weathered part. Boulder clay is not observed above it; but the upper layers are often greatly crumpled as if by the thrust of an ice-sheet. Some sand overlying the silty beds is of Iroquois age. Unless these silty beds without fossils represent the Toronto interglacial formation, which seems improbable, there is no evidence as to what took place during that long and mild portion of the Pleistocene in the region of the Humber and farther west. Apparently any records of it which may have existed have been swept away by later ice-sheets. We may conclude that interglacial soils or sand or gravel are not likely to be preserved where there has been strong glaciation at a later time, except under special conditions. In the Toronto region the necessary condition for their preservation was the presence of the peaty clay of the Scarborough delta, a compact and firm deposit which resisted the later ice advance and forced the ice to climb over it.

The Humber valley seems to mark the western limit of the great delta and also the western boundary of the interglacial beds. Of the eastern boundary less is known, since the overlying drift deposits are much thicker, hiding the earlier part of the Pleistocene record. In cliffs along the shore of Lake Ontario the last certain evidence of the interglacial period is found in peaty clay like that of Scarborough, just west of Frenchman bay, south of the village of Dunbarton. The interglacial clay rises only a few feet above the lake at this point and may continue below water for some miles east of Frenchman bay where the shores are low and exposures poor. This is made probable by the fact that the peaty clay is thick and massive 4 miles to the north where Duffin creek has cut a deep valley near the crossing of the Canadian Pacific railway. The delta materials probably extend much beyond this point and Clarkes Hollow, a mile to the northwest, where similar conditions exist; but there are no stream valleys deep enough to expose them.

**Boulder Pavements at Sunnyside**

Although the interglacial beds are lost toward the west before the Humber is reached, there is some evidence available to show that there were intervals between glaciations, in the form of "boulder pavements" in the drift sections. The best examples of this were to be seen twenty-five years ago in the shore cliff near Sunnyside in Parkdale, before the board walk and sea wall were constructed. As this interesting section will never be seen again, it should be described here. During a low-water stage of the lake in 1907-8 one could walk along the shore below cliffs of clay rising 25 or 30 feet and study two successive boulder pave-

Boulder pavement, Sunnyside.

ments, the upper one exposed for 290 yards. Many boulders of different kinds of rock lay at this level, all with a flattened side uppermost; and on them, when the overlying clay was removed, striae were often very well marked. Compass readings were made of the direction of striation on a dozen of them, which ranged from west to W. 40° N., the average being W. 25° or 30° N.

This northwesterly trend of the striae, about at right angles to the shore of Lake Ontario and to the axis of its basin, seems strange when it is recalled that the general direction of the ice motion is usually said to have been southwest. It seems that these striae were formed when the Ontario basin was occupied by a lobe of ice which came from the east and expanded fan-like in all directions toward the other end. The work was probably done in the waning stage of an ice-sheet when it was too thin to cover the higher ground between the lake basins.

The lower boulder pavement was not so extensive or impressive as the upper one just described. It was about 3 feet lower and not far above water level.

Striae were observed on only one boulder, with a direction of W. 30° N., which is much the same as on the upper one. Boulder pavements result from the advance of an ice-sheet over a surface of till on which boulders are scattered. The on-coming ice presses the boulders down into the clay below, where they are firmly held and probably frozen in, and a flat surface is ground upon them, which leaves them polished and striated when the ice retreats. Such a process does not necessarily mean a true interglacial period, but may only imply a short retreat followed by a re-advance; but in the Sunnyside case, the finding of wood 2½ feet below the upper boulder pavement strongly suggests that the warm climate forest came between the two ice advances.

#### Shore Cliffs to the West

The shore of Lake Ontario has been examined as far west as Burlington in an attempt to find an extension of the interglacial beds or of the three glaciations shown in the Toronto region, but with results very different from what might have been expected. In most places the shale rises a few feet above the lake with no striated surface. On it rests a varying thickness of boulder clay charged with many slabs of the harder shale beds and some Archean boulders, above which are a few feet of thinly stratified silt, often crumpled like that of the brickyards near the Humber, followed by sand of Iroquois age. At a few places the till includes a boulder pavement, showing that there were two glaciations, and the crumpling of the silt above perhaps implies a third. This is found near Port Credit, for instance, but often a cursory glance would suggest only one sheet of till covered by a few feet of lake deposits. There are places, for example near the rifle ranges at Long Branch, where the shale rises several feet above the water and the drift upon it dwindles to a foot or two of weathered clay. Even where thickest the mantle of drift seldom exceeds 15 or 20 feet, and at a number of places inland it diminishes almost to nothing, so that the bed rock practically comes to the surface.

The contrast between the Toronto-Scarborough region, with drift sections nearly 400 feet thick, and the country west of the Humber, where in places scarcely any drift covers the shale, is astonishing and calls for explanation. The cause of this immense difference in the amount of drift in the two closely adjoining regions is to be found in the work of the interglacial river, which brought clay, and later sand, from the flats and hills to the north and dumped its load in the great Scarborough lake, building up a delta 200 feet thick and extending far to the south of the present shore of Lake Ontario as shown by the soundings.

### The Second or Illinoian Glaciation

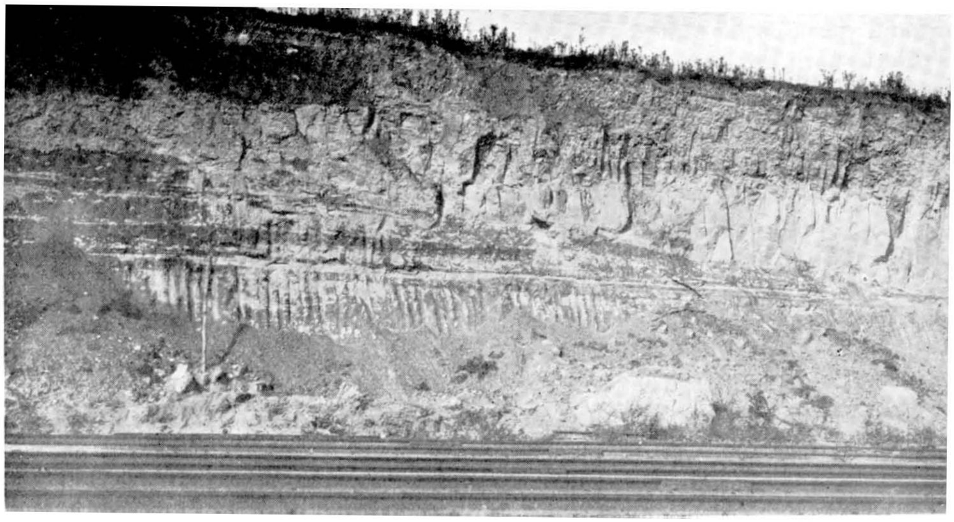
When the second, or Illinoian, glaciation was under way and the ice front reached Toronto, the Scarborough delta presented a solid obstruction which could not be swept away but must be climbed over. The advance in this part of the basin was halted for 1,500 years, according to Antevs, an excellent authority; and during the halt a hundred feet or more of tough varve clay was filled into the depressions, or piled on top, and three sheets of boulder clay were added to the mass.

The same process was at work in the last, or Wisconsin, glaciation. The impeded ice loitered over the obstruction and added to it a complex set of sandy tills and interbedded lenses of silt and sand, especially in the northern, higher part of the city, "on the hill."

Both the second and the last ice-sheets dropped much of this load on, or just behind, the delta mass that halted them and advanced rapidly afterwards, depositing little for a long distance to the west, so that in the lee of the barrier the till-sheet is almost wanting.

Although the middle complex of tills and varves (Illinoian) is well displayed in the Don valley and the higher parts of Scarborough Heights with a thickness of more than a hundred feet, it thins very rapidly to the west and is seldom found with certainty in the Humber region, where it is hidden under the last, or Wisconsin, till-sheet, or the sands of Lake Iroquois.

What took place between the time when the interglacial river was dumping coarse materials with wood and leaves and great clam shells in the valley of the Sun brickyard and the onset of the Illinoian ice is not recorded. The river deposits are of a warm climate character, so that a great change of temperature took place



Interglacial sand and upper till, C.P.R. cut, Leaside.

before the ice cliffs of the advancing glacier pushed their way westwards. There is, however, one curious suggestion of arctic conditions. In digging for a sewer on Dupont Street near Bathurst Street twenty-three years ago, mammoth or mastodon bones were unearthed just beneath boulder clay, one of them projecting up into the clay. It was part of the ulna, or elbow bone, of a large animal and was striated on one end where the ice had passed over it.

Bones of mammoth or mastodon were also found in till when digging for the foundations of Eaton's downtown store, and it is probable that these well-clothed elephants lived near the ice front and left their carcasses to be entombed by the ice. Their occurrence in frozen ground in Siberia shows that they were equipped for a cold climate.

## The Latest Interglacial Period

Sand beds lying between the Illinoian and the last, or Wisconsin, till-sheet are widely spread and have been briefly mentioned as found at Leaside where the C.P.R. ballast pit gives a good section. They are not known to be fossiliferous in Toronto, except at one point west of Yonge Street and opposite Mount Pleasant

Cemetery, where thirty years ago a sand pit, which is now grown over with grass and bushes, contained a few small shells, *Amnicola limosa*, a *Succinea*, and fragments of another species. These were collected 220 feet above Lake Ontario, and the sand in which they occurred reached up to 247 feet and was covered with the Wisconsin till.

This interglacial sand shows itself in the shore cliffs of Lake Ontario as far east as Port Hope, and probably corresponds to the marine interglacial beds between Brockville and Montreal and along the Ottawa river. The latter have until recently been confused with the post-glacial marine beds of the Ottawa and St. Lawrence valleys. Similar marine interglacial sand and clay occur along the tributaries of the Moose river on the James bay slope.

The few shells just mentioned belong to species which still live in our waters and give little information as to climate; but certain trees, such as the maple, the yellow birch, and the poplar, found in concretions in the marine clay at Ottawa, indicate conditions like the present in this latest interglacial period.[1] It should perhaps be stated that the correlation of the upper interglacial sand of Toronto with the beds to the east is not absolutely certain, since it has not been traced continuously to the St. Lawrence and Ottawa valleys; and also that up to the present the officers of the Geological Survey of Canada have described the beds with remains of trees, etc., in their region as post-glacial.

### The Last, or Wisconsin, Till-Sheet

The hilly part of Toronto north of Davenport Road and the Canadian Pacific railway presents a strikingly different appearance from the flat, gently inclined plain that slopes south from that line to Lake Ontario. The part just mentioned was shaped by the waves of Lake Iroquois and has the smooth surface of deposits formed by standing water; while the upper part of the city was shaped by the ice-sheet and has the hummocky hills and depressions characteristic of the work of ice. It is morainic country of a mild type, slightly modified by weather and rainfall, but sometimes channelled by ravines where streams have been at work. On the topographic map the contour of 400 feet above the sea comes somewhat below the foot of the Iroquois cliff, and at several points to the north swells of till reach the 600-foot contour, rarely 625, showing a range of 200 feet. Over all the higher parts, sandy till is to be seen without much variation in appearance, while stream or road cuttings which go below the till open up stratified silty sands, probably interglacial.

This relation is well seen at the high point, sometimes called Eglinton Hills, where Eglinton Avenue dips down toward Weston. A more complicated section was to be seen in 1924 where Maclennan Avenue ascends the Iroquois shore cliff toward Moore Park after crossing the C.P.R. This includes wisps and lenses of sand and gravel caught up in the motion of the ice and left embedded in the till. On Heath Street, just east of the Don, a road-cut shows only brown till except for a thin band of coarse conglomerate 5 feet below the top.

The best sections for the study of the latest till are along the Don west of York Mills (Hoggs Hollow), where, from below up, one finds 20 feet of stratified sand with some clay, followed by 25 feet of blue till, perhaps the upper sheet of the Illinoian, 7 feet of stratified clay, 11 of sand, 3 of coarse gravel, and 14 feet of stratified sand, covered by 17 feet of the usual sandy Wisconsin or upper till. Beyond the Don to the north, the surface of till rises as swelling hills of drumlinoid

[1]J. W. Dawson, "The Canadian Ice Age," Montreal, 1893.
A. P. Coleman, "Glacial and Interglacial Periods in Eastern Canada," Jour. Geol., Vol. XXXV, 1927.

shape, though never with the steep slopes of true drumlins, such as are found northeast of Belleville, but having the character of mild moraines. West of Yonge Street and south of Concord, the surface of boulder clay is unusually flat, almost suggesting an old water level, except where channelled by the Don and its tributary streams, and several flying fields for aircraft have been laid out in the region. Between Maple and Richmond Hill the surface becomes hilly, and to the north true morainic shapes show themselves rising as a group of kame hills, which reach 750 feet above Lake Ontario and 1,000 feet above the sea. This group of hills projects south from the great interlobate moraine which runs from the Trent valley to the escarpment near Caledon and includes tumbled mounds and kettle valleys enclosing pretty ponds or lakes, some with no visible outlets, such as Bond lake. This rough ground is often sandy or stony and has been left as woodland, providing the most picturesque scenery near Toronto, with the exception of the Scarborough cliffs. The morainic type of country is well displayed near Aurora and to the west.

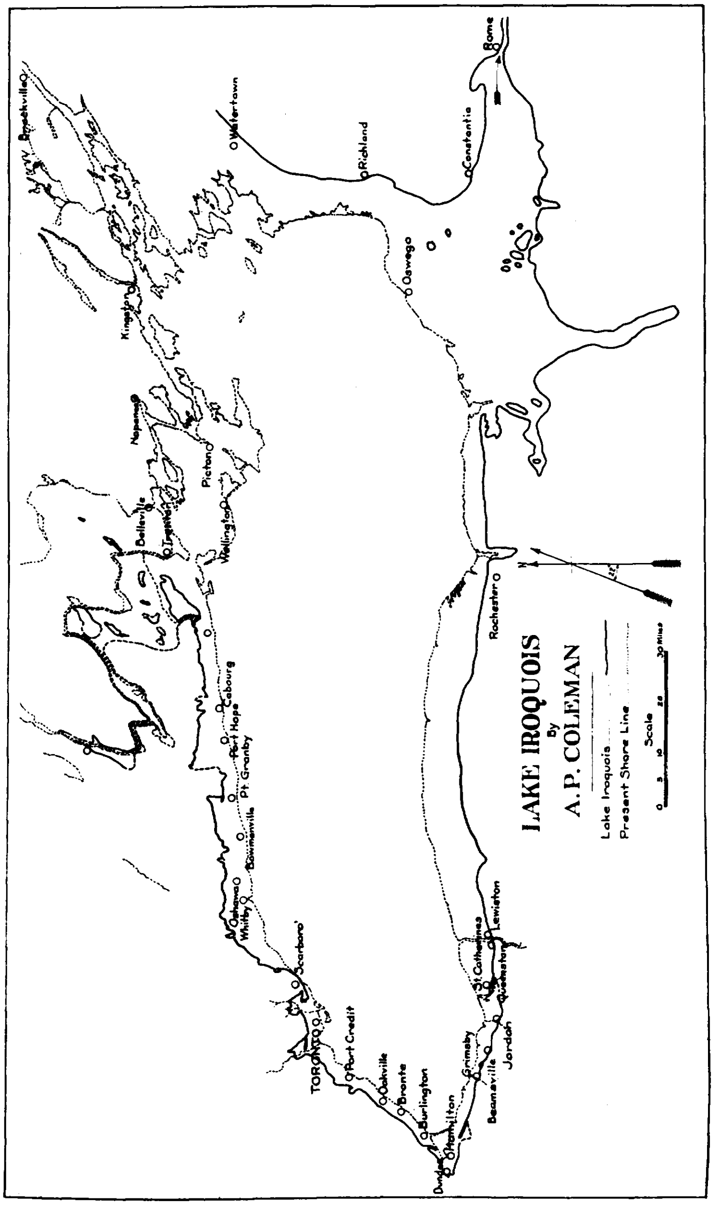
The interlobate moraine has been excellently described by Frank B. Taylor, one of the best American authorities on glacial matters, in Guide Book No. 6 already referred to, and his paper is included as an appendix to this report. The term "interlobate" implies that the moraine was formed by two lobes of the ice-sheet, probably at a late stage of glaciation, the Erie-Ontario lobe dumping its debris toward the northwest and the Georgian Bay–Lake Simcoe lobe toward the southeast.

There is reason to believe that the moraine was largely built during earlier ice invasions, the Wisconsin ice lobes merely finishing the work, so that the history and the structure of this double moraine are complicated and hard to unravel. Much of it consists of barren sand, unsuited for agriculture, but sometimes worked for building material or railway ballast. Large sand pits are in operation on these deposits just northeast of Maple, and there one can study the characteristic features of a kame, formed where glacial waters escaped at the edge of the ice, piling up irregularly stratified sand and gravel, alternating with cobble stones and boulders and sometimes with lenses of typical boulder clay. The striking irregularity of the deposits was caused by the constant shifting of the ice edge and of the torrent flowing from beneath it.

## Shores and Deposits of Lake Iroquois

References have already been made to ancient lakes rising higher than Lake Ontario at various stages in the history of the Toronto region. In addition to the great interglacial lake, which was of so much importance in shaping its history and geography there must have been several glacial lakes in the basin as the different ice-sheets waxed and waned. All three of the glaciations came from the east, and if the drainage of the Ontario valley was eastward to the St. Lawrence, it is evident that its outlet must have been blocked by each ice-sheet as it advanced westward, and also later as it retreated eastward, making two lakes, one before and the other after the greatest extension of the ice-sheet. Direct and positive evidence of the five earlier glacial lakes is, of course, not easily found, since their deposits have been buried under later tills and other materials.

The thick series of varves, which has been referred to as associated with the three sheets of till making up the Middle or Illinoian glaciation, however, supply indubitable proof of one such glacial lake; and, of course, the last lake of the kind has been well recorded. This latest sheet of water, held up by a dam of ice at the Thousand Islands, was suitably named Lake Iroquois by the late J. W. W. Spencer in honour of the tribe of Indians which once occupied the region. Its shore cliffs and gravel bars can be followed almost completely round Lake Ontario except for a broad eastern end occupied by ice; but for our present purpose only the part within the city and extending a few miles east and west need be described. It will be necessary, however, to note some general conditions that affected the




Sketch map of ancient Lake Iroquois showing its relation to the present shore line of Lake Ontario.

lake, in order to understand certain peculiar features of its history in our region.[1]

The burden of the ice-sheet depressed the land beneath it, and as the ice melted the load was lifted and the land rose to correspond. The unloading process

[1]J. W. W. Spencer, "The Falls of Niagara," Geol. Surv. Can., Pub. No. 970, 1907, p. 282 *et seq.*

A. P. Coleman, "The Iroquois Beach in Ontario," Ont. Bur. Mines, Vol. XIII, 1904, pt. 1, pp. 225-244.

was very slow, lasting thousands of years, and the southwest end of the Ontario basin was freed from ice long before the eastern end at the Thousand Islands. Since the natural outlet was blocked the water rose to the level of the next higher one, in the Mohawk valley, where the outflow was past Rome into the Hudson.

During the lifetime of Lake Iroquois the ice was slowly melting at its centre in Quebec, and as a consequence the basin was being tilted up toward that end. Thus there was a contant change of water levels, so that the old beach is no longer horizontal but rises toward the northeast, or rather in the direction N. 20° E. The rate of tilting is about 2 feet per mile in Toronto. Since this process was going on all the time, there was a gradual rise of the water in our region, its work beginning 70 or 80 feet below its final level.

### Low-Water Stage of Lake Iroquois

Deposits formed in the early low-water stage of the lake are usually buried out of sight under its later sediments, but there are two places where these have been found. When Reservoir Park was laid out, the work at the lower end of the small ravine which runs through the park disclosed sand with shells of species such as live in lakes; and this sand bed, about 80 feet below the late Lake Iroquois level, has a shallow-water character. The other locality is a mile and a half east, where a road crosses the Don and climbs toward Leaside. A well sunk on the hill east of the road opened up beds of somewhat cemented sand and gravel with shells of unios and pleuroceras just beneath them. These typical lacustrine shellfish were from 70 to 80 feet below the Iroquois terrace. The well was dug with the aid of funds supplied by the British Association for the Advancement of Science after its meeting in Toronto in 1897.

It may be that a widespread deposit of brick clay between Gerrard and Queen Streets and in the neighbourhood of Leslie Street and Greenwood Avenue was formed at the same time in deeper water; but the whole of the clay has been removed, and the former brickyards are replaced by streets and houses, so that the beds can no longer be studied. The clay was well stratified, with silty partings between the layers, and, except for a foot or two of weathered material on top, burned to a buff brick. It had not the appearance of varves and was not a part of the peaty clay beds, since it did not burn red. The clay was greatly crumpled in places, and in this resembled the silty brick clays west of the Humber; it had a thickness of 15 to 18 feet and, according to the brick men, had no drawback except the presence of "ginger," which is their term for lime concretions that spoil the brick if not carefully picked out. This Queen Street clay rested on boulder clay, and the bottom of the pits was about 10 feet above Lake Ontario.

Half a mile north of these low-lying clay beds, just beyond the Canadian National railway, come the excellent red-burning interglacial clays of the Greenwood Avenue brickyards, which are of an entirely different kind. These end abruptly at the railway, being replaced by sand toward the south. There was apparently a shore cliff cut in the interglacial clay during the low stage of Lake Iroquois, which must have lasted a long time to accomplish so much work.

### Later Work of Lake Iroquois

After the low-water stage, the outlet was elevated with the rest of the eastern glaciated territory, and the lake level rose to correspond. As the water rose its waves carved the morainic hills into a gently inclined plain and filled in hollows and valleys by dumping sand and clay, shaping the flat surface of the lower and older part of Toronto. Finally there seems to have been a long stage of nearly stable water level, during which the shore line of the lake was straightened out by the carving away of promontories and the building of bars of sand and gravel across the mouths of bays. Two small rivers reached the lake in the Toronto region, one on each side of the city, the predecessors of the modern Don and Humber, and as bars were pushed by wave action from east to west across their valleys the rivers were forced to shift their channels westward, as may be seen from a glance at the map. During all this time the rivers were bringing down sand, filling up the basins enclosed by the gravel bars, and forming flat surfaces almost reaching the level of the lake.

After thousands of years of comparative stagnation, the climate at last became milder and the ice dam toward the east melted, draining Lake Iroquois and opening the way down the St. Lawrence. The gently sloping surface south of the Iroquois shore and the flat shallow water beds in the two bays became dry land and have remained so ever since, while the two rivers and smaller streams have carved valleys in them during post-glacial time.

In mapping Lake Iroquois then, we find a shore cliff running a little north of east through the heart of the city, forming the "hill" encountered by northward-running streets, and two great gravel bars extending almost across the mouths of the ancient bays in much the same direction. The gently rolling morainic country north of the old shore has undergone comparatively little change since the ice left it, while the surface to the south has been completely worked over and transformed, its original features being masked by a thick or thin veneer of Iroquois shallow-water deposits, mostly sand. In describing the features left by Lake Iroquois we shall begin at the west and work toward the east.

### The Humber Bay of Lake Iroquois

During the high-water stage of Lake Iroquois a bay reached 3 miles up what is now the Humber valley, at first with a wide mouth, at least 2½ miles from southwest to northeast. During thousands of years the waves of the lake urged by easterly storms slowly built a bar from east to west across the opening of the bay, leaving a gap of half a mile at the west end. The shores of the bay are formed of rather low morainic hills, and since wave action was feeble in the sheltered waters inside the bar, their exact position is hard to determine. In the map the edge of the bay is made to come between the 400- and 425-foot contours of the topographic map, and runs irregularly north from Lambton to Weston, bends a little northeast in the valley of Black creek, and then turns southeast to Davenport railway station.

The Davenport gravel bar was well marked in earlier years, rising as a rather broad ridge 20 feet above the ground to the south, but forming the top of a cliff on the north, where Black creek was cutting its valley. The bar made very poor, sandy soil and thirty or forty years ago was sparsely covered with oak and pine, providing a beautiful walk. Much of the bar has since been carted away for use in building, but one of the sand pits, on Scarlett Road near the Lambton golf links, is still being worked and gives an excellent section of a wave-built bar.

While the building of the bar progressed the Humber was filling up the basin to the north with sediment, gravelly in places, but more often sandy, finishing with a few feet of clay over much of the sand. The river probably flowed through the middle of the valley during the early, low-water stage of Lake Iroquois, but was crowded over to the west as the bar advanced, and toward the end meandered in marshy flats on that side of the shoaling bay. When the ice dam at the Thousand Islands melted and the water fell below the level of Lake Ontario, the Humber quickly cut down its bed through the soft sediments until it reached the rock, but then worked much more slowly. It now flows largely on a rock bottom along the western side of the valley, which has a vertical cliff of shale often 40 feet high; while its small tributary, Black creek, keeps to the opposite side of the valley and nowhere reaches bed rock.

The creek, working in clay and sand and swinging from side to side, has excavated a broad interior valley below the original level, and near the city limit on Weston Road more than 60 feet of sand and clay may be seen between its floor and the flat surface of the Iroquois plain. The steeply walled sides of the valley enclose rich bottom soil used for market gardens, with here and there an island-like remnant rising to the general level, making, when wooded, very picturesque scenery. The five or ten feet of clay which formed the surface of the plain in some parts has been largely removed for making brick, the weathered upper part burning red and the lower part buff.

Sand and gravel pits have been opened at a number of points in the Humber bay of Lake Iroquois, and several of them are still being worked. Others occur

Scarlett Plains sand pit, east of Lambton Golf Club.

up the Humber north of Weston, even as far as Woodbridge, showing how effectively the early river transported materials from the morainic hills to the north.

The sand and gravel deposits north of the Davenport bar vary greatly in thickness and in coarseness. In Montgomery's pit, near the sanitarium in Mount Dennis, 44 feet of sand with coarse gravel can be seen, and there is sand beneath the bottom of the pit, which grows finer and changes to clay at depth. It is estimated that 40 per cent. of the product is stones and the rest sand.

In the Lumley and Fox pit, the second to the north, the thickness worked is 22 feet at the south end, thinning toward the north; and the amount of gravel mixed with the sand is much less. A sewer still farther north showed only clay, suggesting a change from coarse materials to fine as one goes north from the Davenport bar, but this cannot be considered a general rule in the Humber valley.

Across the valley to the west of the sanitarium, the sand pit of Ellins Brothers on Scarlett Road seems to be an extension of those just mentioned, showing 16 feet of sand containing about 25 per cent. of stone. This pit has the distinction of having provided bones of mammoth or mastodon some years ago.

Another interesting sand pit is McCaul's on Weston Road, near Bushy Avenue, where, 20 or 25 feet below the surface, the skull and some bones of a musk-ox were found, suggesting a colder climate than the present. More interesting still are the animal remains unearthed in the main gravel bar running west from Davenport station, where from time to time horns of caribou have turned up at the bottom of the gravel just over the clay beneath. These seem to be shed horns, since bones of the animal are rarely found. In addition a few fragments of elephantine bones prove that mammoths or mastodons frequented the old beach. The mammoth remains found in digging for a basement at Gunn's stockyard should be mentioned also.

Caribou horns have long been known from this gravel bar, and in 1884 Samuel Thompson wrote as follows:—

> While speaking of the Carlton gravel ridge, it is worth while to note that, in taking gravel from its southern face, at a depth of 20 feet, I found an Indian flint arrowhead; also a stone implement similar to what is called by painters a muller, used for grinding paint. Several massive bones and the horns of some large species of deer were also found in the same gravel pit and carried or given away by the workmen. The two articles first named are still in my possession. Being at the very bottom of the gravel deposit they must have lain there when no such beach existed, or ever since the Oak Ridges ceased to be an ocean bed.[1]

By the "Oak Ridges," he probably meant the Davenport bar and not the interlobate moraine to the north, often called the Oak Ridges in later times. In 1898 when the writer made enquiry as to his finds, Mr. Thompson was dead and a search for the arrowhead and muller was fruitless; but his account is straightforward and circumstantial and strongly suggests that Indians lived on the shore of Lake Iroquois thousands of years ago. Unfortunately no scientific man was at hand at the time the finds were made to investigate the matter and settle the question as to whether the Indian tools might not have reached their position by burial.

In closing the account of the Davenport bar it should be mentioned that Sandford Fleming in 1861 read a paper before the Canadian Institute describing what he called the Carlton Gravel Spit and gave a rough but fairly correct map of it and of the old bay to the north, the first recognition of the old shore since Chas. Lyell's brief reference to it in 1842,[2] and the first map of any part of the Iroquois beach.

### The Slopes South of the Old Shore

Long before the bar just described was built across the mouth of the bay the early Humber was transporting sand toward the south, as may be seen on the east side of its valley where the steep banks consist of sand, except at Baby Point, where a westward meander of the river got beyond the pre-glacial valley and exposed a striking promontory of shale cliffs under the sand beds. Near the low bridge over the Humber on Mossom Road the cliff shows 50 feet of sand over a few feet of stratified Illinoian clay, and a newly cut road to the north rises between slopes of the same sand to the general level, 70 or 80 feet above the river. The Humber Drive follows the edge of the valley over sand and silt to the level of Lake Ontario just north of the C.N.R.

The west side of the valley contrasts strongly with the east, consisting mostly of cliffs of shale with very little drift. As the growth of the bar pushed the Humber toward the west, its current cleaned away any early deposits of sand there may have been, leaving the rock exposed. No doubt a large part of the sand forming the floor of the present Humber bay dates back to Iroquois times and

[1]Samuel Thompson, "Reminiscences of a Canadian Pioneer," 1884, p. 286.
[2]Can. Jour., New Series, Vol. VI, 1861, pp. 247-253.

has been shifted and deposited more than once before coming to its final resting place.

South of Bloor Street the sand continues through Swansea sloping down to lake level near the railway and the shore of Humber bay, and growing finer as it descends. The ravine running parallel to the Humber, formerly used by the Belt Line railway, has recently been levelled and smoothed for building lots and displays only sand in its excavations. The side of the steep-walled valley on the way up to Rambert Avenue shows 70 feet of sand. Beneath it there appears to be an impervious layer of glacial clay, where springs come out and join to form small creeks in narrow valleys or ravines, which sometimes end abruptly toward the north and are due to sapping by the underground waters where they emerge as springs.

Three of the larger streams above Bloor Street before it was levelled up formed deep valleys with slipping walls of sand, ending toward the south in ponds or marshes, the largest being Grenadier pond. It is probable that these ponds, which are straight-edged on the south, were formed by the building of a bar by Lake Ontario. At an earlier and lower stage of the lake, the stream valleys continued south and there were no ponds.

The streets in and near these ravines depart from the usual east-west and north-south pattern and follow curves to suit the inclinations, some of the long main thoroughfares, like Windermere and Ellis avenues, winding along ridges between the deep valleys. High Park extends from Bloor Street to the lake shore and owes its picturesque land forms, with hills and ravines and pools and bits of marsh toward the south, to the features just referred to; but several valleys to the west are being levelled or filled in and at present are anything but attractive.

In former years sand was quarried west of Windermere Avenue for making sand-lime brick at the Toronto Brick Company's works. At a number of points where new streets are being graded, elaborate crumpling and folding of the sand beds may be seen, for instance at the corner of Morningside and Durie streets, suggesting the powerful thrust of ice either as large floes or as glaciers; but it may be that these curious structures are really caused by large scale slipping or slumping as the ravines were deepened.

### Between the Humber and the Don

Between the Humber and the Don bays of Lake Iroquois the old shore forms a fairly continuous cliff now, of course, covered with grass and trees, rising usually to 50 or 75 feet above the flat beneath. Several of our northward-pointing streets end at the foot of this "hill," which is really the southern edge of a low morainic tableland; and the much travelled Davenport Road skirts its base as far east as Huron Street, where it turns southeast. There the cliff is interrupted for a quarter of a mile by the valley of a small creek, which gives Glen Edith Drive, Bolton Drive, and Poplar Plains Road a chance to curve their way up to the rolling surface to the north. Farther east Poplar Plains Crescent and other short streets run beneath the cliff to Yonge Street; and the houses on the north side of Woodlawn Avenue follow its crest to the Reservoir. Just east of the Reservoir a small creek has carved a ravine through the cliff, and from this point eastward the Canadian Pacific Railway occupies the shore at its base. Another ravine, used by the abandoned Belt Line railway, intersects the cliff before its termination at Leaside Junction.

Almost everywhere to the south or southeast of the shore cliff, silt or sand is to be found, sometimes as a very thin sheet but at other points thickening to greater depths. This spread of sand forms a sort of padding to fill out depressions and level up the subaqueous terrace to a uniform and gentle slope for two or three miles to the present lake shore. Sometimes sandy boulder clay belonging to the last glaciation, or varves, or blue boulder clay of the middle till-sheet, comes to the surface, showing that the waves of Lake Iroquois had levelled off the drift deposits; but this is infrequent.

The surface beneath the sand was in places very irregular with gullies and hummocky parts suggesting current action, as shown in excavating for the foundations of the Royal Ontario Museum, where sand with boulders filled a trench 10 feet deep cut in varve clay. In the earlier days the valleys of several small streams cut through the veneer of sand and disclosed the beds beneath. The most continuous of these stream channels passed through the Shaw and Christie Street sand pits north of Bloor Street, which have been referred to as forming part of an interglacial river deposit. From this point south it cut its narrow valley deep into boulder clay and still threads its way above ground through a succession of small parks to the former grounds of Trinity University (Queen and Gorevale) and farther south, apparently by Walnut Street to the bay near the old fort.

Most of the small creeks of the area below the cliff, however, have disappeared underground in sewers and can no longer be followed on the surface. The drift sections they once supplied are, of course, now out of reach; but artificial excavations for sewers or foundations give good exposures from time to time, and in this way a number of finds of interglacial fossils have been made, as mentioned earlier in this report. Many notes of the materials exposed in these ways have been gathered, but a detailed account of them would take much space and not add much of value.

One feature that has disappeared seems worthy of mention, however. When Toronto was a small town near the bay, the Iroquois terrace to the north was strewn with boulders of all sorts and sizes, mostly of Archean rocks such as granite, gneiss, various basic eruptives, schists, and marble. These were set free from the boulder clay and left behind as the shore cliff was cut backward by the waves of Lake Iroquois and provided a fine collection from the geological formations to the north and east. One of the earliest references to our geology was made by A. C. Ramsay, a well-known English geologist, who, more than seventy years ago,[1] commented on the huge boulders on the old beach.

Such erratics were still to be seen forty years ago when the writer's studies began in this region, and many specimens of rocks in our collections were got from them, but the scattered boulders have long since been used for building or crushed for road metal. Boulders of the sort are still unearthed, however, when excavations are made through the sheet of sand mentioned earlier; and some of them, weighing tons and of many varieties, had to be removed when the new wing of the Royal Ontario Museum and the Botanical Building of the University were erected, and the same was true in digging the foundations of the East Block of the Parliament Buildings.

### The Don Bay of Lake Iroquois

Though a smaller river than the Humber, the Don branches in such a way as to occupy an even broader bay of Lake Iroquois, running for 5 miles from Leaside to Birch Cliff, with a width of about two miles and a half. Its shores are low and indistinct, of gentle swells of boulder clay, with projections of the bay

[1]Geol. Soc. London, Quart. Jour., 1859, p. 203.

into each of the valleys of the three arms of the Don; and it has been traced largely as coming between the 425- and 450-foot contours of the topographic map, since its feeble waves made very little impression on the enclosing boulder clay.

The Don performed work of the same sort as the Humber, depositing in its bay sand and gravel and, toward the end, clay, but on a much smaller scale corresponding to its smaller volume. Several sand and gravel pits are worked northeast of Leaside, but seem of less importance than those of Mount Dennis on the Humber; and brickyards are in operation on Iroquois clay on Dawes Road.

On the other hand the deposit of sand and gravel which forms its southern shore is longer and much wider than the Davenport bar and has about the shape and dimensions of the present Toronto island.

The valleys of the three branches of the Don disclose a smaller thickness of Iroquois sediments than on the Humber, but the wave-formed peninsula to the south bulks far more massively than the bar south of the western bay.

The sand pits east of Leaside occur north and south of a small stream, which cuts a deep ravine on its way to the Don, and are near the western bank of the river. The sand is overlain by a few feet of silt, which must be stripped before it can be quarried. It is about 12 feet thick in one pit examined, but thicker sand beds can be seen overlying boulder clay along the river bank. Farther south, near a road coming up from the valley to the Thorncliffe race course, gravel has been opened up to a depth of 10 feet, differing entirely from the last pit and containing pebbles 5 or 6 inches in diameter. A low bar can be traced some distance on the surface to the west, but most of the region in this bend of the Don is too heavily wooded to allow the surface features to be followed.

The brick clays on Dawes Road overlie 12 feet of sand and gravel, which rests on boulder clay just north of a stream flowing west to the Don. The clay is silty and well-stratified and its upper weathered part burns red and the lower part buff. About 10 feet of this silty clay may be seen in the brickyards of Phippen and Son and J. E. Laplante.

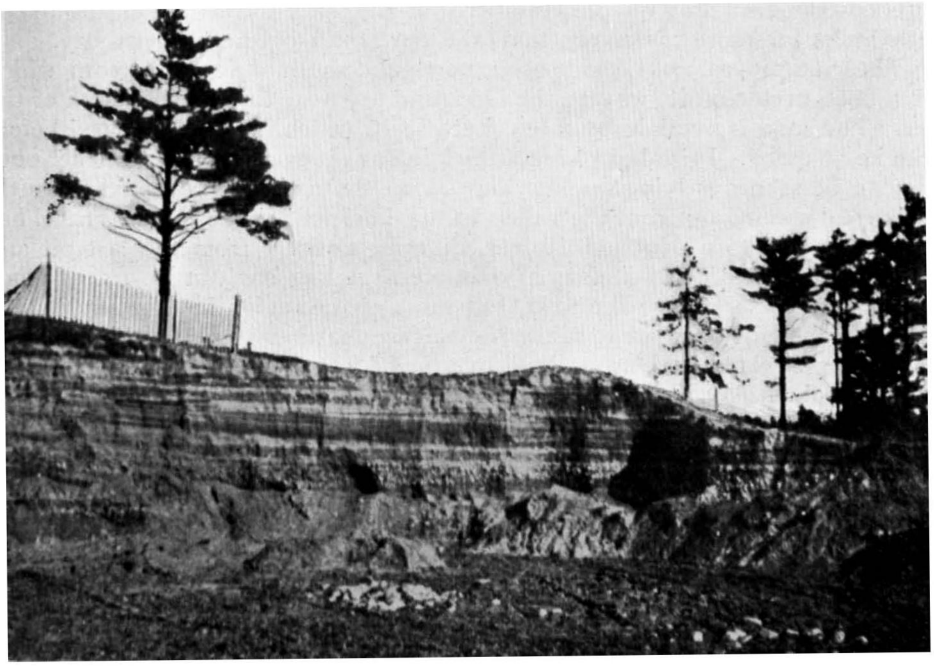
#### The East Toronto Gravel Deposits

Of far more importance than the comparatively small deposits of sand and gravel in the interior of the Don bay are the enormous ones of the peninsula that separated the bay from Lake Iroquois. This peninsula begins as a narrow ridge where the Kingston Road just west of its junction with Danforth climbs up from the general level to the rolling country of Scarborough Heights and expands westwards for 3 or 4 miles. Its precise boundaries are hard to define, since its coarser gravelly portions grade insensibly into sandy slopes toward the south and west, reaching the cliffs of Lake Ontario and the valley of the Don river in those directions. Danforth station on the Canadian National railway, with an elevation of 426 feet, is within its western limits, and on the north a tributary of the Don has cut a ravine where the bay meets the bar.

The surface of the old peninsula has two oval depressions about 15 feet below the general level, which represent lagoons like those of the present Toronto Island, and in every respect the two are alike except that the Iroquois peninsula is 186 feet above Ontario and the island 6 feet. The so-called island is, of course, under usual conditions, a peninsula, though now permanently cut off from the mainland by the eastern gap for convenience in navigation.

The gravelly upper part of the East Toronto peninsula has been a source of building materials for many years, and much of it has been removed between Main Street and the community now known as Birch Cliff; but large sand and gravel pits are still in operation, some of them producing sand-lime brick. Little use has been made of the sand that fringes the peninsula on all sides, although it extends as a thick sheet as far south as Balmy Beach. A good section of this Iroquois sand is presented east of Victoria Park in the cliffs of the present lake, where in places it reaches a thickness of 100 feet and shows well-marked stratification. Some of the beds have been excessively crumpled, like those already referred to near the Humber.

On the beach at the foot of the cliff the waves separate from the sand bands of heavy minerals, especially red garnet and black magnetite, and fairly pure samples can be collected. Both the sand and the other minerals have been derived from the glacial materials of Scarborough Heights and had their original source in the Archean rocks to the northeast.



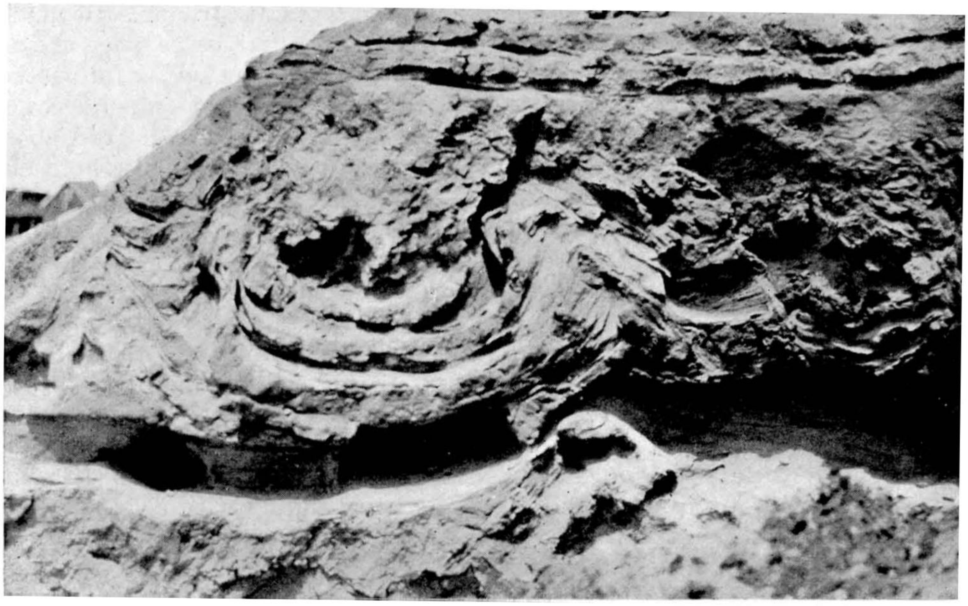
Sand pit (Iroquois gravel bar), East Toronto.

Inland to the west the sand rises 95 feet above the lake at the corner of Queen and Fallingbrook streets, and 140 feet a little father north on Blantyre. The streets to the west, named for trees, go north to Kingston Road up steep slopes of sand; and farther to the west a small stream running through park land has cut a steep-walled ravine. At several points springs coming from under the sand where it rests on clay have undermined it and dug similar narrow ravines.

The Kingston Road follows the summit of the gravel ridge to Main Street and then descends beside a valley carved in the sand to the level plain of clay on Queen Street near the Woodbine.

Farther to the northwest, between the two Lynn avenues just south of Bloor, another spring creek has opened a steep-walled valley, this time above peaty interglacial clay; and the same is true at two or three points beyond, especially at the brickyards on both sides of Greenwood Avenue and just east of Jones Avenue. These have already been described as examples of the cool climate type of interglacial deposits; but the Iroquois sand is here thinning out. Just south of the brickyards and the railway, however, the sand thickens to about 70 feet, evening up the slope where the waves of early Lake Iroquois, working at a much lower level, had cut a cliff in the clay. The ravines just mentioned are rapidly being filled as dumping grounds.

Farther to the south between Gerrard and Queen streets the stratified clay already referred to may have been laid down by Lake Iroquois in its earlier stage, or may belong to a previous glacial lake; and in the same region but beyond the old clay pits, 10 or 15 feet of sandy silt, well stratified and sometimes crumpled, were not unlike deposits worked for brick west of the Humber, but they have now almost disappeared. The age and general relations of these silty beds at opposite ends of Toronto and rising but little above Lake Ontario are still uncertain.



Crumpled bed of Iroquois deposits, near Pape Avenue.

Few fossils have been found in the east Toronto sand and gravel pits, all that are on record being a mammoth tooth toward the eastern end of Gerrard Street, and the skull of a musk-ox from the York Sand and Gravel Company's pit half a mile south of Danforth Avenue and east of Blantyre Avenue.

### The Source of the Sand and Gravel

The two bars across the mouths of bays that have just been described, one on the Humber and the other on the Don, differ greatly in size and shape, the Davenport bar being narrow and in every way smaller than the East Toronto peninsula, which spreads out widely like Toronto Island but on a higher level. Both were made by the waves of the lake; why should they differ?

The cause of the difference is to be found in the much more abundant supply of material for the eastern structure than for the western. In the Humber region the effective easterly storms attacked and destroyed the comparatively low and straight shore of boulder clay south of the present shore cliff at Davenport

Road; while the Don peninsula, like the present Toronto Island, was built of copious materials from the prominent morainic ridge of Scarborough Heights, projecting much farther into the lake then than now. There are still cliffs 170 feet high on the Iroquois shore at Scarborough, more than twice as lofty as any point in the Davenport cliff, so that the raw material for a gravel bar was right at hand and in much larger quantities.

An immense amount of boulder clay must have been worked over to provide the gravel spread over square miles of the old peninsula, and the vast quantities of clay resulting from its destruction must have settled to the bottom in deeper water off shore, though clay beds of this age have not been found. They may have been destroyed by the inroads of Lake Ontario or may in part still remain below its waters.

### The Iroquois Shore to the Northeast

The ancient East Toronto peninsula just described starts within a quarter of a mile of the present Scarborough cliffs, and the cliffs of Lake Iroquois run northeast parallel to them for a couple of miles, leaving a flat terrace between the old lake and the new. This terrace narrows at the Dutch church and is lost altogether a little farther east, where for half a mile the old Scarborough promontory is cut off by the cliffs of Lake Ontario, which here, at their highest point, are 350 feet above the present water level. After this brief interruption the Iroquois shore cliff begins again in a park at one time used for excursions by the suburban railway, and presently reaches its highest point of 175 feet. This was cut in a morainic hill rising more than 600 feet above sea level.

From this highest point the shore swings nearly north round the hill to the crossing of Kingston Road over the C.N.R., where there was formerly a small gravel bar beside the valley of Highland creek. The gravel has been used to level up the highway in order to avoid a dangerous level crossing, and the bar has practically disappeared. For a mile and a half farther north the winding valley of the creek with its wooded banks and low flood plain interrupts the Iroquois shore, and for two miles farther it has not been traced with certainty except by a succession of sand and gravel deposits ending with a large ballast pit of the Canadian Pacific railway. To the west small bays are enclosed by the bars, but with low, wooded landward slopes not easily recognized.

The gravel deposits begin a little west of Danforth Road where it crosses the second concession of Scarborough township at the very edge of the deep Highland Creek valley. They include a township pit where cement pipes are made for culverts, another deposit of gravelly sand worked by the Perry Cement Products Company, and the railway pit near a bend of Rouge river, from which much ballast was taken when the C.P.R. was built. This pit is large and has a depth of 40 feet. A hundred yards to the north of it there is a steep slope descending 100 feet to the river valley. The gravel of the railway pit is coarser than in the two deposits to the south, which are of a sandy nature.

Crossing the two branches of the Rouge, which have deep valleys between irregular ridges and hills, the exact position of the shore is hard to fix, especially as the country is largely wooded; but two narrow bays run up the valleys, and small gravel bars are found on each side of the eastern branch, followed by a low shore cliff and then by a bar south of the Canadian Pacific railway near the town line between Scarborough and Pickering. Beyond this for four miles the Iroquois shore is well marked by the C.P.R. and a branch of the C.N.R., which run close together, taking advantage of the even grade at the foot of the shore cliff and the level surface of the gravel bars, which also furnished ballast when the roads were built.

The brief outline of the shore northeast of Scarborough Heights just given will be sufficient for our present purpose. It will be seen that this part of the Iroquois beach lacks the broad and simple character of the part within the city and its suburbs, the reason being the presence of small and rather low swells of moraine with numerous dips between them instead of the much loftier and broader Scarborough Heights. Another factor influencing this northeastern strip of shore is its relatively sheltered position as part of a widely sweeping bay instead of a projecting point of the shore such as the Scarborough promontory.

It has already been noted that the Iroquois beach rises toward the northeast, and the amount of its deformation should be given here. The elevation of the Davenport or Carlton bar near the Humber has been determined at 176 feet above Lake Ontario, that of the East Toronto bar at 186 feet, a rise of 10 feet in 7 miles from east to west. The shore near Leaside station, 2 miles north, is at about the same level; and the Cherrywood station on the C.P.R. is 215 feet above Lake Ontario, while the old C.N.R. station, according to White's altitudes,[1] is 226 feet above it. An average of 220 feet may be taken as correct. Some of these elevations are taken from gravel bars, perhaps five feet above water level, and others from the foot of shore cliffs, perhaps a little below water level; but the figures are correct enough for practical purposes. Between Davenport station and Cherrywood there is, then, a rise of 44 feet in a distance of 16½ miles northeast, which implies 2⅔ feet per mile in that direction.

### Climatic Factors

It has already been shown that Lake Iroquois existed because the last ice-sheet halted for thousands of years in the Thousand Island region, holding up the water to the level of the Mohawk channel leading to the Hudson. This long halt is a very puzzling feature of our Pleistocene history. While the ice was rapidly thawing and setting free the Ontario basin, before the high-level stage of Lake Iroquois began, there must have been warmth enough to keep up the melting; but when the process slowed down for 8,000 years or more, the climate must have been cooler. It might be supposed that with a wall of ice hundreds of feet thick less than 150 miles to the east, the climate would have been arctic; and with its eastern shore consisting for a hundred miles of the edge of a continental ice-sheet it might be expected that many icebergs would be drifting round on Lake Iroquois as they do on Davis strait near the Greenland ice cap.

Our data for judging the climate are rather meagre. At Toronto the known animals were the caribou, the musk-ox, and the mammoth, all belonging to a colder climate than the present, though within the writer's memory the caribou has lived on the north shore of Lake Superior, not so very far north. The musk-ox within historic times has not been found less than 1,500 miles to the north and may be looked on as a typical arctic animal. The great Burlington bar, near Hamilton, has supplied remains of mammoth, wapiti, beaver, and probably buffalo, the last three animals suggesting north temperate rather than arctic conditions. Beneath thirty feet of Iroquois deposits in Hamilton, wood was found which Penhallow named *Larix americana* and *Picea*, probably *nigra* (tamarac and black spruce), trees that indicate a cooler climate than the present. The only other fossils known from Iroquois deposits are a few freshwater shells collected in a gravel pit, no longer worked, just east of Reservoir Park, Toronto.

[1]Jas. White, "Altitudes in the Dominion of Canada," Geol. Surv. Can., 1901.

These included *Campeloma decisum*, *Pleurocera* sp., *Sphaerium* sp., and fragments of unios, all still living in our waters.[1]

The natural conclusion is that in Iroquois times conditions were cold temperate and not arctic, in spite of the presence of a great ice-sheet toward the northeast. The stagnant margin of the sheet may have been covered and protected by a thick layer of superficial drift on which a hardy forest grew, as happens to-day on the seaward edge of Malaspina glacier in Alaska, where the climate is by no means arctic. The cool stage permitting the ice dam to remain at the Thousand Islands finally gave way to warmer conditions. The ice melted somewhat rapidly, opening lower outlets, and Lake Iroquois came to an end. Of later water levels, belonging to Lake Frontenac[2] and then to a marine invasion of the Ontario basin, there is no positive evidence at Toronto, though it seems certain that they existed for relatively short periods.

## Early Stages of Lake Ontario

After the final removal of the ice-sheet the unloaded area toward the northeast rose to respond to the relief, and at length the Thousand Island region was lifted above sea level and Lake Ontario began. As the northeastward rise continued the outlet was differentially elevated and the water was backed up toward the western end of the basin, which had more nearly reached equilibrium. The result was that the lake in our region was steadily deepened by the tilting of the basin and encroached on the lower (earlier) shore line. As Lake Ontario is now 245 or 246 feet above sea level, it must be supposed that the water rose to that extent; but there is no positive evidence of more than about a hundred feet of rise at Toronto. As we have no proofs of post-glacial faulting on the shore of Lake Ontario we must assume that the upward warping of the region when the ice disappeared was distributed along a very gentle curve toward the southwest so that the differential rise at this distance from the outlet was only about the one hundred feet just mentioned.

The evidence for the rise of the lake level consists mainly in the backing up of the water in the two river valleys of the Toronto region. Both the Don and the Humber have a fairly rapid descent from the highlands to the north down to a certain point in their lower valleys, after which the current almost ceases and they meander sluggishly for a couple of miles before entering the lake. This is well seen on the Humber below the Old Mill, but is not so apparent on the Don because of the straightening of its channel forty years ago.

In 1905, a well sunk by Wickett and Craig, Limited, at the corner of Cypress and Front streets near the mouth of the Don, reached a depth of 102 feet, nearly a hundred feet below the level of the river. Many shells, nuts, and pieces of wood were found at a depth of 50 feet, and below that stony clay (till) to the shale. In 1911, a trunk sewer was passed under the Don by a siphon at Wilton Avenue (now Dundas Street) showing 5 feet of made ground above the river, 18 feet of yellow or brown clay beneath it, followed by 50 feet of sand and clay with wood and shells. In 1915, excavations for a pier of the Bloor Street viaduct showed stratified silt and sand containing logs of wood for 32 feet below the level of the river, and at this depth just above the shale the skull of a half-grown bear was found. All of these sections are post-glacial except the till mentioned in the first one, and represent deposits of the Don at a stage 68 feet or more below its present level, which is practically that of Lake Ontario.

[1]A. P. Coleman, "The Iroquois Beach," Jour. Can. Inst., 1918.
[2]F. B. Taylor, U.S. Geol. Surv., Mon. LIII, p. 445.

The best evidence of the work of the early Humber was supplied in 1930, when the foundations for the new bridge at its mouth were being prepared. Fortunately the engineer who supervised the work, C. W. Cornell, kept track of the finds and provided specimens of everything of interest, so that we have a good record of it. The excavation showed an old channel going 93 feet below the present water level, passing through clay and sand with wood and also peat at various levels from 60 feet down. White pine grew in the Humber valley as shown by the find of a cone, and there were black but fairly well preserved logs and stumps of ash, maple, and a white oak, according to J. H. White, professor of Forestry, University of Toronto. Some of the wood was hard and splinters were elastic. The peaty matter was very different from the Scarborough interglacial peat and contained few mosses and no spruce needles, both of which are very common in the ancient peat. A few seeds and the wing of a beetle have not been determined. There was good forest growth up the Humber during the early stages of Lake Ontario and a climate like the present, as shown by the trees.

One very interesting point remains to be noted in regard to the early Humber. As just shown, its channel went at least 93 feet below the present lake level, but a little way to the west rock comes to the surface on the lake shore, and at Sunnyside, half a mile to the east, rock was to be seen before the filling was done for the amusement park. The cutting of this ravine in solid shale must have demanded a considerable time and suggests that the early low stage of the lake must have been long unless there was a pre-glacial channel at that point.

If the basin of Lake Ontario has been tilted a hundred feet, at a time so comparatively recent, the question naturally arises as to whether the elevation is still progressing. Twenty or thirty years ago this was thought to be true and that in time the flow of Niagara would cease and the waters of the upper lakes would empty past Chicago into the Mississippi; but the determination of water levels at various points on the Great Lakes, on which the suggestion was based, were faulty, and at present the evidence favours a stationary condition. It is probable that the adjustment of this part of the earth's crust, after the removal of the load of ice, has reached equilibrium.

## Time Relationships

A long and very complicated series of changes of climate and physical conditions has been sketched in the foregoing pages, and the time required to accomplish them is a matter of much interest. The estimation of the time needed to bring about the successive stages of the Pleistocene depends on a variety of assumptions, some very accurate and others very vague. In a few cases the actual years required for a given process can be counted up with certainty, but usually the estimate is merely probable, and at certain stages only guesswork.

Leaving out the counting of annual layers of clay, which gives accurate results when available, the best mode of estimating geological time in our region is by the work of waves. We may reasonably suppose that the cutting of cliffs and the building of bars across the mouths of bays will go on with fair regularity in lakes of the same dimensions and under similar conditions. This will apply to Lake Ontario and Lake Iroquois, for example. The carving and broadening of valleys by streams of about the same volume and slope is a process that should go on with some regularity too, and may be used in estimating time, though with less certainty than wave work. The filling of a basin with sediments under given conditions may also supply data of use in the work. All of these methods will be used in the following study of time relations.

### Wave Work as a Measure of Time

The fact that the Scarborough cliffs are being cut back by the waves of Lake Ontario has long been observed by farmers, whose fields were being attacked, and by scientific observers, and the process was described eighty years ago by a famous engineer, Sandford Fleming, in a report on Toronto harbour.[1] In 1912, at the suggestion of R. C. Harris, Commissioner of Works for Toronto, the question of the recession of the cliffs was gone into once more. For this purpose the firm of Speight and Van Nostrand resurveyed the distance between the edge of the cliffs and points fixed by F. F. Passmore fifty years before. Seventeen lines were checked in this way, but only thirteen were considered normal, the others coming out on deep ravines, evidently recently cut by streams at work since the protecting forest was removed. The recession in the fifty years was 81 feet, which works out to an average of 1.62 feet per annum. Soundings in the lake south of Scarborough show that the bottom slopes gently lakeward for 13,000 feet, where a depth of about a hundred feet is reached. Beyond this the contours are more crowded, and it is clear that Scarborough Heights reached thus far when Ontario began its work. This figure divided by 1.62 gives in round numbers 8,000 years since the lake commenced to cut back the cliffs.

A time estimate was made also for the formation of Toronto Island. From a number of borings to bed rock the thickness of sand and gravel was estimated to average 107 feet, and the bulk of the deposit has been calculated at 337,000,000 cubic yards. From thirteen years' accumulation of sand against the eastern pier of the new southern entrance to the harbour, an average addition of 42,000 cubic yards per annum was reached, and this divided into the whole bulk of the island gives 8,000 years also. The latter estimate includes, of course, a number of uncertainties and must not be considered at all accurate, but its coincidence with the other supports the probability that 8,000 years is in round numbers the age of Lake Ontario.[2]

From the description of the cliffs and gravel bars of Lake Iroquois given in earlier pages, it will be seen that the two lakes are closely alike in the maturity of their shores; and since they were of much the same size and shape, it is probable that wave action at any given point would be similar. The inference is that Lake Iroquois required 8,000 years for its work.

How long a time elapsed between Lake Iroquois and Lake Ontario including the Frontenac and other stages and the invasion of the sea, is quite uncertain, and little is known of the earlier phases of Lake Ontario itself, while it was rising to a level 100 feet below the present; but these successive changes must have occupied thousands of years and a guess may be made that another 8,000 years may be added to complete the time since the ice began to leave the Ontario valley. One may conclude, then, that Lake Iroquois began something like 24,000 years ago, and that the last ice-sheet commenced the retreat from its farthest point 25,000 or 30,000 years ago, estimates that accord fairly well with determinations of the age of Niagara falls.

The rough measures just given suggest that Lake Iroquois was drained about 16,000 years ago, and that the valleys cut through its deposits by the Humber, Black creek, and the branches of the Don have been excavated in that time. Valleys of that maturity may therefore be considered to indicate the lapse of about 16,000 years, and more mature valleys must have required a longer time.

[1]Jour. Can. Inst., 1854, pp. 107-223.

[2]A. P. Coleman, "An Estimate of Post-Glacial and Interglacial Time in North America," Proc. Twelfth Internat. Geol. Congr., 1913, pp. 435-449; "Wave Work as a Measure of Time," Am. Jour. Sci., Vol. 44, 1917, pp. 351-359.

To form an estimate of Pleistocene time we require a consideration of the length of three ice ages and two interglacial periods, one of them very long, as well as the 25,000 or 30,000 years of late glacial and post-glacial time just discussed. How long does an ice age last? Unfortunately, we have very little to go upon in estimating the length of an ice age. Antevs by counting the varves in the Don valley and at Scarborough showed that the Illinoian ice-sheet loitered 1,500 years within a few miles of Toronto. This is the only definite determination of glacial time in our region and includes only a tiny part of the movements of a great ice-sheet. Farther north the same experienced student of glacial matters has found varve series extending for several thousands of years, but recording only a relatively small part of the retreat of the Wisconsin ice-sheet.

It is certain that the advance, culmination, and retreat of a great ice-sheet demand a long time, probably more than twice the time since the last retreat began, say at least 60,000 years. The time occupied by the first interglacial period was very long, as will be admitted when the different events which succeeded one another are recalled. The unrecorded interval between the recession of the first ice-sheet and the dropping of tree trunks on the boulder clay it left behind included a change of climate from arctic to 4 or 5 degrees warmer than the present, the damming back of a lake 60 feet higher than Ontario, and the spread of a rich Pennsylvanian forest 200 or 300 miles northward to the Muskoka region. Many thousands of years must have elapsed after the ice departed before the interglacial beds were even begun, and one can hardly allow less time than the retreat of the last ice-sheet demanded, i.e. 25,000 or 30,000 years. Then came the building up of 25 feet of warm climate sand and clay over an area of probably fifty square miles, demanding more thousands of years.

Although the Scarborough beds seem to rest conformably on the Don beds, there must really have been a great unrecorded break between them to account for a change of climate from warm temperate to cool temperate and for the damming of the lake to a level 200 feet higher than before; but to suggest how many thousands of years were needed would be pure guesswork. Ninety feet of peaty clay at Scarborough, at the rate of 34 annual layers per foot, as counted in 19½ feet at one point, give more than 3,000 years; and to this must be added enough time for the deposit of 60 feet of sand upon the clay, perhaps another thousand years, or 4,000 in all.

The Scarborough lake was drained to a depth of more than 166 feet; how long a time this tremendous change in water levels required is unknown. Then came the cutting of important valleys in the delta, now dry land. The best known of them, at the Dutch church as already described, was a mile wide and 166 feet deep and far more mature in cross-section than the Don or Humber valley, requiring at least double their age, or 30,000 years, if not much more.

Next comes the most puzzling of all the interglacial phenomena, another change of climate, this time from cool to warm, and the filling of a valley with tumultuous river deposits, sands and gravels strangely cross-bedded and containing blocks of wood, large bivalves such as live in the Mississippi, and scattered bones of bear and deer and bison as well as mammoth ivory. How many thousand years one should allow for this extraordinary river formation it is impossible to say. In a former discussion of the length of the Toronto interglacial time, the conclusion was reached that it probably included at least 100,000 years,[1] and to the writer that still seems a minimum.

In fact it seems not impossible that the interval between the Lower and Middle tills in our region includes two interglacial periods of warm climate,

[1]A. P. Coleman, Proc. Twelfth Internat. Geol. Congr., 1913, p. 447.

separated by a time of cool climate (Scarborough beds) corresponding to a western glaciation, recorded in the Mississippi states, but not extending to the eastern side of the continent. In that case our lowest till would represent the Nebraskan glaciation, the Don beds would correspond to the Aftonian, the Scarborough beds to the Kansan glaciation, and our late interglacial warm climate river deposits to the Yarmouth, followed by the Illinoian glaciation. However, these speculations lead too far and need to be checked by much more complete information than we have at present.

The later interglacial period between the Illinoian and the Wisconsin glaciations is not well enough represented near Toronto to estimate its character or length. If it includes the land and marine deposits of the St. Lawrence and Ottawa valleys, as seems probable, there was a somewhat long period having a temperature like the present with maple and poplar growing on the banks of the latter river as they do now. The second interglacial time had no complicated succession of climates and water levels. It may have been less than half as long as the earlier one, and 50,000 years would probably be ample for it. If our latest glaciation corresponds to the recently suggested combination of the Iowan, Peorian, and Wisconsin periods in the Mississippi valley it must have included a very long time of cool conditions, probably very much more than twice the length of its final retreat, estimated above at 25,000 or 30,000 years.

In this summing up of the probable time required for the succession of events recorded in the Pleistocene of southern Ontario so many points remain problematic that no precise adding up of definite periods of years seems possible, and one can only say that the time was long—at least several hundred thousand years and probably a million or more.

## Economic Geology of the Pleistocene

From the economic point of view, the Pleistocene is by far the most important geological formation of southern Ontario, since our soils and subsoils consist of drift materials more or less modified by the work of vegetation; but this side of the Pleistocene will not be taken up here, belonging rather to the agriculturist and forester. Next in importance come water supply and building materials.

### Water Supply

Except on the immediate shore of Lake Ontario our region depends for its water supply mainly on wells sunk in the drift, though rivers and ponds or lakes are occasionally used. Even in the latter case the water supply is largely from springs coming from the drift. Of course, ultimately, the water comes from rain and melting snow, but it is stored in porous drift deposits at or beneath the surface and is always more or less modified by gases and solids dissolved in its passage through the ground, thus becoming "hard," or slightly saline, or ferruginous. Practically no strictly artesian water, coming from rocks beneath the drift, is used in our region, though a number of wells have been drilled to great depths, even penetrating the Archean granite and gneiss beneath the Paleozoic shales and limestones. The water thus obtained from bed rock sources is too salt for use, and from the deepest wells it may be highly charged with calcium chloride and other objectionable salts, as was the case with the flowing well on the Page farm 2 miles west of Thornhill, where the water came from the bottom of the Trenton limestone at 1,200 feet.

*Springs.*—Springs are very common, occurring wherever porous materials resting upon an impervious layer are exposed in the slope of a hill side or in the walls of a valley, and may be recognized at a distance by rank vegetation or even marshy growths along the side of the valley. They are found usually where a bed of sand or gravel lies upon a bed of clay, whether glacial or interglacial, or upon the shale which underlies the drift as bed rock. The sands and gravels of the Iroquois beach everywhere supply springs when they rest on boulder clay or varves or the peaty clay of the cool interglacial time; but more copious springs occur at the edge of sandy or gravelly moraines, as south of the great interlobate moraine sometimes called the Oak Ridges. Strong springs come out in many places at the foot of the moraine and serve as water supplies for towns at some distance from Lake Ontario, such as Stouffville, Bowmanville, and Colborne.

Many springs with a limited area of sand or gravel for storage of water run low or cease to flow after a dry summer, but many others are practically permanent, coming from widely extended porous beds, often beneath a sheet of boulder clay. Springs, with their contents of dissolved carbon dioxide, carbonate of lime, and small amounts of common salt and other ingredients, are more agreeable to drink than pure water and may have commercial value, as in the case of York Springs along the western branch of the Don, or the springs on the east side of the Humber. The coldness of spring water, so delightful in hot weather, comes from their origin at a depth below the surface having the average annual temperature, which is much below summer heat. On the other hand they are relatively warm in winter and remain unfrozen.

*Wells.*—In most places in southern Ontario, except where the drift covering the bed rock is very thin, the water may be got by digging 20 or 30 feet, since the latest sheet of boulder clay is generally sandy and porous and the Iroquois deposits, which cover most of the surface near Lake Ontario, are even more so. Only the older tills or the Illinoian varves, which do not often occur, are too impermeable to provide water in wells of ordinary depth. In such cases deeper wells may pass through them and reach water-bearing sand or gravel; but if they rest on compact shale no potable water may be found, since unweathered shale is not porous and is a marine rock charged with salt.

In many parts of southern Ontario, and especially in the region underlain by the interglacial beds, plentiful supplies of water may be got by sinking moderately deep wells through clay into beds of sand; and under special conditions the water may be under pressure and give flowing wells. This is the case, for instance, at Barrie and at many points south of the interlobate moraine, as east and west of Lemonville, where the farmers have splendid flowing wells.

The Engineer for North York, G. H. Baker, gives information in regard to wells for a township water supply. Two wells were sunk near the Don, about where Sheppard Avenue crosses Leslie Street; the first was begun at 415 feet above sea level and passed through clay and quicksand for 120 feet to the underlying shale; and the second reached rock at 130 feet. A moderate supply of water came from sand beneath the upper or Wisconsin till, evidently derived from the interglacial sand referred to above. The latest well, near the corner of Steele Avenue and Leslie Street, about 2 miles north of the former wells, furnishes a fine water supply. It was sunk from ground level 479 feet above the sea to a depth of 170 feet without reaching rock, passing through the following section of drift:—

| | Feet |
|---|---|
| Sandy clay, gravel, and boulders | 40 |
| Clay | 2 |
| Quicksand | 82 |
| Very fine sand | 2 |
| Coarse gravel and boulders, water-bearing | 28 |
| Clay | 2 |
| Dry sand. | |

The well flows 230 gallons per minute. The water is quite hard and contains a perceptible amount of iron, but is excellent for drinking. At present the water flows into the Don and forms a brownish deposit of iron oxide on the pebbles of its bed, no doubt from the passing off of carbon dioxide ($CO_2$), which held the iron in solution.

The whole of the materials passed through appear to be morainic, and hills rise just to the northeast, belonging to the southern margin of the interlobate moraine. The water is under pressure from a head, perhaps at some distance to the north, being confined probably beneath the upper sheet of clay shown in the section.

There are some puzzling problems connected with wells where the water rises above the level of the ground from which it comes; for instance, in the well at the tannery of L. S. Clarke in Barrie the water rises 5 feet above the ground and 10 feet above Lake Simcoe, which is only a hundred yards away, and flows strongly and continuously. The well is 150 feet deep, and there are several other flowing wells in the town. The water must come from morainic hills some distance away, probably confined beneath an impervious sheet of boulder clay like the one in North York.

*An Underground Channel (?).*—A quarter of a century ago J. W. W. Spencer described the route of a great pre-glacial river, which existed before the Great Lakes were formed and drained their valleys south past Toronto, along the south side of the deep Ontario valley, and finally northeast through what is now the Gulf of St. Lawrence to Cabot strait and the Atlantic. The upper part of the Laurentian river, as he named it, came from Georgian bay past Barrie, Newmarket, and Richmond Hill, and the route was suggested by deep wells used as a water supply at each of these towns. He states that a well at Barrie passed through 280 feet of drift without reaching rock, and that one at Newmarket went below the level of Georgian bay without finding rock; and the same was true at Richmond Hill where a well was sunk 400 feet.[1]

Spencer believed the old channel came out to the east of Toronto, but it is more likely that it followed the general direction of the Humber valley, where wells at Weston and Mount Dennis give a great supply of water, while no large flow has been obtained farther east except in North York, as described above. It is possible that water still seeps through interglacial sand and gravel from Georgian bay to Lake Ontario, following underground the old river channel, but final proof of this is not yet at hand.

It is worthy of notice that, in a well sunk for a water supply at Weston, salt water was encountered at about 200 feet after passing through a stratum bearing fresh water, and also that the excavation for the bridge foundations at the mouth of the Humber struck salt water just over bed rock. Instances of the same sort have been reported from wells sunk into the shale at Simpson's store (Richmond and Bay) and at York Mills, and it is evident that this ancient marine deposit is charged with salt. It should be noted also that in towns and cities, water from interglacial sand may be contaminated with sewage and be dangerous to drink, although it appears of excellent quality. Well water from such places should be tested for organic contents and bacteria before being used. This service is performed without charge by the Department of Health, Parliament Buildings, Toronto.

### Building Materials of Pleistocene Origin

The Toronto region is poorly supplied with native building stone, only the limy or sandy layers interbedded with the shale of the bed rock being of any

[1] J. W. W. Spencer, "The Falls of Niagara," Geol. Surv. Can., Pub. No. 970, 1907, pp. 398, 399.

value for that purpose, and these layers are never more than a few inches thick, yet where set free from the crumbling shale they may be used, as they have been in house-building and fencing along the Humber. On the other hand brick-making materials are available in unusual variety. The shale itself is used for brick, and also four different varieties of clay of Pleistocene age.

*Brick Clays.*—Boulder clay, or till, has been employed, though not on a large scale, since the pebbles and boulders it contains have to be carefully removed before it can be used. Varve clay has served very widely for brick-making and this well-stratified glacial clay has supplied the material for buff brick, so much in use at Toronto. The upper two or three feet, from which the excess of lime has been leached, burns red. This type of clay has been worked extensively in Pear's brickyard west of Yonge Street in what is now Ramsden Park; and at the Don Valley brickyard.

The cool climate interglacial clay, where not covered by too thick an overburden, provides perhaps the most desirable source of bricks, since it burns to a good red. It is used at the Don Valley brickyard and at several other yards east and west of Greenwood Avenue and north of the C.N.R. The most extensive deposit of this excellent clay, though exposed for seven or eight miles in the Scarborough cliffs with a thickness of 85 or 90 feet in many places, has not been worked because of the excessive overburden.

A silty clay, half a mile south of the Greenwood Avenue brickyards and just north of Queen Street, for a number of years provided red brick from the weathered upper part and buff brick from the lower part, but was worked out and the denuded district turned into building lots many years ago. Two brickyards are still using a somewhat similar silty clay, often greatly crumpled, west of the Humber. Just where this clay belongs in our time scale is not certain.

Finally, the clay deposited over sand in the two large bays of Lake Iroquois, with a thickness of 5 or 10 feet, has been used, and along Dawes Road it is still being burned to buff and red brick. For a time this clay north of the Humber bar was employed with shale from a quarry west of the river to make paving brick.

On a small scale interglacial clay has been used for making pottery, the material being dug from a hillside between the Don valley and the Sun brickyards.

Enough has been noted to give an idea of the different kinds of brick-making materials in the region. For details of the industry and statistics, reports of the Department of Mines should be consulted.[1]

*Sand, Gravel, and Boulders.*—A modern city in its growth consumes immense quantities of sand for mortar and cement, and of gravel or crushed stone for concrete. Pavements and buildings of all kinds consist largely of these artificial substitutes for stone, and for such purposes square miles of sand and gravel pits have been opened in Toronto and within a radius of twenty miles. In earlier times roads were metalled with gravel also, and the numerous railways centring in Toronto used gravel for ballast.

Under these conditions it is fortunate that the shore of Lake Iroquois passes through the city with two great gravel bars built by its waves across the ancient bays which indented the coast-line. Similar old lake deposits are now being borne citywards by the truckload from points to the east and west.

In addition sand and gravel of glacial origin are coming from Maple and other points to the north. The deposit near Maple is a kame associated with

[1]M. B. Baker, "Clay and the Clay Industry of Ontario," Ont. Bur. Mines, Vol. XV, pt. 2, 1905.

R. J. Montgomery, "The Ceramic Industry of Ontario," Ont. Dept. Mines, Vol. XXXIX, pt. 4, 1930.

the interlobate moraine. It forms a square mile of irregular hills rising 700 feet above the plain to the southwest, mostly forest-covered, so that its composition cannot be seen, but it is probable that much of it will be available. The pits opened on the southwestern side of the hill show less coarse gravel and fewer boulders than most kames.

In modern practice the coarser materials are passed through a crusher and are used for concrete, so that pebbles and small stones are not a disadvantage in a sand pit; but in several of the pits, where sand-lime bricks are made, the gravel and stones are rejected and only the sand is used. In the course of this survey dozens of pits opened for sand and gravel have been examined, most of them operating on Iroquois deposits, especially the two great bars already described from the Don and the Humber regions; and often fine illustrations of cross-bedding due to wave work can be seen, suggesting the time thousands of years ago when the big waves of easterly storms shifted and sorted the debris gathered from their attacks on the shore of boulder clay.

In one important set of deposits, now exhausted, between Christie Street and Ossington Avenue, a very different type of structure was to be seen, due to powerful currents which swung to and fro, piling up in one place and cutting away in another the burden brought down by a river. These deposits were of interglacial age.

In the early days of Toronto, drift boulders were an important source of building stone, especially for foundations, but they have long ago disappeared. In some nearby farming districts a house built of them, or the foundations of a barn may still be seen, giving a picturesque collection of our Archean rocks with a great variety of textures and colours.

### Natural Gas

One of the most interesting features of wells in the Toronto region is the frequent presence of natural gas coming probably in all cases from interglacial sand beneath a covering of clay. The two best known examples of this were at the North Toronto waterworks in Sherwood Park and at St. Augustine Seminary. At the waterworks the wells yielded gas from dry sand 50 feet below the surface under 40 feet of clay. For a time this was used beneath a boiler for the pumps, and R. B. Harkness reports that the flow from the three wells was 63,000 cubic feet per 24 hours.

At the seminary, according to a report by G. R. Mickle,[1] four and a half million cubic feet were produced in all and used for three weeks under boilers. The gas came from a depth of 290 feet, about 11 feet below the lake level, and was under a pressure of 5 pounds. An analysis gave 85.15 per cent. $CH_4$ (methane), 13.2 N (nitrogen) and 1.65 $CO_2$ (carbon dioxide). No sulphur was reported, but the North Toronto gas had a distinct smell of hydrogen sulphide.

Gas has been struck at two places in Thornhill, at Donview, at Bendale northeast of Scarborough village, at Victoria Park, and at one of the Greenwood Avenue brickyards. It has also been found bubbling up through the water toward the east end of Scarborough Heights; and it probably occurs in small amounts in all the sandy varieties of the interglacial formation. The source of this gas is somewhat uncertain. It might be derived from the decay of interglacial plant material, which is widely distributed, or from bituminous shale at considerable depths beneath, as suggested by Col. Harkness.[2] In either case the gas is retained by the impervious sheets of clay overlying the sand.

[1]G. R. Mickle, "The Chemical Composition of Natural Gas Found in Ontario," Ont. Bur. Mines, Vol. XXIII, pt. 1, 1914, p. 246.

[2]R. B. Harkness, Ont. Dept. Mines, Vol. XL, pt. 5, 1931, pp. 51, 52.

**Siderite Iron Ore**

Of no economic importance, but of some mineralogic interest, are the thin sheets of impure siderite or clay ironstone that occur in the interglacial clay at Scarborough and elsewhere. They are seldom an inch thick but may extend for many square yards between the beds of peaty clay, and in the aggregate must contain a considerable tonnage of iron. When fresh they are hard and greenish-grey in colour. Many of the flat pebbles on the beach beneath the Scarborough cliffs have the brown colour due to the oxidation of the siderite. The iron compounds brought down to its delta by the interglacial river must have had their source in the pre-Cambrian rocks to the north and indicate a long period of weathering to set them free.

The fine red colour of brick made from this interglacial clay is largely due to the presence of these thin sheets of iron ore.

# APPENDIX

## MORAINES NORTH OF TORONTO[1]

**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 striae 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

[1]This article was prepared for the use of the Twelfth International Geological Congress which met in Toronto in August, 1913, and was published in Guide Book No. 6 for the excursions of that Congress. This fact explains the phraseology. As the paper had more than fugitive interest and importance, it was reprinted in Part I, Volume XXII, 1913, of the Ontario Bureau of Mines.

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.

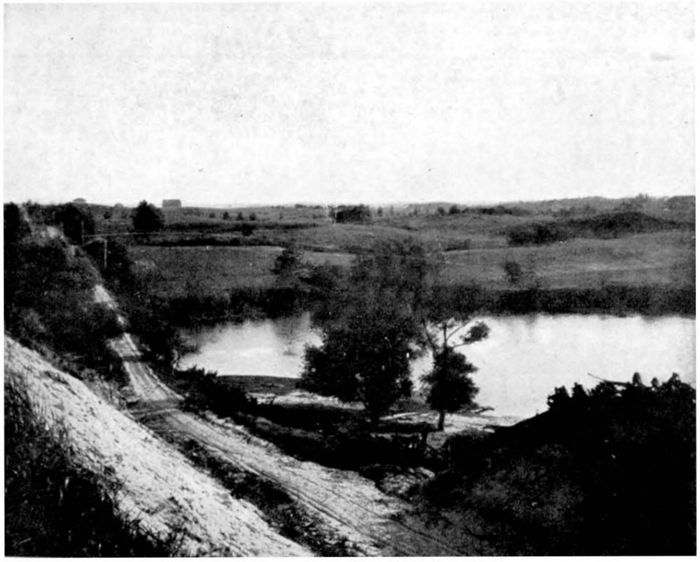
At this stage of retreat the ice did not enter the western part of the Lake Ontario basin over the ridge north of Toronto, but came in at the northeastern end, chiefly in the gap between Trenton, Ontario, and Oswego, New York.

Bond lake, looking east, probably caused by a partly buried ice block which afterwards melted out.

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 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 towards the southeast. The stream valleys



A pond and morainic topography in the northern moraine, looking south three miles west of Aurora.

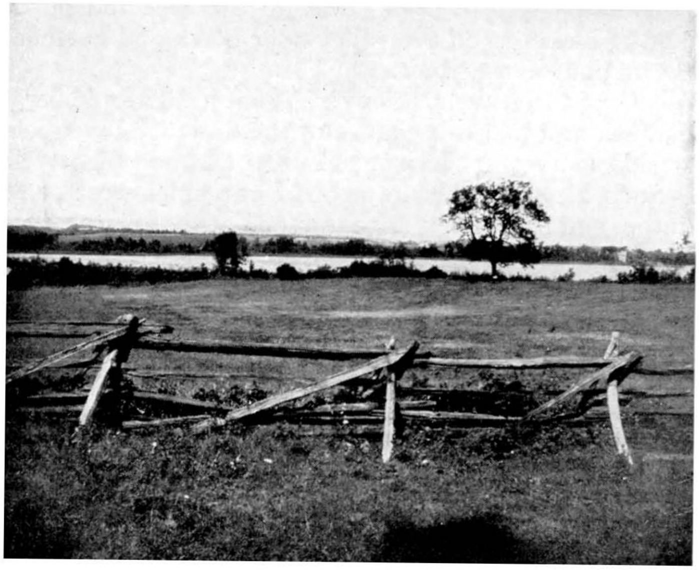
have been cut to only moderate depths, the deepest being the west branch of the Don river, which at York Mills reaches a depth of about 100 feet.

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 aligned 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. 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



View looking north over Willcocks lake, the northern moraine in the distance.

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, 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.

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.

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