61-19

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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 61-19

SURFICIAL GEOLOGY OF THE OTTAWA AREA

REPORT OF PROGRESS

(Report and 2 figures)

31 G

N. R. Gadd

Price 25 cents

1961

CANADA

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SURFICIAL GEOLOGY OF THE OTTAWA AREA

Report of Progress

By

N.R. Gadd

DEPARTMENT OF

MINES AND TECHNICAL SURVEYS

CANADA

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SURFICIAL GEOLOGY OF THE OTTAWA AREA
REPORT OF PROGRESS

In 1956 the writer was assigned a field project to revise and bring up to date a map of the surficial geology of the Ottawa area (Johnston, 1917)[1]. Work of higher priority has delayed progress on this project, but a number of observations have been made that may serve to modify current thinking on the stratigraphy of the area and its significance to adjacent and related areas. This report will review some of the earlier literature in the light of the writer's more recent observations.

The earlier literature on the Ottawa area has proven quite confusing because of repeated references to "upper" and "lower" clays—terms which are applied at times stratigraphically, and at other times topographically. Some additional confusion results from the writer's knowledge that at least three distinct bodies of clay occur in the area and that many critical sections referred to in the literature are either poorly located or have now become covered or destroyed. A critical re-examination of all literature on the glacial and post-glacial geology of the Ottawa area is not justified, but a brief review of the more important papers may show the present status of theories that have grown out of the earlier work.

Previous Work

Johnston (1917) published the first comprehensive regional study of the surficial deposits of the Ottawa area. His map at the scale 1 inch to 1 mile is a classic example of his meticulous attention to detail and a monument to his diligence. It was intended as a map of agricultural soils and, although supplanted by a more recent pedologic map (Hills, Richards, and Morwick, 1944), it still serves as the authoritative source of information on the distribution of parent materials of soils in the region and on the interpretation of their origins. The lack of stratigraphic detail on Johnston's map is due primarily to the lack, at the time of mapping, of deep excavations; these now exist, and serve to clarify the geology. Johnston's report includes a list of all the important papers on the glacial and post-glacial geology of the Ottawa area which were published between 1863 and 1915.

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[1]Names and dates in parentheses refer to publications listed in the References.

Problems Presented in the Literature

The turn of the century marked the disappearance of many of the old concepts on the surficial geology of the Ottawa area, with general acceptance of the theory of continental glaciation as opposed to the marine-drift theory. Several other ideas have been perpetuated to the present and indeed elevated to theory status through repetition over the years. In the writer's opinion three matters remain controversial: (1) the Ottawa Sea concept evolved by Antevs; (2) the question of age of the Champlain Sea; and (3) the interpretation of the sediments and fossiliferous concretions near Green's Creek (Hiawatha Park).

The Ottawa Sea Concept

To discuss this concept let us revert to Johnston's (1917) work for its beginnings. Most of Johnston's text is factual and easily understood, but it is not perfectly clear what he meant by "upper" and "lower" marine clays with distinctive physical properties. At various places in his text (e.g. p. 24, lines 28-38) Johnston stated that unfossiliferous, deltaic, alluvial and lacustrine sands occur in the area at altitudes below 275 feet and that fresh-water shells occur in alluvial terraces "at an altitude of 265 to 275 feet" (p. 28, line 7). Marine shells occurring with the fresh-water shells presumably were derived from marine sediments by erosion. Many sections of "upper" clay are described as unfossiliferous, but Johnston did not clearly relate them to the alluvial terraces, although this correlation seems valid to the writer. Apparently he was convinced that the "upper" clay was lacustrine and younger than fossiliferous marine sediments of the Champlain Sea because previously Johnston (1916, pp. 7-8) had shown the shoreline of a lake "which was formed after the partial or complete withdrawal of the marine waters, for no marine fossils are known to occur in its deposits....." His map of the shoreline of this lake is reproduced here as Figure 1.

Antevs (1925, pp. 73-74) referred to this lake and named it "Lake Ottawa", thus apparently endorsing Johnston's interpretation of the sediments and topography involved. A few years later Antevs (1928) reversed his opinion with this statement: "It has been supposed that a body of fresh water called Lake Ottawa now (after two marine incursions) became isolated in the Ottawa valley west of Hawkesbury but observations by Goldthwait and the writer make it seem probable that the water sheet was a marine estuary." This interpretation accompanies several sections in which the "upper" clays are described variously, but are distinctly reported as being essentially unfossiliferous. Most of the sections are described in earlier publications and no new observations are recorded.

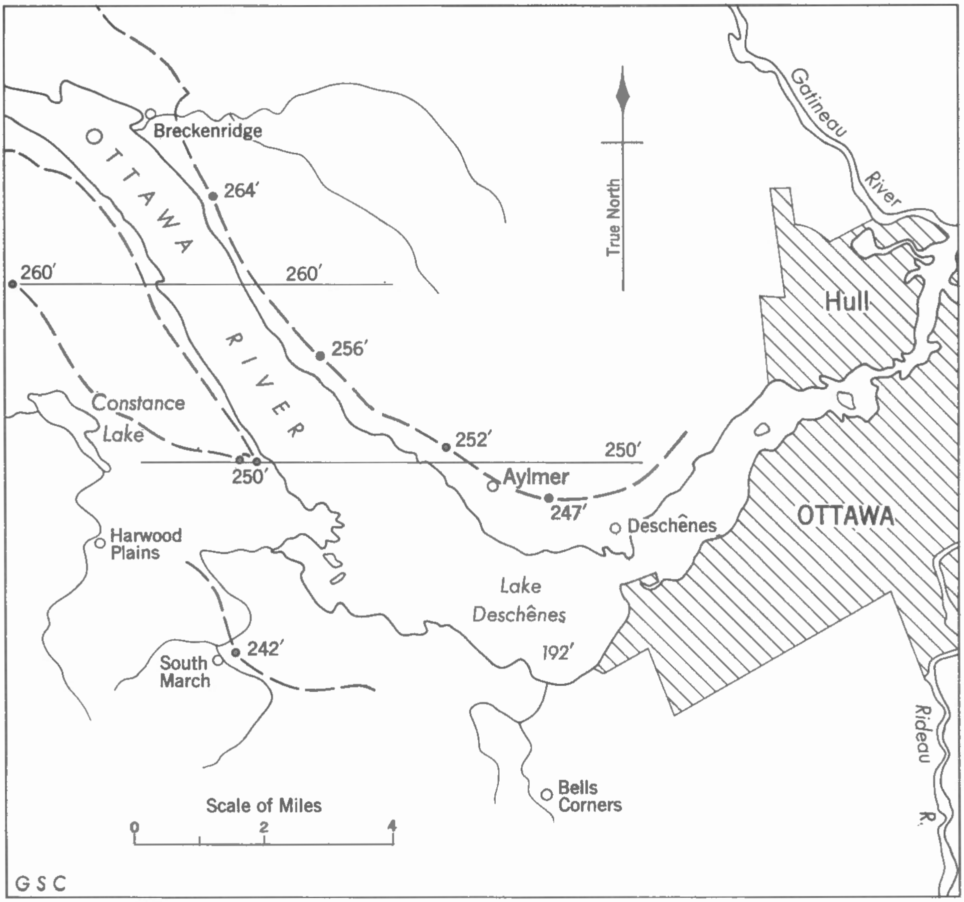

Figure 1. Raised beaches in the Ottawa valley, showing altitudes in feet above sea-level, and isobases. (After Johnston, 1916)

On the same subject Antevs (1939) wrote: "In 1924 the two late Quaternary marine clays at Ottawa, Canada, were held to be deposited in the Champlain Sea, and the beach at 240 feet altitude was believed to record a lake largely of post-glacial age. Although observations by Professor J. W. Goldthwait and the writer in 1925 suggested that the 240-foot beach was formed by a marine estuary, the significance of this—that the upper marine clay was deposited in this estuary, the Ottawa Sea—was not then realized by the writer. Therefore, the writer's old normal section at Ottawa is incorrect, there being in reality two separate sets of top beds—namely, one above and another below, the 240-foot level." In this 1939 publication also there are references to a relatively few sections (e.g. p. 714—Kirk's Ferry) in which the "upper" clay representing Ottawa Sea is described as "marine clay without shells", or as "clay, massive or with faint varves. Near base several shells of P. arctica and one shell of Macoma." The observations recorded in earlier publications were fitted to the new interpretation and, again, no new conclusive evidence was presented and no faunal assemblage was described that identified and characterized sediments of the Ottawa Sea; yet in this publication the "upper" clay was unquestionably referred to as marine.

Antevs (1939, pp. 716-17) also described the shifting of sea-levels in the Ottawa area, but made no attempt to point out the short-comings, if any, in Johnston's work that led him (Johnston) to accept a single marine invasion and subsequent gradual and more or less continuous uplift. Recent work by MacClintock (1958, p. 14) and by the present writer (Gadd, 1960, p. 26) in the St. Lawrence valley found no evidence of two distinct marine invasions or of shifting sea-levels such as claimed by Antevs for the Ottawa area.

From the above we can see that Antevs at first agreed with Johnston that some of the younger clays of the area belonged to a post-marine lacustrine environment. A change of opinion at a later date in the light of new factual information would be quite acceptable, but the present writer has been unable to find where such new data were presented by Antevs and feels that the marine nature of the younger clays below the 240-foot level has merely been inferred. It certainly was not proven! Therefore it would be more logical to support the concept presented by Johnston as being more compatible with facts observed by the earlier writers and by more recent observers (see below).

The Ottawa Sea hypothesis has been recorded in leading texts on glacial geology by Charlesworth (1957) and Flint (1947), but has been omitted from the latter's more recent volume (Flint, 1957). This omission may have been due to a reaction similar to that of Coleman (1941, p. 93): "Experienced geologists such as Johnston, Goldthwait, Antevs, and the present writer have found themselves puzzled over seemingly contradictory field relations..... When one remembers the uniform and beautifully simple curve of uplift of the shore of Lake Iroquois in a region just adjoining, it is evident that the complicated changes of level suggested by Antevs in reality belong to two widely separated periods which have been confused together because the deposits are much alike."

Age of the Champlain Sea

Conforming with the thought expressed in the above quotation, Coleman (1941) claimed an interglacial age for the Champlain Sea. He was undoubtedly greatly influenced by the existence of a coarse "boulder formation" lying on the surface of marine clay. The "boulder formation" was thought to be of glacial origin and the underlying, and therefore older, marine clay was thought to be "interglacial" Another interpretation of the phenomena observed by Coleman is possible (see below), and the writer feels that sediments of the Champlain Sea cannot be shown to be interglacial in the presently accepted sense of the term. Writers before Coleman claimed a post-glacial age for the Champlain Sea on the basis of its sediments generally being superposed on those of glacial origin. We now know that the Champlain Sea existed when the St. Narcisse moraine formed (Gadd, 1960) and therefore, that the beginning of the marine invasion was at least of late Wisconsin age, but we cannot yet say whether any part of the flooding continued to post-glacial time. Radiocarbon dates on various parts of the Champlain Sea give minimum ages for the recession at a particular place within the basin, but the exact stratigraphic position of the beginning or end of the Champlain Sea is not known for any specific area. It is hoped that field work in the Ottawa area, where some of the highest known beaches of the Champlain Sea occur, may reveal some of the critical relationships that would help solve this problem of age.

Any consideration of age of the Ottawa Sea would, of course, presuppose proof of the existence of a body of marine sediment younger than that deposited in the Champlain Sea. In the writer's opinion, such proof simply does not exist.

Sediments and Concretions Near Green's Creek

Since the early discovery (Logan, 1864; Dawson, 1893) of concretions containing a variety of fossils in clays near Green's Creek on the Ottawa River, the sediments and contained fossils have been referred to as marine. It seems that reference to the marine species of fish, Mallotus villosus, and to invertebrate marine fossils has created the impression that the fossil assemblage and sediments are undoubtedly of marine origin. Some doubt must exist in the minds of those who have read of the presence of other fossil remains, both animals and plants, whose origin is not necessarily marine or is distinctly non-marine.

Dawson (1893, p. 31) was the first to claim the marine origin of the Green's Creek fossils and sediments and he claimed also that they belonged among the "upper" clays of the region. It was an easy step for Antevs to create from this an "Ottawa Sea". Johnston, who had postulated a fresh-water lake on the basis of observations of similar clays elsewhere in the area, included the concretionary clays of Green's Creek among "Champlain Deposits" (Johnston, 1917, p. 25) and therefore identified them as marine. However, Johnston's judgment may have been influenced by popular hypotheses of the day and he may have been led to ignore what would seem to be the more significant statement (Johnston, 1917, p. 26) that in the vicinity of Green's Creek "the greater part of the upper clay appears to be barren of fossils."

There is no doubt that two distinct bodies of clay exist at Green's Creek; the older is undoubtedly marine and was deposited in the Champlain Sea, but the nature and age of the younger clay remains controversial. The conflicting evidence supporting both fresh-water and marine origin of the clays and concretions at Green's Creek must be reconciled. The present writer believes, for reasons discussed in the next section, that the weight of evidence favours a fresh-water origin of the younger of the two clays.

Despite the attention of numerous prominent geologists, the number of factual observations in the Ottawa area has grown very little and the concepts of the glacial history have evolved only very slightly from those expressed by Logan and Dawson. The writer feels, however, that enough is now known about the area to raise serious doubts on a number of the ideas expressed above. It is hoped that field work to be undertaken in the summer of 1961 will provide sufficient new facts to resolve the many controversial problems.

Preliminary Field Observations

These comments deal with sediments laid down by the last ice-sheet that was active in the area and by various agents of erosion and deposition acting during and since the last local glaciation.

Ground moraine in the area is generally grey, highly calcareous sandy till with about equal proportions of Precambrian granitic rocks and Palaeozoic sedimentary rocks in the pebble and boulder sizes. In many places, where modified by wave action, the till is veneered with a coarse, poorly sorted lag gravel, which weathers rusty and contains numerous 'rotted' pebbles of both granitic and sedimentary rocks. Much of this type of material was probably classified as 'boulder formation' and 'moraine' by earlier writers and was thought to represent a second glaciation because it rested upon 'boulder clay' or other sediment subsequently classed as 'interglacial'. See, for example, the frontispiece in Dawson (1893) and Coleman (1941, p. 92).

The Ottawa area is traversed by several prominent linear ridges that are capped by sand and gravel. These ridges are easily recognized on the maps by Johnston (1917), Reinecke (1917), and Hills, Richards, and Morwick (1944). All appear to the writer to be morainic ridges that have been overridden by marine waters and modified by wave action. These ridges contain a central core of typical end-moraine materials with steeply dipping sands and gravels and intercalated masses of glacial till, all capped by fossiliferous marine gravel that was probably derived from the underlying glacial materials (see Fig. 2). The glacial structures are truncated by the gently dipping to nearly horizontal structures of the secondary, overlying, marine gravel. Fossiliferous marine clay, continuous with the surrounding marine-clay plain, interfingers with gravel and sand, and pinches out part way up the slope of some ridges. Locally, coarse debris has rolled down the slope to cover part of the surface of the marine clay. The latter phenomenon may have been responsible for the identification of "Marine Interglacial Fossils at Ottawa" (Coleman, 1941, p. 92).

Although evidence is scant, at least some of the ridges probably were formed by ice that stood on their northern and north-eastern flanks. Their formation as recessional (?) moraines may have taken place during the late Wisconsin wastage of the ice from this region. What is probably the youngest of the moraines is represented by a discontinuous ridge that extends eastward from about Bells Corners through the Uplands Airport area, and south of and parallel to the Hunt Club road to the vicinity of the Metcalfe Highway. There is a gap in the moraine at Rideau River that has been at least partly filled by an extensive apron of stratified marine sands and silts that form the flat land about Uplands Airport and whose sediments are exposed in the sand pits along the east bank of the Rideau at the airport (principally in Foster's and Grandmaitre's pits). These sands are interpreted by the writer as having been transported along the moraine by shore currents of the Champlain Sea. They extended as a spit into the broad, late-glacial Rideau valley. The marine nature of the water is proven by the discovery in the sands of Foster's pits of an abundant molluscan fauna typical of shore facies of the Champlain Sea and of at least three skeletons of Beluga—the small white whale.

The late-glacial Rideau valley, blocked by the above-mentioned moraine, drained southward, presumably to the St. Lawrence valley. In a stage just prior to marine submergence the valley contained a glacial lake. Many sections that expose some 10 feet of glacial-lake varved sediments overlying glacial till may be seen

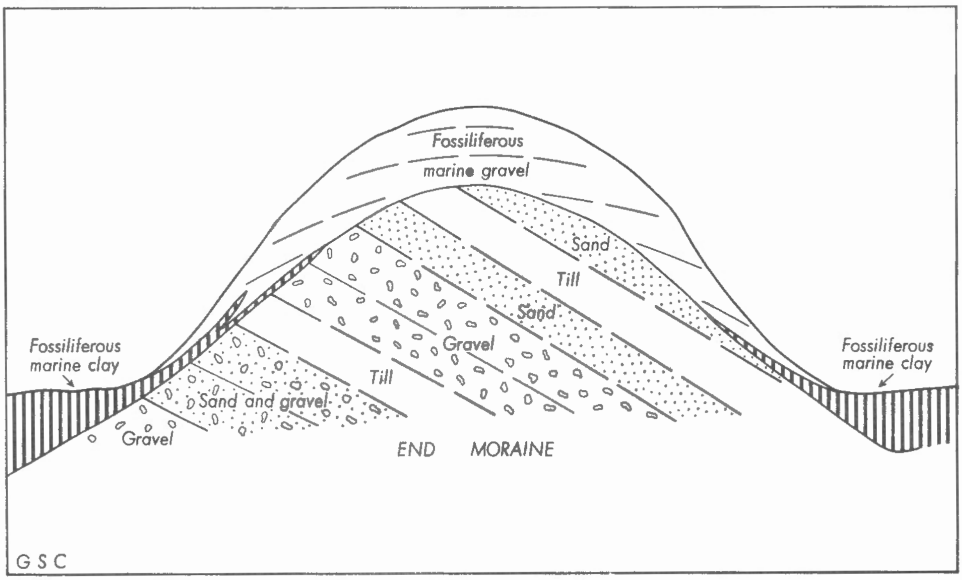

Figure 2. Diagrammatic sketch of typical cross-section through moraine modified by marine overwash

along the banks of the Rideau between Long Island (Manotick) and Uplands Airport. In at least one section near the northern tip of Long Island, the varves grade upward into massive marine clays that contain the typical fossils of the Champlain Sea deep-water sediments. Thus there was a period of open fresh-water conditions, associated with wastage of an ice-sheet, before the valley was flooded by the Champlain Sea.

Late-glacial flooding of the area by the Champlain Sea inundated all of the area south of Ottawa River and left only the Laurentian Highlands (Gatineau Hills) exposed as dry land. Basins were partly filled with soft, homogeneous, bluish grey clay (the so-called 'Leda' clay) that contained an abundant molluscan and protozoan fauna. Shorelines formed at a high level; the highest known is recorded at 690 feet elevation at Kingsmere (Johnston, 1917, p. 17). As differential uplift caused retraction of the marine embayment, shoreline features were developed at progressively lower elevations and materials older than the Champlain Sea came under the disrupting influence of wave action. The modifications to the glacial deposits produced during this period of lowering sea-levels have been the main cause of the prolonged confusion about the glacial stratigraphy of the St. Lawrence Lowland in general and of the Ottawa area in particular.

Shells collected by J.A. Elson from marine features near Uplands Airport, at an elevation of 323 feet, have a radiocarbon age of 10,850 $\pm$ 330 years (Preston, Person, and Deevey, 1955). If this is an acceptable date, it gives only a minimum date for the maximum inundation by the Champlain Sea and therefore it agrees in its order of magnitude with similar, and more reliable, minimum dates obtained on peat in the central part of the St. Lawrence Lowland (Gadd, 1960, p. 27). No subsequent glaciation is known in this area, but the possibility of a late-glacial readvance into the Champlain Sea, similar to that of the St. Narcisse moraine (Gadd, 1960), must be considered. Although the age of the Champlain Sea is still uncertain, it is at least in part contemporaneous with late Wisconsin glaciation; therefore it would seem logical to remove Coleman's 'interglacial' connotation and replace it with 'late-glacial, probably late Wisconsin'.

There are numerous sections throughout the Ottawa area in which two distinct bodies of clay are superposed, but caution must be exercised in assigning the terms 'upper' and 'lower' to these clay bodies as was done by the earlier workers, because there are at least three distinct clays in the area: glacial varved clays, marine clay, and post-marine clay; and all may have distinctive colour or structural facies. In one exposure, marine clay overlies and grades downward into varved clays. Here, the upper clay is marine and the lower is glacial, but the same or a similar section may have been described in earlier reports as having "upper" and "lower" marine clays. Some critical two-clay sections referred to in the literature as a basis for the validity of the Ottawa Sea concept have been examined by the writer. Many were either covered or had been destroyed by erosion or by man, and others could not be found from the information given. For each of the few sections of two marine clays referred to in the literature that were still visible the writer was able to suggest an alternative interpretation of the field relationship—e.g. redeposition of marine clay by landslide or redeposition and modification of originally marine sediments by a fluvial or lacustrine agency.

At least four sections are of interest within the zone below 240 feet elevation that Antevs regarded as comprising sediments of the Ottawa Sea. Two of the four—one in the brickyard at Billings Bridge (Ottawa Brick & Terra Cotta Co. Ltd.) and a second at Green's Creek where it is crossed by Highway 17—contain a brown to brownish grey silty clay unconformably overlying fossiliferous marine sediments that include the typical marine clay. Silty clay that resembles the younger clay of these sections is found at two other localities: near the rifle butts at Connaught Rifle Ranges which is between South March and Lake Deschenes (Fig. 1), and on the bank of the Ottawa River at Hiawatha Park. The latter locality and the section where Highway 17 crosses Green's Creek, occupy the same terrace. The section at Connaught Rifle Ranges is of interest because it lies below the shoreline of the fresh-water lake postulated by Johnston (1917), and that at Hiawatha Park is of interest because it is the most accessible part of the renowned collecting ground for fossiliferous calcareous concretions.

Where the two clays are superposed, certain physical differences may be noted. The overlying clay is brown to brownish grey, stratified, with a varve-like alteration of dark and light bands, the dark bands locally being brick-red, and is stiff, non-calcareous, non-fossiliferous except for concretions, and oxidized and mottled even below the water-table. The underlying clay is light grey, generally massive, soft to very soft, calcareous, fossiliferous (containing foraminifera and pelecypoda), only slightly oxidized in the upper part, but unoxidized below the water-table. If the overlying clay is actually the same clay as the 'upper' clay or 'unfossiliferous' marine clay described by earlier workers, the writer submits that it may be a secondary clay derived from the marine clay upon which it lies in many places, and has been oxidized during transportation and laid down by a fresh-water stream—the Ottawa—at a high-flood or lacustrine, or even estuarine, stage.

About 1/2 mile west of Green's Creek, in the top of a prominent scarp above the terrace containing the Hiawatha Park and Green's Creek sections, borings made at the side of Highway 17 expose fossiliferous grey marine clay at the surface. The younger overlying clay occupies the terrace below this scarp. Thus it would appear that the younger clays were laid on a terrace cut in the marine clay.

It is a disturbing fact that clays at Hiawatha Park and upstream along the bank of the Ottawa to the mouth of Green's Creek, which the writer has just suggested may be fresh-water sediments, are the classic source-beds of the well-known Green's Creek concretions. These concretions have been reported in the literature as containing a marine fauna and have been used to identify the clays as marine. It is quite possible, however, that the marine shells in the concretions were eroded from the somewhat older marine sediments and were transported and redeposited in a fresh-water environment along with some fresh-water shells, as was suggested by Johnston (1917). In support of this hypothesis, the writer can state that in several hundreds of concretions collected from or examined at the classic Green's Creek section, he has yet to find paired valves of large pelecypods like Macoma and Hiatella or valves of pelecypods standing in a living position within a properly oriented concretion. A very few complete, paired shells of Yoldia have been found, but their smaller, rounder form and their dentition may have held them together. The larger shells occur mainly as single valves lying on, or more or less parallel with the bedding plane. The mere presence of the shells, if not in living positions, cannot be held to be a good criterion for indentification of a marine environment.

Many collections of concretions have been made in the Ottawa area, but most publications have referred mainly to the rather spectacular occurrence of complete skeletons of Mallotus villosus, a marine species of fish. However, the collections also contain bones of land mammals, feathers of birds, tree leaves, and grasses, in addition to the marine shells; in short, a wide variety of terrestrial and aquatic plants and animals that could be found in and near a fresh-water stream. If, as may have happened in the Ottawa area, the stream flowed into the sea over soft, fossiliferous beds of marine clay, the presence of marine fossils with the fresh-water fossils is easily explained. The whole question of the significance of the concretions and their contained fossils requires careful review. The writer hopes to make a comprehensive collection and study of materials in concretions from Green's Creek and any nearby localities to permit a better understanding of their origin and significance. The writer also hopes to collect enough organic material (grasses, leaves, twigs etc.) from the concretions for purposes of radiocarbon dating.

The concretions are apparently of secondary origin, the result of cementation "after the complete withdrawal of the marine waters and largely during the time since establishment of the present drainage" (Johnston, 1917, p. 29). Carbonate material apparently concentrated readily around nuclei such as organic material (now fossils) existing in the coarser bands of the stratified silts, but also cemented layers devoid of fossils. Evaporation of laterally percolating ground water of low alkalinity apparently occurs at cut banks and the resultant deposition of dissolved salts produces concretions.

Summary

Although much work and study have been concentrated on the problems of glacial and post-glacial history of the Ottawa area, some of the principal theories developed over the years require further critical examination. It is impossible for the writer, in view of present knowledge of the area, to hold any confidence in the former existence of an Ottawa Sea, or in the mechanism for its formation, as suggested by Antevs. The writer favours Johnston's interpretation that some younger clays and sands at lower elevations in the Ottawa area probably are the products of a post-marine estuarine or fluviatile environment, with the possibility that lake stages were produced by obstructions in the Ottawa valley below the city of Ottawa. Indeed, with minor exception, Johnston's overall interpretation of surficial geology of the Ottawa area (Johnston, 1917) seems more firmly based on field observation than any other proposed since his report was published, and it is more compatible with recent findings in nearby areas.

The history of the Ottawa area seems quite simple, at least from the time of the last major glaciation. As the ice-front receded from the area, glacial lakes formed and probably drained southward into the St. Lawrence system just as other lakes formed in the St. Lawrence valley (MacClintock, 1958; Gadd, 1960; Terasmae, 1960). Marine invasion closed off the late Wisconsin glacial-lake events locally, but probably was contemporaneous with continuing glacial activity in nearby highland areas. The marine invasion may have occurred well within Wisconsin time, perhaps as early as the Two Creeks interval. Antevs' hypothesis of two marine invasions cannot be dismissed yet, but there appears to be no valid evidence of more than one marine invasion. Therefore the writer accepts as an alternative working hypothesis that the land was submerged only once and was uplifted gradually and more or less continuously after the maximum marine invasion, and that the uplift continues to the present. This sequence is thought to be supported by field studies in the adjacent St. Lawrence valley areas (MacClintock, 1958; Terasmae, 1960; Gadd, 1960). In the last stages of uplift, when sea-level stood somewhere below 300 feet present elevation in this area, fresh-water drainage was initiated and broad estuarine, fluvial, and lacustrine terraces were formed. Fine sediments derived from erosion of older glacial and marine sediments were deposited on terraces below this limiting elevation. Modern drainage is cutting its way into these sediments and the underlying bedrock and is producing an alluvium that may have many properties in common with the earlier sediments, but probably will differ from them through admixture of sediments derived from erosion of local bedrock.

Further field work is expected to round out the general picture with corroborative detail. More work is required in the study of the age of the Champlain Sea, of the upper marine limit in the area,

of the nature and origin of calcareous concretions and their contained fossils, and of the age and stratigraphic relations of the sediments containing them. The stratigraphy of those units formed during the period prior to the last ice-advance, and mentioned only briefly by Johnston (1917), will be studied further where available.

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