INTERGLACIAL PERIODS IN CANADA

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MÉXICO.

IMPRENTA Y FOTOTIPÍA DE LA SECRETARÍA DE FOMENTO

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EXTEND OF GLACIATION.

No country in the world shows more striking evidences of glacial action than Canada, where 3,000,000 square miles of territory were covered with ice sheets, though probably not all at one time. So far as known the only parts of the Dominion unoccupied by glacial ice were the interior Yukon basin, including the Klondike, and a little group of islands in the Gulf of St. Lawrence, the Magdalen Islands. Every other part of Canada shows glacially smoothed, rounded and striated rock surfaces, or the boulder clay, moraines, kame deposits or eskers left by great ice sheets, except, where these are hidden under later lake or marine deposits formed of glacial materials.

Three great centres of accumulation of ice are recognized. The Cordilleran, shown by the late Dr. George M. Dawson to have come first, occupied the belt of mountains 400 miles wide forming the Pacific coast side of Canada. The summits of the higher peaks rose as nunataks above the ice, which crossed the straits of Georgia to the west and covered Vancouver island, but did not reach out over the prairies to the east except for a short distance at mountain passes, such as Bow river.

The second glacial sheet in time was that of Keewatin, shown by J. B. Tyrrel to have had its centre of dispersion west of Hudson Bay, and known to have reached nearly if not quite the foot of the Rocky Mountains to the west and to have extended over the prairies and western end of Ontario, ending in the

United States near the junction of the Missouri and Mississippi rivers.

The third sheet, the largest of all, began in Labrador and extended outwards in all directions, filling much of Hudson Bay and joining the Keewatin sheet to the west, probably crossing to Newfoundland on the east, and reaching St. Louis and Cincinnati in latitude 38° in the United States. The territories of the Keewatin and Labradorean ice sheets overlapped in places, some regions, like that of Rainy Lake in Western Ontario, having boulders which came from the north-west, such as Winnipeg limestones, and also the characteristic Archaean boulders belonging to the Hudson Bay country to the north-east. The striae also are often in two directions, one 5° or 10° east of south, the other 35° or 40° west of south. When confluent these two ice sheets formed the greatest stretch of continuous névé known, covering in all not less than 3.000,000 square miles of Canadian and American territory.

The effects of the combined Keewatin-Labradorean ice sheet upon the land surface beneath were profound. From the central regions most of the loose material due to preglacial weathering, no doubt very thick in many places, was removed bodily for hundreds of miles, leaving the bare and rounded surface of unweathered rock deeply carved and scoured. In these central parts there is usually little in the way of morainic deposits except in the lee of rock hills. Near the periphery, on the other hand, loose materials in the shape of boulder clay, moraines, etc., are often piled up to thicknesses of more than a hundred feet, in the aggregate amounting to many cubic miles. Here the land forms are mainly the result of the irregular deposits of glacial materials. Over the whole glaciated region the previous drainage systems were blocked or impeded by drift deposits, giving rice to the myriads of fresh water basins so characteristic of Canada, which probably has a larger number of lakes than the rest of the world put together.

CLASSIFICATION OF ICE SHEETS AND DRIFT DEPOSITS.

The direction of at least the latest ice movements from the three centres described, and the southern boundaries of the ice sheet are now well known, and in most of the northern United States the drift deposits have been elaborately mapped or are now being studied by competent pleistocene geologists. In Canada, though much has been done in acquiring a general knowledge of the drift, very little detailed work has been done. On this account the general classification of the North American drift and of the ice sheets which were associated with its formation is much more completely worked out for the United States than for Canada. There are also special reasons why the relationships of the successive ice sheets and their drift deposits should be better known in the United States than in eastern Canada. The successive ice advances reached to different distances from the central gathering-ground of névé, and their boulder clays and moraines can often be differentiated at the margins by differences in weathering or in composition. It is found for instance, that the Kansas drift sheet is the most extensive and also in most places the oldest occurring in the States of the Mississippi valley, and that it has no marked terminal moraine.[1] (See map by Chamberlain, p. 727. The Great Ice Age, Dr. James Geikie). Its till is greatly oxidized and weathered, with boulders crumbling to pieces. Followed north it runs beneath a later and weathered boulder clay. In similar ways other, later, till sheets can be distinguished, and between each pair are found interglacial soils or peat beds or stratified gravels, showing a change of climate. The series of glacial and interglacial formations in the Mississippi basin has been given by Prof. Chamberlin as follows:

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1 Jour. Geol., 1896, p. 874.

9. Wisconsin Till Sheets (earlier and later).
 8. Interglacial deposits.
7. Iowan Till Sheet.
 6. Interglacial deposit.
5. Illinois Till Sheet (Leverett).
 4. Interglacial deposit (Buchanan of Calvin).
3. Kansan Till Sheet.
 2. Aftonian beds, Interglacial.
1. Albertan Drift Sheet (Dawson).

In the clasification just sketched the name Albertan is given tentatively to the earliest glacial deposits in the Mississippi region; but it has not been shown that this till sheet is directly connected with the one described by Dawson from the far west.

In regard to the succession of the deposits found in Iowa and other states near the margin of the glaciated area two views may be held, 1st. that the central ice sheet diminished and expanded according to climatic changes but never completely disappeared until the end of the Wisconsin period; 2nd, that the melting in interglacial times was complete, so that the successive till sheets represent the work of separate glaciations. According to the first theory, strongly urged by Mr. Warren Upham, the interglacial deposits simply indicate recessions of the ice front for a few miles and for a comparatively short time, perhaps not one hundred years, followed by a readvance. The second theory demands far greater climatic changes and a much longer time, running into thousands of years. It is evident that the correlation of Canadian interglacial deposits with those found hundreds of miles to the south would greatly favor, if not completely establish the theory of disappearance of the ice sheet in interglacial times. Up to the present this correlation has not been made with certainty.

DISTRIBUTION OF INTERGLACIAL BEDS IN WESTERN CANADA.

Interglacial deposits have been little studied in Canada except in the immediate neighborhood of Toronto, though they are known to exist in the west, in Alberta and Manitoba, and widely also on the Hudson Bay slope in Ontario. In many cases, no doubt, former deposits have been away by later ice sheets, since most of Canada lies so near the centers of dispersion as to have undergone powerful erosive action. In consequence most of our glaciated area hardly shows even the last sheet of boulder clay, all the loose materials having been removed to be redeposited under the thinner, marginal parts of the ice sheet. Except round the edges of the glaciated areas, where the thin edge of the ice can over ride even the loosest materials because of its relatively slight pressure, interglacial beds of soft sand and clay cannot be expected to survive. They will be preserved only under special circumstances, where protected in the lee of ridges, or in ravines, or where they are unusually thick and hard. Except near the margin of glaciation, as in southwestern Alberta and southern Ontario, where drift deposits are thick, interglacial beds will be rare and only locally developed.

The best known of the western interglacial beds are those described by the late Dr. Dawson from Alberta,[1] where stratified and often carbonaceous layers occur between two sheets of boulder clay. The drift deposits may be 100 feet thick, resting on Cretaceous shales and sand stones. Along the Belly River at Wolf Island there is a section of the following character:

Upper boulder clay	100 feet.
Purplish sandy clay with ironstone and lignite	8 „
Lower boulder clay	15 „
Yellowish and brownish sands	15 „
Purplish clay	4 „
Yellowish sands	6 „
Quartzite shingle	15 „
Cretaceous shales	10 „

The quartzite shingle is of fluvio-glacial materials brought from the Rocky Mountains by glacial streams flowing from the Cordilleran ice sheet and passes westward into the boulder clay of the Albertan Stage, so that there are really two sets of interglacial beds with three glacial deposits.

In 1885 Mr. McConnell named the lowest bed the Saskatchewan gravels, and later the two geologists together reexamined the drift of the region, extending somewhat the area of inter-

1 Geol. Sur. Can., 1882-4, part C, pp. 139-145.

glacial beds; but found that in many places the lower till sheet rests directly on the Saskatchewan gravels. The width of the interglacial formation cut by Belly River from east to west is 50 miles, but the lignite occurs only locally. In conclusion Dr. Dawson states that probably the lower boulder clay represents the Kansan formation, while the interglacial deposits, best developed along the Belly River, are post-Kansan, and the upper boulder clay corresponds to the Iowan. He then gives the name Albertan to the till sheet into which the Saskatchewan gravels merge westward.[1] In the later form of the classification for the Mississippi valley the upper boulder clay of Alberta would correspond to the Illinois sheet, rather than the Iowan.

In 1886 Mr. J. B. Tyrrell found interglacial stratified material with seams of lignite on Rose Bud Creek, a tributary of Red Deer River in Alberta more than 100 miles,[2] to the north of Dr. Dawson's sections; and later the same writer has described 70 feet of stratified sand and clay underlying boulder clay and probably interglacial at Rolling River in Manitoba. From these deposits a number of plants and fresh water shells were obtained, the plants including five species of diatoms, *Elodea canadensis* (?), *Vallisneria* (?), seeds of a conifer and *Taxus baccata*. They include also seven or eight species of shell fish which inhabit the same region at present.[3]

As Dr. Dawson has found interglacial stratified beds between two boulder clays in the interior of British Columbia and on Vancouver Island, though not on an extensive scale,[4] it seems that at least one interglacial period covered much, if not all, of western Canada.

DISTRIBUTION OF INTERGLACIAL BEDS IN SOUTHERN ONTARIO.

Interglacial beds in Ontario appear to have been described for the first time in 1878. In the Canadian Naturalist for that year (p. 82) Mr. D. F. H. Wilkins briefly states that at Port

1 Bull. Geol. Soc. Am., Vol. 7 pp. 31-66.
2 Geol. Sur. Can., 1886, p. 5B.
3 Ibid., 1890-91, p. 307 E.
4 Ibid., 1886, p. 105 B.

Rowan in Norfolk County, north of Lake Erie, there is the following succession from below upwards:

4. Stratified lacustrine sand..............................	120 feet.
3. Brown stratified clay with boulders of various rocks..	20 „
2. Quicksand..	2 „
1. Blue Erie Clay with leaves in its upper layers, thickness unknown. The leaves from the lower clay include apparently birch, maple, elm and poplar.	

I have visited the Port Rowan region twice with the object of examining these deposits, but have found no leaves, probably because of land slides or other changes which easily take place in shore cliffs of sand clay. The lower blue stratified clay in some places along the north shore of Lake Erie is seen to rest on boulder clay, and higher up on the cliff boulder clay is commonly found. I have traced interglacial stratified sand and clay for many miles along the shore cliffs, and have no doubt that the leaf bed mentioned by Wilkins was interglacial.

Interglacial sand and clay occur at Niagara Falls and the Whirlpool below the falls, but no fossils have been found in these beds; and the same is true for the stratified beds between two boulder clays at Dundas, west of Lake Ontario.

In the same year as Mr. Wilkins, Dr. George Jennings Hinde published an admirable account of the interglacial and glacial deposits at Scarboro Heights east of Toronto.[1] This was the first clear recognition of the importance of interglacial deposits in Canada, if not in North America, and is much to the credit of Dr. Hinde.

In his published section there are two interglacial levels represented, a lower one containing peaty layers and wood, and an upper one in which no fossils have been found. In reality there are no less than four sheets of till to be seen at Scarboro with stratified sand and clay between them, and as recognized by Dr. Hinde, another bed of till under his lowest interglacial beds, at Scarboro beneath the level of Lake Ontario. The present writer has described an interesting set of interglacial beds in

1 Can. Journal, 1878, pp. 388, etc., with sections.

the Don Valley some miles away, and has shown that similar beds underlie the peaty clay at Scarboro.

The lower interglacial beds, which are rich in fossil plants and shells, extend 20 or 25 miles along the shore of Lake Ontario and are known to go six miles inland, beyond which they are buried beneath the later drift. The uppermost of the stratified beds just under the highest sheet of till probably extends for 100 miles to the east, since Dr. A. W. G. Wilson has found a very similar set of boulder clays and interstratified beds 40 miles long in that region. The upper stratified bed was deeply eroded before the last bed of till was laid down in the eastern region.[1]

The lowest and most important interglacial series near Toronto has been named by Prof. Chamberlin the Toronto Formation, and was at first put tentatively between the Iowan and Wisconsin glacial periods. As suggested by. Mr. Leverett, the Toronto Formation probably lies between the Illinoion and Iowan stages;[2] and in this case the most important of the upper interglacial times would correspond to the interval between the Iowan and Wisconsin.

The Toronto Formation will be described more fully on a later page, when the climate and duration of that interglacial period will be discussed as throwing light on the question of complete or only partial removal of the ice sheet during interglacial times.

The latest publication on interglacial beds in southern Ontario is by Dr. Chalmers, who describes the relationships at the west end of Lake Erie. He finds interglacial beds often 100 to 150 feet thick, sometimes containing fresh water and land shells. He thinks the period must have been of long duration.[3]

INTERGLACIAL BEDS IN EASTERN CANADA.

Comparatively little is known of interglacial beds east of Ontario. Chalmers described the gold-bearing gravels near Rivière du Loup in Quebec in a way suggesting that they are

1 Trans. Can. Inst., Toronto, Vol. VIII, Part. I, pp. 11-22.
2 Jour. Geol. 1903, p. 501.
3 Geol. Sur. Can., Sum. Rep., 1901, p. 166.

either interglacial or preglacial. Above the auriferous gravel there are sections of stratified sand and clay between sheets of till that must be interglacial. No fossils are mentioned as occurring in them.[1]

Sir William Dawson in 1872 described a very interesting bed of peat or coal, probably interglacial, under about twenty feet of boulder clay and over gray clay at Riviere des Habitants in Cape Breton Island. The material, which was nearly as hard as coal and broke with a shining fracture, contained some twigs and branches which Sir William thought allied to the spruces.[2] It is of course possible that this peaty deposit is preglacial, since the lower clay is not reported to contain boulders.

Beyond these two references I have found no accounts of interglacial beds in eastern Canada; but evidence of repeated ice advances in the shape of striations crossing one another at considerable angles are not uncommon, and may indicate an interglacial interval.

INTERGLACIAL BEDS ON THE HUDSON BAY SLOPE.

In 1865 lignite coal was reported by Dr. Robert Bell from some of the tributaries of Moose Creek not far south of James Bay; and in 1885 Mr. Borron collected specimens of this coal for the Ontario government, some of a hard but peaty character, others brown and woody, a few dark brown with a lustrous fracture.

In 1903 an expedition consisting of Dr. J. M. Bell and Dr. W. A. Parks with canoemen was sent to examine the more promising deposits. Their report shows that much, if not all, of the lignite is interglacial in age.[3] Dr. Bell's report gives many details of the different deposits, which have been found at points along a line more than 100 miles long from east to west and 50 miles from north to south. Though so widely spread it is not supposed that the lignite is continuous over this area, since it crops out only for short distances along river banks. Twenty

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1 Geol. Sur. Can., 1897, pp. 43-4 J.
2 Can. Nat., Series, Vol. VI, pp. 178-9.
3 Bur. Mines, Ont., 1904, Part I, pp. 135-197.

seven points where it occurs are noted on the map, and in most cases where good outcrops occur there is evidence that the beds are interglacial. The material varies in character but is always associated with hard stratified clay, sometimes as numerous thinsheets in the clay, sometimes as beds several feet in thickness. Very often boulder clay with striated stones was to be found both above and below the clay with lignite, but Dr. Bell thinks the beds may not all belong to the same interglacial period. Above the upper boulder clay there are sometimes deposits with marine shells, and at one point under the lignite also. The lignite is partly of a peaty character and can be softened in water and washed, when bits of moss may be picked out. Reedy materials sometimes occur and wood of more than one kind sometimes in very flattened forms. The general character of the peaty and woody material is very like the plant remains found at Scarboro and near the Don in the Toronto Formation, and it is very probable that part or all of the lignite beds are equivalent in age to the Toronto interglacial beds.

THE DON BEDS.

Let us return to the Toronto Formation, as the best known and most complete of the Canadian interglacial deposits, and enquire as to the climate and duration of interglacial time indicated by the series of beds and their fossils. It is evident that these two factors have much to do with the problem as to whether interglacial periods imply only short recessions of the ice or its complete removal, followed by a new ice sheet when the climate again became cold. The Toronto Formation may be divided conveniently into two series of beds, an earlier one, the Don beds, showing a warmer climate than the present, and a later one, the Scarboro beds which rest conformably upon the Don beds, but with fossils indicating a somewhat cooler climate than the present.

Before the Don beds began this part of Ontario had been free from ice at least long enough to allow a stream to cut its valley through the Illinoian boulder clay and the underlying shale to a depth of about 15 feet; and to permit a rich forest growth with trees like those of Ohio or Pennsylvania to advance from the south as far as the north shore of Lake Ontario. The deposits as found at the bend of the Don began in shallow water, perhaps along a river, with coarse shingle made of the harder beds of the shale beneath, passing up into clay with peat, reeds, bark and branches and trunks of trees such as red ceder, elm, pawpaw and three kinds of oak. Afterwards, as shown at the Don Valley brickyard, the water rose to about 60 feet above the present Lake Ontario; and beds of clay, sand and gravel were deposited and in the main oxidized, so that the sand and grave are brown and often cemented with iron oxide. The upper beds contain wood and leaves, as well as many unios and other shells. Several of the trees now have their northern limit at the southern edge of Canada, and a third of the unios are now not found in Canada but inhabit the Mississippi waters. During the deposit of the 40 feet of Don beds the climate seems to have remained mild, as shown by the list of trees and other plants given below determined by Prof. Penhallow:[1]

FLORA.

Acer pleistocenicum.
,, spicatum.
Asimima triloba.
Carya alba.
Chamaecyparis sphaeroidea.
Clethra alnifolia.
Crategus punctata.
Cyperaceae sp.
Eriocaulon sp.
Fraxinus quadrangulata.
,, sambucifolia.
,, americana.
Festuca ovina.
Hippuris vulgaris.
Hypnum sp.
Juniperus virginiana.
Larix americana.
Maclura aurantiaca.
Picea nigra.
,, sp.
Pinus strobus.
Platanus occidentalis.
Populus balsamifera.
,, grandidentata.
Prunus sp.
Quercus obtusiloba.
,, alba (?).
,, rubra.
,, tinctoria.
,, oblongifolia.
,, macrocarpa.
,, acuminata.
Robinia pseudacacia.
Salix sp.
Taxus canadensis.
Thuya occidentalis.
Tilia americana.
Ulmus americana.
,, racemosa.
Vaccinium uliginosum.
Chara.

1 Brit. Ass., Bradford, 1900, Rep. on Canadian Pleistocene Fauna and Flora.

FAUNA.

Vertebrate: mammoth or mastodon, bison, an undetermined fish.

Arthropoda: several undetermined beetles and cyprids.

Mollusca:

Unio undulatus	still living in lake Ontario.
„ rectus	
„ luteolus	
„ gibbosus	
„ phaseolus	still living in lake Erie, but not reported from lake Ontario.
„ trigonus	
„ coccineus	
„ occidens	not known in the St. Lawrence system of waters, but living farther south.
„ solidus	
„ clavus	
„ pyramidata	

Anodonta grandis, not reported from Canada.

Sphaerium rhomboideum.
„ striatinum.
„ sulcatum.
„ solidulum.
„ similis (?).
Pisidium adamsi.
„ compressum.
„ novaboracense (?)
Pleurocera subulare.
„ elevatum.
„ lewisi (?).
Goniobasis depygis.
„ haldemani.
Limnaea deciaiosa.
„ elodes.
Planorbis parvus.
„ bicarinatus.
Amnicola limosa.
„ porata.
„ sagana.
Physa heterostropha.
„ ancillaria.
Succinea avara.
Bithinella obtusa.
Somatogyrus isogonus.
Valvata sincera.
„ tricarinata.
Campeloma decisa.
Bifidaria armata (land snail).

Of the 42 species of molluscs eight or ten have not been reported from Ontario but occur farther south, thus reinforcing the evidence of the plants in favor of a warmer climate in the times of the Don beds than now. As trunks of trees having sometimes 120 or more annual rings are found at various levels from the bottom to the top of these deposits it is certain that the time occupied by the Don stage of the interglacial could not have been less than some hundreds of years. How long the warm climate had lasted before the lowest beds began one can only guess, but a rich and varied forest growth could not have advanced 100 or more miles from the unglaciated region to the south in any short period of time.

THE SCARBORO BEDS.

Above the rusty sand of the warm climate beds on the Don there are eight or ten feet of stratified clay beneath the upper sheet of till, in which no fossils but a little peaty matter have been obtained. Farther north the upper, peaty layers grow thicker; but the best section of these beds is to be seen at Scarboro Heights, which will be taken as typical. This is the section described by Dr. Hinde.

A well sunk below lake level at Scarboro disclosed five feet of peaty clay like that of the cliff above and 35 feet of sand and clay with Unios and wood, evidently the equivalent of the Don beds. Above lake level there are 90 feet of gray clay well stratified, often having a thin sheet of peaty material mixed with a little silt and mica scales every inch or two, perhaps indicating annual floods. In the peaty layers moss, seeds, spruce leaves and fragments of some deciduous leaves are found, as well as wings and other parts of beetles.

Above the clay are 50 or 60 feet of stratified sand occasionally containing small shells (Sphaerium, Limnaea, Planorbis and Valvata) with a few peaty layers consisting largely of wood and bark. Two trees have been determined from this material by Prof. Penhallow, *Larix americana* and *Abies balsamea.*

The beetles' wings, etc. have been studied by Dr. S. H. Scudder who names them as follows:

Fauna of Cool Climate, chiefly from Scarborough.

Arthropoda (almost wholly beetles):

Carabidae (9 gen., 34 sp.).
Elaphrus irregularis.
Loricera glacialis.
,, lutosa.
,, exita.

Hydroporus inanimatus.
,, inundatus.
,, sectus.
Agabus perditus.
Gyrinidae (1 sp.).

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.
,, Harttii.
,, delapidatus.
,, exterminatus.
,, interglacialis.
,, interitus.
,, longaevus.
Harpalus conditus.
Dytiscidae (3 gen., 8 sp.).
Coelambus derelictus.
,, cribrarius.
,, infernalis.
,, disjectus.
Gyrinus confinis LeC.
Hydrophilidae (1 sp.).
Cymbiodyta exstincta.
Staphylinadae (11 gen., 19 sp.).
Gymnusa absens.
Quedius deperditus.
Philonthus claudus.
Cryptobium detectum.
,, cinctum.
Lathrobium interglaciale.
,, antiquatum.
,, debilitatum.
,, exesum.
,, inhibitum.
,, frustum.
Oxyporus stiriacus.
Bledius glaciatus.
Geodromicus stiricidii.
Acidota crenata, Fabr. (*var.* nigra.)
Arpedium stillicidii.
Olophrum celatum.
,, arcanum.
,, dejectum.
Chrysomelidae (1 gen., 2 sp.).
Donacia stiria.
,, pompatica.
Curcolionidae (4 gen., 6 sp.).
Erycus consumptus.
Anthonomus eversus.
,, fossilis.
,, lapsus.
Orchestes avus.
Centrinus disjunctus.
Scolytidae (1 sp.)
Phloeosinus squalidens.

Though 70 of the 72 species of beetles are extinct, Dr. Scudder concluded from their relationship to living species that "the coleoptera from this Scarboro horizon indicate a climate closely resembling that of Ontario to-day, or perhaps a slightly colder one, a considerable proportion of their present allies being known from a more northern habitat."

Dr. Macoun, who examined fragments of leaves from the peaty clay a number of years ago, thinks the climate may have been like that of Lake Superior, and Prof. Penhallow expresses a similar opinion. The climate during the deposition of the Scarboro beds was somewhat cooler than at present but not very cold, certainly not at all suggesting subarctic or arctic conditions.

The peaty matter and wood, as well as the insects, were probably brought down from the north by a large river which built its delta of clay and sand in a bay extending northward from an interglacial lake Ontario 150 feet deeper than at present. The Don valley was now under water, and there is no evidence that the splendid deciduous forest trees of the Don stage continued to live on the unsubmerged shores. The climate had probably become a little too severe for them.

INTERGLACIAL LAKE LEVELS.

It is very probable that as the Illinoian ice front retreated an interglacial lake Warren and later a lake Algonquin and a lake Iroquois resulted from the opening up of the great lake basins while their outlet down the St. Lawrence was still blocked with ice. The first of these bodies of water was connected with the Mississippi and may have provided a route for the southern unios whose shells are found along the Don to reach their present position. Beyond these shellfish we have no direct evidence as to the early stages of water in interglacial times.

The Section presented at Scarboro Heights is as follows:

Glacial and interglacial beds above the Toronto Formation 203 ft.

Toronto Formation...	Scarboro beds.	stratified sand...	59	186
		peaty clay.........	92	
	Don beds (below level of L. Ont).		35	

Of this section 345 feet are above lake Ontario and 44 feet below it. How much lower the Don beds reach is not known, since the well sunk for exploring purposes filled with water at that depth.

The Don beds were formed in shallow water, as shown by their cross bedding and the coarseness of some gravel layers, while the beautifully stratified clay and sand of the Scarboro beds, which extend about 25 miles from east to west and six miles north before they are lost under later glacial beds, have all the character of delta deposits where a great river enters a lake. This great river was the outlet of the upper lakes region of interglacial times, before the present lofty morainic ridge had been dumped across its valley by the Wisconsin ice sheet.

At the beginning of the Don beds the lake was not far from the level of the present Ontario. As time went on the water rose, reaching 60 feet above the present level at the end of the Don beds, and then 150 feet above it while the wide delta of the Scarboro beds was being formed.

What caused the rise of the Lake? The only reasonnable explanation is to suppose that the outlet, at the east end of the Ontario basin, was gradually rising and holding back the water, as is known to be the case at present.

When the delta was complete the waters of interglacial lake Ontario were drained off to a lower level than now and the sand and clay were cut into by three rivers whose valleys are now found more or less filled with boulder clay and later stratified clay and sand. The most easily studied of these fossil river valleys is at the "Dutch church," where a bold cliff of boulder clay, deposited probably by the Iowan ice, compels attention because of its striking differences from the stratified interglacial beds on each side. This section of the old stream valley is partly submerged by the present lake, so that the water in Ontario must have been lower than now. The sides of the valley rise gently to the east and west, reaching a height of about 150 feet and a width across the top of about a mile. The valley was far more mature in form than that of the present Don, which has steeply walled sides though cut in similar materials, so that the old valley apparently represents a much greater lapse of time than has pased since the last ice sheet left Ontario.

LENGTH AND CHARACTER OF THE INTERGLACIAL PERIOD.

The Don and Scarboro beds themselves present only a small fragment of the history of the interglacial period in which they were formed. I have estimated that the full thickness of these beds, at least 190 feet, could not have been laid down under 1,000 years, and probably required many thousand years. The length of time after the Illinoian ice sheet set the basin free until the Don beds began to form in a lake not unlike Ontario at present probably equalled the time since the last ice sheet vanished from our region, variously estimated at from 7,000 to 35,000 years. The time required for the interglacial lake Ontario to rise to 150 feet above the present level, and then to sink to a point considerably more than 150feet below it is hard to estimate; but the rising and sinking of the outlet of the basin causing these changes of level were probably very deliberate operations. The time required to cut the interglacial river valleys and soften down their slopes to what we see at the Dutch Church must have been greater than that since the last ice age. The total interglacial period therefore can hardly have been less than three times the life of Niagara, say from 20,000 to 100,000 years, with the probability strongly in favor of the larger number.

As to climate we may supose a somewhat gradual rise of temperature while the rich forest, reminding of Pennsylvania, slowly spread northwards till the Don valley was filled with oaks and elms and basswoods and hickories, as well as osage oranges and pawpaws. There must have been warm and fairly dry summers, like those of the States south of the Great Lakes. How long the warmer climate lasted is unknown, but there was a perceptible cooling while the Scarboro delta was forming, giving a climate like that of northern Ontario. At last came the advancing chill of the next ice age, and finally the basin of Ontario was filled by the glacier, which climbed over its southern bank and advanced far to the south. The climatic cycle was complete. The length of time the ice remained and the complexity of its advances and retreats, as shown in the succession of boulder clays and stratified beds of the Scarboro cliffs, need not be discussed here. The last interglacial period disclosed in the cliff seems to have been connected with a recession of at least 100 miles, which must have demanded hundreds of years of retreat and advance.

EXTENT OF THE RECESSION OF THE ICE.

It is held by some glacial geologists, such as Mr. Warren Upham and Mr. Frederick G. Wright, that comparatively small oscillations of the ice front would permit the formation of interglacial deposits like those described; and the rank forest near the Malaspina glacier in Alaska and the fields and orchards near Swiss glaciers are quoted as evidence that rich vegetation may exist close to ice sheets. To make this argument of value it must be shown that a forest growth requiring the hot dry summers of Pensylvania could exist close beside a vast ice sheet from which killing frosts must descend with every north wind that blew at night; and also that ice sheets could survive summers with days and nights having a temperature of 90° or 100°.

One only requires to imagine such an ice sheet a few miles from Cleveland or Pittsburg in midsummer to see the impossibility of such a combination.

The Malaspina and Muir glaciers are rapidly vanishing even under the cool, moist summer of Alaska, and the little tongues of ice descending thousands of feet below the small Alpine névés afford no parallel for the effect of a neighboring continental ice sheet.

As shown in a former section there are interglacial deposits including leaf beds at the west end of lake Erie, probably of the same age as the Toronto Formation. Years ago some beetles' wings were obtained from peaty clay just like that of Scarboro on the south shore of lake Erie near Cleveland. Dr. Scudder has determined four species from the material sent him by Dr. Hinde, all extinct, and one of them, *Pterostichus dormitans* is also found at Scarboro; so that it appears that the Toronto Formation extended to Cleveland, 240 miles southwest of the Don valley. It should be mentioned, however, that the Cleveland peaty clay has not been directly proved to be interglacial, i.e. it has not been shown to lie between two sheets of boulder clay, though the plant beds near Port Rowan, north of Lake Erie, are certainly interglacial.

The delta at Scarboro was formed by a river flowing from the north along an old channel from Georgian bay, now filled with drift, but shown to exist as a rock valley by a number of well borings. This fact implies that the region of the upper lakes and the country to the north of Toronto for at least 70 miles were free from ice and had a climate not much different from the present, for the delta deposits contain insects and trees evidently drifted down by a stream from the country to the north. The delta beds contain no glacial material, no striated stones nor calcareous clay such as we find in the stratified layers between the latter till sheets. The brick makers note the difference, since the peaty clay burns to red brick, while the upper clay rich in lime burns to gray brick. There is no reason to suppose that glaciers contributed any water to the river flowing from Georgian Bay to Scarboro.

Toronto is only 700 miles from the hight of land in Labrador in latitude 53°, the region which Mr. Lowe has shown to be the center from which the Labrador ice spread out; and the country 70 miles to the north has been proved free from ice at the time. It is highly improbable that a stagnant glacial mass should have remained in central Labrador only 600 or 700 miles from the Don valley with its mild climate lasting for a much longer time than has elapsed in the recent period since the last ice sheet disappeared. There is no ice sheet in Labrador now, and it must have been even less possible during the Toronto Formation.

Whether the Toronto Formation has its equivalent north of the Hudson Bay watershed in the lignitic interglacial beds described by Bell and Parks along Moose river and its tributaries cannot yet be answered positively, though it is highly probable. The Moose river interglacial beds of stratified clay, sand and gravel, containing peaty matter and wood, resemble greatly those near Toronto. The interglacial wood has undergone about the same amount of change as that found near the Don, and the pressure of later ice sheets has flattened the trunks and branches in both to about the same degree.

Shells are seldom found in the Moose river interglacial beds, though Dr. Parks mentions marine shells below a seam of lignite on the Kwatabeahegan river,[1] giving evidence of oscil

[1] Bur. Min., 1904, p. 168.

lations of level in the Moose river basin like those in the great lakes region during the interglacial period. The shell beds are now at least 300 feet above sea level.

The nearest point of the lignites is about 400 miles north of Toronto; and they are known to extend eastward to within 300 miles of the center of the Labrador ice sheet. Deposits of stratified materials 70 feet thick including sometimes ten feet of peaty or lignitic beds must have required a long time to form; but thus far we have little information as to the events which took place during the interglacial time except the shifting of level proved by the marine shells. Before the lignite bed was formed the region now 70 miles west of James bay, was under a shallow sea, then the land rose sufficiently to allow peat bogs to grow. The level was rising therefore during the Moose basin interglacial formation as it was during the earlier part of the Toronto Formation, the changes in the two regions probably being synchronus, just as both regions are rising at the present day.

If the interglacial period of the Toronto Formation reached James bay and lasted long enough to allow important changes of level in that region and the deposit in some places of thick sedimentary beds accompanied by lignite, the assumption of a lingering ice sheet a little way to the northeast becomes still more unlikely, and may be dismissed altogether. The total retreat of the ice from the west end of lake Erie to the Hudson bay slope, in case all the interglacial deposits described in Ontario are of the same age, was not less than 600 miles.

CONCLUSIONS.

From the account just given it will be seen that extensive interglacial beds of at least three ages occur in Canada, the oldest in British Columbia and Alberta; two later ones, probably between the Illinoian and Iowan, and the Iowan and Wisconsin ice ages, in southern and northern Ontario. Extensive interglacial periods have not yet been disclosed in eastern Canada, though an interesting lignite bed in Cape Breton island is probably interglacial. The most thoroughly studied interglacial formation, that of Toronto, has furnished a large flora and fauna showing temperate conditions during a time long enough to cut a river channel 15 feet deep, then to build a delta 25 miles wide and in places 186 feet thick, and finally to cut river valleys with a width of a mile through the delta to the depth of more than 150 feet. These changes in the hydrography were associated with great changes in the level of an interglacial lake Ontario, caused by the upward and afterwards downward warping of its outlet at least 150 feet. It is estimated that the whole series of events required not less than three times as much time as has elapsed since the retreat of the last ice sheet, when Niagara Falls began its work. This interglacial period lasted therefore from 20,000 to 100,000 years. Interglacial beds of almost certainly the same age occur on lake Erie 240 miles to the south-west; and the interglacial lignite beds of the Hudson Bay slope were probably formed at the same time. There is no permanent ice sheet at present in Labrador, and conditions were even less favorable for the continuance of an ice sheet in that region during the Toronto and Moose river interglacial period.

It appears certain therefore that during at least one interglacial period eastern America enjoyed climatic conditions like the present and was entirely free from glaciers. That the deglaciation in the other recognized interglacial periods was as complete is probable but not yet proved. These conclusions imply a very great complexity and a very long time for the Pleistocene. The full series of Ice Ages and Interglacial periods must have required several hundred thousand years, and recent times may represent only the first third of another interglacial period.

Confusion has been caused in the past by the assumption that local Alpine glaciers afford a model of the methods and conditions of continental ice sheets. Nothing can be more misleading than to infer from the habits of little tongues of ice flowing down steep valleys that sheets of ice covering millions of square miles moving outwards under the pressure due to their own thickness of 10,000 feet or more at the center will act in the same way. Even Greenland with ist mountainous border confining the inland ice and permitting it to excape only through certain passes does not reproduce the conditions of our continental ice sheets spreading unhampered over vast plains.

Alpine glaciers respond to climatic changes, as shown in their rythmic advance and retreat in modern times, but in high mountains they do not disappear completely in warm periods, since by merely shrinking to higher elevations glacial conditions are retained, though on a smaller scale. From his point of view the higher Rockies and Selkirks of the west are still in the Glaciel Period, and the same is true of the Alps. But when milder conditions prevail in the area occupied by a continental ice sheet with no mountain range to retreat to, it is merely a question of time when the ice must totally disappear and the thawing will probably go on somewhat rapidly. The Malaspina glacier, which is a piedmont ice sheet no longer sufficiently fed by its tributary glaciers descending from the snow fields of Mt. St. Elias, is very rapidly disappearing even under the chill sunshine of latitude 60°. If the remnant of the Labradorean ice sheet wasted at a similar rate under latitude 53° with a warmer climate than the present, it could only have lasted a few hundred years and must have melted completely long before the middle of the interglacial period of the Toronto Formation.

The general result of the inquiry into Canadian interglacial deposits supports the view that our eastern Pleistocene included several Glacial periods completely separated by warm periods free from glacier ice. We should no longer speak of the Ice Age as a unit, since it is really a complex series of geological periods.